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EVALUATION OF BATTERY ENERGY STORAGE SYSTEM (BESS) IN SOUTHERN INDIA

GREENING THE GRID - RENEWABLE INTEGRATION AND SUSTAINABLE ENERGY (RISE) PROGRAM

A JOINT INITIATIVE BY USAID/ INDIA AND MINISTRY OF POWER, INDIA

Summary Report

Disclaimer

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April, 2021


Type: Advanced Lead Acid
Storage Capacity: 250 KWh
Rated Power: 500 KW

SUMMARY

India is making steady progress toward its target of 175 GW of renewable energy (RE) capacity by 2022. Alongside, the country is attending to challenges — related to existing grid interactive services, ancillary reserves, power balancing, and transmission congestion — that emerge from integrating RE into the grid. Large-scale integration of energy from variable, unpredictable renewable sources requires system operations to be more flexible, with rapid response capabilities that balance and enhance the resilience of real-time grid operations. Ancillary services can help maintain the proper flow and direction of electricity, address imbalances between supply and demand, and assist the system in recovering after a power system event. In systems with significant RE penetration, additional ancillary services may be needed to manage the increased variability and uncertainty. The imbalance between energy demand and supply can be mitigated through various ancillary reserves, such as pumped hydro storage, spinning/non-spinning reserves, and battery storage. The usage of these ancillary reserves depends on the characteristics of the power system's ecosystem (geographic factors, regulation, economic response, etc.). Electrical energy storage systems have a fast response, which can suitably be used as a flexible balancing source for grid services, including for inertial response and primary and secondary frequency control. Battery energy storage systems (BESS), a technology for storing electric charge on specially developed batteries, is a globally accepted solution to minimize the need for flexible generation and operating reserves. However, operational mechanisms, policy, and regulations for adopting BESS technologies are still at a nascent stage in many countries.

In India, the Central Electricity Regulatory Commission (CERC) has provided a roadmap for operationalizing reserves. Per this roadmap, primary reserves are to be maintained at the all-India level, while each region must maintain secondary reserves corresponding to the largest unit size in the region. In the Southern region, the secondary reserve requirement would be 1,000 MW[1].

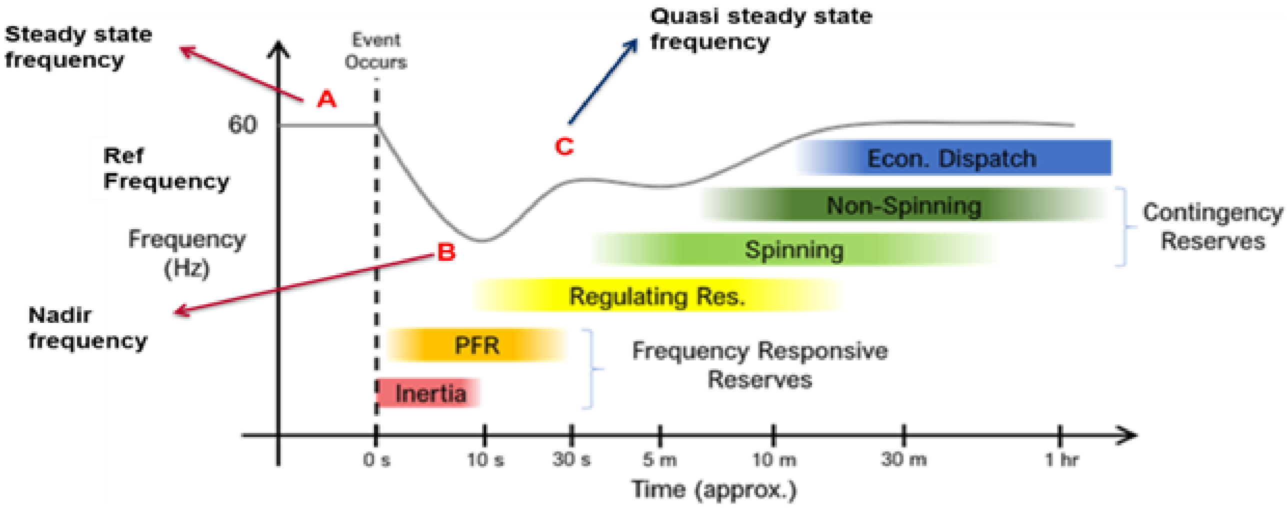
Aiming to build evidence on the potential of BESS, USAID's Greening the Grid-Renewable Integration and Sustainable Energy (GTG-RISE) initiative studied the techno-economic feasibility of BESS in providing ancillary services (frequency reserves) for the Southern region. GTG-RISE, a key initiative under the U.S. Government's Asia EDGE (Enhancing Development and Growth through Energy) program, conducted the study as part of its innovative pilot efforts aimed at supporting the Government of India in managing large-scale RE integration into the Indian power grid. Titled 'Evaluation of battery energy storage system for the Southern region', the study conducted a simulation based on the Southern region's network data to come up with the required frequency reserves for the Southern region. GTG-RISE carried out a detailed modelling assessment to gauge the BESS requirement for ancillary market operation. The study had two aims: i) to understand the required frequency reserves under primary and secondary reserves; and ii) to understand the role of BESS for these reserves.

