

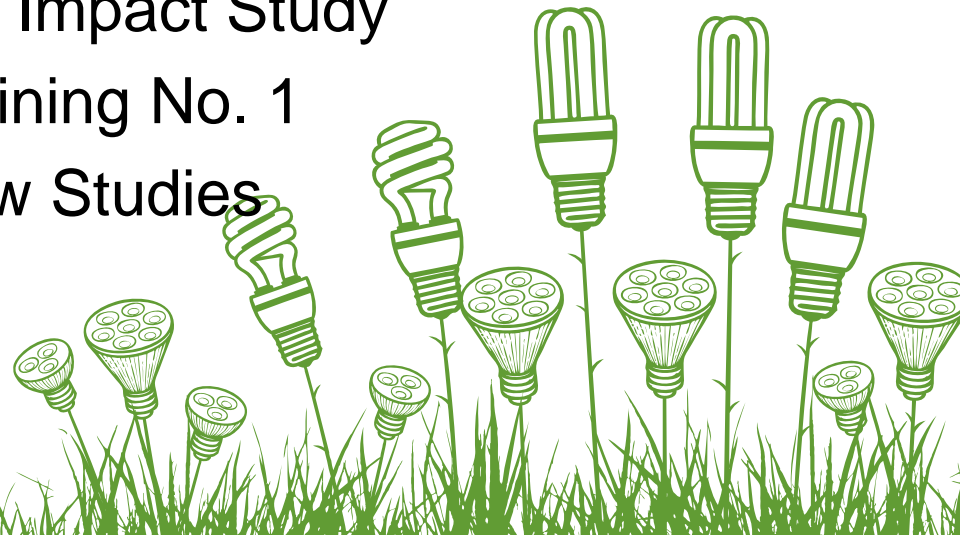


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Energy Sector Capacity Building (ESCB)

PV Plant Grid Impact Study
CYME Training No. 1
Load Flow Studies

5 December 2016





IDECO 5 MW Plant-Agenda

- Day 1:
 - Reviewing model and data
 - PV inverter/electrically coupled generator modeling
 - Steady state voltage regulation
 - Reactive power capability of inverters
 - Snapshot analysis
 - Comparing results of shadow study
- Day 2:
 - Grid code compliance
 - Long term dynamics
 - Reverse power flow



Work Flow

- Day 1:
 - Setting up the model
 - Substation Transformer Assumptions
 - Exercise 1.1: Calculating substation short circuit levels
 - Exercise 1.2: Populate PV inverter PF table
 - Discussing IRR-DCC-MV 5 Voltage Requirements
 - Load Allocation
 - Steady state snapshot analysis, Grid code compliance
- Day 2:
 - Exercise 1.3: Quasi steady state analysis-Long term dynamics
 - Exercise 1.4: Short Circuit Study
 - Comparing results of shadow study



Work Flow

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Setting up/reviewing model

- What is the current load and power factor assumed in the model?
 - Is this minimum or peak load?
- What is the source voltage?
- Are there any voltage regulating devices in the model?
- Run a load flow and generate the following results:
 - Load Flow Summary Report
 - Overloaded Lines & Cables Report
 - Overloaded Transformer Report
 - Voltage Profile at every point along the Feeder (p.u.)



Sample report -Summary Report: Load Flow

Total Summary	kW	kvar	kVA	PF(%)
Sources (Swing)	8588.24	4303.41	9606.10	89.40
Generators	0.00	0.00	0.00	0.00
Total Generation	8588.24	4303.41	9606.10	89.40
Load read (Non-adjusted)	8192.98	4014.42	9123.62	89.80
Load used (Adjusted)	8193.00	4014.46	9123.66	89.80
Shunt capacitors (Adjusted)	0.00	-277.77	277.77	0.00
Shunt reactors (Adjusted)	0.00	0.00	0.00	0.00
Motors	0.00	0.00	0.00	0.00
Total Loads	8193.00	3736.69	9004.90	90.98
Cable Capacitance	0.00	-11.65	11.65	0.00
Line Capacitance	0.00	-305.00	305.00	0.00
Total Shunt Capacitance	0.00	-316.65	316.65	0.00
Line Losses	243.94	533.73	586.84	41.57
Cable Losses	1.16	1.39	1.80	64.00
Transformer Load Losses	82.51	348.28	357.92	23.05
Transformer No-Load Losses	67.64	0.00	67.64	100.00
Total Losses	395.25	883.40	967.79	40.84



Setting up the Model: Reviewing 33 KV network

- Locate PV project in the model
- Model as ECG-suitable for load flow studies
- Verify size, PF of project
- 132 kV infeeder assumptions:
 - 3 ph short circuit level at 33 KV : 986 MVA
 - X/R Ratio : 25
 - 1 ph short circuit : 78 MVA
 - Resistance grounded : 15 ohms



Setting up the Model: Adding in the PV Inverter

- PV Plant Assumptions:
 - (4) Electronically Coupled Generators
 - Rated Power: 1260 kVA
 - Active Power Rating: 1260 kW
 - Rated Voltage: 0.4 kV
 - Short Circuit Current: 122.5%



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Inverter type	Short-circuit surge current i_p (A)	Initial symmetrical short-circuit current I_k'' (A)	Uninterrupted short-circuit current I_k (A)		Maximal current I_{max} (A)
			Mode 1	Mode 2	
STP 5000TL-20	56.56	9.71	7.3	0	7.3
STP 6000TL-20	59.39	9.79	8.7	0	8.7
STP 7000TL-20	64.76	14.07	10.2	0	10.2
STP 8000TL-20	67.65	14.19	11.6	0	11.6
STP 9000TL-20	71.52	14.40	13.1	0	13.1
STP 10000TL-20	77.65	15.98	14.5	0	14.5
STP 12000TL-20	76.36	19.14	17.4	0	17.4
STP 10000TL-10	72.99	20.60	16.0	0	14.5
STP 12000TL-10	76.03	20.89	19.2	0	17.4
STP 15000TL-10	92.85	26.45	24.0	0	21.7
STP 17000TL-10	98.94	26.88	24.6	0	24.6
STP 15000TLEE-10	94.94	25.85	24.0	0	21.7
STP 20000TLEE-10	106.84	31.14	29	0	29
STP 20000TL-30	98.58	31.07	29	0	29
STP 25000TL-30	116.37	40.06	36.2	0	36.2
STP 12000TL-US-10	81.30	17.27	14.4	0	14.4
STP 15000TL-US-10	89.29	20.57	18	0	18
STP 20000TL-US-10	101.44	26.46	24	0	24
STP 24000TL-US-10	111.92	30.91	29	0	29
STP 30000TL-US-10	181	50.68	36.2	0	36.2
STP 60-10 / STP 60-US-10	201.2	106.6	87	0	87



