6) RELAY & PROTECTION REQUIREMENTS

General Need for System Protection in the Presence of Parallel Generation

The components of the transmission system are subject to a variety of natural and man-made hazards; among these are lightning, wind, wildlife, and vandalism. Damaged or short-circuited equipment should be switched out of service as soon as possible to minimize safety hazards, to avoid minimize equipment damage, and to maintain system stability. Generation operated in parallel with the transmission system provides an additional source of energy that must also be disconnected in case of an emergency. It is essential that a suitable system of protection be used to minimize these hazards and to prevent the reduction of quality of service to other transmission customers.

General Effects of Interconnected Generation on System Protection Requirements

The addition of GIC's generation shall not introduce a hazard or adversely affect the quality of service to ComEd customers. Protective equipment must be added to standard ComEd facilities to provide adequate protection of the transmission system. ComEd's protection system designs and requirements are based on years of system operating experience and analysis of events both internal and external to ComEd as well as requirements from the various regulatory organizations. Requirements for additional protective equipment due to interconnected operation will vary depending on the size of the GIC's generation and on the nature of the ComEd local system.

Interconnection Overview

Designs intended for generation interconnections on the ComEd distribution system can be found in the Exelon Energy Delivery's Interconnection Guideline for generators greater than 2MVA and less than or equal to 20MVA.

Protective relaying designs for new interconnections are required to match the most current requirements and standards for protection used on the rest of the ComEd system at the voltage level of the interconnection. The 345 kV and above transmission lines that make up ComEd's transmission system are vital to maintaining system stability, regional stability, and crucial to ensuring the reliable power flow through the service territory. Thus, at ComEd, requirements for equipment connected to or operating at 345kV and above are subject to the most stringent requirements while equipment connected to operating at 138kV or below are subject to somewhat lesser requirements. Although 138kV plays a lesser role in maintaining system stability than 345kV, a majority of ComEd's customers are connected at the 138kV level so protection systems still require a high level of reliability. Some 138kV areas within ComEd's system are subject to nearly the same requirements as 345kV and above due to very high load densities or other reasons. Requirements for 345kV and up and 138kV or below interconnections are described herein for the most commonly encountered configurations. These protection schemes and requirements are guidelines; final requirements are established during the engineering process.

Detailed protection requirements for adding generation to a ComEd transmission line with existing generation must be made on a case-by-case basis. Adding generation to the transmission line may require additional protection at other existing installations.

As a rule, generation that is less than 20 MVA may be connected to the distribution system, generation from 20 to 300 MVA is usually connected to the 138 kV, and generation in excess of 300 MVA is connected to the 345 kV.

6.1) Protection Requirements of 345kV and above Interconnections:

When connecting to an existing station, the interconnection configuration will follow the configuration at that station (ring bus, straight bus, or breaker and a half (generation hub)) with new breaker/breakers or bus position as required. In some cases, system conditions may require that a generator be connected to an existing line by splitting the line. Typically, a 3 breaker ring configuration is used when splitting a 345kV line.

Three terminal lines are not allowed by ComEd or PJM at 345kV and above voltage (EHV) level.

For some GIC Plant installations, the most appropriate interconnection point to the ComEd system would be directly into the bus at an existing ComEd substation. If the ComEd substation had a ring bus configuration, the GIC interconnection point would have to maintain the integrity of the substation design. This would require the addition of at least one new circuit breaker at the substation. The effect on the substation protection would depend on the site specifics. Protection also would have to be installed on the line to the generator.

Redundancy of protection is required per ComEd standards, NERC Planning Standards, PJM Standards, and/or RFC Standards which specify that no single protection system component failure can cause a fault to remain on the system. Protective relaying systems on the 345 kV and above system shall include two complete schemes, each including primary and back-up protection. Independent current transformers, potential transformer secondaries, and DC source (separate batteries are required at 345kV) will feed each system. The relaying schemes will be complementary in terms of their principle of measurement rather than redundant and be of varying construction to minimize the chance of a common mode failure. The standard medium of system protection communication on the 345kV system is fiber optic and/or digital microwave based equipment. The following one line drawing and minimum protection scheme design requirements drawings illustrate these concepts for 345kV and above interconnections:

