# Voltage/VAR Control of SCE Transmission Network

## Wide Area Monitoring, Protection & Control

## Southern California Edison (SCE)

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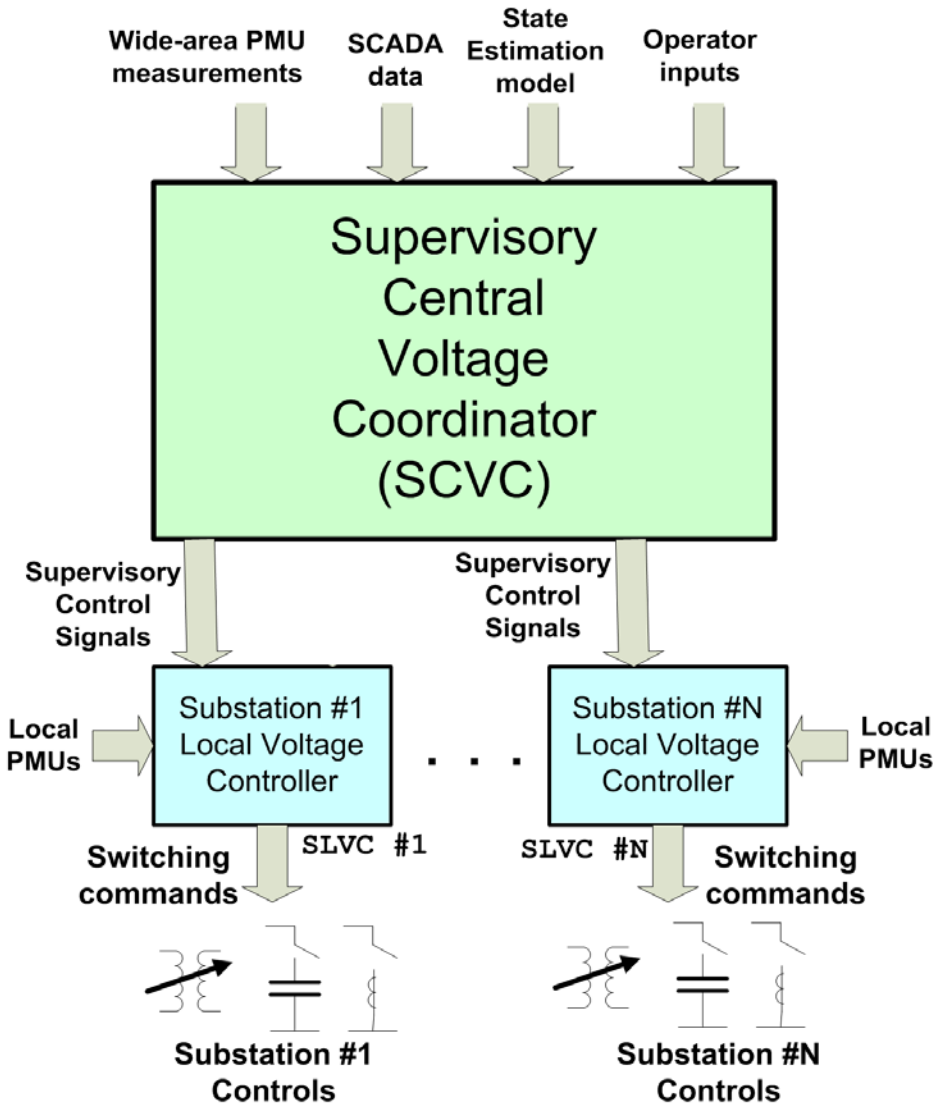
# Introduction – Voltage Control

- SCE's bulk power transmission system (500 kV & 230 kV) voltage control basically is done manually in accordance with the SOB 17 and system operator's experience and preferences.
- The increased interest in greater power system automation is aimed to relieve operators from repetitive tasks and improve system security and reliability.
- Automatic voltage control is a perfect choice for transmission system voltage regulation.

