Value Assessment of Energy Storage in Hybrid Renewable Projects

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Abstract — **Wind and Solar PV hybrid plants would have higher utilization factor as compared to individual plants due to complementary nature of wind and solar resources. Collocation of wind and solar PV plant have several other benefits like lower operational costs, lower investment in transmission infrastructure, effective land usage etc. These benefits are further augmented with addition of Battery Energy Storage System (BESS). BESS addition helps hybrid plant as well as system (grid) by offering different services or applications. However, business models are to be developed beforehand considering these applications and regulatory framework in order to justify investment in BESS. Value of BESS can be quantified with evaluation of benefits and economic assessment. In this paper, value assessment of BESS is discussed with qualitative description of benefits offered by BESS to hybrid plant and to the system. Quantitative analysis is presented for a case study with a BESS Hybrid plant in Southern region of India. For this plant, financial evaluation is performed to estimate impact of BESS on the plant's Levelized Tariff. Further, investment performance indicator is calculated to indicate the profitability of the plant and measures (viability gap funding) are investigated in case plant is not financially viable.**

Keywords- Wind solar PV hybrid projects, Battery Energy Storage Systems, Levelized Tariff, Equity IRR, Financial Evaluation, Viability Gap Funding

I. Introduction

In year 2015, India had set up an ambitious target of installing 175 GW of Renewable Energy (RE) generation resources by year 2022. It included 60 GW of wind, 100 GW of Solar PV (SPV) and 15 GW of other RE sources like small-hydro, biomass etc. [1]. Integrating RE generation of such a quantum in the grid requires conscious effort for reliable and secure grid operation due to intermittent RE generation. Intermittency of RE generation is due to 'variability' which cannot be controlled as it depends on nature (wind and sunlight). Due to seasonal and daily variation of natural resources, wind and SPV projects developed and operated on standalone basis normally have low capacity utilization. In India, wind and SPV generation output complement each other and thus collocated wind, SPV hybrid plant (termed as 'Hybrid Plant' now onwards) would have higher utilization as compared to standalone plants. There are several benefits of hybrid plants which further gets augmented with addition of 'Battery Energy Storage System' (BESS). Such a hybrid plant with BESS can be termed as 'BESS Integrated Hybrid' plant

This paper describes the case study on 'value assessment of BESS' from the larger study completed in April 2016. The study was aimed to evaluate the business opportunities of utilizing BESS to firm up the variable wind and SPV generation, shift energy to meet peak demand and finally make variable wind and SPV generation more dispatchable. A BESS Integrated Hybrid Plant of 41 MW (16 MW wind, 25 MW SPV, 10MW/15MWh BESS) located in Southern Region of India was considered for analysis. BESS technology selected was 'Li-NMC' (Lithium Nickel Manganese Cobalt) and designed to provide 'power' as well as 'energy' services. In the beginning, the issue of value assessment of BESS is explained. Benefits of 'Hybrid Plant' and 'BESS Integrated Hybrid' are discussed followed by the description of possible services offered by BESS to the hybrid plant as well as to the grid. Lastly, BESS's design procedure is discussed in brief along with its financial evaluation.

II. Issues of BESS Value Assessment

It is important for any technology to be viable for its application in the commercial project; this is also applicable to BESS. BESS technologies are evolving and thus have higher capital cost as compared to matured wind and SPV generation technologies. Wind and SPV plants may have a revenue model as simple as selling energy generated in the real time to the consumer at a fixed or negotiated price. Thus, energy sale price negotiation and cost optimization are a key trait of the project to earn profit. However, for BESS, it is not straightforward. Unlike wind and SPV, BESS does not generate energy; instead BESS gets charged with either grid or RE generation and with certain loss (due to efficiency), discharges this energy. In order to discharge (sale) BESS's energy, services (applications) are to be well thought in advance. Sound commercial value needs to be assigned for BESS services in order to justify the investment. These applications may vary every project based on region and regulatory framework. So, a case by case evaluation is required rather than common evaluation criteria

The 'value' of a service or technology is a relative term and it is evaluated in association with of the project developer's aim as well as regulatory framework. The value of a technology may be correctly assessed with the thorough understanding of the benefits achieved with it and the capabilities which are attributed to the project by this technology. In context of BESS Integrated Hybrid, the value of BESS is intricate and may be evaluated with assessment of 'benefits achieved by Hybrid Plant with BESS' and 'Hybrid plant's ability to provide additional services' at technical and regulatory front with BESS's addition. These benefits and services (applications) are explained in detail in progressive sections. Benefits are discussed at qualitative level and services are quantified at quantitative level.