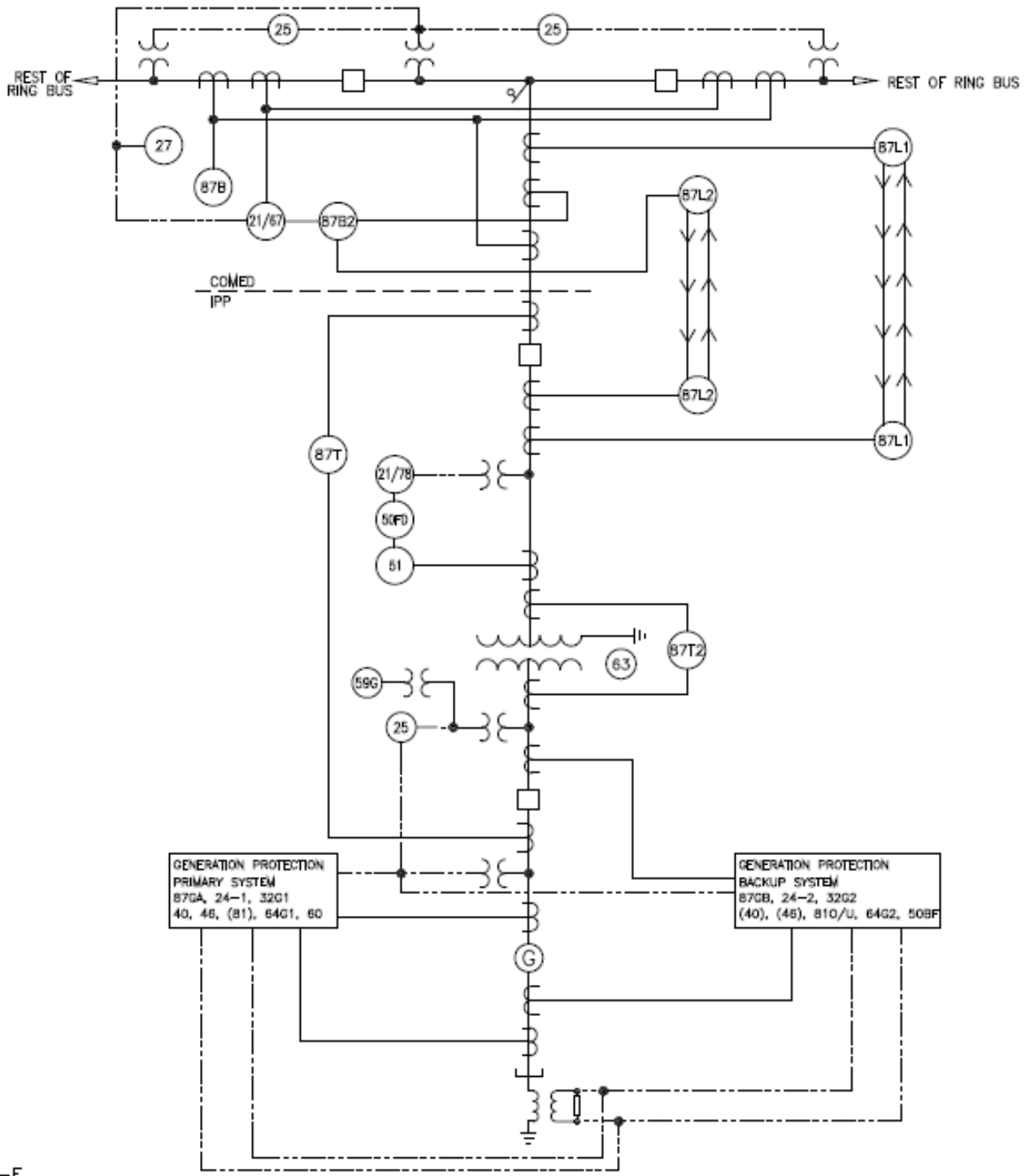
PRELIMINARY RELAY REQUIREMENTS
CUSTOMER OWNED GENERATION PARALLELED WITH COMED

PLAN F

A. A TOTAL GENERATION GREATER THAN OR EQUAL TO 10MVA