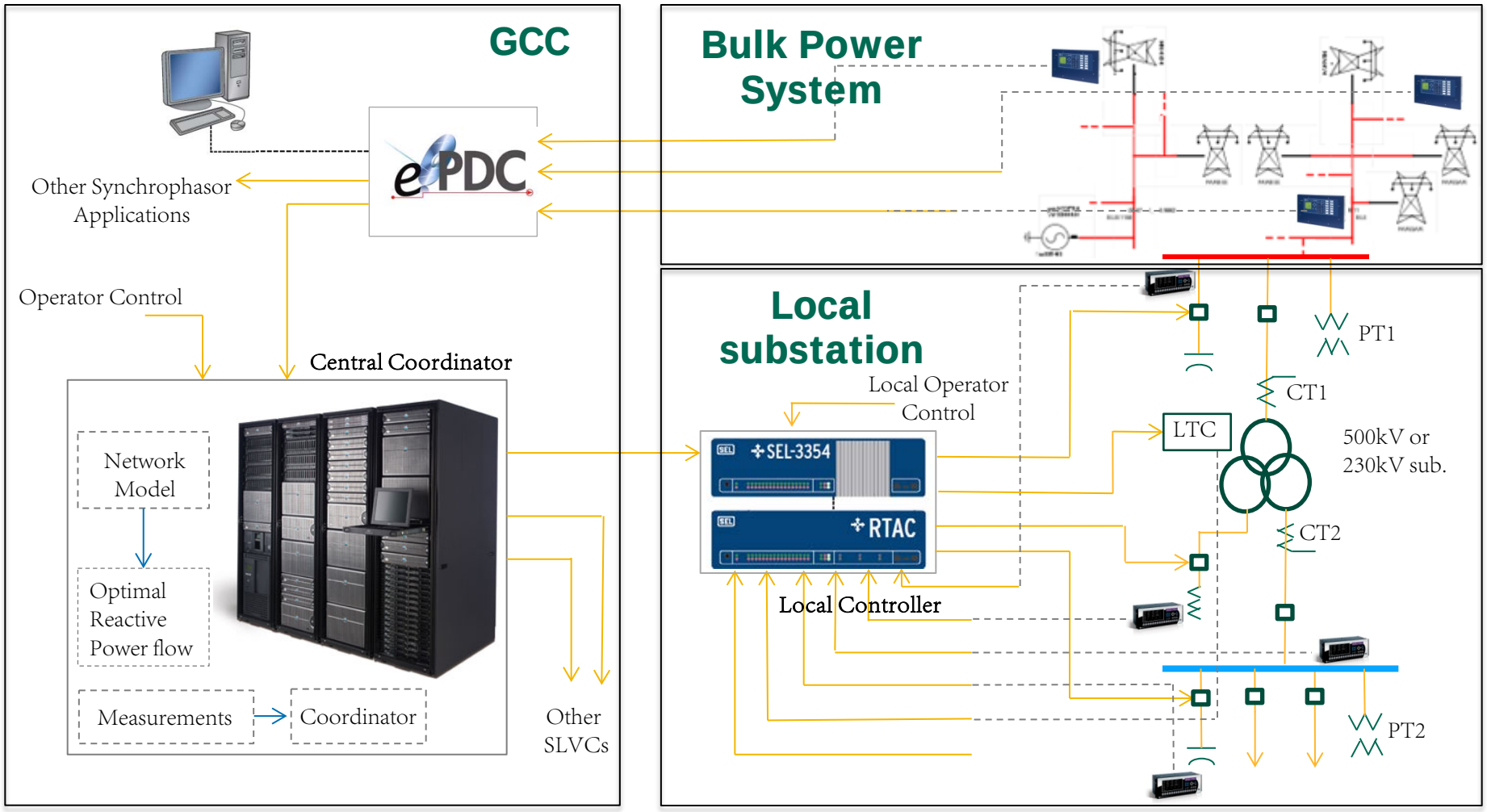
# SCE's Wide-Area Transmission Voltage Control System

- The SCE transmission system voltage controller is a two-level controller consisting of a Supervisory Central Voltage Coordinator (SCVC), and Substation Local Voltage Controllers (SLVCs). The SCVC performs an Optimal Power Flow (OPF) type of calculations to determine optimal bus voltage set points (schedule), enables/disables each SLVC, and each SLVC maintains the buses voltage schedule by controlling local shunt VAR resources in an optimal fashion.
- The control system is aimed at maintaining transmission voltage profile at steady state. SCVC serves as a Tertiary Voltage Control element, and SLVC serves as a Secondary Voltage Control element. Primary Control is not directly activated, but its reactive power output is kept at a minimum so that its full capacity is available during a large disturbance.

