

Dominion Energy Virginia – Electric Transmission Facility Interconnection Requirements

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Electric Transmission Planning

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Facility Interconnection Requirements Supporting Documents

- Attachment 1 – Electric Transmission Planning Criteria (Rev 23.0)
- Attachment 2 – Customer Request Form (Revision 1.0)
- Attachment 3 – Generator Interconnection Protection Requirements (Rev 6.0)
- Attachment 4 – Ride-Through Requirements for Bulk Power System Generators (Rev 4.0)
- Attachment 5 – Generator Interconnection Data Communications and Data Exchange Requirements (Rev 1.0)
- Attachment 6 – Technical Requirements for Generation Interconnection Substations (Rev 11.0)

Acronyms

ANSI	American National Standards Institute
DEV-ET	Dominion Energy Virginia – Electric Transmission
IEEE	Institute of Electrical and Electronic Engineers
NERC	North American Electric Reliability Corporation
OATT	PJM Open Access Transmission Tariff
PCC	Point of Common Coupling
POI	Point Of Interconnection
SERC	SERC Reliability Corporation

Definitions


Words starting with a capital letter are considered defined terms. Defined terms are terms with a specific, agreed upon, meaning. Definitions for these terms are found in the NERC glossary of terms, the PJM OATT and the table below.

Capacity	Seasonal maximum generating capability of a generation Interconnection Customer’s Facility, measured in megawatts.
Customer	Interconnection Facility owner or requester who will apply for a new interconnection or change to an existing interconnection.
Distribution Facilities	Facilities rated at less than 69 kV which are owned and operated by the Company, and which are necessary to connect the Interconnection Customer’s Facility to the Transmission System.
Emergency Condition(s)	A condition or situation (i) that in the judgment of either party is imminently likely to endanger life or property; (ii) that in the sole judgment of The Company is imminently likely to affect adversely or impair the Transmission System or imminently will affect or impair the transmission systems of others to which the Transmission System is directly or indirectly connected; or (iii) that in the sole judgment of the generation Interconnection Customer is imminently likely to adversely affect or impair the Facility. Such a condition or situation includes, but is not limited to, overloading, or potential overloading of, excessive voltage drops, or other unusual operating conditions on the Transmission System or the generation Interconnection Customer’s Facility such that the output of the Facility must be shut down or curtailed to avoid damaging the Facility or the Transmission System.
Facility	A set of electrical equipment that operates as a single Bulk Electric System Element (e.g., a line, a generator, a shunt compensator, transformer, etc.)



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Good Utility Practice	Any of the practices, methods, and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts that, in the exercise of reasonable judgment in light of the facts known at the time the decision is made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition. Good Utility Practice is not intended to be limited to the optimum practice, method, or act to the exclusion of all others, but intended to include acceptable practices, methods, or acts generally accepted in the region.
Governmental Authority	Any federal, state, local or other governmental, regulatory, or administrative agency, court, commission, department, board, or other governmental subdivision, legislature, rulemaking board, tribunal, arbitrating body, or other governmental authority.
Interconnection Facilities	All structures, equipment, devices, and apparatus owned or leased by, or under contract to each party presently in place or proposed to be installed, which are necessary to connect the Interconnection Customer's Facility(ies) to the DEV-ET System.
Interconnection Customer	A transmission, generation, or end user connected to, or seeking to connect to, the DEV-ET System.
Interconnection Point	The point at which the Facilities are physically connected to the Transmission System (including any Distribution Facilities required to facilitate the interconnection).
Inverter Based Resource (IBR)	A non-synchronous generator which supplies power to the system using inverter technology.
Metering Equipment	All metering equipment currently installed at the Interconnection Customer's Facility and/or any other metering equipment to be installed at the metering points designated in the Interconnection Facilities, including Revenue Meters.
RTO	A Regional Transmission Organization or any successor thereof which becomes responsible for operating the Company Transmission System to which the Interconnection Customer's Facility is connected. PJM Interconnection, L.L.C. is DEV-ET's RTO.
Transmission Element	Transmission Elements are primary equipment (69kV and above) that constitutes, or interconnects with, the DEV-ET System. Examples include buses, lines, or transformers with low side voltage 69kV or above, regardless of BES status.
Transmission System	The Facilities owned by DEV-ET that are used to provide transmission service, including any Distribution Facilities required to provide Wholesale Distribution Service, under the PJM Open Access Transmission Tariff (OATT).
Wholesale Distribution Service	The provision of distribution service to wholesale customers, including generator Facilities, over Distribution Facilities as necessary to effectuate transmission service under the PJM OATT or Interconnection Service under this Agreement.

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1.0 INTERCONNECTION STUDIES

Planning for transmission interconnections is done to ensure that the transmission system can continue to support power transfers between utilities, including firm transactions, following a fault, or failure, which forces the removal of a generator and/or transmission element from service.

To ensure that the DEV-ET system continues to meet its operational objectives, DEV-ET performs studies to evaluate changes to the existing system. These changes may come in the form of a new interconnection or changes to an existing interconnection. When studies are complete, they are reviewed to determine the impact a new interconnection, or change, may have on DEV-ET's system or the surrounding system.

1.1 Procedure for Coordinating New Interconnection Studies

Should DEV-ET receive an interconnection request, or system change request, which may impact a neighboring transmission system, DEV-ET will initiate contact with the affected system, or systems, for the purpose of coordinating joint interconnection studies.

DEV-ET is a member of PJM and PJM is the Regional Transmission Organization (RTO) responsible for the reliability of the affected systems. The joint interconnection studies between neighbors are performed in coordination with PJM. In this way, PJM is notified of the changes created by the interconnection request.

1.2 Procedure for Notifying those Responsible for Reliability

New interconnection projects and other system changes are communicated to those responsible for reliability of affected systems by participation in regional and subregional working groups and committees. It is through the study process that parties responsible for reliability are notified of new interconnections, or changes. DEV-ET has entered into Inter-Area Reliability Agreements with neighboring utilities and participates in the coordinated planning and operation activities with the groups listed here:


- SERC East-RFC (SER) Studies under the Eastern Interconnection Reliability Assessment Group (ERAG) Agreement
- SERC Intra-Regional Near-Term Studies
- SERC Intra-Regional Long-Term Studies
- ERAG – Multi-Regional Modeling Working Group (MMWG)

Each of these groups have Working Groups, Study Groups, Committees and Task Forces which deal with various aspects of power system reliability and security. These groups perform studies to assess the reliability of the system at the interconnection level. When complete, study results are presented to the appropriate group for review. The results are used to identify system deficiencies and create corrective action plans when needed.

1.3 Wholesale Delivery Points

DEV-ET provides transmission service to wholesale delivery points throughout its service area under Mutual Operating Agreement(s) (MOA). The criteria for serving wholesale Interconnection Customers are the same as that used to serve DEV-ET's other customers. The criteria are based on Good Utility Practice, sound engineering judgement and economic principles without regard for the Interconnection Facilities ownership.

Regardless of the generation source, all power supplied to wholesale customers is delivered over the company's transmission Facilities to the wholesale customer. Therefore, it is essential that

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wholesale Interconnection Customer load requirements be included in the company’s planning process.

Joint planning studies between DEV-ET’s and its wholesale Interconnection Customers are to be conducted periodically. The following criteria apply to all joint planning studies:

- Contractual obligations must be observed.
- Studies must be based on sound engineering and economic principles consistent with long range system plans.
- All applicable sections of the DEV-ET Planning Criteria, provided as Attachment 1, apply to the connection of any wholesale Interconnection Customer to DEV-ET’s Transmission System.
- The joint planning study would begin with a review of each company’s construction plans based on the company’s annually updated load forecasts for the area. The study scope will include the following:
 - The wholesale interconnection customers will prepare a load forecast for each year of the next of the next ten year for their area.
 - DEV-ET will prepare load forecasts for the area around the Interconnection Customer.
 - For both conventional and alternative (solar, wind, etc.) distributed generation supply the maximum output of each unit/site, the coincident output of each unit/site for the summer peak day and the winter peak day for the DEV zone.
 - The Interconnection Customer and DEV-ET will each prepare preliminary studies of their respective systems for meeting the future load requirements identified by the forecasts.
 - The Interconnection Customer and DEV-ET will exchange study information and based on joint analysis, prepare a long-range plan.

There will be instances where deviations from the long-range joint planning process are necessary to accommodate third party delivery point requests. In these cases, DEV-ET and, if needed, entities interconnected to DEV-ET facilities, will expedite review of appropriate Elements of the long-range plan to address such projects.


2.0 FACILITY INTERCONNECTIONS OR MODIFICATIONS

When a Customer wishes to install, modify, or remove DEV-ET Facilities at a Delivery Point or Point of Interconnection (POI), the Customer must initiate the request in writing using the Customer Request Form found in Attachment 2 of this document. Note, a Customer must submit a Customer Request Form when making changes to Customer’s Facilities that are anticipated to (i) lead to a modification to DEV-ET’s Facilities or (ii) impact the operation of DEV-ET’s Facilities.

2.1 Required Simulation Data

All changes to DEV-ET’s transmission system affect the system’s behavior. This includes new interconnections and changes to existing interconnections. As such, DEV-ET will perform studies to assess the transmission system’s performance with the change and to determine if there are any adverse impacts introduced by the change.

DEV-ET maintains a model of the existing system, but when system changes are proposed, DEV-ET will require a model of the change (new interconnection or changes to an existing

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interconnection). These can only be supplied by the interconnection customer. Consequently, the interconnection customer must supply DEV-ET with the computer models requested by DEV-ET.

DEV-ET will require developers and owners to supply a steady-state power flow model, a positive sequence (fundamental frequency) transient stability dynamics model and a short circuit model of the system change they are sponsoring. In some instances, DEV-ET will request an EMT (Electromagnetic Transient) model which the interconnection customer must supply. EMT models are needed to assess the system’s response to transients, to evaluate the behavior of Inverter-Based Resources¹ (IBRs) during and after system events and to determine the effect large industrial loads may have on power quality. EMT simulations are also used to investigate harmonics², determine proper protection system settings and evaluate IBR control settings.

The Customer Request Form is to be submitted by the Customer as soon as useful information is available. As additional information becomes available, the Customer is to submit a revised Request Form.

Studies of DEV-ET system are not a one-time occurrence. As part of DEV-ET’s reliability obligation DEV-ET will continue to perform studies of its system with models provided by interconnection customers. After construction is complete and the project becomes operational, it is the responsibility of the project owner to supply DEV-ET with up-to-date models of their system when requested by DEV-ET. The models must be delivered to DEV-ET in electronic format and must be accompanied by an attestation stating that the models conform to all requirements and is an accurate representation of the facility. Information that is requested by or provided to DEV-ET outside of the Customer Request process should be provided through the designated DEV-ET Project Manager or alternate designated DEV-ET point of contact.

2.2 Voltage level and MW and MVAR capacity or demand at point of interconnection

Except as may be otherwise provided for in applicable tariffs or agreements, or as may be otherwise agreed by DEV-ET and the Interconnection Customer, the Interconnection Customer should use the “Customer Request Form,” detailed in Attachment 2, to provide DEV-ET with the necessary information regarding the voltage level and MW and MVAR capacity or demand at point of connection. Since voltage and interconnection points are site-and project-specific, DEV-ET will perform studies and exercise engineering judgment to determine appropriate voltage levels, interconnection points, and system capabilities.

2.3 Breaker duty and surge protection

High voltage circuit breakers are subjected to continuous current. As such, the circuit breakers selected must be able to carry the maximum continuous currents found by load flow analysis. If the load flow analysis shows that the current flowing through a circuit breaker exceeds its “nameplate” or “normal” design capabilities, then the circuit breaker may only be used when allowed by manufacturers design documentation or standard industry practices. Otherwise, a larger circuit breaker must be used, or some other design change must be made to limit the amount of short circuit current.

High voltage circuit breakers are to be designed to interrupt continuous and short circuit current. Therefore, the circuit breakers selected are to be able to interrupt the worst-case short circuit current calculated using engineering software.

¹ IEEE Std 2800-2022, “IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems”, pg 91. Identifies the models required to assess IBRs.

² IEEE Std 3002.8-2018, “IEEE Recommended Practice for Conducting Harmonic Studies and Analysis of Industrial and Commercial Power Systems”.

Circuit breakers are to be designed and tested according to the latest Institute of Electrical and Electronics Engineers (IEEE) C37 collection of standards.

Shielding, and surge protective devices are to meet the requirements as determined by lightning and switching surge analysis, and the latest IEEE C62 standards.

Electrical equipment, including high voltage substation buses, are to meet or exceed DEV-ET's standard Basic lightning Impulse insulation Levels (BIL)³ listed in the table below.

Equipment & Bus Nominal Voltage Rating (phase-to-phase) kV, rms	BIL – Basic lightning Impulse Insulation Level (phase-to-ground) kV, crest
115	550
138	650
230	900
500	1550

The Interconnection Customer must meet the following requirements:

- The Interconnection Customer is responsible for designing equipment to meet the short circuit capabilities of their Facilities.
- The Interconnection Customer is responsible for specifying the ratings of their interrupting devices.
- The Interconnection Customer are to provide existing and future fault current levels when requested.
- It is the responsibility of the Interconnection Customer to notify DEV-ET of any changes in their Facilities that may cause an increase in fault currents (generator and transmission Interconnection Customers).
- For IBRs connecting to the DEV-ET system, it is the responsibility of the Interconnection Customer to ensure that the isolation device used to isolate an IBR plant from the DEV-ET system follows IEEE Std 2800-2022.


2.4 System Protection and Coordination

DEV-ET is to own and maintain transmission Protection System Elements necessary to protect the transmission portion of the interconnection; however, DEV-ET is not responsible for protection of the Interconnection Customer's equipment and other electrical assets.

The Interconnection Customer is responsible for providing a properly designed and tested Protection System that will coordinate with the DEV-ET Protection Systems. Prior to designing its Protection Systems and establishing the protection settings, the Interconnection Customer should complete all the appropriate studies needed to ensure a sound design. These studies may include, but are not limited to, protection coordination studies, grounding studies, short circuit studies, stability studies, and power quality studies.

Once complete, the study results are to be made available to DEV-ET for their assessment and agreement.

³ IEEE Std C62.82.1 - 2010, IEEE Standard for Insulation Coordination – Definitions, Principles, and Rules.

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Using simulation software (ASPEN, PSCAD, PSS/E), DEV-ET will confirm that the Interconnection Customer’s protection system design and settings are properly coordinated with DEV-ET’s protection systems. The Interconnection Customer is required to provide the models required for the simulations performed by DEV-ET.

When a simulation shows that the Interconnection Customer’s protection system does not coordinate with DEV-ET’s protection system, the Interconnection Customer will work with DEV-ET to make the changes necessary to coordinate the Interconnection Customer’s protection system with DEV-ET’s protection system.

Good Utility Practice dictates that the Protection Systems installed by the Interconnection Customer follow the latest IEEE C37 and IEEE C57 guides and standards for protective relaying systems and adhere to NERC and PJM standards related to system protection.

For information on generator interconnection, see Attachment 3, DEV-Generator Interconnection Protection Requirements.

2.4.1 Protection System Design

The Interconnection Customer is responsible for the design of its Protection System. Faults or failures on the Interconnection Customer’s Facilities may affect the DEV-ET Transmission System or other customers tied to the system. Consequently, the Interconnection Customer’s Protection System will be designed to minimize the effects of faults and disturbances originating at the Interconnection Customer’s Facilities. The Interconnection Customer Protection System design must meet the following design principles:

- Detects all faults and abnormal conditions for which it is designed to detect (sensitivity),
- Only operates for faults and failures within its zone of protection (selective).
- Can coordinate between protection zones (no overtripping),
- Operates quickly to isolate faulted element(s).


If DEV-ET finds that the Interconnection Customer’s design is inadequate, DEV-ET will require the Interconnection Customer to install additional equipment as necessary to address issues such as, but not limited to, relay overreach, transformer penetration, weak source, source impedance ratio (SIR), anti-islanding, and power quality.

Additionally, the Interconnection Customer’s Protection System is to protect against abnormal operating conditions. These include, but are not limited to, over/under-voltage, over/under-frequency, harmonics, overloads, short circuits, open circuits, phase imbalance, switching surges, lightning surges, and other harmful electrical conditions.

Utility grade protective relays and fault clearing systems are to be used on the interconnected power system. All protective relays are to meet or exceed American National Standards Institute (ANSI)/IEEE Standard C37.90. Mechanical and electrical logic, interlocking mechanisms, and operational data may be required between interconnected Facilities to ensure safe and reliable operation. Examples of mechanical and electrical logic, interlocking mechanisms, and operation data include, but are not limited to, breaker and switch auxiliary contacts, synch-check relays, physical locking devices, solar irradiance, and inverter operating modes or setpoints.

2.4.1.1 Inverter Based Resource (IBR) Protection Systems

The response of an IBR to a fault is influenced by the inverter’s fast controls acting on changes to the IBR’s terminal conditions. Inverter controls differ between Original Equipment Manufacturers (OEMs) and therefore each IBR has a unique response to a fault. The injection of positive-sequence current into a fault is somewhat consistent among OEMs, but the injection of negative

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sequence current can vary greatly between OEMs. Some OEMs allow their inverters to inject negative sequence current and some don't.⁴

Protection schemes that rely on negative sequence currents may not operate correctly. To ensure the protection system is both dependable and secure, IBR connections to the DEV-ET system must supply an EMT model with the IBR control setting to DEV-ET for evaluation.

The protection function requirements of IBRs must comply with IEEE Std 2800⁵. Specifically, the IBR plant's protection system must not limit the IBR plant's ride-through capability.

2.4.1.2 Dual Primary Phase and Ground Protection Systems

Protection Systems classified as Dual Primary are required for all transmission Elements connecting to DEV-ET's transmission grid. This scheme will require two independent high-speed, phase and ground fault Protection Systems designated System 1 and System 2. Together these systems provide a redundant set of all normal primary and backup functions. Further explanation can be found in IEEE Std C37.120⁶.

2.4.1.3 Breaker Failure Protection

The protection scheme must include a breaker failure function for all interrupting devices connecting to a DEV-ET transmission bus. For Generation Interconnections, there are additional requirements as outlined in Attachment 3, DEV Generator Interconnection Protection Requirements, Section 3 Interconnection Protection Requirements.

2.4.1.4 Protection System Components

The Interconnection Customer's Protection System, including the protective relays, associated communication systems, voltage and current sensing devices, station batteries and DC control circuitry, must be compatible with DEV-ET's standard design for common equipment and/or common zones of protection. Compatibility includes protection application, redundancy, operating speed, communication type, and communication medium.


The Interconnection Customer's Protection System must be powered by a DC battery for reliability. The battery is to be sized to power continuous loads for a minimum of 8 hours and power all momentary tripping loads without the need for a charger. The battery sizing calculation should be done in accordance with IEEE Std 485⁷. The battery powered DC system must be monitored by a DC under-voltage alarm. This alarm must be monitored by the Facilities owner at all times using remote communications. If the DC under-voltage alarm detects a system failure and notifies the Facilities owner, it is the responsibility of the Facilities owner to take immediate action to restore power to the protective equipment. If the alarm signal not sent directly to DEV-ET operations, then it is the responsibility of the Facilities owner to inform DEV-ET operations directly of the failure and report the status of the protection system restoration.

⁴ Sandia Report, "Impact of Inverter-Based Resource Negative-Sequence Current Injection on Transmission System Protection," SAND2020-0265, Jan. 2020.

⁵ IEEE Std 2800-2022, "IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems", Feb 2022.

⁶ IEEE Std C37.120-2021, "IEEE Guide for Protection System Redundancy for Power System Reliability", Nov 2021.

⁷ IEEE Std 485-2020, "IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications", May 2020.

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2.4.2 Protection System Operation and Misoperation

The Interconnection Customer is to investigate all operations and misoperations of their Protection Systems which affect the interconnection Facility. Within the code of conduct restrictions, DEV-ET will cooperate with the Interconnection Customer and provide its findings related to the incident. The Interconnection Customer is to provide its findings to DEV-ET.

2.5 Metering and Telecommunications

2.5.1 Metering Equipment

DEV-ET approved revenue metering equipment is to be installed for energy accounting and billing purposes. Except as may be otherwise provided for in applicable tariffs or agreements, or as may be otherwise agreed by DEV-ET and the Interconnection Customer, the Interconnection Customer is to install, own, operate, and maintain all revenue metering equipment as set forth below.

Interconnection Customers that will be a PJM market participant are to install metering that is to be of sufficient quality to meet the applicable requirements as defined in PJM Manuals,

- 14A – New Services Request Process,
- 14C – Generation and Transmission Interconnection Facility Construction,
- 14D – Generator Operational Requirements,
- 01 – Control Center and Data Exchange Requirements.

Additional requirements may be applicable on a case-by-case basis.


Revenue metering equipment includes, but is not limited to, current transformers, voltage transformers, revenue meters, meter sockets, test switches, communication circuits and associated devices. The revenue metering equipment is to be located at the Interconnection Customer's Facility unless otherwise agreed to by DEV-ET, PJM, and the Interconnection Customer (referred to collectively in this section as the "Parties"). The revenue metering equipment is to meet or exceed all applicable industry standards (e.g., NERC, PJM, ANSI, IEEE, and National Electrical Manufacturers Association (NEMA)). At least (N-1) metering Elements are to be used for the revenue metering, where N is the number of wires in the electrical system associated with the revenue metering. Three metering Elements are to be the standard for revenue metering unless otherwise agreed to by the Parties. The revenue metering installation is to meet all applicable industry standards for phase-to-phase and phase-to-ground electrical clearances.

DEV-ET will provide the Interconnection Customer with manufacturer's installation information for the current and voltage transformers when these devices will be furnished by DEV-ET and installed by the Interconnection Customer.

2.5.1.1 Revenue Meters

The revenue meters are to be capable of recording, storing, and transmitting bi-directional megawatt-hour (MWh) data and megavar-hour (MVARh) data. However, if required by the applicable tariffs, or if mutually agreed by the Parties, the revenue meters are to instead record bi-directional kilowatt-hour (kWh) data and kilovar-hour (kVARh) data. In general, this data is to be recorded in hourly intervals unless other interval lengths are required by the applicable tariffs or agreed upon by the Parties.

The revenue meters are to have an accuracy class of 0.2% standards as defined in ANSI C12.20. In addition, the revenue meter should meet ANSI C12.1 and C12.10 standards. Testing of meters

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in service may be requested by DEV-ET, any regulatory agency having jurisdiction over the interconnection, or any other lawfully constituted authority having jurisdiction over meter accuracy.

2.5.1.2 Revenue Metering Current Transformers

The revenue meters are to be connected to current transformers (CTs) having a minimum metering accuracy class of 0.15% (as defined in IEEE C57.13⁸) at a minimum burden designation of B-1.8 from 1% of nameplate to rating factor. CTs with standard accuracy and/or lower burden designations may be allowed by DEV-ET in special cases, but the secondary burden on the CTs must not exceed the nameplate burden rating. In addition, the CTs meet the ANSI C12.11 standard. The continuous current on the CTs is not to exceed the primary nameplate rating with the thermal current rating factor (RF) applied. The available fault current must not exceed the mechanical and short time thermal limits of the CTs. The revenue meters are to generally be connected to dedicated metering CT secondary circuits and should not share the same circuits with relays or other devices. In cases where power flow varies significantly (e.g., at wind generation Facilities), the Interconnection Customer may be required to provide extended range CTs or additional metering equipment at their own expense.

2.5.1.3 Revenue Metering Data Communication


The Interconnection Customer is to, at its own expense, install, operate, test, and maintain any communications equipment required by DEV-ET to remotely retrieve revenue metering data from the Interconnection Customer's Facility on a real-time or periodic basis as specified in the sections below for wholesale generation Facilities, transmission Facilities, and end user Facilities. The communication capability of remote interrogation of the revenue data should be compatible with commonly used billing data systems such as MV-90 and Primestone. The Interconnection Customer is to also be responsible for any high voltage isolation equipment that the local telecommunications company may require at the Interconnection Customer's Facility to protect their communication systems from damaging transient voltages that can occur in electrical substations and generation Facilities.

DEV-ET provides the Interconnection Customer access to bi-directional kWh and kVARh pulses from the DEV-ET revenue meters installed at Interconnection Customer Facilities. The pulses, which are provided upon request, is to be used as the source of the revenue metering data where applicable. Alternatively, kWh and kVARh register accumulator data may be provided by other means, e.g., DNP, MODBUS, or similar protocol, to the Interconnection Customer Facilities, in lieu of, or in addition to, analog kWh and kVARh pulses, if such arrangements are agreed upon by both Parties.

2.5.2 Operational Metering Data from Revenue Meters

Operational metering data (e.g., MW and MVAR) is generally not available from DEV-ET revenue meters that are provided by DEV-ET at Interconnection Customer Facilities. Except as may be otherwise provided for in applicable tariffs or agreements, or otherwise agreed by DEV-ET and the Interconnection Customer, the Interconnection Customer is to, at its own expense, install, operate, test, and maintain any metering and communications equipment necessary to provide operational metering data required from the Interconnection Customer's Facility by one or more of the Parties.

⁸ IEEE Std C57.13-2016, "IEEE Standard Requirements for Instrument Transformers", Jan 2016.

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Revenue meters are to be capable of communicating with data acquisition system (“DAS”) equipment such as Remote Terminal Unit (“RTU”) to provide the following real-time bi-directional power and energy data for operational purposes:

- instantaneous power flow
- per phase and three-phase averaged Root-Mean-Squared (“RMS”) voltages
- per phase and three-phase averaged RMS currents with at least two decimal points

A continuous accumulating record of active and reactive energy flows are to be provided by means of the registers on the meters. The revenue meter(s) are to be capable of providing bi-directional energy data flow in either KYZ pulse signals format, or accumulated counters to RTU. Energy data flow accumulator counters may also include register accumulator data delivered to RTU via DNP, MODBUS, or similar protocol. All Parties are to share the same data register buffers regardless of the types of employed data communication methods. For generation Facilities that interconnect to DEV-ET generator interconnection substations, this revenue meter data is to be shared across serial data links established between the two facilities. Further details regarding the requirements for this data exchange can be found in Attachment 5, Electric Transmission Generator Interconnection Data Communications and Data Exchange Requirements. This data is shared between facilities at generator interconnection substations. Requirements for this data exchange are provided in Attachment 5, Electric Transmission Generator Interconnection Data Communications and Data Exchange Requirements. If the accumulation counter method is used, the owner of the meter is to be responsible for freezing the accumulator buffers and no other Party is to freeze them. The accumulator freezing signals are to be synchronized to Universal Time Coordination (UTC) within ½ seconds.

The revenue meters’ internal clocks and real-time DAS equipment is to be synchronized with Universal Time Coordination (UTC) with 15 seconds resolution.

2.5.3 Revenue Metering Access, Security, and Testing

Where DEV-ET provides revenue metering equipment, the Interconnection Customer is to grant DEV-ET employees and authorized agents’ access to the equipment at all reasonable hours and for any reasonable purpose. Regardless of meter ownership, the Interconnection Customer is to not permit unauthorized persons to have access to the revenue metering equipment.


The meters, test switches and any other secondary devices that could have an impact on the performance of the revenue metering is to be sealed and the seals are to be broken by the party responsible for the equipment only when tests, adjustments, and/or repairs are required.

The revenue metering is to be tested for accuracy as specified by the applicable interconnection service agreement, PJM requirements or regulatory commission regulations by the owner of the metering equipment.

2.5.4 Wholesale Generation Facilities Revenue Metering Equipment

For the interconnection Facilities of Wholesale Generators, except as may be otherwise provided for in applicable tariffs or agreements, or as may be otherwise agreed by DEV-ET and the Interconnection Customer, the revenue metering equipment is to be located at the Interconnection Customer’s Facility. The revenue metering is to be compensated for losses to the Point of Interconnection (POI) if the metering equipment is not located at the POI.

The revenue metering CTs and VTs are to be installed on the transmission voltage side of the Interconnection Customer’s generator step-up transformer(s) or Facility main step-up transformer and/or station service power transformers.

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2.5.5 Wholesale Generation Facilities Revenue Meter Requirements

Generation Connected at 69 kV or Above

The Interconnection Customer is to install, own, operate, test, and maintain the revenue metering equipment at the Interconnection Customer's expense. A redundant revenue meter and real-time Supervisory Control and Data Acquisition (SCADA) data is also required. The SCADA data consists of analog MW and MVAR at all generation, load, and transmission line terminals; analog kV at all buses 69 kV and greater; circuit breaker open/close status for all breakers; other device status points (for example, automatic reclosing on/off). It is preferred that the redundant meter have a different method of telecommunications than the primary meter. DEV-ET provides revenue metering for station service power supply at a generation Facility if the supply is from the DEV distribution system.

Generation Connected Below 69 kV

DEV-ET is to install own, operate, test, and maintain the revenue metering at the Interconnection Customer's expense. A redundant revenue meter is also required. It is preferred that the redundant meter have a different method of telecommunications than the primary meter.

Generation Connected Behind-The-Meter and Participating in the PJM or Wholesale Energy Markets

DEV-ET is to own, operate, test, and maintain the revenue metering equipment at the POI, except as otherwise specified by the applicable retail tariff or interconnection service agreement. The physical arrangements of such Facilities are often complex. As such, DEV-ET makes a case-specific review of each installation and determines the revenue metering required. Any additional metering equipment or metering data that one or more of the Parties may require for the generation equipment is the responsibility of the Interconnection Customer.

Specific Revenue Metering Requirements for Existing Non-Utility Generator Facilities That Are Ending Power Purchase Agreements with DEV-ET


For an existing non-utility generator (NUG) that is ending its power purchase agreements with DEV-ET and will sell its power in the PJM energy market, DEV-ET is to continue to own, operate, test, and maintain the existing revenue metering equipment at the Interconnection Customer's expense, except as otherwise specified by the applicable tariff or service agreement. The customer is responsible for all PJM meter data reporting requirements; DEV-ET will not report the generation on behalf of the NUG to PJM. The Interconnection Customer's RTU is to provide DEV-ET access to the operational and revenue metering data specified in Telecommunication Section.

2.5.6 Transmission Owner Facilities

For the interconnection Facilities of Transmission Owners, except as may be otherwise provided for in applicable tariffs or agreements, or as may be otherwise agreed by DEV-ET and the Interconnection Customer, the Interconnection Customer is to install, own, operate, test, and maintain the revenue metering equipment at its Facility. The revenue metering is to be compensated for losses to the POI if the metering equipment is not located at the POI.

The revenue metering CTs and VTs are to be installed at the point(s) where the Interconnection Customer's Facility connects to the DEV-ET System. The exact location of the revenue metering CTs and VTs are to be as determined by agreement between DEV-ET and the Interconnection Customer.

The Interconnection Customer is to provide primary and redundant revenue meters with SCADA data. It is preferred that the redundant meter have a different method of telecommunications than the primary meter.

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2.5.7 End-User Facilities

Except as may be otherwise provided for in applicable tariffs or agreements, or as may be otherwise agreed by DEV-ET and the Interconnection Customer, the provisions of this section apply to all end user revenue metering whether installed by DEV-ET or the interconnected end user.


For the interconnected Facilities of end users, the revenue metering is to be installed on either the primary side or the secondary side of the Interconnection Customer's step-down transformer in accordance with the applicable interconnection agreements. DEV-ET utilizes its best engineering judgment to determine the appropriate location for the revenue metering equipment if the interconnection agreement provides DEV-ET the option to choose either the primary side or the secondary side.

If the revenue metering is installed on the primary side of the Interconnection Customer's step-down transformer, the DEV-ET's CTs and VTs are to be located on the high side of the Interconnection Customer's step-down transformer. When revenue metering is installed by the Interconnection Customer, the proposed metering installation design must be reviewed and accepted by DEV-ET prior to installation.

If the revenue metering is installed on the secondary side of the Interconnection Customer's step-down transformer, it is to be compensated for losses in the transformer. The revenue metering is to also be compensated for losses in any significant length of conductors between the metering point, the step-down transformer, and the POI.

If Interconnection Customer revenue metering is compensated, the Interconnection Customer is to provide DEV-ET with the following information:

- Certified manufacturer test data for the step-down transformer including nameplate ratings, no-load losses, load losses, exciting current, and impedance.
- Primary side voltage tap setting planned for the step-down transformer if equipped with a no-load tap changer. The transformer test data specified above is to be provided for all available taps.
- Information regarding the conductors on the primary side of the Interconnection Customer's step-down transformer, if applicable, and the secondary side including conductor type, number of conductors per phase, length, resistance, and reactance (in Ohms per conductor per 1000 feet or per mile).
- If DEV-ET specifies compensated revenue metering on the secondary side of a step-down transformer, the Interconnection Customer may install the CTs and VTs in any one of the following configurations after DEV-ET review and acceptance of the proposed design:
 - An outdoor overhead metering structure with visible break switches or disconnects on both the incoming and load sides.
- Pad mounted metering enclosure with dead-front disconnecting elbows on both the incoming and load sides.
- Switchgear metering compartment with a visible break switch or disconnect on both the incoming and load sides. The compartment must be sealable with doors on the front and back. The CTs and VTs can be picked up from the closest DEV-ET office to the interconnecting site. The Interconnection Customer must provide DEV-ET with detailed metering compartment drawings (front, side, and rear views) that show the orientation of the CTs on the bus work and indicate electrical clearances. There must be adequate

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working clearances around the CT and VT secondary terminal boxes for DEV-ET meter personnel to install the secondary wires.

For end-user Interconnection Customer’s Facility with behind-the-meter generation, DEV-ET may require the Interconnection Customer to install, own, operate, test, and maintain additional revenue metering at the output of the generation equipment, which is to meet any requirement specified in the applicable tariffs or interconnection agreements. If Interconnection Customer owned metering is installed, the Interconnection Customer is to also provide DEV-ET with the generation revenue metering data if required.

When the end user has non-conforming load, a primary revenue meter along with SCADA data is required. Non-conforming load is load of more than 50 MW that exhibits one of more of the following characteristics:

- Expected load swings of approximately 50 MW or more and ramp rates of approximately 10 MW or more per minute.
- Loads with expected daily reactive power ramp rates of 50 MVAR or more per minute.
- Loads that may create voltage flicker exceeding the limits set out in IEEE Standard 1453.
- Loads that may create harmonic current distortions exceeding the limits set out in IEEE Standard 519.

2.5.8 Telecommunications

In recognition that the coordination of the system operations by the Parties may be facilitated by the sharing of power flow and other real-time information from meters and other equipment at the Interconnection Points, the Parties may agree to cooperate on the installation and operation of data acquisition system (“DAS”) equipment including, but not limited to, remote terminal units (RTU), meters, MW/MVAR and Volt transducers, telecommunication devices, lease lines, and any related equipment at points which from time to time are to be mutually agreed upon.

If a backup telemetry system or data is required by one Party for their own use, the requesting Party is to be responsible for installing and/or maintaining the field devices and associated telecommunication system at their cost.

The following real-time operational data is to be provided to all Parties as available: three phase bi-directional energy flows (e.g., MWh, MVARh), three phase instantaneous power flows (e.g., MW, MVAR), per phase RMS voltages, and per phase RMS currents with at least two decimal points resolution is to be provided. In addition to the real-time operational data, the status of all switching devices associated with the interconnection circuit(s) are to be provided. The real-time data requirements defined in the PJM manuals, including PJM Manual 01 – Control Center and Data Exchange Requirements and PJM Manual 03 – Transmission Operations, is to be provided to PJM to fulfill its roles as Reliability Coordinator (RC), Balancing Authority (BA), and Transmission Operator (TOP).

Metering, Data, and Communications requirements between a generation Facility and PJM are resolved in the kickoff meeting between the PJM client manager and the generation owner, as described in §4.2.2 of PJM Manual 14D – Generator Operational Requirements.

For generation Facilities that interconnect to DEV-ET via generator interconnection stations, serial telemetry data exchange is required between the two facilities. The Data Exchange and Communications requirements between a generation Facility and the DEV-ET interconnection station are specified in Attachment 5, Electric Transmission Generator Interconnection Data Communication and Data Exchange Requirements.

2.6 Grounding and Safety Issues

All electrical equipment, electrical components, fences, metal buildings, protective controls, and structures are to be properly grounded and bonded. A safe grounding design must accomplish two basic functions:

- Personnel safety: Ensure that Facility personnel, their contractors and the public are not exposed to harmful step-and-touch potentials.
- Current path to earth: Provide a path for electric currents into the earth under normal and fault conditions. Under normal conditions currents do not exceed any operating and equipment limits. Under fault conditions the currents do not adversely affect the continuity of service.

Accordingly, each electrical Facility must have a grounding system or grid that solidly grounds all metallic structures and equipment in accordance with standards outlined in the latest revisions of IEEE 80, "*IEEE Guide for Safety in AC Substation Grounding*", and IEEE C2, "*National Electrical Safety Code (NESC)*". Designs must ensure that step and touch potentials and transferred voltages are limited to safe levels. Furthermore, testing must be performed to verify the integrity of the installed grounding system and ensure safe step and touch potential parameters have been met in accordance with the latest revision of IEEE 80.

Utility scale solar power plants cover large areas and present a special case for grounding. The interconnection substation for a solar power plant would follow IEEE 80, but grounding practices for the solar field may differ from IEEE 80. Therefore, it is recommended that new solar power plant interconnections include IEEE Std 2778-2020, "*IEEE Guide for Solar Power Plant Grounding for Personal Protection*", in their design.

When various switching devices are opened on an energized circuit, its ground reference may be lost if all sources are not effectively grounded. This situation may cause over voltages that can affect personnel safety and damage equipment. This is especially true when one phase becomes short-circuited to ground. Therefore, the interconnected transmission power system is to be effectively grounded from all sources.

This is defined as:

$$X0/X1 \leq 3$$

$$R0/X1 \leq 1$$

This relationship assumes $R1/X1 = 0$, which is a worst-case condition.

Interconnected generators should provide for effective system grounding of the high-side transmission equipment by means of a grounded high-voltage generation step-up transformer.

Shield wires should be considered, where applicable, to protect conductors and equipment from lightning strikes. A recommendation for maximum resistance values for all new stand-alone (not connected to a ground grid) structures carrying shield wires are as follows: 25 Ohms for structures supporting Facilities at or below 230 kV, and 20 Ohms for structures supporting Facilities from above 230 kV to 500 kV.

Safety is of utmost importance. Any work conducted within a Facility is to be performed in accordance with all applicable laws, rules, and regulations and in compliance with Occupational Safety and Health Administration (OSHA), NESC, and Good Utility Practice. Automatic and manual disconnect devices, with visible disconnect, are to be provided as a means of removing all sources of current to any Element of the power system. Only trained operators are to perform switching functions within a Facility under the direction of the responsible dispatcher or

designated person as outlined in the NESC. The Interconnection Customer and DEV-ET must agree to switching and Lock Out/Tag Out procedures that are adhered to for the safety of all personnel. DEV-ET follows its own standard operating practices and grounding procedures for safety of personnel.

2.7 Insulation and Insulation Coordination

Insulation coordination is defined by IEEE 62.82.1 as “The selection of insulation strength of equipment in relation to the voltages, which can appear on the system for which equipment is intended and taking into account the service environment and the characteristics of the available protective devices.” Insulation coordination must be designed properly both for personnel safety and to protect the electrical equipment from the harmful over-voltages resulting from faults, lightning or switching transients. An insulation design must accomplish two basic functions:

- **Electrical isolation:** Electrically isolate the maximum anticipated voltage of energized parts from supporting structures or ground.
- **Mechanical support:** Mechanically support energized parts as intended.

Surge arresters and static wires are used to safeguard the electric power equipment against harmful over-voltages. Basic Impulse Levels (BIL) for electrical equipment and high voltage substation buses are to meet or exceed DEV-ET’s standard listed below:

Equipment & Bus Nominal Voltage Rating (phase-to-phase) kV, rms	BIL – Basic lightning Impulse Insulation Level (phase-to-ground) kV, crest
115	550
138	650
230	900
500	1550

Equipment BIL shielding and surge protection is to be designed as determined by lightning and switching surge analysis to meet all applicable ANSI/IEEE standards and DEV-ET and substation engineering standards.


DEV-ET Specifications for Transmission Line Insulators include:

- TE VEP 1115 – Porcelain and Glass Insulators
- TE VEP 1117 – Suspension Type Non-Ceramic Insulators
- TE VEP 1118 – Non-Ceramic Post Type Insulators

ANSI/IEEE standards include, but are not limited to:

- ANSI C29 collection of standards – Insulators for Electric Power Lines

Interconnection Facilities to be constructed in areas with salt spray contamination or other types of contamination are to be properly designed to meet or exceed the performance of Facilities in a non-contaminated area. Typically, this involves more insulation, higher leakage distances and/or non-standard insulating components and materials.

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The following is to be submitted, as applicable, with the Customer Request Form, provided in Attachment 2, for evaluation as part of the interconnection plan:

- Surge arrester ratings
- Basic switching surge levels
- Surge arrester, conductor spacing and gap application
- Substation and transmission line insulation strength
- Protection and/or shielding schemes
- Overhead static wire location
- Equipment BIL ratings
- Insulator BIL ratings


2.8 Voltage, Reactive Power, and Power Factor Control

2.8.1 Generation Facilities

PJM is responsible for ensuring the stability and reliability of its electric transmission system. In turn, all generation Interconnection Customers are responsible for operating their units in a stable manner while those units are connected to DEV-ET's Facilities. Generator excitation and prime mover controls are key elements in ensuring electric system stability and reliability. To meet its responsibility, PJM must have the ability to establish voltage and governor control requirements for all generators connected to its system, including units connected through DEV-ET's Facilities. These requirements may vary depending on the location, size, and type of generation installed.

Generator Interconnection Customers are required to follow the current NERC and SERC standards and guides for generator operation, protection, and control.

- All synchronous generators are to be operated with their excitation system in automatic voltage control mode unless otherwise approved by PJM. PJM and DEV-ET are to be notified any time a generator control system is removed from service, or its control logic is modified. These control systems may include, but are not limited to, voltage regulators, power system stabilizers, governor, and prime mover controls.
- Generators are to maintain a network voltage or reactive power output as required by DEV-ET, with governance by PJM, within the reactive capability of the units. Generator step-up and auxiliary transformer are to have their tap settings coordinated with electric system voltage requirements.
- All new inverter-based resources (IBRs), such as wind and solar, connecting to the DEV-ET system must be able to provide leading and lagging reactive power. This includes, but is not limited to, nighttime voltage support. The duration of the voltage support will not be limited by any facility component. Prior to commissioning, any logic associated with voltage support capability must be enabled and turned ON to allow an operator to readily control the Automatic Voltage Regulator (AVR) setpoint via the SCADA system. During commissioning, testing will be done to confirm that the IBR can supply continuous voltage support during daytime hours, nighttime hours and the transition from day to night or night to day.
- For battery storage systems, testing of charging, discharging and idle modes will be done to show that the system can supply voltage support. Requirements for the DEV-ET

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SCADA voltage setpoint control function are found in Attachment 5, Generator Interconnection Data Communication and Data Exchange Requirements.

- Temporary excursions in voltage, frequency, and real and reactive power output that a generator is to be able to sustain is to be defined and coordinated on a regional basis.
- Voltage regulator controls and limit functions (such as over and under excitation and volts/hertz limiters) are to coordinate with the generator’s short duration capabilities and protective relays.
- Prime mover controls (governors) are to operate with appropriate speed/load characteristics to regulate frequency.

All new generation interconnection requests and generators seeking to increase their output must adhere to the power factor requirements documented in Section 4 of the PJM Manual 14G, “*Generation Interconnection Requests*”. PJM will perform a System Impact Study that will determine the reactive power compensation requirements for asynchronous generators.


All interconnected generation must meet the following criteria:

- All new synchronous generators connecting to the transmission system are to be designed to deliver continuous rated power with a power factor in the range of 0.95 leading to 0.90 lagging at the high side of the facility substation transformer.
- All new wind-powered and non-synchronous generators (IBRs) connecting to the transmission systems are to be designed to deliver continuous rated power with a power factor in the range of 0.95 leading to 0.95 lagging at the high side of the facility substation transformer.
- All new intermittent resources (wind and solar) connecting to the transmission system will be studied for reactive power capabilities in a manner that considers the variability of the entire intermittent generation fleet within the DEV-ET footprint. DEV-ET will provide input and support these studies as needed. The System Impact Study for asynchronous, intermittent generation will consider the generator under study as well as variability of the entire intermittent generation fleet when determining if the voltage fluctuation criteria is met.
- Voltages at the Point of Interconnection of any generating station should not vary more than 1.0% for expected changes in generation output caused by fluctuations in the prime mover output.
- New variable generation resources that cannot meet the 1% voltage deviation criteria provide dynamic reactive compensation as specified in the PJM System Impact Study, with DEV-ET support and studies incorporated.

Specific requirements for voltage regulators, power system stabilizers, governor controls, and remote control and telemetry of such devices are determined during the System Impact Study. These specific requirements for a generator will be part of the Interconnection Service Agreement. (PJM Manual 14A, Section 5: Summary of Agreements).

2.8.2 Transmission Facilities

The Transmission System must be capable of moving electric power from areas of generation to areas of load under a wide variety of expected system conditions. Adequate reactive power supplies are of paramount importance to the capability of the Transmission System to reliably support a wide variety of transfers. All new Transmission Facilities must be designed to support

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system voltage when the transmission system is heavily loaded and to prevent excessively high voltages when the transmission system is lightly loaded.

2.8.3 End-User Facilities

The voltage variation limitations for interconnections with End-User Facilities are as stated in the applicable tariff or agreement. End-User Facilities connected directly to the Transmission System should plan and design their systems to operate at close to unity power factor to minimize the reactive power burden on the Transmission System.

2.9 Power Quality

New interconnections shall not adversely impact the power quality of the power system. As such, the customers will be responsible for adding the equipment necessary to eliminate, or minimize, the adverse impact identified by DEV-ET.

2.9.1 Flicker Requirements

As discussed in IEEE Standard 1453, Flicker will be measured at the Point of Common Coupling (PCC) using an instrument that is compliant with International Electro Technical (IEC) 6100-4-15.

The flicker measured at the PCC is to be 0.8 or less for the short-term flicker (Pst) and 0.6 or less for the long-term Flicker (Plt). Based on a probability distribution calculated for a one-week period, the Pst and Plt values measured are not to be exceeded more than 1% of the time.

2.9.2 Harmonic and Inter-Harmonic Requirements

Harmonic levels are measured at the PCC with an instrument that can take individual samples of voltage and current waveforms and determine the probability distribution of the individual harmonic levels for both the current and the voltage. Harmonic distortion levels at the PCC should meet the requirements contained in the latest revision of IEEE Standard 519.

In addition, the individual inter-harmonic currents are to be limited to 25% of the values in IEEE Standard 519 and the THD (Total Harmonic Distortion) and TDD (Total Demand Distortion) calculation is to include the inter-harmonic components. The Inter-harmonics are to be calculated in 10 Hz increments. The current distortion levels specified in IEEE Standard 519 is to not exceed more than 5% of the time based on a probability distribution calculated for a one-week period.

2.10 Equipment Ratings

Electrical equipment and associated interconnected Facilities are to be capable of safely interrupting the worst-case short circuit faults calculated for the protection zone.

All current-carrying equipment and devices are to be designed to carry the maximum loads that are predicted and used in load flow analysis, tested against all applicable NERC Reliability Standards, PJM Transmission Planning Criteria and DEV-ET Planning Criteria. Loads exceeding nameplate or normal design capacities are acceptable only when allowed by manufacturers' design documentation or standard industry practice or by DEV-ET's Facility Rating Methodology (FRM).

Circuit breakers and disconnect switches are to be designed and tested according to the latest IEEE C37 collection of standards. Power transformer and Instrument transformers are to be designed and tested according to IEEE C57 standards. Rigid bus structures are to be designed to meet the latest revision to IEEE 605. Current carrying conductors and tubing are to be braced and supported for the expected worst case, short circuit currents, ice loading and wind loading. For overhead line Facilities, ground clearance is to be maintained according to the latest IEEE

C2, “National Electrical Safety Code (NESC)”. All Facilities designed for voltages greater than 230 kV are considered Extra High Voltage (EHV) and designed accordingly.

