RENEWABLE POWER INTEGRATION TECHNICAL ASSISTANCE AND CAPACITY BUILDING IN SUPPORT OF USAID/DELOITTE TASK ORDER NO. AID-278-TO-13-00004, JORDAN ESCB

ELECTRIC POWER ENGINEERS INC, TASK 3 - SHADOW GRID IMPACT STUDIES

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General Overview

The USAID Jordan Energy Sector Capacity Building (ESCB) project has contracted with Electric Power Engineers, Inc. (EPE) to execute on a scope of work focused on supporting NEPCO in integrating renewable power projects into Jordan's transmission grid. Task 3 of the scope focuses on "Building NEPCO's Grid Impact Study Capability" through shadow studies to be completed in the order listed below:

1. Steady State Study
2. Short Circuit Study
3. Dynamic Study

Shadow studies, in this context, are analyses that were executed in parallel by both EPE and NEPCO Grid Impact Study (GIS) team of engineers using PSS/E simulator; these studies started after the technical training provided by EPE to NEPCO for each type of these studies.

In addition the to the grid impact study, the scope of work for third party grid impact studies as well as standardized Input/Output Template for System Impact Studies, are provided as appendices at the end of this report.

The training material provided as part of Task 3, Building NEPCO's Grid Impact Study Capability, is separately attached to this report.

1. Steady State Analysis

1.1 Executive Summary

1.1.1 Introduction

Electric Power Engineers, Inc. (EPE) performed a steady state analysis study for the proposed Fujeij wind farm interconnecting to the National Electric Power Company (NEPCO) transmission grid in 2016. The 89.1 MW Fujeij wind farm, using Vestas V126 turbines, is proposed to interconnect to the 132 kV Maan-Reshadya line.

The purpose of the Steady State study is to determine the transmission system impact due to the addition of the Fujeij wind generating facility interconnecting to the NEPCO transmission system.

This steady state analysis report includes the following two component studies:

- Thermal and Voltage Loadflow Analysis to identify thermal and voltage violations, if any, under various system conditions.
- Reactive Power Compliance Study to evaluate the reactive power at the Point of Common Coupling (PCC) in order to investigate its compliance with NEPCO's Intermittent Renewable Resource Transmission Interconnection Code (IRR-TIC).

The Jordan Grid is an islanded system with the exception of an interconnection with Egypt through one AC point of interconnection. Therefore the Loadflow analysis in this report was conducted for the following two scenarios:

- Scenario #1: Wheeling power from Egypt in effect (tie with Egypt closed)
- Scenario #2: Jordan islanded with the connections between Jordan and Egypt opened

AC Contingency Solution (ACCC) was run on the base case with and without the Fujeij wind farm in order to identify the thermal and voltage violations, if any, triggered by the addition of Fujeij. ACCC was run under system-intact (N-0) as well as single-contingency (N-1) conditions. A system-intact condition is the condition where there are no transmission elements out of service. A single-contingency is the loss of a transmission element on the grid due to planned or forced outages. The section titled "Study Assumptions" describes in detail the assumptions adopted in the Steady State analysis, the generation/load dispatch methodology followed in setting up the base case, as well as NEPCO Transmission Planning criteria adopted in the Steady State analysis.

Results of this study are a snapshot in time and largely depend on the generation dispatch and transmission system configuration. Any change in the assumptions underlying this study may impact the findings in this report.

1.1.2 Conclusion

System Impact Study:

The Steady State analysis to identify the impact of adding 89.1 MW Fujeij wind farm revealed the following major findings. More details are provided in the section titled "Study Findings".

- No voltage violations are triggered by the addition of the Fujeij wind farm, under N-0 and N-1 contingency conditions for both scenarios under study, Jordan wheeling power from Egypt and Jordan islanded.

- No thermal violations are triggered by the addition of the Fujeij wind farm under N-0 conditions for both scenarios under study, Jordan wheeling power from Egypt and Jordan islanded. However, under N-1 contingency conditions and for both scenarios, the base case (before the addition of the Fujeij wind farm) revealed several thermal overloads and warnings listed in the second column of Table 1 and Table 2 below. The findings also indicated that the Fujeij wind farm contributes to some of the base case thermal overloads and warnings, demonstrated by the increase in loading as shown in the third column of these tables; these transmission elements are marked in red.

  The study further ran a sensitivity analysis in which it was determined that the base case overloads are due to the addition of all the projects with signed PPAs to the base case that are in the NEPCO "queue" prior to Fujeij. All these overloads occur under N-1 contingency conditions, and NEPCO a) may interconnect this project but reserve the right to resort to curtailment of generation on the grid under contingency conditions, b) refuse interconnection of this project until the necessary system upgrades are implemented to mitigate these overloads.

  The 132 kV El Hasa – Tafila PCC double circuit line shows significant increase in loading by the addition of the Fujeij wind from around 73% to 98% and NEPCO has no plans to upgrade this double circuit line. Although this analysis does not show an overload on this line, however it indicates that this line is getting close to its thermal limit.

- Scenario 2 (Jordan Islanded) revealed similar findings to those of Scenario 1 with the identified loading percentage on some of the transmission elements less than Scenario 1, as shown in Table 1 and Table 2 below. The impact of Jordan being islanded will be further studied from the standpoint of dynamic analysis as a next step to this study.

NEPCO is planning to expand their system via a major transmission project, running South-North in order to reinforce the electric grid, known as the "Green Corridor" by 2018. NEPCO, upon customer request, may provide additional addendum studies to this report to evaluate the ability of the Green Corridor to mitigate the overloads identified in this study within the time frame of the completion of this upgrade.

Table 1 - Scenario 1 - Summary Table under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage in the Base Case before the Addition of the Fujeij Wind Farm	Loading Percentage after the Addition of the Fujeij Wind Farm
132 kV Manar - Abdali line, circuit 1, 180 MVA	131%	131%
132 kV Manar - Abdali line, circuit 2, 180 MVA	131%	131%
132 kV Marqa - HTPS line, circuit 1, 180 MVA	120%	120%
132 kV Marqa - HTPS line, circuit 2, 180 MVA	120%	120%
400/132 kV Amman North transformer, 400 MVA	118%	117%
400/132 kV Amman South transformer, 400 MVA	111%	110%
132 kV Queen Alia International Airport - Qatrana line, 180 MVA	109%	115%
132 kV Qatrana - Cement line, 180 MVA	101%	106%
132 kV Bayader - Amman South line, circuit 1, 180 MVA	98%	99%
132 kV Bayader - Amman South line, circuit 2, 180 MVA	98%	99%
132 kV Queen Alia International Airport - Cement line, 180 MVA	96%	101%
132 kV El Hasa – Tafila PCC line, circuit 1, 180 MVA	73%	98%
132 kV El Hasa – Tafila PCC line, circuit 2, 180 MVA	73%	98%

Table 2 - Scenario 2 - Summary Table under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage in the Base Case before the Addition of the Fujeij Wind Farm	Loading Percentage after the Addition of the Fujeij Wind Farm
132 kV Manar - Abdali line, circuit 1, 180 MVA	130%	130%
132 kV Manar - Abdali line, circuit 2, 180 MVA	130%	130%
132 kV Marqa - HTPS line, circuit 1, 180 MVA	120%	120%
132 kV Marqa - HTPS line, circuit 2, 180 MVA	120%	120%
400/132 kV Amman North transformer, 400 MVA	119%	118%
400/132 kV Amman South transformer, 400 MVA	110%	110%
132 kV Queen Alia International Airport - Qatrana line, 180 MVA	104%	110%
132 kV Qatrana - Cement line, 180 MVA	97%	102%
132 kV Bayader - Amman South line, circuit 1, 180 MVA	96%	98%
132 kV Bayader - Amman South line, circuit 2, 180 MVA	96%	98%
132 kV Queen Alia International Airport - Cement line, 180 MVA	92%	97%
132 kV El Hasa – Tafila PCC line, circuit 1, 180 MVA	69%	94.5%
132 kV El Hasa – Tafila PCC line, circuit 2, 180 MVA	69%	94.5%

Reactive Power Study:

The reactive power study was run on the detailed plant design provided by the developer, and evaluated the required reactive power support for the project in order to maintain the power factor at boundary PCC conditions as required in the IRR-TIC. The project, as shown in Appendix A, interconnects at 132 kV via two 132/33 kV transformers. The addition of reactive support occurs at the 33 kV side of each of the interconnecting transformers. The findings of this analysis revealed that a minimum of 2 x 12.5 MVArs of automatically switchable static capacitor will be required to be installed at the 33 kV in the Project's collection substation, namely 12.5 MVAr at each of the two project's busses in order to ensure that none of the project turbines will be triggered to trip due to voltage conditions exceeding its operating range. Note that calculations identified that connecting one 25 MVAr device at one of the two project's busses would increase the voltage at the turbines' terminals beyond their operating range and forcing them to trip.

Additionally, and in order to minimize the voltage change caused by the switching operations of the reactive devices, the study also recommends installing 4 x 3.125 MVArs capacitor banks at each 33 kV bus of the project's collection substation.

Refer to the section titled "Reactive Power Compliance Assessment" for more details.

1.2 Study Assumptions

Point of Study and Base Case Model:

Historically, the high wind speeds in Jordan are typically seen in July. The on-peak scenario was studied for the purpose of this analysis. Per the 2016 hourly load forecast, the peak load in July (3,356 MW) is forecasted to occur on the 31st of July at Hour 16 or on a similar hot day.

The current base case model available was updated by NEPCO to represent the on-peak scenario described above along with the suitable generation re-dispatch to take into account the on-peak load as well as the addition of wind and solar projects with signed Power Purchase Agreements (PPAs) as further described below.

It should be noted that the Jordan grid has an AC connection with Syria, however this connection has been permanently disabled for the foreseeable future, which was reflected in the base case by opening the 400 kV Amman North – Dir Ali transmission line.

Generation Re-Dispatch:

The renewable projects with signed PPAs, listed in Table 3 below, were added to the NEPCO base case model. The Tafila wind project was added at full capacity and the solar projects with signed PPAs were added at 80%.

The addition of the renewable projects with signed PPAs was offset by reducing the MW power of IPP3 as planned by NEPCO dispatch operations.

Table 3 - Generation Dispatch of Renewable Projects with Signed PPAs

<table>
<tr><th colspan="2">Project Name</th><th>POI</th><th>Type</th><th>MW Size</th><th>Dispatch Level</th><th>Pgen in the Base Case</th></tr>
<tr><td rowspan="9">Maan Development Area (MDA)</td><td>EJRE - 20MW</td><td rowspan="9">132 kV Maan-Shediya line
10 km from Maan</td><td rowspan="9">Solar</td><td rowspan="9">160 MW</td><td>80%</td><td>16 MW</td></tr>
<tr><td>Greenland (GLAE) - 10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td>Shams Ma'an - 50 MW</td><td>80%</td><td>40 MW</td></tr>
<tr><td>Ennera - 10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td>Sun Edison - 20.5 MW</td><td>80%</td><td>16.4 MW</td></tr>
<tr><td>Catalyst (Falcon) - 21 MW</td><td>80%</td><td>16.8 MW</td></tr>
<tr><td>CEC - 10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td>Mertifier 10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td>Bright Power - 10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td colspan="2">Shamsuna (Aqaba)</td><td>33 kV ATP substation</td><td>Solar</td><td>10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td colspan="2">Scatec (Maan) (ORYX)</td><td>33 kV Maan substation</td><td>Solar</td><td>10 MW</td><td>80%</td><td>8 MW</td></tr>
<tr><td colspan="2">Jordan Solar</td><td>33 kV Al Hassan</td><td>Solar</td><td>20 MW</td><td>80%</td><td>16 MW</td></tr>
<tr><td colspan="2">Tafila</td><td>132 kV Rashadia-Hasa line
8 km from Rashadia</td><td>Wind</td><td>117 MW</td><td>100%</td><td>117 MW</td></tr>
</table>

Transmission Planning Criteria:

The following NEPCO criteria, as per NEPCO Grid Code and IRR-TIC were adopted in the analysis to identify system constraints or violations:

- Transmission element rating shall be as provided in Rate A in the PSS®E models, and shall apply for normal and contingency conditions.
- A transmission element shall be considered thermally overloaded if its loading is at or above 100% of Rate A.
- Transmission elements loaded at or above 95% shall be marked as warnings.
- N-0 and N-1 contingency conditions are investigated in the steady state analysis. N-1 conditions shall explore the outage of any transmission line, transformer, or generator on the grid.
- The following criteria shall be applied for voltage variation range violation under both normal and contingency conditions:
    - +/-10% for the 132 kV transmission elements
    - +/-5% for the 400 kV transmission elements

Modeling of Fujeij Wind Farm:

The Fujeij wind farm was provided by the developer as described in Appendix A. The detailed collection system model for the Fujeij wind farm was added to the base case model.

Based on NEPCO dispatch operations, the addition of 89.1 MW Fujeij wind farm was offset by reducing the MW power at IPP3.

Islanding the Jordanian Network:

Scenario 2 of the steady state analysis studied the impact that the Fujeij wind farm may have on the transmission system when the Jordanian network is islanded (no connection with Egypt). Islanding was carried out in the model by allocating a slack bus, at the 400 kV IPP3 bus, in the Jordan grid and opening the interconnection to Egypt (opening the 400 kV Aqaba-Taba transmission line). When Egypt is not connected to Jordan, the load will have to be fed only by generators on the Jordanian grid where generation will be taken from IPP3.

1.3 Study Methodology

1.3.1. Thermal and Voltage Violations

In order to identify the thermal and voltage violations that may be triggered by the addition of the Fujeij wind farm to the network, loadflow calculations were run on the base case, including the projects with signed PPAs, before adding Fujeij wind farm and then loadflow calculations are run on the base case after adding Fujeij wind farm. The findings were compared in order to identify the adverse impact on the transmission Jordan network that may be triggered by the addition of the Fujeij wind farm. Table 4 below lists the simulations that were run as part of this investigation. The results of the analysis with and without Fujeij were then compared, and any additional or aggravated system violations or constraints were identified.

Table 4 - Scenarios to Investigate the Thermal and Voltage Violations

Scenario	Loadflow Calculations Before Adding Fujeij	Loadflow Calculations After Adding Fujeij
Scenario 1 (Wheeling Power from Egypt)	N-0 and N-1 (ACCC)	N-0 and N-1 (ACCC)
Scenario 2 (Jordan Islanded)	N-0 and N-1 (ACCC)	N-0 and N-1 (ACCC)

1.3.2. Reactive Power Compliance of the Fujeij Wind Farm

For this study, the wind farm detailed collection system was modeled as provided by the developer and detailed in Appendix A. The model then was connected to a slack bus in order to run the following scenarios. These scenarios are based on the NEPCO IRR-TIC code, and were each investigated in order to determine if additional reactive support is needed at the Point of Common Coupling of the Fujeij wind farm in order to comply with NEPCO grid requirements.

- Scenario 1: 100% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 2: 100% output & maximum leading (absorbing Vars); 1.1 pu at the PCC
- Scenario 3: 10% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 4: 10% output & maximum leading (absorbing Vars); 1.1 pu at the PCC

The figure below illustrates the study methodology that was adopted in order to run this investigation for each of the scenarios described above. Note that after identification of the amount of reactive support required, the analysis was re-run with the set amount in order to ensure that none of the project turbines will be triggered to trip due to voltage conditions exceeding its operating range, as well as to minimize the voltage change caused by the switching operations of the reactive devices.

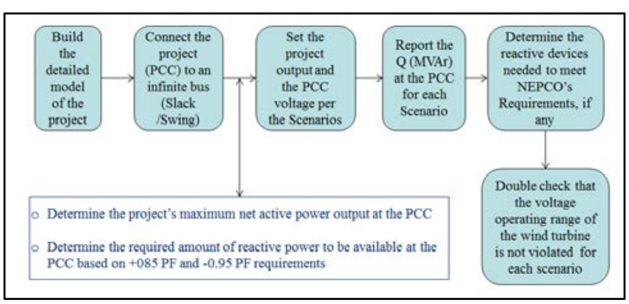


Figure 1 – Study Methodology for the Reactive Power Compliance Analysis

1.4 Study Findings

1.4.1 Thermal and Voltage Violations

N-0 Conditions:

Table 5 below summarizes the findings of the loadflow calculations that were run under system-intact (N-0) conditions for both scenarios under study, each investigated without and with the addition of the Fujeij wind farm.

Table 5 - Steady State Findings under N-0 Conditions

	Scenario 1 (Wheeling from Egypt)		Scenario 2 (Jordan Islanded)	
	Without Fujeij	With Fujeij	Without Fujeij	With Fujeij
Thermal Violations (Loading at or above 100%)	None	None	None	None
Thermal Warnings (Loading between above 95% and below 100%)	None	None	None	None
Voltage Violations (+/-10% for the 132 kV busses +/-5% for the 400 kV busses)	None	None	None	None

N-1 Contingency Conditions:

Scenario 1 (Wheeling Power from Egypt)

Voltage Violations

The loadflow calculations did not identify any concerns with voltage violations, with and without Fujeij.

It should be noted however that one over voltage violation was observed at the 400 kV Aqaba showing a voltage of 1.07 pu (428 kV), above the 1.05 NEPCO criteria, due to the loss of the 400 kV Aqaba – ATP line. This violation however results in islanding of Aqaba with the Egypt grid through the 400 kV Taba substation, and is a system condition that is not related to Fujeij or other parts of the Jordanian system.