------AND------

B. CONNECTED TO 345KV OR 765KV



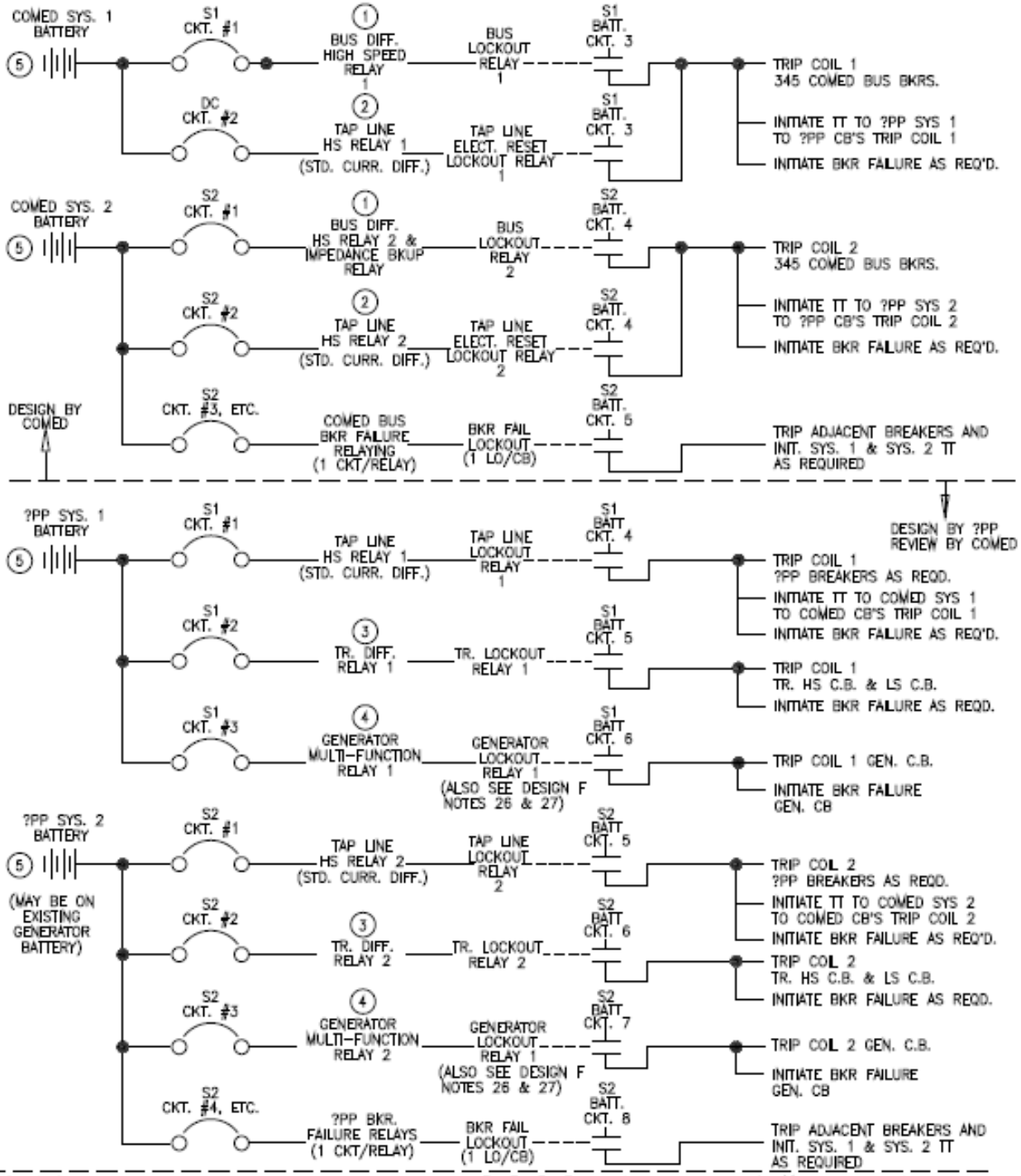
KD-F

THIS DIAGRAM IS PRESENTED AS A TYPICAL PLAN TO ILLUSTRATE THE LOCATIONS OF REQUIRED RELAY FUNCTIONS.

