



Deploying an Advanced Distribution Management System

**Minnesota Power Systems Conference
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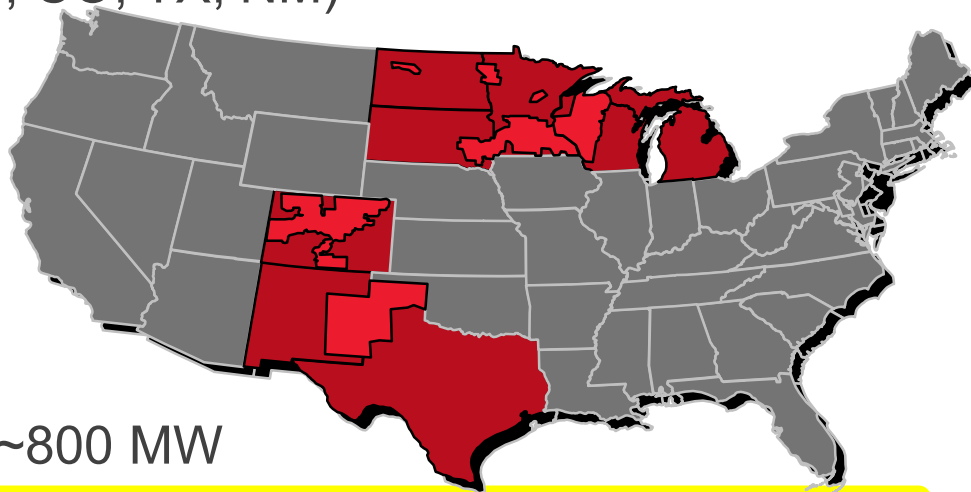


Today's Topics:

- **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 mi²
- Renewables: 25%
- Distribution Connected Solar: ~800 MW
- Carbon Goal: 80% Reduction by 2030*. 100% Carbon Free by 2050
- Natural Gas Customers: 1.8 M



Xcel Energy – Together – 2030 and 2050 Goals

Local

<https://youtu.be/dx55TQ2LDaM>



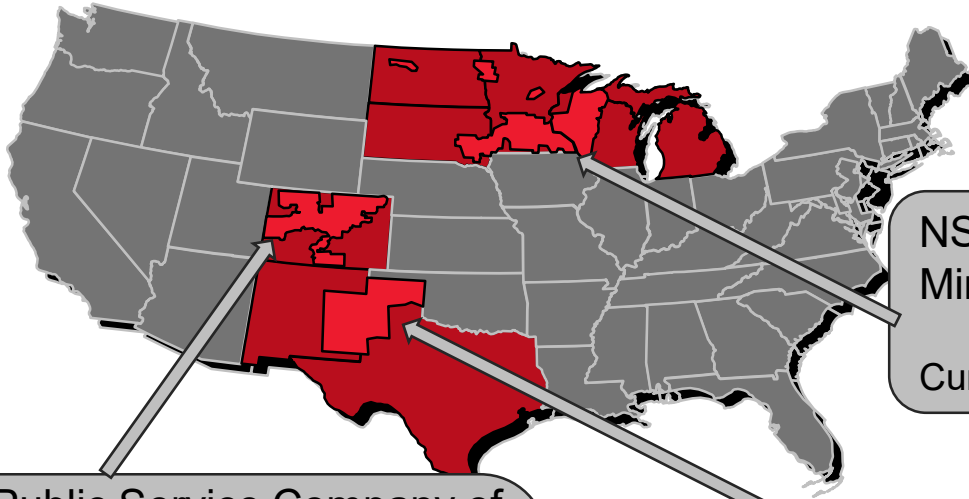
ADMS Overview

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



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

NSP – Northern States Power,
Minnesota and Wisconsin

Currently in Site Acceptance Testing

SPS – Southwest Public Service

Server hardware is in place



Network Model

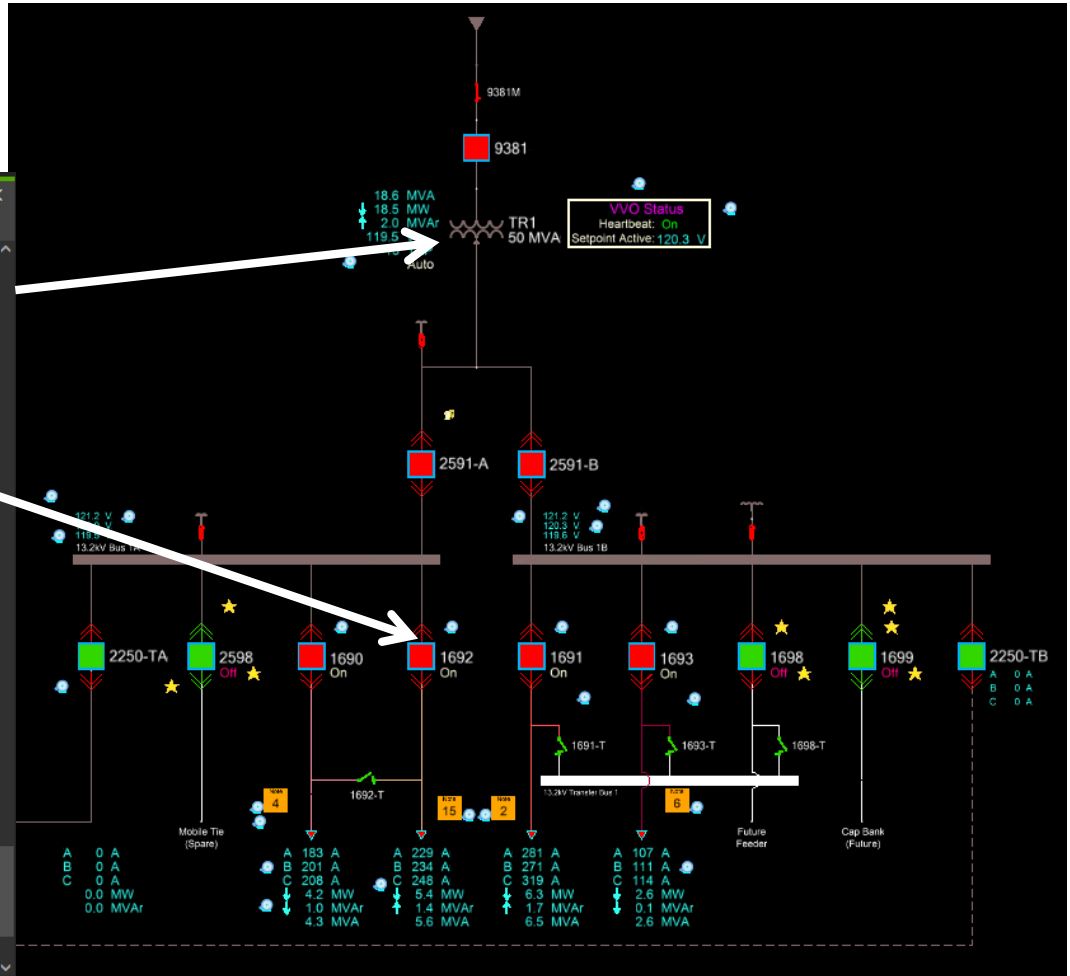
Pre-Project Perception – Network Model

- 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.

