Transmission ITP

Operational Parameters/Limits and Reactive Resources

PJM State & Member Training Dept.

Objectives

At the end of this course the student will be able to:

- Define the purpose of thermal, voltage & stability
- Define the purpose of SOLs
- Define the purpose of IROLs
- Define PJM's thermal operating criteria
- State the consequences of violating thermal limits
- State the actions to take to control violations of thermal limits
- Describe how IROLs are determined and monitored in PJM
- Identify the IROLs in the PJM footprint

Objectives

- Define PJM's voltage operating criteria
- State the consequences of violating voltage limits
- State the actions to take to control violations of voltage limits
- Identify PJM's voltage schedule guidelines
- Describe the effects of capacitors & reactors on voltage levels on the BES
- Identify which reactive resources can be switched without instruction from PJM
- Describe the effects of LTCs & PARs adjustments on the voltage profile of the BES

Objectives

- Identify the requirements to submit eDART data for outages of reactive resources
- Verify actions to be taken if reactive capability curve data needs to be updated
- Describe the purpose and process of the Reactive testing program and identify the reporting requirements for test data
- Identify the requirements to verify reactive capability curve data in your EMS

Agenda

- Purpose of limits
- PJM Thermal Operating Criteria
- IROLs in PJM
- Post Contingency Local Load Relief Warning (PCLLRW)
- Post Contingency Congestion Management Program
- Transmission Loading Relief (TLR)

Agenda

- Constraint Management Mitigation Program
- Voltage Operating Criteria
- Voltage Control with Generators
- Caps and Reactors
- Transformer Load Tap Changer Operations
- Generator Reactive Testing
- Reactive Capability Changes and Reporting

Purpose of Limits

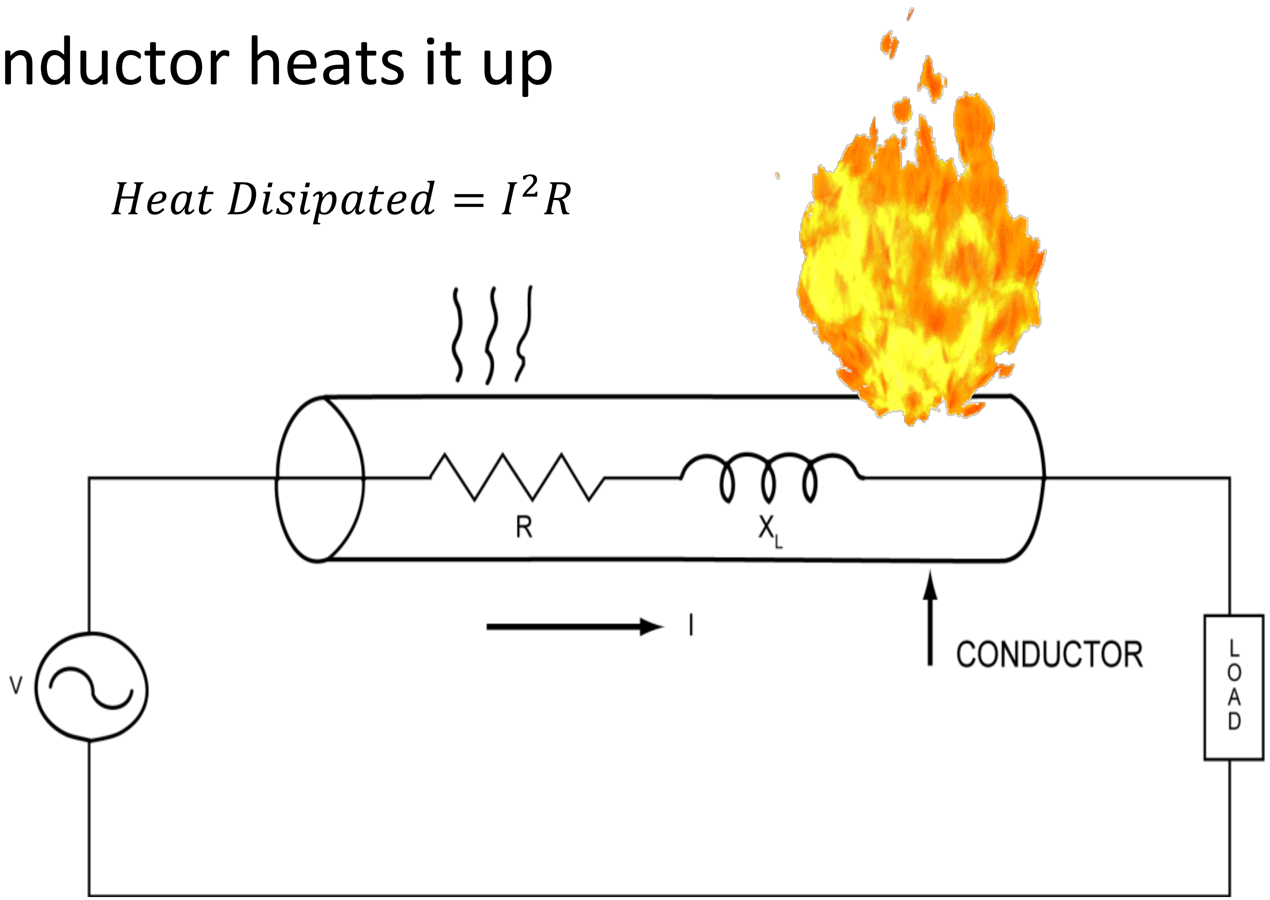
Definitions

- Thermal Limit/Rating
  - A boundary on the current carrying capability of equipment to prevent operation at excessive temperatures
    - A thermal restriction is placed on every piece of equipment that carries current
  - Most commonly stated in MVA but also could be in Amps
  - Varies with
    - Temperature (8 temperature sets)
    - Wind speed (Ratings calculated at fixed wind speed)
    - Daylight intensity (Day vs Night ratings)
    - Equipment (Various limitations on equipment)
    - Time of applied current
(Normal, Long/Short-Term Emergency, Load Dump)

Determination of Thermal Limits/Ratings

- Current - Carrying Capability
  - Depends on ability to dissipate heat
  - Current flowing through conductor heats it up
  - Heat is dissipated through I^2R losses in the conductor

$$Heat\ Disipated = I^2R$$

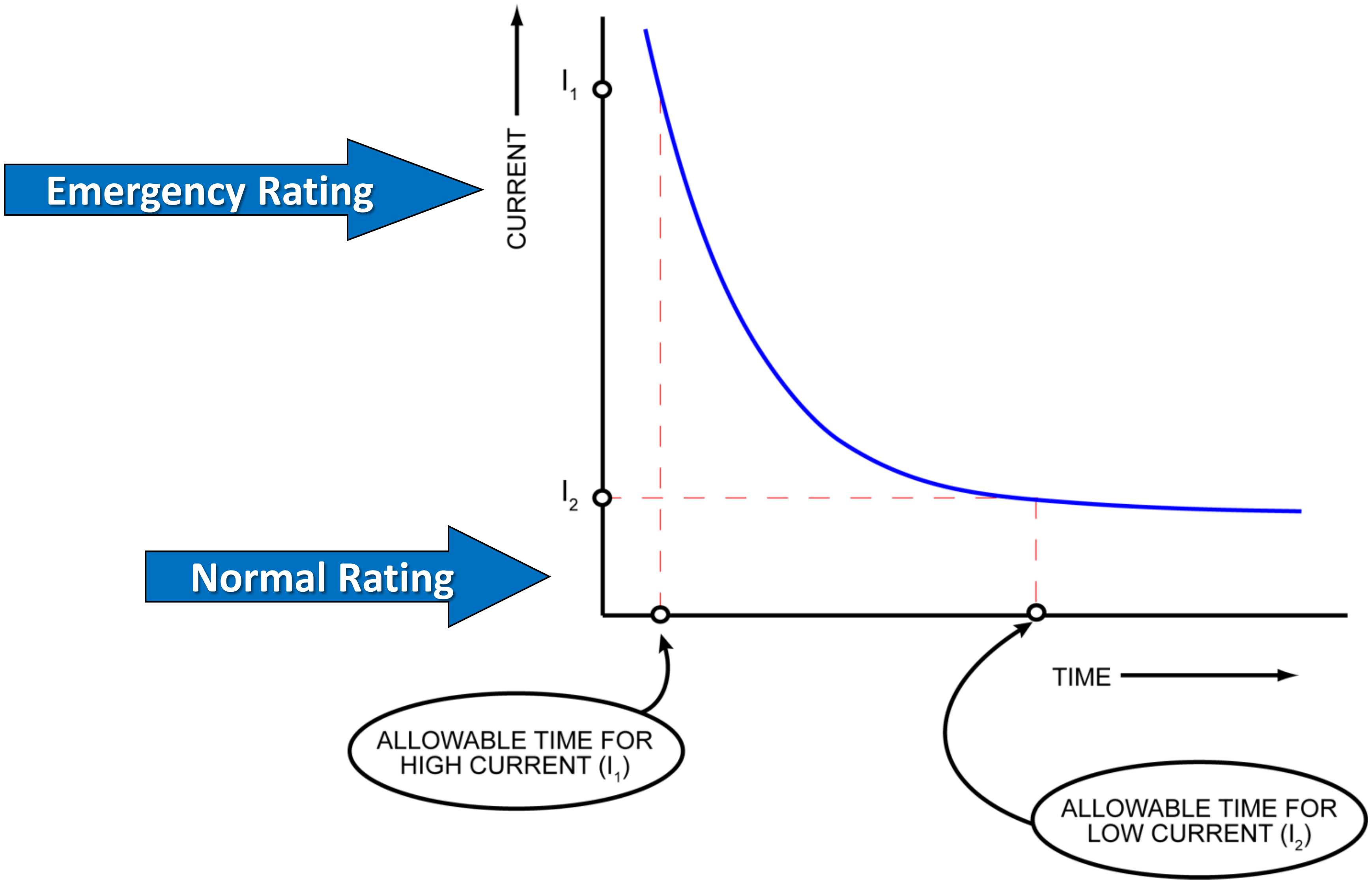


Determination of Thermal Limits/Ratings

- Factors Effecting Ratings
  - Season/Ambient Temperature
    - How fast can heat from the device be transferred to the air
    - As ambient temperature decreases, heat transfer increases
    - As ambient temperature increases, heat transfer decreases
    - PJM has 8“Ambient-adjusted” Rating sets

  - Time
    - As the current increases, it takes less time to incur damage to equipment
    - PJM uses Normal, Long/Short-Term Emergency, Load Dump Rating sets

Determination of Thermal Limits/Ratings



Rating Sets Definition

- All equipment ratings are provided by the owner of the equipment but are based on PJM's rating methodology
  - Normal (Continuous) Rating
    - Equipment can operate at this level for any length of time without incurring damage
  - Emergency Rating (Long-Term – LTE or Short-Term - STE)
    - Used to trigger contingency operation
    - Equipment can be damaged if rating exceeded in real-time
  - Load Dump Rating
    - Aids system operator in identifying speed to correct overload
    - Operation at Load Dump Rating for 15 minutes should not cause line to trip
    - Shed load to return actual flow under Load Dump Rating within 5 minutes

Thermal Limits

- LTE and STE limit are identical in most cases
- Many equipment limitations possible: Conductor, CB, CT, Meter, Relay, Clearance, Transformer, Wave Trap, Other

Temperature	Normal Limit	Long-Term Emergency Limit	Short-Term Emergency Limit	Load Dump Limit
95°	2650	3015	3015	3467
86°	2725	3090	3090	3554
77°	2780	3145	3145	3617
68°	2830	3195	3195	3674
59°	2849	3250	3250	3738
50°	2855	3300	3300	3795
41°	2855	3350	3350	3853
32°	2855	3405	3405	3916

Equipment Ratings – Dynamic vs. Static

- As previously stated, the rating for a piece of equipment is determined by how effectively the equipment can dissipate the heat generated within it by the flow of power

- Wind, rain/snow, or significant shade effects may allow equipment to exceed its default rating set for a given temperature, because it dissipate more heat

- By using Dynamic ratings, we can make adjustments to the default ratings set to allow for higher flow on a facility when conditions permit

Equipment Ratings – Dynamic vs. Static

- Additional equipment needs to be installed in the field to:
  - Allow real-time monitoring of the specific conditions occurring on the facility with the dynamic ratings, and
  - Send those readings back to the company (and PJM) EMS to determine the adjusted ratings to be used

- PJM has used Dynamic ratings at selected facilities in the PS area for several years to help reduce congestion costs

Equipment Ratings – Variations Across the Footprint

- PJM uses the actual temperatures in each zone to determine that zone's rating set
- Some zones (i.e. – AEP) have multiple sub-zones because of their size
  - If conditions are such that variations in temperatures are severe across the sub-zones, different rating sets can be used
    - If a line of thunderstorms is crossing the footprint in the summer, it may be cooler behind the storm system
    - The western sub-zone of AEP may be 10 degrees or more cooler than the eastern sub-zones

Equipment Ratings – Variations across the footprint

Mid-Atlantic

Zone	Reference City
PS	Newark, NJ
PE	Philadelphia PA
PL	Allentown, PA
JC	Morristown, MJ
ME	Reading, PA
PN	Erie, PA
PN	Johnstown, PA

Mid-Atlantic/Southern

Zone	Reference City
AE	Atlantic City, NJ
DPL	Dover, DE
BC	Baltimore, MD
PEP	Washington, DC
DOM	Richmond VA
DOM	Mount Storm, WV

APS/ATSI/DUQ

Zone	Reference City
APSNE	State College, PA
APSNW	Wheeling, WV
APSSE	Cumberland, MD
APSSW	Morgantown, WV
FETOL	Toledo, OH
FESPR	Springfield, OH
FEAKR	Akron, OH
DUQ	Pittsburgh, PA

AEP/COMED/DAY/DEOK

Zone	Reference City	Zone	Reference City
AEPAB	Abingdon VA	COMED	Chicago, IL
AEPCH	Charleston, WV	OVEC	Piketon, OH
AEPCL	Columbus, OH	DAY	Dayton, OH
AEPFW	Fort Wayne, IN	DEOK	Cincinnati, OH
AEPRN	Roanoke, VA		

Distribution Factors

Introduction to Distribution Factors

- Definition
  - The percentage of flow currently on a line that will transfer to another line as a result of the loss of the first line
- Characteristics of Distribution Factors
  - Determined by line impedances
  - Computer generated
  - Expressed as a decimal number of 1.0 or less
  - Distribution factor for a line for the loss of itself is -1.0 if line flow is positive

Introduction to Distribution Factors

- Characteristics of Distribution Factors (cont.)
  - Can be a positive or negative factor
  - Sum of all distribution factors in a closed system is zero

- Formula:

New flow on line = Previous flow + [(Dfax) (Flow on outaged facility)]

Example Simple Calculations

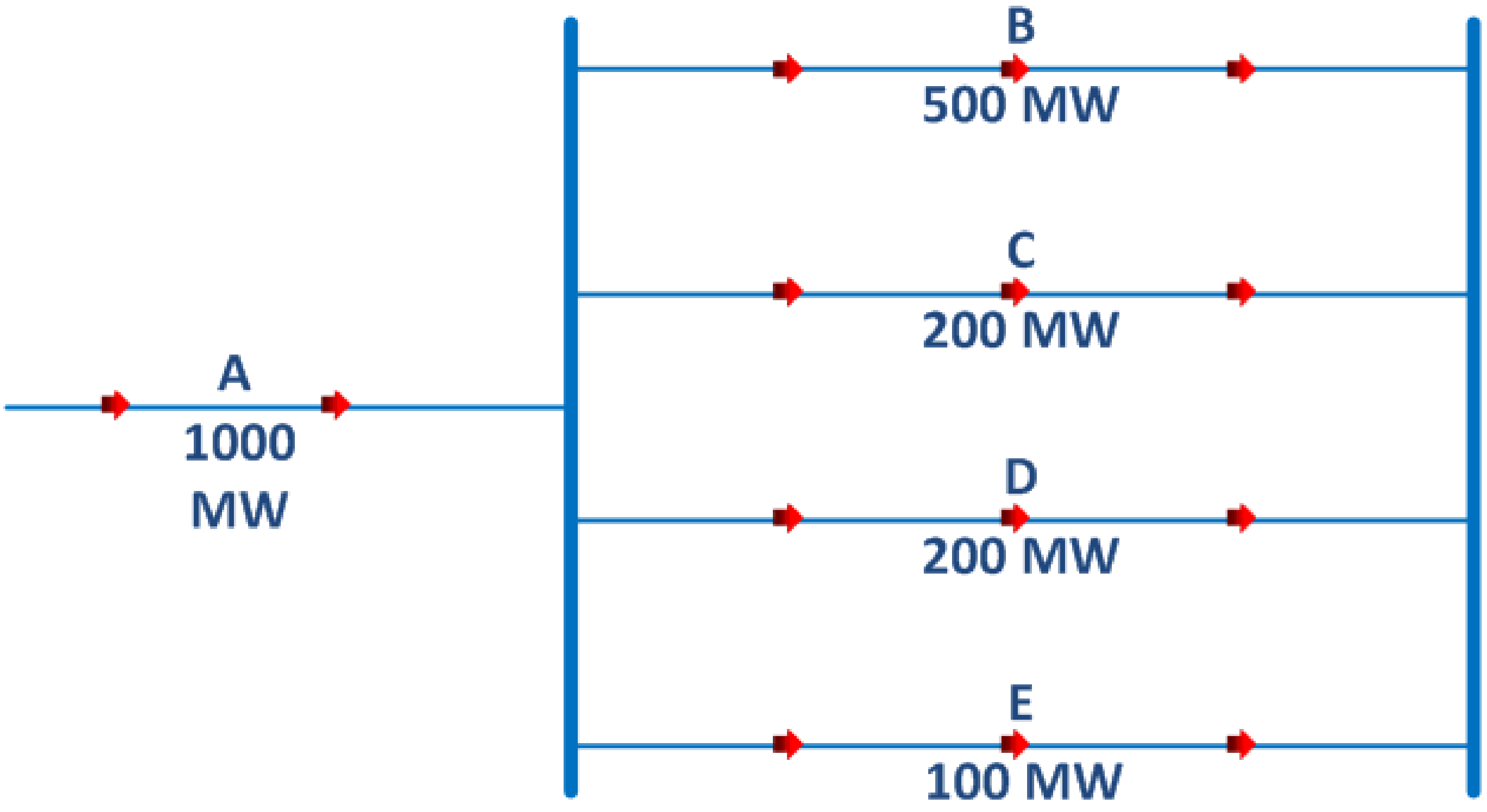
For the loss of line C:

$Dfax_B = 0.5$

$Dfax_C = -1.0$

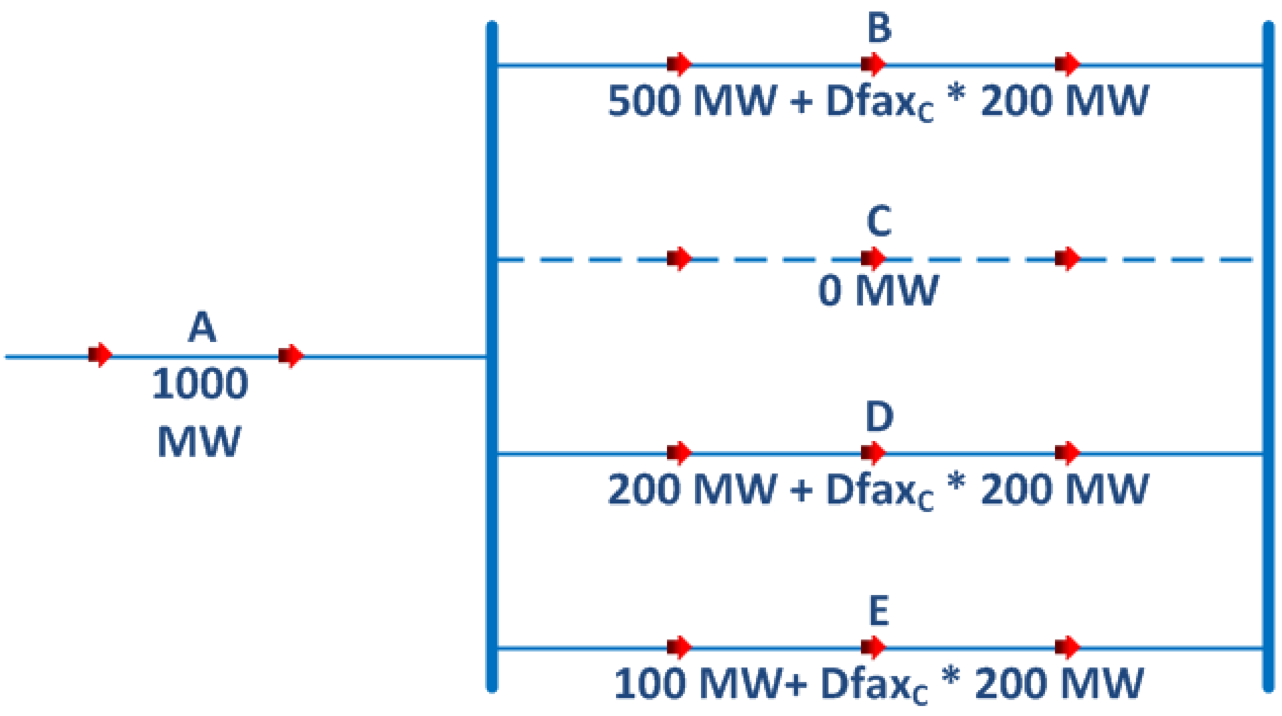
$Dfax_D = 0.3$

$Dfax_E = 0.2$



Example Simple Calculations

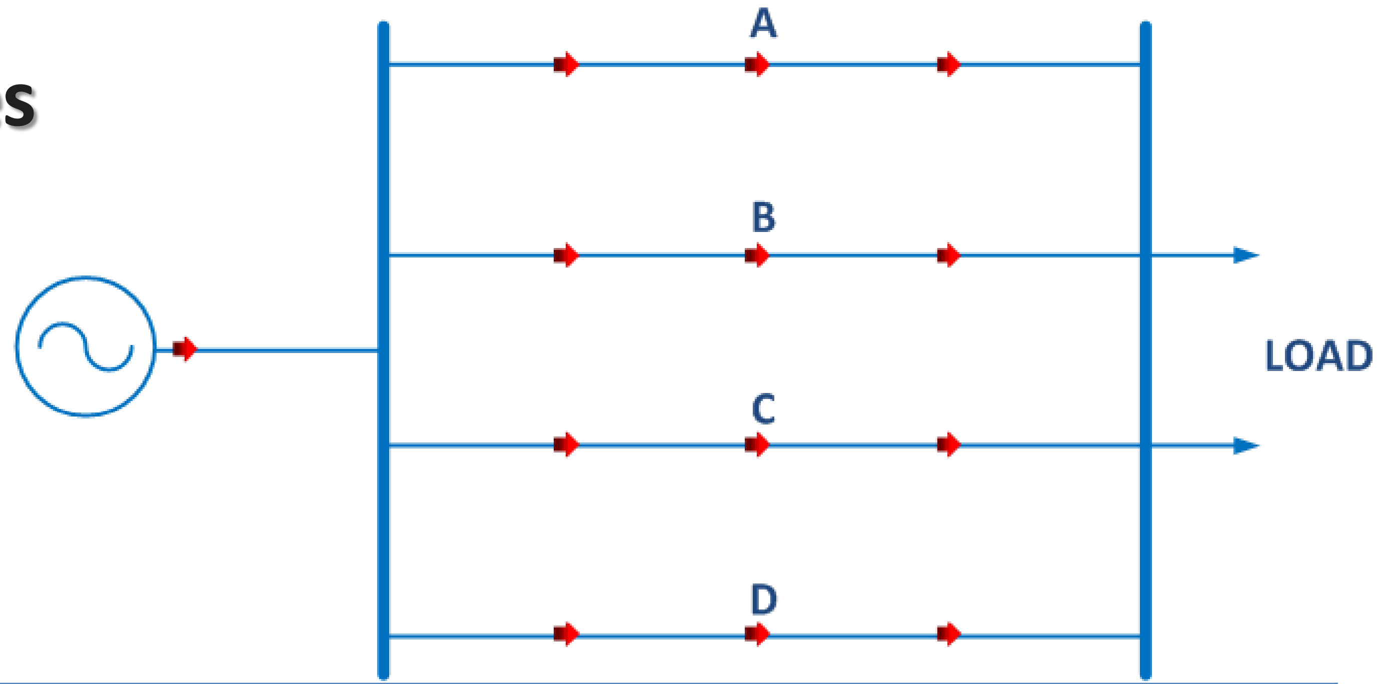
Line B	= 500 MW+ (0.5)(200 MW) = 500 MW + 100 MW = 600 MW
Line C	= 200 MW + (-1.0)(200 MW) = 200 MW – 200 MW = 0 MW
Line D	= 200 MW + (0.3)(200 MW) = 200 MW + 60 MW = 260 MW
Line E	= 100 MW + (0.2)(200 MW) =100 MW + 40 MW = 140 MW



Applications of Distribution Factors

- Line Outages
  - Use distribution factors to estimate how power will flow and predict any flow problems which may result from a line outage
    - Generally performed by computer tool
- Flow Analysis
  - Used to predict the results of losing a specific piece of equipment (Contingency analysis)

Distribution Factor Exercises



Distribution Factors for Loss of:				
	Line A	Line B	Line C	Line D
On A	-1.0	0.5	0.3	0.3
On B	0.5	-1.0	0.3	0.3
On C	0.25	0.25	-1.0	0.4
On D	0.25	0.25	0.4	-1.0

Distribution Factor Exercises

1) Calculate the line flows for each line following the loss of line B, if the initial flows were:

Line A **400 MW**	= 400 MW+ (0.5)(400 MW) = 400 MW + 200 MW = 600 MW
Line B **400 MW**	= 400 MW + (-1.0)(400 MW) = 400 MW – 400 MW = 0 MW
Line C **300 MW**	= 300 MW + (0.25)(400 MW) = 300 MW + 100 MW = 400 MW
Line D **300 MW**	= 300 MW + (0.25)(400 MW) =300 MW + 100 MW = 400 MW

Distribution Factor Exercises

2) Calculate the line flows for each line following the loss of line D, if the initial flows were:

Line A **600 MW**	= 600 MW+ (0.3)(675 MW) = 600 MW + 202.5 MW = 802.5 MW
Line B **500 MW**	= 500 MW + (0.3)(675 MW) = 500 MW + 202.5 MW = 702.5 MW
Line C **450 MW**	= 450 MW + (0.4)(675 MW) = 450 MW + 270 MW = 720 MW
Line D **675 MW**	= 675 MW + (-1.0)(675 MW) = 675 MW - 675 MW = 0 MW

Generation Shift Factors

Generation Shift Factors

- Similar to Distribution Factors
  - Decimal Fraction
  - Used to analyze the effect of generation shifts on MW flow
  - Does NOT add up to 0

- Definition
  - Fraction of change in generation MW output that will appear on a line or facility
  - Used to predict the effect of generation changes on transmission line flow

Generation Shift Factors

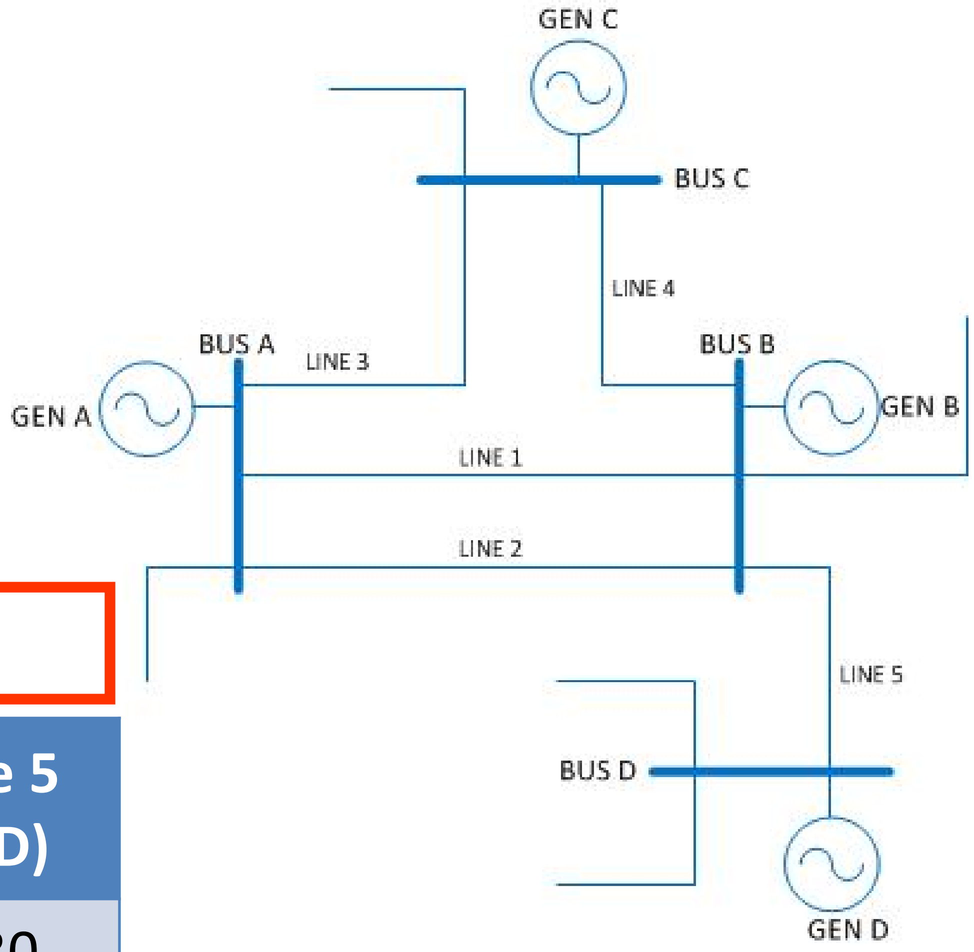
- Formula

New flow on line = Previous flow + [(Gen Shift Factor)(Amount of MW Shift)]

Generation Shift Factors

- Line 3 Flow = 500 MW
- Increase Gen A by 100 MW
- What is resultant flow on Line 3?

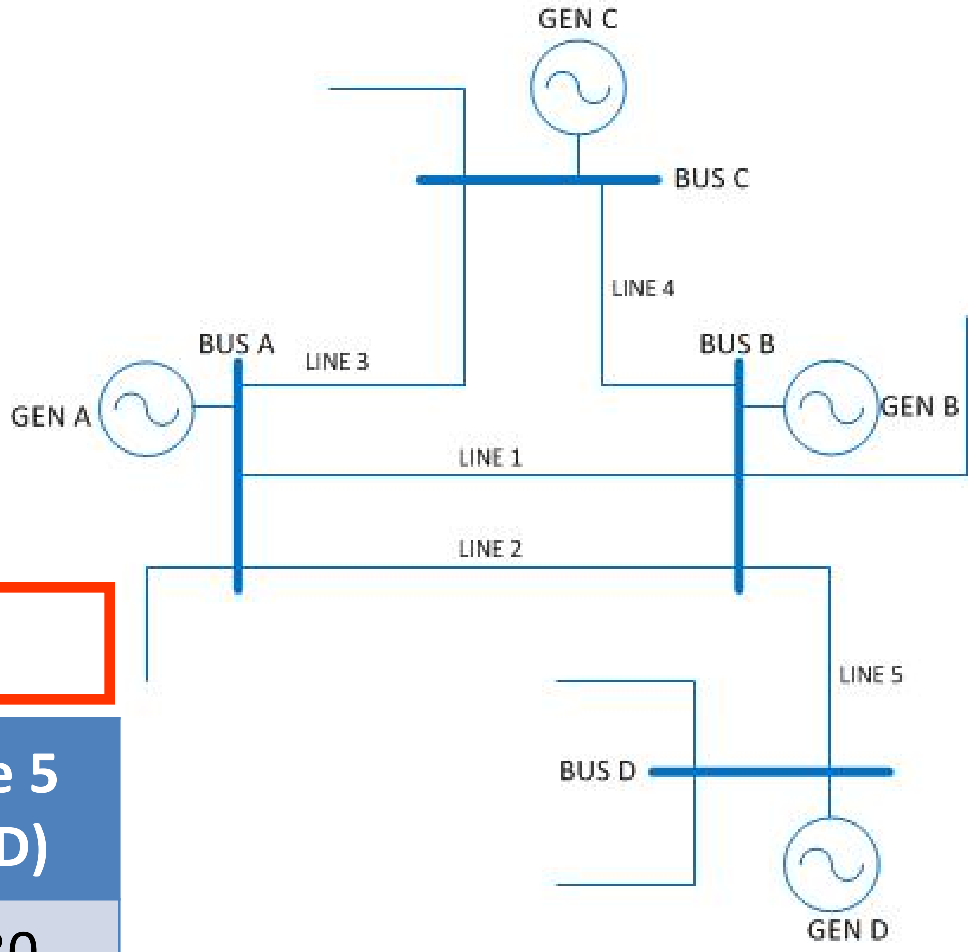
New Flow = 500 MW + (.12)(+100MW) = 512 MW



	Line 1 (A-B)	Line 2 (A-B)	Line 3 (A-C)	Line 4 (C-B)	Line 5 (B-D)
Gen A	0.30	0.30	0.12	0.12	0.30
Gen B	-0.20	-0.20	-0.06	-0.06	0.40
Gen C	-0.08	-0.08	-0.60	0.60	-.15
Gen D	-0.12	-0.12	-0.03	-0.03	-0.50

Generation Shift Factors

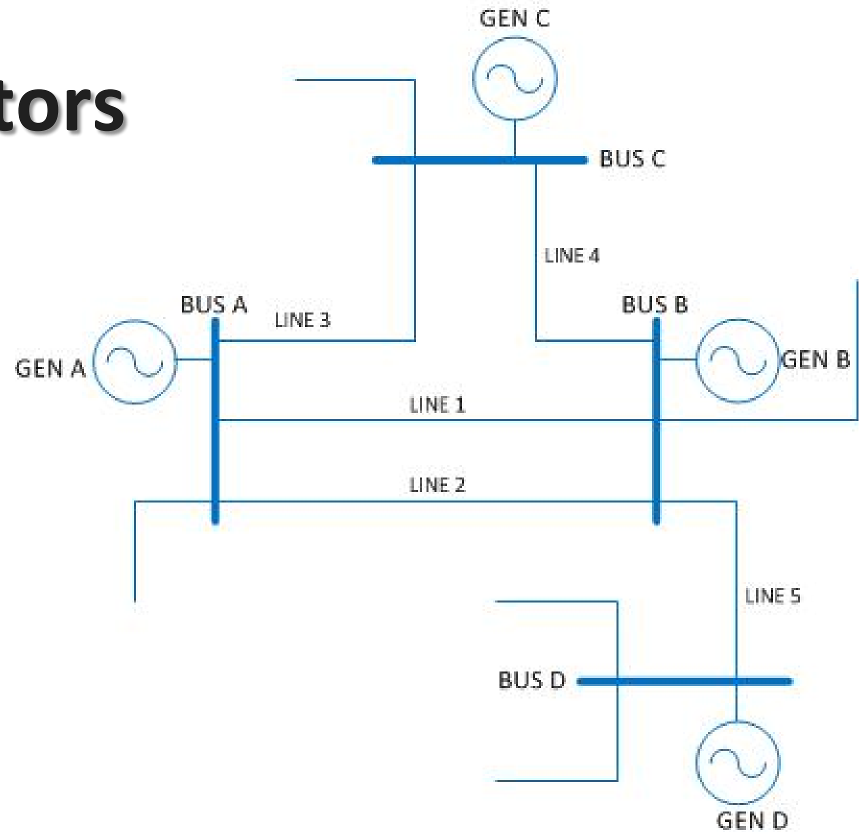
- Line 3 Flow = 512 MW
- Now, decrease Gen C by 100 MW
- What is resultant flow on Line 3?



New Flow = 512 MW + (-0.6)(-100MW) = 572 MW

	Line 1 (A-B)	Line 2 (A-B)	Line 3 (A-C)	Line 4 (C-B)	Line 5 (B-D)
Gen A	0.30	0.30	0.12	0.12	0.30
Gen B	-0.20	-0.20	-0.06	-0.06	0.40
Gen C	-0.08	-0.08	-0.60	0.60	-.15
Gen D	-0.12	-0.12	-0.03	-0.03	-0.50

Generation Shift Factors



	Line 1 (A-B)	Line 2 (A-B)	Line 3 (A-C)	Line 4 (C-B)	Line 5 (B-D)
Gen A	0.30	0.30	0.12	0.12	0.30
Gen B	-0.20	-0.20	-0.06	-0.06	0.40
Gen C	-0.08	-0.-8	-0.60	0.60	0.15
Gen D	-0.12	-0.12	-0.03	-0.03	-0.50

Generation Shift Factors Exercises

	Line 1 (A-B)	Line 2 (A-B)	Line 3 (A-C)	Line 4 (C-B)	Line 5 (B-D)
Gen A	0.30	0.30	0.12	0.12	0.30
Gen B	-0.20	-0.20	-0.06	-0.06	0.40
Gen C	-0.08	-0.-8	-0.60	0.60	0.15
Gen D	-0.12	-0.12	-0.03	-0.03	-0.50

1) The flow on Line 1 (A-B) is 850 MW. Generator A output is increased by 100 MW. What is the new flow on Line 1 (A-B)?

New Line 1 Flow= 850 + (100)(0.30)=850+30=880 MW

2) Now Generator B decreases output by 100 MW. What is the new flow on Line 1 (A-B)?

New Line 1 Flow= 880 + (-100)(-0.20)=880+20=900 MW

Generation Shift Factors Exercises

	Line 1 (A-B)	Line 2 (A-B)	Line 3 (A-C)	Line 4 (C-B)	Line 5 (B-D)
Gen A	0.30	0.30	0.12	0.12	0.30
Gen B	-0.20	-0.20	-0.06	-0.06	0.40
Gen C	-0.08	-0.-8	-0.60	0.60	0.15
Gen D	-0.12	-0.12	-0.03	-0.03	-0.50

3) The flow on Line 1 (A-B) is 1100 MW. This flow must be reduced to 1000 MW to relieve an overload. You want to reduce the flow by reducing Generator A output and increasing Generator B output an equal amount. How much should the output on each unit be adjusted? (Hint: Let the change on A be -X MW, and the change on B will be X MW)

Line 1 Flow

1000 MW = 1100 MW + [(-X)(0.3)+(X)(-0.2)]
1000 MW = 1100 MW + -0.3X + -0.2X
1000 MW = 1100 MW + -0.5X
1000 MW – 1100 MW = -0.5X
-100 MW = -0.5X
-100 MW/-0.5 = X = 200 MW
Gen A reduce by 200 MW, Gen B increase by 200 MW

Generation Shift Factors Exercises

	Line 1 (A-B)	Line 2 (A-B)	Line 3 (A-C)	Line 4 (C-B)	Line 5 (B-D)
Gen A	0.30	0.30	0.12	0.12	0.30
Gen B	-0.20	-0.20	-0.06	-0.06	0.40
Gen C	-0.08	-0.-8	-0.60	0.60	0.15
Gen D	-0.12	-0.12	-0.03	-0.03	-0.50

4) The flow on Line 5 (B-D) is 1200 MW and the flow must be reduced to 1000 MW by shifting generation. Select two units to adjust output to eliminate the overload while maintaining a balanced ACE. How many MW does each unit have to change to reduce Line 5 (B-D) flow to 1000 MW?

