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**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 1: INTERMITTENT RENEWABLE
RESOURCES TESTING, COMMISSIONING
AND CERTIFICATION PROCEDURES
DELIVERABLES REPORT**

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1. GENERAL OVERVIEW	1
2. TASK 1: INTERMITTENT RENEWABLE RESOURCES TESTING, COMMISSIONING AND CERTIFICATION PROCEDURES.....	2
2.1. Background on EPE’s Preparations and Material Provided Prior to EPE’s Second Visit	2
2.2. Second Visit Kick-off Meetings	4
2.2.1. Pre-Kickoff Meeting	4
2.2.2. Kickoff Meeting	4
2.3. Tafila Wind Power Project Grid Compliance Testing.....	6
2.4. Tafila Grid Compliance Testing – Summary Meeting & Next Steps	7
2.5. Tafila Wind Power Project Grid Compliance Testing Data Analysis and Compliance Check	8
2.6. Tafila Wind Power Project Grid Compliance Testing Results and Final Meeting	9
2.7. Intermittent Renewable Resources (IRR) Wind & PV Grid Compliance Testing Procedures (GCTP)	9
3. OTHER TECHNICAL ASSISTANCE	10
4. TAFILA TESTING VISIT SCHEDULE	11
APPENDIX A, TAFILA GRID COMPLIANCE TESTING AND COMMISSIONING PROCEDURES	12
APPENDIX B, PPA SCHEDULE 8 5_GRID COMPLIANCE CERTIFICATION	12
APPENDIX C, GRID COMPLIANCE TESTING WORKSHOP.....	12
APPENDIX D, TAFILA GRID COMPLIANCE TESTS REPORT COMMENTS.....	12
APPENDIX E, INTERMITTENT RENEWABLE RESOURCES (IRR) WIND & PV GRID COMPLIANCE PROCEDURES (GCTP)	13

1. General Overview

The USAID Jordan Energy Sector Capacity Building (ESCB) project has contracted with Electric Power Engineers, Inc. (EPE) to execute a scope of work focused on supporting National Electric Power Company (NEPCO) to integrate renewable power projects into Jordan's transmission grid. The following report summarizes the main meetings, data collected, testing, analysis and training provided in support of Testing and Commissioning of the Tafila Wind Project as well as final deliverables for this efforts. This work effort is part of the scope of **Task 1: Intermittent Renewable Resources Testing, Commissioning and Certification Procedures** of EPE's mission as described in the following paragraph.

Task 1 covers assistance in grid compliance testing of Jordan's first large-scale renewable project, the Tafila wind project, as well as a review of the testing and commissioning protocols that NEPCO adopted during this project. The objective of this task is to build upon the experience and lessons learned from the testing and commissioning of Tafila wind power project in order to improve the testing and commissioning/certification procedures to be used in future power purchase and interconnection agreements. This report provides all deliverables that EPE completed while supporting NEPCO in the Tafila Wind Project Grid Compliance Testing efforts as well as the final version of the Intermittent Renewable Resources (IRR) Wind & PV Grid Compliance Testing Procedures (GCTP).

This report provides the following deliverables as stated within the RFP Renewable Power Integration as part of **Task 1: Intermittent Renewable Resources Testing, Commissioning and Certification Procedures**:

2. Adequacy review of proposed testing and commissioning protocols.
3. Identification of additional testing or metrology equipment needs.
4. Plan for NEPCO participation in the AI Tafila certification process.
5. Recommendations for commercial readiness certification procedures to be applied to and included in future power purchase and interconnection agreements.

Table 1 below lists EPE's team members participating in this task with respective roles in their mission in Jordan.

Table 1 - List of EPE's Team Members and Roles

Team Member	Role
Hugo Mena	Leading Task 1: Intermittent Renewable Resources Testing, Commissioning and Certification Procedures
Carlos Matar	Technical Support for Task 1: Intermittent Renewable Resources Testing, Commissioning and Certification Procedures

2. Task 1: Intermittent Renewable Resources Testing, Commissioning and Certification Procedures

2.1. Background on EPE's Preparations and Material Provided Prior to EPE's Second Visit

Task 1 of EPE's scope of work started during the Inception Mission visit. A kick-off meeting for EPE's Inception Mission was held on July 27 at NEPCO's National Control Center (NCC). During this meeting, NEPCO provided a list of engineers/personnel who would work with EPE on this task - the NEPCO Testing, Commissioning and Operations (TCO) team. Following the kick-off meeting, EPE met with the TCO team to discuss the immediate needs for grid compliance testing for the interconnection of Jordan Wind Power Company (JWPC) 117 MW Tafila Wind Project into the NEPCO grid.

