

# Energy Sector Capacity Building (ESCB)

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

5 December 2016



# Agenda

- Introductions
- Morning Session
  - 9:15 1:00 PM: Setting up the Model
    - Review Existing Feeder Model
    - Project Background
    - Model Updates
    - Review Load/Generation Data

#### Afternoon Session

- 2:00 3:00 PM: Load Flow Analysis Part 1 Steady State
  - Criteria Review
  - Study Cases
  - Analysis
- 3:00 3:30 PM: Comparing Shadow Study Results



#### **Review Existing PSS SINCAL Feeder Model**





# Q.A.A. NEPCO





# **Q.A.A. EXTENDED NEPCO**



![](_page_5_Picture_0.jpeg)

#### **AL-DESSIE MAIN**

![](_page_5_Figure_2.jpeg)

![](_page_6_Picture_0.jpeg)

## **AL-ANDALOSIEH MAIN**

![](_page_6_Figure_2.jpeg)

![](_page_7_Picture_0.jpeg)

#### **MADABA SOUTH**

![](_page_7_Figure_2.jpeg)

![](_page_8_Picture_0.jpeg)

## Q.A.A. NEPCO

![](_page_8_Figure_2.jpeg)

![](_page_9_Picture_0.jpeg)

![](_page_9_Figure_1.jpeg)

![](_page_9_Figure_2.jpeg)

![](_page_10_Picture_0.jpeg)

#### **Q.A.A. Extended NEPCO**

![](_page_10_Figure_2.jpeg)

![](_page_11_Picture_0.jpeg)

![](_page_11_Figure_1.jpeg)

![](_page_12_Picture_0.jpeg)

#### **AL DESSIE MAIN**

![](_page_12_Figure_2.jpeg)

![](_page_13_Picture_0.jpeg)

![](_page_13_Figure_1.jpeg)

![](_page_14_Picture_0.jpeg)

# **AL ANDALOSIEH MAIN**

![](_page_14_Figure_2.jpeg)

![](_page_15_Picture_0.jpeg)

![](_page_15_Figure_1.jpeg)

![](_page_16_Picture_0.jpeg)

# **Review Existing PSS SINCAL Feeder Model**

• Open "AJIB BANK STUDY-SINCAL MODEL.sin"

## • Questions:

- 1. What is the source voltage in percentage of nominal?
- 2. What is the system short circuit MVA?
- 3. What is the load power factor?
- 4. What load condition does this model represent?
- 5. How is voltage regulation achieved?
- Perform a load flow simulation

![](_page_17_Picture_0.jpeg)

#### **Perform Load Flow Simulation**

S AJIB BANK STUDY-SINCAL MODEL_Peak_noPV - PSS SINCAL										
File Edit View Insert Data Calculate Tools Table Extras Window Help										
i 🗅 📂 🖬 🗛   🕰 🖂   🗈 🖌 📟	, 🎒 🗈 👷 Settings 📰 🏨 🗐 🍵 🖀 🚼 🌏 🗸									
	Methods	🚓 🛪 🔲 🔹 📜 Arial								
i 🔓 • 🗕   S 🖲 📾 A I 🗌	Load Flow	Standard H								
	Short Circuit	Load Profile								
Toolbox P ×	Results •	Load Profile (Maximum)								
Standard	🗌 🖙 🕶 Default	Load Development								
🖓 🖓 Σ	a 🔲 Input Data	Scenarios								
	▲ TO Topology	ŋ								
	O Node	Contingency Analysis								
	O Network	Transfer Capacity								
	⊖ Terminal									

![](_page_18_Picture_0.jpeg)

## **Project Background**

- The Arab Investment Bank of Jordan (AJIB) is developing 3600 kVA PV plant in south Amman
- Seeking "Power Wheeling" mechanism in Jordan's distribution network
- Project designed to not exceed AJIB load

![](_page_18_Figure_5.jpeg)

Figure 4-1: Expected PV Power and Consumption of AJIB

![](_page_19_Picture_0.jpeg)

# **Project Background**

- Project Details:
  - New 33 kV switching station between Madaba and Amman
  - 6 km from the Al-Dessie Main 33 kV switching station
  - 3.5 km from the Al-Andalosieh Main 33 kV switching station (Al-Andalosieh Main end normally opened)

![](_page_20_Picture_0.jpeg)

![](_page_20_Figure_1.jpeg)

![](_page_21_Picture_0.jpeg)

#### System One-Line Diagram in PSS SINCAL

![](_page_21_Figure_2.jpeg)

![](_page_22_Picture_0.jpeg)

#### System One-Line Diagram in PSS SINCAL

![](_page_22_Figure_2.jpeg)

![](_page_23_Picture_0.jpeg)

