Exploring SATA integration

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PC Special Session - Storage As a Transmission Asset
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Transmission Planning

Storage affects local load curve

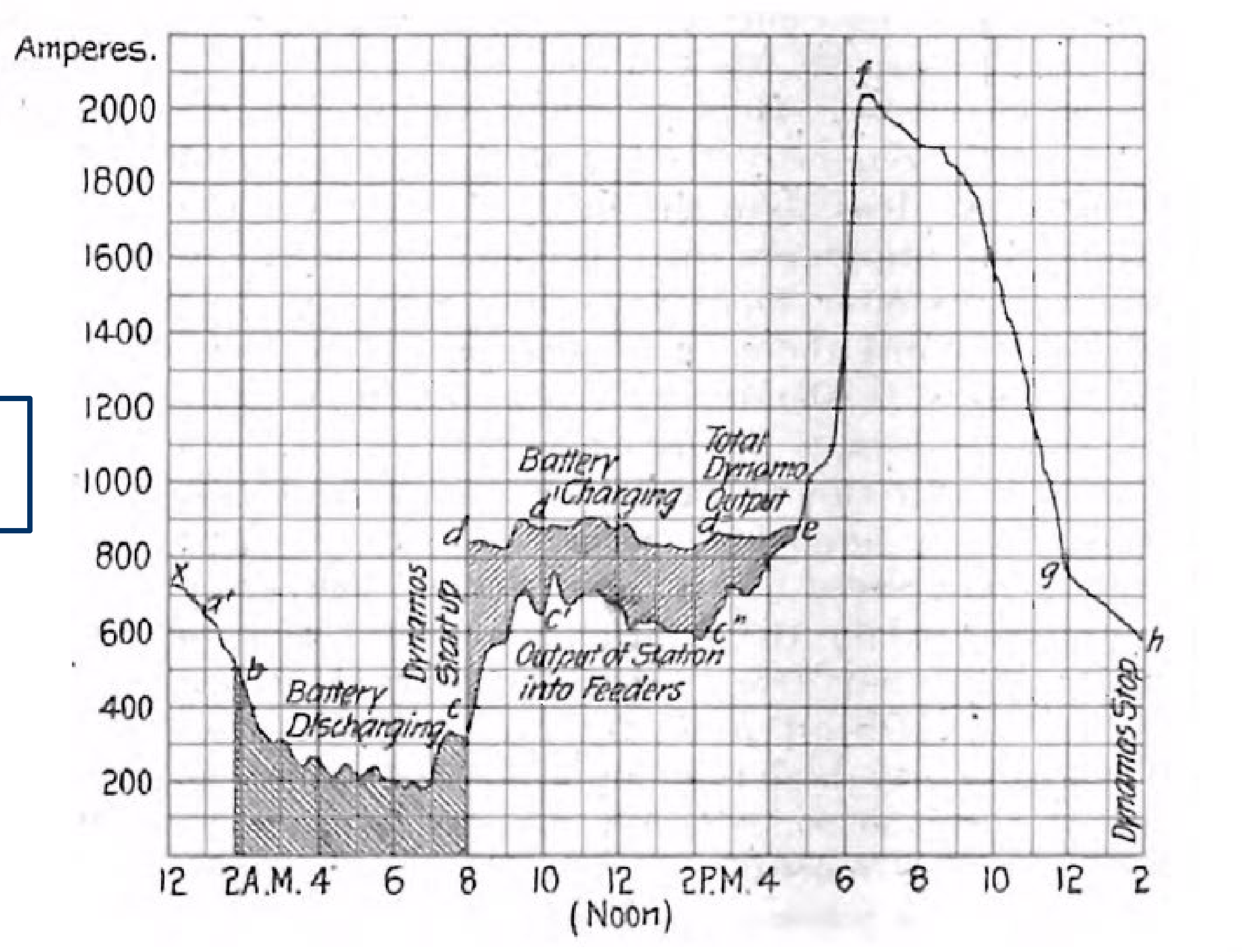


Fig. 3 —Load Diagram of 53d St. Station, Edison Illuminating Co., of New York City, Sept. 30. 1893.

Source: Engineering News, Vol. 30, p 358, Nov. 2, 1893.

"After a 100-year Hiatus, Batteries are Helping Again"

More than 120 years ago, batteries were commonplace on the power grid. Thanks to Thomas Edison's vision, many central station power plants and distribution networks utilized battery systems in the 1890s. This chart shows a 19th century "duck curve" for New York City, and demonstrates the key role that batteries played in smoothing the peaks and valleys of electricity demand throughout the day and night in Edison's time.

Presented by Fluence Energy, LLC at the RFC Storage As Transmission Workshop May 7, 2020

Historical Peak (PJM 2020 Load Forecast Report)

