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Texas Commission on Environmental Quality
New Technology Implementation Grant (NTIG) Program

Elbow Creek Battery Storage Project

Final Report

for:

New Technology Implementation Grant (NTIG) Program

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Submitted by:

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Task Deliverable/Final Status Report Overview

NRG has successfully completed the construction of the battery storage project (2MW) and interconnected with the ERCOT/Sharyland systems near Elbow Creek in west Texas. The facility was constructed by Toshiba under a lump sum turnkey contract and utilized Toshiba.

Introduction/Background

NRG Texas Power is the owner and operator of the Energy Storage Project (ESP) at Elbow Creek, an integrated lithium-ion (li-ion) battery system providing 2 megawatt (MW) of electric output of energy from wind and other renewable power. Toshiba is the technology holder for the li-ion battery modules. NRG entered into a lump sum turnkey EPC contract with Toshiba to cause the purchase of the batteries, balance of plant equipment and to construct the ESP. NRG via its contract with Toshiba will be responsible for assuring the delivery, installation, and commissioning of the battery and other components comprising the Energy Storage System (ESS). NRG will integrate the ESS with the SCADA (supervisory control and data acquisition) industrial control system and 2 MW of wind power so that wind energy captured by the Elbow Creek wind farm and other renewable resources is stored and delivered via the ERCOT system to the ESS and then in turn delivered back to the electric grid.

Project Objectives/Technical Approach

We had several objectives we wanted to accomplish in the deployment of this battery system across the grant period some of which evolved over the project execution time period. The primary objectives are as follows:

- To successfully utilize energy produced from renewable energy resources, in this case wind generation, and redeploy the stored energy at times when required by the ERCOT system. This essentially replaces conventional generation sources and thus off-sets the associated emissions. This is true for both traditional peak shifting storage and frequency response applications
- To demonstrate the successful interconnection and integration of a ESS with the ERCOT and Sharyland systems.
- To evaluate the relationship between the production of renewable resources, battery charging and the needs of the ERCOT system
- To demonstrate the ability of the ESS to dispatch based on the various conditions of the ERCOT and Sharyland electric systems

- To evaluate the performance of the ESS as compared to our pre- project technical view (round trip charging efficiency, battery degradation, invertor performance, and project life cycle costs of the system)
- Understand the proper application of ERCOT market protocols, regulatory requirements and protocols to successfully interconnect a facility and participate in the market place.

NRG undertook an economic and technical evaluation using proprietary information of various battery suppliers and chemistries in making its ultimate final project design decisions. We evaluated the results across a 20 year projected project life to arrive at our preferred ESS supply option.

Tasks

To reach the successful completion of the construction and interconnection of the facility NRG under took the following Tasks.

Task 1 - Site Control

Site control was more complicated than originally expected for several factors:

- NRG went through a reorganization and the original project team was no longer with the company
- NRG sold the Elbow Creek Wind project to a tax equity investor and NRG Yield
- The ERCOT protocols to allow for the battery to participate in the ERCOT market were more complicated and undeveloped than at the time of the grant application and amendment

After executing an initial lease with the new owners of the Elbow Creek Wind project NRG ultimately had to relocate the project immediately adjacent to the Sharyland Elbow Creek substation and execute a replacement lease with another property owner. This did not cause any delays in the implementation of the project.

Task 2 - Secure all necessary installation and operation permits, finalize project plans, and select subcontractor(s)

To complete Task two (and to some extent Task 3) we broke down the project execution into its various components:

- Permits – fortunately there were no permits required to construct the facility. For operations there were no required permits, although there were regulatory requirements

(Electric Interconnection Agreement) that was required before the facility could be energized and connected to the ERCOT and Sharyland electric system.

- Finalized Project Plans and contractor selection was a parallel path executed as follows:
  - There was a competitive process run for a fully designed, delivered and construction system. This included all engineering, design and construction required for the project in a lump, sum turnkey contracting arrangement
  - NRG evaluated the results of the competitive process based on our view of the needs of the electric system that match best for an ESS in the ERCOT market place. This evaluation included a life cycle cost analysis that considered initial system cost, battery degradation across time and potential cycling profiles, maintenance requirements and the ability to meet the project schedule requirements.
  - Upon the completion of the above steps NRG selected Toshiba and its Lithioum Titrate battery chemistry to perform the requirments of this portion of the task.

Task 3 Purchase and install ESS components

Upon completion of Task 2 NRG negotiated a lump sum, turnkey contract arrangement with Toshiba to design, engineer, construct and commission the ESS project at Elbow Creek. Construction of the project was completed in March 2017. During this process we experienced several lessons learned which are covered in detail in the sections below but are summarized as follows:

- The integration of a ESS into an operating asset is extremely difficult given the prevalent tax equity structures in the renewable space.
- ERCOT and Sharyland discovered gaps in the integration of battery storage systems into the electric system both from a physical and regulatory perspective
- IT and communication protocols are vitally important tasks that require significant efforts and time allowances to address properly

We successfully, with the full support and assistance, overcame these challenges to successful install the project and physically interconnect with the electric system.

Task4 – Testing of Final Design

NRG's contractor Toshiba is responsible for the final testing of the facility. The facility, as can be expected with any first of the kind installation has experienced issues in meeting the projects intended output due to various issues which we continue to work through: Here is what we can report:

- The ESS is capable of charging and discharging the stored energy to the ERCOT system
- The system is capable of doing multiple cycles of charging and discharging
- The system due to unanticipated heating of the invertors is only capable of operating at one half to three quarters of its intended 2MW design

NRG and Toshiba are taking the following actions which we believe will result in meeting the intended design parameters;

- Increased the size of the chiller water piping and pumps feeding the invertor section
- Installing a third invertor to reduce invertor loading and the associated heating on individual invertor
- Evaluating a field design modification to address cooling in the invertor
- Goal is to achieve full design output by May 31. 2017

NRG does not consider this a failure but a correctable conditions and a very important lesson learned for future project designs.