# **Equipment Details**

- AJIB Plant Data
- PV Modules
- Inverter Data
- Inverter SC Data

AJIB PV Power Plant	Data
Installed capacity (DC peak power)	3,910.92 kWp
Total power (AC) nom. inverter output	3,600 kVA AC
Number of strings	920
PV Modules	
Manufacturer	Sunpower
Module type	SPR-X20-327-COM
Nominal power at STC	327 Wp
Technology	Monocrystalline
Number of modules	11,960
Number of modules per string	13
Mounting Structure	
Manufacturer	-
Orientation	East/West (Azimuth 88.4°, -91.6°)
Installation type	Fixed
Inclination	10°
Row distance	3 m
Inverters	and the second second second
Inverter manufacturer	SMA
Inverter type	Sunny Tripower 60
Nominal output power	60 kVA
Number of inverters	60
Number of strings per inverter	15 x 40 / 16 x 20
Voltage	400 V (3 phase)
Frequency	50 Hz
Cabling	
DC ohmic losses	0.5% (STC)
AC losses	1.5% (STC)
Transformer	
Transformer manufacturer	Siemens
Transformer type	0.4 kV / 33 kV
Nominal power	1,800 kVA

![](_page_24_Picture_0.jpeg)

#### **Review Load Data**

- Load and generation profiles required to perform steady state analysis
- Identify the peak and minimum load date and time
- 8760 branch flows provided by JEPCO

   1/11/2015 1/11/2016
- Peak/Minimum load date and time identified in "MODEL LOADS.txt"
- Composite load profiles will be created and discussed during the Long-Term Dynamics training

![](_page_25_Picture_0.jpeg)

#### **Review Load Data**

- AL DESSIE 33KV LOAD PROFILE
- ANDALOSIEH 33KV LOAD PROFILE
- Q.A.A Ext. NEPCO 33KV LOAD PROFILE
- Q.A.A NEPCO 33KV LOAD PROFILE
- MODEL LOADS

![](_page_26_Picture_0.jpeg)

#### **Generator Profile**

- Solar data was not available at the time of the study
- Black & Veatch utilized the PV profiles from the IDECO project
- The IDECO profiles were per-unitized so they can be applied to this project
- <u>Generator Profile</u>

![](_page_27_Picture_0.jpeg)

- Include 132/33 kV transformer
- Update infeeder parameters

![](_page_27_Figure_4.jpeg)

![](_page_27_Figure_5.jpeg)

![](_page_28_Picture_0.jpeg)

# Setting up the Model: 132/33 kV Transformer

• Two-Winding Transformer parameter assumptions:

<ul> <li>Apparent Power Rating:</li> </ul>	100 MVA
<ul> <li>Impedance Voltage at Rated Current:</li> </ul>	6%
<ul> <li>R/X Ratio:</li> </ul>	4%
<ul> <li>Vector Group:</li> </ul>	DNY11

- Assume  $Z_1 = Z_0$
- Fixed secondary taps (95% to 105%, 2.5% steps)
- Adjust secondary tap position to maintain approximately nominal voltage at the 33 kV bus

![](_page_29_Picture_0.jpeg)

#### Setting up the Model:

## 132/33 kV Transformer

Start Node		N363		▶ ◀ W123 ▼
End Node		N4		▶ ◄
Element Name		2T279		
Network Level		High Volt	age (132 k\	- Generator Unit
Standard Type		(none)		<ul> <li>▼</li> <li>■ Out of service</li> </ul>
Transformer Data				Zero-Phase Sequence
Rated Voltage Side 1	Vn1	132.0	kV	
Rated Voltage Side 2	Vn2	33.0	kV	Zero/Pos. Impedance Z0/Z1 1.0 pu
Rated Apparent Power	Sn	100.0	MVA	Resistance/Reactance R0/X0 1.0 pu .
Full Load Power	Smax	100.0	MVA .	l
Ref. SC Voltage	vsc	6.0	%	
SC Voltage - Ohmic Part	vr	4.0	%	Neutral Point Imp. Side 2 Fixed Grounded
iron Losses	Vfe	0.0	kW	
No Load Current	iO	0.0	%	
Additional Rotation	φ	0.0	٠	
Vector Group		DYN11	•	

![](_page_30_Picture_0.jpeg)

•  $SC_{MVA} = 1039.4 MVA at 33 kV$ 

![](_page_30_Figure_3.jpeg)

![](_page_31_Picture_0.jpeg)

• 
$$S_{BASE} = 100 MVA$$

• 
$$I_{BASE} = \frac{100 \ MVA}{\sqrt{3} \ 33 \ kV} = 1749.5 \ A$$

• 
$$I_{F,pu} = \frac{18.2 \ kA}{1.75 \ kA} = 10.39 \ pu$$

![](_page_31_Figure_5.jpeg)

![](_page_32_Picture_0.jpeg)

• 
$$I_F = \frac{V}{X_S + X_T} = 10.39 \ pu = \frac{1}{X_S + X_T}$$

• 
$$X_S + X_T = 0.096 \, pu$$

• Assume  $X_T = 0.06$ 

• 
$$SC_{MVA,new} = \frac{V}{X_S} = \frac{1}{0.036} = 27.7 \ pu = 2777.7 \ MVA$$

![](_page_33_Picture_0.jpeg)