Thermal Overloads and Warnings

Table 6 and Table 7 list the Jordanian transmission elements, loading at or above 95%, for the base case without Fujeij and after adding Fujeij, respectively, under N-1 conditions, for the Scenario of Jordan connected to Egypt. Table 7 marks in red the transmission elements for which the loading percentage was increased due to the addition of the Fujeij wind farm.

Table 6 - Thermal Overloads and Warnings - Base Case Without Fujeij - Scenario 1 - Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage
132 kV Manar - Abdali line, circuit 1, 180 MVA	131%
132 kV Manar - Abdali line, circuit 2, 180 MVA	131%
132 kV Marqa - HTPS line, circuit 1, 180 MVA	120%
132 kV Marqa - HTPS line, circuit 2, 180 MVA	120%
400/132 kV Amman North transformer, 400 MVA	118%
400/132 kV Amman South transformer, 400 MVA	111%
132 kV Queen Alia International Airport - Qatrana line, 180 MVA	109%
132 kV Qatrana - Cement line, 180 MVA	101%
132 kV Bayader - Amman South line, circuit 1, 180 MVA	98%
132 kV Bayader - Amman South line, circuit 2, 180 MVA	98%
132 kV Queen Alia International Airport - Cement line, 180 MVA	96%

Table 7 - Thermal Overloads and Warnings - Base Case With Fujeij - Scenario 1 - Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage
132 kV Manar - Abdali line, circuit 1, 180 MVA	131%
132 kV Manar - Abdali line, circuit 2, 180 MVA	131%
132 kV Marqa - HTPS line, circuit 1, 180 MVA	120%
132 kV Marqa - HTPS line, circuit 2, 180 MVA	120%
400/132 kV Amman North transformer, 400 MVA	117%
132 kV Queen Alia International Airport - Qatrana line, 180 MVA	115%
400/132 kV Amman South transformer, 400 MVA	110%
132 kV Qatrana - Cement line, 180 MVA	106%
132 kV Queen Alia International Airport - Cement line, 180 MVA	101%
132 kV Bayader - Amman South line, circuit 1, 180 MVA	99%
132 kV Bayader - Amman South line, circuit 2, 180 MVA	99%
132 kV El Hasa - Tafila PCC line, circuit 1, 180 MVA	98%
132 kV El Hasa - Tafila PCC line, circuit 2, 180 MVA	98%

As shown in the tables above, the base case (before the addition of the Fujeij wind farm) revealed several thermal overloads and warnings listed in the second column of Table 6. The findings indicated that the Fujeij wind farm contributes to some of the base case thermal overloads and warnings, demonstrated by the increase in loading as shown in the second column of Table 7.

It is to be noted that the 132 kV El Hasa – Tafila PCC double circuit line shows significant increase in loading by the addition of the Fujeij wind from 73% to 98% and NEPCO has no plans to upgrade this double circuit line. Although this analysis does not show an overload on this line, however it indicates that this line is getting close to its thermal limit.

Scenario 2 (Jordan Islanded)

Voltage Violations

None.

Thermal Overloads and Warnings

Table 8 and Table 9 list the Jordanian transmission elements, loading at or above 95%, for the base case without Fujeij and after adding Fujeij, respectively, for the Scenario of Jordan islanded. Table 9 marks in red the transmission elements for which the loading percentage was increased due to the addition of the Fujeij wind farm.

Table 8 - Thermal Overloads and Warnings - Base Case Without Fujeij - Scenario 2 - Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage
132 kV Manar - Abdali line, circuit 1, 180 MVA	130%
132 kV Manar - Abdali line, circuit 2, 180 MVA	130%
132 kV Marqa - HTPS line, circuit 1, 180 MVA	120%
132 kV Marqa - HTPS line, circuit 2, 180 MVA	120%
400/132 kV Amman North transformer, 400 MVA	119%
400/132 kV Amman South transformer, 400 MVA	110%
132 kV Queen Alia International Airport - Qatrana line, 180 MVA	104%
132 kV Qatrana - Cement line, 180 MVA	97%
132 kV Bayader - Amman South line, circuit 1, 180 MVA	96%
132 kV Bayader - Amman South line, circuit 2, 180 MVA	96%

Table 9 - Thermal Overloads and Warnings - Base Case With Fujeij - Scenario 2 - Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage
132 kV Manar - Abdali line, circuit 1, 180 MVA	130%
132 kV Manar - Abdali line, circuit 2, 180 MVA	130%
132 kV Marqa - HTPS line, circuit 1, 180 MVA	120%
132 kV Marqa - HTPS line, circuit 2, 180 MVA	120%
400/132 kV Amman North transformer, 400 MVA	118%
400/132 kV Amman South transformer, 400 MVA	110%
132 kV Queen Alia International Airport - Qatrana line, 180 MVA	110%
132 kV Qatrana - Cement line, 180 MVA	102%
132 kV Bayader - Amman South line, circuit 1, 180 MVA	98%
132 kV Bayader - Amman South line, circuit 2, 180 MVA	98%
132 kV Queen Alia International Airport - Cement line, 180 MVA	97%
132 kV El Hasa - Tafila PCC line, circuit 1, 180 MVA	94.5%
132 kV El Hasa - Tafila PCC line, circuit 2, 180 MVA	94.5%

As shown in the tables above, the base case (before the addition of the Fujeij wind farm) revealed several thermal overloads and warnings listed in the second column of Table 8. The findings indicated that the Fujeij wind farm contributes to some of the base case thermal overloads and warnings, demonstrated by the increase in loading as shown in the second column of Table 9.

It is to be noted that the 132 kV El Hasa – Tafila PCC double circuit line shows significant increase in loading by the addition of the Fujeij wind from 69% to 94.5% and NEPCO has no plans to upgrade this double circuit line. Although this analysis does not show an overload on this line, however it indicates that this line is getting close to its thermal limit.

1.4.2 Reactive Power Compliance Assessment

In order to investigate Fujeij compliance with the IRR NEPCO code for the reactive power compliance, the detailed Fujeij wind farm was modeled and connected to an infinite bus. The following scenarios were run and the findings were summarized in Table 10 below.

- Scenario 1: 100% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 2: 100% output & maximum leading (absorbing Vars); 1.1 pu at the PCC
- Scenario 3: 10% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 4: 10% output & maximum leading (absorbing Vars); 1.1 pu at the PCC

The findings of this analysis revealed that a minimum of 2 x 12.5 MVArs of automatically switchable static capacitor will be required to be installed at the 33 kV buses of the Project's collection substation, namely 12.5 MVAr at each bus to ensure that none of the project turbines will be triggered to trip due to voltage conditions exceeding its operating range. In order to minimize the voltage change caused by the switching operations of the reactive devices, it is recommended to install 4 x 3.125 MVArs capacitor banks at each 33 kV bus of the project's collection substation. The capacitor bank step sizes were calculated in such a way as to reduce the inrush current and other transients during the switching operation of the capacitor bank; according to, industry practice, the capacitor steps are split in such a way to keep the voltage rise that may be seen at the POI below 1%. The number of steps of a switched shunt is determined according to this formula:

%V change = Capacitor Size [MVAr] x Transformer Reactance [%] / MPT MVA Base

Table 10 lists the scenarios evaluated as part of this analysis in the first row as well as summarizes the results of each of these scenarios. This table shows the amount of reactive devices needed to be installed at the 33 kV bus of the Project's collection substation in order to meet the reactive power requirements at the PCC, namely 54.3026 MVArs (0.85 pf) and -28.8935 MVArs (-0.95 pf); this information is marked in bold red. This table also shows the lowest and highest voltages at the turbines' terminal for each scenario in order to verify that the continuous operating voltage ranges of the Vestas V126 turbines, namely 0.9 pu to 1.1 pu, are not violated after the addition of the reactive support.

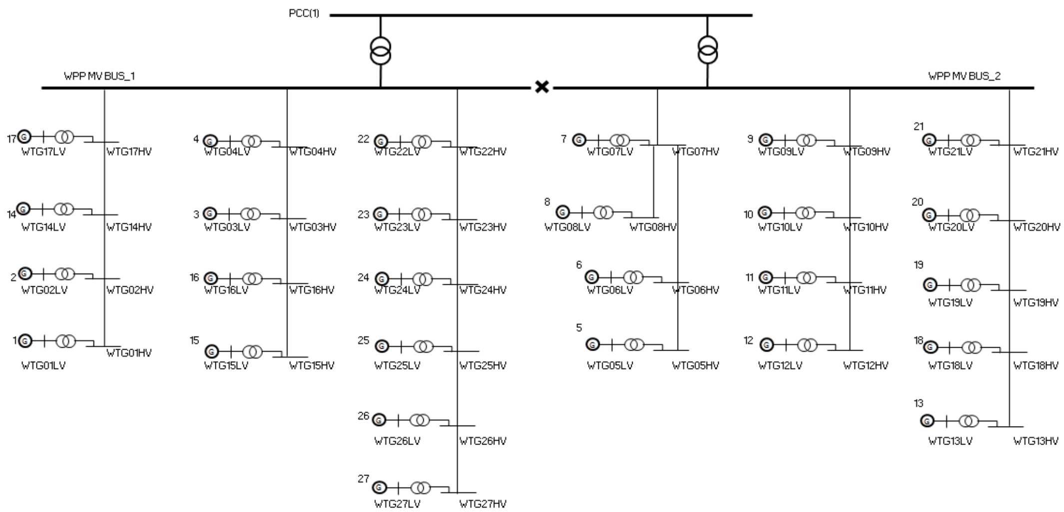
Note that in this table, a positive sign in front of the reactive power values means the VArs are being provided (produced/lagging) from Fujeij to the grid; whereas a negative sign means that the VArs are being absorbed (consumed/leading) by Fujeij from the grid.

Table 10 – Reactive Power Compliance Assessment

Scenario Number	1	2	3	4
Scenario Description	100% Output; 0.9 pu @ PCC	100% Output; 1.1 pu @ PCC	10% Output; 0.9 pu @ PCC	10% Output; 1.1 pu @ PCC
Power Factor Required at the PCC	0.85	-0.95	0.85	-0.95
Pmax at PCC for 100% Output	87.6211 MW	87.9066 MW	87.6211 MW	87.9066 MW
Turbine MW ∣ MVArs	3.3 MW ∣ 1.932 MVArs	3.3 MW ∣ -1.273 MVArs	0.33 MW ∣ 2.2 MVArs	0.33 MW ∣ -2.2 MVArs
Q needed at the PCC to Meet NEPCO Reactive Power Requirements	**54.3026 MVArs**	**-28.8935 MVArs**	**54.3026 MVArs**	**-28.8935 MVArs**
Q Calculated at the PCC	**31.1894 MVArs**	**-50.6535 MVArs**	**53.6627 MVArs**	**-65.2101 MVArs**
Are Reactive Devices Needed?	**YES**	**NO**	**YES**	**NO**
Reactive Devices Needed at the PCC to Meet NEPCO Reactive Power Requirements	2 x 12.5 MVArs	None	1 MVAr	None
Lowest Voltage @ Turbine's Terminal	1.0871 pu	1.07 pu	1.076 pu	1.01 pu
Highest Voltage @ Turbine's Terminal	1.0961 pu	1.08 pu	1.087 pu	1.02 pu

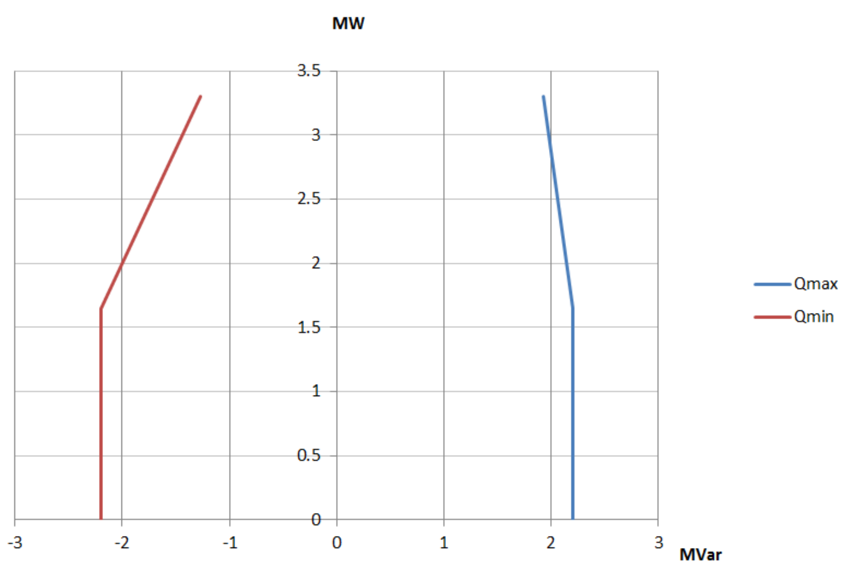
Appendix A, Modeling Data Information for the Fujeij Wind Farm

Fujeij Oneline Diagram



Generator Data for the Fujeij Wind Farm

The following PQ graph was provided as generator data information. This graph refers to LV (0.65 kV) side of the Wind Turbine Generator (WTG) transformer and with the LV side voltage between 0.9 pu and 1.1 pu.



The impedance source values of the WTG were extracted from the loadflow model provided by Vestas for the dynamic models as follows: Rsource = 0.0047 and Xsource = 0.8219.

Collection Feeders Data for the Fujeij Wind Farm

From Bus	To Bus	Length km	R1 p.u	X1 p.u	R0 p.u	X0 p.u	B1 p.u	B0 p.u	Irated kA
WPP MV BUS_1	WTG17HV	3.45	0.0194	0.0329	0.1030	0.0168	0.0038	0.3524	0.407
WTG14HV	WTG17HV	0.34	0.0039	0.0037	0.0039	0.0037	0.0003	0.0210	0.284
WTG02HV	WTG14HV	0.33	0.0095	0.0041	0.0186	0.0025	0.0002	0.0105	0.173
WTG01HV	WTG02HV	0.355	0.0103	0.0044	0.0200	0.0027	0.0002	0.0113	0.173
WPP MV BUS_1	WTG04HV	2.14	0.0120	0.0204	0.0639	0.0104	0.0023	0.2186	0.407
WTG04HV	WTG03HV	0.345	0.0039	0.0037	0.0040	0.0037	0.0003	0.0214	0.284
WTG03HV	WTG16HV	0.346	0.0100	0.0043	0.0195	0.0026	0.0002	0.0110	0.173
WTG16HV	WTG15HV	0.335	0.0097	0.0042	0.0189	0.0025	0.0002	0.0107	0.173
WPP MV BUS_1	WTG22HV	1.471	0.006538	0.013508	0.042144	0.006808	0.001761	0.1820556	0.461
WTG22HV	WTG23HV	0.354	0.001573	0.003251	0.010142	0.001638	0.000424	0.0438122	0.461
WTG23HV	WTG24HV	0.354	0.001991	0.003381	0.010565	0.001726	0.000388	0.0361608	0.407
WTG24HV	WTG25HV	0.388	0.011223	0.004846	0.021841	0.002929	0.000239	0.0123856	0.173
WTG25HV	WTG26HV	0.437	0.01264	0.005457	0.024599	0.003299	0.000269	0.0139497	0.173
WTG26HV	WTG27HV	0.656	0.018975	0.008192	0.036926	0.004952	0.000404	0.0209405	0.173
WPP MV BUS_2	WTG07HV	1.505	0.008463	0.014373	0.044915	0.007338	0.001648	0.1537343	0.407
WTG07HV	WTG06HV	0.341	0.003873	0.003664	0.003914	0.003664	0.00028	0.0211108	0.284
WTG06HV	WTG05HV	0.342	0.009893	0.004271	0.019251	0.002581	0.000211	0.0109172	0.173
WTG07HV	WTG08HV	0.367	0.010616	0.004583	0.020658	0.00277	0.000226	0.0117152	0.173
WPP MV BUS_2	WTG09HV	2.091	0.011758	0.019969	0.062404	0.010196	0.002289	0.2135936	0.407
WTG09HV	WTG10HV	0.347	0.010037	0.004334	0.019533	0.002619	0.000214	0.0110768	0.173
WTG10HV	WTG11HV	0.345	0.009979	0.004309	0.01942	0.002604	0.000212	0.0110129	0.173
WTG11HV	WTG12HV	0.352	0.010182	0.004396	0.019814	0.002657	0.000217	0.0112364	0.173
WPP MV BUS_2	WTG21HV	1.076	0.004782	0.009881	0.030828	0.00498	0.001288	0.1331692	0.461
WTG21HV	WTG20HV	0.363	0.002041	0.003467	0.010833	0.00177	0.000397	0.0370801	0.407
WTG20HV	WTG19HV	0.347	0.010037	0.004334	0.019533	0.002619	0.000214	0.0110768	0.173
WTG19HV	WTG18HV	1.048	0.030314	0.013088	0.058992	0.007911	0.000645	0.0334538	0.173
WTG18HV	WTG13HV	0.51	0.014752	0.006369	0.028708	0.00385	0.000314	0.01628	0.173

Transformer Data for the Fujeij Wind Farm

From Bus	To Bus	Connection	Rating MVA	R1 p.u	X1 p.u	R0 p.u	X0 p.u
PCC(1)	WPP MV BUS_1	Ynyn	65	0.004631	0.166186	0.00296	0.1523
PCC(1)	WPP MV BUS_2	Ynyn	65	0.004631	0.166186	0.00296	0.1523
HV	LV	Dyn5	3.75	0.008133	0.089632	0.007	0.087

2. Short Circuit Analysis

2.1 Executive Summary

2.1.1 Introduction

Electric Power Engineers, Inc. (EPE) performed a Short Circuit analysis study for the proposed Fujeij wind farm interconnecting to the National Electric Power Company (NEPCO) transmission grid in 2016. The 89.1 MW Fujeij wind farm, using Vestas V126 turbines, is proposed to interconnect to the 132 kV Maan-Reshadya line.