Equipment Basic Impulse Levels (BIL), shielding, and surge protective device application must meet requirements as determined by the latest IEEE C62 standards. DEV-ET provides the BIL for the system in the interconnection area. Also, equipment must meet all applicable ANSI/IEEE standards and specifications communicated by PJM and DEV-ET. BILs for electrical equipment and high voltage substation buses are to meet or exceed DEV-ET’s standard listed below.

Equipment & Bus Nominal Voltage Rating (phase-to-phase) kV, rms	BIL – Basic lightning Impulse Insulation Level (phase-to-ground) kV, crest
115	550
138	650
230	900
500	1550

2.11 Synchronizing of Facilities

Synchronizing equipment consisting of potential devices and associated protective relay and controls is required on Facilities where energy can be sourced on both sides of an interconnection circuit breaker. The Interconnection Customer is to not synchronize with the Transmission System prior to obtaining approval from DEV-ET.

The following explains the various synchronizing options.

2.11.1 Generation Facilities


Live line, dead bus (LLDB) control is used in the interconnection circuit breaker reclosing scheme when generation Facilities are connected to DEV-ET. The circuit breaker cannot be closed unless the generation side has zero voltage. The interconnection circuit breaker should not be used to synchronize a generator to the Transmission System. Instead, the generation Facilities should have their own synchronizing Facilities. In the event a generation Interconnection Customer’s Facility becomes disconnected from DEV-ET’s system, it is to remain disconnected until system voltage and frequency are within an established range. In all scenarios, DEV-ET is to retain operational control of the interconnection breaker.

2.11.2 Interconnected and Separate Systems for Generators

The Interconnection Customer may elect to run its generator in parallel (interconnected) with DEV-ET or as a separate system with the capability of nonparallel load transfer between the two independent systems.

Parallel System

A parallel system is one in which the Interconnection Customer’s generation equipment can be connected to DEV-ET’s system resulting in a transfer of power between the two systems. A consequence of such parallel operation is that the parallel generator becomes an electrical part of the DEV-ET system, which must be considered in the operation and protection of DEV-ET’s Facilities. The general and specific requirements for parallel generation installations are discussed in this document.

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Synchronizing equipment consisting of potential transformers and associated protective relaying/controls is required on Facilities where energy can be sourced on both sides of an interconnection circuit breaker. This equipment serves the following purposes:

- Verifies the voltages on both sides of a circuit breaker fall within set tolerances, which must meet DEV-ET’s approval, as to the magnitude and phase angle established by system conditions
- Supervises the closing and automatic reclosing of the circuit breaker
- Prevents the closing of the circuit breaker when the two systems are out of sync Voltage magnitudes, phase angles, and frequency constraints are to be determined on a case-by-case basis.

Separate System with Non-parallel Load Transfer Capability

A separate system is one in which there is no possibility of delivering energy to the DEV-ET system from the Interconnection Customer’s equipment. The Interconnection Customer may maintain the capability of transferring load between the two systems, but such transfer must be accomplished in an open-transition or nonparallel mode. This can be accomplished by either an electrically or mechanically interlocked switching arrangement that precludes both the switch connecting the load to DEV-ET’s system and the switch connecting the load to the Interconnection Customer’s generation being in the closed position simultaneously. If the Interconnection Customer has a separate system, the Interconnection Customer is to not operate the system until DEV-ET has verified that the transfer scheme meets the nonparallel requirements. This verification is accomplished by review and approval of drawings and equipment specifications by DEV-ET and, if DEV-ET so elects, by field inspection of the transfer scheme. DEV-ET is not responsible for approving the Interconnection Customer’s generation equipment and assumes no responsibility for its design or operation.

2.11.3 Maintenance Coordination


2.11.3.1 Testing

DEV-ET requires interconnecting entities with protection systems which coordinate with DEV-ET network protection systems to have a documented maintenance program for those systems in accordance with NERC Reliability Standard PRC-005 requirements. Documentation of the maintenance program is to be supplied to DEV-ET upon request. Additionally, the interconnecting entity, on maintenance intervals identified within their documented program and following any apparent malfunction of the protection equipment, is to perform and document both calibration and functional trip tests of its protection equipment as outlined within its maintenance program. Customer is to maintain evidence of such activities and make them available to DEV-ET upon request.

2.11.3.2 Coordination

DEV-ET may remove its lines and associated equipment from service for testing of relays and maintenance of lines or substations in accordance with its maintenance program. The Interconnection Customer, DEV-ET, and PJM coordinate for these planned outages.

The interconnection parties agree to confer regularly to coordinate the planning, scheduling, and performance of preventative and corrective maintenance on the Interconnection Customer’s Facility, the Interconnection Facilities and associated Facilities owned by DEV-ET. The Interconnection Customer must coordinate its approach and schedule for maintenance and testing with DEV-ET to ensure the reliability of the BES.

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2.11.3.3 Generator Interconnection

On occasion, the generation Interconnection Customer may not be allowed to operate in parallel with the DEV-ET or distribution system. A generator Interconnection Customer with multiple interconnection points may be permitted to operate only in parallel with specific lines so DEV-ET can perform “live line maintenance” on the Facilities serving the generator Interconnection Customer. The generator Interconnection Customer, DEV-ET and, as needed, PJM, coordinate with these conditions and requests.

2.11.4 **Operational Issue (Abnormal Frequency and Voltage)**

PJM is the Transmission Operator for DEV-ET System. The Interconnection is operated consistent with PJM requirements and procedures. Specific transmission conditions and procedures for operation of Transmission Facilities (defined by PJM) within PJM are found in PJM Manual 03 – Transmission Operations on the PJM website (www.pjm.com).

2.11.5 **Load Shed Program as Required by PJM**

The transmission system is designed to automatically activate a load-shed program as required by PJM in the event of an under-frequency system disturbance. A generation Interconnection Customer is to implement under-frequency and over-frequency relay set points for the generation Interconnection Customer as required by PJM to ensure ‘ride through’ capability of the transmission system. The generation Interconnection Customer Facility is to stay connected to and synchronized with the Transmission System during system disturbances within a range of under-frequency and over-frequency conditions, in accordance with Good Utility Practice. For more information on ride through requirements of inverter-based generation, see Attachment 4, DEV Bulk Power System Generator Ride-Through Requirements. In addition, additional information is found in PJM Manual 14D – Generator Operational Requirements. The response of a generation Interconnection customer’s Facility to frequency deviations of predetermined magnitudes; both under-frequency and over-frequency deviations are studied and coordinated with PJM in accordance with Good Utility Practice. Additional information is found in PJM Manual 14D – Generator Operational Requirements. Inspection requirements for new or materially modified existing Interconnections.


DEV-ET has established inspections as a component of its maintenance program for DEV-ET’s owned assets. DEV-ET may require right of access to the Interconnection Customer’s Facility for purposes of conducting inspections: to include observing tests, visual inspections, and auditing maintenance and testing records.

Additionally, DEV-ET may require right of access to conduct initial (pre-operational) inspection and/or require copies of pre-operational procedures and test reports.

Each party is to, at its own expense, have the right to observe the testing of any of the other party’s metering equipment whose performance may be expected to affect the accuracy of the observing party’s telemetry and revenue. If requested, each party is to notify the other in advance of metering or other equipment testing and maintenance and may have a representative attend and be present during such testing.

If DEV-ET identifies any deficiencies, defects, or inconsistencies of the Interconnection Customer’s Facility that may adversely affect the reliability of the bulk power system and/or potentially constitute a compliance concern for DEV-ET, then DEV-ET is to provide notice to the Interconnection Customer outlining the concern and the suggested corrective action. Customer is to provide DEV-ET with a corrective action plan resolving identified concern(s).

If Interconnection Customer observes any deficiencies, defects, or inconsistencies of its Interconnection Facility that may adversely affect the reliability of the bulk power system and/or

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potentially constitute a compliance concern for DEV-ET, then the Customer is to provide notice to DEV-ET outlining the identified concern and the corrective actions that are taken to resolve the concern.

2.11.6 **Communications and Procedures During Normal and Emergency Operating Conditions**

Complete, precise, and timely communication is an essential element for maintaining reliability and security of a power system. Under normal operating conditions, the major link of communication with various interconnects is to be by telephone lines. DEV-ET and the Interconnection Customer is to maintain communications which are to include, but not be limited to exchanging up-to-date information regarding:

- Contact information for maintenance personnel
- Maintenance schedules
- Meter tests
- Relay tests
- System paralleling or separation
- Scheduled or unscheduled shutdowns
- Equipment clearances
- Periodic load reports
- Tagging of Interconnection interrupting devices
- Billing
- Other routine communication

In case of emergency or abnormal operating conditions, various communication channels may be used depending on the interconnect category. Emergency telephone numbers should be agreed upon by both parties prior to the date of initial Interconnection. Each Interconnection party is to notify the other parties promptly when it becomes aware of an emergency condition that may be expected to affect operation of the Interconnection Customer's Facility, the Interconnection Facilities, the DEV-ET Interconnection Facilities, or the Transmission System.

2.11.7 **Generation and Transmission Interconnection Customer Obligations**

Generation and transmission Interconnection Customers are to install and maintain satisfactory operating communications with PJM's system dispatcher or its other designated representative and with DEV-ET system dispatcher. Generation and transmission Interconnection Customers are to provide standard voice line, dedicated voice line, and facsimile communications at their Facility control room through use of the public telephone system. Generation and transmission Interconnection Customers also are to provide and maintain backup communication links as specified by both PJM and DEV-ET for use during abnormal conditions. Satellite phones compatible with PJM and DEV-ET equipment should be available for emergency communications. Generation and transmission Interconnection Customers further are to provide the dedicated data circuit(s) necessary to provide Interconnection Customer data to PJM and DEV-ET as necessary to conform to applicable technical requirements and standards.

2.12 Transmission Line Connections – Generation

Transmission Facilities may be used for providing service to generation developers when the use of distribution feeders is not practicable. The use of transmission Facilities should be considered for the following conditions:

- All generating Facilities over 20 MW
- Locations remote from distribution Facilities
- Remote locations where distribution Facilities are not adequate.

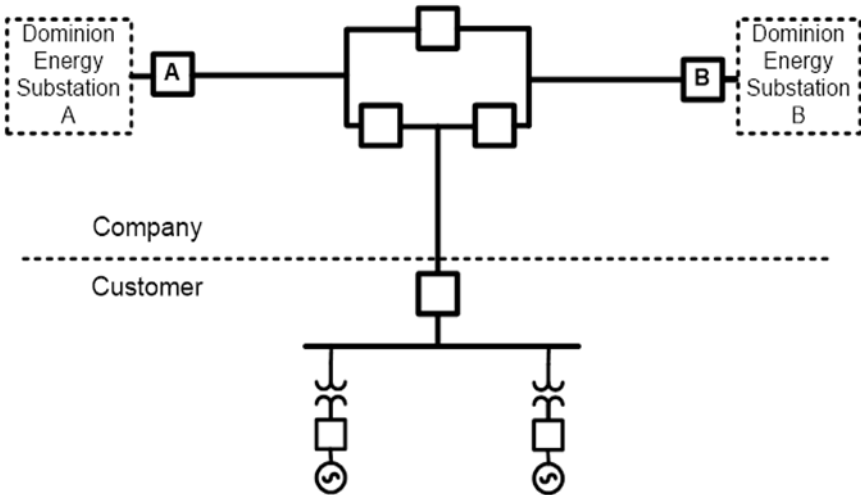
For Interconnection to the 500 kV network, the preferred minimum generation capability at a single point of connection is 500 MW. The Interconnection of generating plants on the 500 kV network below this level are permitted for cases where no other lower transmission voltage option is available.

The descriptions and figures in this section are typical from an Interconnection standpoint; they are subject to further modification as necessary to comply with Attachment 3 – DEV Generator Interconnection Protection Requirements, Section 3 – Interconnection Protection Requirements.

2.12.1 Single Circuit Interconnection to a Transmission Line

In general, the arrangement shown in Figure 1 can be used to interconnect a new generating Facility of any size that will be located within one mile of the transmission system. The arrangement can also be used to interconnect facilities of 500 MW or less that are greater than one mile from the Transmission System. With this arrangement, loss of generation does not interrupt flow on the Transmission System and loss of a transmission line does not result in loss of generation. However, final System Protection requirements along with Interconnection substation requirements are to be based on the reliability impact conducted through the PJM Interconnection Queue process as defined in PJM Manual 14C – Generation and Transmission Interconnection Facility Construction. The customer should reserve property for construction of the DEV-ET -owned Interconnection station.

Figure 1 – Generator Connecting to Adjacent Transmission Line



Note, violation(s) of DEV-ET Planning Criteria found in Section C of Attachment 1, may require a four-breaker ring bus.

2.12.2 Transmission Interconnections Located Remote from a Transmission Line

If the proposed Generating Facility is greater than 500 MW and located more than one mile from an existing transmission line, then the proposed arrangement shown in Figure 2 or Figure 3 could be used. With these arrangements, the loss of generation does not interrupt flow on the Transmission System and loss of a transmission line does not result in loss of generation. Arrangement A, shown in Figure 2, places the interconnection substation next to the transmission line. Arrangement B, shown in Figure 3, places the interconnection substation next to the generation site.

DEV-ET Planning criteria outlined in Section C of Attachment 1 may require a four-breaker ring bus. The customer should reserve property for construction of the DEV-ET owned Interconnection station.

The final System Protection requirements along with Interconnection substation requirements are to be based on the reliability impact assessment conducted through the PJM Interconnection Queue process as defined in PJM Manual 14C – Generation and Transmission Interconnection Facility Construction.

Figure 2 – Arrangement A for Large Generation Facility Over 1-Mile from Transmission Line

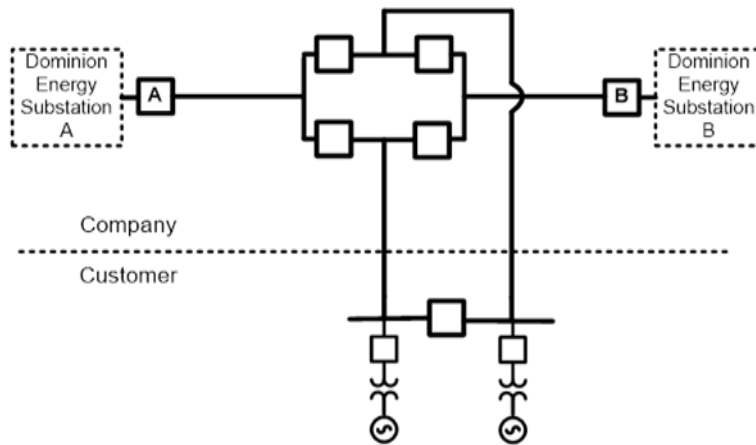
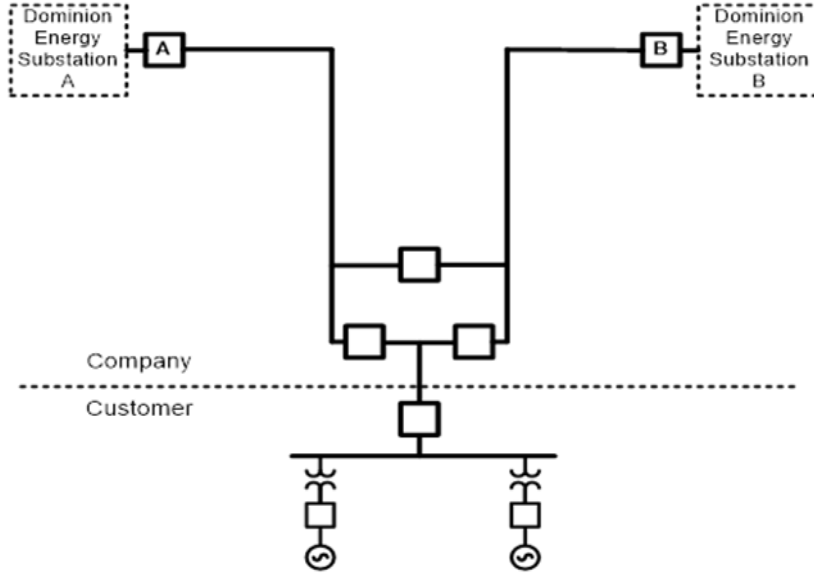


Figure 3 – Arrangement B for Large Generation Facility Over 1-Mile from Transmission Line



2.12.3 Interconnection to Radial Transmission Line or Radial Transmission Tap

A proposed generating Facility may be connected to a radial transmission line. A radial transmission line is defined as a single line that has one transmission source and does NOT tie to any other transmission network source (line or substation).

As shown in Figure 4, Figure 5 and Figure 6 a proposed generating Facility may be connected to a transmission tap line portion of a network transmission line. This is subject to protection requirements documented in Attachment 3, “DEV Generator Interconnection Protection Requirements”, Section 3, “Interconnection Protection Requirements”.

Figure 4 – Connection to a Radial Transmission Line

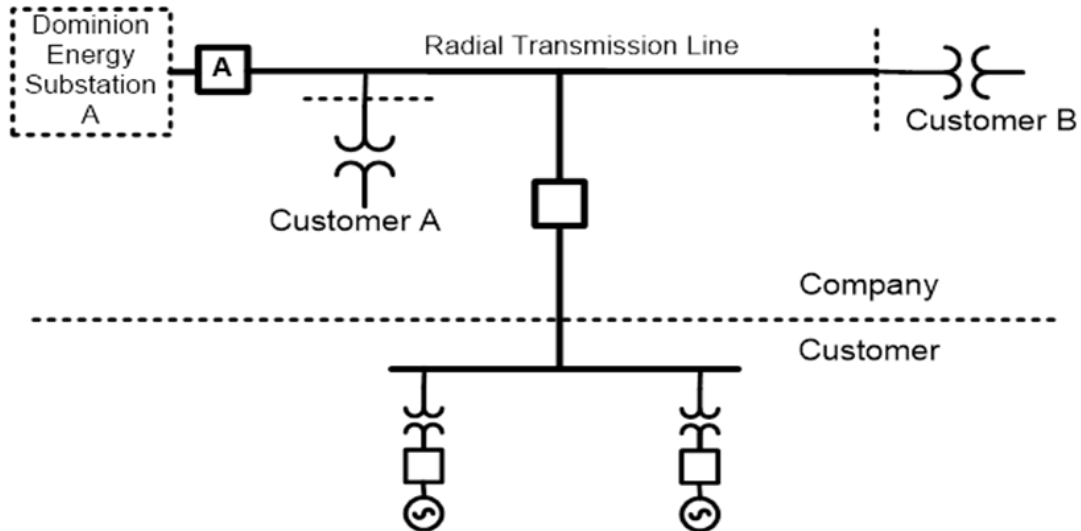


Figure 5 – Connection to a Radial Transmission Line with a Line Tap

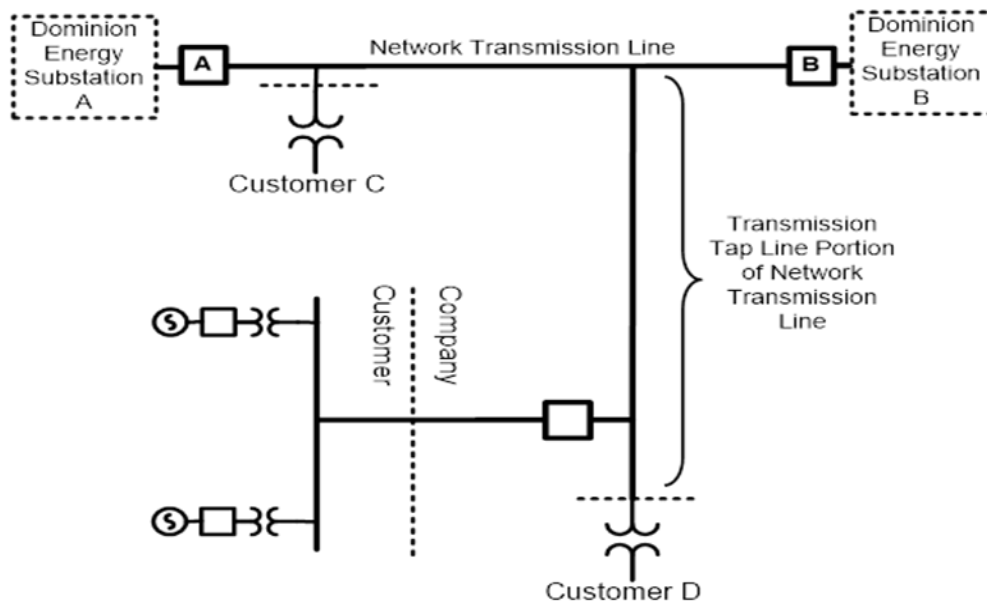
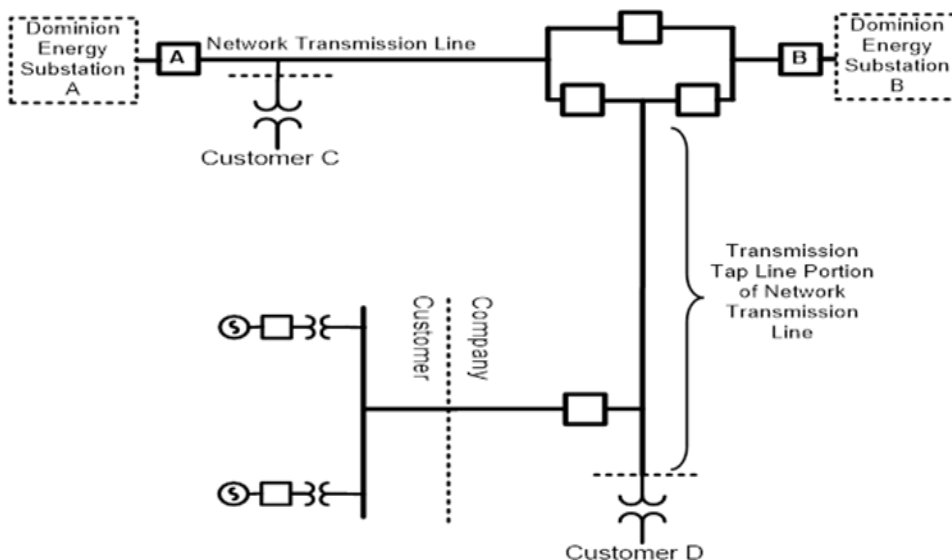


Figure 6 – Connection to a transmission line Using a Ring Bus and a Line Tap



2.12.4 Isolation Device

A visible-break isolation device will be installed between DEV-ET and the generator. DEV-ET will own the device. In the case of a Gas-Insulated Substation (GIS), the generator interconnection Customer will consult with DEV-ET to determine an alternative means to provide DEV-ET workers with a method to confirm that the generation substation is not connected to the DEV-ET system.

2.12.5 Substation Interconnection Requirements

All generation interconnection substation designs include all switches and devices required to permit maintenance of all breakers and transmission lines without the loss of the ability to use the generation capacity when required. Small units can be bussed together behind breakers unless reliability studies indicate issues. For more information, refer to Attachment 6, "Generation Interconnection Substation Technical Requirements".

2.12.6 Transmission Interconnection Breakers

If new transmission lines are required by the addition of generator capacity at a new or existing power station, the breaker arrangement at the existing substation determines both the number of breakers and the breaker arrangement required for the Interconnection. Line terminations that result in a four-breaker or less ring bus are acceptable. If more than a four-breaker ring bus is required, a breaker and a half arrangement would be used for reliability considerations.

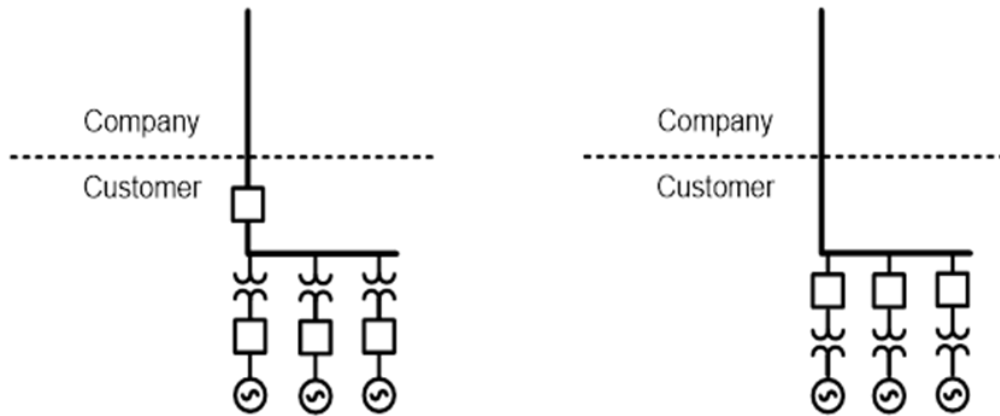
2.12.7 Generation Interconnection Breakers

Figure 7 shows two possible circuit breaker arrangements: low side circuit breakers on the generators with a single high side circuit breaker on the transmission line and high side circuit breakers on the generators. Both arrangements provide similar protection.

The final System Protection requirements along with Interconnection substation requirements are to be based on the reliability impact conducted through the PJM Interconnection Queue process

as defined in PJM Manual 14C – Generation and Transmission Interconnection Facility Construction.

Figure 7 – Potential Circuit Breaker Arrangements for Generation Substations

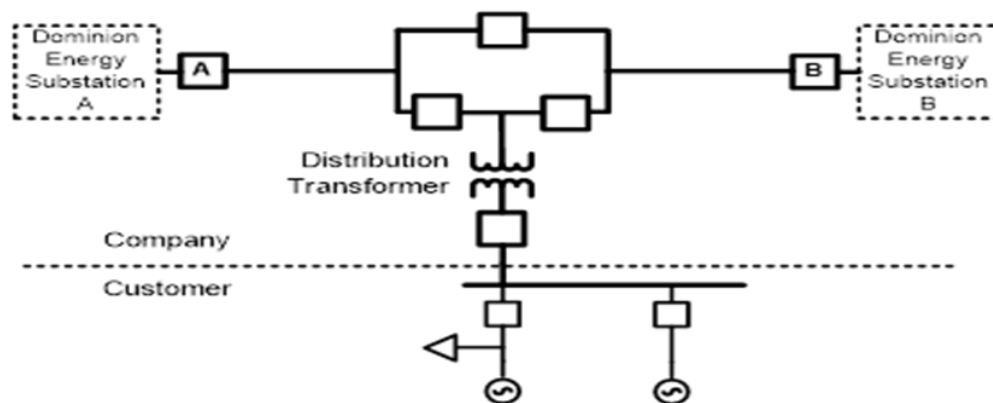


2.12.8 Interconnection Requirements for Distribution Connected Generation.

The Distribution Connected Generation is defined as a generator who is requesting connection to distribution Facilities serving retail customers (excluding the station service load for the respective generator).

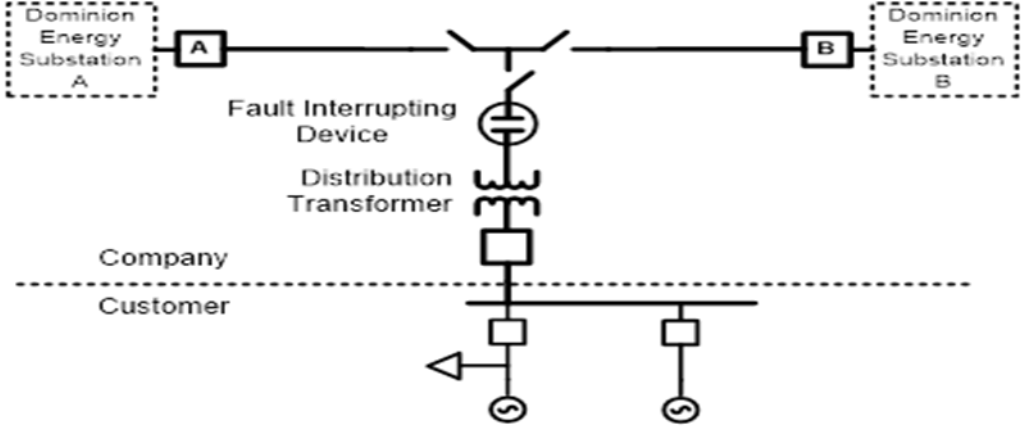
Distribution connected generation resources where the aggregate nameplate rating of all the generating resources (dispersed generation resources) is greater than 100 MVA, require a three-breaker ring at the point of connection to the transmission system. Figure 8 shows an example of generation connecting to the distribution system through a distribution transformer.

Figure 8 – Distribution Connected Generation Greater Than 100 MVA



Distribution connected generation resources where the aggregate nameplate rating of all the generating resources (dispersed generation resources) is less than 100 MVA can be connected behind a single interrupting device (circuit breaker or circuit switcher).

Figure 9 – Distribution Connected Generation Less Than 100 MVA



2.13 End User Facilities (Load Interconnection)


Transmission Facilities may be used for providing service to commercial, industrial, municipal, cooperative and cogeneration customers when the use of distribution feeders is not practicable. The use of transmission Facilities should be considered for the following conditions:

- All loads over 20 MW
- Locations remote from distribution Facilities
- Remote locations where distribution Facilities are not adequate
- Loads with nonstandard voltage requirements
- Loads having large surge requirements

The following are minimum load levels within the ten-year planning horizon for the direct Interconnection of loads to existing transmission lines:

- 500 kV – Reserved for bulk power transfers
- 230 kV – 30 MW
- 138 kV – 20 MW
- 115 kV – 20 MW

The interconnection of loads below these levels are permitted after a thorough planning analysis concludes that the cost and reliability of distribution alternatives are clearly inferior to the overall cost and reliability of a transmission Interconnection which includes, without limitation, considerations of any transmission reliability or operational concerns that may arise from adding the transmission Interconnection. For consideration of an interconnection of loads below the specified levels, the requesting party is to prepare documentation explaining and supporting why distribution alternatives are inferior and must supply additional documentation which may require DEV-ET to undertake its own analysis.

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The feasibility of serving customers direct from the transmission along with determining the final recommended transmission Interconnection Facilities requires a comprehensive study and coordination. Factors to be considered prior to agreeing on a customer connection are as follows:

- Economics of distribution versus transmission alternates
- Customer parallel generation
- Transmission line tap or loop length
- Economics of radial line versus looping even when typical thresholds (e.g., length, load level) are not met
- Mitigation of economic risk in the event actual load varies materially from planned load
- Customer transformer characteristics
- Customer switching
- Effect on protective relaying at remote terminals
- Problems of large through power on looped lines
- Extent of customer Facilities

In general, a tap line more than one mile requires a terminal station. If the tap line is long enough to require a terminal substation, a three-breaker or four-breaker ring bus may be required. With these arrangements, loss of line to the customer does not interrupt flow on the Transmission System and loss of a transmission line does not result in loss of service to the customer. The total projected load and MW-Mile exposure are also factors to be taken into consideration. The final number of breakers and breaker arrangement is however based on the specific interconnection request and reliability impact on Transmission System.

2.13.1 ***Tapping Line for Loads Below 100 MW***

A transmission line tap, as shown in Figure 10, can be used to interconnect a proposed customer Facility when the distance from the tap point to the load substation is one mile or less. For this arrangement, the company installs necessary system protection equipment and associated components at the customer’s Facility.

A transmission line tap, as shown in Figure 11 can be used to interconnect a proposed customer Facility when the distance from the tap point to the load is greater than one mile. A three-breaker or four-breaker ring bus may be required. For this arrangement, the company installs all necessary equipment at the Interconnection substation at or near the transmission line.

The final System Protection and Interconnection substation requirements communicated to the customer are to be based on the site-specific detailed reliability impact as determined by DEV-ET.

Figure 10 – Tapped line for less than 100 MW, less than 1-Mile

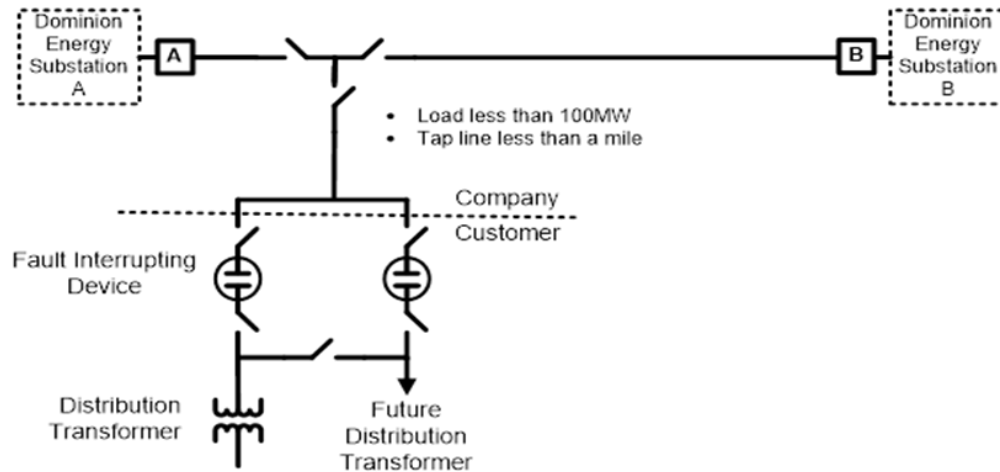


Figure 11 – Tapped line for less than 100 MW, more than 1-mile, less than 700 MW-Mile

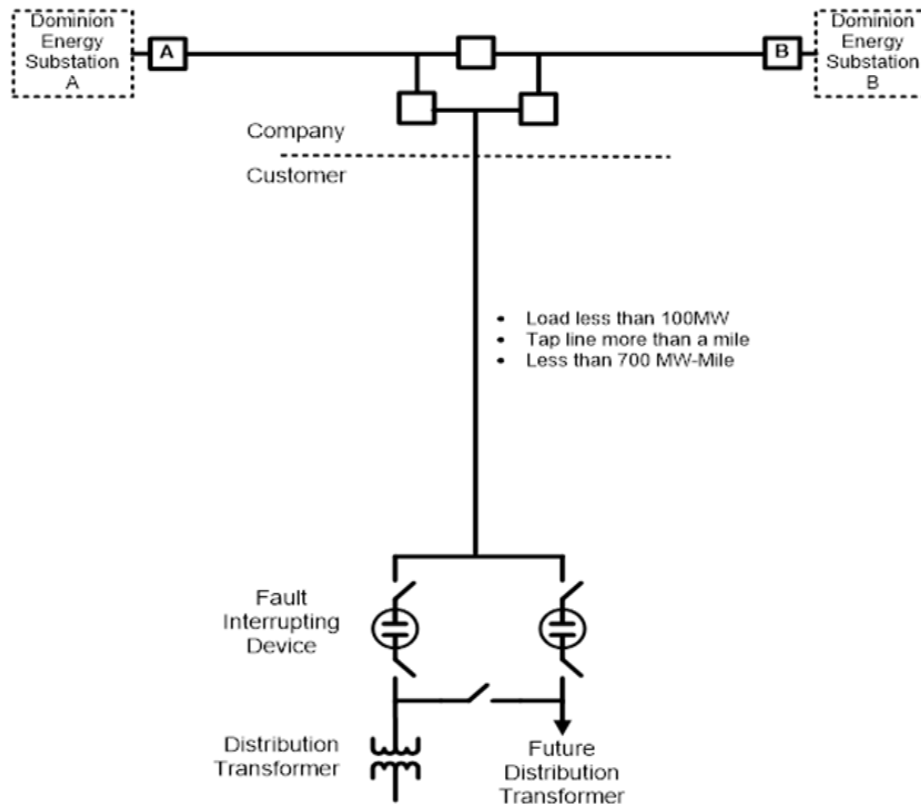
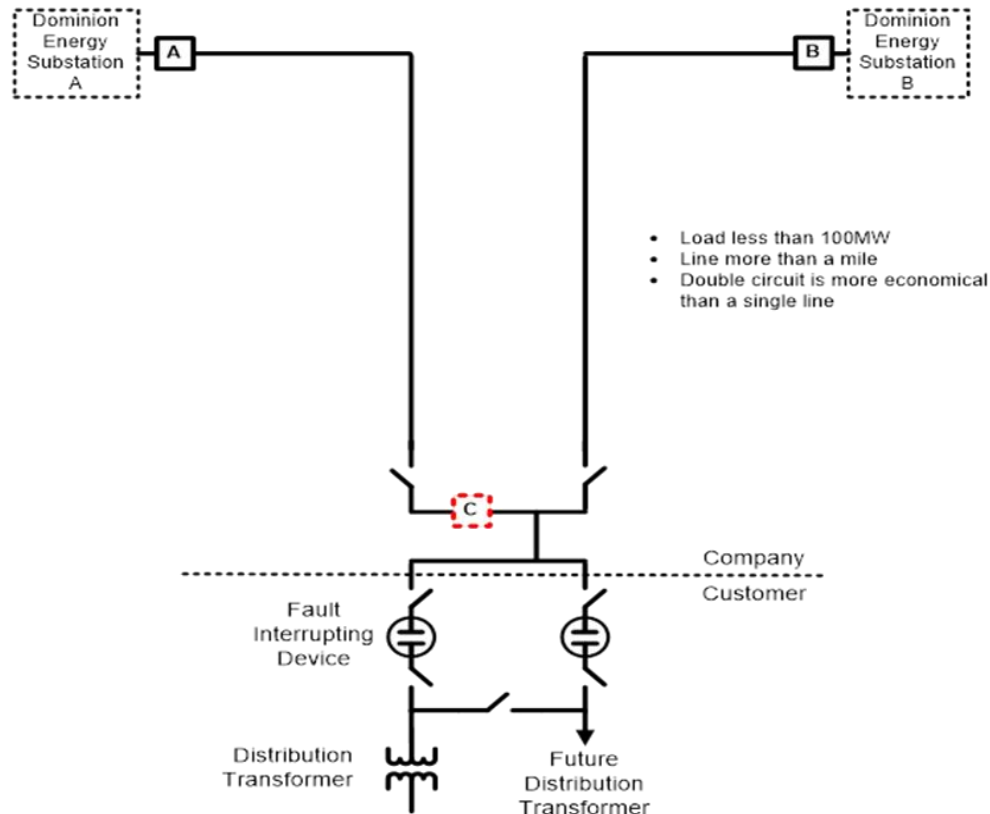


Figure 12 – Tapped line for less than 100 MW, more than 1-Mile, two feeds



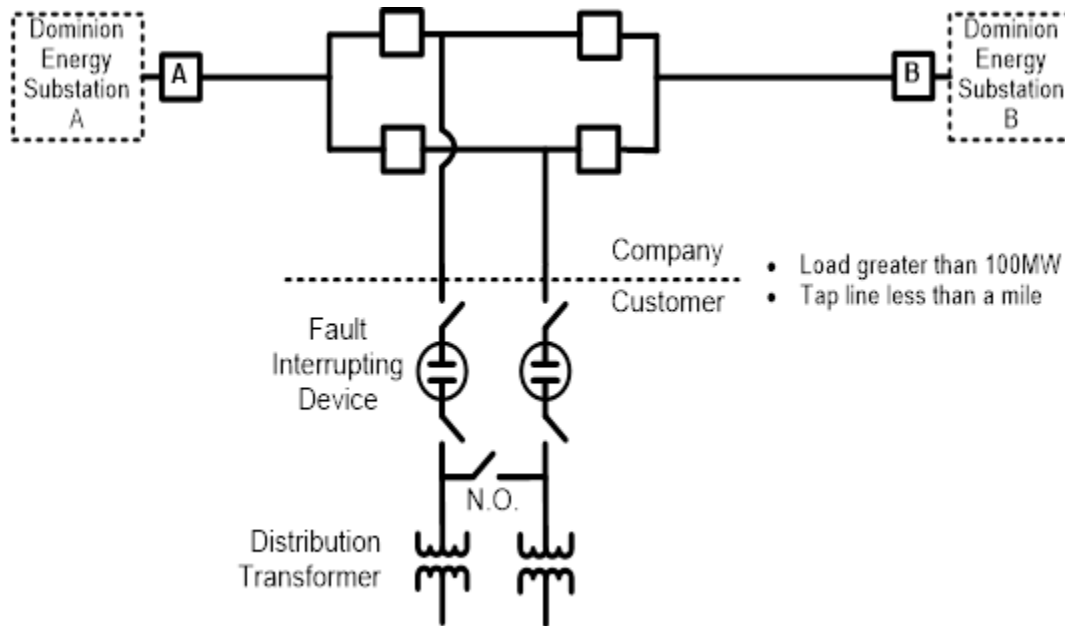
A transmission line tap, as shown in Figure 12, can be used to interconnect a proposed customer Facility of less than 100 MW and when it is more economical to build double circuit rather than a single line. The customer may reserve property for the DEV-ET owned Interconnection station if one is required.

The addition of breaker “C” may be required to limit the number of direct-connect loads (tapped Facilities) to four, or as otherwise required based on detailed System Protection and Interconnection substation assessments.

2.13.2 Tapping Lines for Loads 100 MW and Greater

The addition of customer load more than 100 MW should be connected to the Company’s Transmission System as shown below in Figure 13 and Figure 14. When available, 230 kV transmission lines are the preferred voltage level to connect loads greater than 100 MW.

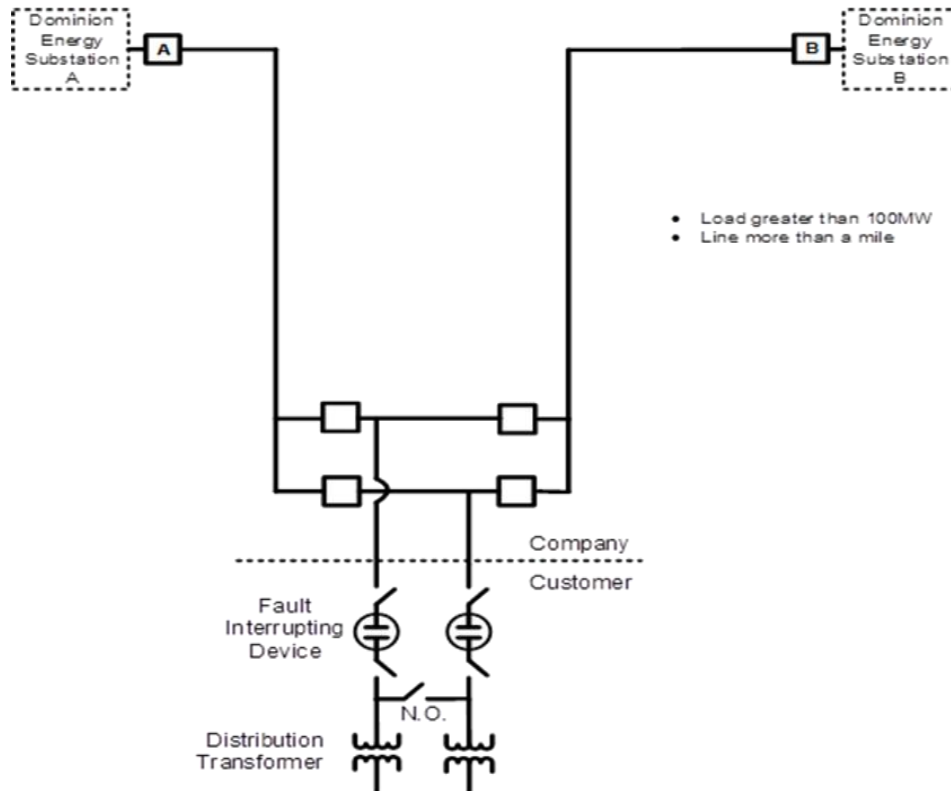
Figure 13 – Tapped line for greater than 100 MW, less than 1-Mile.



A four-breaker ring bus arrangement as shown in Figure 13 can be used to interconnect a proposed customer Facility of 100 MW or greater having two customer transformers, or to address a specific violation of the NERC standard outlined in Section C of Attachment 1. For cases in which there is only one customer transformer, a three-breaker ring bus may be acceptable. With either arrangement, loss of line to the customer does not interrupt flow on the Transmission System and loss of a transmission line does not result in loss of service to the customer.

The final System Protection and Interconnection substation requirements communicated to the customer are to be based on the site-specific detailed reliability impact as determined by DEV-ET. The customer could reserve property for construction of the DEV-ET-owned Interconnection station if customer parcel is adjacent to or in very close proximity of transmission right of way.

Figure 14 – Tapped line for greater than 100 MW, more than 1-Mile.



As an alternative to constructing a switching station at the tap point, the transmission line can be cut and looped in and out to a switching station located adjacent to the customer station as shown in Figure 14. This arrangement can have its advantages since acquiring land and permitting a new station at the tap point would not be required. The customer should reserve property for construction of the DEV-ET owned Interconnection station.

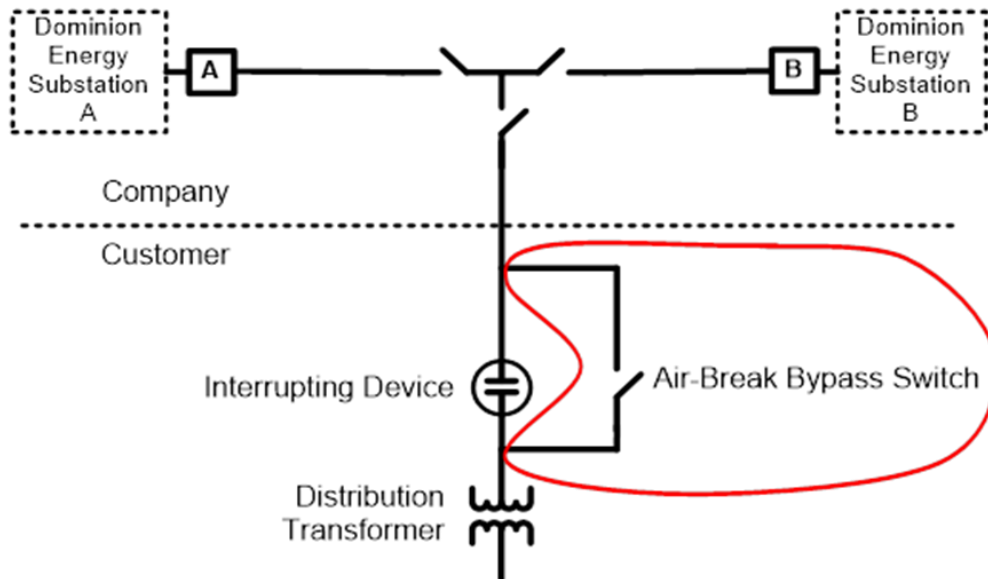
A four-breaker ring bus arrangement as shown in Figure 14 can be used to interconnect a proposed customer Facility of 100 MW or greater having two customer transformers, or to address a specific violation of the NERC standard outlined in Section C of Attachment 1. For cases in which there is only one customer transformer, a three-breaker ring bus may be acceptable. With either arrangement, loss of line to the customer does not interrupt flow on the Transmission System and loss of a transmission line does not result in loss of service to the customer.

2.14 Prohibited Arrangements and Allowable Alternatives

DEV-ET **does not** allow by-pass switches around primary interrupting devices on the customer's distribution transformer at the point of Interconnection as shown in Figure 15. DEV-ET's current system protection principles require that each system Element, (line, transformer, bus, etc.) always have primary relay protection in service when the Element is energized and placed in service. This ensures that all Elements have adequate protection for safe and reliable operation of the Transmission System and are ready to remove the Element from service should a fault

occur. This is even more critical in cases like distribution tapped transformers where upstream line protection cannot provide backup coverage. The use of an air-break bypass switch would expose customer's personnel and equipment in an unprotected zone. This places risk to the BES' integrity as well as impacting all other customers served by the same transmission line.

*Figure 15 – **Prohibited** by-pass switch.*



2.14.1 Allowable Sample Alternatives

A parallel circuit switcher arrangement as shown in Figure 16 provides a fully redundant capability. Another approach is the fused bypass as depicted in Figure 17.

The exact design, system protection configuration and operating arrangement may be customized as necessary, subject to review and approval by both DEV-ET and the Customer.