Table F-1

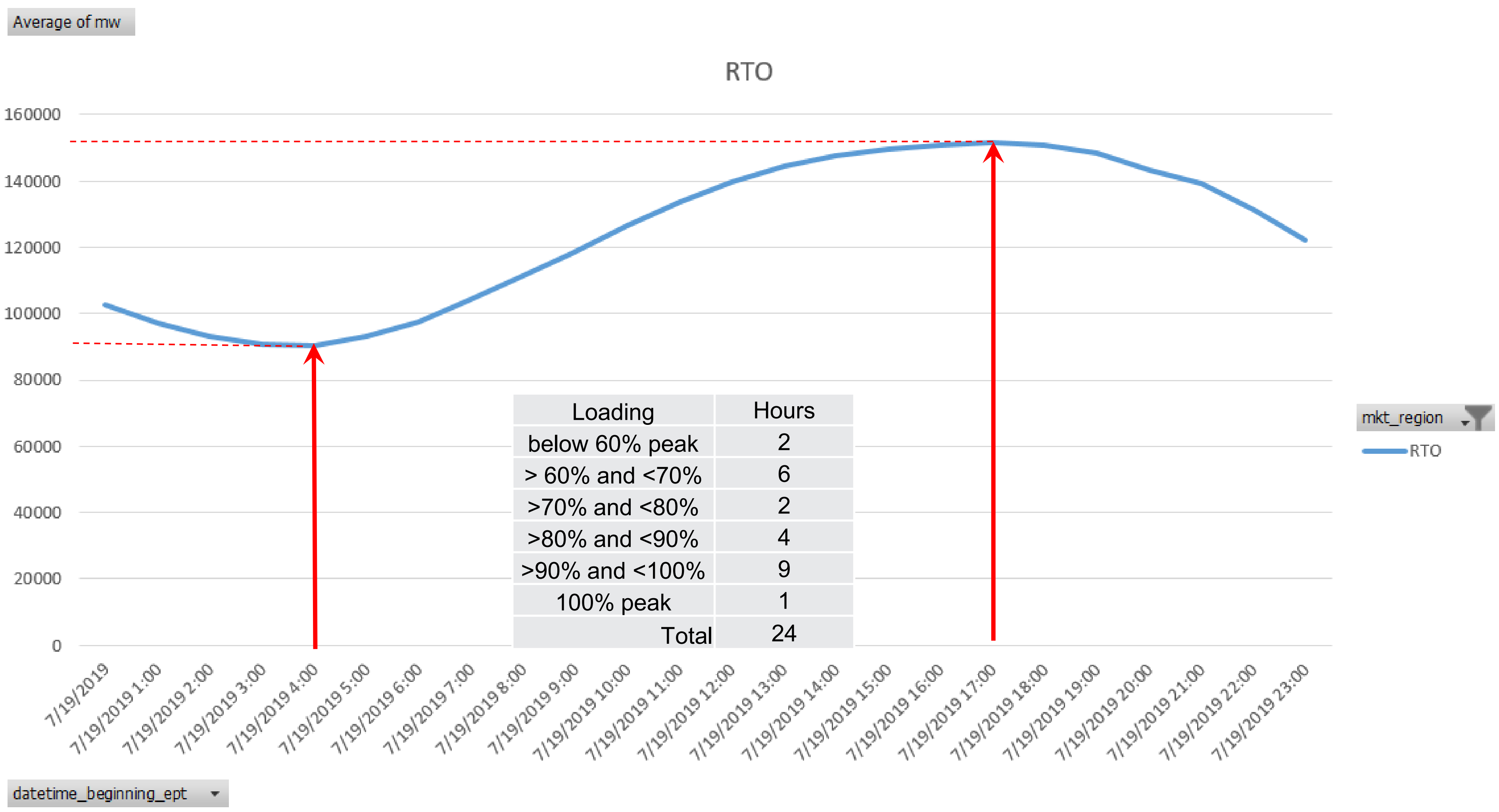
PJM RTO HISTORICAL PEAKS
(MW)

SUMMER

YEAR	NORMALIZED BASE	NORMALIZED COOLING	NORMALIZED TOTAL	UNRESTRICTED PEAK	PEAK DATE	TIME
1998				133,275	Tuesday, July 21, 1998	17:00
1999				141,491	Friday, July 30, 1999	17:00
2000				131,798	Wednesday, August 9, 2000	17:00
2001				150,924	Thursday, August 9, 2001	16:00
2002	92,747	52,408	145,155	150,826	Thursday, August 1, 2002	17:00
2003	93,710	54,444	148,153	145,227	Thursday, August 21, 2003	17:00
2004	95,225	55,350	150,576	139,279	Tuesday, August 3, 2004	17:00
2005	95,846	57,340	153,186	155,257	Tuesday, July 26, 2005	16:00
2006	95,311	58,919	154,230	166,929	Wednesday, August 2, 2006	17:00
2007	96,738	58,703	155,441	162,035	Wednesday, August 8, 2007	16:00
2008	97,213	57,816	155,029	150,622	Monday, June 9, 2008	17:00
2009	94,732	56,668	151,400	145,112	Monday, August 10, 2009	16:00
2010	93,191	58,825	152,016	157,247	Wednesday, July 7, 2010	17:00
2011	93,397	58,794	152,191	165,524	Thursday, July 21, 2011	17:00
2012	93,024	57,447	150,472	158,219	Tuesday, July 17, 2012	17:00
2013	92,558	57,425	149,984	159,149	Thursday, July 18, 2013	17:00
2014	91,934	57,703	149,637	141,509	Tuesday, June 17, 2014	18:00
2015	91,214	57,891	149,105	143,579	Tuesday, July 28, 2015	17:00
2016	89,900	59,137	149,036	152,069	Thursday, August 11, 2016	16:00
2017	88,999	60,063	149,062	145,434	Wednesday, July 19, 2017	18:00
2018	89,895	58,470	148,365	150,565	Tuesday, August 28, 2018	17:00
2019	89,624	57,683	147,307	151,302	Friday, July 19, 2019	18:00

