Volt/VAR Control at Progress Energy Carolinas
Past, Present and Future

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SMART GRID INITIATIVES

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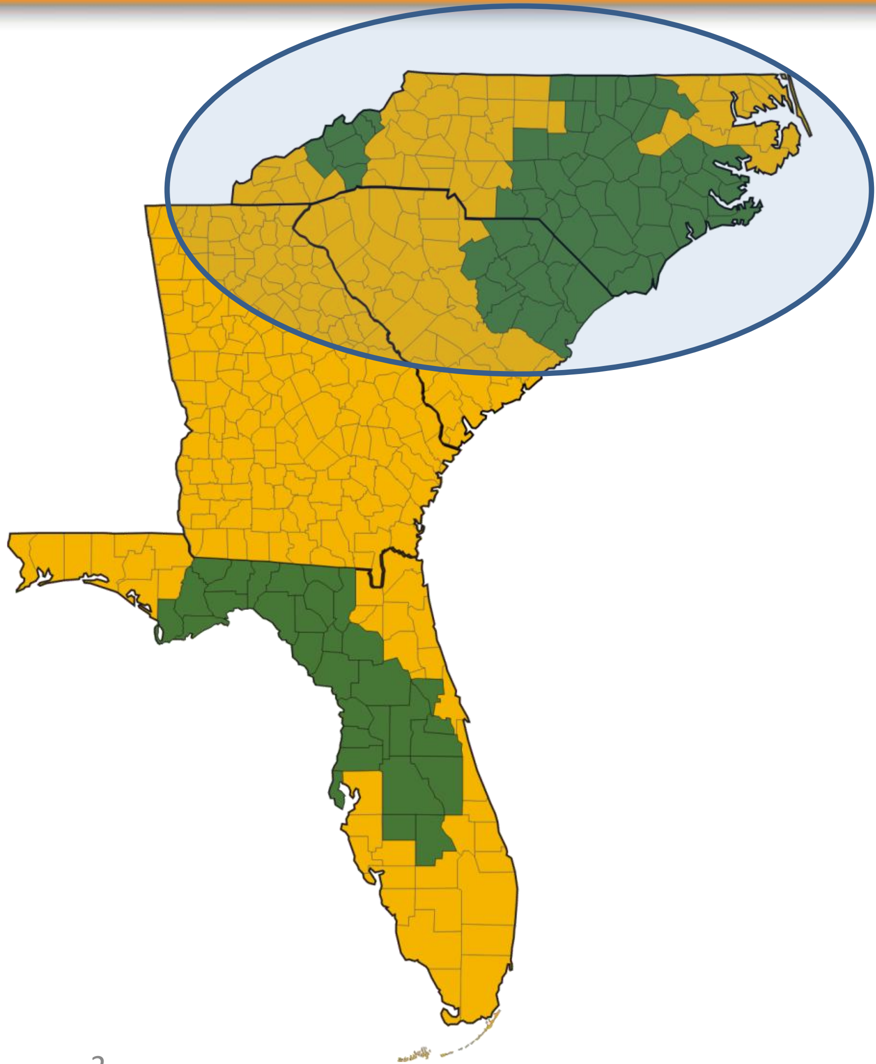

- 33,000 Square Miles
- 1.4 million customers
- 47,000 miles of distribution primary
- 380+ T/D substations & 1,190+ distribution feeders
- 72% distribution feeders served overhead
- 19% at 12kV and 81% at 23kV
- 1,200 customers per feeder
- 41 miles average primary feeder length
- 9% of feeders > 100 miles long

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Early Volt/VAR Management

- Transmission Planning & Distribution Planning performed complete system volt/VAR studies in accordance with annual planning calendar
- Transmission System required VAR support and voltage support during peak load periods and during certain contingency situations
- During light load times, capacitive VARs need to be removed from the system to avoid stability problems at major base load nuclear generating plants
- Standard model for a regulated T/D substation was a 5400 kVAR capacitor bank for each 25 MVA of capacity. A fully loaded 25 MVA transformer has 3000 to 3600 kVAR in losses