# Block Diagram of Wide-Area Voltage Control Scheme



# Functional Diagram of Wide-Area Voltage Control Scheme

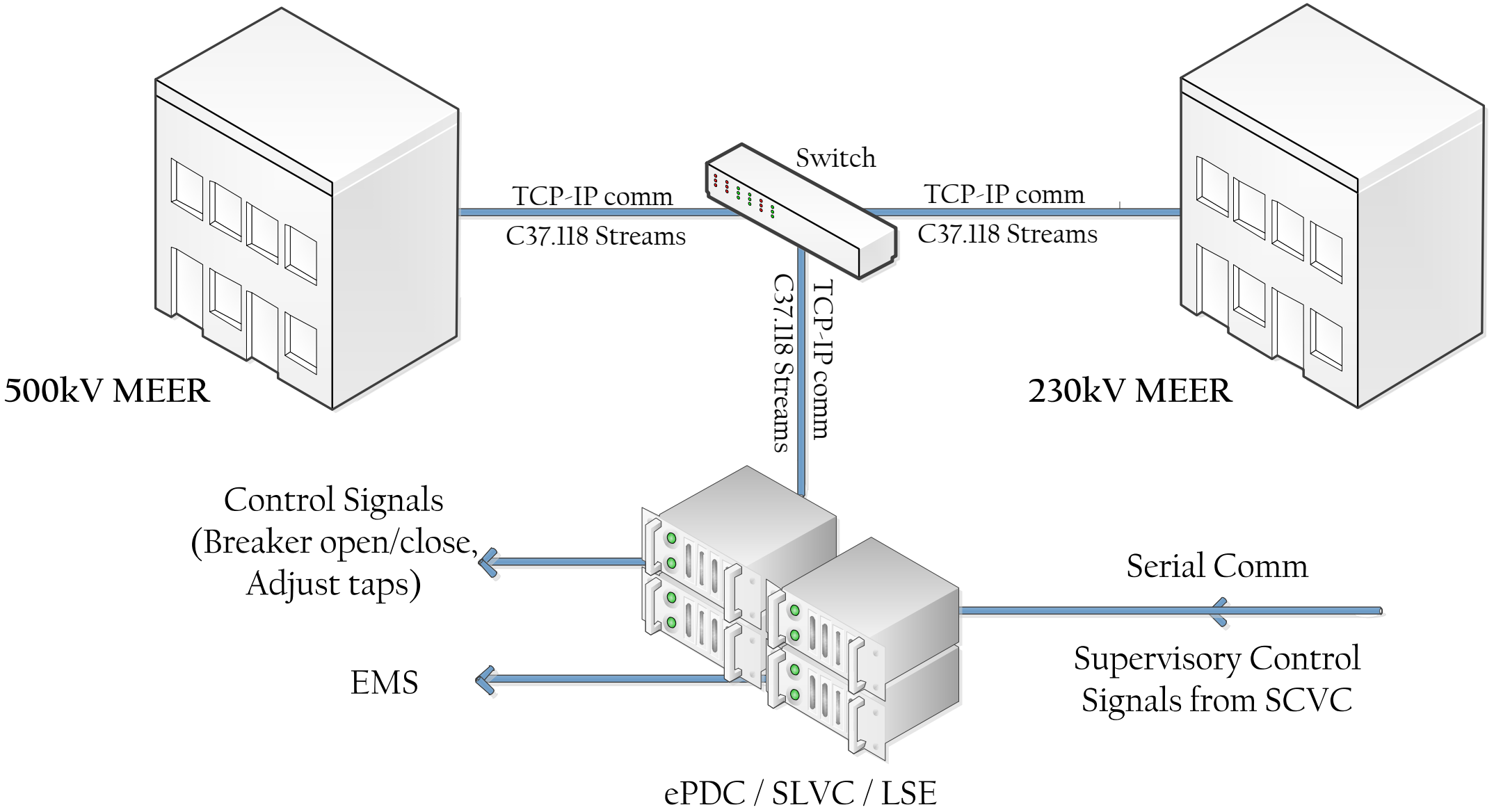


# Substation Controller (SLVC) Design Details

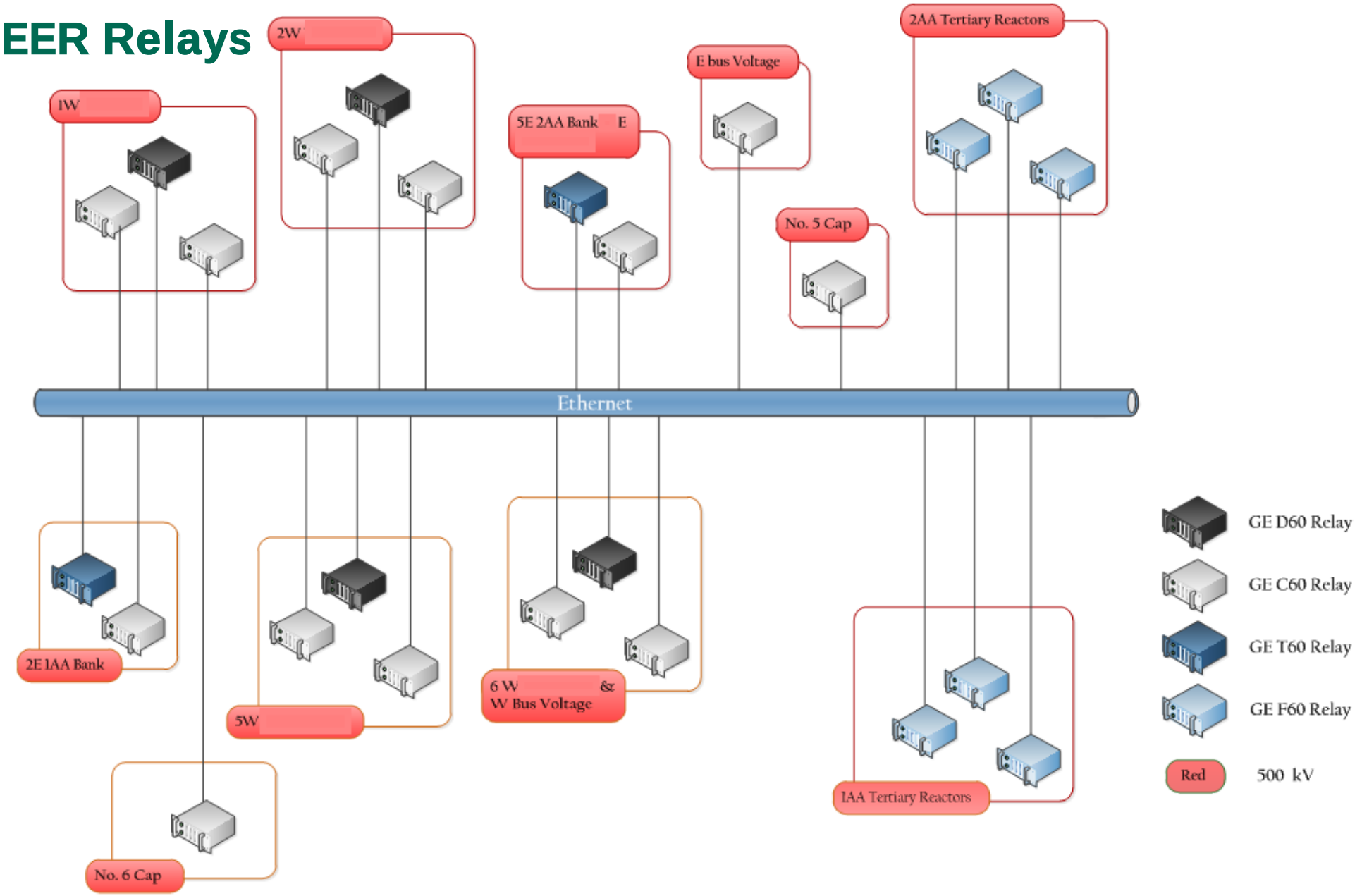
- **Master Mode (SVC at 500kV out-of-service)**
  - Maintain 115 kV, 230 kV and 500 kV bus voltages by switching local VAR devices, transformer banks LTC, capacitor and reactor banks

- **Slave Mode (SVC at 500kV in-service)**
  - Maintain 115 kV and 230 kV bus voltages by switching local VAR devices – transformer banks LTC, capacitor banks and reactor banks
  - Maintain SVC VAR output within limits and other VAR flow constraints