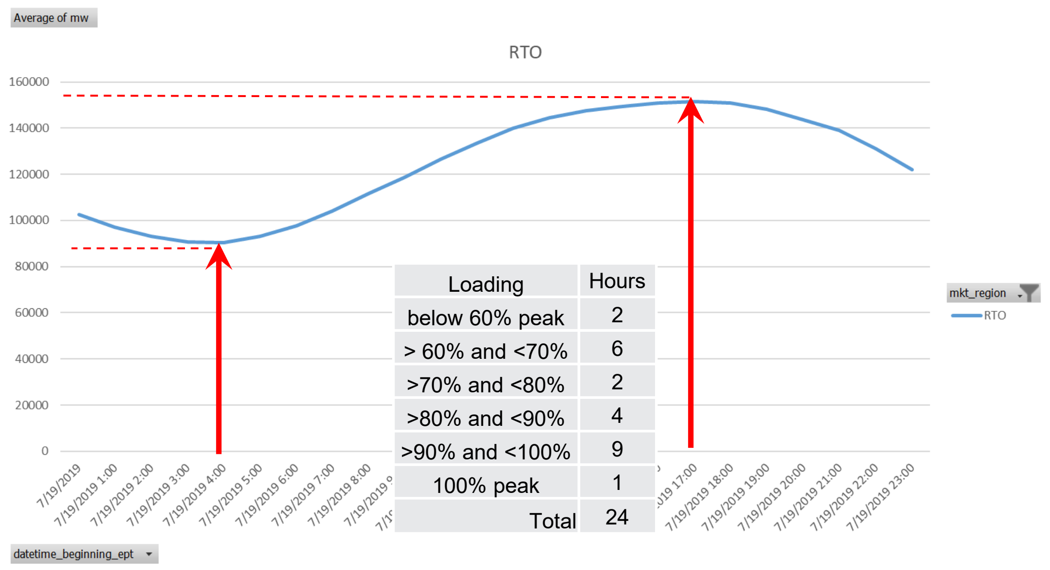
PJM RTO Load Curve on a Peak Summer Day

Average of mw	Column Labels	
Row Labels	RTO	PCT of Peak
7/19/2019	102536.119	67.6%
7/19/2019 1:00	97037.728	64.0%
7/19/2019 2:00	92994.294	61.4%
7/19/2019 3:00	90671.44	59.8%
7/19/2019 4:00	90493.667	59.7%
7/19/2019 5:00	93233.677	61.5%
7/19/2019 6:00	97590.642	64.4%
7/19/2019 7:00	104170.717	68.7%
7/19/2019 8:00	111515.098	73.6%
7/19/2019 9:00	118662.533	78.3%
7/19/2019 10:00	126536.657	83.5%
7/19/2019 11:00	133590.814	88.1%
7/19/2019 12:00	139792.958	92.2%
7/19/2019 13:00	144396.83	95.3%
7/19/2019 14:00	147502.769	97.3%
7/19/2019 15:00	149496.06	98.6%
7/19/2019 16:00	150835.341	99.5%
7/19/2019 17:00	151570.041	100.0%
7/19/2019 18:00	150957.282	99.6%
7/19/2019 19:00	148272.671	97.8%
7/19/2019 20:00	143479.734	94.7%
7/19/2019 21:00	139151.036	91.8%
7/19/2019 22:00	131240.897	86.6%
7/19/2019 23:00	122045.375	80.5%

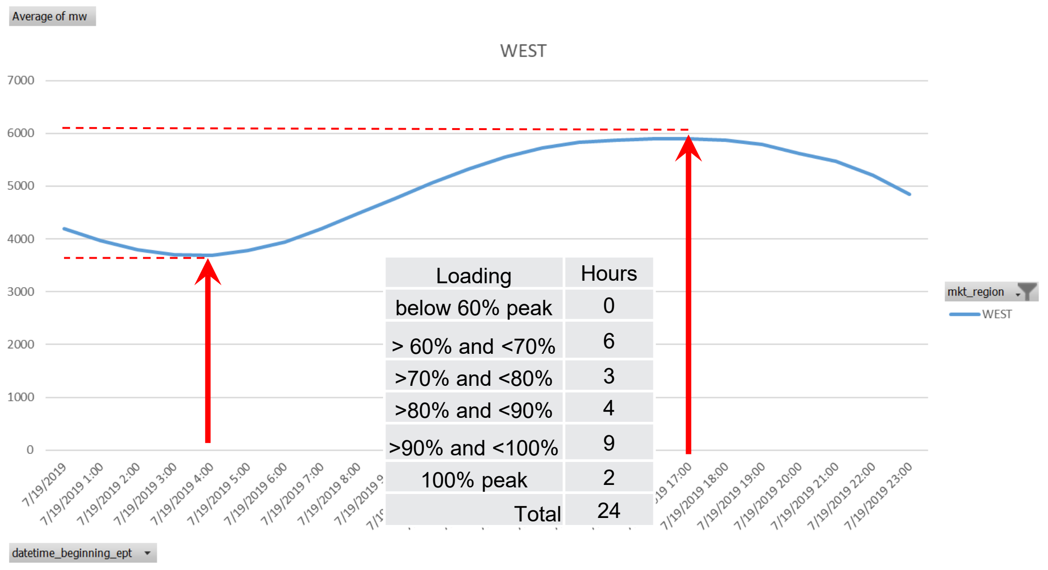


Loading	Hours
below 60% peak	2
> 60% and <70%	6
>70% and <80%	2
>80% and <90%	4
>90% and <100%	9
100% peak	1
Total	24