The Tafila Grid Compliance Testing Procedure drafted JWPC was reviewed and revised throughout the first visit (Inception Mission Visit). These revisions were accomplished through close cooperation with NEPCO, EPE, JWPC, JWPC's owner engineer, and Vestas. Appendix A, Tafila Grid Compliance Testing and Commissioning Procedures, lists the Tafila Grid Compliance Testing and Commissioning Procedures first draft as provided during the Inception Mission.

The following milestones were completed by EPE for the process of evaluating and revising the Tafila Grid Compliance Testing and Commissioning procedures:

- On July 27, EPE collected data relevant to the testing and commissioning procedures, including but not limited to the first draft Appendix A, Tafila Grid Compliance Testing and Commissioning Procedures.
- On July 28, EPE visited the Tafila Wind Project site and conducted meetings with JWPC and their engineering representatives CUBE.
- On July 30, EPE conducted a Testing and Commissioning Workshop (Appendix C, Grid Compliance Testing Workshop) which covered training and discussions on the following:
 - NEPCO's participation in Tafila's testing and commissioning
 - Grid Compliance Testing and Procedure revisions
 - Interaction with NEPCO's Control Center during Testing
 - Types of tests and results
 - Overview of Study vs. Testing in Grid Compliance
 - Discussions on commissioning tests and preparation for the specific upcoming Grid Compliance tests

- On August 4, EPE provided revisions to the testing procedures that have been forwarded by NEPCO to CUBE (Appendix A), where EPE:
 - Added detailed procedures and tables for testing
 - Adjusted requirements on testing conditions
- Based on the meeting with JWPC at NCC on August 5, EPE negotiated with JWPC adding new testing requirements to the Tafila testing procedures, as follows:
 - Test the voltage support requirement per Schedule 22 of the PPA, which shall include testing the ability to switch from power factor mode to voltage support when the voltage at the PCC is outside the +/-5% voltage dead-band
 - Test the minimum and maximum available reactive power
 - It is worth to note that during this meeting, the JWPC team re-iterated their commitment to NEPCO to add AVR capability after commissioning; likely to be added to PPA revisions.

During the inception mission, NEPCO engineers indicated that there is a need for an immediate and early revision to section 8.5 of their PPA (Grid Compliance Tests) to include in PPA agreements for their upcoming round two of solicitations for renewable energy. EPE, hence, delivered a revised list of grid compliance tests as provided in **Appendix B, PPA Schedule 8 5_Grid Compliance Certification** while waiting for the development of the NEPCO IRR Grid Compliance Testing Procedures that is a deliverable item of Task 1 of EPE's scope of work. EPE then revised this document on September 10, 2015 to include a section on Project Design Modifications and Studies.

At the last day of the Inception Mission, the Grid Compliance test was set for August 17-18 which later was moved to August 20-21, but was finally set for August 24-25. EPE adjusted travel plans to accommodate these changes to be alongside NEPCO during the grid compliance testing.

EPE's testing and commissioning team, namely Hugo Mena and Carlos Matar, arrived to Jordan on Saturday August 22, 2015 for the Tafila Grid Compliance tests. EPE's team was in-briefed on Sunday August 23, 2015 at the Energy Sector Capacity Building (ESCB) Project's offices by Mr. Grayson Heffner. During this meeting, EPE's team discussed the schedule for the mission as well as prepared for a pre-kickoff meeting with NEPCO personnel to go through the testing procedures in details and answer any concerns that they may have as well.

EPE's scope was discussed for the Tafila Grid Compliance Testing schedule. EPE's role during this mission was to train and support NEPCO during the performance of test on site, as well as in analyzing the test data to determine compliance.

The following sections of this report will provide more information on the work completed and training provided during the visit spanning August 22 to September 3, 2015.

2.2. Second Visit Kick-off Meetings

2.2.1. Pre-Kickoff Meeting

On August 23, 2015 at 12:00, EPE met with members of the NEPCO TCO team, listed in [Table 2](#), to discuss the Grid Compliance Tests of the 117 MW Tafila Wind Project.