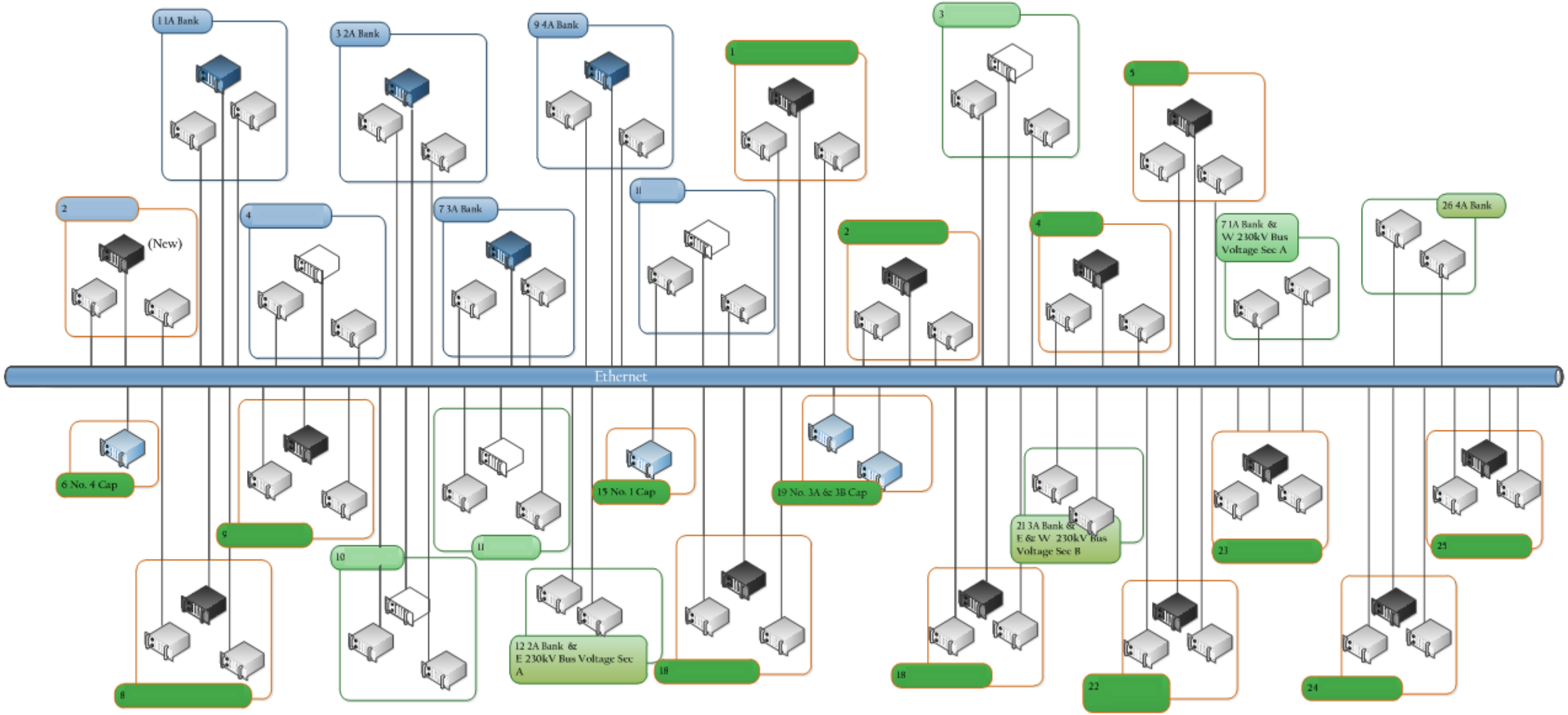
# Substation Controller (SLVC) Functional Diagram



# 500kV MEER Relays



# 230kV MEER Relays



# Central Coordinator (SCVC) Functions

- **Coordinate** switching of substation SLVC controllers
  - Enable specific substation SLVCs as needed in case of violations
  - Disable other substations to prevent hunting between controllers

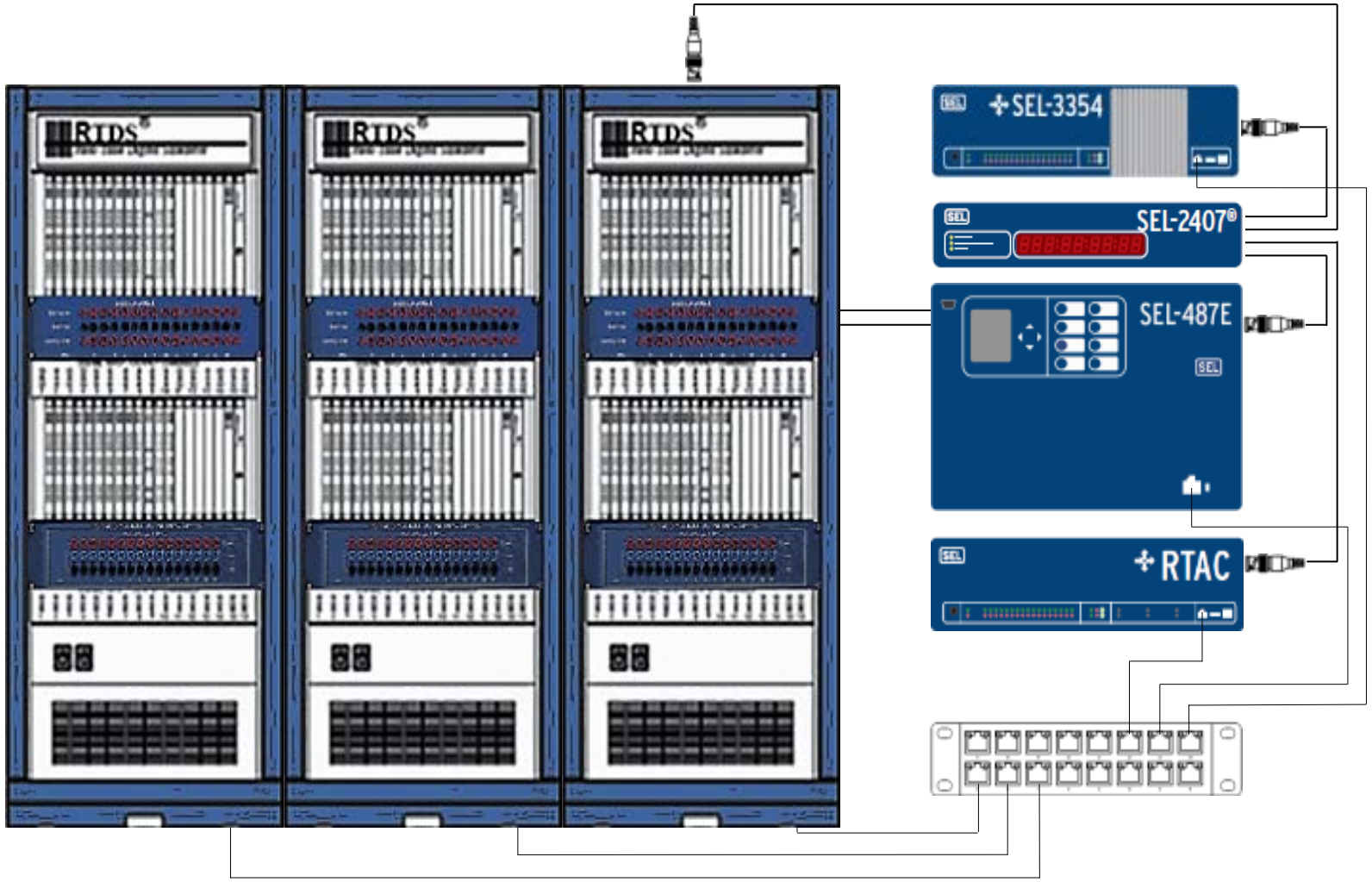
- **Optimize** voltage profile towards minimizing transmission losses
  - sends voltage schedules and/or target voltages to substation controllers.