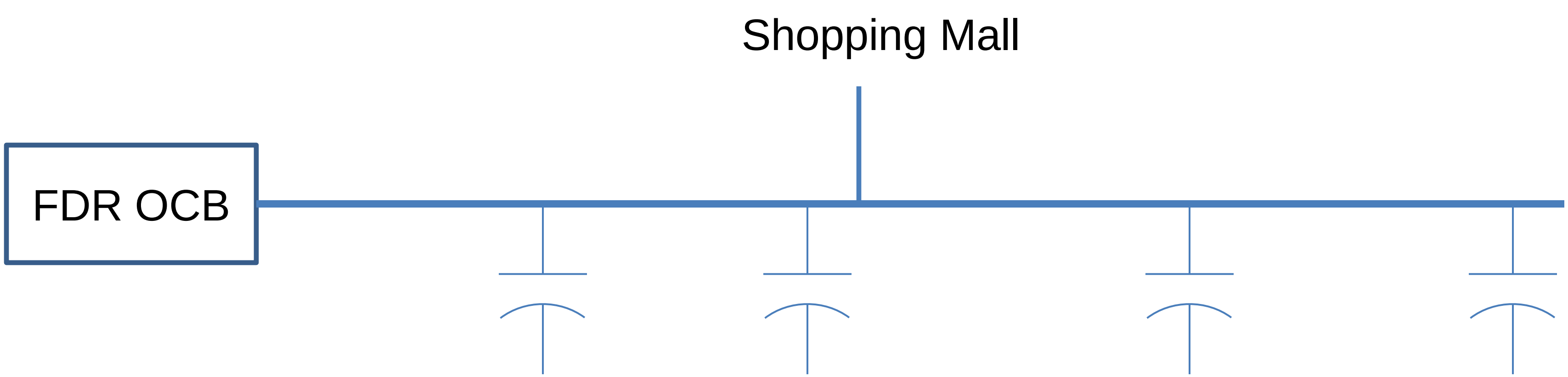
Early Volt/VAR Management

- Transmission Planning to maintain voltage on transmission side of T/D substation between 90-105% of nominal during normal and contingency conditions with fluctuations during contingency to no more than 8% from pre-contingency voltage level
- VARs are needed on the distribution system to support end-of-line voltage and meet distribution VAR requirements during peak load periods
- Planning guidelines called for capacitors to be installed on the distribution system to maintain 95% PF on feeders
- During light load periods, distribution line capacitors and substation capacitors will be controlled such that the power factor on the high side of the T/D substation bus will not go leading except during emergency conditions

Distribution Feeder Control Application

- Static (no control) – provide best loss savings at minimum load. Also installed on taps serving large industrial or commercial load if customer runs three shifts.
- Volt/Time/Temp (VTT) – Apply near the end of the line for the 1st bank to be switched. Time setting best applied for daily load patterns and temp settings for seasonal load patterns.
- Current – Apply on the tap serving large industrial/commercial load or instead of a VAR control for the bank nearest the sub
- VAR – Apply on the bank nearest the substation
- Power Factor – Reserved for special applications requiring sequencing of multiple banks at a single location

Typical Distribution Application



Bank Size	600/1200 kVAR	600/1200 kVAR	600/1200 kVAR	600/1200 kVAR
Typical Control	VAR/Current	VTT (Time)	Static	VTT (Temp)
Load Type	Peak	Daily	Minimum	Seasonal

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T/D Substation Control Application

- Size capacitor bank to maximize investment
  - 2700 kVAR initial size for 12.5 MVA bank
  - 5400 kVAR initial size for 25 MVA bank
  - 7200 kVAR maximum size for contingency voltage support
- Utilize zero-closing breaker where possible to limit power quality problems to large industrial or commercial customers utilizing sophisticated solid-state controls
- Apply VAR controls with voltage override capability in all substations to protect distribution system against high or low voltage extremes

Volt/VAR Management With Distribution Automation

- Progress Energy implemented the Energy Delivery Strategic Initiative (EDSI) during the 1996-1999 time period
  - Installed RTU in all 380 T/D subs
  - Now monitoring voltage, current, KW, KVAR, PF, and harmonics on all 1190 distribution feeders
  - Captured voltage, current, and fault events on all substation bus and distribution feeders using a Feeder Monitoring Systems (FMS)
  - Ability to see cap bank switching by monitoring VAR flow
- Substation capacitor controlled by program resident inside of RTU
- Capacitor application now revised to provide a 99% PF on the high side of the T/D transformer bank

Volt/VAR Management With Distribution Automation

- Radio Controlled Capacitor System (RCCS) installed to utilize a central computer providing automated control of distribution feeder capacitor banks
  - RCCS utilized a one-way paging system to control cap banks
  - Switching order determined by Planning Engineer
  - Utilized the monitoring capability of FMS to determine if feeder cap bank switched when called upon by RCCS
  - Trouble tickets associated with switching failures identified by FMS would be electronically generated and sent to repair crews
- Analysis of power factor before and after implementation of EDSI Project revealed a reduction in distribution losses of 2.8%

