Xcel Energy®

Deploying an Advanced Distribution Management System

Minnesota Power Systems Conference

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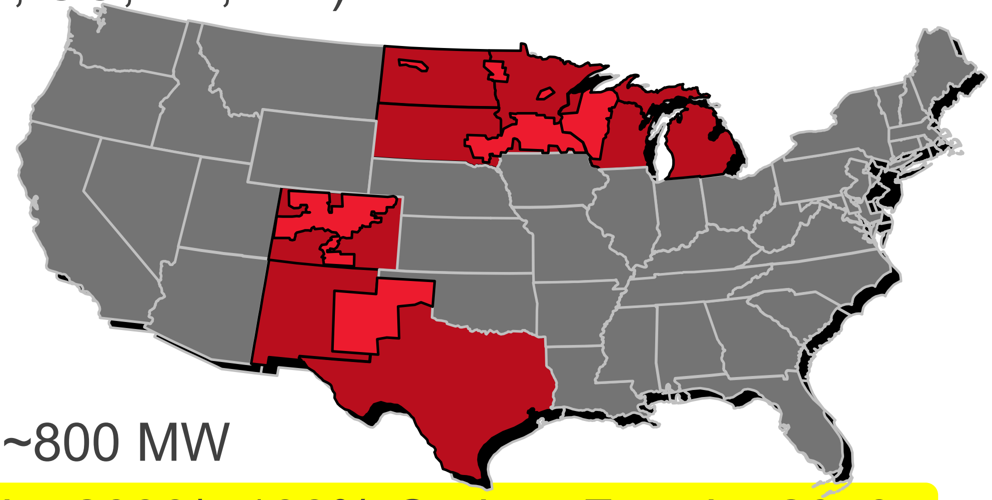
Today's Topics:

- **Xcel Energy Overview**
- **Advanced Distribution Management System (ADMS) Overview**
- **Network Model**
  - Static Data
  - Real-Time Data
- **Advanced Applications**
- **Overall ADMS**
- **Questions**

Company Profile – Xcel Energy

- Operating Companies: 3 (NSP, PSCO, SPS)
- States: 8 (MN, WI, ND, SD, MI, CO, TX, NM)
- Electric Customers: 3.7 M
- Transmission: 87,000 miles
- Distribution: 223,000 miles
- Service Area: ~110,000 mi^2
- Renewables: 25%
- Distribution Connected Solar: ~800 MW
- Carbon Goal: 80% Reduction by 2030*. 100% Carbon Free by 2050
- Natural Gas Customers: 1.8 M



* Based on 2005 emissions

Xcel Energy – Together – 2030 and 2050 Goals

Local

https://youtu.be/dx55TQ2LDaM

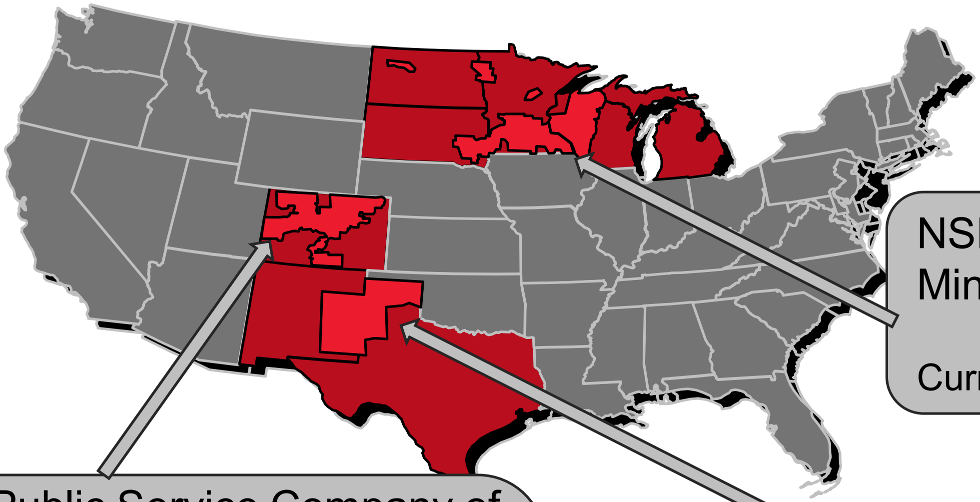
ADMS Overview

Xcel Energy ADMS/SCADA (Schneider Electric):

- **3 separate systems – one for each operating company.**
- **Virtualized hardware and converged infrastructure**
- **Primary and Backup system separation: 1000 miles**
- **Distribution Control Center Locations: 5**
- **Network Model - Feeders* / Substations*:**
    - NSP MN/WI: (1700) Feeders, (437) Substations
    - PSCO: (940) Feeders, (186) Substations
    - SPS: (660) Feeders, (281) Substations
- **SCADA Sizing:**
    - Points: 1,000,000 per Operating company
    - Remotes: 10,000 per Operating company

* Approximations

Current Implementation Status



NSP – Northern States Power, Minnesota and Wisconsin

Currently in Site Acceptance Testing

PSCO – Public Service Company of Colorado

Network Model
- 150+ Feeders
- 186 Substations

IVVO
- Live on two substations
- Voltage Reduction > 2%

Control Center go-live – December 2019

SPS – Southwest Public Service

Server hardware is in place

Network Model

Pre-Project Perception – Network Model

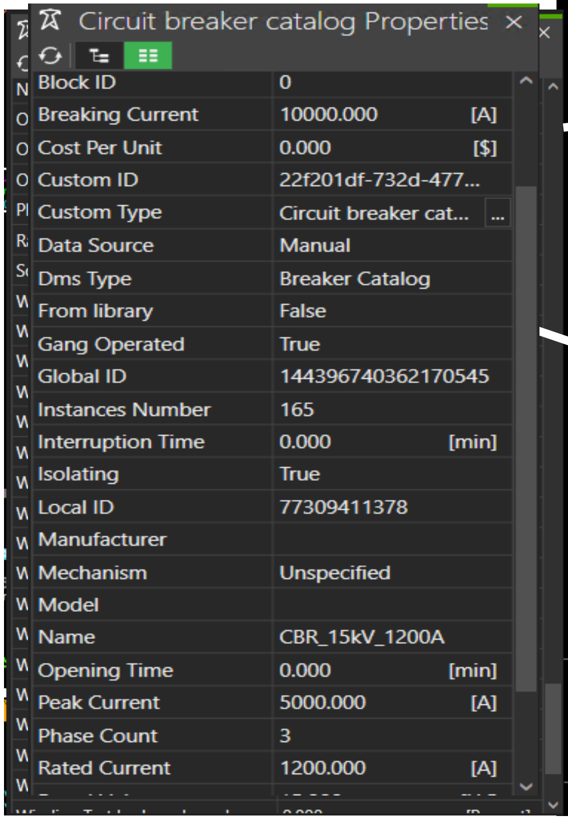
- The ADMS System is similar in size to our current EMS and OMS systems.

- ADMS is just an ‘Impedance Model’

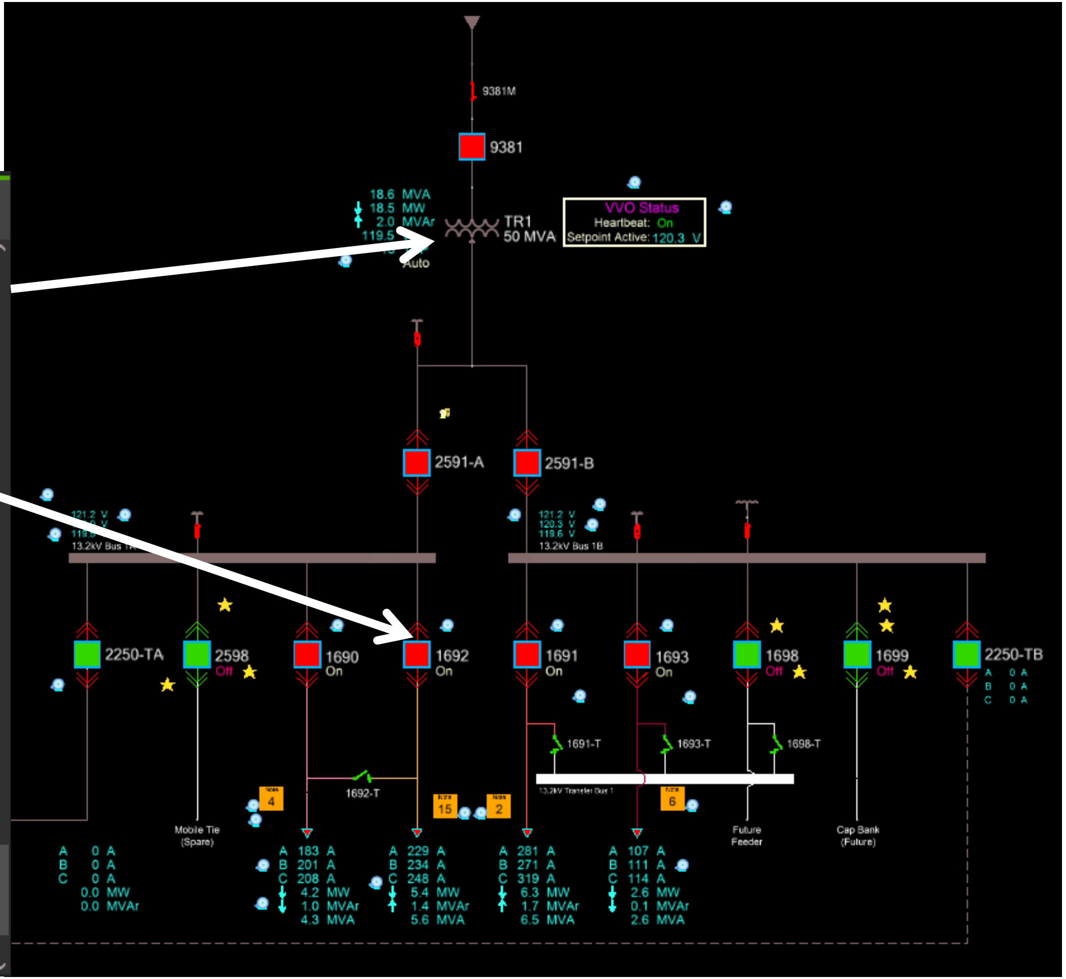
- The ADMS model is a simple replication of the GIS Model.

- The ADMS substation model is a simple replication of the EMS Substation display.