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Substation Transformer Assumptions

- Two-Winding Transformer parameter assumptions
 - Voltage Rating 132/33 KV
 - Apparent Power Rating 100 MVA
 - Transformer Impedance 10 %
 - X/R Ratio: 25
 - Assume Off Load Tap Changer present
 - Fixed secondary taps (95% to 105%, 2.5% steps), assume 102.5% secondary tap position



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Substation short circuit calculations-IDECO model

The screenshot shows the 'Network Properties' dialog box with the 'Source' tab selected. The fields are as follows:

Field	Value
Source type:	Equivalent (From Eq Database)
Device ID:	HASSAN
Name:	3
Operating Voltage:	33.0 kVLL
Source Node Name:	19614_HEAD
Zone:	UNDEFINED
Display:	Display as a node
X coordinate:	246599.459
Y coordinate:	211622.307

Buttons: OK, Cancel



Substation short circuit calculations-IDECO model


Network Properties

Network | Source | **Equivalent** | Demand | Limiting | Harmonic | Comments

Load Model

Model: **DEFAULT**

Configuration



Source Equivalent Voltages

Nominal: **33.0** kVLL ☒ **Balanced**

Operating: A: **1.0** B: **1.0** C: **1.0** p.u.

Angle: A: **0.0** B: **-120.0** C: **120.0** deg.

Utility Equivalent

Mode: **Short-Circuit Level**

MVA **X/R**

3-phase: **986.70987** **28.70973**

1-phase: **78.31** **0.51**

Load Equivalent

A B C Load Type:

kW **0.0** **0.0** **0.0** **kW & kvar**

kvar **0.0** **0.0** **0.0**

OK **Cancel**



Substation short circuit calculations-IDECO model

Exercise: Calculate short circuit MVA to model 132 KV source

- Model 132 KV source.
- Perform fault calculations using available SC MVA.
- Model substation transformer
- Simulate fault with transformer
- Compare fault levels if 132 KV and 33KV network
- Now, assume 2.5 % secondary tap position for load flow studies



Save Base Case

- Save your model as:

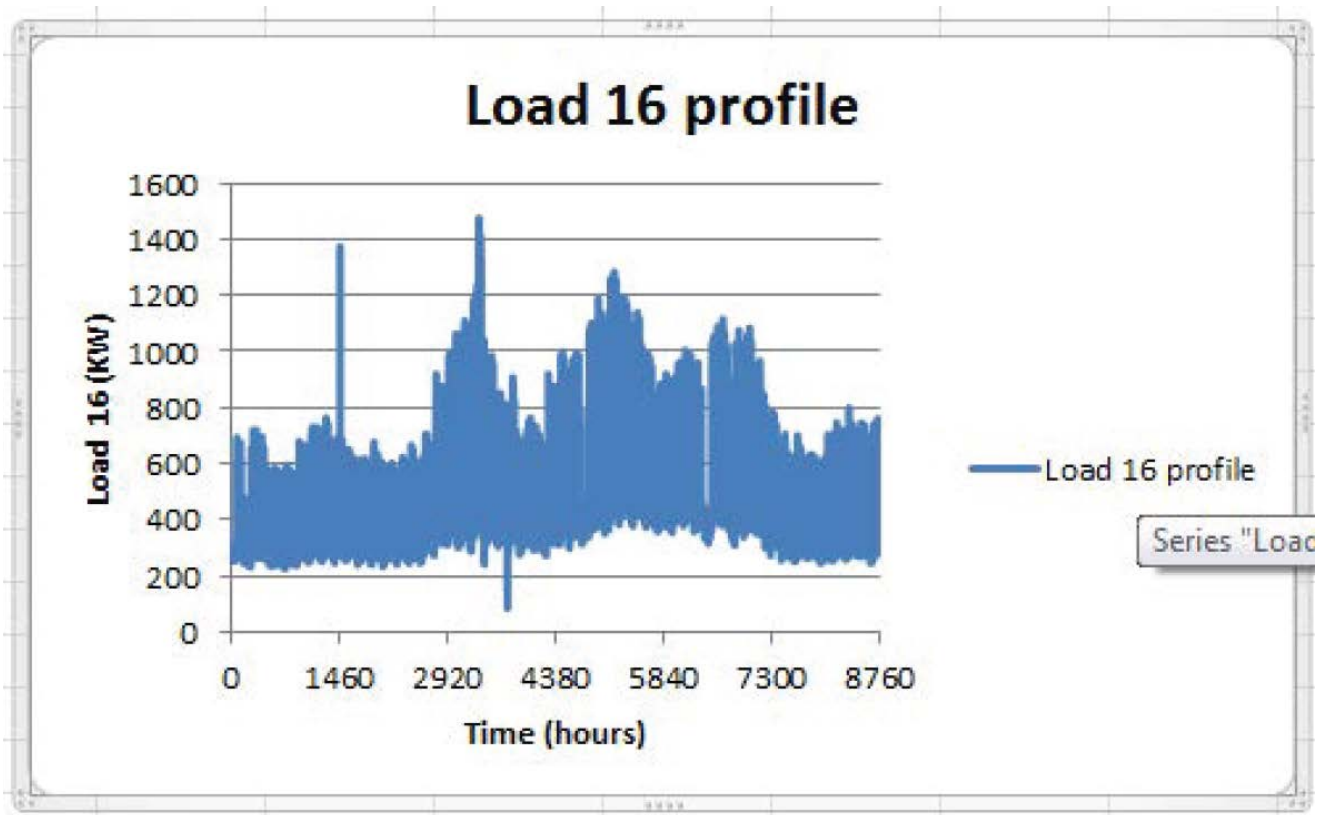


Work Flow

- Day 1:
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Load profile





Load Allocation

- Allocate the load in the circuit to match the meter demand
- Balanced/Unbalanced phase demand ?
- What format is the load data available in ?
- Loads can be classified according to customer type if necessary-to assign different load factor.
- Analyze the circuit in peak and day minimum load conditions for planning purposes.



