

# Voltage Control at PJM

**Chantal Hendrzak**  
**Director Applied Solutions**  
**PJM Interconnection**  
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# Voltage Control Background

- System Operator Monitors
  - Bus voltages in system
  - Voltage limits and alarms
  - VAR flows



# Monitoring System Voltages

- Observe Critical Bus Voltages
- Observe Voltages in an Area
- Observe Voltage Alarms
- Monitoring Sources
  - EMS, Mapboard, Trend Reports, Field Reports, Customer Complaints (through PJM members)

# Analyzing Voltage Problems

- Low Voltage
  - Due to excessive VAR loading
  - Due to voltage regulation malfunction
  - Due to excess VAR loads on system
  - Due to Solar Magnetic Disturbance
- High Voltage
  - Due to light load
  - Due to switching in a line with high capacitive charging current
- Temporary Voltage Fluctuations
  - Temporary voltage fluctuation can be caused by load surge
  - Flicker can be caused by large pulsating loads

- NERC Standard VAR-001:
  - Generation Owners who have not been provided a voltage schedule or a low and high bandwidth by a Transmission Owner are required to follow the PJM default voltage
  
- R4. Each Transmission Operator shall specify a voltage or Reactive Power schedule <sup>1</sup> at the interconnection between the generator facility and the Transmission Owner's facilities to be maintained by each generator. The Transmission Operator shall provide the voltage or Reactive Power schedule to the associated Generator Operator and direct the Generator Operator to comply with the schedule in automatic voltage control mode (AVR in service and controlling voltage).

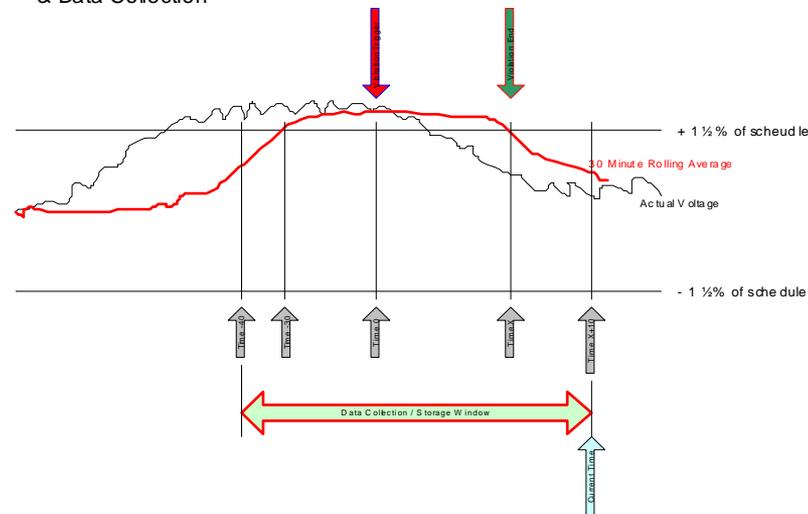
<b>PJM Default Generator Voltage Schedules</b>							
<b>Voltage Level</b>	<b>765 kV</b>	<b>500 kV</b>	<b>345 kV</b>	<b>230 kV</b>	<b>138 kV</b>	<b>115 kV</b>	<b>69 kV</b>
Schedule	760	525	350	235	139.5	117.0	68.0
Bandwidth	+/-10.0	+/- 8.0	+/- 7.0	+/- 3.0	+/- 3.0	+/- 3.0	+/- 1.5

# Generation Performance Monitor (GPM)

- Track MW/MVar Generation Performance (MW phase II)
- Provide real-time visualization to PJM, Transmission Owner, MOC, and Generators.
- Enhance real-time coordination between PJM, TO, and GO.
- Provide feedback loop to enhance quality of real-time data.

**Note 1:** PJM uses the Generation Performance Monitor (GPM) to track a generators ability to follow a designated voltage schedule. GPM compares the integrated 30 minute average to the designated voltage schedule and flags performance outside a threshold. Generation Owners are expected to resolve performance issues within 30 minutes through generator modifications or updating reactive D-curve and/or voltage regulator status within eDart.