The purpose of the Short Circuit study is to identify the maximum interrupting fault current at the Point of Common Coupling (PCC) and to determine the impact of the Fujeij wind farm on the existing transmission grid protective equipment and flag any under-rated equipment.

The short circuit calculations were run before and after adding Fujeij wind farm in order to identify the adverse impact of the Fujeij wind farm, if any.

For that purpose the short circuit current flowing through nearby protection switchgear will be determined and tabulated before and after the addition of the project.

The section titled "Study Assumptions" describes the assumptions adopted in the Short Circuit analysis, the NCSFCC (Non-Conventional Sources Fault Current Contribution) added to the base case for the wind and solar projects with signed Power Purchase Agreements (PPAs) dispatch as well as the NEPCO Interruption Ratings (kA) for the circuit breakers at the transmission substations adopted in the Short Circuit analysis.

Results of this study are a snapshot in time and largely depend on the transmission system configuration, detailed Fujeij collection model and the fault current contribution provided by the wind turbine and inverter’s manufacturers. Any change in the assumptions underlying this study may greatly impact the findings in this report.

2.1.2 Conclusion

Maximum Interrupting Fault Current at the PCC:

Table 11 below provides the three phase fault current and the single line to ground fault at the PCC before and after adding the Fujeij wind farm.

Table 11 - Fault Current at the PCC

Fault Current at the PCC	Before Fujeij Wind Farm	After Fujeij Wind Farm
Three phase fault	6.829 kA	7.109 kA
Single line to ground fault	5.316 kA	5.446 kA

Impact of Adding Fujeij wind farm:

None.

The Short Circuit analysis identified that there will be slight increases to the fault current level of the 132 kV bus bars and surrounding network to which the planned Fujeij wind farm generation will be connected to. The highest increase in the fault current, triggered by the addition of the Fujeij wind farm, is seen at the 132 kV Maan and Reshadya substations, as well as at the 132 kV Tafila PCC, showing an increase of around 200 Amps. The bus bar fault current levels do not, however, exceed the switchgear ratings and thus no further action is required.

It is worth to note that the following bus bars were identified to be exceeding 90% of their interruption ratings, before adding the Fujeij wind farm. Although the addition of the Fujeij wind farm is slightly increasing these fault current levels, the Fujeij wind farm did not trigger the excess of fault current beyond the 90% interrupting rating:

- 132 kV HTPS
- 132 kV Qatrana

The findings of the Short Circuit calculations, before and after adding the Fujeij wind farm, are provided in the section titled “Study Findings”.

2.2 Study Assumptions

Base Case Models:

The base case models (without and with Fujeij wind farm) used for the Steady State analysis were adopted for the purpose of the Short Circuit analysis. These cases were updated by NEPCO and revisions to the short circuit data for the existing transmission system in these cases were provided by NEPCO.

These cases include all the renewable projects with signed PPAs. The fault current contribution of these projects was added to the base cases as provided by the manufacturers; the fault current contribution is listed in Table 12 below. For the Short Circuit analysis, each of these projects were represented within PSS/E as a current limited generator by utilizing the Non-Conventional Source Fault Current Contribution (NCSFCC) model. This allows to set the fault contribution of the generator accordingly.

Table 12 - Fault Current Contribution of the Renewable Projects

Inverter/Turbine Manufacturer	Project(s)	Fault Current Contribution in PU
Bonfiglioli	SunEdison	**1.458 pu**
SMA	EJRE, GLAE Shams Ma'an Catalyst Scatec	**2.2 pu**
Ultra Inverter	CEC, Mertifier Bright Power Jordan Solar Shamsuna	**0.9 pu**
Vestas V112	Tafila	**1.05 pu**
Vestas V126	Fujeij	**1.05 pu**
Schneider	Ennera	**1.5 pu**

List of NEPCO Interruption Ratings for the Circuit Breakers:

Table 13 below lists the Interruption Ratings (kA) for the circuit breakers at the transmission substations. Per NEPCO's criteria, the actual short circuit current should not exceed 90% of the switchgear rating.

Table 13 - Interruption Ratings for NEPCO Circuit Breakers

Equipment	Rating (kA)
All 132 kV bus section	31.5 kA
All 400 kV bus section	40 kA
132 kV Amman East bus	40 kA
132 kV Manara bus section	40 kA
132 kV Samra bus section	40 kA
132 kV Amman North bus section	40 kA
400 kV Amman East bus section	50 kA

2.3 Study Methodology

The short circuit studies are carried out in accordance with IEC 60909. The short circuit calculations are run to provide the three phase fault and the single line-to-ground fault at every transmission bus on the NEPCO grid.

The fault study results for the base case (before Fujeij wind farm) are compiled and compared to those for the case with the Fujeij wind farm connected to assess the impact of connecting the new generation on overall fault current levels on the system.

2.4 Study Findings

Table 14 below summarizes the findings of the short circuit calculations before and after adding the Fujeij wind farm. The substations marked in red have their fault current level exceeding 90% of their interruption ratings for either a three phase fault or a single line-to-ground fault. It is worth to note that those were identified before adding the Fujeij wind farm.

Table 14 - Short Circuit Analysis Findings

Substation Name	Three Phase Fault (Amps)				Single Line to Ground Fault (Amps)			
	Before Adding Fujeij		After Adding Fujeij		Before Adding Fujeij		After Adding Fujeij	
	3 Phase Fault (Amps)	% of the Interruption Rating	3 Phase Fault (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating
[HTPS_1_132 132.00]	23085.3	73.29%	23088.7	73.30%	28427.5	90.25%	28431	90.26%
[REHAB_132 132.00]	21324.4	67.70%	21326.6	67.70%	24211.9	76.86%	24214.1	76.87%
[IRBID_132 132.00]	8621.1	27.37%	8621.5	27.37%	8708.1	27.64%	8708.4	27.65%
[MARQA 132.00]	11233.6	35.66%	11234.4	35.66%	12277.7	38.98%	12278.3	38.98%
[ASHRAFIA 132.00]	20791.1	66.00%	20798	66.03%	19892.8	63.15%	19897.1	63.17%
[SAHAB-132 132.00]	21270.9	67.53%	21279.3	67.55%	21855.7	69.38%	21861.7	69.40%
[BAYADER 132.00]	20798	66.03%	20806.5	66.05%	25321.2	80.38%	25329.7	80.41%
[FUHIES 132.00]	15128.5	48.03%	15132.9	48.04%	14008.3	44.47%	14011	44.48%
[AMSTH 132.00]	20339.1	64.57%	20348.4	64.60%	24452.7	77.63%	24461.9	77.66%
[SUBIH_132 132.00]	13728.2	43.58%	13732.3	43.59%	15145.4	48.08%	15148.9	48.09%
[QAIA_132 132.00]	16996.3	53.96%	17008.8	54.00%	18452.2	58.58%	18462.2	58.61%
[CEM_QAT 132.00]	14267.9	45.29%	14327.6	45.48%	14346	45.54%	14386.7	45.67%
[QATRANA 132.00]	24469	77.68%	24571	78.00%	29741.7	94.42%	29842.9	94.74%
[KARAK 132.00]	9400.6	29.84%	9414.1	29.89%	10217.3	32.44%	10228.1	32.47%
[GHORSAFI 132.00]	6017.5	19.10%	6022.6	19.12%	6071.5	19.27%	6075	19.29%
[ELHASA 132.00]	8704.7	27.63%	8847.3	28.09%	5357.4	17.01%	5394.5	17.13%
[RSHADYA 132.00]	6944.2	22.05%	7168.3	22.76%	5345.4	16.97%	5444	17.28%
[MAAN 132.00]	7927.6	25.17%	8129.2	25.81%	8419.5	26.73%	8588.1	27.26%
[QUWIERA 132.00]	8439.3	26.79%	8528.5	27.07%	8412.5	26.71%	8473.1	26.90%
[ATPS 132KV 132.00]	11018.7	34.98%	11053.3	35.09%	12206.5	38.75%	12235.1	38.84%
[KHARAN 132.00]	7858.8	24.95%	7859.7	24.95%	8014.1	25.44%	8014.8	25.44%

Substation Name	Three Phase Fault (Amps)				Single Line to Ground Fault (Amps)			
	Before Adding Fujeij		After Adding Fujeij		Before Adding Fujeij		After Adding Fujeij	
	3 Phase Fault (Amps)	% of the Interruption Rating	3 Phase Fault (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating
[AZRAQ 132.00]	5170.5	16.41%	5170.9	16.42%	4361.5	13.85%	4361.7	13.85%
[RESHA 132.00]	2300.8	7.30%	2300.8	7.30%	3198.1	10.15%	3198.2	10.15%
[SABHA_ 132.00]	8022.1	25.47%	8022.6	25.47%	7951.7	25.24%	7951.9	25.24%
[AE_132 132.00]	31470.7	78.68%	31485.7	78.71%	35111.8	87.78%	35124.5	87.81%
[MANAR_132 132.00]	29853.5	74.63%	29867.6	74.67%	32131.7	80.33%	32142.9	80.36%
[UNIV_132 132.00]	21786.7	69.16%	21795.6	69.19%	26623.3	84.52%	26632.4	84.55%
[MADBA_132 132.00]	12546.9	39.83%	12552.8	39.85%	13518.1	42.91%	13522.8	42.93%
[TAREQ_132 132.00]	22983.6	72.96%	22993.2	72.99%	27813.9	88.30%	27823.6	88.33%
[HTPS_2_132 132.00]	23085.3	73.29%	23088.7	73.30%	28427.5	90.25%	28431	90.26%
[MWQRIND 132.00]	9914	31.47%	9915.6	31.48%	10740	34.10%	10741.3	34.10%
[MWQR_132 132.00]	19779.1	62.79%	19785.6	62.81%	21440.3	68.06%	21445.5	68.08%
[DULIL_132 132.00]	14355	45.57%	14356.2	45.58%	14499.2	46.03%	14500.1	46.03%
[SALT_132 132.00]	15983.4	50.74%	15990.2	50.76%	16969.3	53.87%	16974.6	53.89%
[SWEMH_132 132.00]	12518.2	39.74%	12523.2	39.76%	14245.6	45.22%	14250	45.24%
[ISHTFENA_132132.00]	7074.9	22.46%	7076	22.46%	7634.6	24.24%	7635.4	24.24%
[WQAS_132 132.00]	4866.5	15.45%	4867	15.45%	5522.8	17.53%	5523.3	17.53%
[HASAN_132 132.00]	12948.4	41.11%	12949.2	41.11%	12809.2	40.66%	12809.8	40.67%
[ABDOON 132.00]	17496.7	55.55%	17503.6	55.57%	21350.8	67.78%	21357.8	67.80%
[CEM_MNSR 132.00]	10271.6	32.61%	10284.9	32.65%	9636	30.59%	9643.9	30.62%
[IRBDEST_132 132.00]	8360.8	26.54%	8361.1	26.54%	8889.3	28.22%	8889.6	28.22%
[AQBACBL 400.00]	10182.9	25.46%	10197.9	25.49%	9312.5	23.28%	9320.9	23.30%
[ABDALI 132.00]	21915.3	69.57%	21919.8	69.59%	23173.3	73.57%	23176.8	73.58%
[SHEDIYA 132.00]	5006.6	15.89%	5081.8	16.13%	5751.6	18.26%	5820	18.48%
[DISI_132 132.00]	3756.5	11.93%	3785.1	12.02%	4370.9	13.88%	4397.1	13.96%
[AQBIND 132.00]	10206.9	32.40%	10243	32.52%	11104	35.25%	11132.7	35.34%
[HASHMIA 132.00]	18815.1	59.73%	18817.2	59.74%	19044.7	60.46%	19046.3	60.46%
[ATP400 400.00]	10779.3	26.95%	10796.9	26.99%	10849.5	27.12%	10861.5	27.15%
[AMM.SHT 400.00]	15340.7	38.35%	15357.2	38.39%	15734.9	39.34%	15746.8	39.37%
[AMM.NOR 400.00]	15420	38.55%	15431.2	38.58%	16418.3	41.05%	16427	41.07%
[AMNOR_132 132.00]	25913.6	64.78%	25925.2	64.81%	31584.9	78.96%	31596.8	78.99%
[IPP3 400.00]	14979.5	37.45%	14991.5	37.48%	14904.4	37.26%	14912.5	37.28%
[MFRAQ_132 132.00]	12128.8	38.50%	12129.8	38.51%	13112	41.63%	13112.9	41.63%
[RESHA_132KV 132.00]	2299.8	7.30%	2299.8	7.30%	3192.2	10.13%	3192.3	10.13%
[RUWASHED 132.00]	1935	6.14%	1935	6.14%	1986.7	6.31%	1986.7	6.31%
[AMNEAS 400.00]	16407.5	32.82%	16421.9	32.84%	17983.4	35.97%	17995.2	35.99%
[SAFAWI 132.00]	2686.2	8.53%	2686.3	8.53%	2456.4	7.80%	2456.5	7.80%
[CITYCN_132KV132.00]	13239.6	42.03%	13242.7	42.04%	17336.9	55.04%	17340.6	55.05%
[ATPSPST 132.00]	17577.6	55.80%	17635.2	55.98%	21276.8	67.55%	21333.5	67.73%
[SAMR132 132.00]	24451.9	61.13%	24455.2	61.14%	28625.7	71.56%	28628.8	71.57%
[SMRA_BB1 400.00]	14245	35.61%	14253.5	35.63%	15408.3	38.52%	15415.1	38.54%

Substation Name	Three Phase Fault (Amps)				Single Line to Ground Fault (Amps)			
	Before Adding Fujeij		After Adding Fujeij		Before Adding Fujeij		After Adding Fujeij	
	3 Phase Fault (Amps)	% of the Interruption Rating	3 Phase Fault (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating
[AMSTH_2_132 132.00]	25306.3	80.34%	25322.4	80.39%	24322.5	77.21%	24332.7	77.25%
[RAJHI_132 132.00]	11232.2	35.66%	11232.9	35.66%	10862.1	34.48%	10862.5	34.48%
[QATRANA 400.00]	12533.6	31.33%	12556.5	31.39%	10948.1	27.37%	10959.8	27.40%
[SAMRA 400.00]	14245	35.61%	14253.5	35.63%	15408.3	38.52%	15415.1	38.54%
[MDA 132.00]	7482.6	23.75%	7652.3	24.29%	7963.7	25.28%	8104.8	25.73%
[TAFILAWIND 132.00]	7083.1	22.49%	7290.6	23.14%	5018.1	15.93%	5094.3	16.17%
[PCC 132.00]	6829	21.68%	7109.5	22.57%	5316.9	16.88%	5446.8	17.29%

3. Dynamic Analysis

3.1 Executive Summary

3.1.1 Introduction

Electric Power Engineers, Inc. (EPE) performed a Dynamic analysis study for the proposed Fujeij wind farm interconnecting to the National Electric Power Company (NEPCO) transmission grid in 2016. The 89.1 MW Fujeij wind farm, using Vestas V126 turbines, is proposed to interconnect to the 132 kV Maan-Reshadya line.

The objective of the Dynamic study is to evaluate the behavior and response of the system as well as the Fujeij wind farm after a credible fault/contingency event (disturbance) and ensure that the NEPCO system returns to a state of equilibrium following the disturbance. The Dynamic study also includes a High Voltage Ride Through (HVRT) and Low Voltage Ride Through (LVRT) study in order to determine if the Fujeij wind farm is in compliance with the Intermittent Renewable Resources (IRR) Transmission Interconnection Code (TIC) sections 5.2 and 5.3.

The following two (2) scenarios were studied for the purpose of this analysis:

- Scenario #1: Wheeling power from Egypt in effect (tie with Egypt closed)
- Scenario #2: Jordan islanded with the connections between Jordan and Egypt opened

The dynamic analysis was performed for each scenario without the Fujeij wind farm (A) and with the Fujeij wind farm (B) in order to identify the adverse impact of the Fujeij wind farm, if any.

Only single contingencies (N-1) were evaluated during this analysis with the assumption that all other system elements are in service as specified within the Steady State analysis prior to any disturbance. The fault/contingency events were modeled as normally cleared permanent faults with a clearing time of four (4) cycles as specified by NEPCO. Each simulation was run for twenty (20) seconds with a one (1) second steady state run prior to invoking the fault/contingency event. System stability was evaluated based on monitoring nearby conventional generators power output, rotor angle, voltage and frequency. Additionally, the Fujeij wind farm power output, voltage and frequency as well as nearby buses voltage and frequency were monitored in order to evaluate the impact of the Fujeij wind farm.