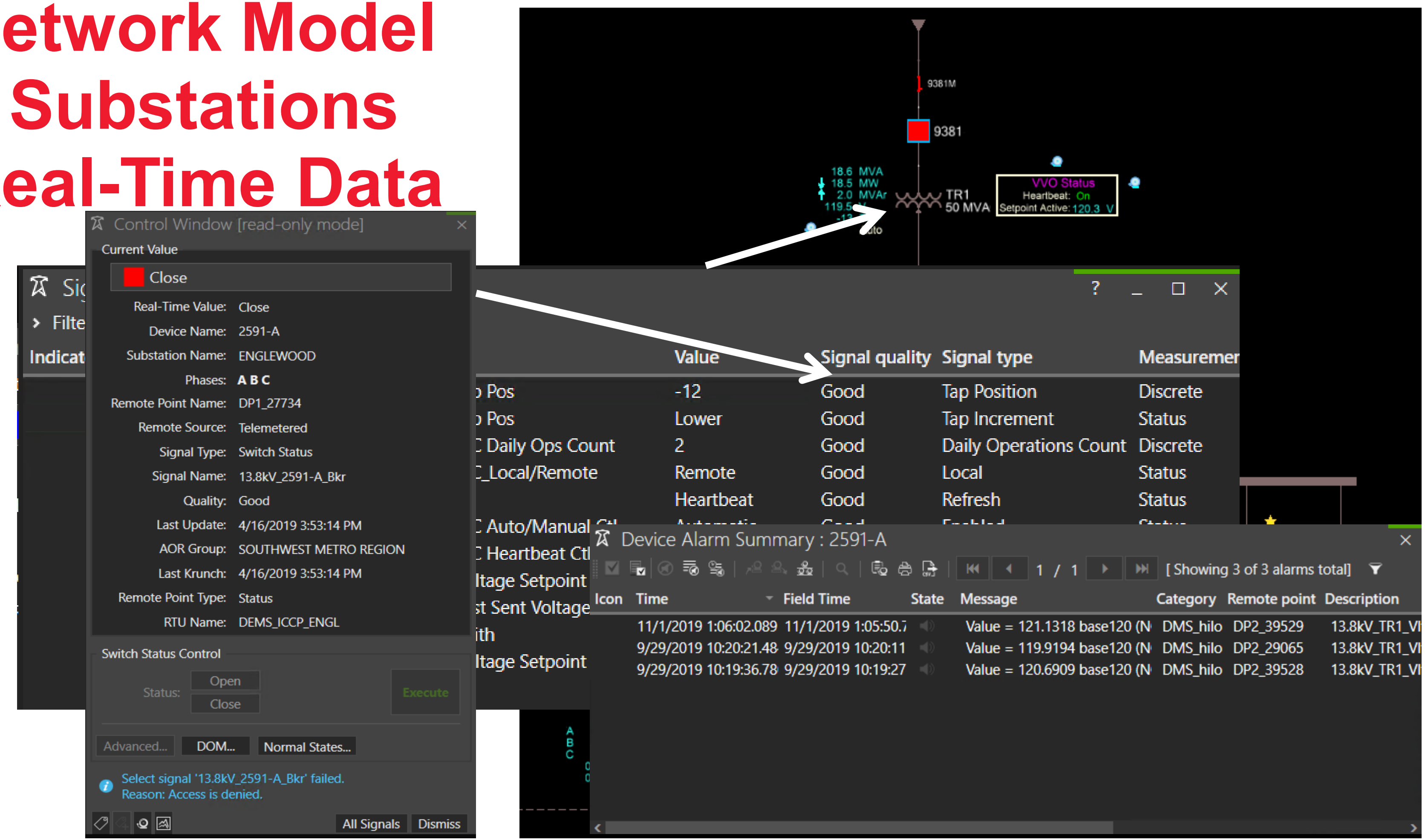
Network Model - Substations



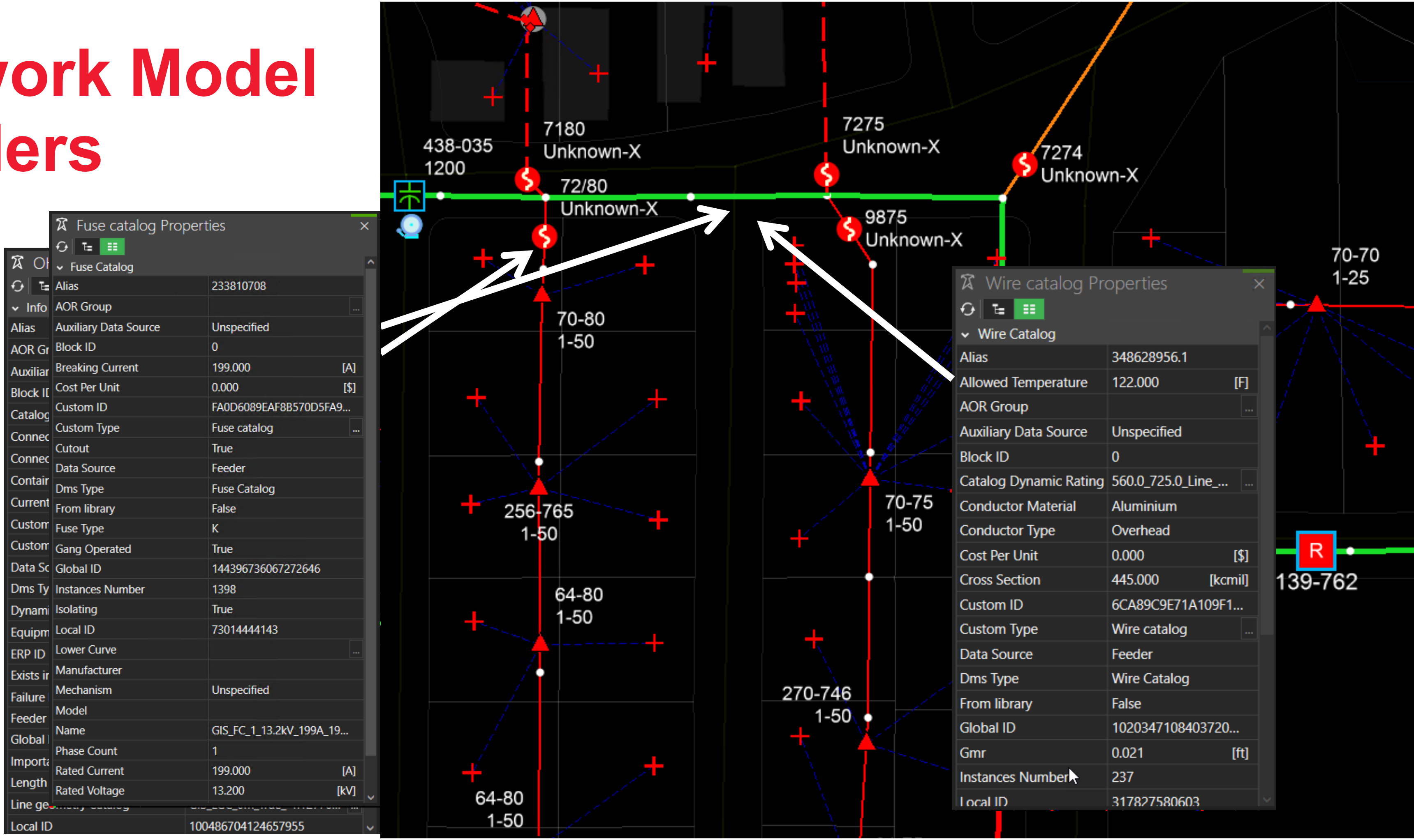
Circuit breaker catalog Properties	
Block ID	0
Breaking Current	10000.000 [A]
Cost Per Unit	0.000 [$]
Custom ID	22f201df-732d-477...
Custom Type	Circuit breaker cat...
Data Source	Manual
Dms Type	Breaker Catalog
From library	False
Gang Operated	True
Global ID	144396740362170545
Instances Number	165
Interruption Time	0.000 [min]
Isolating	True
Local ID	77309411378
Manufacturer	
Mechanism	Unspecified
Model	
Name	CBR_15kV_1200A
Opening Time	0.000 [min]
Peak Current	5000.000 [A]
Phase Count	3
Rated Current	1200.000 [A]



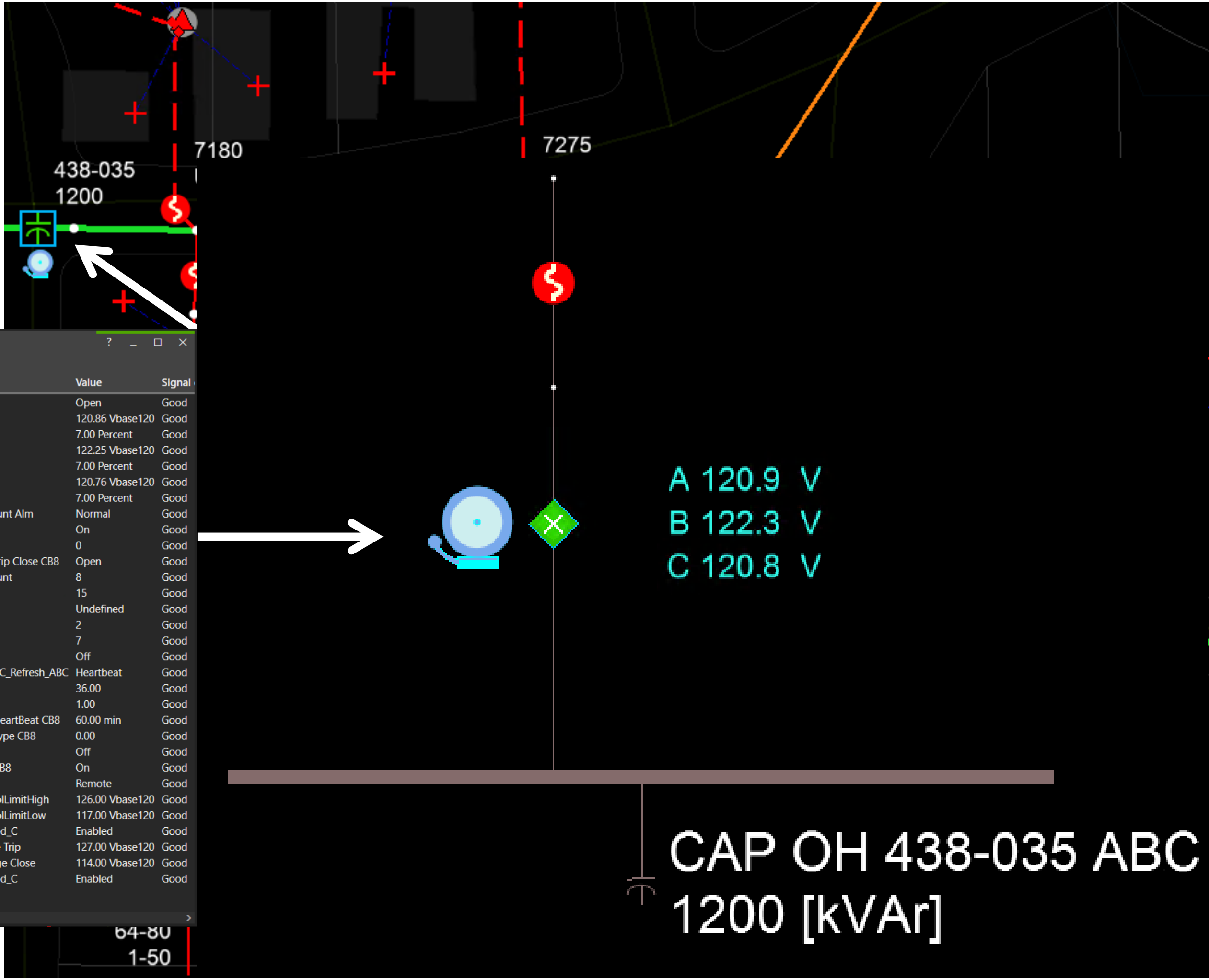
Network Model – Substations Real-Time Data