# Central Coordinator (SCVC) Design Details

- **Supervisory Coordination**
  - Monitor grid voltage profile and select optimal substation controllers to address voltage problems.
  - Issue Enable/Disable commands as needed
    - Coordination Mode: voltage control done by local SLVCs
    - Backup Mode: voltage control done by SCVC
  - Mostly based on PMU measurements (Combined PMU and SCADA data is under consideration)
- **Optimal Voltage Profile**
  - Optimize grid voltage profile to minimize transmission losses by coordinating substation voltage schedules

# Substation Controller (SLVC) Closed-loop test bed

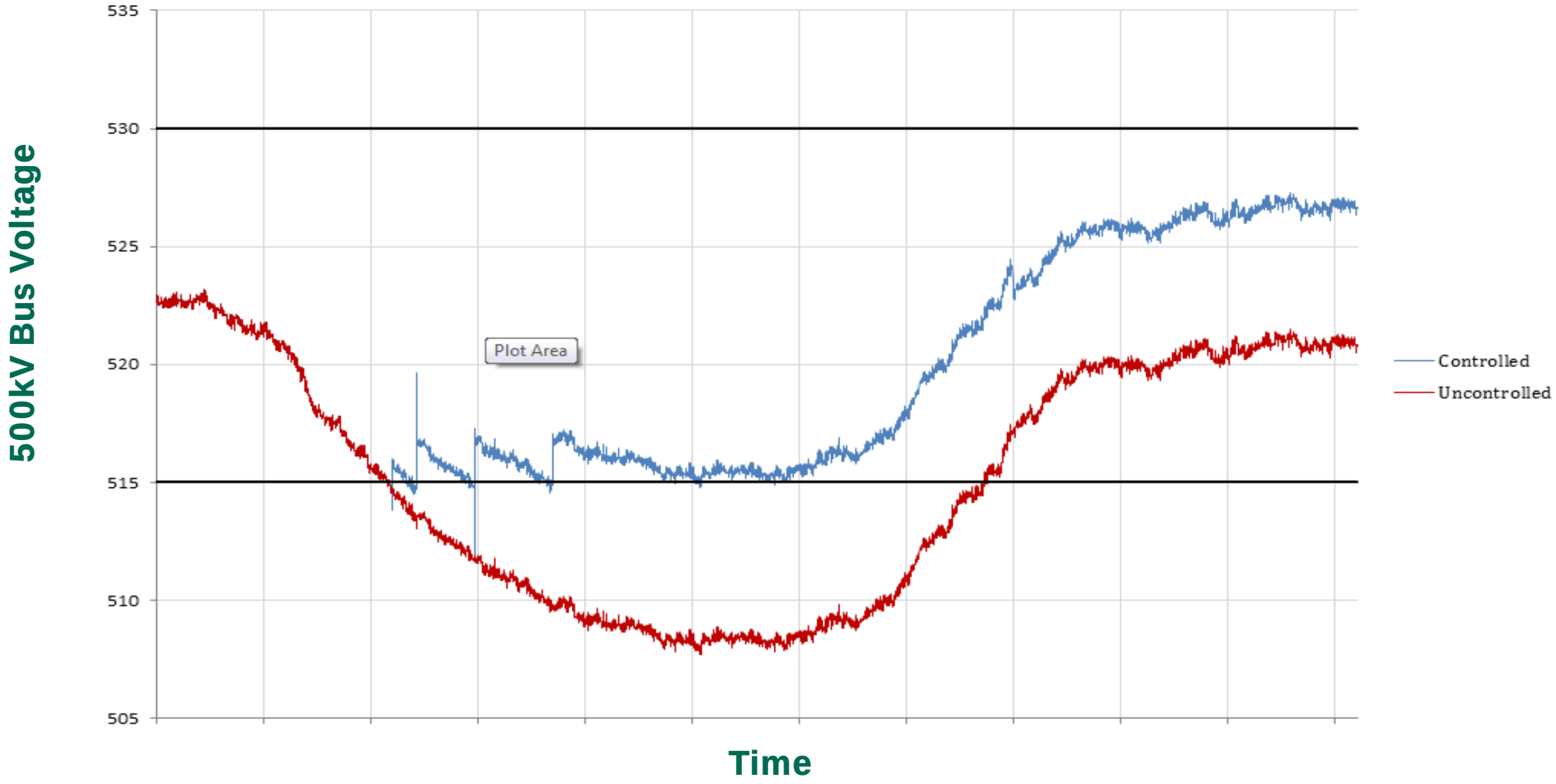
- RTDS (5 Racks).
- GPS Clock.
- RTAC
- SEL-487E Relay.
- Substation computer.