Node       Node       Node       Node       Node       III23 ▼         Element Name       I4       Equivalent Supp       Equivalent Supp       Out of service         Standard Type       (none) ▼ ▼       III23 ▼       Equivalent Supp         Short Circuit Power       Sk <sup>*</sup> 2,777.7       MVA       Sk <sup>*</sup> 1,000.0       MVA       Sk <sup>*</sup> 1,000.0       MVA         Resistance/Reactance       R/X       0.1       pu       R/X       0.1       pu       R/X       0.1       pu         Voltage Sk <sup>*</sup> vc       1.0       1       vc       1.0       1       vc       1.0       1         Operating State       0.0       %       NW       Nit.       Value React. Power       Pst       0.0       MW       Nit.       Value React. Power       Qst       0.0       *       Voltage       v       101.0       %         Zero-Phase Sequence       Grounding       Not grounded ▼       Maximum       Minimum       Minimum         Zero/Pos. Impedance       20/21       0.0       pu       R0/X0       0.0       pu         Resistance/Reactance       R0/X0       0.0       pu       R0/X0       0.0       pu <th></th>	
Element Name       I4         Network Level       High Voitage (132 kV) $\checkmark$ Standard Type $(none)$ $\checkmark$ $\bigcirc$ Short Circuit Power       Sk <sup>*</sup> 2,777.7       MVA       Sk <sup>*</sup> 1,000.0       MVA       Sk <sup>*</sup> 1,000.0       MVA         Short Circuit Power       Sk <sup>*</sup> 2,777.7       MVA       Sk <sup>*</sup> 1,000.0       MVA       Sk <sup>*</sup> 1,000.0       MVA         Resistance/Reactance       R/X       0.1       pu       R/X       0.1 <th< th=""><th></th></th<>	
Network Level       High Voltage (132 kV)       ▼         Standard Type       (none)       ▼         Out of service       Out of service         Short Circuit Power       Sk*       2,777.7         MVA       Sk*       1,000.0         Maximum       Minimum         Short Circuit Power       Sk*       2,777.7         MVA       Sk*       1,000.0       MVA         Resistance/Reactance       R/X       0.1       pu       R/X       0.1       pu         Voltage Sk*       vc       1.0       1       vc       1.0       1       vc       1.0       1         Internal Reactance       xi       0.0       %       NW       1.0       1       vc       1.0       1         Operating State       Load Flow Type       [vsrc] and δ       ▼       Init. Value Active Power       Pst       0.0       MWv         Init. Value React. Power       Qst       0.0       %       Voltage       Voltage       0       °         Voltage Angle       δ       0.0       °       Maximum       Minimum         Zero-Phase Sequence       Grounding       Not grounded       Maximum       Minimum         Zer	
Standard Type       (none)       ▼         Maximum       Minimum         Short Circuit Power       Sk*       2,777.7       MVA       Sk*       1,000.0       MVA       Sk*       1,000.0       MV/A         Resistance/Reactance       R/X       0.1       pu       R/X       0.1       pu       R/X       0.1       pu       R/X       0.1       pu         Voltage Sk*       vc       1.0       1       vc       1.0       1       vc       1.0       1         Internal Reactance       xi       0.0       %        1.0       1       vc       1.0       1         Operating State       Load Flow Type       [vsrc] and δ       ▼	ny
Maximum       Minimum         Short Circuit Power       Sk <sup>*</sup> 2,777.7       MVA       Sk <sup>*</sup> 1,000.0       MVA       Sk <sup>*</sup> 1,000.0       MVA         Resistance/Reactance       R/X       0.1       pu       R/X       0.1       pu       R/X       0.1       pu         Voltage Sk <sup>*</sup> vc       1.0       1       vc       1.0       1       vc       1.0       1         Internal Reactance       xi       0.0       %       -       1.0       1       vc       1.0       1         Operating State       -	
Short Circuit Power       Sk <sup>*</sup> 2,777.7       MVA       Sk <sup>*</sup> 1,000.0       MVA       Sk <sup>*</sup> 1,000.0       MVA         Resistance/Reactance       R/X       0.1       pu       R/X       0.1       pu       R/X       0.1       pu         Voltage Sk <sup>*</sup> vc       1.0       1       vc       1.0       1       vc       1.0       1         Internal Reactance       xi       0.0       %       •       1.0       1       vc       1.0       1         Operating State	