Structure of business models for BESS's services is complex as value of some of the services can be explicitly expressed while some service's value is tacit. E.g. it is possible to create a revenue stream for primary applications like 'peak energy shifting' offered by BESS to the Hybrid Plant. Under this service, energy generated by Hybrid Plant in non-peak demand hours is stored in BESS and discharged (sold) at differential rate during peak-demand hours. With the understanding of demand pattern and sale tariff, business model for BESS Integrated Hybrid plant can be created. However, in the Indian context, business model creation for secondary services like 'ramp management for system' is difficult as mechanisms like Automatic Generation Control (AGC) are not fully developed and revenue stream creation for such service may not be straightforward.

Value of BESS is required to be deduced at planning level keeping in mind the services it going to serve recognized by regulatory framework. With this judgment, final BESS design (technology and sizing in terms of MW /MWh) is to be confirmed. This would consider number of factors including available BESS technologies, capital cost, operation cost, replacement cost, profitability, operation pattern, predicted wind and solar profiles of the site, control methodology etc. This is the first and the critical stage at which the maximum value with BESS can be created. In the next step, commercial value of BESS's services can be estimated with financial evaluation and expressed in conventional terms like 'Levelized Tariff' and investment performance indicators like 'Internal Rate of Return' (IRR). These two steps are discussed in this paper.

III. BENEFITS OF BESS INTEGRATED HYBRID PLANT

This section presents the qualitative analysis of benefits of Hybrid Plant as well as BESS Integrated Hybrid plant [2]. Exact quantification of benefits (quantitative analysis) is beyond the scope of this paper.

A. Benefits of Hybrid plant

1. Optimization of project development costs: There are number of project development steps involved in developing a renewable energy project (wind or SPV). Many of the activities involved like project development studies (feasibility study, socio-economic impact study, market study, environmental impact study, grid impact study, legal and regulatory framework evaluation), applications for permits and licenses (land lease agreements, construction permits, grid interconnection agreements, power purchase agreements) are required by both wind and SPV projects. By combining wind and solar plants, the time, effort and costs for these activities can be optimized.

2. Effective land use: Large areas of land will be required for fulfilment of India's RE target of 175 GW. This is because, 160 GW of these installations would be in the form of wind and SPV. For effective usage of land, wind and SPV plants can be collocated. This would conserve the space and result in increased energy density or the amount of energy produced per acre of area.

3. Lesser need of local balancing resources: Complementary nature of wind and SPV generation is beneficial for the hybrid plant as it has an effect of leveling out the generation. Hybrid Plants may reduce the need of local balancing resources as co-location would cancel out variability in wind and SPV's generation for several hours.

4. Potential savings in evacuation and transmission upgrade costs: Co-locating wind and SPV plants may reduce the spending on evacuation infrastructure and save possible transmission upgrade costs. As per typical design practice, the collector system is designed to transfer the full output of the wind and SPV plants from plant to grid. However, average cumulative hourly generation of wind and solar may rarely reach to the level of combination of the maximum ratings of the (wind and SPV) plants. Thus, it is possible to design the evacuation system, with a lower rating than the sum of the maximum capacities of the wind and solar plants resulting saving the transmission infrastructure spending.

5. Sharing of Operations and maintenance expenses: As some of the plant components and activities in the wind and SPV plant are similar, Hybrid Plant would share resources for thereby reducing the operation and maintenance cost of the plant.

B. Benefits of BESS Integrated Hybrid Plant

BESS addition can be beneficial to Hybrid Plant as well as to system. Advantages listed in section A would augment with addition of BESS.