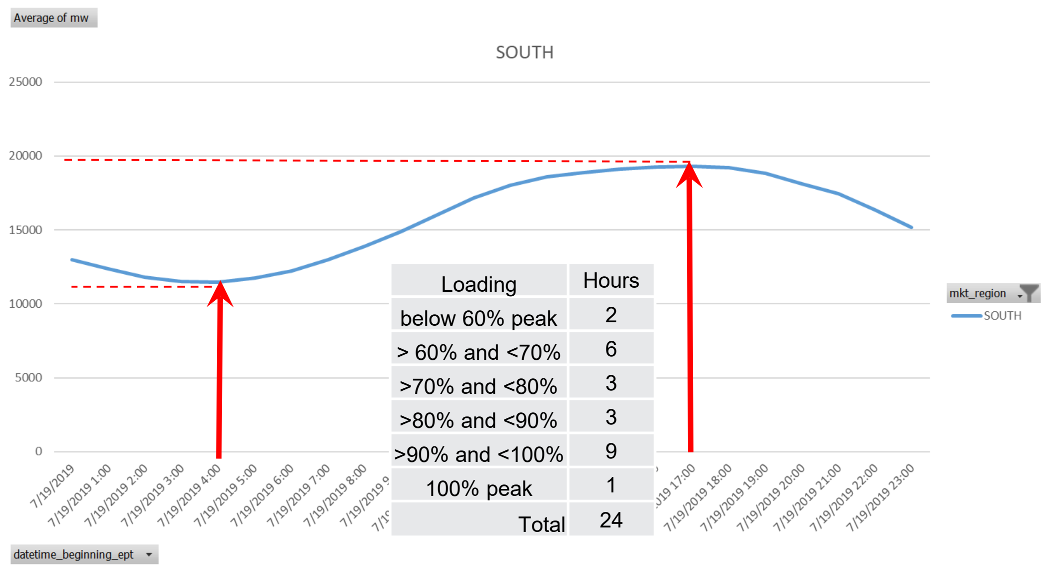
Similar Load Curves on Peak Summer Day



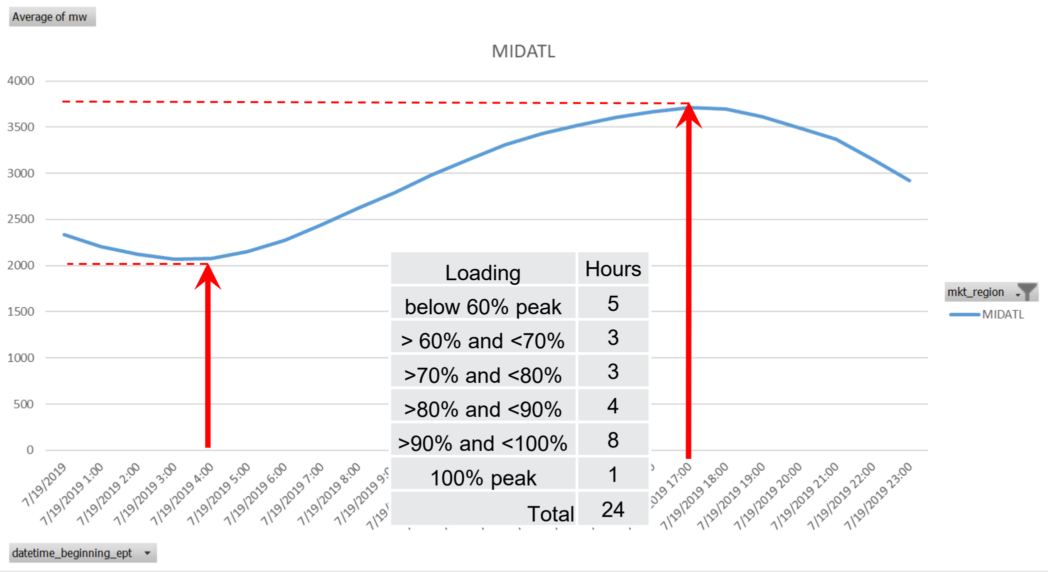
Loading	Hours
below 60% peak	2
> 60% and <70%	6
>70% and <80%	2
>80% and <90%	4
>90% and <100%	9
100% peak	1
Total	24



Loading	Hours
below 60% peak	0
> 60% and <70%	6
>70% and <80%	3
>80% and <90%	4
>90% and <100%	9
100% peak	2
Total	24

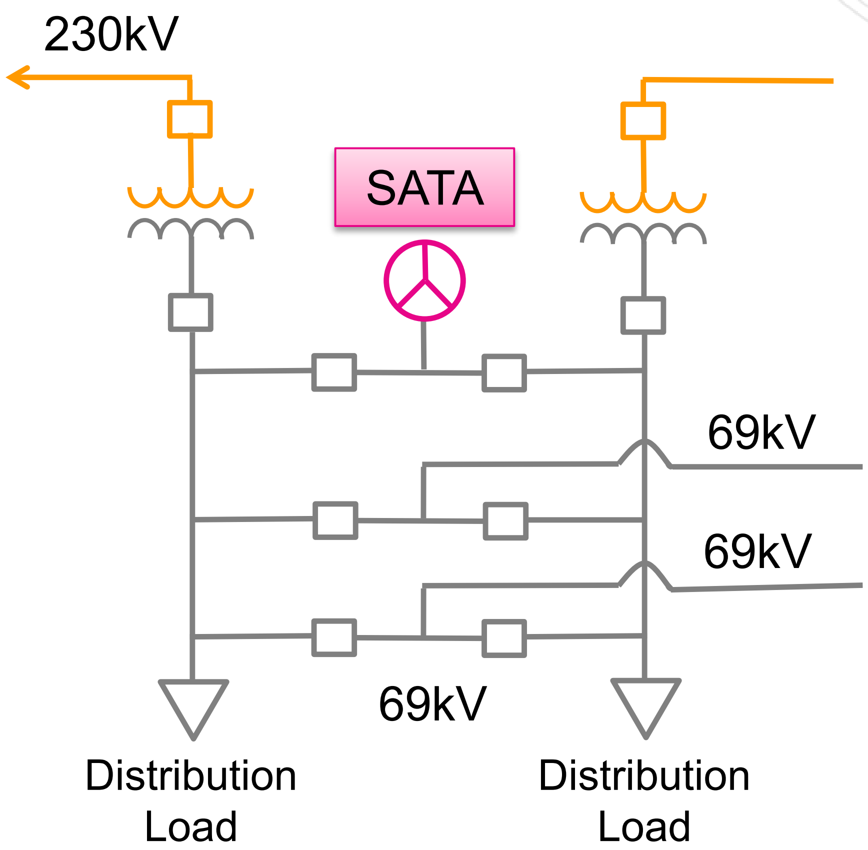


Loading	Hours
below 60% peak	2
> 60% and <70%	6
>70% and <80%	3
>80% and <90%	3
>90% and <100%	9
100% peak	1
Total	24