Network Model Feeders



Network Model
Feeders
Real-Time Data



Signals

› Filter

Indicators	No.	Remote point name	Signal name	Value	Signal
	1.	GP499598539D_BankState	Bank State CB8	Open	Good
	2.	GP499598539D_VltA	VltA	120.86 Vbase120	Good
	3.	GP499598539D_VltA_THD	VltA_THD	7.00 Percent	Good
	4.	GP499598539D_VltB	VltB	122.25 Vbase120	Good
	5.	GP499598539D_VltB_THD	VltB_THD	7.00 Percent	Good
	6.	GP499598539D_VltC	VltC	120.76 Vbase120	Good
	7.	GP499598539D_VltC_THD	VltC_THD	7.00 Percent	Good
	8.	GP499598539D_MaxDailyOpsAlm	Max Daily Ops Count Alm	Normal	Good
	9.	GP499598539D_RemoteMode	Remote Mode	On	Good
	10.	GP499598539D_DailyOpsCount	Daily Ops Count	0	Good
	11.	GP499598539D_OvrdTripClose	SCADA Override Trip Close CB8	Open	Good
	12.	GP499598539D_DailyAutoCtlLimit	Daily Max Ops Count	8	Good
	13.	GP499598539D_TotalOpsCount	Total Ops Count	15	Good
	14.	GP499598539D_OVOpsCount	OV Ops Count	Undefined	Good
	15.	GP499598539D_UVOpsCount	UV Ops Count	2	Good
	16.	GP499598539D_CloseOpsCount	Close Ops Count	7	Good
	17.	GP499598539D_ManualMode	Manual Mode	Off	Good
	18.		499598539_ABC_RC_Refresh_ABC	Heartbeat	Good
	19.	GP499598539D_FirmwareMajor	Firmware Major	36.00	Good
	20.	GP499598539D_FirmwareMinor	Firmware Minor	1.00	Good
	21.	GP499598539D_SCADAOvrdHB	SCADA Override HeartBeat CB8	60.00 min	Good
	22.	GP499598539D_SCADAOvrdType	SCADA Override Type CB8	0.00	Good
	23.	GP499598539D_AutoMode	Auto Mode	Off	Good
	24.	GP499598539D_SCADAOvrd	SCADA Override CB8	On	Good
	25.	GP499598539D_SetRemoteMode	Set Remote Mode	Remote	Good
	26.		612061255_ControlLimitHigh	126.00 Vbase120	Good
	27.		612061255_ControlLimitLow	117.00 Vbase120	Good
	28.		612061255_Enabled_C	Enabled	Good
	29.	GP612061256D_EmerOVTrip	Emer Over Voltage Trip	127.00 Vbase120	Good
	30.	GP612061256D_EmerUVClose	Emer Under Voltage Close	114.00 Vbase120	Good
	31.		612061256_Enabled_C	Enabled	Good

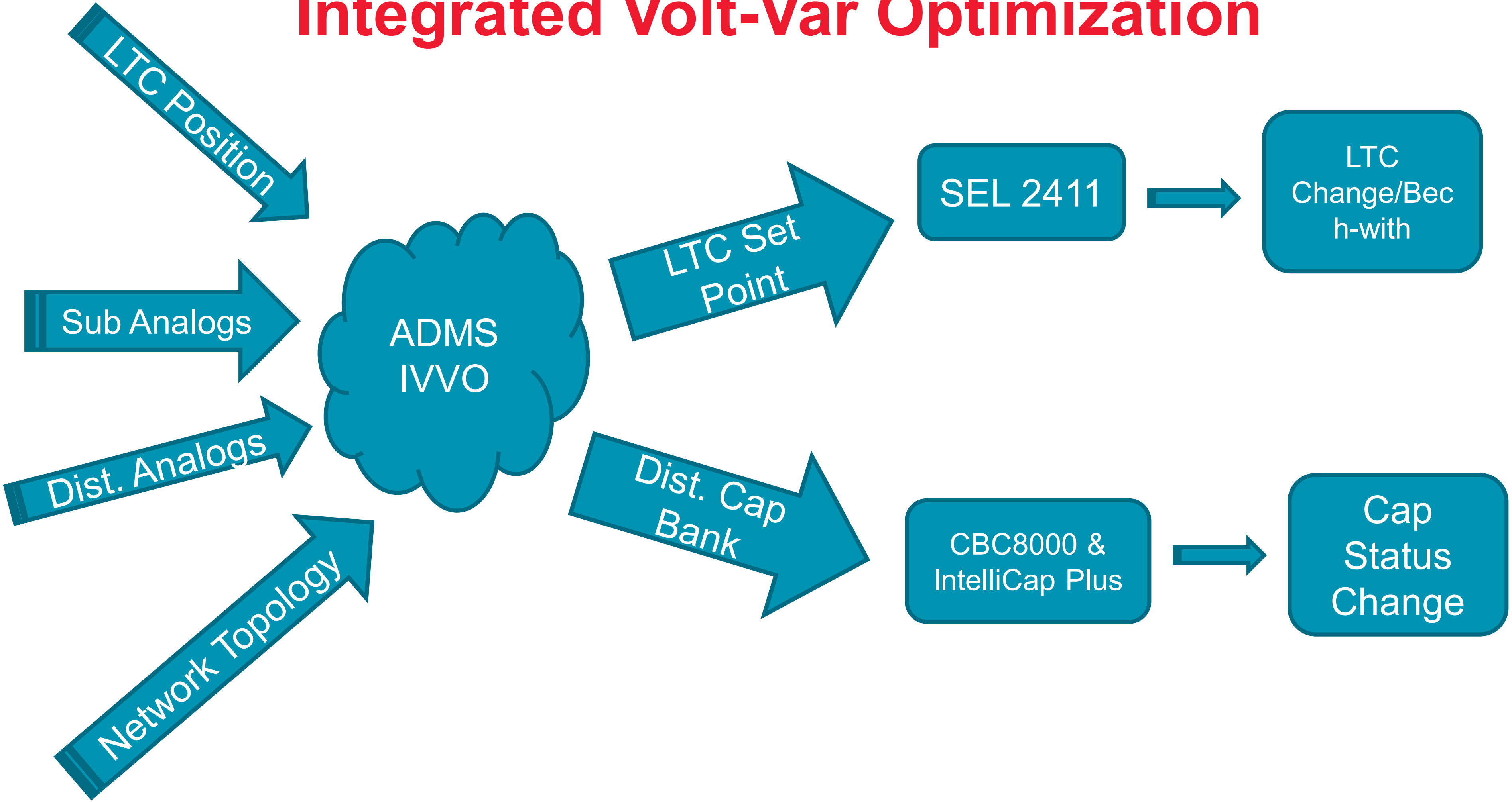
Lesson Learned - Network Model includes static and dynamic data

- As-Operated Impedance model of Distribution Grid
  - Substations
  - Feeders
- Automated Devices
- SCADA – Substations, Automated Devices, Data Concentrators
- Customer Data/Loads
- Distributed Energy Resources
- Protection data

Advanced Applications

Integrated Volt-Var Optimization (IVVO)