Resistance/Reactance       R/X       0.1       pu       R/X       0.1       pu       R/X       0.1       pu         Voltage Sk*       vc       1.0       1       vc       1.0       1       vc       1.0       1         Internal Reactance       xi       0.0       %       0.1       1       vc       1.0       1         Operating State       0.0       %       •       •       1.0       1       vc       1.0       1         Load Flow Type       [vsrc] and δ       •	
Voltage Sk <sup>∞</sup> vc       1.0       1       vc       1.0       1       vc       1.0       1         Internal Reactance       xi       0.0       %       0.0       1       vc       1.0       1         Operating State       Load Flow Type       [vsrc] and δ       ▼       0.0       MW         Init. Value Active Power       Pst       0.0       MW       1       1       Voltage Angle       δ       0.0       *         Voltage       n       101.0       %       0.0       Nvar       Voltage       Voltage       v       101.0       %         Zero-Phase Sequence         Grounding       Not grounded       Maximum       Minimum         Zero/Pos. Impedance       Z0/Z1       0.0       pu       Z0/Z1       0.0       pu         Resistance/Reactance       R0/X0       0.0       pu       R0/X0       0.0       pu	
Internal Reactance xi 0.0 % Operating State Load Flow Type  vsrc  and δ  Init. Value Active Power Pst 0.0 MW Init. Value React. Power Qst 0.0 MVvar Voltage Angle δ 0.0  Voltage v 101.0 % Zero-Phase Sequence Grounding Not grounded  Voltage Z0/Z1 0.0 pu Z0/Z1 0.0 pu Z0/Z1 0.0 pu Resistance/Reactance R0/X0 0.0 pu R0/X0 0.0 pu R0/X0 0.0 pu	
Operating State         Load Flow Type       [vsrc] and δ ▼         Init. Value Active Power       Pst       0.0       MW         Init. Value Active Power       Qst       0.0       Mvar         Voltage Angle       δ       0.0       °         Voltage       v       101.0       %         Zero-Phase Sequence         Grounding       Not grounded ▼       Maximum       Minimum         Zero/Pos. Impedance       Z0/Z1       0.0       pu       Z0/Z1       0.0       pu         Resistance/Reactance       R0/X0       0.0       pu       R0/X0       0.0       pu	
Load Flow Type  vsrc  and δ Init. Value Active Power Pst 0.0 MW Init. Value React. Power Qst 0.0 MVar Voltage Angle δ 0.0 Voltage v 101.0 % Zero-Phase Sequence Grounding Not grounded Zero/Pos. Impedance Z0/Z1 0.0 pu Z0/Z1 0.0 pu Resistance/Reactance R0/X0 0.0 pu R0/X0 0.0 pu Rolx0 0.0 pu R0/X0 0.0 pu	
Init. Value Active Power Pst 0.0 MW Init. Value React. Power Qst 0.0 Mvar Voltage Angle δ 0.0 ° Voltage v 101.0 % Zero-Phase Sequence Grounding Not grounded マ Maximum Minimum Zero/Pos. Impedance Z0/Z1 0.0 pu Z0/Z1 0.0 pu Z0/Z1 0.0 pu Resistance/Reactance R0/X0 0.0 pu R0/X0 0.0 pu R0/X0 0.0 pu	
Init. Value React. Power Qst 0.0 Mvar Voltage Angle δ 0.0 ° Voltage v 101.0 % Zero-Phase Sequence Grounding Not grounded マ Maximum Minimum Zero/Pos. Impedance Z0/Z1 0.0 pu Z0/Z1 0.0 pu Resistance/Reactance R0/X0 0.0 pu R0/X0 0.0 pu R0/X0 0.0 pu	
Voltage Angle δ 0.0 ° Voltage v 101.0 % Zero-Phase Sequence Grounding Not grounded = Maximum Minimum Zero/Pos. Impedance Z0/Z1 0.0 pu Z0/Z1 0.0 pu Resistance/Reactance R0/X0 0.0 pu R0/X0 0.0 pu R0/X0 0.0 pu	
Voltage     v     101.0     %       Zero-Phase Sequence     Maximum     Minimum       Grounding     Not grounded     Maximum     Minimum       Zero/Pos. Impedance     Z0/Z1     0.0     pu     Z0/Z1     0.0     pu       Resistance/Reactance     R0/X0     0.0     pu     R0/X0     0.0     pu	
Zero-Phase Sequence       Not grounded       Maximum       Minimum         Grounding       Not grounded       ✓       Maximum       Minimum         Zero/Pos. Impedance       Z0/Z1       0.0       pu       Z0/Z1       0.0       pu         Resistance/Reactance       R0/X0       0.0       pu       R0/X0       0.0       pu       R0/X0       0.0       pu	
Grounding     Not grounded     Maximum     Minimum       Zero/Pos. Impedance     Z0/Z1     0.0     pu     Z0/Z1     0.0     pu       Resistance/Reactance     R0/X0     0.0     pu     R0/X0     0.0     pu     R0/X0     0.0     pu	
Zero/Pos. Impedance         Z0/Z1         0.0         pu         Z0/Z1         0.0         pu         Z0/Z1         0.0         pu           Resistance/Reactance         R0/X0         0.0         pu         R0/X0         0.0         pu         R0/X0         0.0         pu	
Resistance/Reactance R0/X0 0.0 pu R0/X0 0.0 pu R0/X0 0.0 pu	