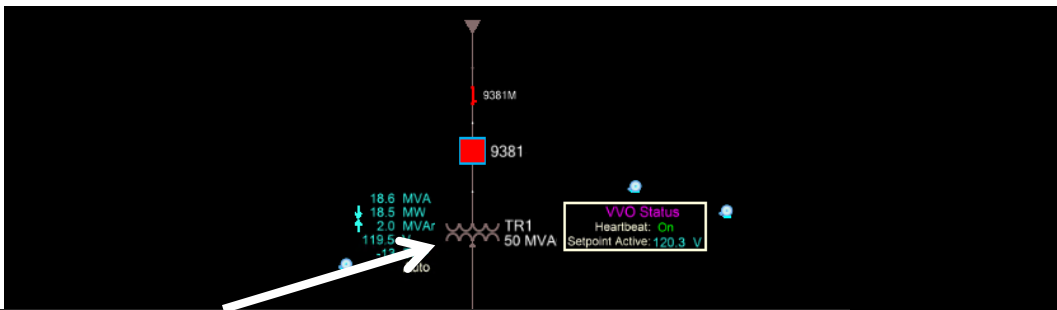
Network Model - Substations

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	Unspecified
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



Control Window [read-only mode]

Close

Real-Time Value: Close
Device Name: 2591-A
Substation Name: ENGLEWOOD
Phases: **A B C**
Remote Point Name: DP1_27734
Remote Source: Telemetered
Signal Type: Switch Status
Signal Name: 13.8kV_2591-A_Bkr
Quality: Good
Last Update: 4/16/2019 3:53:14 PM
AOR Group: SOUTHWEST METRO REGION
Last Krunch: 4/16/2019 3:53:14 PM
Remote Point Type: Status
RTU Name: DEMS_ICCP_ENGL

Switch Status Control

Status:

Advanced...

Select signal '13.8kV_2591-A_Bkr' failed.
Reason: Access is denied.

All Signals Dismiss

	Value	Signal quality	Signal type	Measurement
Pos	-12	Good	Tap Position	Discrete
Pos	Lower	Good	Tap Increment	Status
Daily Ops Count	2	Good	Daily Operations Count	Discrete
Local/Remote	Remote	Good	Local	Status
Auto/Manual	Heartbeat	Good	Refresh	Status

Device Alarm Summary : 2591-A

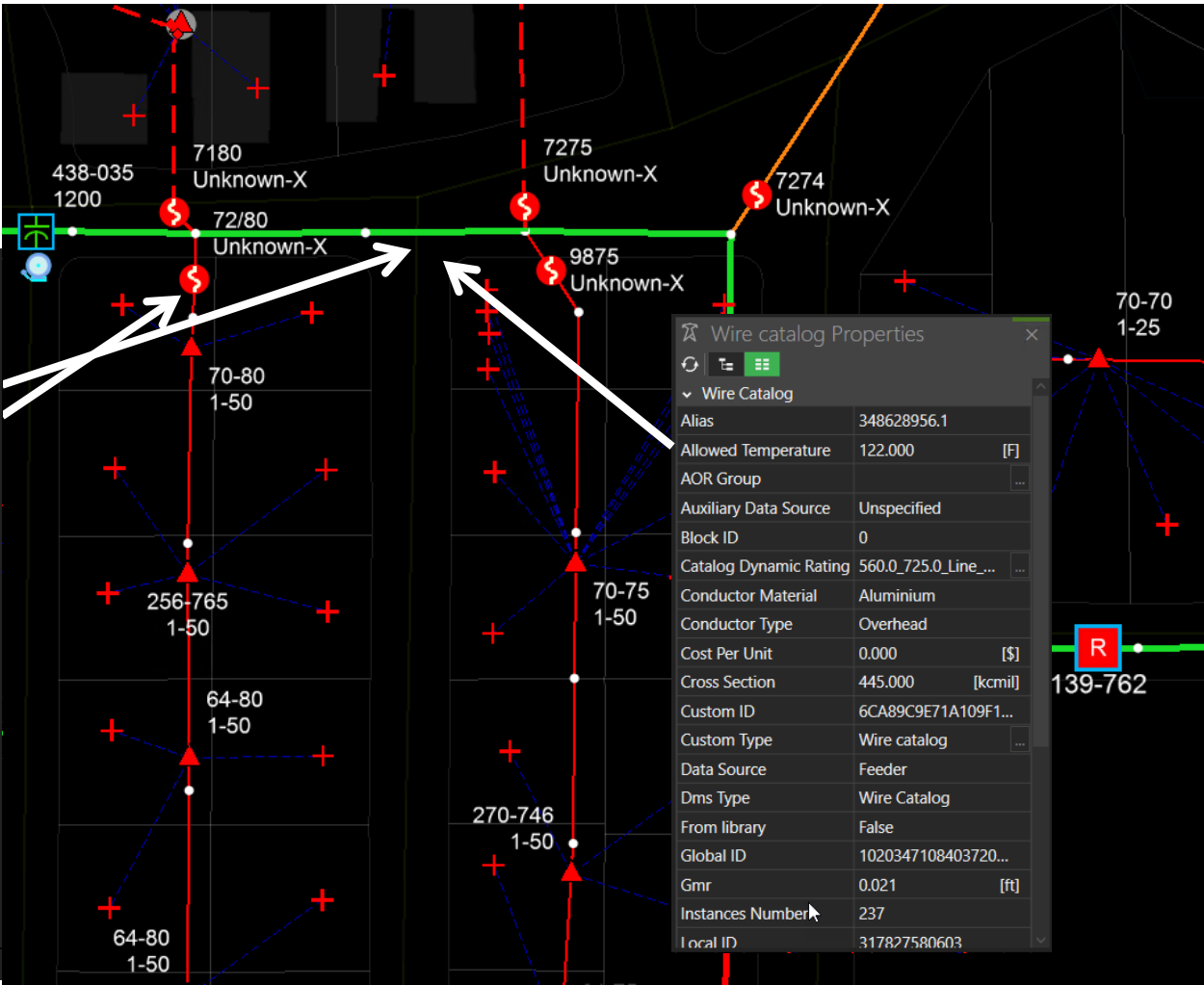
[Showing 3 of 3 alarms total]

Icon	Time	Field Time	State	Message	Category	Remote point	Description
	11/1/2019 1:06:02.089	11/1/2019 1:05:50.7	◀	Value = 121.1318 base120 (N	DMS_hilo	DP2_39529	13.8kV_TR1_VI
	9/29/2019 10:20:21.48	9/29/2019 10:20:11	◀	Value = 119.9194 base120 (N	DMS_hilo	DP2_29065	13.8kV_TR1_VI
	9/29/2019 10:19:36.78	9/29/2019 10:19:27	◀	Value = 120.6909 base120 (N	DMS_hilo	DP2_39528	13.8kV_TR1_VI