Volt/VAR Management With Distribution Automation

- Prior to EDSI
  - PF determined by installing temporary metering
  - Distribution line capacitors controlled via time clocks with voltage override, current, straight voltage and some VAR
  - Cap bank operation checked manually to determine if they were operating properly
  - Maintenance of cap banks was performed three times a year to check switch operation and identify blown fuses

Volt/VAR Management With Distribution Automation

- After EDSI Project
  - RTU installed in all substations to monitor voltage, current, KW, KVAR, PF, and harmonics
  - Through implementation of the Radio Controlled Capacitor System (RCCS) able to control line cap banks to maintain 99% PF on high side of T/D transformer
  - Using RCCS and FMS, cap bank operation can be checked remotely and repair tickets issued electronically
  - Eliminated need to visit and maintenance cap banks three times per year
  - Failed cap banks are expected to be back in service within 2-3 weeks of notification of failure vs. the possible 12 weeks lag prior to EDSI

Volt/VAR Management With Smart Grid

- Implemented Distribution System Demand Response (DSDR) Program in 2007
  - Feeder Conditioning to achieve a 2 volt profile on all feeders
  - Upgraded DSCADA system to handle more control points
  - Developing a Distribution Management System to perform demand reduction at peak and maintain loss optimization the remainder of the time
  - Expanding Voltage Reduction Program to achieve consistent demand reduction over a sustained six hour peak period
- Installing a two-way communication system to all distribution controlled devices; regulators, capacitors, reclosers, and switches