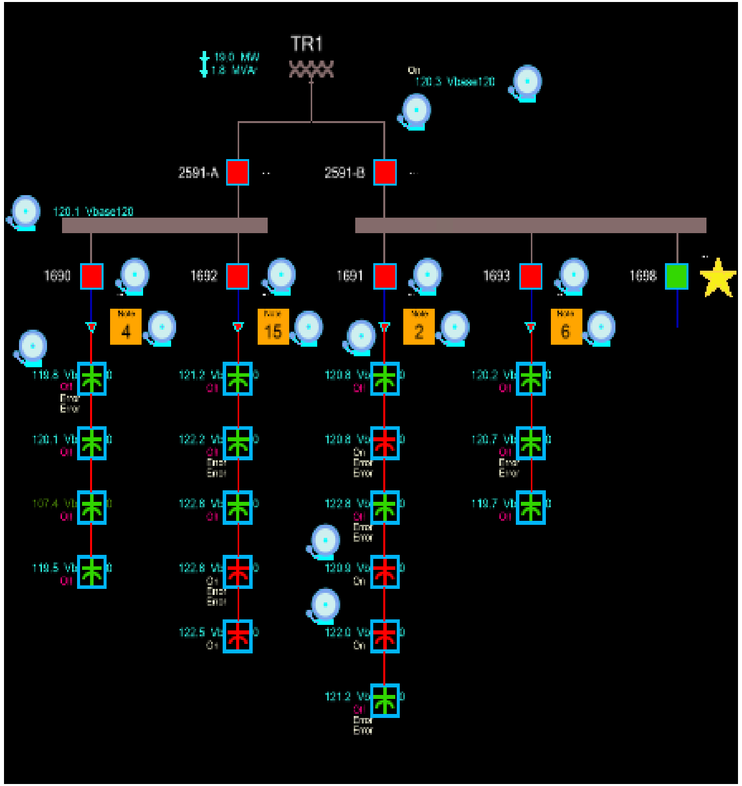
Integrated Volt-Var Optimization

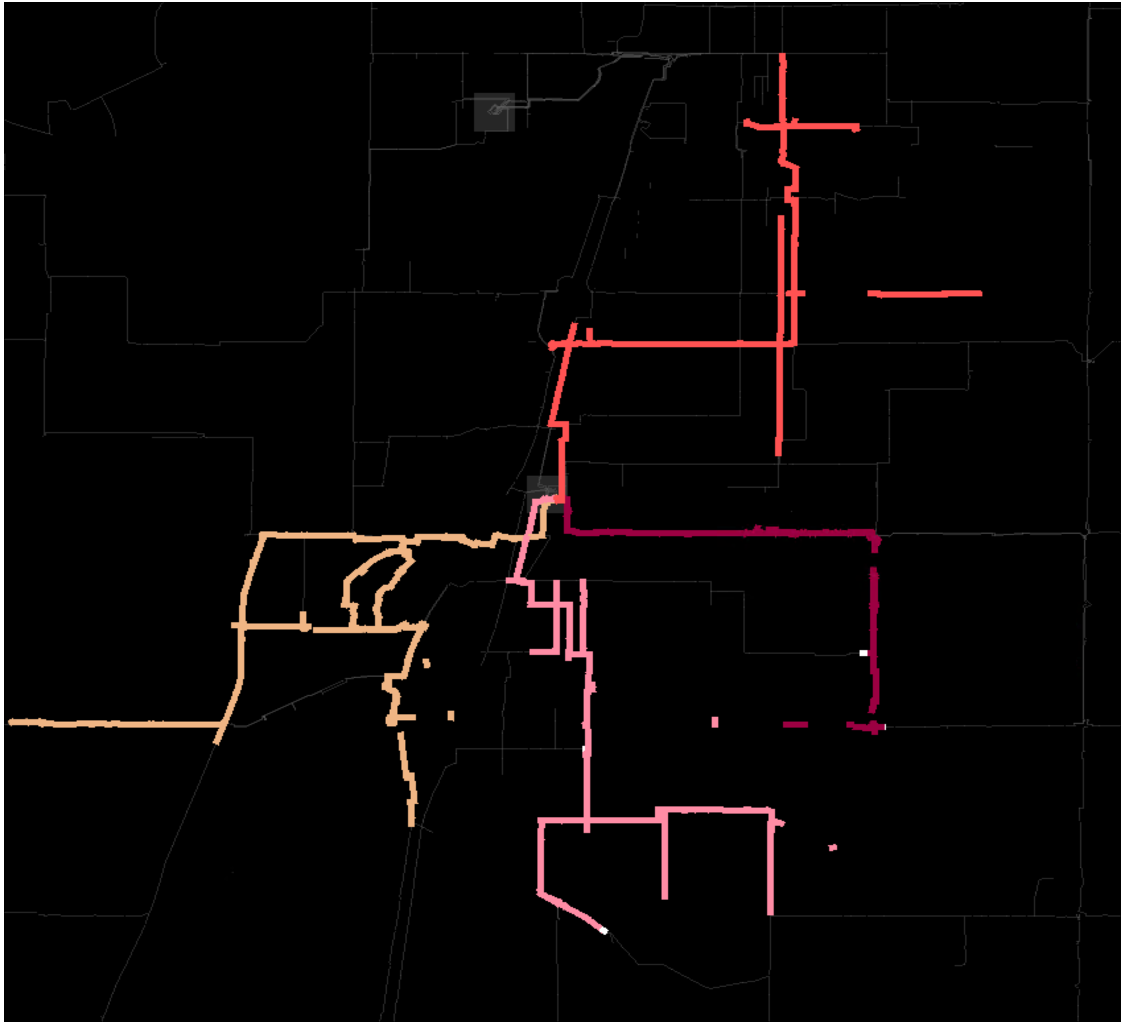


Pre-Project Perception #2 - IVVO

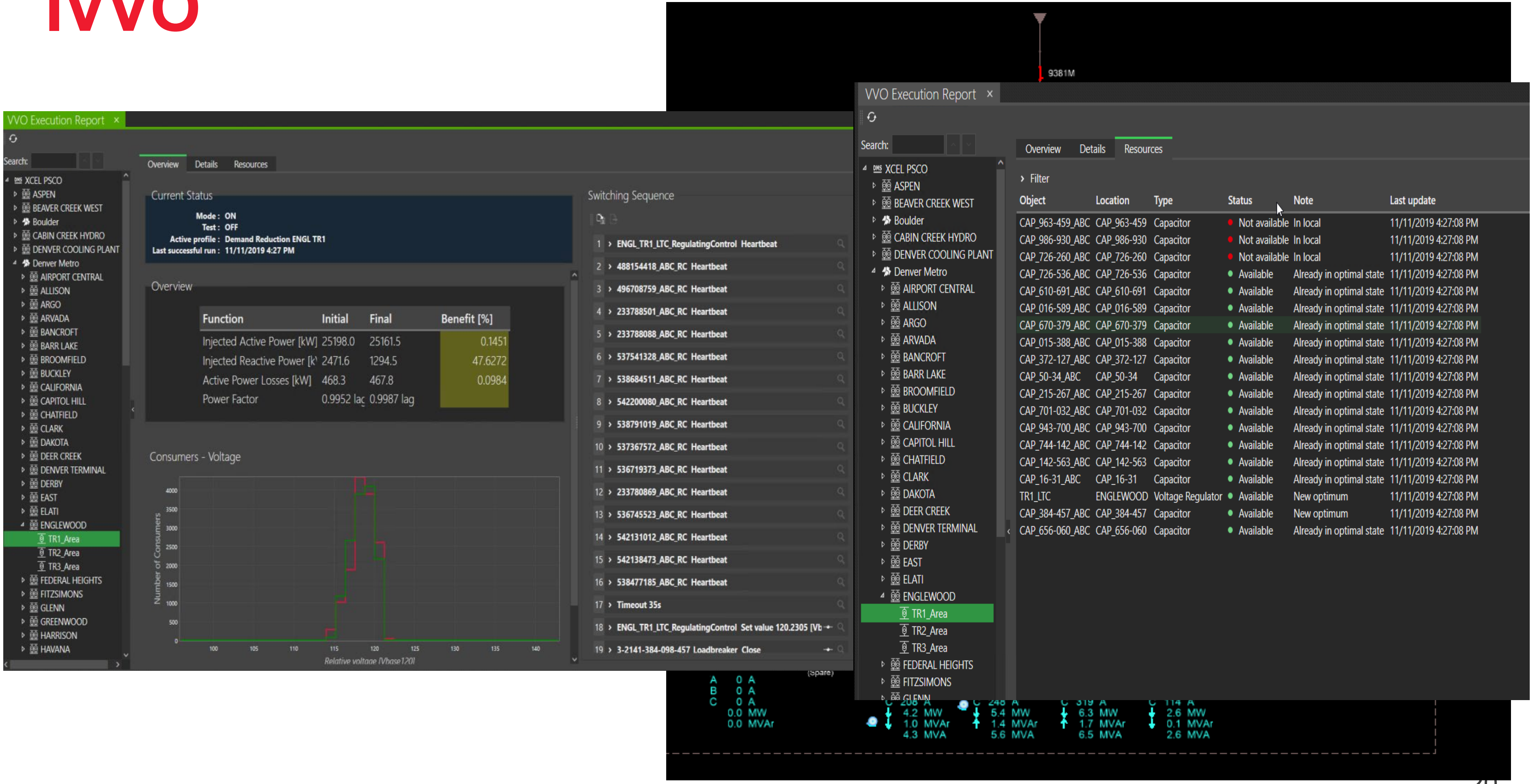
- Model based IVVO can be run on a multitude of LTC Controller types
- Single phase sensing on Distribution feeder sensor and capacitor banks was adequate
- Dropping voltage to 117v at the sub has only voltage profile limitations.
- IVVO profile Constraints??