Figure 16 – Allowable alternative with interrupting devices

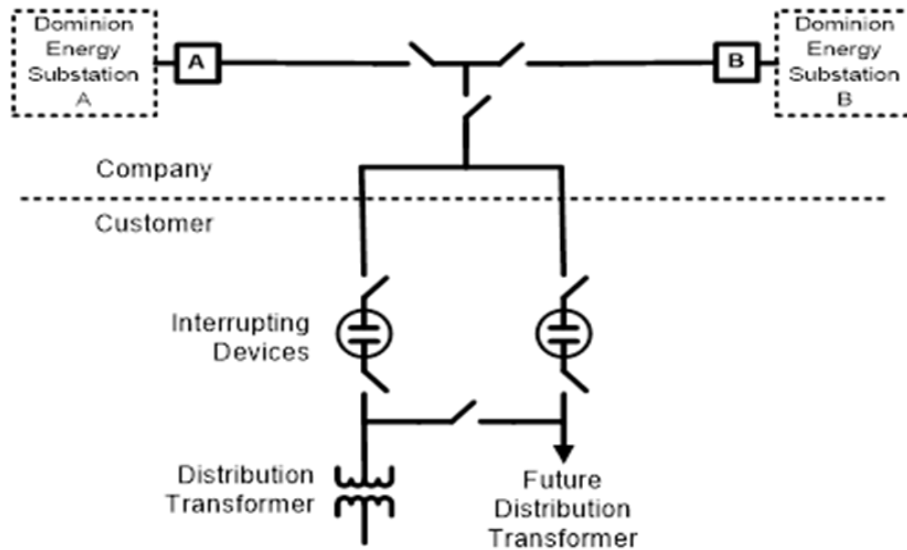
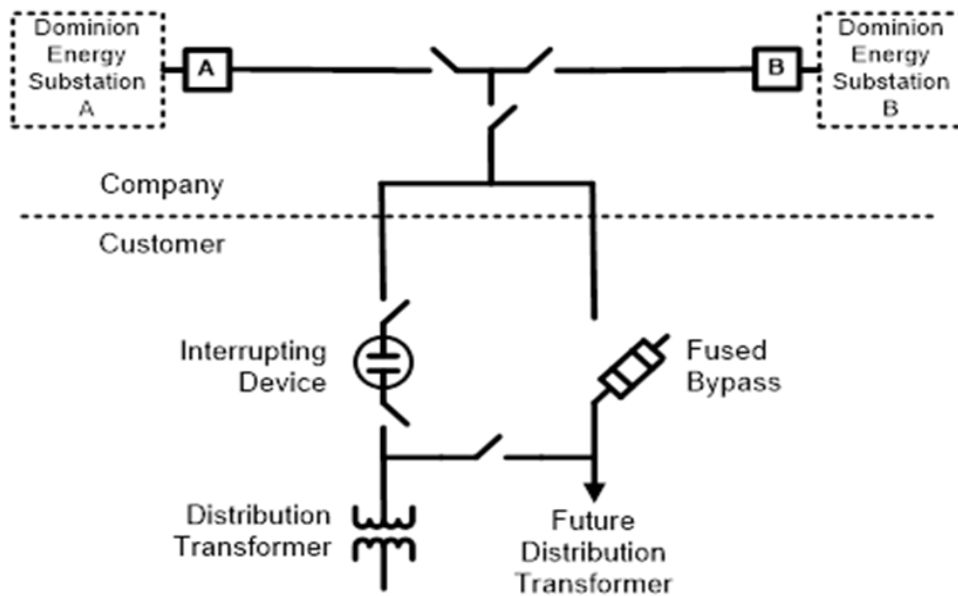


Figure 17 – Allowable alternative with fused bypass.



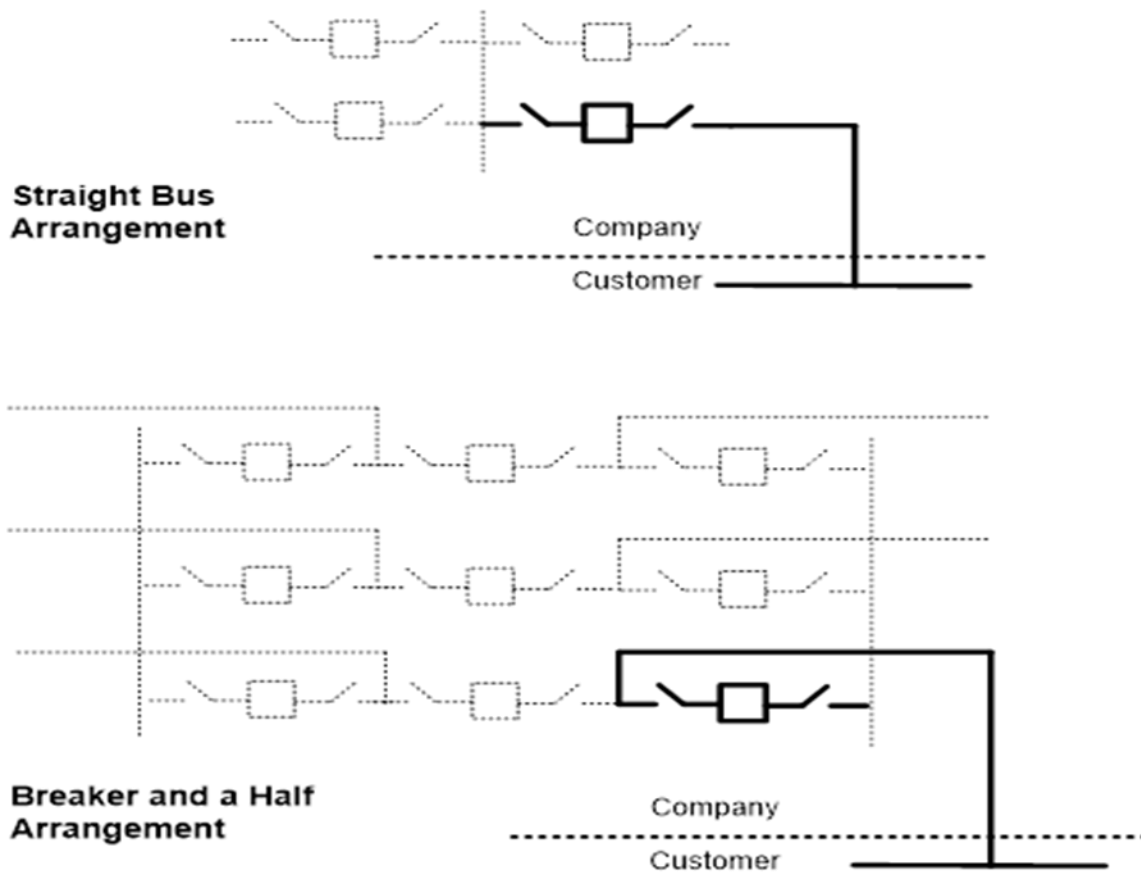
2.15 Tapping Company's Bus


The requirements for direct interconnection to company's transmission bus is determined on case-by-case basis. The following are preferred minimum load levels within the ten-year planning horizon for the direct interconnection of loads to the existing substation busses:

- 230 kV – 75 MW
- 138 kV – 50 MW
- 115 kV – 50 MW

In those cases where it may be practicable to tap an existing transmission substation bus to serve a customer, Figure 18 indicates the typical Facilities arrangement for normal service.

Figure 18 – Connecting to existing substation with load that is less than 100 MW.



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3.0 OPTION-TO-BUILD

3.1 Summary

Some Customers may choose to build all the substation and transmission elements required to create an interconnection to the DEV-ET system.

3.2 Requirements


Customers choosing to build all the substation and transmission elements themselves, as opposed to having DEV-ET construct the interconnection, will be required to build to DEV-ET standards using DEV-ET approved equipment and material suppliers. An NDA must be signed by the customer and the customer’s contractors before DEV-ET standards documents can be released. Furthermore, during the construction process DEV-ET will perform inspections to ensure the construction meets DEV-ET standards.

4.0 PROJECT COMMISSIONING

The configuration and settings of equipment is an important aspect of maintaining a safe, reliable system. Therefore, projects connected to the DEV-ET system will be subject to the DEV-ET Configuration Management Program (CMP). The CMP is used to gather information about the GOs equipment settings. These setting include, but are not limited to, protection equipment settings, transformer control settings, IBR control settings, data center control settings and any other equipment settings needed to evaluate the behavior of the transmission system.

After a project is connected to the DEV-ET system and is in operation, the owner is responsible for keeping the control settings of its equipment up to date with the DEV-ET CMP. Specifically, when an owner makes changes to, adjusts, removes a control function or removes from service the control system of any equipment, the owner is obligated to inform DEV-ET of the change.

Keeping DEV-ET informed of control setting enables DEV-ET to perform its function as the transmission owner.

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5.0 REFERENCE

Available at North American Electric Reliability Corporation website, www.nerc.com.

NERC Glossary of Terms

NERC Reliability Standards

Available at PJM website at www.pjm.com

PJM Manual 14A: New Services Request Process

PJM Manual 14C: Generation and Transmission Interconnection Facility Construction

PJM Manual 14D: Generator Operational Requirements

PJM Manual 14G: Generation Interconnection Requests

PJM Manual 14H: New Service Request Cycle Process

PJM Manual 01: Control Center and Data Exchange Requirements

PJM Manual 03: Transmission Operations

PJM Manual 07: Protection Standards

The Institute of Electrical and Electronics Engineers (IEEE)

IEEE C2-2023, IEEE Standards Association “The National Electrical Safety Code” (NESC)


IEEE Std 2800, “IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems”.

IEEE Std 80, “IEEE Guide for Safety in AC Substation Grounding”.

IEEE Std C37, IEEE standards related to System Protection.

IEEE Std C57, IEEE standards related to Transformers.

IEEE Std 485, “IEEE Recommended Practice for Sizing Lead-Acid Batteries for Stationary Applications”.

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6.0 REVISION HISTORY

Revision Date	Revision #	Description	Revised By	Effective Date
08/24/1999	0.0	Original document created to meet the requirements of NERC Planning Standard I.C.S1.M1.	ET Planning staff	08/24/1999
05/01/2001	1.0	See Details for Revision 1.0 below	ET Planning staff	05/01/2001
09/07/2005	2.0	See Details for Revision 2.0 below	ET Planning staff	09/07/2005
05/29/2007	3.0	See Details for Revision 3.0 below	ET Planning staff	05/29/2007
12/22/2009	4.0	See Details for Revision 4.0 below	ET Planning staff	12/22/2009
12/22/2011	5.0	See Details for Revision 5.0 below	William F. Bigdely	12/22/2011
10/10/2012	6.0	See Details for Revision 6.0 below	William F. Bigdely	10/10/2012
11/22/2013	7.0	See Details for Revision 7.0 below	William F. Bigdely	11/25/2013
03/31/2014	8.0	See Details for Revision 8.0 below	William F. Bigdely	03/31/2014
07/16/2014	9.0	See Details for Revision 9.0 below	William F. Bigdely	07/18/2014
01/09/2015	10.0	See Details for Revision 10.0 below	William F. Bigdely	01/15/2015
03/26/2015	11.0	See Details for Revision 11.0 below	William F. Bigdely	03/27/2015
12/15/2015	12.0	See Details for Revision 12.0 below	William F. Bigdely	01/01/2016
05/15/2017	13.0	See Details for Revision 13.0 below	William F. Bigdely	06/01/2017
03/29/2018	14.0	See Details for Revision 14.0 below	William F. Bigdely	04/01/2018
12/13/2018	15.0	See Details for Revision 15.0 below	William F. Bigdely	01/01/2019
03/11/2019	16.0	See Details for Revision 16.0 below	William F. Bigdely	03/15/2019
03/11/2020	17.0	See Details for Revision 17.0 below	David Witt	04/01/2020
06/30/2020	18.0	See Details for Revision 18.0 below	David Witt	07/08/2020
02/22/2021	19.0	See Details for Revision 19.0 below	Hamidreza Sadeghian	04/01/2021
03/10/2022	20.0	See Details for Revision 20.0 below	Mark Gill	04/01/2022
02/16/2023	21.0	See Details for Revision 21.0 below	Amirreza Sahami	04/01/2023
11/15/2023	22.0	See Details for Revision 22.0 below	Aaron Winter	01/01/2024
08/01/2024	23.0	See Details for Revision 23.0 below	Kristen Custer	09/01/2024


Details for Revision 1.0

- Revised to include information regarding Dominion's generation interconnection procedures/process.

Details for Revision 2.0

- Revised to reflect transition from old NERC Planning Standards to NERC Reliability Standards, including changing the naming convention of all referenced standards throughout the document.

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Details for Revision 3.0

Revised to reflect the following:

- Updates to NERC Reliability Standards
- Dominion’s PJM Membership
- References to new SERC regional studies processes

Details for Revision 4.0

Revised to reflect the following:

- PJM Generation Queue Changes Section 4
- General Revisions all sections

Details for Revision 5.0

Revised the following:

- Section 2.12: Clarified content regarding synchronizing of Facilities.
- Exhibit A: Changed loading criteria to not exceed emergency rating of transmission Facility.
- Various errata changes.

Details for Revision 6.0

- Comprehensive overhaul to better align with the numerical flow of NERC Reliability Standard FAC-001.

Details for Revision 7.0

Revised to reflect the following:

- Annual review of Facility Connection Requirement document.
- Updated titles for approval process on page 1.
- Incorporated changes to reflect FERC approval of FAC-001-1 effective 11/25/2013.
- Section 3.1.5 – Removed “Coordination and Compatibility” and “Performance Tracking and Compliance”; Added “Protection System Misoperations”.
- Section 3.1.13 – Added “Testing” paragraph
- Various errata changes.

Details for Revision 8.0


Revised Exhibit A – Transmission Planning Criteria R8 as listed below:

- Expanded description for Section G.1. TAPPING LINE BELOW 100 MW LOAD to emphasize the requirement of a fused bypass arrangement.
- Recreated diagrams throughout for consistency of style.

Details for Revision 9.0

Revised Exhibit A – Transmission Planning Criteria as listed below:

- Added Section C.2.8 – End of life criteria
- Reformatted headers to improve PDF navigation via bookmarks

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Details for Revision 10.0

Revised Facility Connection Requirement document to reflect the following:

- Minor clarifications and annual review.
- Section 1 Purpose and Introduction: Added statement regarding applicability of document.
- Section 3.1.9 Voltage, Reactive Power, and power factor control; Generation Facilities subsection:
- Revised first bullet regarding generator control systems.
- Added new series of bullets regarding interconnected generation criteria.
- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)

Details for Revision 11.0


- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)

Details for Revision 12.0

- Made revisions to align with new version of the standard, FAC-001-2.
- Updated signature page to reflect personnel change.
- Relocated Section 3 content formerly associated with R3 in the prior version (FAC-001-1) to Section 3.3 Additional items per FAC-001 Application Guidelines and Technical Basis.
- Section 3.1 added bullet regarding distributed generation output for both conventional and alternative (solar, wind, etc.) sources
- Added sections 3.3.1 and 3.3.2 due to new information contained within Application Guidelines and Technical Basis of FAC-001-2.
- 3.3.5. Refined discussion of Protection System Design
- 3.3.6. Added reference to PJM Manual 01 – Control Center and Data Exchange Requirements
- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)
- Integrated prior content from Transmission Planning Criteria, refined drawings, and associated discussions:
 - Section 5. TRANSMISSION LINE CONNECTIONS – GENERATION (previously Section F of Transmission Planning Criteria). Established minimum generation MW level for interconnection to the Transmission System.
 - Section 6. LOAD CRITERIA – END USER (previously Section G of Transmission Planning Criteria)
- Added Exhibit C DVP Electric Transmission Generator Interconnection Protection Requirements.
- Altered capitalization throughout the document to ensure consistent application of defined terms.

Details for Revision 13.0

- Performed annual review of document and exhibits.
- Updated approval page per personnel change since prior version.
- Revised references for new Dominion Energy corporate identity.
- Removed references to registration as an “LSE” (deactivated through NERC December 2015)
- Added Section 5.6 Interconnection Requirements for Distribution Connected Generation.
- Section 3.3.6. Metering and telecommunications, subsection “Revenue Metering Data Communications”: added reference to Primestone billing data system.
- Revised Exhibit A – Dominion Energy Electric Transmission Planning Criteria (for details, see Revision History within Exhibit A)

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Details for Revision 14.0

- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)

Details for Revision 15.0

- Section 3.3: Added new section per new NERC FAC-001-3 standard; content within Section 3.3 of prior versions of this document is now in Section 3.4.
- Section 3.4.5 System protection and coordination (Protection system design) - added content re: Breaker Failure Protection.
- Section 5: Added reference to Exhibit C Protection Requirements; renumbered all sections and diagrams occurring after newly inserted section 5.3.
- Section 5.3: Added new section regarding generation connected to transmission tap lines.
- Section 8.1: Added definition for Transmission Element.
- Made all remaining revisions for Dominion Energy corporate identity, in text and in images (Rev 13 included initial related changes along with a clarifying statement in Section 1).
- Revised Exhibit C – Dominion Energy Electric Transmission Generator Interconnection Protection Requirements_Rev3 (for details, see Revision History within Exhibit C)

Details for Revision 16.0

- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)

Details for Revision 17.0

- Performed annual review of document and exhibits.
- Updated approval page per personnel change since prior version.
- Section 1: Removed references to Section 3 for additional explanation.
- Section 3: Revised references to the FAC-001 R3 ‘Application Guidelines’ to ‘Supplemental Guidelines’.
- Section 3.2: Revised bullets for the subsequent changes list.
- Section 3.4.8: Revised reference and definition of ‘insulation coordination’.
- Section 3.4.10: Updated IEC standard reference to 6100-4-15 and removed reference to UIE 96-10.
- Section 5: The Notes listed for Diagrams 5.1 and 5.2.B were updated to reference Section C of Exhibit A of this FAC-001 NCP.
- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)

Details for Revision 18.0

- Revised Exhibit A – Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)

Details for Revision 19.0

- Updated signature page.
- Updated Purpose to match Purpose in NERC standard.
- Updated Dominion Energy to Dominion Energy Virginia
- Various grammatical and formatting changes
- Section 3 – Moved section from number 7 to 3 and updated wording on applicability.

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- Updated section and diagram numbers accordingly.
- Section 5.4.9 – Added the nighttime var requirements.
- Section 5.4.14 – Added reference to Attachment 4
- Revised naming of attached Exhibits to Attachments
- Revised Attachment 1 – Dominion Energy Virginia Electric Transmission Planning Criteria (for details, see Revision History within Transmission Planning Criteria)
- Revised Attachment 3 - Dominion Energy Virginia Generator Interconnection Protection Requirements (for details, see Revision History within Generator Interconnection Protection Requirements)
- Added Attachment 4 – Dominion Energy Virginia Bulk Power System Generator Ride-Through Requirements

Details for Revision 20.0

- Section 2 – Added references to PJM manuals
- Section 4.1.9 – Updated references to PJM manuals
- Updated signature page
- Updated formatting throughout the document
- Combined Sections 4, 5, 6, 7 from Revision 19.0 into Section 4.0 – Procedure in this Revision

Details for Revision 21.0

- Updated Signature Page
- Minor wording update
- Section 4.0, Compliance Requirement R3.3 – Reworded to clarify.
- Section 4.1.6 – Added reference to Attachment 5
- Section 4.1.9 – Added reference to Attachment 5
- Updated Attachment 1, to reflect TPL001-5.1
- Attachment 5, Added new attachment.

Details for Revision 22.0

- Updated Signature Page
- Reviewed and updated Requirement language where applicable for new version of Standard FAC-001-4
- Conducted Annual Review of the document and Attachments.

Details for Revision 23.0

- Revision contributors include: Aaron Winter, Amirreza Sahami, Andrea Pinceti, Colleen Wallace, Harrison Potter, Ibukunoluwa Korede, Katelynn Vance, Keith Graham, Mark Gill, Nedim Besirevic, Peter Nedwick, Praveen Dhanasekar, YaJun Zheng, Nancy Ashberry, Ronnie Bailey, SooKwon Ha, and Quanta-Technology Services.
- Updated Signature Page to include Managers and Directors from Supporting Document Attachments 1-6.
- Made the Facility Interconnection Requirements a standalone document by removing reference to NERC Compliance Procedure and removing the chapters 1 and 3.
- Removed Chapter 1 “Purpose”. This chapter describes FAC-001 and DEV’s compliance as it relates to interconnection requirements and is not useful to the interconnection customer.
- Removed Chapter 3 “Applicability”. This chapter describes DEV’s FAC-001 compliance role and is not useful to the interconnection customer.

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- Moved Acronyms into a table at the beginning of document to be consistent with industry practices.
- Moved Definitions to beginning of document to be consistent with industry practices.
- Moved References to the end of the document to be consistent with industry practices.
- Added Chapter 3 – “Option To Build”. This chapter was added to alert interconnection customer to the need to sign an NDA and to follow DEV design and construction practices.
- Added Chapter 4 – “Project Commissioning”. This chapter was added to alert the interconnection customer to the project owner’s reliability responsibility and the need to keep DEV informed of the plant’s control settings. This chapter includes reference to a future Configuration Management Program (CMP).
- Added Attachment 6, “Technical Requirements for Generation Interconnection Substations”
- Revised Attachment 2, “Customer Request Form”.
- Renumbered figures to match formatting.
- Renamed section 2.1 (was 4.2.1.1) from “Data Required to Properly Study the Interconnection” to “Required Simulation Data”. This is more concise.
- Added language, with footnotes, to section 2.1 (was 4.2.1.1) to include IBR EMT models and the need for interconnection customers to keep their EMT model updated.
- Removed table showing voltages from section 2.2 (was 4.2.2) “Voltage level and MW and MVar capacity or demand at point of interconnection”. This information is in other locations.
- Edited language in section 2.3 (was 4.2.3) to be more understandable.
- Updated headings in table found in section 2.3 (was 4.2.3) to match industry defined terminology.
- Added a bullet to the list in section 2.3 to alert the interconnection customer to unique IBR design requirements.
- Added language to section 2.4 (was 4.2.4) to the requirement more understandable.
- Added section 2.4.1.1 “Inverter Based Resource (IBR) Protection Systems”.
- Added language to section 2.6 (was 4.2.6) to refer developers to IEEE Guide for Solar Power Plant Grounding for Personal Protection.
- Change the voltage table headers in section 2.7 (was 4.2.7) to match industry definitions.
- Added additional references added to REFERENCE section.
- Added a bullet to Section 2.8.1 (was 4.2.8.1) to account for FERC synchronous and non-synchronous generator power factor requirements.
- Added reference to IEEE Standard in section 2.9.1 (was 4.2.9.1) Flicker Requirements.
- Change the voltage table headers in section 2.10 (was 4.2.10), Equipment Ratings, to match industry definitions.
- Added section 2.12.4 “Isolation Device”. This was added to be more specific about the type of isolation device used between DEV and the interconnection customer.

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Attachment 1

Planning Criteria

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A. Scope and objective

The function of the transmission system is to transport power from generating resources to distribution systems to serve the demand of the end-user customers. Reliable transmission system operation implies maintaining continuity of service at sufficient voltage levels without overloading equipment under a wide range of operating conditions.

Virginia Electric and Power Company is doing business as (d/b/a) Dominion Energy Virginia (DEV). In this document, “DEV-ET” refers to the electric transmission system owned by DEV. “Transmission system” refers to networked and radial facilities within the DEV-ET system at voltage levels of 69, 115, 138, 230, and 500 kV. This document provides approved criteria upon which the needs for reinforcements and enhancements to the DEV-ET are determined.

DEV-ET’s criteria ensure adherence to the transmission planning standards of the North American Electric Reliability Corporation (NERC) and those of the SERC Reliability Corporation (SERC), one of the six regional reliability organizations (RRO) of NERC. Unless noted, the Criteria in this document apply to generation, transmission, and end user facilities.

B. Standards, guides, and criteria used for transmission planning.

B.1. NERC transmission planning standards and documents


The North American Electric Reliability Corporation was established to promote the reliability of the bulk electric systems and is the Electric Reliability Organization (ERO) for North America. NERC develops and enforces reliability standards, including transmission planning standards, to ensure reliable operation of the interconnected bulk electric systems. The NERC transmission planning standards can be found at the NERC homepage (<https://www.nerc.com>). NERC also publishes guidelines, standardized data and special requirements to aid transmission planners. A list of relevant NERC documents can be found in the REFERENCE section of this document.

B.2. Regional transmission planning standards

NERC consists of six regional reliability organizations. DEV-ET is a member of the SERC Reliability Corporation (SERC), one of the six regional reliability organizations. DEV-ET plans its portion of bulk electric system (BES) in coordination with its Transmission Planner (TP), PJM, to meet the requirements of NERC and SERC.

B.3. PJM transmission planning standards

The DEV-ET is integrated into planning and operations of the PJM Interconnection, LLC (PJM) Regional Transmission Operator (RTO). PJM manages a regional planning process for generation and transmission expansion to ensure the continued reliability of the electric system. PJM annually develops a Regional Transmission Expansion Plan (RTEP) to meet system enhancement requirements for firm transmission service, load growth, interconnection requests and other system enhancements. The criteria PJM uses in developing the RTEP is set forth in PJM Manual 14B – PJM Region Transmission Planning Process.

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B.4. IEEE Industry Standards

Institute of Electrical and Electronics Engineers (IEEE) has not developed performance standards for planning transmission. Instead, transmission system performance standards have been developed by NERC and the regional entities. Instead, IEEE members have created useful equipment and practices standards that can be used to aid in the transmission planning process. A list of useful IEEE standards is found in the REFERENCE section of this document.

C. Transmission planning, steady-state criteria

C.1. Planning principles and standards

The transmission system must perform reliably for a wide range of conditions. Because system operators can exercise only limited direct control, it is essential that studies be made in advance to identify the facilities necessary to assure a reliable transmission system in future years.


The voltages and equipment loadings on the transmission system should be within acceptable limits, both during normal operation and for an appropriate range of potential system faults and equipment outages. The more probable contingency conditions should not result in voltages or equipment loadings beyond emergency limits. These 'emergency limits' can vary based on equipment type and allowable time period.

Tables 1A and 1B specify outage events that are analyzed by DEV-ET at the forecasted load levels to determine if any thermal or voltage violations exist. Thermal capability is given with equipment ratings in amps or MVA. Voltage limits are in reference to the nominal design voltage. Adherence to the criteria given in these tables ensure that DEV-ET meets the applicable reliability requirements of NERC, SERC, and PJM.

System readjustment is allowed when attempting to reduce line loadings or improve voltage profile (only as allowed by NERC Criteria). System readjustments considered in planning analysis include:

- Generation re-dispatch (excludes nuclear generation)
- Phase angle regulator adjustment¹
- Load tap changer adjustment
- Shunt and series capacitor bank switching
- Line switching
- Shunt and series reactor switching
- Adjustment of Flexible AC Transmission System (FACTS) devices

¹ For DEV, phase angle regulator adjustment is used to relieve loadings on the 115kV system in Yorktown and Chesapeake Energy areas. Phase shifting transformers control the division of real power among parallel paths. Chesapeake Energy Center and Yorktown Power Station have phase shifters between the 230 kV and 115 kV systems. The phase shifter transfers load from one voltage level to the other. Phase angle adjustment will be allowed within the parameters noted in PJM's Manual 14B – PJM Regional Transmission Planning Process (RTEP Reliability Planning section).

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DEV-ET facilities loaded over their normal rating, following a contingency, must be adjusted to the facilities normal rating, or below, within the time limit given for the short-term emergency rating. Any of the above listed system readjustments are allowable in this situation as DEV-ET employs an 8-hour short-term emergency rating on transmission equipment. This allows sufficient time to implement any adjustments needed to reduce loadings to the normal rating.

Loadings on facilities over their short-term emergency ratings, following a contingency, must be adjusted back down to the short-term emergency rating within the 15-minute time frame of the load dump rating using the system readjustments listed above, which are only those readjustments that are feasible within 15-minutes by System Operators.

Dominion performs N-1-1 contingency analysis on transmission lines by taking a branch of a given line out of service as the first contingency. This mirrors real world conditions where after a fault takes an entire line out of service (breaker-to-breaker), branches of the line are restored through switching except for the branch that experienced the original fault. For the second contingency, breaker-to-breaker line outages are applied and analyzed.

If the criteria described in this document cannot be met, a Corrective Action Plan² will be developed. The Corrective Action Plan will bring the system into compliance through the most judicious use of a variety of feasible options. These include the development of an operator action plan in conjunction with the use of short term ratings, generation re-dispatch, phase angle regulator adjustments, bus-tie switching, Remedial Action Schemes, or the installation of a physical reinforcement.

A Remedial Action Scheme (RAS), as interpreted from the NERC Reliability Standards Glossary of Terms, is designed to detect abnormal system conditions and take automatic corrective action to provide acceptable transmission system performance. The RAS isolates equipment other than faulted elements and/or reconfigures equipment outside of a zone containing faulted elements. A RAS may be applied as required to address thermal, voltage, or stability issues in accordance with NERC Transmission Planning (TPL) Standards and is subject to the RAS requirements of NERC Protection and Control (PRC) Standards 012 through 017. A RAS does not include automatic restoration to service of un-faulted elements within a faulted zone, under frequency and under voltage load shedding schemes, conventional generator out of step tripping schemes, or remote backup tripping schemes. DEV-ET reviews all existing RASs periodically and adjusts settings as deemed necessary. DEV-ET will normally install a RAS as a temporary measure until a more robust solution can be completed to provide acceptable system performance. Operating steps implemented as part of a RAS shall be considered, provided that the failure of such system does not result in cascading outages or overloads.

In addition to those events and circumstances included in Tables 1A and 1B, Table 1C defines more severe but less probable scenarios that should also be considered for analysis to evaluate resulting consequences. As permitted in the NERC Planning Standards, judgment shall dictate whether and to what extent a mitigation plan would be appropriate.

² NERC Glossary of Terms defines a Corrective Action Plan as “A list of actions and an associated timetable for implementation to remedy a specific problem”.


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Table 1A Steady-State Performance PLANNING Events and Dominion Energy CRITERIA
HIGH VOLTAGE (HV): 230 kV, 138 kV, 115 kV & 69 kV Facilities

NERC TPL-001 Events (excludes DC)						Dominion Energy Criteria		
Category	Initial Condition	Event ¹	Fault Type ²	Interruption of Firm Transmission Service Allowed ⁴	Non-Consequential Load Loss Allowed*	Thermal Limits	Low Voltage Limit **	High Voltage Limit **
P0 No Contingency	Normal System	None	N/A	No	No	94% N	95%	105% & 103%
P1 Single Contingency	Normal System	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶	3Ø	No ⁹	No ¹²	94% STE	93%	105% & 103%
P2 Single Contingency	Normal System	1. Opening of a line section w/o a fault ⁷	N/A	No ⁹	No ¹²	94% STE	93%	105% & 103%
		2. Bus Section Fault	SLG	Yes	Yes	100% STE	90%	105% & 103%
		3. Internal Breaker Fault ⁸ (non-Bus-tie Breaker)	SLG	Yes	Yes	100% STE	90%	105% & 103%
		4. Internal Breaker Fault (Bus-tie Breaker) ⁸	SLG	Yes	Yes	100% STE	90%	105% & 103%
P3 Multiple Contingency [see Dom Energy Note "A", "B" & C]	Loss of generator unit followed by System adjustments ⁹	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶	3Ø	No ⁹	No ¹²	94% STE	93%	105% & 103%
P4 Multiple Contingency (Fault plus stuck breaker ¹⁰) [see Dominion Energy Note "B"]	Normal System	Loss of multiple elements caused by a stuck breaker ¹⁰ (non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶ 5. Bus Section 6. Loss of multiple elements caused by a stuck breaker ¹⁰ (Bus-tie Breaker) attempting to clear a Fault on the associated bus	SLG	Yes	Yes	100% STE	90%	105% & 103%
P5 Multiple Contingency (Fault plus relay failure to operate) [see Dominion Energy Note "B"]	Normal System	Delayed Fault Clearing due to the failure of a non-redundant component of a Protection System ¹³ protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶ 5. Bus Section	SLG	Yes	Yes	100% STE	90%	105% & 103%

Table 1A continued on next page.

**Table 1A Steady-State Performance PLANNING Events and Dominion Energy CRITERIA
(continued)**

HIGH VOLTAGE (HV): 230 kV, 138 kV, 115 kV & 69 kV Facilities

NERC TPL-001 Events (excludes DC)						Dominion Energy Criteria		
Category	Initial Condition	Event ¹	Fault Type ²	Interruption of Firm Transmission Service Allowed ⁴	Non-Consequential Load Loss Allowed*	Thermal Limits	Low Voltage Limit **	High Voltage Limit **
P6 Multiple Contingency (Two overlapping singles) [see Dominion Energy Note "B" & C]	Loss of one of the following followed by System adjustments. ⁹ 1. Transmission Circuit 2. Transformer ⁵ 3. Shunt Device ⁶	Loss of one of the following: 1. Transmission Circuit 2. Transformer ⁵ 3. Shunt Device ⁶	3Ø	Yes	Yes	100% STE	90%	105% & 103%
P7 Multiple Contingency (Common Structure)	Normal System	The loss of any two adjacent (vertically or horizontally) circuits on common structure ¹¹	SLG	Yes	Yes	100% STE	90%	105% & 103%

Dominion Energy Notes for Table 1A

See separate listing *Table 1 (A & B) Footnotes* for superscript numbered footnotes.

Note "A" - See *Section C.2.1.3 – Critical stress case development and studies* for details.

Note "B" - Areas of the system that become radial post-contingency will be included for monitoring of thermal and voltage violations for all load levels served by the radial.

Note "C" – System adjustment should be performed after first contingency event (Initial Condition).

* If the aggregated consequential or non-consequential load loss exceeds 300 MW, system reinforcements will be required.

** Percent of Nominal Voltage (Note: Voltage limits for North Anna and Surry Power Stations are governed by the requirements of their respective Nuclear Plant Interface Requirements (NPIR) with Dominion Energy Electric Transmission as noted in Section E.3). A lower overvoltage limit of 103% is applied to 138 kV facilities based on the age and number of legacy switches on the network at this voltage.

N – Normal Rating

STE – Short Term Emergency

LD – Load Dump

Table 1B Steady-State Performance PLANNING Events and Dominion Energy CRITERIA
EXTRA HIGH VOLTAGE (EHV): 500 kV Facilities

NERC TPL-001 Events (excludes DC)						Dominion Energy Criteria		
NERC Category	Initial Condition	Event ¹	Fault Type ²	Interruption of Firm Transmission Service Allowed ⁴	Non-Consequential Load Loss Allowed [*]	Thermal Limits	Low Voltage Limit ^{**}	High Voltage Limit ^{**}
P0 No Contingency	Normal System	None	N/A	No	No	94% N	102.5%	108%
P1 Single Contingency	Normal System	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶	3Ø	No ⁹	No ¹²	94% STE	101%	109.6%
P2 Single Contingency	Normal System	1. Opening of a line section w/o a fault ⁷	N/A	No ⁹	No ¹²	94% STE	101%	109.6%
		2. Bus Section Fault	SLG	No ⁹	No	100% STE	100%	109.6%
		3. Internal Breaker Fault ⁸ (non-Bus-tie Breaker)	SLG	No ⁹	No	100% STE	100%	109.6%
		4. Internal Breaker Fault (Bus-tie Breaker) ⁸	SLG	Yes	Yes	100% STE	100%	109.6%
P3 Multiple Contingency [see Dominion Energy Note "D", "E" & "F"]	Loss of generator unit followed by System adjustments ⁹	Loss of one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶	3Ø	No ⁹	No ¹²	94% STE	101%	109.6%
P4 Multiple Contingency (Fault plus stuck breaker ¹⁰) [see Dominion Energy Note "D"]	Normal System	Loss of multiple elements caused by a stuck breaker ¹⁰ (non-Bus-tie Breaker) attempting to clear a Fault on one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶ 5. Bus Section 6. Loss of multiple elements caused by a stuck breaker ¹⁰ (Bus-tie Breaker) attempting to clear a Fault on the associated bus	SLG	No ⁹	No	100% STE	100%	109.6%
P5 Multiple Contingency (Fault plus relay failure to operate) [see Dominion Energy Note "D"]	Normal System	Delayed Fault Clearing due to the failure of a non-redundant component of a Protection System ¹³ protecting the Faulted element to operate as designed, for one of the following: 1. Generator 2. Transmission Circuit 3. Transformer ⁵ 4. Shunt Device ⁶ 5. Bus Section	SLG	No ⁹	No	100% STE	100%	109.6%

Table 1B continued on next page.

**Table 1B Steady-State Performance PLANNING Events and Dominion Energy CRITERIA
(continued)**

EXTRA HIGH VOLTAGE (EHV): 500 kV Facilities

NERC TPL-001 Events (excludes DC)						Dominion Energy Criteria		
NERC Category	Initial Condition	Event ¹	Fault Type ²	Interruption of Firm Transmission Service Allowed ⁴	Non-Consequential Load Loss Allowed*	Thermal Limits	Low Voltage Limit **	High Voltage Limit **
P6 Multiple Contingency (Two overlapping singles) [see Dominion Energy Note "D" & "F"]	Loss of one of the following followed by System adjustments. ⁹ 1. Transmission Circuit 2. Transformer ⁵ 3. Shunt Device ⁶	Loss of one of the following: 1. Transmission Circuit 2. Transformer ⁵ 3. Shunt Device ⁶	3Ø	Yes	Yes	100% STE	100%	109.6%
P7 Multiple Contingency (Common Structure)	Normal System	The loss of any two adjacent (vertically or horizontally) circuits on common structure ¹¹	SLG	Yes	Yes	100% STE	100%	109.6%

Dominion Energy Notes for Table 1B

See separate listing *Table 1 (A & B) Footnotes* for superscript numbered footnotes.

Note "D" - See *Section C.2.1.3 – Critical stress case development and studies* for details.

Note "E" - Areas of the system that become radial post-contingency will be included for monitoring of thermal and voltage violations for all load levels served by the radial.

Note "F" – System adjustments should be performed after first contingency event (Initial Condition).

* If the aggregated consequential or non-consequential load loss exceeds 300 MW, system reinforcements will be required.

** Percent of Nominal Voltage (Note: Voltage limits for North Anna and Surry Power Stations are governed by the requirements of their respective Nuclear Plant Interface Requirements (NPIR) with Dominion Energy Electric Transmission as noted in Section E.3).

N – Normal Rating


STE – Short Term Emergency

LD – Load Dump

Table 1C Steady-State Performance EXTREME Events and Dominion Energy CRITERIA

NERC TPL-001 Events (excludes DC)				Dominion Energy Criteria			
Category	Event Note "G"		Interruption of Firm Transmission on Service Allowed	Non-Consequential Load Loss Allowed	Thermal Limits	Low Voltage Limit **	High Voltage Limit **
N-2 Two Contingencies	Loss of a single generator, Transmission Circuit, shunt device, or transformer forced out of service followed by another single generator, Transmission Circuit, shunt device, or transformer forced out of service <u>prior to System adjustments.</u>		YES	YES	100% LD	90%	Note "M"
LAE Local Area Events	Local area events affecting the Transmission System such as:	a. Loss of a tower line with three or more circuits. ¹¹	YES	YES	100% LD Note "H"	90%	Note "M"
		b. Loss of all Transmission lines on a common Right-of-Way ¹¹ .	YES	YES	100% LD Note "I"	90%	Note "M"
		c. Loss of a switching station or substation (loss of one voltage level plus transformers).	YES	YES	100% LD Note "J"	90%	Note "M"
		d. Loss of all generating units at a generating station.	YES	YES	100% LD Note "K"	90%	Note "M"
		e. Loss of a large Load or major Load center.	YES	YES	100% LD Note "L"	90%	Note "M"
WAE Wide Area Events	Wide area events affecting the Transmission System based on System topology such as:	a. Loss of two generating stations resulting from conditions such as: <ul style="list-style-type: none"> i. Loss of a large gas pipeline into a region or multiple regions that have significant gas-fired generation. ii. Loss of the use of a large body of water as the cooling source for generation. iii. Wildfires. iv. Severe weather, e.g., hurricanes, tornadoes, etc. v. A successful cyber attack. vi. Shutdown of a nuclear power plant(s) and related facilities for a day or more for common causes such as problems with similarly designed plants. 	YES	YES	100% LD for both HV and EHV		Note "M"
		b. Other events based upon operating experience that may result in wide area disturbances.	YES	YES			Note "M"

** Percent of Nominal Voltage (Note: Voltage limits for North Anna and Surry Power Stations are governed by the requirements of their respective Nuclear Plant Interface Requirements (NPIR) with Dominion Energy Electric Transmission as noted in Section E.3).
N – Normal Rating, STE – Short Term Emergency, LD – Load Dump

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Dominion Energy Notes for Table 1C

See separate listing *Table 1 (A, B & C) Footnotes* for superscript numbered footnotes.

Note “G” – For all extreme events evaluated:

- Simulate the removal of all elements that Protection Systems and automatic controls are expected to disconnect for each Contingency.
- Simulate Normal Clearing unless otherwise specified.

Note “H” – The loss of three or more transmission circuits on a common structure should not result in cascading outages beyond the load area immediately involved. The overall supply system to a major load area should be able to withstand the loss of all circuits on a common structure and still supply most of the load in the area with tolerable voltage (at least 90% of nominal). A major load area would be an area similar to the Norfolk/Virginia Beach area or the Northern Virginia area.

Note “I” – The loss of transmission circuits on a common right of way should not result in cascading outages beyond the load area immediately involved. The overall supply system to a major load area should be able to withstand the loss of all circuits on a common right of way and still supply most of the load in the area with tolerable voltage (at least 90% of nominal). A major load area would be an area similar to the Norfolk/Virginia Beach area or the Northern Virginia area.

Note “J” – The loss of a switching station or substation (one voltage level plus transformers) should not result in cascading outages or intolerably low voltages (less than 90% of nominal voltage) nor should any overhead transmission facility be loaded to more than its load dump rating during the period required to make prompt power supply adjustments to reduce overloads to less than its emergency rating (STE). The consequential load due to the loss in the affected station is not to exceed 300 MW.


Note “K” – The loss of all generation at a generating station should not result in cascading outages or intolerably low voltages (less than 90% of nominal voltage) nor should any overhead transmission facility be loaded to more than its load dump rating during the period required to make prompt power supply adjustments to reduce overloads to less than its emergency rating (STE).

Note “L” – The loss of a large load or major load center should not result in cascading outages or intolerably low voltages (less than 90% of nominal voltage) nor should any overhead transmission facility be loaded to more than its load dump rating during the period required to make prompt power supply adjustments to reduce overloads to less than its emergency rating (STE).


Note “M” - High Voltage (HV): 105%; Extra High Voltage (EHV): 109.6%

Table 1 (A, B & C) Footnotes [NERC Reliability Standard TPL-001-4]

1. If the event analyzed involves BES elements at multiple System voltage levels, the lowest System voltage level of the element(s) removed for the analyzed event determines the stated performance criteria regarding allowances for interruptions of Firm Transmission Service and Non-Consequential Load Loss.
2. Unless specified otherwise, simulate Normal Clearing of faults. Single line to ground (SLG) or three-phase (3Ø) are the fault types that must be evaluated in Stability simulations for the event described. A 3Ø or a double line to ground fault study indicating the criteria are being met is sufficient evidence that a SLG condition would also meet the criteria.
3. Bulk Electric System (BES) level references include extra-high voltage (EHV) Facilities defined as greater than 300 kV and high voltage (HV) Facilities defined as the 300 kV and lower voltage Systems. The designation of EHV and HV is used to distinguish between stated performance criteria allowances for interruption of Firm Transmission Service and Non-Consequential Load Loss.
4. Curtailment of Conditional Firm Transmission Service is allowed when the conditions and/or events being studied formed the basis for the Conditional Firm Transmission Service.
5. For non-generator step up transformer outage events, the reference voltage, as used in footnote 1, applies to the low-side winding (excluding tertiary windings). For generator and Generator Step Up transformer outage events, the reference voltage applies to the BES connected voltage (high-side of the Generator Step Up transformer). Requirements which are applicable to transformers also apply to variable frequency

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- transformers and phase shifting transformers.
6. Requirements which are applicable to shunt devices also apply to FACTS devices that are connected to ground.
 7. Opening one end of a line section without a fault on a normally networked Transmission circuit such that the line is possibly serving Load radial from a single source point.
 8. An internal breaker fault means a breaker failing internally, thus creating a System fault which must be cleared by protection on both sides of the breaker.
 9. An objective of the planning process should be to minimize the likelihood and magnitude of interruption of Firm Transmission Service following Contingency events. Curtailment of Firm Transmission Service is allowed both as a System adjustment (as identified in the column entitled 'Initial Condition') and a corrective action when achieved through the appropriate re-dispatch of resources obligated to re-dispatch, where it can be demonstrated that Facilities, internal and external to the Transmission Planner's planning region, remain within applicable Facility Ratings and the re-dispatch does not result in any Non-Consequential Load Loss. Where limited options for re-dispatch exist, sensitivities associated with the availability of those resources should be considered.
 10. A stuck breaker means that for a gang-operated breaker, all three phases of the breaker have remained closed. For an independent pole operated (IPO) or an independent pole tripping (IPT) breaker, only one pole is assumed to remain closed. A stuck breaker results in Delayed Fault Clearing.
 11. Excludes circuits that share a common structure (Planning event P7, Extreme event steady state 2a) or common Right-of-Way (Extreme event, steady state 2b) for 1 mile or less.
 12. An objective of the planning process is to minimize the likelihood and magnitude of Non-Consequential Load Loss following planning events. In limited circumstances, Non-Consequential Load Loss may be needed throughout the planning horizon to ensure that BES performance requirements are met. However, when Non-Consequential Load Loss is utilized under footnote 12 within the Near-Term Transmission Planning Horizon to address BES performance requirements, such interruption is limited to circumstances where the Non-Consequential Load Loss meets the conditions shown in Attachment 1. In no case can the planned Non-Consequential Load Loss under footnote 12 exceed 75 MW for US registered entities. The amount of planned Non-Consequential Load Loss for a non-US Registered Entity should be implemented in a manner that is consistent with, or under the direction of, the applicable governmental authority or its agency in the non-US jurisdiction.
 13. For purposes of this standard, non-redundant component of a Protection System to consider are as follows:
 - a. A single protective relay which responds to electrical quantities, without an alternative (which may or may not respond to electrical quantities) that provides comparable Normal Clearing times.
 - b. A single communications system associated with protective functions necessary for correct operation of a communication-aided protection scheme required for Normal Clearing (an exception is a single communication system that is both monitored and reported at a Control Center).
 - c. A single station dc supply associated with protective functions required for Normal Clearing (an exception is a single station dc supply that is both monitored and reported at a Control Center for both low voltage and open circuit).
 - d. A single control circuitry (including auxiliary relays and lockout relays) associated with protective functions, from the dc supply through and including the trip coil(s) of the circuit breakers or other interrupting devices, required for Normal Clearing (the trip coil may be excluded if it is both monitored and reported at a Control Center).

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C.1.1. Voltage limits at generating stations

Plant auxiliary power equipment requires adequate voltages to maintain operation of on-line generators as well as to provide for startup capability for offline generators. Minimum transmission voltages at generating stations ensure plant auxiliary equipment will have adequate voltage during both online and offline operation. These voltage limits apply to all classes of generation except wind turbines and PV arrays.

In cases where plant auxiliary power is supplied by power transformers not equipped with a load tap changer (LTC) or equivalent voltage control device, the voltage limits at the low side of the Generator Step-up transformer Unit (GSU) are established as 0.95 per unit (minimum) and 1.05 per unit (maximum) unless otherwise specified by the generator owner.

C.2. Detailed steady-state criteria

C.2.1. System load level

C.2.1.1. Peak period studies


The peak load period must be studied to determine future requirements for the transmission system. The basic references for system peak load to be used in studies for future years are the total corporate system load projection provided by the PJM Load Analysis. The actual peak load in any given future year is likely to be higher or lower than the forecast value. A '50/50' forecast provides a peak load projection with a 50% probability that the actual peak will be higher than the level forecasted in that year.