Load Allocation

- What load data/ demand type is available ?
 - Substation load data ? (EDCO)
 - AMI data ? (IDECO)
 - Data resolution?
- Other requirements
 - Load power factor
 - Transformer taps
 - Shunt capacitors
- Specify demand at the substation (P,PF),(Amps,PF)
- Fix load power factor and allow source to swing



Load Allocation

Load Allocation Analysis

Load Model
DEFAULT

Networks and Meters
Feeder
L_SWAQAH

Allocation Method
Actual kVA

Load Flow Parameters
DEFAULT

Demand
Feeder :
L_SWAQAH

☒ Connected
kW-PF ☐ Total

A	3193.0	0.0
B	3193.0	0.0
C	3193.0	0.0

Factors...

Downstream Information

A	B	C	Total
4899.77	4899.77	4899.77	14699.32

Actual kVA

Save Run OK Cancel



Load Allocation

Load Flow Box

Transformer - 7

	kVLL	kVLN	i (A)	kVA	kW	kVAR	V(pu)	PF
A	33.3	19.2	48.9	3714.1	3170.8	1934.1	1.009	85.37
B	33.3	19.2	48.9	3714.1	3170.8	1934.1	1.009	85.37
C	33.3	19.2	48.9	3714.1	3170.8	1934.1	1.009	85.37
Total:				11142	9512	5802		

S C L

Bar chart icon | Plus icon | Edit icon | Refresh icon | Calculator icon | .00 +/- .00



Work Flow

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Reactive power capability

Exercise : Populate PF table



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 - Steady state snapshot analysis, Grid code compliance



Intermittent Renewable Resources-Distribution Connection Grid Code at medium voltage (IRR-DCC-MV)

- IRR-DCC-MV 5 Voltage Requirements:
 - Voltage step limit following sudden loss or start of IRR shall not exceed 3% measured at the PCC
 - Voltage Control at the PCC required
 - Power Factor Control at the PCC required (+/- 0.88 pf)
 - Full lagging capability required from 100% to 95% nominal voltage
 - Full leading capability required from 100% to 105% nominal voltage
 - OLTC required for transformers ?



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 - ***Steady state snapshot analysis, Grid code compliance***



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BEGIN MODELING



Load Flow Analysis Part 1 – Steady State Analysis

- (4) Study Cases Created:
 - Case 1: Peak Load, No PV
 - Case 2: Peak Load, Max PV
 - Case 3: Min Load, No PV
 - Case 4: Min Load, Max PV
- Power Factor Capability Analysis:
 - (3) Scenarios per Study Case
 - PV operating at 0.88 leading pf
 - PV operating at 1.0 pf
 - PV operating at 0.88 lagging pf



Load Flow Analysis Part 1 – Steady State Analysis

- Power Factor Capability/Control Analysis:
 - Voltage Step Limit Requirement:
 - Calculate step change in voltage between Case 1 and 2, and Case 3 and 4 for all scenarios, **PCC most important, but do for all nodes**
 - Losses:
 - Calculate losses for each of the runs, compare with and without PV
 - Reverse Power Flow:
 - Monitor power flow at the distribution substation for each case
 - Thermal Overloads:
 - Check overhead lines, cables , transformers against their current ratings (Rate A)



Load Flow Analysis Part 1 – Steady State Analysis

- Voltage Control Capability:
 - Study all (4) cases with the PVs operating in voltage control mode, determine whether voltage can be controlled to within 0.90 and 1.10 per-unit
 - Voltage Step Limit Requirement:
 - Calculate step change in voltage between Case 1 and 2, and Case 3 and 4 for all scenarios, **PCC most important, but do for all nodes**
 - Losses:
 - Calculate losses for each of the (12) runs, compare with and without PV
 - Reverse Power Flow:
 - Monitor power flow at the distribution substation for each case
 - Thermal Overloads:
 - Monitor power flow at the distribution substation for each case
 - PV Inverter Documentation Review:
 - Confirm PV inverters can supply full 0.88 leading reactive capability for voltages between 100% to 105%
 - Confirm PV inverters can supply full 0.88 lagging reactive capability for voltages between 100% to 95%



Snapshot Analysis -No PV (Basecase)

Section Properties

Section ID: 74

Phase: ☒ A ☒ B ☒ C

Zone: UNDEFINED

Environment: Unknown [More...](#)

Devices: [Add](#) [Remove](#)

- Nodes
 - Electronically Coupled Generator
 - Inverter
 - Inverter Controls
 - Long-Term Dynamic Curve
 - Harmonic Model

Electronically Coupled Generator

Id: DEFAULT

Number: 74-1

Status: Connected

Location: Stage: Undefined

Settings

Grid-Side Output Generation

Load Model: DEFAULT

Rated Power: 1260.0 kVA

Active Generation: 0.0 kW

Short-Circuit Fault Contribution

☒ Percentage: 150.0 % of Rated Current

☐ Current: 2727.98 A

[Profiles...](#)

[Collapse](#) [OK](#) [Cancel](#)



Snapshot Analysis-Max PV

Section Properties

Section ID: INV1

Phase: ☒ A ☒ B ☒ C

Zone: UNDEFINED

Environment: Unknown [More...](#)

Devices: [Add](#) [Remove](#)

- Nodes
 - Electronically Coupled Generator
 - Inverter
 - Inverter Controls
 - Long-Term Dynamic Curve
 - Harmonic Model

Electronically Coupled Generator

Id: 21*STP60

Number: INV1

Status: Connected

Location:

Stage: Undefined

Settings

Grid-Side Output Generation

Load Model: DEFAULT

Rated Power: 1260.0 kVA

Active Generation: 1100.0 kW

Profiles...