Network Model Feeders

Fuse catalog Properties

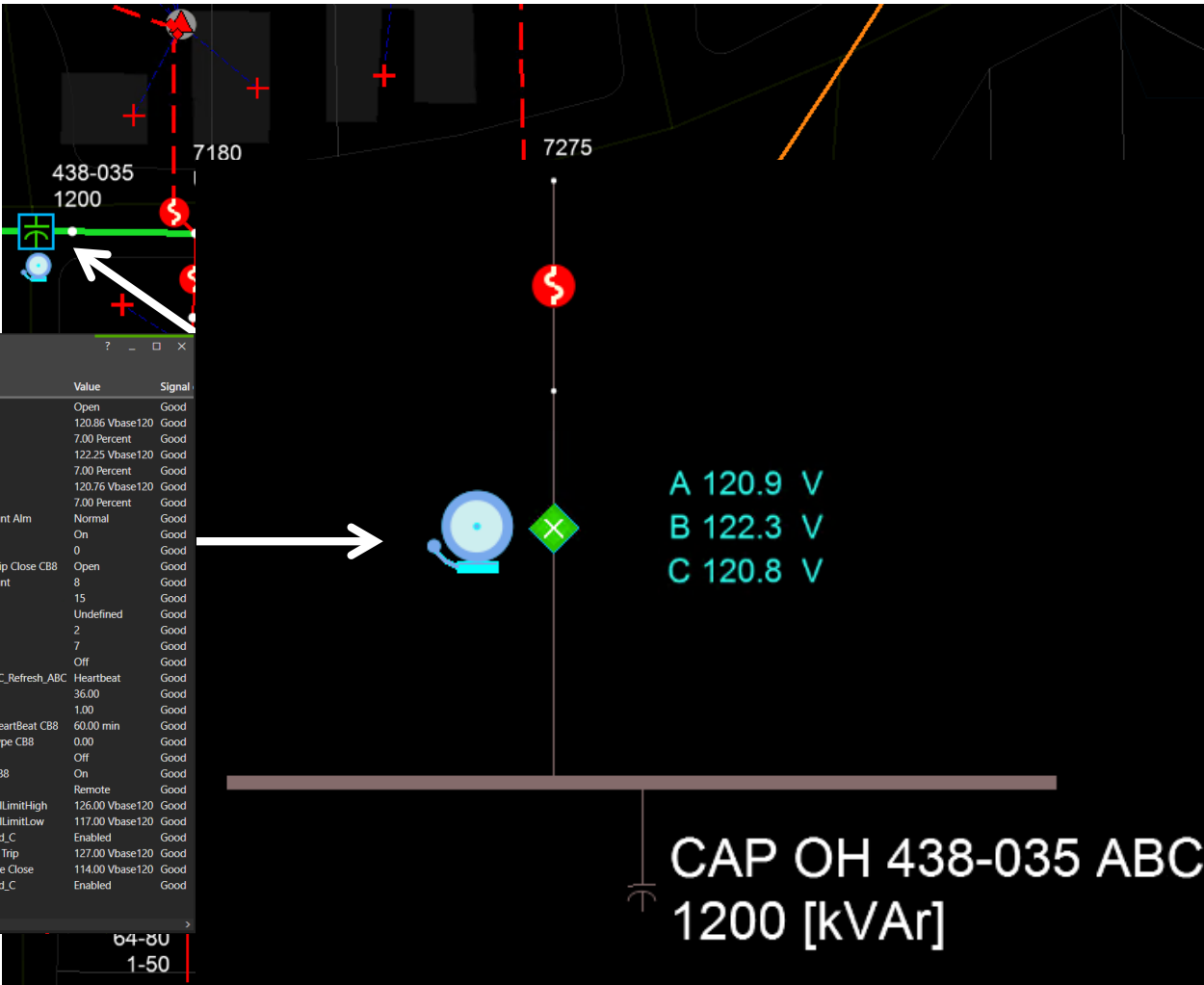
Alias	233810708
AOR Group	
Auxiliary Data Source	Unspecified
Block ID	0
Breaking Current	199.000 [A]
Cost Per Unit	0.000 [\$]
Custom ID	FA0D6089EAF8B570D5FA9...
Custom Type	Fuse catalog
Cutout	True
Data Source	Feeder
Dms Type	Fuse Catalog
From library	False
Fuse Type	K
Gang Operated	True
Global ID	144396736067272646
Instances Number	1398
Isolating	True
Local ID	73014444143
Lower Curve	
Manufacturer	
Mechanism	Unspecified
Model	
Name	GIS_FC_1_13.2kV_199A_19...
Phase Count	1
Rated Current	199.000 [A]
Rated Voltage	13.200 [kV]
Local ID	100486704124657955



Wire catalog Properties

Alias	348628956.1
Allowed Temperature	122.000 [F]
AOR Group	
Auxiliary Data Source	Unspecified
Block ID	0
Catalog Dynamic Rating	560.0_725.0_Line_...
Conductor Material	Aluminium
Conductor Type	Overhead
Cost Per Unit	0.000 [\$]
Cross Section	445.000 [kcmil]
Custom ID	6CA89C9E71A109F1...
Custom Type	Wire catalog
Data Source	Feeder
Dms Type	Wire Catalog
From library	False
Global ID	1020347108403720...
Gmr	0.021 [ft]
Instances Number	237
Local ID	317827580603

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_VitA	VitA	120.86 Vbase120	Good
	3.	GP499598539D_VitA_THD	VitA_THD	7.00 Percent	Good
	4.	GP499598539D_VitB	VitB	122.25 Vbase120	Good
	5.	GP499598539D_VitB_THD	VitB_THD	7.00 Percent	Good
	6.	GP499598539D_VitC	VitC	120.76 Vbase120	Good
	7.	GP499598539D_VitC_THD	VitC_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