GEN B&D

Line 5 Flow

1000 MW = 1200 MW + [(-X)(0.4)+(X)(-0.5)]

1000 MW = 1200 MW + -0.4X + -0.5X

1000 MW = 1200 MW + -0.9X

1000 MW - 1200 MW = -0.9X

-200 MW = -0.9X

-200 MW/-0.9 = X = 222 MW

Gen B reduce by 222 MW, Gen D increase by 222 MW

Generation Shift Factors Exercises

GEN A&D

Line 5 Flow

1000 MW = 1200 MW + [(-X)(0.3)+(X)(-0.5)]
1000 MW = 1200 MW + -0.3X + -0.5X
1000 MW = 1200 MW + -0.8X
1000 MW - 1200 MW = -0.8X
-200 MW = -0.8X
-200 MW/-0.8 = X = 250 MW
Gen B reduce by 250 MW, Gen D increase by 250 MW

GEN C&D

Line 5 Flow

1000 MW = 1200 MW + [(-X)(0.15)+(X)(-0.5)]
1000 MW = 1200 MW + -0.15X + -0.5X
1000 MW = 1200 MW + -0.65X
1000 MW - 1200 MW = -0.65X
-200 MW = -0.65X
-200 MW/-0.65 = X = 307.7 MW
Gen B reduce by 307.7 MW, Gen D increase by 307.7 MW

$/MW Effect

- Adjustment of Shift Factors due to Economics
- Definition
  - $/MW Effect = (Current Dispatch Rate - Unit Bid) / Unit Generator Shift Factor
  - Unit with lowest $/MW effect is redispatched when system is constrained
  - Other unit operating constraints taken into account (I.e. min run time, time from bus, etc)
  - In an emergency, economics takes the “back seat” to reliability

Types of Limits

Types of Limits

- Thermal Limit/Rating
  - A boundary on the current carrying capability of equipment to prevent operation at <u>excessive temperatures</u>
    - A thermal restriction is placed on every piece of equipment that carries current
- Voltage limit
  - Maintain system reliability
    - High voltage limit protects equipment from damage
    - Low voltage limit protects system from voltage instability and equipment damage

Types of Limits

- Stability Limits
  - Stability is related to the angular separation between points in the power system
  - Prevents electrical separation of a generating unit or a portion of the PJM RTO
  - Typical angular separation of the voltages for a high voltage transmission is small, ranging from 5° to 15°
  - When a system is angle unstable, angle differences grow to larger values
    - For example, angle differences may exceed 90°. System operators lose control of both MW and MVAR flows in an angle unstable system

Types of Limits

- System Operating Limit (SOL)
  - The value (such as MW, MVAR, Amperes, Frequency or Volts) that satisfies the most limiting operating criteria for a specified system configuration to ensure operation within acceptable reliability criteria
  - Based upon certain operating criteria. These include, but are not limited to:
    - Facility Ratings
    - Transient Stability Ratings
    - Voltage Stability Ratings
    - System Voltage Limits

Types of Limits

- Interconnection Reliability Operating Limit (IROL)
  - A System Operating Limit that, if violated, could lead to instability, uncontrolled separation, or cascading outages that adversely impact the reliability of the Bulk Electric System

PJM Thermal Operating Criteria

PJM Thermal Operating Criteria

- Thermal Operating Criteria
  - Actual Flow less than Normal Rating
  - Contingency Flow less than Long-Term Emergency Rating
  - Operators must be aware when line flows are approaching a limit on both an actual and contingency basis
    - Approaching a system limit
      - Analyze situation
      - Develop game plan
      - Implement plan

PJM Thermal Operating Criteria

- System Operating Limit in PJM
  - All BES facilities and those sub- BES facilities identified as “Reliability and Markets” facilities that are not considered IROL facilities are considered System Operating Limits (SOL)
    - An SOL violation is defined as a non-converged contingency or actual thermal overload violating a limit consistent with the facilities rating duration (i.e. Normal limit = 24 hours, LTE limit = 4 hours)

PJM Thermal Operating Criteria

- Interconnection Reliability Operating Limit in PJM if exceeded, could expose a widespread area of the Bulk Electric System to instability, uncontrolled separation(s) or cascading outages
  - PJM classifies a facility as an IROL facility on the PJM system if wide-area voltage violations occur at transfer levels that are near the Load Dump thermal limit
    - An IROL violation is defined as either flows exceeding the last convergent case transfer limit for 30 minutes or post-contingency simulated flows exceeding the facility load dump limit for 30 minutes

PJM Thermal Operating Criteria

- Interconnection Reliability Operating Limit T_V
  - The maximum time that an IROL can be violated before the risk to the Interconnection or other Reliability Coordinator Area (s) becomes greater than acceptable
  - Each IROLs T_V shall be less than or equal to 30 minutes
    - PJM uses 30 minutes as its T_V for all its IROLs

PJM Thermal Operating Criteria

- Thermal Operating Criteria
  - Control all constraints (actual and contingency) within 30 minutes 100% and within 15 minutes 80% of the time
  - At times, operator may be faced with multiple problems at the same time and have to prioritize the order in which to address them

PJM Thermal Operating Criteria

- Control Prioritization
  - First: Non-Converged Contingency
    - Could be worst problem (voltage collapse) or due to bad data
      - Operator needs to determine cause of non-convergence and take action if problem is real
  - Second: IROL violations
    - Contingency could result in a system collapse
    - Must be controlled within 30 minutes, 100% of time
      - If not, it must be reported to NERC

PJM Thermal Operating Criteria

- Control Prioritization
  - Third: Reactive Transfer Interfaces
    - These are all currently IROL facilities
  - Fourth: Actual Violations
    - Actual flows > Normal limit
    - Prioritize Actual violations based on amount that rating is exceeded and potential system impact
  - Fifth: Contingency Violations
    - Smaller chance of contingency actually occurring
    - If contingency occurs, it becomes actual

PJM Thermal Operating Criteria

Thermal Limit Exceeded	Corrective Actions	Time to correct with Load Shed (Note 1)
Normal Rating (Actual flow greater than Normal Rating but less than Emergency Rating)	Non-cost actions, off-cost actions, emergency procedures except Load Shed Operating Instruction (See M-13, Emerg. Proc.)	Within 15 minutes, load shed is not used
Emergency Rating (Actual flow greater than Emergency Rating but less than Load Dump Rating)	All of the above including Load Shed Operating Instruction to control flow below Emergency Rating	Within 15 minutes (Note 2)
Load Dump Rating (Actual flow greater than Load Dump Rating)	All of the above including Load Shed Operating Instruction to control flow below Emergency Rating	Within 5 minutes (Note 1) (Note 3)

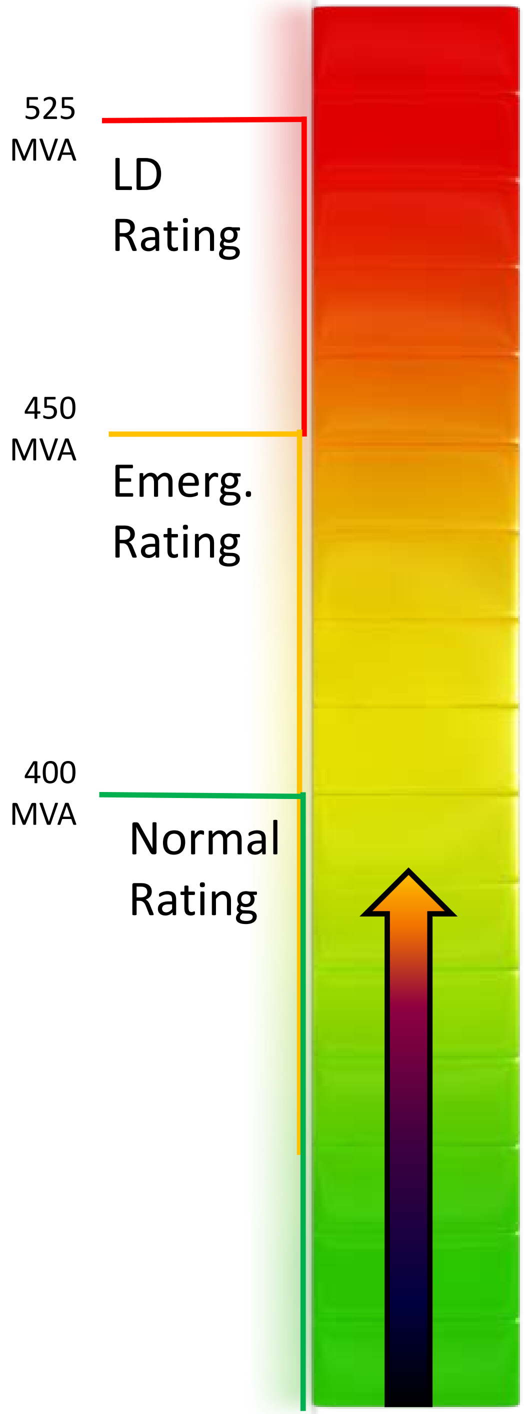
Legend
Non-Cost
Off-Cost
Load Shedding

Note 1: For unplanned load shed events, TO must initiate load dump action within 5 minutes after PJM issues a Load Shed Operating Instruction. TO must not exceed the time based duration of any emergency rating/load dump rating.
Note 2: TOs have the option of providing STE limits that are least 30-minutes in duration. The STE rating allows the time before load shed to be extended provided the actual flow does not exceed the STE rating. If the actual flow is above the LTE but below STE, load must be shed within the times indicated in Attachment F for the facility, if other corrective actions were not successful
Note 3: Dump load to get below Emergency Rating within 5 minutes.

Example

If Actual Flow < Normal Rating:

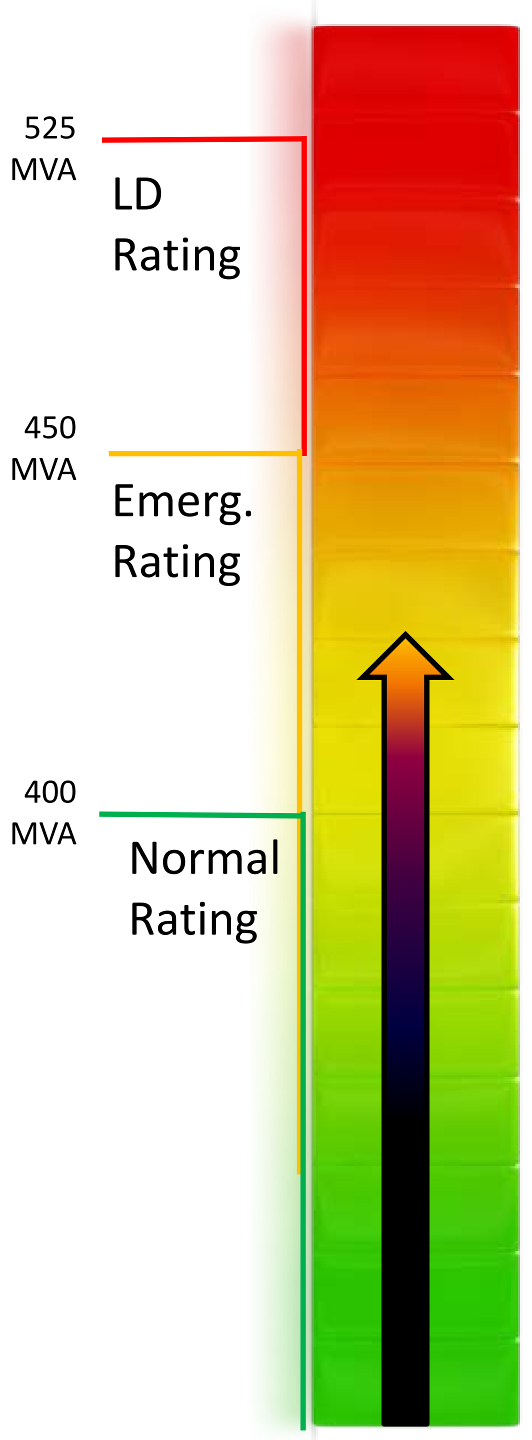
- No corrective actions are required
- No limits are violated



Example

Actual Flow (430 MVA) is < LTE but > Normal Rating:

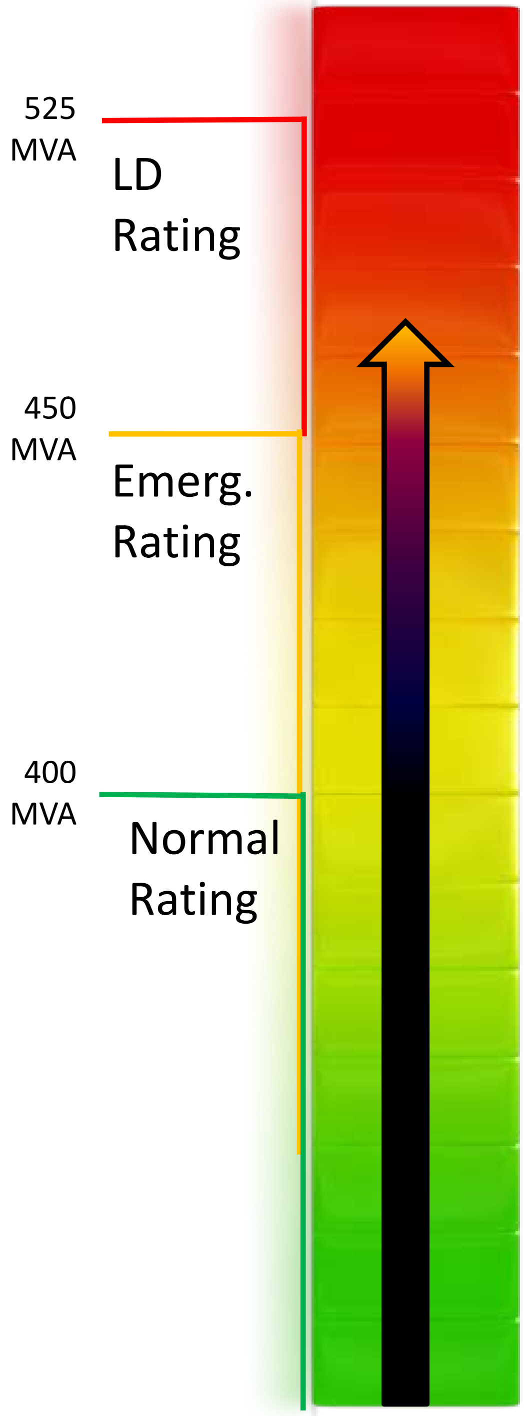
- Corrective Actions:
  - Non-cost
  - Off-cost options
  - No load shed would be performed
- Goal is to correct problem in:
  - 15 minutes
    - May not be possible since load shed is not a controlling action



Example

Actual Flow (520 MVA) is > LTE but < LD:

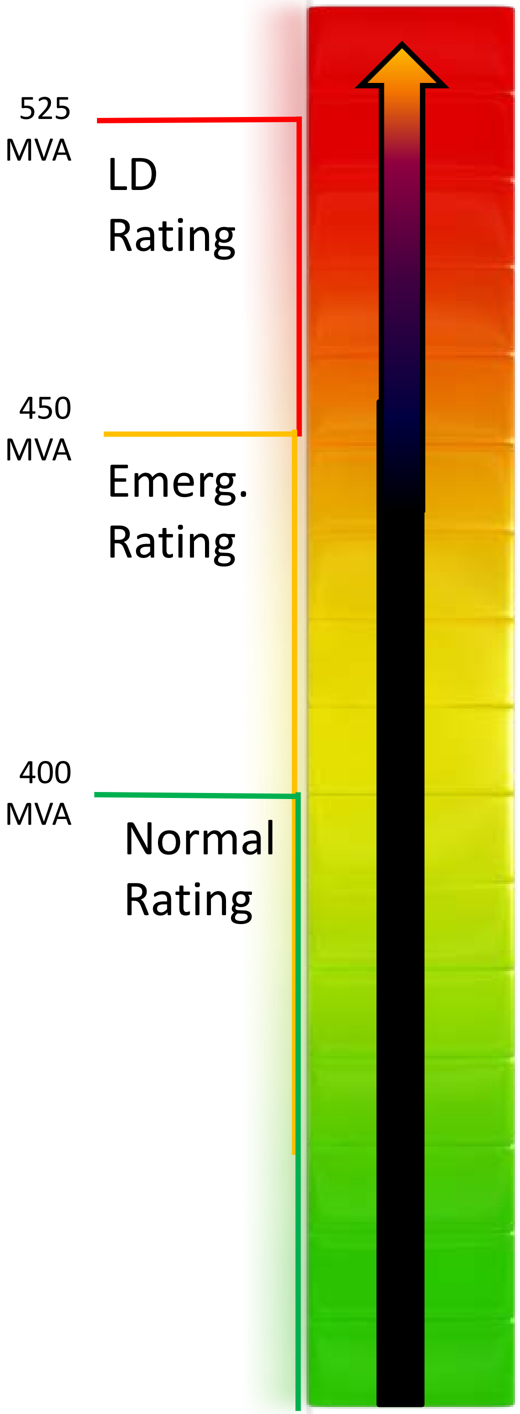
- Corrective Actions:
  - Non-cost
  - Off-cost
  - Load shed options
- Load shed performed to return Actual flow below:
  - LTE rating: Within 15 minutes
- Relief needed?
  - 70 MVA
    - May require more than 70 MVA of load shed based on Dfax



Example

Actual Flow (550 MVA) > LD:

- Corrective Actions include:
  - Non-cost
  - Off-cost
  - Load shed
- Load shed performed to return Actual flow below:
  - LD rating: Within 5 minutes
  - LTE rating: Within time remaining
  - Times are not cumulative!
- Relief needed:
  - 100 MVA
    - This may require more than 100 MVA of load shed based on Dfax

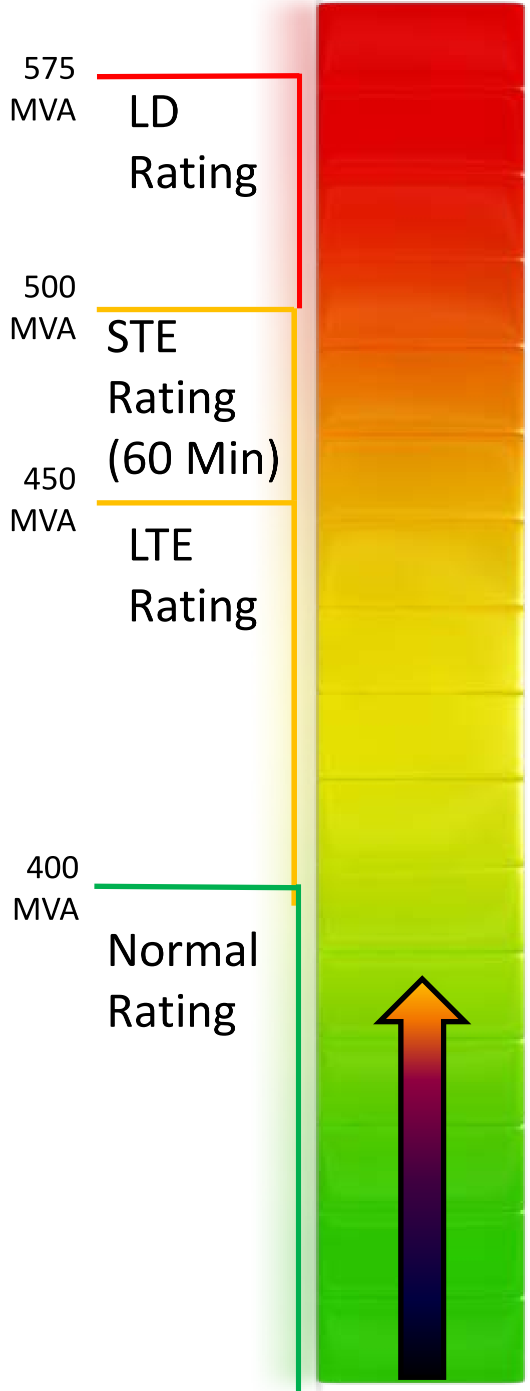


Normal, Long Term, Short Term and Load Dump Example

Example

If Actual Flow < Normal Rating:

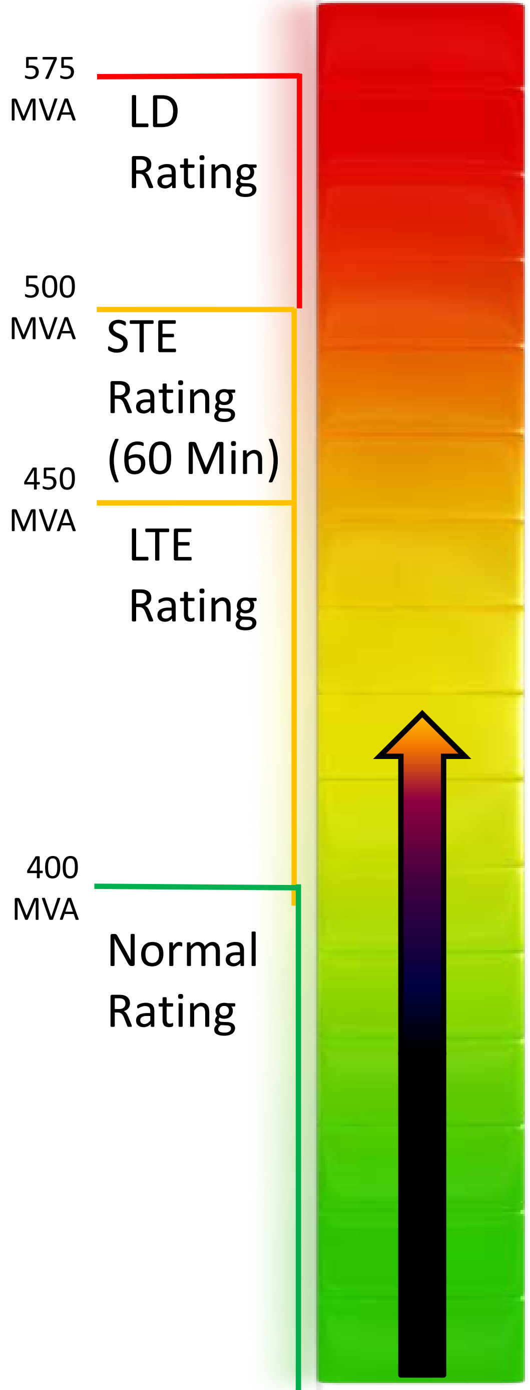
- No corrective actions are required
- No limits are violated



Example

Actual Flow (425 MVA) is < LTE but > Normal Rating:

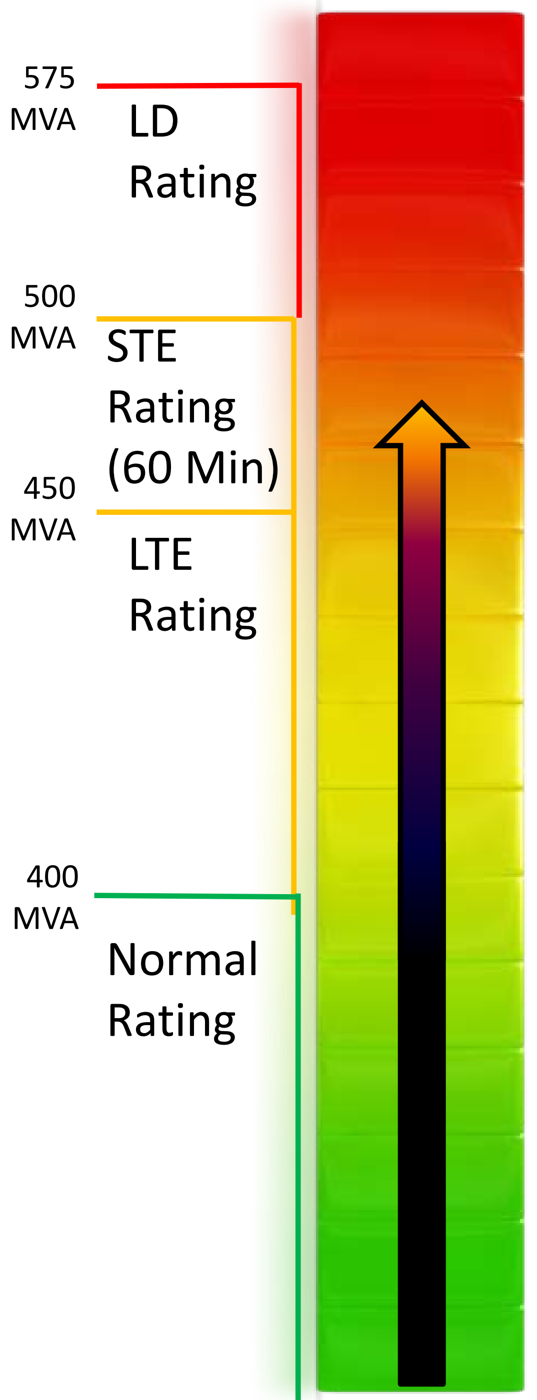
- Corrective Actions include:
  - Non-cost
  - Off-cost options
  - No load shed would be performed
- Goal is to correct problem in:
  - 15 minutes
    - May not be possible since load shed is not a controlling action



Example

Actual Flow (475 MVA) is > LTE but < STE:

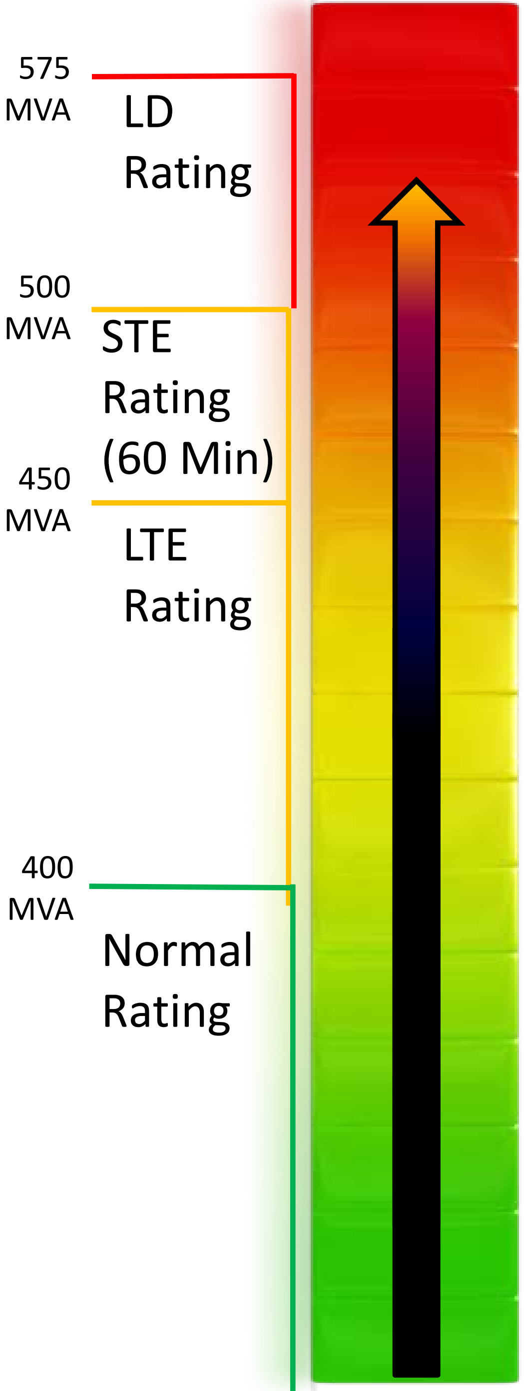
- Corrective Actions include:
  - Non-cost
  - Off-cost
  - Load shed
- Load shed would be performed to return Actual flow:
  - LTE rating
    - Within the rating duration of the STE
      - In this example; within 60 minutes
- Relief needed:
  - 25 MVA
    - This may require more than 25 MVA of load shed based on distribution factor effect



Example

Actual Flow (530 MVA) is > STE but < LD:

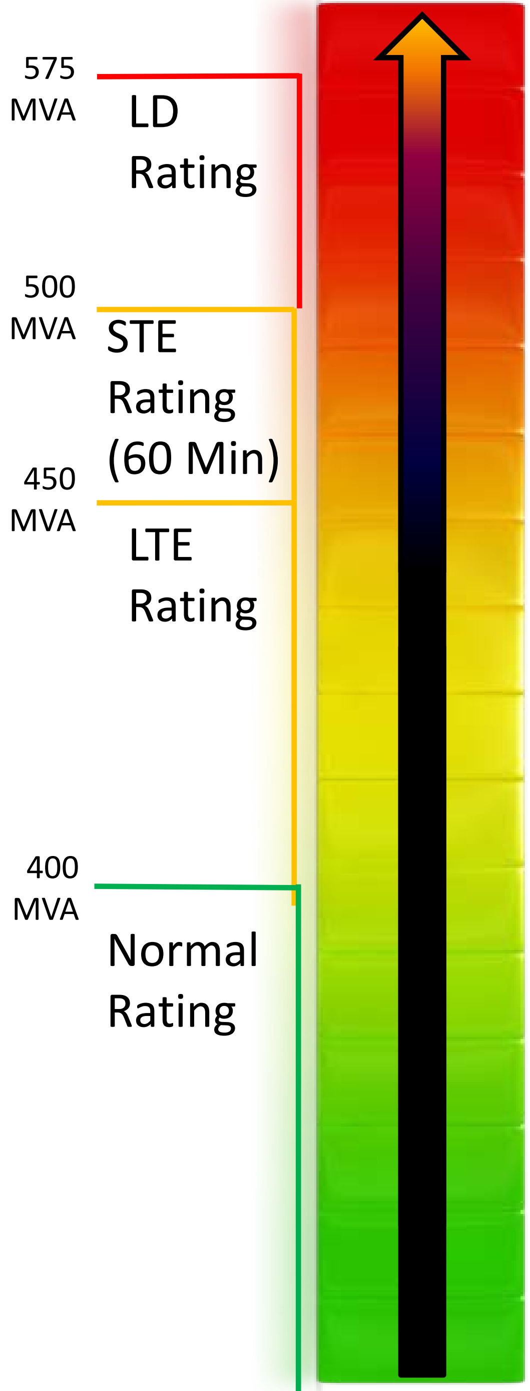
- Corrective Actions include:
  - Non-cost
  - Off-cost
  - Load shed
- Load shed performed to return Actual flow below:
  - STE rating: Within 15 minutes
  - LTE rating: Within the remaining time
  - Times are not cumulative!
- Relief needed:
  - 80 MVA
    - This may require more than 80 MVA of load shed based on Dfax



Example

Actual Flow (600 MVA) > LD:

- Corrective Actions include:
  - Non-cost
  - Off-cost
  - Load shed
- Load shed performed to return Actual flow below:
  - LD rating: Within 5 minutes
  - STE rating: Within 15 minutes, or time remaining
  - LTE rating: Within 60 minutes, or time remaining
  - Times are not cumulative!
- Relief needed:
  - 150 MVA
    - This may require more than 150 MVA of load shed based on Dfax



PJM Thermal Operating Criteria

Thermal Limit Exceeded	If Post Contingency simulated loading exceeds limit	Time to correct
Normal	Trend – continue to monitor. Take non-cost actions to prevent contingency from exceeding emergency limit	**N/A**
Emergency	Use all effective actions and emergency procedures except load dump	**30 minutes**
Load Dump	All of the above however, shed load only if necessary to avoid post-contingency cascading	**30 minutes**

Legend
Non-Cost
Off-Cost
Load Shedding

Exhibit 2: PJM Post-Contingency Simulated Thermal Operating Policy

Note : System readjustment should take place within 30 minutes. PCLLRW should be implemented as post-contingency violations approach 60 minutes in duration. However, PCLLRW can be issued sooner at the request of the Transmission Owner of if the PJM Dispatcher anticipates controlling actions cannot be realized within 60 minutes due to longer generator start-up + notification times

Consequences of Violating Thermal Limits

Consequences of Violating Thermal Limits

- Lines
  - Conductor Sag
  - Could lead to loss of the facility
  - Flows will be redistributed on other lines
    - Rule of Thumb - For the loss of a line flowing towards station, the other lines flowing toward station will increase while the lines flowing out of station will decrease
    - Rule of Thumb - For the loss of a line flowing out of a station, the other lines flowing out of station will increase while the lines flowing toward a station will decrease
  - Increased flows could lead to more overloads and if severe enough, possible cascading trips, system separation and blackout

Consequences of Violating Thermal Limits

- Transformers
  - Overheating may cause damage to the winding insulation or thermal damage to the oil
- Generators
  - Rotor and stator winding insulation damage
  - Generator could trip off line to protect it from damage
  - Results in possible voltage drop and MW and MVAR in-flow from the rest of the system
  - Affects on system power flows
    - Rule of Thumb - For a loss of generation, flows toward station will increase and flows out of station will decrease

Controlling Thermal Violations

- ***Non-cost Responses to Thermal Violations***
  - Restore tripped equipment quickly if possible
    - Generally cables and transformers are not reclosed following a tripping
  - Remove faulted equipment from system
    - Isolate faulted equipment through switching
  - Activate Special Purpose Relays
  - Approved switching procedures
  - Adjust Phase Angle Regulators (PARS)

Controlling Thermal Violations

- ***Off-cost Responses to Thermal Violations***
  - Curtail Non-firm transactions NOT willing to pay congestion
  - Re-dispatch generation
  - Cancel maintenance
    - Request return of outage equipment
  - NERC Transmission Loading Relief (TLR)
  - Initiate ALL Emergency Procedures EXCEPT Load Shed
    - Including Manual Load Dump Warning and Post Contingency Local Load Relief Warning

Controlling Thermal Violations

- ***Load Shedding Response to Thermal Violations***
  - Determine if load shedding is required
    - All other control actions have been exhausted
    - Over emergency or load dump rating on an actual basis
    - Over load dump rating on contingency basis if analysis indicates potential for cascading thermal overloads
  - Determine amount of load shed necessary
  - Determine location of load shed
    - Local vs. System-wide
  - Shed load proportional among Native Load customers, Network customers and firm point-point service

Remedial Action Schemes

Disclaimer

- This presentation explains the types of RASs that are able to be employed on transmission and distribution systems
- Examples of RASs will be provided for schemes that are used in the PJM RTO. Each individual scheme on the PJM system is not covered in this presentation
- Further information regarding specific RASs can be located in **Section 5 of PJM Manual 3**

Solution: Use Remedial Action Schemes (RAS)

- Remedial Action Schemes (RAS)
  - Designed to **detect abnormal system conditions and initiate predetermined actions** to maintain the reliability of the bulk electric system (BES)
- Actions include:
  - Changes in demand
  - Changes in generation output
  - Changes in system configuration

- Goals of an RAS:
  - Maintain system stability
  - Maintain acceptable system voltages
  - Maintain all facilities within acceptable thermal limits

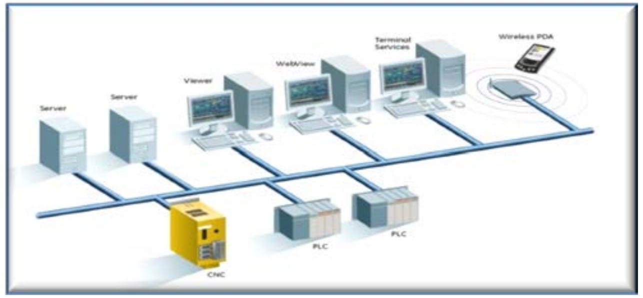
Names of RAS

- These schemes can be referred to in multiple ways:
  - Remedial Action Schemes (RAS)
  - Wide-area monitoring, protection, automation and control system (WAMPACS)
  - Wide-area protection system (WAPS)
  - Emergency control system (ECS)

RAS Requirements

Relays

Communication Network



Scheme Logic

IF circuit breaker X trips ***THEN*** circuit breakers Y and Z will____?

RAS Questions for Activation

- Does the scheme require manual activation (communication protocol)?
- What are the conditions that will activate the scheme?
- What conditions make the scheme nonfunctional?
- What procedures are in place should the SPS/RAS become unavailable?
- Is my contingency analysis modeled properly based on the relay scheme logic?
- Is the bulk electric system in a reliable posture following the activation of the SPS/RAS?

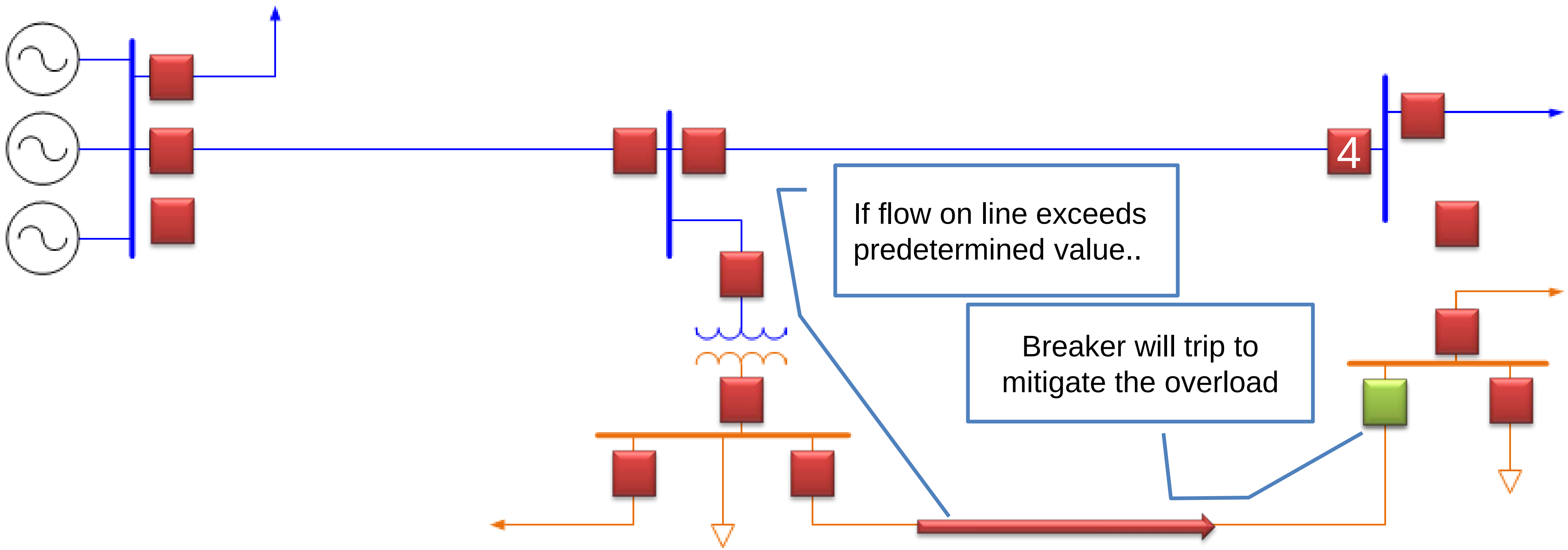
Types of RAS

Types of RAS

- Remedial Action Schemes are designed to perform several functions. These include:
  - Trip or transfer trip a facility
  - Initiate generator run-back/load rejection/fast valving schemes
  - Shed load

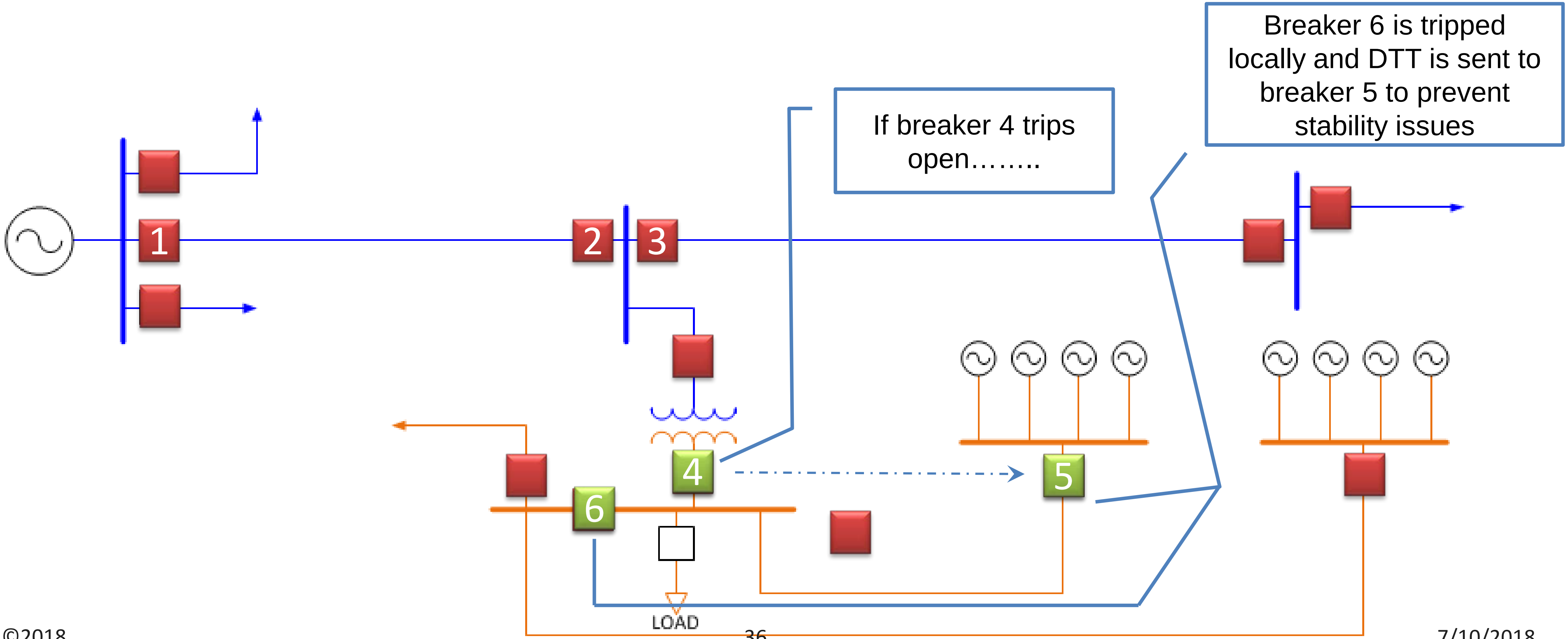
Trip Scheme

- Trip scheme will initiate breaker operation to mitigate overload



Transfer Trip Scheme

- Will coordinate breaker operations to initiate remote tripping based on a predetermined set of conditions



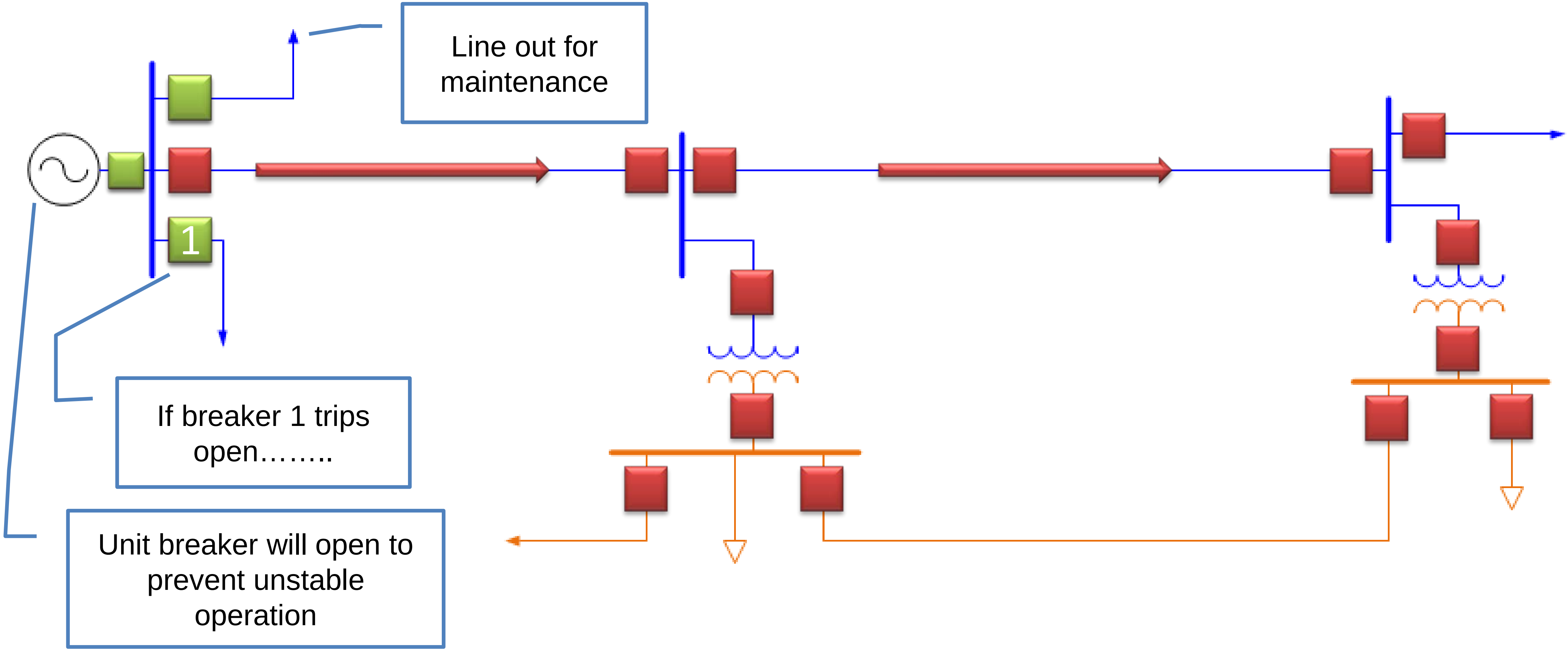
Generation Runback/Load Rejection

- Used to maintain system stability following loss of load events
  - Full Load Rejection (Generator Runback)
  - Partial Load Rejection
  - Fast Valving
- Most PJM generator runback schemes are Full Load Rejection

Generation Runback/Load Rejection

- Full Load Rejection
  - Main generator breakers trip
  - Loss of synchronization and full load
  - Steam generators runback from full load to no-load

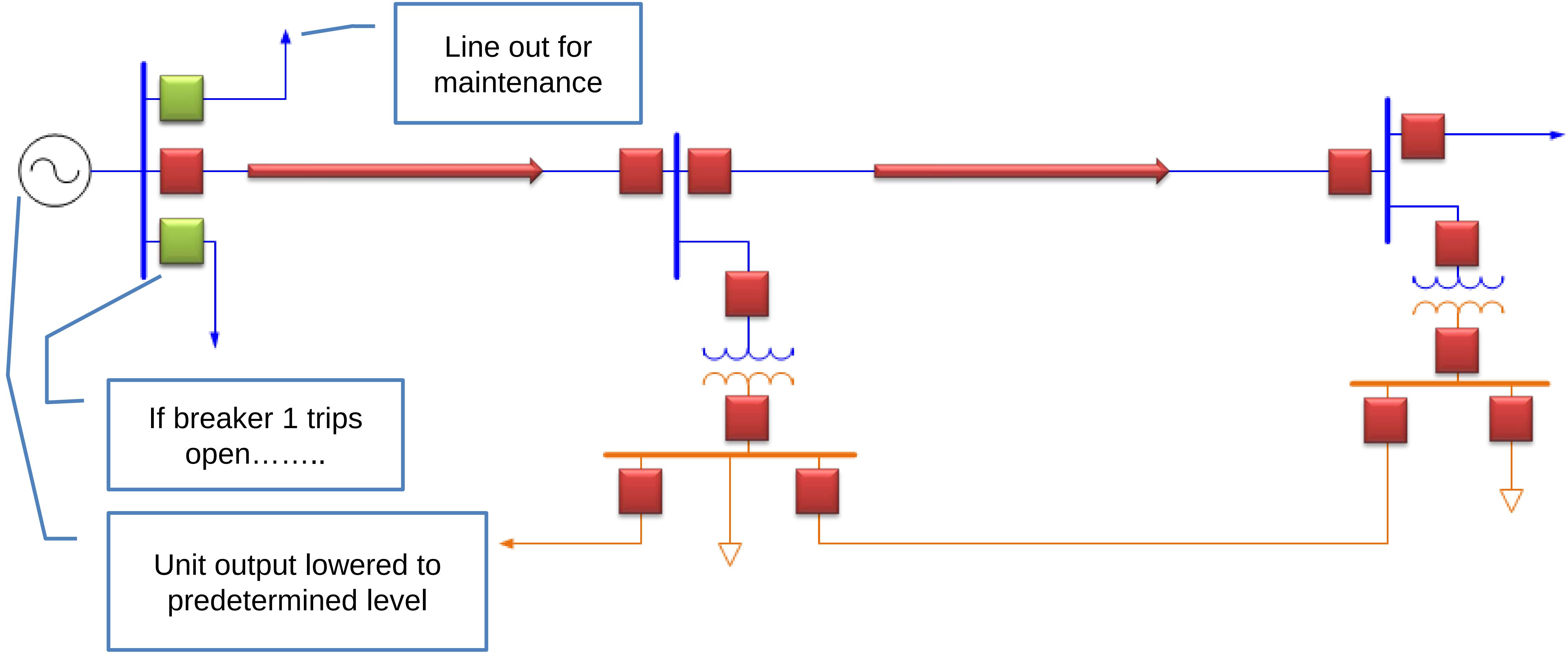
Generation Runback/Load Rejection



Generation Runback/Load Rejection

- Partial Load Rejection:
  - Main generator breakers remain closed
  - Loss of partial load (10% to 50%)