Short-Circuit Fault Contribution

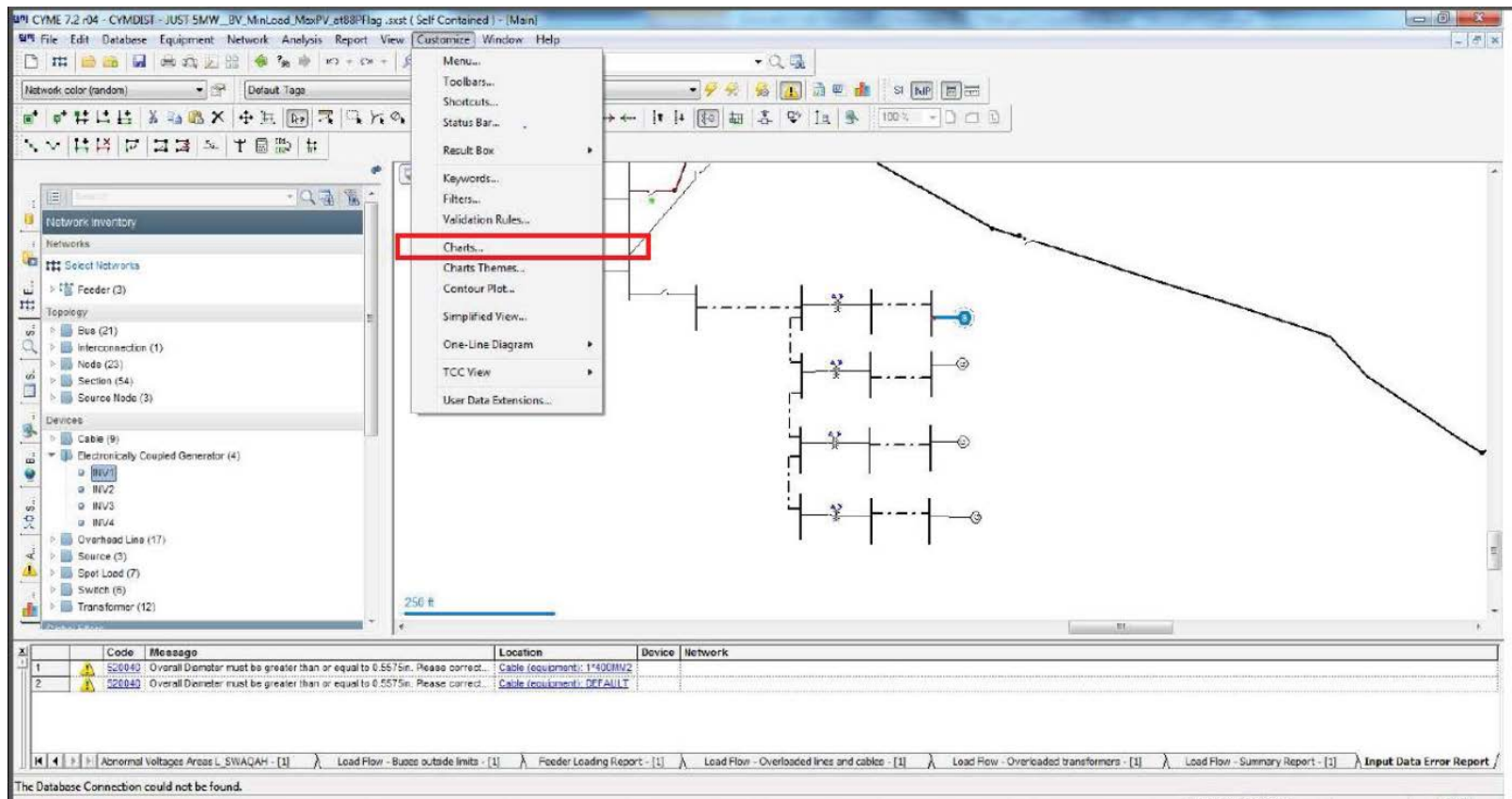
☒ Percentage: 150.0 % of Rated Current

☐ Current: 2727.98 A

[Collapse](#) [OK](#) [Cancel](#)



