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ENERGY STORAGE SITUATION IN JORDAN – A REVIEW REPORT

JANUARY 2017

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ENERGY STORAGE SITUATION REVIEW

Draft Report

PROGRAM TITLE: INTEGRATING RENEWABLE POWER ON MEDIUM AND LOW-VOLTAGE NETWORKS -

SPONSORING USAID OFFICE: ENERGY SECTOR CAPACITY BUILDING PROGRAM

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List of Acronyms

AGC	Automatic Generation Control
B&V	Black & Veatch
DISCO	Distribution Company
EMRC	Energy and Mineral Regulatory Commission
Eng.	Engineer
ESCB	Energy Sector Capacity Building
ESCO	Energy Service Company
ESP	Energy Service Provider
JEPCO	Jordan Electric Power Company
JREEF	Jordan Renewable Energy and Energy Efficiency Fund
kW	Kilo Watt
kWh	Kilo Watt Hour
MWh	Mega Watt Hour
NEPCO	National Electric Power Company
PJM	Pennsylvania New Jersey Maryland Interconnection LLC
RE	Renewable Energy
REES	Renewable Energy Establishments Society
SCADA	Supervisory Control and Data Acquisition
USAID	United States Agency for International Development

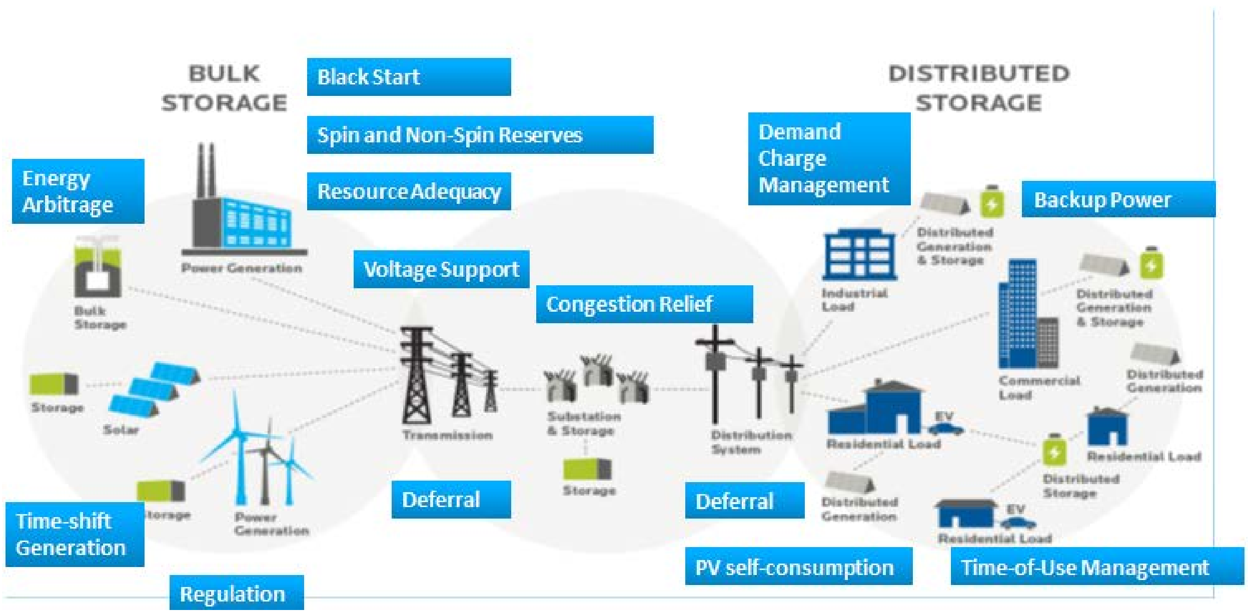
1.0 INTRODUCTION

Black & Veatch was retained by Energy Sector Capacity Building (ESCB), a USAID program, to review the energy storage situation in Jordan and perform a workshop for an energy storage strategy tailored for the Jordanian power sector. Black & Veatch's review included discussions with many different Jordanian power sector entities stakeholders including regulators, energy policy makers, utilities, and the private sector. An inception trip was undertaken by Black & Veatch in November 2016 and the Inception Trip report is attached as Annex 1. Through these consultations and research Black & Veatch has published this document to help guide all parties in implementing a successful energy storage strategy in Jordan.

2.0 BENEFITS OF ENERGY STORAGE

Energy storage has become an important grid resource in recent years at the transmission as well as the distribution level. Although it is not a generation resource, energy storage can perform many of the same functions of a traditional generator by using stored energy from the grid or from other distributed generation resources. These applications range from traditional uses such as providing capacity or ancillary services to more unique applications such as micro-grids or renewable energy integration applications. A snapshot of various energy storage applications across the electric utility system can be found in Figure 1.