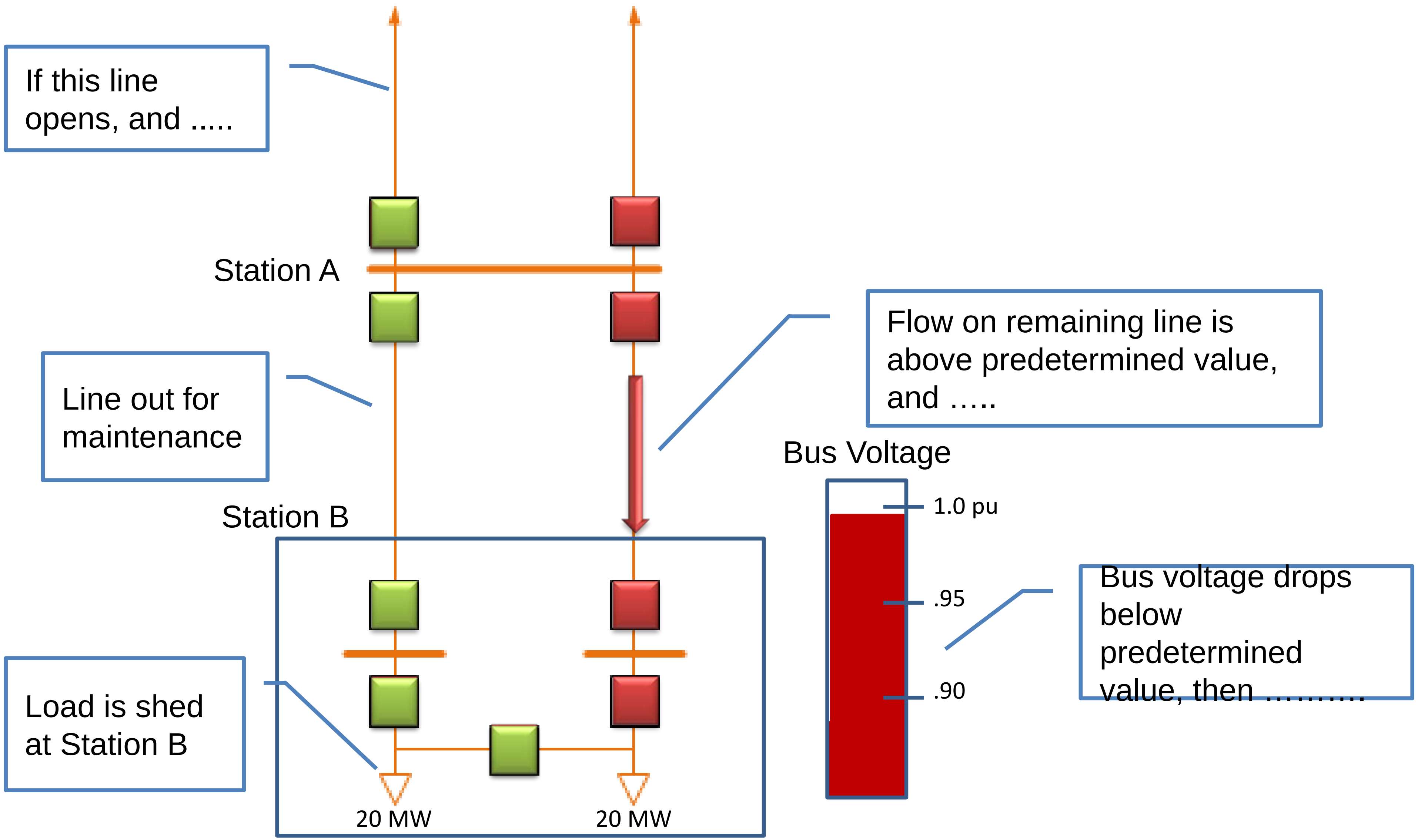
Generation Runback/Load Rejection



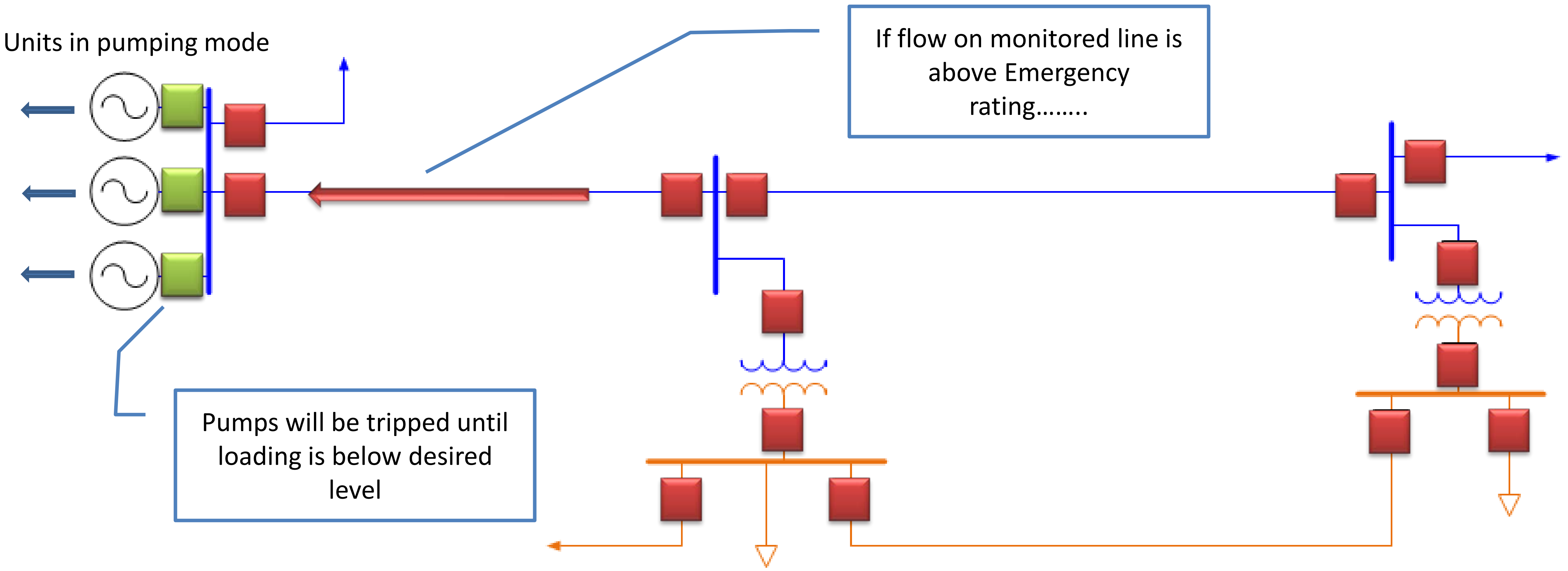
Load Shed Scheme

- Reduce system load for a given set of conditions

Load Shed Scheme



Load Shed


Units in pumping mode
If flow on monitored line is above Emergency rating……..
Pumps will be tripped until loading is below desired level

PJM RAS Actions

1. PJM will contact the TO to verify EMS results and direct the RAS to be Enabled
2. PJM will modify the contingency definition to simulate the N-1 condition in the EMS with the RAS activated
3. PJM will log the activation/deactivation of the RAS scheme that is a change from its “Normal” status
4. PJM will control all actual facility loadings below the Normal ratings and all contingency loadings below the Emergency rating

committee review unless required for reliability, operational performance, or to restore the system to the state existing prior to a significant transmission facility event, in which case the scheme will be implemented as soon as practicable. PJM will conduct an annual review of automatic sectionalizing schemes to ensure that the results of the initial qualifying analysis remain in effect. A list of accepted Automatic Sectionalizing Schemes is located in Attachment E.

Automatic Special Protection Scheme (SPS) Operating Criteria

Under normal operating conditions, PJM's EMS will perform an N-1 contingency analysis for the loss of each Bulk Electric System line and transformer within the PJM RTO. PJM will then control as indicated in **Manual M-03 Section 3: Thermal Operating Criteria**.

When PJM's EMS indicates that a simulated N-1 contingency will result in an overload on a facility that can be mitigated by a Special Protection Scheme (SPS) that has been documented in **PJM Manual M-03 Section 5: “Index and Operating Procedures for PJM RTO Operation”***, the following actions should be taken:

PJM Actions:

1.) PJM will contact the Transmission Owner based on EMS results and direct the SPS to be changed from its ‘Normal Status’ (enabled/disabled). PJM will also verify that the SPS is operational and that its status can be changed.

2.) Once the Transmission Owner has changed the SPS status, PJM will modify the contingency definition(s) to simulate the N-1 condition and the subsequent activation of the associated SPS within the PJM EMS System.

3.) PJM will log activation/deactivation for an SPS that is a change from its ‘Normal Status’

4.) PJM will control all actual facility loadings below the normal ratings and all subsequent contingency loadings below the emergency limits as indicated in **PJM Manual M-03, Section 3: Thermal Operating Criteria.**

TO Actions:

Upon PJM's direction, for any SPS involving a transmission line, the TO will change the SPS from its ‘Normal Status’ (enable/disable)

The TO will not place the SPS back in its ‘Normal Status’ until PJM has directed to do so.

GO Actions:

Upon PJM' direction, for any SPS involving a generating unit, the GO will change the SPS from its ‘Normal Status’ (enable/disable)

The GO will not place the SPS back in its ‘Normal Status’ until PJM has directed to do so.

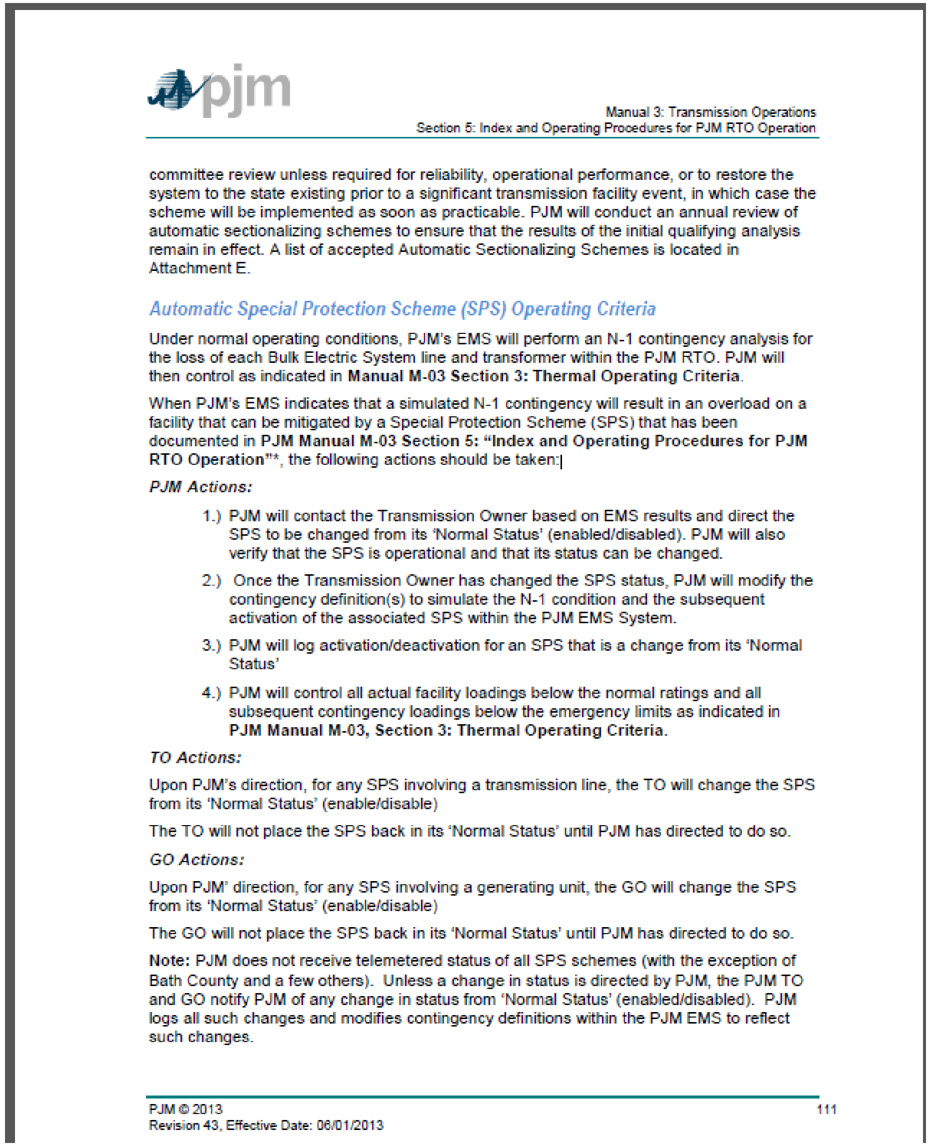
Note: PJM does not receive telemetered status of all SPS schemes (with the exception of Bath County and a few others). Unless a change in status is directed by PJM, the PJM TO and GO notify PJM of any change in status from ‘Normal Status’ (enabled/disabled). PJM logs all such changes and modifies contingency definitions within the PJM EMS to reflect such changes.

PJM TO/GO SPS/RAS Actions

1. TO/GO will change the RAS status upon PJM's direction

2. TO/GO will not change the RAS status back to "Normal" unless directed to do so by PJM

3. TO/GO must report any condition that would prevent the use of the RAS or cause the RAS to become inoperable



pjm

Manual 3: Transmission Operations
Section 5: Index and Operating Procedures for PJM RTO Operation

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PJM Actions:

1.) PJM will contact the Transmission Owner based on EMS results and direct the SPS to be changed from its 'Normal Status' (enabled/disabled). PJM will also verify that the SPS is operational and that its status can be changed.

2.) Once the Transmission Owner has changed the SPS status, PJM will modify the contingency definition(s) to simulate the N-1 condition and the subsequent activation of the associated SPS within the PJM EMS System.

3.) PJM will log activation/deactivation for an SPS that is a change from its 'Normal Status'

4.) PJM will control all actual facility loadings below the normal ratings and all subsequent contingency loadings below the emergency limits as indicated in **PJM Manual M-03, Section 3: Thermal Operating Criteria.**

TO Actions:

Upon PJM's direction, for any SPS involving a transmission line, the TO will change the SPS from its 'Normal Status' (enable/disable)

The TO will not place the SPS back in its 'Normal Status' until PJM has directed to do so.

GO Actions:

Upon PJM' direction, for any SPS involving a generating unit, the GO will change the SPS from its 'Normal Status' (enable/disable)

The GO will not place the SPS back in its 'Normal Status' until PJM has directed to do so.

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Thermal Limits Exercises

Thermal Limit Exercises

Scenario #1:

On a 77˚ summer day there are 2546 MW and 1823 MVAR flowing on the Elmer-Wenatchee 500 kV line.

Is the flow exceeding any actual thermal limit? If so which one, how much relief is needed, and how long do you have to correct and what actions are used?

Actual flow is 3131.4 MVA

Exceeds Emergency rating of 3084 MVA

Need 48 MVA worth of relief in 15 minutes to return under the Emergency Limit

Thermal Limit Exercises

Scenario #2:

On a 41˚ winter evening there are 582 MW and 175 MVAR flowing on the Ellensburg-Wenatchee 230 kV line.

Is the flow exceeding any actual thermal limit? If so which one, how much relief is needed, and how long do you have to correct and what actions are used?

Actual flow is 607.75 MVA

Exceeds Normal rating of 603 MVA

Need 5 MVA worth of relief in 15 minutes to return under the Normal Limit

Thermal Limit Exercises

Scenario #3:

On a 50˚ autumn morning there are 3218 MW and 1891 MVAR flowing on the Everett-Wenatchee 500 kV line.

Is the flow exceeding any actual thermal limit? If so which one, how much relief is needed, and how long do you have to correct and what actions are used?

Actual flow is 3732.48 MVA

Exceeds Load Dump rating of 3543 MVA

Need 190 MVA worth of relief in under 5 minutes to return under the Load Dump

And 604 MVA total relief in under 15 minutes to return under the Emergency Rating of 3129 MVA

Thermal Limit Exercises

Scenario #4:

On that same 77˚ summer day your security analysis program shows that for the loss of the Elmer-Wenatchee 500 kV line the flow on Ellensburg-Wenatchee 230 kV line would go up to 701 MVA

Is the flow exceeding any post-contingency simulated thermal limit? If so which one, how much relief is needed, and how long do you have to correct and what actions are used?

Post-contingency simulated flow is 701 MVA

Exceeds Load Dump rating of 673 MVA

Need 59 MVA worth of relief in 30 minutes to return under the Emergency Limit of 643 MVA

Thermal Limit Exercises

Scenario #5:

On a 41˚ winter evening your security analysis program shows that for the loss of the Ellensburg-Wenatchee 230 kV line the flow on Elmer-Wenatchee 500 kV line would go up to 3133 MVA.

Is the flow exceeding any post-contingency simulated thermal limit? If so which one, how much relief is needed, and how long do you have to correct and what actions are used?

Post-contingency simulated flow is 3133 MVA

Exceeds Normal rating of 2983 MVA

Do not need relief for this simulated flow, just have to monitor the trend

Thermal Limit Exercises

Scenario #6:

On a 50˚ autumn morning your security analysis program shows that for the loss of the Ellensburg-Wenatchee 500 kV line the flow on Everett-Wenatchee 500 kV line would go up to 3333 MVA.

Is the flow exceeding any post-contingency simulated thermal limit? If so which one, how much relief is needed, and how long do you have to correct and what actions are used?

Post-contingency simulated flow is 3333 MVA

Exceeds Emergency rating of 3129 MVA

Need 205 MVA worth of relief in 30 minutes to return under the Emergency Limit\

IROLs in PJM

How are IROLs determined and Monitored within PJM?

- PJM Manual 37 outlines the IROLs within the PJM footprint, and how they are monitored

- IROL analysis is performed in:
  - long-term and short-term planning studies
  - day-ahead studies
  - real time

- Studies include a long list of possible contingencies
  - studied at estimated peak loads
  - include facilities identified as requiring special attention
    - Facilities contributing to the 2003 Blackout
    - The RFC (ECAR) list of critical facilities
    - MAAC assessment limits
    - Others identified by operating experience

How are IROLs determined and Monitored within PJM?

- Flows are increased across a given piece of equipment or interface
  - Looking for any resulting voltage and thermal violations
  - PJM EMS increases load in Eastern PJM (sink) with an increase in Western Generation (MISO) until a voltage violation (or collapse) is identified
- Thermal limit violations alone allow PJM (and company) Dispatchers time to respond without jeopardizing system reliability, and are ***NOT*** IROLs

How are IROLs determined and Monitored within PJM?

- PJM classifies a facility as an IROL facility:
  - If wide-area voltage violations occur at transfer levels that are near the Load Dump thermal limit
    - Plus case-by-case exceptions as identified in the studies
- In most cases, the IROLs are a limit on MW flows to prevent a ***post-contingency*** voltage violation or collapse…

How are IROLs determined and Monitored within PJM?

- Determination of Reactive Transfer Limits
  - Limits are calculated every 2 – 5 minutes on PJM's EMS
  - Each transfer interface has its own set of contingencies and monitored buses

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
Eastern	5058 Breinigsville-Alburtis 500 kV Line
	5009 Juniata-Alburtis 500 kV Line
	5026 TMI-Hosensack 500 kV Line
	5010 Peach Bottom-Limerick 500 kV Line
	5025 Rock Springs-Keeny 500 kV Line
	5063 Hopatcong-Lackawanna 500 kV Line
Central	5004 Keystone-Juniata 500 kV Line
	5005 Conemaugh-Juniata 500 kV Line
	5012 Conastone-Peach Bottom 500 kV Line

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
5004/5005	5004 Keystone-Juniata 500 kV Line
	5005 Conemaugh-Juniata 500 kV Line
Western	5004 Keystone-Juniata 500 kV Line
	5005 Conemaugh-Juniata 500 kV Line
	5006 Conemaugh-Hunterstown 500 kV Line
	5055/522 Doubs-Brighton 500 kV Line
Bedington – Black Oak	544 Black Oak-Bedington 500kV line

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
AP South	583 Bismark-Doubs 500 kV Line
	540 Greenland Gap-Meadowbrook 500 kV Line
	550 Mt Storm-Valley 500 kV Line
	Mt Storm-Meadowbrook 500 kV Line
AEP Dominion	Kahawha River-Matt Funk 345 kV Line
	Wyoming-Jacksons Ferry 765 kV Line
	Baker-Broadford 765 kV Line

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
Cleveland	Chamberlain-Harding 345 kV Line
	Hanna-Juniper 345 kV Line
	Star-Juniper 345 kV Line
	Davis Besse-Beaver 345 kV Line
	Hayes-Beaver 345 kV Line
	Carlisle-Beaver 345 kV Line
	Erie West-Ashtabule 345 kV Line
	Mansfield-Glen Willow 345 kV Line Lake Avenue #1 345 kV/138 kV Lake Avenue #2 345 kV/138 kV
	Ford-Beaver 138 kV Line
	NASA-Beaver 138 kV Line

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
Cleveland	Henrietta-Beaver 138 kV Line
	West Akron-Bath 138 kV Line
	West Akron-Brush 138 kV Line
	Johnson-Beaver 138 kV Line
	Black River-Beaver 138 kV Line
	Charleston-Lorain 138 kV Line
	National Bronze-Lorain 138 kV Line

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
CE-East	Dumont-Wilton Center 765 kV Line
	Olive-University Park North 345 kV Line
	St. Johns-Crete 345 kV Line
	Sheffield-Burnham 345 kV Line
	Sheffield-Stateline 345 kV Line
	Munster-Burnham 345 kV Line

What Are the IROLs in the PJM Footprint?

Transfer Interface	Interface Definition
BC/PEPCO	Doubs-Brighton 500 kV Line
	Hunterstown-Conastone 500 kV Line
	Peach Bottom-Conastone 500 kV Line
	Possum Point-Burches Hill 500 kV Line
	Dickerson-Aqueduct 230 kV Line
	Doubs-Dickerson 23102 230 kV Line
	Cooper-Graceton 230 kV Line
	Edwards Ferry-Dickerson 230 kV Line
	Otter Creek-Conastone 230 kV Line
	Safe Harbor-Graceton 230 kV Line
	Face Rock-Five Forks #1 115 kV Line
	Face Rock-Five Forks #2 115 kV Line

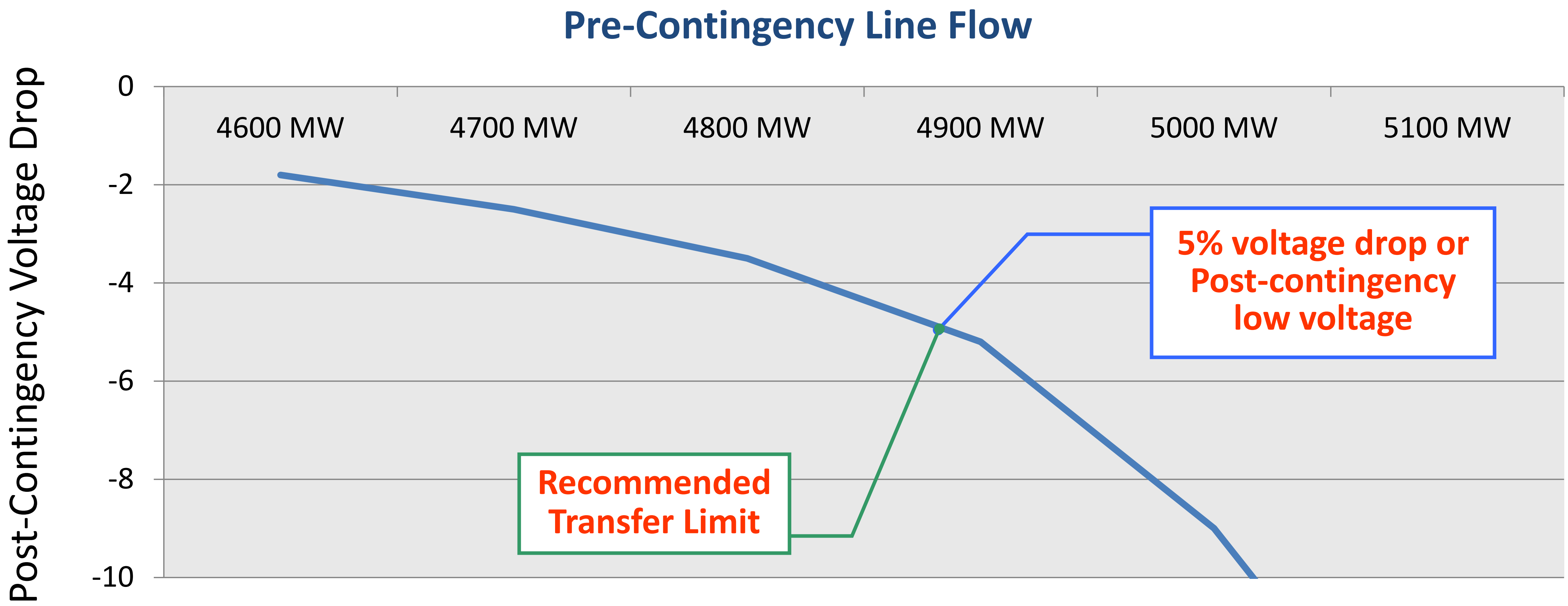
What Are the IROLs in the PJM Footprint?

- The Reactive Transfer Limit for an interface is determined as the more restrictive of:
  - The minimum pre-contingency transfer interface flow where a post-contingency voltage drop violation (5%) or post-contingency low voltage violation first occurs

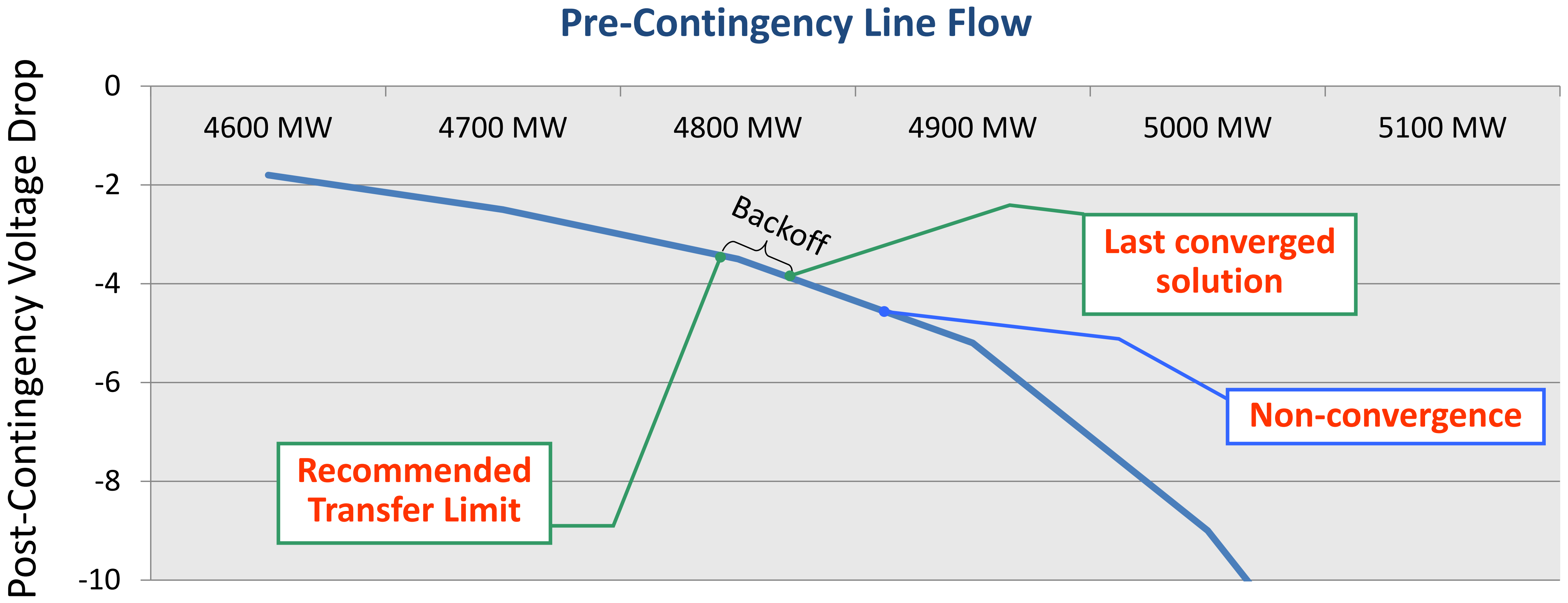
    OR

  - The minimum pre-contingency transfer interface flow with a converged power flow solution minus the user specified MW "back-off" value
    - Generally 50 – 300 MW

What Are the IROLs in the PJM Footprint?



What Are the IROLs in the PJM Footprint?



IROL Load Shed Procedure

- Purpose of the IROL Manual Load Dump:
  - Provide loading relief on IROL facilities as a last step
  - Prevent exceeding an IROL Limit for 30 minutes (IROL Violation)
  - Quickly act to mitigate IROL facilities in accordance with operating procedures
  - PJM Transmission Operations Manual (M03)
    - Section 2: Thermal Operating Guidelines
    - Section 3: Voltage & Stability Operating Guidelines
  - PJM Emergency Operations Manual (M13)
    - Section 5: Transmission Security Emergencies

IROL Load Shed Procedure

- IROL Manual Load Dump Warning
  - Issued via the PJM All-Call System when the IROL Limit has been exceeded for **5 minutes** or longer
    - The purpose is to **PREPARE** Transmission dispatchers/LSEs to curtail load within 5 minutes to return flows below the IROL Limit

IROL Load Shed Procedure

- IROL Manual Load Dump Warning
  - Transmission Owner Operators/LSEs
    - Once an IROL Manual Load Dump Warning has been implemented:
      - Promptly review IROL Manual Load Dump Allocation Table (Attachment N, M-13) in preparation of Manual Load Dump
    - To determine your required amount of Load Shed, determine your company multiplier for that IROL
    - Multiply the amount of relief requested by PJM by your multiplier to determine your company's load shed amount
    - Validate Load Dump Plan, Identifying critical or priority load(s)
    - **PREPARE** to shed load

IROL Load Shed Procedure

- IROL Manual Load Dump Action
  - Issue via the PJM All-Call System when the IROL Limit has been exceeded for **25 minutes or longer**
  - PJM dispatch:
    - Notifies PJM management
    - Public information personnel, and members
    - Other Control Areas through the RCIS
    - Notifies DOE, FEMA, and NERC
    - Notifies FERC via the FERC Division of Reliability's electronic pager system

IROL Load Shed Procedure

- IROL Manual Load Dump Action
  - Transmission Owner Operators/LSEs
    - Promptly **(within 5 minutes)** shed an amount of load equal to or in excess of the amount requested by PJM dispatcher in accordance with Attachment N, but consider/recognize priority/critical load
      - A Grey Box on Attachment N indicates your company has no responsibility to shed load for that IROL
    - Notify governmental agencies, as applicable
    - Maintain the requested amount of load relief until the load dump order is cancelled

IROL Load Shed Procedure

Attachment N: IROL Load Dump Tables

IROL	East	Central	5004/05	West	AP South	Bed-BO	AEP/DOM	CLVLND	CE-EAST
TO Zone	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier
DPL	0.21	0.16	0.40	0.18					
DPL-Dover	0.01	0.01	0.02	0.01					
DPL-DEMEC	0.02	0.01	0.03	0.02					
DPL-Easton	0.00	0.00	0.01	0.00					
DPL-ODEC	0.05	0.04	0.10	0.05					
AE	0.14	0.11	0.27	0.12					
AE-Vineland	0.01	0.01	0.02	0.01					
PS	0.59	0.46	1.10	0.49					
RECO	0.02	0.02	0.04	0.02					
PE	0.60	0.47	1.12	0.50					
FE East-JC	0.32	0.25	0.60	0.27					
PL		0.51	1.23	0.55					
UGI		0.01	0.03	0.01					
FE East-ME		0.18	0.43	0.19					
FE East-PN									
BC				0.44	0.93	3.98	1.48		
PEP				0.35	0.75	3.20	1.19		
PEP-SMECO				0.05	0.10	0.44	0.17		
FE South									
Dom					2.91	4.10	4.62		
Dom-NCEME					0.26	1.11	0.41		
Dom-ODEC					0.05	0.19	0.07		
DLCO									
AEP							1.00		
Dayton									
FE West								0.93	
CPP								0.07	
ComEd									0.998
DEOK									
EKPC									
Rochelle									0.002

IROL Load Shed Procedure

- ***Example:*** IROL Load Shed Request
  - PJM announces an IROL Load Shed Warning for 350 MW of Relief on the Western Transfer IROL
  - Your company is Public Service (PS)
  - You consult Attachment N and determine that your company Multiplier for the Western Transfer IROL is 0.49

IROL Load Shed Procedure

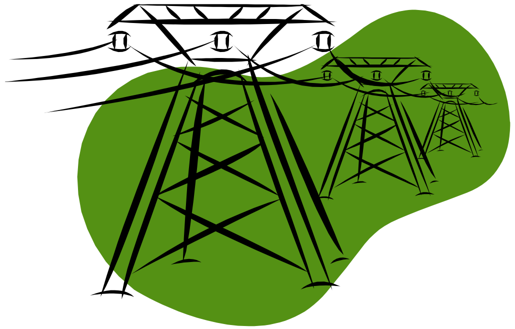
Attachment N: IROL Load Dump Tables

IROL	East	Central	5004/05	West	AP South	Bed-BO	AEP/DOM	CLVLND	CE-EAST
TO Zone	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier	Multiplier
DPL	0.21	0.16	0.40	0.18					
DPL-Dover	0.01	0.01	0.02	0.01					
DPL-DEMEC	0.02	0.01	0.03	0.02					
DPL-Easton	0.00	0.00	0.01	0.00					
DPL-ODEC	0.05	0.04	0.10	0.05					
AE	0.14	0.11	0.27	0.12					
AE-Vineland	0.01	0.01	0.02	0.01					
PS	0.59	0.46	1.10	0.49					
RECO	0.02	0.02	0.04	0.02					
PE	0.60	0.47	1.12	0.50					
FE East-JC	0.32	0.25	0.60	0.27					
PL		0.51	1.23	0.55					
UGI		0.01	0.03	0.01					
FE East-ME		0.18	0.43	0.19					
FE East-PN									
BC				0.44	0.93	3.98	1.48		
PEP				0.35	0.75	3.20	1.19		
PEP-SMECO				0.05	0.10	0.44	0.17		
FE South									
Dom					2.91	4.10	4.62		
Dom-NCEME					0.26	1.11	0.41		
Dom-ODEC					0.05	0.19	0.07		
DLCO									
AEP							1.00		
Dayton									
FE West								0.93	
CPP								0.07	
ComEd									0.998
DEOK									
EKPC									
Rochelle									0.002

IROL Load Shed Procedure

- Example: IROL Load Shed Request
  - You multiply the amount of PJM requested relief (350 MW) by your company multiplier (0.49) to get your required Loadshed amount
    - 350 X 0.49 = 171.5 MW
  - You identify where in your Zone that load will be shed
  - If/When PJM issues the IROL Load Shed Action, you would shed at least 171.5 MW within 5 minutes and keep that amount of load off the system until PJM gives you the OK to restore the load
    - Rotating load is OK so long as the minimum shed is at least 171.5 MW

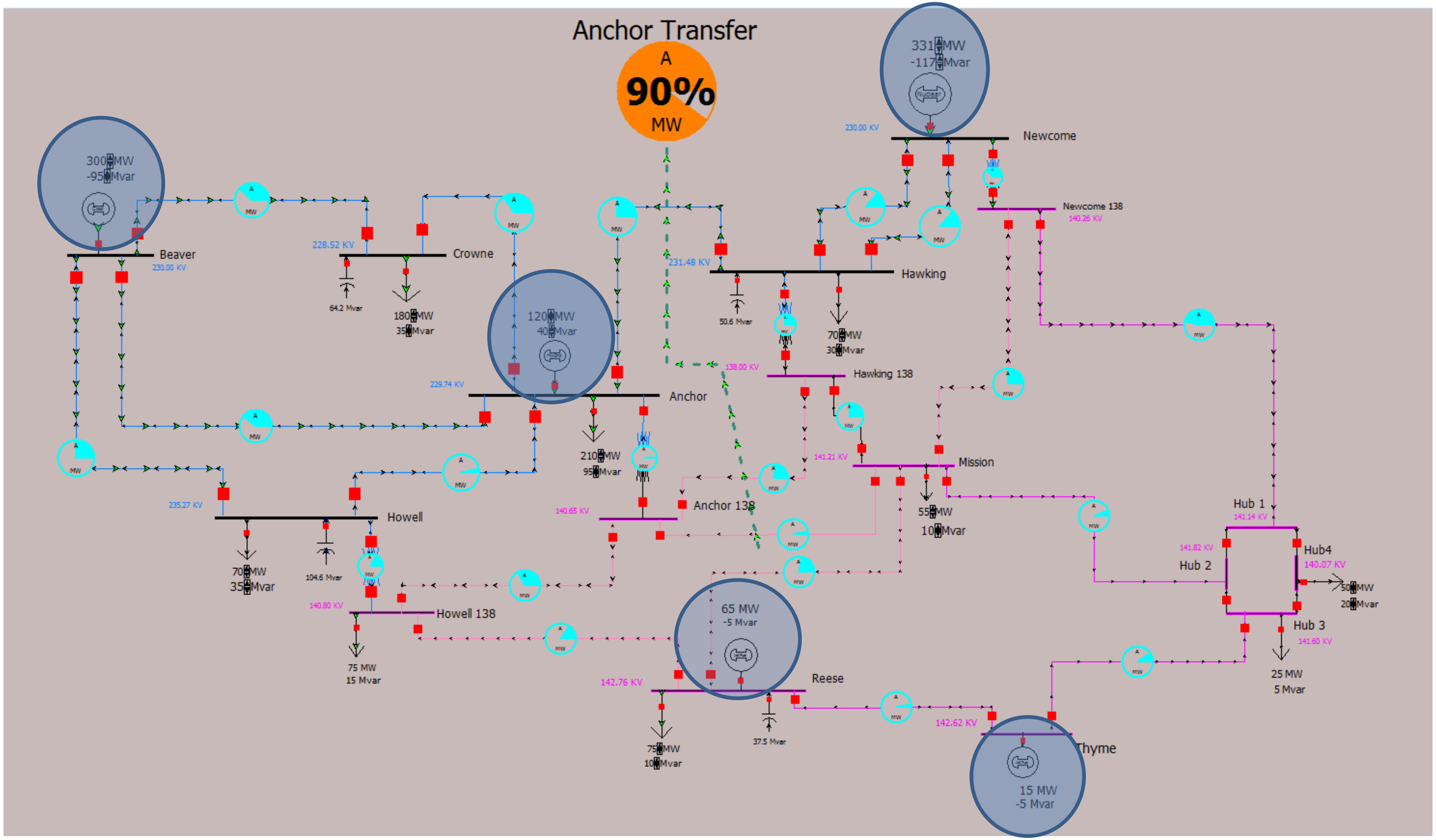
Interconnection Reliability Operating Limits (IROL) Simulations



Some Simulation Exercises...

- We are going to look at some Potential IROL Load shedding situations
- For each case, your system will start with actual values within limits
  - A situation will occur causing an IROL violation
  - Your job will be to determine the most efficient way of getting the IROL back within real-time limits

Some Simulation Exercises...



Some Simulation Exercises...

- Maximum Unit output values are;

Beaver - 300 MW		Anchor - 200 MW
Newcome - 650 MW		Reese - 65 MW*
		Thyme - 15 MW*

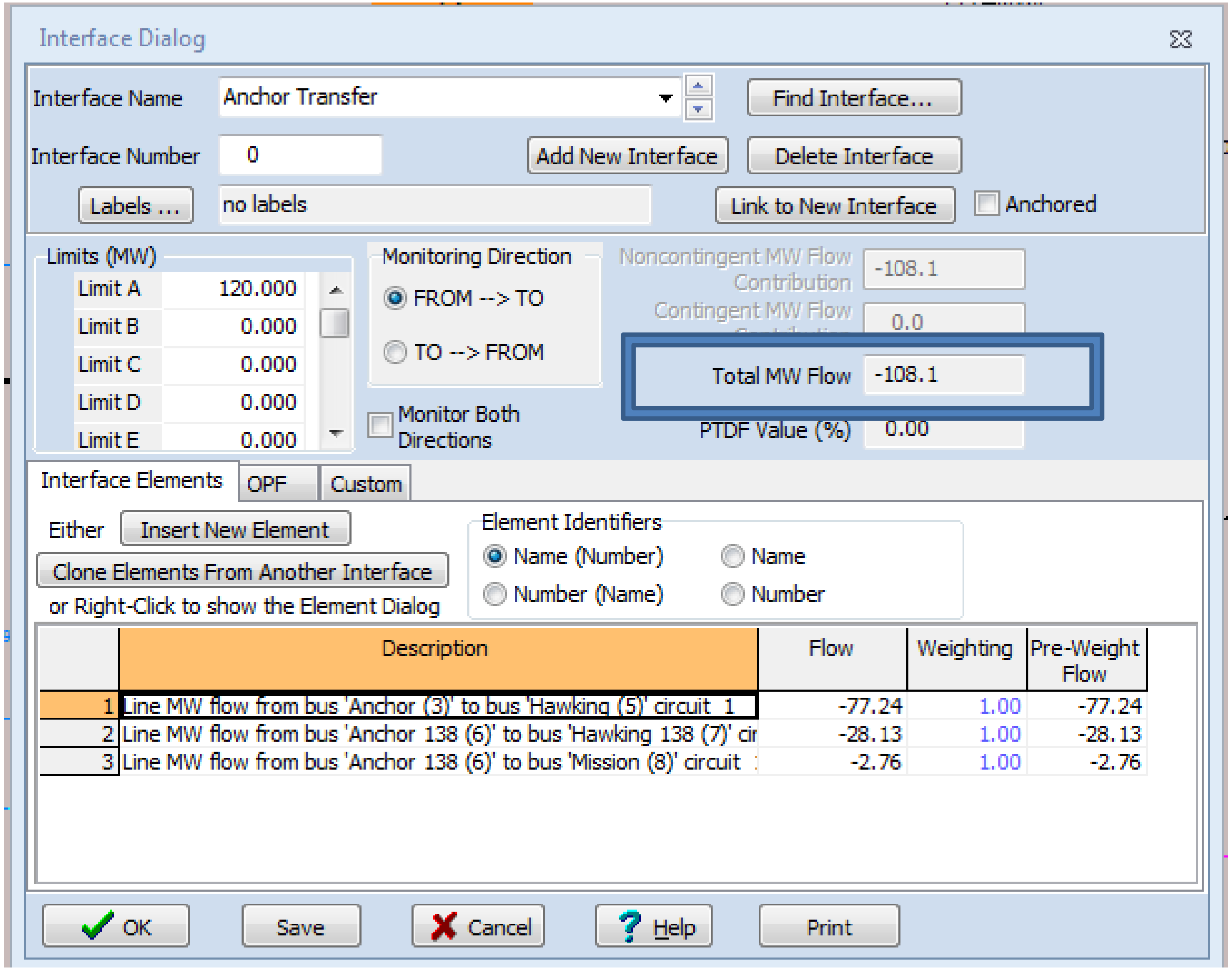
* Reese and Thyme are wind units, and are either full on, or fully off.
Their output is not adjustable

- Newcome is the “slack” unit. It will adjust it’s output to maintain the system’s ACE as you adjust the output of the other units

Some Simulation Exercises...