64-8U
1-50

Lesson Learned - Network Model includes static and dynamic data

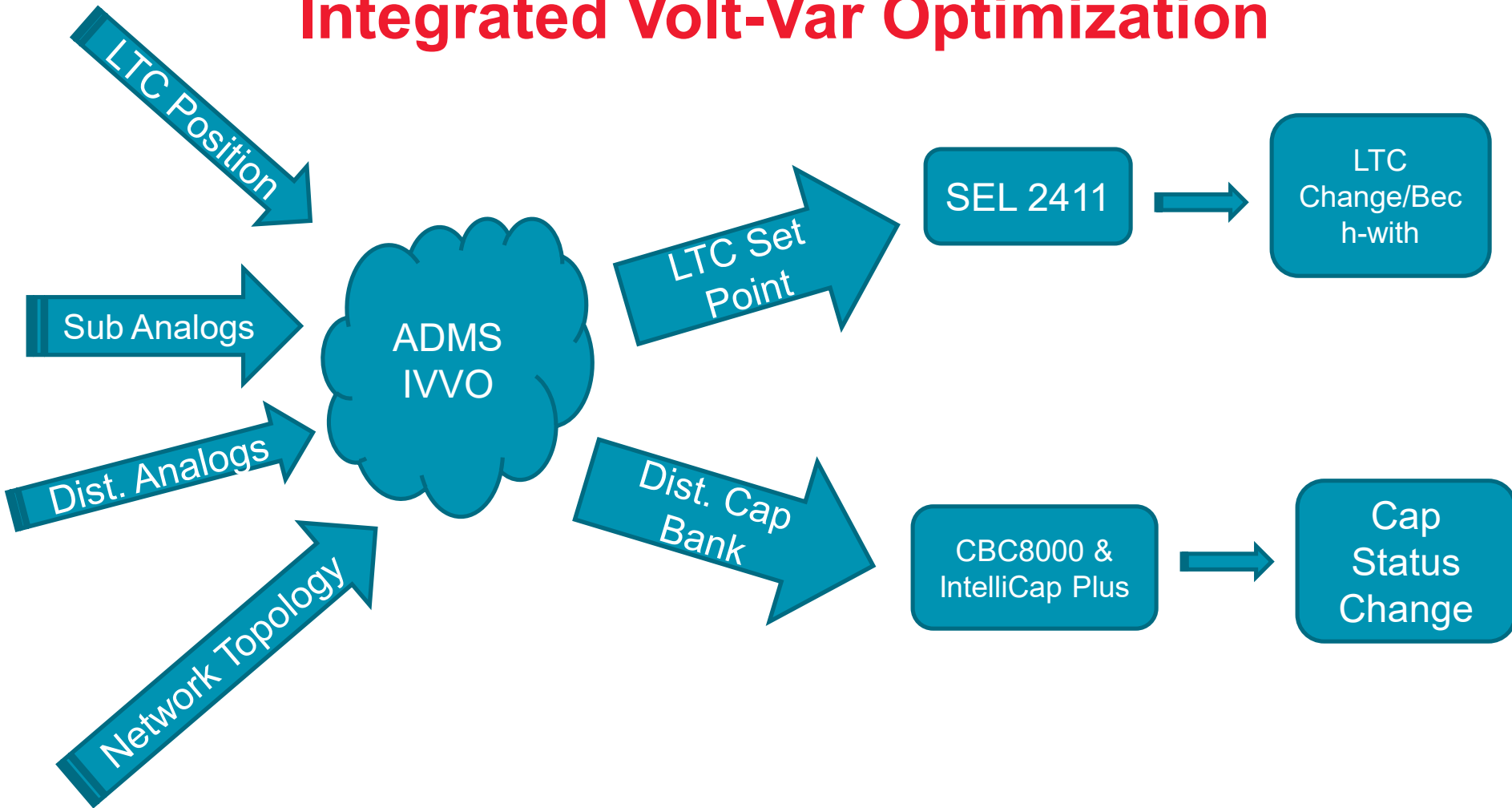
- As-Operated Impedance model of Distribution Grid
 - Substations
 - Feeders
- Automated Devices
- SCADA – Substations, Automated Devices, Data Concentrators
- Customer Data/Loads
- Distributed Energy Resources
- Protection data



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??

VVO Execution Report

Search: []

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 [kVAr]	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

Switching Sequence

- ENGL_TR1_LTC_RegulatingControl Heartbeat
- 488154418_ABC_RC Heartbeat
- 496700759_ABC_RC Heartbeat
- 233788501_ABC_RC Heartbeat
- 233788088_ABC_RC Heartbeat
- 537541328_ABC_RC Heartbeat
- 538684511_ABC_RC Heartbeat
- 542200080_ABC_RC Heartbeat
- 538791019_ABC_RC Heartbeat
- 53767572_ABC_RC Heartbeat
- 536719373_ABC_RC Heartbeat
- 233780869_ABC_RC Heartbeat
- 536745523_ABC_RC Heartbeat
- 542131012_ABC_RC Heartbeat
- 542138473_ABC_RC Heartbeat
- 538477185_ABC_RC Heartbeat
- Timeout 35s
- ENGL_TR1_LTC_RegulatingControl Set value 120.2305 [Vb →
- 3-2141-384-098-457 Loadbreaker Close

VVO Execution Report

Search: []

Overview Details Resources

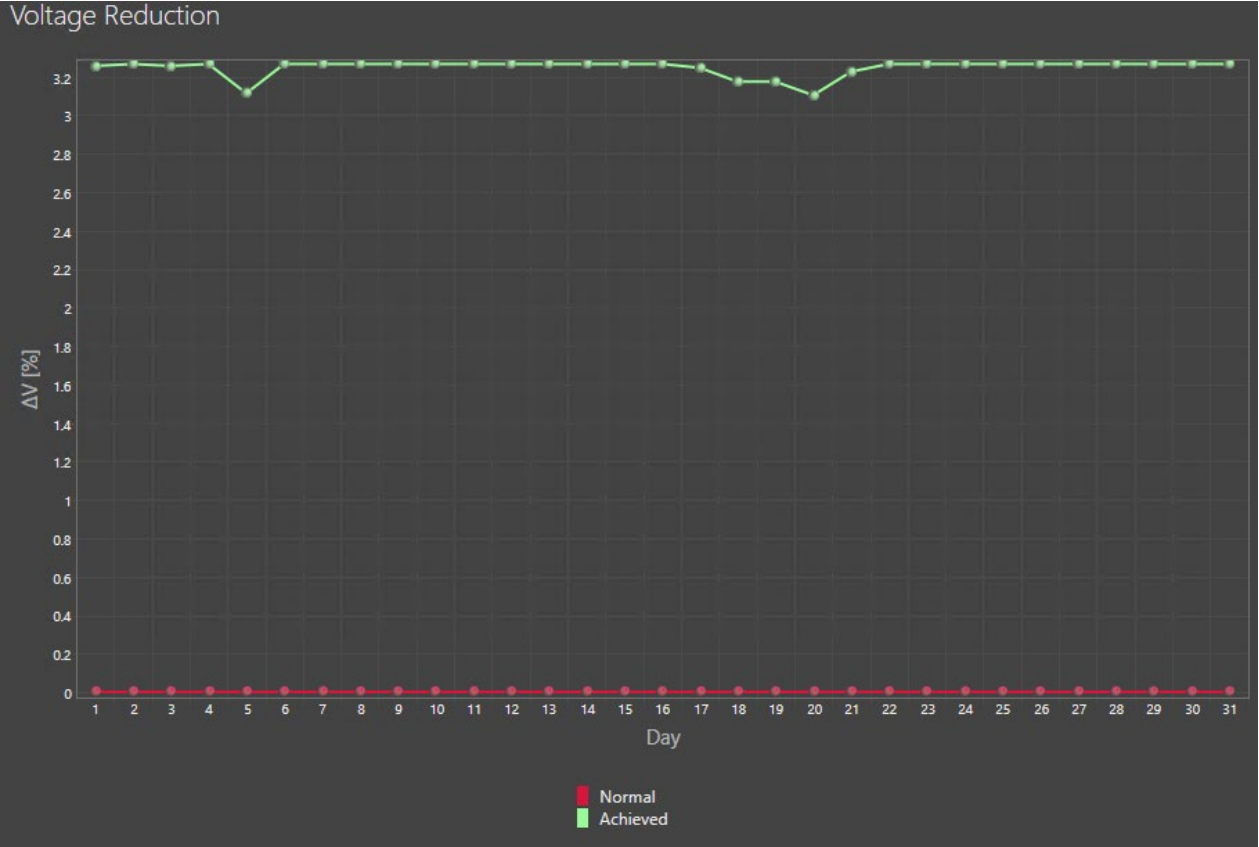
Filter

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	ENGL000	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