Figure 1: Applications of Energy Storage Devices



Utility scale energy storage applications with their brief descriptions are provided below:

- Electric Energy Time-Shift (Arbitrage): The use of energy storage to purchase energy when prices are low and shift that energy to be sold when prices are higher (during peak times).
- Electric Supply Capacity: The use of energy storage to provide system capacity during peak hours.
- Frequency Regulation: The use of energy storage to mitigate load and generation imbalances on the second to minute interval to maintain grid frequency.

- Spinning Reserve: The use of energy storage that is online and synchronized to supply generation capacity within 10 minutes.
- Non-Spinning Reserve: The use of energy storage that is offline but can be ramped up and synchronized to supply generation capacity within 10 minutes.
- Voltage Support: The energy storage converter can provide reactive power for voltage support and respond to voltage control signals from the grid.
- Variable Energy Resource Capacity Firming: The use of energy storage to firm energy generation of a variable energy resource so that output reaches a specified level at certain times of the day.
- Variable Energy Resource Ramp Rate Control: Ramp rate control can be used to limit the ramp rate of a variable energy resource to limit the impact to the grid.
- Transmission or Distribution Upgrade Deferral: The use of energy storage to avoid or defer costly transmission or distribution upgrades.

Some of these applications (e.g., Ramp Rate Control or Capacity Firming) can only be delivered in close proximity to the variable energy source, whereas other applications (e.g., Electric Energy Time-Shift or Frequency Regulation) can be performed at different locations on the grid.

Services provided by energy storage infrastructure are often grouped into either power or energy applications. Power applications are generally shorter duration (approximately 30 minutes to one hour) that may involve frequent rapid responses or cycles. Frequency regulation or other renewable integration applications such as ramp rate control/ smoothing are good examples of power applications. Energy applications generally require longer duration (approximately 2 hours or more) energy storage systems. Electric Supply Capacity, Electric Energy Time-Shift, and Transmission Upgrade Deferral are examples of energy applications.

3.0 CURRENT SITUATION FACING JORDAN'S GRID

Jordan's grid will go through a major transformation over the next few years as many renewable energy generation facilities will come on line. Based on experiences elsewhere and a quick review of Jordan's power sector, Black & Veatch has identified five critical power and energy applications that energy storage might contribute in Jordan (Table 1).

Table 1: Critical Renewable Energy Integration Issues for Jordan's Grid

OPERATING RESERVES
Frequency Reserves
Managing Renewables Curtailment
Load Following Requirements due to Peak PV
Limitations of Renewable Energy Interconnections on the Distribution System

For this section, Black & Veatch relied mostly on consulting with Jordanian power sector personnel and reviewing data from a 2014 renewable integration study performed by the Italian consultancy firm CESI[1]. This study analyzed a wide range of grid issues (reliability, system operating constraints, need for additional operating reserves, growing incidence of renewable production curtailments, violations of transient stability criteria, switching, and higher operating costs) that NEPCO would face as a result of a large-scale renewable energy build out to 2024.

3.1 Operating Reserves (Spinning / Non-Spinning)

CESI estimated that spinning and non-spinning reserve requirements would increase to as much as 9.3% and 1.9% of system load, respectively, by 2020 (see Table 2). NEPCO's operating reserves are presently sourced from the Egyptian intertie, part-load operation of baseload thermal units, and peaking units. These reserves are insufficient to meet the growth in variable renewable power production over the next three years. NEPCO will need to move quickly to consider new operating reserves or have to operate existing plants even more inefficiently to meet these needs.

Table 2: Required Reserves by 2020 as Identified in CESI Study

Tab. 30-47 – Year 2020 Summary of Estimated Operational Reserve

Reserve Category	Load Alone				Net Load			
	Up direction		Down direction		Up direction		Down direction	
	MW	%	MW	%	MW	%	MW	%
Balancing	133	3.3%	196	4.8%	161	4.0%	214	5.3%
Contingency Reserve	200	4.9%	200	4.9%	375	9.3%	375	9.3%
Operational Reserve	46	1.1%	46	1.1%	55	1.4%	55	1.4%
Load Following (Spinning)	150	3.7%	150	3.7%	336	8.3%	313	7.7%
Load Following (Not Spinning)	91	2.3%	91	2.3%	76	1.9%	76	1.9%
Total Spinning	200	4.9%	242	6.0%	375	9.3%	375	9.3%
Total Not Spinning	91	2.3%	91	2.3%	76	1.9%	76	1.9%

Source: Integration of RES in the National Electric System of Jordan Final Report, CESI 2014

3.2 Frequency Reserves

CESI's report estimated that operating reserves needed for frequency regulation (labeled as Balancing - up and down directions - in Table 2) would increase to 4.0% and 5.3% respectively of system load by 2020. This equates to having 161 MW and 214 MW on installed capacity for that period as seen in Table 2. Similarly to the operating reserves, NEPCO will be presented with a need to operate existing plants inefficiently or procure fast-acting generation or perhaps energy storage.