GENERAL MINIMUM PROTECTION SCHEME DESIGN REQUIREMENTS FOR

DESIGN F

2 SEGREGATED HIGH SPEED SCHEMS MUST COVER A FAULT AT ANY LOCATION FOR EHV ?PP'S
SENSING MUST BE SEGREGATED AS WELL FOR TRIPPING



GENERAL NOTES:
- BATTERY/CHARGER ALARM MONITORING IS REQUIRED.
- MICROPROCESSOR RELAY FAILURE ALARM MONITORING IS REQUIRED.

DESIGN F

(1)(2)(3)(4) RELAYS TO BE DIFFERENT MODELS, PREFERABLY BY DIFFERENT MANUFACTURERS.

(5) SEGREGATION OF SYSTEMS BETWEEN TRIP COIL 1 AND TRIP COIL 2 IS RECOMMENDED IF AVAILABLE.

6.2) Protection Requirements of 138kV and below Interconnections:

When connecting to an existing station, the interconnection configuration will follow the configuration at that station (straight bus or ring bus) with a new breaker or bus position. In some cases, system conditions may require that a generator be connected to an existing line by splitting the line. Typically, a three breaker T configuration is used when splitting a 138kV line. Large generators connected to the 69 kV or 138 kV transmission systems may require the use of a ring bus.

Adding a fourth source to a three-terminal line or a third source to a two-terminal line limits the effectiveness of protective relay schemes and reduces system reliability. This type of configuration can limit the amount of power that can be supplied by the weakest source to the line, cause compromises and degradation of line protection, and limit transmission availability to the GIC. Thus, ComEd typically does not allow three terminal line configurations for generator interconnects and the line will be broken into two lines. A three breaker straight or ring bus substation will be installed if connection to an existing ComEd substation is not feasible. New line protection packages are needed for the two new lines created by splitting the existing ComEd line and for the line to the generator.

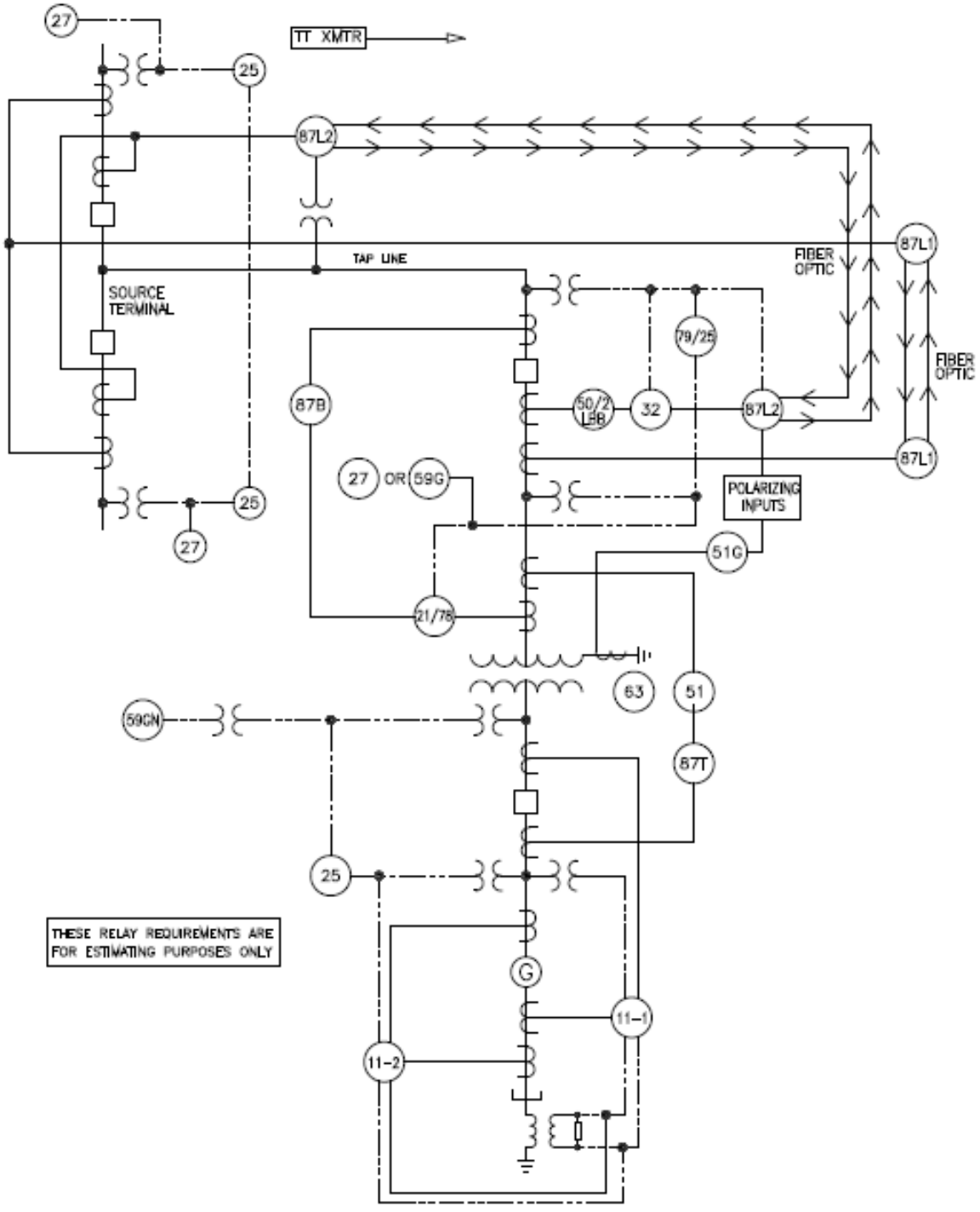
For some GIC Plant installations, the most appropriate interconnection point to the ComEd system would be directly into the bus at an existing ComEd substation. If the ComEd substation is a ring bus configuration, the GIC interconnection point would have to maintain the integrity of the substation design. This would require the addition of at least one new circuit breaker at the substation. The effect on the substation protection would depend on the site specifics. Protection also would have to be installed on the line to the generator.