C.2.1.2. Off-peak period studies

Studies should also be conducted for the purpose of determining risks and consequences at light load or shoulder peak conditions, and for any other period for which system adequacy cannot be evaluated from peak period study results. For these off-peak periods, it is assumed that the number of hours of occurrence is substantially higher than the number of hours at or near peak load levels. In addition, severe drought conditions effecting hydro generation plant availability and its impact on the transmission system are also studied.

C.2.1.3. Critical stress case development and studies

DEV-ET studies the transmission system under both normal and critical system stress conditions. For NERC Category P3 Analysis, DEV-ET will outage the most critical generator in the area being studied, and the resulting power flow case is considered a critical stress case. Under this critical stress case condition, the generator being studied is taken off-line and the remaining generators connected to the DEV-ET System are proportionally increased to

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make-up for the lost generation. If there are not enough generation resources available within the DEV-ET system, or the use of DEV-ET generation resources would not provide an adequate base case, then PJM generation resources should be utilized to make-up any generation deficiency. This resulting critical stress case is then analyzed for NERC Compliance based on the transmission contingency events listed in Table 1A and Table 1B Category P3(Multiple Contingency).

C.2.2. Power transfers

All studies should consider known firm power transfers affecting the DEV electric transmission system. This includes known firm transmission service reservations, including those with rollover rights, as well as parallel path power transfers through the system that may impact system reliability.


DEV-ET is part of a larger regional power system that must be capable of withstanding certain levels of power transfers between or through sub areas of the region. PJM conducts load and generator deliverability tests for specific sub areas as part of the Regional Transmission Expansion Plan (RTEP) process to determine whether the system can accommodate these transfers. The DEV electric transmission system must meet this transfer Load and Generator Deliverability Requirement. A description of the deliverability testing procedures can be found in PJM Manual 14B – PJM Region Transmission Planning Process³. SERC Reliability Corporation also performs transfer limit testing to trend the strength of the transmission system. The results of these studies may also indicate a need to increase transfer strength on the DEV-ET system.

DEV-ET routinely tests the capability of the transmission system to transfer reasonable amounts of power (approximately 2000 MW) in excess of firm purchases, sales and transfers, between and among the Company and the neighboring utilities. Such tests are conducted under two basic scenarios: (1) with all transmission facilities in service at or below the maximum continuous normal rating; and (2) with one transmission circuit or transformer out of service while maintaining the loading on all remaining transmission facilities at or below the maximum continuous emergency rating. Any new facilities connected to the transmission system shall not significantly decrement, the First Contingency Incremental Transfer Capability (FCITC) for transfers between utilities. A FCITC decrement in excess of 5% will be considered significant in most cases.

C.2.3. Equipment ratings

Ratings for transmission facilities are maintained by DEV-ET and documented in an equipment ratings database. In most cases, equipment is assigned a normal continuous

³ Based on DEV criteria for Generation Deliverability, the thermal thresholds for No contingency (NERC P0 category) is 94% of Normal rating, Single contingencies (NERC P1 category) and Non-Single contingencies (NERC P2, P4, and P7 categories) are 94% of Short Term Emergency (STE) and 100% of Load Dump (LD), respectively.

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rating and one emergency rating of limited duration. This is not always the case. Some equipment is assigned a normal continuous rating and multiple emergency ratings with different durations. The different emergency ratings are referred to as short-term, long-term, and load dump.

The process used for determining equipment ratings is outlined in the DEV Electric Transmission Facility Ratings Methodology technical reference document.

C.2.4. Circuit breaker capability


Short circuit analysis is performed to determine the maximum current that circuit breakers will be required to interrupt. All circuit breakers must be able to interrupt the currents determined by short circuit analyses. Likewise, circuit breakers must be able to carry the maximum continuous current found with power flow analysis.

C.2.5. Reactive power planning

The objective of system reactive power planning is to efficiently coordinate the reactive requirements of the transmission and distribution systems to satisfy voltage criteria. Meeting this objective ensures voltage stability, provides generator auxiliary power systems on the distribution system with adequate voltage, and minimizes transmission losses and reactive interchange. System reactive requirements can be controlled by changing generation excitation, operating synchronous condensers, changing transformer tap positions, switching transmission and distribution level static capacitors, switching shunt reactors, and adjusting solid-state reactive compensation devices (SVCs, etc.).

The DEV-ET system is planned so that transmission voltages will be maintained within an acceptable range for normal and emergency conditions as described in Tables 1A and 1B.

Low transmission voltage will lead to undesirable effects in both the transmission and distribution systems, such as higher losses, reduced insulation life, and reduced effectiveness of capacitors. These effects would also increase the difficulty in recovering from low transmission voltage situations. The outage events analyzed to assess voltage adequacy are the same as those listed in Tables 1A and 1B. Distribution facilities which are maintaining power factors at the Transmission Point of Interconnection (POI) that are less than PJM’s requirement (per Manual 14B – PJM Region Transmission Planning Process) and DEV’s requirement (97.3% lagging) may not be able to maintain satisfactory voltage to customers served from these distribution facilities when transmission system voltages are at or near the lower voltage limits of normal and emergency transmission system operations. Conversely, high transmission voltages that exceed operating voltage schedules can stress generation, distribution, and transmission equipment and lead to premature fatigue or even failure.

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C.2.6. Radial transmission lines

A Radial transmission line is defined as a single line that has one transmission source, serves load, and does NOT tie to any other transmission source (line or substation). Unlike load served from a network transmission line having two sources where a downed conductor or structure can be sectionalized for load to be served before repairs are completed, load served from a single source radial transmission line cannot be reenergized until all repairs to the line are completed. Accordingly, loading on single source radial transmission lines will generally be limited to the following:

- 100 MW Maximum
- 700 MW-Mile Exposure (MW-Mile = Peak MW X Radial Line Length)

A factor in evaluating the load limitation on a radial transmission line is the degree to which the distribution load can be switched to circuits served from other sources and whether such capability can be reasonably added. Other factors include the ability to perform maintenance on the radial transmission line, the outage history of the radial transmission line, load density and type, tie capability, etc.

Once a radial loading limit exceeds any of these thresholds, an additional transmission source may be required. Acceptable transmission sources include but are not limited to the following:

- Network from a separate transmission substation source (Preferred)
- Loop back to same transmission substation source
- Normally open network or loop transmission source


C.2.7. Network transmission lines – Limitations on direct-connect loads

A network transmission line is defined as one that connects two network transmission sources (connect to other lines & substations) and a “Tap point” is defined as a direct connection of a customer to a network transmission line without addition of any transmission breaker or breakers to split the line. Network transmission lines facilitate network flows and could serve directly connected (Tapped) loads. In the Dominion Energy system, 500, 230, 138, 115 and 69 kV lines are considered transmission, and all with the exception of 500 kV could be tapped to serve customer load.

In general, the number of direct-connect loads (tapped facilities) should be limited to four (4); however, Good Utility Practice and sound engineering judgment must be exercised in application of this criteria.

C.2.8. Substation – Limitation on direct-connect loads

The amount of direct-connect load at any substation will be limited to 300 MW.

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C.2.9. End of life criteria

Electric transmission infrastructure reaches its end of life as a result of many factors. Some factors such as extreme weather and environmental conditions can *shorten* infrastructure life, while others such as maintenance activities can *lengthen* its life. Once end of life is recognized, in order to ensure continued reliability of the transmission grid, a decision must be made regarding the best way to address this end-of-life asset.

For this criterion, “end of life” is defined as the point at which infrastructure is at risk of failure, and continued maintenance and/or refurbishment of the infrastructure is no longer a valid option to extend the life of the facilities consistent with Good Utility Practice and Dominion Energy Transmission Planning Criteria. The infrastructure to be evaluated under this end-of-life criteria are all regional transmission lines operated at 500 kV and above.

The decision point of this criterion is based on satisfying two metrics:

- 1) *Facility is nearing, or has already passed, its end of life, and*
- 2) *Continued operation risks negatively impacting reliability of the transmission system.*


For facilities that satisfy both of these metrics, this criterion mandates either replacing these facilities with in-kind infrastructure that meets current Dominion Energy standards or employing an alternative solution to ensure the Dominion Energy transmission system satisfies all applicable reliability criteria.

Dominion Energy will determine whether the two metrics are satisfied based on the following assessment:

1. End of Life

Factors that support a determination that a facility has reached its end of life include, but are not limited to,

- **Condition** of the facility, taking into consideration:
 - Industry recommendations on service life for the particular type of facility
 - The facility’s performance history
 - Documented evidence indicating that the facility has reached the end of its useful service life
 - The facility’s maintenance and expense history
- **Third party assessment** - While not required, Dominion Energy has the option of seeking a third party assessment of a facility to determine if industry specialists agree the facility has reached the end of its useful service life.

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2. Reliability and System Impact

The reliability impact of continued operation of a facility will be determined based on a planning assessment and operational performance considerations. The end-of-life determination for a facility to be tested for reliability impact will be assessed by evaluating the impact on short term and long term reliability with and without the facility in service. The existing system with the facility removed will become the base case system for which all reliability tests will be performed.

The primary four (4) reliability tests to be considered are:

1. NERC Reliability Standards
2. PJM Planning Criteria – As documented in PJM Manual 14B – PJM Region Transmission Planning Process
3. Dominion Energy Transmission Planning Criteria contained in this document
4. Operational Performance – This test will be based on input from PJM and/or Dominion Energy System Operations as to the impact on reliably operating the system without the facility

Additional factors to be evaluated under system impact may include but not be limited to:


1. Market efficiency
2. Stage 1A ARR sufficiency
3. Public policy
4. SERC reliability criteria

Failure of any of these reliability tests, along with the end-of-life assessment discussed herein, will indicate a violation of the End-of-Life Criteria and necessitate replacement as mandated earlier in this document.

After the end of service life and reliability impact of a facility are evaluated and it has been determined that the facility violates the End-of-Life Criteria, a determination will be made as to whether replacement of the facility is the most effective solution for an identified reliability need, or whether an alternative solution should be employed. One or more of the following factors may be considered in determining whether to proceed with facility replacement or with an alternative solution:

- Planning analysis which may include power flow studies
- Operational performance
- System Reliability
- Effectiveness of the alternative as compared to the replacement facility
- Future load growth in the study area

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- Future transmission projects or interconnects that impact the study area
- Constructability comparison
- Cost comparison

C.3. Generation dispatch used in DEV-ET Power Flow Studies

The PJM RTEP Power Flow case for the year under study is the starting point for DEV-ET Power Flow Studies. The generation dispatch in the PJM RTEP case is developed based on PJM's Study Methodologies as outlined in PJM's Manual 14B. DEV may modify this generation dispatch to develop a Base Power Flow case which is used as the starting point of DEV-ET's Analysis to support PJM's RTEP Study Process. These modifications may include the following:

- Generating Units which have significant environmental limitations which severely limit the unit's availability in real time operation may be modeled as being off-line.
- Generating Units which rely on the weather and time of day for operation (PV, WT, hydro) may be modeled off-line, or at a reduced output, to match the conditions being studied.
- Generating Units which have been identified in DEV-ET's IRP Filings in Virginia/North Carolina as being "Potential" Generation Retirements may be modeled as being off-line.
- Known outages of a generating unit which are consistent with NERC Reliability Standard TPL-001 selection criteria may be modeled as being off-line.


The base power flow dispatch provided to DEV-ET in a power flow case which is used to analyze the reliability impact (Feasibility Study/System Impact Study) of generators in the PJM Generation Queue is typically modified by DEV-ET. Since the case provided to DEV-ET typically has all queue generation located on the DEV-ET system as being off-line, DEV-ET will modify the generation dispatch for power flow studies. Specifically, will turn on all higher order queue generators then the queue request under study as the base case condition for the generator under study. To account for this additional generation, generators located on the PJM System are proportional re-dispatched to account for this additional generation.

Per NERC power flow case quality metrics⁴, the following rules must be respected when developing a generation dispatch.

1. Generators must not be dispatched outside the generators real power MW capabilities.

$$P_{max} \geq P_{gen} \geq P_{min}$$

⁴ NERC 2020 Case Quality Metrics Assessment, October 2020.

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- Generator should not be dispatched with the generators reactive power Mvar at either limit.

$$Q_{gen} \neq Q_{max} \text{ and } Q_{gen} \neq Q_{min}$$

- Generator should have reasonable reactive power limits. When compared with maximum active power (P_{max}) the power factor should be with +0.8 (producing vars) and -0.85 (consuming).
- Generator terminal bus voltages should be between 0.95 and 1.05 when the generator is regulating a non-terminal bus. This does not apply to wind farms and solar arrays.

C.4. Setup of IBR generation

C.4.1. Wind and Solar generation

The energy supply for wind and solar generator plants varies with time of day and the season. As such, the IBR plant output must match the load scenario being simulated. For instance, when studying peak load during winter months, solar plant output may be less than its maximum, or zero, depending on the time of day the winter peak is expected to occur. Also, during summer peak months, an extreme peak load conditions are usually the result of high heat and low wind. When setting up for an extreme summer peak scenario, wind generators should be set to zero.


C.4.2. Battery Storage

Depending on the scenario being studied, battery storage units can act as either load or generation. As such, battery storage units should be set to mimic the behavior expected during the scenario being studied.

- Set as Generation when the scenario being simulated calls for no, or low, output from wind and/or solar generators. These may include winter peak (night), summer peak (no wind) or other potential interruptions to generation which requires the use of battery storage.
- Set as Load when simulating light load conditions with an excess of generation in service. These may include wind generators during high wind periods, solar generators during mild spring conditions, steam generators with long startup times and nuclear power plants.

C.4.3. Power factor for non-synchronous generation

FERC requires that all non-synchronous generators be designed to supply dynamic reactive power within the power factor range from 0.95 leading to 0.95 lagging while

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supplying continuous rated real power at the high side of the generator substation⁵. This is a minimum design requirement. It does not prevent a non-synchronous generation to operate outside this range. The full capability of the non-synchronous generator should be used to support voltage⁶. As such, non-synchronous generation shall provide a reactive capability curve which defines the reactive limits of the non-synchronous generator. Similar to reactive capability curves for a synchronous generator, the reactive capability curve for a non-synchronous generation plant will be constructed with the voltage at the POI held at 1.00 pu. Leading and lagging reactive capability at different levels of real power output (100%, 90%...0% of rated MW) will be listed. The table generated will describe the reactive capability of the non-synchronous generator.

Non-synchronous generation includes wind generators, solar generators and battery storage.

D. Transmission planning, system stability criteria

D.1. Introduction

There are many variables that affect the results of a stability study. These factors include but are not limited to:

- pre-fault and post-fault system configurations
- system load level and load characteristics
- generation dispatch patterns, unit dynamic characteristics and proximity to other generating unit types and locations of system disturbances
- type of generation dispatched (wind, solar, steam, gas turbine, battery)
- type of load being served (residential, commercial, industrial, agricultural)
- fault clearing time(s)
- the amount of flow interrupted as a result of switching out faulted elements
- level of detail and accuracy of available models/data


Many of these factors change in the operating area on a continuous basis. Every effort should be made to evaluate the most severe, yet credible/probable stability study scenarios in the planning area.

D.2. General criteria

Since 2005, PJM becomes the Transmission Planner (TP) for DEV-ET. PJM conducts stability studies to ensure that the planned system can withstand NERC criteria disturbances and maintain stable operation throughout the PJM planning horizon, as well as the DEV-ET's specific

⁵ Required by FERC Order 827, Reactive Power Requirements for Non-Synchronous Generation, at paragraph 34.

⁶ NERC Reliability Guideline, "BPS-Connected Inverter-Based Resource Performance", Sept. 2018, p 25.

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stability practices in ET Planning Criteria. Such stability analyses include but are not limited to:

- System impact stability study for Bulk Electric System⁷ (BES) generation interconnection queue projects prior the in-service date of the projects
- Periodical Baseline, N-1-1 stability study for individual BES generation stations in compliance with the NERC Reliability Standard TPL-001
- Periodical Baseline, N-1-1 stability study for selected area using dynamic load model for voltage stability purpose in compliance with the NERC Reliability Standard TPL-001
- Periodical extreme events dynamic study for selected area for voltage stability purpose in compliance with the NERC Reliability Standard TPL-001
- Under frequency load shedding (UFLS) study for selected area periodically in compliance with the NERC Reliability Standard PRC-006 and SERC Reliability Standard [PRC-006](#)
- Studies to evaluate the capabilities of IBRs tied to the DEV-ET system. This includes Low Voltage Ride Through (LVRT), High Voltage Ride Through (HVRT), primary frequency response⁸ and dynamic voltage response⁹.
- Other studies as needed to investigate and evaluate system disturbances.

DEV-ET Planning team supports PJM on their stability analysis responsibilities and conducts internal stability analyses. Stability study activities performed by ET Planning include but are not limited to:

- Assisting and reviewing PJM's system impact stability study for BES generation interconnection queue projects.


Stability analysis is not required for units that are not part of the BES as defined by NERC. In PJM practice, generators rated 20 MVA or less in size and with aggregate plant capacity less than or equal to 75 MVA are not required to be studied in the system impact stability study process. DEV-ET Planning determines whether to conduct the stability study for these units.

- Assisting, reviewing, and supporting PJM's stability study in compliance with the NERC Reliability Standard TPL-001
- Delayed protective relay tripping system stability analysis per the requests from DEV-ET System Protection group
- Stability studies required in PJM Regional Transmission Expansion Plan (RTEP) projects (include but are not limited to projects involving FACTS devices)

⁷ NERC Bulk Electric System Definition Reference Document, link: https://www.nerc.com/pa/Stand/2018%20Bulk%20Electric%20System%20Definition%20Reference/BES_Reference_Doc_08_08_2018_Clean_for_Posting.pdf

⁸ FERC Order 842, Essential Reliability Services and the Evolving Bulk-Power System—Primary Frequency Response.

⁹ FERC Order 827, Reactive Power Requirements for Non-Synchronous Generation.

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- The substation physical security stability analyses in compliance with the NERC Reliability Standard CIP-014
- Special stability studies required by long-term (above 5 years) strategic planning projects

D.3. Study horizon

Stability studies performed for the near-term horizon (1-5 years) include but not limited to following types and can be implemented in a relatively short period of time:

- System dynamic performance
- Transmission protection enhancement
- Generation protection enhancement
- Generation equipment enhancement
- Apply/modify/remove Remedial Action Scheme (RAS)
- Install/modify FACTS devices
- Establish operating restrictions for a contingency period covering forced or maintenance outages


New transmission infrastructure may be required to ensure stability for safe and reliable operation of the electric grid. In cases where a near-term stability study finds a potential problem and the plan to correct the problem requires a lead time beyond the near term, a stability study will be performed for longer term to determine the impact.

Stability studies performed for the long-term horizon (above 5 years) are determined by specific long-term strategic planning projects. The scope of the long-term studies is to better understand the grid performance of the DEV-ET transmission system in a longer time scale and prepare for challenges with the rapidly changing generation and load environment and from the adoption of new technologies. Study results of such scenarios are carefully analyzed, and the findings provide important supplemental information to the development of DEV-ET's transmission expansion plan.

D.4. Dynamic data collection

PJM will collect dynamic data and submit to Multi-Regional Modeling Working Group (MMWG) as outlined in the Eastern Interconnection Reliability Assessment Group (ERAG) MMWG Procedural Manual.

Dominion Energy Electric Transmission Planning is responsible for submitting dynamic data to PJM for Transmission Owner equipment with dynamic characteristics (e.g. FACTS devices) and dynamic load¹⁵⁴⁷ data. The dynamic load data is collected from load serving entities tied to DEV-ET.

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D.5. Stability study case development

Planning area studies for stability analysis are performed using estimated snap-shots (scenarios) of the expected system operating conditions for the study period selected. The power flow base cases that match dynamics data for the Eastern Interconnection are prepared by the Multi-regional Modeling Working Group (MMWG) for selected years on an annual basis.

For individual stability analysis, the analysis performer is responsible to work with DEV-ET Planning modeling team to develop most appropriate load flow and dynamic cases for the study. Such model development activities may include:

- Changes to the model topology to include projects that will be completed before the targeted study date.
- Changes to area load levels and generator dispatch patterns to match the targeted study date and study scenario.
- Adjustments to dynamic model parameters to match assumptions described study scenario.
- Addition of meters to dynamics model to measure voltage, frequency or any other parameter needed to confirm the perform of new, or existing, loads and generators.

After the dynamics model setup, the model is tested to ensure that the system is at a steady-state operating point. The test is performed by starting simulation without any disturbance or changes. The simulation continues for 20 -30 seconds. When done, the simulation plots are checked for oscillations. If all plots are flat (flat run) and no oscillations are found, the model is in steady state. If the plots show oscillations, the initial conditions of the models must be edited.

D.6. Selection of generation dispatch


The economic dispatch used in internal power flow base cases may not represent conditions which could pose a stability risk. Therefore, the power flow cases may be stressed to test the area or generation under study. For example, increased transfers near generating facilities can have an adverse impact on transient stability and therefore need to be accounted for when creating stressed yet credible system dispatches for the stability studies.

Unit dispatch for transient stability studies also differs from the conventional power flow analysis. Units in the study region are generally dispatched to maximum real power output (Pmax), and at leading power factor at the low side of the GSU provided that the equipment voltage limits are not violated.

D.7. Selection of contingencies

Contingency categories and simulation specifications are based on Table 1 of NERC Reliability Standard TPL-001.

For a generation interconnection System Impact Study (SIS) or a TPL-001 compliance study, DEV-ET Planning uses the same contingency criteria and margins as PJM uses in its stability

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analysis.¹⁰ For other stability analyses initiated by ET Planning, the most appropriate contingency criteria and margins are selected by ET Planning.

D.8. What to look for in study results

Checks are performed to make sure all on-line units initialize properly without any error messages.

Checks are performed to make sure the system is stable within the acceptable operating criteria:

- **Acceptable Transient Voltage Recovery:** When a fault occurs on the transmission system, system voltages are temporarily reduced. Once the fault is cleared, voltages follow transient voltage recovery trajectories governed by system dynamics. Regardless of the load model that is selected, the voltage following fault clearing shall recover to a minimum of 0.7 p.u. after 2.5 seconds. The transient voltage recovery criteria should be satisfied at BES buses.
- **Acceptable Damping:** Following the disturbance, the oscillations of the monitored parameters display positive damping. The damping ratio should reach 3% or better for inter-area oscillations and 4% or better for local mode oscillations.
- **Acceptable Generator Voltage Performance:** Generators are required to supply dynamic voltage support within the capability of the machine. For IBRs (non-synchronous machines), each generator must automatically respond to the need for voltage support and each generator must be capable of supplying reactive power within a minimum power factor range of 0.95 leading to 0.95 lagging while supplying maximum real power output. For synchronous machines, each generator must automatically respond to the need for voltage support and must be capable of supplying reactive power within a minimum power factor range of 0.95 leading to 0.90 lagging while supplying maximum real power output.¹¹
- **Acceptable generator frequency response:** Generators models are required to provide primary frequency response with a maximum 5% droop and +/- 0.036 Hz deadband. Each generator, including IBRs, must have real power controls with the ability to respond to frequency changes to halt a sudden rise or drop in frequency.¹²


If inter-area oscillations occur that have an unacceptable damping ratio and it is found that another entity's units are participating significantly in the oscillation, then a joint study between the affected parties is required.

To ensure transient stability is maintained with positive damping, N-1-1 contingencies are simulated with no re-dispatch after the first (N-1) contingency has occurred. If the oscillation damping is positive but does not reach the 3% limit for inter-area oscillations (4% for local oscillations), operational restrictions may be applied to ensure sufficient system damping.

¹⁰ PJM Manual 14B: PJM Region Transmission Planning Process Attachment G: PJM Stability, Short Circuit and Special RTEP Practices and Procedures

¹¹ PJM OATT VI, Part IX.B, GIA Appx 2 Section 4.6.1.1.1 New Facilities

¹² PJM OATT VI, Part IX.B, GIA Appx 2 Section 4.6.2.1 Governor or Equivalent Controls

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For system conditions and contingencies that result in generator instability, additional analysis is performed to quantify the risk of a cascading event. Cascading failure analysis will consider a risk-based study of the loss of the generating unit based on expected protection and control as well as unexpected tripping. Depending on the size and expanse of the affected area, other solution options, operating restrictions, or transmission investments may be considered.

D.9. Implementation procedure


Stability analysis may warrant corrections or additional requirements to meet the criteria. The implementation procedure for such items depends on the type of corrections and the nature of installation. The following is a general guideline for Transmission Planning to implement the plans needed to correct unacceptable system behavior.

D.9.1. For existing installations

- System modifications that change fault clearing times by making changes to existing relay set points shall be communicated to DEV-ET System Protection group for implementation. PJM will be informed as to the results of the analysis.
- A Capital project shall be created to correction unacceptable system behavior related to transmission fault clearing times which cannot be corrected by changing the relay set points. Capital projects shall first be validated, approved and assigned cost and construction responsibility by the PJM Regional Transmission Expansion Planning (RTEP) process.
- Output restrictions and/or unit trip(s) for the next pending contingency condition identified by DEV-ET in routine planning studies, will be communicated to the SOC. In turn, the SOC shall inform PJM for implementation as appropriate.
- In case of scheduled maintenance or construction outages, the results/recommendations shall be conveyed to the person through whom the stability analysis request came to the stability engineers. For example, if a Project Manager requests such analysis to the load Planning Engineer, the stability engineer shall forward his analysis to the load Planning Engineer. If SOC requests such analysis, the results/recommendations shall be forwarded to SOC which in turn shall inform PJM for implementation as appropriate.

D.9.2. For all new installations or capacity additions

New generating resources are studied as part of the PJM Generation Interconnection Queue process. PJM shall document the fault clearing time requirements and/or any additional protection requirements in its Impact Study report. PJM shall also communicate the requirements on the generation side to the GO requesting the Interconnection in PJM Queue. For the transmission related requirements, DEV-ET shall communicate these to the Substation Engineering group for design and implementation.

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D.9.3. New IBRs and loads dominated by electronics.

Wind turbine power plants, PV power plants, battery storage units and data centers are inverter-based equipment which are dominated by the behavior and controls of inverter-based systems. Inverter-based equipment introduce system responses not normally encountered with rotating machines (generators and motors). Consequently, EMT simulations are performed to determine the systems response to a fault when inverter-based equipment is present. IEEE Std 2800-2022¹³ provides guidance on the EMT data requirements for IBRs connected to the transmission system and should be followed. Due to the unique design of the equipment, the equipment manufacturer is the best source of EMT models. Therefore, EMT models for generators and loads that are dominated by inverters should be supplied by the equipment manufacturer(s).

E. Nuclear plant interface coordination

E.1. Introduction

Nuclear power plants have special needs for backup station service not found in other plants. In order to safely shut down a nuclear unit, the station service must have an adequate supply of power under tight voltage tolerances to the safety systems. Although nuclear plants have diesel generators as a backup supply, their preferred power source is the transmission grid. This allows multiple levels of redundancy which is the hallmark of the nuclear plant's endeavor to the highest level of safety.


E.2. NRC regulations

The Federal Nuclear Regulatory Commission (NRC) lays out certain regulations on the design and operation of Nuclear Plants. **Appendix A of Regulation 10 CFR 50** "General Design Criteria for Nuclear Power Plants" states:

"Criterion 17--Electric power systems. An onsite electric power system and an offsite electric power system shall be provided to permit functioning of structures, systems, and components important to safety. The safety function for each system (assuming the other system is not functioning) shall be to provide sufficient capacity and capability to assure that (1) specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded as a result of anticipated operational occurrences and (2) the core is cooled and containment integrity and other vital functions are maintained in the event of postulated accidents.

The onsite electric power supplies, including the batteries, and the onsite electric distribution system, shall have sufficient independence, redundancy, and testability to perform their safety functions assuming a single failure.

¹³ IEEE Std 2800-2022, "IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems", Annex G.

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Electric power from the transmission network to the onsite electric distribution system shall be supplied by two physically independent circuits (not necessarily on separate rights of way) designed and located so as to minimize to the extent practical the likelihood of their simultaneous failure under operating and postulated accident and environmental conditions. A switchyard common to both circuits is acceptable. Each of these circuits shall be designed to be available in sufficient time following a loss of all onsite alternating current power supplies and the other offsite electric power circuit, to assure that specified acceptable fuel design limits and design conditions of the reactor coolant pressure boundary are not exceeded. One of these circuits shall be designed to be available within a few seconds following a loss-of-coolant accident to assure that core cooling, containment integrity, and other vital safety functions are maintained.

Provisions shall be included to minimize the probability of losing electric power from any of the remaining supplies as a result of, or coincident with, the loss of power generated by the nuclear power unit, the loss of power from the transmission network, or the loss of power from the onsite electric power supplies.”

The above regulation General Design Criterion 17 is often abbreviated “GDC-17.”

E.3. Design requirements

PJM and DEV-ET will design the system to meet the GDC-17 requirements. In order to provide adequate voltage to safety systems, the Nuclear group periodically provides Nuclear Plant Interface Requirements (NPIR) to Dominion Energy Electric Transmission. Dominion Energy transmission planners should consult the latest version of applicable Interface Agreements between Dominion Energy Electric Transmission and the nuclear plants for applicable normal and emergency voltage limits, voltage drops and contingency scenarios.


Because emergency systems require adequate voltage immediately following an event, transmission LTC’s should be locked post-contingency.

For violations of the NPIRs, the transmission planner will contact the GDC-17 coordinator for Electric Transmission Planning. PJM/Dominion Energy Electric Transmission Planning will notify DEV-NUC of any NPIR criteria violations. Transmission study criteria violations based on standard PJM/Dominion Energy criteria testing will be handled by the procedures described in the PJM agreements and manuals. For study violations that are beyond applicable PJM criteria, DEV-NUC will determine if any further action is required and respond to Dominion Energy Electric Transmission Planning. Dominion Energy Electric Transmission Planning will work with PJM to resolve concerns identified by DEV-NUC.

For contingencies more severe than those within the NPIRs, standard planning voltage range criteria will be applied.

E.4. Underfrequency studies

The underfrequency load shed program (UFLS) should be designed to coordinate with station underfrequency trip settings. The North Anna reactor coolant pump (RCP) is set to trip at 56.55

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Hz with a time delay of 100 milliseconds. The Surry reactor coolant pump (RCP) is set to trip at 58.05 Hz with a time delay of 100 milliseconds.

E.5. Angular stability studies

Angular stability studies are performed on nuclear plants using the standard methodology used for any synchronous machine. The results of these studies should be forwarded to Nuclear Engineering.

E.6. System analysis protocol


The Nuclear Switchyard Interface Agreement System Analysis Protocol (CO-AGREE-000-IA1-4 or its successor) outlines the types and frequency of studies which may be performed in support of the nuclear plant. It also specifies the type of communications necessary and the frequency of the analysis. In order to show compliance with NERC Reliability Standard NUC-001-2 (or its successor), the GDC-17 coordinator shall retain evidence of communications with the appropriate nuclear contacts.

E.7. Changes to the system

The NERC Reliability Standard NUC-001-2, R8 states that the "...Transmission Entities shall inform the Nuclear Plant Generator Operator of actual or proposed changes to electric system design, configuration, operations, limits, protection systems, or capabilities that may impact the ability of the electric system to meet the NPIRs."

F. References

- NERC Reliability Standard TPL-001, Transmission System Planning Performance Requirements
- NERC Reliability Standard PRC-012, Remedial Action Schemes
- NERC Reliability Standard PRC-017, Remedial Action Scheme Maintenance and Testing
- NERC Technical Reference Document, Dynamic Load Modeling, December 2016
- NERC Reliability Guideline, Reactive Power Planning, December 2016
- NERC Reliability Guideline, Electromagnetic Transient Modeling for BPS Connected Inverter-Based Resources—Recommended Model Requirements and Verification Practices, March 2023
- NERC Libraries of Standardized Powerflow Parameters and Standardized Dynamics Models, Version 1 – October 15, 2015
- NERC 2012 Special Assessment Interconnection Requirements for Variable Generation, September 2012
- NERC Reliability Standard NUC-001
- IEEE Std 1110, IEEE Guide for Synchronous Generator Modeling Practices and Parameter Verification with Applications in Power System Stability Analyses.
- IEEE Std 2800, IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems.

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- IEEE Std 519, IEEE Standard for Harmonic Control in Electric Power Systems.
- IEEE Std 1547, IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces.
- Transmission System Performance SERC Supplement
- Nuclear Switchyard Interface Agreement CO-AGREE-000-IA1
- Nuclear Switchyard Interface Agreement System Analysis Protocol CO-AGREE-000-IA1-4
- PJM Manual 39 – Nuclear Plant Interface Coordination
- PJM Manual 14B – PJM Region Transmission Planning Process

G. Abbreviations & definitions

- **AAR** - Auction Revenue Rights (see PJM Manual 06 – Financial Transmission Rights for more details)
- **ANSI** - American National Standards Institute
- **ERAG** - Eastern Interconnection Reliability Assessment Group
- **FCITC** - First Contingency Incremental Transfer Capability
- **Good Utility Practice** - Any of the practices, methods, and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods and acts that, in the exercise of reasonable judgment in light of the facts known at the time the decision is made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety and expedition.
- **GSU** - Generator Step-up Transformer
- **IEEE** - Institute of Electrical and Electronic Engineers
- **MMWG** - Multi-Regional Modeling Working Group
- **NERC** - North American Electric Reliability Corporation
- **POI** - Point of Interconnection
- **RTO** - Regional Transmission Organization
- **PSS** - Power System Stabilizer
- **SERC** - SERC Reliability Corporation

H. REVISION HISTORY

Revision Date	Revision #	Description	Revised By	Effective Date
08/24/1999	0.0*	Original document created to meet the requirements of NERC Planning Standard I.C.S1.M1.	ET Planning staff	08/24/1999
05/01/2001	1.0*	See Details for Revision 1.0 below	ET Planning staff	05/01/2001
09/07/2005	2.0*	See Details for Revision 2.0 below	ET Planning staff	09/07/2005
05/29/2007	3.0*	See Details for Revision 3.0 below	ET Planning staff	05/29/2007
12/22/2009	4.0*	See Details for Revision 4.0 below	ET Planning staff	12/22/2009
12/22/2011	5.0*	See Details for Revision 5.0 below	William F. Bigdely	12/22/2011
10/10/2012	6.0	See Details for Revision 6.0 below	William F. Bigdely	10/10/2012
11/22/2013	7.0	See Details for Revision 7.0 below	William F. Bigdely	11/22/2013
03/31/2014	8.0	See Details for Revision 8.0 below	William F. Bigdely	03/31/2014
07/16/2014	9.0	See Details for Revision 9.0 below	William F. Bigdely	07/16/2014
01/09/2015	10.0	See Details for Revision 10.0 below	William F. Bigdely	01/15/2015
03/26/2015	11.0	See Details for Revision 11.0 below	William F. Bigdely	03/27/2015
12/15/2015	12.0	See Details for Revision 12.0 below	William F. Bigdely	01/01/2016
05/15/2017	13.0	See Details for Revision 13.0 below	William F. Bigdely	06/01/2017
03/29/2018	14.0	See Details for Revision 14.0 below	William F. Bigdely	04/01/2018
12/13/2018	15.0	See Details for Revision 15.0 below	William F. Bigdely	01/01/2019
03/11/2019	16.0	See Details for Revision 16.0 below	William F. Bigdely	03/15/2019
03/10/2020	17.0	See Details for Revision 17.0 below	David C. Witt	03/24/2020
06/22/2020	18.0	See Details for Revision 18.0 below	David C. Witt	07/01/2020
02/22/2021	19.0	See Details for Revision 19.0 below	Hamidreza Sadeghian	04/01/2021
03/03/2022	20.0	See Details for Revision 20.0 below	Mark Gill	04/01/2022
02/16/2023	21.0	See Details for Revision 21.0 below	Amirreza Sahami	04/01/2023
01/01/2024	22.0	Revision as a part of Facilities Interconnection Requirements	ET Planning Staff	01/01/2024
08/01/2024	23.0	See Details for Revision 23.0 below	Kristen Custer	09/01/2024

**For these revisions, the planning guideline was an attachment within the DEV facilities interconnection requirements document. Associated comments for these revisions do not necessarily apply to the contents of the planning guideline specifically.*


Details for Revision 1.0

- Revised to include information regarding Dominion's generation interconnection procedures/process

Details for Revision 2.0

- Revised to reflect transition from old NERC Planning Standards to NERC Reliability Standards, including changing the naming convention of all referenced standards throughout the document.

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Details for Revision 3.0

- Revised to reflect the following:
 - Updates to NERC Reliability Standards
 - Dominion's PJM Membership
 - References to new SERC regional studies processes

Details for Revision 4.0

- Revised to reflect the following:
 - PJM Generation Queue Changes Section 4
 - General Revisions all sections

Details for Revision 5.0

- Revised the following:
 - Section 2.12: Clarified content regarding synchronizing of facilities.
 - Exhibit A: Changed loading criteria to not exceed emergency rating of transmission facility.
 - Various errata changes.

Details for Revision 6.0

- Overhaul and expansion of entire Planning Criteria.
- Document previously called "Transmission Planning Guidelines"

Details for Revision 7.0

- Updated to include future reference to TPL-001-4 (R1 and R7 NERC enforcement date of 01-01-2015)
- Updated titles for approval process
- Various errata changes

Details for Revision 8.0


- Expanded description for Section G.1. TAPPING LINE BELOW 100 MW LOAD to emphasize the requirement of a fused bypass arrangement.
- Recreated diagrams throughout for consistency of style.

Details for Revision 9.0

- Added section C.2.8 - End of life criteria
- Reformatted headers to improve PDF navigation via bookmarks.

Details for Revision 10.0

- Clarifications and annual review.
- Reformatted approval area and moved to title page.
- Reformatted Revision History and moved to end of document (Section J).

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- Modified throughout to reflect NERC Reliability Standard TPL-001-4, including replacement of Tables 1A and 1B and deletion of “Category D Multiple Testing Requirements” (previously Section C.2.7 in Revision 9.0 document).
- Section C.2.6 Radial lines: Expanded to introduce new criteria and metrics.
- Section C.2.7 Network transmission lines – Limitations on direct-connect loads: Inserted new section.
- Section D.4 Study cycle – Clarified that PJM (not DEV-ET) performs simulations to cover all generating plants over a three-year study cycle (not five-year).
- Section G: Modified electrical arrangements and clarified lines of demarcation.

Details for Revision 11.0

- Section C1, Table 1A Notes – Added Note “C”
- Section C1, Table 1B Notes – Added Note “G”; re-numbered other notes to differentiate from Table 1A [Note G became Note I in v15]
- Section D7 Selection of generation dispatch – Rephrased the content to improve clarity.

Details for Revision 12.0

- Changed references of Special Protection System (SPS) to Remedial Action Scheme (RAS).
- Tables 1A and 1B: Removed references to DC line (does not apply to Dominion), and
- Table 1A, Note B and Table 1B, Note F: Clarified “may NOT be required if the loss of consequential and non-consequential load up to 300 MW achieves a return to the STE rating.”
- Section E.3. Updated NPIR Limits.
- Former Section F (Transmission Line Connections – Generation) and former Section G (Load Criteria – End User) have been removed from this document and integrated into the Facility Interconnection Requirements as Sections 5 and 6.
- Section G Abbreviations & definitions: Added definition of “Good Utility Practice”.

Details for Revision 13.0

- Revised references for new Dominion Energy corporate identity.
- Section C.1. Added Table 1C Steady-State Performance EXTREME Events and Dominion Energy CRITERIA, and associated notes; refined notes for Tables 1A and 1B.
- Added Section C.2.8. Substation – Limitation on direct-connect loads.

Details for Revision 14.0

- Clarified that some notes to Tables A, B and C are “Dominion Energy” notes.
- Edited Dominion Energy Note “B” for Table 1A and Note “F” for Table 1B to remove phrase “and non-consequential” [load]. [Note F became Note H in v15]
- Edited Dominion Energy Note “C” for Table 1A and Note “G” for Table 1B to refer to new section C.2.1.3. [Note G became Note I in v15]
- Added Section C.2.1.3 - Critical stress case development and studies

Details for Revision 15.0

- Reviewed to ensure alignment with Facility Interconnection Requirements, v15, effective 1/1/2019.

Public

- Tables 1A, 1B, 1C: Added new notes to Tables 1A and 1B, requiring re-labeling of notes in Tables 1A, 1B and 1C as follows:

Previously	Now
A	A
B	B (edited)
-	C (NEW)
C	D
-	E (NEW)
D	F

Previously	Now
E	G
F	H
G	I
-	J (NEW)
H	K
I	L

Previously	Now
J	M
K	N
L	O
M	P
N	Q

- Section C.1. Planning principles and standards - Simplified reference to Nuclear generation re-dispatch.
- Section C.2.9. End of life criteria - Edited discussion and list of factors considered.
- Section C.3. Selection of generation dispatch used in DEV-ET Power Flow Studies - New section.
- Section E Nuclear plant interface coordination:
 - E.3. Design Requirements – Removed tables of NPIR voltage limits, voltage drops, and contingency scenarios.
 - E.7. Changes to the system – Simplified content to contain only the NUC-001-2, R8 quotation.

Details for Revision 16.0


- Table 1A, Note B: Deleted specific reference to 230 kV (table applies to several voltages).
- Table 1B, Notes F & G: Removed specific references to 500 kV (500 kV is inherent to this table).

Details for Revision 17.0

- Updated dates, names and revision number.
- Tables 1A and 1B – Added contingency for Category P4, Event 6
- Section C.1 Planning principles and standards – Added language describing N-1-1 contingency analysis.
- Section C.2.6. Radial transmission lines – Edited discussion.
- Section C.2.9. End of life criteria – Removed evaluation of lines operating below 500kV and edited assessment language.
- Section D Transmission planning, system stability criteria – General update of this section including language expanding the stability study horizon beyond 5 years to accommodate longer term strategic projects.
- Section F – Updated to include reference to PRC Standards 12 -17.

Details for Revision 18.0

- Table 1A – Decreased the high voltage limits for 138kV lines.
- Table 1B – Revised the high voltage limits for 500kV and above lines.
- Table 1C – Revised Note “Q” Extra High Voltage (EHV) limit to 109.6%.

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Details for Revision 19.0

- Updated Signature Page.
- Section C.1 Planning principles and standards – Revised time frame of system adjustments.
- Table 1A – Removed the Note “A”, “B”, and “C” and set the Thermal Limits to 100% of Short Term Emergency (STE). Note C added for system adjustments at initial condition in P3 and P6. In addition, system reinforcements for load loss more than 300 MW are indicated.
- Table 1B – Removed the Note “F”, “G”, and “H” and set the Thermal Limits to 100% STE. Note F added for system adjustments at initial condition in P3 and P6. In addition, system reinforcements for load loss more than 300 MW are indicated.
- Table 1C – Changed the Note References.

Section C.2.2. Added footnote for DEV-ET criteria on Generation Deliverability.

Details for Revision 20.0

- Updated Signature Page.

Details for Revision 21.0

- Updated Signature Page.
- Minor typos and grammatical edits through the entire document.
- Section C.1., Table 1A, Table 1B: P5 is updated to include future reference to TPL-001-5.1 (Effective date is 07/01/2023).
- Section C.1., Note 13 is updated to include future reference to TPL-001-5.1 (Effective date is 07/01/2023).
- Section C.2.6 Radial transmission lines criteria is modified to address wider range of situations.


Details for Revision 22.0

- Updated Signature Page.
- Revision as a part of Facilities Interconnection Requirements


Details for Revision 23.0

- Revision contributors include: Aaron Winter, Amirreza Sahami, Andrea Pinceti, Colleen Wallace, Harrison Potter, Katelynn Vance, Keith Graham, Mark Gill, Mohsen Mahoor, Nedim Besirevic, Peter Nedwick, Praveen Dhanasekar, YaJun Zheng, and Quanta-Technology Services.
- Removed signature page and consolidated on FIR cover page.
- Added language and a link to NERC standards in section B.1.
- Language and style edits to make more readable.
- Added section B4 to explain the use of IEEE standards.
- In section C1 the definition of CAP was expanded to “Corrective Action Plan” and added a footnote to NERC glossary of terms.
- In section C.1.1. Voltage limits at generating stations, PV arrays was added to the exception with wind turbines.
- The language in section C.2.3 “Equipment ratings” was changed to match industry usage.
- Added bullet point in section C3 to include generation which is dependent on the weather.
- Added language and list items 1 – 4 to section C3 to align DEV power flow case setup with NERC power flow case quality metrics.

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- Added section C4 to account for IBR generation during power flow case setup.
- Added section C.4.2 to account for Battery Storage during power flow case setup.
- Added section C.4.3 with footnotes to account for non-synchronous generator pf settings.
- Added bullets to section D.1. “Introduction” to account for the type of generation and type of load.
- Added bullet to section D.2. “General criteria” with language to require evaluation of voltage and frequency response.
- Added bullet to section D.3. “Study horizon” to include system dynamic performance.
- Added language to section D.5 to include flat start of a model.
- Added bullets to section D.8. to help identify generator voltage performance and frequency performance.
- Added section D9.3 to account for generation and load that used inverters.
- Fixed naming convention in reference section and added references.

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Attachment 2

Customer Request Form

**Dominion Energy Virginia – Electric Transmission
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Customer Requests Impacting Dominion Energy Virginia Facilities

Customers shall initiate all requests which impact a Dominion Energy Virginia (DEV) facility by electronically submitting the required information through the online Dominion Energy Virginia Delivery Point Exchange website. Should this web-based request site be unavailable, requests may be submitted in writing using the request form within this document. Requests shall be submitted for any of the following:


- Request to install, modify, or remove DEV’s facilities.
- Request to install, modify, or increase load being served at a DEV delivery point.
- Discontinue the delivery of electricity to a DEV delivery point.
- Install, modify, or increase generation at a DEV point of interconnection.

Additionally, customers shall submit a request when making changes to the customer’s facilities which are reasonably anticipated to impact the operation of, or lead to a modification to DEV facilities.

Customer requests may be submitted as soon as useful information is available. As the project matures, and additional or updated information becomes available, it is the responsibility of the Customer to submit a revision to the original request with the new information. Each request revision will supersede information from any previous revision.

Customer Request Special Instructions:

1. When Request Forms are submitted with estimated dates, the Parties shall determine a schedule for submitting actual dates and actual information.
 - 1.1. If an estimated date for the “Requested Date to Energize” is initially provided, then the final “Requested Date to Energize” shall not be before the originally submitted date unless it is mutually agreed-upon by both the Customer and DEV-ET, prior to submission of a revised request form.
2. If no information is appropriate for a particular field, enter “N/A”.
3. It is understood that equipment information may not be known during the early stages of the project. If the equipment details are not known, enter “TBD” with the date that the information is expected to be available (*TBD by [date]*) in the either the applicable field or in the section comments field.
4. Each Required Attachment shall be provided or shall be substituted by a page bearing the attachment description and the date by which the attachment shall be provided.
5. Upon receiving a request, DEV shall evaluate the request consistent with PJM requirements. The evaluation may include investigation of alternative solutions and estimates for DEV’s portion of the project. Customers shall provide reasonable assistance during the evaluation in the event that DEV asks for additional information. DEV shall complete its evaluation in a reasonable time after the Customer has supplied all required information as firm or final information.
6. Upon concluding its evaluation, DEV shall provide a written response documenting request approval, approval with modifications, or deny the request. Upon approval of a request, or approval with modifications, DEV will describe, consistent with the Agreement, any required modifications and provide an estimate for project costs, cost responsibilities between the Parties, and any other actions that the Parties must take to implement the request in its approved form. In the event that a request is denied, DEV will provide an explanation for the denial. If the Customer chooses to continue to pursue this project, new request must be submitted which addresses the issues described in the denial.