Snapshot Analysis- Voltage Profile





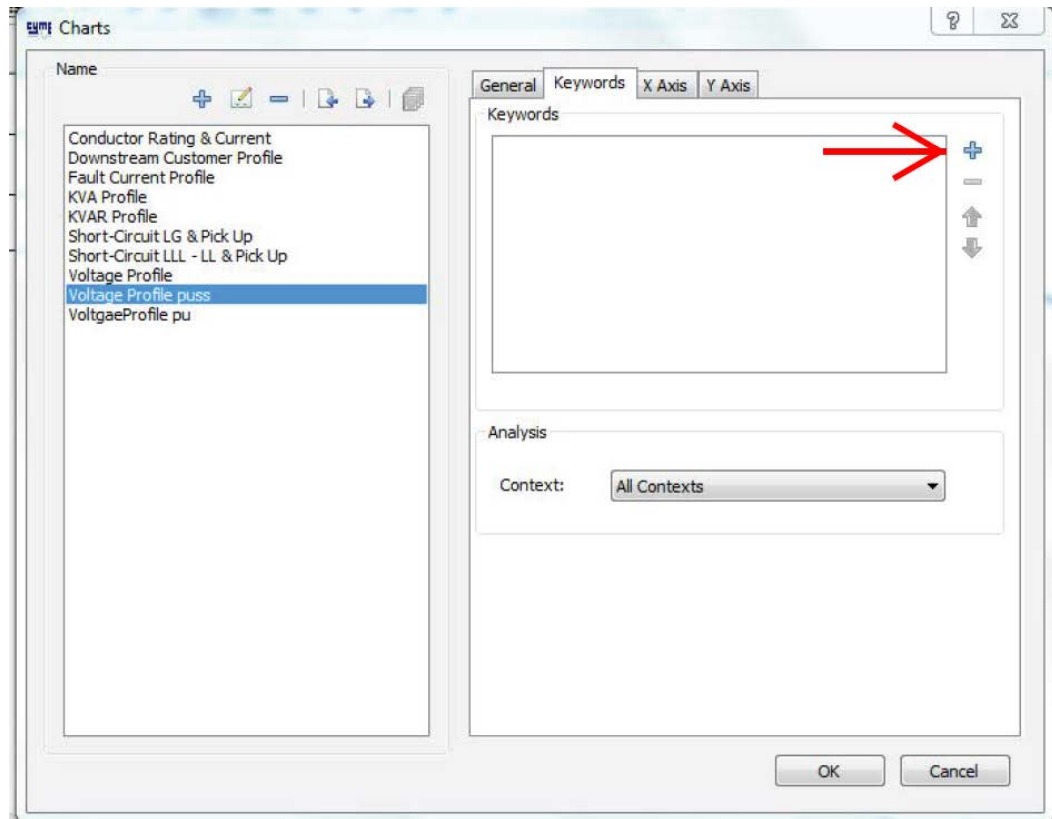
Snapshot Analysis- Voltage Profile

The screenshot displays the CYME 7.2 software interface. The main window shows a network diagram with various components like buses, cables, and transformers. A 'New Chart' dialog box is open, allowing the user to select a chart type and enter a name. The 'Name' field contains 'Voltage Profile pu'. The 'Chart Type' dropdown is set to 'Scatter with lines'. The 'Text' section has checkboxes for 'Title' and 'Subtitle', both of which are checked. The 'General' tab is selected in the dialog box. The background network diagram shows a complex system with multiple buses and cables. The status bar at the bottom of the window displays several error messages, including 'Overall Diameter must be greater than or equal to 0.5575in. Please correct...' and 'Cable equipment: 176000M2'. The system tray at the bottom shows the date and time as 10:59 PM on 12/1/2016.

Code	Message	Location	Device	Network
520040	Overall Diameter must be greater than or equal to 0.5575in. Please correct...	Cable equipment: 176000M2		
520040	Overall Diameter must be greater than or equal to 0.5575in. Please correct...	Cable equipment: DEFAULT		

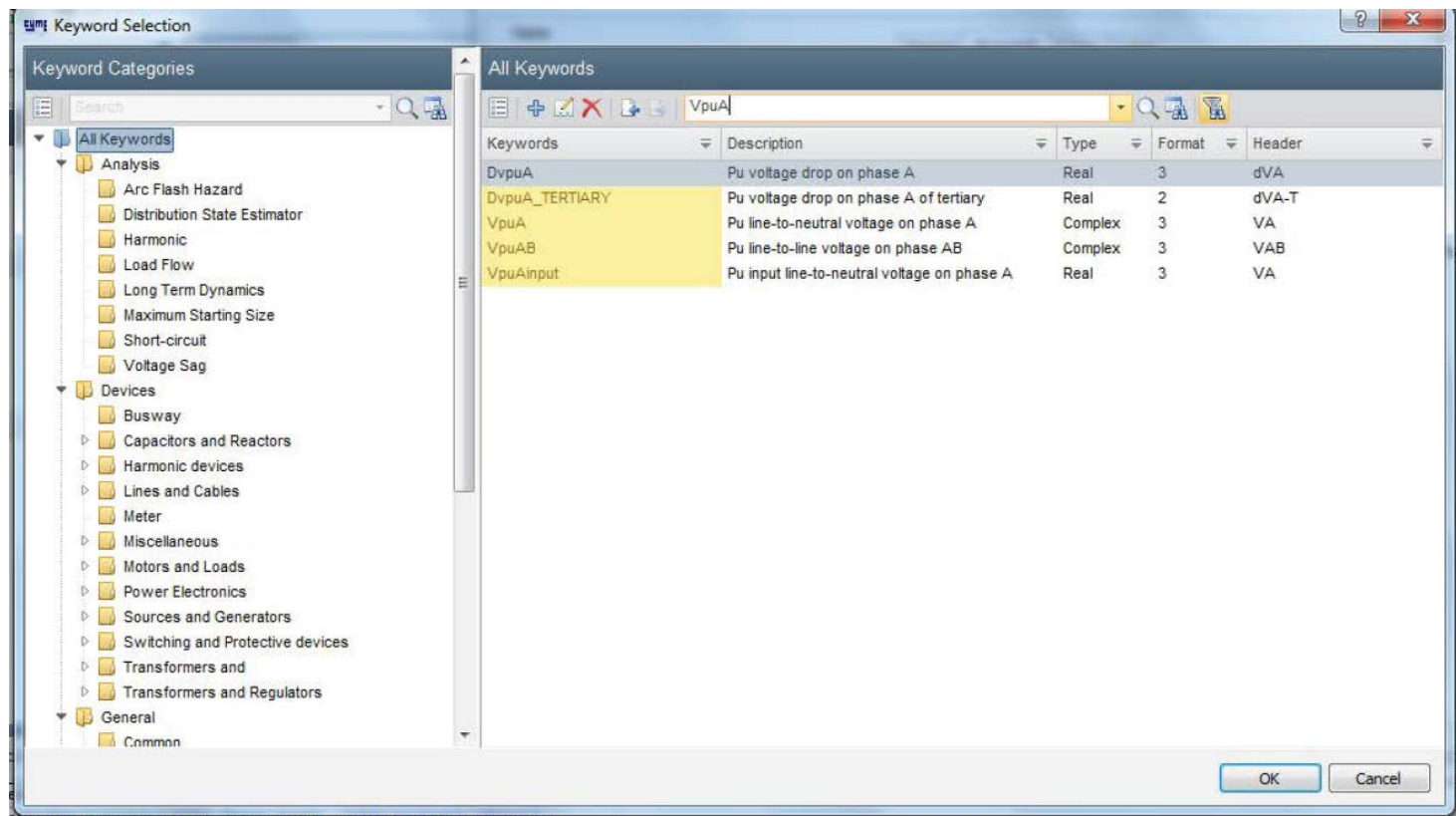


Snapshot Analysis- Voltage Profile





Snapshot Analysis- Voltage Profile





Snapshot Analysis- Voltage Profile

Chart Selector

Display

Destination: New Chart

Theme: DEFAULT

Results

Search

Load Flow

- ☐ Conductor Rating & Current
- ☐ KVA Profile
- ☐ KVAR Profile
- ☒ Voltage Profile

All Contexts

- ☐ Downstream Customer Profile
- ☒ VoltageProfile pu

X-Axis

Distance from source

Series

- ☐ VpuA
- ☐ VpuB
- ☐ VpuC

Apply on

ALHASSAN

☐ Enable Filter

Commercial Cust.