Study methodology and key parameters

The GTG-RISE study addressed the inertia response and primary frequency reserves (PFR) and secondary reserves (regulating reserves). Figure 1 shows how reserves typically are deployed. The frequency nadir is defined as the minimum value of frequency reached during the transient period. The nadir depends on system inertia and PFR. The frequency that changes slowly enough to be considered constant is referred to as the "quasi steady state frequency."

[1] Central Electricity Regulatory Commission. December 2015. Roadmap to operationalize reserves in the country. Available at: http://www.cercind.gov.in/2015/orders/SO_11.pdf.

Figure 1: Sequence of reserve deployments in response to a contingency event (NREL[2] report)



The study modelled the entire grid of India's Southern region as 765kV to 220kV voltage level; this was based on system data received from the Southern Regional Power Committee (SRPC). Frequency reserves were evaluated based on system disturbances being categorized as 'event' and 'non-event', where 'event' represented the loss of generation plant or transmission corridor connected with the generation plant and 'non-event' referred to the possible load-generation imbalance due to renewables and load variations.

The study evaluated the system reserve requirements in case of a fault in the system, using the historical data for financial year (FY[3]) 2018–19 and the forecast for FY 2021–22. The peak demand considered for FY 2018–19 and FY 2020–21 stood at 45,834 MW and 53,092 MW, respectively. An outage of the National Thermal Power Corporation's (NTPC) Ramagundam (2,372 MW), which is the largest power plant in the Southern region in terms of installed capacity, was considered an 'event' by the simulation study. The load-generation impact due to changes in RE generation and load was considered as 200 MW/min for the purpose of studying the frequency response. Further, the scheduling of plants, RE penetration, load, import, and export were considered appropriately as per historical data.

The system's model for dynamic simulations was developed in MiPower software[4]. Key considerations for the simulation study included inertial response from convention generation, network dynamics, centralized automatic generation control (AGC) for participating generation units through control blocks, and dynamic modelling for BESS. Assumptions for the BESS model was based on the model[5] developed by the International Council on Large Electric Systems (CIGRE) and the Western Electricity Coordinating Council (WECC). The model included components such as BESS power and energy ratings, initial state of charge (SOC), rate of charge, rate of discharge, P-control logic, Q-control logic, current limit logic, convertor module, and active and reactive power injection.

GTG-RISE considered simulations to evaluate the technical benefits of BESS for primary and secondary reserves for peak, off-peak, and high RE scenarios. GTG-RISE considered the following cases for each scenario:

- Participation of conventional generators for primary reserve support as per grid regulations
- Participation of conventional generators for primary reserve and secondary reserve (AGC) support
- Participation of conventional generators and BESS for primary reserves
- Participation of conventional generators for primary and secondary reserves and BESS for primary reserves
- Participation of conventional generators for primary and secondary reserves and BESS for secondary reserves

Dynamic simulations were executed with frequency criteria for nadir and quasi steady state frequency limit. Nadir frequency of 49.5 Hz was adopted, as recommended by the CERC 50 Hz expert group[6]. Quasi steady state

[2] National Renewable Energy Laboratory (NREL). January 2019. Modelling Primary Frequency Response for Grid Studies, NREL Technical report.
[3] financial year (April to March for India)
[4] Mi Power is a highly interactive, user friendly windows based Power System Analysis package.
[5] International Council on Large Electric Systems. May 2018. Modeling of inverter-based generation for power system dynamic studies.
[6] CERC Report by Expert Group to review and suggest measures for bringing power system operation closer to National Reference Frequency (Volume-I)

frequency of 49.8 Hz was adopted as per international standards. Droop of 5% was considered for convention generation units as per Indian Electricity Grid Code (IEGC) guidelines, which allow 3% to 6% droop.