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PART 1: Delivery Point Submittal Information

Customer Submittal Information

Requestor Company Name:		Request Date:	
Requestor Address:			
Name of Contact Person:			
Contact Phone Number:		Alternate Phone Number:	
Contact Fax Number:		Contact Email Address:	
Is this a revision to an existing request? <i>If so, please provide the delivery point name, location, or request number.</i>			
List any related delivery point requests?			


Request Information

Name of Requested Delivery Point:	
Description of Request: <i>(Attach Detail)</i>	
Reason for Request: <i>(Attach Detail)</i>	

Customer Timing

*Requested Date to Energize:	
Expected Date Customer's Construction to Commence:	
Expected Completion Date of Customer Work:	
Date Requested for Dominion Construction to Commence:	
Requested Completion Date of Dominion Energy Work (De-energized):	
Other Milestones:	
Required Attachments:	1. Construction One-line Diagram 2. Site Plan showing substation notable characteristics (pad size allocated and access road plans). 3. Geospatial Coordinates

* The required Customer Equipment Information included in Part 2 of this request must be submitted at least 90 days prior to the energization date determined during Dominion Energy's review of project feasibility.

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Select the type of request.

Then, provide the information requested below **ONLY** for the selected request type.

- New Delivery Point**
 Modification of an Existing Delivery Point


Request for New Delivery Point

Delivery Point Location: <i>(Attach Detail)</i>	
Description of Delivery Point Facilities Route:	
New Delivery Point Voltage (kV):	
New Peak kVA Capacity of Delivery Point Facilities:	
New Peak kVA Demand of Delivery Point Facilities	
Noteworthy Load Characteristics:	Complete the <i>Noteworthy Load Characteristics</i> form attached and include with delivery point request submission.

Additional Comments:

Provide anticipated peak seasonal demand (kW/KVAR) for the years and seasons below.

	Applicable Year	Summer Peak Demand (kW)	Summer Peak Demand (KVAR)	Winter Peak Demand (kW)	Winter Peak Demand (KVAR)
Year 1					
Year 2					
Year 3					
Year 4					
Year 5					
Year 6					
Year 7					
Year 8					
Year 9					
Highest peak in first 10 years					
Year 15					

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Request for Modification of an Existing Delivery Point

Existing Delivery Point:	
Noteworthy Load Characteristics:	Complete the <i>Noteworthy Load Characteristics</i> form attached and include with delivery point request submission.

Present Delivery Point Voltage (kV):	
Present Summer Peak kW Demand:	
Present Summer Peak kVAR Demand:	
Present Winter Peak kW Demand:	
Present Winter Peak kVAR Demand:	
Present Maximum kVA Capacity of Delivery Point Facilities:	
Present Maximum kVA Demand of Delivery Point Facilities:	

New Delivery Point Voltage (kV):	
New Peak kVA Capacity of Delivery Point Facilities:	
New Peak kVA Demand of Delivery Point Facilities:	

Additional Comments: _____

Provide anticipated peak seasonal demand (kW/KVAR) for the years and seasons below.

	Applicable Year	Summer Peak Demand (kW)	Summer Peak Demand (KVAR)	Winter Peak Demand (kW)	Winter Peak Demand (KVAR)
Year 1					
Year 2					
Year 3					
Year 4					
Year 5					
Year 6					
Year 7					
Year 8					
Year 9					
Highest peak in first 10 years					
Year 15					

Requirement of Authorization

Signature below authorizes Dominion Energy to proceed with design, engineering, and estimation of Project cost as appropriate for Dominion Energy to evaluate and respond to this request. This authorization is pursuant and subject to all terms and conditions of the Agreement of which this Appendix is a part.

Authorizing Signature: _____


Authorization Date: _____

Printed Name: _____

Phone: _____

Title: _____

Email: _____

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PART 2: Customer Equipment

Customer Equipment information must be submitted at least 90 days prior to the energization date determined during Dominion Energy's review of project feasibility.

Transformer Primary Voltage:		Transformer Secondary Voltage:	
Transformer Nameplate Capacity:			
Transformer Temperature Rise:		Transformer Taps:	
Connection (e.g. Wye-Wye):		Transformer Impedance:	
Isolation Device Type and Rating:			
Protection Device Type and Rating:			

- Required Attachments:
1. Operating One-line Diagram
 2. Transformer test report(s)
 3. Transformer loss curve
 4. Operating procedures description
 5. Protection Scheme functional diagram
 6. Protection device information – Include:
 - a. Device types
 - b. Serial and Model numbers
 - c. Relay settings

Noteworthy Load Characteristics Form

Load Composition

<p>Motor A</p> <p>Percent of load consisting of 3-phase induction motors with low inertia (H=0.1 sec) driving constant torque loads. These motors are found in commercial/industrial air conditioning compressors and refrigeration systems (not NEMA B).</p> <ul style="list-style-type: none"> • smaller 5-15 HP compressor motors typical of rooftop air conditioning units commonly found at grocery stores, consumer products stores, and malls. • larger 200-500 HP compressor motors typical of large commercial buildings' central cooling systems. 	%
<p>Motor B</p> <p>Percent of load consisting of 3-phase induction motors with high inertia (H=0.25-0.1 sec) driving loads whose torque is proportional to speed squared. These motors are found in commercial ventilation fans and air-handling systems.</p> <ul style="list-style-type: none"> • 5-25 hp fan motors which are normally NEMA B motors. 	%
<p>Motor C</p> <p>Percent of load consisting of 3-phase induction motors with low inertia (H = 0.1-0.2 sec). This represents motors commonly found in commercial water circulation pumps in central cooling systems.</p> <ul style="list-style-type: none"> • 5-25 HP pump motors which are usually NEMA B motors. 	%
<p>Motor D</p> <p>Percent of load consisting of 1-phase air conditioners. This represents commonly found residential single phase air conditioners.</p>	%
<p>Electronic</p> <p>Percent of load consisting of power electronic converters. These are constant active and reactive power loads that include, consumer electronics (Plasma and LED televisions, cell phones and tablets, clocks, radios, etc), appliances (High efficiency appliances such as refrigerators, washing machines, etc.) and office equipment (Printers, copy machines, servers, etc.).</p>	%
<p>Static</p> <p>Percent of load that will be static. This represents electric ovens, water heaters, incandescent lighting, and all other loads whose behavior changes with voltage magnitude.</p>	%
<p>Total Load Percent =</p>	100 %

* The listed load characteristics are parameters needed to perform simulations using the composite load model referenced in, "NERC Technical Reference Document for Dynamics Load Modeling, December 2016".

Composite Load Model (CLM)

Total installed load (kW):	kW
Total installed distributed generation (kW):	kW
Total installed low side capacitor bank demand (kVar):	kVar
Total synchronous motor load (kW)	kW
Motor start type	
Motor speed control method	

Data Center Load Information

Total rated load including IT, power distribution and cooling (kW)	kW
Overall Data Center Power Factor (Lead/Lag)	Lead/Lag

Load Percentages

	Summer Daytime	Summer Nighttime	Winter Daytime	Winter Nighttime
Computing/Server Load:				
Lighting Load:				
Power Distribution Losses:				
Cooling load:				

Data Center Cooling System

Forced cooling system:	<input type="checkbox"/> None
	<input type="checkbox"/> Computer Room Air Conditioners (CRACs) with internal compressors
	<input type="checkbox"/> Computer Room Air Handlers (CRAHs) supplied with chilled water.
	<input type="checkbox"/> Air-Handling Units (AHUs) dedicated to the data center space
	<input type="checkbox"/> Other:
Cooling system motor driven components:	<input type="checkbox"/> Single-speed motors that are operated across the line (Motors connected directly to the AC supply)
	<input type="checkbox"/> Motors controlled by variable/adjustable speed drives or electronically commutated motors (ECMs)
	<input type="checkbox"/> Other:

Data Center Voltage Performance

Voltage <u>sag</u> level/duration at which the computer/server load disconnects from the utility system (these may transfer to a local UPS):	volts	sec
Voltage <u>sag</u> level/duration at which the cooling load disconnects from the system (these may transfer to an emergency generator or local power source):	volts	sec
How are voltage <u>sag</u> levels measured for the disconnect action?	<input type="checkbox"/> Per phase <input type="checkbox"/> 3-phase RMS	
Voltage <u>swell</u> level/duration at which the computer/server load disconnects from the utility system (these may transfer to a local UPS):	volts	sec
Voltage <u>swell</u> level/duration at which the cooling load disconnects from the system (these may transfer to an emergency generator or local power source):	volts	sec
How are the voltage <u>swells</u> measured for the disconnection action?	<input type="checkbox"/> Per phase <input type="checkbox"/> 3-phase RMS	

Data Center Frequency Performance

The lowest frequency at which the data center will disconnect from the system:	hz
The highest frequency at which the data center will disconnect from the system:	hz

Data Center Reconnection Method After Automatic Disconnect from Service Provider System

Manual	<input type="checkbox"/> YES <input type="checkbox"/> NO
---------------	---

Immediate Reconnect <i>(No Deliberate Time Delay)</i>	<input type="checkbox"/> YES <input type="checkbox"/> NO	If YES , Complete the below information.		
V_{high} : reconnect when voltage is below:	volts	deadband	msec	
V_{low} : reconnect with voltage is above:	volts	deadband	msec	
f_{high} : reconnect when frequency below:	hz	deadband	msec	
f_{low} : reconnect when frequency above:	hz	deadband	msec	


Delayed Reconnection	<input type="checkbox"/> YES <input type="checkbox"/> NO	If YES, Complete the below information	
Time delay after voltage is within acceptable limits to reconnect:	sec		
V_{high} : reconnect when voltage is below:	volts	deadband	msec
V_{low} : reconnect with voltage is above:	volts	deadband	msec
Time delay after frequency is within acceptable limits to reconnect:	sec		
f_{high} : reconnect when frequency below:	hz	deadband	msec
f_{low} : reconnect when frequency above:	hz	deadband	msec

Reconnect Loading Process

Is all load reconnected at once?	<input type="checkbox"/> YES <input type="checkbox"/> NO		
Continuous ramp rate for ramping to reconnect:	kW/sec		
Number of steps for stepwise ramping to reconnect:	Step(s)		
Load increase per step for stepwise ramping to reconnect:	kW/step		

Data Center Emergency Backup Power System Details

Emergency Generator (EG) capacity:	kW
Duration of EG based on available fuel:	hours
Battery Energy Storage (BESS) discharging capacity:	kW
Duration of BESS discharge based on fully charged battery capacity:	hours
Percent of Data Center Load which can be carried by EG and/or BESS:	%
Can the Data Center Backup Power System participate in demand side management in a grid emergency or as an ancillary service?	<input type="checkbox"/> YES <input type="checkbox"/> NO
In event of a planned or unplanned disconnection from grid, can the Data Center be Islanded and operate with the EG and/or BESS?	<input type="checkbox"/> YES <input type="checkbox"/> NO
What percent of the server farm load could be redistributed to redundant server sites across the world?	%
If the data center trips offline, what percent of the load will be transferred to other server farms?	%
How fast can load transfers be completed?	sec


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REVISION HISTORY

Revision Date	Revision #	Description	Revised By	Effective Date
		Original document has been superseded by this Revision 1.0	ET Planning staff	
08/01/2024	1.0	See Details for Revision 1.0 below	Kristen Custer	09/01/2024

Details for Revision 1.0

- Revision contributors include: Aaron Winter, Colleen Wallace, Harrison Potter, Keith Graham, Amirreza Sahami, Rahul Chakraborty, Kristen Custer and Quanta-Technology Services.
- The Customer Request Form has undergone a complete re-write and supersedes the original form which was included in the last revision of the Facility Interconnection Requirements document package.
- Instructions revised to reflect new process of using the web-based Delivery Point Exchange for submittal and status review of customer requests.
- Form has been revised to request more specific customer information including additional data describing anticipated demand.
- Creation of Noteworthy Load Characteristics Form intended to obtain more detailed data to support planning studies.

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Attachment 3

Generator Interconnection Protection Requirements

Dominion Energy Virginia – Electric Transmission Facility Interconnection Requirements

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ABBREVIATIONS

CCVT (also CVT) – Coupling Capacitor Voltage Transformer (similar to Capacitor Voltage Transformer)

DCB – Directional Comparison Blocking

GSU – Generation Step-Up Transformer

IBR – Inverter Based Resource

MW – Megawatt(s)

N-1 – Single Contingency Outage (Normal minus One Transmission Element)


OPGW – Optical Ground Wire

PCC or POI – Point of Common Coupling or Point of Interconnection

PJM – Regional transmission organization of which Dominion Energy is a member (www.pjm.com)

PLC – Power Line Carrier

SIR – Source Impedance Ratio

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DEFINITIONS

Transmission Element – Transmission elements are primary equipment (69 kV and above) that constitutes, or interconnects with, the Dominion Energy Electric Transmission System. Examples include buses, lines, or transformers with low side voltage 69 kV or above, regardless of Bulk Electric System status.

Breaker Failure Transfer Trip - Trips remote sources in the event of a breaker failure.

Customer Interconnected Generation Station or Customer Interconnected Collector Station – Customer owned substation containing line or collector line terminals, breakers, transformers, and protection, metering, and monitoring equipment.

Dominion Energy Interconnected Switching Station – Dominion Energy owned substation containing line terminals, breakers, transformers, and protection, metering, and monitoring equipment. The Dominion Energy Interconnected Switching Station is included as a line terminal transmission substation.

Islanding Transfer Trip - Trips interconnection in the event a generating facility is operating disconnected from the transmission grid.

Line Transfer Trip - Trips remote sources that are not capable of clearing a fault because current magnitude is below the protective relay scheme setpoints.


Networked Transmission Line – A transmission line that connects to two or more network transmission sources (lines and/or substations).

Radial Transmission Line - A radial transmission line is defined as a single line that has one transmission source and does NOT tie to any other transmission network source (line or substation).

Transmission Tap Line – A transmission tap line is defined as a radial line that connects to either a network or radial transmission line. Dominion Energy Facility Interconnection Requirements diagrams 5.3.2.A and 5.3.2.B provides examples.

N-1 – Contingency analysis for determining relay settings. This may be the lowest flow first contingency outage, or the highest flow first contingency outage depending on the relay element being analyzed.

Power Line Carrier (also Carrier; PLC) – Higher frequency signal coupled to the AC transmission system used to transmit one bit of information.

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1. PURPOSE AND INTRODUCTION

Virginia Electric and Power Company is commonly referred to as Dominion Energy.

The purpose of the *Dominion Energy Electric Transmission Generator Interconnection Protection Requirements* document is to provide protection requirements and expectations to any individual or group seeking to connect electric power generation to Dominion Energy's electric transmission system.

Two primary drivers for these protection requirements are safety of personnel and customers, and the reliability of the electric transmission system.

This document supplements Dominion Energy's Facility Interconnection Requirements document.

2. WIDE AREA PROTECTION AND ISOLATION


Boundary analysis and protection studies are required for identifying transfer-trip and anti-islanding requirements. Transfer trip and anti-islanding requirements are dependent on system configuration.

2.1. Line Transfer Trip Requirements

Weak, partial, or variable sources may not provide enough fault current for protective relaying to completely isolate faulted transmission elements. Dominion Energy will require installation of transfer trip equipment on all lines contained within the identified transfer trip boundary. The transfer trip boundary is expanded from the POI out to the nearest remote transmission terminal substation where three or more non-generation sources are encountered. The line connecting the interconnect station to the remote station is counted towards meeting the criteria. The line connecting to the substation, which satisfies the boundary requirement, also requires transfer trip. All transmission elements within the transfer trip boundary are subject to transfer trip requirements. Additional transfer-trip equipment (such as transfer-trip electronics, including relays and accessories, wave traps, CCVTs, etc.) may be required due to the installation of the generation station. Transfer trip equipment will also be used for breaker failure conditions outlined in Section 3.5.

2.2. Anti-Islanding Requirements

Dominion Energy will require application of its anti-islanding protection standard at all customer interconnected switching stations. Dominion Energy's anti-islanding protection standard requires each breaker or terminal's status within the anti-island boundary be sent to Dominion Energy's interconnected switching station to determine whether the generation source is isolated from the rest of the electric transmission system. The purpose of the anti-islanding scheme is to prevent individual generators from energizing transmission elements within the islanding and to prevent unsynchronized reclosing on the generator. The anti-islanding boundary is expanded from the POI out to the nearest terminal substations with three, or more, non-generation sources. The boundary substations may be included in the anti-islanding scheme depending on boundary substation configuration. The anti-islanding boundary may also be extended beyond three sources if one of the lines at the boundary exceeds its thermal limits due to unloading the generation, trips due to excessive loading, or trips due to a power swing in a power system simulation. All transmission elements within the anti-islanding boundary are subject to anti-islanding requirements. Anti-islanding schemes require separate relaying at each substation inside the anti-islanding boundary and a method to transmit breaker statuses between substations. Breaker or line terminal status will be transmitted via fiber, where available, or via power line carrier where existing fiber is unavailable and power line carrier is an acceptable transmission method (see Section 4.1 for more details).

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3. INTERCONNECTION PROTECTION REQUIREMENTS

Interconnection protection requirements include specifications for fault protection of the interconnection line, breaker failure and reclosing, generation step-up transformers, and instrument transformers. Determination of the necessary protection for the POI is dependent on the individual and aggregate total MW of the generation resource(s), length and configuration of the interconnection line, and technical limitations of existing facilities.

3.1. Point of Interconnection Protection Requirements

A customer-owned transformer-high-side breaker is required at the POI to separate the POI line zone of protection and the customer-owned transformer zone of protection. The customer-owned high-side breaker will be the disconnecting element should the generation source become islanded from the rest of the electric transmission system.

A high-side breaker in conjunction with a breaker ring station provides optimal isolation should a device fail to operate and initiate breaker failure (also see Section 3.5, Breaker Failure and Reclosing Requirements). To ensure reliability of the transmission system, this configuration, shown in Figure 1, is required for a POI at any network transmission line on Dominion Energy's transmission system.

For simplicity, the customer interconnection generation station can be represented as a simplified single source as shown in Figure 1.

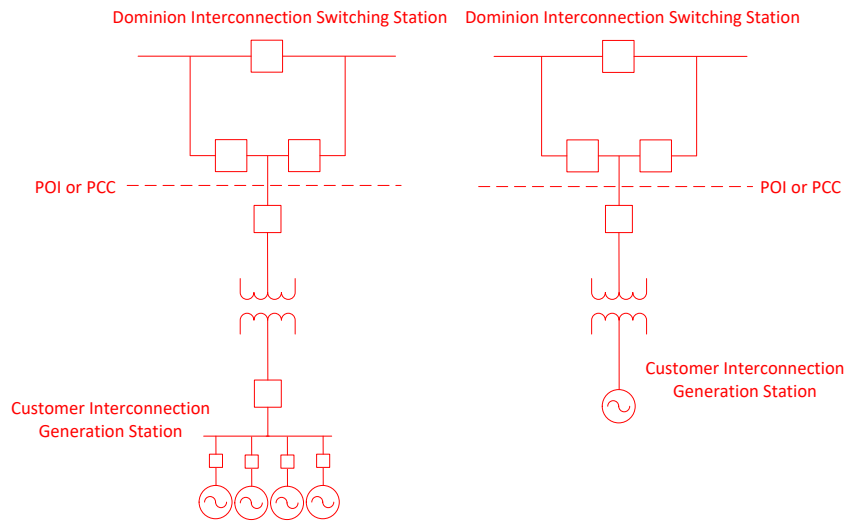


Figure 1: Complex (left) and Simplified (right) Customer Interconnection Generation Station

3.1.1. Networked Transmission Line Interconnection

The Dominion Energy Interconnection Switching Station will be a three- or four-breaker ring, or comparable layout as outlined in Section 5 of the main document [1] for generation resources of any MW size that connect to a network transmission line. A breaker station ring ensures separation in zones of protection between the Dominion Energy electric transmission system and the customer interconnection generation station. The three-breaker ring provides increased reliability as two paths are available to export power from the generation source to the electric transmission system. The breaker ring station also

creates two independent zones of protection for adjacent transmission lines allowing the generator to stay online for any single momentary or sustained line outage. See Figure 2.

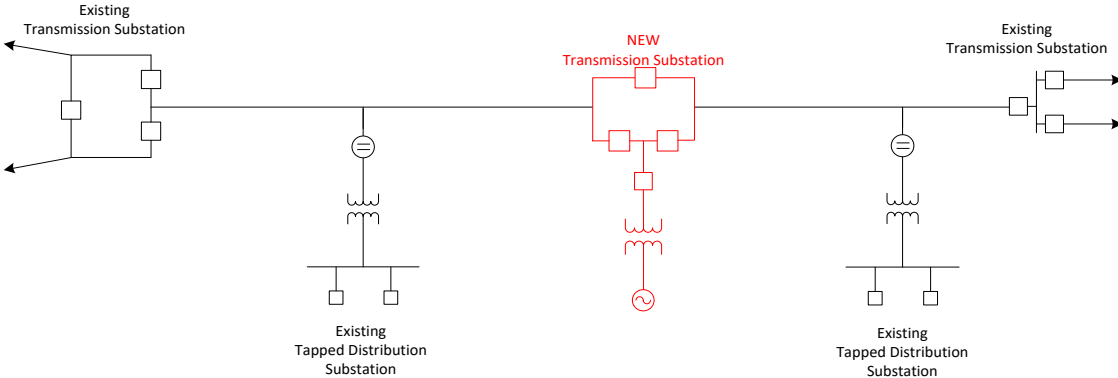


Figure 2: Network Transmission Line Interconnection

3.1.2. Transmission Tap Line Interconnection

The Dominion Energy Interconnection Switching Station may be a single breaker when the total aggregate generation resource connected to the tap line is less than or equal to 20 MW and connecting to a line segment that is tapped off of a networked transmission line (Figure 3). A breaker ring substation will be required for an individual generation resource or the aggregate total of generation resources from all sources on the tap line greater than 20 MW (Figure 4).

There may be instances when the generation resource(s) connected to a tap line will desensitize the network relays and not allow proper protection. Additionally, design constraints (e.g., limitations on power line carrier or transfer trip communications channels) may prove unresolvable without system upgrades including line reconductoring, expanding communication channels, building a breaker ring station, or interfacing to the transmission system through a more distant POI. A detailed protection study will be required to determine if a breaker ring station or other upgrades are required regardless of the generation resource's size.

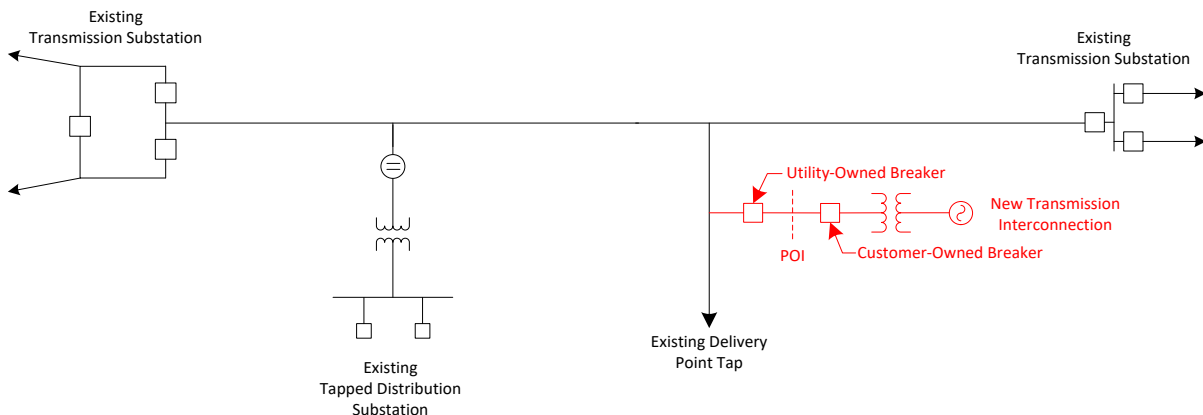


Figure 3: Typical Tap Line Customer Generation Interconnection Station (Generation Resources ≤ 20 MW)

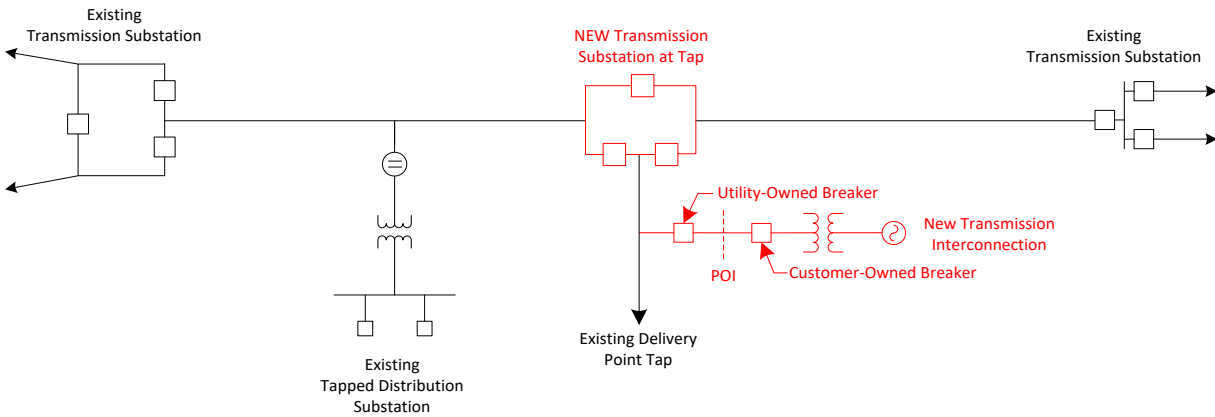


Figure 4: Typical Tap Line Customer Generation Interconnection Station (Generation Resources > 20 MW)

3.1.3. Radial Transmission Line Interconnection

The Dominion Energy Interconnection Switching Station may be a single breaker. However, generation resource POIs on radial transmission lines in Dominion Energy’s transmission system must be considered on a case-by-case basis to evaluate potential reduction of relay sensitivity due to fault current contributions from the generation sources. If existing line relays cannot adequately protect against fault conditions with the addition of the generation resource, additional upgrades may be required.

3.1.4. Other Considerations

A generation resource may choose to have a breaker ring substation installed at the tap point to provide a more reliable interconnection regardless of POI, see Table 1 for further detail.

Table 1: Ring Bus Considerations

	Ring Bus connection	Single Breaker connection on tap line or radial line
Advantages	<ul style="list-style-type: none"> Increased Reliability: The generation resource would have two outlets to delivery power. An outage on the networked line would only remove one side of the ring and still allow generation. More uptime for the generation resource that leads to higher revenue. Initial cost savings for no utility owned breaker at POI. 	<ul style="list-style-type: none"> Possible decrease of initial capital cost for not building line back to networked transmission line.

Disadvantages	<ul style="list-style-type: none"> • Possible increase of initial capital cost for building line back to networked transmission line. 	<ul style="list-style-type: none"> • Decreased Reliability: The generation resource would only have one outlet to delivery power. An outage on the tap line would remove the generation resource from service and not allow generation. • Less uptime for the generation resource that leads to lower revenue. • Additional cost for utility owned breaker at POI.
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3.2. Interconnection Generator Step-up Transformer Requirements

The customer interconnected generation step-up transformer (GSU) is required to provide a source of zero sequence current to the transmission system aiding in ground fault detection. The utility side of the GSU will be effectively grounded to prevent an excessive increase in voltage during single phase to ground faults. A GSU that can pass, but is not a source of, zero sequence current is only appropriate if a ground source is present on the medium voltage terminal and will require evaluation prior to permission being granted. The interconnected GSU will be protected using dual high-speed current differentials.

The following transformer configurations are commonly used to meet the above requirements:

- Utility side – grounded wye, generator side – delta (typical for synchronous generation)
- Utility side – grounded wye, generator side – grounded wye, delta on the tertiary (typical for inverted-based generation)


While utility side delta – generator side grounded wye transformers are appropriate for applications in a fully radial system where energy always flows from transmission-level voltages to distribution-level voltages, this design blinds high-side residual and/or ground devices to potential problems behind the transformer. For applications in systems with the ability to produce network flows, ground sources are required.

See Section 3.7 for more details concerning modeling of generator step-up transformers.

3.3. Instrument Transformer Requirements

Three-phase capacitor coupled voltage transformer (CCVT) and current transformers (CT) connections are required for protective relaying, revenue metering, and power quality monitoring purposes at the point of interconnection.

Protection class CTs “C800” will be required for all protective relaying. Protection class CTs with “T ratings” (accuracy determined by testing) will not be used without prior approval by Dominion Energy; any CT with T800 ratings must demonstrate the same performance characteristics as C800 to be considered. Independent CTs will be used for each of the protective relays on equipment connected to transmission voltages (for example transmission lines or GSUs). If other devices (such as digital fault recorders) will

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share the CT secondary circuit with a protective relay, the total burden of all secondary devices and conductor will not exceed eight (8) ohms.

Accuracy class “0.15B1.8” (metering class high accuracy extended range) CTs will only be used for revenue metering or devices not used for protection. Protective relays will not be connected to metering class CTs. Additionally, no other devices will share secondary circuits on metering class CTs when used for revenue metering. The total burden of all secondary devices and conductor will not exceed 1.8 ohms.

Accuracy class “0.3WXYZ,ZZ” (metering class) CCVTs will be required. These CCVTs will be used for revenue metering. The metering class CCVT can also be used for protective relaying and other functions requiring voltage assuming the CCVT can handle the additional burden not to exceed 400 volt-amperes. If the metering class CCVT cannot handle the combined revenue meter and protective relay burden, a second three-phase CCVT with at least an accuracy class of “1.2RWXYZ,ZZ” (protection class) will be needed for the protective relays. If protective relays will be connected to any CCVT (metering or protection class), protective relays will be connected to separate secondaries on the CCVT.

3.4. Transmission Elements Requirements

Protection systems classified as dual primary are required for all equipment connected to the transmission grid at operating voltages 69 kV and above [2]. Schemes will require two independent high speed, phase and ground fault protection systems designated system one and system two. Together these systems provide a redundant set of all normal primary and backup functions.

3.4.1. Interconnection Zone Protection

All interconnections will be treated as a transmission line regardless of length and will be protected using dual line current differential relays as shown in the oneline equivalent in Figure 5. Additionally, directionalized backup elements are required thus potential is needed at both terminals. In all cases, dedicated, redundant single mode fiber pairs will be required between the Dominion Energy Interconnection Switching Station (1) and the Customer Switching Station (2). Customers should contact Dominion Energy prior to purchasing protective relaying and fiber optic equipment and materials that plans to use to interface with Dominion Energy to obtain the Dominion Energy’s latest specifications; this is to ensure that customers purchase equipment and materials that are compatible with Dominion Energy’s facilities.

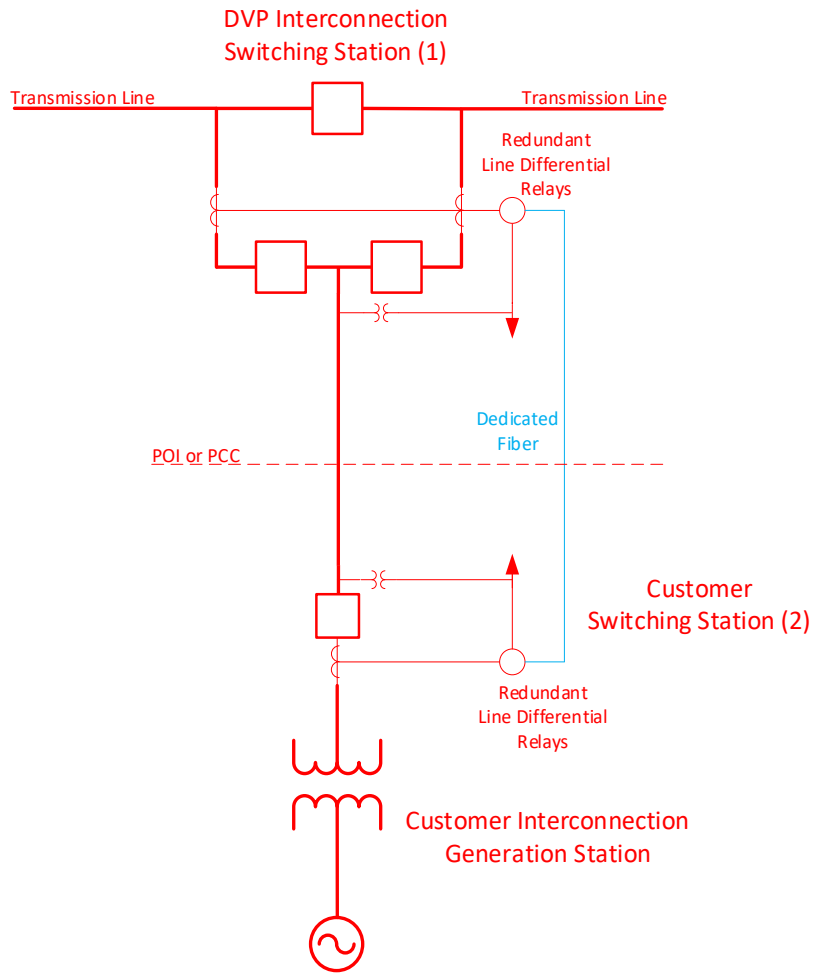



Figure 5: Interconnection Zone of Protection

3.5. Breaker Failure and Reclosing Equipment

Separate breaker failure and reclosing relays (Figure 6) will be installed on all transmission breakers (the customer-owned high-side generation step-up transformer (GSU) breaker will only require breaker failure). All breaker failure relays will be required to send transfer trip to remote stations. A reclosing synchronism check will be performed prior to the breaker closing for all time delayed reclosing attempts.

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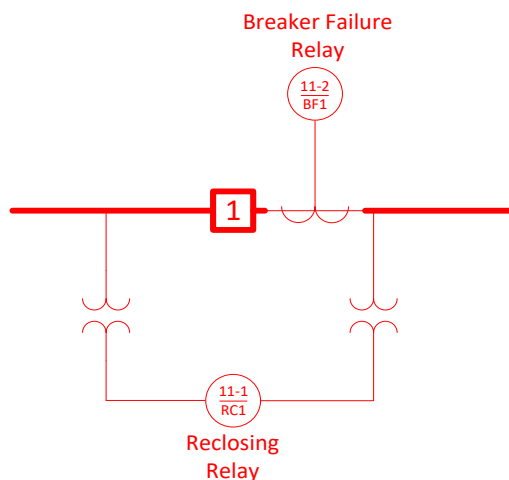


Figure 6: Breaker Failure and Reclosing Relays

3.6. Mandatory Protective Relay Element Coordination


Per NERC Reliability Standard PRC-027, all protective relay elements subject to the standard must be analyzed by Dominion Energy System Protection Engineering prior to energization. The customer will refer to the latest version of the standard to determine any protective element that must comply. The customer will communicate all applicable protective relay settings and facility drawings to Dominion Energy in an electronic form at least forty-five (45) days prior to energization. The customer will clearly identify any protective relay elements that can detect faults on the Dominion Energy transmission system. The customer's failure to provide protective relay settings and facility drawings in a timely manner may result in delayed energization.

Per NERC Reliability Standard PRC-027, in the event of future work nearby on the Dominion Energy transmission system, Dominion Energy and the customer may need to coordinate changes to protective relay elements. The customer will respond in a timely manner to communications requesting reviews of protective relay element coordination with its system. Likewise, Dominion Energy will respond in a timely manner to communications requesting reviews of protective relay element coordination with its system.

The customer will provide Dominion Energy with long-term contact information for a person or group of people who Dominion Energy can reliably contact with respect to protective relays if the need should arise. This contact will be valid in perpetuity for as long as the customer's facility is connected to the Dominion Energy transmission system. Failure to respond in a timely manner to inquiries sent to the last known good contact for a facility may result in Dominion Energy reporting the customer's facility to SERC for violation of NERC Reliability Standard PRC-027. The customer is responsible for providing Dominion Energy updated contact information as needed. Any type of sale or transfer of ownership of the facility to another entity does not remove the new owner's obligation to respond timely to inquiries or to provide updated contact information. Customers will refer to the standard's text available on the NERC website to learn more about communication requirements.

3.7. Electrical Models of Customer Facilities

To support coordination of protective relay elements and accuracy of Dominion Energy's short circuit, planning, and operational models of the transmission grid, the customer will provide Dominion Energy with electrical models of the customer's facilities and manufacturer test reports that corroborate the customer's electrical model. The electrical models will accurately reflect the customer's facility. Therefore, all changes that may occur during the project will be communicated to Dominion Energy in new electrical

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models and updated manufacturer test reports that reflect the changes. The final electrical model and final manufacturer test reports for the customer’s facility will be communicated electronically to Dominion Energy at least forty-five (45) days prior to energization. The electrical models will be sufficiently detailed such that Dominion Energy can appropriately assess the impact of the customer’s facilities. The term “sufficient detail” means the equipment parameters needed to model the customer’s facility such as but not limited to:

- Step up transformer impedance*
- Step down station service transformer impedance
- Transformer winding configuration
- Transformer voltage fixed tap selection (the fixed tap selection that will be used)
- Transmission line impedance
- For synchronous generation, unit impedances and grounding impedance
- For asynchronous generation, inverter make and model, and functionally accurate model of the inverter’s controls during dynamic and short circuit system conditions

*For generation step-up transformers (the transformers connecting generation to the transmission system), a frequent choice for the transformer’s winding configuration is a grounded wye-grounded wye with a *buried* delta tertiary winding. For short circuit electrical models, the buried delta tertiary is relevant to the development of electrical models for the zero-sequence network. Since the buried tertiary is not accessible for testing, customers will obtain *estimated* values for the primary-tertiary reactance and secondary-tertiary reactance based on the transformer design from the manufacturer. Dominion Energy will not contact transformer manufacturers on behalf of customers to obtain this information. The information will be present in test reports or other official documents from the customer.

Dominion Energy will not accept missing or incomplete electrical models for a facility. A customer’s failure to provide adequate electrical models of their facility may result in project delays.

4. IMPACT OF NETWORKED TRANSMISSION LINE SPLIT ON LINE TERMINAL PROTECTION

In many cases, interconnection switching stations are built near an existing transmission line (Figure 7) resulting in the existing transmission line being split into two shorter transmission lines (Figure 8). The two shorter transmission lines may require protection modifications due to power line carrier or relaying constraints (ex. a medium length line now becomes two short length lines).

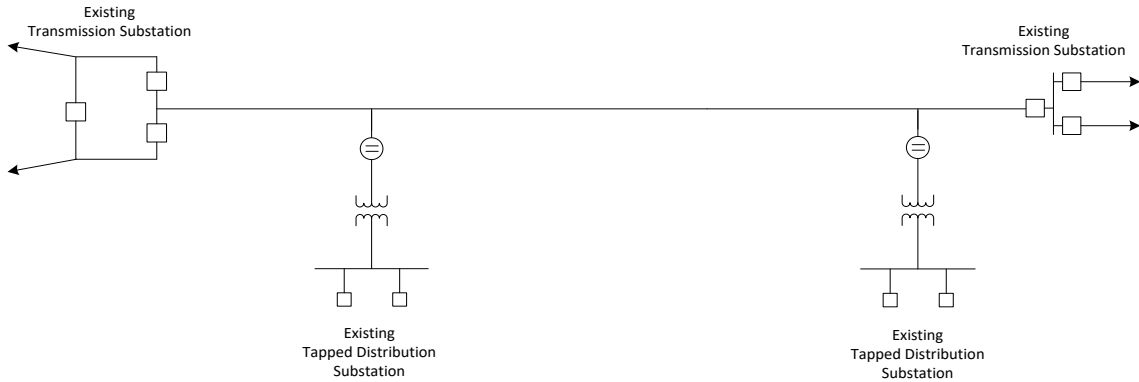


Figure 7: Existing Transmission Line

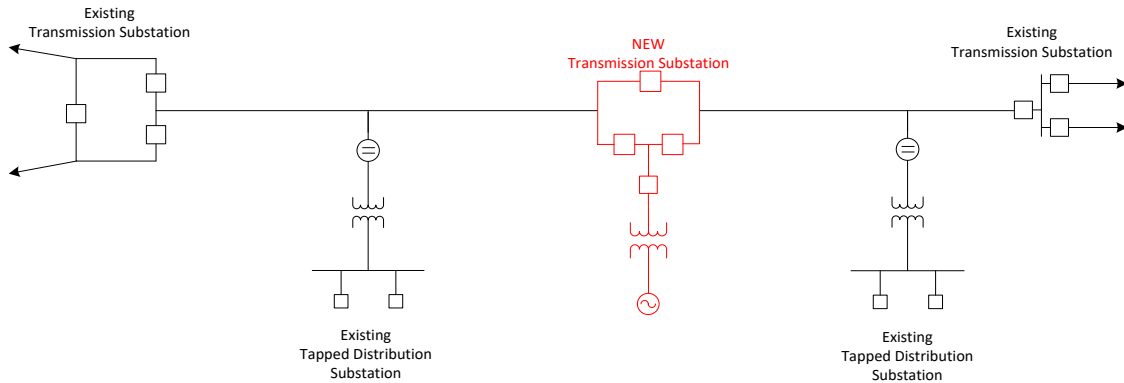



Figure 8: Transmission Line Split

4.1. Short Transmission Line Protection

Short transmission lines and line segments less than five (5) miles will be protected using dual line current differential relays. Line current differential relays require dedicated fiber be available between line and tap terminals. Relaying constraints permit the allowance of one tapped distribution substation within the line differential as shown in Figure 9.

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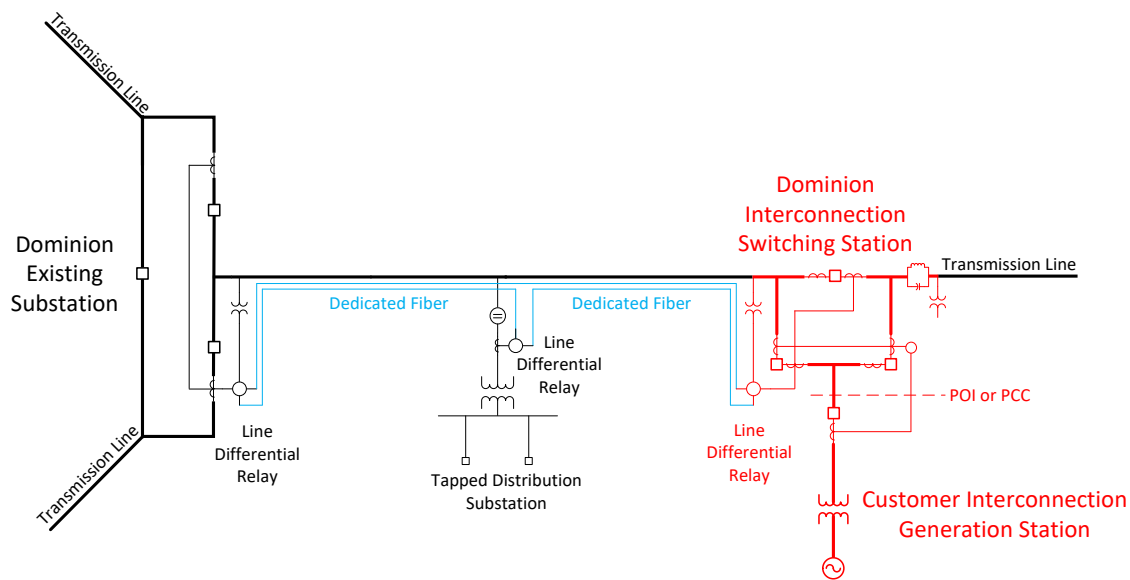


Figure 9: Short Line with Fiber

When a direct fiber connection is not available between the interconnect station (Dominion Energy Interconnection Switching Station), remote terminal station (Dominion Energy Existing Substation), and tapped distribution station, modifications to the lines, structures, towers, conduits, terminating and other equipment may be required to accommodate a direct fiber connection between the interconnect substation, existing remote substation, and tapped distribution substation. Shown in Figure 10, the 5-mile requirement is normally between line terminal stations.

If the distance between line terminal stations is greater than 5 miles and impedance relays would require carrier blocking be installed at a tapped distribution substation due to transformer penetration, then the 5-mile requirement is between the line terminal substation and the tapped distribution substation shown in Figure 11. In summary, the 5-mile requirement is between a location with a power line carrier transmitter and a location with a power line carrier receiver.

Power line carrier will **not** be used on transmission lines less than 5 miles long to maintain a high level of protection system dependability. Power line carrier systems coupled to short transmission lines have low signal attenuation causing several problems. Most prominently, low signal attenuation results in high voltage standing wave ratios and can cause carrier beating between opposite terminal power line carrier equipment [3] [4]. Carrier beating results in the power line carrier strength oscillating between zero and two times rated power resulting in power line carrier equipment being damaged, shutting down entirely, or misoperating.

Short lines are also problematic for impedance relaying. Transmission lines with a source impedance ratio (SIR) of 4.0 or greater are considered electrically short [5]. Source impedance ratio is the ratio of Thévenin equivalent source impedance to line impedance. Short lines protected by impedance relays are subject to transient overreach due to suppressed voltage measured at the relay, and transient instrument and relay errors [6].

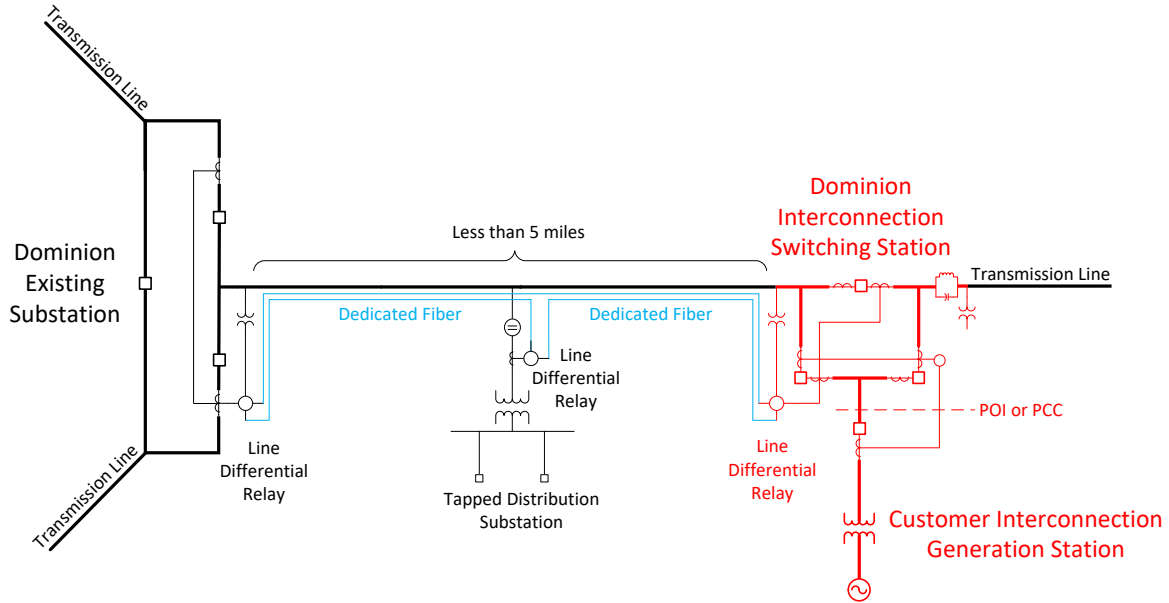


Figure 10: Traditional Zone of Protection for a Short Line

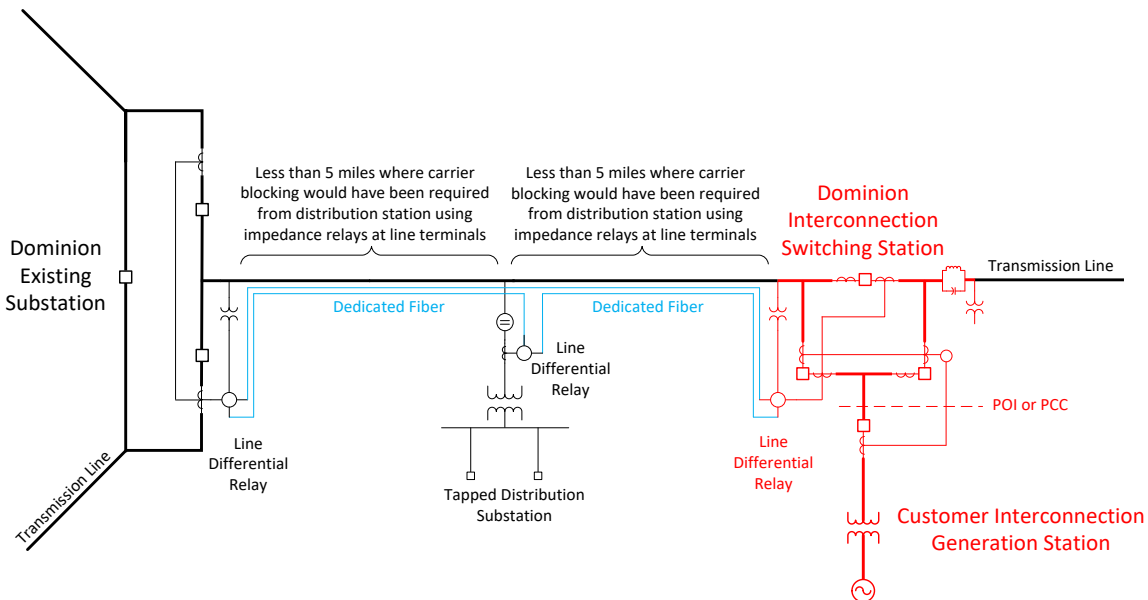


Figure 11: Medium Line Requiring Carrier Blocking at Distribution Substation Follows Short Line Requirements

4.2. Medium and Long Transmission Line Protection

Medium and long transmission lines, longer than five (5) miles, will be protected using either dual impedance or dual differential relays.