For the LVRT/HVRT portion of the Dynamic analysis, a detailed model of the Fujeij wind farm connected to an infinite bus at the Point of Common Coupling (PCC) was utilized in order to evaluate the compliance with the IRR-TIC sections 5.2 and 5.3. The following two (2) scenarios were evaluated for this analysis:

- Scenario #1: Fujeij providing 100% active power and maximum lagging reactive power
- Scenario #2: Fujeij providing 100% active power and maximum leading reactive power

The Voltage Ride Through (VRT) profiles as shown within the IRR-TIC were introduced at the PCC. The LVRT simulation was run for 180 seconds and the HVRT simulation was ran for 60 seconds, each with a one (1) second steady state run prior to introducing the VRT profile. VRT compliance was evaluated by monitoring the voltage and power output of each of the Fujeij wind turbines.

The section titled "Study Assumptions" describes the assumptions adopted in the Dynamic analysis.

Results of this study are a snapshot in time and largely depend on the transmission system configuration, detailed Fujeij collection model and the conventional generator dynamic models as well as the wind and solar dynamic models. Any change in the assumptions underlying this study may greatly impact the findings in this report.

3.1.2 Conclusion

Dynamic Analysis:

For the Dynamic analysis, EPE evaluated two (2) scenarios with (A) and without (B) the Fujeij wind farm for selected single contingencies (N-1). The results of this study are shown in Table 15 and Table 16. All contingencies performed on the NEPCO system for both Scenario 1 and Scenario 2 with and without the Fujeij wind farm show post-contingency stability with the generators maintaining synchronism as well as damped voltage, frequency, power and rotor angle oscillations within twenty (20) seconds. The plots for each scenario and contingency can be found in Appendix C – G.

LVRT/HVRT Analysis:

For the LVRT/HVRT analysis, EPE evaluated two (2) scenarios with the Fujeij wind farm producing 100% active power and maximum lagging reactive power (1) and maximum leading reactive power (2) in order to determine compliance with the VRT requirements specified within the IRR-TIC sections 5.2 and 5.3. The results of this study are shown in Table 17. The Fujeij wind farm does not meet the LVRT requirements for both Scenario 1 and Scenario 2. For Scenario 1, the Fujeij wind farm trips offline after 61 seconds due to the voltage within the collection system being approximately 0.8876 pu. For Scenario 2, the Fujeij wind farm trips offline after 11.2 seconds due to the voltage within the collection system being approximately 0.8364 pu. Per the Vestas V126 specifications, the under voltage trip settings for voltages between 0.8 to 0.9 pu is 60 seconds. This value will need to be increased to 180 seconds in order to meet the NEPCO IRR-TIC requirements. The Fujeij wind farm meets the HVRT requirements for both Scenario 1 and Scenario 2. However, for Scenario 2, the power output of the wind turbines ramps down and ramps back up at around twenty (20) seconds. This behavior will need to be discussed with Vestas to ensure that this will not occur during operation.

Table 15 – Scenario 1 Dynamic Analysis Results

Contingency Label	Description	Scenario 1 (Egypt tie - closed)	
		A (Without Fujeij)	B (With Fujeij)
CTG_1	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_2	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_3	Three phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_4	Three phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_5	Three phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable
CTG_6	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_7	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_8	Single phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_9	Single phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_10	Single phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable

Table 16 – Scenario 2 Dynamic Analysis Results

Contingency Label	Description	Scenario 2 (Egypt tie - opened)	
		A (Without Fujeij)	**B (With Fujeij)**
CTG_1	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_2	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_3	Three phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_4	Three phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_5	Three phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable
CTG_6	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_7	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_8	Single phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_9	Single phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_10	Single phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable

Table 17 – LVRT/HVRT Dynamic Analysis Results

VRT Profile	Scenario 1	Scenario 2
	100% P Max Lagging Q	**100% P Max Leading Q**
LVRT	**Fail**	**Fail**
HVRT	Pass	Pass

3.2 Study Assumptions

3.2.1 Dynamic Analysis

The Steady State base case models (without and with Fujeij wind farm) were adopted along with the Dynamic base case models, as provided by NEPCO, for the purpose of the Dynamic analysis. The Dynamic base case provided by NEPCO contained only conventional generators and their dynamic settings were not modified prior to adding the renewable generators. The Dynamic cases were updated to include all the renewable projects with signed Power Purchase Agreement (PPAs). The dynamic models for these projects were added to the dynamic base cases as provided by the manufacturers; the models used are listed in Table 12.

Table 18 – Renewable Generator Dynamic Model Description

Project	Inverter/Turbine Type	PSS®E Model
Sun Edison	Bonfiglioli	BFGLIO
EJRE	SMA	SMASC
GLAE	SMA	SMASC
Shams Ma'an	SMA	SMASC
Catalyst	SMA	SMASC
Scatec	SMA	SMASC
CEC	Ultra	ULTRAINV
Mertifier	Ultra	ULTRAINV
Bright Power	Ultra	ULTRAINV
Jordan Solar	Ultra	ULTRAINV
Shamsuna	Ultra	ULTRAINV
Tafila	Vestas V112	GSCOR1
Fujeij	Vestas V126	GSCOR1
Ennera	Schneider	N/A[1]

Note 1: This model was not available when the study was completed and therefore was modeled as a negative load.

The dynamic model settings for the Fujeij wind farm are shown in Appendix A. The dynamic model settings for each of the projects listed in Table 12 were modified, if necessary, in order to be in compliance with the NEPCO IRR-TIC. The following changes were made prior to performing the dynamic analysis and are highlighted in Appendix B:

- Update the Bonfiglioli inverter frequency settings to reflect 50 Hz
- Update the Ultra inverter frequency trip setting time for 47.5 Hz to 0.05 seconds
- Update the SMA inverter to be in voltage control mode
- Update the Vestas turbine to be in Q control mode

3.2.2 LVRT/HVRT Analysis

In order to complete the LVRT/HVRT analysis, a separate model was created that included the Fujeij wind farm in detail, using the Vestas V126 wind turbine, connected to an infinite bus at the project's PCC. The Fujeij wind farm was modeled for two different operating conditions:

- Scenario #1: Fujeij providing 100% active power and maximum lagging reactive power (+1.93 MVAr per turbine)
- Scenario #2: Fujeij providing 100% active power and maximum leading reactive power (-1.26 MVAr per turbine)

The infinite bus dynamic model was represented in PSS®E by the Play-In model (PLBVFU1) which allows the user to set and control the voltage and frequency signals of the bus to which the model is connected. For the purpose of this study, the frequency portion of the model was disabled. The voltage was set to follow the VRT requirements as shown in the IRR-TIC with the values placed within a text file with a file extension of "plb". These values are shown in Table 19.

Table 19 – Play-In Model Settings for LVRT/HVRT Analysis

LVRT		HVRT	
Time (s)	**Voltage (pu)**	**Time (s)**	**Voltage (pu)**
1	1	1	1
1.001	0	1.001	1.2
1.251	0	1.201	1.15
3.501	0.8	1.202	1.15
10	0.8	10	1.15

3.3 Study Methodology

3.3.1 Dynamic Analysis

A Dynamic analysis was performed in order to evaluate the interconnection of the Fujeij wind farm, for the 2016 year, under selected single contingencies (N-1). The purpose of this analysis is to study stability impacts on the system due to the addition of Fujeij wind farm. The following two (2) scenarios were studied for the purpose of this analysis:

- Scenario #1: Wheeling power from Egypt in effect (tie with Egypt closed)
- Scenario #2: Jordan islanded with the connections between Jordan and Egypt opened

The dynamic analysis was performed for each scenario without the Fujeij wind farm (A) and with the Fujeij wind farm (B) in order to identify the adverse impact of the Fujeij wind farm, if any.

Each simulation was ran for twenty (20) seconds with a one (1) second steady state run prior to invoking the fault/contingency event. The fault/contingency events were cleared in four (4) cycles (0.08 s) prior to removing a transmission element or generator. System stability was evaluated based on monitoring nearby generators power output, rotor angle, voltage, and frequency as well as nearby buses voltage and frequency.

<u>Voltage Criteria</u>

- For this analysis, EPE monitored nearby buses and generators for each contingency in order to identify any voltage stability events.
- The following criteria were used to identify the voltage violations for system intact (N-0) and single contingency (N-1):
    - ±10% for the 132 kV transmission elements
    - ±5% for the 400 kV transmission elements

<u>Frequency Criteria</u>

The frequency relaying requirements for NEPCO are shown in Table 20. For this study, the frequency was monitored at buses near to the contingency to ensure that the frequency remained within the normal operating range.

Table 20 – Frequency Relaying Requirements

Frequency Range (Hz)	Delay to trip (s)
51.5 < Freq	0.5
47.5 ≤ Freq ≤ 51.5	Continuous
47.0 < Freq < 47.5	20
Freq ≤ 47	0.5

Stability Criteria

The NEPCO system should show adequate stability for voltage, rotor angle, and frequency following a three phase or single phase fault which will result in the tripping of a transmission element. The fault clearing time for all faults is four (4) cycles as specified by NEPCO.

Contingency Description

EPE evaluated the contingency conditions, described in Table 21, for both Scenario 1 and Scenario 2 in order to investigate the impact of the interconnection of the Fujeij wind farm.

Table 21 – Single Contingencies (N-1) Evaluated

Contingency Label	Description
CTG_1	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1
CTG_2	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1
CTG_3	Three phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project
CTG_4	Three phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1
CTG_5	Three phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1
CTG_6	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1
CTG_7	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1
CTG_8	Single phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project
CTG_9	Single phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1
CTG_10	Single phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1

3.3.2 LVRT/HVRT Analysis

An LVRT/HVRT analysis was performed in order to determine if the Fujeij wind farm is in compliance with the VRT requirements as stated within the IRR-TIC sections 5.2 and 5.3. For this analysis, a detailed model of the Fujeij wind project was developed and connected to an infinite bus at the PCC. The following two scenarios were evaluated:

- Scenario #1: Fujeij wind farm producing 100% active power and maximum lagging reactive power

- Scenario #2: Fujeij wind farm producing 100% active power and maximum leading reactive power

The voltage at the PCC was modified in order to evaluate compliance with the VRT requirements. The LVRT simulation was run for 180 seconds and the HVRT simulation was run for 60 seconds, each with a one (1) second steady state run prior to introducing the VRT profile. VRT compliance was evaluated by monitoring the voltage and power output of each of the Fujeij wind turbines. The VRT profiles are shown in Figure 2 and Figure 3.

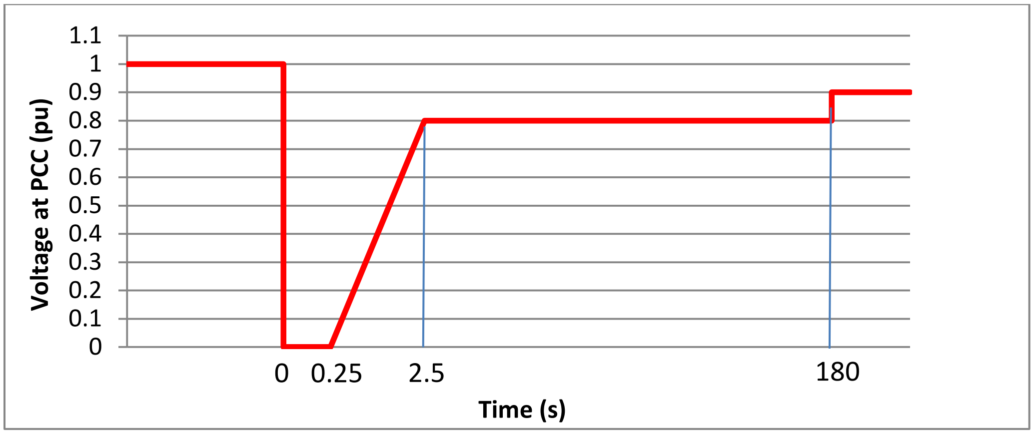


Figure 2 – LVRT Relaying Requirements

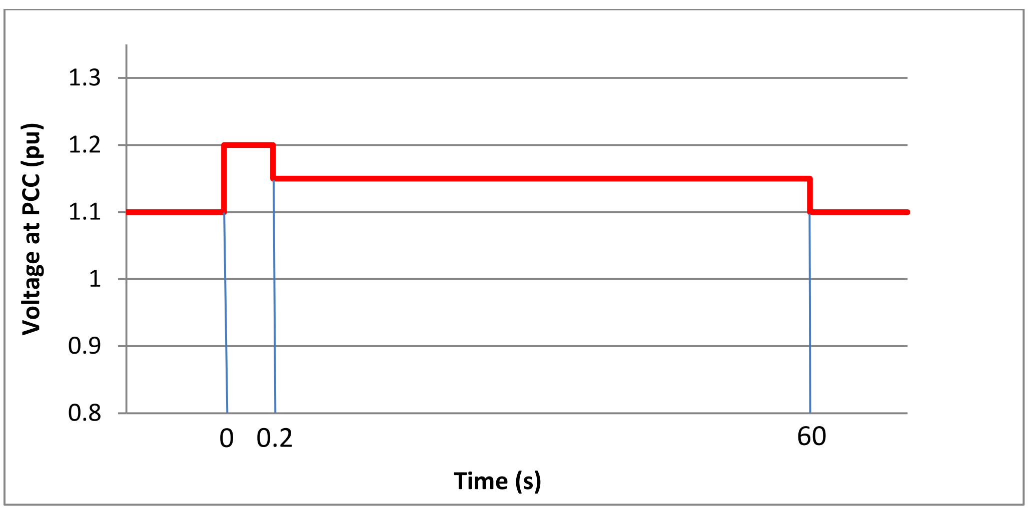


Figure 3 – HVRT Relaying Requirements

3.4 Study Findings

3.4.1 Dynamic Analysis

EPE evaluated a total of ten (10) contingency events for both Scenario 1 and Scenario 2 without the Fujeij wind farm (A) and with the Fujeij wind farm (B) in order to identify the adverse impact of the Fujeij wind farm.

Scenario #1A: Wheeling power from Egypt in effect (tie with Egypt closed) without Fujeij

For all contingencies shown in Table 22, the nearby generators and buses showed a damped response for the rotor angle, voltage and frequency. For each of these contingencies, the nearby bus voltages and frequencies remained within the contingency voltage stability limits defined in "Study Methodology". The associated plots for this scenario can be found in Appendix C.

Scenario #1B: Wheeling power from Egypt in effect (tie with Egypt closed) with Fujeij

For all contingencies shown in Table 22, the nearby generators and buses showed a damped response for the rotor angle, voltage and frequency. For each of these contingencies, the nearby bus voltages and frequencies remained within the contingency voltage stability limits defined in "Study Methodology". The associated plots for this scenario can be found in Appendix D.

Table 22 – Scenario 1 – Dynamic Analysis Results

Contingency Label	Description	Scenario 1 (Egypt tie - closed)	
		A (Without Fujeij)	B (With Fujeij)
CTG_1	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_2	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_3	Three phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_4	Three phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_5	Three phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable
CTG_6	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_7	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_8	Single phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_9	Single phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_10	Single phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable

Scenario #2A: Jordan islanded with the connections between Jordan and Egypt opened without Fujeij

For all contingencies shown in Table 23, the nearby generators and buses showed a damped response for the rotor angle, voltage and frequency. For each of these contingencies, the nearby bus voltages and frequencies remained within the contingency voltage stability limits defined in "Study Methodology". The associated plots for this scenario can be found in Appendix E.

Scenario #2B: Jordan islanded with the connections between Jordan and Egypt opened with Fujeij

For all contingencies shown in Table 23, the nearby generators and buses showed a damped response for the rotor angle, voltage and frequency. For each of these contingencies, the nearby bus voltages and frequencies remained within the contingency voltage stability limits defined in "Study Methodology". The associated plots for this scenario can be found in Appendix F.

Table 23 – Scenario 2 – Dynamic Analysis Results

Contingency Label	Description	Scenario 2 (Egypt tie - opened)	
		A (Without Fujeij)	B (With Fujeij)
CTG_1	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_2	Three phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_3	Three phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_4	Three phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_5	Three phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable
CTG_6	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Maan circuit 1	N/A	Stable
CTG_7	Single phase fault at Fujeij cleared in four (4) cycles by tripping the 132 kV transmission line from Fujeij to Rashadiya circuit 1	N/A	Stable
CTG_8	Single phase fault at Fujeij cleared in four (4) cycles by tripping the Fujeij Wind Project	N/A	Stable
CTG_9	Single phase fault at Maan cleared in four (4) cycles by tripping the 132 kV transmission line from Maan to Fujeij circuit 1	Stable	Stable
CTG_10	Single phase fault at Rashadiya cleared in four (4) cycles by tripping the 132 kV transmission line from Rashadiya to Fujeij circuit 1	Stable	Stable

3.4.2 LVRT/HVRT Analysis

EPE evaluated two (2) scenarios with the Fujeij wind farm producing 100% active power and maximum lagging reactive power (1) and maximum leading reactive power (2) in order to determine compliance with the VRT requirements specified within the IRR-TIC sections 5.2 and 5.3.