1. Potential savings in evacuation and transmission upgrade costs: As mentioned in section A, designing transmission infrastructure of lower rating would result in saving in transmission system cost; however this would also result in the curtailment of some energy as plant would generate peak energy during some hours of the year. In such events, BESS enables some of the curtailed energy to be stored and it can be to be discharged later when there are no transmission constraints. The optimal design of the transmission infrastructure can be finalized with the comparison of the cost savings in the transmission system and with the cost of the energy storage, (with the permission of the grid operator).

2. Provide value added services to wind and solar plants: BESS can be beneficial to the Hybrid Plant as it can provide services like 'firming' (reduction of the forecast deviations of wind and solar generation and thus reduction in penalties) and 'the shaping or peak shifting' (shifting off-peak renewable energy of wind and solar generation to peak durations).

3. Assist the system in recovering from faults: BESS Integrated Hybrid plant can support the system to recover from faults that results in sudden imbalance between generation and load. It can also improve the transient stability of the system (by providing instantaneous response after a fault) and the dynamic stability of the system (by properly tuning the controls to provide damping to the system oscillations after a fault). The response of BESS would either be in the form of an inertial response, fast frequency response or primary frequency response.

4. *Assist the system in maintaining tie line flows and frequency:* A co-located BESS can be used by the system operator to meet steep ramps in net load which would minimize the impact on thermal power plants

5. *Serve as a capacity and energy source during peak hours:* BESS can be used along with co-located wind and SPV plant to shift renewable generation from off-peak hours (or excess RE generation hours) to on-peak hours. It can also provide this energy arbitrage function using inexpensive (or excess) energy from any source.

6. *Assist in managing transmission congestion:* A properly located BESS can assist in managing transmission congestion in the system and potentially defer transmission upgrades. Ideally, for this service, BESS should be located near to load center which is supplied by transmission line congested for certain hours. In addition, BESS may serve as generation resource during the certain hours when the transmission line is congested; enabling transmission upgrade deferral.

7. *Assist in maintaining system voltage and power quality:* Voltage variations may occur in the system with the higher penetration of wind and SPV plants on account of intermittent output of these resources. BESS can support the system to maintain voltages within an acceptable range by dynamically providing the required active/reactive power. At distribution level, under certain circumstances, BESS may be used to tackle power quality issues (e.g. voltage flicker and harmonics).

8. *Assist wind and solar plants in complying with technical standards:* With the increase in RE penetration in the grid, it would be required by RE plants to perform functions like primary frequency response or limiting the ramps. BESS would assist plant to comply with such technical standards.

9. *Provide black start capability:* BESS system designed with due considerations can assist system to recover from blackout.

IV. APLLICATIONS OF BESS

BESS can be used for multiple applications. A process of designing optimal BESS would start with the identification of valuable services that BESS can provide to the Hybrid Plant or to the grid. "Figure 1" shows application of BESS in various domains of electricity supply chain based on its duration. BESS applications can be categorized as primary and secondary applications based on a simple criterion. Primary applications would be those applications where an immediate need for it exists or there is a mechanism available to compensate storage for the service provided. On the other hand, Secondary applications provide lot of value to the system, but require regulatory intervention. TABLE I lists out BESS services classified into the categories of primary and secondary applications [2].