Voltage vs Violation Graph  
& Data Collection



# Voltage Problems Requiring Operator Action

- Deviation from Voltage Schedule
- Voltage Limits Exceeded
- Possible Operator Actions
  - Voltage may be controlled by
    - Generating MVAR
    - Absorbing MVAR
    - Redistributing flow of MVAR
  - Control techniques
    - Switch capacitors in/out
    - Switch reactors in/out
    - Parallel synchronous condensers
    - Adjust generator MW
    - Change excitation on generators
    - Change tap positions on transformers
    - Switch lines/cables

# 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.	Immediate
Normal Low	Use all effective non-cost actions, off-cost actions, and emergency procedures except load dump.	15 minutes
Emergency Low	All of the above plus, shed load if voltages are decaying.	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.	15 minutes or less depending on the severity

Legend
NON-COST
OFF-COST
LOAD SHEDDING

Voltage Limit Exceeded	If post contingency simulated voltage limits are violated	Time to correct (minutes)
High Voltage	Use all effective non-cost actions.	30 minutes
Normal Low	Use all effective non-cost actions.	Not applicable
Emergency Low	Use all effective non-cost actions, off-cost actions, and emergency procedures except load dump.	15 minutes
Load Dump Low	All of the above plus, shed load if analysis indicates the potential for a voltage collapse.	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.	15 minutes

# Generator Automatic Voltage Regulator Status

- Per NERC Standard VAR-002
  - R3.** Each Generator Operator shall notify its associated Transmission Operator as soon as practical, but within 30 minutes of any of the following:
    - R3.1.** A status or capability change on any generator Reactive Power resource, including the status of each automatic voltage regulator and power system stabilizer and the expected duration of the change in status or capability.
    - R3.2.** A status or capability change on any other Reactive Power resources under the Generator Operator's control and the expected duration of the change in status or capability.
- Reporting of AVR status and Reactive Capability changes accomplished via eDART generator reporting

# Existing Tools

SIEMENS

Disp MU SE SA TLC Other Apps NA Prog TT

NA Monitor Disp Monitor Exec Ctrl SE Config SE Results SA Config SA Results TLC TT Help

Disp>TLC>Results Summary

Transfer Limit Calculations  
 TLC Executed At 11/29/2011 12:40:25      TLC Converged YES

DONE      View CPF Output Files

Messages

Message

Starting parallel execution of 12 combinations

TLC Interface Results Summary

Interface	Volt Viol Point	Last Conv Point	Interface Margin	SE MW Flow	Pre Recom-Limits	Post MW Flow	Post Recom-Limits	Current Limits	Status
EAST	99999	5201	300	2468	4901	2873	5278	5086	Enabled
CENTRAL	2098	2472	200	-402	2098	-439	2076	2217	Enabled
WEST	99999	4291	200	1568	4091	1554	4116	4158	Enabled
EAST-X	99999	5491	300						
BED-BLA	1908	1914	100						
APSOUTH	3822	3968	100						
50045005	2309	2482	100						
NE-OHIO	1171	1276	200						
CLVLND	992	1190	200						
ECAR-CE	-2181	-324	50						
BCPEP	5399	5610	100						
AEP-DOM	4601	4672	100						

### Generator Ticket (Review/Revise)

User ID:      t Number: 823121      Company:

Generation Type: Steam/Fossil      Unit Name:      Est./Ramp Start: 10/21/2011 16:30

Ticket Status: Complete      Timestamp: 10/21/2011 16:18      Est. End: 10/21/2011 17:00

Company Ticket ID :       Actual Start: 10/21/2011 16:30

Actual End: 10/21/2011 16:41

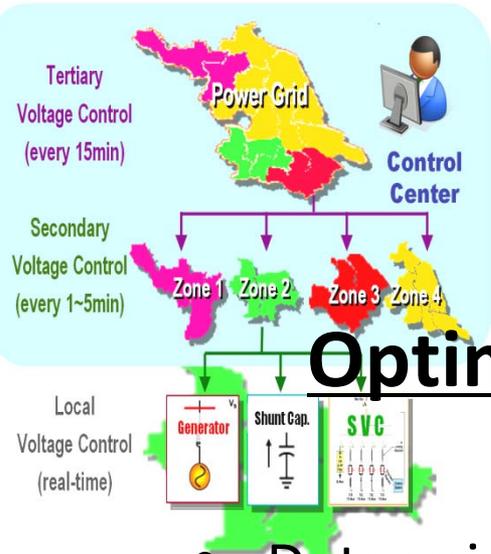
Description	PJM Comments
AVR coming out of service to clear HP exciter alarm.	

### Voltage Regulator Ticket Info

The Voltage Regulator should always be in service if available.

Out of Service: No      Emergency: No

Submit      Refresh      History Log      Main Menu



## Optimal Dynamic Voltage Control System (AVC):

- Determine voltage schedule and VAR control system-wide
- Achieve the objective of minimize system loss, or maximum of MW transfer
- Improve system voltage profile, real time security and reliability

### Results from pilot:

- Average reduction of transmission system loss 1.19% (anticipated energy savings >220 million kWh/year or > \$17 million/year)
- Average increase of system VAR reserve about 1.08%;
- Improvement on security indices in potential voltage limits violations and potential voltage stability limits violations