IVVO



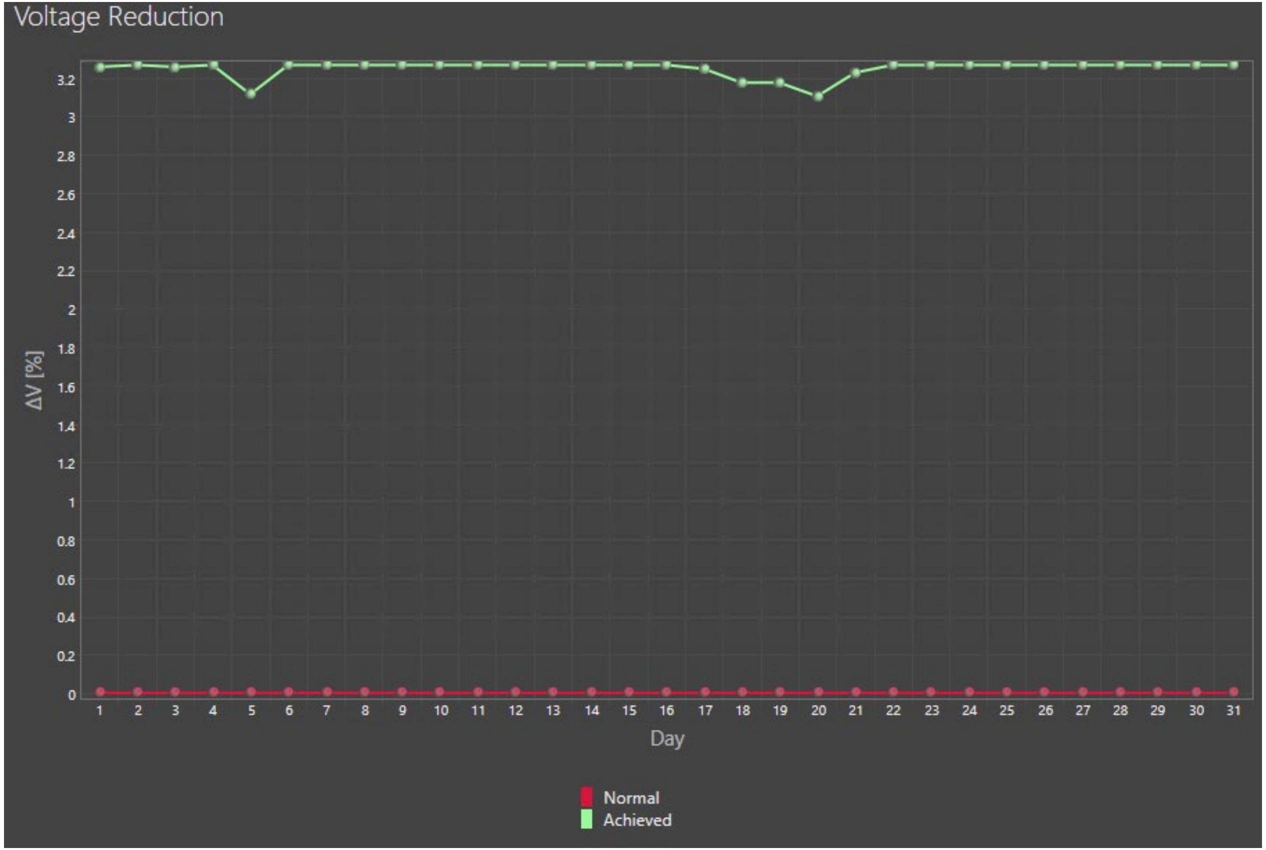


IVVO

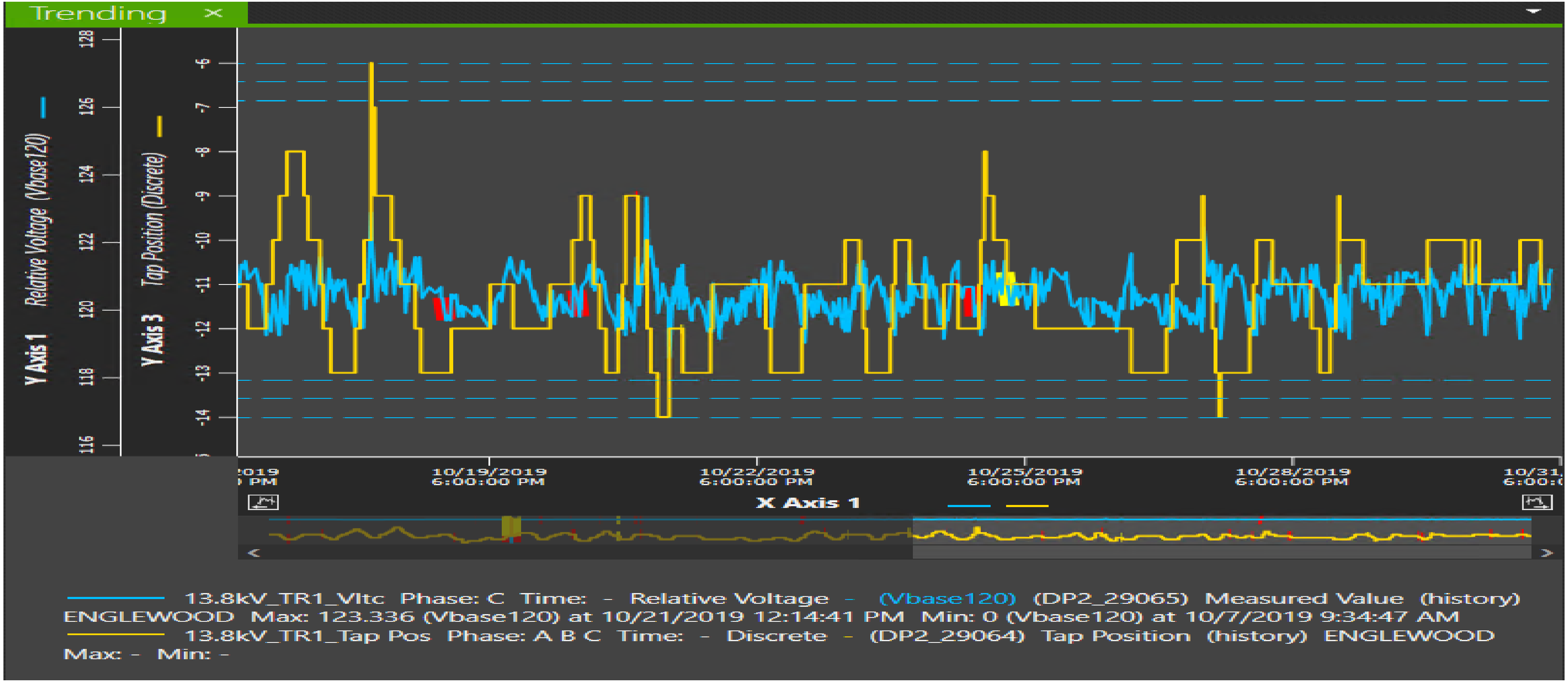


VVO Execution Report
Search:
XCEL PSCO
ASPEN
BEAVER CREEK WEST
Boulder
CABIN CREEK HYDRO
DENVER COOLING PLANT
Denver Metro
AIRPORT CENTRAL
ALLISON
ARGO
ARVADA
BANCROFT
BARR LAKE
BROOMFIELD
BUCKLEY
CALIFORNIA
CAPITOL HILL
CHATFIELD
CLARK
DAKOTA
DEER CREEK
DENVER TERMINAL
DERBY
EAST
ELATI
ENGLEWOOD
TR1_Area
TR2_Area
TR3_Area
FEDERAL HEIGHTS
FITZSIMONS
GLENN
GREENWOOD
HARRISON
HAVANA
Overview
Details
Resources
Current Status
Mode : ON
Test : OFF
Active profile : Demand Reduction ENGL TR1
Last successful run : 11/11/2019 4:27 PM
Overview
Function
Initial
Final
Benefit [%]
Injected Active Power [kW] 25198.0 25161.5 0.1451
Injected Reactive Power [k' 2471.6 1294.5 47.6272
Active Power Losses [kW] 468.3 467.8 0.0984
Power Factor 0.9952 lag 0.9987 lag
Consumers - Voltage
Number of Consumers
Relative voltage [Vphase120]
Switching Sequence
1 ENGL_TR1_LTC_RegulatingControl Heartbeat
2 488154418_ABC_RC Heartbeat
3 496708759_ABC_RC Heartbeat
4 233788501_ABC_RC Heartbeat
5 233788088_ABC_RC Heartbeat
6 537541328_ABC_RC Heartbeat
7 538684511_ABC_RC Heartbeat
8 542200080_ABC_RC Heartbeat
9 538791019_ABC_RC Heartbeat
10 537367572_ABC_RC Heartbeat
11 536719373_ABC_RC Heartbeat
12 233780869_ABC_RC Heartbeat
13 536745523_ABC_RC Heartbeat
14 542131012_ABC_RC Heartbeat
15 542138473_ABC_RC Heartbeat
16 538477185_ABC_RC Heartbeat
17 Timeout 35s
18 ENGL_TR1_LTC_RegulatingControl Set value 120.2305 [Vb
19 3-2141-384-098-457 Loadbreaker Close
VVO Execution Report
Filter
Object Location Type Status Note Last update
CAP_963-459_ABC CAP_963-459 Capacitor Not available In local 11/11/2019 4:27:08 PM
CAP_986-930_ABC CAP_986-930 Capacitor Not available In local 11/11/2019 4:27:08 PM
CAP_726-260_ABC CAP_726-260 Capacitor Not available In local 11/11/2019 4:27:08 PM
CAP_726-536_ABC CAP_726-536 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_610-691_ABC CAP_610-691 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_016-589_ABC CAP_016-589 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_670-379_ABC CAP_670-379 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_015-388_ABC CAP_015-388 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_372-127_ABC CAP_372-127 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_50-34_ABC CAP_50-34 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_215-267_ABC CAP_215-267 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_701-032_ABC CAP_701-032 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_943-700_ABC CAP_943-700 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_744-142_ABC CAP_744-142 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_142-563_ABC CAP_142-563 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
CAP_16-31_ABC CAP_16-31 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
TR1_LTC ENGLEWOOD Voltage Regulator Available New optimum 11/11/2019 4:27:08 PM
CAP_384-457_ABC CAP_384-457 Capacitor Available New optimum 11/11/2019 4:27:08 PM
CAP_656-060_ABC CAP_656-060 Capacitor Available Already in optimal state 11/11/2019 4:27:08 PM
9381M