If fiber is already available on a transmission line, Dominion Energy may require customers, at its sole discretion, to upgrade existing impedance relays to differential relays at *both* terminals to mitigate the effects that inverter based resources have on fault detection and directionality detection by protection relays.

In cases where fiber exists on a line, but the line has a tapped distribution station that does not need carrier blocking at the tapped substation, Dominion Energy may require customers, at its sole discretion, to upgrade existing impedance relays to new impedance relays at *both* terminals that can accommodate a directional comparison blocking (DCB) scheme or other communication-aided scheme over fiber to help mitigate the effects of inverter based resources.

In cases where carrier blocking is needed at a tapped distribution station or there is no existing fiber on the line, a DCB scheme via power line carrier may be specified. Regardless, customers will not be required to install fiber on transmission lines where the total length or the length of all line segments is longer than five (5) miles.

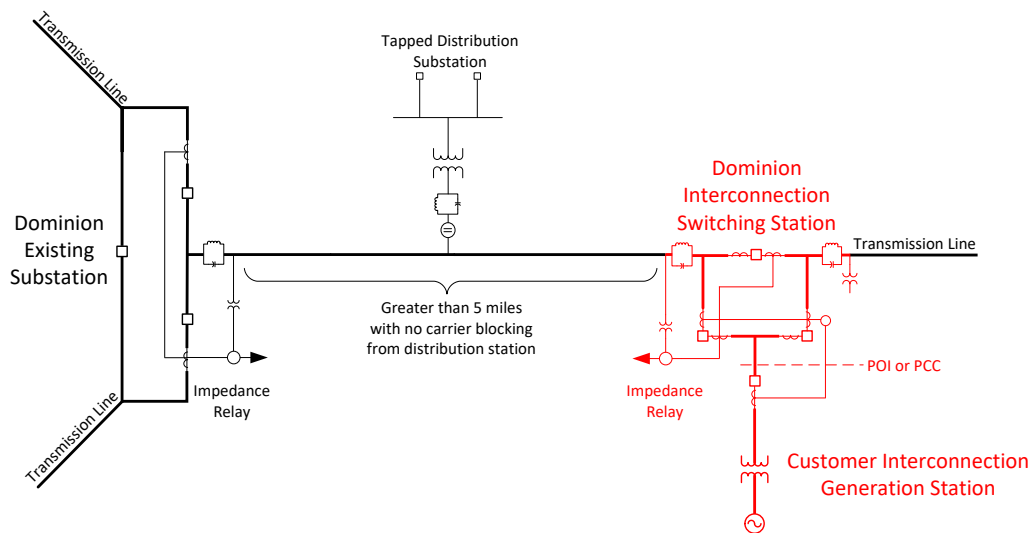


Figure 12: Medium or Long Transmission Line Zone of Protection

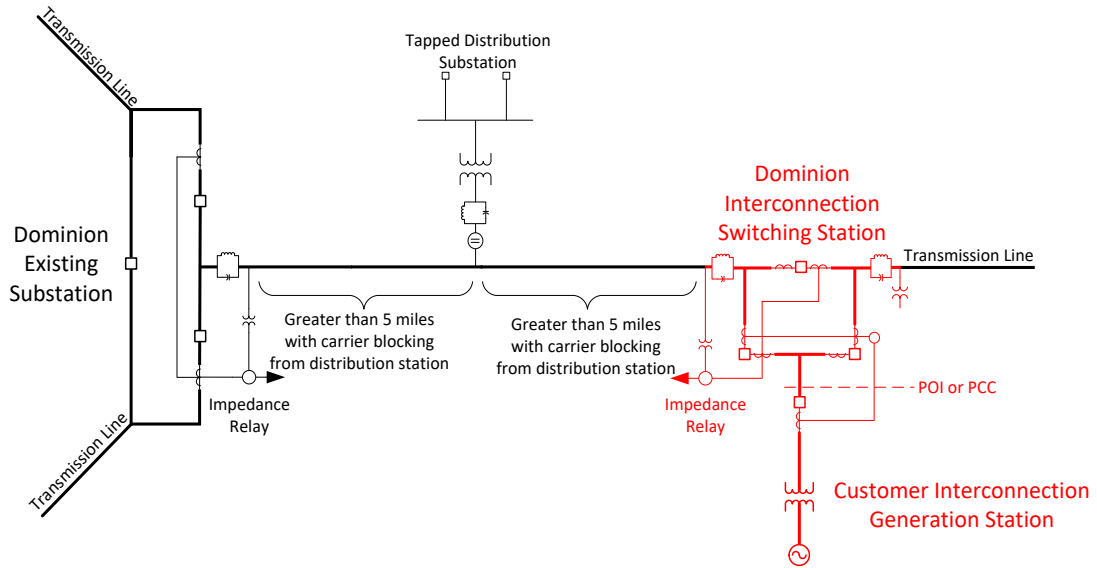



Figure 13: Medium or Long Transmission Line Zone of Protection with Carrier Blocking Tap

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5. POWER QUALITY PROTECTION AT POINT OF COMMON COUPLING

Power quality relaying capable of tripping will be required at all generator interconnections for criteria listed in IEEE Standard 1159 [7] and other applicable standards. Power quality concerns associated with solar photovoltaic are reiterated in IEEE Standard 2800 [8]. Protective relays can make erroneous directional determinations due to waveform distortion and other power quality issues [9]. All power quality protective elements will measure individual phase quantities. Quantities include but are not limited to:

5.1. Undervoltage (27)

An undervoltage is an RMS decrease in AC voltage.

5.2. Overvoltage (59)

An overvoltage is an RMS increase in AC voltage.

5.3. Under/Overfrequency (81/U, 81/O)

Frequency deviations above or below nominal frequency.

5.4. Reverse Power (32)

Reverse power protection may be implemented as a supervisory function or to ensure contracted power agreements are not exceeded.

5.5. Power Factor

Power factor requirements will be based on contracted power factor agreement.

5.6. Imbalance

Imbalance will be measured through differing phase quantities of voltage or current.

5.7. Waveform Distortion


Waveform distortion is defined as steady-state deviation from an ideal power frequency sinusoid characterized by the spectral content of the deviation. Five primary types of waveform distortion are DC offset, harmonics, inter-harmonics, notching, and noise.

5.7.1. Harmonics

Voltage or current harmonics may be calculated in terms of total harmonic distortion (THD) or total demand distortion (TDD) as outlined in IEEE Standard 519 [10].

5.8. Voltage Fluctuations

Voltage fluctuations are defined as a varying voltage between 0.95 and 1.05 per-unit. Voltage flicker, an undesirable result of voltage fluctuations, may be measured or monitored using methods outlined in IEEE Standard 1453 [11], which is an adoption of IEC 61000-4-15.

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6. DISTURBANCE AND POWER QUALITY MONITORING

Disturbance and power quality monitoring equipment must be independent of any protective equipment used for tripping outlined in Section 2 through Section 5 and must be time synched to UTC with a satellite clock with a local UTC offset as appropriate based on equipment location.

7. DIGITAL FAULT RECORDER REQUIREMENTS

A digital fault recorder (DFR) is required at all interconnected transmission substations. This device will provide high integrity triggered oscillography (minimum 4800 Hz sampling), triggered long-term RMS plus phase data (minimum 960 Hz sampling) and continuous oscillography data (minimum 960 Hz sampling) for the purpose of disturbance location and analysis. The device must also serve as a sequence of events recorder (minimum 1 millisecond resolution) logging all circuit breaker activity. Digital fault recorder data will be the primary means for fault and event analysis. Data must adhere to the IEEE Standard for Common Format for Transient Data Exchange (COMTRADE), revision C37.111-1999 [12] or later and IEEE Standard for Common Format for Naming Time Sequence Data Files (COMNAME), revision C37.232-2011 [13] or later.

- Customers must provide breaker position for all GSU high side breaker(s) via the a-finger contacts to the utility's DFR. This is to ensure millisecond accuracy of the sequence of events report.
- Customers must provide breaker failure lockout position for all GSU high side breaker(s) via a physical contact to the utility's DFR. This is to ensure millisecond accuracy of the sequence of events report.
- Any additional trip paths from the Customer Interconnection site to the utility must be monitored and recorded by the utility's DFR. This is to ensure millisecond accuracy of the sequence of events report.

7.1. Phasor Measurement Units/Synchrophasors Requirements


Phasor measurement units are required at all interconnection substations to provide real time synchrophasor data to Dominion Energy's synchrophasor system. PJM Manual 14D specifies all generation greater than 100 MW must provide synchrophasor data to PJM's synchrophasor system as well.

7.2. Power Quality Monitoring

Power quality monitoring must be independent of power quality protection and may trigger on several layers of set points. Data collected from power quality monitors will strictly be used for engineering analysis.


7.3. Requests for Data from Customer Devices

Upon request from DEV, Customer power quality and Relay data will be provided electronically to Dominion Energy no later than 14 calendar days after the date requested.

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- [1] "Facility Interconnection Requirements," Section 5
- [2] "Facility Interconnection Requirements," Dominion Energy, most recent version.
- [3] *Special Considerations in Applying Power Line Carrier for Protective Relaying*, IEEE Power Systems Relaying Committee, Working Group H9.
- [4] *IEEE Guide for Power-Line Carrier Applications*, IEEE Std 643, 2004.
- [5] M. J. Thompson and A. Somani, *A Tutorial on Calculating Source Impedance Ratios for Determining Line Length*, 2015.
- [6] D. Costello and K. Zimmerman, *CVT Transients Revisited - Distance, Directional Overcurrent, and Communications-Assisted Tripping Concerns*, 2012.
- [7] *IEEE Recommended Practice for Monitoring Electric Power Quality*, IEEE Std 1159, 2009.
- [8] *IEEE Standard for Interconnection and Interoperability of Inverter-Based Resources (IBRs) Interconnecting with Associated Transmission Electric Power Systems*, IEEE Std 2800, 2022.
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- [11] *IEEE Recommended Practice--Adoption of IEC 61000-4-15:2010, Electromagnetic compatibility (EMC)--Testing and Measurement Techniques--Flickermeter--Function and Design Specifications*, IEEE Std 1453, 2011.
- [12] *IEEE Standard for Common Format for Transient Data Exchange (COMTRADE)*, IEEE C37.111.
- [13] *IEEE Standard for Common Format for Naming Time Sequence Data Files (COMNAME)*, IEEE C37.232.

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REVISION HISTORY

Revision Date	Revision #	Description	Revised By	Effective Date
7/16/2015	0.0	Document Creation	Christopher Mertz	-
8/17/2015	1.0	See Details for Revision 1.0	Christopher Mertz	01/01/2016
5/26/2017	2.0	See Details for Revision 2.0	Marlu Deverick	06/01/2017
12/11/2018	3.0	See Details for Revision 3.0	Douglas Ladd	01/1/2019
2/23/2021	3.1	See Details for Revision 3.1	Joseph Saylor	04/01/2021
02/10/2022	4.0	See Details for Revision 4.0	Daniel Ridenour	04/01/2022
02/16/2023	5.0	See Details for Revision 5.0	Daniel Ridenour	04/01/2023
08/01/2024	6.0	See Details for Revision 6.0	Daniel Ridenour / Quanta Services	09/01/2024

Details for Revision 1.0

- Updated short-line requirement drawings to show fiber into relaying at tapped distribution station
- Modified wording to exclude customer owned GSU breaker from reclosing requirement

Details for Revision 2.0

- Revised references for new Dominion Energy corporate identity.
- Added additional definitions and minor sentence changes
- Updated reference 6

Details for Revision 3.0


- Added clarification for interconnections on network tap lines and radial lines.
- Expanded on Section 3.4
- Rearranged layout of several sections to improve flow of material

Details for Revision 3.1

- Updated the signature page
- Added Section 3.6 and 3

Details for Revision 4.0

- Minor formatting changes throughout document
- Expanded on Section 3.6
- Updated the signature page


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Details for Revision 5.0

- Updated signature page
- Added reference to Section 3.2 pointing to Section 3.7.
- Expanded on Section 3.6
- Expanded on Section 3.7
- Minor typographical and grammatical improvements throughout document
- Removed Section 7; Attachment 5 now contains this information and additional detail

Details for Revision 6.0

- Revision contributors include: Daniel Ridenour, Jacob Midkiff, Micah Till, Aaron Winter, Colleen Wallace, Keith Graham, Mark Gill, Mohsen Mahoor, Peter Nedwick, and Quanta-Technology Services.
- Removed signature page and consolidated on FIR cover page.
- Revised Section 3.3 to add specificity about instrument transformer requirements
- Revised Section 3.4.1 to add details about fiber optic requirements
- Revised Section 4.2 to clarify requirements when customers would need to pay to install new transmission line relays and when customers would need to install fiber optic on transmission lines taps that require carrier blocking
- Revised Section 6 introduction to specify the DFRs will be UTC time synchronized *and* have an appropriate local time offset
- Revised Section 6.1 to change the continuous oscillography sample rate to 960 Hz
- Typographical and grammatical improvements throughout document
- Updated reference from IEEE 929 to IEEE 2800.

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Attachment 4

Ride-Through Requirements for Bulk Power System Resources

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Ride-Through Requirements for Bulk Power System (BPS) Resources

NERC PRC-024 currently defines voltage and frequency ride through requirements for both synchronous and non-synchronous generators (IBRs). NERC PRC-024 is being modified to apply to synchronous machines only and a new standard is being created for IBRs. As NERC requirements are created or modified, Dominion Energy expects Generator Owners to adopt new requirements and apply the most up to date version of existing requirements.

All synchronous and non-synchronous generation tied to Dominion Energy’s system must respect Dominion Energy’s voltage and frequency ride-through requirements. As the industry evolves and NERC requirements change, Dominion Energy’s requirements may change. Generator Owners are expected to implement the changes when Dominion Energy informs them of any new or updated requirement.

VOLTAGE RIDE THROUGH

Dominion Energy’s voltage ride-through requirements are derived from NERC PRC-024 and other NERC guidelines. Table 1 below lists the voltage operating point for generation connected to buses with nominal voltage greater than or equal to 69 kV, but less than 500 kV. These voltage operating points are plotted in Figure 1.

Voltage Range (p.u.)	Operating Mode	Clearing Time (s)
1.30 - 1.20	May Ride-Through or May Trip	0.30
1.20 - 1.10	Mandatory Operation	3.00
1.10 - 0.90	Continuous Operation	∞
0.90 - 0.75	Mandatory Operation	3.00
0.75 - 0.65	Mandatory Operation	2.00
0.65 - 0.10	Mandatory Operation	0.30
0.10 - 0.00	Mandatory Operation	0.15

Table 1: Dominion Energy Ride-Through Requirements (69 - 499 kV)

In some instances, existing IBRs lack sufficient setpoints within the internal controls to match to the setpoints listed in Table 1. When an existing IBR does not have enough setpoints, the longest ride-through time duration shall be retained for all thresholds of increasing severity. For example, if the inverter has only one (1) low voltage setpoint, the low voltage ride-through duration shall be set to three (3) seconds.

All new interconnections should have controls capable of meeting the requirements listed in Table 1.

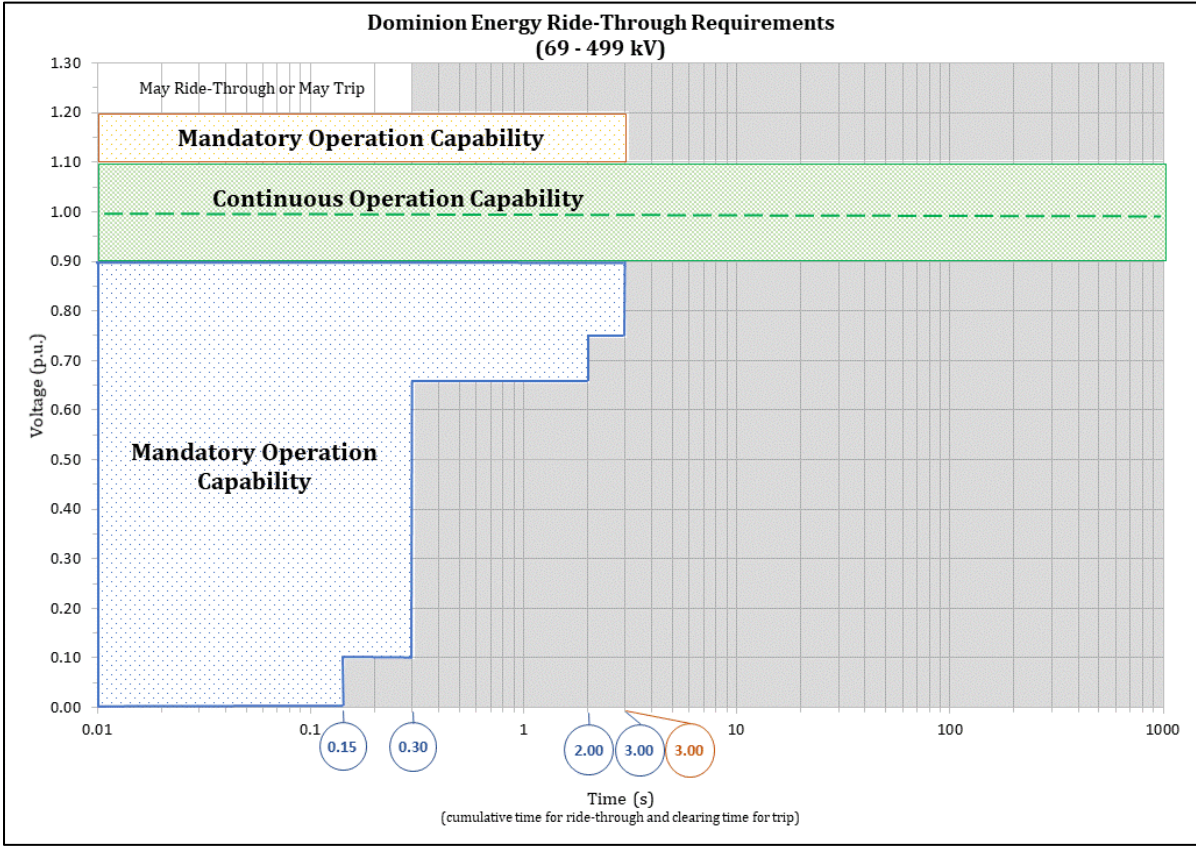



Figure 1: Dominion Energy Ride-Through Requirements (69 - 499 kV)

Generators interconnecting at 500 kV must be able to continuously operate through 1.15 V_{pu} , as Dominion Energy operates the 500 kV system typically between 1.00 and 1.10 V_{pu} . The operating points for generation connected to the 500 kV system are listed in Table 2 and are plotted in the Figure 2.

Voltage Range (p.u.)	Operating Mode	Clearing Time (s)
1.30 - 1.25	May Ride-Through or May Trip	0.30
1.25 - 1.15	Mandatory Operation	3.00
1.15 - 0.90	Continuous Operation	∞
0.90 - 0.75	Mandatory Operation	3.00
0.75 - 0.65	Mandatory Operation	2.00
0.65 - 0.10	Mandatory Operation	0.30
0.10 - 0.00	Mandatory Operation	0.15

Table 2: Dominion Energy Ride-Through Requirements (500 kV)


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be set to the maximum and minimum frequency operating points available for safe operation of the plant. Even if those points are outside the Eastern Interconnection frequency ride through curves shown in NERC PRC-024, Attachment 1.

According to NERC, inverters should be able to operate in the frequency range between 57 Hz and 63 Hz¹. NERC PRC-024 requires generators located within the Eastern Interconnect to operate, without tripping, between 57.8 Hz and 61.8 Hz². This implies that IBRs should, in general, operate at all frequencies between 57.8 Hz and 61.8 Hz.

¹ NERC Inverter-Based Resource Performance Guideline, Sept 2018

² NERC PRC-024, “Generator Frequency and Voltage Protective Relay Settings”, Attachment 1.

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REVISIONS

Revision Date	Revision #	Description	Revised By	Effective Date
01/19/2021	1.0	Initial creation of document	Chris Mertz	04/01/2021
02/07/2022	2.0	Add frequency ride-through requirements	Jiecheng Zhao	04/01/2022
02/27/2023	3.0	Updated signature page Fixed typo in Table 2	Amirreza Sahami	04/01/2023
08/01/2024	4.0	See Details for Revision 4.0 below	Kristen Custer	09/01/2024

Details for Revision 4.0

- Revision contributors include: Daniel Ridenour, Jacob Midkiff, Micah Till, Aaron Winter, Colleen Wallace, Keith Graham, Mark Gill, Mohsen Mahoor, Peter Nedwick, Ronnie Bailey and Quanta-Technology Services.
- Removed signature page and consolidated on FIR cover page.
- Added explanation at start of document with reference to PRC-024.
- Arranged document into two sections: “Voltage Ride Through” and “Frequency Ride Through”.
- In the “Voltage Ride Through” section, added language about how to interpret the requirement.
- In the “Frequency Ride Through” section, added language about how to interpret the requirement.
- Added language to frequency ride through requirement.
- Added references to support requirement.

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Attachment 5

Generator Interconnection Data Communications and Data Exchange Requirements

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ABBREVIATIONS

AGC – Automatic Generation Control

BESS – Bulk Electric Storage System

CCVT (also CVT) – Coupling Capacitor Voltage Transformer (similar to Capacitor Voltage Transformer)

DEGM – Dominion Energy Generation Marketing

DE - Dominion Energy

DEV – Dominion Energy Virginia

DNP – Distributed Network Protocol

EMS – Energy Management System

FIR – Facilities Interconnection Requirements

GI – Generator Interconnection

GMS – Generation Management System

GSU – Generation Step-Up Transformer

GVL – Global Variable

MOC – Market Operations Center

MW – Megawatt(s)

MVAR – Megavar(s)

OPGW – Optical Ground Wire

PCC or POI – Point of Common Coupling or Point of Interconnection

PID - (Proportional Integral Derivative), PID controllers use a control loop feedback mechanism to control process variables

PJM – Regional transmission organization of which Dominion Energy is a member (www.pjm.com)

PPA – Power Purchase Agreement

PPC – Power Plant Controller

PQM – Power Quality Meter

RQM – Revenue Quality Meter


RTAC – Real Time Automation Controller

RTU – Remote Terminal Unit

SCADA – Supervisory Control And Data Acquisition

SCU – System Control Unit, used in the context of an inverter skid controller.

SOC – System Operations Center

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DEFINITIONS

Breaker Failure Transfer Trip - Trips remote sources in the event of a breaker failure.

Generator Collector Station – Customer owned substation containing line or collector line terminals, breakers, transformers, and protection, metering, and monitoring equipment.

Dominion Energy Generator Interconnect (GI) Station – Dominion Energy owned substation containing line terminals, breakers, transformers, protection, metering, and monitoring equipment. The Dominion Energy Interconnected Switching Station is included as a line terminal transmission substation.

Islanding Transfer Trip - Trips interconnection in the event a generating facility is operating disconnected from the transmission grid.

Line Transfer Trip - Trips remote sources that are not capable of clearing a fault because current magnitude is below the protective relay scheme setpoints.

System Control Unit – For inverters that operate in a skid configuration, the SCU acts as a centralized controller for the entire skid.


Night Vars –An operational mode for PV inverters where the inverter can provide reactive power output when there is insufficient DC voltage and current to produce real power output. Battery Storage inverters have a similar mode when the unit is sitting idle between charge and discharge cycles.

No Load Reactive Support –An operational mode for certain wind turbines where in cases where there is insufficient wind to generate real power output, the turbine can still produce reactive power output.

Automatic Generation Control – A control scheme where a generator can follow a real power setpoint control signal from the centralized Generation Management System. The control signals are continuously sent, even if the setpoint remains static for a period.

Net Metering – Metering measured at the POI with Dominion Energy, where all auxiliary station service loads, transformer losses, and transmission line losses are compensated.

Gross Metering – Metering measured at the direct output of the generator and doesn't factor in losses due to auxiliary station service loads, transformer losses, and transmission line losses.

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1. PURPOSE AND INTRODUCTION

Virginia Electric and Power Company is commonly referred to as Dominion Energy.

The purpose of the *Dominion Energy Electric Transmission Generator Interconnection Data Communication and Data Exchange Requirements* document is to provide data communications architecture, data exchange, and standard SCADA application requirements and expectations to any individual or group seeking to connect electric power generation to Dominion Energy’s electric transmission system.

A primary driver for these requirements is ensuring operational visibility of the interconnected facility to PJM, the Dominion SOC, the Dominion MOC/DEGM (if applicable), and local site personnel. Another primary driver is the consistent and reliable operation of standard SCADA control applications from site to site.

The primary facilities targeted with this document are for renewable energy generation like Solar, Wind, and Battery Storage. Traditional generation facilities, like fossil fuel, fired steam turbines, nuclear, and hydroelectric power stations will need to be considered on a case-by-case basis.

This document supplements Dominion Energy’s Facility Interconnection Requirements document.

2. DATA COMMUNICATIONS ARCHITECTURE

2.1. GI Switching Station Data Communication

All GI switching stations will be required to have T1 or better digital communications service. The service will transmit all required metering, protection, and monitoring information from the applicable station to centrally located operational, engineering, and data servers.

2.2. Architecture Description

There are between two to four separate parallel communications paths between the generation facility and the attached Dominion Generator Interconnect Substation, depending on the site configuration, type, and operating agreement with Dominion Energy. The standard overall communications architecture between the GI substation and attached generation facility is depicted in Figure 1.

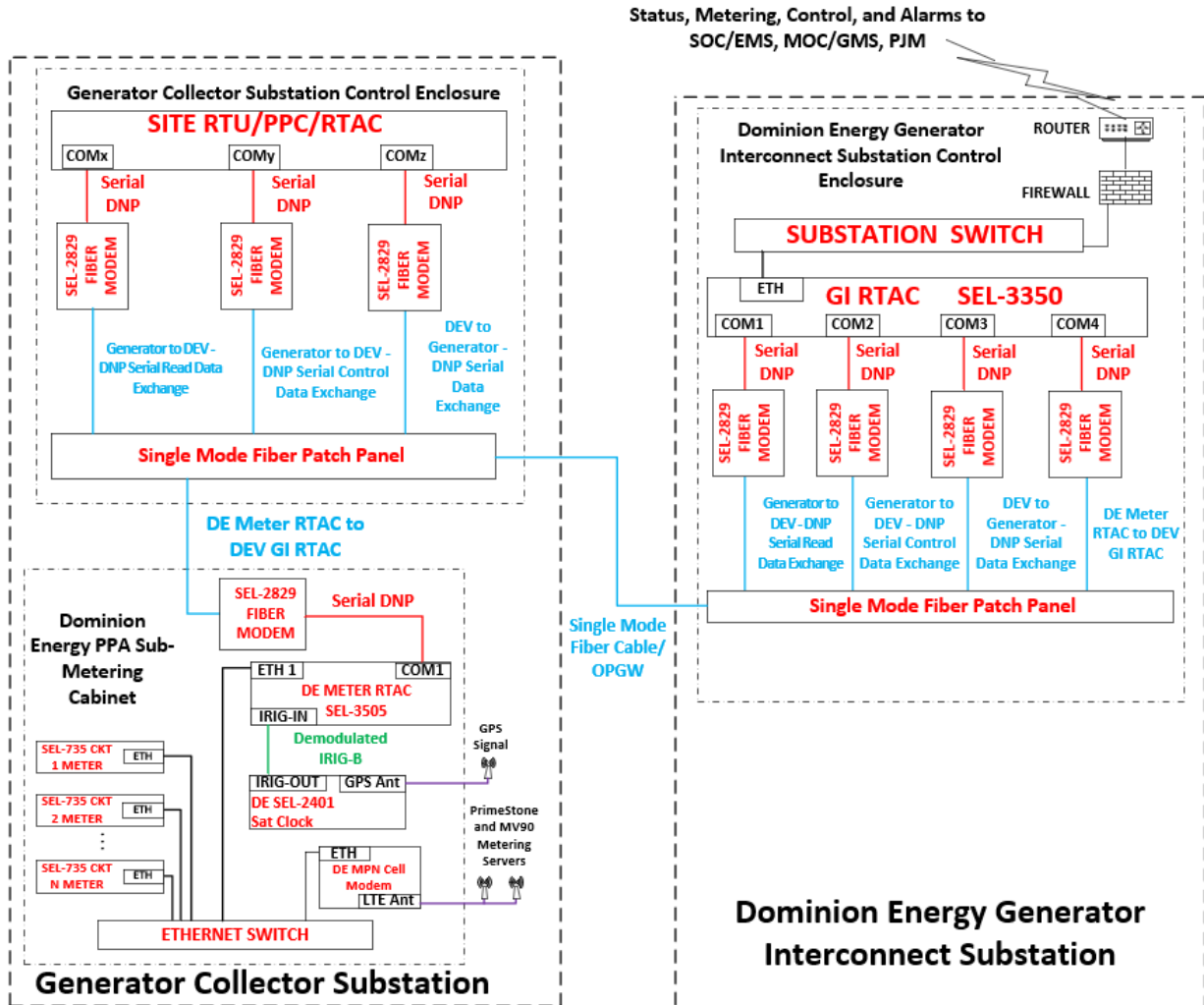



Figure 1: Generator Interconnection Substation to Generation Facility Overall Communications Architecture

The communications link between the two facilities will be single mode fiber over the optical ground wire (OPGW) or fiber cable pulled in conduit between the two attached switchyards. Usage of OPGW versus fiber cable will be dictated by distance requirements specified in the protection requirements outlined in Attachment 3 - Generator Interconnection Protection Requirements. This is the same fiber bundle also utilized for the line differential protection scheme on separate fiber pairs from the communications links. The communications method/protocol will be serial DNP3 over single mode fiber using Schweitzer SEL-2829 fiber transceivers. Each communication link will use a pair of fiber strands. Enough fiber pairs are to be pulled between the facilities to leave ample spares in case of future failures for both protection and communication applications. On either end of fiber bundle there will be a single mode fiber patch panel

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where the fiber pairs are terminated, individual connections will patch from these panels with single-mode fiber jumpers. The SEL-2829 fiber transceiver uses ST type fiber connectors. The fiber type is Single Mode 9/125 Micron.

2.2.1. Generator to DEV – DNP Serial Read Data Exchange Connection


The connection labeled “Generator to DEV - DNP Serial Read Data Exchange” in Figure 1 will contain all “read data” from the generation facility that is required by PJM, DEV SOC, DEV MOC, DE DEGM, and site personnel at the GI substation. No control commands are to be sent over this link due to the high data volume and throughput restrictions of using DNP Serial. The universal DNP map for this link is defined in an Excel spreadsheet that is available upon request. There are separate versions of this document used for solar and wind generation facilities. Section 3.2.1 details the specific data exchange requirements for the data points in the document. The required serial settings for this link are 19200 Baud, 8 Data Bits, No Parity, 1 Stop Bit. DNP client address 100, DNP server address 1. The GI RTAC is the DNP client device and the Site RTU/PPC/RTAC is the DNP server for this link. This connection will be required in all scenarios regardless of site type, configuration, and operational agreement with Dominion Energy.

2.2.2. Generator to DEV – DNP Serial Control Data Exchange Connection

The connection labeled “Generator to DEV - DNP Serial Control Data Exchange” in Figure 1 will contain all control commands and their associated feedback points from the generation facility that is required by PJM, DEV SOC, DEV MOC, DE DEGM at the GI substation. The separate control link is specified to eliminate latency and throughput concerns that may come about on a higher data volume serial data link. The universal DNP map for this link is defined in an Excel spreadsheet that is available upon request. Section 3.2.2 details the specific data exchange requirements for the data control points included in the document. The required serial settings for this link are 19200 Baud, 8 Data Bits, No Parity, 1 Stop Bit. DNP client address 100, DNP server address 2. The GI RTAC is the client and the Site RTU/PPC/RTAC is the server for this link. This connection will only be required where DNP control exchanges need to occur between the two facilities.

2.2.3. DEV to Generator – DNP Serial Data Exchange Connection

The connection labeled “DEV to Generator- DNP Serial Data Exchange” in Figure 1 will contain all GI substation read data to be provided to the generation facility for operational awareness and data historization. The universal DNP map for this link is defined in an Excel spreadsheet that is available upon request. Section 3.2.3 details the specific categories and characteristics of this data required under various circumstances. The required serial settings for this link are 19200 Baud, 8 Data Bits, No Parity, 1 Stop Bit. DNP Client Address 100, DNP Server Address 1. The Site RTU/PPC/RTAC is the Client, and the GI RTAC is the Server for this link. This connection will be required in all scenarios regardless of site type, configuration, and operational agreement with Dominion Energy.

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2.2.4. DE Sub-Metering RTU Serial Link

The connection labeled “DE Meter RTAC to DEV GI RTAC - DNP Serial Meter Real Time Data” in Figure 1 will contain all real time metering data and associated communication status of all Dominion Energy owned sub-metering on premises at the generator collector substation. No further details regarding data specification are needed since this connection will be internal between two DEV owned RTUs. This connection will only be required in circumstances where Dominion Energy MOC/DEGM has entered a PPA with the generation facility and is only purchasing a portion of the total power output of the plant, thus necessitating additional DEV-Owned sub-metering to be installed on premises at the generator collector substation. Extension of the GI substation network to support remote access to this equipment is prohibited by DE cyber security requirements.

3. DATA EXCHANGE REQUIREMENTS


Data exchange between the two facilities is specified via data models for each connection depicted in Figure 1. These data models are defined by a set of universal DNP data exchange point maps. Section 3.1 defines the attributes of these point maps and how to apply them at each site. Section 3.2 and its subsections detail the data exchange requirements for each of the connections defined in section 2.2.1-2.2.3. For the connections defined in sections 2.2.1 and 2.2.2, the customer is required to use the associated universal documentation template, fill out site-specific details, mark available points, define point sources, and provide the documentation to Dominion Energy to be used by Data Communication Engineering. For the connection defined in section 2.2.3, Dominion Energy Data Communications Engineering is required to use the associated universal documentation template, fill out site-specific details, mark available points, define point sources, and provide the documentation to the customer.

3.1. Universal DNP Data Exchange Documentation

The universal data exchange spreadsheets contain a superset list of all possible points required in the data exchanges between the two facilities. While every attempt has been made to proactively predict the data exchanges needed into the future, the very nature of renewable generation and its rapid advancements will likely require that the exact data exchange requirements will continue to evolve. These data exchanges are meant to be tools to speed development time and reduce custom engineering and programming from site to site.

There may be cases where the exact needs of the site fall outside of the parameters defined by the universal maps. In these cases, the customer will need to work with Data Communications Engineering at Dominion Energy to work through the details that deviate from the standard and develop custom modifications to meet the needs of the site.

In practice, the data needs from site to site are relatively stable, where the only variables are typically the number of GSUs, Breakers, Inverters, Meters, Wind Turbines, Meteorological Stations, etc. Data points defining parameters for these common attributes of the generation facility appear at rigidly defined DNP

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addresses. Evolutions in the data exchanges will occur in such a way that previously defined standard points will remain at their original DNP addresses and newer points appearing in the standard will be appended to the end of the map to avoid “point shifts” and reduce potential errors. Due to project timing between when sites enter the PJM queue and actual construction, exact revision numbers for these documents will not be specified by the FIR. The customer and Dominion Energy project teams must coordinate which map revision they are working from and work from the most recent revision at the time of construction.

There may be cases where the existing generator interconnection at a GI station followed data requirements from a legacy data standard while the new interconnection being added to the station is following the most recent data standard. The expectation is that the new interconnection must follow the latest standard. This is an inevitable consequence of the progression of data exchange requirements over time.

3.2. Data Exchange Requirements Per Serial Link


The following sections detail the data exchange requirements for the each serial link defined in sections 2.2.1-2.2.3. These are to be treated as minimum requirements, the requirements for a given site may not be limited to what is defined below. Please also note that for traditional generation facilities like fossil/hydro/nuclear plants, the data exchange requirements will need to be considered on a case-by-case basis due the widely varying configuration and design of these facilities, and how infrequently these types of generators interconnect to the system in recent years. The data exchange requirements contained in the following section primarily pertain to solar, wind, and battery storage facilities.

3.2.1. Generator to DEV – “Read Data” Data Exchange Requirements

The data exchange requirements for the read data link are categorically defined below. The categories align with the entries in the Sections column in the universal documentation template. Please note that there are separate versions of the “Read Data” documentation for solar and wind.

High-side Breakers: The customer is to provide the status and the breaker failure lockout indication for each transmission breaker on the high-side of each GSU. The phase-phase voltage, phase-neutral voltage, per-phase current, and frequency and watt/var power measurements are to be provided from the protection relay associated with each breaker. The communications failure alarm for each breaker relay is to be provided. The customer is to identify from which relay each point is sourced.

Motor Operated Disconnects: The customer is to provide the status for each transmission voltage motor operated disconnect that serves as an electrical disconnect between the generation facility and the utility. If there are multiple MODs in series between the utility, as shown in Figure 2, the MOD electrically closest to the GI substation will be mapped to the first MOD status point, and the next to the second, etc.

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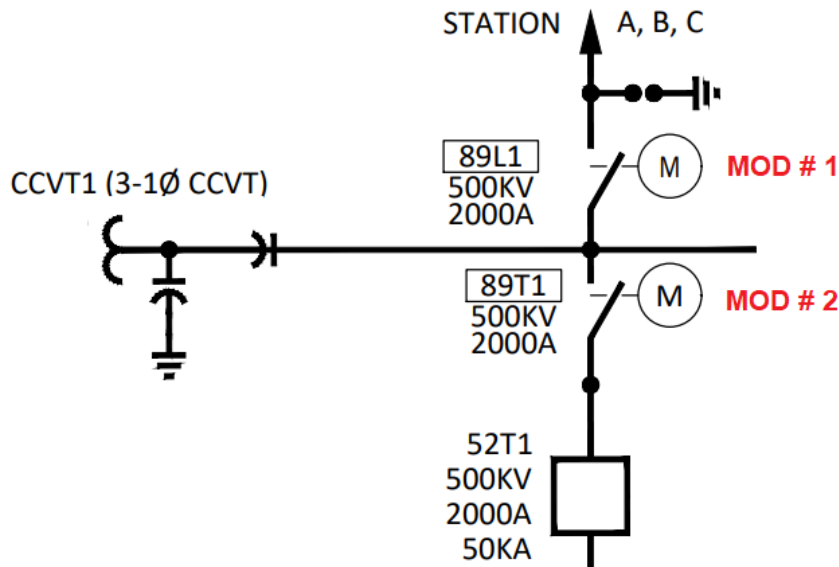



Figure 2: Example Series Motor Operated Disconnect Configuration

The customer is to identify which protection relay or I/O device this status is sourced from.

Feeder And Capacitor Bank Breakers: For the feeder and capacitor bank breakers on the medium voltage side of the GSU, the customer is to provide the status of each feeder and capacitor bank breaker. The phase-phase voltage, phase-neutral voltage, per-phase current, frequency, and watt/var power measurements are to be provided from the protection relay associated with each breaker. The communications failure alarm for each breaker relay is to be provided. The customer is to identify from which relay each point is sourced.

Transmission Line: Line differential protection is required between the two facilities. The following information is required from both differential relays: the month, day, year, hour, minute, second, millisecond, fault location, fault amps, and faulted phases (transmitted as a DNP binary input per faulted phase) for the four most recent fault records in the relay. The customer is to provide the phase-phase voltage, phase-neutral voltage, per-phase current, frequency, and watt/var power readings from each line relay. The customer is to provide the differential fiber channel failure alarm, the abnormal potential alarm, and line lockout indication from each relay. The communications failure alarm for each line relay is to be provided.

Site Control Meters: Generation facilities will have a variety of different metering configurations, to ensure complete information is supplied to Dominion Energy, the requirement for facility owned control, check, and sub-metering is as follows: The customer is to supply phase-phase voltage, phase-neutral voltage, per-phase current, frequency, and watt/var power from every substation meter at the site. The customer is to provide the communications failure alarm for each meter at the facility. The universal documentation has provisions for up to two high-side control meters, up to four low-side control meters per GSU with up to three GSUs, and up to two circuit sub-meters per feeder circuit, up to 12 circuits. These meters are referred


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to as the “PQM” meters in some contexts, as they are not the revenue meters of record for PJM. If the metering requirements at this facility fall outside of these options, the customer is to add the additional points to the end of the analog map, this change is to be coordinated with Data Communications Engineering.

Power Plant Controller/Park Pilot. The customer is to provide the operating state of the Real Power (MW) PID Control Program, the Voltage PID Control Program (commonly referred to as the “AVR”), the Reactive Power (MVAR) PID Control Program, and the Power Factor PID Control Program. If there is more than one PPC, with a maximum of three PPCs, a per-program status per PPC is required. The customer is to provide the present operating setpoint of each PID control program per PPC (MW/MVAR/Voltage/Power Factor).

Meteorological Station: PJM requires meteorological data for operational purposes [2]. The customer is to provide the global horizontal irradiance (GHI) measurements from every GHI sensor at every met station measured in watts per meters squared (solar only). The customer is to provide the plane of array (POA) measurements from every POA sensor at every met station measured in watts per meters squared (solar only). The customer is to provide the humidity measurements from every humidity sensor at every met station measured as a percentage (wind only). The customer is to provide the barometric pressure measurements from every pressure sensor at every met station, measured in units of hectoPascal (hPa) (wind only). The customer is to provide the ambient temperature readings from every ambient temperature sensor at every met station measured in degrees Fahrenheit (wind and solar). The customer is to provide the back of module (BOM) temperature readings from every BOM sensor at every met station measured in degrees Fahrenheit (solar only). The customer is to provide the wind speed readings from every wind speed sensor at every met station measured in meters per second (wind and solar). The customer is to provide the wind direction readings from every sensor at every met station measured in degrees from true north (wind and solar). The customer is to provide the communications failure alarm for every met station at the facility. The customer is to identify the site-specific name of each met station for reporting data issues to the future O&M provider.

PV Array (Solar Version Only): All inverters referenced in this section are associated with the PV array and are not related to battery storage; there is a separate section in the DNP map for battery storage information. The customer is to provide the inverter online status for each inverter or skid of inverters. If the inverters are a skid-based system with a system control unit (SCU), then the customer is to provide the number of inverters on that skid that are online. “Inverter online” is defined as the operational state where the inverter is grid-connected and is producing AC real power and can produce reactive power output if directed to do so by the PPC. The customer is to provide the inverter nighttime var online status for each inverter of a skid of inverters. If the inverters are a skid-based system with a system control unit (SCU), then the customer is to provide the number of inverters on that skid that are online in nighttime var mode. “Inverter Night Var Online” is defined as the operational state where the inverter is grid-connected and can produce only reactive power output if directed to do so by the PPC.

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The customer is to provide the maximum allowed real power output capability of all inverters at the facility in the form of a DNP analog input point. This is maximum real power setpoint that the PPC is allowed to write to each inverter when controlling POI MW output. This value is typically the nameplate rating of the inverter but can sometimes be artificially curtailed to ensure site maximum power capacity is not exceeded at the POI. The customer is to provide the maximum lead/lag allowed reactive power output capability of all inverters at the facility in the form of two separate DNP analog input points. These two points are the maximum lead/lag reactive power setpoints that the PPC is allowed to write to each inverter when operating in the various Voltage/MVAR/Power Factor control modes.

The customer is to provide the real-time real and reactive AC power output of each inverter or skid of inverters. If the inverters are a skid-based system with a System Control Unit (SCU), the totalized watt/var readings from the SCU can be used; individual SCU sub-inverter real time power readings are not required. The customer is to provide the site-specific inverter name for the source device for each inverter point for reporting data issues to the future O&M provider. Communication failure alarms for each inverter do not need to be sent, a non-communicating inverter is to be considered offline, since it cannot be controlled by the PPC.

Wind Turbines (Wind Version Only) - The customer is to provide the turbine online status for each wind turbine. "Turbine online" is defined as the operational state where the wind turbine is grid-connected and can produce AC real power output if there is sufficient wind and can produce AC reactive power output if directed to do so by the PPC/Park Pilot. The customer is to provide the maximum allowed real power output capability of all wind turbines at the facility in the form of a DNP analog input point. This is the maximum real power setpoint that the PPC/Park Pilot is allowed to write to each wind turbine when controlling POI MW output. This value is typically the nameplate rating of the Turbine but can sometimes be artificially curtailed to ensure site maximum power capacity is not exceeded at the POI. The customer is to provide the maximum lead/lag allowed reactive power output capability of all wind turbines at the facility in the form of two separate DNP analog input points. These two points are the maximum lead/lag reactive power setpoints that the PPC/Park Pilot is allowed to write to each inverter when operating in the various Voltage/MVAR/Power Factor control modes.

The customer is to provide the real-time real and reactive AC power output of each wind turbine. The customer is to provide the site-specific wind turbine name for the source device for each turbine point for reporting data issues to the future O&M provider. Communication failure alarms for each Turbine do not need to be sent, a non-communicating turbine is to be considered offline, since it cannot be controlled by the PPC/Park Pilot.

Battery Storage (Solar or Wind Version) – The generation facility can be a stand-alone bulk electric storage system (BESS) or can be a solar or wind generation facility with incorporated battery storage. For a stand-alone BESS system, or a solar generation facility with incorporated battery storage, use the solar version of the documentation template. For a wind generation facility with incorporated battery storage, use the wind version of the documentation template. The customer is to provide the BESS operational state in the form of four separate DNP Binary Input statuses: (Charging, Discharging, Standby, Off). "Standby" is

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defined as the operational state where the BESS is online but is currently in between charging and discharging cycles and is sitting idle. “Off” is defined as the operational state where BESS is not online and is not ready to perform a charge or discharge cycle. The customer is to provide the following quantities via DNP analog input points: BESS total MWH capacity, BESS stored MWH, BESS available MWH storage, BESS state of charge (“SOC” - expressed as a percentage), BESS maximum charge MW, BESS maximum discharge MW.

For individual BESS inverters, the customer is to provide an “inverter online” status. “Inverter online” for a BESS inverter is defined as the operational state where the inverter is grid-connected and is capable of provide positive or negative AC real power flow in support of charging and discharging the batteries, and in a state where it can provide AC reactive power if directed to do so by the BESS Controller/PPC/Park Pilot. The customer is to provide the real-time real and reactive AC power output of each BESS inverter. The customer is to provide the site-specific BESS inverter name for the source device for each inverter point for reporting data issues to the future O&M provider. Communication failure alarms for each BESS inverter do not need to be sent, a non-communicating inverter is to be considered offline, since it cannot be controlled by the PPC.