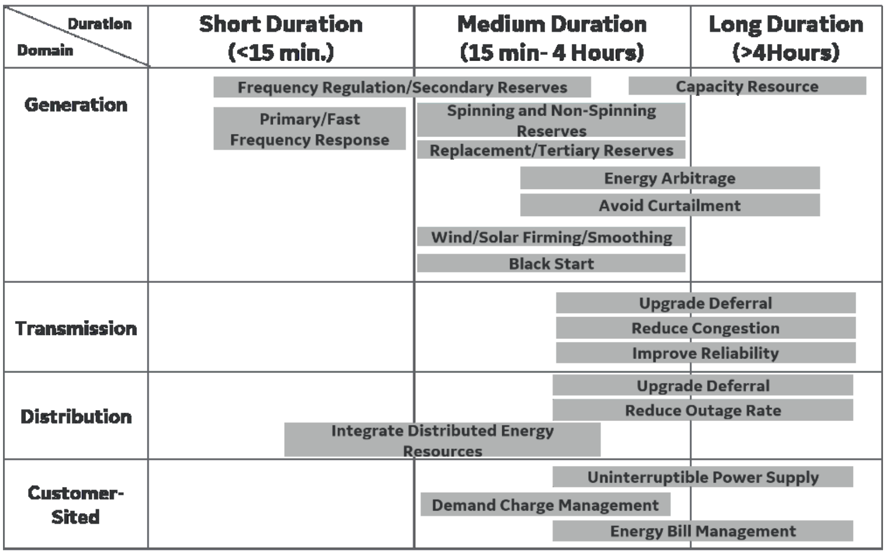

Figure 1. Application of BESS: Domain and Duration

TABLE I. PRIMARY AND SECONDARY APPLICATIONS OF BESS

Sr. No.	BESS Application	Category
1	Deviation Settlement Mechanism (DSM) penalty charge management	Primary
2	Time shifting of renewable energy to peak hours	Primary
3	Forecast deviation reduction for wind and solar plants	Primary
4	Ramp management for wind and solar plants	Secondary
5	Synthetic Inertia and fast frequency response for the system	Secondary
6	Primary frequency response for the system	Secondary
7	Ramp management for the system	Secondary

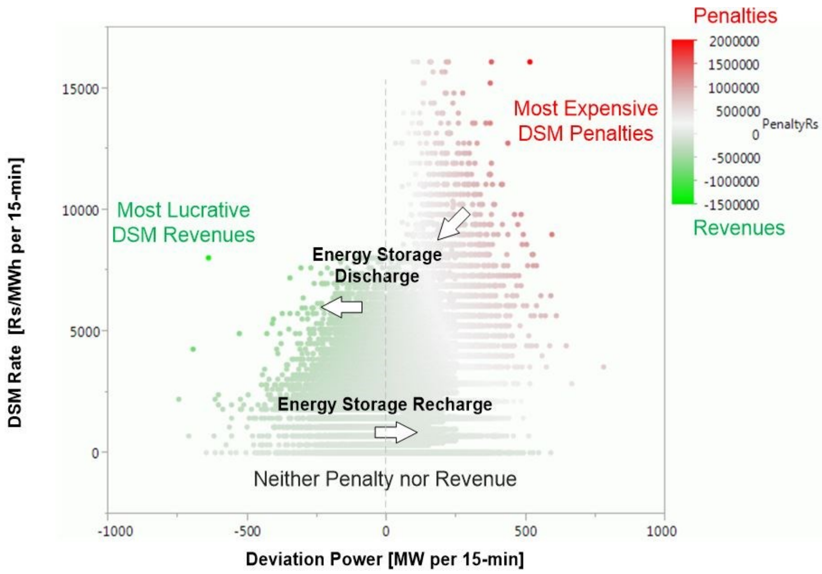

Figure 2. BESS Application for DSM Penalty Reduction

Selected BESS applications which are analyzed to design BESS for case study are described below.

1. *Penalty charge management under the deviation settlement mechanism (2015 regulation) [3]:* The first primary application of energy storage addresses financial penalty reduction in the deviation settlement mechanism (DSM). Deviations from day-ahead inter-state schedules are determined on a 15-minute basis and penalties and incentives associated with these deviations are determined according to the system condition (frequency) prevailing at that time of deviation. In general, when the frequency is below 50.05 Hz and if a generator under produces or a beneficiary overdraws, there is a penalty (payable). Conversely, when the frequency is below 50.05 Hz and if a generator over produces or a beneficiary under draws, there is an incentive (receivable).

"Figure 2" shows a plot of DSM Penalties for one of the states in Southern India in year 2015 which ranged from a maximum of 20 Rs. lakh in one 15-min time block (red dots) to a peak revenue of 15 Rs. lakh in one 15-min time block (green dots) [4]. The plot also shows that the Deviation Power (error between scheduled consumption and actual consumption) ranged from +800MW (over consumption), to -750MW (over production). The plot also shows how a BESS can discharge during periods of high over consumption to reduce the DSM penalty (and Deviation Power Level), or how a BESS can be discharged during periods of moderate revenue to increase the revenue in that time block. The BESS can also recharge during periods of low Power Deviation (and near nominal system frequency) with no impact on the DSM fee.