3.3 Reliability and Renewables Curtailment

CESI also studied how renewable power production would affect network loading, operating reserve requirements, and grid reliability. CESI projected a high incidence of operator-dispatched production

[1] Integration of RES in the National Electric System of Jordan Final Report, January 23, 2015, CESI

curtailments in the years 2018-2020 in order to maintain grid reliability. CESI identified the main causes of production curtailments as inflexibility of operating reserves and insufficient network carrying capacity. Worst case projections of curtailment range to 5.9% of MWh produced in year 2018, which would cause a significant financial exposure for NEPCO. The CESI study noted that the incidence of RES production curtailment is inversely related to the amount of operating reserves available. This is because operating reserves requirements increase according to the total generation in service, especially when the generation fleet is relatively inflexible. Introducing more flexible sources of both generation and operating reserves should allow for better overall management of both system reserves and exploitation of renewable generation. The tradeoff between the inflexibility of operating reserves and curtailment incidence is illustrated in Figure 2.

Figure 2: Forecast Renewable Production Curtailments Required to Maintain System Reliability

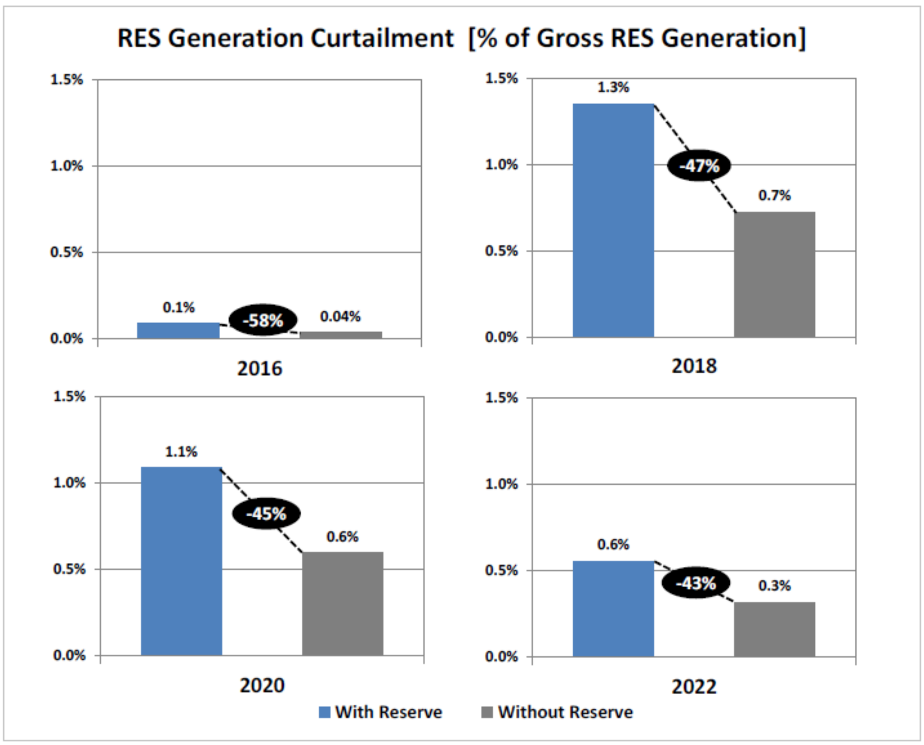


Fig. 26.26 – RES generation curtailment with and without power system reserve (base cases)

Source: Integration of RES in the National Electric System of Jordan Final Report, CESI 2014

3.4 Load Following Requirements Due to Peak PV

CESI also studied load following requirements required to accommodate renewable power ramping and intermittency, applying the same method used to determine operating reserves. CESI found a worst-case scenario for solar PV ramping of 16.4 MW/min in 2020 (Figure 3). Such a rapid ramp rate downward in the late afternoon will drastically alter the operating profiles of Jordan's baseload generators. Operating the load following reserves now available to meet these new requirements will be inefficient and may result in some generators operating outside their operating limits.

Figure 3: Peak ramp rate required to accommodate renewable power production in 2020