![](_page_34_Picture_0.jpeg)

#### **Check Short Circuit Calculation Settings**

S AJIB BANK STUDY-SINCAL MODEL_Base - PSS SINCAL										
File Edit View Insert Data	Cal	culate Tools	Format Extras Window Help							
: 🗅 💕 🖬 🗛 🗔 🎒 🖬 🕺	<b>D</b>	Settings	🔤 🛄 🗐 🍙 😭 🚼 🖓 🗸 🗄							
		Methods	Arial							
		Load Flow	►							
Toolbox 7×		Short Circuit	-SINCAL MODEL_Base × AJIB B							
		Results	•							
· · · · · · ·										

![](_page_35_Picture_0.jpeg)

#### **Check Short Circuit Calculation Settings**

	Infeeder 🕄 🛃							
	Basic Data Element Data Additional Data Controller							
Calculation Settings								
	Node Node L123 V							
Basic Data Load Flow Load Flow ext. Short Circuit	Element Name 14 Equivalent Supply							
	Network Level High Voltage (132 kV)							
Short Circuit Method VDE 0102/2002 - IEC 909/2001 👻	Standard Type (none) 🔻 🔻							
Short Circuit Data Type User Defined 🗸 Sym. Components 👻								
Temperature at End of SC User Defined	Maximum Minimum							
Peak Current Calculation Maximum n -	Short Circuit Power Sk 2,777.7 MVA Sk 1,000.0 MVA Sk 1,000.0 MVA							
Tripping Current Calculation IANEU VDE0102/1.90 - IEC 909 👻	Resistance/Reactance R/X 0.1 pu R/X 0.1 pu R/X 0.1 pu "							
	Voltage Sk" vc 1.0 1 vc 1.0 1 vc 1.0 1							
Options	Internal Reactance xi 0.0 %							
V Join Motors V Join Windpower								
V Join Photovoltaik	Operating State							
	Load Flow Type  vsrc  and δ 🔻							
Additional Fault Data	Init. Value Active Power Pst 0.0 MW							
	Init. Value React. Power Qst 0.0 Mvar							
	Voltage Angle δ 0.0 °							
	Voltage v 101.0 %							
	CZero-Phase Sequence							
	Grounding Not grounded V Maximum Minimum							
	Zero/Pos. Impedance 70/71 0.0 pu 70/71 0.0 pu							
	Periotance/Deactance P0//0 00 pu P0//0 00 pu P0//0 00 pu							
OK Cancel								
	OK Cancel							

![](_page_36_Picture_0.jpeg)

- Run Load Flow simulation
  - Check voltage at Q.A.A. NEPCO 33 kV bus
  - Check 132/33 kV transformer tap settings
  - Compare with original case

![](_page_37_Picture_0.jpeg)

wo-Winding Transformer									? 🛃
Basic Data Element Data	Additi	onal Data	Control	ler					
Start Node		N363				<b>н</b> н		W123 -	
End Node		N4				н н			
Element Name		2T279							
Network Level		High Volt	age (132	kV)	+	•		Conceptor	Init
Standard Type		(none)			<b>~</b>	•		Out of serv	ice
- /					7 8 6				
Transformer Data					Zero-Phase Seque	nce			<b>V</b>
Rated Voltage Side 1	Vn1	132.0	kV		Zero/Pos. Impedar	nce	Z0/Z1	1.0	u 🗌
Rated Voltage Side 2	Vn2	33.0	kV		Resistance/Reacta	nce	R0/X0	1.0	
Rated Apparent Power	Sn	100.0	MVA	_	neosonance, neuera				
Full Load Power	Smax	100.0	MVA						
Ref. SC Voltage	VSC	6.0	%						
SC Voltage - Ohmic Part	vr	4.0	%		Neutral Point Imp.	Side 2	•	Fixed Ground	led 🔻
Iron Losses	Vfe	0.0	kW						
No Load Current	iO	0.0	%						
Additional Rotation	φ	0.0	٠						
Vector Group		DYN11	-						
							_		
								ОК	Cancel

![](_page_38_Picture_0.jpeg)

eeder										?		
asic Data Element Data	Additi	onal Data	Contro	ller								
Node		NDCD					1					
Flement Name		14				, ,		.23 🔻				
Network Level		Equivalent Su					/					
Standard Type		(none)	aye (152	( KV)	-	•			Out of service			
Standard Type		(none)		•	•							
						Maximum			Minimum			
Short Circuit Power	Sk"	2,777.7	MVA		Sk"	1,000.0	MVA	Sk"	1,000.0	MVA	$\square$	
Resistance/Reactance	R/X	0.1	pu		R/X	0.1	pu	R/X	0.1	pu		
Voltage Sk <sup>+</sup>	vc	1.0	1		vc	1.0	1	vc	1.0	1	_	
Internal Reactance	xi	0.0	%									
Operating State												
Load Flow Type		vsrc  and	δ	-								
Init. Value Active Power	Pst	0.0	MW									
Init. Value React. Power	Qst	0.0	Mvar									
Voltage Angle	δ	0.0	۰									
Voltage	v	101.0	%									
Zero-Phase Sequence												
Grounding		Not grour	nded	-		Maximum			Minimum			
Zero/Pos. Impedance	Z0/Z1	0.0	pu		Z0/Z1	0.0	pu	Z0/Z1	0.0	pu		
Resistance/Reactance	R0/X0	0.0	pu		R0/X0	0.0	pu	R0/X0	0.0	pu		
								_				
									OK	Car	ncel	

![](_page_39_Picture_0.jpeg)

- Save your model as:
  - AJIB BANK STUDY-SINCAL MODEL\_Base.sin

![](_page_40_Picture_0.jpeg)