Key findings of the study

Table 1 presents the simulation study' findings about the primary and secondary reserves required in the Southern region in FY 2021–22 for a nadir frequency of 49.5 Hz and quasi steady state of 49.8 Hz.

Table 1: Summary on reserve requirements in the Southern region for FY 2021¬–22

Scenario	Primary	Secondary	BESS in primary	F nadir (Hz)	F settling (Hz)
Peak - Primary (without battery); Settling 49.8 Hz	**1,986**	-	-	49.60	49.8
Peak - Primary + AGC (without battery); Settling 49.8 Hz	1,412	605	-	49.56	49.8
Peak Primary + AGC + BESS; Settling 49.8 Hz	331	605	1,085	49.60	49.8
Peak - Primary + BESS; Settling 49.8 Hz	926	-	1,085	49.68	49.8
High RE - Primary (without battery) [Figure 2]	2,040	-	-	49.54	49.8
High RE - Primary + AGC (without battery) [Figure 3]	1,408	605	-	49.51	49.8
High RE - Primary + AGC + BESS [Figure 4]	308	605	1,085	49.51	49.8
High RE - Primary + BESS; Settling 49.8 Hz [Figure 5]	927	-	1,085	49.66	49.8

Figure 2: Frequency response curve for High-RE scenario with conventional primary only for FY 2021–22

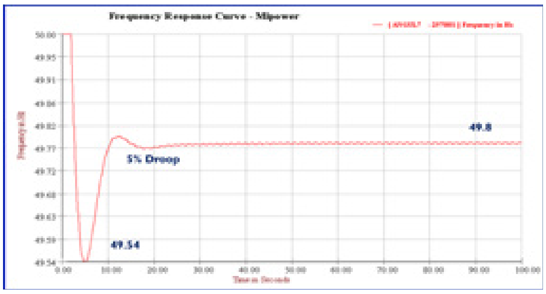


Figure 3: Frequency response curve for High-RE scenario with conventional primary and secondary for FY 2021–22

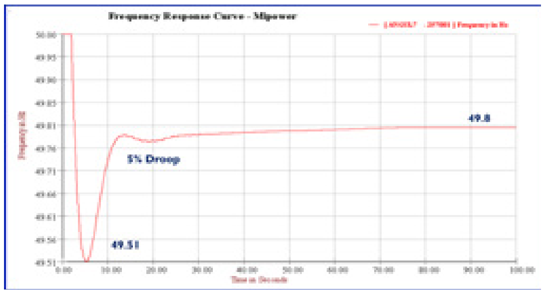


Figure 4: Frequency response curve for High-RE scenario with conventional primary, secondary and BESS in primary for FY 2021–22

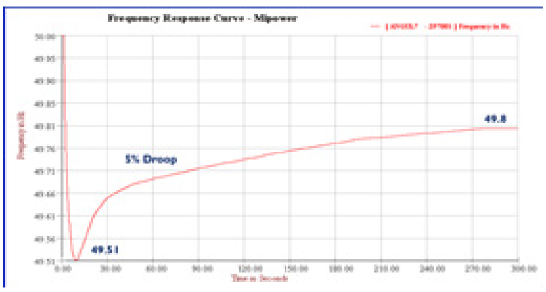
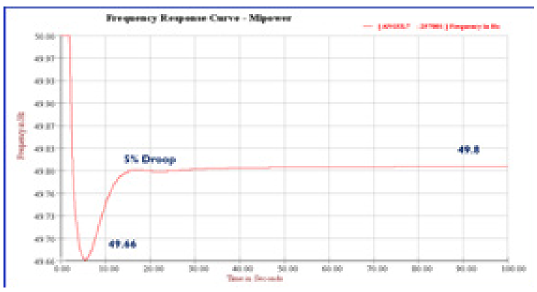


Figure 5: Frequency response curve for High-RE scenario with conventional primary and BESS in primary for FY 2021–22



Simulation outcomes indicate that frequency reserves of 2,017 MW — primary reserves of 1,412 MW and secondary reserves of 605 MW — are needed from convention generation units in the Southern region in FY 2021–22. For the same frequency response, primary reserves from conventional units are used up to the extent of 330 MW instead of 1,412 MW. Both scenarios maintain secondary reserves of 605 MW.