The customer is to provide the maximum allowed real power output capability of all battery storage inverters at the facility in the form of a DNP analog input point. This is maximum real power setpoint that the PPC is allowed to write to each inverter when controlling POI MW output. This value is typically the nameplate rating of the inverter but can sometimes be artificially curtailed to ensure site maximum power capacity is not exceeded at the POI. The customer is to provide the maximum lead/lag allowed reactive power output capability of all inverters at the facility in the form of two separate DNP analog input points. These two points are the maximum lead/lag reactive power setpoints that the PPC is allowed to write to each inverter when operating in the various Voltage/MVAR/Power Factor control modes.

A note on the BESS Controller and the Power Plant Controller: the BESS controller might be a separate control system from the PPC that controls the PV array/wind turbines or could be integrated into the PV/wind PPC as a hybrid resource. The customer is to identify the BESS controller in this documentation as one of the PPCs if it is a separate control system from the PV/wind PPC.

3.2.2. Generator to DEV – “Control Data” Data Exchange Requirements

The data exchange requirements for the control data link are specific to the power plant controllers. An important note on this section, this is only defining the technical requirements for each control data exchange, not the operational requirements for each control. The customer is required to provide these controls across the link; however, the usage of these controls will be dictated by operational agreements between the customer and Dominion Energy. If there are no operationally agreed upon controls that will be issued from the utility to the generator, then there is no need to have the serial control data link established.

Real Power (MW) Control: The customer is to provide a real power analog setpoint control per PPC, this will be the setpoint that the “Real Power (MW) PID Control Program” follows. There is a corresponding point

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in the DNP analog input map that serves as feedback that the PPC has received the updated setpoint. This feedback point is identical to the MW setpoint analog input specified in the “PPC/Park Pilot” requirements in section 3.2.1. The customer is to provide binary output controls that allow the “Real Power (MW) PID Control Program” to be enabled or disabled. There is a corresponding point in the DNP binary input map that serves as feedback that the PPC has been directed to change the operational mode of this program. This feedback point is identical to the operating state point specified in the “PPC/Park Pilot” requirements in section 3.2.1.

Voltage (AVR) Control: The customer is to provide a voltage analog setpoint control per PPC, this will be the setpoint that the “Voltage PID Control Program (AVR)” follows. There is a corresponding point in the DNP analog input map that serves as feedback that the PPC has received the updated setpoint. This feedback point is identical to the voltage setpoint analog input specified in the “PPC/Park Pilot” requirements in section 3.2.1. The customer is to provide binary output controls that allow the “Voltage PID Control Program (AVR)” to be enabled or disabled. There is a corresponding point in the DNP binary input map that serves as feedback that the PPC has been directed to change the operational mode of this program. This feedback point is identical to the operating state point specified in the “PPC/Park Pilot” requirements in section 3.2.1.

Reactive Power (MVAR) Control: The customer is to provide a reactive power analog setpoint control per PPC, this will be the setpoint that the “Reactive Power (MVAR) PID Control Program” follows. There is a corresponding point in the DNP analog input map that serves as feedback that the PPC has received the updated setpoint. This feedback point is identical to the MVAR setpoint analog input specified in the “PPC/Park Pilot” requirements in section 3.2.1. The customer is to provide binary output controls that allow the “Reactive Power (MVAR) PID Control Program” to be enabled or disabled. There is a corresponding point in the DNP binary input map that serves as feedback that the PPC has been directed to change the operational mode of this program. This feedback point is identical to the operating state point specified in the “PPC/Park Pilot” requirements in section 3.2.1.

Power Factor Control: The customer is to provide a power factor analog setpoint control per PPC, this will be the setpoint that the “Power Factor PID Control Program” follows. There is a corresponding point in the DNP analog input map that serves as feedback that the PPC has received the updated setpoint. This feedback point is identical to the power factor setpoint analog input specified in the “PPC/Park Pilot” requirements in section 3.2.1. The customer is to provide binary output controls that allow the “Power Factor PID Control Program” to be enabled or disabled. There is a corresponding point in the DNP binary input map that serves as feedback that the PPC has been directed to change the operational mode of this program. This feedback point is identical to the operating state point specified in the “PPC/Park Pilot” requirements in section 3.2.1.

Site Vs. Utility Control: The customer is to create logic in each PPC that establishes a site/local versus utility/remote control mode. When a PPC is in local or site mode, it will only follow locally issued commands (commands not issued from the utility). When a PPC is in remote or utility mode, for the controls that are operationally agreed upon to be issued by the utility, the PPC will only accept commands for those specific

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controls from the utility. The customer is to report the status of this control mode per PPC via the specified site/utility status points in the DNP binary input map.

3.2.3. DEV to Generator – DNP Serial Data Exchange Requirements


These are the data exchange requirements for the link where the generation facility can collect switchyard information from the GI substation. The provided documentation template for this link provides a superset of all data for a variety of GI configurations. Dominion Energy is to mark up this documentation and provide to the customer the data points that will be provided based on the site configuration.

Transmission Breakers: Dominion Energy is to provide to the customer the status of all breakers that directly connect the generation facility to the transmission network. The customer will be provided breaker failure lockout indications for each transmission breaker that can issue a transfer trip to the generation facility. The customer is to be provided the source device for each of these indications and a communications failure alarm for each source device.

Transmission Line: Line Differential protection is required between the two facilities. Dominion Energy is to provide the following information to the customer from both differential relays: The month, day, year, hour, minute, second, millisecond, fault location, fault amps, and faulted phases (transmitted as a DNP binary input per faulted phase) for the four most recent fault records in the relay. The customer is to be provided the phase-phase voltage, phase-neutral voltage, per-phase current, frequency, and watt/var power readings from each relay. The customer is to be provided the differential fiber channel failure alarm, the abnormal potential alarm, and line lockout indication from each relay. The communications failure alarm for each line relay is to be provided to the customer.

Islanding: Dominion Energy is to provide status that an anti-islanding transfer trip has been issued from the GI substation to the generation facility. The customer is also to be provided the communications failure alarm for the islanding protection relay that generates this indication.

POI Metering: There is a primary and backup revenue meter at the POI within the GI substation. These meters are referred to as the “RQM” meters in some contexts, as these are the revenue meters of record for PJM. These meters provide the “net” metering for the generation facility. Dominion Energy is to provide to the customer the following points from each meter: phase-phase voltage, phase-neutral voltage, per-phase current, three-phase average current, three-phase average voltage, frequency, and watt/var power readings. The customer is also to be provided received and delivered watt-hour and var-hour counters, presented in both an end-of-interval and continuously running format. “End-of-Interval” counters will report at the top of every hour the total watt-hours and var-hours measured for the entirety of the previous hour. The meters are time synchronized using a global positioning system (GPS) synchronized satellite clock. The usage of the continuously running counters will require the facility to perform their own precisely timed freeze, read, and time differential calculation to determine the total counts for the previous hour. Dominion Energy is to provide the communications failure alarms for each POI revenue meter.

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SOC Voltage Control: The SOC voltage control SCADA application will generate alarms if the facility operates outside of the allowed voltage schedule voltage band. The voltage band upper and lower threshold values will be sent to the customer each as DNP analog input points. There will be an initial alarm marking the start of a 30-minute timer, and a second alarm marking that voltage at the POI has been out of band for more than 30 minutes. Section 5.1 expands further on this application.


4. CUSTOMER SITE DOCUMENTATION REQUIREMENTS TO DOMINION ENERGY

Dominion Energy needs to know the configuration and capabilities of the facility in order to integrate the site into the transmission network and for various operational and contractual arrangements. The customer is to provide the following documentation to Dominion Energy in support of data exchange between the facilities and EMS/GMS modeling activities.

- The AC protection single line diagram for the attached collector substation.
- The AC single line diagram for the PV array showing which inverters are connected to each feeder circuit (if solar).
- The AC single line diagram for the wind turbines showing which wind turbines are connected to each feeder circuit (if wind).
- The AC single line diagram for a BESS showing which battery inverters are connected to each feeder circuit.
- The Continuous Unit Reactive Capability Curve or “D-Curve” for the facility. If there is more than one unit, this must be expressed per unit. A unit is defined per PPC.
- The generation facility nameplate real power and reactive capabilities, as in the maximum MW and MVAR output capability of the plant at the POI.
- The details of all meteorological stations, detailing the total number of met stations, the attached sensors and available measurements at each station. A single representative example can be provided if all stations are identical. Identify the site-specific name of each met station.
- For solar- the per-inverter watt/var maximum capability. If the inverters are skid based, identify the per-skid watt/var maximum capability. If the number of inverters varies per skid, this will need to be broken down on a skid-by-skid basis. Identify if the inverters maximum var capability differs when utilized for nighttime var support, and the actual maximum var capability.
- For wind- the per turbine watt/var maximum capability. Identify which turbines (if any) support no-load reactive power support and the maximum var capability when the turbine is operating in no-load reactive support (if it differs from the value while generating).
- For battery storage- the per-BESS inverter watt/var maximum capability, the total BESS storage capacity, and the maximum charge/discharge rating for the system.

5. COMMON SCADA APPLICATION CONTROL NARRATIVES

There may be a wide variety of SCADA control schemes deployed from site to site, however some will be common to all or most sites, these are discussed below.

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5.1. SOC Voltage Control

Each PPC is to follow a voltage setpoint signal issued from the Dominion Energy System Operations Center (SOC). The setpoint is issued through the GI Substation via the GI RTAC Generator to DEV – “Control Data” serial link and via the voltage setpoint controls per PPC in that link (as described in section 3.2.2). This setpoint will electronically transmit the voltage schedule from the transmission operator. The setpoint is setting the voltage setpoint in the “Voltage PID Control Program (AVR)” per-PPC as referenced throughout the section 3 data exchange requirements. The GI RTAC will monitor the setpoint versus the measured voltage at the POI, if the voltage deviates outside of the allowed band, an alarm will be generated to the generation facility across DEV to Generator read data link as described in section 3.2.3. The upper and lower bounds of this voltage band will be provided as DNP analog inputs to the customer across the DEV to Generator read data link as described in section 3.2.3. The initial alarm indicates to both parties that since the generator has fallen outside of the allowed voltage band, that there has been a “status change” in the AVR functionality of the site, according to requirement R3 of the NERC VAR-002 standard [3]. This alarm also marks the start of a 30 minute timer. If the voltage continues to stay out of band for more than 30 minutes, a second alarm will trigger for both the generator and the SOC. Please note that the generator operator is still required to alert the transmission operator (the SOC) when this 30 minute threshold is crossed as per the NERC VAR-002 standard [3].


If the generation facility is a solar generation site, the voltage setpoint is to be followed as the site inverters seamlessly transition from daytime generation to nighttime var-only reactive support. Similarly if the generation facility is a solar generation site, the voltage setpoint is to be followed as the inverters seamlessly transition from nighttime var-only support to daytime generation.

The setpoint is to be issued from the SOC when a change is required. The PPC is to hold the setpoint static until a different setpoint is issued from the SOC. The PPC will only accept a voltage setpoint if the unit is running with its AVR enabled and if the site/utility control mode is running in utility control mode.

The PPC is to reject any voltage setpoint received that is outside the operational band of the voltage schedule.

5.2. MOC/DEGM-PJM Curtailment

Under certain operational arrangements the Dominion MOC/DEGM will need to issue a PJM Curtailment MW setpoint to the PPC. The setpoint is issued through the GI Substation via the GI RTAC Control link and via the real power setpoint controls. This setpoint will electronically transmit the unit requested real power output from the MOC or DEGM. The setpoint is setting the real power setpoint in the “Real Power (MW) PID Control Program” for the given PPC as referenced throughout the section 3 data exchange requirements.

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The setpoint is to be issued from the MOC/DEGM on a continuous regular update cycle, typically every 4 seconds, akin to a traditional generation AGC signal. The PPC is to hold the setpoint static until a different setpoint is issued from the MOC/DEGM. The PPC will only accept a real power setpoint if the unit is running with its MW control mode enabled and if the site/utility control mode is running in utility control mode.

The PPC is to reject any real power setpoint received that is outside the operational parameters of the site interconnection agreement (IA).

6. CONSTRUCTION PROJECT MILESTONES AND DOMINION ENERGY SOC SCADA REQUIREMENTS

Certain SCADA requirements must be met before the Dominion Energy SOC will allow the generation facility to back-feed and reach first-sync and start generating power to the grid. There are also SCADA tests that must be performed once the site is fully commissioned prior to substantial completion, these are detailed in the following sections. Please note that the following requirements pertain to solar/wind/battery storage facilities. SOC SCADA requirements for a traditional fossil/hydro/nuclear generation facility will be evaluated on a case-by-case basis and communicated to the customer.

6.1. Back Feed


For the generation facility to back feed and start receiving off-site power from the transmission network the following SOC SCADA requirements must be met:

- The SOC must have visibility of generation facility high side breaker status, breaker failure and transmission voltage motor operated disconnect (MOD) status points. These are provided by the customer to Dominion via the “Generator to DEV – Read Data” link as specified in section 3.2.1.
- The SOC must have visibility of the voltage readings from the transmission voltage CCVT at generation facility. These readings are sourced from high side breaker failure relays, line relays, and high side control meters. These are provided by the customer to Dominion via the “Generator to DEV – Read Data” link as specified in section 3.2.1.
- The SOC must have visibility of the POI revenue metering data. This is provided by Dominion Energy to the Dominion SOC.

6.2. Generation First Sync

For the generation facility to first sync and start producing power to the transmission network, the following SOC SCADA requirements must be met:

- The SOC must have visibility to the low side “gross” real and reactive power readings. These readings either come from the summation of metering data from medium voltage feeder breaker/cap bank breaker protection relays, from per-circuit sub-meters, or GSU low-side control meters.
- The SOC must have visibility to the low side “gross” real and reactive power readings. These readings either come from the summation of metering data from medium voltage feeder

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breaker/cap bank breaker protection relays, from per-circuit sub-meters, or GSU low-side control meters.

- The SOC must have modeled the generation units as per the site D-curve and nameplate characteristics into EMS system and state-estimator. The EMS modeling team requires the documentation as specified in section 4 to complete this task.
- All per-PPC AVR (“Voltage PID Control Program” enable/disable) status points must be SCADA checked from the PPC to the SOC.

6.3. Site Substantial Completion


Frequently the full site is not yet commissioned as of the first sync date, so some finalized testing must wait for full site commissioning to occur. Prior to site substantial completion, the SOC voltage control SCADA application must be tested and verified, as well as other remaining SCADA checks that could not be completed at the time of First Sync. The following verifications must be performed:

- The SOC voltage control application must be tested and verified such that the site accepts and follows a voltage setpoint issued from the SOC.
- The upper and lower bounds of the voltage application must be tested and rejection of unreasonable voltage setpoints must be verified.
- The site/utility control mode functionality must be verified. The site must reject commands if in site mode and accept agreed upon commands if in utility mode.
- If a solar facility, the transition of daytime generation to nighttime AVR support for the voltage control application must be verified. Likewise- the transition from nighttime AVR support to daytime generation AVR support must be verified.
- All PV array/turbine/battery storage/met station SCADA read data is to be verified once full site commissioning is completed.

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7. REFERENCES

- [1] "Facility Interconnection Requirements," Dominion Energy, most recent version.
- [2] *PJM Manual 14D: Generator Operational Requirements*
- [3] *VAR-002 Generator Operation for Maintaining Network Voltage Schedules*, North American Electric Reliability Corporation.


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8. REVISION HISTORY

Revision Date	Revision #	Description	Revised By	Effective Date
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Attachment 6

Generation Interconnection Substation Technical Requirements

**Dominion Energy Virginia – Electric Transmission
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1. Introduction

1.1. Purpose

This document establishes minimum standard requirements for Interconnect Customer to design and build safe, efficient, and reliable substations for Virginia Electric and Power Company, dba Dominion Energy Virginia. Accordingly, DEV Electric Transmission (ET) will be responsible for designing and building the transmission line that will connect with the Interconnect Customer substation. Therefore, from now on, throughout this document, Dominion Energy Virginia will be referred to as DEV-ET.

For the application of this document, essential requirements for building DEV-ET substations are outlined. These include general requirements from Civil/Site, Physical, Electrical, and Protection and Control. Once an Interconnection Agreement (IA) is finalized, the Interconnect Customer shall use the provided DEV-ET specifications, standard designs, construction documents, and drawings. Since this document is intended to focus on the layout and design of the substation, Interconnection Customers shall refer to the DEV's Facility Interconnection Requirements document¹, [PJM Tariffs](#), and governing documents² for an essential understanding of the generation interconnection Option-to-Build process and procedures.

Interconnection Customers and DEV-ET shall also adhere to the North American Electric Reliability Corporation ([NERC](#)) Standard FAC-001,³ which requires Transmission Owners and applicable Generator Owners to provide Facility Interconnection Requirements documentation to prospective entities seeking to connect to DEV-ET systems.

Refer to [References](#).

1.2. Intended Audience

The intended audiences for this Technical Requirements for Generation Interconnect Substations document include:

- Interconnection Customers' respective engineering, construction, and operations staff and consultants
- Transmission Owners' respective engineering, construction staff, contractors⁴, and consultants

1.3. Abbreviations and Definitions


Abbreviations and definitions are listed in [Appendix A](#).

¹ DEV's Facility Interconnection Requirements: [facility-connection-requirements1.ashx \(pjm.com\)](https://www.pjm.com/~/media/committees-and-panels/et/interconnect-requirements/2023-09-01-facility-connection-requirements1.ashx)

² PJM Governing Documents: <https://pjm.com/library/governing-documents>

³ NERC FAC-001: <https://www.nerc.com/pa/Stand/Reliability%20Standards/FAC-001-3.pdf>

⁴ DEV-ET refers to *Contractors* as *Engineering Service Providers*; these terms interchangeable

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1.4. Roles and Responsibilities

1.4.1. Interconnect Customer


Interconnect Customers exercising an option-to-build a substation facility are responsible for, but not limited to, the following:

- Quality Control walkthrough and review of provided list of point of contacts for each approved contractor, standard drawings and specifications.
- Adherence to DEV-ET’s environmental and permitting requirements.
- Build and design DEV-ET’s substations as outlined in the Interconnect Agreement
- Training of substation systems
- Procurement of DEV-ET’s approved equipment and materials outlined in [Appendix F](#) for all option-to-build substations.
- Use of DEV-ET’s list of approved contractors, outlined in [Appendix G](#)
- Compliance with non-disclosure agreements, NERC requirements, and DEV-ET Cyber Security systems
- Inspection, tests, and energizing of DEV-ET’s substations.
- Adhering to any applicable federal, state, and local codes along with any applicable NERC, RF, or PJM requirements
- Deeding the facility to DEV-ET after completed work is approved.

1.4.2. Transmission Owner

The Transmission Owner (DEV-ET) is responsible for, but is not limited to the following during an Interconnection project:

- Providing the Generation Interconnect Substation Specifications Portfolio outlining list of point of contacts for each approved contractor, standard drawings, and specifications at the time of IA
- Quality Control walkthrough and review of provided list of point of contacts for each contractor, standard drawings, and specifications
- Review and comment on design work performed by the Interconnect Customer
- Review of Equipment Acceptance Test
- Calibration of Remote Terminal Units and Relay Settings

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- Review of approved contractors outlined in [Appendix G](#)
- Review of construction
- Assistance with Permitting, Land Rights, and Authorizations
- Quality Assurance review to ensure standards and specification accuracy.
- Maintenance of the facility after work is approved and the substation is deeded to DEV-ET

1.5. Scope

An Interconnect Customer exercising the option-to-build a DEV-ET substation or connect a generation facility to a substation must guarantee that all work is safe to the public, reliable, and of high quality, ensuring DEV-ET’s effortless maintenance of the facility after taking ownership. Therefore, it is pertinent that the Interconnect Customer adhere to the outlined DEV-ET’s Substation design and build requirements. Further, they must follow the NERC Reliability Standards⁵.

The requirements outlined in this document are basic and don’t include specifications, detailed documentation, and drawings. These details will be provided in a portfolio during an Interconnect Agreement between the Interconnect Customer and DEV-ET. Further, during a Generation Interconnection project, the Interconnect Customer shall comply with all requirements outlined in the portfolio and the Interconnection Agreement.


This document references DEV-ET’s *Facility Interconnection Requirements (FIR)*⁶ which provides a broader scope of Interconnection requirements. In addition, transmission Interconnection documents are available on the DEV website⁷ for additional guidance.

Although planning is out of scope for this document, the DEV-ET *Facility Interconnection Requirements* guide the planning phase of a typical project. DEV-ET safeguards the transmission planning standards of NERC and those of the SERC Reliability Corporation (SERC), one of the six regional reliability organizations (RRO) of NERC.

⁵ NERC Reliability Standards:
<https://www.nerc.com/pa/Stand/Pages/ReliabilityStandards.aspx>

⁶ 1214 FAC-001 *Facility Interconnection Requirements*:
[facility-connection-requirements1.ashx \(pjm.com\)](https://www.pjm.com/~/media/committees-and-panels/fir/1214-fac-001-facility-interconnection-requirements1.ashx)

⁷ Dominion Energy Virginia website:
<https://www.dominionenergy.com/virginia>

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2. Requirements

2.1. Design Drawing Requirements

When an Interconnect Customer design and builds a DEV-ET substation, drawings shall emulate the DEV-ET engineering drawing package required to construct the substation. Upon completion of the substation, a set of as-built construction drawings and documentation are to be provided to DEV-ET. The As-built drawing set shall contain the following:

- Electrical;
- Protection and Control (P&C);
- Structural;
- Civil drawings; and
- Vendor documentation.

Nomenclature and numbering shall emulate DEV-ET standards such as those outlined in the Uniform Numbering System.

Note:	Once an Interconnection Agreement (IA) is finalized, DEV-ET specifications, drawing templates, and other required documents will be provided upon request.
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2.2. Voltage level and MW and MVAR capacity or demand at the point of interconnection


The Interconnection Customer shall refer to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.2.

2.3. Breaker duty and surge protection

The Interconnection Customer shall refer to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.3.

2.4. System Protection Coordination

The Interconnection Customer is responsible for the accurate design and tested Protection system that ensures that all work is safe to the public, reliable, and protects its equipment against disturbances on DEV-ET's system and minimize the effects of disturbances from its facilities on DEV-ET's equipment and Transmission System. Therefore, the Interconnection Customer shall adhere to the *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.4.

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2.5. Metering and telecommunications

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.5.

2.6. Grounding and Safety Issues

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.6.

2.7. Insulations and insulation coordination

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.7.

2.8. Voltage, reactive power, and power factor control

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.8.

2.9. Power quality impacts flicker

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.9.

2.10. Equipment ratings

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.10.

2.11. Synchronizing of Facilities


The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.11.

2.12. Maintenance coordination

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.11.3.

2.13. Operational issues (abnormal frequency and voltages)

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection*

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Requirements, section 2.11.4.

2.14. Load-shed program as required by PJM

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.11.5.

2.15. Communications and procedures during normal and emergency operating conditions

The Interconnect Customer shall adhere to *Dominion Energy Virginia, Facility Interconnection Requirements*, section 2.11.6.

2.16. Site Grading

The installation of a DEV standard substation begins with the proper site selection. Accordingly, many factors such as site accessibility, drainage, erosion protection, and the amount of necessary site preparation must be considered. Also, the necessary permits to work on a site must be acquired before starting construction. During the design and build a DEV-ET substation, the Interconnect Customer shall adhere to the Substation Civil-Site Grading Specification and related standards documentation provided by DEV-ET. Standard documentation shall be provided to the Interconnect Customer at the time of an Interconnect Agreement.

2.17. Fencing


Substation fences shall be installed at the beginning of construction. This applies particularly to construction projects involving trenches and structures that unauthorized persons might climb.

Specifications cover perimeter fence specifications based on the station's functionality where it is being installed. A perimeter fence constructed of steel fabric is the preferred physical barrier for substation sites. In some cases, the county, city, or residence may require a decorative fence.

2.18. Foundations

Substation foundation design primarily depends on the in-place density and strength/strain characteristics of the soil (supporting the wide range of ground line reactions) that are associated with structures and equipment. The heterogeneous characteristics of soils or their localized variability make the foundation design much less exact than the analysis associated with structural design or some facets of electrical design.

There are various types of substation structures, having a wide variety of ground line reactions. The foundations used to support these structures and equipment depends upon the soil information, constructability concerns, and preferences of the design engineer. Some common foundations used in substations are 1. Drilled piers (or drilled shafts) 2. Spread footings 3. Slabs on grade 4. Single application "Special" foundation (e.g., piles, rock anchors, and/or direct embedment)

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2.19. Structures

Substation structures fix above-grade components and electrical equipment such as conductors (rigid and strain bus); switches; surge arresters; insulators, and other equipment to specified locations. The structures are designed to safely support equipment and electrical components through applicable mechanical loads from wind, ice, line tensions, earthquakes, construction and maintenance, and other specified or unusual service conditions.

2.20. Bus Design

The design and installation of rigid bus are common in all DEV-ET substations. Bus designs shall adhere to minimum electrical and structural properties as governed by the conditions below.

Applicable bus design conditions:

- Minimum ampacity requirements
- Maximum anticipated short-circuit current
- Maximum operating voltage
- Maximum anticipated wind speed
- Maximum expected icing conditions combined with wind
- The altitude of the station
- Basic substation layout

2.21. Lighting


Yard lighting shall be provided in substations to deter criminal activity and flood the general area. Yard lighting is not intended to furnish sufficient lighting to permit all forms of night work. For this purpose, portable spots and floodlights shall be used. The number of permanent lights provided depends upon the size of the substation.

2.22. DEV Interface Documents

Two essential interface documents include the Substation / Transmission Engineering Interface and Substation / Distribution interface:

- **Interconnect Customer Substation / DEV-ET Transmission Engineering Interface**

This section summarizes the responsibilities of, and the communication interface between Transmission Line Engineering and Substation Engineering for the design of transmission line structures inside substations. Transmission Line Engineering is responsible for designing, specifying, and procuring the transmission line structures located within the substation fence. Transmission Line Engineering is also responsible for designing and procuring the foundation

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materials.

Substation Engineering is responsible for specifying and procuring the line disconnect switches and necessary grounding material for those structures. The definition of a transmission line structure inside a substation is any structure supporting a flexible conductor using strain insulators. Included in this definition are the following:

- a. Tubular backbone structures
- b. Tubular line structures
- c. Steel "A" structures
- d. Strain-bus structures
- e. Static pole structures Transmission Line Engineering shall develop the line phasing diagram with the required approvals and forward it to substation engineering for review. Substation Engineering shall develop the substation construction one-line diagrams and obtain the required approvals. Transmission Line Engineering will review the drawings for any transmission work, including phase positions, line switches, and termination positions.

- **Interconnect Customer Substation / DEV Distribution Interface**


Where applicable, this section summarizes the responsibilities of, and the communication interface between Distribution Design and Substation Engineering. This established exchange of information is essential for the design of distribution get-a-ways and other interface points between substations and distribution lines. Substation Engineering will provide Distribution Planning with a copy of the General Arrangement Plan. Planning will provide Substation Engineering with a copy of the distribution line construction plan so that the poles and underground circuits can be properly located inside the substation. The circuit get-a-way circuit shall be overhead construction whenever possible. When an underground get-a-way is required, a spare conduit must be included with the terminal structure foundation. A spare conduit will allow more efficient recovery of lost circuits due to cable failures. As required, Distribution Planning must specify the need for dual terminal structures. Disconnects or other means of isolation may be required on distribution circuits, to facilitate maintenance.

2.23. Grounding

In designing a substation grounding system, the primary objective is to provide safe conditions for equipment and personnel operating in and about the substation during both normal and abnormal conditions.

Grounding of power systems is achieved by embedding electrical conductors into the earth and electrically connecting these conductors to the neutral of the power system. In this way, a low impedance is provided between the power system neutral and the vast conducting soil, which guarantees that the voltage of the neutral, concerning earth, will be low under all conditions.

Grounding is necessary for several reasons: (a) to assure correct operation of electrical devices, (b) to provide safety during normal or fault conditions, (c) to stabilize the voltage during transient conditions, and (d) to dissipate lightning strokes.

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2.24. Electrical Connections

Connections in substations are designed for extremely high reliability. In support of high reliability, connector design is influenced by certain factors. These factors are creep (cold flow), surface oxide, corrosion, and thermal effects.

Types of Connections include:

- Bolted
- Compression
- Welded
- Exothermic

2.25. Station Shielding

The IEEE Guide for Direct Lightning Stroke Shielding of Substations presents four significant methods of protecting substations from lightning strikes: fixed angles, empirical curves, the computer program SBSHLD, and the rolling sphere method. SBSHLD and the rolling sphere method are generally the more conservative methods, and both are based on the Electrogeometric Model; both depend greatly on the voltage withstand capability of the substation. The methods of fixed angles and empirical curves, however, depend only on distances between masts or shield wires and the objects they protect.


All four methods require similar resources to protect higher voltage substations, but the methods vary significantly in protecting lower voltage levels (230 kV or less). DEV-ET policy provides the most significant protection to higher voltage substations. They are a more critical part of the power system—both SBSHLD and the rolling sphere method attempt to provide equal protection to all substations. Because of the reduced voltage withstand capability associated with low voltage substations, using these methods results in a greater concentration of masts and wires per area unit at these locations. These methods soon become impractical and excessive. Since the voltage withstand capability is not a factor in either the fixed angle or empirical curve methods, they inherently provide the best protection at higher voltages.

Although fixed angles and empirical curves have similarities, they differ in the size of the protection zone. The method of empirical curves protects more significant areas at lower elevations. We believe this is a more accurate representation because the information presented in each curve results from actual lightning strikes and has been compiled for over 50 years. The fixed angle method is a straight-line approximation of the empirical method.

As much as possible, substation equipment will be protected from lightning by either shield wires or lightning masts. However, it is impossible to provide 100% protection to all equipment because of the randomness and uncertainty associated with lightning strikes. For this reason, equipment is protected within a certain failure rate or percentage at which the protection system fails.

For design purposes, it is recommended that the engineer use a failure rate of .1% whenever possible. However, a failure rate of greater than .1% may be used if the recommended method is not feasible or if the need for protection is not significant enough to warrant the cost; this is left to the engineer's discretion.

Once the height (d) of the device to be protected is known, the curves can be used to determine the maximum allowable distances between the device and the static wire(s) or mast(s) protecting it. The empirical shielding curves provide information about the vertical and horizontal locations necessary for adequate protection. The vertical distance (h) is measured from the ground, while the horizontal distance

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(x) is measured from the protected object.

Figures 1 through 5 ([Appendix C](#)) below give the empirical curves for five different shielding situations at a 0.1% and a 1% failure rate. The lower curve is more restrictive in each case and indicates a 0.1% failure rate.

2.26. Electric Clearances

Maintaining electrical clearance around energized conductors and parts is one of the most critical aspects of substation design. “Clearance” or distance from a live electrical part is necessary for the safety of personnel working in the area and for the reliable operation of the electrical substation equipment.

2.26.1. Codes and Standards

The National Electric Safety Code (NESC), 2007 revision, was used to develop the clearance tables. NESC provides safety rules for the design of electrical supply equipment and associated work practices.

IEEE documents C37.32 and C1427 were used where applicable.

2.26.2. Personnel Clearances

NESC rule 124.A.1 states, "Guards shall be provided around all live parts operating above 300V...unless their location gives sufficient horizontal or vertical clearance".

2.26.3. Roadway Clearances

Bus conductors that span substation roadways must be high enough to allow the tallest utility truck, crane, or apparatus to be driven or transported underneath it and maintain phase-to-ground clearance from live parts. The tallest apparatus to be transported in the substation is the power transformer.

2.26.4. Equipment Disassembly and Movement

Consideration must be given to providing adequate clearances for disassembling and moving equipment. The primary example is removing the bushings from a transformer and moving them out of the substation. The manufacturer's outline drawing for the electrical equipment shall be used to determine the clearance needed. The minimum electrical clearances in Table ([Appendix D](#)), column a, must be adhered to during the disassembly and moving process to provide adequate clearances.

2.26.5. Clearances at a Perimeter Fence

This section clarifies design requirements for the location of substation fences concerning overhead conductors or live parts inside a substation. The intent of the electrical clearance safety zones, noted in the body of this interpretation is listed below.


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Table 1 – Electrical Clearance Safety Zones Interpretation

Safety Type	Description
Public Safety	Reduce possible hazards to anyone outside the substation fence.
Minimum approach distance	Ensure proper working clearance from the fence to overhead conductors and live parts inside the substation. The National Electric Safety Code will assign electrical clearance requirements per voltage class.

2.26.6. Tables and Figures

Electrical Clearances Figures and Tables are outlined in [Appendix D](#).

2.27. Equipment

Surge Arresters are required to protect power system equipment from overvoltages. Arresters shall be of a MOV design for substation applications.

Refer to [Appendix E](#)

3. Approved Major Substation Equipment

Interconnect Customers exercising an option-to-build substation facility as a part of an Interconnect project must procure equipment and materials from DEV-ET's list of approved contractors.


4. Approved Contractors

All Option-to-Build work, defined in Tariff Section 3.2.3, must be performed by contractor approved by DEV-ET. A DEV-ET representative will provide a list of approved contractors and a point of contact(s) for each approved contractor along with a portfolio of standard drawings and specifications at the time of the IA. Contractors currently under contract and working on DEV-ET property will not be available for Interconnect Customer Option-to-Build work.

Interconnect Customer Right to Build Contractor crews shall be approved by DEV-ET and will not be allowed to work more than 40 hours per week without DEV-ET review and approval. Further, additional criteria, such as insurance, contract provisions, etc., shall be required for review before the approval of IC Option-to-Build work on DEV-ET's distribution system.

Review of a detailed schedule from the Interconnect Customer using DEV-ET-approved contractors for the specified upgrades shall be required to determine the reasonableness of the proposed schedule.


Note:	Once the Interconnection Customer has entered into an interconnection agreement, the Interconnection Customer shall contact DEV to review the most up-to-date list.
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References

- Dominion Energy Facility Interconnection Requirements, Standard Requirements #: FAC-001 R1 and R3
- Dominion Energy Substation Engineering Manual
- Dominion Technical Standards: <https://www.pjm.com/planning/design-engineering/to-tech-standards/private-dominion>
- IEEE Std 998 – 1996, IEEE Guide for Direct Stroke Lightning Stroke Shielding of Substations
- Manual 14B- PJM Region Transmission Planning Process
- NERC Planning Standard TPL-001
- NERC PRC Standards 12 - 17
- NERC Reliability Standard NUC-001
- North American Electric Corporation website at www.nerc.com
- Nuclear Switchyard Interface Agreement CO-AGREE-000-IAI
- Nuclear Switchyard Interface Agreement System Analysis Protocol CO-AGREE-000-IAI-4
- PJM Manual 39- Nuclear Plant Interface Coordination
- Transmission System Performance SERC Supplement

Note:	Once the Interconnection Customer has entered into an interconnection agreement with DEV-ET, a portfolio containing detailed documentation and drawings will be provided for option-to-build generation interconnection work.
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Appendices


Appendix A: Abbreviations and Definitions

Table 2 – Abbreviations and Definitions

Term/Abbreviations	Definition
ANSI	American National Standards Institute
Basic Impulse Level (BIL)	A basic impulse insulation level (BIL) is a reference impulse insulation strength expressed in terms of the crest value of withstand voltage of a standard full impulse voltage wave.
Clearance, Minimum Phase-to-Ground	The shortest metal-to-metal distance between an energized part(s) and the adjacent grounded part(s)
Clearance, Minimum Phase-to-Phase	The shortest metal-to-metal distance between any energized part(s), where the parts are different phases or different voltage magnitudes.
DEV-ET	Dominion Energy Virginia – Electric Transmission
ERAG	Eastern Interconnection Reliability Assessment Group
Extra-high Voltage	Transmission lines rated 765 kV, 500 kV, and 345 kV, and transformers with secondary voltages at or above 345 kV, are considered extra-high voltage (EHV) facilities and are referred to as EHV facilities in this document. These facilities are part of the B.E.S.
Engineering Service Provider	Refers to contractors and suppliers who provide D.E.'s engineering services.
Facility	A set of electrical equipment that operates as a single electric system element (e.g., a line, a generator, a shunt compensator, a transformer).
Facility Construction Agreement	Refers to the agreement that details the costs, construction schedule, and responsibilities of each party during the construction of the Interconnection Facilities.
Facility-Owned Interconnection Facilities	Refers to facilities or portions of facilities owned by the Facility Owner, from the Facility up to the Interconnection Point, which, in conjunction with the Facilities, are necessary to affect the transfer of power between the Facility and the Transmission System.
Facility Owner	Refers to the organization that is the actual owner of the facilities being connected into the Transmission System.

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Term/Abbreviations	Definition
Flicker	Refers to low-frequency voltage fluctuations observed through changes in intensity or color of illumination. Flicker is measured using an I.E.C. flicker meter.
Federal Energy Regulatory Commission (FERC)	A commission regulates the interstate transmission of electricity, natural gas, oil, hydropower projects, and natural gas terminals.
Generation	Refers to the electrical capacity and energy produced at the Facility.
Generator Connection	New or materially modified (affiliated or non-affiliated) connection for a generating facility, typically connected directly to the D.E. transmission system, to participate in a wholesale market.
Generator Capability Curve	Refers to the production of megawatts and megavars throughout its output range, which the generating unit manufacturer typically provides.
Good Utility Practice	Any of the practices, methods, and acts engaged in or approved by a significant portion of the electric utility industry during the relevant time period, or any of the practices, methods, and acts that, in the exercise of reasonable judgment in light of the facts known at the time the decision is made, could have been expected to accomplish the desired result at a reasonable cost consistent with good business practices, reliability, safety, and expedition.
Ground Grid	A system of ground rods and interconnected bare cables buried in the earth to limit touch and step voltages to acceptable levels and provide a common ground for electrical devices and metallic structures.
GSU	Generator Step-up Transformer
Harmonics	Refers to the content of a signal whose frequency is an integer multiple of the actual system frequency (e.g., the main frequency produced by the generators or, for the United States, 60 cycles per second).
High Voltage	Transmission lines typically rated 230 kV, 161 kV, and 138 kV, and transformers with secondary voltages above 100 kV but below 345 kV are considered High Voltage (H.V.) facilities and are referred to as H.V. facilities in this document. These facilities are part of the B.E.S.
IEEE	Institute of Electrical and Electronics Engineers
Interconnection Agreement (IA)	Refers to the agreement that documents the physical interconnection between the Facility Owners and D.E. and defines the continued responsibilities
Interconnection Facilities	Refers to the Change of Ownership at which point the Facility-Owned Interconnection Facilities are connected to the D.E. Interconnection Facilities.

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Term/Abbreviations	Definition
Maximum Continuous Operating Voltage (MCOV)	The maximum power frequency voltage can be applied to a metal oxide arrester continuously.
Metal Oxide Varistor (MOV)	A surge arrester utilizing valve elements fabricated from a metal oxide material.
NERC	North American Electric Reliability Corporation
POI	Point of Interconnection
Rigid Conductor	Wire or tubular bus that does not sag or move appreciably due to load, temperature, ice, or wind loading.
SERC	SERC Reliability Corporation
Surge Arrester	A protective device for limiting surge voltage on equipment by diverting surge current and returning the device to its original status. It is capable of repeating these functions as specified.

Appendix B: Station Insulation Levels

The following table gives our standard equipment and basic insulation levels.

Table 3 – Station Insulation Levels

System Voltage (kV)	Transformer BIL	Other BIL
500	1550	1800
	1425 *	
	1300 *	
230	750	900
	650 *	
138	550	650
	450 *	
115	450	550
	350 *	
69	350	350
46	250	250
34.5	200	200 and 150
23	150	150
13.2	95	110
12.5	95	110
11.5	95	110
6.0	95	95
4.16	75	75
2.4	60	60

Notes:

1. * Insulation levels are old standards, but many of these transformers are on the system.
2. "Other" equipment includes switches, insulators, breakers, etc.

Appendix C: Substation Shielding

Figure 1 – Protection of an Exposed Object by a Single Lightning Mast

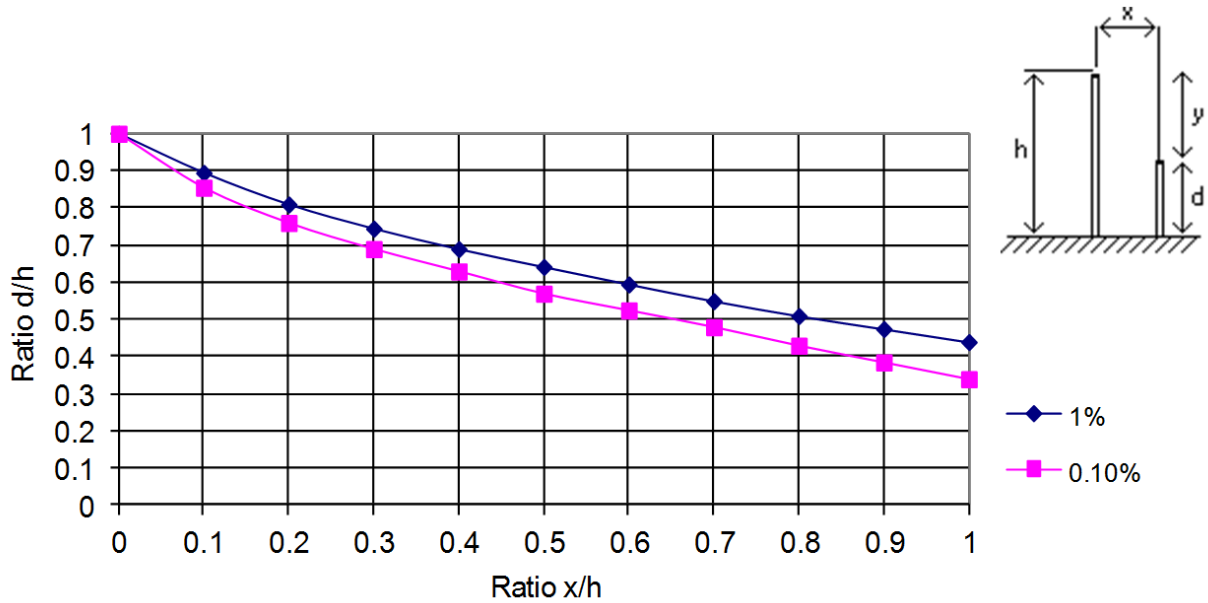


Figure 2 – Protection of Ring of Exposed Objects by a Single Lightning Mast

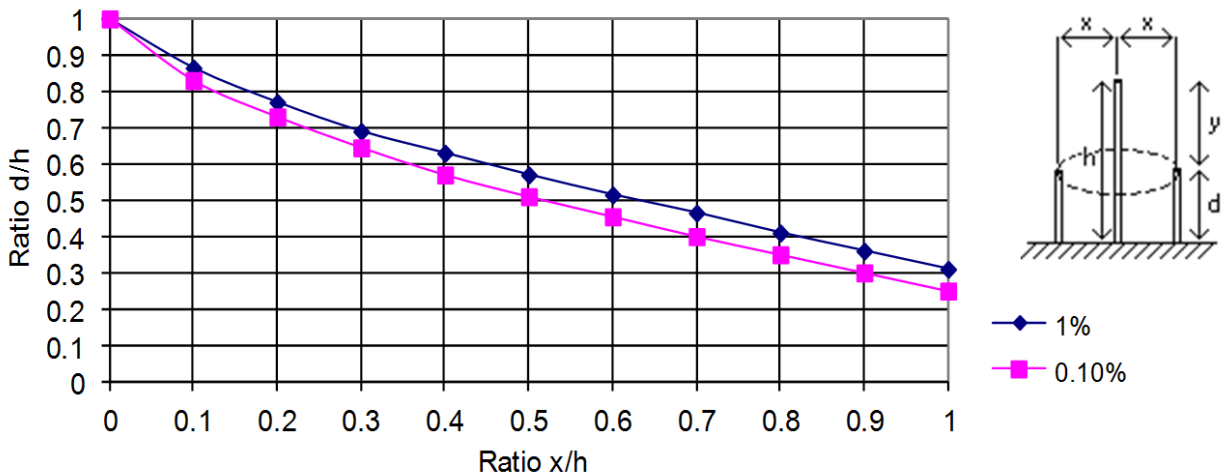


Figure 3 – Protection of an Exposed Object by Two Lightning Masts

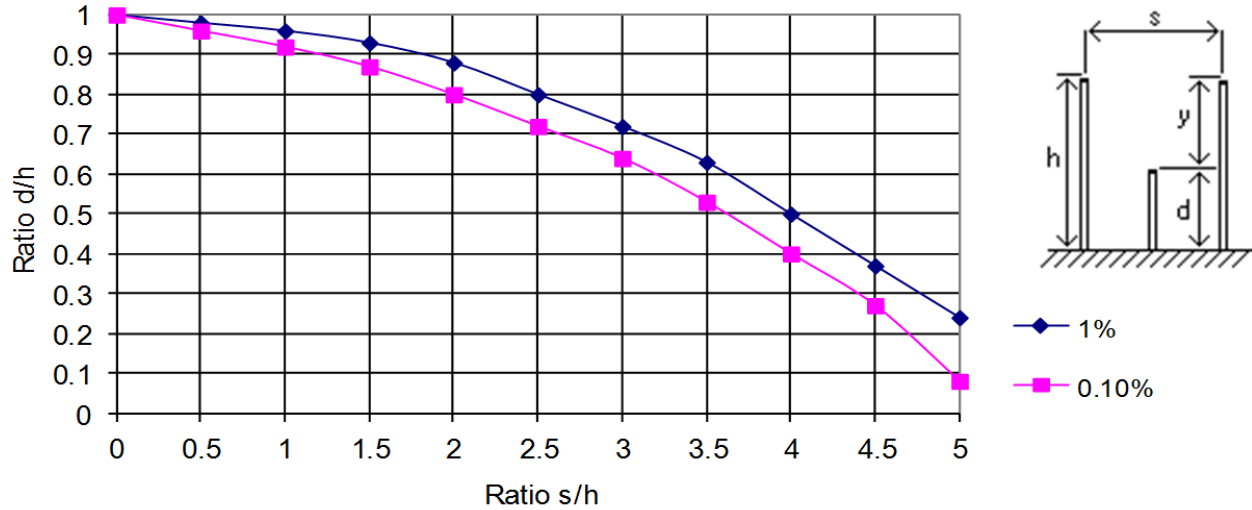


Figure 4 – Protection of Exposed Horizontal Conductors by Single Wire

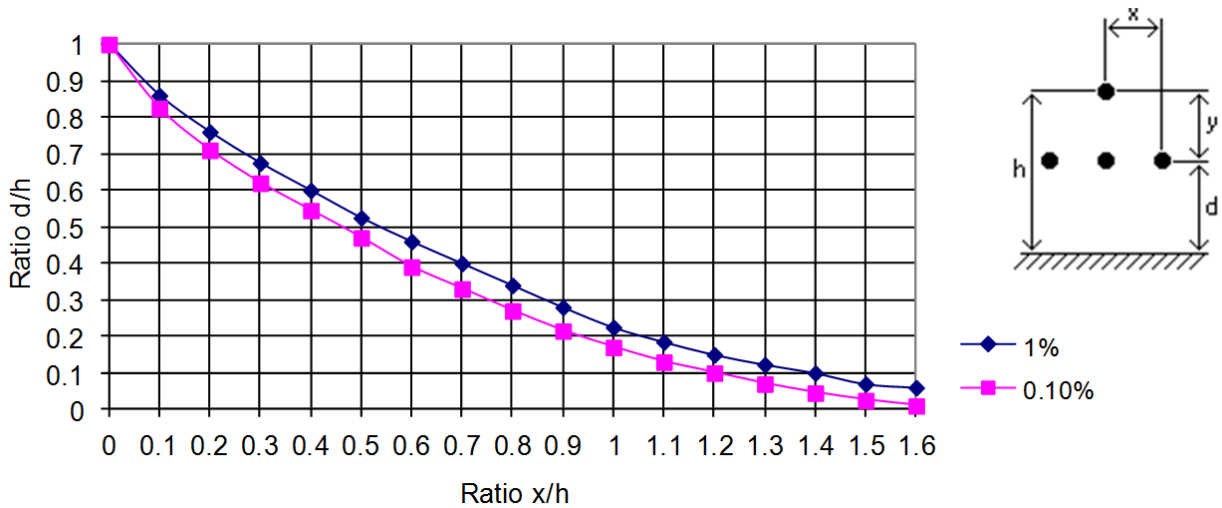
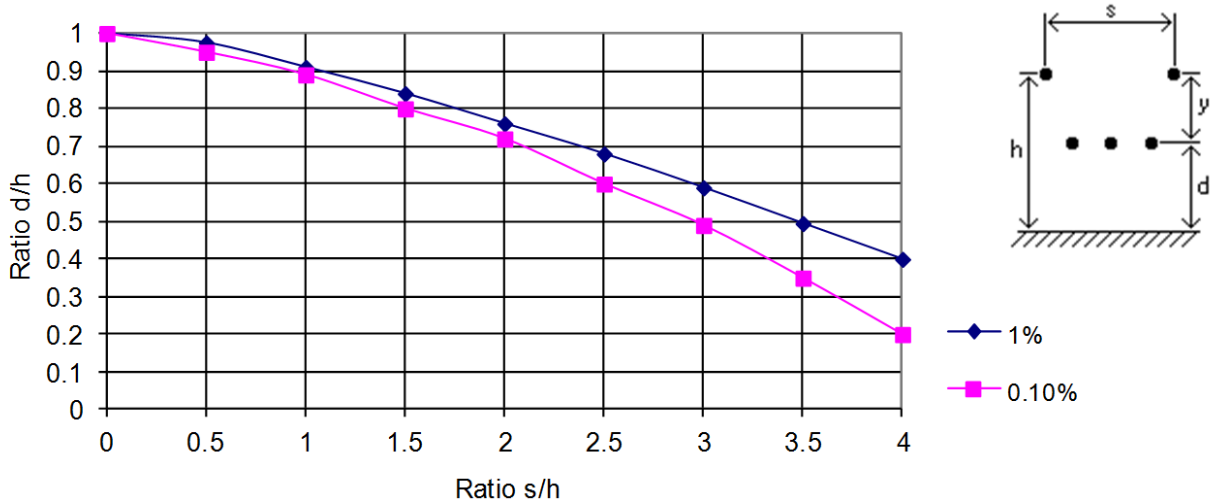


Figure 5 – Protection of Exposed Horizontal Conductors by Two Shield Wires



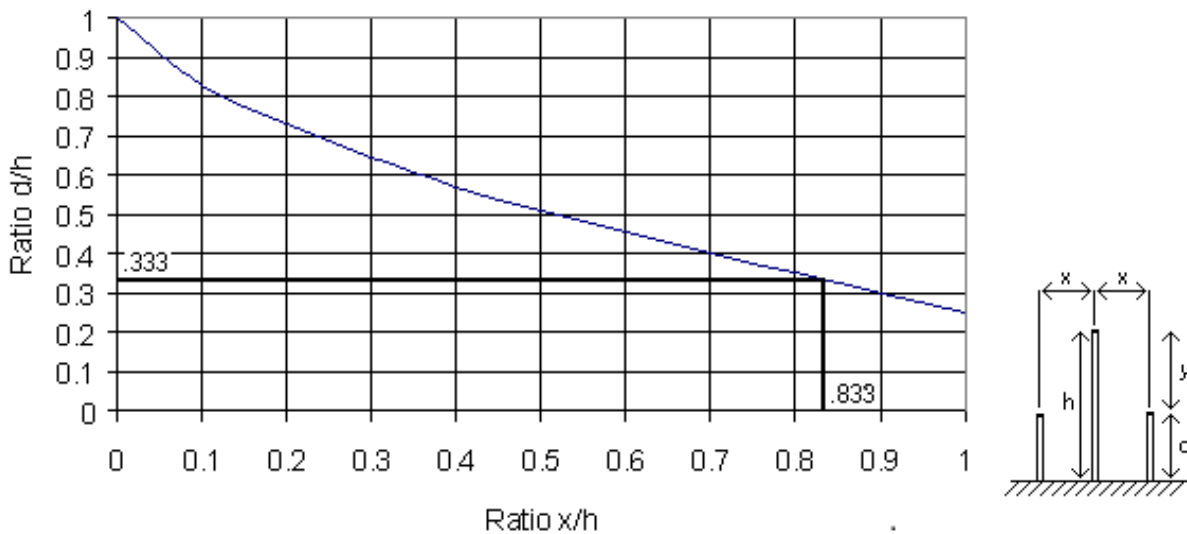
For an example of how to use these curves, from Figure 2 (using 0.1% exposure), it can be seen that a mast at the height of 60 feet can protect all objects up to 20 feet high within a radius of up to 50 feet.