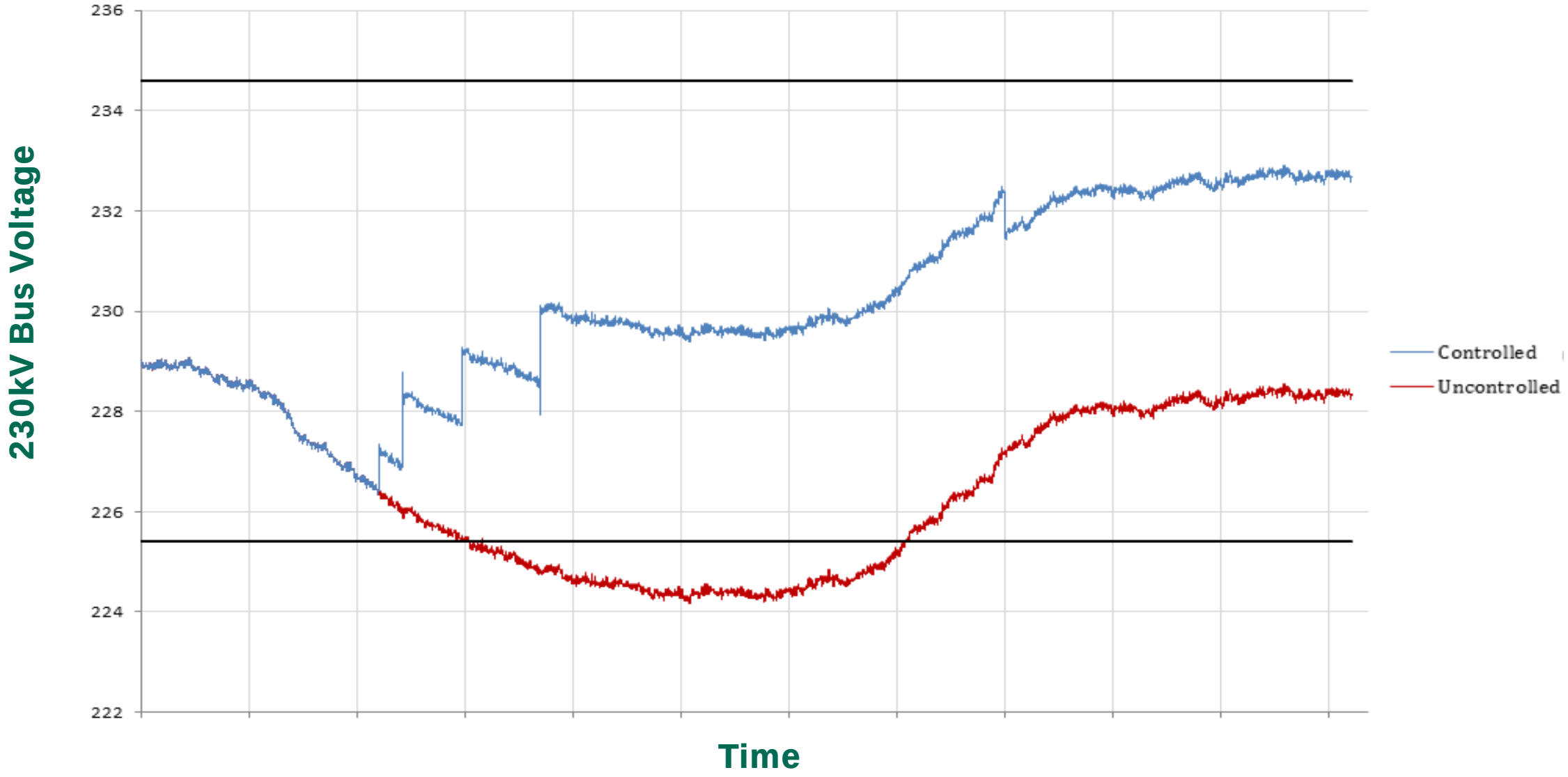
# RTDS substation model

- A specific SCE High-voltage substation was modeled in details including:
- (3) Three **bus voltage levels**; 500kV, 230kV & 115kV.
- (2) Two **500/230 kV Transformers** (AA banks) in parallel equipped with ULTCs.
- (6) six shunt **reactor banks** at tertiary side of AA banks (3 at each transformer).
- (3) Three **230/115 kV Transformers** (A banks) in parallel equipped with ULTCs.
- (4) Four shunt **capacitor banks** at 230kV bus.
- (3) Three shunt **capacitor banks** at 115kV bus.
- (1) one **Static VAR Compensator (SVC)** able to supply 405MVAR capacitive and 110MVAR reactive.
- Multiple **dynamic Loads** are modeled at load buses to simulate a real-time voltage trend.