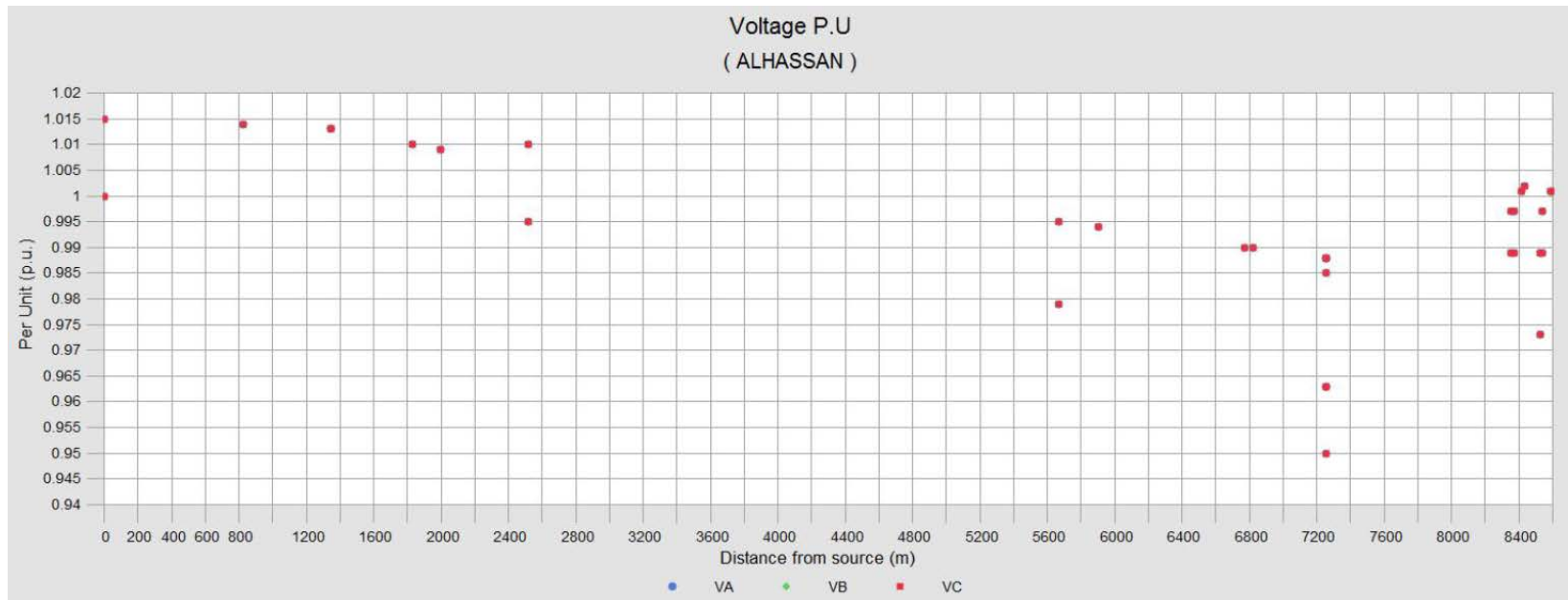
Result Set

Display

Close



Snapshot Analysis- Voltage Profile





Snapshot Analysis- Exporting Reports

Options

☒ Display iterations report☐ Display the summary status dialog
☐ Only on non-convergence
☐ Use same iterations report

Reports

☒ Select
Load Flow - Abnormal Voltages Areas
Load Flow - Buses outside limits
Load Flow - Feeder loading
Load Flow - Overloaded lines and cables
Load Flow - Overloaded transformers
Load Flow - Summary Report

+ Add

- Remove

One-Line-Diagram Result Tags

☐ Select
Conductor Tags

One-Line-Diagram Color Coding

☐ Select



Step Voltage Requirement

- Calculate step voltage change at the PCC
- Analyze with no PV and Max PV
- Compare against IRR-DCC-MV 5 Voltage Requirements.



Step Voltage Requirement

Group Properties

Types

☒ Devices ☐ Sections ☐ Nodes ☐ Buses ☐ Networks

Properties

Type	Device Type	Name	Phase	Section	Device ID	Status
Device	Electronically Coupled	INV3	ABC	INV3	21*STP60	Connected
Device	Electronically Coupled	INV4	ABC	INV4	21*STP60	Connected
Device	Electronically Coupled	INV1	ABC	INV1	21*STP60	Connected
Device	Electronically Coupled	INV2	ABC	INV2	21*STP60	Connected

Reset Column Filters ☒ Show only the selected items

Apply Cancel



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Snapshot Analysis-Reverse power flow

- Plot KWTOT at the substation



Snapshot Analysis

- Repeat analysis for 0.88 PF lead and lag.
- Repeat analysis for Max Load.
- Tabulate the results and compare.



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Quasi steady state analysis-Time series analysis

- Why is quasi steady state analysis needed ?
- Need to study coincident PV analysis
- Help identify the time dependent aspects of power flowing in distribution systems
- Captures interaction between changing load and PV output.
- 8760 (hourly analysis) done for this study.