The total conventional generation that participates in primary reserves, per IEGC guidelines (thermal: >200 MW, Gas: >50 MW, and Hydro: >25 MW) for FY 2021–22, is 62,951 MW. Out of this capacity, 40,920 MW would be scheduled per load generation balance requirement for the peak load scenario. With 5% droop characteristics, conventional units can contribute primary reserves of 3,274 MW to maintain quasi steady state frequency of 49.8 Hz. However, by enabling primary support from BESS, primary support from conventional units can be limited to 331 MW instead of 3,274 MW. So adding BESS can release 2,943 MW (3,274 – 331= 2,943), which can be used for scheduling and dispatch purposes.

Key insights from GTG-RISE's technical analysis of frequency reserves for the Southern region include:

- BESS will help arrest the nadir frequency with its fast-response characteristics, as is the case with inertial support from conventional units and will also help achieve the target value for quasi steady state frequency. Thus BESS reduces the burden on conventional units due to high RE additions to the grid.
- BESS support in primary reserves can drastically reduce the primary reserves support required from conventional units for frequency reserves.
- If BESS is deployed to provide primary reserves, the reserve capacity of conventional units can be released to meet consumer/system demand.
- With 5% droop for conventional generation (as per IEGC guidelines) from the Southern region, about 3,000 MW of conventional capacity can be released for frequency reserves with BESS support.

Financial impact

The GTG-RISE study also included an economic analysis to: i) assess the benefits of centralized market operations in the day-ahead horizon; and ii) estimate the overall cost savings with and without the additional conventional capacity that might be released from primary reserves because of BESS deployment in such a market. The analysis combined the power generation resources of five states (Andhra Pradesh, Telangana, Karnataka, Maharashtra, and Chhattisgarh) for scheduling and dispatch to ascertain the savings scope. GTG-RISE used a Python-based optimization tool to simulate and demonstrate the benefits in a scenario where the states participate in the market in a closed mode.

For the purpose of simulation, GTG-RISE calculated cumulative generation from all the generators for each of the 96 time slots in the year. The generating stations were dispatched per merit order stacking based on the quantum of declared capacity. The model determined the total cost of generation, based on total demand and entitlement, and then dispatched generators over the one-year timeframe subject to the demand-supply balance constraint. The model showed cost savings compared to the present mechanism that dispatches generators based on their respective portfolio of contracts. The existing mechanism underutilizes more efficient (lower variable cost) generators while costly (or relatively inefficient) generators serve the demand. The GTG-RISE model calculated total system cost by summing generator cost of production for all the slots in a year, assuming no additional capacity is released because of BESS deployment. The model then assumed that the 3,000 MW conventional capacity released from the primary reserves was scheduled optimally in the electricity market to meet the system demand. The model then calculated total system costs and compared it to system costs for the scenario in which no additional capacity is deployed. Finally, the model determined the net reduction in system costs due to participation of the additional capacity released from primary reserves.

The model shows that savings of approximately INR3,000 crore[7] can be generated on an annual basis because of the additional capacity being made available. A 1,200 MW BESS system would cost approximately INR 1,100 crore a year (based on year 2020 costs, with financing assumptions aligned to market practices). The estimated savings would thus be almost three times the cost if BESS were to be deployed as a reserve for providing primary response, and the conventional capacities reserved for such response released to meet consumer demand.

The study's insights are compelling and can bolster efforts to secure the effectiveness and security of the Indian grid. Its outcomes will help Indian regulators to make evidence-based decisions on introducing regulatory pathways for grid connected BESS for ancillary services (frequency regulation).

[7] 1 crore = 10 million

About Greening the Grid Program

USAID's Greening the Grid (GTG) is a five-year program implemented in partnership with India's Ministry of Power (MOP) under the USAID's ASIA EDGE (Enhancing Development and Growth through Energy) Initiative.

The GTG-RISE supports Government of India (GOI) in managing large-scale integration of renewable energy (RE) into the Indian power grid by implementing series of innovative pilots. GTG-RISE Initiative is implemented by Deloitte Consulting LLP

This report is available at no cost from the GTG-RISE initiative at *https://www.gtg-india.com/resources/*

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