Scenario #1: Fujeij wind farm producing 100% active power and maximum lagging reactive power

The LVRT analysis revealed that the Fujeij wind farm will not meet the low voltage requirements for this scenario with the standard Vestas voltage relay settings. All of the Vestas wind turbines trip offline at 61 seconds with a minimum voltage of 0.8876 pu at WTG22 prior to the trip. This can be seen in Figure 4. This response is expected considering the default voltage trip setting for voltages of 0.8 – 0.9 pu is 60 seconds. It is recommended to increase this trip setting to be at a minimum of 180 seconds in order to meet the IRR-TIC requirements. All associated plots for this scenario can be found in Appendix G.

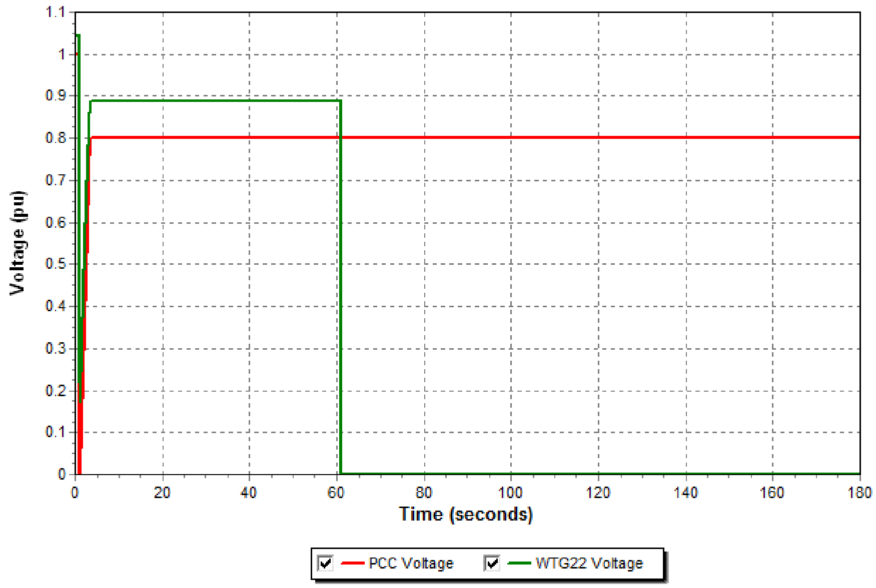


Figure 4 – Voltage Response of WTG22

The HVRT analysis revealed that the Fujeij wind farm will meet the high voltage requirements for this scenario with the standard Vestas voltage relay settings. However, it was observed that all of the turbines ramped down and ramped back up their output between 18 – 30 seconds. This is shown in Figure 5 and EPE recommends discussing this response with Vestas in order to understand what is causing the model to perform this way. The highest voltage observed within the Fujeij wind farm was 1.228 pu at WTG13. This is shown in Figure 6. All associated plots for this scenario can be found in Appendix G.

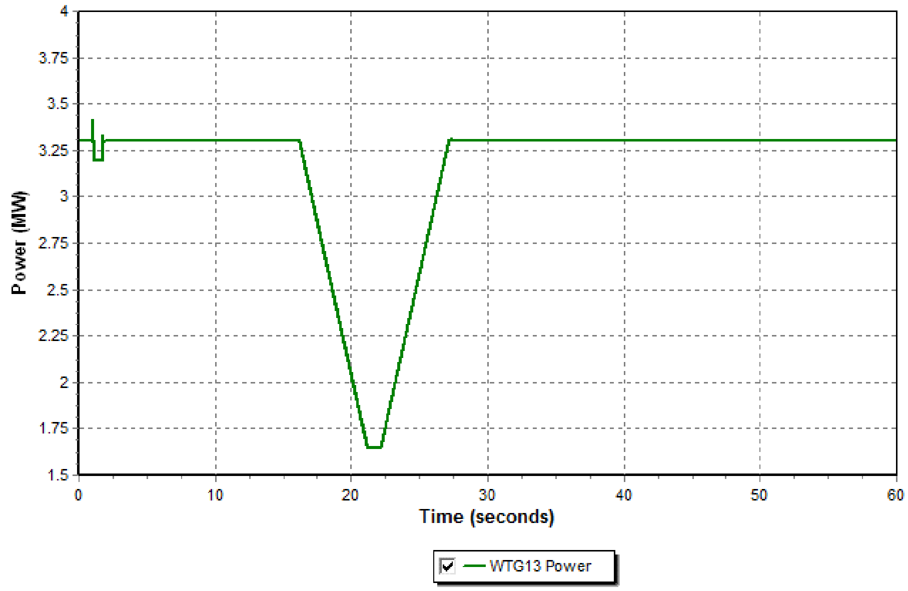


Figure 5 – Power Response of WTG13

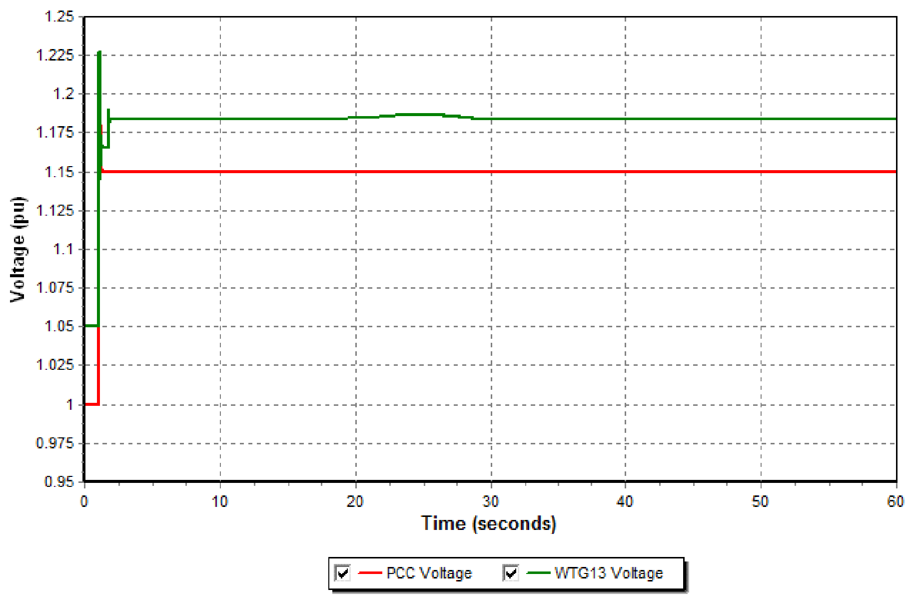


Figure 6 – Voltage Response of WTG13

<u>Scenario #2: Fujeij wind farm producing 100% active power and maximum leading reactive power</u>

The LVRT analysis revealed that the Fujeij wind farm will not meet the low voltage requirements for this scenario with the standard Vestas voltage relay settings. All of the Vestas wind turbines trip offline at 11.21 seconds with a minimum voltage of 0.8364 pu at WTG21 prior to the trip. This can be seen in Figure 7. This response is not expected considering the default voltage trip setting for voltages of 0.8 – 0.9 pu is 60 seconds. However, it was noticed that within the Vestas dynamic model settings there is a voltage trip setting at 0.85 pu for 10.2 seconds. This matches the response observed. It is recommended to increase this trip setting to be at a minimum of 180 seconds in order to meet the IRR-TIC requirements. All associated plots for this scenario can be found in Appendix G.

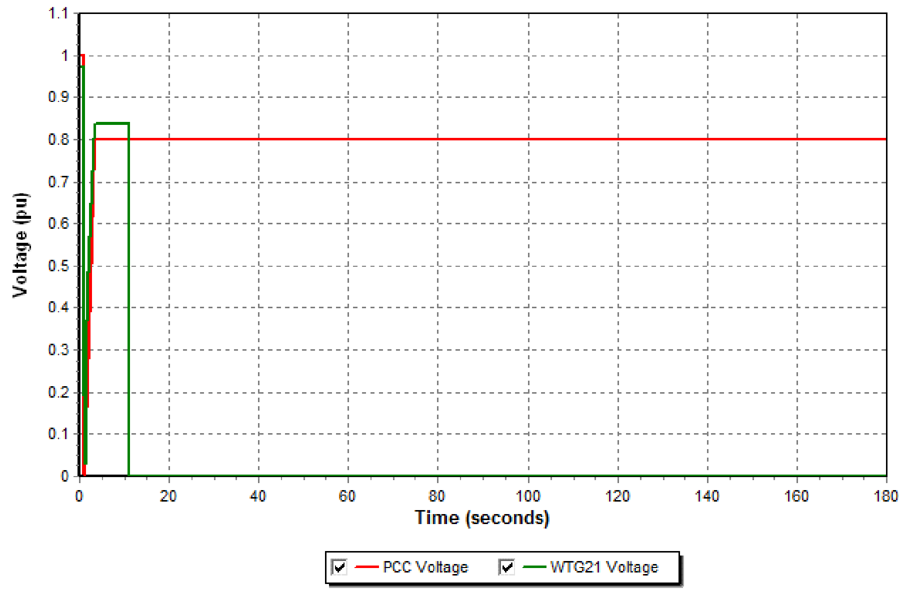


Figure 7 – Voltage Response of WTG21

The HVRT analysis revealed that the Fujeij wind farm will meet the high voltage requirements for this scenario with the standard Vestas voltage relay settings. The highest voltage observed within the Fujeij wind farm was 1.21 pu at WTG27. This is shown in Figure 8. All associated plots for this scenario can be found in Appendix G.

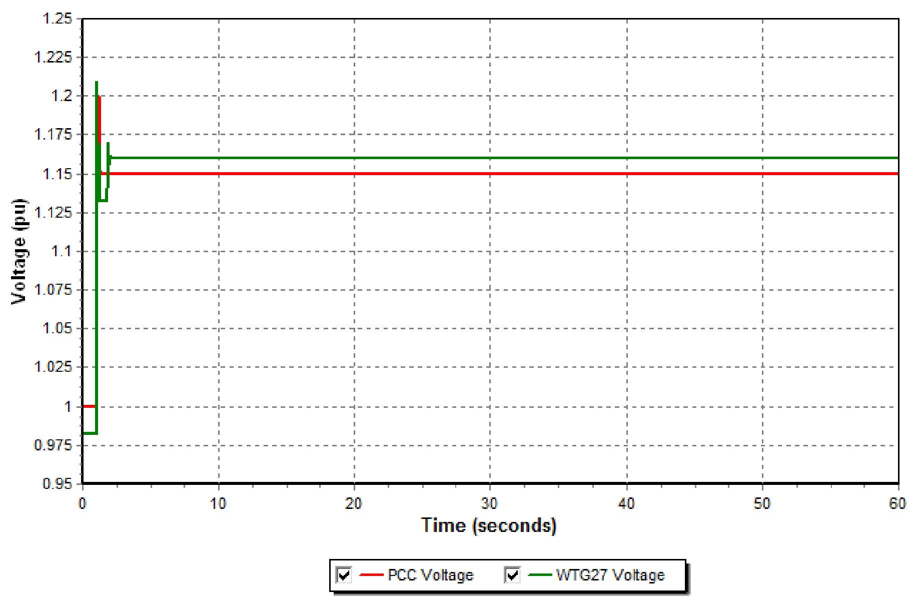


Figure 8 – Voltage Response of WTG27

Appendix A, Fujeij Wind Farm Dynamic Model

Table 24 – Vestas V126 GSCORE Dynamic Model Settings

CON	Value	Description
J	3300	Generator kVA rating
J+1	650	Generator voltage rating
J+2	4144	Rated rotor current (A)
J+3	0.01	Time constant for 10ms moving average filter
J+4	0	Not Used
J+5	0	Not Used
J+6	0	Not Used
J+7	0.35	P control proportional gain
J+8	7.85	P control integral gain
J+9	0.0001	Q control proportional gain
J+10	940	Q control integral gain
J+11	-3700	Pref lower limit
J+12	3700	Pref upper limit
J+13	-3300	Qref lower limit
J+14	3300	Qref upper limit
J+15	0.97	Not Used
J+16	0.85	Not Used
J+17	0.75	Not Used
J+18	1	Not Used
J+19	1	Not Used
J+20	0	Not Used
J+21	0	Not Used
J+22	0	Not Used
J+23	0	Model interface MI
J+24	0.03	Time const for Us filter (current injection)
J+25	0.3	Threshold of stator voltage (current injection)
J+26	0	Current injection mode
J+27	0	Reserved for future ver
J+28	0	Reserved for future ver
J+29	0	Reserved for future ver
J+30	0	Reserved for future ver
J+31	0	Reserved for future ver
J+32	0	Reserved for future ver
J+33	0	Reserved for future ver
J+34	0	Reserved for future ver
J+35	0	Reserved for future ver
J+36	0	Reserved for future ver
J+37	0	Reserved for future ver
J+38	0	Reserved for future ver
J+39	0	Reserved for future ver
J+40	0	Reserved for future ver
J+41	0	Reserved for future ver
J+42	0	Reserved for future ver
J+43	0	Reserved for future ver
J+44	0	Reserved for future ver

Table 25 – Vestas V126 GSLVR1 Dynamic Model Settings

CON	Value	Description
J	0.85	AGO threshold, V_{AGO}
J+1	0	Disp.
J+2	0.6	RegainPQ delay
J+3	10	LVRT I_P pos slope, R_{IP+}, If equal zero then disabled
J+4	200	LVRT I_P neg slope, R_{IP-}, If equal zero then disabled
J+5	100	LVRT I_Q pos slope, R_{IQ+}, If equal zero then disabled
J+6	200	LVRT I_Q neg slope, R_{IQ-}, If equal zero then disabled
J+7	0	Active Current Priority 1- Active current priority 0- Reactive current priority
J+8	1.08	Current Overload Factor (Ip priority)
J+9	0.005	Offset (Ip priority)
J+10	1.005	Gain (Ip priority)
J+11	1.44	Short term current overload threshold, I_R*
J+12	1	Disp.
J+13	650	Rated voltage, V
J+14	4145.2	Rated current, I_R
J+15	0	Disp.
J+16	0	Disp.
J+17	0	Disp.
J+18	0	Disp.
J+19	0	Disp.
J+20	0	Disp.
J+21	0	Disp.
J+22	0	Disp.
J+23	0	Disp.
J+24	0.9	AGO threshold, V_{AGO2}., Leaving AGO [pu]
J+25	0	Disp.
J+26	2	Disp.
J+27	0.01	Time Constant for FRT Voltage Filter [s] (10ms filter)
J+28	1.3	Disp.
J+29	0	I_offset for LVRT curve
J+30	2	K Parameter for LVRT curve
J+31	1	QoffsetEnab for LVRT curve (1 to enable offset)Reserved for future ver
J+32	0	Fassym flag for Asymmetrical fault (1 to enable asymmetrical Derating; 0 is default)

CON	Value	Description
J+33	1.05	Upper limit of reactive current (CC_Lim)
J+34	-1	Lower limit of reactive current (IC_Lim)
J+35	1.2	Reactive Current Point1U
J+36	0.85	Reactive Current Point2U
J+37	0.15	Reactive Current Point4U
J+38	0.05	Reactive Current Point5U
J+39	0.1	Active Current Zone3U2
J+40	0.49	Active Current Zone3U1
J+41	0.5	Active Current Zone2U2
J+42	0.8	Active Current Zone2U1
J+43	0.39	Active Current Zone3I
J+44	0.4	Active Current Zone2I
J+45	0	Reactive Current Point1I
J+46	0	Reactive Current Point2I
J+47	0.05	Reactive Current Point5I
J+48	0.9	Lower limit of voltage (U_LL_LIM)
J+49	1.1	Higher limit of voltage (U_HL_LIM)
J+50	0.08	Disp.
J+51	0.8	Qref Derate1
J+52	0.9	Qref Derate2
J+53	1.1	Qref Derate3
J+54	1.2	Qref Derate4
J+55	0.1	Asym Reduc deadband
J+56	2.5	Asym Reduc kfactor
J+57	0.6	Asym Reduc limit
J+58	1199.8	TotalCF
J+59	60	Time Constant for one min Voltage Filter [s]
J+60	1	Upper limit of OneMinAvg
J+61	1	Lower limit of OneMinAvg
J+62	1.25	HVRT Entry Threshold
J+63	1.2	HVRT Leaving Threshold
J+64	0.7	LVRT instantaneous Voltage Threshold

Table 26 – Vestas V126 GSPWR1 Dynamic Model Settings

CON	Value	Description
J	1	Real power export lim
J+1	0.667	Reactive pwr export lim
J+2	-0.667	Reactive pwr import lim
J+3	-0.1626	Max active power when Q at export limit
J+4	0.5528	Max active power when Q at import limit
J+5	0.863	Min power factor for export at max real pwr
J+6	0.9333	Min power factor for import at max real pwr
J+7	0	Min power factor for export at any pwr level
J+8	0	Min power factor for import at any pwr level
J+9	0.1	P pos slope limit, R_{P+}
J+10	0.1	P neg slope limit, R_{P-}
J+11	20	Q pos slope limit, R_{Q+}
J+12	20	Q neg slope limit, R_{Q-}
J+13	0.032	P ref time constant, T_P
J+14	0.032	Q ref time constant, T_Q
J+15	1	QoverP Flag (0 for P priority and 1 for Q Priority; 0 is default)
J+16	0.85	Qcap Degrade starting Voltage (pu)
J+17	0.9	Qcap Degrade complete Voltage (pu)
J+18	0.93	Qind Degrade starting Voltage (pu)
J+19	1.08	Qind Degrade complete Voltage (pu)
J+20	1.1	Degrade Qcap Level (pu)
J+21	1.2	Degrade Qind Level (pu)
J+22	1	Reserved for Future Version
J+23	1.4	Reserved for Future Version
J+24	0	Reserved for Future Version
J+25	0	Reserved for Future Version
J+26	0	Reserved for Future Version
J+27	0	Reserved for Future Version
J+28	0	Reserved for Future Version
J+29	0	Reserved for Future Version