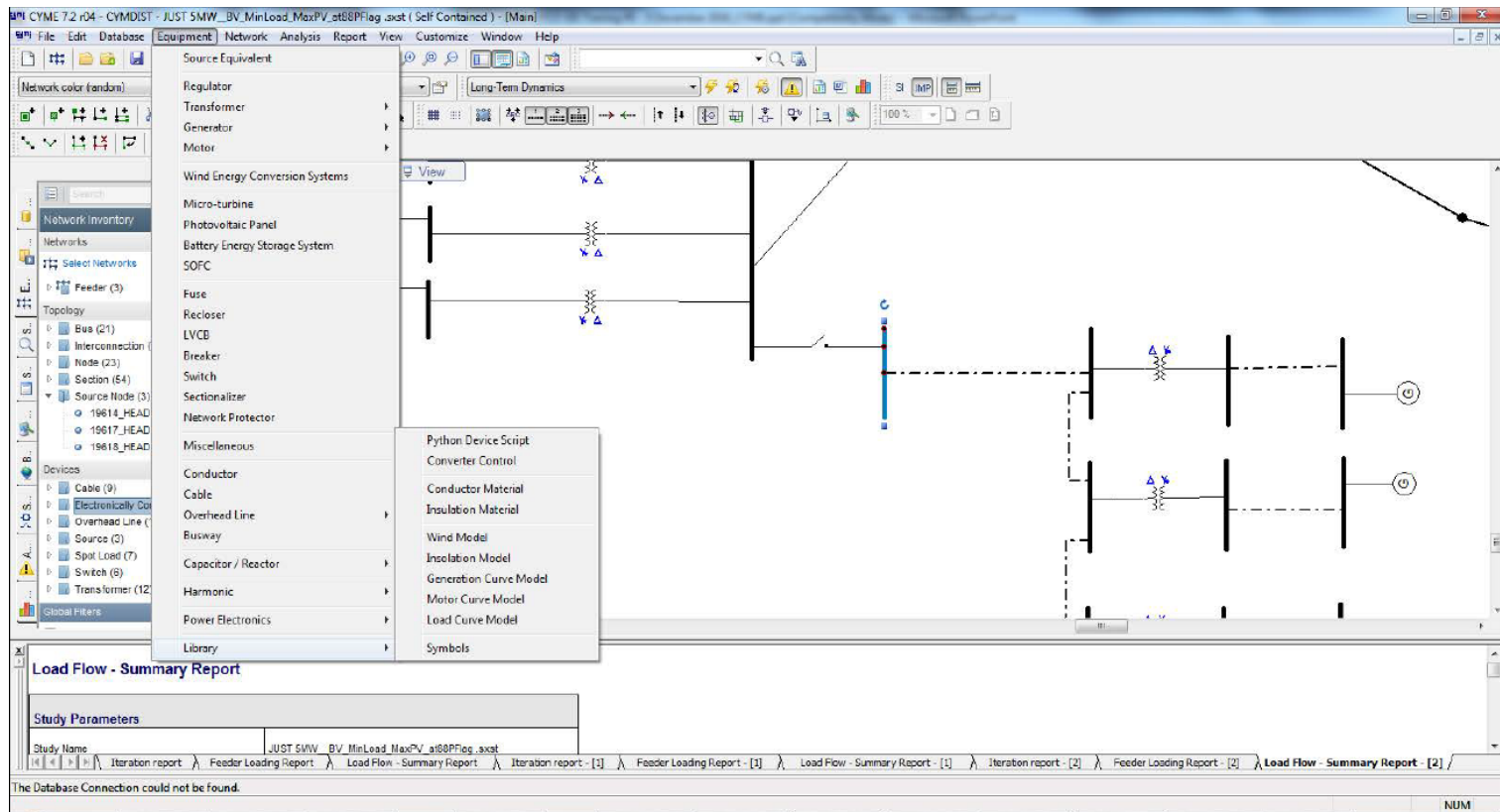


Quasi steady state analysis-Long term dynamics

- Setting up the model
- Defining load and generation curves in the library
- Assigning the curves
- Visualizing results
 - Voltage profile of the feeder
 - Power flow at the substation
 - Power factor at the substation
 - Voltage regulation and status of voltage regulating equipment ?