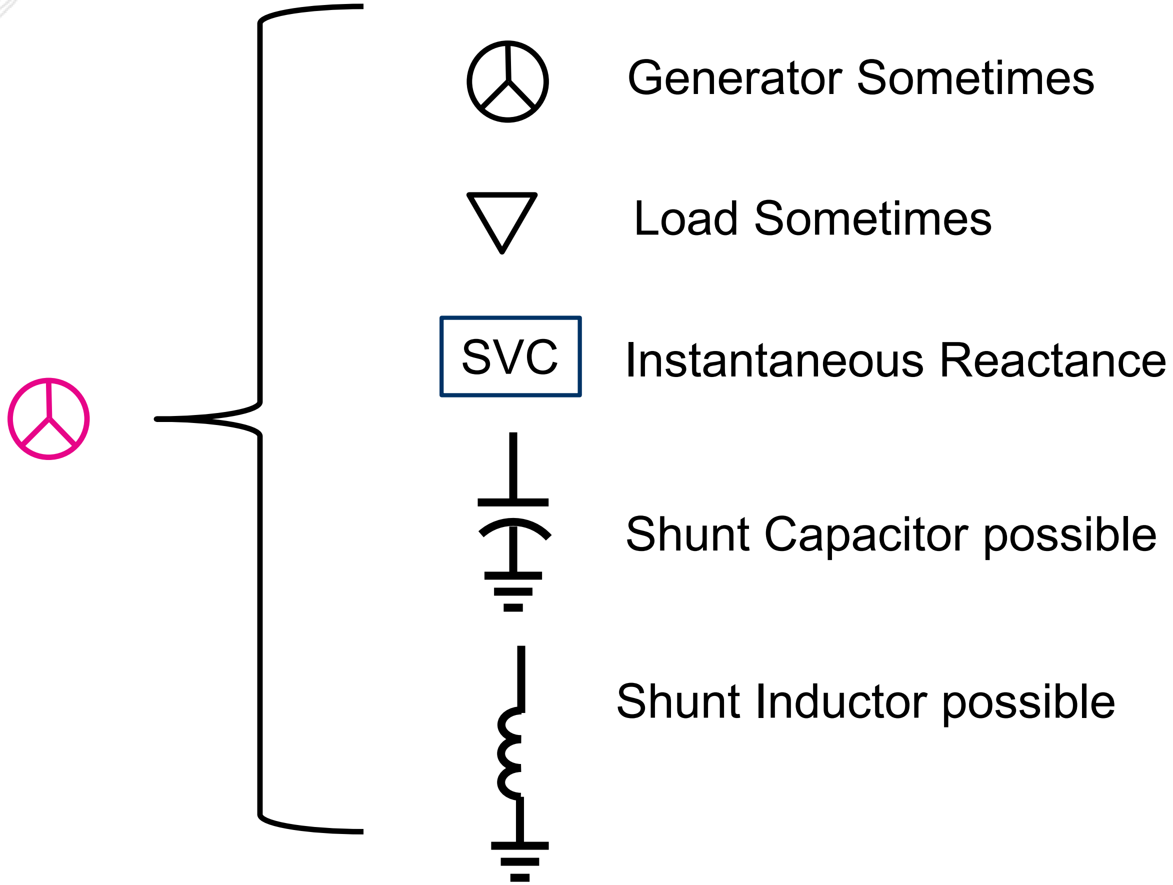


Loading	Hours
below 60% peak	5
> 60% and <70%	3
>70% and <80%	3
>80% and <90%	4
>90% and <100%	8
100% peak	1
Total	24

SATA characteristics and capabilities



Battery + Inverter = versatility



Example – 1.5 MW and 3.0 MW SATA Characteristics

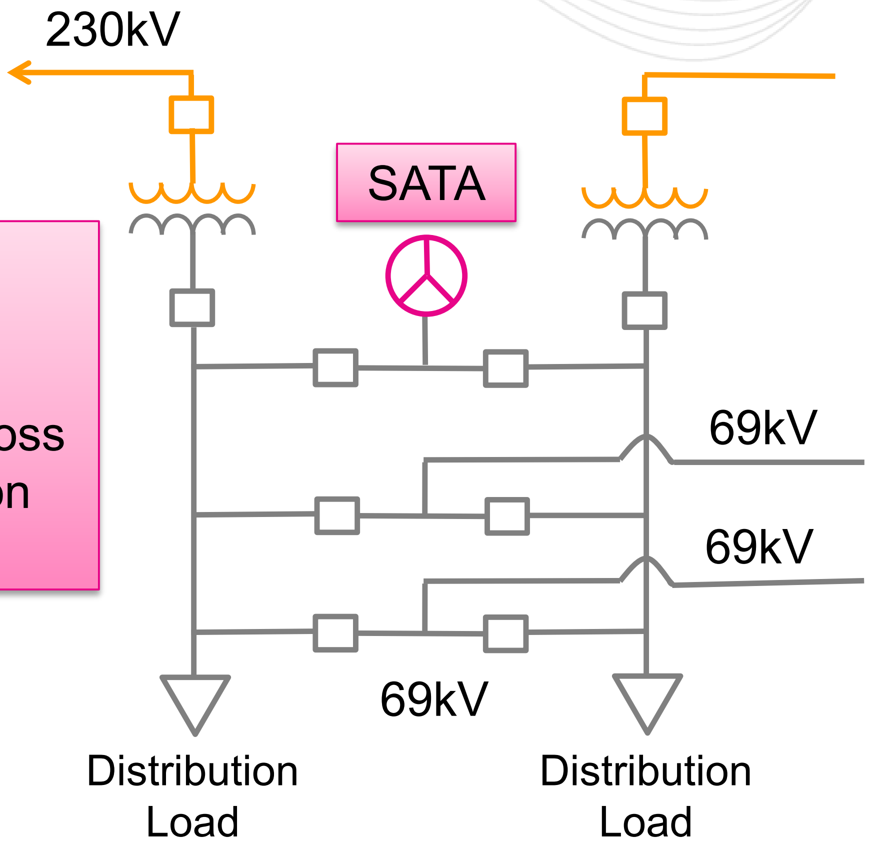
BATTERY SPECIFICATIONS	
System Duration	1, 2, 4, and 6 Hour
Power Rating	CPS®-i-1500: 1200kW @ 480v 1500kW @ 600v CPS®-i-3000: 2400kW @ 480v 3000kW @ 600v
Certifications	UL 1973 (Tray), UL 1642

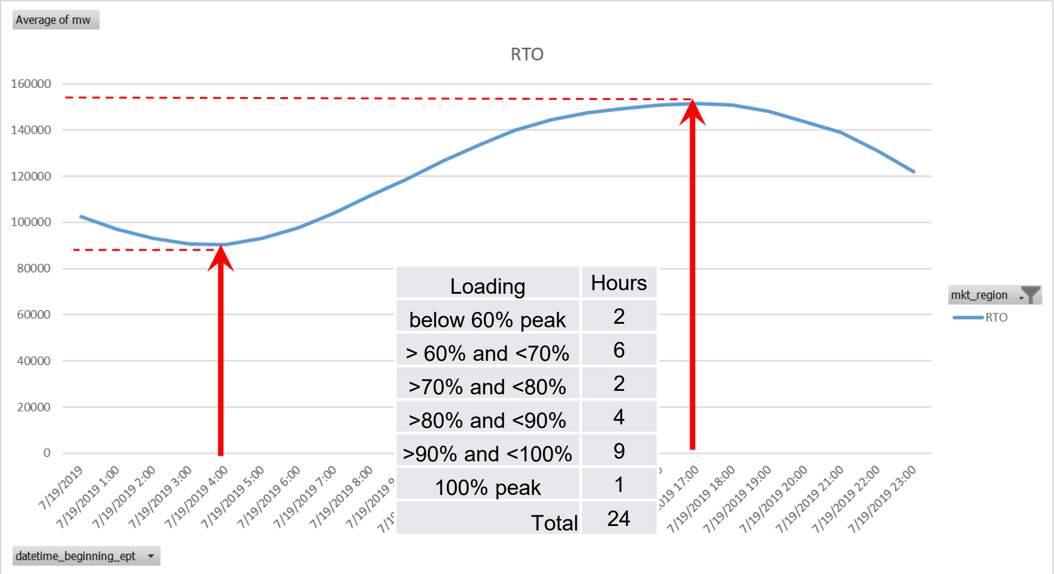
GRID CONNECTION	
AC Line Voltage	480 - 600 V_{AC} 3 Phase
AC Line Nominal Frequency	60 Hz
Continuous AC Current	1444/2888 A RMS
Overload AC Current	1729/3458 A RMS
Continuous AC Power	1200 kW (@480) 1500 kW (@600)
Power Factor	0 - 1.0 Leading or Lagging
Current Harmonics	IEEE 1547 Compliant, <5% TDD
Roundtrip Efficiency	93%