## **Review of MRR-DCC-MV Criteria**

- IRR must be able to operate in reactive power control mode and follow operating point within 0.88 lag power factor to 0.88 lead power factor at the PCC
- Full 0.88 lagging reactive capability shall be available at 100% to 95% of nominal voltage
- Full leading reactive capability of 0.95 power factor shall be made available at 100% to 105% of nominal voltage
- The reactive power support must be dynamic up to the plant's rated capacity
- Maximum step voltage change at PCC limited to 3%

![](_page_41_Picture_0.jpeg)

# Review of MRR-DCC-MV Criteria Required PQ Capability

![](_page_41_Figure_2.jpeg)

Figure 5-3 - Minimum PQ Diagram to be Fulfilled by IRR plant

![](_page_42_Picture_0.jpeg)

## Review of MRR-DCC-MV Criteria Voltage Tolerance at PCC

Voltage Range (% Vnominal)	Delay to Trip
V=119%	0.5s
V=114%	1s
$90 \le V \le 110$	Continuous Operation
V = 87%	2.5s
V = 81%	0.5s

Table 5-1 -IRR Plant Voltage Protection Setting Requirements at the PCC

![](_page_43_Picture_0.jpeg)

# Load Flow Analysis Part 1 – Steady State Analysis

- Steady State analysis is a static analysis:
  - Load flow calculations performed at fixed load and generation values...snapshot in time
- (4) Study Cases:
  - Case 1: minimum load, AJIB offline
  - Case 2: minimum load, AJIB at nameplate output
  - Case 3: peak load, AJIB offline
  - Case 4: peak load, AJIB at nameplate output
- Assess system performance with and without the AJIB PV plant

![](_page_44_Picture_0.jpeg)

# Load Flow Analysis Part 1 – Steady State Analysis

- (3) Scenarios per Study Case, (8) runs total
  - PV operating at 0.88 leading pf
  - PV operating at 1.0 pf
  - PV operating at 0.88 lagging pf
- Voltage Step Limit Requirement: Calculate step change in PCC voltage between Case 1 and 2, and Case 3 and 4 for all scenarios
- Calculate losses for each of the cases
- Monitor for reverse power flow at the distribution substation for each case
- Monitor all lines, cables, and transformers for thermal overloads for each case

![](_page_45_Picture_0.jpeg)

### **Create Study Cases**

- Open the model:
  - AJIB BANK STUDY-SINCAL MODEL\_Base.sin
- Create the following cases:
  - AJIB BANK STUDY-SINCAL MODEL\_\_Peak\_\_noPV
  - AJIB BANK STUDY-SINCAL MODEL\_\_Peak\_\_MaxPV\_\_100
  - AJIB BANK STUDY-SINCAL MODEL\_\_Peak\_\_MaxPV\_\_88lag
  - AJIB BANK STUDY-SINCAL MODEL\_\_\_Peak\_\_\_MaxPV\_\_\_88lead
  - AJIB BANK STUDY-SINCAL MODEL\_\_\_Min\_\_\_noPV
  - AJIB BANK STUDY-SINCAL MODEL\_\_\_Min\_\_\_MaxPV\_\_\_100
  - AJIB BANK STUDY-SINCAL MODEL\_\_Min\_\_MaxPV\_\_88lag
  - AJIB BANK STUDY-SINCAL MODEL\_\_Min\_\_MaxPV\_\_88lead
- Load data available in MODEL LOADS.txt

![](_page_46_Picture_0.jpeg)

## **Update Load Data in PSS SINCAL**

• Check the Tabular View (F9) to see the load levels

S A	S AJIB BANK STUDY-SINCAL MODEL_Peak_noPV - PSS SINCAL										
File	Edit	View	Insert	Data	Calculate	Tools	Table	Extras	Window	Help	
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![](_page_47_Picture_0.jpeg)

S AJIB BANK STUDY-SINCAL MOD	ELPeaknoPV - PSS SINCAL										
File Edit View Insert Data	Calculate Tools Table Extras Window	н	elp								
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		Τ.	0.00.0.1.1								
Toolbox 9 ×	AJIB BANK STUDY-SINCAL MODEL	ak i		NK STUDY-SING	AL MODEL Pea	k noPV - Tabu	lar View >				
Standard		9	V A Z I		Σ						
_		۳ ۱۳	→   Z * A *   □	a 7v3   + +	-						
Lip μ <sub>2</sub> Σ	Input Data		Node 1	Element Name	Network Level	Load Type	Load Flov				
	Node		NI4	10170	Mardiner Mathema	land	Dand O a				
	Note     Network Element		N4	10170	Medium Voltage	Load	Pand Q o				
			INO NO	10170	Medium Voltage	Load	Pand Q o				
			NA	10170	Medium Voltage	Load	Pand Q o				
			N26		Low Voltage	Load	Pand Q o				
	INE Node Flowerst		N26	هرير تنبي ار الهد	Low Voltage	Load	Pand Q d				
			N26		Low Voltage	Load	Pand Q o				
	Integer		N26		Low Voltage	Load	P and Q o				
	• Load		N26		Low Voltage	Load	P and Q o				
	O DC-Infeeder		N26		Low Voltage	Load	P and O o				
	BE Branch Element		N26		Low Voltage	Load	P and O o				
	DA Additional Data		N26		Low Voltage	Load	P and Q c				
	Results		N26		Low Voltage	Load	P and Q o				
	Database Queries		N26		Low Voltage	Load	P and Q c				
			N26		Low Voltage	Load	P and Q o				
			N26		Low Voltage	Load	P and Q o				
			N26		Low Voltage	Load	P and Q o				
			N26		Low Voltage	Load	P and Q o				
			N26		Low Voltage	Load	P and Q c				