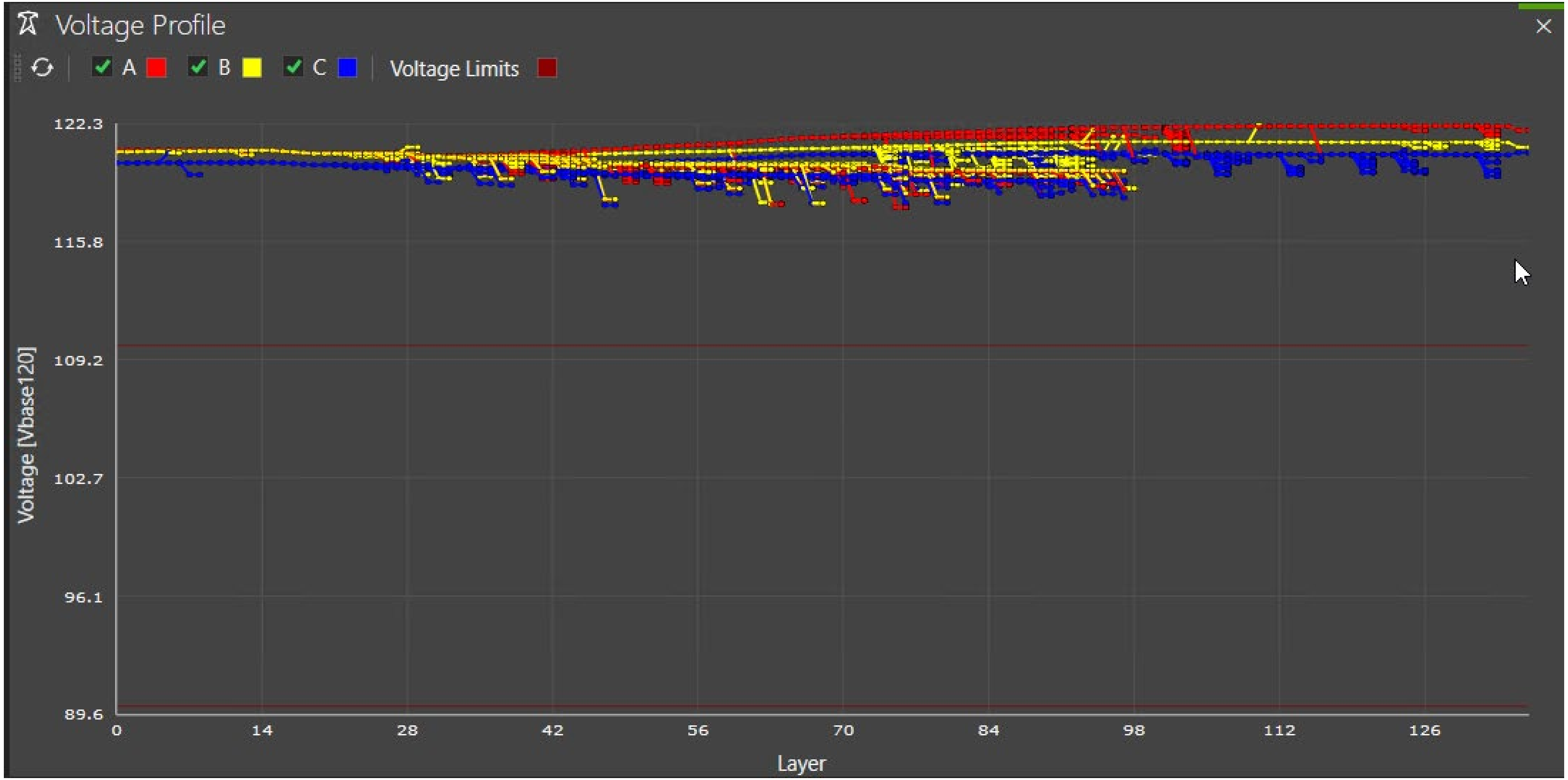
IVVO Benefits October, 2019



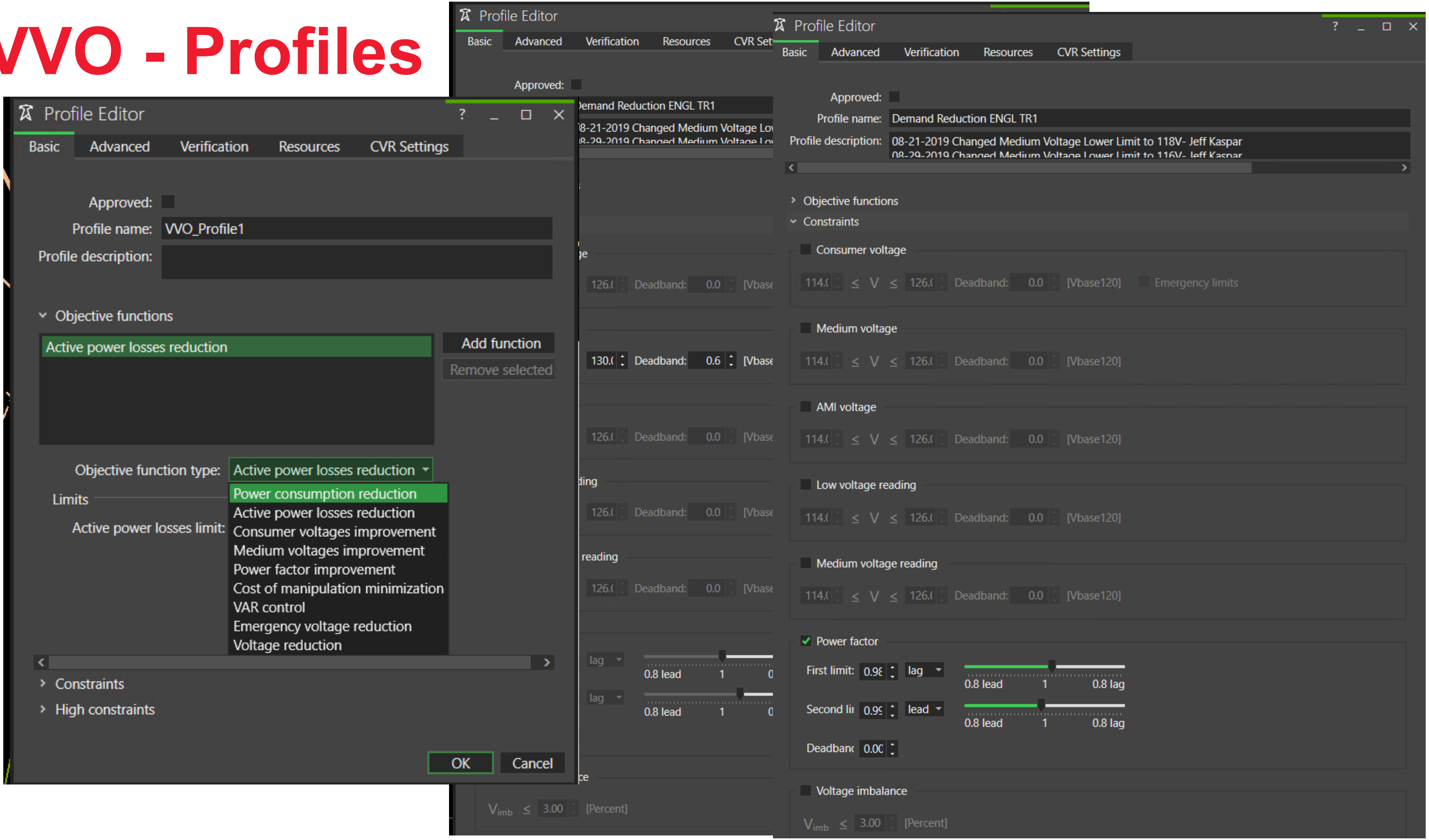
IVVO – LTC Voltage Setpoint and Tap Position



IVVO – Feeder Voltage Profile



IVVO - Profiles



Lessons Learned - IVVO

- LTC Controllers - ‘Heart-beat’ signal from ADMS.
- IVVO voltage reduction limited by voltage limits in LTC Controller.
- SCADA Voltage alarm limits adjusted.
- Single phase sensing inadequate – Need 3ph Watts, Vars, Volts for State Estimation and adequate LF results.
- Profile constraints adjusted for voltage ahead of power factor.

Fault Location, Isolation, and Supply Restoration (FLISR)

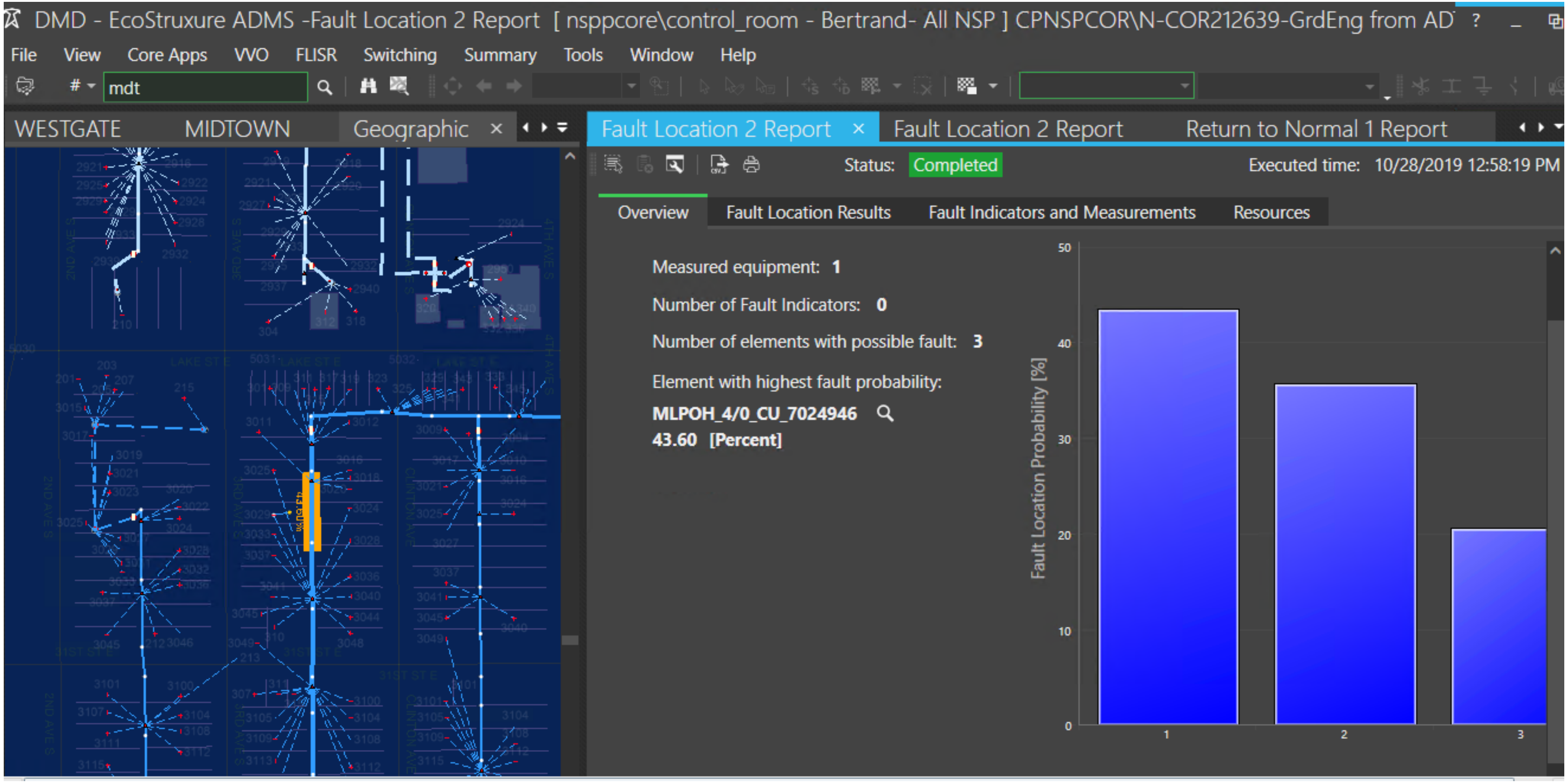
FLISR Components

- Relays with lock-out and fault current magnitude signals
- Impedance Model with Transmission source impedance and current transformer tap position for fault location accuracy
- Accurate, As-Operated grid topology
- Accurate Loadflow and SE results for switching validations
- Remote switchable feeder devices
- Communications
- RTU Templates – Network Model and Field Devices
- FLISR Profile Configuration

FLISR- Application deployment (In Process)

- Manual FLISR
- Fault Location – Enable Auto Fault Location
- Semi-Auto FLISR – Auto Fault Location with suggested steps for Element Isolation and Supply Restoration
- Auto FLISR – Full device restoration control by application