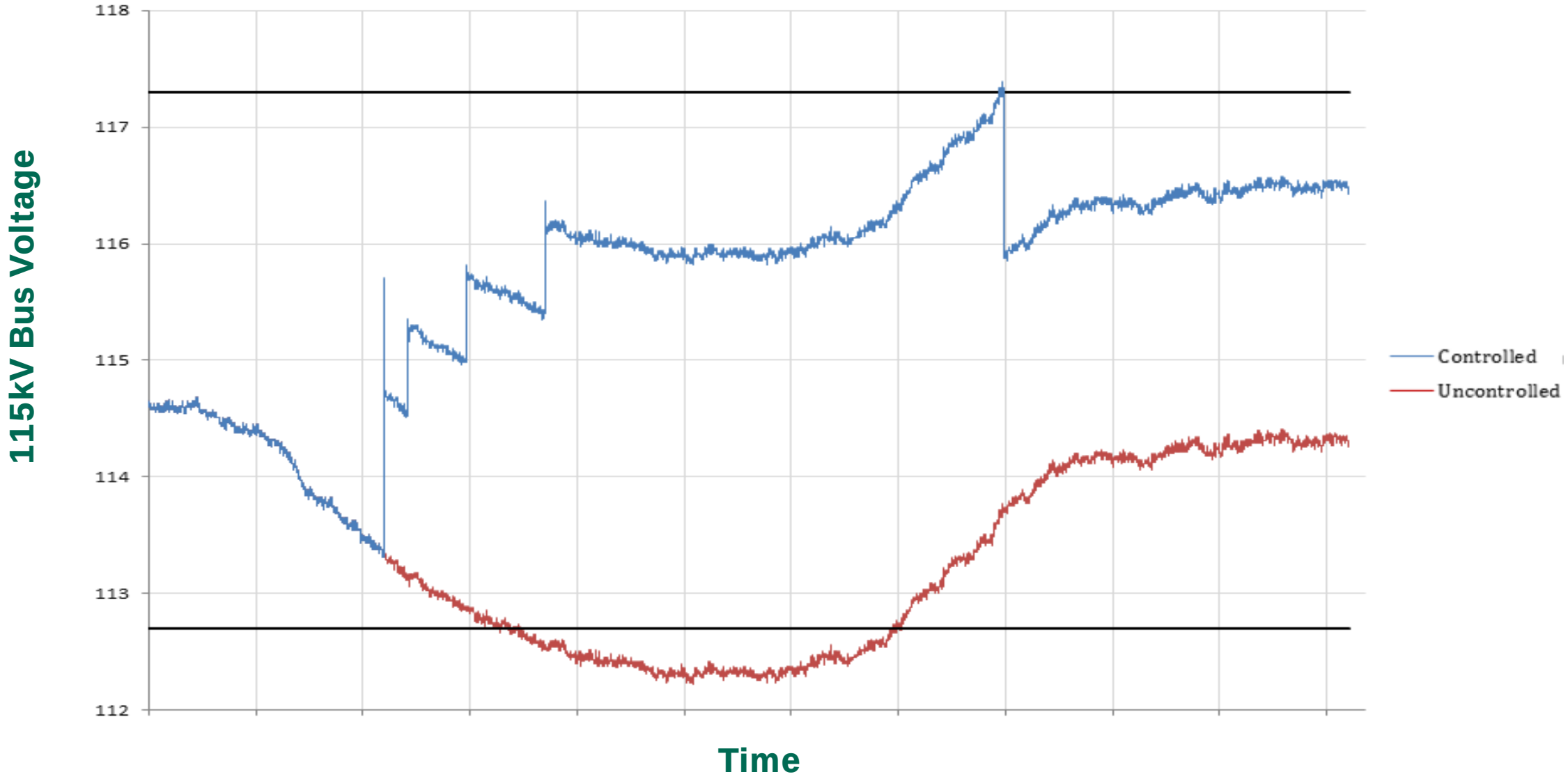
# RTDS test - Master Mode (SVC Out-Of-Service)



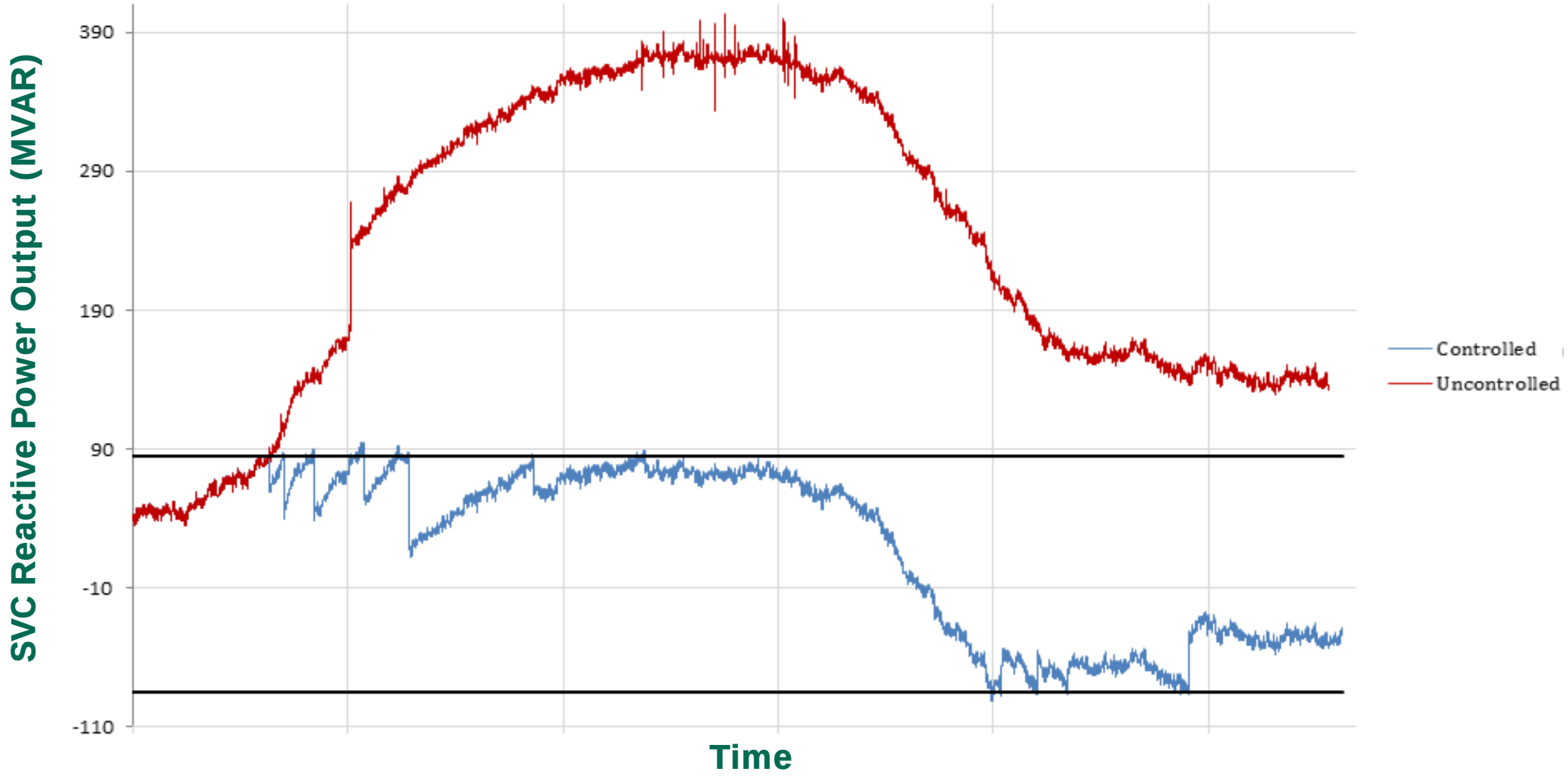
# RTDS test - Master Mode (Continued..)