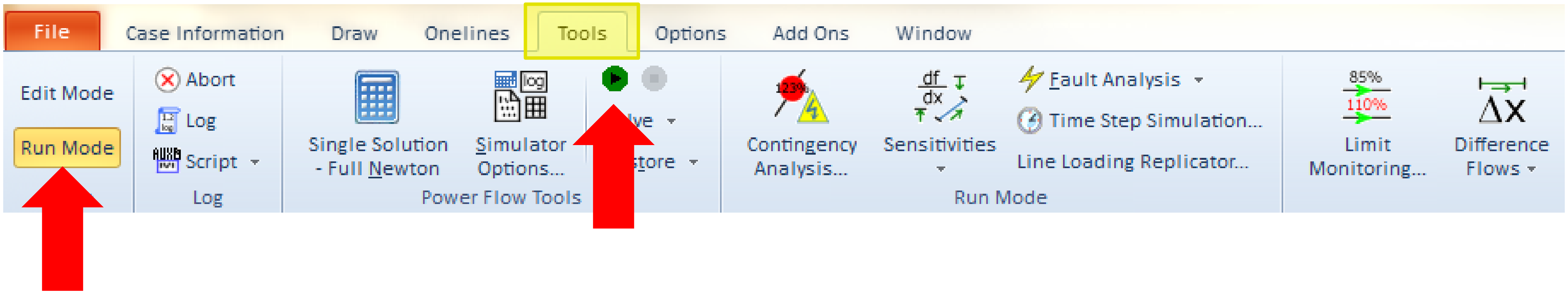
- The IROL interface Limit is 120 MW
  - Pie chart at the top of the display shows the percentage of the limit at which the current IROL value is operating
  - For these scenarios we are simply looking at real-time values, not contingency values…
- To see the actual MW value currently across the interface, place the pointer above the IROL line and right click

Some Simulation Exercises...



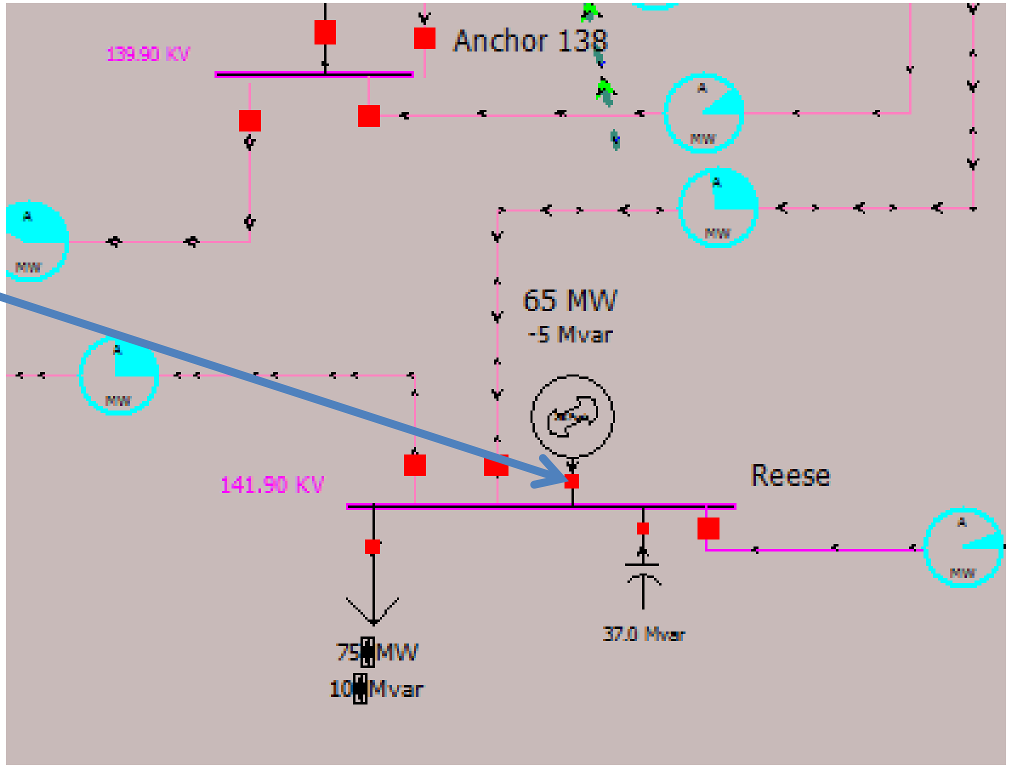
Some Simulation Exercises…

- Once the case is open:
  - Ensure Run Mode is selected
  - Left click on the "Tools" tab, then the green button directly below it to start the animation for the simulation



Some Simulation Exercises…

- **Case #1:**
  - Once your animation is up and running, here is your situation;
    - The wind has died down causing the Wind unit at Reese to come offline. Take the Reese unit offline by clicking on the unit output breaker….
  - Answer the questions on the Instructor Screen……..
    We will de-brief in ~ 5 minutes



Some Simulation Exercises...

- **Case #1 Questions:**

1. Has taking the Reese Unit offline caused an IROL violation ?
   Yes, the interface is now at 109% (131 MW)

2. If so, by how many MW are you over the IROL limit? 11 MW

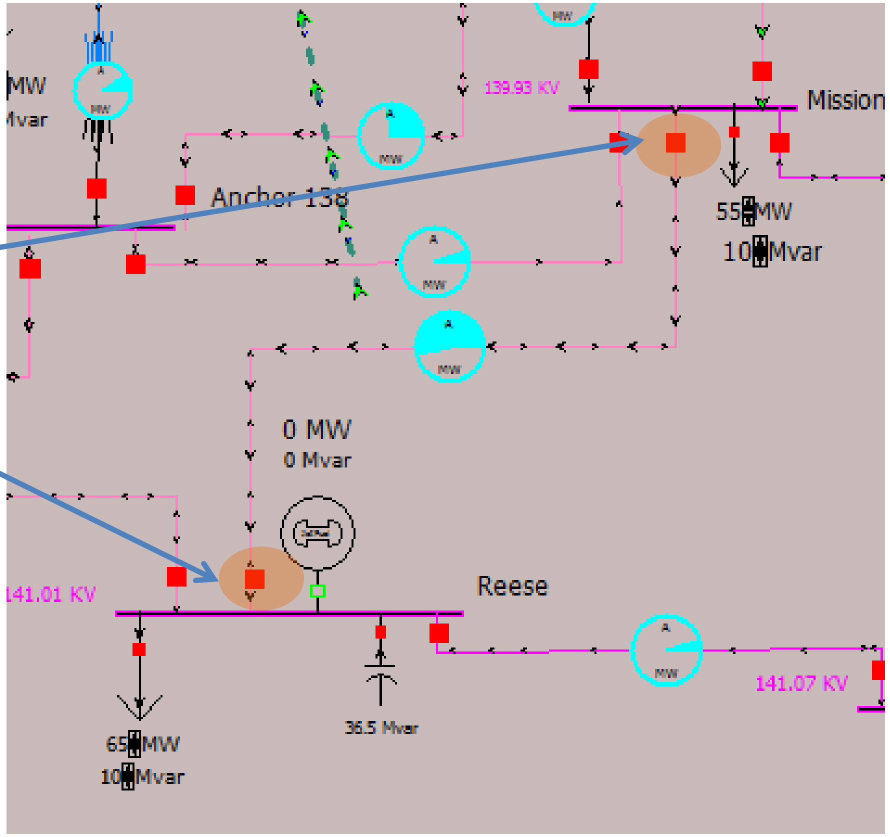
3. For this scenario there are no non-cost options that are effective at controlling the violation. There are no transactions that can be cut that will help. What is your next most desirable option? Raise Generation at Anchor

4. What course of action do you suggest?
   Increase Anchor output from 120 to 140 MW

5. How does the action you took compare to the initial violation of the IROL?
   Needed to increase generation by about 20 MW to control

Some Simulation Exercises...

- **Case #2:**
  - Once your animation is up and running, here is your situation;
    - Both Wind units are offline, and will remain offline
    - The Mission-Reese 138 kV Line trips out of service. Open the line by clicking on the CB at Either terminal….
    - Answer the questions on the Instructor Screen…….. We will de-brief in ~ 5 minutes



Some Simulation Exercises...

- **Case #2 Questions:**

1. Has the line trip caused an IROL violation ? Yes, the interface is now at 120% (144 MW)

2. If so, by how many MW are you over the IROL limit? 24 MW

3. For this scenario there are no non-cost options. There are no transactions that can be cut that will help. What is your next most desirable option? Raise Generation at Anchor

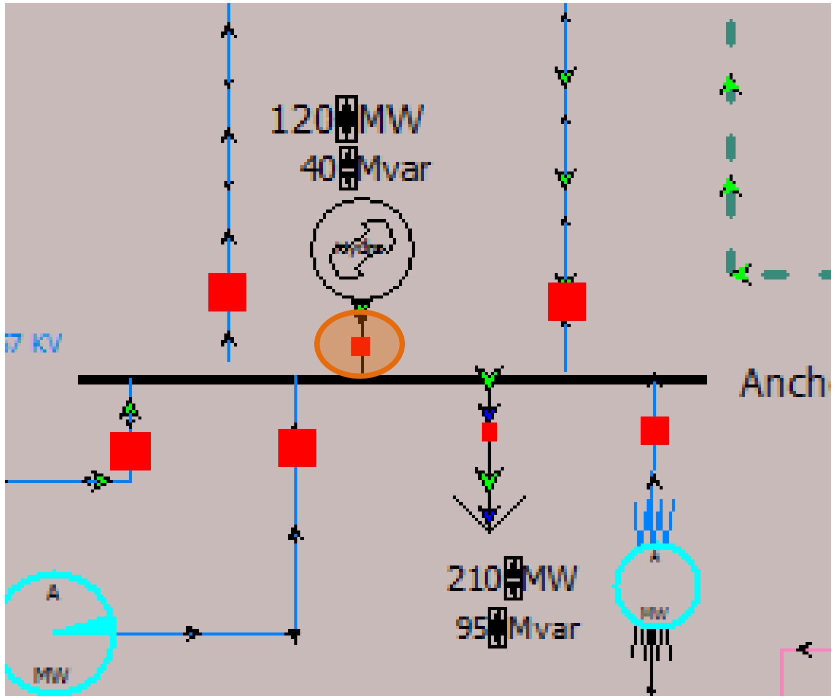
4. What course of action do you suggest? Increase Anchor output from 180 to 200 MW

5. Is Generation adjustment sufficient to control the IROL violation?
   No, the interface is still at 105% with 200 MW output at Anchor (126 MW)

6. What other action(s) must be taken? Shed load in the West. A load shed of 10 MW is needed

Some Simulation Exercises...

- **Case #3:**
  - Once your animation is up and running, here is your situation;
    - The Anchor Unit trips offline. Take the Anchor unit offline by clicking on the unit output breaker....
    - Answer the questions on the Instructor Screen……..
      We will de-brief in ~ 5 minutes.



Some Simulation Exercises...

- ## Case #3 Questions:

1. Has the unit trip caused an IROL violation ?
   Yes, the interface is now at 184% (221 MW)

2. If so, by how many MW are you over the IROL limit? 101 MW

3. For this scenario there are no non-cost options that are effective at controlling the violation. There are no transactions that can be cut that will help. What is your next most desirable option?
   Shed Load in the West

4. Consulting your IROL Load shed table, you find out that your multiplier for this interface is 1.2. Using the amount of MW the interface is in violation from #2 above, determine the amount of load you need to shed in the West. 101 X 1.2 = 121 MW

5. Shed that amount of load. Is the interface now within the IROL's? Yes, the interface is at 97%

6. What concept from this module does this example reinforce?
   More load must be shed to control a violation than the amount of MW that the IROL is in violation

Post Contingency Local Load Relief Warning (PCLLRW)

PCLLRW

Manual 13, Section 5.4

- Purpose: To provide advance notice to Transmission Owners (TOs) of the potential for manual load dump in their area(s)
- Issued after all other means of transmission constraint control have been exhausted or until sufficient generation is on-line within limits/timelines to control the constraint
  - Intended to relieve localized constraints (230kV and below)
  - Implemented as post-contingency violations approach 60 minutes
  - Issued sooner at the request of the Transmission Owner or at the discretion of the PJM Dispatcher

Warning to be communicated to the applicable TO and posted via the Emergency Procedures Posting Application, but not communicated via the "PJM All-Call"

PCLLRW

Manual 13, Section 5.4

- PJM and TO Operator actions:
  - Review contingency flows / limits
  - Discuss off-cost operations/switching solutions prior to implementation of a PCLLRW, system conditions and time permitting
  - Review and implement acceptable pre-contingency switching, load dispatch, and generation redispatch options in lieu of issuing a Post-Contingency Local Load Relief Warning

Note: If post contingency flows exceed the Load Dump rating, PJM will direct the Transmission Owner to implement any available switching solutions, provided they do not create any additional actual overloads in exceedance of their normal rating or post-contingency overloads

PCLLRW

Manual 13, Section 5.4

- PJM dispatcher actions:
  - Commit/de-commits effective generation
  - Adjust hydro/pumping schedules
  - Curtail interchange transactions
  - Commit quick-start generation
  - Market to market re-dispatch implemented where applicable

Note: As indicated in M-12, for “Reliability Only” facilities (i.e. facilities not under PJM Congestion Management) the Transmission Owners have the option to pay for generation redispatch on a pre-contingency basis or accept a PCLLRW. However, if a “Reliability Only” facility exceeds its Load Dump rating, PJM will manually dispatch generation to maintain flows below the Load Dump rating

PCLLRW

Manual 13, Section 5.4

- PJM dispatcher actions:
  - Determine desired flow on affected facility
    - Post-contingency flow < LTE rating
  - Issue PCLLRW
    - Communicate verbally to affected TO(s)
    - Post on Emergency Procedure Posting Application
      - Include area affected, desired flow, any post-contingency switching, generation reductions or load transfer options
    - Email load Dfax report to affected TO(s)

PCLLRW

Manual 13, Section 5.4

- PJM dispatcher actions:
  - Establish mutual awareness with appropriate TO of the need to address the post-contingency actions with minimal delay
  - Direct load shed should contingency occur
  - Cancel PCLLRW when appropriate
    - Post-contingency flow drops below LTE rating and is not expected to reappear in the near future
    - Notify TO prior to canceling PCLLRW
    - Cancel in Emergency Procedure application
    - Log

PCLLRW

Manual 13, Section 5.4

- Member Actions:
  - Update load shedding plan in PCLLRW eTool application
  - Monitor expected post-contingency flows and adjust load dump strategy as appropriate
  - Advise appropriate stations and key personnel
    - Staff substations as necessary if load shed can't be accomplished via SCADA
  - Review load dump procedures and prepare to dump load in amount requested when directed by PJM

PCLLRW

Manual 13, Section 5.4

- Member Actions:
  - Prepare to implement post-contingency switching options, manual generation trip or SCADA load transfer
    - Prepare to implement load shedding if above fails
  - Man substations if SCADA fails or is insufficient
  - Notify PJM if post-contingency flow drops below LTE limit and PCLLRW has not yet been cancelled

Implementation of PCLLRW

When to Issue a PCLLRW?

Post Contingency Flow> Emergency Rating

AND

Monitored facility is at 230 kV or below

AND

Contingency is NOT a reactive transfer limit or a "multi-area transmission constraint"

AND

No effective generation re-dispatch to control facility

OR

Generation re-dispatch to fix contingency will take longer than the 15-30 minute criteria

OR

All controlling actions including the following have been exhausted and contingency remains

Posting of PCLLRWs

pjm | Emergency Procedures

Postings

Postings | Message Definitions | Message Priorities | Regions | Emergency Bid Form

From * 05/03/2015 To * 05/05/2015 Regions Message Types PJM Drill Include Active Only Reset

Last Updated: 05.05.2015 15:54:16 Filters: 05/03/2015 to 05/05/2015; Include PJM Drill

Records Per Page: 15 (1 of 1)

History	Msg ID	Priority	Message Type	Posting Timestamp	Regions	Emergency Message	Cancellation Timestamp
	100202	Warning	Post Contingency Local Load Relief Warning	05.05.2015 15:54	DEOK	As of 15:52 on 05.05.2015 a Post Contingency Local Load Relief Warning to maintain 08CRSNT1-WENDCIN 1587 at 253 MVA in the DEOK area has been issued for Transmission Contingency Control. Additional Comments: Load -No Generation or Switching available	
	100201	Warning	Post Contingency Local Load Relief Warning	05.05.2015 11:50	PPL	As of 11:46 on 05.05.2015 a Post Contingency Local Load Relief Warning to maintain WESCOSVI 2 XFORMER at 257 MVA in the PPL area has been issued for Transmission Contingency Control. Additional Comments: Post Contingency Switching available	
	100200	Warning	Post Contingency Local Load Relief Warning	05.05.2015 10:04	EKPC	As of 09:58 on 05.05.2015 a Post Contingency Local Load Relief Warning to maintain CNTRLHAR 138 KV at 127 KV in the EKPC area has been issued for Transmission Contingency Control. Additional Comments: Post Contingency Switching available	

PCLLRW e-mail

From: PCLLRW <pcllrw-donotreply@pjm.com>
Date: March 28, 2017 at 12:43:49 PM EDT
To:
Subject: New Non-Market Post Contingency Local Load Relief Warning for DAY. As of 03-28-2017 12:41:22 a new Post Contingency Local Load Relief Warning issued to control WMILTON-09GRNVIL L/O 138/69.WestMilton.T7 to 165 MVA

New Non-Market Post Contingency Local Load Relief Warning for DAYTON. As of 03-28-2017 12:41:22, a Non-Market Post Contingency Local Load Relief Warning to maintain line MVA flow below 165 MVA in the WMILTON-09GRNVIL area of DAYTON has been issued for Transmission Contingency Control. Additional Comments: Post-contingency Thermal on WMILTON-09GRNVIL for the loss of 138/69.WestMilton.T7.
Post Contingency Switching Solution: NA

THE FOLLOWING ARE THE DFACTS WHICH AFFECT
WMILTON-09GRNVIL
ACTUAL MVA = 96 MVA CONTINGENCY MVA = 168.3 MVA

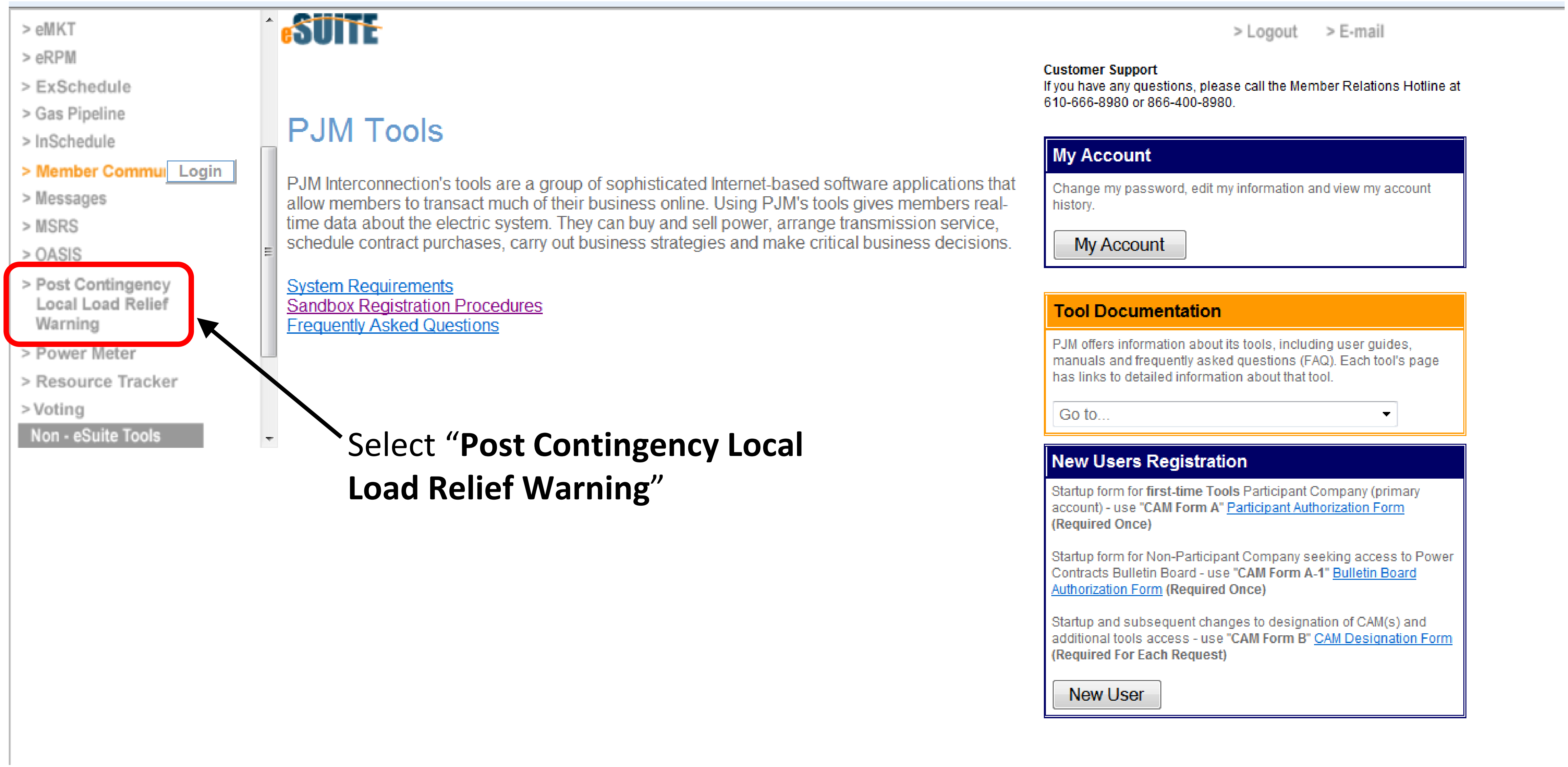
WHEN THE FOLLOWING FACILITIES ARE OUTAGED : (CONTINGENCY #31210)

-0.1899	WMILTON BK-7 XFORMER	69 KV	-122.1

PCLLRW e-mail

ZONE	STATION	NAME	DFAX	LOAD MW
DAYTO	09GRNVIL	BK-1	0.4232	13
DAYTO	09GRNVIL	BK-2	0.4232	13
DAYTO	09GRNVIL	BK-3	0.4232	10
DAYTO	TREATY	BK-3	0.3815	5
DAYTO	TREATY	BH2	0.3815	5
DAYTO	HURSCHRD	BK-1	0.3247	2
DAYTO	GETTYSBU	BK-2	0.2874	4
DAYTO	GETTYSBU	BK-1	0.2874	3
DAYTO	09WMANCH	BK-3	0.2595	3
DAYTO	09WMANCH	BK-1	0.2595	2
DAYTO	09ROSSBG	BK2	0.2459	0
DAYTO	LEWISBUR	BK-2	0.2257	3
DAYTO	WSORONA	DARKEREA	0.2257	1
DAYTO	LEWISBUR	BK-1	0.2257	3
DAYTO	ROSEREA	ROSEHILL	0.2196	5
DAYTO	GARAGERD	BK-5	0.2069	3
DAYTO	GARAGERD	BK-1	0.2069	10
DAYTO	GARAGERD	BK-2	0.2069	10
DAYTO	SHARPREA	BK1	0.1949	0
DAYTO	VERSAILL	SUB3	0.1872	2
DAYTO	VERSAILL	SUB1	0.1872	2
DAYTO	VERSAILL	SUB2	0.1872	2
DAYTO	FTRECOVE	BK-2	0.1809	2
DAYTO	FTRECOVE	BK-1	0.1809	2
DAYTO	CRYSTL	LOAD	0.1697	11
DAYTO	BUCKREA	SR 66	0.1575	5

PCLLRW Tool Access



Select “**Post Contingency Local Load Relief Warning**”

TO PCLLRW Application View

Branch ID | Contingency Information | Limits Information | Contingency Title | Status

Thermal PCLLRW Information

Co	Branch ID	KV	Pre MVA	Post MVA	NL	LT	ST	LD	MVA	(%)	MP	Contingency Title	Status
AEP	LAPORTE-MICHIGA2 NIP TIE	138	107	182	172	172	191	191	-8	106	1	L765.Dumont-Wilton Center.11215	
CPP	CPP_EAST-POFOK EAS-HOLT	138	142	228	194	237	237	273	[illegible]	[illegible]	[illegible]	[illegible]	
APS	BUTL APS-KARNSCIT KC-BT	138	98	179	168	190	190	198	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	CLOVERD2 . 10 XFORMER	765	1496	1743	1680	1859	1859	2045	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	KAMMER-NATRIUM	138	144	253	218	270	270	278	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	CLAYBURN-ROSS	138	114	153	166	167	167	167	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	MARYSVI2-TANGY TIE	345	552	915	1000	1000	1000	1000	[illegible]	[illegible]	[illegible]	[illegible]	
COMED	55 HEGEW-17714 17714 2	138	148	311	316	343	392	461	[illegible]	[illegible]	[illegible]	[illegible]	
COMED	156 CHERRY 38TR82 CT	138	289	414	400	465	514	530	[illegible]	[illegible]	[illegible]	[illegible]	
APS	CRUPPERN-NETTIE 162	138	123	156	146	174	174	196	-17	89	[illegible]	L500.Cloverdale-Lexington.566	

(1 of 4) 1 2 3 4 10 ▾

Option to change number of contingencies shown in a window

- Choose 10, 20 or 50

Special Thermal PCLLRW Information

Co	Branch ID	KV	Pre MVA	Post MVA	NL	LT	ST	LD	MVA	(%)	MP	Contingency Title	Status
AEP	LAPORTE-MICHIGA2 NIP TIE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	NEWCOMER-SCOSHOCT NEW-SCO	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	BUCKHORN-TAZEWELL	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
AEP	CLAYBURN-ROSS	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

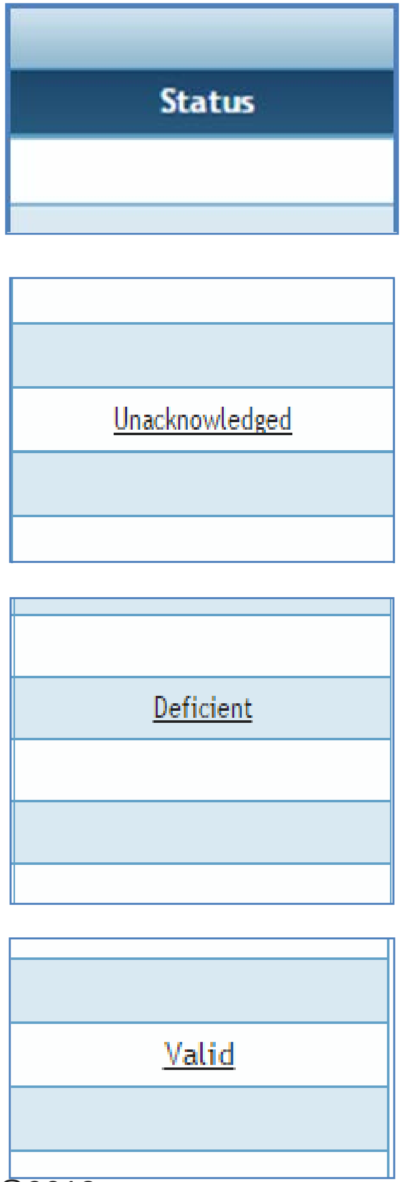
Contingencies are listed with *most severe at top*

- As analysis continues, PCLLRW may move further down list or to another page

Low Voltage PCLLRW Information

Co	Bus ID	Pre (KV)	Post (KV)	NL	EM	LD	Under (KV)	% of EM/LD	MP	Contingency Title	Status
AEP	REYNOLD2 138 KV BB_17299	136.9	126.3	131.1	127.0	124.2	0.7	99.5	2	L230.Cayuga-Veedersburg	
PS	WARDAV 138 KV *F02	138.7	130.9	135.0	131.0	124.0	0.1	99.9	2	L138.Trenton-Yardville.WardAve.K1363	
PS	CROSSWIC 138 KV *F08	138.9	131.4	135.0	131.0	124.0	-0.4	100.3	1	L138.Trenton-Yardville.WardAve.K1363	
PN	SHAWVILL 115 KV 115-2	117.8	106.7	109.0	106.0	103.0	-0.7	100.7	1	Shawville #2 unit	
AEP	DEWEY 138 KV BB_773	138.5	130.3	131.1	127.0	124.2	-3.4	102.6	2	L138.MorganFork-HaysBranch	
AEP	THELMA 138 KV BB_2193	138.1	130.4	131.1	127.0	124.2	-3.4	102.7	2	L138.MorganFork-HaysBranch	

PCLLRW Status



Unacknowledged – TO hasn't responded to PCLLRW

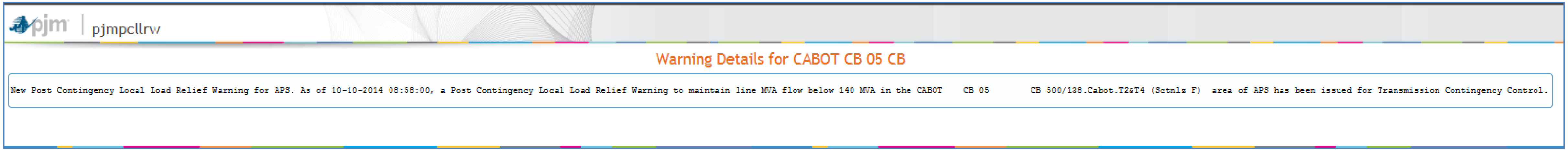
Deficient – Load Shed plan is not enough to meet the PCLLRW.

Valid – Load shed plan is sufficient to meet the PCLLRW

Changing system conditions can cause a **Valid** load shed plan status to change to **Deficient**

- 5 MVA Bandwidth +/-

TO Load Shed Plan Display



Clicking on “Unacknowledged” opens the Load Shed Plan for the specific PCLLRW

- TO must still identify locations and amount of planned load shed should Load Shed Directive be issued

TO Load Shed Plan Display

Current Post Contingency Local load Relief Warnings

Last SA Timestamp: 10/10/2014 09:33:00

Thermal PCLLRW Information

Co	Branch ID	KV	Pre MVA	Post MVA	NL	LT	ST	LD	MVA	(%)	MP	Contingency Title	Status
APS	CABOT CB 05 CB	500	427	634	130	135	140	145	494	469	1	L500.South Bend-Yukon	
PS	BERGEN F-1306 CB	138	98	139	60	80	80	85	59	174	1	L138.Bergen-East Rutherford.R-1344	
PS	49STREET-HOBOKEN R-2270-3	230	355	466	200	200	225	986	241	233	1	L138.Marion-Homestead-NorthBergen-Bergen.E-1305	
COMED	55 HEGEW-17714 17714 2	138	175	330	316	343	392	461	-61	96	1	L345.Burnham-Sheffield.17705 TIE	
BC	BAGLEY - GRACETON 2304	230	426	665	587	703	703	703	-37	94	1	L500.Brighton-Conastone	
PE	EMILIE 8TR XFORMER	230	258	427	341	453	453	515	-25	94	1	230/138.Emilie.7TR	
COMED	7713 -981 CRES 7713 2	138	110	164	174	174	174	185	-9	94	1	L345.Nelson-Electric Junction.15502	
APS	ALLDAM6-KITTANNI SP-KT	138	47	144	159	159	159	178	-14	91	1	L345.Armstrong-HomerCity	
COMED	0905 LINE 38L0905 10	138	151	175	175	195	195	201	-19	89	2	345L11124 Electric Jct-Lombard 345 kV Line	
BC	BAGLEY -RAPHAERD BAG-RAP	230	387	626	587	703	703	703	-76	89	1	L500.Brighton-Conastone	

(1 of 5) 1 2 3 4 5 10

Special Thermal PCLLRW Information

Co	Branch ID	KV	Pre MVA	Post MVA	NL	LT	ST	LD	MVA	(%)	MP	Contingency Title	Status
APS	CABOT CB 05 CB	500	427	823	130	135	140	145	683	610	1	500/138.Cabot.T2&T4 (Sctnlz F)	Unacknowledged
COMED	0905 LINE 38L0905 10	138	151	181	175	195	195	201	-13	92	2	345L11602 SF Goodings Grove-E Frank 345kV SPOG3-29	

(1 of 1) 1 10

Low Voltage PCLLRW Information

Co	Bus ID	Pre (KV)	Post (KV)	NL	EM	LD	Under (KV)	% of EM/LD	MP	Contingency Title	Status
AEP	REYNOLD2 138 KV BB_17299	136.9	109.8	131.1	127.0	124.2	14.4	88.4	2	MeadowLake-Reynolds-Olive 345kV & Reynolds Xfmr	
COMED	176 STIL 138 KV BB_10	138.4	125.6	131.1	127.0	124.2	1.4	98.9	1	L345.Nelson-Electric Junction.15502	
COMED	937 LEE 138 KV BB_16	132.2	127.1	131.1	127.0	124.2	-0.1	100.0	2	6 Byron.U1	
COMED	959ERDBS 138 KV BB_3	134.6	128.2	131.1	127.0	124.2	-1.2	101.0	2	6 Byron.U1	
AEP	HUFFMAN 138 KV BB_5792	141.9	129.0	131.1	127.0	124.2	-2.0	101.6	2	L138.Jac	
AEP	PIPERSGA 138 KV BB_6325	141.7	129.2	131.1	127.0	124.2	-2.2	101.7	2	L138.Ja	
AEP	INDUSTRY 138 KV BB_3139	140.0	129.6	131.1	127.0	124.2	-2.7	102.1	2	L138.Na	
AEP	HOW 138 KV BB_3120	140.1	129.8	131.1	127.0	124.2	-2.8	102.2	2	L138.Na	
FE	02ARMCO 138 KV *E08	134.7	129.8	131.1	127.0	124.2	-2.8	102.2	1	345/13	
PN	CORRYE 115 KV 115-2	114.0	108.3	109.0	106.0	103.0	-2.3	102.2	1	L230.Gl	

(1 of 5) 1 2 3 4 5 10

Special Low Voltage PCLLRW Information

Co	Bus ID	Pre (KV)	Post (KV)	NL	EM	LD	Under (KV)	% of EM/LD	MP	Contingency Title	Status
AEP	CLOVERD2 765 KV *A05	776.1	708.7	726.8	703.8	688.5	-4.9	100.7	1	765/345.Cloverdale.T.10 FAILED SECTIONALIZE	
AEP	BOXWOOD 138 KV BB_5097	137.8	128.1	131.1	127.0	124.2	-1.1	100.9	2	765/345.Cloverdale.T.10 FAILED SECTIONALIZE	
AEP	IVYHILL 138 KV BB_5867	139.2	128.2	131.1	127.0	124.2	-1.3	101.0	2	765/345.Cloverdale.T.10 FAILED SECTIONALIZE	
AEP	CENTRVIL 138 KV BB_5242	138.7	128.2	131.1	127.0	124.2	-1.3	101.0	2	765/345.Cloverdale.T.10 FAILED SECTIONALIZE	
AEP	COFFEE 138 KV *E02	138.8	128.3	131.1	127.0	124.2	-1.3	101.0	2	765/345.Cloverdale.T.10 FAILED SECTIONALIZE	

Unacknowledged PCLLRW

TO Load Shed Plan Display

- The required MW amount to relieve the PCLLRW will be listed
- As data is entered, the Cumulative Load Shed Relief will update
  - This box is highlighted **red** until the desired amount has been reached
  - The box will change to **green** when the desired amount is reached
- When the TO is satisfied with the report, select “Confirm Load Plan” button to submit to PJM

TO Load Shed Plan

- The required MW amount to relieve the PCLLRW will be listed

Load Reduction Megawatt Amount Needed	19

- As data is entered, the Cumulative Load Shed Relief will update

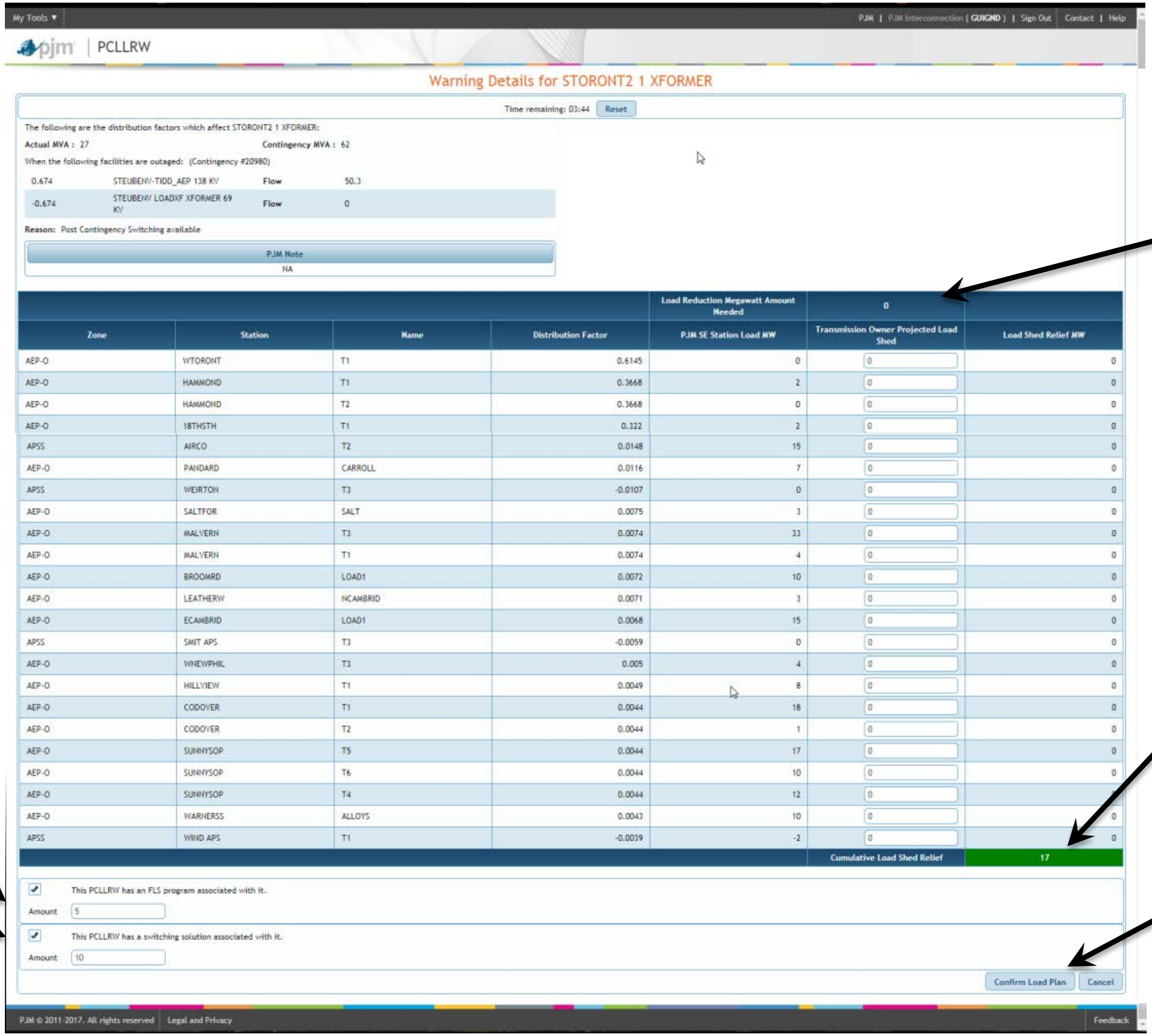
Cumulative Load Shed Relief	0

  - Highlighted **red** until desired amount has been reached
  - Box then changes to **green**

- When the TO is satisfied with the report, select “Confirm Load Plan” button to submit to PJM

Confirm Load Plan | Cancel

TO Load Shed Plan Display


My Tools ▾ PJM | PJM Interconnection (GUIGND) | Sign Out | Contact | Help

PCLLRW

Warning Details for STORONT2 1 XFORMER

Time remaining: 03:44 Reset

The following are the distribution factors which affect STORONT2 1 XFORMER:

Actual MVA : 27 Contingency MVA : 62

When the following facilities are outaged: (Contingency #20980)

0.674	STEUBENV-TIDD_AEP 138 KV	Flow	50.3
-0.674	STEUBENV LOADXF XFORMER 69 KV	Flow	0

Reason: Post Contingency Switching available

PJM Note

NA

				Load Reduction Megawatt Amount Needed	0	
Zone	Station	Name	Distribution Factor	PJM SE Station Load MW	Transmission Owner Projected Load Shed	Load Shed Relief MW
AEP-O	WTORONT	T1	0.6145	0	0	0
AEP-O	HAMMOND	T1	0.3668	2	0	0
AEP-O	HAMMOND	T2	0.3668	0	0	0
AEP-O	18THSTH	T1	0.322	2	0	0
APSS	AIRCO	T2	0.0148	15	0	0
AEP-O	PANDARD	CARROLL	0.0116	7	0	0
APSS	WEIRTON	T3	-0.0107	0	0	0
AEP-O	SALTFOR	SALT	0.0075	3	0	0
AEP-O	MALVERN	T3	0.0074	33	0	0
AEP-O	MALVERN	T1	0.0074	4	0	0
AEP-O	BROOMRD	LOAD1	0.0072	10	0	0
AEP-O	LEATHERW	NCAMBRID	0.0071	3	0	0
AEP-O	ECAMBRID	LOAD1	0.0068	15	0	0
APSS	SMIT APS	T3	-0.0059	0	0	0
AEP-O	WNEWPHIL	T3	0.005	4	0	0
AEP-O	HILLVIEW	T1	0.0049	8	0	0
AEP-O	CODOVER	T1	0.0044	18	0	0
AEP-O	CODOVER	T2	0.0044	1	0	0
AEP-O	SUNNYSOP	T5	0.0044	17	0	0
AEP-O	SUNNYSOP	T6	0.0044	10	0	0
AEP-O	SUNNYSOP	T4	0.0044	12	0	0
AEP-O	WARNERSS	ALLOYS	0.0043	10	0	0
APSS	WIND APS	T1	-0.0039	-2	0	0
					Cumulative Load Shed Relief	17

☑ This PCLLRW has an FLS program associated with it.

Amount 5

☑ This PCLLRW has a switching solution associated with it.