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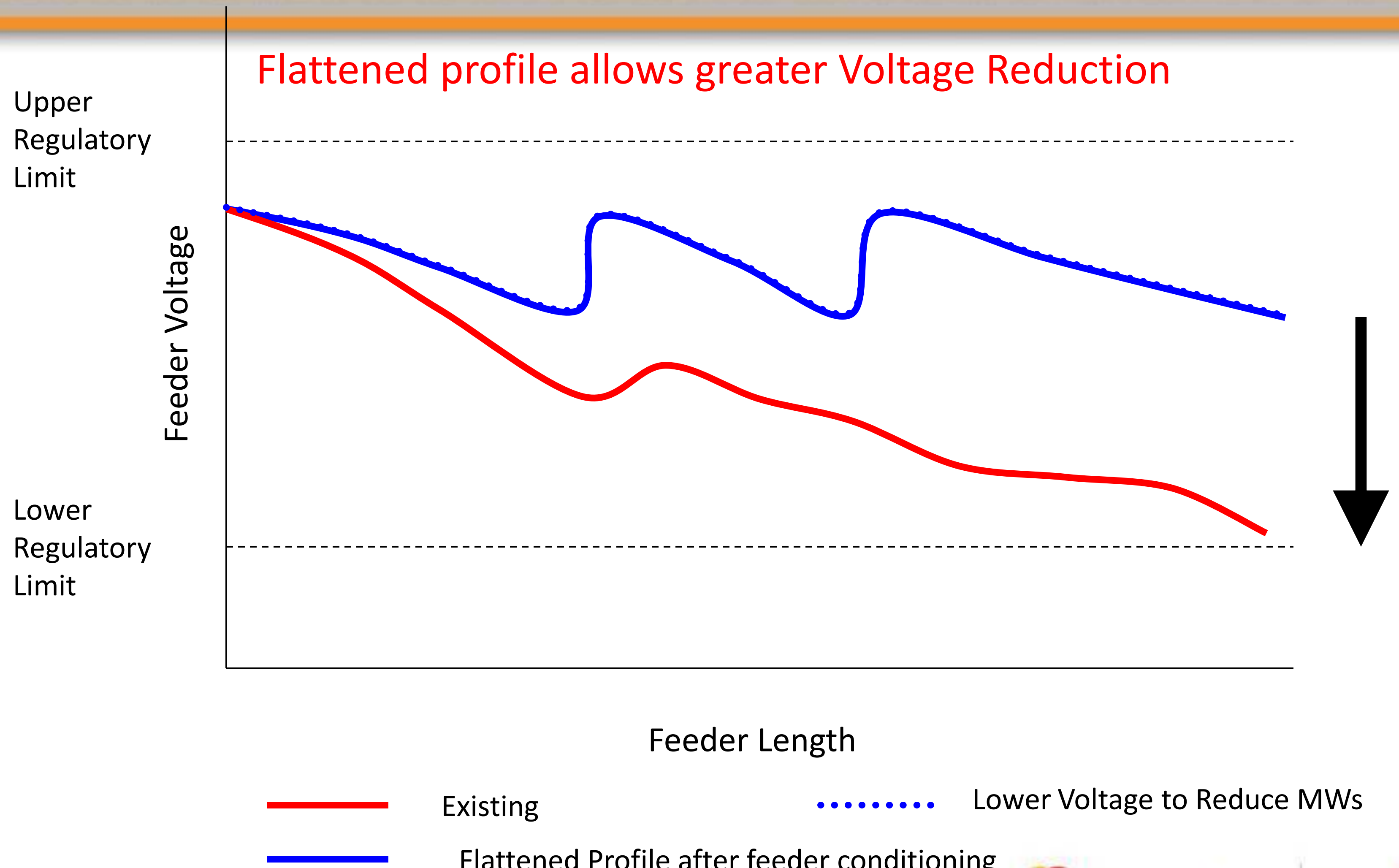
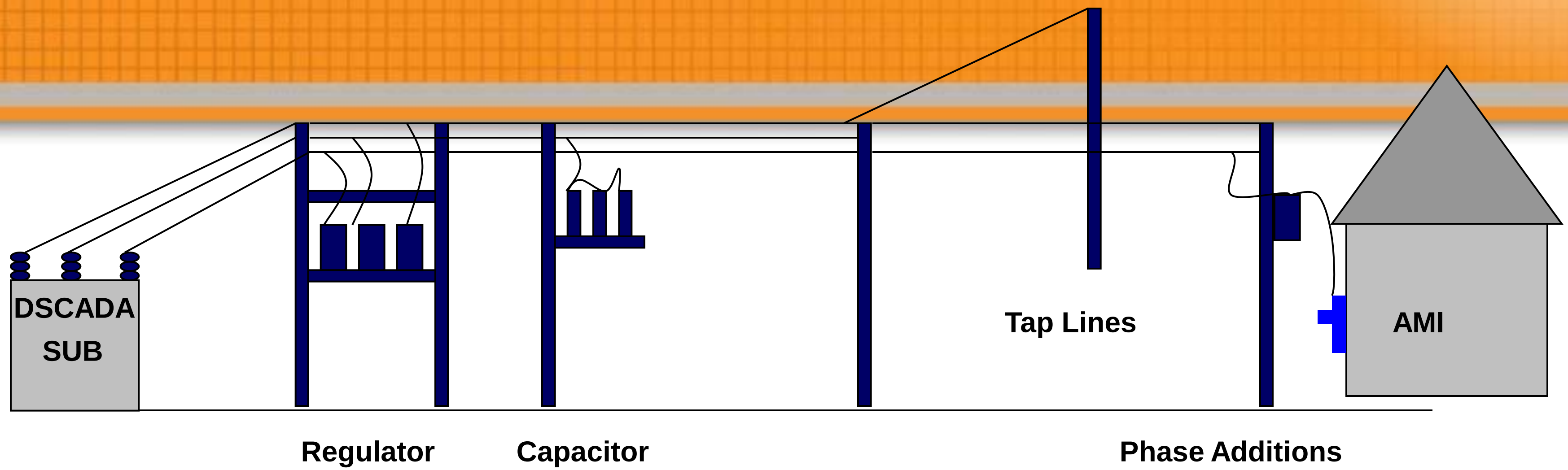
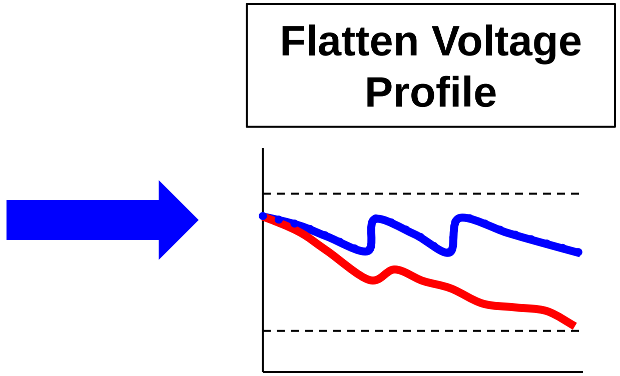
Changing Voltage Profile by Feeder Conditioning



Distribution Feeder Conditioning



- **Balance Load**
  - Re-tap ~5,000 transformers and line taps
- **Capacitors**
  - Add ~400 new line capacitors
  - ~2,500 existing today
- **Regulators**
  - Add ~2,000 line regulators
  - ~600 existing today
- **New Phase Additions**
  - Add ~300 miles of new phase wire