- SATA manufacturers provide performance characteristics…for example
  1. Generate power (MW) at a specified power factor
  2. Absorb power (MW) to recharge itself
  3. Provide capacitive reactance (produce VARs) to support low voltage
  4. Provide inductive reactance (absorb VARs) to suppress high voltage
  5. IEEE 1547 for anti-islanding
  6. Roundtrip (charge/discharge) efficiency < 100%

Consider a Regional Sub with a Load Curve profile similar to the RTO Load Curve

SATA installed to mitigate thermal overload on either transformer for the loss of one transformer on the other





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100% peak	1
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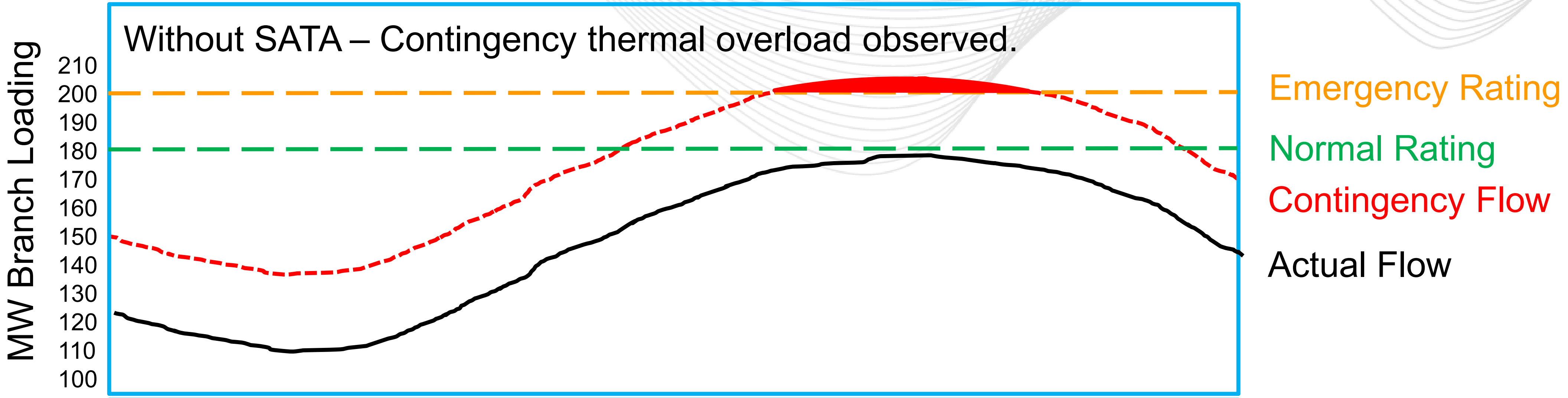
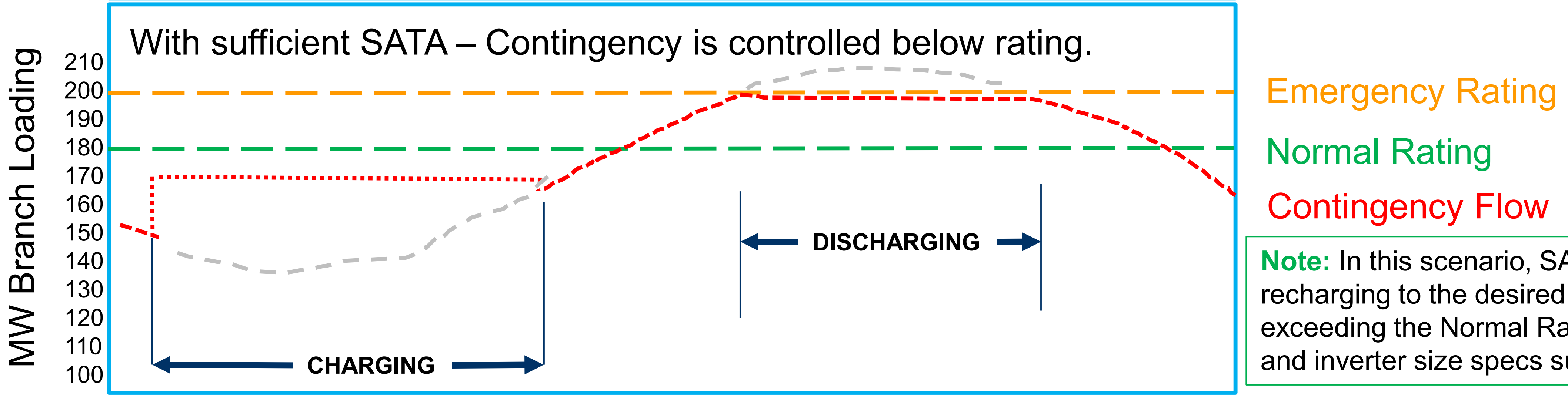
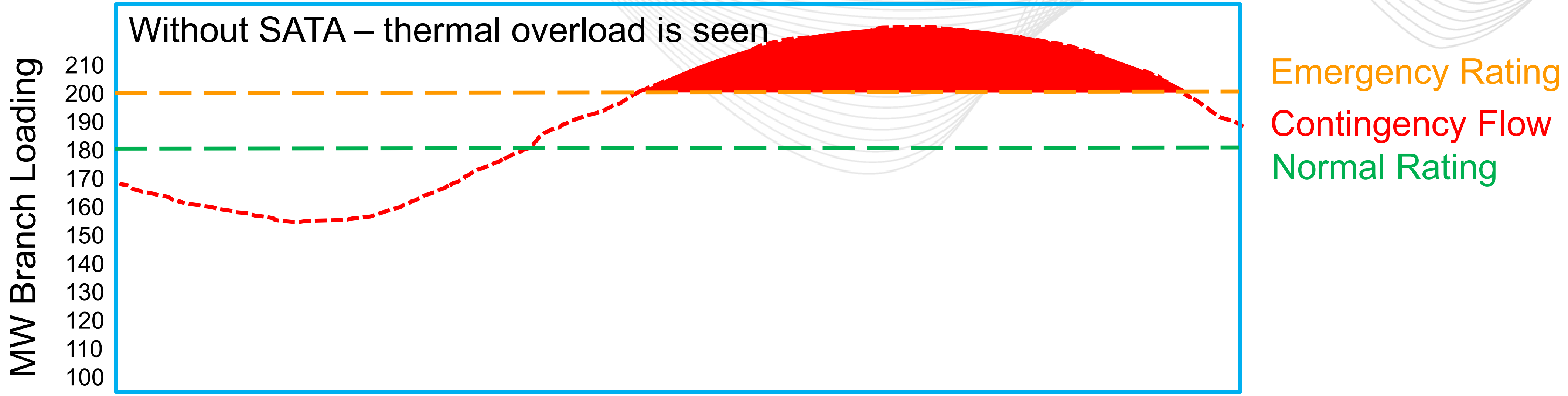
Sufficient SATA to Mitigate N-1 Thermal Overload