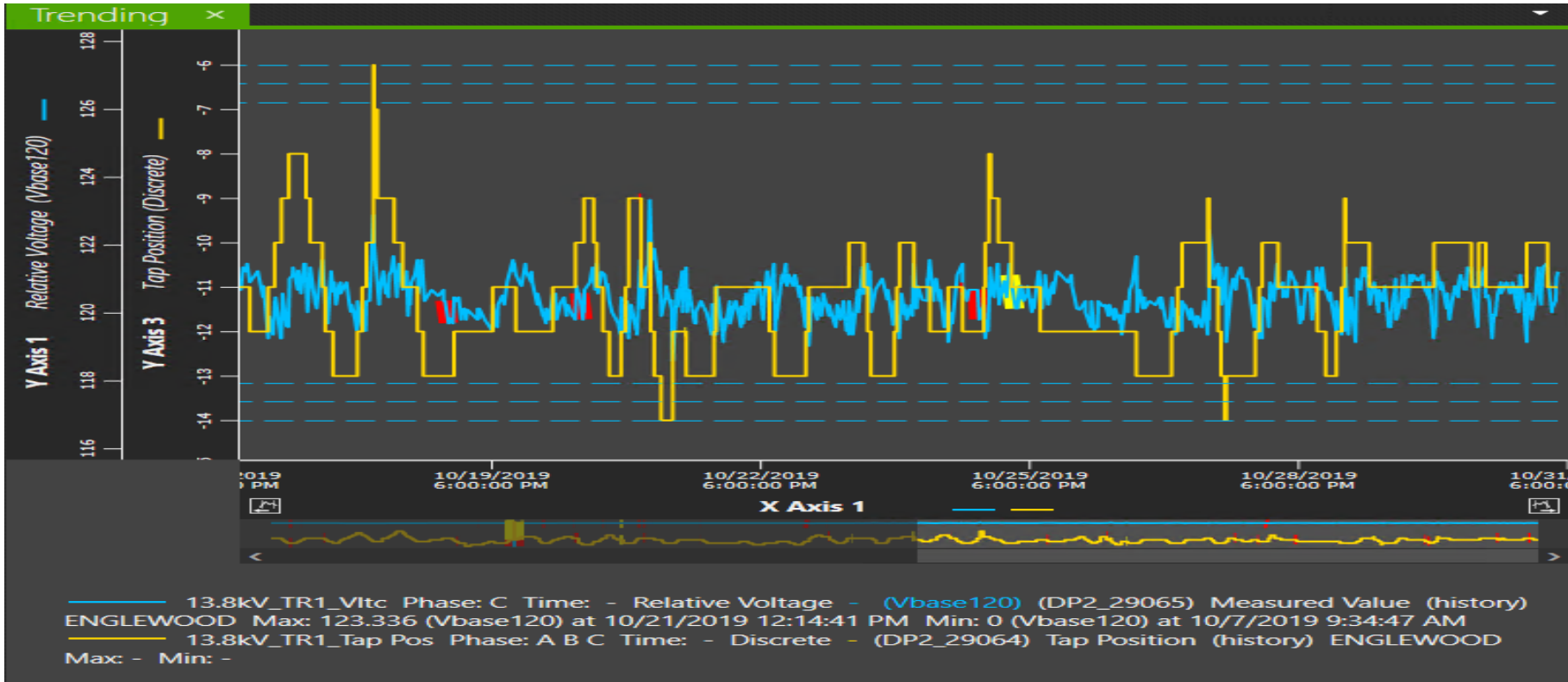
A 0 A
B 0 A
C 0 A
0.0 MW
0.0 MVar

248 A 5.4 MW
1.4 MVar
6.6 MVA
319 A 6.3 MW
1.7 MVar
6.5 MVA
114 A 2.6 MW
0.1 MVar
2.6 MVA

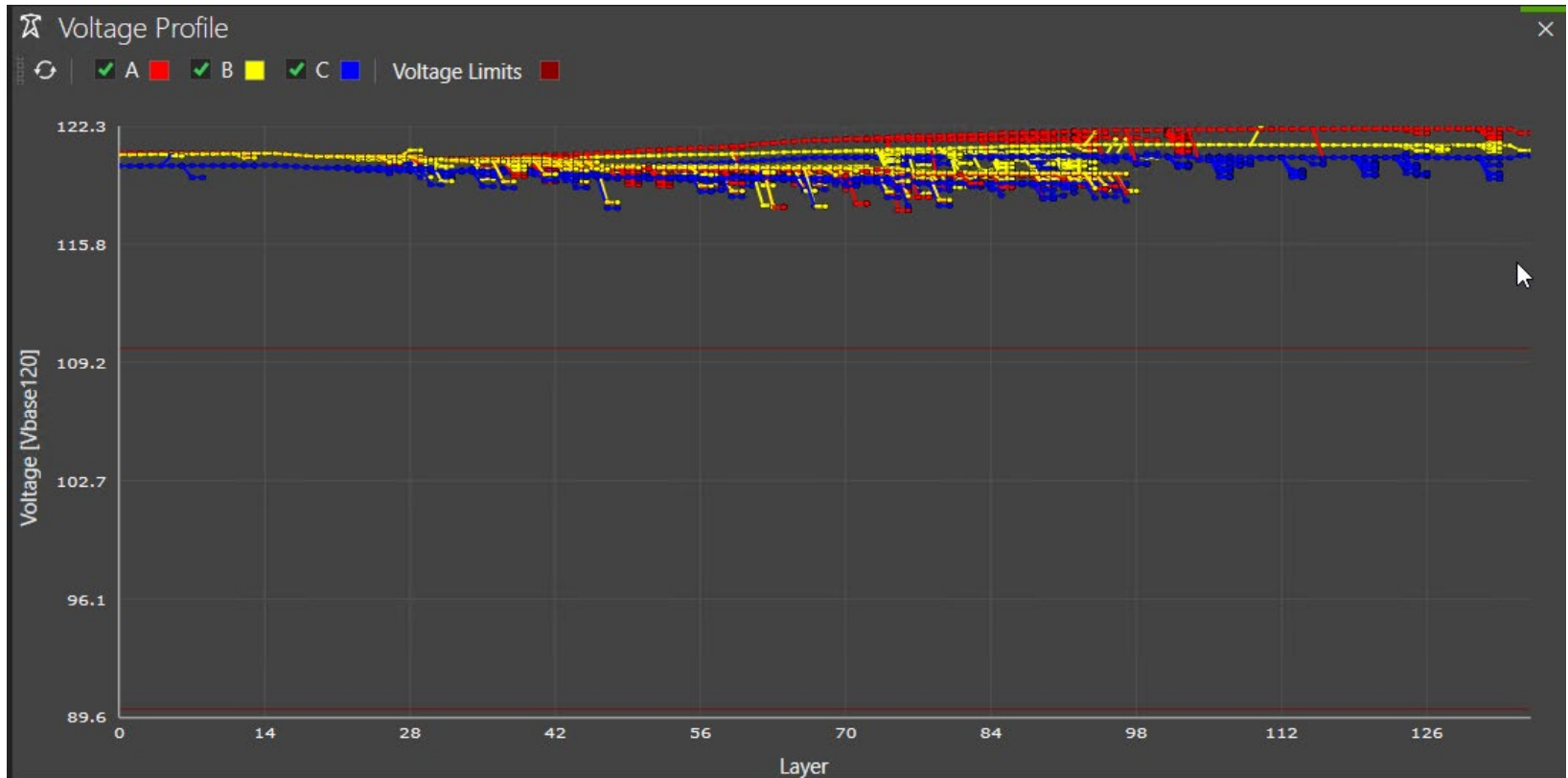
IVVO Benefits October, 2019



IVVO – LTC Voltage Setpoint and Tap Position



IVVO – Feeder Voltage Profile



IVVO - Profiles

Profile Editor

Basic | Advanced | Verification | Resources | CVR Settings

Approved:

Profile name: **WVO_Profile1**

Profile description:

Objective functions

- Active power losses reduction **Add function**
- Remove selected

Objective function type: **Active power losses reduction**

Limits

Active power losses limit:

- Power consumption reduction
- Consumer voltages improvement
- Medium voltages improvement
- Power factor improvement
- Cost of manipulation minimization
- VAR control
- Emergency voltage reduction
- Voltage reduction

Constraints

High constraints

OK **Cancel**

Profile Editor

Basic | Advanced | Verification | Resources | CVR Settings

Approved:

Profile name: **Demand Reduction ENGL TR1**

Profile description: **08-21-2019 Changed Medium Voltage Lower Limit to 118V- Jeff Kaspar**
08-29-2019 Changed Medium Voltage Lower Limit to 116V- Jeff Kaspar


Objective functions

Constraints

- Consumer voltage: $114.0 \leq V \leq 126.0$ Deadband: 0.0 [Vbase] Emergency limits
- Medium voltage: $114.0 \leq V \leq 126.0$ Deadband: 0.0 [Vbase120]
- AMI voltage: $114.0 \leq V \leq 126.0$ Deadband: 0.0 [Vbase120]
- Low voltage reading: $114.0 \leq V \leq 126.0$ Deadband: 0.0 [Vbase120]
- Medium voltage reading: $114.0 \leq V \leq 126.0$ Deadband: 0.0 [Vbase120]
- Power factor
 - First limit: 0.95 lag $0.8 \text{ lead} \quad 1 \quad 0.8 \text{ lag}$
 - Second limit: 0.95 lead $0.8 \text{ lead} \quad 1 \quad 0.8 \text{ lag}$
 - Deadband: 0.00
- Voltage imbalance: $V_{imb} \leq 3.00$ [Percent]

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.

The background is a solid red color. On the left and right sides, there are white, angular shapes that resemble stylized arrows or chevrons pointing towards the center. The text is centered in the middle of the red area.

**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

DMD - EcoStruxure ADMS -Fault Location 2 Report [nspcore\control_room - Bertrand- All NSP] CPNSPCOR\N-COR212639-GrdEng from AD ?

File View Core Apps WVO FLISR Switching Summary Tools Window Help

mdt

WESTGATE MIDTOWN Geographic x Fault Location 2 Report x Fault Location 2 Report Return to Normal 1 Report

Status: **Completed** Executed time: 10/28/2019 12:58:19 PM

Overview Fault Location Results Fault Indicators and Measurements Resources

Measured equipment: **1**

Number of Fault Indicators: **0**

Number of elements with possible fault: **3**

Element with highest fault probability:
MLPOH_4/0_CU_7024946 🔍
43.60 [Percent]

Element ID	Fault Location Probability [%]
1	43.60
2	~35
3	~20

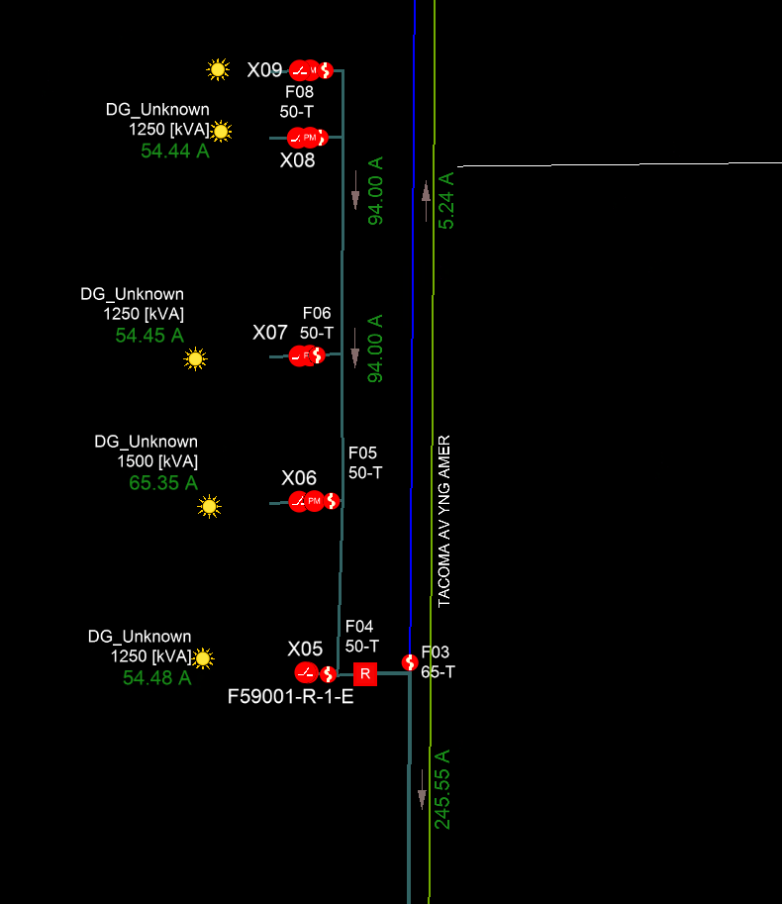
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Distributed Energy Resource Management (DER)