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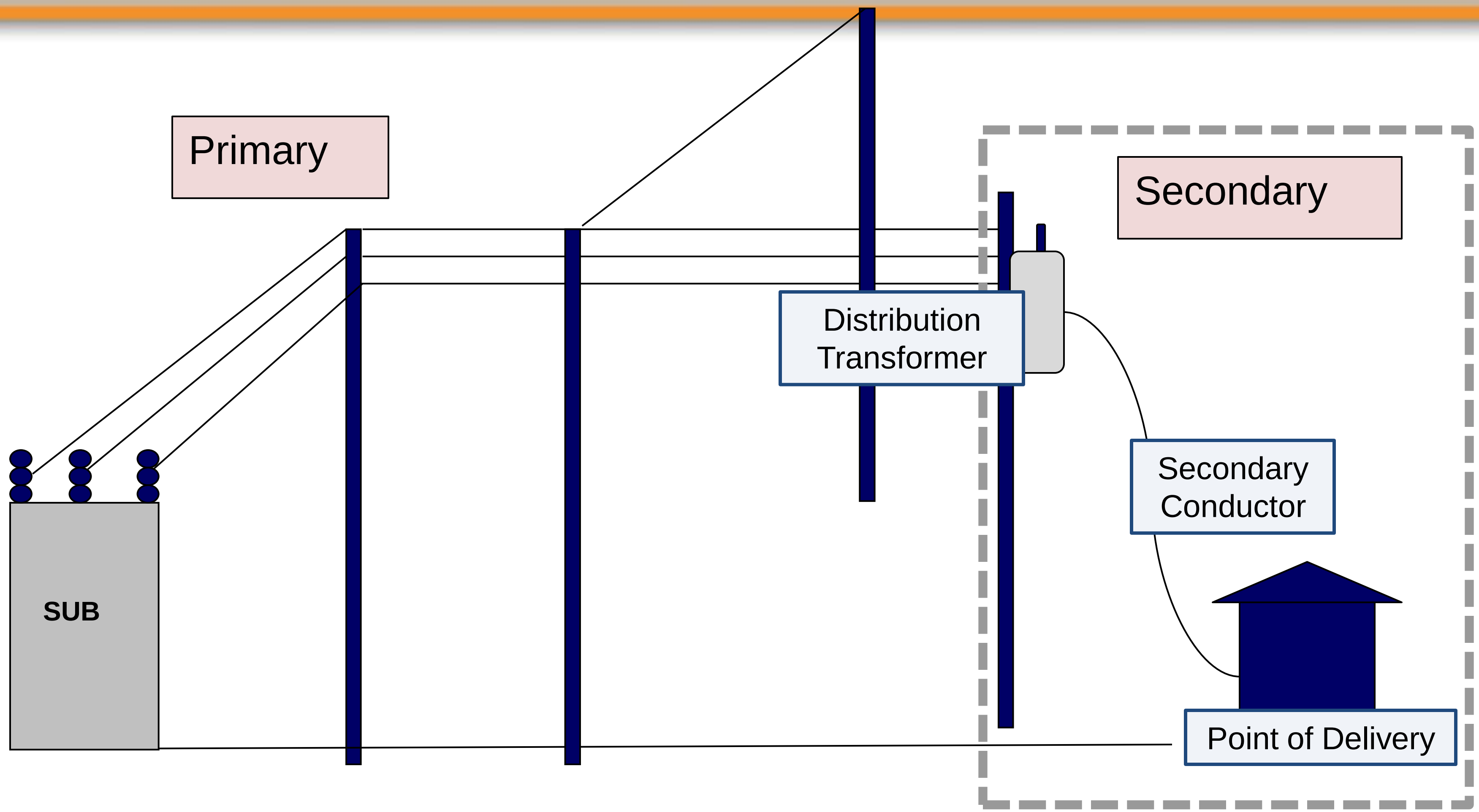
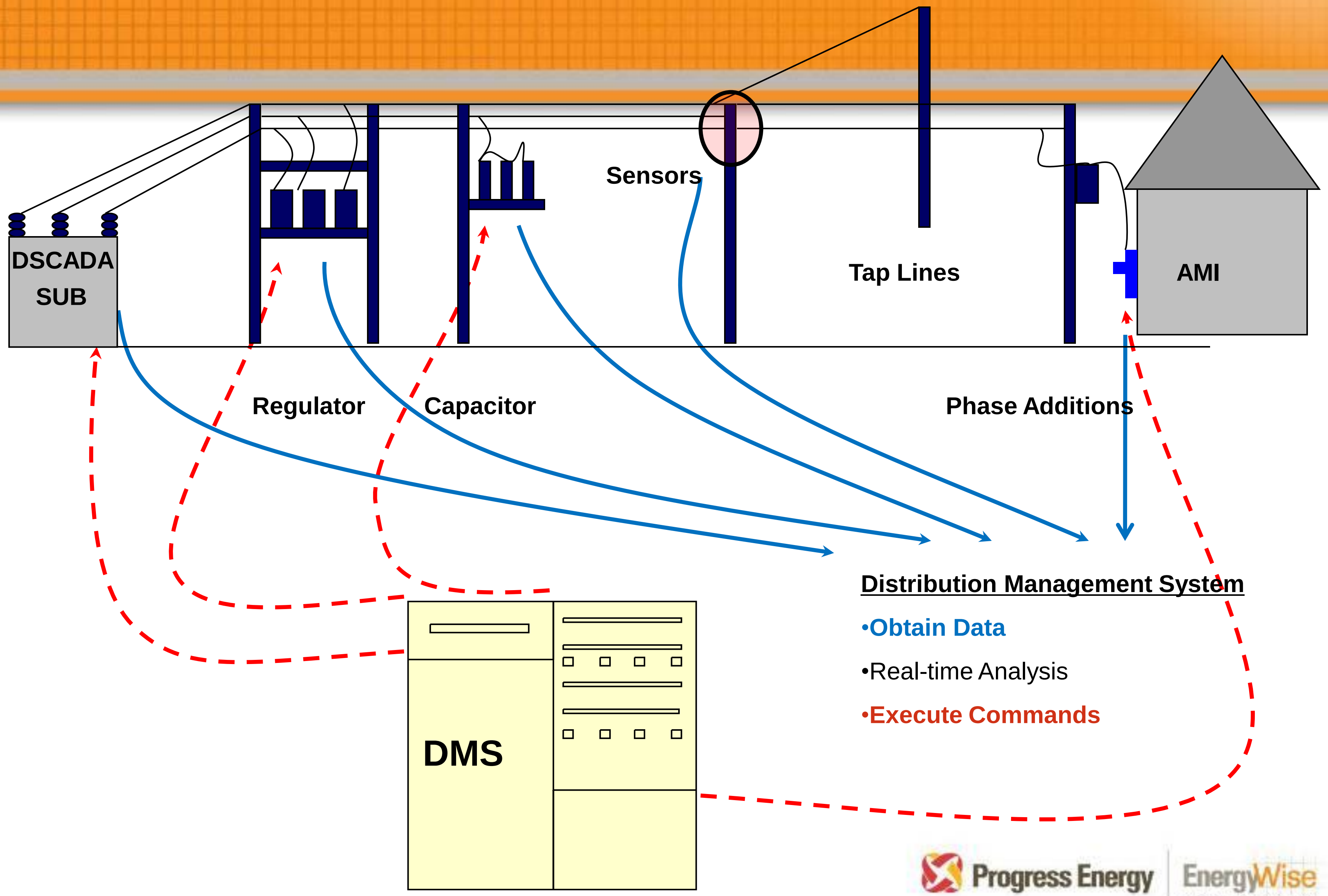
Secondary Optimization