Task 5 – Implementation Reporting/Operation Reportinig

This required the submission of quarterly reports to TCEQ. NRG met the quarterly report requirements and deadlines through the project construction period.

Task 6 – Operate Project for Five Years and Submit Annual Reports

NRG will be operating the facility for the minimum 5 years and have a design life of 20. During that time period NRG will be posting annual operating reports on the performance of the battery system. These reports will be posted on the project website for public viewing at the following link: http://www.nrg.com/renewables/projects/elbow-battery/

Discussion/Observations

Objectives and Results

NRG believes the project has met and even exceeded its objectives up to this point in time in the project life. We have summarized those below and are inclusive of the issues from Task 3 above:

Objectives and Accomplishments

- Overall objective was to successfully design, engineer and install an ESS system

- Design
  - Objective was accomplished as the system designs received during the competitive process where in line with NRG expectations and own internal high level design assumptions for a containerized system. There were several lessons learned including the design and layout of racking systems, invertor placement, communications equipment design and chiller design for cooling,
- Engineering
  - Objective was accomplished as the Toshiba engineered system was consistent with what we had expected based on our internal view of what an engineered package should look like for a containerized system.
- Successful installation
  - Objective was accomplished and was as expected based on the completed design and engineering with little surprises.

- Technical objective and Accomplishments
  - Evaluate various battery system designs and chemistries and the projected performance for various operating scenarios.
    - This objective was accomplished. Duty cycle projections (typical charge at low cost and discharge at high cost versus frequency response) clearly show that you must consider battery chemistry. For example a lithium titrate battery may appear to be more expensive initially versus a typical lithium-ion battery the life cycle results show it is in fact the least cost alternative for a frequency response product but the most expensive for a typical store and discharge based on economics.
    - Degradation curves of the manufactures are based on the number of cycles. However in the frequency response case it requires significant interaction to equate fast short duration charges and discharges to a cycle equivalent. The understanding obtained during this process by both NRG and the battery suppliers will provide for clearer system design and performance projections on future projects.
  - Clearly understand the IT/Communications protocols required external to the battery system to integrate with the ERCOT system.
    - This objective was accomplished as communications and IT requirements are easy to overshadow but equally important. The result of this project

for NRG, ERCOT and Sharyland is a much better understanding of what is required for a battery system to communicate within the ERCOT system to both safely operate and to participate in the market to realize revenues.

- Evaluate battery performance
  - This will be an on-going evaluation over the grant period and will be reported on in our annual reports on the website.

Critical issues/Technical goals and barriers

Issues and lessons learned to date can be summarized as follows:

- Electric Interconnection – the lessoned learned is that before final project design and engineering is completed all aspects of the electric interconnection requirements should be fully agreed upon and documented. Failure to do such could potentially delay the energizing of the project. We overcame these issues with the support and close interaction of ERCOT and Sharyland.
- IT/Communications – two lessons learned in this category.
  - Due to the remote locations of many renewable installations the lead time to acquire reliable communications infrastructure should be considered a major schedule milestone. Proper hardwire data circuits can take a long as 6 to 9 months to have installed depending on location. As stop-gap measure a cellular communications circuit can be utilized for most applications except for frequency response. Future Project Recommendation – once the site is finalized make request for communication circuits and build 9 months into a project schedule
  - Communication protocols will vary vastly across various vendors on both the battery system, energy management system and interconnecting utility. All communication protocols should be agreed upon and documented prior to finalizing design and engineering. Future Project Recommendation – early meetings with all entities to cooridinate the protocols required for proper communication should take place at project kick-off
- Invertor Cooling design –
  - Invertor can generate a significant amount of heat during the discharge process particularly when addressing frequency response. Careful attention needs to be given to the overall system design including pumps and piping size into the invertor. While the overall system design may be sufficient flow to specific areas

needs closely evaluated. Future Project Recommendation – require equipment specific cooling load calculations

- (List the practical problems, do's/do not's observed during the project that would be of use in future work and research. Were the goals of the project technically achievable? Have the technical barriers been identified and addressed? Is the technology likely to overcome those technical barriers?)

Scope for future work

NRG view of future work in the battery storage area is to broaden the scope of battery technologies to do comparative analysis between the systems for power applications in similar applications as the Elbow Creek Project. This would include the evaluation of flow battery technology and other lithium-ion battery chemistries.

Summary/Conclusions

NRG believes this project has successfully met its objectives to this point and has provided valuable lessons learned to make future projects better and more reliable. What the project has clearly demonstrated to this point is that due to the relatively early life cycle of this technology significant collaboration is required among all parties that will be involved during the design, engineering and schedule planning phases of the project.

NRG has gained significant insight on how to better design and deploy a project that will benefit battery storage as a way to better utilize the carbon and emission free energy generated by renewable resources.

Acknowledgments

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- Texas Commission on Environmental Quality, Texas Emissions Reduction Plan, Implementation Grants Section team for their guidance and patience through the process
- Sharyland Electric – for the outstanding customer service and guidance in the installation of the necessary interconnection facilities and solving communication issues
- Electric Reliability Council of Texas (ERCOT) – for help in navigating the market protocols and rules necessary to electrically interconnect the facility
- Toshiba – for providing the lump sum turnkey EPC contract that allowed for the deployment of the battery system.

Appendices

Appendix A: Project Picture

Appendix B: Diagram of Interconnection

One-line Diagram