Amount 10

Confirm Load Plan Cancel

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Required Relief

Actual Relief
(RED is deficient)

Click to submit to PJM

Use if TO has FLS program

or Switching Solution is available

TO Load Shed Plan Display

Distribution Factor **X** Operator entered MW amount **=** Total MW Relief (Dfax x MW selected)

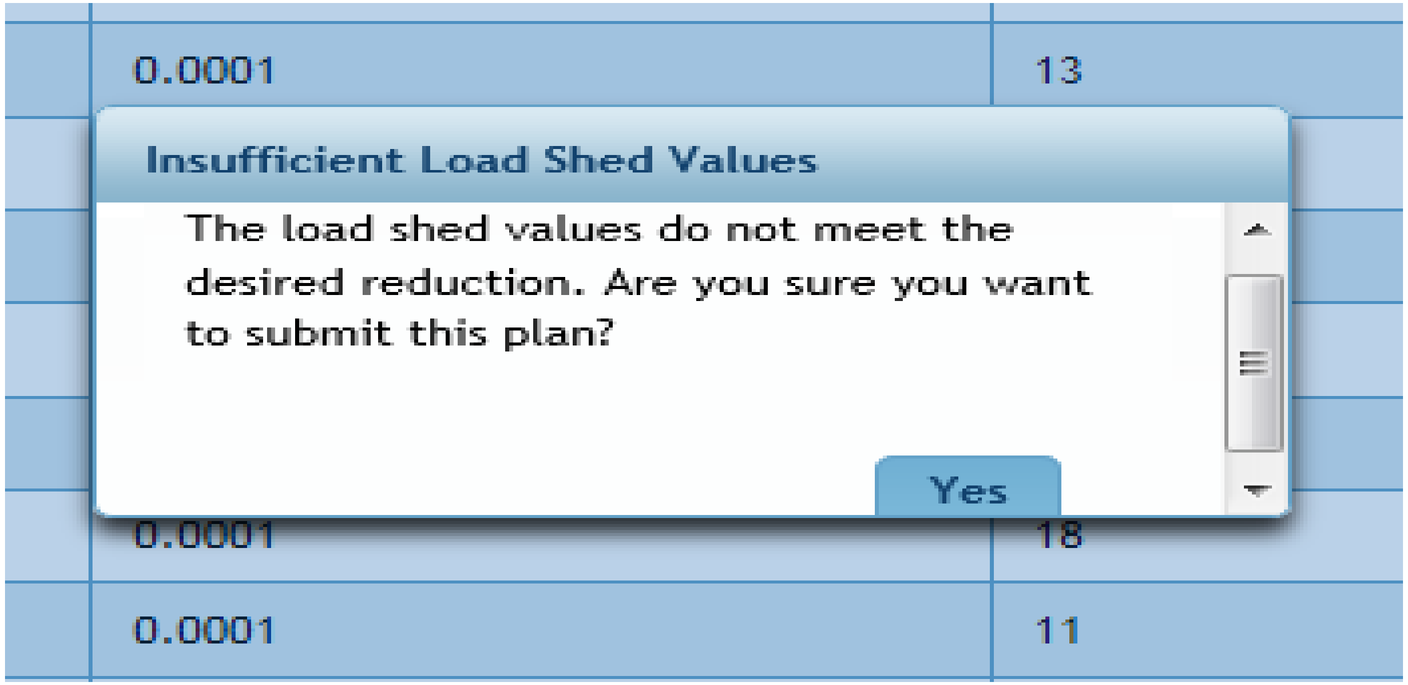
Equipment Name

Equipment MWs

				Load Reduction MegaWatt Amount Needed	62	
Zone	Station	Name	Distribution Factor	PJM SE Station Load MW	Transmission Owner Projected Load Shed	Load Shed Relief MW
AEP	TORREY	T4	0.6623	36	33	22
AEP	REEDURBA	T2	0.6154	13	12	7
AEP	REEDURBA	T1	0.6154	12	11	7
AEP	MILESAVE	T1	0.5914	12	11	7
AEP	WCANTON	T3	0.5554	4	0	0
FE	DALEOE	TR2	0.2733	1	0	0
FE	CLOVEROE	B	0.2611	46	0	0
FE	CLOVEROE	A	0.256	50	0	0
FE	DALEOE	B	0.2185	87	0	0
FE	MOOREOE	TR1	0.1959	13	0	0

TO Load Shed Plan Deficient

- If a submitted TO Load Shed is deficient:
  - A warning message received indicating such
  - Adjust load shed to satisfy needed amount



PCLLRW - Multiple Zones

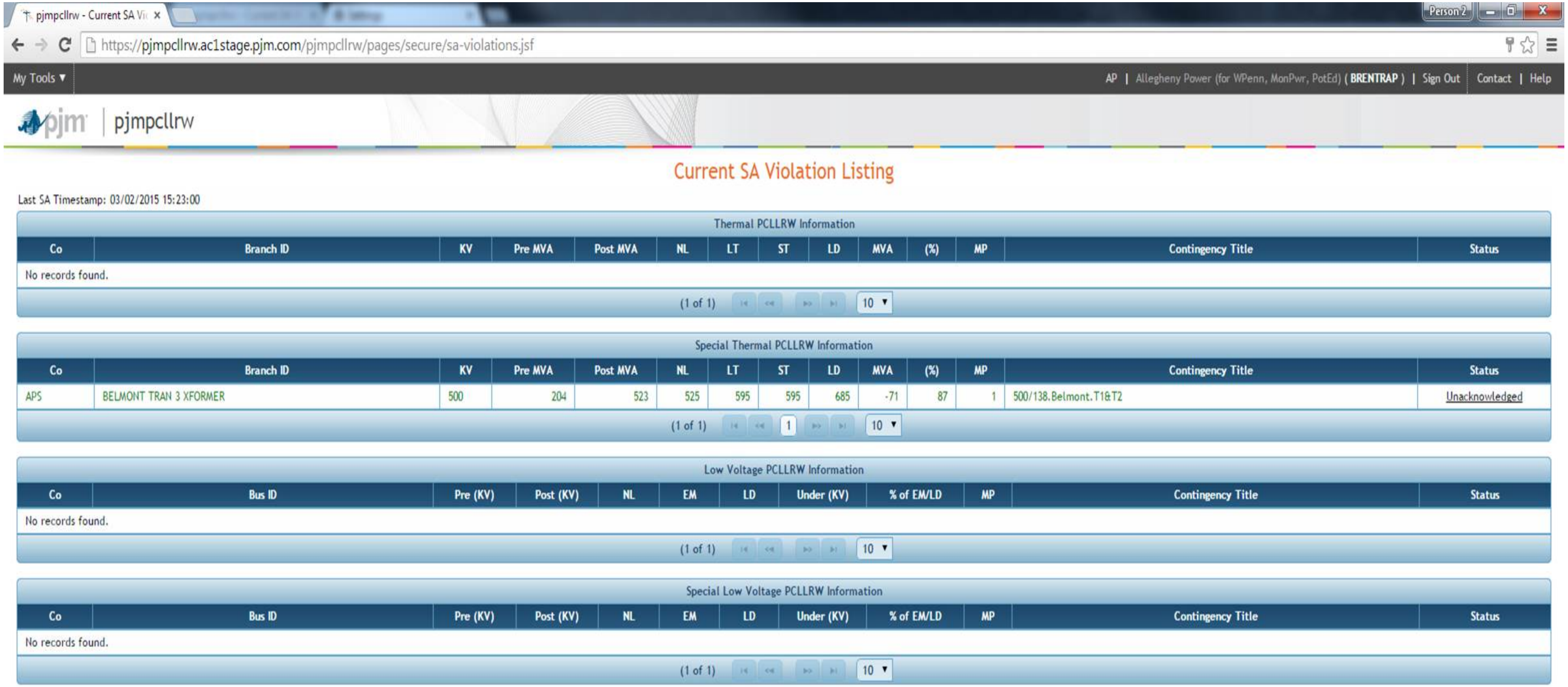
Multiple Zones, Manual 13:

- PCLLRW is issued to TO of overloaded equipment
  - Enough load must be shed to maintain flows on the monitored facility below the Emergency Rating or an agreed upon level
  - If sufficient load is not available to shed or sufficient time to shed is not adequate
    - TO shall inform PJM so they to include neighboring TO loads if applicable or develop an alternative plan to control

Note: If all of the load to be shed is in the non-owning Transmission Owner's territory, PJM may issue the PCLLRW to the Transmission Owner with the load and not the Transmission Owner of the limiting equipment. However, PJM will inform/coordinate the post contingency load shed plan with the Transmission Owner of the equipment

PCLLRW - Multiple Zones

- The tool will create TWO emails w/ the DFAX and send APS and AEP each a copy of the DFAX
- The DFAX and SA alarm will show up on BOTH company's PCLLRW tool screens:



PCLLRW - Multiple Zones

- Here's the AEP PCLLRW screen. Notice the APS SA violation is there.
- Both TOs can contribute to the load shed plan; however, only one at a time can edit it

pjmpcllrw - Current SA Vi… | New Tab

https://pjmpcllrw.ac1stage.pjm.com/pjmpcllrw/pages/secure/sa-violations.jsf

My Tools ▾ — AEPSCT | Appalachian Power Company (AEP Transmission) (BRENTRAEP1) | Sign Out | Contact | Help

pjm | pjmpcllrw

Current SA Violation Listing

Last SA Timestamp: 03/02/2015 15:14:00

Thermal PCLLRW Information

Co	Branch ID	KV	Pre MVA	Post MVA	NL	LT	ST	LD	MVA	(%)	MP	Contingency Title	Status
No records found.													

(1 of 1) 10

Special Thermal PCLLRW Information

Co	Branch ID	KV	Pre MVA	Post MVA	NL	LT	ST	LD	MVA	(%)	MP	Contingency Title	Status
APS	BELMONT TRAN 3 XFORMER	500	204	521	525	595	595	685	-73	87	1	500/138.Belmont.T1&T2	Unacknowledged

(1 of 1) 1 10

Low Voltage PCLLRW Information

Co	Bus ID	Pre (KV)	Post (KV)	NL	EM	LD	Under (KV)	% of EM/LD	MP	Contingency Title	Status
AEP	ENEWCONC 138 KV BB_11547	142.4	130.7	131.1	127.0	124.2	-3.7	102.9	1	L138.Newcomerstown-W.Cambridge	
AEP	WCAMBRI2 138 KV BB_12408	142.4	130.7	131.1	127.0	124.2	-3.7	102.9	2	L138.Newcomerstown-W.Cambridge	

(1 of 1) 1 10

Special Low Voltage PCLLRW Information

Co	Bus ID	Pre (KV)	Post (KV)	NL	EM	LD	Under (KV)	% of EM/LD	MP	Contingency Title	Status
No records found.											

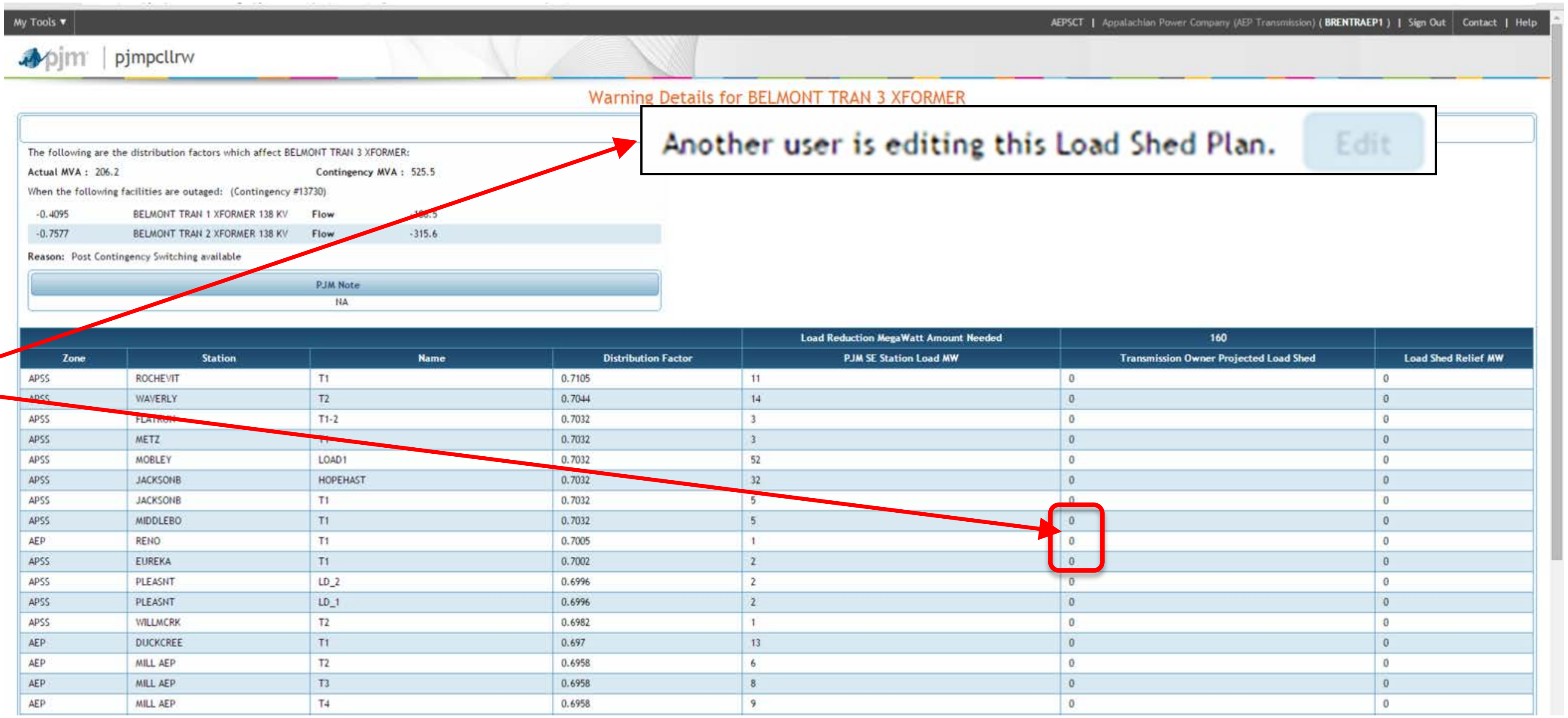
(1 of 1) 10

PCLLRW - Multiple Zones

If a TO tries to edit the PCLLRW while another is working on it, they will see the following:

Notice, the Box: **"Another user is editing this Load Shed Plan"**

The "***Transmission Owner Projected Load Shed***" column cannot be edited



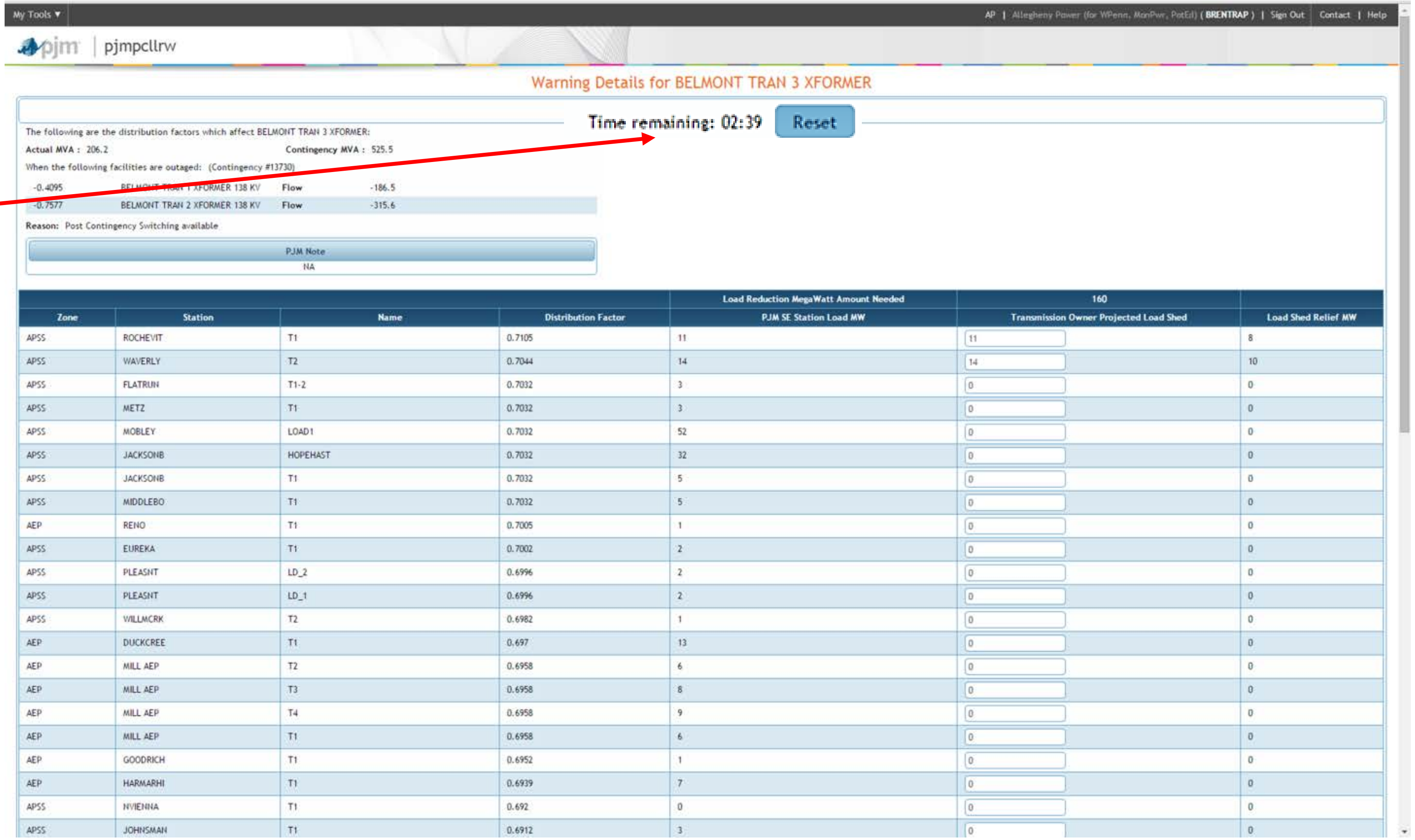
				Load Reduction MegaWatt Amount Needed	160	
Zone	**Station**	**Name**	**Distribution Factor**	**PJM SE Station Load MW**	**Transmission Owner Projected Load Shed**	**Load Shed Relief MW**
APSS	ROCHEVIT	T1	0.7105	11	0	0
APSS	WAVERLY	T2	0.7044	14	0	0
APSS	FLATRON	T1-2	0.7032	3	0	0
APSS	METZ	T1	0.7032	3	0	0
APSS	MOBLEY	LOAD1	0.7032	52	0	0
APSS	JACKSONB	HOPEHAST	0.7032	32	0	0
APSS	JACKSONB	T1	0.7032	5	0	0
APSS	MIDDLEBO	T1	0.7032	5	0	0
AEP	RENO	T1	0.7005	1	0	0
APSS	EUREKA	T1	0.7002	2	0	0
APSS	PLEASNT	LD_2	0.6996	2	0	0
APSS	PLEASNT	LD_1	0.6996	2	0	0
APSS	WILLMCRK	T2	0.6982	1	0	0
AEP	DUCKCREE	T1	0.697	13	0	0
AEP	MILL AEP	T2	0.6958	6	0	0
AEP	MILL AEP	T3	0.6958	8	0	0
AEP	MILL AEP	T4	0.6958	9	0	0

PCLLRW - Multiple Zones

The editing TO gets 5 minutes (but can be reset and add more time if needed)

Note: the form ***DOES NOT ENFORCE*** TOs changing or accidentally putting data in the wrong row

In this example, APS could enter numbers for AEP and vise-versa



My Tools ▾ AP | Allegheny Power (for WPenn, MonPwr, PotEd) (BRENTRAP) | Sign Out | Contact | Help

pjm | pjmpcllrw

Warning Details for BELMONT TRAN 3 XFORMER

Time remaining: 02:39 Reset

The following are the distribution factors which affect BELMONT TRAN 3 XFORMER:

Actual MVA : 206.2 Contingency MVA : 525.5

When the following facilities are outaged: (Contingency #13730)

-0.4095	BELMONT TRAN 1 XFORMER 138 KV	Flow	-186.5
-0.7577	BELMONT TRAN 2 XFORMER 138 KV	Flow	-315.6

Reason: Post Contingency Switching available

PJM Note

NA

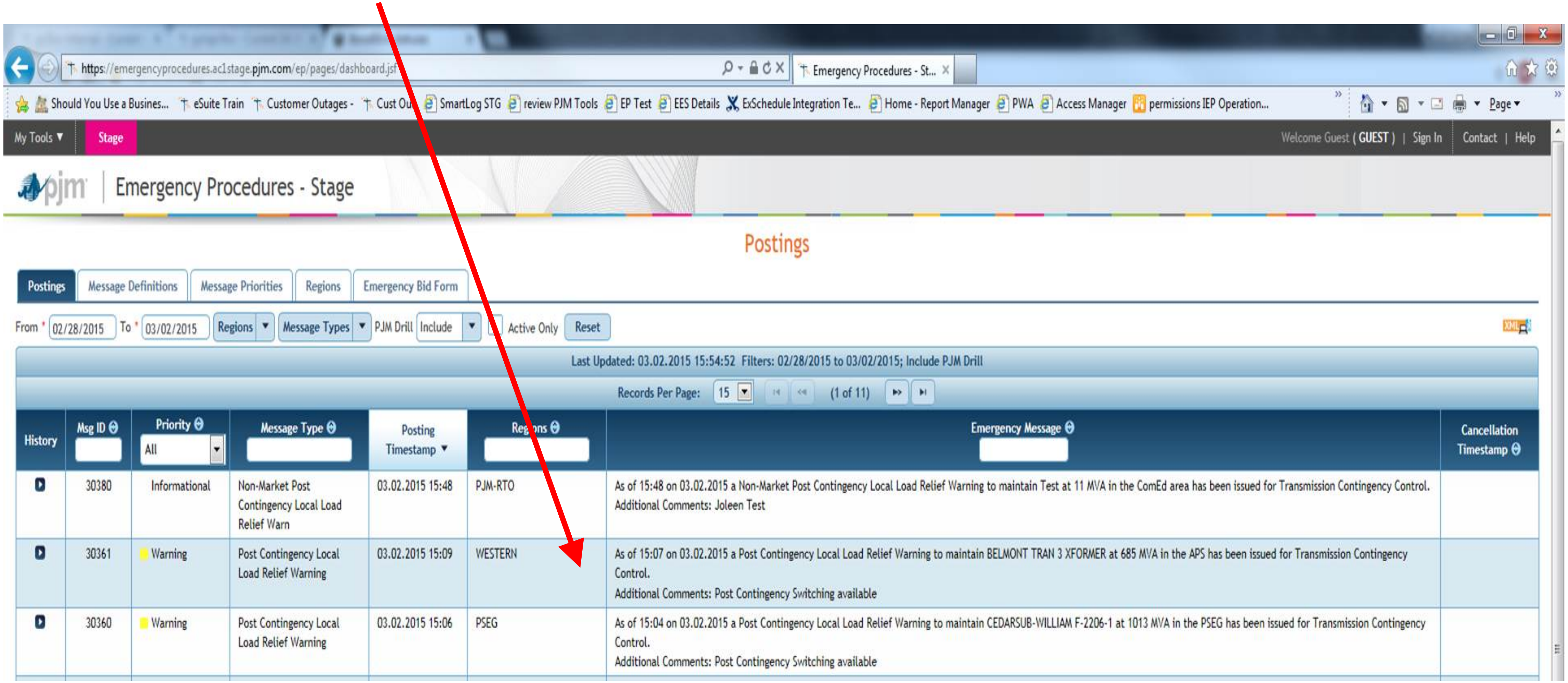
				Load Reduction MegaWatt Amount Needed	160	
Zone	Station	Name	Distribution Factor	PJM SE Station Load MW	Transmission Owner Projected Load Shed	Load Shed Relief MW
APSS	ROCHEVIT	T1	0.7105	11	11	8
APSS	WAVERLY	T2	0.7044	14	14	10
APSS	FLATRUN	T1-2	0.7032	3	0	0
APSS	METZ	T1	0.7032	3	0	0
APSS	MOBLEY	LOAD1	0.7032	52	0	0
APSS	JACKSONB	HOPEHAST	0.7032	32	0	0
APSS	JACKSONB	T1	0.7032	5	0	0
APSS	MIDDLEBO	T1	0.7032	5	0	0
AEP	RENO	T1	0.7005	1	0	0
APSS	EUREKA	T1	0.7002	2	0	0
APSS	PLEASNT	LD_2	0.6996	2	0	0
APSS	PLEASNT	LD_1	0.6996	2	0	0
APSS	WILLMCRK	T2	0.6982	1	0	0
AEP	DUCKCREE	T1	0.697	13	0	0
AEP	MILL AEP	T2	0.6958	6	0	0
AEP	MILL AEP	T3	0.6958	8	0	0
AEP	MILL AEP	T4	0.6958	9	0	0
AEP	MILL AEP	T1	0.6958	6	0	0
AEP	GOODRICH	T1	0.6952	1	0	0
AEP	HARMARHI	T1	0.6939	7	0	0
APSS	NVIENNA	T1	0.692	0	0	0
APSS	JOHNSMAN	T1	0.6912	3	0	0

PCLLRW - Multiple Zones

- The system sends two emails, one to each TO

PCLLRW - Multiple Zones

- Single posting in Emergency Procedures



Post Contingency Local Dump Limit Exceedance Analysis

Post-Contingency Load Dump Limit Exceedance Analysis

Manual 13, Section 5.4.1

- NERC Standard PRC-023 R1.2 and R1.11
  - Transmission line relays and transformer overload protection relays are set so they do not operate at or below 115% of the facility's highest emergency rating
- PJM facilities highest rating is the Load Dump rating.
  - PJM will perform the following analysis for any facility that reaches or exceeds 115% of its Load Dump limit:
  - Study the loss of the contingency element and the overloaded facility

Post-Contingency Load Dump Limit Exceedance Analysis

Manual 13, Section 5.4.1

- PCLLRW is issued after:
  - All other means of transmission constraint control have been exhausted, or
  - Until sufficient generation is on-line to control the constraint within designated limits and timelines
- If post-contingency flow were to exceed the 15-minute Load Dump rating, the facility may trip before actions can be taken to reduce the flow within limits
- To prepare for this potential N-2 (initial contingency plus the overloaded facility) and prevent a cascade:
  - PJM will perform up to an N-5 on facilities over 115% of their 15-minute Load Dump rating

Post-Contingency Load Dump Limit Exceedance Analysis

Manual 13, Section 5.4.1

- If the study results indicate that:
  - No additional facilities will be overloaded over 115% of their Load Dump limit:
    - This is a localized event, and no additional pre-contingency actions will be taken
  - Additional facility(s) over 115% of its Load Dump rating, the operator will continue the analysis to also trip the additional circuits:
    - Analysis will be performed, tripping a maximum of 5 facilities
  - Either a non-converged case, or continues to show facilities exceeding 115% of their Load Dump limits:
    - This will be considered a potential cascade situation

Post-Contingency Load Dump Limit Exceedance Analysis

PJM's EMS has a Cascade Analysis program which is set to…

- Run automatically whenever SA detects a post contingency violation which is equal to or greater than 115% of the load dump rating
- Results are shown on the SA Thermals display in TNA
- Provides more accurate results than manually performing cascade analysis because it removes multiple facilities from service in a single contingency

This will give different results than running Power Flow after each line is removed from service in study mode

Post-Contingency Load Dump Limit Exceedance Analysis

Manual 13 Section 5.4.1

- PJM operator will review the results with the Transmission Owner and direct pre-contingency Load Shed
- If the analysis at any point results in a valid non-converged contingency indicating a potential cascade
  - The PJM Operator will review the results with the Transmission Owner, and
  - Direct pre-contingency Load Shed within 30 minutes to mitigate the potential cascade situation

Note: Load Shed will be directed in the amount needed to maintain the post contingency flow below 115% of the Load Dump limit on the original contingency within 30-minutes of detection of the potential cascade situation

Cascade Analysis Simulation

Manual Load Shed Determination Procedure

For a facility exceeding its LD, STE or LTE rating:

- Contact between PJM and TO should be made immediately
  - In particular for a facility exceeding its LD rating
- Compare real-time flows to state estimator flows

  For any discrepancies:
  - The reason is obvious and facility is not overloaded
    - PJM and TO should work together to resolve the discrepancy, log it and cease Load Shed Determination Procedure
  - The reason is not immediately obvious
    - PJM and TO shall agree upon the most conservative values

Manual Load Shed Determination Procedure

- Compare LD and Emergency ratings

  For any discrepancies:

  - The reason is obvious and facility is not overloaded
    - PJM and TO should work together to resolve the discrepancy, log it and cease Load Shed Determination Procedure
  - The reason is not immediately obvious
    - PJM and TO shall agree upon the most conservative values

Manual Load Shed Determination Procedure

- Switching and Generation option
  - For a LD rating overload, there are only 3 options available to alleviate:
    - A reclose attempt on the facility that tripped to cause the violation
    - Pre-studied switching solution
    - Generation re-dispatch (if generation can move fast enough)

<u>Note: A Pre-Studied Switching Solution must be …</u>

- A switching that had been agreed upon by both the TO and PJM which:
  - Had been studied prior to the initiating event for present Load Dump overload
  - The study should have accurately reflected the initiating event and present system topology for the area presently experiencing the Load Dump overload
  - The switching solution CANNOT place any other facility into a Normal Rating overload

Manual Load Shed Determination Procedure

- For an Emergency (LTE or STE) overload:
  - May be time to study Switching Solutions and/or Generation Re-dispatch
  - Once overload is 5 minutes away from becoming a violation, and
  - If a switching solution and/or re-dispatch is not expected to relieve the overload in the next 5 minutes
- Commence **Load Shed Directive** immediately and without delay

Note: The amount of load shed required in a ***Load Shed Area*** is typically dependent upon the amount of load under SCADA control in the *Load Shed Area*. As such, the TO may have to shed a substantial amount of load that significantly reduces the flow across the *Overloaded Facility* (sometimes well below the NL rating on said facility) due to limited SCADA control.

However, this is the desired effect, to protect the *Overloaded Facility*. If significant load shed is required, the TO should shed the load first to protect the facility… then, in coordination with PJM, fine-tune the load shed afterwards with the help of additional TO personnel (substation, switchman, etc.)

Manual Load Shed Determination Procedure

- The following is meant to be a template script for issuance of a Load Shed Directive
- The Script should be readily available to both PJM and TO operators as a reference
- The intent of the script is for familiarity and easy recognition of the gravity of the situation
- Both operators should take special note that the tone of the Directive is meant to be formal, clear and specific
- At the beginning, during and at the completion of the Directive, there should be no ambiguity as to what is taking place or what needs to be done to alleviate the situation
  - As such, no extraneous conversation outside of the directive should take place either during the Directive or at the end of the Directive
- **If at any time during the issuance of the Directive, either party becomes distracted for any reason, they should cancel the order and commence from the beginning**

Example Script

Keywords:

- ***PJM Operator***: John Doe
- ***TO Company***: XYZ Energy
- ***TO Operator***: A.J. Jones
- ***Present Time***: 1208
- ***Overloaded Facility:*** Victorstation 345/138kV #2 Transformer
  (which is presently overloaded with flow from the 345kV high side down to the 138kV low side)
- ***Facility Flow***: 705 MVA
- ***Rating***: LD rating. (650 MVA)
- ***Overload Time***: 1206
- ***Desired Flow***: 590 MVA LTE/STE rating
- ***Load Shed Area***: Victorstation 138kV and below

Script Verbiage

PJM Operator:

- “This is PJM Dispatcher John Doe with a Load Shed Directive.”
- “As of 1208, the Victorstation 345/138kV #2 Transformer is determined to be exceeding its Load Dump rating of 650 MVA and is presently loaded at 705 MVA. The facility has been exceeding its Load Dump rating since 1206.”

TO Operator:

- “I agree that as of 1208, the Victorstation 345/138kV #2 Transformer is determined to be exceeding its Load Dump rating of 650 MVA and is presently loaded at 705 MVA. I also agree that the facility has been exceeding its Load Dump rating since 1206.”

PJM Operator:

- "That is correct."

Script Verbiage

PJM Operator:

- "At this time PJM is initiating a Load Shed Directive to reduce the flow across the Victorstation 345/138kV #2 Transformer to a level not to exceed 590 MVA. XYZ Energy should commence load shed in the Victorstation 138kV and below area immediately."

TO Operator:

- "I agree that a Load Shed Directive has been ordered to immediately commence load shed in the Victorstation 138kV and below area with the intent to reduce the flow across the Victorstation 345/138kV #2 Transformer down to a flow that does not exceed 590 MVA."

PJM Operator:

- "That is correct. Please call me back to confirm once the load shed is completed."

Post Contingency Congestion Management Program

Post-Contingency Congestion Management Program

- Background
  - PJM analysis indicates that probability of contingent facility tripping during an off-cost event is less than .05%
  - It's prudent to operate to a higher pre-contingency threshold (i.e. 30 minute rating)
    - If ample quick-start generation or switching actions are available, eliminate an actual overload should a contingent facility tripping occur
    - Generation must demonstrate a history of adequate availability and response

Post-Contingency Congestion Management Program

- Criteria
  - Outage of contingent facility must not cause a cascading outage or precipitate an uncontrolled separation within and/or external to the PJM RTO
  - EHV facilities not included in the program
  - Transmission owner of the facility will have an established short-term emergency rating (normally 30 minutes)
  - Facilities must have more than one quick-start CT or diesel in the vicinity, and off-line, to eliminate the contingency should it occur

Post-Contingency Congestion Management Program

- Criteria: Quick-start CT or diesel must meet the following criteria:
  - An availability of 120% of necessary generation to obtain the required MW relief from 30 minute rating to normal rating must be demonstrated (Account for the possibility of some generation not starting)
  - Net generation must have history of being on-line and loaded within 30 minutes 85% of the time
  - Where available, condensers will be brought on-line for control once a contingency flow reaches the 4-hour emergency rating
  - This program will be implemented during non-winter months for facilities where fast-start generation is used for control
  - Switching procedures that demonstrate successful winter implementation may be included under the program year-round

Post-Contingency Congestion Management Program

- Alternative Controlling Options
  - TO may offer generation run-back schemes to control for these facilities
    - Subject to ramp rate testing data as supplied by the Generation Owner
  - TO may utilize switching and reclosing procedures to control for these facilities
    - Procedures must be studied and approved by PJM
    - Post-contingency switching must be implemented via SCADA control
    - TO must have ability to dump sufficient load via SCADA if switching procedure can not be implemented
    - Switching procedures may be implemented pre-contingency once contingency flow exceeds the 30-minute rating and all generation has been called

Post-Contingency Congestion Management Program

- Systems designed for post-contingency switching:
  - On a pre-contingency basis, off-cost operations will commence once simulated contingency flow, using *Guide Implemented* contingency definitions, reaches the Long-term emergency rating
  - On a pre-contingency basis, off-cost operations will commence once simulated contingency flow, using the *Guide Failed* contingency definitions, approaches the Load Dump Rating
  - In the event of a contingent facility tripping, the appropriate guide scheme will be used to ensure flow drops below the Long-term emergency rating.
    - Generation redispatch, if needed, will be used to bring the flow below the normal rating

Post-Contingency Congestion Management Program

- **PJM Roles/Responsibilities**
  - Selection/analysis/approval for facilities in program
  - Communicate and consult with the Transmission Owner to ensure that the analysis is accurate
  - Publish facilities in Manual M-03, Transmission Operations
  - Operate facility to Short-term rating provided by Transmission Owner
    - If the rating is exceeded pre-contingency, off-cost operations will be used to mitigate the simulated overload

Post-Contingency Congestion Management Program

- **Transmission Owner Roles/Responsibilities**
  - Review and comment on the proposed facilities
  - For any disagreements concerning proposed facilities:
    - PJM has a Dispute Resolution Process in place
    - PJM will delay implementation of the facility until the disagreement is resolved
  - May offer additional facilities to be studied for inclusion into the program

Post-Contingency Congestion Management Program

- **Generation Owner Roles/Responsibilities**
  - Operate fast-response generation in accordance with PJM's current rules and procedures
  - When called upon to mitigate a transmission outage on a facility included in the program, the generation owner shall start the unit in accordance with PJM's instructions

Post-Contingency Congestion Management Program

- The list of facilities is in Transmission Operations **Manual 3, Attachment D**


PJM Manual 03: Transmission Operations
Attachment D: Post Contingency Congestion Management Program

Attachment D: Post Contingency Congestion Management Program

PJM has historically operated on a pre-contingency basis under which it calls for off-cost generation to be run to alleviate contingency overloads. The amount of off- cost generation can total in excess of millions of dollars per year in congestion. PJM analysis indicates that the probability of contingent facility tripping during an off-cost event is less than .05%.

PJM believes that it is prudent to operate to a higher pre-contingency threshold (i.e., 30-minute rating) in areas where analysis demonstrates that there is ample fast-start generation or switching actions available to eliminate an actual overload should contingent facility tripping occur. This generation must demonstrate a history of adequate availability and response as defined below.

PJM's post-contingency congestion management program is operated for monitored facilities that meet the following criteria:

1. Outage of the contingent facility must not cause a cascading outage or precipitate uncontrolled separation within and external to the PJM Balancing Authority.
2. EHV facilities will not be included in this program. However there are cases in some areas where facilities up to and including 345 kV may be studied for inclusion in the program as long as there is no adverse impact on the transmission system.
3. The Transmission Owner of the facility will have established a short-term emergency rating for the facility (nominally 30 minutes).
4. Facilities must have more than one fast-start combustion turbine or diesel generator in the vicinity (and off-line) to eliminate a contingency should it occur. Normally, availability of 120% of the necessary generation to obtain the required MW relief from the 30-minute rating to normal rating will need to be demonstrated to account for the possibility that some generation will not start.
5. The net area generation has to have a history of being on-line and loaded for control within 30 minutes 85% of the time. (Normally, review of the previous 12 month performance will be sufficient to establish the historical performance.)
6. Where available, condensers will be brought on-line for control once contingency flow reaches the 4-hour emergency rating.
7. This program will be implemented during non-winter months for facilities where fast-start generation is used for control. Switching procedures that demonstrate successful winter implementation may be included under the program year-round.
8. Facilities in transmission systems that were designed to operate on a post-contingency basis as outlined in the next section will be considered on a case by case basis.

Alternative Controlling Options

1. The TO may offer generation run-back schemes to control for these facilities. These will be considered as controlling actions under this program after PJM tests the ramp-rate data as supplied by the generation owner. Further discussion and analysis is needed in this area prior to accepting these options. This document will be revised once these procedures are submitted, tested, and approved.