If the objects in that same circle were at a height of 25 feet (instead of 20 feet), a mast of approximately 68

$$h = 60, \quad d = 20, \quad \frac{d}{h} = \frac{20}{60} = .333 \xrightarrow{\text{therefore}} \frac{x}{h} = .833 \quad x = \frac{x}{h}(h) = .833(60) \cong 50 \text{ feet}$$

feet would be required to provide the same failure rate of 0.1%. (If d=25 and x=50, then h can be determined through a trial and error method.)

Figure 6 – Example 1



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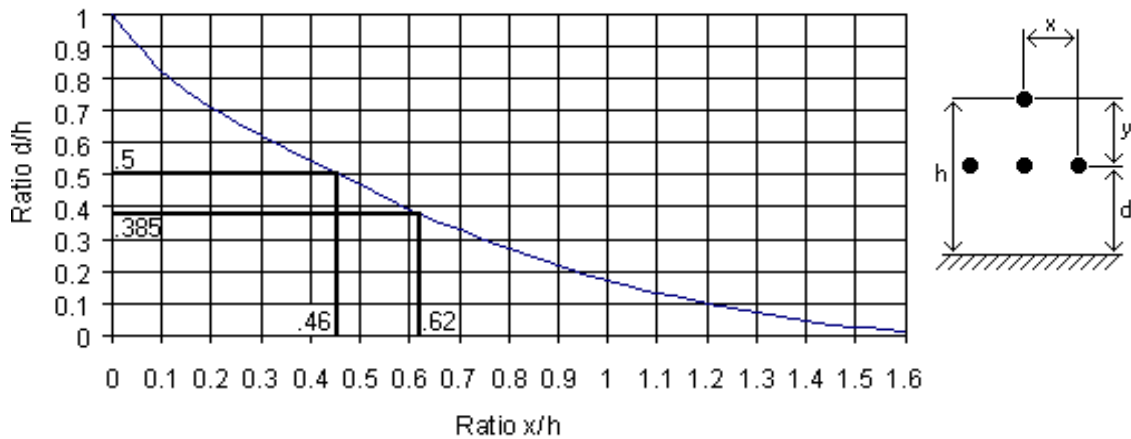
A similar example with shielding wires can be found using Figure 4. A static wire at a height of 65 feet can protect a 25-foot tall object at a horizontal distance of up to 40 feet. (See Figure 7 below.)

$$h = 65, \quad d = 25, \quad \frac{d}{h} = \frac{25}{65} \cong .385 \xrightarrow{\text{therefore}} \frac{x}{h} = .62 \quad x = \frac{x}{h}(h) = .62(65) \cong 40.3 \text{ feet}$$

For a wire at a height of only 50 feet to protect the same object (with the same failure rate), the horizontal distance between the two must be no greater than 23 feet.

$$h = 50, \quad d = 25, \quad \frac{d}{h} = \frac{25}{50} = .5 \xrightarrow{\text{therefore}} \frac{x}{h} = .46 \quad x = \frac{x}{h}(h) = .46(50) \cong 23 \text{ feet}$$

Figure 7 – Example 2



The most used method of protection against lightning strokes is that of the single shield wire. This information is displayed graphically in Figures 4 and 5 below. These graphs can be used to find the relationship between the height of an object and the allowable distance between that object and the shield wire protecting it. For example, Figure 4 shows that a shield wire at 65 feet can protect an object 20 feet high at a distance of approximately 47 feet.

Figure 8 – Protection Provided by Shield Wires at Different Heights

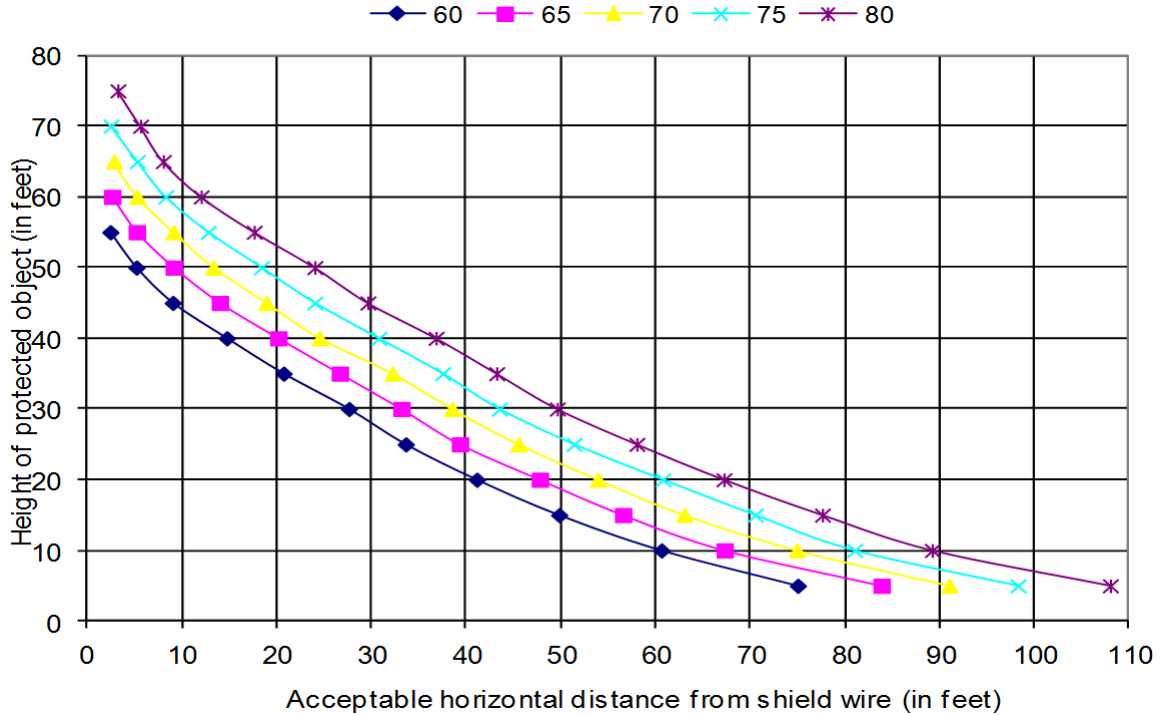
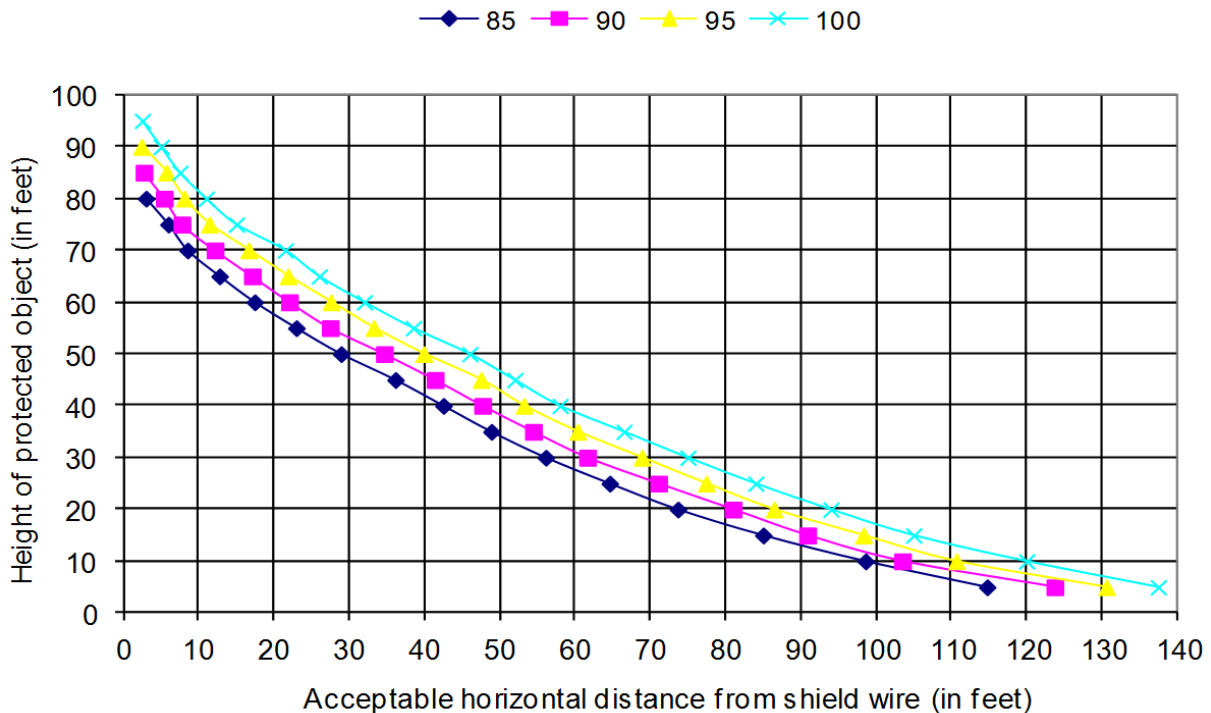


Figure 9 – Protection Provided by Shield Wires at Different Heights



The method of empirical curves for protection against lightning strokes has been used and modified for decades, yet it continues to be an effective method of protection, and it remains highly accepted in the industry. Other more complex lightning protection methods have been developed, but none have been proven to be any more effective than the simple shielding of equipment, provided by static wires or lightning masts.

Appendix D: Electrical Clearances Figures and Tables

Table 4 – Phase to Ground Clearances

PHASE TO GROUND CLEARANCES @ Elevations Below 3300 feet						
P-P kV	BIL	(a) P-G Rigid Parts (Min) ⁸	(b) Vertical to Ungrounded (Min) ⁹	(c) Vertical to Live Parts (Min) ¹⁰	(d) Horizontal to Ungrounded (Min) ¹¹	(e) Horizontal to Live Parts (Min) ¹²
7.5	95	0'-4"	8'-6"	8'-10"	3'-0"	3'-4"
15	110	0'-6"	8'-6"	9'-0"	3'-0"	3'-6"
23	150	0'-9"	8'-6"	9'-3"	3'-0"	3'-9"
34	200	1'-0"	8'-6"	9'-6"	3'-0"	4'-0"
46	250	1'-4"	8'-6"	9'-10"	3'-0"	4'-4"
69	350	1'-11"	8'-6"	10'-5"	3'-0"	4'-11"
115	550	3'-1"	8'-6"	11'-7"	3'-0"	6'-1"
138	550	3'-1"	8'-6"	11'-7"	3'-0"	6'-1"
138	650	3'-8"	8'-6"	12'-2"	3'-0"	6'-8"
230	900	5'-3"	8'-6"	13'-9"	3'-0"	8'-3"
345	1050	7'-0"	8'-6"	15'-6"	3'-0"	10'-0"
345	1300	8'-8"	8'-6"	17'-2"	3'-0"	11'-8"
500	1550	10'-4"	8'-6"	18'-10"	3'-0"	13'-4"
500	1800	12'-0"	8'-6"	20'-6"	3'-0"	15'-0"

Minimum physical clearance is 1'-0", regardless of voltage class.

8 NESC Table 124-1, Column 4 (Part A < 345 kV > Part B)

9 NESC Table 124-1, Column 2 minus Column 4 (124-1 Part A < 345 kV > Part B)

10 NESC Table 124-1, Column 2 (Part A < 345 kV > Part B)

11 Column (e) - Column (a)

12 NESC Table 124-1, Column 3

Table 5 – Phase to Phase Clearances @ Switch

PHASE TO PHASE CLEARANCES @ SWITCH (CL to CL except for Column (f))							
P-P kV	BIL	(a) Vertical Break Disc (Typ)	(b) Vertical Break Disc (Min) ¹³	(c) Horizontal Break Disc (Typ)	(d) Horizontal Break Disc (Min) ¹⁵	(e) Air Interr. Switch (Min) ¹⁴	(f) P-P Metal to Metal (Min) ¹⁵
7.5	95		1'-6"		2'-6"	3'-0"	0'-8"
15	110	3'-0"/5'-0"	2'-0"	5'-0"	2'-6"	3'-0"	0'-9"
23	150	3'-0"/5'-0"	2'-6"	5'-0"	3'-0"	4'-0"	1'-0"
34	200	3'-0"/5'-0"	3'-0"	5'-0"	4'-0"	5'-0"	1'-4"
46	250		4'-0"		5'-0"	6'-0"	1'-9"
69	350		5'-0"		6'-0"	7'-0"	2'-5"
115	550	10'-0"	6'-2"	10'-0"	8'-9"	10'-0"	3'-9"
138	550	10'-0"	6'-2"	10'-0"	8'-9"	10'-0"	3'-9"
138	650	10'-0"	6'-11"	10'-0"	9'-6"	12'-0"	4'-6"
230	900	13'-0"	8'-6"	13'-0"	12'-4"	16'-0"	6'-2"
345	1050	18'-0"	9'-6"	18'-0"	16'-6"	18'-0"	7'-2"
345	1300	20'-0"	11'-5"	20'-0"	18'-5"	20'-0"	8'-11"
500	1550	25'-0"	13'-4"	25'-0"	21'-6"	25'-0"	10'-10"
500	1800	27'-0"	15'-0"	27'-0"	23'-2"	27'-0"	12'-6"

Minimum physical clearance is 1'-0", regardless of voltage class.

13 Minimum P-P clearance for switches rated 7.5 through 69 kV per ANSI C37.32 Table #5. For switches rated 115 through 500 kV the clearance was determined by adding the horizontal dimension of the switch measured from centerline to edge of hot part (HP) with the switch in the "open" position + column (f) + a 12" safety factor.

14 Per ANSI C37.32 Table #5

15 Per Table 3 in IEEE 1427 "Electrical Clearance in Air Insulated Substations"

Table 6 – Phase to Phase Clearances @ Bus

PHASE TO PHASE CLEARANCES @ BUS (CL to CL except for Column (f))							
P-P kV	BIL	(a) Bus (Typ)	(b) AL ¹⁶ Angle Bus 3 1/4 x 3 1/4 x 1/4 (Min)	(c) AL Bus ¹⁸ Tubular 3 1/2 IPS (Min)	(d) AL Bus ¹⁸ Tubular 5 IPS (Min)	(e) AL Bus (EHV) ¹⁸¹ Tubular 5 and 6 IPS (Min)	(f) P-P Metal ¹⁷ to Metal (Min)
7.5	95		1'-6"	3'-2"			0'-8"
15	110	2'-6"	1'-7"	3'-3"			0'-9"
23	150	2'-6"	1'-10"	3'-6"			1'-0"
34	200	2'-6"	2'-2"	3'-10"			1'-4"
46	250			4'-3"			1'-9"
69	350			4'-11"			2'-5"
115	550	10'-0"		6'-9"	7'-4"		3'-9"
138	550	10'-0"		6'-9"	7'-4"		3'-9"
138	650	10'-0"		7'-6"	8'-1"		4'-6"
230	900	13'-0"		9'-2"	9'-9"		6'-2"
345	1050	18'-0"				10'-8"	7'-2"
345	1300	20'-0"				12'-5"	8'-11"
500	1550	25'-0"				14'-4"	10'-10"
500	1800	27'-0"				16'-0"	12'-6"

Minimum physical clearance is 1'-0", regardless of voltage class.

16 Centerline to centerline bus clearance was determined by adding the maximum width of bus part (BP) for each kV + column (f) + Safety Factor (SF). Bus Part maximum dimension for various bus configurations are as follows: 3 1/4 " AL Angle Bus - BP = 3.25", 3 1/2 " AL IPS Tubular Bus - BP = 24", 5" AL IPS Tubular Non-EHV Bus - BP = 31" (SN 42155968), 5" AL IPS Tubular EHV Bus - BP = 30" (SN 42014215), and 6" AL IPS Tubular EHV Bus - BP=30" (42207982). Safety Factor for buses at 69 kv and below is 3" (SF) at each bus part, or 6" total CL-CL measurement. Safety factor for 115 kV and above is 6" SF at each bus part, or 12" total CL-CL measurement.

17 Per Table 3 in IEEE 1427 Electrical Clearance in Air Insulated Substations

Table 7 – Clearance at Arrester Termination

STATION CLASS ARRESTERS				
Arrester Duty kV	Arrester MCOV kV	Discharge Voltage 8/20 μ s Crest 20kA Surge ¹⁸ kV	(a) P-G Metal to Metal (Min) ¹⁹	(b) P-P Metal to Metal (Min) ²⁰
3	2.55	8.4	0'-4"	0'-7"
6	5.1	16.8	0'-5"	0'-9"
12	10.2	34	0'-5"	0'-9"
18	15.3	51	0'-7"	0'-11"
30	24.4	81	0'-9"	1'-2"
39	31.5	106	1'-0"	1'-5"
48	39	126	1'-2"	1'-4"
60	48	150	1'-4"	1'-8"
72	57	188	1'-8"	2'-2"
90	74	239	2'-0"	2'-7"
108	88	274	2'-7"	2'-11"
120	98	304	2'-7"	3'-1"
180	144	461	4'-2"	6'-6"
264	212	657	5'-8"	6'-5"
396	318	984	8'-1"	9'-3"

Minimum physical clearance is 1'-0", regardless of voltage class.

18 The largest value presently purchased for the listed voltage class.

19 In accordance with the compared longest P-G distance, provided by the manufacturer or listed in IEEE Std. C62.22-2009.

20 In accordance with the compared longest P-P distance, provided by the manufacturer or listed in IEEE Std. C62.22-2009.

Table 8 – Electrical Clearances at Substation Fence

Electrical Clearances at Substation Fence @ Elevations Below 3300 feet							
P-P kV	(A) P-G Public Safety²¹	P-G Minimum Approach²² (Live Parts)	(B) P-G Live Parts²³ (Substation)	(C) P-G Live Parts²⁴ (Overhead Line)	(D) Vertical Clearance Overhead Line to Outside the Substation		
					H = 12'	H = 15'	H = 20'
15	10'-2"	2'-2"	7'-2"	8'-0"	20'-0"	23'-0"	28'-0"
23	10'-4"	2'-5"	7'-5"	8'-0"	20'-0"	23'-0"	28'-0"
34	10'-8"	2'-5"	7'-5"	8'-0"	20'-0"	23'-0"	28'-0"
46	10'-11"	2'-7"	7'-7"	8'-3"	20'-3"	23'-3"	28'-3"
69	11'-8"	2'-11"	7'-11"	8'-9"	20'-9"	23'-9"	28'-9"
115	13'-0"	3'-1"	8'-1"	9'-8"	21'-8"	24'-8"	29'-8"
138	13'-9"	3'-7"	8'-8"	10'-2"	22'-2"	25'-2"	30'-2"
230	15'-5"	5'-3"	10'-3"	12'-0"	24'-0"	27'-0"	32'-0"
345	18'-4"	8'-5"	13'-5"	14'-4"	26'-4"	29'-4"	34'-4"
500	19'-10"	11'-1"	16'-1"	17'-5"	29'-5"	32'-5"	37'-5"

21 NESC - Rule 110: Safety clearance to electric supply station fences.

22 NESC - Rule 441: AC live work minimum approach distance (MAD).

23 MAD + 5', design value for the safety zone to live parts inside the substation.

24 NESC - Rule 232: Vertical clearance for overhead lines to signs, chimneys, antennas, billboards, etc.

Figure 10 – Personnel and Wavetrapp Clearances

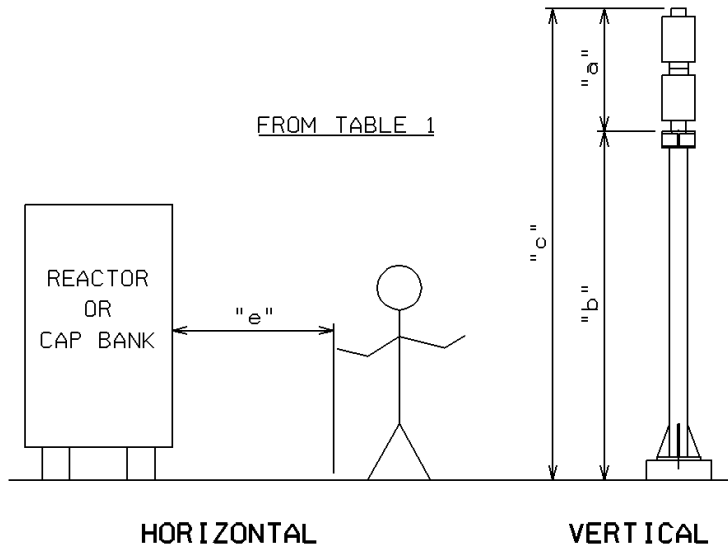


Figure 11 – Wavetrapp Clearances

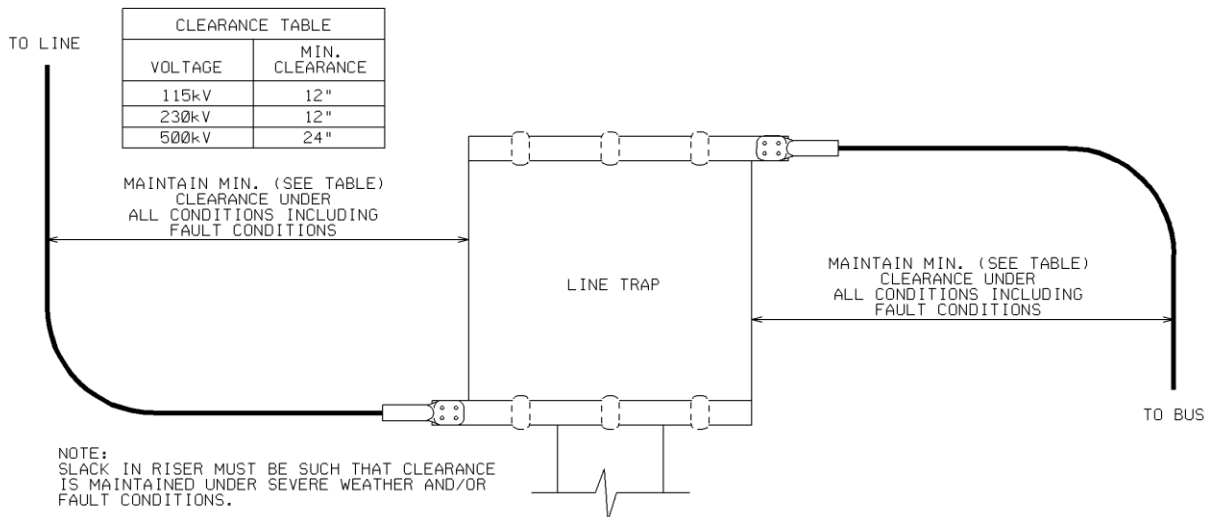
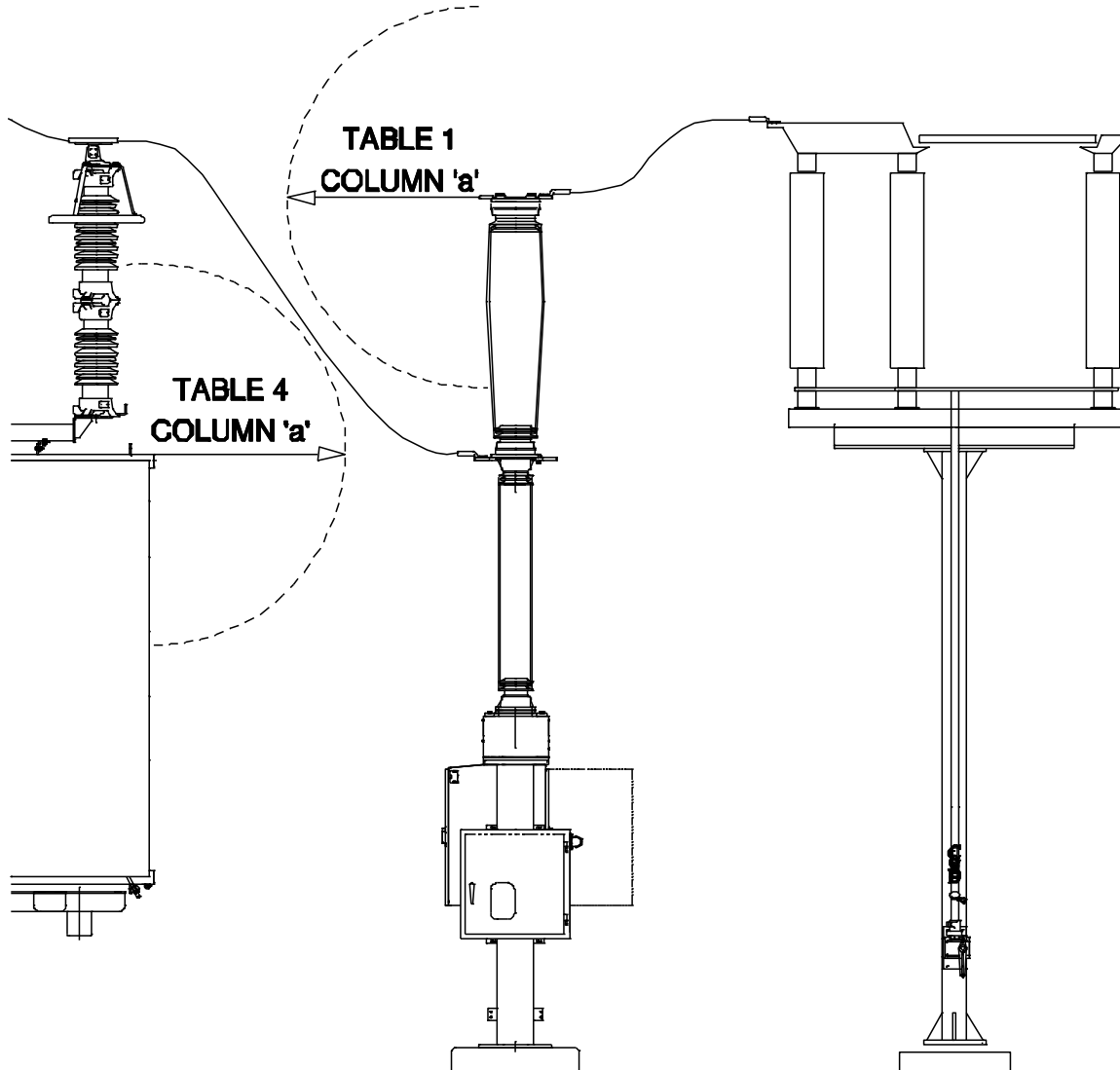


Figure 12 – Circuit Switcher Clearances




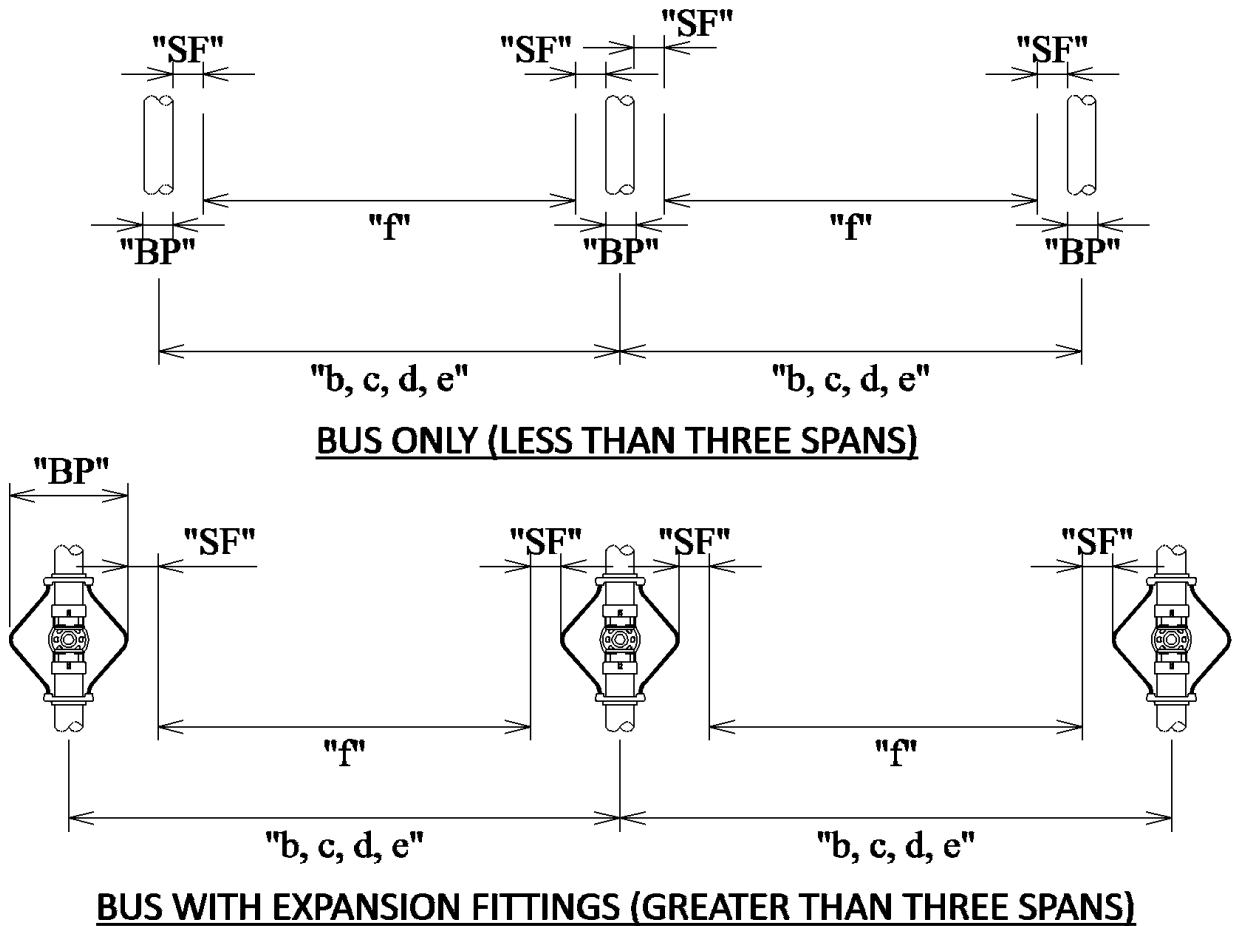
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Figure 13 – Bus Clearance (Reference Table 6)




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Figure 14 – Vertical Break Switch and Center Break Switch Clearances (Reference Table 5)

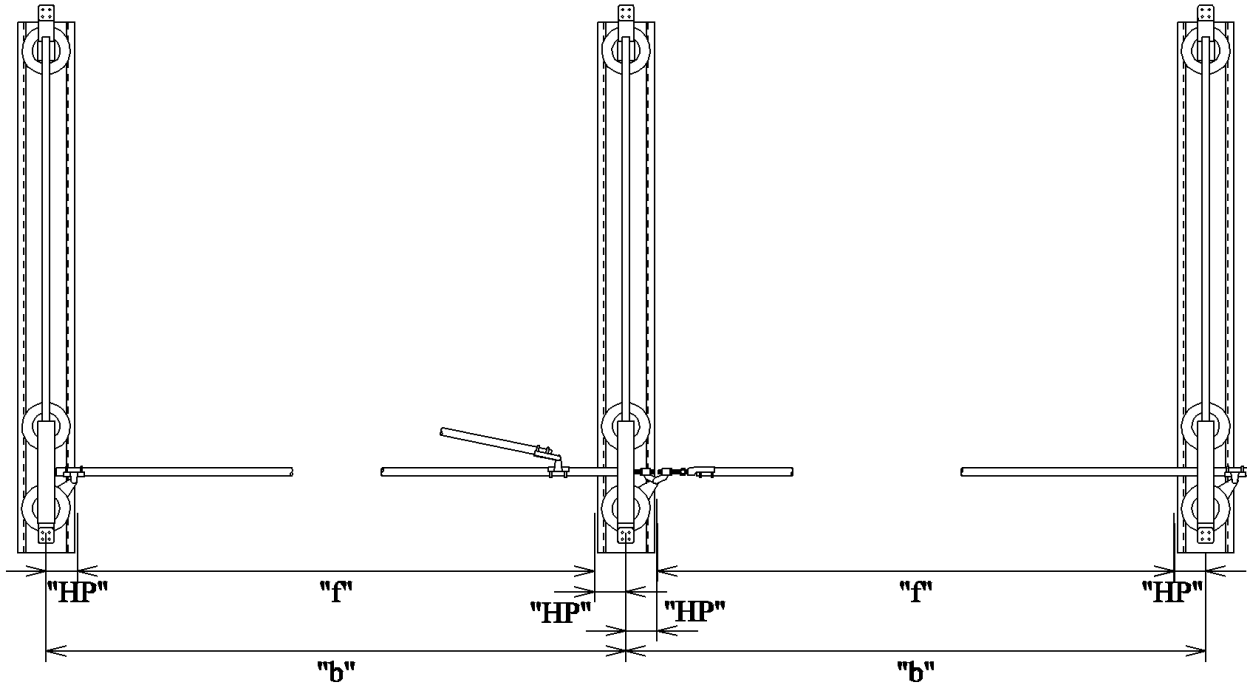
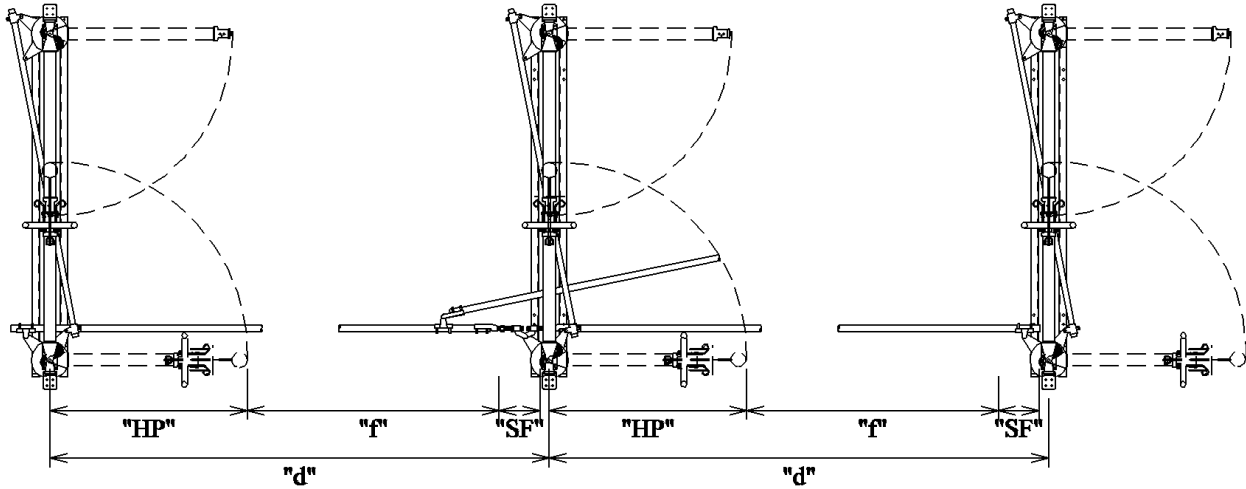


Figure 15 – Center Break Switch Clearance (Reference Table 5)




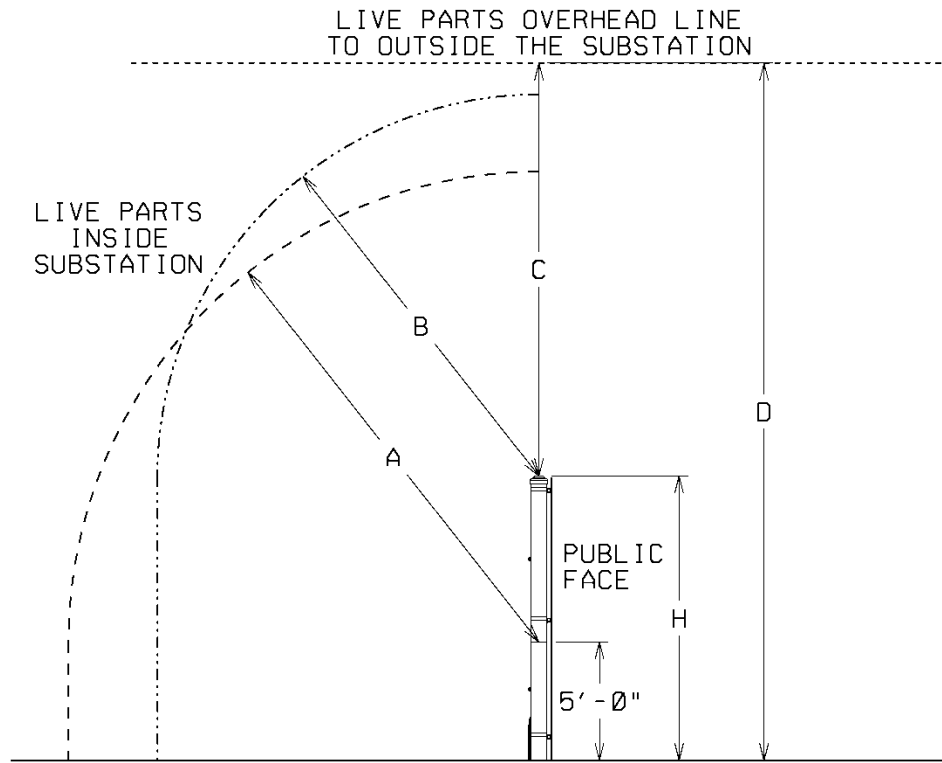
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Figure 16 – Safety Zones at Substation Fence




Appendix E: Arresters

Table 9 – DEV Approved Substation Arrester Ratings

Line-Line Voltage (kV)		Arrester Class*	Duty Cycle Rating (kV)	Approximate MCOV (kV)
Grounded	Ungrounded			
500	-	S	396	318
230	-	S	180	144
138	-	S	108	88
115	-	S	90	74
69	46	S	60	48
-	34.5	S	48	39
46	-	S	39	31.5
34.5	-	S	30	24.4
		DI**	30	24.4
23	13.2	S	18	15.3
		DI**	18	15.3
13.2	-	S	12	10.2
		DI**	12	10.2
12.5	-	S	10	8.4
		DI**	10	8.4
6.0	-	S	6	5.1
4.16	2.4	S	3	2.55
		I**	3	2.55

* Station Class – S, Intermediate Class – I, Distribution Riser Pole - DI

** Used on circuit get-a-ways (overhead and underground) and the terminals of intra-substation cable runs.

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Revision History

Revision Date	Revision #	Description	Revised By	Effective Date
06/21/2022	0	See Details for Revision 1.0 below	Theresa Robinson	06/21/2022
06/22/2022	1	See Details for Revision 2.0 below	Theresa Robinson	06/22/2022
07/21/2022	2	See Details for Revision 3.0 below	Theresa Robinson	07/21/2022
10/21/2022	3	See Details for Revision 4.0 below	Theresa Robinson	10/21/2022
10/31/2022	4	See Details for Revision 5.0 below	Theresa Robinson	10/31/2022
11/28/2022	5	See Details for Revision 6.0 below	Theresa Robinson	-
11/29/2022	6	See Details for Revision 7.0 below	Theresa Robinson	-
12/12/2022	7	See Details for Revision 8.0 below	Theresa Robinson	12/12/2022
07/06/2023	8	See Details for Revision 9.0 below	Theresa Robinson	07/06/2023
08/21/2023	9	See Details for Revision 10.0 below	Theresa Robinson	08/21/2023
12/20/2023	10	See Details for Revision 11.0 below	Theresa Robinson	12/20/2023
06/11/2024	11	See Details for Revision 1.0 below	ET Planning	09/01/2024

Details for Version 0.0


- Contributors include Theresa Robinson, Justin Harsh, Gustavo Leal, Patrick J Loepker, Chase Chambers, William "Chase" Bland, Joel Trivitte, and Tania Jones
- Initial Draft.

Details for Revision 1.0

- Contributors include Keith Graham
- Cover Page – Updated Document ID and Title

Details for Revision 2.0

- Contributors include Keith Graham
- Cover Page – Updated Document ID and Title to reflect the title used in the kick-off Email.

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Details for Revision 3.0

- Contributors include Keith Graham, Justin Harsh, Wilson Velazquez, Philip VanSant, David Logan, Suinna Duncan, Theresa Robinson, and Gustavo Leal
- Cover Page – Updated date and added
- Table of Figures – Added new figures
- Table of Tables – Added new section
- Through document – Replaced “should” with “shall”; corrected grammatical and format issues
- Section 1.1 – Added the IC “shall use the provided DEV-ET standard designs”
- Section 2.1 – Added a new section to address Design Drawing Requirements
- Section 2.4 – Added reference to the Substation Civil-Site Grading Specification and related standards documentation provided by DEV-ET.
- Section 2.2 – Reiterated IC “shall use DEV-ET standard designs”
- Appendix G – Added Power Engineers to the list of approved contractors and added Civil-Site approved contractors

Details for Revision 4.0

- Contributors include Nickolaus N Dillon
- Cover Page – Updated date and added the final edits to complete document
- Appendix F – Added the suppliers of 115 kV transformers

Details for Revision 5.0

- Contributors include Theresa Robinson
- Cover Page – Changed date before creating PDF
- All pages – Removed line numbers from document

Details for Revision 6.0


- Contributors include Phillip VanSant
- Page 14 – Refined equation with Word tool and added Equation label
- Page 15 – Added Table 1 and label
- All Appendices – Modified all tables and table references
- Table of Tables – Updated table sequence
- Signature Page – Removed until further notice

Details for Revision 7.0

- Contributors include Phillip VanSant
- Section 2.2 – 2.15 Removed content and referenced Facility Interconnection Requirements, Standard/Requirement # FAC-001 R1 and R3, section, 4.1.3 – 4.1.16.

Details for Revision 8.0

- Contributors include Justin Bell
- Section 1.2 – Replaced 2021 version of FIR with 2023 version
- Section 1.5 – Replaced 2021 version of FIR with 2023 version

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- Appendix G – Removed individual names from all contractor lists in lieu of establishing one Dominion Energy point of contact that provides detail information upon signing an IA.

Details for Revision 9.0

- Contributors include Keith Graham and Sarah Craig
- Section 1.4.1 – Added the following text:
 - Quality Control walkthrough and review of provided list of point of contacts for each approved contractor, standard drawings and specifications
- Section 1.4.2 – Added the following verbiage:
 - Providing the Generation Interconnect Substation Specifications Portfolio outlining list of point of contacts for each approved contractor, standard drawings, and specifications at the time of IA
 - Quality Control walkthrough and review of provided list of point of contacts for each approved contractor, standard drawings, and specifications
- Section 4 – Added the following verbiage: A DEV-ET representative will provide a list of point of contact(s) for each approved contractor along with a portfolio of standard drawings and specifications at the time of the IA.

Details for Revision 10.0

- Contributors include Keith Graham and Sarah Craig
- Appendix G – DEV-ET Approved List of Contractors (Table 11) based on Rev#25.30.23 doc.

Details for Revision 11.0

- Revision contributors include: Theresa Robinson, Pamela Torrez, and Quanta-Technology Services.
- Replaced cover page with title page consistent with other attachments.
- Removed signature page and consolidated on FIR cover page.
- Removed Appendix F – DEV Approved Materials and Equipment Suppliers to be maintained outside of this document.
- Removed Appendix G – DEV-ET Approved List of Contractors to be maintained outside of this document.
- Updated references.