Table 2 – NEPCO TCO Team – Pre-Kickoff Meeting

Contact Person	Position
Ahmad Aldohni	Generation Contracts & Agreements Section Head
Faisal Abu Zaid	Power Generation Projects & Contracts
Mazen Al Nabolsi	Operation Section Head
Fawwaz El Karmi	Local Advisor at ESCB

In this meeting, EPE's team went through the Wind Power Plant (WPP) grid compliance test procedures for Tafila wind project and discussed the concerns of the NEPCO TCO team, including but not limited to:

- Available active power reference value for the active power test
- The need to run the power factor test at 40% of the reference value
- Available active power reference value for the voltage droop control test
- The need for an Automatic Voltage Regulation (AVR) test schedule after the project's Commercial Operation Date (COD)
- The power factor requirements
- The Low Voltage Ride Through (LVRT) test certification and the need of the test results along with it
- The deviation (error) from the set point value in the active power test
- The availability of NEPCO personnel during the entire period of the tests
- Agenda of the kickoff meeting

2.2.2. Kickoff Meeting

Immediately after EPE's meeting with the NEPCO TCO team, the EPE/NEPCO team met with the project's owner engineer (Cube), turbine's manufacturer (Vestas), project's developer (JWPS) as well as SGS Czech Republic, s.r.o. (SGS), the Independent Engineer selected by NEPCO and JWPC as part of Schedule 21 – Independent Engineer of the Power Purchasing Agreement (PPA), listed in [Table 3](#), to kick-off the Tafila Grid Compliance Testing mission and

to finalize the grid compliance test procedures as well as to discuss the testing schedule for the upcoming two days for the 117 MW Tafila Wind Project.

Table 3 – Kickoff Meeting Attendees

Name	Institution	Email
Hugo Mena	EPE	hmena@epeconsulting.com
Carlos Matar	EPE	cmatar@epeconsulting.com
Faisal Abu Zaid	NEPCO	fabuzaid@nepco.com.jo
Ahmad Aldohni	NEPCO	adohni@nepco.com.jo
Mazen Al Nabolsi	NEPCO	mazen@nepco.com.jo
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Sean Miller	JWPC	smiller@jordanwind.com
Mohammad Al Mahassne	JWPC	mmahassne@jordanwind.com
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Udo Schneider	CUBE	Udo.schneider@terrawatt.de
Jiri Rozmarin	SGS	Jiri.rozmarin@senergos.cz
Yannis Yaxas	Vestas	yyiyax@vestas.com
Michele Annese	Vestas	mie@vestas.com
Mohammad Taher	Vestas	moata@vestas.com

After a brief introduction from Mr. Heffner on the ESCB mission, EPE went through the latest version of the WPP Grid Compliance Test (GCT) procedures for Tafila wind project, discussed the outstanding items of the procedures with CUBE and Vestas, and agreed on the following:

1. Final GCT procedures to adopt for the Tafila wind project and that any further changes will be discussed, agreed and documented directly on site based on wind conditions. A final version of these procedures is provided within this report under Appendix A.
2. GCT schedule to be used as a base of the testing steps while taking into account that the actual individual periods may differ. The following sequences were agreed upon and the initiation of the testing steps will be done in coordination with NCC.
 - a) Monday, August 24, starting at 9am: complete the Active Power test. If time and conditions allow, complete also the Voltage Droop Control test.
 - b) Tuesday, August 25: NEPCO will have an outage on one of the 132 kV double circuits connecting Tafila to El Hasa/Rashadiya, between 9:00 and 12:00. Parties agreed to start with the Power Factor (PF) test and to decide based on the results if the full test can be completed under the condition of this outage. Should this not be the case, the PF test will be re-started after lunch.
 - c) Wednesday, August 26: buffer day to complete any additional testing that may be still needed.