Long term dynamics-Adding curves to the library





Long term dynamics-Assign curves to loads and generators

Customer Types

Name

- Commercial
- Industrial
- Other
- Residential
- domestic

Load Flow Load Allocation Long-Term Dynamics Harmonic Properties

Long-Term Dynamics Curve Model

Adjustment: Adjust using Load Curve Model

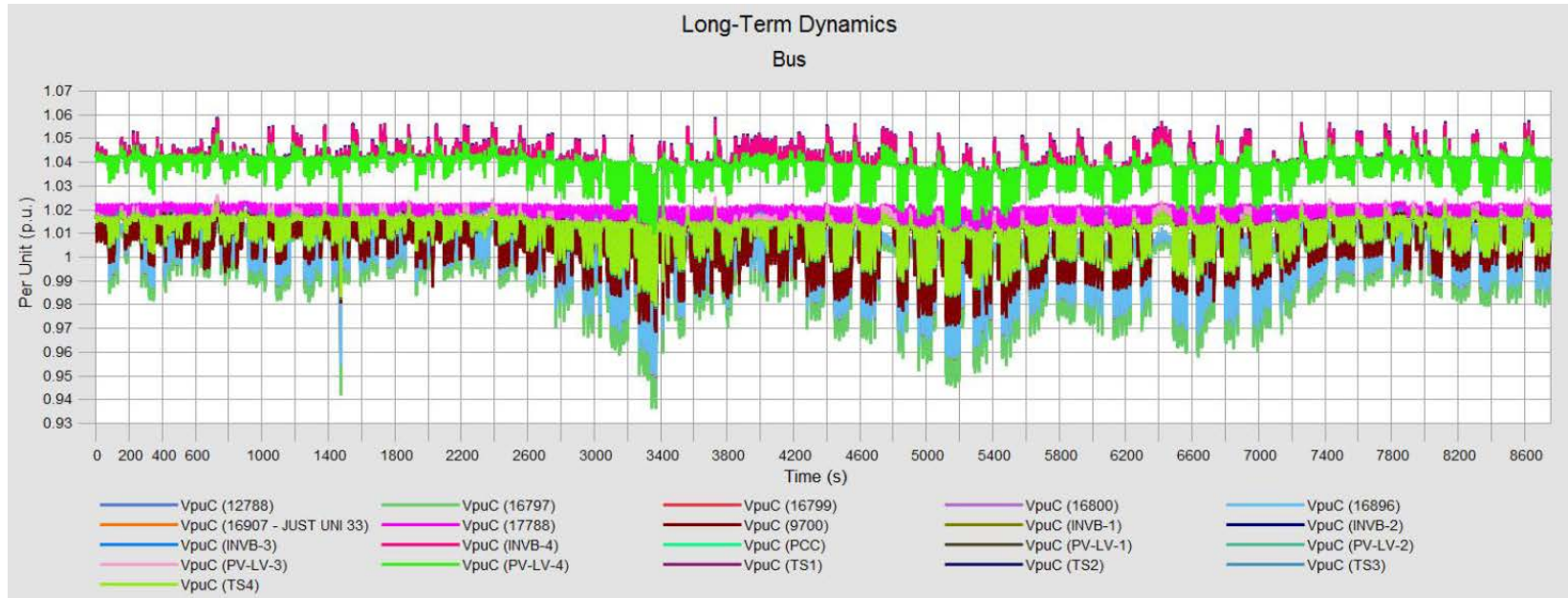
Curve Type: P, PF

Model Id: DEFAULT

+ Add - Remove OK Cancel

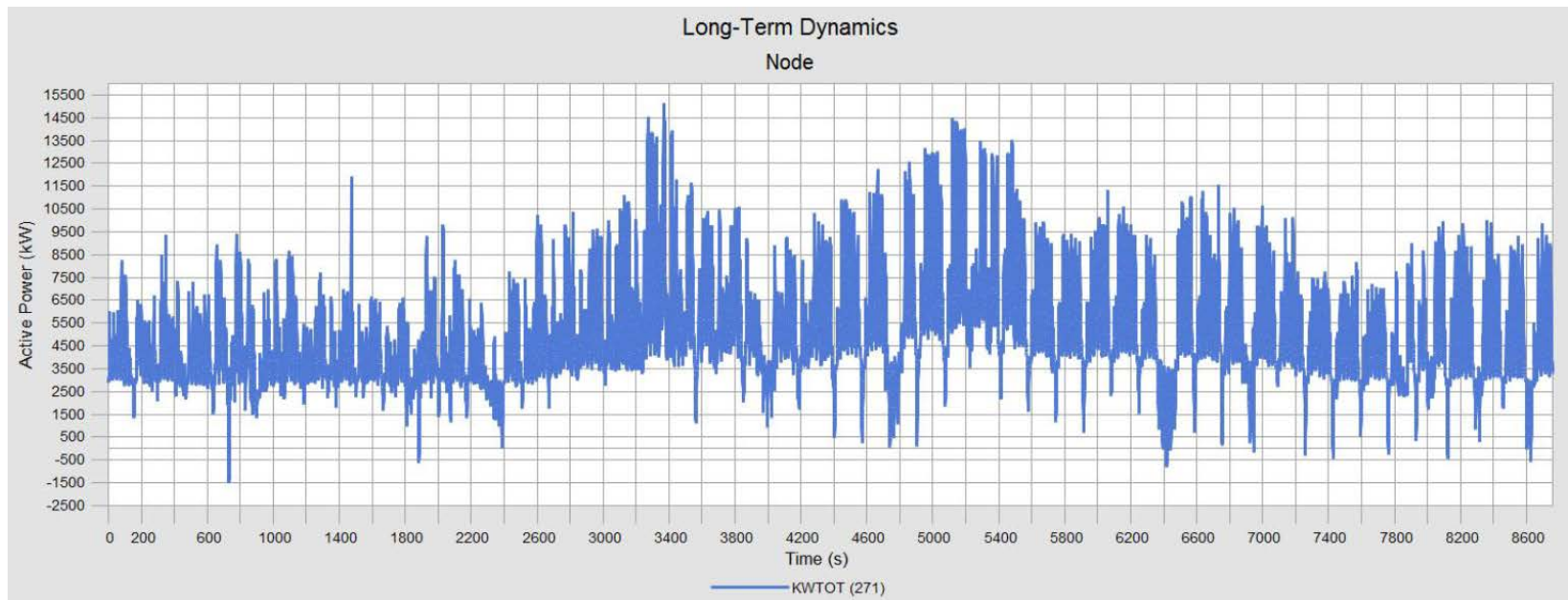


Visualizing results-Voltage Profile



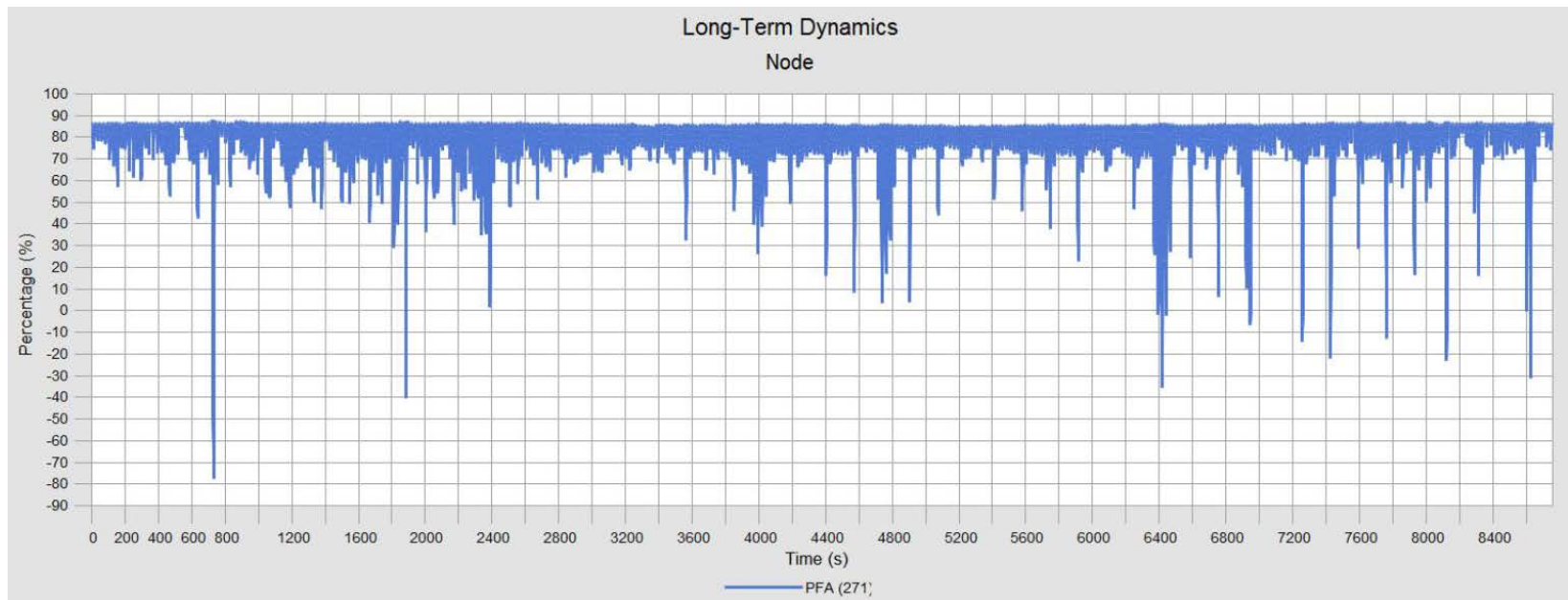


Visualizing results-Active power at the substation





Visualizing results-Power factor at the substation





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Short Circuit Study

- Compute fault current contribution from the project



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Comparing Shadow Study Results