![](_page_48_Picture_0.jpeg)

- 33 kV loads specified as current, power factor, and voltage (I, cos(θ), and V)
  - 33 kV loads assumed to have 0.92 power factor
  - Current levels specified in MODEL LOADS.txt
- 0.415 kV loads specified as a factor of total connected kVA
  - 0.415 kV loads assumed to have 0.90 power factor
  - fS = 0.16 for peak load conditions
  - fS = 0.11 for minimum load conditions
  - Based on observance of current flows from:
    - Q.A.A. Extended NEPCO
    - AL ANDALOSIEH MAIN

![](_page_49_Picture_0.jpeg)

• Updating 33 kV loads

	Node 1	Element Name	Network Level	Load Type	Load Flow Type	Load Input	P [kW]	Q [Mvar]	v [%]	V [kV]	S [MVA]	cosφ	l [kA]
►	N4	LO170	Medium Voltage	Load	P and Q const 🔻	I, cosφ and V				33.00		0.92	0.853
	N8	LO170	Medium Voltage	Load	P and Q const	I, cosφ and V				33.00		0.92	0.087
	N8	LO170	Medium Voltage	Load	P and Q const	I, cosφ and v			100.0			0.97	0.261
	N4	LO170	Medium Voltage	Load	P and Q const	I, cosφ and V				33.00		0.92	0.577
	N26	مركز صحي ام التمد	Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.250	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.400	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.250	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.100	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.250	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.100	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.250	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.050	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.050	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.100	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.050	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.100	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.500	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.500	0.90	
	N26		Low Voltage	Load	P and Q const	S, cosφ and V				0.41	0.250	0.90	$\checkmark$

![](_page_50_Picture_0.jpeg)

• Updating 0.415 kV loads:

l [kA]	E [MWh]	t [s]	EP [kWh]	EQ [kvarh]	Pi [kW]	Qi [kvar]	fP	fQ	fS
0.853									
0.087									
0.261									
0.577									
									0.16
									0.16
									0.16
									0.16
									0.16
									0.16
									0.16
									0.16
									0.16
									0.16
									0.16
									0.15
									0.16
									0.16
									0.16

![](_page_51_Picture_0.jpeg)

## Solve Load Flow and Confirm Load Levels

Run Load Flow simulation

![](_page_51_Picture_3.jpeg)

![](_page_52_Picture_0.jpeg)

#### **Run Load Flow Studies on Study Cases**

• Objective is to populate this table of results:

Control Mode	Inverter PF	Inverter (MW)	Inverter (MVA)	PCC PF	PCC Voltage	PCC Voltage Step Change (%)	Feeder Load (Peak/Min)	Feeder Losses (MW)	Thermal Overload s (Y/N)	Reverse Power Flow (Y/N)	Acceptabl e (Y/N)	Notes
N/A	N/A	0.00										
Power Factor	1.00	3.60										
Power Factor	0.88	3.60										
Power Factor	-0.88	3.60										
N/A	N/A	0.00										
Power Factor	1.00	3.60										
Power Factor	0.88	3.60										
Power Factor	-0.88	3.60										

Open Load Flow Results Summary (BLANK).xlsx

![](_page_53_Picture_0.jpeg)

## Load Flow Analysis Part 1 – Steady State Peak Load, No PV

- This scenario constitutes the pre-project case
- Open the model:
  - AJIB BANK STUDY-SINCAL MODEL \_\_\_\_Peak\_\_\_noPV.sin
- Run Load Flow simulation
- Populate the relevant results into summary table
- Extract system results to spreadsheet

![](_page_54_Picture_0.jpeg)

#### **Confirm Load Flow Settings**

cul	lati	on	Setti	na	s	
				_		

oad Flow Procedure	Newton-Ra	🔹 🗖 Flat Sta	rt						
Store Results	Due to me		ow Change						
Extended Calculations	None		culate						
Imped. Load Conversion	No	•	Enable Controllers	Yes	•				
Max. Number of Iterations	200		Island Operation	Yes	•				
Voltage Limit Load Reduction	90.0	%	LF Speed Factor	1.0	1				
Power Accuracy	1.0	%	Min. Power Accuracy	0.001	MVA % %				
Mesh Accuracy	0.01	%	Node Accuracy	0.01					
Voltage Lower Limit	90.0	%	Voltage Upper Limit	110.0					
Element Utilization Limit	100.0	%	Line Utilization Limit	95.0	%				
Settings for Controlling									
Activate Transformer Tap Cha	anger		🔲 Activate Generator Cont	rolling					
🔲 Activate Shunt Tap Changer			📝 Activate Area Interchange						
📝 Acitvate Load Shedding		Activate Redistribute Power							

![](_page_55_Picture_0.jpeg)

# Load Flow Analysis Part 1 – Steady State Peak Load, No PV

- Perform Load Flow simulation
- What is the power factor at the PCC?
- What is the voltage in percent at the PCC?
- What are the total feeder losses?
- Are there any thermal overloads?
- Is there reverse power flow at the Q.A.A. NEPCO station?
- Does this scenario comply with the IRR-DCC-MV requirements?