3. GCT results. The following has been agreed in terms of submittals by JWPC/Vestas:
 - a) All parties to sign final GCT procedures (including any changes that are agreed on site) for the sections that have been tested on the above days;
 - b) Vestas/JWPC to provide CSV files once the individual tests or steps are completed on a daily basis. All parties to confirm that the provided data was produced during the respective tests at the end of each testing day;
 - c) After the completion of all tests, JWPC/Vestas to prepare a summary of the test results (using the tables as per the GCT procedures) and a short report indicating the pass/fail status of the tests.
4. LVRT
It has been agreed that an updated transient study will be provided as soon as possible after completing the GCT. The link on the type of test report for the V112 as per IEC 61400-21 was provided in an e-mail from Ms. Mueller with Cube.
5. Voltage set-point
NEPCO's request to implement a voltage set-point at the Tafila project, in addition to the power factor set-point that has already been implemented, was discussed. JWPC, CUBE and NEPCO agreed that this subject will be investigated further after the GCT is finished.

2.3. Tafila Wind Power Project Grid Compliance Testing

Members of the USAID, ESCB and EPE team along with NEPCO visited the Tafila site on August 24th and August 25th, to observe the Grid Compliance testing for the Tafila project. During this visit, the EPE/NEPCO Team assembled together with members from JWPC, Cube and Vestas.

During the first day (August 24th), which started at 10:00 and ended at 22:30, the following tests were completed:

- Active Power Test with ramp rate of 400 kW/s
- Reactive Power Test for the active power output above 80% of P_{rated}
- Voltage Droop Control Test

During the second day (August 25th), which started at 11:00 and ended at 00:00, the following tests were completed:

- Active Power Test with ramp rate of 200 kW/s

- Reactive Power Test for the active power output less than 40% of P_{rated} . This test was performed after receiving confirmation from NEPCO that the outage on one of the 132 kV double circuits connecting Tafila to El Hasa/Rashadiya was completed.

Note that during the tests, the parties involved had to adjust some of the pre-conditions of the tests as well as the duration due to the fact that the wind speed was not as high as expected. Based on these adjustments to the test procedures, that were agreed by all parties (JWPC, Vestas, CUBE, SGS, NEPCO & EPE) during test, CUBE revised the GCT procedures and provided it to all parties for a final review. A version of these procedures can be found under Appendix A. NEPCO and EPE further discussed these procedures on August 27th during the Tafila Grid Compliance Testing – Summary Meeting & Next Steps and added several changes that were provided to CUBE and the JWPC team for final agreement. These suggested changes can be found under Appendix A.

A list of members who attended the testing is shown in [Table 4](#).

Table 4 – Tafila Grid Compliance Test Attendees

Name	Institution	Email
Hugo Mena	EPE	hmena@epeconsulting.com
Carlos Matar	EPE	cmatar@epeconsulting.com
Faisal Abu Zaid	NEPCO	fabuzaid@nepco.com.jo
Ghassan Naji	ESCB	gnaji@escb-jordan.org
Michel Jallad	JWPC	mjallad@jordanwind.com
Mohammad Al Mahassne	JWPC	mmahassne@jordanwind.com
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Michele Annese	VESTAS	mie@vestas.com
Cristian Virlanuta	VESTAS	crsvi@vestas.com
Alexandros Sofianopoulos	VESTAS	alsof@vestas.com

2.4. Tafila Grid Compliance Testing – Summary Meeting & Next Steps

On August 27, 2015 at 12:00, EPE met with members of NEPCO (TCO team, listed in [Table 5](#), to discuss the grid compliance test of the 117 MW Tafila Wind Project.

Table 5 – NEPCO TCO Team – Summary Meeting & Next Steps

Contact Person	Position
Ahmad Aldohni	Generation Contracts & Agreements Section Head
Faisal Abu Zaid	Power Generation Projects & Contracts
Ali Hamaideh	Operation Department
Raed Khasarneh	SCADA

In this meeting and as part of the training, EPE's team summarized the WPP grid compliance tests for Tafila wind project and discussed with NEPCO's team the final WPP grid compliance test procedures. The final version of these procedures is provided within Appendix A of this report. The meeting also addressed the next steps required to attain the commercial operation date of the project, namely:

- Discuss and evaluate the test results provided in the CSV files as well as the summary report provided by the Tafila Project
- Discuss and evaluate the data pulled from NEPCO SCADA system
- Follow-up with the independent engineer, namely SGS, to provide the test certificate to NEPCO & JWPC
- Schedule a meeting with the project's team and NEPCO to finalize the grid compliance tests.