Redundancy of protection is required per ComEd standards, NERC Planning Standards, PJM Standards, and/or RFC Standards which specify that no single protection system component failure can cause a fault to remain on the system. ComEd 138kV protection system standards may be greater in some areas of the service territory than shown in the diagrams. The following one line drawing and minimum protection scheme design requirements drawings illustrate these concepts for 138kV and below interconnections:

PRELIMINARY RELAY REQUIREMENTS
CUSTOMER OWNED GENERATION PARALLELED WITH COMED

PLAN E

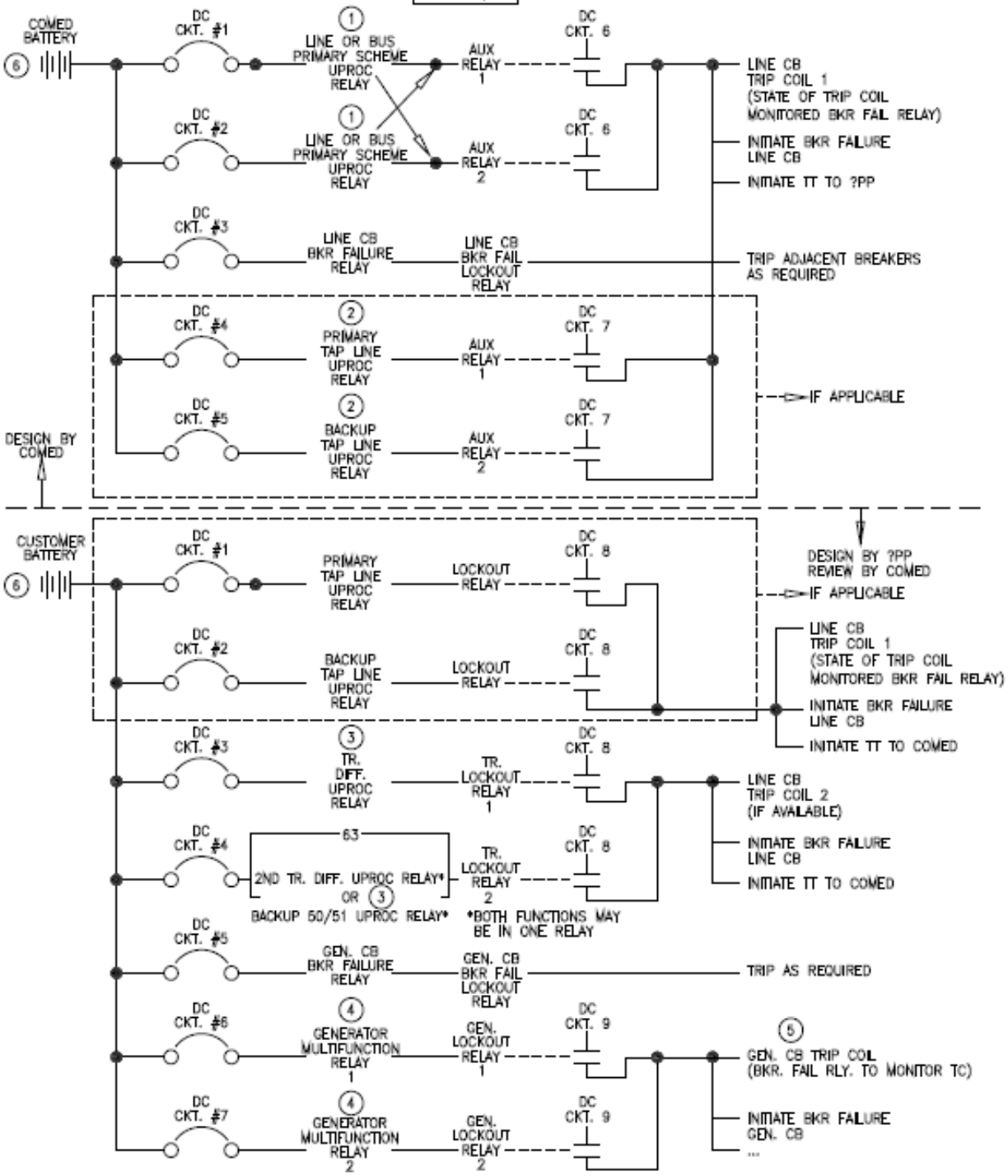
A. A TOTAL GENERATION GREATER THAN 10MVA
——————AND——————
B. CONNECTED TO 69KV OR 138KV
——————AND——————
C. RING BUS OR T-TAP CONNECTION



S00BYT

GENERAL MINIMUM PROTECTION SCHEME DESIGN REQUIREMENTS FOR

DESIGN E



GENERAL NOTES:
- BATTERY/CHARGER ALARM MONITORING IS REQUIRED.
- MICROPROCESSOR RELAY FAILURE ALARM MONITORING IS REQUIRED.

DESIGN E

(1)(2)(3)(4) RELAYS TO BE DIFFERENT MODELS, PREFERABLY BY DIFFERENT MANUFACTURERS.

(5) USE OF TRIP COIL 2 & SEGREGATION OF SYSTEMS BETWEEN TRIP COIL 2 IS RECOMMENDED IF AVAILABLE. (SEE DESIGN F)

Review and Approval of GIC Protection System Designs:

ComEd will review and approve the design of all customer owned protection systems that are identified in the 345kV and above and 138kV and below one line diagrams and minimum design requirement drawings above. ComEd approval is required prior to the start of detailed customer design work.

ComEd will review and approve the settings of protective relays for any intertie tap lines, GSUs, and for any generator setting that must coordinate with the ComEd Transmission System. ComEd approval is required prior to energization of GIC equipment.

Testing of GIC Protection System Designs:

ComEd will witness customer testing of any GIC protection system where the design is required to be reviewed and approved including proper application and testing of relay settings required for coordination with the ComEd transmission system. ComEd's approval of all testing is required prior to energization of GIC equipment.

ComEd requires a high current test (also known as a through-fault test) for any bus or GSU transformer differential schemes prior to energization of these schemes. ComEd will witness this test. ComEd review and approval of the results of this test is required prior to energization of GIC equipment. This test is typically performed just prior to livening.

A witness test list will be provided for a given site and will be the ultimate governing document on what is required. A ComEd tester's time is generally scheduled at least 5 weeks in advance by the Regional Testing Group Work Management department. Testing Group individuals are not scheduled for work until completed and approved prints, and other required documentation, are in hand. GIC representatives shall work with ComEd work management to schedule tester's time for witness testing and review of testing documentation. Four (4) sets of approved blueprints (as built) must be provided to the ComEd testing department. The project delays may be caused by untimely submittal of approved blueprints by the GIC.