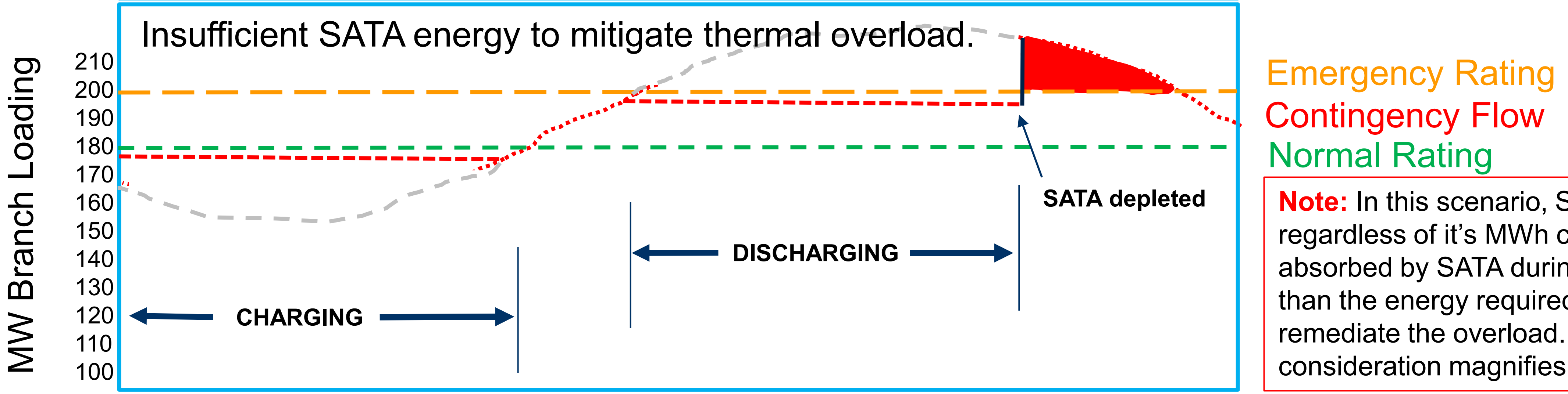




Note: In this scenario, SATA is capable of recharging to the desired SOC without exceeding the Normal Rating. MWh Rating and inverter size specs support this application.

SATA depletes before Thermal Overload is fully mitigated





Note: In this scenario, SATA depletes itself regardless of it's MWh capacity. The energy absorbed by SATA during charging is less than the energy required for SATA to fully remediate the overload. Roundtrip efficiency consideration magnifies the issue.

Considerations for SATA Performance Evaluation

- Can SATA mitigate the violation for the entire outage duration?
  - The SATA effective duration is known but the outage duration is unknown
  - The load curve of the SATA interconnection point has uncertainty
    - The load curve is the main ingredient for evaluating/specifying SATA performance
    - Load curve forecasts based on historical load curves may be inaccurate
    - Conditions at the SATA interconnection point may not support recharging for a long duration outage.
      - Is a depleted SATA considered an additional N-1 and/or combine with the original contingency that drove the violation resulting in the installation of the SATA?

Baseline Thermal and Voltage considerations

- M14B.2.3.6 - 7 Baseline Thermal - Voltage Analysis
  - *"…is a thorough analysis of the reference power flow to ensure thermal - voltage adequacy based on normal (applicable to system normal conditions prior to contingencies)"*
- SATA model considerations
  - Appears in the Base Case – SATA in standby
  - Appears in Sensitivity cases – SATA as a generator and as a load
    - Pre contingency violation – SATA has cost responsibility for reinforcement
    - Post contingency violation – SATA has cost responsibility for reinforcement only if it "causes harm" for a contingency it is NOT designed to address.
      - » SATA charge/discharge cycling must be secure following a single or common mode outage.