Distribution Feeder Control



Distribution Management System

- **Obtain Data**
- Real-time Analysis
- **Execute Commands**

Controlled Feeder Equipment

Two-Way Communications

Feeder Voltage Regulator

Feeder Capacitor

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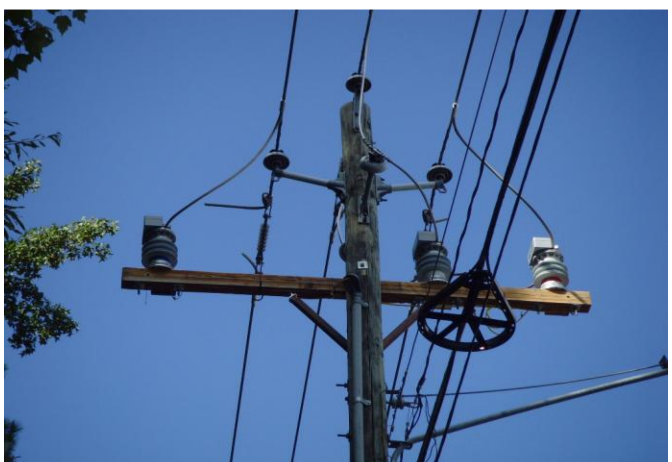
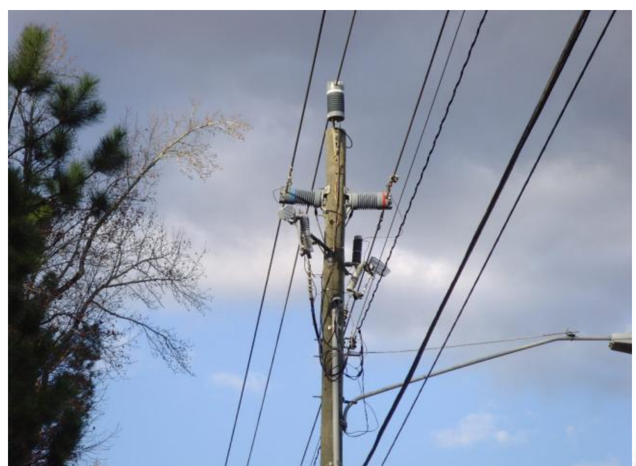
Medium Voltage Sensors