Table 27 – Vestas V126 GSMEA1 Dynamic Model Settings

CON	Value	Description
J	0.032	Real pwr time const, T_P
J+1	0.032	React pwr time const, T_Q
J+2	0	Reserved for Future Version
J+3	0	Reserved for Future Version
J+4	0	Reserved for Future Version
J+5	0	Reserved for Future Version
J+6	0	Reserved for Future Version
J+7	0	Reserved for Future Version
J+8	0	Reserved for Future Version
J+9	0	Reserved for Future Version

Table 28 – Vestas V126 GSVPR1 Dynamic Model Settings

CON	Value	Description
J	0.85	Extreme UV limit
J+1	10.2	Extreme UV timeout
J+2	0.85	Short-term UV limit
J+3	10.2	Short-term UV timeout
J+4	0.9	Continuous UV limit
J+5	60	Continuous UV timeout
J+6	1.1	Continuous OV limit
J+7	3600	Continuous OV timeout
J+8	1.21	Short-term OV limit
J+9	2	Short-term OV timeout
J+10	1.36	Extreme OV1 limit
J+11	0.15	Extreme OV1 timeout
J+12	1.36	Extreme OV2 limit
J+13	0.15	Extreme OV2 timeout
J+14	1.36	Extreme OV3 limit
J+15	0.15	Extreme OV3 timeout
J+16	0	Reserved for Future Version
J+17	0	Reserved for Future Version
J+18	0	Reserved for Future Version
J+19	0	Reserved for Future Version

CON	Value	Description
J+20	0	Reserved for Future Version
J+21	0	Reserved for Future Version
J+22	0	LVRT extreme UV limit
J+23	0.55	LVRT extreme UV limit timeout
J+24	0.7	LVRT short-term UV
J+25	2.6	LVRT short-term UV timeout
J+26	0.7	LVRT mid-term UV
J+27	2.6	LVRT mid-term UV timeout
J+28	0.7	LVRT continuous UV limit
J+29	2.6	LVRT continuous UV limit timeout

Table 29 – Vestas V126 GSMEA1 Dynamic Model Settings

CON	Value	Description
J	47	Extreme Under-Freq limit
J+1	0.2	Extreme Under-Freq timeout
J+2	47	Short-term Under-Freq limit
J+3	0.2	Short-term Under-Freq timeout
J+4	47	Continuous Under-freq limit
J+5	0.2	Continuous Under-freq timeout
J+6	53	Continuous Over-freq limit
J+7	0.2	Continuous Over-freq timeout
J+8	53	Short-term Over-Freq limit
J+9	0.2	Short-term Over-Freq timeout
J+10	53	Extreme Over-Freq limit
J+11	0.2	Extreme Over-Freq timeout

Appendix B, Renewable Generator Dynamic Model Updates

Table 30 – Bonfiglioli Dynamic Model Settings

CON	Description	Value
J	PV ARRAY VOC/VMP RATIO (VRATIO)	1.25
J+1	PV ARRAY ISC/IMP RATIO (IRATIO)	1.07
J+2	DC LINK TIME CONSTANT, SEC (TDC)	0.1
J+3	INVERTER AC THERMAL CURRENT LIMIT, PU (ILIM)	1.1
J+4	DC VOLTAGE REGULATOR PROPORTIONAL GAIN (KPDC)	1
J+5	DC VOLTAGE REGULATOR INTERGRAL GAIN (KIDC)	5
J+6	Q REGULATOR PROPORTIONAL GAIN (KPQ)	0.1
J+7	Q REGULATOR INTEGRAL GAIN (KIQ)	40
J+8	PLL PROPORTIONAL GAIN (KPPLL)	0.3
J+9	PLL INTEGRAL GAIN (KIPLL)	1
J+10	FREQUENCY START POWER REDUCTION (HZ) (FSTART)	50.5
J+11	FREQUENCY STOP POWER REDUCTION (HZ) (FSTOP)	50.05
J+12	GRADIENT FOR POWER REDUCTION (PERECENT) (PSLP)	20
J+13	POWER FACTOR LIMIT FOR OPEARTION MODE 1 (PFLIM)	0.95
J+14	OPERATION MODE 1 : ACTIVE POWER SATURATION LIMIT (MAX) UNDER (PU) (PMAX)	0.1
J+15	OPERATION MODE 1: ACTIVE POWER SATURATION LIMIT (MIN) UNDER (PU) (PMIN)	0.9
J+16	OPERATION MODE 3: MINIMUM UNDER VOLTAGE LIMIT (PU) (VMIN)	0.9
J+17	OPERATION MODE 3: MAXIMUM OVER VOLTAGE LIMIT (PU) (VMAX)	1.1
J+18	RESPONSE TIME Q-V CHARACTERISTICS (SEC) (QVT)	0
J+19	MAXIMUM UNDER VOLTAGE LIMIT FOR Q(V) CHARACTERISTICS (PU) (UVVMAX)	0.5
J+20	MINIMUM ADDITIONAL REACTIVE CURRENT FOR OVER VOLTAGE CONDITION FOR Q(V) CHARACTERISTICS (PU) (UVIMAX)	0.1
J+21	MAXIMUM ADDITIONAL REACTIVE CURRENT FOR OVER VOLTAGE CONDITION FOR Q(V) CHARACTERISTICS (PU) (UVIMIN)	0.5
J+22	MAXIMUM OVER VOLTAGE LIMIT FOR Q(V) CHARACTERISTICS (PU) (OVVMAX)	1.5
J+23	MINIMUM ADDITIONAL REACTIVE CURRENT FOR UNDER VOLTAGE CONDITION FOR Q(V) CHARACTERISTICS (PU) (OVIMIN)	0.1
J+24	MAXIMUM ADDITIONAL REACTIVE CURRENT FOR UNDER VOLTAGE CONDITION FOR Q(V) CHARACTERISTICS (PU) (OVIMAX)	0.5
J+25	LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 1 (PU) (LV1)	0.9
J+26	LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 2 (PU) (LV2)	0.7
J+27	LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 3 (PU) (LV3)	0.2
J+28	LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 4 (PU) (LV4)	0.2
J+29	RESPONSE TIME FOR LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 1 (SEC) (LVT1)	3
J+30	RESPONSE TIME FOR LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 2 (SEC) (LVT2)	1.5
J+31	RESPONSE TIME FOR LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 3 (SEC) (LVT3)	0.16

J+32	RESPONSE TIME FOR LOW VOLTAGE RIDE THROUGH: UNDER VOLTAGE SET POINT 4 (SEC) (LVT4)	0.16
J+33	OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 1 (PU) (OV1)	1.1
J+34	OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 2 (PU) (OV2)	1.2
J+35	OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 3 (PU) (OV3)	1.3
J+36	OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 4 (PU) (OV4)	1.3
J+37	RESPONSE TIME FOR OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 1 (SEC) (OVT1)	2
J+38	RESPONSE TIME FOR OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 2 (SEC) (OVT2)	1
J+39	RESPONSE TIME FOR OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 3 (SEC) (OVT3)	0.16
J+40	RESPONSE TIME FOR OVER VOLTAGE RIDE THROUGH: OVER VOLTAGE SET POINT 4 (SEC) (OVT4)	0.16
J+41	LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 1 (HZ) (LF1)	49.4
J+42	LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 2 (HZ) (LF2)	47.8
J+43	LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 3 (HZ) (LF3)	47.3
J+44	LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 4 (HZ) (LF4)	47
J+45	RESPONSE TIME FOR LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 1 (SEC) (LFT1)	180
J+46	RESPONSE TIME FOR LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 2 (SEC) (LFT2)	30
J+47	RESPONSE TIME FOR LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 3 (SEC) (LFT3)	0.75
J+48	RESPONSE TIME FOR LOW FREQUENCY RIDE THROUGH: UNDER FREQUENCY SET POINT 4 (SEC) (LFT4)	0.1
J+49	OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 1 (HZ) (OF1)	50.6
J+50	OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 2 (HZ) (OF2)	51.6
J+51	OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 3 (HZ) (OF3)	51.7
J+52	OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 4 (HZ) (OF4)	51.7
J+53	RESPONSE TIME FOR OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 1 (SEC) (OFT1)	180
J+54	RESPONSE TIME FOR OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 2 (SEC) (OFT2)	30
J+55	RESPONSE TIME FOR OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 3 (SEC) (OFT3)	0.1
J+56	RESPONSE TIME FOR OVER FREQUENCY RIDE THROUGH: OVER FREQUENCY SET POINT 4 (SEC) (OFT4)	0.1
J+57	POST LVRT ACTIVE CURRENT RAMP UP RATE LIMIT, PU/SEC (PRLIM)	0.1
J+58	POST LVRT REACTIVE CURRENT RAMP UP RATE LIMIT, PU/SEC (QRLIM)	0.1
J+59	UP RAMP RATE LIMIT, PU/SEC (URLIM)	0.1
J+60	DOWN RAMP RATE LIMIT, PU/SEC (DRLIM)	0.1

Table 31 – Ultra Inverter Dynamic Model Settings

CON	Description	Value
J	Ratio of PV array open circuit to peak power voltage (Vratio)	1.19
J+1	Ratio of PV array short circuit to peak power current (Iratio)	1.08
J+2	Inverter DC capacitor bank time constant (TDC), sec	0.05
J+3	DC voltage regulator proportional gain (KPDC)	1
J+4	DC voltage regulator integral gain (KIDC)	30
J+5	Inverter AC thermal current limit (ILIM), pu on plant base	1.11
J+6	Overvoltage pickup (OV1L), pu	1.2
J+7	Overvoltage time delay (OV1T), sec	0.035
J+8	Overvoltage pickup (OV2L), pu	1.15
J+9	Overvoltage time delay (OV2T), sec	60
J+10	Undervoltage pickup (UV1L), pu	0.8
J+11	Undervoltage time delay (UV1T), sec	1.5
J+12	Undervoltage pickup (UV2L), pu	0
J+13	Undervoltage time delay (UV2T), sec	0.25
J+14	Overfrequency pickup (OF1L), Hz	51.5
J+15	Overfrequency time delay (OF1T), sec	0.04
J+16	Overfrequency pickup (OF2L), Hz	51.5
J+17	Overfrequency time delay (OF2T), sec	0.04
J+18	Underfrequency pickup (UF1T), Hz	47.5
J+19	Underfrequency time delay (UF1L), sec	0.04
J+20	Underfrequency pickup (UF2T), Hz	47.5
J+21	Underfrequency time delay (UF2L), sec	0.05
J+22	Active power vs. frequency slope (FSLP)	-0.4
J+23	Frequency set point for active power reduction (FSET), Hz	50.2
J+24	Frequency reset point for active power reduction (FRES), Hz	50.05
J+25	Low Voltage Ride Through (LVRT) enable/disable (LVE)	0
J+26	LVRT low voltage for reactive current management (VLIQ), pu	0.95
J+27	LVRT high voltage for reactive current management (VHIQ), pu	0.97
J+28	LVRT low voltage for active current management (VLID), pu	0.82
J+29	LVRT high voltage for active current management (VHID), pu	0.85
J+30	LVRT active current minimum (IDSP), pu	0.022
J+31	LVRT time delay for detecting voltage recovery (THIQ), sec	0.5
J+32	LVRT reactive current minimum (IQMIN), sec	0.87
J+33	LVRT dIq/dV slope for reactive current management (KSLP)	2
J+34	Mode of operation (QMOD) (0 = Constant PF, 1 = Constant Q, 2 = Variable Q as a function of terminal voltage	2
J+35	Variable reactive power mode Q/V characteristic - point X0	0.9
J+36	Variable reactive power mode Q/V characteristic - point X1	0.92
J+37	Variable reactive power mode Q/V characteristic - point X2	1.08
J+38	Variable reactive power mode Q/V characteristic - point X3	1.1

J+39	Variable reactive power mode Q/V characteristic - point Y0	0.386
J+40	Variable reactive power mode Q/V characteristic - point Y3	-0.386
J+41	PLL gain (KPLL)	30
J+42	System frequency (FSYS), Hz	50

Table 32 – SMA Dynamic Model Settings

CON	Description	Value
J	PPRIM	1
J+1	PWNOM	1
J+2	PF_PFEXTSTR	0
J+3	PF_PFSTR	0.9
J+4	PF_WNOMSTR	0.5
J+5	PF_PFEXTSTOP	1
J+6	PF_PFSTOP	0.9
J+7	PF_WNOMSTOP	0.9
J+8	PWCTLHZMOD	0
J+9	PHZSTR	0.2
J+10	PHZSTOP	0.05
J+11	PHZWGRA	0.4
J+12	VARCTLVOL_VARTM	2
J+13	QVARMOD	3
J+14	VARCTLVOL_VOLREF	1
J+15	VARCTLVOL_VOLDB	0
J+16	VARCTLVOL_VARGRA	5
J+17	VARCTLVOL_VARMAX	0.5
J+18	PFEXT	0
J+19	PF	1
J+20	QVARNOM	0
J+21	DGSMOD	1
J+22	DGSARGRANOM	2
J+23	DGSQPWMVOLNOM	0
J+24	DGSQPWMTM	5
J+25	DGSNQPWMVOLNOM	0.9
J+26	DGSNQPWMTS	0
J+27	DGSHYSTVOLNOM	0.05
J+28	VOLCTL_HHHLIM	1.2
J+29	VOLCTL_HHHLIMTM	0.16
J+30	VOLCTL_HHLIM	1.2
J+31	VOLCTL_HHLIMTM	0.16
J+32	VOLCTL_HLIM	1.1
J+33	VOLCTL_HLIMTM	1

J+34	VOLCTL_LLIM	0.88
J+35	VOLCTL_LLIMTM	2
J+36	VOLCTL_LLLIM	0.5
J+37	VOLCTL_LLLIMTM	0.16
J+38	VOLCTL_LLLLIM	0.5
J+39	VOLCTL_LLLLIMTM	0.16
J+40	VOLCTL_RECONMAX	1.06
J+41	VOLCTL_RECONMIN	0.95
J+42	FRQCTL_HHHLIM	52.5
J+43	FRQCTL_HHHLIMTM	0.1
J+44	FRQCTL_HHLIM	51.5
J+45	FRQCTL_HHLIMTM	0.2
J+46	FRQCTL_HLIM	50.5
J+47	FRQCTL_HLIMTM	0.76
J+48	FRQCTL_LLIM	48
J+49	FRQCTL_LLIMTM	4
J+50	FRQCTL_LLLIM	47.5
J+51	FRQCTL_LLLIMTM	3
J+52	FRQCTL_LLLLIM	47
J+53	FRQCTL_LLLLIMTM	2
J+54	FRQCTL_RECONMAX	51.5
J+55	FRQCTL_RECONMIN	47.5
J+56	KPLL1	30
J+57	PLLFLAG	1
J+58	KPPLL2	10
J+59	KIPLL2	30
J+60	WRITEFILENUM	0
J+61	WRITETIMESPAN	0
J+62	GENTRPFLAG	0
J+63	DGSQRCVRTM	0.2
J+64	DGSNQRCVRTM	0.2
J+65	WGRA	0.35
J+66	VARGRA	0.35
J+67	PFGRA	0.3491
J+68	DGSARGRANOMHI	2
J+69	DGSARGRANOMLO	2
J+70	DBVOLNOMMAX	0.1
J+71	DBVOLNOMMIN	-0.1
J+72	VOLCTLCHARENA	0
J+73	VOLCTLLGTM	0.15
J+74	VOLCTLCORTM	0.1

Appendix C, Scenario 1A Dynamic Stability Results

Contingency 4	CTG_4.pdf
Contingency 5	CTG_5.pdf
Contingency 9	CTG_9.pdf
Contingency 10	CTG_10.pdf

Appendix D, Scenario 1B Dynamic Stability Results

Contingency 1	CTG_1.pdf
Contingency 2	CTG_2.pdf
Contingency 3	CTG_3.pdf
Contingency 4	CTG_4.pdf
Contingency 5	CTG_5.pdf
Contingency 6	CTG_6.pdf
Contingency 7	CTG_7.pdf
Contingency 8	CTG_8.pdf
Contingency 9	CTG_9.pdf
Contingency 10	CTG_10.pdf

Appendix E, Scenario 2A Dynamic Stability Results

Contingency 4	CTG_4.pdf
Contingency 5	CTG_5.pdf
Contingency 9	CTG_9.pdf
Contingency 10	CTG_10.pdf

Appendix F, Scenario 2B Dynamic Stability Results

Contingency 1	CTG_1.pdf
Contingency 2	CTG_2.pdf
Contingency 3	CTG_3.pdf
Contingency 4	CTG_4.pdf
Contingency 5	CTG_5.pdf
Contingency 6	CTG_6.pdf
Contingency 7	CTG_7.pdf
Contingency 8	CTG_8.pdf
Contingency 9	CTG_9.pdf
Contingency 10	CTG_10.pdf

Appendix G, LVRT/HVRT Dynamic Results

	LVRT	HVRT
Maximum Lagging	LVRT_180.pdf	HVRT_60.pdf
Maximum Leading	LVRT_180.pdf	HVRT_60.pdf

Appendix I - Scope of Work for Third Party GIS

National Electric Power Company (NEPCO) will perform a Grid Impact Study (GIS) to analyze the impact of the following generation facility interconnecting to NEPCO Transmission system at the Point of Common Coupling (PCC) indicated with the specified in-service date listed below.