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Transmission Loading Relief (TLR)

Transmission Loading Relief Procedure (TLR)

- NERC TLR
  - Transmission Loading Relief is a NERC procedure that is used to safely and effectively reduce flow on a transmission element on the bulk power system
  - Used in the Eastern Interconnection
  - Respects transmission service reservation priorities
  - Mitigates potential or actual Operational Security Limit violations

Transmission Loading Relief Procedure (TLR)

- PJM TLR Definition:
  - The PJM procedure includes the NERC procedure but incorporates generation re-dispatch prior to implementing the Transmission Loading Relief Procedure as a means for managing congestion

Transmission Loading Relief Procedure (TLR)

- PJM TLR Procedure
  - Step 1 - Implement non-cost measures to control power flow
  - Step 2 - Curtail transactions in PJM that are “not willing to pay through congestion”
  - Step 3 - Adjust output of generators off-cost to alleviate overloads
  - Step 4 - Implement the NERC TLR procedure
  - Step 5 - Curtail external customers or charge external customers for congestion
  - Step 6 - Curtail remaining transactions in priority order

Transmission Loading Relief Procedure (TLR)

NERC TLR Procedure Levels

TLR Levels 1 - Notification

TLR Level 2 - Hold Interchange Transactions

TLR Level 3a - Reallocation Non-firm Point-to-Point

TLR Level 3b - Curtailment Non-firm Point-to-Point

TLR Level 4 - Reconfiguration

TLR Level 5a - Reallocation Firm Point-to-Point

TLR Level 5 b - Curtailment Firm

TLR Level 6 - Emergency Procedure

TLR Level 0 - TLR Concluded

Transmission Loading Relief Procedure (TLR)

Transmission Service Priorities

Priority 0 NX - Next -hour Market Service

Priority 1 NS - Service over secondary receipt and delivery points

Priority 2 NH - Hourly Service

Priority 3 ND - Daily Service

Priority 4 NW - Weekly Service

Priority 5 NM - Monthly Service

Priority 6 NN - Network Integration Transmission Service from sources not designated as network resources

Priority 7 F - Firm point-to-point Trans Service and Network Integration Transmission Service from designated resources

Transmission Loading Relief Procedure (TLR)

- Other concepts you need to know:
  - Power Flow Model
  - Flowgates
  - Transfer Distribution Factors
  - NERC E-Tags
  - Transmission Service Priorities
  - IDC (Interchange Distribution Calculator)

Transmission Loading Relief Procedure (TLR)

- **Power Flow Model**
  - Models the actual configuration of the Eastern Interconnection
  - Contains Generator & Transmission status
  - Created once every hour
  - Can be updated three times an hour
  - Reliability Coordinators are responsible for updating the model

Transmission Loading Relief Procedure (TLR)

- **Flowgates**
  - A flowgate is a boundary between two parts of a transmission system across which there **may** be congestion
  - Flowgates may cut across a number of circuits and because they “cut” across circuits, they are known as CUT SETS
  - The key characteristic of a flowgate is that it has a well defined limit of power that can flow across it
  - A flowgate may have thermal, voltage, phase angle and/or stability limitations

Transmission Loading Relief Procedure (TLR)

- **Transfer Distribution Factors**
  - Transfer Distribution Factors represent the impact of an interchange transaction between one control area to another control area on a given flowgate
  - There are two types of Transfer Distribution Factors (TDF) calculated
    - Power Transfer Distribution Factors (PTDF) - These factors are calculated to consider the effect of a transaction on a flowgate
    - Outage Transfer Distribution Factor (OTDF) - These factors are calculated to consider the effect of a transaction on a flowgate after an outage of another facility

Transmission Loading Relief Procedure (TLR)

NERC E-Tags

- Provide a tag name to determine the Source and Sink Control Areas
  - Provides OASIS information to determine priority
  - Provides the energy profile to determine MW flow
  - Each E-TAG will have Transfer Distribution Factor assigned by the IDC per individual flowgate
  - Only Interchange Transactions with a TDF of 5% or greater are subject to TLR Curtailments

Transmission Loading Relief Procedure (TLR)

- **Interchange Distribution Calculator (IDC)**
  - Primary tool used for NERC TLR
  - Calculates Transfer Distribution Factors (TDF) for specific flowgates
  - Uses an updated power flow model of the Eastern Interconnection
  - Obtains interchange transaction data from NERC E-Tags
  - Provides TLR Level notification
  - Creates Curtailment report for specific flowgates

Constraint Management Mitigation Procedure

Constraint Management Mitigation Procedure

- Purpose
  - Allows for BRIEF deviations from thermal operating criteria to accommodate switching
    - Results in maintaining system integrity by keeping lines/facilities in service during these short term excursions
    - Reduces the occurrence of unnecessary off-cost operation
    - Normal Limits can be exceeded briefly without damaging equipment due to the lengthy thermal time constants for heat build-up in equipment
      - Supported by Equipment Engineers

Constraint Management Mitigation Procedure

- Requirements
  - Pre-agreement by PJM OPD, PJM Dispatch and TO Dispatch (and anyone else who is involved)
    - If the above parties are not in agreement on the use of this procedure, the procedure should not be utilized
  - Planned event MUST be pre-studied on a case by case basis
    - Each operation or use of this procedure should be documented and logged

Constraint Management Mitigation Procedure

- Requirements *(con't)*
  - PJM will **NOT** allow actual operation over the Emergency thermal rating on an actual basis for ANY period of time
    - Operation over the normal rating will be tolerated for up to 5 minutes (with an approved "back-out" plan)
  - PJM will **NOT** allow operation over the Load Dump rating on a post-contingency basis for ANY period of time
    - Operation over the Emergency Rating on a post-contingency basis will be tolerated for up to 5 minutes (with an approved "back-out" plan)

Constraint Management Mitigation Procedure

- Requirements *(con't)*
  - Planned event (overload) should take no longer than 5 minutes
  - "Back-out" plan must be in place to alleviate the overload should event be extended due to unexpected circumstances

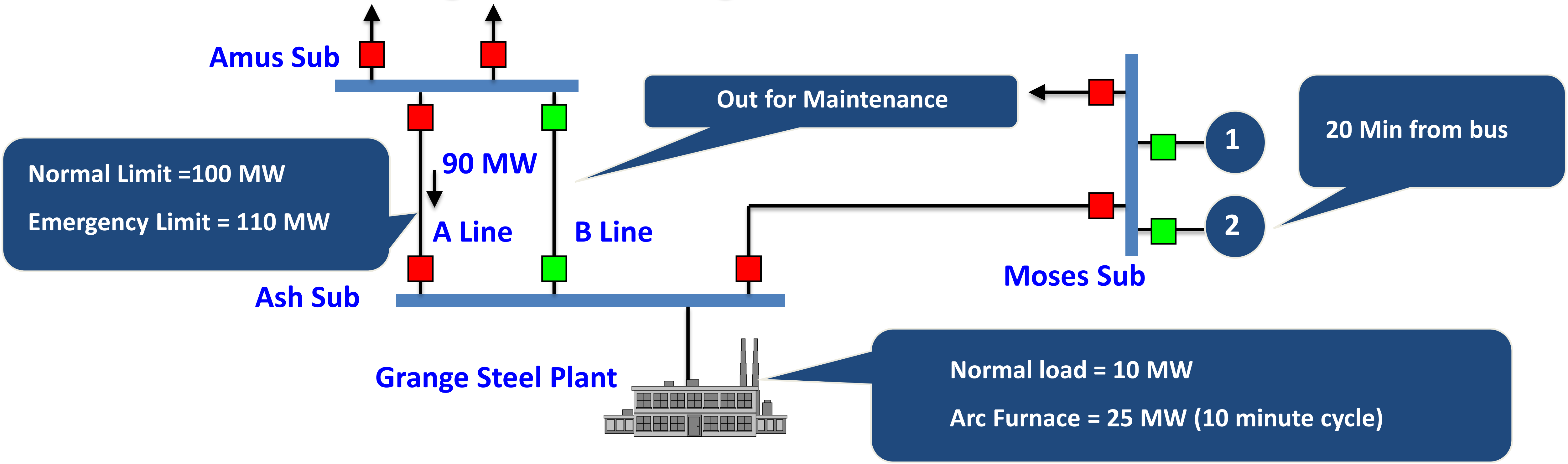
Constraint Management Mitigation Procedure

- Back-out Plan
  - Must be agreed to by all parties
  - Must not impact other members
  - Must return overloaded facility within limits in **15 minutes or less** from the start of the outage
  - Must have sufficient redundancy
    - SCADA and physical control
    - Variety of options
      - Multiple CTs
  - Must be pre-studied and studied for actual system conditions

Constraint Management Mitigation Procedure

- General
  - Communication and Coordination are the keys to success of this procedure
    - PJM ⟺ TO, TO ⟺ Field
  - All personnel must be in place and ready to implement "Back-out" plan if it becomes necessary
  - No safety or standard switching procedures should be violated in implementing the back out plan
  - ALL requirements of this procedure must be met to allow for the application of this procedure
  - This procedure is an option available to the TO and may not be applicable for all situations

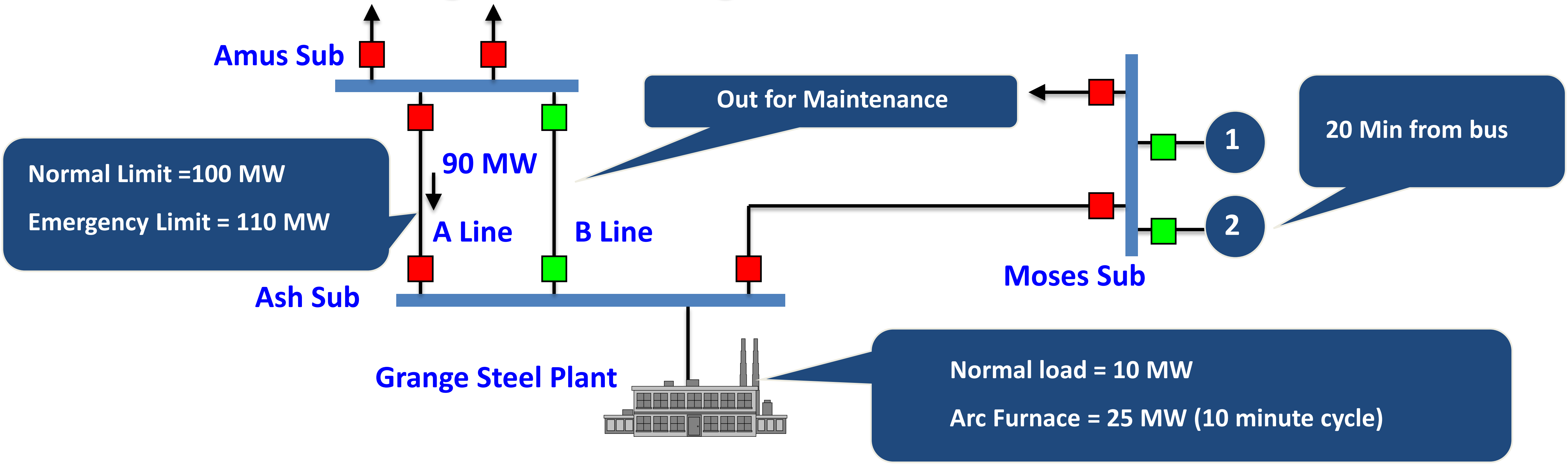
Constraint Management Mitigation Procedure



PAL Power wants to take out line Amus – Ash B Line for maintenance. If the Grange Steel Plant arc furnace is on, the load on the A Line increases to 115 MW. PAL Power says that these furnaces generally only run for a 10 minute cycle, then the loading will return to under the 100 MW limit. They have a “back-out” plan in case the arc furnace stays on longer than expected, running the Moses CTs will reduce the A Line flow under the 100 MW limit

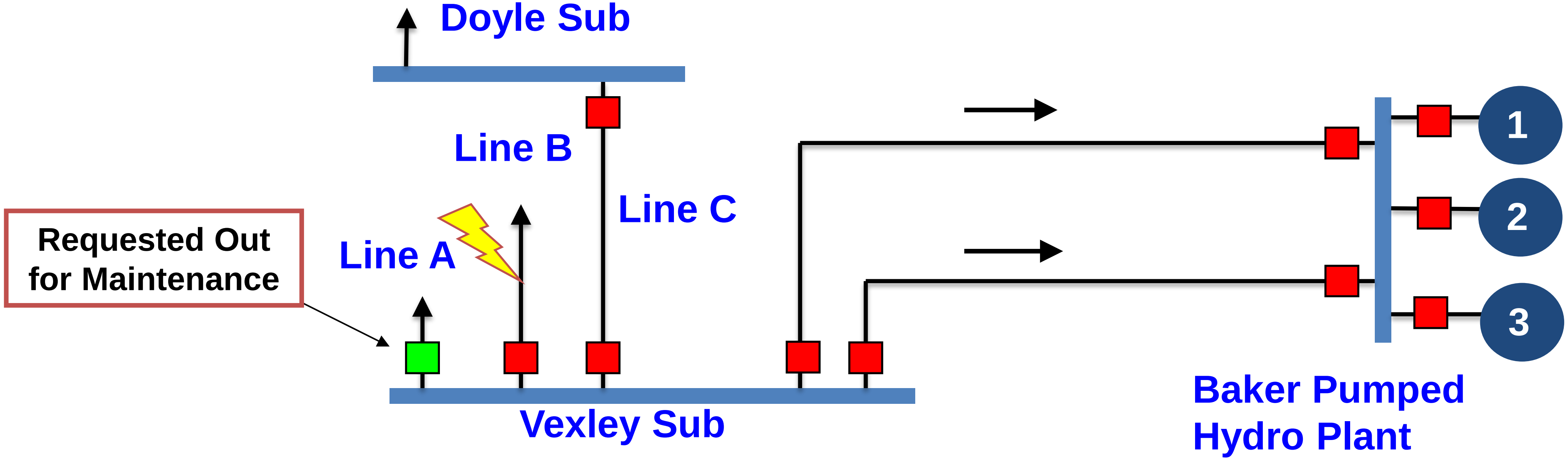
Is this a candidate for the Constraint Management Mitigation Procedure?

Constraint Management Mitigation Procedure



- This action is NOT a candidate for the Constraint Management Mitigation Procedure for the following reasons:
  - The Emergency limit on A Line can not be exceeded for any length of time
  - In this example the Emergency limit would be exceeded for at least 10 minutes
- The Moses CTs are 20 minutes from the bus
  - The “back-out” plan must alleviate the overload within 15 minutes

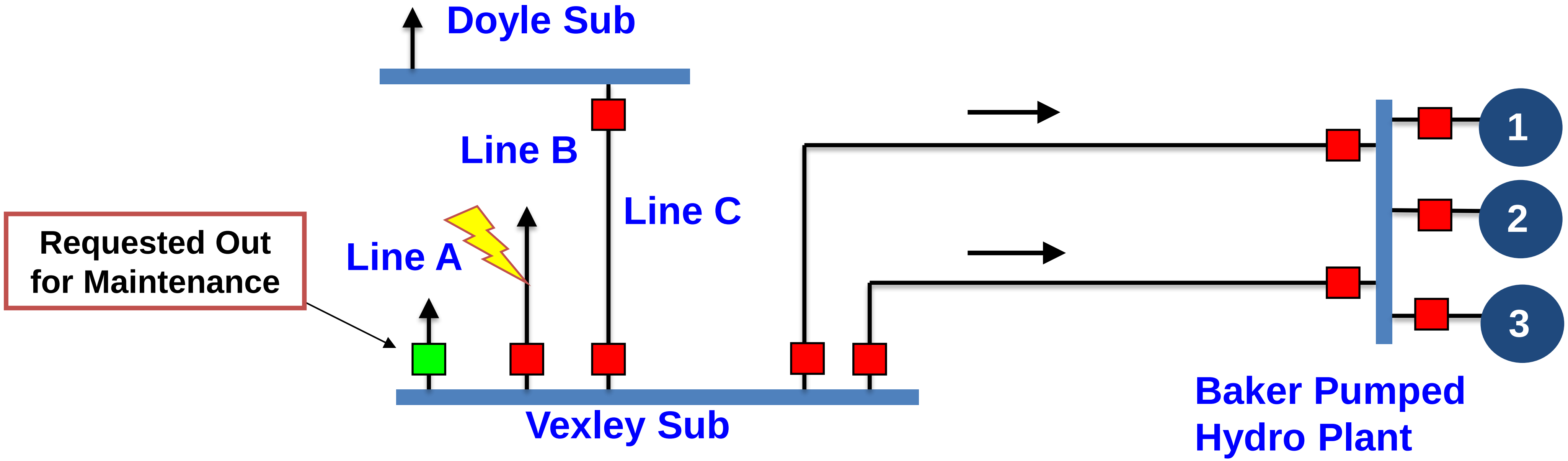
Constraint Management Mitigation Procedure



PAL Power wants to take out Line A for 1 week for maintenance. If all 3 pumps are on at the Baker Pumped Hydro Plant, a contingency exists on Line C for the loss of Line B (with Line A out of service). This contingency is over the emergency rating on Line C (on a contingency basis) but under the Load Dump Rating. PAL Power has a "back-out" plan of dumping one of the three pumps at Baker Pumped Hydro Plant (which they own) to bring the loading on Line C back under the normal rating in within 10 minutes

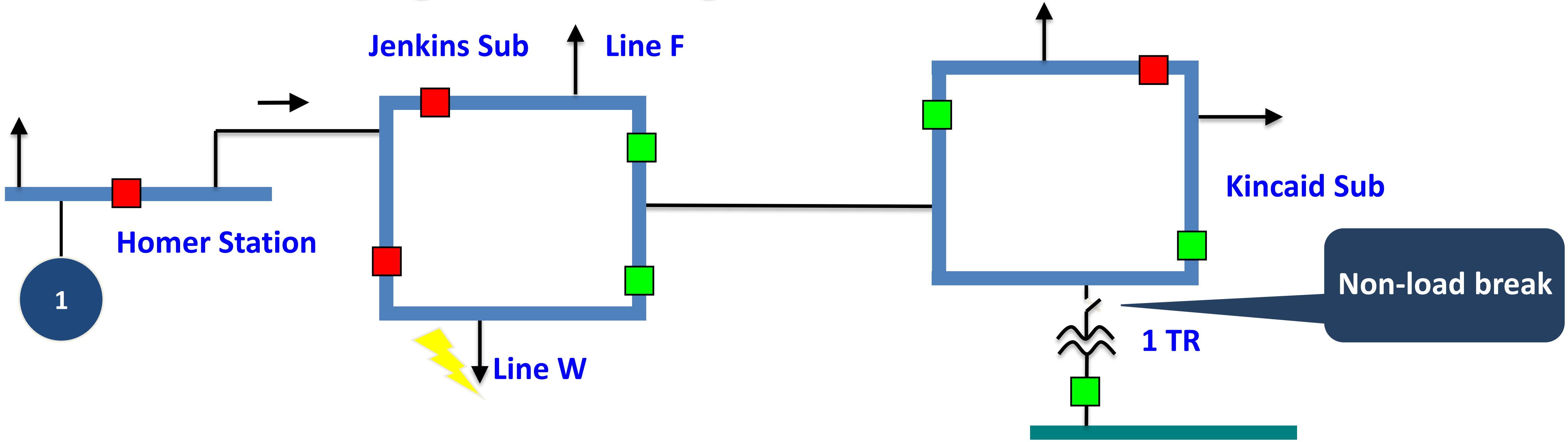
Is this a candidate for the Constraint Management Mitigation Procedure?

Constraint Management Mitigation Procedure



- This action is NOT a candidate for the Constraint Management Mitigation Procedure for the following reason:
  - The Contingency on Line C will exist for more than 5 minutes
- The Constraint Management Mitigation Procedure allows for operation over the applicable Emergency Rating on a post contingency basis for up to 5 minutes only

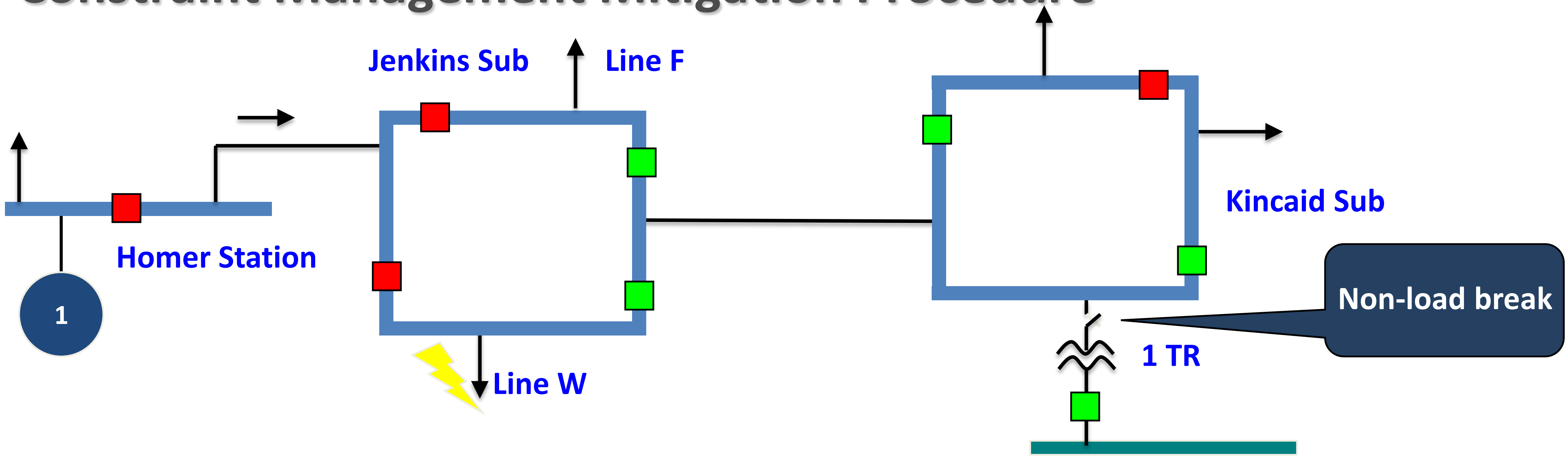
Constraint Management Mitigation Procedure



PAL Power wants to take out the 1 TR at Kincaid Sub for maintenance. The high side disconnect of the transformer is non-load break and must be operated de-energized. This will entail switching out the Jenkins – Kincaid line to open the disconnect. The Jenkins – Kincaid line can then be switched back into service. However, while the Jenkins – Kincaid line is off, studies indicate Line F will be over emergency rating (under Load Dump) for the loss of Line W. The back-out plan is to open the bus tie CB at Homer Station to alleviate the contingency if necessary. This plan has been studied and will alleviate the contingency immediately upon opening the tie CB. Personnel are in place at all three substations for the switching and it is anticipated that the disconnect can be opened in less than 5 minutes. All those affected by this plan have been notified and are in agreement with the plan

Is this a candidate for the Constraint Management Mitigation Procedure?

Constraint Management Mitigation Procedure



- This action IS a candidate for the Constraint Management Mitigation Procedure for the following reasons:
  - The contingency on Line F for the loss of Line W is only expected to last for less than 5 minutes
  - The contingency on Line F is over the Emergency Rating but UNDER the Load Dump Rating
- The Back-out plan will relieve the contingency in a total time of under 15 minutes. The back-out plan was approved by all parties and studied thoroughly

Voltage Operating Criteria

Voltage Limits

- Definition
  - A high and/or low limit placed on voltage to avoid damage to equipment and maintain power system voltage levels at a reliable level
- Determination of Voltage Limits
  - Established by equipment manufacturers
  - Affected Equipment
    - Motors
    - Transformers
    - Generators
    - Loads
    - Capacitors

Voltage Limits

- Determination of Voltage Limits *(cont.)*
  - System voltage limits
    - Maintain system reliability
      - High voltage limit protects equipment from damage
      - Low voltage limit protects system from voltage instability and equipment damage
    - ANSI Standards provide basis for voltage schedules
      - 97.5% - 105.0% Normal
      - 95.0% - 105.8% Emergency
        - These limits are for customer voltage

Voltage Limits

- Consequences of deviations from voltage limits
  - Low voltage
    - Dim lights
    - Slow heating of heating devices
    - Difficulty starting motors
    - Overheating/damage to motors
  - High voltage
    - Light bulb life decreased
    - Electronic devices life decreased

Voltage Limits

Limit	765 kV	500 kV	345 kV	230 kV	161 kV	138 kV	115 kV	69 kV
Normal High	803.3	550	362.3	241.5	169.1	144.9	120.8	72.5
Normal Low	726.8	500	327.8	218.5	153	131.1	109.3	65.6
Emerg Low	703.8	485	317.4	211.6	148.1	127	105.8	63.5
Load Dump	688.5	475	310.5	207.0	144.9	124.2	103.5	62.1
V-drop Warning	5%	2.5%	5%	5%	5%	5%	5%	5%
V-drop Limit	8%	5%	8%	8%	10%	10%	10%	10%

Voltage Limits

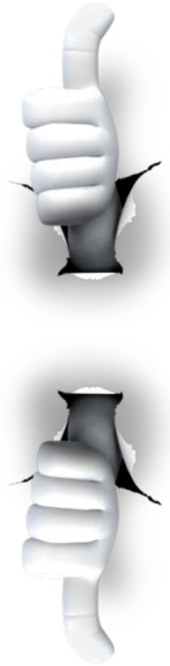
- Transmission Owners may specify bus-specific voltage limits
  - Submit limit in writing to PJM, Manager Operations Planning
  - PJM will evaluate these limits for reasonableness
  - PJM will return confirmation of new limits to SOS representative when limits are in EMS
  - PJM will forward new limits to System Planning for use in future planning studies
  - Provided engineering justification exists, PJM allows member company to set more restrictive voltage limits
    Manual M-03, Attachment C for details

Detection of Voltage Problems

- Observe Critical Bus Voltages
  - Where do problems appear first?
- Observe Voltages in an Area
  - Determine if deviation is on a single bus or over an area on the system
- Observe Voltage Alarms
- Monitoring Sources
  - EMS, map board, trends, field reports, customer complaints
  - Monitor voltages, limits, alarms, and MVAR flow

VAR Sources and Sinks

- Voltage Control Means MVAR Control
  - Control of voltage and reactive power are inseparable!
    - MVAR sources support or hold up voltages
      - Capacitors
      - Generators / Synchronous Condensers
      - Static VAR Compensators
      - System Capacitance
    - MVAR sinks pull down voltages
      - Reactors
      - Generators / Synchronous Condensers
      - Loads
      - Mvar Losses
      - Static VAR Compensators



Causes of Low Voltage

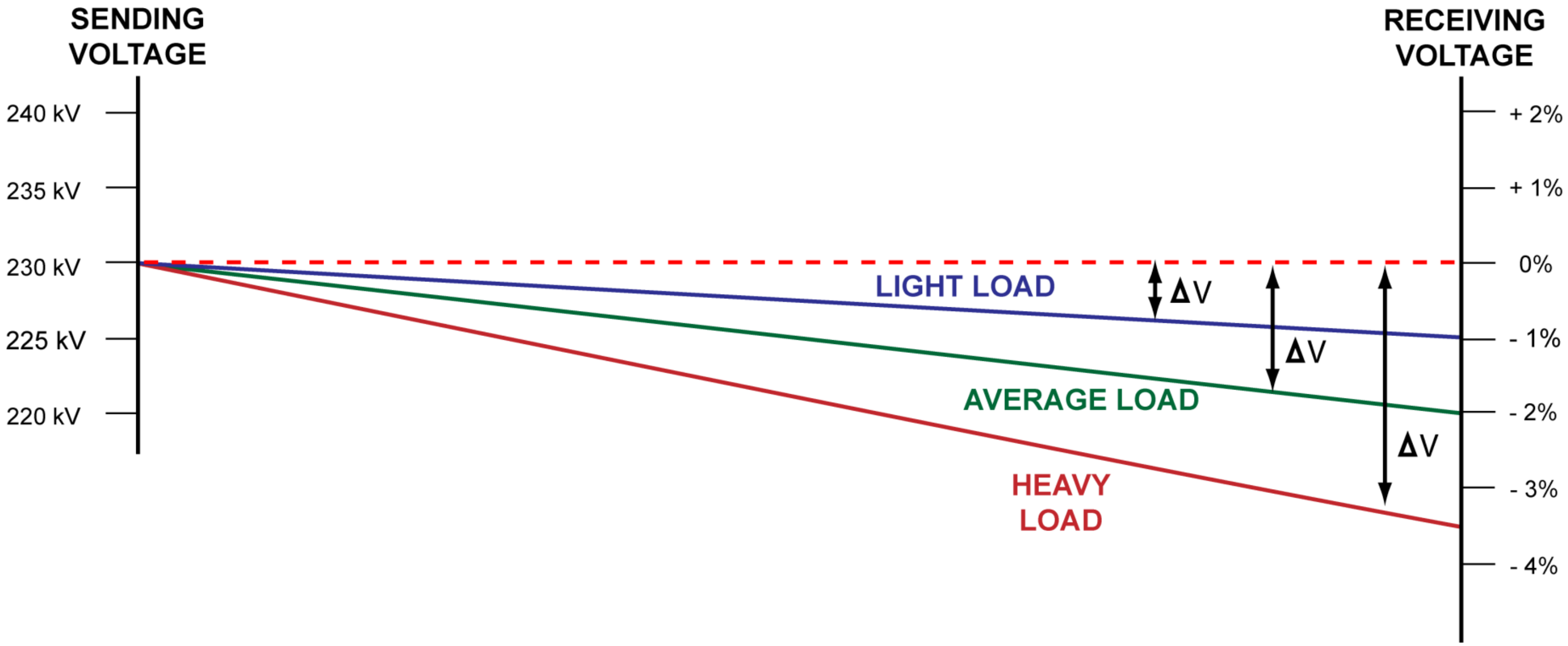
- Due to excessive VAR loading
  - Usually seen as voltage drop in an area rather than a single bus
- Due to voltage regulation malfunction
  - Generator voltage regulator may fail
  - Transformer tap hang-up
  - Usually seen as voltage decrease at a single bus
  - May result in an imbalance in MVAR flows or circulating MVAR
- Due to Geo-Magnetic Disturbance
  - Increased VAR requirement in system
    - Var absorption by EHV transformers

Causes of High Voltage

- Due to light load
  - Caused by excess line capacitance
  - Voltage rise in area rather than a single bus
- Due to switching in a line with high capacitive charging current
  - Reactive supplied by charging of line
- Also caused by:
  - Voltage regulation malfunction
  - Excess VAR sources on system

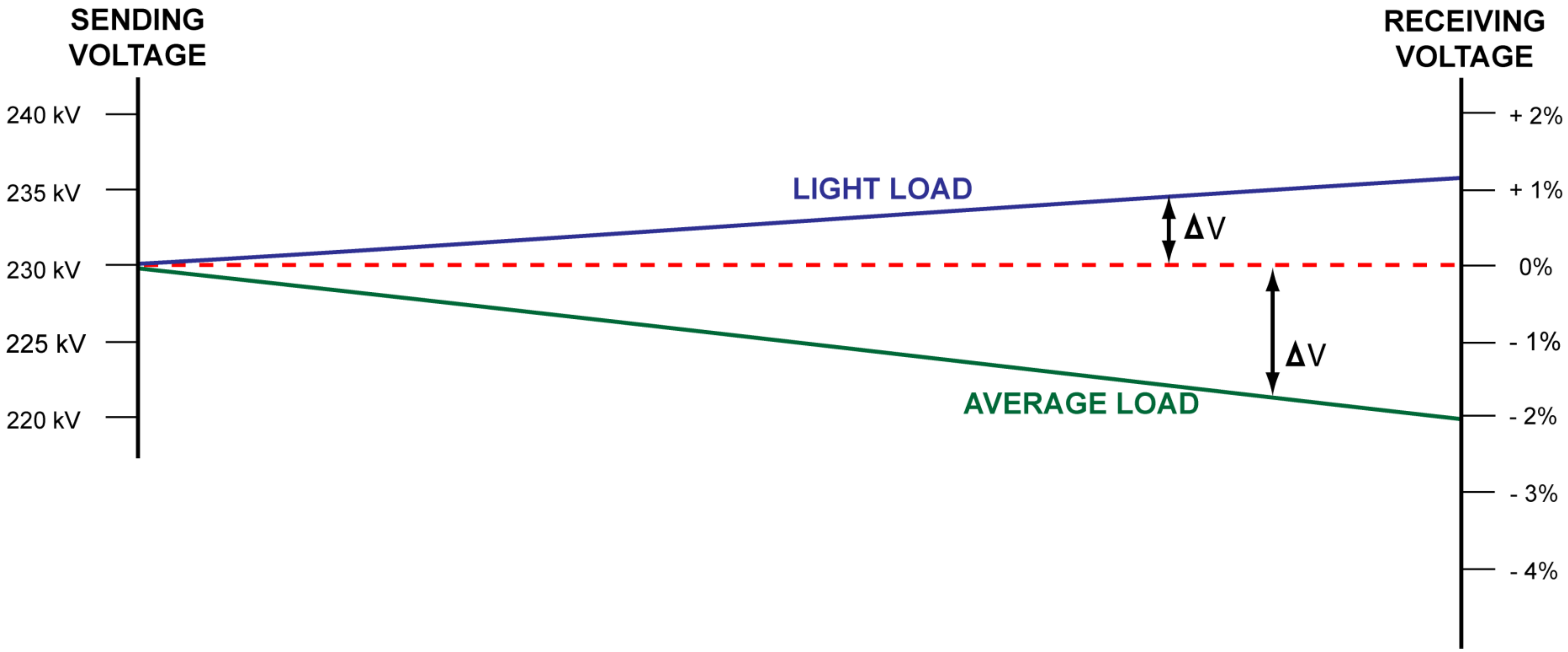
System Voltage Characteristics

- Results - a constantly changing voltage profile



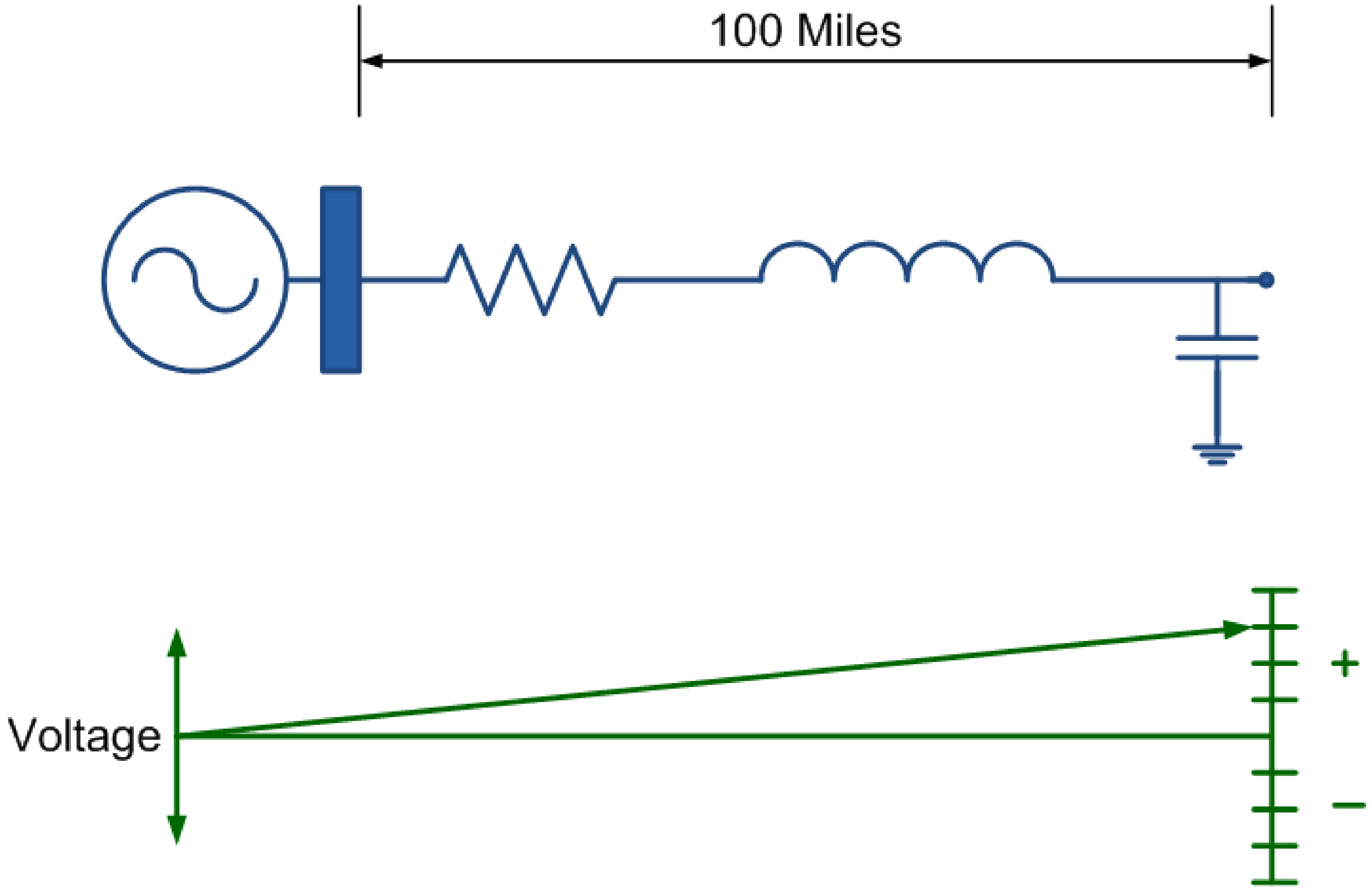
System Voltage Characteristics

- Results - for light loads, voltage can rise due to low losses and line capacitance



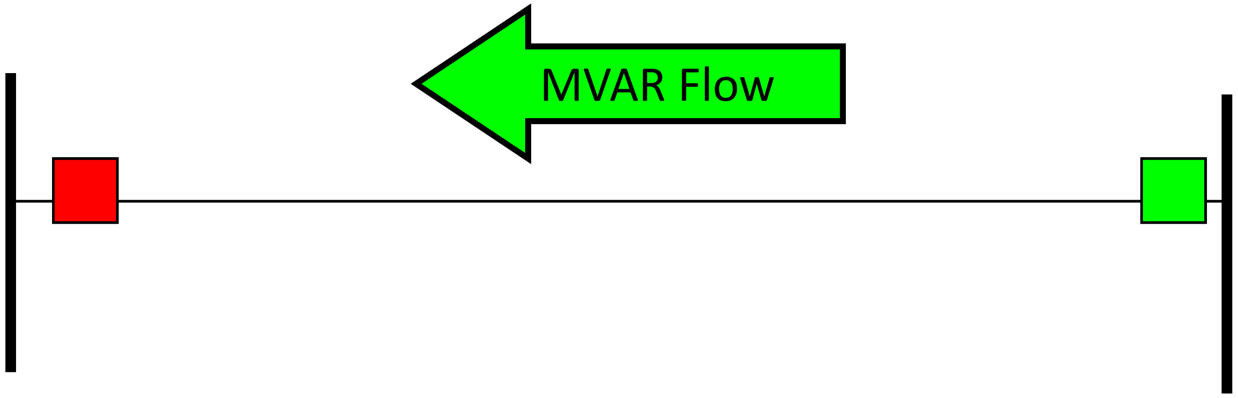
VARs From Transmission Lines

- Line open at one end



VARs From Transmission Lines

- Switching Operations
  - Open one end
    - Provides VARs to closed end of line due to line capacitance



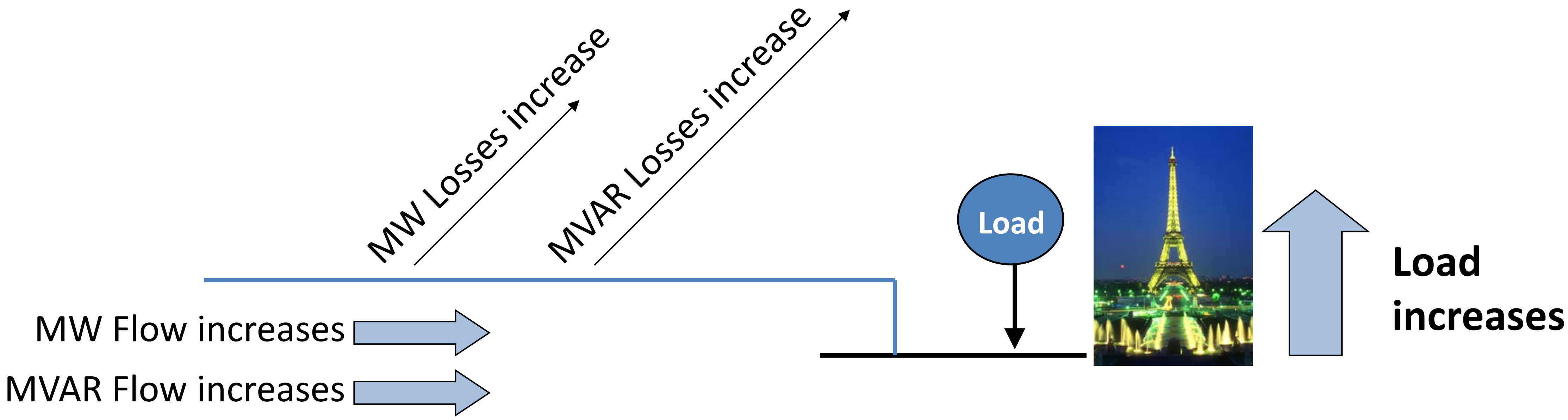
VARs From Transmission Lines

- VARs supplied by charging of line

MVARs Supplied by Lines and Cables		
Voltage	**Transmission Line**	**Transmission Cable**
765 kV	4.6 MVAR/Mile	
500 kV	1.7 MVAR/Mile	
345 kV	0.8 MVAR/Mile	15–30 MVAR/Mile
230 kV	0.3 MVAR/Mile	5-15 MVAR/Mile
115 kV	0.1 MVAR/Mile	2-7 MVAR/Mile

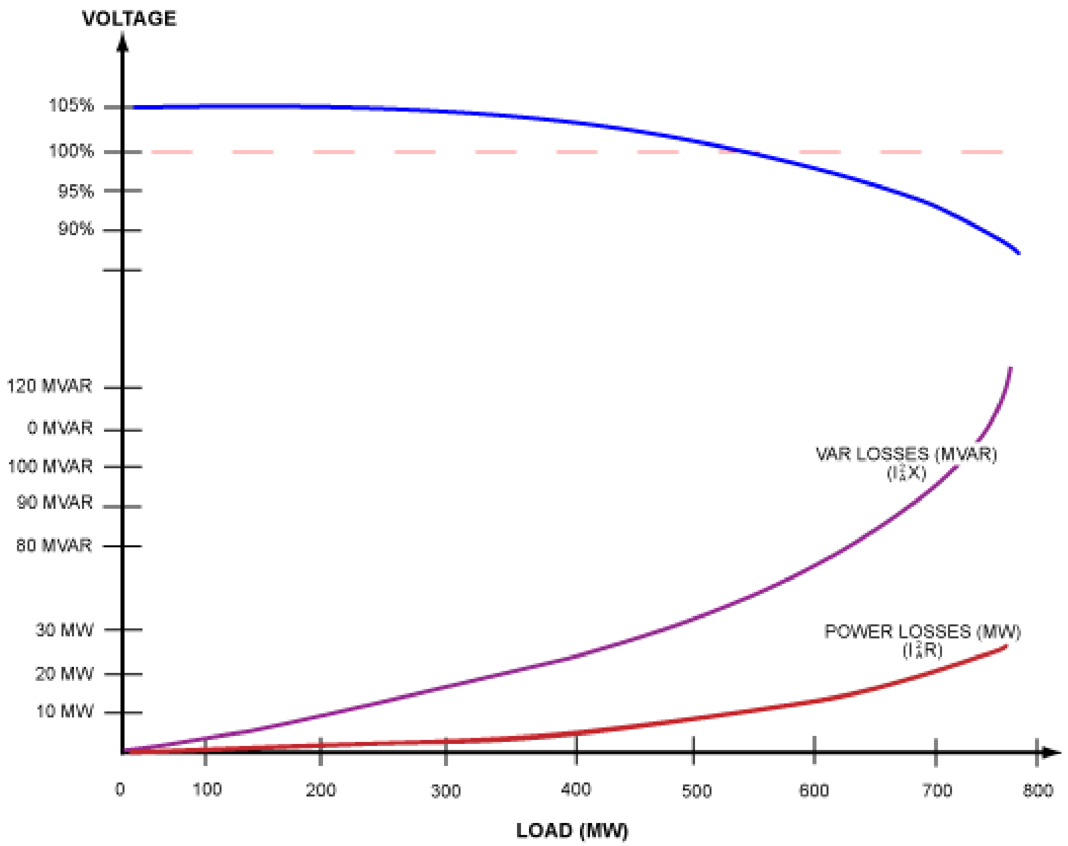
VARs From Transmission Lines

- Line connected to load
  - Power (MW) losses increase with load
  - Reactive (MVAR) losses increase with load



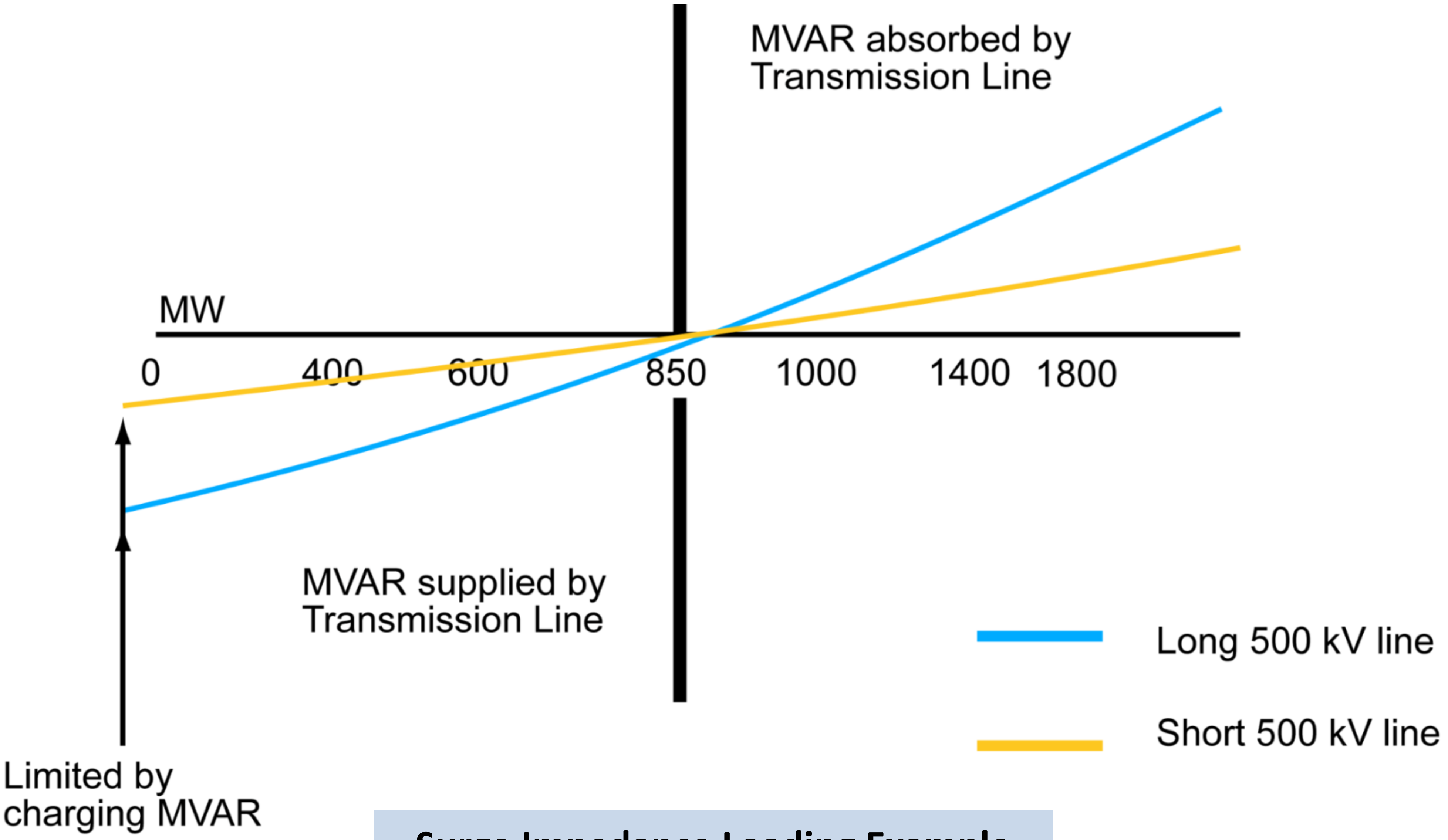
VARs From Transmission Lines

- Surge Impedance Loading
  - Loading point where VAR losses on a line equal VARs generated by line
  - 765 kV = 2100 MW
  - 500 kV = 850 MW
  - 345 kV = 400 MW
  - 230 kV = 135 MW