Line Voltage/Current Sensor





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Low Voltage Sensors

Voltage Sensor at Residence

AMI Metering
w/voltage sensing

Metering Socket
w/radio or modem

Metering Adapter

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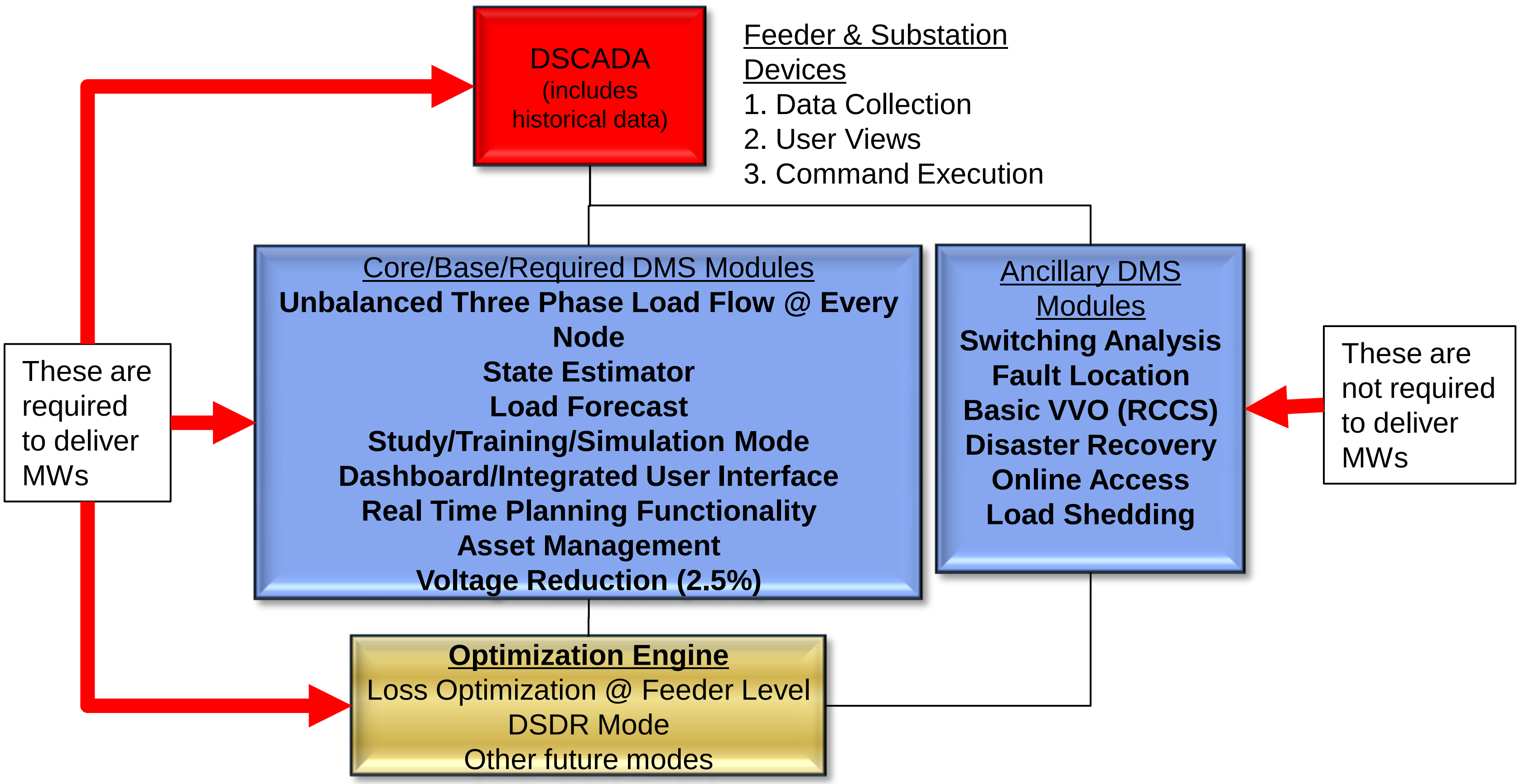
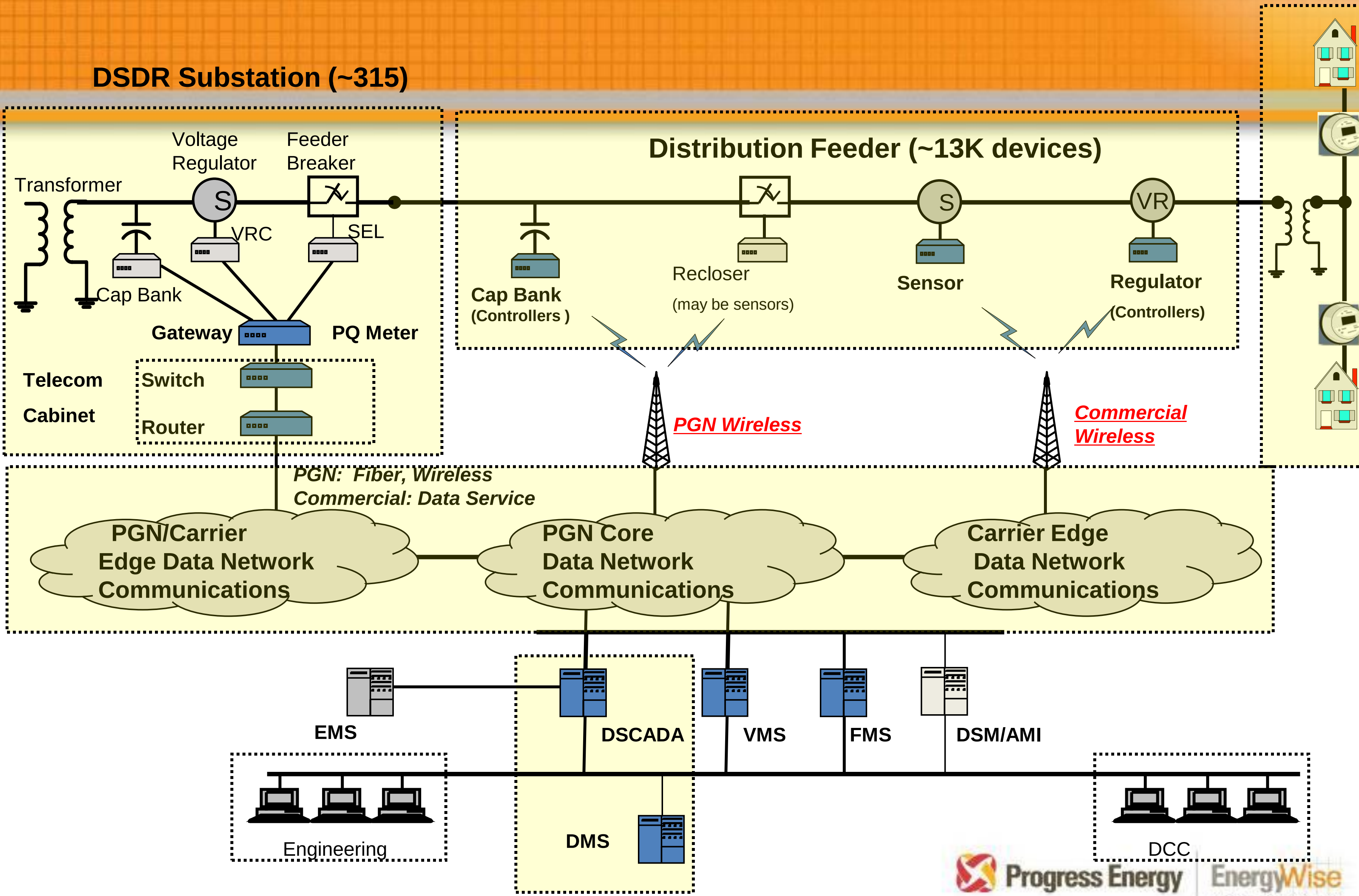
Functionality of the DMS



DSDR: An Integrated Grid; New Capability



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Future of Volt/VAR Management

- Penetration level of Distributed Generation (DG) before voltage stability is impacted
- Islanding and the impacts on customer voltage
- Impact on voltage as PV and wind generators fluctuate on and off line
- Impact of DG on transmission voltage and generator VAR requirements
- Smart Grid will result in more monitoring and control
- Communications infrastructure becomes even more critical

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Questions ?

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