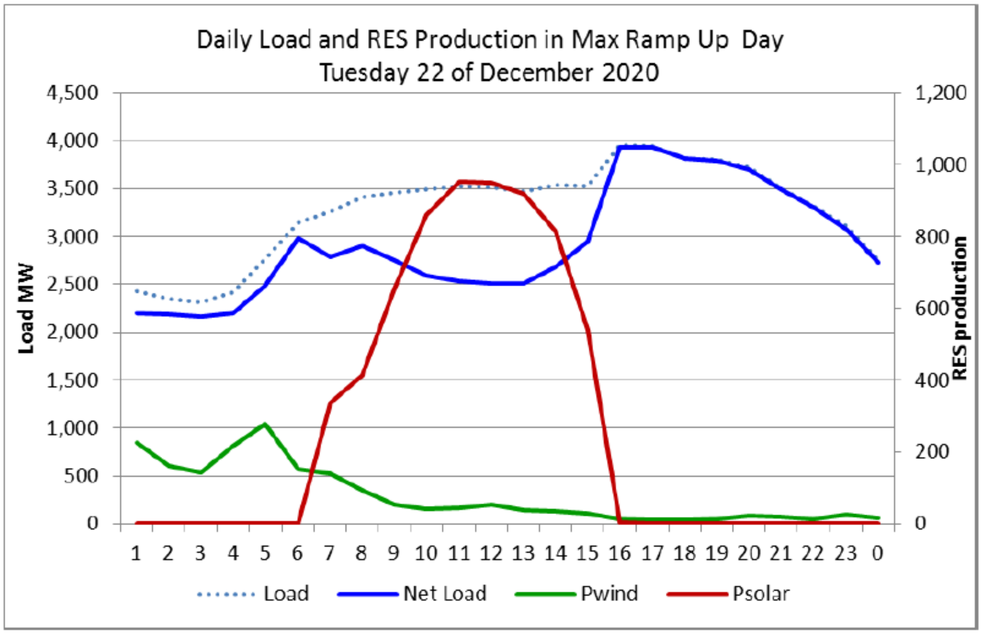


Fig. 30-11: Maximum Day Year 2020 Loads, Wind Generation and Solar Generation

Source: Integration of RES in the National Electric System of Jordan Final Report, CESI 2014

3.5 Limitations of Renewable Energy Interconnections on the Distribution System

NEPCO has recently imposed a "hold" on new wheeling solar PV projects larger than 1 MW until the Green Corridor transmission improvements are completed. This was done to limit reverse power flows from the medium-voltage to the high-voltage network. Locating batteries or other flexibility on the distribution system may allow for more flexibility and the ability to host higher penetrations of renewables on the distribution network.

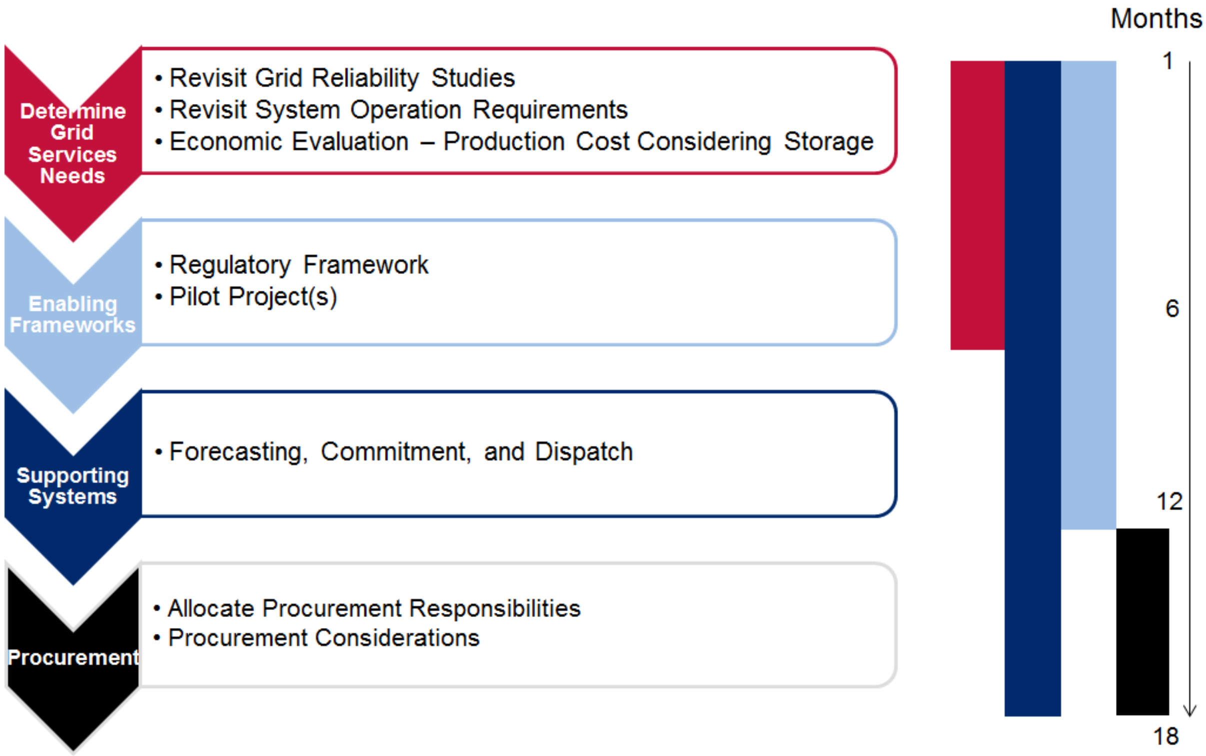
4.0 AN ENERGY STORAGE ROAD MAP FOR JORDAN

4.1 Overview

Drawing from a review of Jordan's current situation and best practices for developing energy storage infrastructure, Black & Veatch has developed an energy storage road map for Jordan. The road map is divided into four phases: (i) determine the need for grid services; (ii) develop frameworks to enable energy storage infrastructure; (iii) address the supporting systems needed for effective integration of renewables into grid operations; and (iv) infrastructure procurement. This presentation shows the several activities needed to develop and advance an energy storage strategy, and which individual activities can be implemented in parallel. The roadmap provides a useful structure for identifying and organizing the activities needed to integrate energy storage into the Jordanian power sector.