Project Name	Fuel Type	Project Size	Point of Common Coupling	Requested In-Service Date

The GIS consists of the following components: steady state analysis, short circuit analysis and dynamic analysis. The steady state study will include a reactive compliance component, and the dynamic study shall include a voltage ride through component. Prior to performing any of the studies, the base case must be set up to reflect the study conditions. Below is an outline of this analysis.

BASE CASE SETUP

Steady State Base Case

The study year shall be in-line with the proposed in-service date of the Project under study. The base case will be setup to include, but not limited, the following modifications:

- Start with the last good known steady state base case available
- Apply any proposed transmission upgrades that are scheduled to be online by the in-service date of the Project
- Add any proposed generation projects that may come online by the Project in-service date
- Apply load and generation re-dispatch depending on the conditions that the Project under study should be studied under. Generation re-dispatch and load levels shall be selected generally to reflect most stressed system conditions relevant to the Project under study and the area of the Project.

Dynamic Base Case

The dynamic base case shall be prepared starting from the latest available dynamic base case. To the dynamic base case, all existing generator dynamic models shall be added, if not already modeled, as well as the models for the proposed generators that may have been added as part of the generation re-dispatch. If any user defined generator dynamic models are not available, generic models will be used based on information provided by the generators' manufacturers.

STEADY STATE ANALYSIS

Thermal and Voltage Constraints

The Steady State Analysis goal is to identify transmission system thermal and voltage limitations (if any) due to the addition of the proposed generation facility connecting to the NEPCO system under steady state conditions. The steady state study shall be conducted for each of the following two scenarios:

- Scenario #1: Wheeling from Egypt
- Scenario #2: Jordan islanded with the connections between Jordan and Egypt open

NEPCO Transmission Reliability Criteria will be adhered to during the Steady State Analysis, and the impact of the addition of the project onto the grid shall be analyzed by observing the system voltage and thermal loading conditions before and after the addition of the project. The below describes the NEPCO criteria that will be used for the study:

- Transmission element rating shall be as provided in Rate A in the PSS®E models and shall apply for normal and contingency conditions.
- A transmission element shall be considered thermally overloaded if its loading is at or above 100% of Rate A.
- Transmission elements loaded at or above 95% shall be marked as warnings.
- Normal (N-0) and contingency (N-1) conditions shall be investigated in the steady state analysis. Under N-0 all transmission elements and generators are assumed to be in service. N-1 conditions shall explore the outage of any transmission line, transformer, or generator on the grid.
- The following criteria shall be applied for voltage variation range violation under both normal and contingency conditions:
    - +/-10% for the 132 kV transmission elements
    - +/-5% for the 400 kV transmission elements

Reactive Power Compliance Study

The reactive power at the Point of Common Coupling (PCC) will be studied to investigate compliance with the Intermittent Renewable Resource Transmission Interconnection Code (IRR-TIC) Code as follows:

- The project must be capable of providing reactive power at 0.85 lagging power factor (pf) (capacitive, or generator producing VArs into the grid) to 0.95 leading pf (inductive, or the generator absorbing VArs from the grid) at the generating unit's nameplate capacity.
- The reactive power requirements must be analyzed at the PCC.
- The full lagging reactive capability of 0.85 pf of the project should be studied at 100% and 90% of the nominal voltage. The full leading reactive capability of 0.95 pf of the rated project capacity shall be made studied at 100% and 110% of the nominal voltage.
- The reactive power requirements shall be available at all MW output levels at or above 10% of the unit nameplate capacity. This reactive power profile is depicted graphically as a rectangle.
- For MW output levels below 10% of the unit nameplate capacity, the required reactive power profile is depicted graphically as a triangle.

SHORT CIRCUIT ANALYSIS

The transmission configuration for this analysis will be identical to that used in the steady state analysis, however must include any system improvements determined to be necessary to facilitate the interconnection of the Project under study, including those requirements resulting from the Steady State Study. The short circuit analysis shall:

- Identify the maximum interrupting fault current at the PCC and will propose the switchgear ratings at the PCC accordingly.
- Determine the impact of Project under study on the nearby existing transmission grid protective equipment and will flag any under-rated equipment. For that purpose the short circuit current flowing through nearby protection switchgear shall be determined and tabulated before and after the addition of the project.

NEPCO will calculate the short circuit fault current at the 132 and 400 kV busses, before and after adding the Project under study. Fault currents will be calculated for three-phase and single line-to-ground faults. At the end of this analysis, a list of the existing facilities will be produced indicating any facilities that may need to be upgraded as a result of the increased short circuit fault duties due to the addition of the Project under study.

DYNAMIC STABILITY ANALYSIS

This dynamic analysis shall identify system instabilities due to the addition of the Project under study as well as evaluate the Project's capability to respond to localized fault conditions. The dynamic analysis will evaluate the stability of the system and the Project for rotor angle stability, voltage stability and frequency stability. The analysis shall also determine additional enhancements over those identified in the steady state and short circuit analyses that are required to accommodate this generation interconnection request. The dynamic analysis will be performed on the scenarios mentioned within the steady state analysis. Additionally, the dynamic analysis will include a voltage ride through (VRT) capability study to determine if the Project remains online during high and low voltage events. Both of these studies are described in detail here below.

The Dynamic case, prepared under the base case setup, will be used for this analysis. The transmission configuration for this analysis will be identical to that used in the steady state analysis including improvements determined to be necessary to facilitate the interconnection of the Project under study. The dynamic models of the Project under study will be added to the dynamic case as well as any proposed project added as part of the generation re-dispatch.

Stability Response

NEPCO will study the behavior and response of the system and the Project under study for selected contingencies as defined from the steady state analysis as well as faults at the PCC, each separately and independently, and will make comments on the ability of the Project to maintain stability after the fault clearance. The faults to be studied are described below

- Three-phase fault with normal clearing of 4 cycles

- Single line-to-ground fault with normal clearing of 4 cycles

The transient voltages that occur immediately following the fault clearing period shall be monitored at both the PCC and within the collection system of the Project under study to ensure that the project units continue operation during voltage events as required by the IRR Grid Code.

VRT Requirements Compliance

A transient analysis shall be run on the Project under study to determine compliance with NEPCO's IRR Gird Code for High Voltage Ride Through (HVRT) and Low Voltage Ride Through (LVRT) requirements. For the purpose of this analysis, the following voltage profiles will be applied at the PCC:

- LVRT
  - Zero volts for 0.25 seconds
  - Voltage ramp from zero volts to 0.8 pu from 0.25 to 2.5 seconds
  - 0.8 pu from 2.5 to 180 seconds
- HVRT
  - 1.2 pu for 0.2 seconds
  - 1.15 pu from 0.2 seconds to 60 seconds

The model to be used for this study shall include a detailed model of the Project under study connected to an infinite bus. The infinite bus generator will be used to apply the voltage profile scenarios listed above (which shall represent the PCC for the Project). The voltages at the PCC and within the collection system will be monitored to evaluate the project's capability to meet the LVRT/HVRT requirements.

The LVRT and HVRT studies will be completed for two operating conditions with the initial voltage at the PCC being set to 1.0 pu, as follows:

- Operating Condition 1: Active power at 100% and reactive power at maximum lagging at the Project
- Operating Condition 2: Active power at 100% and reactive power at minimum leading at the Project

DELIVERABLES

A final report will be provided to include, but not be limited to, the following:

1. A report on the steady state analysis will be issued that identifies system conditions causing any reliability criteria violations as a result of the proposed generation interconnection.

This report should also include the reactive power analysis confirming compliance with the IRR Code and indicating whether additional reactive power equipment is necessary to meet the requirements.

2. A report on the short circuit analysis will be provided and will identify the maximum interrupting fault current at the PCC and will flag any under-rated equipment for the nearby existing transmission grid.

3. A report of the dynamic stability analysis providing:
    a. The study assumptions, contingencies simulated as well criteria to pass or fail a test and the results of each scenario.
    b. A list of disturbances resulting in dynamic stability problems, if any, will be provided, along with recommended solutions.
    c. Plots of machine and system electrical parameters (frequency, voltage, active power, reactive power, rotor angle) will be provided in order to show the stability behavior of Project under study.

Appendix II - Output Template for System Impact Studies

Steady State Analysis

Executive Summary

Introduction

Provide a Description of the Project.

This steady state analysis report includes the following two component studies:

- Thermal and Voltage Loadflow Analysis to identify thermal and voltage violations, if any, under various system conditions.
- Reactive Power Compliance Study to evaluate the reactive power at the Point of Common Coupling (PCC) in order to investigate its compliance with NEPCO's Intermittent Renewable Resource Transmission Interconnection Code (IRR-TIC).

The Jordan Grid is an islanded system with the exception of an interconnection with Egypt through one AC point of interconnection. The following two scenarios should be studied:

- Scenario #1: Wheeling power from Egypt in effect (tie with Egypt closed)
- Scenario #2: Jordan islanded with the connections between Jordan and Egypt opened

Loadflow calculations should be run under system-intact (N-0) as well as single-contingency (N-1) conditions. A system-intact condition is the condition where there are no transmission elements out of service. A single-contingency is the loss of a transmission element on the grid due to planned or forced outages.

Conclusion

<u>System Impact Study:</u>

Describe the major findings and provide the following tables.

Table 33 - Scenario 1 - Summary Table under N-0 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage in the Base Case before the Addition of the Project Under Study	Loading Percentage after the Addition of the Project Under Study

Table 34 - Scenario 1 - Summary Table under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage in the Base Case before the Addition of the Project Under Study	Loading Percentage after the Addition of the Project Under Study

Table 35 - Scenario 2 - Summary Table under N-0 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage in the Base Case before the Addition of the Project Under Study	Loading Percentage after the Addition of the Project Under Study

Table 36 - Scenario 2 - Summary Table under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage in the Base Case before the Addition of the Project Under Study	Loading Percentage after the Addition of the Project Under Study

Summarize the impact of the Project under Study, if any, based on the findings.

Reactive Power Study:

Indicate the reactive support identified to be needed and provide the following table.

Table 37 – Reactive Power Compliance Assessment

Scenario Number	1	2	3	4
Scenario Description	100% Output; 0.9 pu @ PCC	100% Output; 1.1 pu @ PCC	10% Output; 0.9 pu @ PCC	10% Output; 1.1 pu @ PCC
Power Factor Required at the PCC	0.85	-0.95	0.85	-0.95
Pmax at PCC for 100% Output				
Turbine/Inverter MW | MVArs				
Q needed at the PCC to Meet NEPCO Reactive Power Requirements				
Q Calculated at the PCC				
Are Reactive Devices Needed?				
Reactive Devices Needed at the PCC to Meet NEPCO Reactive Power Requirements				
Lowest Voltage @ Turbine/Inverter Terminal				
Highest Voltage @ Turbine/Inverter Terminal				

Study Assumptions

Point of Study and Base Case Model:

Indicate the base case model as well as the load forecast applied including the month, day and hour for the load assumed.

Generation Re-Dispatch:

Indicate the generation dispatch applied for the purpose of the study, as agreed upon with NEPCO.

Transmission Planning Criteria:

List the criteria to identify thermal and voltage violations, as agreed upon with NEPCO.

Modeling of the Project Under Study:

Provide a description of how the Project under Study was modeled.

Islanding the Jordanian Network:

List the study assumptions for Scenario 2.

Study Methodology

Thermal and Voltage Violations

Table 38 - Scenarios to Investigate the Thermal and Voltage Violations

Scenario	Loadflow Calculations Before Adding the Project Under Study	Loadflow Calculations After Adding the Project Under Study
Scenario 1 (Wheeling Power from Egypt)	N-0 and N-1 (ACCC)	N-0 and N-1 (ACCC)
Scenario 2 (Jordan Islanded)	N-0 and N-1 (ACCC)	N-0 and N-1 (ACCC)

Reactive Power Compliance of the Project Under Study

The following scenarios will be studied:

- Scenario 1: 100% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 2: 100% output & maximum leading (absorbing Vars); 1.1 pu at the PCC
- Scenario 3: 10% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 4: 10% output & maximum leading (absorbing Vars); 1.1 pu at the PCC

The figure below illustrates the study methodology that should be adopted in order to run this investigation for each of the scenarios described above. Note that after identification of the amount of reactive support required, the analysis was re-run with the set amount in order to ensure that none of the project turbines/inverters will be triggered to trip due to voltage conditions exceeding its operating range, as well as to minimize the voltage change caused by the switching operations of the reactive devices.

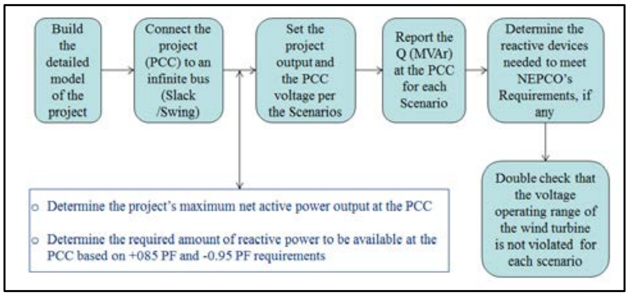


Figure 9 – Study Methodology for the Reactive Power Compliance Analysis

Study Findings

Thermal and Voltage Violations

N-0 Conditions:

Table 39 - Steady State Findings under N-0 Conditions

	Scenario 1 (Wheeling from Egypt)		Scenario 2 (Jordan Islanded)	
	Without Project	With Project	Without Project	With Project
Thermal Violations (Loading at or above 100%)				
Thermal Warnings (Loading between above 95% and below 100%)				
Voltage Violations (+/-10% for the 132 kV busses +/-5% for the 400 kV busses)				

N-1 Contingency Conditions:

Scenario 1 (Wheeling Power from Egypt)

Voltage Violations

Table 40 – Voltage Violations under N-1 Conditions – Scenario 1

Bus	Contingency	Voltage Without Project	Voltage With Project

Thermal Overloads and Warnings

Table 41 - Thermal Overloads and Warnings - Base Case Without Project - Scenario 1 Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage

Table 42 - Thermal Overloads and Warnings - Base Case With Project - Scenario 1 Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage

Scenario 2 (Jordan Islanded)

Voltage Violations

Table 43 – Voltage Violations under N-1 Conditions – Scenario 2

Bus	Contingency	Voltage Without Project	Voltage With Project

Thermal Overloads and Warnings

Table 44 - Thermal Overloads and Warnings - Base Case Without Project - Scenario 2 Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage

Table 45 - Thermal Overloads and Warnings - Base Case With Project - Scenario 2 Under N-1 Contingency Conditions

Transmission Elements Loading at or above 95%	Loading Percentage

Reactive Power Compliance Assessment

In order to investigate Project compliance with the IRR NEPCO code for the reactive power compliance, the detailed Project was modeled and connected to an infinite bus. The following scenarios were run and the findings were summarized in Table 14 below.

- Scenario 1: 100% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 2: 100% output & maximum leading (absorbing Vars); 1.1 pu at the PCC
- Scenario 3: 10% output & maximum lagging (producing Vars); 0.9 pu at the PCC
- Scenario 4: 10% output & maximum leading (absorbing Vars); 1.1 pu at the PCC

Table 46 – Reactive Power Compliance Assessment

Scenario Number	1	2	3	4
Scenario Description	100% Output; 0.9 pu @ PCC	100% Output; 1.1 pu @ PCC	10% Output; 0.9 pu @ PCC	10% Output; 1.1 pu @ PCC
Power Factor Required at the PCC	0.85	-0.95	0.85	-0.95
Pmax at PCC for 100% Output				
Turbine/Inverter MW | MVArs				
Q needed at the PCC to Meet NEPCO Reactive Power Requirements				
Q Calculated at the PCC				
Are Reactive Devices Needed?				
Reactive Devices Needed at the PCC to Meet NEPCO Reactive Power Requirements				
Lowest Voltage @ Turbine/Inverter Terminal				
Highest Voltage @ Turbine/Inverter Terminal				

Short Circuit Analysis

Executive Summary

Introduction

Provide a Description of the Project.

The purpose of the Short Circuit study is to identify the maximum interrupting fault current at the Point of Common Coupling (PCC) and to determine the impact of the Project under Study on the existing transmission grid protective equipment and flag any under-rated equipment.

The short circuit calculations should be run before and after adding the Project under Study in order to identify the adverse impact of the Project under Study, if any.

For that purpose the short circuit current flowing through nearby protection switchgear should be determined and tabulated before and after the addition of the Project.

Conclusion

Maximum Interrupting Fault Current at the PCC:

Table 15 below provides the three phase fault current and the single line to ground fault at the PCC before and after adding the Project under Study.