FLISR – Auto Fault Location

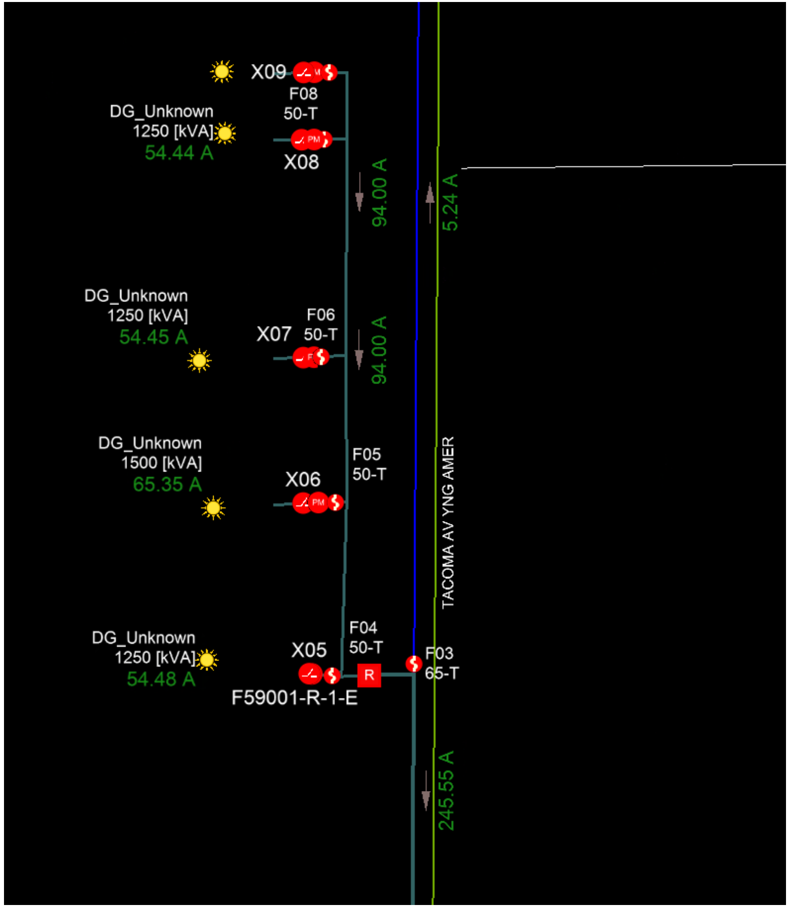


Distributed Energy Resource Management (DER)

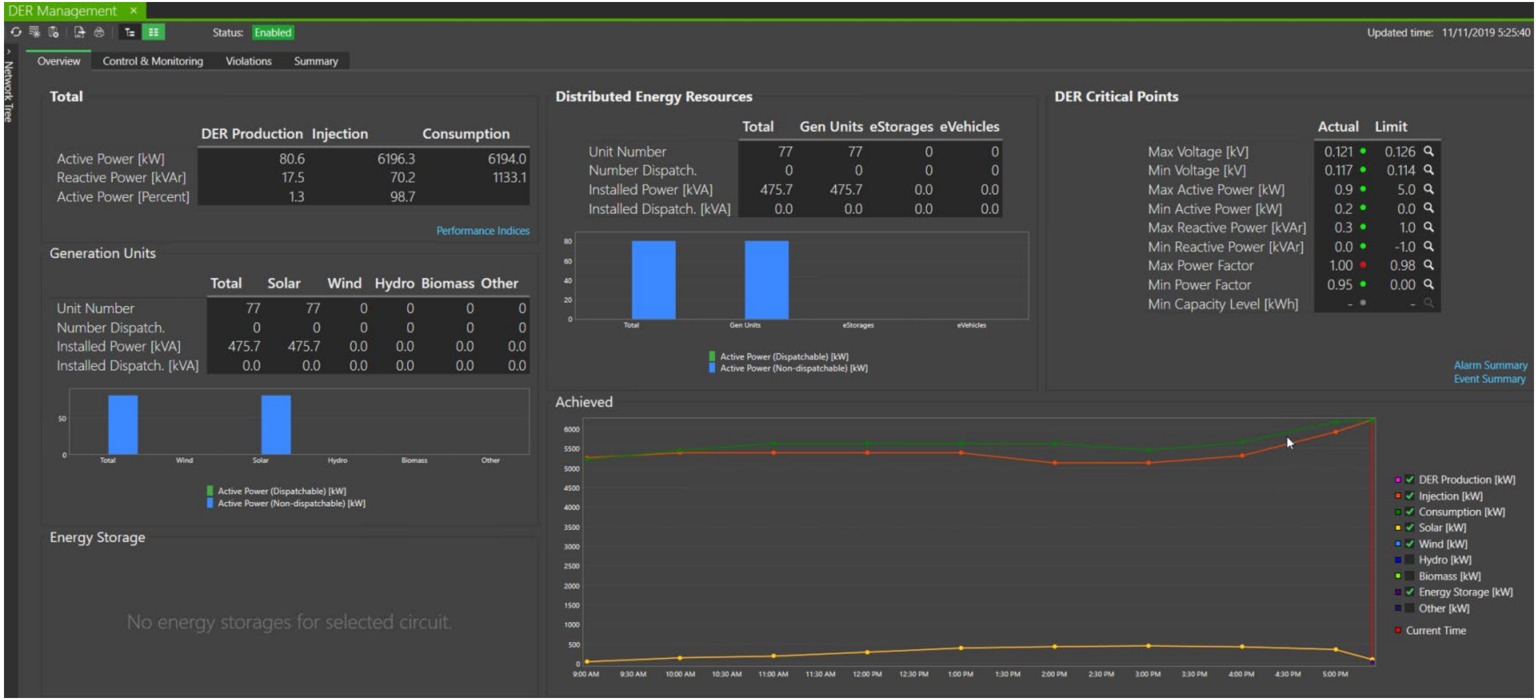
Distributed Energy Resources

- Impacts to FLISR and Load-Flow
- Fault Location calculation does not currently account for:
  - Secondary DG (rooftop)
  - Grounding Banks (required for a majority of solar gardens)
  - Fault location not currently accounting for real-time output (i.e. solar gardens at night)
- FLISR –Fault current contribution, per DG type is being calculated based on a percentage of KVA rating.
- Hidden Load visible to Operations during outage restoration

Solar Garden



DER Management



Additional Advanced Applications

Pre-Project Perception – IVVO and FLISR Only

- The ADMS System is being implemented to run IVVO and FLISR only.

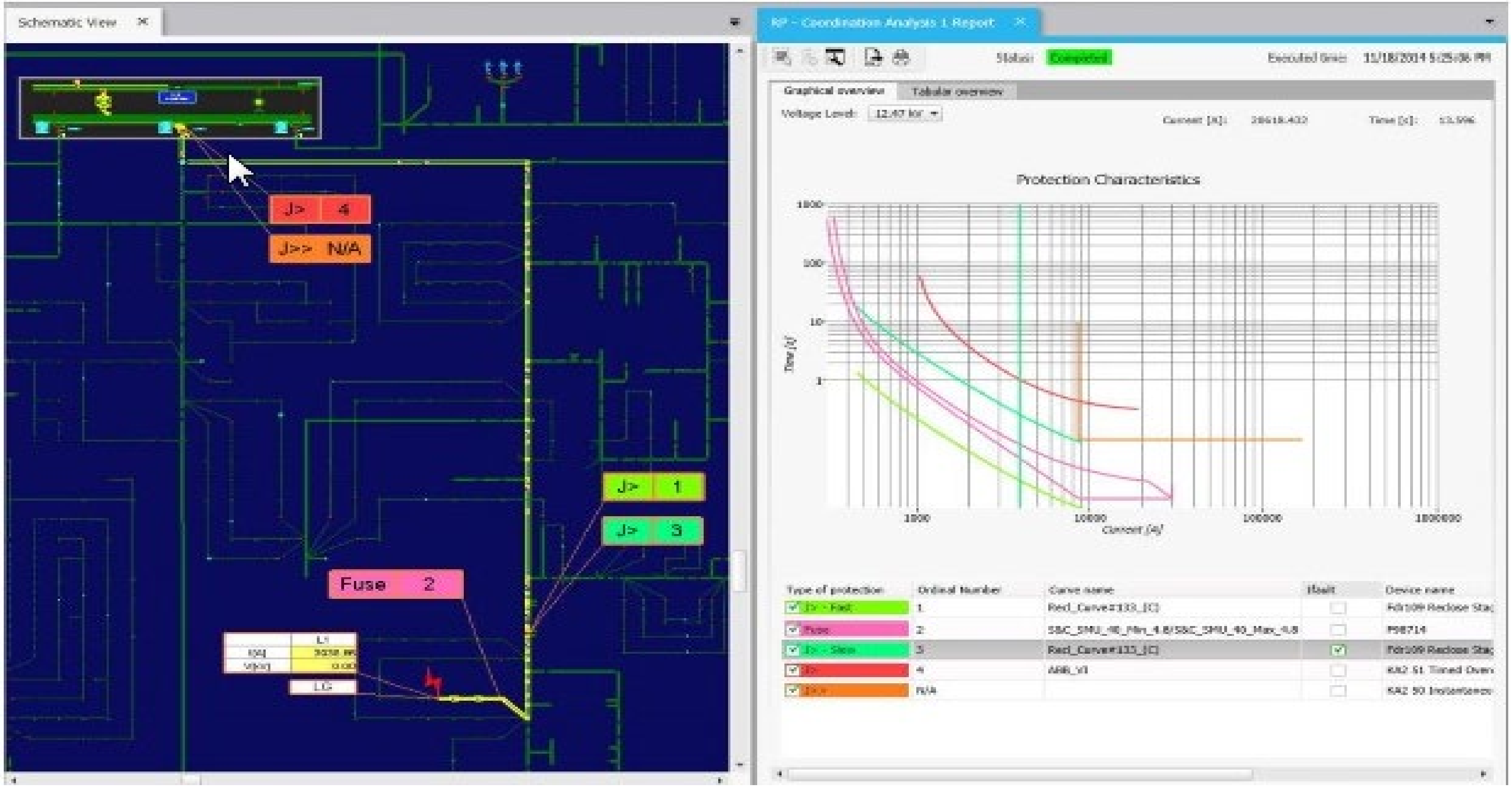
Lesson Learned – One Model

- One, As-Operated model
- Load Flow accuracy due to State Estimation
- Institutionally accurate due to Operations
- Integral SCADA
- Workforce efficiency and accuracy
- Not a sub-cycle or transient analysis tool

Lesson Learned – One model with additional Applications

- Switch Management
- Protection Coordination
- Outage Management
- Hosting Capacity

Relay Protection Coordination/Adaptive Relaying



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Overall ADMS

Pre-Project Perception – Overall ADMS

- The ADMS System implementation is typical 'IT' project with typical management requirements.