As shown in Figure 4, the first step is to study the technical and operating parameters of the Jordanian grid as well as the economic viability of storage compared with other solutions. In parallel, the regulatory framework will have to be modified to incorporate energy storage or other grid stability and support as a new class of asset. Pilot project(s) should be developed to build an understanding of how to integrate storage into transmission and distribution networks. With these activities underway, NEPCO should focus on improving existing forecasting, commitment, and dispatch strategies of renewable and traditional generation assets. By improving these activities, the amount of grid services can be minimized, thus reducing storage requirements. Lastly, both policy and regulatory bodies of the government must allocate procurement responsibilities and develop specific mechanisms. Each of these phases will be discussed in detail in the following sections of the report.

Figure 4: An Energy Storage Roadmap for Jordan

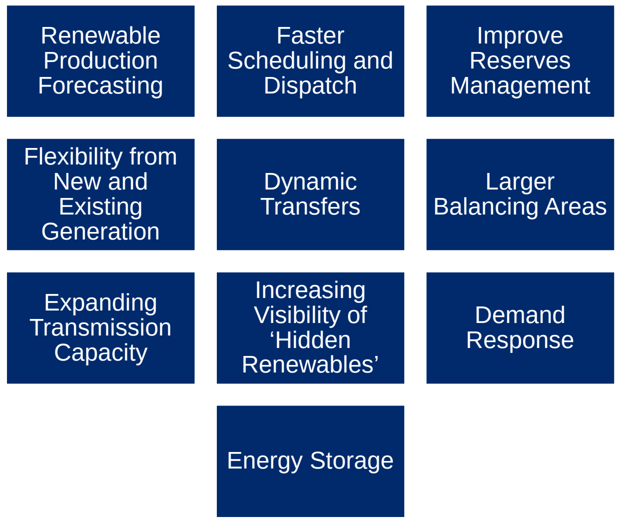


4.2 Determine Grid Services Needs

Determining the need for energy storage in Jordan should begin by updating the most-recent comprehensive study of how large-scale, high-penetration renewable power will impact NEPCO's grid. The 2014 CESI Masdar study referenced throughout this report is the logical starting point. This 2014 study needs to be updated to reflect: (i) new operational date of Green Corridor improvements; (ii) somewhat-smaller pipeline of renewable power projects, and different mix and location of wind and solar PV; (iii) absence of the Syrian intertie; and (iv) early completion of the King Hussein Thermal Power Station (KHTPS). Based on these new projections the grid services needs of NEPCO - operating reserve requirements, frequency regulation needs, and the incidence of reliability-related renewable curtailments – can be to be updated. The system reliability impact study and dynamic analysis should also be reexamined to look at the potential contributions of energy storage. Ideally, these studies would be coordinated through NEPCO.

With the system and reliability studies are being undertaken, NEPCO should build its capability to perform production costing studies of alternative arrangements for providing grid services. NEPCO should consider the candidate sources of grid services, including multiple energy storage, generation and other arrangements including adding natural gas generation facilities, repurposing existing generation, demand response, and new interconnection arrangements (Figure 5). This study will help NEPCO to understand its grid service options including energy storage and begin thinking about a procurement strategy for grid services to match the pipeline of renewable power additions.

Figure 5: Sources of Grid Services



4.3 Enabling Frameworks

Enabling energy storage in Jordan will require significant changes to how the power sector is organized and operated. A starting point will be incorporating energy storage into the power sectors' regulatory structure. Important regulatory determinations will include how energy storage is treated as a grid asset; how provision of grid services through energy storage and other assets will be compensated; who will be allowed to develop and own energy storage; and how the provision of grid services, including multiple services to multiple users, will be organized and regulated.

The development of a pilot project(s) is an important early step to prove the use cases, or value proposition, of energy storage for NEPCO, distribution companies, and possibly project developers. The pilot project(s) also serves as a test best for integrating storage into grid planning and operations - essential to have in place before undertaking major procurements of new grid asset types.

4.4 Regulatory Framework

Enabling the introduction of energy storage into Jordan's grid will require multiple actions to be taken by EMRC. Table 3 summarizes the keys issues that the regulatory commission (EMRC) should consider and decide if energy storage is to be procured in the future. Of course the regulatory treatment in Jordan should reflect existing law and other legal frameworks (e.g., transmission and distribution company licenses) as well as the characteristics and needs of Jordan's grid.