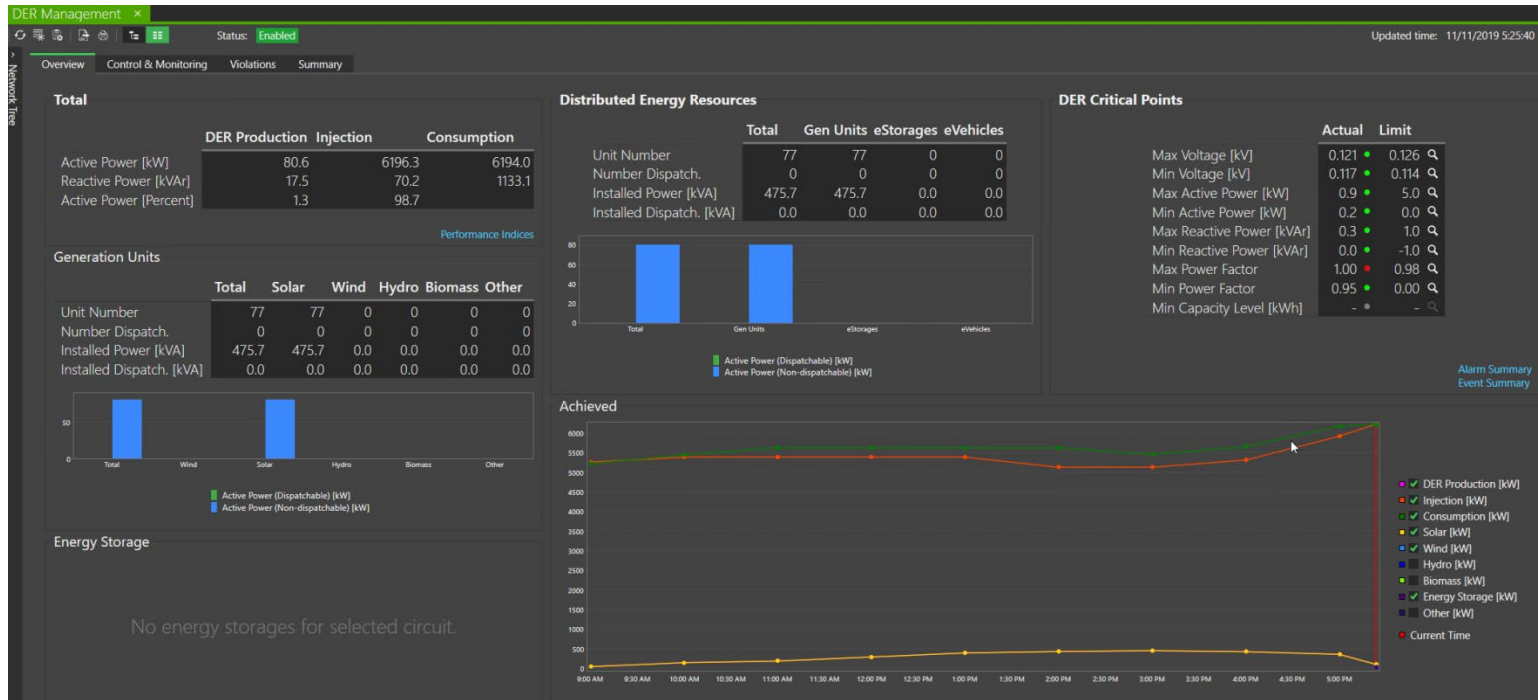
Distributed Energy Resources

- 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.

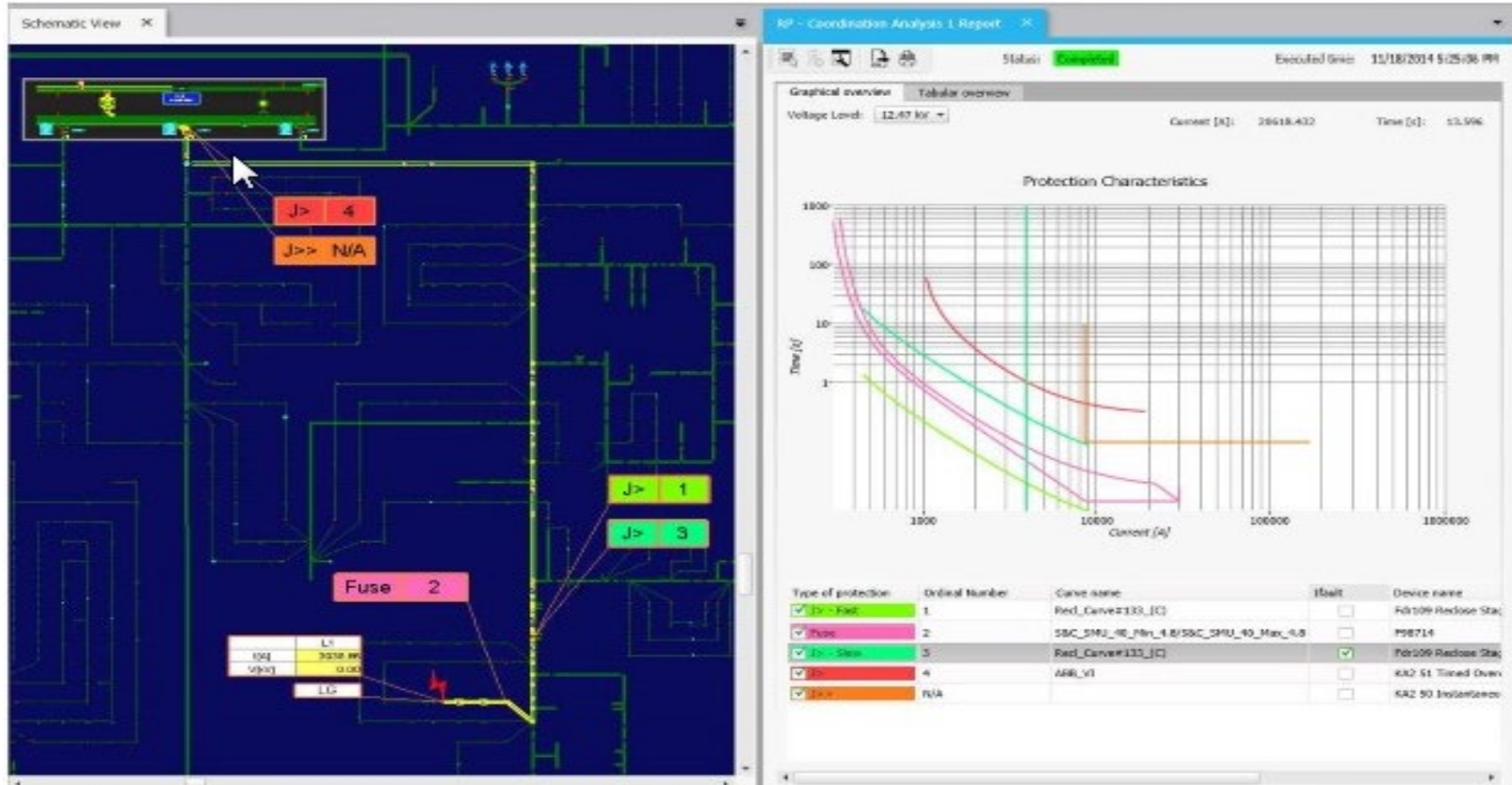
Lesson Learned – One Model

- 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





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.