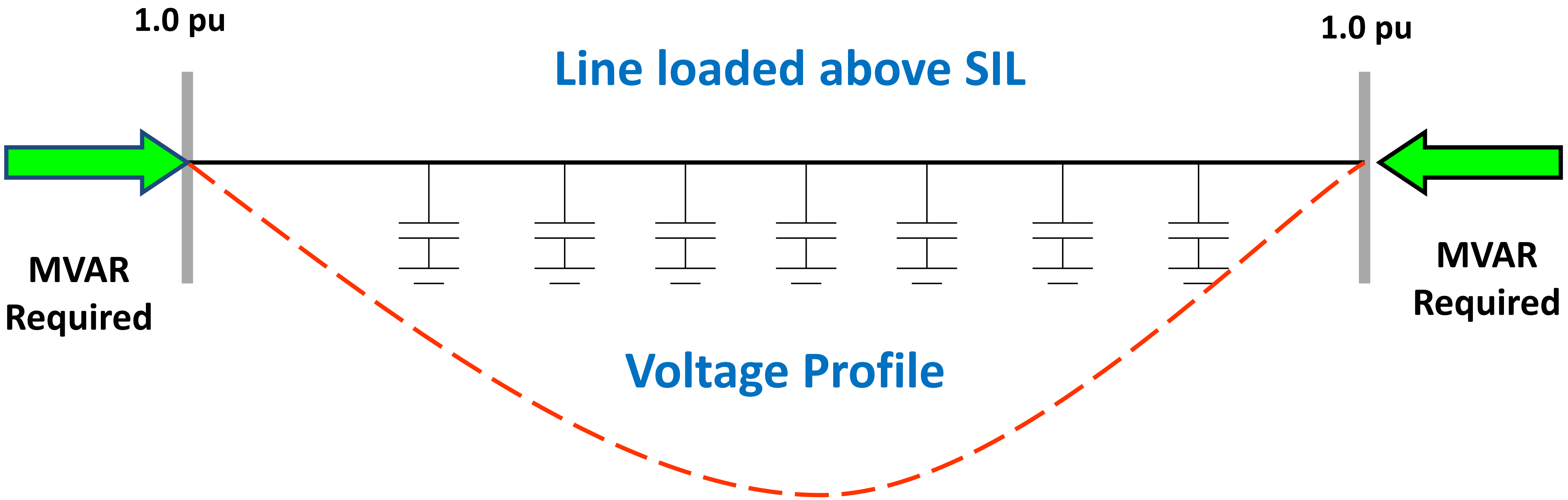
LINE LOSSES AND VOLTAGE DROP

VARs From Transmission Lines



Surge Impedance Loading Example

VARs From Transmission Lines

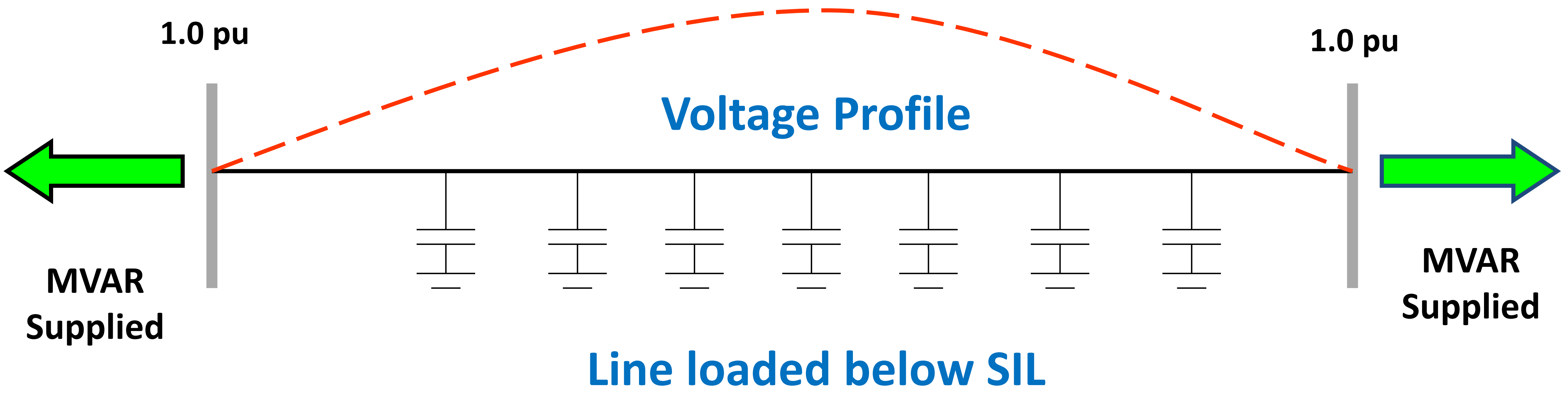


As line loading increases:

Reactive losses <u>increase</u> proportional to I^2

Reactive supply <u>decreases</u> proportional to V^2

VARs From Transmission Lines



As line loading decreases:

Reactive losses <u>decrease</u> proportional to I^2

Reactive supply <u>increases</u> proportional to V^2

Voltage Operating Criteria

Voltage Limit Exceeded	If Actual Voltage Limits Are Violated	Time to Correct (Minutes)
High Voltage	Use all effective non-cost and off-cost actions	Within 15 minutes
Normal Low	Use all effective non-cost actions, off-cost actions and emergency procedures except load dump	Within 15 minutes, load shed is not used
Emergency Low	All of the above plus, shed load if voltages are decaying	Within 5 minutes
Load Dump Low	All of the above plus, shed load if analysis indicates the potential for a voltage collapse	Immediate
Transfer Limit Warning Point (95%)	Use all effective non-cost actions. Prepare for off-cost actions. Prepare for emergency procedures except load dump	Not applicable
Transfer Limit	All of the above, plus shed load if analysis indicates the potential for a voltage collapse	Within 15 minutes or less depending on the severity

Voltage Operating Criteria

Voltage Limit Exceeded	If Post Contingency Simulated Voltage Limits Are Violated	Time to Correct (Minutes)
High Voltage	Use all effective non-cost actions	Within 30 minutes
Normal Low	Use all effective non-cost actions	Not applicable
Emergency	Use all effective non-cost actions, off-cost actions, and emergency procedures except load dump	Within 15 minutes, load shed is not used
Load Dump Low	All of the above plus, shed load if analysis indicates the potential for a voltage collapse	Within 5 minutes
Voltage Drop Warning	Use all effective non-cost actions	Not applicable
Voltage Drop Violation	All effective non-cost and off-cost actions plus, shed load if analysis indicates the potential for a voltage collapse	Within 15 minutes

Controlling Voltage Violations

Non-Cost Responses to Voltage Violations

- Switch capacitors in/out of service
- Switch reactors out/in to service
- Adjust output of Static Var Compensators
- Adjust generator excitation
- Adjust transformer tap position
- Switch lines or cables out of service
  - Pre-studied for high voltage control

Controlling Voltage Violations

Off-cost Responses to Voltage Violations

- Curtail Non-firm transactions NOT willing to pay congestion prior to re-dispatch of generation
- Re-dispatch generation
- Dispatch synchronous condensers
- Initiate ALL Emergency Procedures EXCEPT Load Shed
  - Including Manual Load Dump Warning

Controlling Voltage Violations

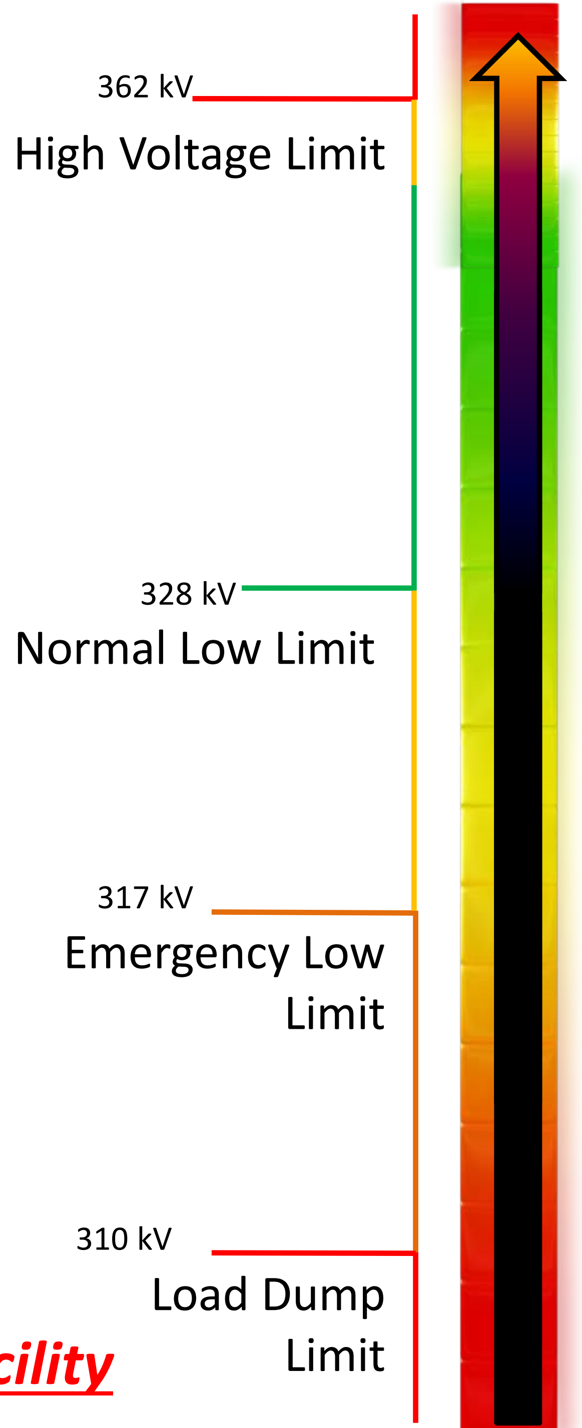
Load Shedding Response to Voltage Violations

- Determine if load shedding is required
  - All other control actions have been exhausted
  - Under emergency low or load dump low voltage limit on an actual basis or Reactive Transfer Limit to avoid voltage collapse
  - Under load dump low voltage limit or voltage drop violation limit on contingency basis if analysis indicates potential for voltage collapse
- Determine amount of load shed necessary
- Shed load proportional among Native Load customers, Network customers and firm point-point service

Corrective Actions

Condition: **Actual Voltage** exceeds High Voltage limit

- Time to correct: 15 minutes
  - Corrective Actions include:
    - Capacitor/Reactor switching
    - Tap changer adjustment
    - Generator/synchronous condenser excitation adjustment
    - Switching lines/cables out of service*
      (*Facilities 500 kV & Above)
    - Off-cost generation adjustments

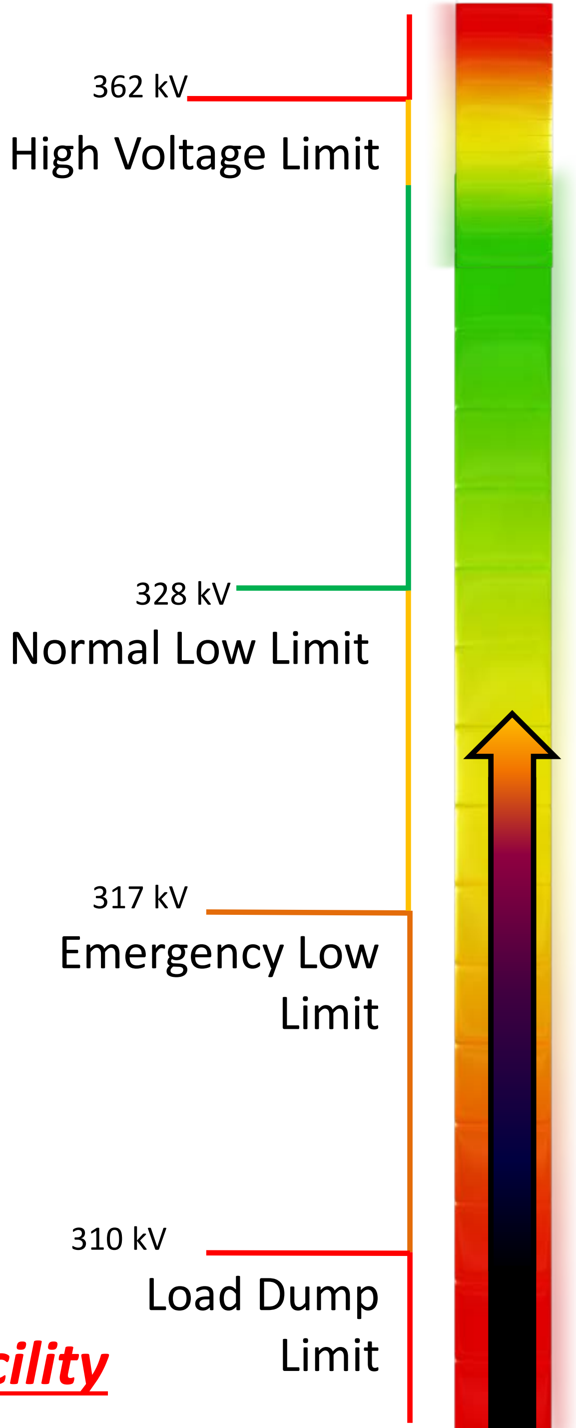


Example 345 kV Facility

Corrective Actions

Condition: **Actual Voltage** is <u>less than</u> Normal Voltage limit but <u>greater than</u> Emergency Low Voltage limit

- Time to correct: 15 minutes
- Corrective Actions include:
  - Non-cost actions
    - Capacitor switching
    - Generator excitation adjustment
    - Tap changer adjustment
- Off-cost generation adjustment
- All emergency procedures <u>EXCEPT</u> load dump

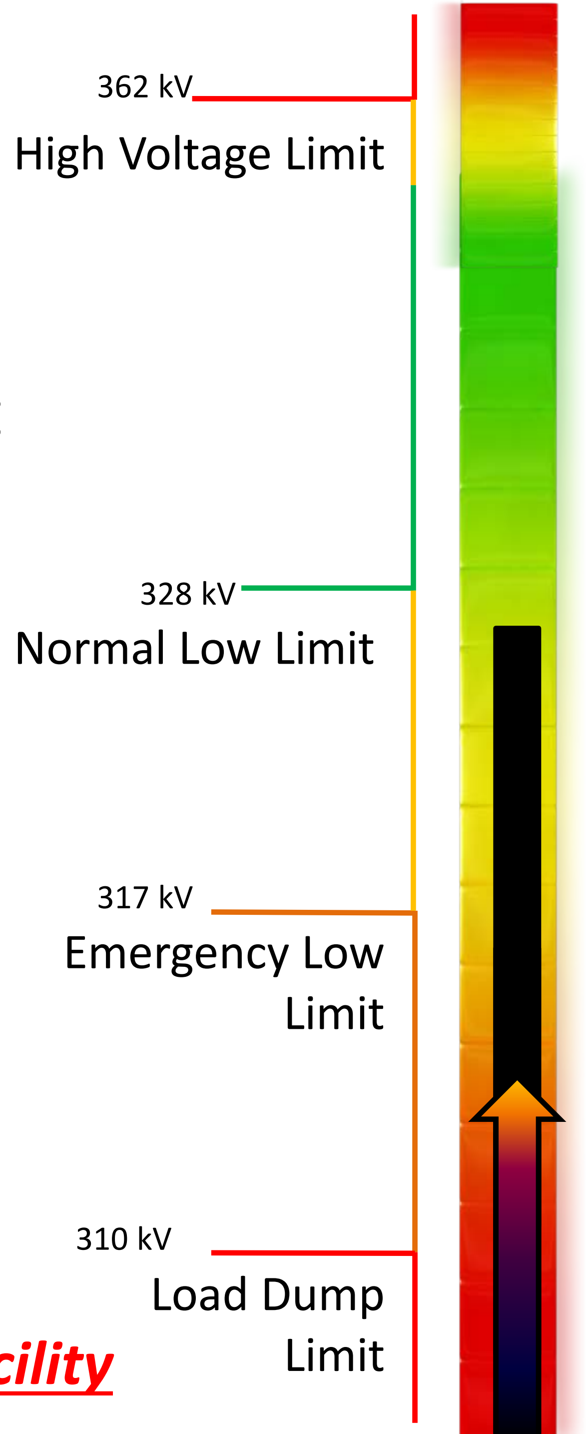


<u>Example 345 kV Facility</u>

Corrective Actions

Condition: **Actual Voltage** is <u>less than</u> Emergency Low Voltage limit but <u>greater than</u> Load Dump Low Voltage limit

- Time to correct: 5 minutes
- Corrective Actions include:
  - Non-cost actions
    - *See previous slide*
  - Off-cost generation adjustment
  - All emergency procedures
  - If voltages are decaying to Load Dump limit, shed load to return voltages to Normal Low

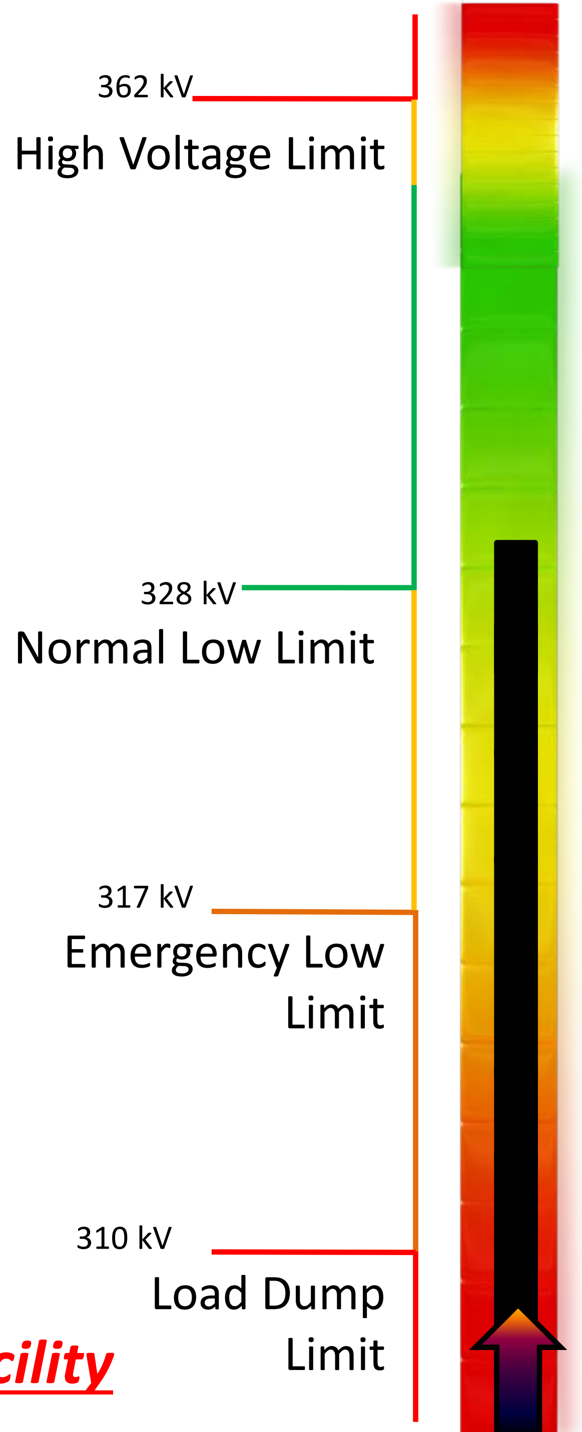


<u>Example 345 kV Facility</u>

Corrective Actions

Condition: **Actual Voltage** <u>less than</u> Load Dump Low Voltage limit

- Time to correct: Immediate
- Corrective Actions include:
  - Non-cost actions
  - Off-cost generation adjustment
  - All emergency procedures
  - If voltages are at or below Load Dump limit, shed load to return voltages to Normal Low limit

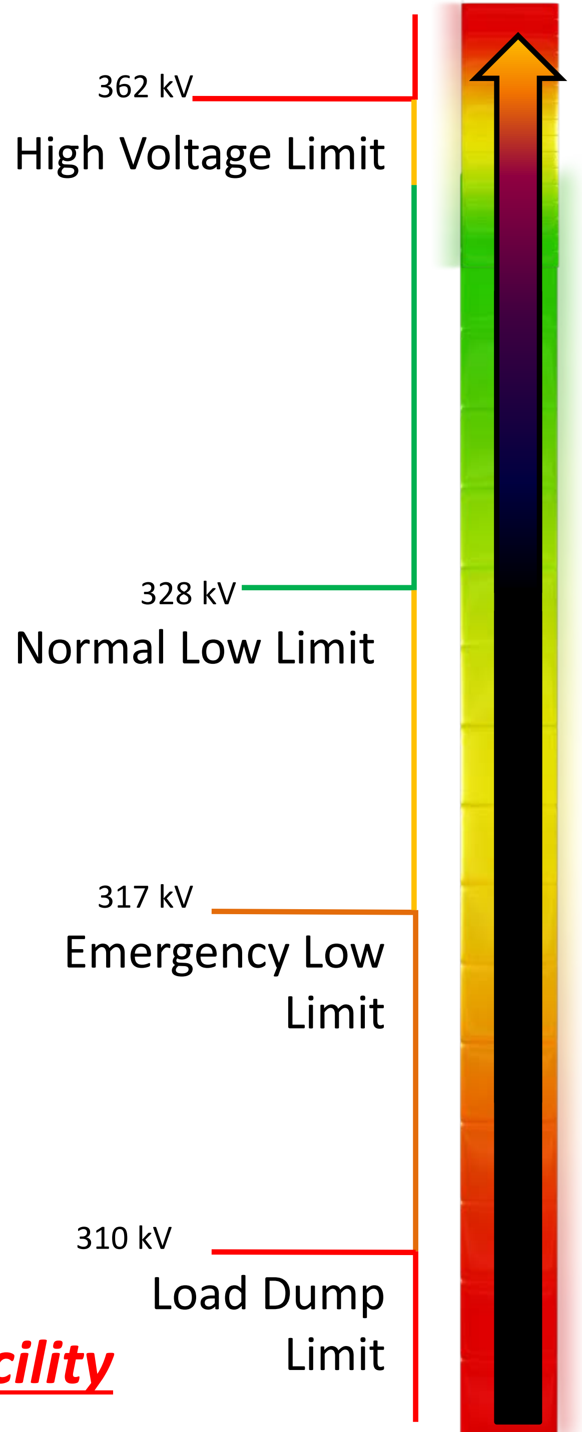


Example 345 kV Facility

Corrective Actions

Condition: **Post-contingency Voltage** exceeds High Voltage limit

- Time to correct: 30 minutes
- Corrective Actions include:
  - Capacitor/Reactor switching
  - Tap changer adjustment
  - Generator/synchronous condenser excitation adjustment
  - Switching lines/cables out of service (*Facilities 500 kV & Above)

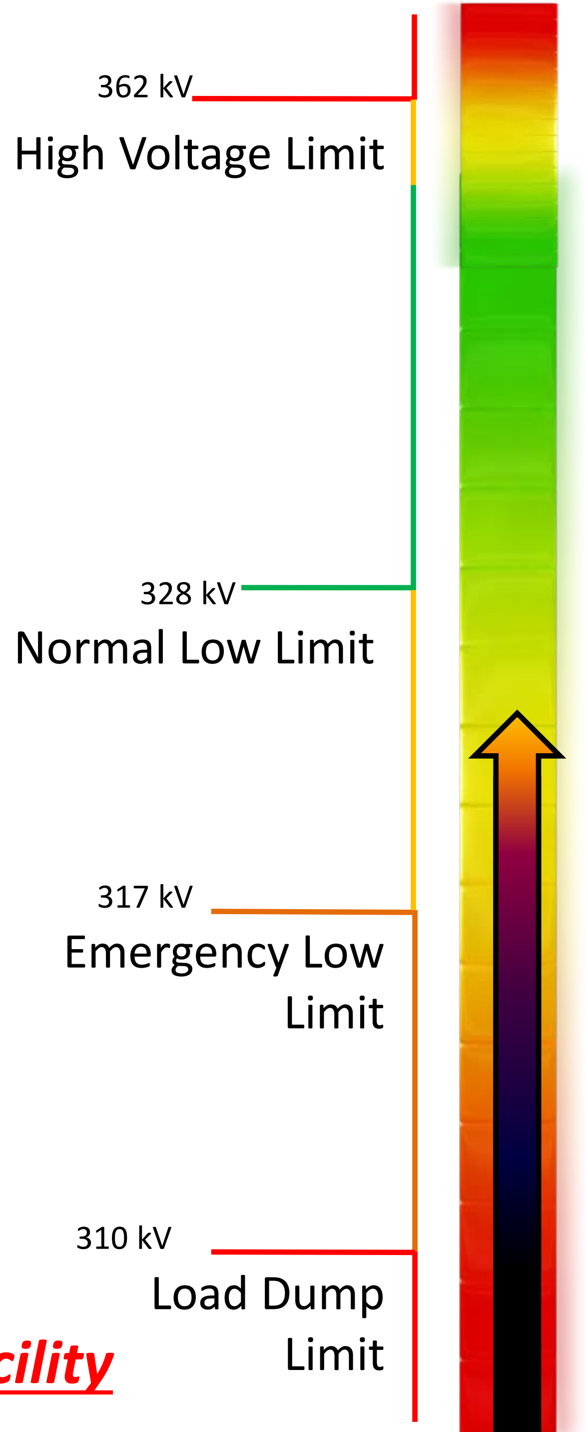


Example 345 kV Facility

Corrective Actions

Condition: **Post-contingency Voltage** <u>less than</u> Normal Low Voltage limit but <u>greater than</u> Emergency Low Voltage limit

- Time to correct: not applicable
- Corrective Actions include:
  - Non-cost actions only
  - This situation is considered a Trend and should be monitored, however, no off-cost measures will be taken to correct

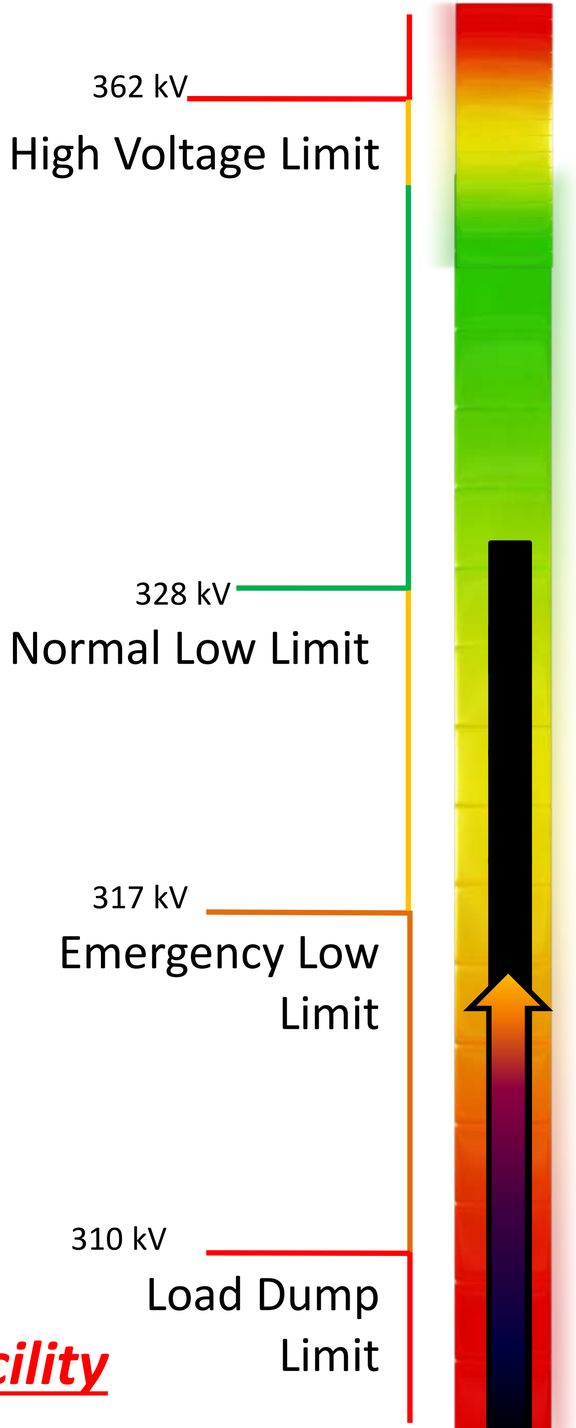


<u>Example 345 kV Facility</u>

Corrective Actions

Condition: **Post-contingency Voltage** less than Emergency Low Voltage Limit but greater than Load Dump Low Voltage Limit

- Time to correct: 15 Minutes
- Corrective Actions include:
  - Non-cost actions
  - Off-cost generation adjustment
  - All emergency procedures EXCEPT load dump

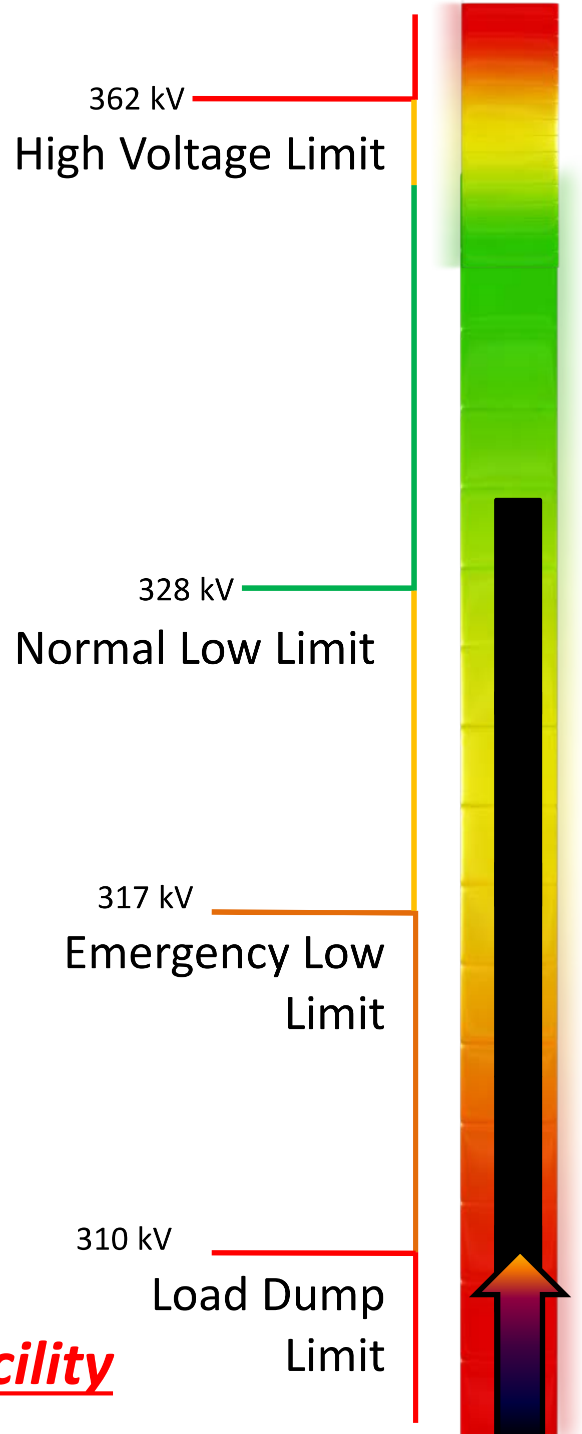


Example 345 kV Facility

Corrective Actions

Condition: **Post-contingency Voltage** less than Load Dump Low Voltage Limit

- Time to correct: 5 Minutes
- Corrective Actions include:
  - Non-cost actions
  - Off-cost generation adjustment
  - All emergency procedures
  - Shed load pre-contingency if necessary to avoid voltage collapse (System wide problem)

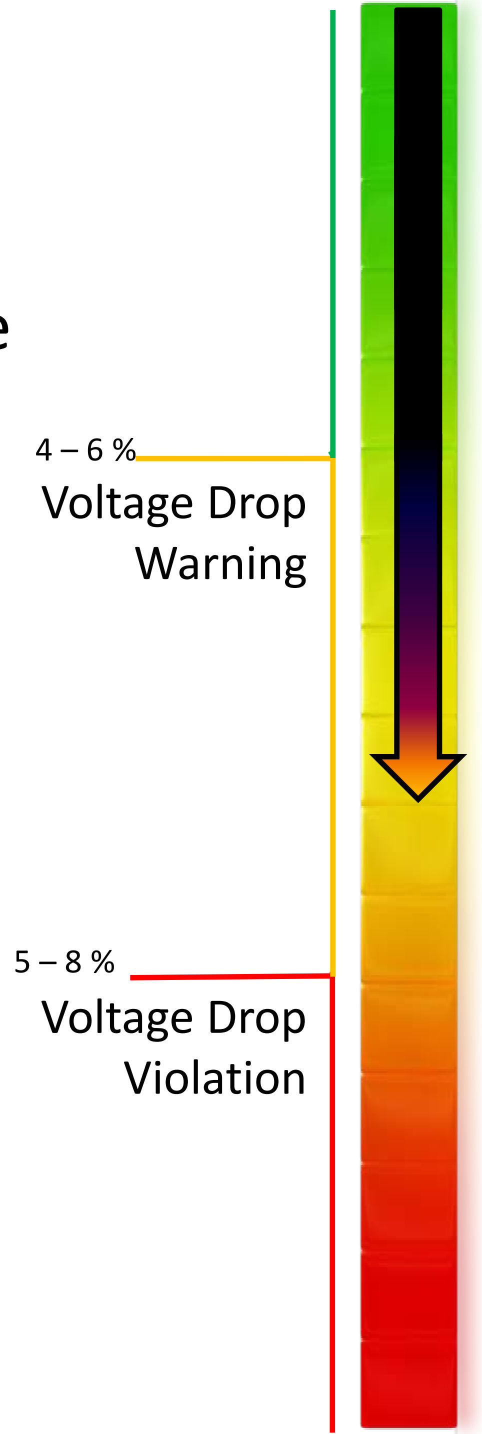


Example 345 kV Facility

Corrective Actions

Condition: **Post-contingency Voltage Drop (%)** exceeds Voltage Drop Warning but is less than Voltage Drop Violation

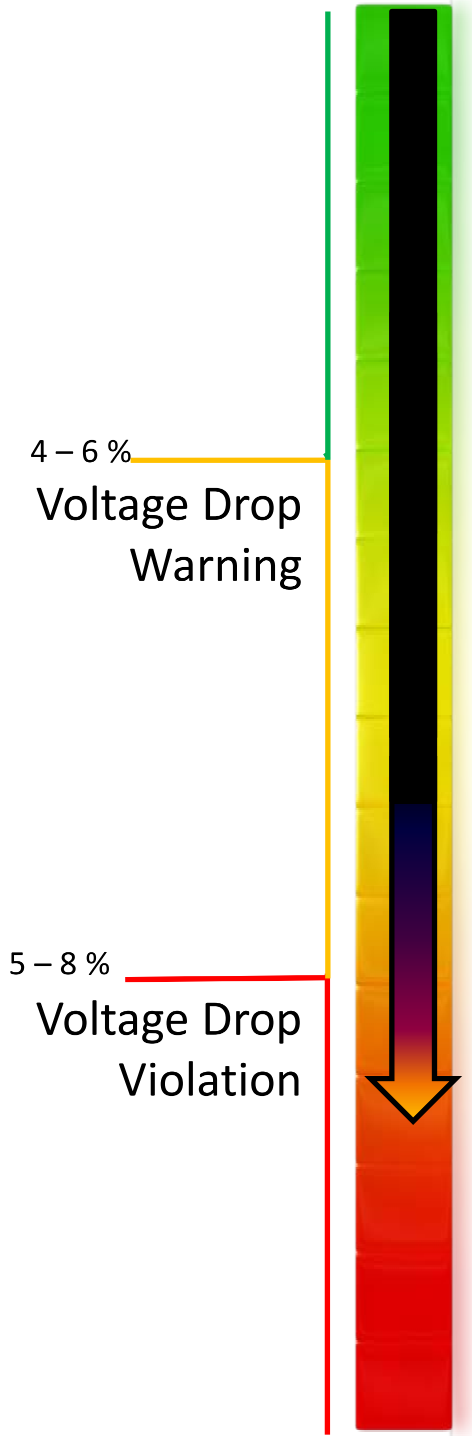
- Time to correct: N/A
- Corrective Actions include:
  - Non-cost actions only
    - This situation is considered a Trend and should be monitored, however, no off-cost measures will be taken to correct



Corrective Actions

Condition: **Post-contingency Voltage Drop (%)** exceeds Voltage Drop Violation

- Time to correct: 15 Minutes
- Corrective Actions include:
  - Non-cost actions
  - Off-cost generation adjustment
  - All emergency procedures
  - Shed load pre-contingency if necessary to avoid voltage collapse



Voltage Schedules

- PJM requires the following subset of generators to follow voltage schedules:
  - Individual generating units greater than 20 MVA
  - Generators that aggregate to 75 MVA or greater that are connected to a common bus
  - Black start generators
  - Any other Generation Owners/Operators that request a voltage schedule
  - Any other GO/GOPs that request a voltage schedule

PJM Default Generator Voltage Schedules									
Voltage Level (kV)	**765**	**500**	**345**	**230**	**161**	**138**	**115**	**69**	**66**
Schedule (kV)	760.0	525.0	350.0	235.0	164.0	139.5	117.0	70.0	67.0
Bandwidth (+/- kV)	+/-10.0	+/- 8.0	+/- 7.0	+/- 4.0	+/- 4.0	+/- 3.5	+/- 3.0	+/- 2.0	+/- 1.5

Voltage Schedules

- **PJM:**
  - Requires generators that fall within defined criteria to follow a voltage schedule
  - Will define exception criteria
    - Reactive and Power Factor Schedules are considered as exceptions
  - Requires PJM Transmission Owners to notify generators in writing of TO voltage schedules or PJM default schedule
- **Transmission Owners:**
  - Should notify generators located within their zone of TO voltage schedule
  - If the TO does not provide a TO voltage schedule to a generator in their zone they must notify PJM and PJM will notify generator in writing of PJM default voltage schedule

Maintaining Voltage Schedules

- **PJM:**
  - May elect to deviate from default voltage schedules based on load levels, transfer patterns, transmission or generation outages, or as required to honor pre-/post-contingency voltage limits or to maximize transfer capability based on PJM Security Analysis
  - Has the responsibility and authority to direct generators to increase or decrease MVAR output as well as direct the switching of reactive control devices to maintain voltages as system conditions dictate
  - Has the exclusive authority to request a generator to adjust voltage schedules if such a direction adversely impact the units MW output

Maintaining Voltage Schedules

- **Transmission Owners:**
  - May supply voltage schedules and a low and high bandwidth
  - Are required to coordinate voltage schedules, as well as adjustments to voltage schedules with PJM Dispatch. PJM Dispatch will approve/deny adjustments based on PJM EMS Security Analysis results
  - Have the authority to direct generators to adjust voltage schedules after coordinating with PJM Dispatch

Voltage Operating Criteria Exercises

Voltage Limit Exercises

- Scenario #1:

  Your security analysis program shows that for the loss of the Elmer Unit #1 the 500kV Bus voltage at Elmer would drop to 470 kV. Is this exceeding any post-contingency simulated voltage limit? If so which one and how long do you have to correct and what actions are used?

Below Load Dump limit of 475 kV
Need to return above the Load Dump limit within 5 minutes

Voltage Limit Exercises

- Scenario #2:

  Your security analysis program shows that for the loss of the Elmer – Rockford 500 kV Line the Rockford 230 kV Bus voltage drops to 215 kV. Is this exceeding any post-contingency simulated voltage limit? If so which one and how long do you have to correct and what actions are used?

Below Normal Low limit of 219 kV
This is a Trend and will be monitored.

Voltage Limit Exercises

- Scenario #3:

  Your security analysis program shows that for the loss of the Elmer – Wheeler 230 kV Line the Wheeler 230 kV Bus voltage drops to 209 kV. Is this exceeding any post-contingency simulated voltage limit? If so which one and how long do you have to correct and what actions are used?

Below Emergency Low limit of 212 kV
Need to return above the Emergency Low Limit within 15 minutes.

Voltage Limit Exercises

- Scenario #4:

  Your security analysis program shows that for the loss of the St. John Unit #1 the St. John 230 kV bus voltage will experience a 9% voltage drop. Is this exceeding any post-contingency simulated voltage operating criteria? If so which one and how long do you have to correct and what actions are used?

Voltage Drop Violation limit
Need to correct within 15 minutes

Voltage Limit Exercises

- Scenario #5:

  The Elmer terminal of the Elmer – Rockford 500 kV Line trips open. As a result the Rockford bus voltage is now 554 kV. Is this exceeding any voltage limit? If so which one and how long do you have to correct and what actions are used?