Table 3: Key Regulatory Issues

ACTION	REASON
Characterizing Energy Storage as a Grid Asset	

Make storage a distinct regulated activity from generation	Enables 3rd parties and NEPCO/DISCOS to enter into agreements specific to storage
Compensating Energy Storage for Services Provided	
Frequency Reserves	Necessary to price and procure grid services Storage has unique characteristics compared to generators
Enable Energy Storage to Provide Multiple Services to Multiple Users	
Allow for storage assets to be placed on either transmission or distribution level networks	Storage will be most cost effective if allowed to participate in both transmission and distribution systems
Allow storage providers to offer multiple services to multiple users	Storage is most cost effective if allowed to offer benefits to multiple beneficiaries
Flexible Ownership Models	
Enable ownership of storage by both third parties and entities licensed under the Electricity Law	Flexible ownership will enable the multiple benefits of storage to be captured
Project developers should be able to enter into multiple agreements with multiple off-takers of electricity production and grid services	Should storage be located in parallel with a RE project the storage resources should be able to participate as a grid asset and not just a generator.

4.5 Pilot Project

Developing a pilot project(s) in Jordan will be essential for both distribution companies and NEPCO to learn how to incorporate the asset into their existing control and dispatch systems. It will allow both companies to also get familiar with use cases that they may use the asset for in the future, many which will be very different from existing generation technologies. The pilot project should be designed to demonstrate the applications of storage that provide grid services: frequency regulation, curtailment management, load following, and operating reserves. The main considerations to be had will be the size, placement, ownership(s), and procurement.

4.6 Supporting Systems

Scaling-up renewable power production in Jordan will vastly increase the complexity of power system planning and operations. NEPCO should, in parallel with efforts to define grid service needs, evaluate the economics of different grid services infrastructure, and create enabling frameworks, improve its methods of forecasting, unit commitment, and dispatch. The production costing capability acquired earlier will be a key tool in improving daily production scheduling and operations. Forecasting minimum load conditions and adjusting unit commitments accordingly will become more critical as NEPCO accommodates growing renewable power production.. Future load forecasts will need to take into account not only weather-related demand variability but also the growth in "hidden" renewable power, e.g., the output of renewable power projects connected at medium and low-voltages. Moving from hourly to more granular scheduling will improve accuracy, responsiveness, and more optimal use of reserves which could in turn reduce the overall amount of storage needed. Secondly, AGC (automatic generation control) must be enabled for both storage and traditional generation facilities in order to procure regulation that will be needed. Finally, improving forecasting methods and implementing them in dispatch strategies my also lead to a reduction in overall storage amounts needed.

4.7 Procurement

One of the major hurdles when considering the procurement of storage is the matter of who can own the asset. Using storage for multiple applications can make this issue even more complex. Different applications of storage may require multiple ownership models. On a high level, this can be separated into two models: third party and utility ownership. Jordan should consider both models depending on how use cases evolve.

THIRD PARTY OWNERSHIP

Third party energy storage has been one of the more popular procurement mechanisms in the United States over the past few years. The California energy storage mandate and merchant markets in PJM have seen many third party owned projects sell their services to either an off taker such as an investor owned utility as in the case of California or an independent system operator as in the case of PJM. In California, many of the third-party contracts that are stand-alone energy storage projects are being contracted and procured via a tolling power purchase agreement. Within the agreement, the owner agrees to provide the utility with the rights of the asset to be called upon based on the owner's limitations. The off taker of the services will contract for a fixed monthly capacity payment and a separate variable O&M charge depending on how the asset is used. An example of this can be seen in the figure below where a bulk storage facility may be used for Regulation, Spin / Non-Spin Reserves and Load Following services.

UTILITY OWNERSHIP

There are some applications of energy storage that may require utility companies to consider owning and operating an asset. Applications to date have been transmission & distribution deferral projects combined with market participation services such as the most recent solicitation of energy storage in the 2016 California energy storage RFO for Pacific Gas & Electric. Another has been allowing energy storage to act as an energy arbitrage device as seen in the recent San Diego Gas & Electric procurement where they will use a 37.5 MW lithium ion energy storage facility to balance renewables.

In Jordan's case it may at times make sense to allow either NEPCO or distribution companies the ability to own and operate an energy storage facility. For example when integrating renewable energy there may be transmission and distribution upgrades required along with congestion and curtailment issues that NEPCO has to manage. Allowing NEPCO or distribution companies to own and rate base these applications may be more beneficial than procuring such services via 3rd party contract.

5.0 SUMMARY

The expansion of renewable power in Jordan will create a demand for grid services. Energy storage is one of several means to provide these services. This energy storage roadmap lays out a possible means of evaluating the role of energy storage in Jordan. As Jordan follows this roadmap there will be a need for significant changes in how the power sector is currently owned, operated and regulated. The value of this roadmap will come from all parties having a common understanding of the potential for and steps required to develop energy storage infrastructure that is beneficial for Jordan.