Lesson Learned – Overall ADMS

- The ADMS project is an, extreme, IT/OT collaboration.
- Strong Executive leadership required.
- Crosses all T/D traditional organizational and system boundaries.
- Forces Utility to deal with all ‘work-arounds’ and inconsistent data practices.

Lesson Learned – Overall ADMS

- Plan and Adjust the Plan frequently. Rigid dates are leading to bad decision-making and higher costs.

- Requires an agile, nimble, and cross-boundary organization with autonomy to make decisions and effect action in all aspects of the project.

Lesson Learned – Overall ADMS

- Requires a clearly defined project organization, both on the Company side and the Vendor side.

- Requires talent management and retention, at all levels of the company – Executive, Management, and Technical.

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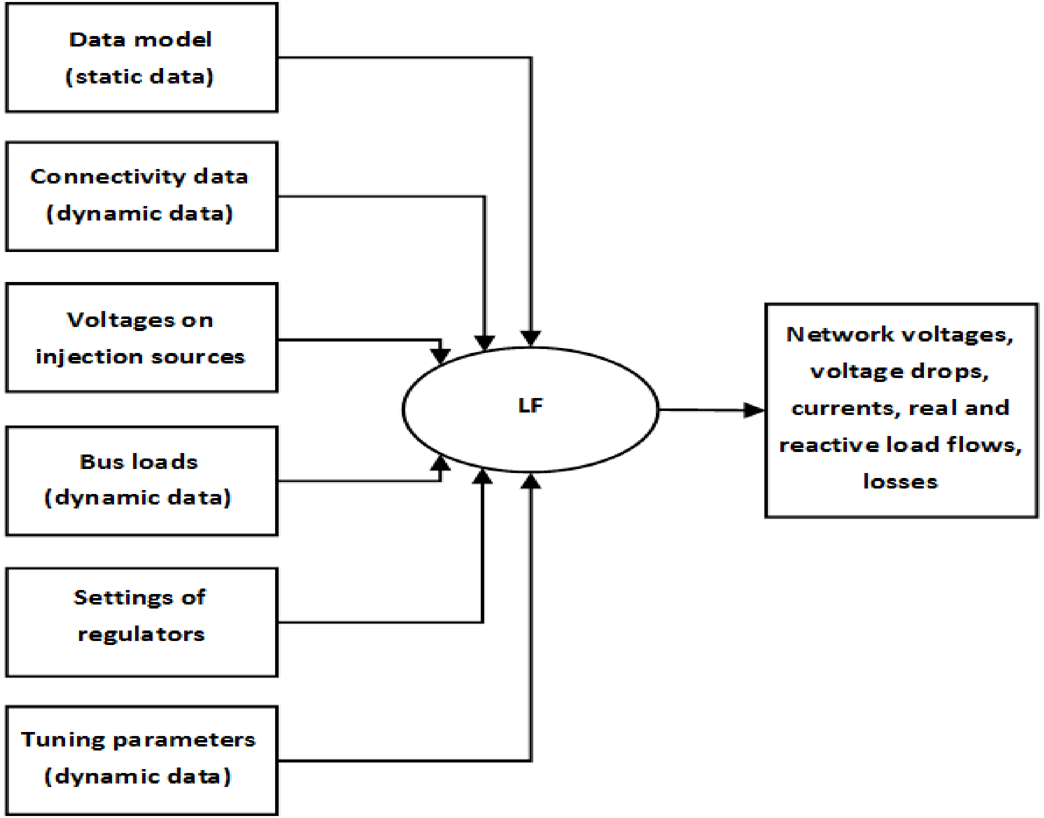
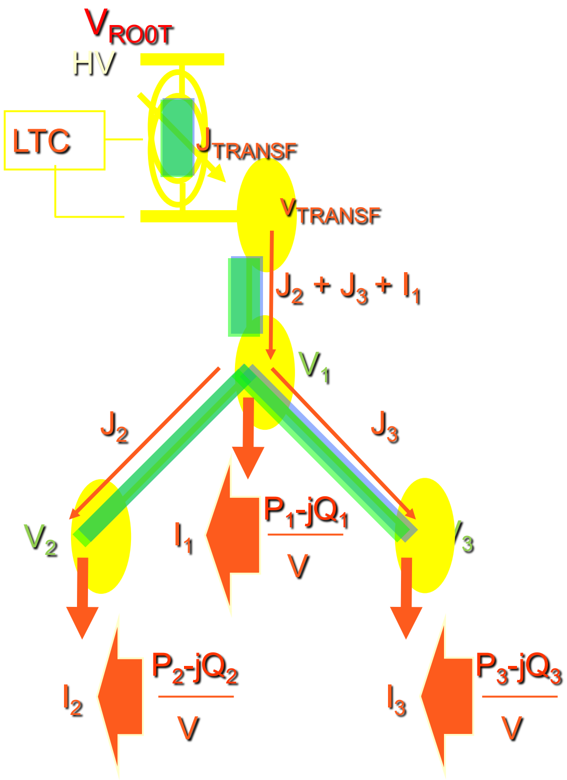
Questions?

Appendix

Load Flow


Data model
(static data)
Connectivity data
(dynamic data)
Voltages on
injection sources
Bus loads
(dynamic data)
Settings of
regulators
Tuning parameters
(dynamic data)
LF
Network voltages,
voltage drops,
currents, real and
reactive load flows,
losses

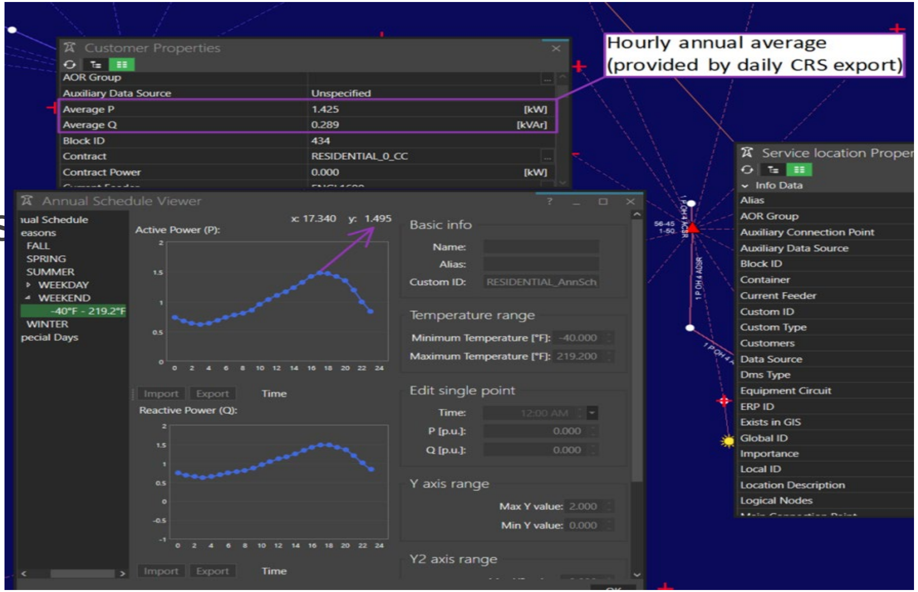
Load Flow Algorithm



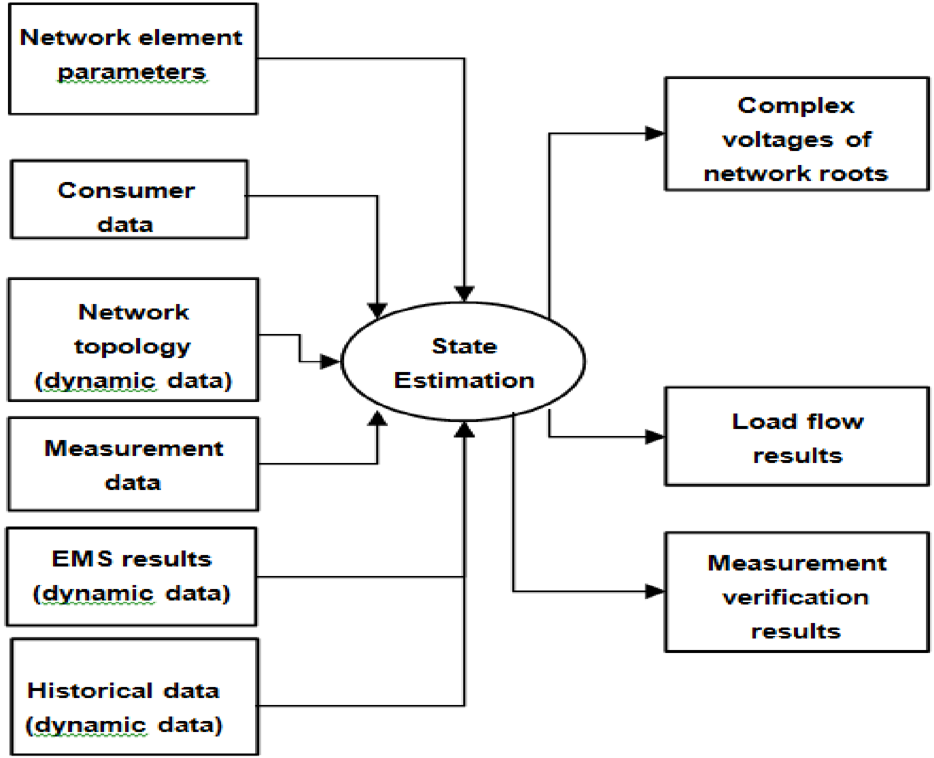
1. Calculate injected current
2. Calculate Branch Currents (Backward Sweep)
3. Calculate Node Voltages (Forward Sweep)
4. Adjust Local Automation
5. Convergence Criteria Check

Load Distribution- Load Flow

- Load Profiles
  - Currently Provided by Load Research Group on Yearly Basis
    - One for Residential Customers
    - Unique for all Primary Customers
  - After AMI Integration
    - ADMS Load Profile Generator Yearly Updates



State Estimation



Load Distribution- State Estimation

- State Estimation- Algorithm Overview
  - 1. Initial Load Flow Execution to get Expected/Pre-Estimated Values
  - 2. Determine Bad Measurements
  - 3. Sectionalize Network by Available Measurements
  - 4. Estimated Value by Minimization of Sum of Squares

$$\sum_{i=0} |Est - Meas(TF)|^2 + |Est - PEst|^2$$

  - 5. Calibration/Load Allocation
  - 6. Final Load Flow Execution