Table 47 - Fault Current at the PCC

Fault Current at the PCC	**Before Project**	**After Project**
Three phase fault		
Single line to ground fault		

Impact of Adding the Project under Study:

Summarize the impact of the Project under Study, if any, based on the findings.

Study Assumptions

Base Case Model:

Provide a description of the base case model used to run the Short Circuit study as well as any other relevant information such as the fault current contribution of the Project under Study as well as other projects added to the base model.

Table 48 - Fault Current Contribution of the Renewable Projects

Inverter/Turbine Manufacturer	Project(s)	Fault Current Contribution in PU

List of NEPCO Interruption Ratings for the Circuit Breakers:

Table 49 - Interruption Ratings for NEPCO Circuit Breakers

Equipment	Rating (kA)
All 132 kV bus section	
All 400 kV bus section	
Other different substations	

Study Methodology

The short circuit studies should be carried out in accordance with IEC 60909. The short circuit calculations should be run to provide the three phase fault and the single line-to-ground fault at every transmission bus on the NEPCO grid.

The fault study results for the base case (before Project) are compiled and compared to those for the case with the Project connected to assess the impact of connecting the new generation on overall fault current levels on the system.

Study Findings

Table 50 - Short Circuit Analysis Findings

Substation Name	Three Phase Fault (Amps)				Single Line to Ground Fault (Amps)			
	Before Adding Project		After Adding Project		Before Adding Project		After Adding Project	
	3 Phase Fault (Amps)	% of the Interruption Rating	3 Phase Fault (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating	SLG (Amps)	% of the Interruption Rating

Dynamic Analysis

Executive Summary

Introduction

Provide a Description of the Project.

The objective of the Dynamic study is to evaluate the behavior and response of the system as well as the Project under Study after a credible fault/contingency event (disturbance) and ensure that the NEPCO system returns to a state of equilibrium following the disturbance. The Dynamic study also includes a High Voltage Ride Through (HVRT) and Low Voltage Ride Through (LVRT) study in order to determine if the Project under Study is in compliance with the Intermittent Renewable Resources (IRR) Transmission Interconnection Code (TIC) sections 5.2 and 5.3.

The following two (2) scenarios should be studied for the purpose of this analysis:

- Scenario #1: Wheeling power from Egypt in effect (tie with Egypt closed)
- Scenario #2: Jordan islanded with the connections between Jordan and Egypt opened

The dynamic analysis was performed for each scenario without the Project under Study (A) and with the Project under Study (B) in order to identify the adverse impact of the Project under Study, if any.

For the LVRT/HVRT portion of the Dynamic analysis, a detailed model of the Project under Study connected to an infinite bus at the Point of Common Coupling (PCC) should be utilized in order to evaluate the compliance with the IRR-TIC sections 5.2 and 5.3. The following two (2) scenarios should be evaluated for this analysis:

- Scenario #1: Project providing 100% active power and maximum lagging reactive power
- Scenario #2: Project providing 100% active power and maximum leading reactive power

Conclusion

Dynamic Analysis:

Provide a summary on the findings.

Table 51 – Scenario 1 Dynamic Analysis Results

Contingency Label	Description	Scenario 1 (Egypt tie - closed)	
		A (Without Project)	B (With Project)
CTG_XX		Stable/Unstable	Stable/Unstable

Table 52 – Scenario 2 Dynamic Analysis Results

Contingency Label	Description	Scenario 2 (Egypt tie - opened)	
		A (Without Project)	B (With Project)
CTG_XX		Stable/Unstable	Stable/Unstable

LVRT/HVRT Analysis:

Provide a summary on the findings.

Table 53 – LVRT/HVRT Dynamic Analysis Results

VRT Profile	Scenario 1	Scenario 2
	100% P Max Lagging Q	100% P Max Leading Q
LVRT	**Fail**/Pass	**Fail**/Pass
HVRT	**Fail**/Pass	**Fail**/Pass

Study Assumptions

Dynamic Analysis

Provide a description of the dynamic base case model used for the purpose of this analysis as well as indicate the dynamic models of other Projects added to the dynamic base case model.

Table 54 – Renewable Generator Dynamic Model Description

Project	Inverter/Turbine Type	PSS®E Model

LVRT/HVRT Analysis

In order to complete the LVRT/HVRT analysis, a separate model is to be created that includes the Project under Study connected to an infinite bus at the project's PCC. The Project Under Study should be modeled for two different operating conditions:

- Scenario #1: Project providing 100% active power and maximum lagging reactive power
- Scenario #2: Project providing 100% active power and maximum leading reactive power

Study Methodology

Dynamic Analysis

Describe the study methodology as agreed upon with NEPCO.

Voltage Criteria

List the voltage criteria as agreed upon with NEPCO.

Frequency Criteria

The frequency should be monitored at buses near to the contingency to ensure that the frequency remained within the normal operating range, as agreed upon with NEPCO.

Table 55 – Frequency Relaying Requirements

Frequency Range (Hz)	Delay to trip (s)

Stability Criteria

The NEPCO system should show adequate stability for voltage, rotor angle, and frequency following a three phase or single phase fault which will result in the tripping of a transmission element. The fault clearing time for all faults should be set as specified by NEPCO.

Contingency Description

Table 56 –Contingencies Evaluated

Contingency Label	Description
CTG_XX	

LVRT/HVRT Analysis

The following two scenarios should be evaluated:

- Scenario #1: Project producing 100% active power and maximum lagging reactive power
- Scenario #2: Project producing 100% active power and maximum leading reactive power

The VRT profiles are shown in Figure 2 and Figure 3.

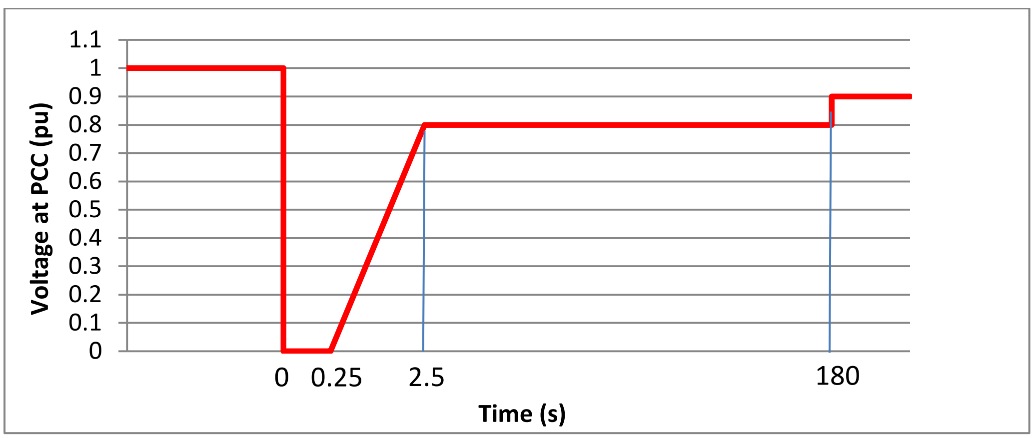


Figure 10 – LVRT Relaying Requirements

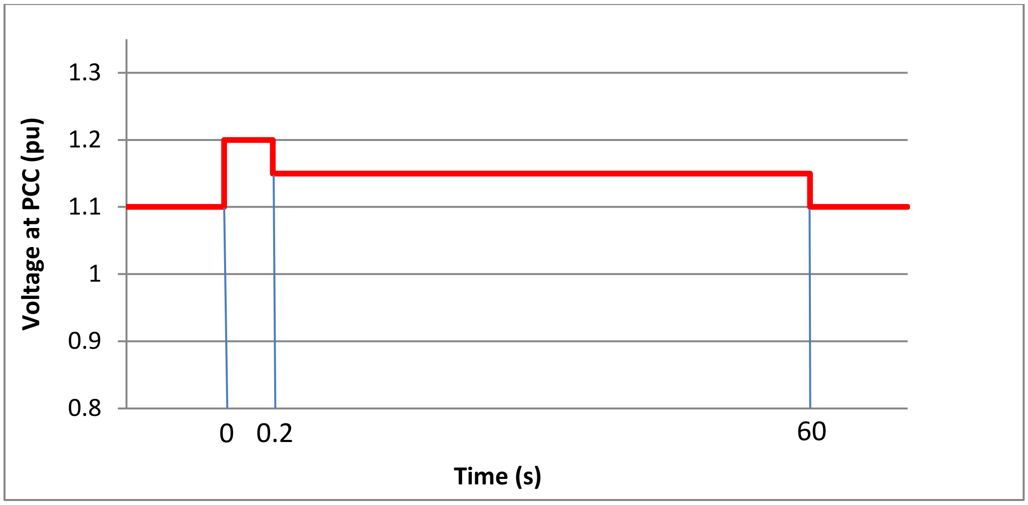


Figure 11 – HVRT Relaying Requirements

Study Findings

Dynamic Analysis

<u>Scenario #1: Wheeling power from Egypt in effect (tie with Egypt closed)</u>

Table 57 – Scenario 1 – Dynamic Analysis Results

Contingency Label	Description	Scenario 1 (Egypt tie - closed)	
		A (Without Project)	B (With Project)
CTG_XX		Stable/Unstable	Stable/Unstable

<u>Scenario #2: Jordan islanded with the connections between Jordan and Egypt opened</u>

Table 58 – Scenario 2 – Dynamic Analysis Results

Contingency Label	Description	Scenario 2 (Egypt tie - opened)	
		A (Without Project)	B (With Project)
CTG_XX		Stable/Unstable	Stable/Unstable

LVRT/HVRT Analysis

Scenario #1: Project producing 100% active power and maximum lagging reactive power

Describe the findings and provide corresponding plots.

Scenario #2: Project producing 100% active power and maximum leading reactive power

Describe the findings and provide corresponding plots.

Appendix H, Project Dynamic Model

Table 59 –Dynamic Model Settings

CON	Value	Description
J		
J+1		
J+X		

Appendix I, Scenario 1A Dynamic Stability Results

Contingency X	Insert the Complete Plots
Contingency Y	Insert the Complete Plots

Appendix J, Scenario 1B Dynamic Stability Results

Contingency X	Insert the Complete Plots
Contingency Y	Insert the Complete Plots

Appendix K, Scenario 2A Dynamic Stability Results

Contingency X	Insert the Complete Plots
Contingency Y	Insert the Complete Plots

Appendix L, Scenario 2B Dynamic Stability Results

Contingency X	Insert the Complete Plots
Contingency Y	Insert the Complete Plots

Appendix M, LVRT/HVRT Dynamic Results

	LVRT	HVRT
Maximum Lagging	Insert Complete Plots	Insert Complete Plots
Maximum Leading	Insert Complete Plots	Insert Complete Plots

Appendix III – Data Input Template

1. **Provide one set of original prints or soft copy on cd/flashdrive of the following:**
   - A. Site drawing to scale, showing generator location and Point of Interconnection.
   - B. Single-line diagram showing applicable equipment such as generating units, step-up transformers, auxiliary transformers, switches/disconnects of the proposed interconnection, including the required protection devices and circuit breakers. For wind and photovoltaic generator plants, the one line diagram should include the distribution lines connecting the various groups of generating units, the generator capacitor banks, the step up transformers, the distribution lines, and the substation transformers and capacitor banks at the Point of Common Coupling with the NEPCO Controlled Grid.

2. Generating Facility Information

- A. Total Generating Facility rated output (MW): _____
- B. Generating Facility auxiliary Load (MW): _____
- C. Project net capacity (A.-B.) (MW): _____
- D. Standby Load when Generating Facility is off-line (MW): _____
- E. Number of Generating Units: _____

  (Please repeat the following items for each generator)
- F. Individual generator rated output (MW for each unit): _____
- G. Manufacturer: _____
- H. Year Manufactured: _____
- I. Nominal Terminal Voltage (kV): _____
- J. Rated Power Factor (%):_____
- K. Type (Induction, Synchronous, D.C. with Inverter): _____
- L. Phase (three phase or single phase): _____
- M. Connection (Delta, Grounded WYE, Ungrounded WYE, impedance grounded): _____
- N. Generator Voltage Regulation Range (+/- %): _____
- O. Generator Power Factor Regulation Range: _____

7a. **Wind Generators**

Number of generators to be interconnected pursuant to this Interconnection Request: _____

Average Site Elevation: _____ ☐Single Phase ☐Three Phase

Field Volts: _____

Field Amperes: _____

Motoring Power (MW): _____

Neutral Grounding Resistor (if applicable): _____

I22t or K (Heating Time Constant): _____

Rotor Resistance: _____

Stator Resistance: _____

Stator Reactance: _____

Rotor Reactance: _____

Magnetizing Reactance: _____

Short Circuit Reactance: _____

Exciting Current: _____

Temperature Rise: _____

Frame Size: _____

Design Letter: _____

Reactive Power Required in VArs (No Load): _____

Reactive Power Required in VArs (Full Load): _____

Total Rotating Inertia, H: _____ Per Unit on 100 MVA Base

Note: A completed dynamic model must be supplied with the Interconnection Request. If other data sheets are more appropriate to the proposed device then they shall be provided and discussed at the Scoping Meeting.

8. Generator Short Circuit Data

For each generator model, provide the following reactances expressed in p.u. on the generator base:

- X"1 – positive sequence subtransient reactance: _____p.u**
- X2 – negative sequence reactance: _____p.u**
- X0 – zero sequence reactance: _____

Generator Grounding (select 1 for each model):

A. ☐ Solidly grounded

B. ☐ Grounded through an impedance

(Impedance value in p.u on generator base R: _____p.u. X: _____p.u.)

C. ☐ Ungrounded

9. Step-Up Transformer Data

For each step-up transformer, fill out the data form provided in Table 1.

10. Interconnection Facilities Line Data

There is no need to provide data for new lines that are to be planned by the Participating TO (NEPCO). However, for transmission lines that are to be planned by the generation developer, please provide the following information:

Nominal Voltage: _____kV

Line Length: _____miles

Line termination Points: _____

Conductor Type: _____ Size: _____

If bundled. Number per phase: _____, Bundle spacing: _____in.

Phase Configuration. Vertical: _____, Horizontal: _____

Phase Spacing: A-B: _____ft., B-C: _____ft., C-A: _____ft.
Distance of lowest conductor to Ground at full load and 40ºC: _____ft
Ground Wire Type: _____ Size: _____ Distance to Ground: _____ft
Attach Tower Configuration Diagram
Summer line ratings in amperes (normal and emergency) _____
Positive Sequence Resistance (R): _____ p.u.** (for entire line length)
Positive Sequence Reactance: (X): _____ p.u**(for entire line length)
Zero Sequence Resistance (R0): _____ p.u.** (for entire line length)
Zero Sequence Reactance: (X0): _____ p.u** (for entire line length)
Line Charging (B/2): _____ p.u**
** On 100-MVA and nominal line voltage (kV) Base

10a. For Wind/photovoltaic plants, provide collector System Equivalence Impedance Data Provide values for each equivalence collector circuit at all voltage levels.

Nominal Voltage: _____
Summer line ratings in amperes (normal and emergency) _____
Positive Sequence Resistance (R1): _____ p.u. ** (for entire line length of each collector circuit)
Positive Sequence Reactance: (X1): _____ p.u** (for entire line length of each collector circuit)
Zero Sequence Resistance (R0): _____ p.u. ** (for entire line length of each collector circuit)
Zero Sequence Reactance: (X0): _____ p.u** (for entire line length of each collector circuit)
Line Charging (B/2): _____ p.u** (for entire line length of each collector circuit)
** On 100-MVA and nominal line voltage (kV) Base

11. Inverter-Based Machines

Number of inverters to be interconnected pursuant to this Interconnection Request: _____

Inverter manufacturer, model name, number, and version:

_____

List of adjustable set points for the protective equipment or software:

_____

Maximum design fault contribution current:

_____

Harmonics Characteristics:

_____

Start-up requirements:

_____

Note: A completed dynamic model must be supplied with the Interconnection Request. If other data sheets are more appropriate to the proposed device then they shall be provided and discussed at the Scoping Meeting.

12. Load Flow and Dynamic Models (to be provided on DVD, CD, or USB Flash Drive):

Provide load flow model for the generating plant and its interconnection facilities in PSS/E or DIgSILENT format, including new buses, generators, transformers, interconnection facilities. An equivalent model is required for the plant with generation collector systems.

TABLE 1 - TRANSFORMER DATA
(Provide for each level of transformation)

UNIT_____

NUMBER OF TRANSFORMERS_____ PHASE _____

RATING	H Winding	X Winding	Y Winding
Rated MVA	_____	_____	_____
Connection (Delta, Wye, Gnd.)	_____	_____	_____
Cooling Type (OA,OA/FA, etc) :	_____	_____	_____
Temperature Rise Rating	_____	_____	_____
Rated Voltage	_____	_____	_____
BIL	_____	_____	_____
Available Taps (% of rating)	_____	_____	_____
Load Tap Changer? (Y or N)	_____	_____	_____
Tap Settings		_____	_____
IMPEDANCE	H-X	H-Y	X-Y
Percent	_____	_____	_____
MVA Base	_____	_____	_____
Tested Taps	_____	_____	_____
WINDING RESISTANCE	H	X	Y
Ohms	_____	_____	_____

CURRENT TRANSFORMER RATIOS

H_____ X_____ Y_____ N_____

Percent exciting current at 100% Voltage _____ 110% Voltage _____

Supply copy of nameplate and manufacture’s test report when available