Reclosing of ComEd Supply Lines

Most faults on overhead lines are transient. That is, if the line is de-energized promptly, it can be reclosed and returned to service. Examples of such transient faults include momentary tree contact due to wind, and insulator flashover due to lightning. Automatic reclosing of overhead lines is standard industry practice to improve the reliability of supply. In many cases, the line can be de-energized and reclosed within one second, with minimal disruption of service to the GIC.

Effects of Interconnected Generation on Automatic Reclosing

Automatic reclosing on ComEd's transmission lines can potentially damage generating equipment operated in parallel with the T&D system. Severe mechanical stress on the

generating equipment may occur if the line is reclosed while the generator is still connected to the ComEd system. This applies to both synchronous and induction generators. With synchronous generators, damage may occur when they are out of synchronism when the supply is restored; with induction generators, damage may occur if they are operating at a speed higher or lower than normal when reclosed to the system. ComEd will not eliminate automatic reclosing of overhead supply lines because that would severely reduce the reliability of service to other GICs. ComEd will attempt to reclose into a dead line from a non-generating terminal. At 345kV and above, a delayed reclose attempt long enough for a generator to cease oscillation will be applied at the most stable generating terminal of a line with generation at both ends. At 138kV and below, the first reclosing attempt is typically high-speed to maintain reliability to distribution customers and standard distribution substations require this mode. Although unlikely, some 138kV configurations may require direct tripping of connected generation for line faults.

Possible Reclosing Scenarios and GIC Responsibilities

The GIC is responsible for protecting the generating facility's equipment so that automatic or manual reclosing, faults, or other disturbances on the ComEd System do not cause damage to the equipment.

When automatic reclosing may result in equipment damage or a safety hazard, either to the ComEd System or the GIC facilities, ComEd and/or PJM may require that additional protective equipment be installed. This will usually consist of communication and/or control equipment to disconnect the GIC’s generator (or to confirm that it is disconnected) before the ComEd transmission line is reclosed.

7) SCADA REQUIREMENTS

Some generators will require continuous telemetry to ComEd's and PJM's operation facilities. These will typically be large generators, generators involved in wholesale transactions or generators that are dispatchable by PJM. Telemetry may be required for one or more of the following reasons:

a) **System Control.** PJM has an obligation to maintain frequency and generation/load balance within its service territory. Changes in the status of large amounts of generation, without real-time telemetry, are detrimental to system control.

b) **Transmission System Operation.** The status of large generators significantly impacts operating decisions. Operators need to know the status of these large generators before performing routine or emergency switching.

c) **Public Safety.** Generators can potentially keep a portion of the electrical grid energized while isolated from the ComEd System. It is critical to detect these situations as soon as they occur so that corrective action can be taken, since the safety of the public and of ComEd workers is at stake.

Generators that meet the following criteria require implementation of telemetry to ComEd's and PJM's control center and dial-up telephone communication to the revenue meter. Required telemetry is listed below each criterion. If more than one criterion applies to a generator, the telemetry requirements of each criterion must be met.

If the GIC is involved in a Power Purchase Agreement (PPA) or participating in the PJM capacity markets which contains unit specific performance or a unit specific payment structure

- Continuous telemetry required.
- Instantaneous revenue grade MW and MVAR; and cumulative revenue grade MWhr and MVARhr at the generator's step-up transformer high side (or equivalent net output) for each unit.
- Instantaneous revenue grade MW and MVAR; and cumulative revenue grade MWhr and MVARhr at all points of interconnection with ComEd and all points of service from ComEd.

If multiple GIC's generators over a large area with an aggregate generation greater than 40 MW are being centrally controlled

- Continuous telemetry required.
- Aggregate instantaneous MW of all generators.

7.1) General Design Requirements

There are two concerns with telemetry at GIC sites:

- The normal requirements for substation remote supervision and operation
- The unique requirements for GIC service, as emphasized in this document.

PJM requirements

When telemetry is required, as described earlier in this document, the following design will be used.