Generation Deliverability considerations

- M14B.attachment C.3
  - *"…the test attempts to ensure that bottled capacity conditions that limit the availability and usefulness of certified Capacity Resources to system operators will not exist."*
  - SATA is under study
    - SATA appears in the Base Case – SATA in standby
    - SATA appears in Sensitivity cases – SATA as a generator and as a load
      - As a helper – possible expanded use of SATA as a reinforcement
      - As a harmer – SATA has cost responsibility for reinforcement
  - Gen in queue under study
    - SATA appears in the Base Case – SATA in standby
    - SATA appears in Sensitivity cases – SATA as a generator and as a load
      - As a helper – possible expanded use of SATA as a reinforcement
      - As a harmer – Gen has cost responsibility for reinforcement

M14B.2.3.8 - NERC P3 and P6 “N-1-1” considerations

- SATA reinforcing for the first N-1 event
  - Post-contingency, all elements are within their Emergency limits
  - Followed by system adjustments such that
    - All elements are within their Normal limits AND
    - SATA can be recharged without exceeding Normal limits
- SATA reinforcing for the second event
  - Pre-contingency, the SATA can be recharged without exceeding Normal limits
  - Post-contingency, all elements are within their Emergency limits
  - Followed by system adjustments such that
    - SATA can be placed in Standby without exceeding Emergency limits

SATA Considerations for Load Flow Modeling

- As a generator
  - Maximum MW at prescribed power factor
    - Limited by inverter and other SATA characteristics
  - Effective Duration
    - Limited by SATA MWh
    - Desired State Of Charge (SOC)
- As a load
  - Maximum rate of charging
    - Limited by inverter and other SATA characteristics
  - Recharge time
    - A function of SATA MWh
    - A function of Initial SOC and Desired SOC
- Standby mode
  - Auxiliary loads for maintaining ambient conditions for optimum SATA performance

Market Efficiency

Transmission Planning - Market Efficiency Experience

- Battery proposals were accepted as solutions for target congestion drivers
- During previous Long-Term Windows, PJM evaluated a number of battery proposals:
  - 2016/17 RTEP Window – 2 proposals
  - 2018/19 RTEP Window – 6 proposals
- Some battery proposals submitted as stand-alone, others as combination with new lines
- Proposal Statistics:
  - Peak MW: 10 to 50 MW
  - Duration: 2 to 4 hrs
  - Capital Cost: $17.36 to $165.74

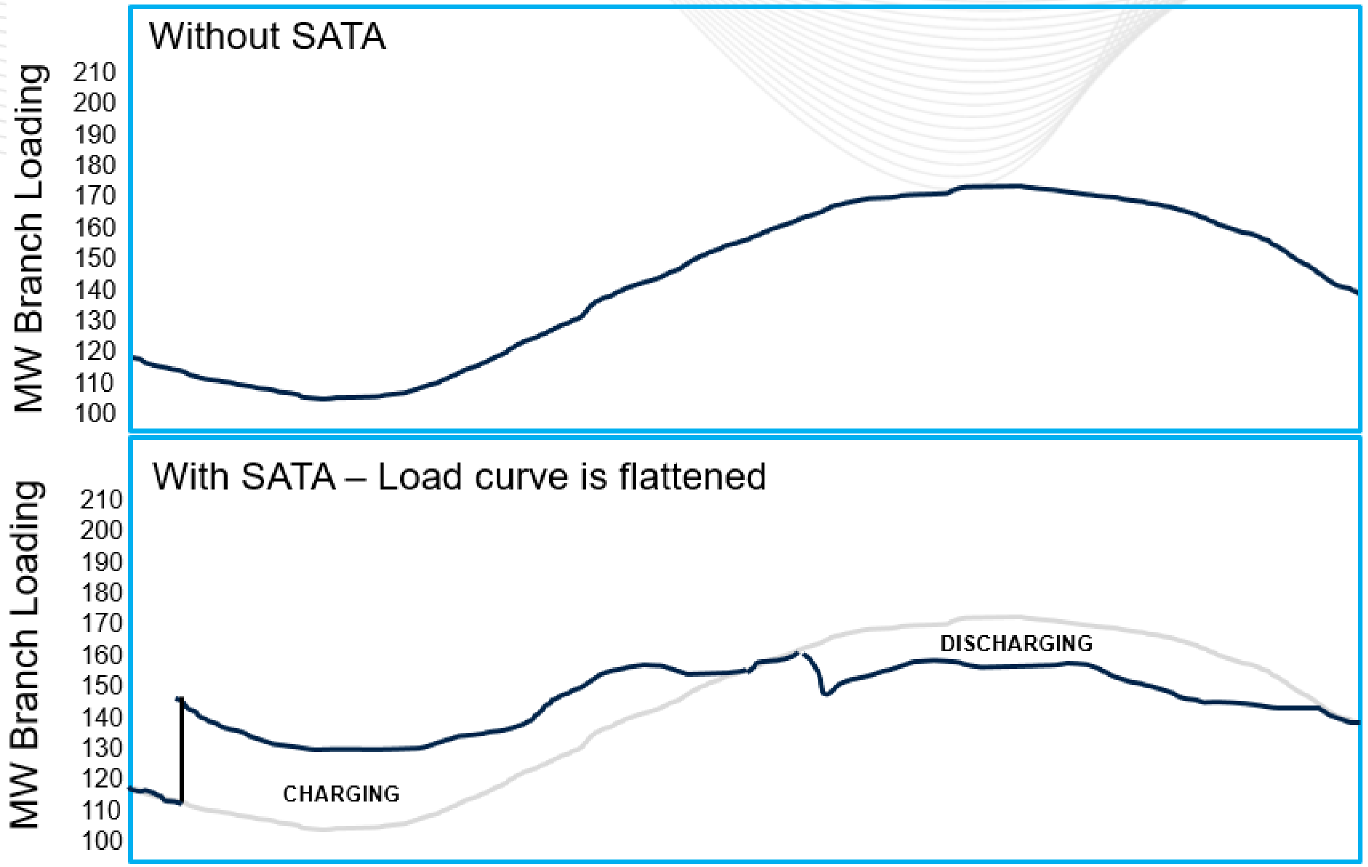
Market Efficiency – Energy Storage Model

- Battery proposals were analyzed consistent with manuals 14B and 14F
- Benefits calculated as decreases in annual net load payments for benefiting zones
- Costs based on assumed annual revenue requirements
- Energy storage model assumes operations based on economics: off-peak charge / on-peak discharge
- Bright line test criteria:
  - Pass B/C Ratio Threshold of 1.25
  - Address the target congestion driver

Market Efficiency – Zonal Load Impact

- Energy Storage model assumed operations based on economics:
  - off-peak charge “valley fill-in”
  - on-peak discharge “peak clipping”

– Objective function: minimize system production cost



SATA Considerations

- SATA performance evaluated based on congestion reductions and net load payment savings

- SATA not an active market participant
  - can not set LMP

- SATA participation in Markets is a topic for Phase 2