High Voltage Limit
Need to correct within 15 minutes

Voltage Control with Generators

Voltage Control Background

- Generators are a Major Source of MVARs
  - VAR supply controlled by field excitation
  - VARs don't travel well
    - Use units electrically close to the voltage problem
- Response to Generator Excitation Changes
  - Voltage at output of generator controlled by voltage regulator
    - Normally on automatic control (NERC Standard VAR-002)
      - If voltage regulator is out of service, eDART ticket is required
      - Can be manually controlled

Adjustments in Generation to Control Voltage

- Response to Generator Excitation Changes
  - Voltage regulator controls excitation
    - System voltage decreases
      - Voltage regulator senses decrease --> Excitation increased by voltage regulator --> VAR generation increases --> Output voltage increases (VAR flow on transmission line increases)
    - System voltage increases
      - Voltage regulator senses increase --> Excitation decreased by voltage regulator --> VAR generation decreases --> Output voltage decreases (VAR flow on transmission line decreases)
    - Power (MW) output not affected by excitation

Generator Automatic Voltage Regulator Status

- Per NERC Standard VAR-002-4
  - R3. Each Generator Operator shall notify its associated Transmission Operator of a status change on any generator reactive power resource, including the status of each automatic voltage regulator, power system stabilizer, or alternative controlling device within 30 minutes of the change
  - If the status has been restored within 30 minutes of such change, then the Generator Operator is not required to notify the Transmission Operator of the status change
- Reporting of AVR status and Reactive Capability changes accomplished via eDART generator reporting

Adjustments in Generation to Control Voltage

- Effect of Adjusting MVAR Output of a Single Generator with Radial Load
  - Increase in excitation
    - MVAR output increases
    - Voltage profile shifts upward
    - Results in voltage increase at generator output and at load bus
    - Effect is reduced further from generator due to MVAR losses on line

Adjustments in Generation to Control Voltage

- Effect of Adjusting MVAR Output of a Single Generator with Radial Load
  - Decrease in excitation
    - MVAR output decreases
    - Voltage profile shifts downward
    - Results in voltage decrease at generator output and at load bus

Adjustments in Generation to Control Voltage

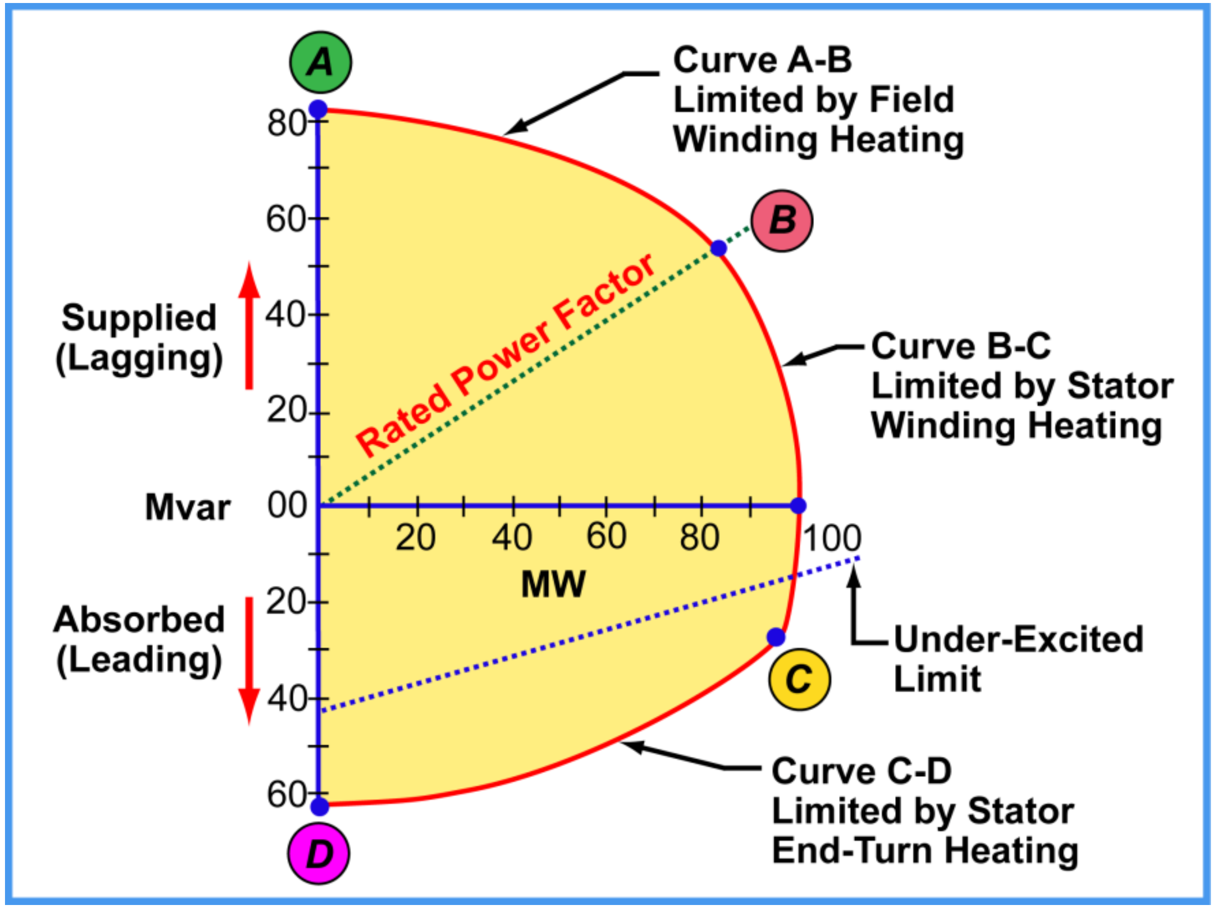
- Adjustments of Multiple Units at Single Station
  - Coordinate shifts of multiple units together
  - Otherwise, voltage regulators of other units may increase or decrease excitation to compensate for desired change
    - Results in unwanted VAR flow
  - Result of not adjusting all units
    - Voltage does not change as planned
    - Units may shift to absorbing VARs
    - Units may become under or over-excited

Adjustments in Generation to Control Voltage

- Adjustments in an Interconnected System
  - More complicated due to VAR flows
  - Voltage response
    - Increased VAR supply in local area will cause voltage rise in that area
    - Amount of voltage rise is diminished by VAR flow out of that area
    - Voltage rise is largest near VAR supply
      - Gradually decreases further from VAR supply
      - At some distance and beyond, no voltage effect will be see

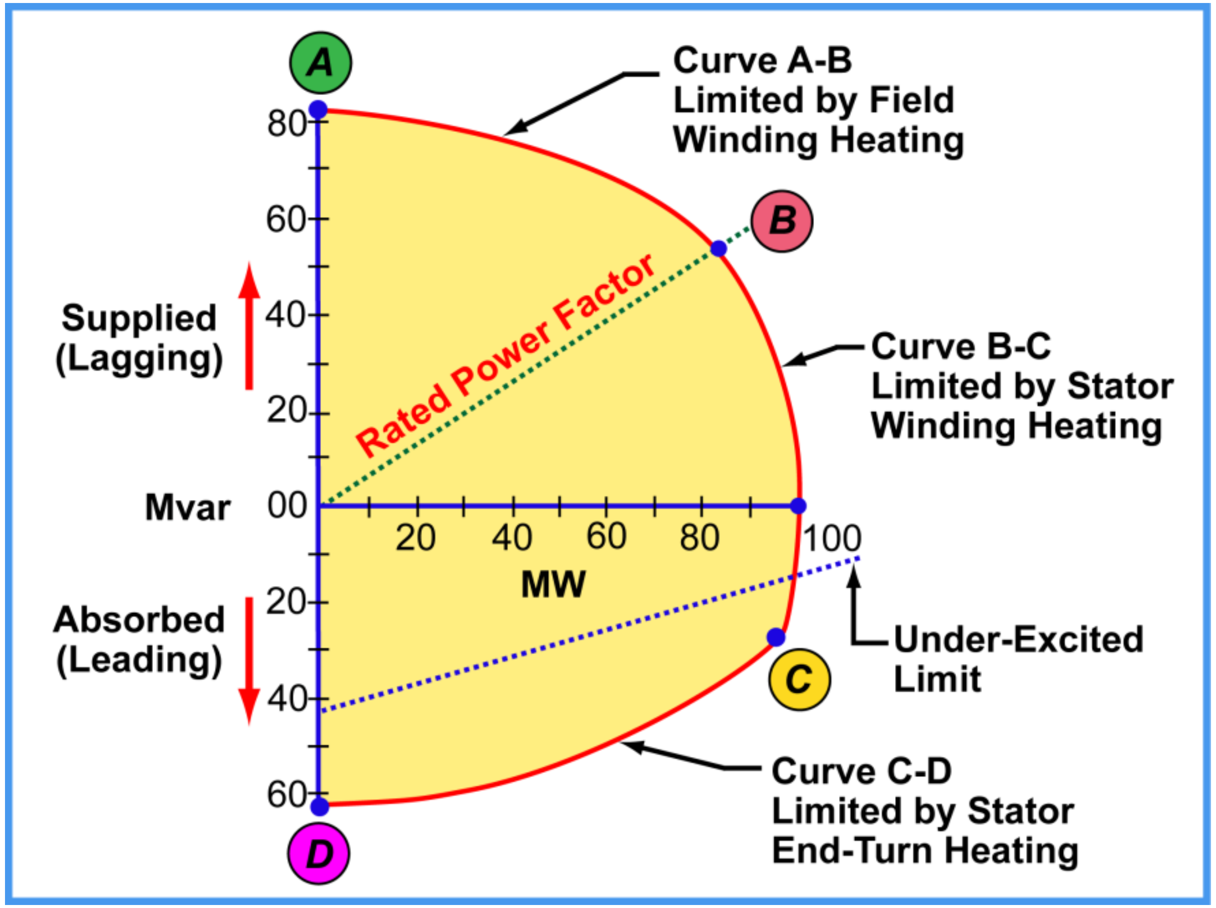
Restrictions and Limitations

- Generating Unit
  - Unit Over-excitation
    - Limit on field heating, limits MVAR generation
    - Rotor overheating is I2R heating caused by dc current over-excitation



Restrictions and Limitations

- Generating Unit
  - Unit Under-excitation
    - Limit on end turn heating
    - Unit instability
      - Field strength too weak, unit goes unstable
      - Area Stability, Salem, PS South



Restrictions and Limitations

- Generating Unit
  - MVAR output limited by D-curve
  - May be limited by auxiliary bus voltage limits
  - Voltage regulator limits
    - Voltage regulator operates only within designed voltage limits
    - Designed to limit amount of MVARs that can be generated
  - Power factor limits
    - Units are limited to operating within certain pf limits
  - MW tradeoff
    - Above certain MVAR output, MW must be traded to get additional MVAR output

Restrictions and Limitations

- Power System
  - Must coordinate shifts in generation to obtain desired MVAR flows and voltage adjustments
  - Should coordinate generation voltage adjustments with switchable sources (capacitors and reactors)
  - Do not remove all VAR reserve from a generating unit

Capacitors and Reactors

Capacitors and Reactors

- Peak Loads
  - Maximum load period cause large voltage drops across system due to heavy MVAR flow
  - Maximum VAR loading degrades voltage support
  - System voltages are lowered
  - Voltages most affected near VAR loads
  - Voltages can be improved by increasing VAR supply as close as possible to loads
    - Switch reactors out of service
    - Switch capacitors into service

Capacitors and Reactors

- Light Load Periods
  - Real power flows are minimized
  - Fixed capacitors and system capacitance dominate
  - System voltages rise
  - Customer voltages may exceed upper limits
  - Voltages can be lowered by adding VAR sinks to the system
    - Switch capacitors out of service
    - Switch reactors into service

Capacitors and Reactors

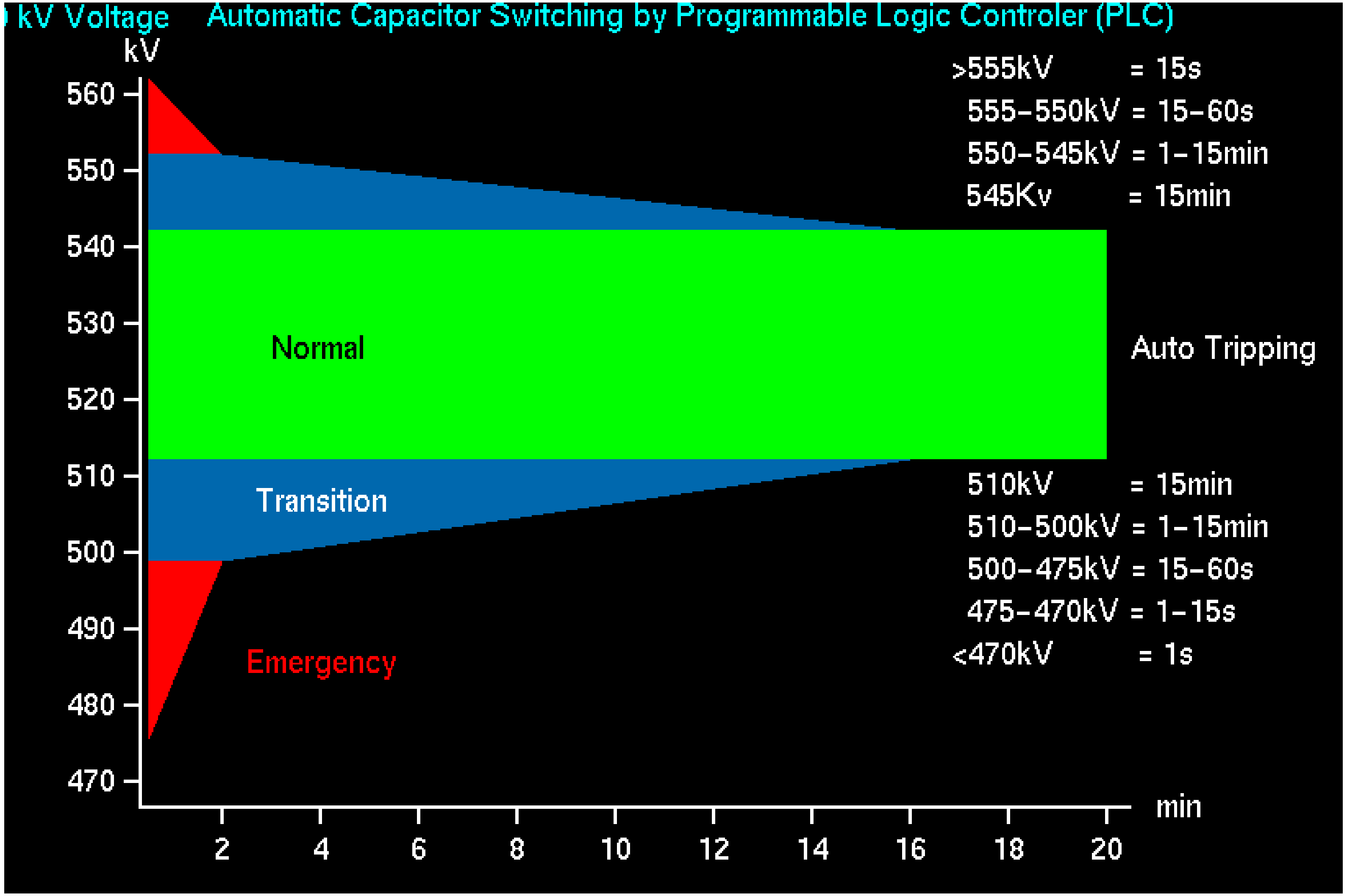
- Capacitors
  - Supply VARS
  - Locating capacitors near the load has two effects
    - Reduces system VAR flow to the load
      - Reduces line loading
      - Reduces voltage drops due to IX component
    - Provides additional VARs to the system which causes voltage to rise

Capacitor Switching Philosophy

- PJM, in coordination with the TOs, attempts to minimize capacitor switching when possible
- Switching of reactive resources 230 kV and above must be done at the direction of the TOP
  - Automatic capacitor switching capability on facilities 230 kV and above must be documented in Manual 3, Section 3
  - Switching reactive devices connected to 138 kV and below may be done without notifying PJM
    - However TOs should evaluate the impact of adding and removing reactive devices as well as adjusting LTCs so as not to violate any voltage limits

Automatic Switching of Capacitors

- Programmable Logic Controller



Capacitors and Reactors

- Reactors
  - Reactors serve as VAR sinks
    - Absorb VARs from the system
    - Cause voltage to decrease
  - Placed on transmission system
    - Most effective when close to VAR sources
      - End of transmission cables
    - Prevent unnecessary VAR flows

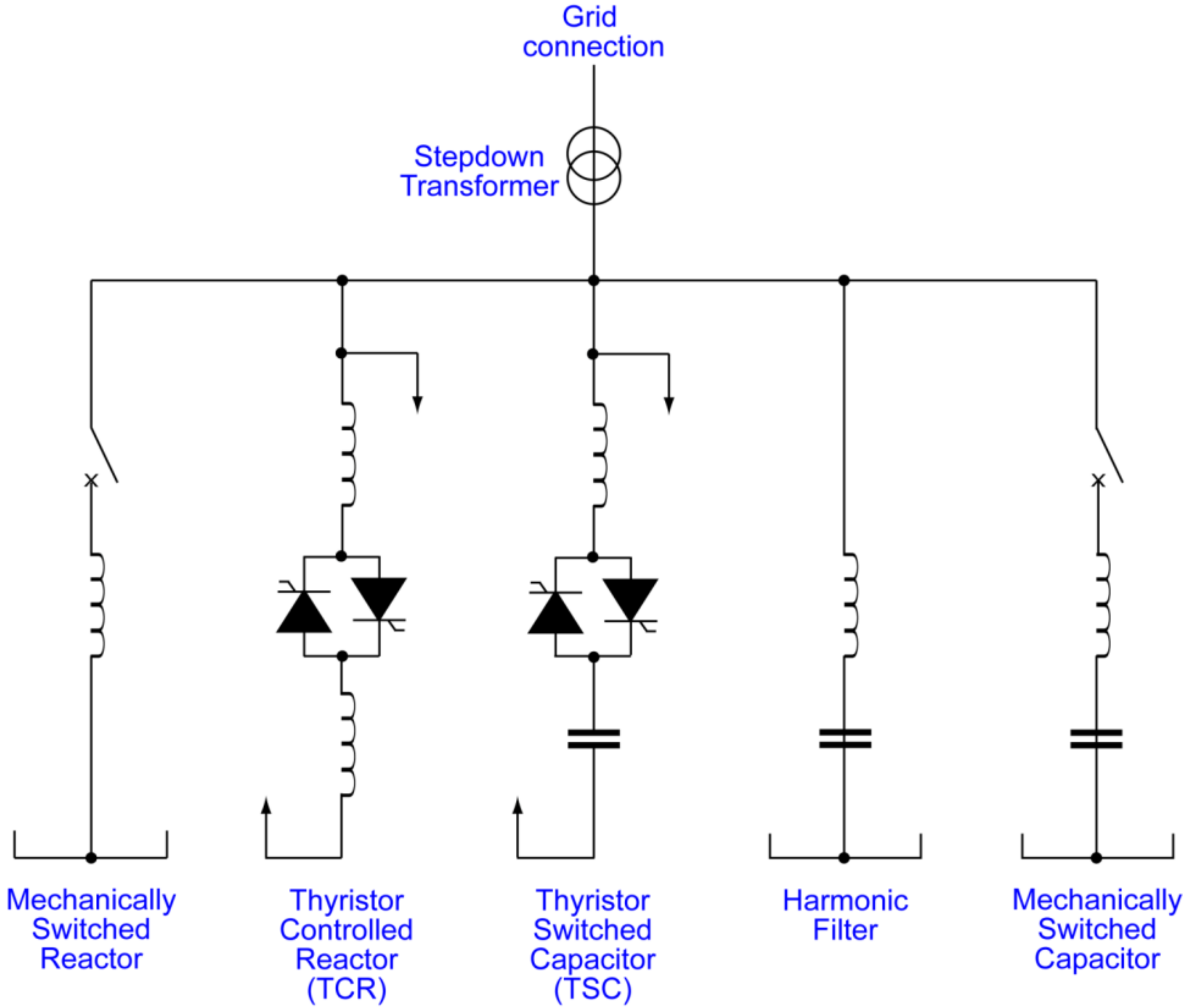
Capacitors and Reactors

- Static VAR compensators
  - Automated impedance matching device
    - Set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks
  - No significant moving parts
  - Comprised of one or more banks of fixed or switched shunt capacitors or reactors
    - At least one bank is switched by thyristors

Capacitors and Reactors

- Static VAR compensators
  - Used in two main situations:
    - On the power system, to regulate transmission voltage
    - Near large industrial loads, to improve power quality

Capacitors and Reactors



Limitations and Restrictions

- Switching Schedules
  - Many capacitors and reactors are switched by schedule
    - Fixed capacitors and reactors
    - Time switched
    - Load switched
    - kVAR load switched
    - Voltage switched
    - Manual switched
    - Programmable Logic Controller (PLC)

Limitations and Restrictions

- Capacitor is Less Effective as Voltage Decreases
  - MVAR output proportional to square of voltage
  - When needed most, capacitors provide the least support

$$MVAR\ Output = MVAR_{Rated}\left(\frac{V_{Actual}}{V_{Rated}}\right)^2$$

Limitations and Restrictions

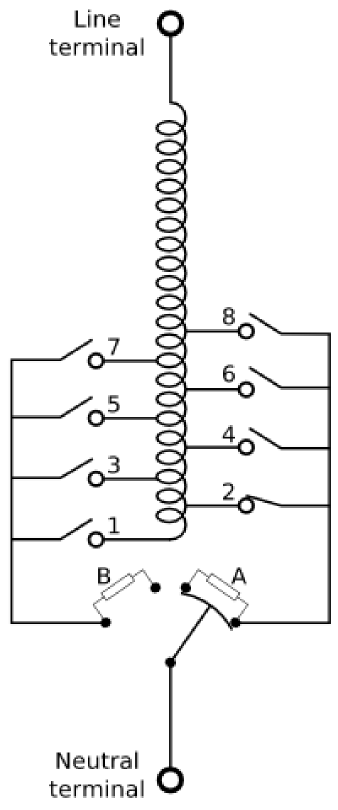
- As an example, if a 100 Mvar capacitor (rated 100 Mvar at 345 kV) is in service at a voltage of 340 kV the capacitor output is:

$$MVAR\ Output = 100\ MVAR\left(\frac{340\ kV}{345\ kV}\right)^2 = 97\ \text{MVAR}$$

Transformer Load Tap Changer Operations

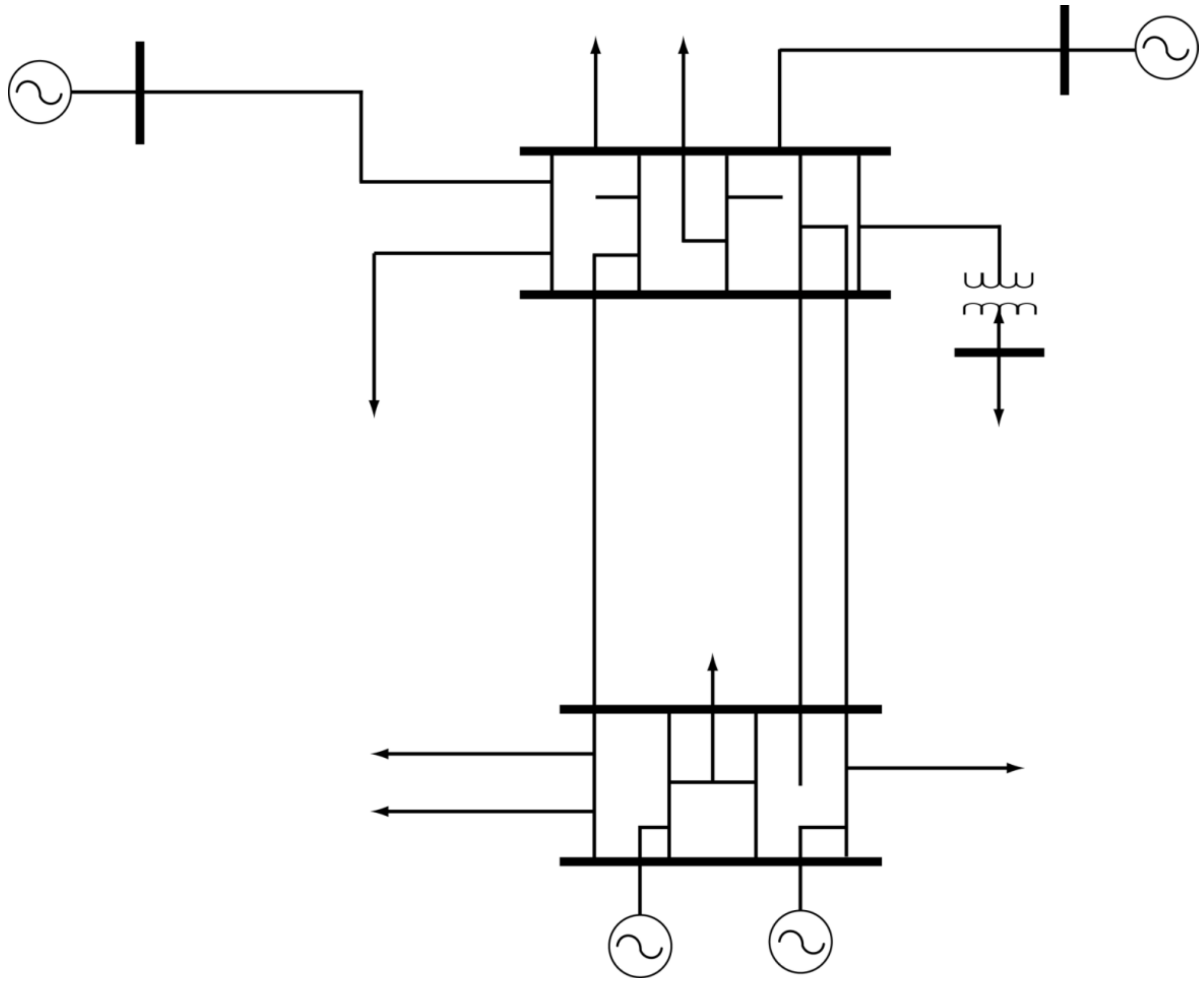
Voltage Control with LTCs

- Load Tap Changer (LTC) or Tap Changer Under Load (TCUL) Operation:
  - Weak bus vs. strong
  - If a transformer is connected to a "weak" reactive power source, it will not be effective in controlling the voltage on the other winding
  - When it "pulls" VARs from the primary, the primary voltage drops
  - This offsets any gains that might have been made to the secondary voltage

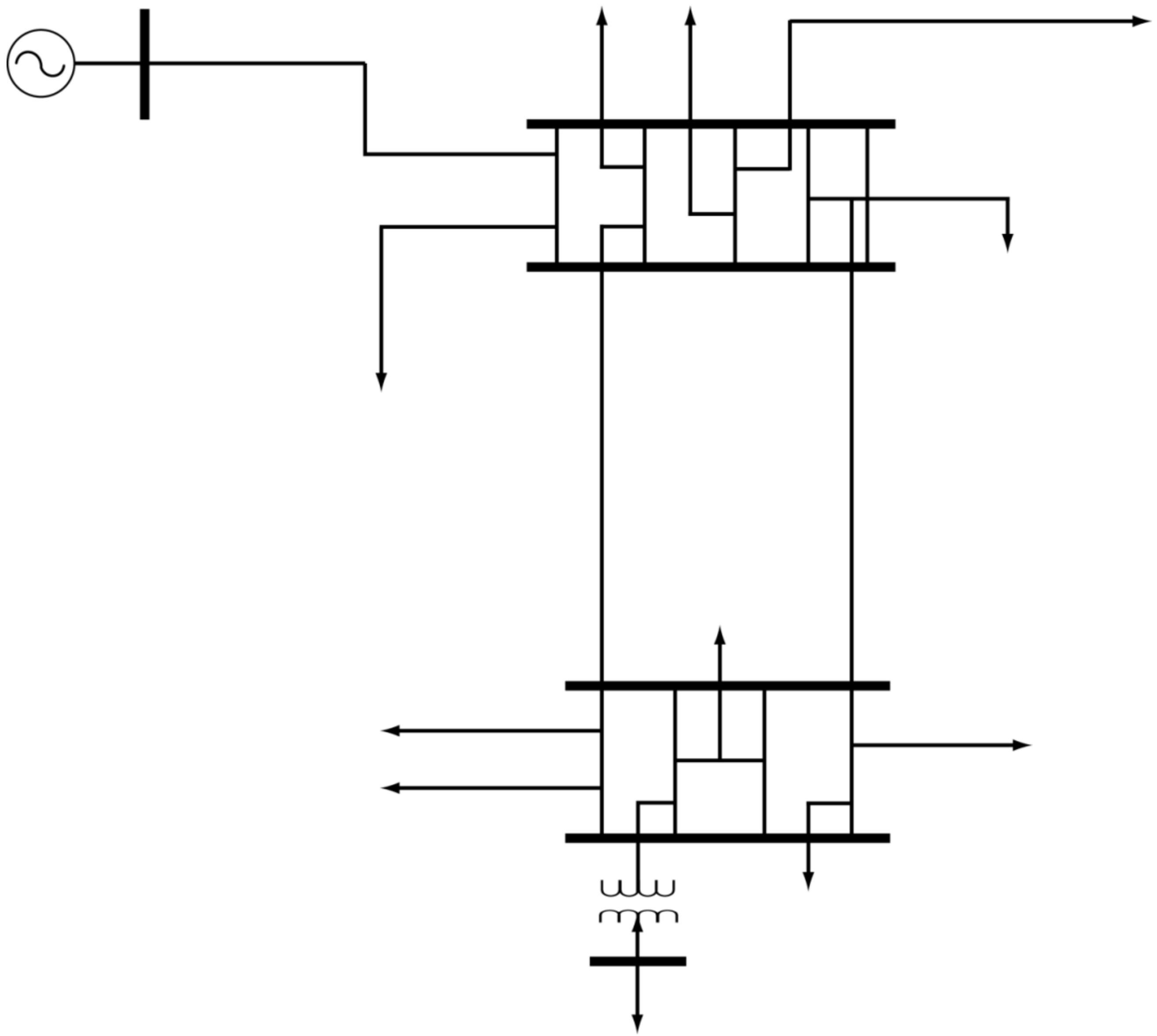


A mechanical **under- load tap changer (ULTC)** design, changing back and forth between tap positions 2 and 3

Strong Bus Example



Weak Bus Example



Tap Change Operation

- Maintain System Voltage Profile
  - Transformer tap changers act as VAR shovels
  - Adjust voltage on both sides of transformer
  - Most adjustments to maintain constant voltage at sub-transmission and distribution levels are accomplished by automatic load tap changing
- Correct Voltages Which Exceed Limits
- Reduce Undesirable MVAR Flow
  - VAR flow control within a power system
  - Adjust VAR flow through a transformer
    - Reduce losses

Effects of Tap Change Operation on the Power System

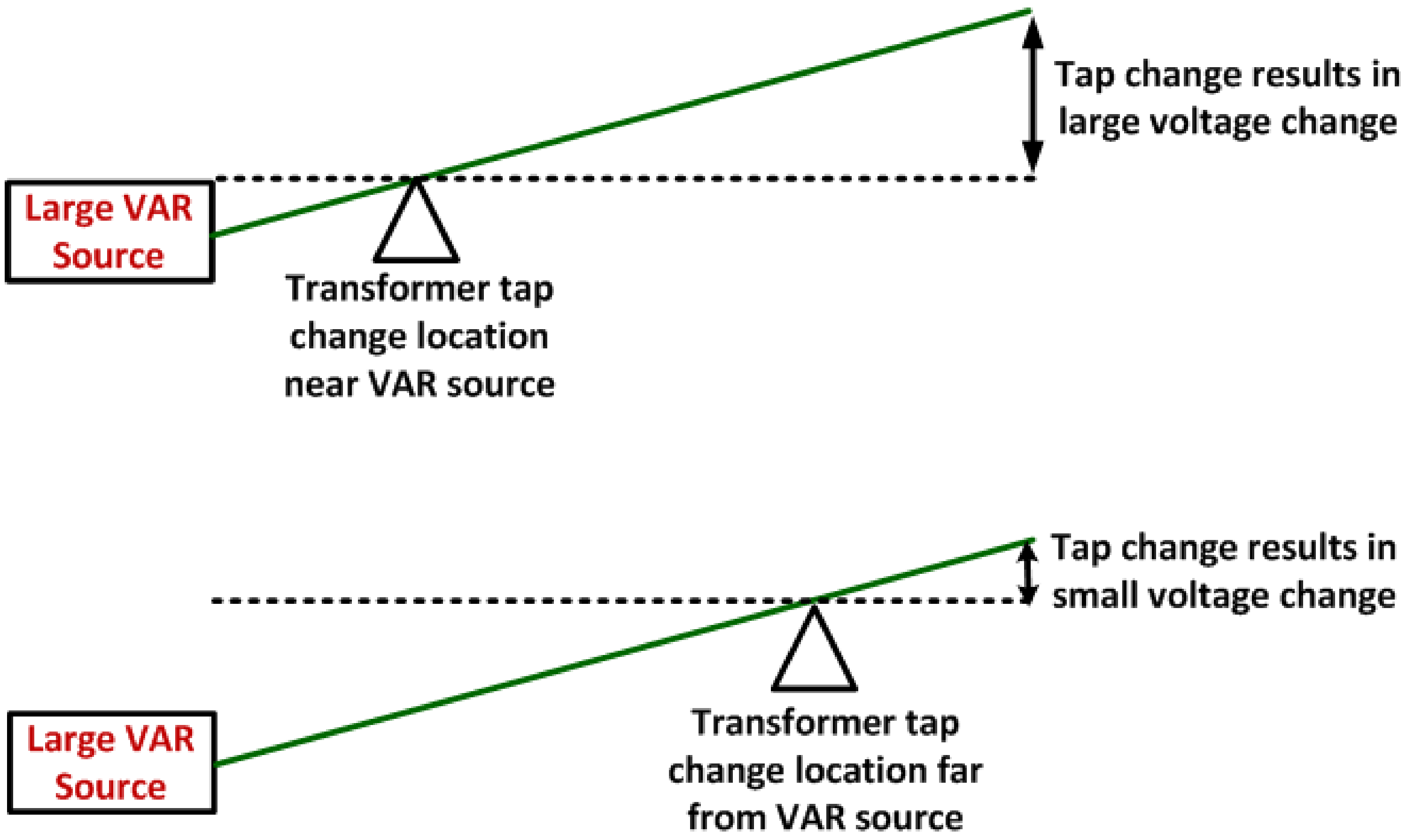
- Effect on Transmission Line Voltage Profile
  - If tap position is referenced to the low side voltage:
    - Voltage profile shifts upward when tap is raised
    - Voltage profile shifts downward when tap is lowered
    - Percent shift of tap position results in equal shift in percent voltage at transformer terminals

Effects of Tap Change Operation on the Power System

- Effect of Location of Transformer on System Voltages
  - Effect of tap change is determined by how close transformer is to VAR sources and VAR loads
  - Magnitude of voltage change determined by:
    - Distance of tap changer from VAR source or VAR load
      - Tap change will have greater effect near source and less effect away from source
    - Magnitude of VAR source or VAR load

Effects of Tap Change Operation on the Power System

- Effect of Location of Transformer on System Voltages

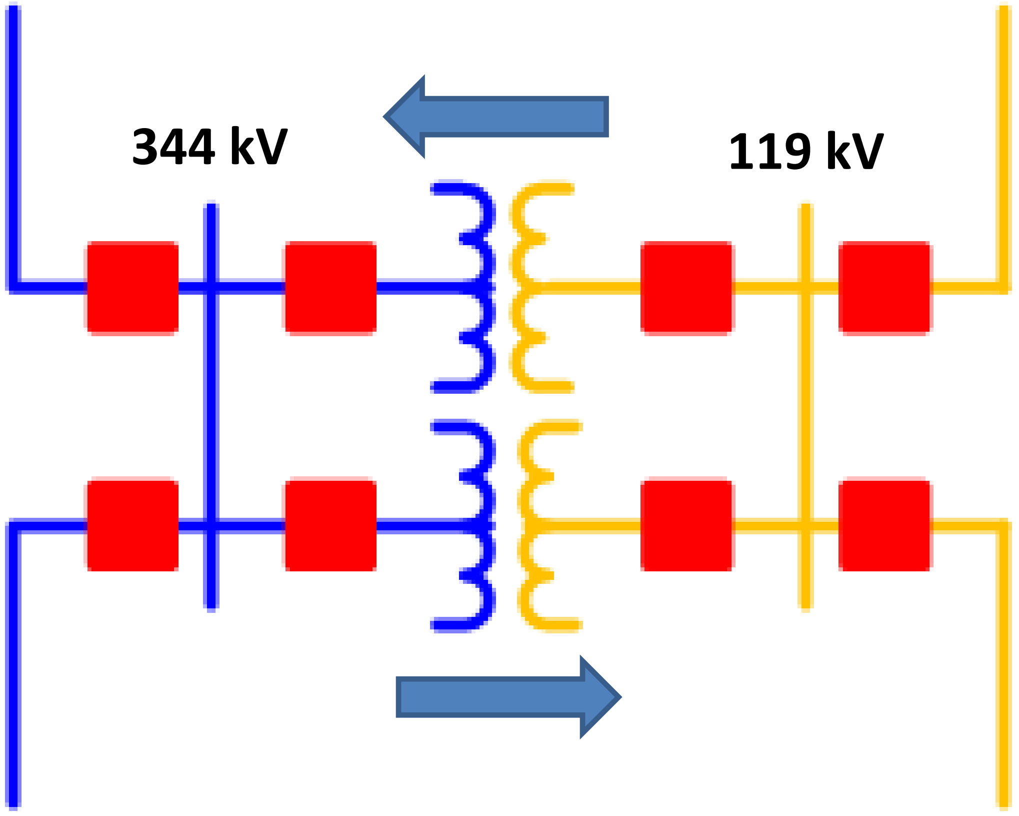


Restrictions and Limitations

- Effect on Interconnected Voltages
  - On interconnected system, changing voltage at one location will also affect interconnected voltages
  - Cannot adjust single individual voltage due to interconnected nature of system
    - Generally must change all taps into an area to achieve the desired effect on the voltage
  - Must observe effects of a tap change on surrounding voltages close to tap change and coordinate tap moves

Restrictions and Limitations

- Unwanted VAR Flows
  - Shifting voltages can cause unwanted VAR flows



Restrictions and Limitations

- Summary of Restrictions and Limitations
  - Use voltage schedule to determine need to change voltage
  - Coordinate tap changes
    - Transformers in parallel must be balanced to prevent unwanted VAR flows
    - Change of one voltage must be coordinated with interconnected voltages

PAR Operation to adjust voltage

- Phase Angle Regulators (PARs) change the power system phase angle at their location, allowing power flows to be regulated
  - All though they don’t directly control voltage, they can have an impact on the voltage profile in the area they are located
  - If you increase the flow on parallel lines by adjusting the tap of a PAR, those lines will consume more reactive power to support the increased MW flow
  - This could lead to a decrease in voltage in the area of those flows if there are not any local reactive resources

Reactive Resource Outages

- The Transmission Owners are responsible for reporting outages on all facilities contained within the Transmission Facilities List Database
  - These lists include reactive resources and can be found on PJMs website at the following link:
    - http://www.pjm.com/markets-and-operations/transmission-service/transmission-facilities.aspx
  - In addition to complete outages, if a capacitor bank's rated MVAR capability has been significantly changed:
    - Should also be communicated to PJM for modeling purposes as well as updated in the Transmission Owner's EMS model

Generator Reactive Testing

Generator Reactive Testing

- Reactive capability testing:
  - Necessary to improve transmission system reliability by accurately determining generator reactive capability on a regular basis
  - Intended to demonstrate reactive capabilities for those conditions where reactive reserves would be required
  - Coordinated between all affected parties to minimize impact on system conditions

Generator Reactive Testing

- Reactive capability testing
  - All individual units >20 MVA, and all aggregate units > 75 MVA, which are connected to the BES
    - includes variable resources such as wind, solar, run of river
  - All units designated as Black-Start
  - All Synchronous Condensers > 20 MVA which are connected to the BES
  - Testing is required once very 5 years
    - No more than 66 months between consecutive tests

Generator Reactive Testing

Unit Type	MW Output	MVAR Output	Test Duration
Fossil, Hydro & Black Start	Maximum Maximum Minimum Minimum	Max Lag Max Lead Max Lag Max Lead	One Hour When limit reached When limit reached When limit reached
Synchronous Condenser or Generator that operates in Synchronous Condenser mode	N/A	Max Lag Max Lead	One Hour When limit reached
Nuclear	Maximum Maximum	Max Lag Max Lead	One Hour When limit reached
Variable (i.e. – Wind & Solar) Testing must done with at least 90% of turbines or inverters online	Variable Variable	Max Lag Max Lead	When limit reached When limit reached

Generator Reactive Testing

- Test Window
  - Testing targeted between May 1 and September 30
  - Preferred testing time is between 1200–1800 on weekdays
  - Required testing period for over-excitation is 1 hour, under-excitation capability recorded as soon as a limit is met

Generator Reactive Testing

- Test Scheduling
  - Generation Owners schedule their units during testing period
  - Tests scheduled through eDART by submitting a MVAR test ticket by noon 3 business days prior to test
    - Allows testing to be incorporated into the day-ahead studies
  - If separate testing is required, separate eDART tickets are required for each test

Generator Reactive Testing

- Study Process
  - PJM and TO perform studies to determine impact of testing on system
    - Studies done day(s) ahead and 30 minutes prior to test
  - If studies indicate actual or post-contingency violations that can’t be mitigated, test will be rescheduled
  - Voltage schedule changes may be needed to accommodate testing

Generator Reactive Testing

- Communication and Coordination
  - MOC/GO
    - Schedules tests via eDART
    - Contacts PJM three hours prior to start of test to initiate study process
    - Coordinate and implement mitigations steps, exit strategy as required
  - TO
    - Communicate concerns found during study process to PJM
    - Coordinate and implement mitigation steps, exit strategy as required

Generator Reactive Testing

- Communication and Coordination (cont.)
  - PJM
    - Directs and coordinates all communications for test scheduling and actual testing process
    - Communication between MOC and TO channeled through PJM Dispatch
    - Coordinate and implement mitigations steps and exit strategy with MOC and TO as required

Generator Reactive Testing

- Exit Strategy
  - Reactive Capability testing cannot place system in unacceptable state
    - Each test will be studied and approved on case by case basis
    - All mitigation steps are to be agreed upon and coordinated will all parties

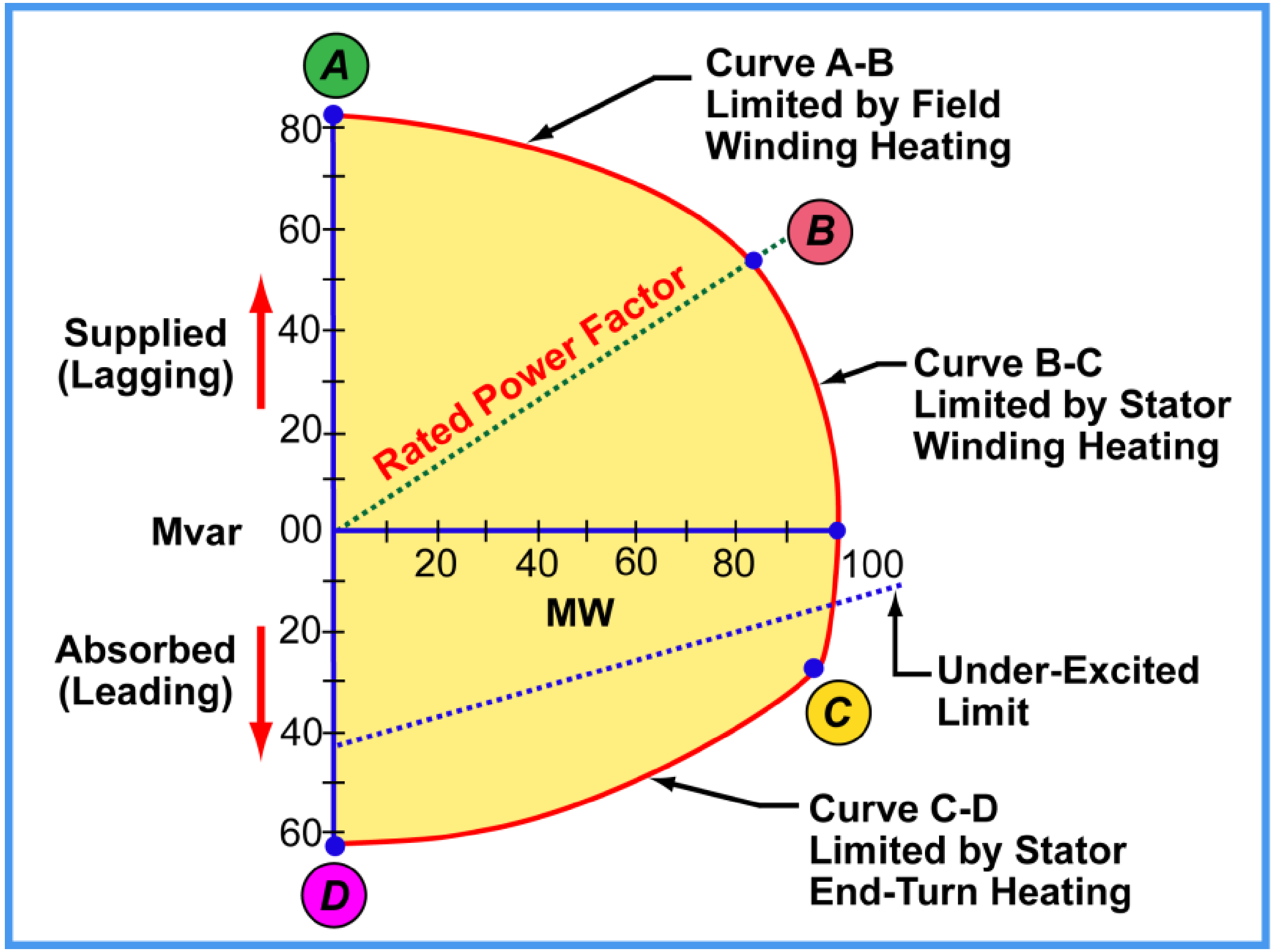
Generator Reactive Testing

- Results Reporting
  - MOC/GO
    - Submit all required testing results to PJM within 30 days
    - Test results submitted on “PJM Leading and/or Lagging Test Form R”
  - PJM
    - Provide feedback to Generation Owners on status of their test results
    - Also provide test results to appropriate TO
    - Conduct periodic audits of test results and provide results to OC and SOS

Reactive Capability Changes and Reporting

Generator Reactive Reporting

- Reactive Capability (or “D”) Curves
  - Generators Report "Continuous Unit Reactive Capability Curve"
    - Realistic usable capability sustainable during continuous unit operation
    - Should be based on actual operating experience (or testing)
    - Takes into consideration any normal unit or plant restrictions at 95 degrees F ambient or above



Generator Reactive Reporting

- Reactive Capability (or "D") Curves
  - Sufficient number of curve points must be provided
    - Min of 2
    - Max of 8
  - Limits specified as measured at the low side of the step up transformer
    - Excludes any station service load fed off the terminal bus

Generator Reactive Reporting

- Reactive Capability (or “D”) Curves
  - Semi annual Reviews
    - Generator Owners required to review Capability and update any changes in eDART
      - Pre-Summer - During month of April
      - Pre-Winter - During month of October
    - Transmission Owners and PJM to review D-Curve changes in eDART and update respective EMS systems
      - Pre-Summer – During month of May
      - Pre-Winter – During month of November

Generator Reactive Reporting

- Reactive Capability (or “D”) Curves
  - Permanent Updates
    - Generator must notify PJM and TO
      - via eDART ticket
      - Check “New Default” field on ticket
    - EMS Updates
      - PJM and TOs act on notifications, updating generator reactive capability in Security Programs

Generator Reactive Reporting

- Reactive Capability (or “D”) Curves
  - Real-Time Updates
    - Generator must notify PJM and TO
      - via eDART ticket
      - AND via phone call
    - EMS Updates
      - PJM and TOs act on notifications, updating generator reactive capability in Security Programs

Contact Information

PJM Client Management & Services

Telephone: (610) 666-8980

Toll Free Telephone: (866) 400-8980

Website: www.pjm.com

The Member Community is PJM's self-service portal for members to search for answers to their questions or to track and/or open cases with Client Management & Services

Resources and References

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