2.5. Tafila Wind Power Project Grid Compliance Testing Data Analysis and Compliance Check

Due to the number of tests completed at the Tafila Project, the analysis of the test data took several days. EPE reviewed all the data provided by the Tafila Project as well as the data obtained from the NEPCO SCADA engineers. During EPE's analysis, it was determined that the NEPCO SCADA data had frequency issues as well as several values were not matching with the data provided by the Tafila Project. Due to these discrepancies, a meeting on September 2, 2015 was scheduled with Mr. Faisal Abu Zaid and some of the SCADA and Operations engineers.

During this meeting, the SCADA engineers provided insight on the SCADA points and calculations done at NEPCO. It was determined that the SCADA testing for the Tafila Project had not been approved and that the issues seen are due to SCADA problems within the Tafila Project and NEPCO. These SCADA issues are outside EPE's scope of work but it was determined that these issues will need to be resolved soon in order to allow NEPCO to have a good visibility of the projects production.

After the SCADA discussion, Mr. Faisal Abu Zaid and the EPE team reviewed the following test results and summary tables within the test results report provided by the Tafila Project:

- Reactive Power Test for the active power output above 80% of P_{rated}
- Reactive Power Test for the active power output less than 40% of P_{rated}
- Voltage Droop Control Test
- Active Power Test with ramp rate of 400 kW/s
- Active Power Test with ramp rate of 200 kW/s

After reviewing all test data and completing the review of each test performed, it was determined that the project meets all grid requirements as set for within the PPA. However, it was identified that the report provided by the Tafila Project had some errors that needed to be corrected. Due to these errors, EPE provided a set of comments as shown under Appendix D.

2.6. Tafila Wind Power Project Grid Compliance Testing Results and Final Meeting

After all the test results were reviewed by the EPE/NEPCO team, a final meeting took place at the NEPCO NCC, on September 2, to discuss the test results and provide final recommendations for Tafila's commercial operations date. Each test completed at the Tafila Project was discussed and the EPE/NEPCO team, who reviewed and analyzed the data, provided input on the methodology used to review these results.

The consensus of the meeting was that the Tafila Project meets all the Grid Compliance requirements as stated within the PPA.

2.7. Intermittent Renewable Resources (IRR) Wind & PV Grid Compliance Testing Procedures (GCTP)

As part of deliverable number 5 of the RFP Renewable Power Integrations, EPE completed the Intermittent Renewable Resources (IRR) Wind & PV Grid Compliance Testing Procedures (GCTP). A draft version of this document was provided to the NEPCO team on November 16, 2015 and was discussed with the NEPCO Testing and Commissioning Engineers during a meeting on Wednesday November 18th at 8:30 AM at NEPCO Headquarters. During this meeting, the EPE team gathered comments and suggestions regarding the draft version of the procedures. Additionally, the EPE team gathered other comments provided by interested parties after the meeting. Based on these comments and suggested changes, the EPE team updated the draft GCTP into a final version and submitted to NEPCP. This document can be found in **Appendix E, Intermittent Renewable Resources (IRR) Wind & PV Grid Compliance Procedures (GCTP)** of this report.

3. Other Technical Assistance

During this mission, the EPE team led by Mr. Hugo Mena, worked on other Tasks that are part of EPE's scope of work with ESCB focused on supporting NEPCO in integrating renewable power projects into Jordan's transmission grid. Below is a summary and description of other meetings and work completed during this mission:

- Wind & Solar Power Plant Equivalent Model Calculation Training

During this second visit, EPE provided a training for the NEPCO Grid Impact Study (GIS) team. This training was conducted by Mr. Hugo Mena at NEPCO NCC on Sunday August 30th, 2015 from 1 PM to 4 PM. The training session was developed so that NEPCO GIS engineers can complete equivalent circuit calculations for wind and solar projects before completing Grid Impact Studies for such resources within the NEPCO grid.

During the training, the Western Electricity Coordinating Council (WECC) of the United States of America procedures for calculating equivalent circuits for Wind and Solar projects were explained in full. Each section of the procedures was discussed in details and each NEPCO engineer had a chance to ask questions. After the WECC procedures were studied and discussed, EPE/NEPCO team completed an exercise with one of the solar projects that has already applied to interconnect to the NEPCO Grid.