ANNEXES

1. INCEPTION TRIP REPORT

Energy Storage Situation Review – Inception Trip
USAID Energy Sector Capacity Building (ESCB)

Black & Veatch's Energy Storage Team (Dr. Sankar and Andrew Breyer) and ESCB (Dr. Heffner) met with various stakeholders of Jordan's power sector from October 16th to 20th, 2016 to obtain their views on "Battery Energy Storage System" in general with respect to Jordanian context. Dr. Fawwaz and Ramzi Sabella of USAID joined the meetings at NEPCO and MEMR. The feedback received from the stakeholders will be taken into consideration by Black & Veatch while preparing a report on "Jordanian Situation for Battery Energy Storage". The Black & Veatch team met with the following stakeholders:

- National Electric Power Company (NEPCO) Operations and Planning Engineers
- Constant Group representing USTDA, Mr. Mark Germer
- Energy and Minerals Regulatory Commission (EMRC), Commissioner Wejdan
- Ministry of Energy and Minerals Resources (MEMR), Eng. Ziad Jibril Sabra
- Secretary General Amani
- AES Jordan, Mr. Mohammad Hammad and Mr. Meftaur Rahman
- Philadelphia Solar, Eng. Mohammad Zaitawal
- USAID Jordan Competitiveness Program (JCP), Mr. Shada El-Sharif

The following are the main points that came out of the discussions:

<u>Meeting with NEPCO</u>

- NEPCO was under the impression that the ESCB/B&V scope included the studies necessary for Battery Energy Storage sizing and location. It was explained to NEPCO that Black & Veatch's scope was about "Battery Energy Storage System Situation Review", rather than quantifying the energy storage requirement for NEPCO system. Detailed studies will have to be performed after this initial task for sizing and the location of storage devices.
- NEPCO informed that their view on the energy storage is to solve the transmission system issues arising due to more renewable projects coming on line by 2020 and beyond. Some of the issues cited by NEPCO are generation intermittency, system stability, frequency regulation, voltage regulation, dispatchability, load following, spinning reserves and generation curtailment. NEPCO does not face any of these issues currently, except for frequency regulation which is regulated by the Egyptian grid.
- As per the agreement with the neighboring countries, Jordan's share of spinning reserve is 45 MW, Syria's share is 129 MW and Egypt's share is 350 MW. Currently the NEPCO system is not connected with Syria.
- NEPCO has about 800 MW contingency reserves of diesel engines, which can be brought on line in 10 to 15 minutes. NEPCO's question was whether the energy storage can reduce the contingency reserves economically and at the same time would be technically acceptable.
- NEPCO also requested to address whether the combination of diesel engines as reserves and demand response would be a cheaper option to energy storage.

- Currently NEPCO does not permit any reverse power flow from the distribution feeders to the transmission system and it is mainly due to the lack of available capacity on the sub-transmission and transmission lines. This situation is not true for every distribution feeder, however NEPCO has adopted a blanket policy until the proposed Green Corridor project is completed.
- Currently the NEPCO system is operated with either no or very limited spinning reserve, depending on the time of the day. If the frequency declines below the acceptable limit before the contingency reserves come on line, under frequency load shedding kicks in to arrest the frequency decline.

Meeting With Constant Group (USTDA Representative)

- USTDA is in the process of identifying renewable projects, including energy storage, for sponsoring feasibility studies. The USTDA mission objectives are quite distinct from the USAID-ESCB-Black and Veatch effort and there appear to be no conflicts between them.

Meeting With Commissioner Wejdan

- EMRC Commissioner Wejdan noted that NEPCO is currently refusing any new retail wheeling projects on the grounds that many transmission lines are loaded to capacity
- A committee has been established, chaired by Wejdan, to consider rejected renewable projects on a case-by-case basis. This committee has requested a feeder-by-feeder review of available capacity to host renewable projects
- A battery storage demonstration project is under development by Philadelphia Solar and Badiya.
- Any wheeling project larger than 1 MW is being referred to NEPCO for further study
- EMRC Commissioner Wejdan requested the Energy Storage Report to specifically address the following:
    - Can storage relieve the overloading of transmission lines?
    - What studies are needed to identify the need for energy storage?
    - What are the options for procuring energy storage? IPPS? Auctions?
    - What are the different benefits of storage for the HV, MV and LV networks?
    - Can storage provide frequency or voltage regulation? How would NEPCO utilize the storage for these purposes?
    - What should be in the Energy Storage PPA?
    - What need to be considered from the regulatory aspects, including licensing of battery storage infrastructure?
    - The current PPAs for the renewable projects are based on capacity charge and includes take all or leave type contract. What should be the model for energy storage?
    - What should be the next steps?

Meeting With Eng. Ziad

- Eng. Ziad of MEMR informed that the Ministry has received good support from USAID for their Energy Sector and the Energy Storage is very important to Jordanian’s renewable energy program. He requested that the report provides guidance to NEPCO in the right direction and highlight whether the storage is needed for grid stability or for any other purposes. The report should identify the optimum use of the energy storage.
- A total of 1300 MW of renewable has been contracted so far, which includes 500 MW of wind and 800 MW of PV solar. By the end of 2016, 400 MW of renewables will be in operation, of which 200

MW will be PV solar and the other 200 MW will be wind. By 2019, all 1300 MW would be in operation and this will coincide with the energization of Green Corridor.