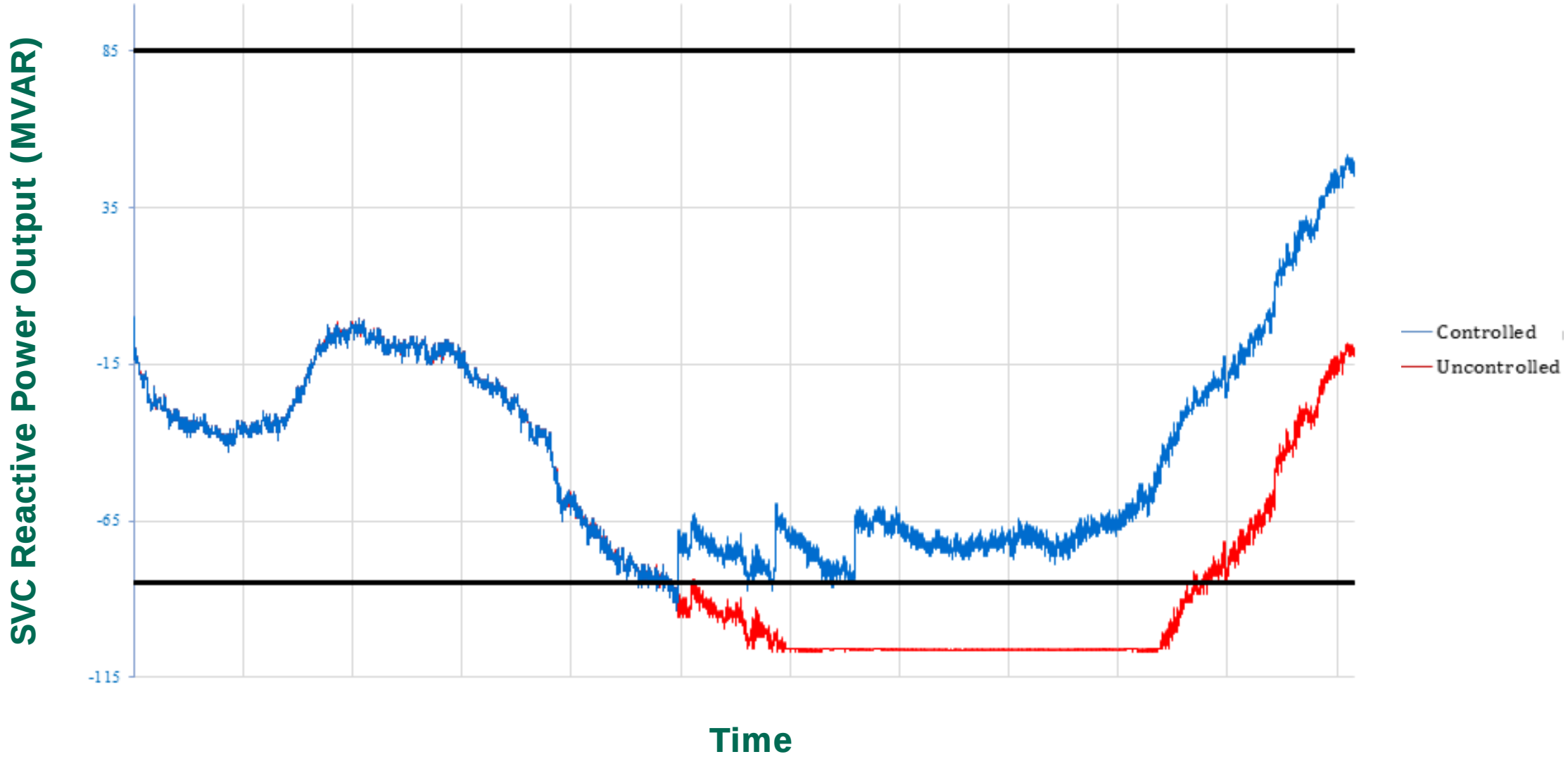
# RTDS test - Master Mode (Continued..)



# RTDS test - Slave Mode (Continued..)



# RTDS test - Slave Mode (Continued..)



# Questions ?