Using DigSilent, the trainer showed the NEPCO GIS team what information is needed to export the load flow model data and the detailed collector circuit of the generation plant to excel to calculate the equivalent impedance of the plant. Once the data from DigSilent was exported, the EPE/NEPCO team continued to calculate the equivalent impedance of the project based on the collected information.

EPE emphasized to the GIS team that for any future interconnection application, they need to request the equivalent model as this is part of the latest IRR Grid Code.

- Intermittent Renewable Resources (IRR) Operating Protocols

During this visit, the EPE team reviewed the operating procedures developed for the Tafila Project as well as the operating procedures for Al-Qatrana Power Plant in order to start developing the outline that will be used for the development of the IRR Operating Protocols. This falls under Task 2 of EPE's Scope of Work, Intermittent Renewable Resources Operating Protocols.

4. Tafila Testing Visit Schedule

Saturday	Sunday	Monday	Tuesday	Wednesday	Thursday
August 22	August 23	August 24	August 25	August 26	August 27
Hugo Mena & Carlos Matar arrive	<div>8:30 – 9:30 ESCB/USAID Hugo & Carlos In-briefing</div> <div>12 – 1:30 NHQ Kick-off meeting with NEPCO & EPE</div> <div>2:00 – 3:30 NHQ Meeting with NEPCO, CUBE, JWPC, SGS & EPE</div>	<div>9:30-17:00 Tafila Site</div> <div>Tafila Grid Compliance Tests <u>ON SITE</u> Wind Forecast Dependent</div>	<div>9:30-17:00 Tafila Site</div> <div>Tafila Grid Compliance Tests <u>ON SITE</u> Wind Forecast Dependent</div>	<div>9:00 – 13:00 Return from Tafila Site Visit</div> <div>13:00 – 17:30 ESCB/USAID</div>	<div>8:30 – 12:00 ESCB/USAID</div> <div>12:30 – 15:30 NCC Meeting with NEPCO, ESCB & EPE to discuss Tafila tests.</div> <div>13:00 – 16:30 ESCB/USAID</div> <div>Carlos Matar departs</div>
August 29	August 30	August 31	September 1	September 2	September 3
	<div>8:30 – 12:00 ESCB/USAID</div> <div>13:00 – 16:00 NCC Training with GIS Team on Equivalent Models for Wind and Solar Projects</div>	<div>8:30-17:30 ESCB/USAID</div>	<div>8:30-17:30 ESCB/USAID</div>	<div>9:00 – 13:00 NCC Meeting with NEPCO & EPE to discuss Tafila test results.</div> <div>14:00 – 15:30 NCC Meeting with NEPCO, ESCB & EPE to discuss Tafila test analysis and approval.</div>	<div>Hugo Mena departs</div>

Appendix A, Tafila Grid Compliance Testing and Commissioning Procedures

See separately attached pdf documents representing several revisions of the Tafila grid compliance and testing procedures:

Appendix A-1 - JWPC Tafila (JO) - Vestas GCC Test Procedure rev2_EPE-NEPCO Comments

Appendix A-2 JWPC Tafila (JO) - Vestas GCC Test Procedure rev4_NEPCO_re JWPC_revEPE

Appendix A-3 - JWPC Tafila (JO) - Vestas GCC Test Procedure rev5_EPE

Appendix A-4 - JWPC Tafila (JO) - Vestas GCC Test Procedure rev13 - As-built

Appendix A-5 - JWPC Tafila (JO) - Vestas GCC Test Procedure_final_rev2

Appendix B, PPA Schedule 8 5_Grid Compliance Certification

See separately attached pdf document titled:

Appendix B- PPA Schedule 8 5_Grid Compliance Certification_2015-07-30_Rev 2015_09_10

Appendix C, Grid Compliance Testing Workshop

See separately attached pdf document titled:

Appendix C - Intermittent Renewable Resource (IRR) Testing and Commissioning Workshop I_2015_07_30.pdf

Appendix D, Tafila Grid Compliance Tests Report Comments

See separately attached pdf document titled:

Appendix D - Tafila_GCT report_EPE Comments_2015_09_01

Appendix E, Intermittent Renewable Resources (IRR) Wind & PV Grid Compliance Procedures (GCTP)

See separately attached pdf document titled:

Appendix E - NEPCO IRR Grid Compliance Test Procedures - REV 1 - 2016_01_08

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