- In addition to the auctions, direct unsolicited proposals are also accepted for the renewable projects. These proposals should meet the following criteria: similar experience of similar capacity, should be a complete proposal and the price should be less than the reference price bid. The reference price per kWh for solar energy was US$0.17 in 2013, US$0.14 in 2015 and currently it is US$0.07.
- CESI study has indicated that 800 MW to 1000 MW of renewables can be accommodated without any transmission reinforcements. The study was conducted in 2014.
- MEMR advises the development areas for the renewable projects.
- PPA templates are in place for the renewable projects. The negotiations for the Round 1 took about 2 years, whereas it took only about 6 months for the Round 2 projects.
- 450 MW (200 MW wind and 250 MW PV solar) is contemplated for Round 3 and they will be located in the south. The EOI will be published shortly. The EOI may include an invitation to submit storage proposals.
- Generation curtailment up to 10% is included in the PPAs.
- It is anticipated that 1600 MW of renewables (1000 MW of PV and 600 MW of wind) will be on line by 2020. More than 50 MW of net metering will be in place.
- One of the issues faced now is about the wheeling projects due to lack of available capacity on the transmission lines. NEPCO has stated that no more renewables beyond that planned for 2020 can be accommodated without additional integration capacity.
- A study performed for NEPCO by JICA/Chubu Electric has indicated that no more renewable projects can be accommodated beyond 2020 due to lack of spinning reserves.
- MEMR requested that the Energy Storage report should convince NEPCO so that renewables can be accommodated even beyond 2020.
- MEMR indicated that the Energy Storage could be an option as part of Round 3 auction. MEMR is working with its Consultant, Fichtner, to develop the EOI. Fichtner is also studying whether storage projects should be subject to a grid impact study (GIS).
- Several pilot energy storage projects are underway or begin considered:
    - 13 MW project with 6 MWh of storage under development by Philadelphia Solar and Badiya.
    - AHBTU Sha'ams Maan 50 MW solar PV project is considering adding storage to firm-up its production.
    - Water Authority project in Dhuliel/Al Zatari is considering pairing 25 MW of storage with the approved 50 MW solar PV project.

Meeting With SG Amani

- SG Amani informed that the Energy Storage report should address the next steps and a road map (for example, centralized versus project specific) for Jordan. The Energy Storage could be part of Round 3 auction. SG Amani also requested to coordinate the efforts with JCP.
- The new EHV facilities will have low utilization factor and SG Amani requested to address how energy storage will fit.
- The report should recommend whether grid impact studies are necessary for the Energy Storage projects.

- Currently the renewable projects are not counted as firm capacity to meet evening peak loads, unless there is a way to make them firm capacity.
- SG Amani suggested that the Philadelphia Solar's energy storage project could be selected as a case study for the GIS training.

Meeting With AES Jordan

- AES's IPP-1 is a combined cycle plant of 370 MW capacity (as contracted) and the IPP-4 comprises of trifuel diesel engines of 240 MW capacity (as contracted). NEPCO supplies the fuel and AES supplies the electricity. IPP-4 is mainly used as peaker units.
- As per Eng. Hammad of AES, Jordan's lost revenue is about $2 billion in the last two years, mostly in paying capacity charges without any return in terms of energy. As an example, the capacity factor of IPP-3 is about 2%.
- NEPCO does not perform its own System Impact Studies and requires the project developers to perform the studies. However, NEPCO in most cases does not verify or check the study reports. Preliminary System Impact Studies are prerequisite for NEPCO to sign the interconnection agreements.
- The exiting power producers and the Universities are allowed to build renewable projects as "direct proposals".
- On average, about 20 reciprocal engines are started every evening to meet the peak load.
- There are two types of tariffs in place, one from 7 am -7pm and the other from 7pm-7am. However, the peak load shifts from one tariff period to the other depending on the season.
- As per AES, Energy Storage for NEPCO system is required for relieving overloaded lines and transformers and also for solving voltage and frequency issues. NEPCO is able to cope with these for now, but will have problems when more renewables come on line by 2019 or 2020.
- As per AES, the CESI report is outdated and the renewables capacity as contracted has already exceeded what was studied in 2014.
- AES Jordan has MOU in place with NEPCO for developing Energy Storage projects.
- AES gave a tour of their IPP-4 control room and showed how the AGC was not in operation, and the resulting high fluctuation in frequency. If Energy Storages are installed for frequency regulation, NEPCO will need some kind of AGC.

Meeting With Philadelphia Solar

- Philadelphia Solar explained how their proposed Battery Energy Storage at Mafraq can increase the annual energy production from 21 GWh to 46 GWh, without exceeding the maximum capacity limit imposed by IDECO. The energy storage will be used for load shifting and to meet the evening peak.
- According to Philadelphia Solar, the main challenge for Energy Storage program in Jordan is the lack of regulatory framework and also about knowing NEPCO's need.

Meeting With JCP

- JCP is responsible for parts of the tariff creations for EVS, installation, permitting and rates.

- There is a possible collaboration between ESCB and JCP programs for advising regulatory framework for energy storage procurement. A follow up will be made after the Situation Review report is completed.

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