![](_page_56_Picture_0.jpeg)

#### **Checking the Power Factor and Voltage at the PCC**

![](_page_56_Figure_2.jpeg)

![](_page_57_Picture_0.jpeg)

#### **Determine Total Feeder Losses**

![](_page_57_Figure_2.jpeg)

![](_page_58_Picture_0.jpeg)

#### **Check for Thermal Overloads**

AJIB BANK STUDY-SINCAL MODEL_Pea	ak_no	PV AJIB BAN	K STUDY-SINCA	L MODEL_Peak	_noPV - Tabula	r View x							
🔲 🖙 🕶 Default 📼 🎸	Y W		δ										
🔺 📰 Input Data		dV	dø	<b>Mb</b>	I/Ib1	l/lb2	I/Ib3	lbp	l/lbp	lbs	l/lbs	Sb	S/Sb
▲ TO Topology		[kV]	[°]	[%]	[%]	[%]	[%]	[kA]	[%]	[kA]	[%]	[MVA]	[%]
O Node		8.381	1.664	106.875	0.000	0.000	0.000	0.437	105.817	1.750	100.778	100.000	106.876
O Network Element		2.200	-1.664	100.871	0.000	0.000	0.000	0.437	105.817	1.750	100.778	100.000	100.871
<ul> <li>Terminal</li> </ul>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	100.000
O Network Level		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	100.000
<ul> <li>Network Area</li> </ul>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	100.000
▲ ME Node Element		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	4.973	100.000
<ul> <li>Infeeder</li> </ul>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	48.755	100.000
O Load		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	100.000
O DC-Infeeder		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.064	100.000
BE Branch Element		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	100.000
Additional Data		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	100.000
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	100.000
in the suits		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	100.000
Nede Perults (LE)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	100.000
O Node Results (LF)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	100.000
Branch Results (LF)		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	32.980	100.000
Power Data Result		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.016	100.000
O Power Balance Result		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	100.000
<ul> <li>Accuracy Result</li> </ul>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	14.918	100.000
<ul> <li>Subnetwork Losses Result</li> </ul>		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.040	100.000
O Load Flow Area Result		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	100.000
O Load Flow Area Transfer Result		0.001	-0.002	46.875	0.000	0.000	0.000	0.988	46.873	0.988	46.875	56.472	46.917
<ul> <li>Tap Position Result</li> </ul>		0.001	0.002	46.873	0.000	0.000	0.000	0.988	46.873	0.988	46.875	56.472	46.917
SC Short Circuit		0.001	-0.002	45.475	0.000	0.000	0.000	0.988	45.474	0.988	45.475	56.472	45.516
Database Queries		0.001	0.002	45.474	0.000	0.000	0.000	0.988	45.474	0.988	45.475	56.472	45.516
		0.153	0.176	28.304	0.000	0.000	0.000	0.340	28.304	0.340	28.319	19.434	28.3/8
1 1		0.153	-0.176	28.319	0.000	0.000	0.000	0.340	28.304	0.340	28.319	19.434	28,245

![](_page_59_Picture_0.jpeg)

#### **Check for Reverse Power Flow**

![](_page_59_Figure_2.jpeg)

![](_page_60_Picture_0.jpeg)

#### **Extract Results to Spreadsheet**

- Save the following result sets to a spreadsheet:
  - Node Results
  - Branch Results
  - Load Flow Area Result
- Copy contents of each to a separate tab in a blank spreadsheet
- Save the spreadsheet as "Peak\_\_\_noPV.xlsx"

![](_page_61_Picture_0.jpeg)

#### **Update Load Flow Results Summary Table**

Control Mode	Inverter PF	Inverter (MW)	Inverter (MVA)	PCC PF	PCC Voltage	PCC Voltage Step Change (%)	Feeder Load (Peak/Min)	Feeder Losses (MW)	Thermal Overload s (Y/N)	Reverse Power Flow (Y/N)	Acceptabl e (Y/N)	Notes
N/A	N/A	0.00	0.00	0.11	99.21	0.00%	Peak	4.89	Ν	Ν	Y	Pre-Project Case
Power Factor	1.00	3.60										
Power Factor	0.88	3.60										
Power Factor	-0.88	3.60										
N/A	N/A	0.00										
Power Factor	1.00	3.60										
Power Factor	0.88	3.60										
Power Factor	-0.88	3.60										

![](_page_62_Picture_0.jpeg)

## **Repeat for all Study Cases**

- Open the model:
  - AJIB Bank Study-SINCAL Model\_\_Peak\_\_maxPV\_\_100.sin

![](_page_63_Picture_0.jpeg)

# **Comparing Shadow Study Results**

- Review and compare Black & Veatch results with JEPCO results
- Are they different?
- Discuss why...