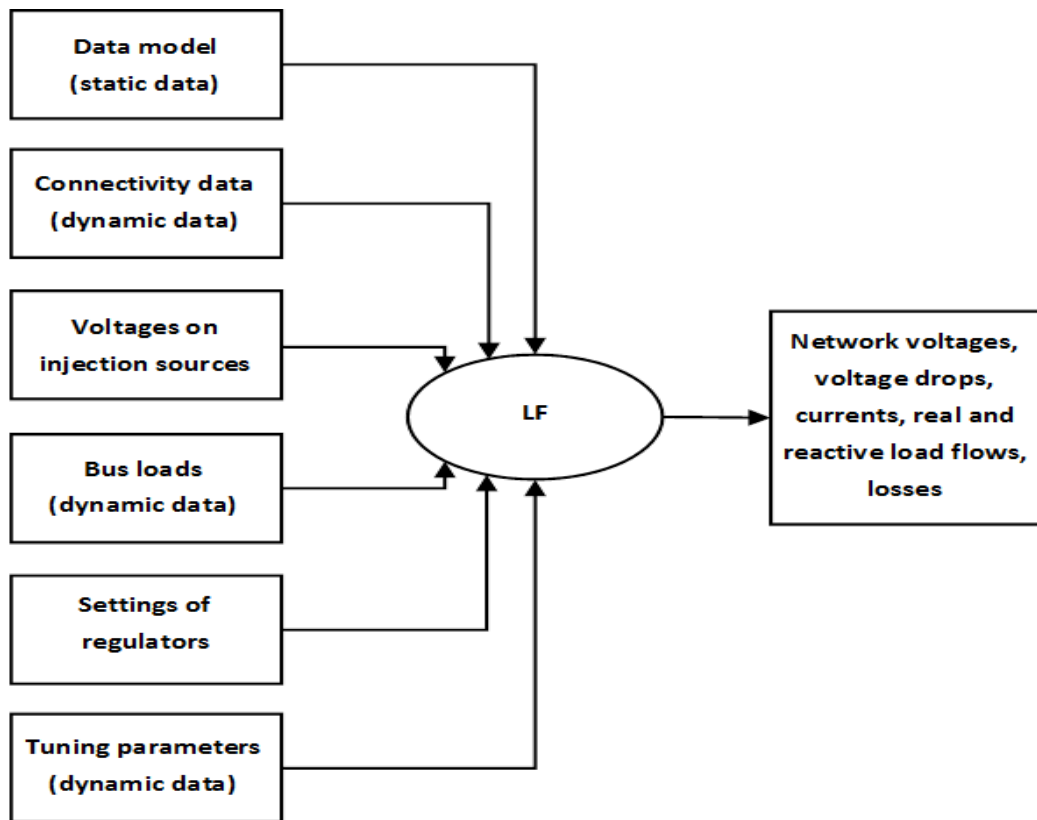


Questions?

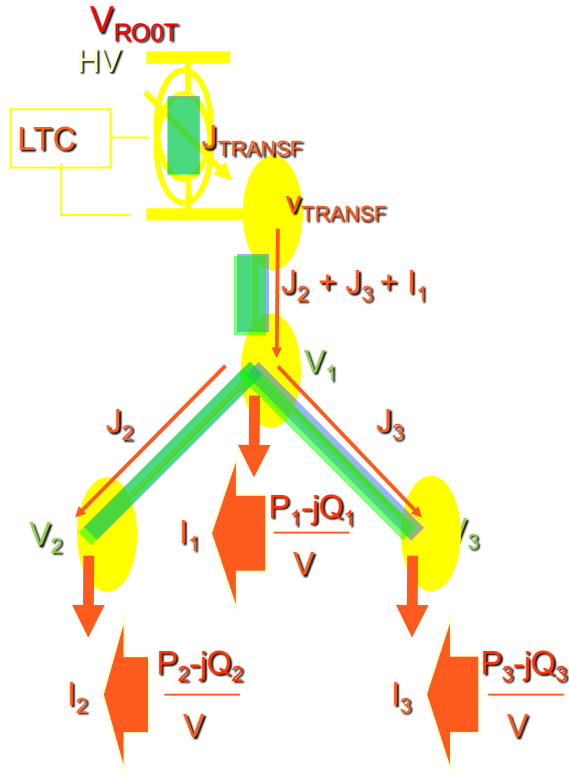


Appendix

Load Flow



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

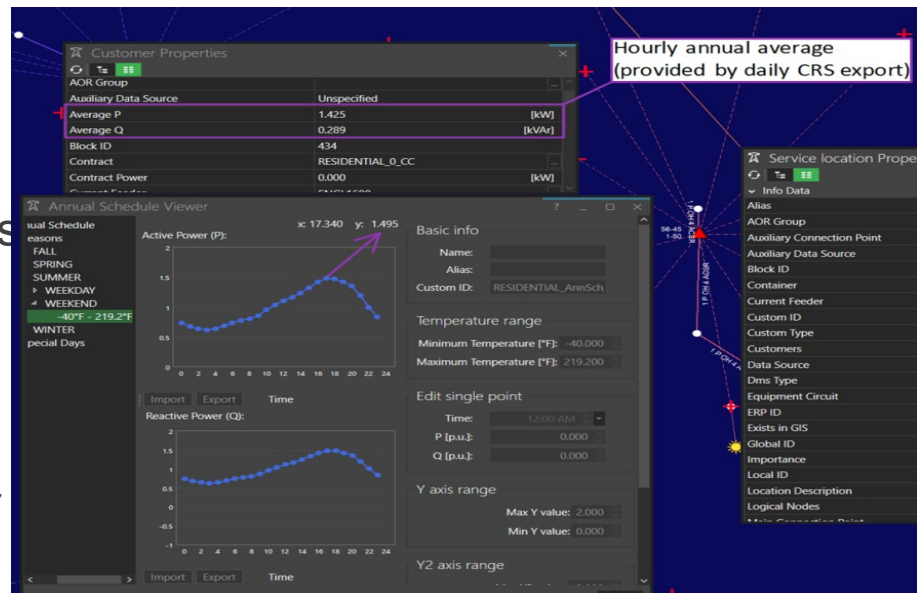
- Load Profiles

- Currently Provided by Load Research Group on Yearly Basis

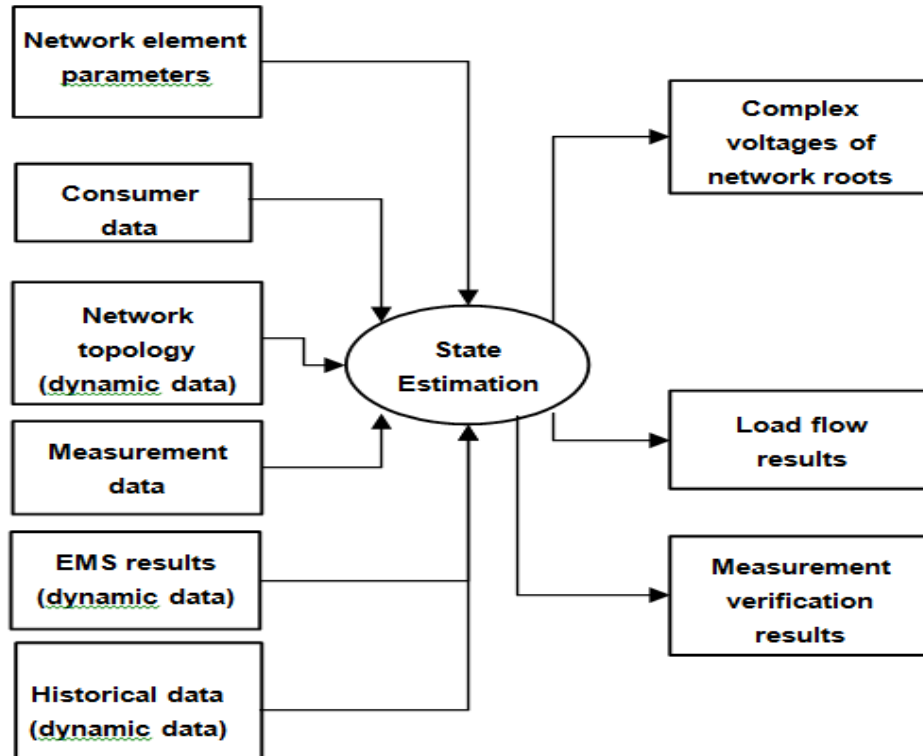
- One for Residential Customers
 - Unique for all Primary Customers

- 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