ComEd SCADA Engineering will specify the SCADA system required. SCADA technology is constantly evolving, so specific devices are not referenced in this document. But the system will typically provide the following 5 basic functions:

1. Monitor status, control, and metering of the ComEd substation and any ComEd equipment.

    a) One or more input/output modules/cards to accommodate any hard-wired alarms, status and controls

    b) Serial and/or IP data connections to protective IEDs, equipment monitors, revenue meters, etc.

2. Provide substation information to the ComEd SCADA system

    a) A serial or IP data connection to the ComEd SCADA system from the SCADA data concentrator

    b) The data connection can be via a telco circuit, a fiber optic cable, a microwave channel, or a radio pathway as specified by ComEd based on availability at the site and ability to meet all ComEd SCADA and security requirements.

3. Provide substation information to onsite personnel

    A utility-grade pc is typically used to act as a substation HMI. The pc will have a serial or IP connection to the SCADA data concentrator to acquire the substation data.

4. Provide ComEd substation information to the GIC

    a) Current practice is to establish a DNP 3.0 serial connection between the ComEd data concentrator and the GIC control system. The GIC will act as the DNP master and poll the ComEd system for any desired information.

b) For larger installations, a fiber optic cable is typically installed between the ComEd and GIC facilities. This DNP connection is most easily accomplished by using a pair of fibers in this cable.

c) The ComEd system will be programmed to only provide information relevant to the GIC connection. This data typically includes the revenue metering data, as well as status of equipment relating to the GIC connection/tap on the ComEd system.

5. Provide ComEd SCADA system with GIC substation information

a) Current practice is to establish a 2nd DNP 3.0 serial connection between ComEd and the GIC. ComEd will now act as the DNP master and poll the GIC on this 2nd DNP connection to gather information about the GIC facility.

b) Like with the first DNP connection, for larger installations a fiber optic cable is typically installed between the ComEd and GIC facilities. This DNP connection is most easily accomplished by using a pair of fibers in this cable.

8) COMMUNICATION REQUIREMENTS

Communications will be required for Relay Protection schemes, SCADA, telemetry, voice/data, Revenue Metering, and other Substation services. The Substation is a harsh environment that will require extraordinary means of construction in order to provide safe, dependable, and reliable service for all required connections.

Relay Requirements

Communications for Relay schemes need to be provided on equipment that meets the same IEEE C.37.90 requirements as the Relays themselves. The type of Communications equipment utilized will vary based on the Transmission voltage level that is being protected. As mentioned in 6.1, the standard medium of system protection communication on the 345kV system is fiber optic and/or digital microwave based equipment. For 138kV systems, the standard medium of system protection communication equipment is power line carrier, although fiber optic and/or digital microwave based equipment could be considered. Any other technologies must be reviewed and approved by Com Ed prior to the start of customer design work. This review will occur at the same time the Relay schemes are reviewed.

SCADA/Telemetry/Revenue Metering Requirements

Communications for SCADA/Telemetry/Revenue Metering have slightly less stringent requirements unless they are using the same equipment that the Relay schemes are using. These communications can be made on fiber optic and/or digital microwave based equipment, depending on availability. They can also be provided on leased lines, but all connections to telephone companies will require protection on the phone cabinets for the incoming copper cables. A Ground Potential Rise (GPR) study will be required for any copper cable connections to the phone company. Any other technologies must be reviewed and approved by Com Ed prior to the start of customer design work.

Other Voice/Data Requirements

Communications for other voice/data services, including Plain Old Telephone Service (POTS) lines, Fire Protection, LAN/Internet, etc. also do not have the same stringent requirements as the Relay schemes, unless they are using the same equipment. Any communications provided by leased lines from the phone company will require the same GPR studies as described above in the SCADA Requirements. These communications can be provided over fiber optic and/or digital microwave based equipment, with some exceptions:

1) A POTS line intended for voice use cannot be provided over fiber optic and/or digital microwave based Com Ed systems due to concerns for the use of “911” calls. So this must be provided by the phone company.

2) The primary Fire Protection circuit, if required, cannot be provided over a “private network” (i.e., a Com Ed based fiber optic and/or digital microwave system) per NFPA72. However, if Fire Protection is not required, and is simply

being added because it’s wanted, then this channel can be through SCADA or some other communications means, as approved by Com Ed.

3) Any other technologies must be reviewed and approved by Com Ed prior to the start of customer design work.