2. *Shifting renewable energy to peak demand hours:* This is one of the practical (primary) applications that BESS can support. This application is based on the concept that, BESS can be dispatched to support a RE plant meet power and energy delivery commitments during peak load hours. In the example shown in "Figure 3", the BESS charges during off-peak load hours (8am to 2pm) using renewable energy and discharges during the peak load hours (6pm to 10 pm) such that a firm amount of energy from the combination of wind, solar and energy storage plant can be counted on during the peak hours.

3. *Forecast deviation reduction for wind and solar plants:* Energy Storage can provide the service of forecast deviation reduction for wind and solar plants. The basic idea of this service it that, the energy storage can be dispatched to reduce a renewable energy plant's forecast errors to prevent lost revenues from a tiered rate structure. As shown in "Figure 4", BESS can be employed to discharge during 'under production periods' (relative to forecast) and recharge during 'over production periods' (relative to forecast).

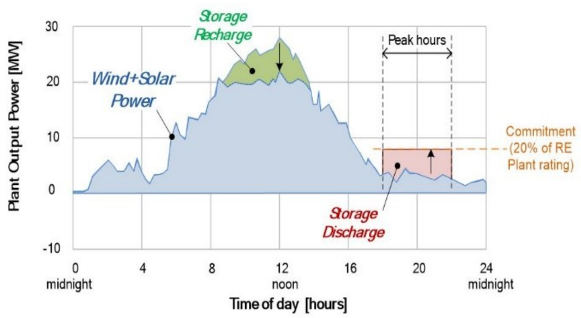

Figure 3. BESS application for Peak Energy Shifting

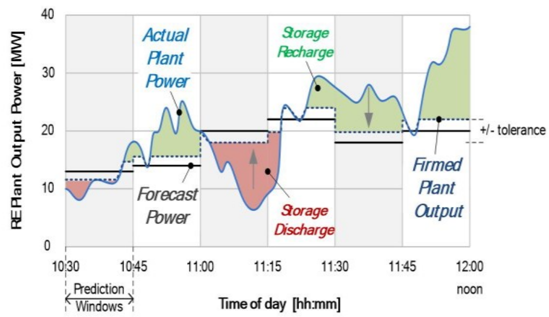

Figure 4. BESS Application for firming Renewable Plant forecast

V. BESS Design

This is the first step of value creation with BESS. The design methodology of BESS sizing for this case study used a time-based simulation tool to assess the actual operation and impact of Energy Storage on the application over the course of a single year [2]. The structure of this model is summarized in "Figure 5" and various blocks are briefly described below:

a) Application Model & Rates: The basic mechanism of working principles of applications, penalty structures, or revenue mechanisms.

b) Time-based Simulation: A simulation of the operation of the Energy Storage with respect to the application.

c) Energy Storage database: The database of performance and cost characteristics of several Energy Storage (ES) technologies.

d) Wind and Solar 15-minute profiles: Actuals and forecasted wind and solar profiles

e) Dispatch Thresholds and Control Logic: A control block which adjusts the various settings and thresholds that are used to drive the BESS dispatch decision.

f) Performance and Cost Assessment: The output of the time-based simulation is an estimate of how the BESS will perform, based on the selected BESS technology, and the dispatch thresholds. A simple cost effectiveness or profitability calculation was used as a screening tool for the BESS sizing and selection. "Figure 6" shows the components of the BESS cost estimate to serve the performance and cost assessment block. The replacement cost block uses the Energy Storage pricing in the future, once the original ES block has reached end-of-useful life.

g) Recommendations: Final BESS sizing is based on the most cost effective or best profitability calculation for all the BESS sizing as well as technology performances.

It was assumed that the BESS design (technology and size) should be able to serve multiple applications (primary and secondary). It is worth knowing that BESS designed via above procedure can be used for performing these applications sequentially in time, rather than simultaneously.

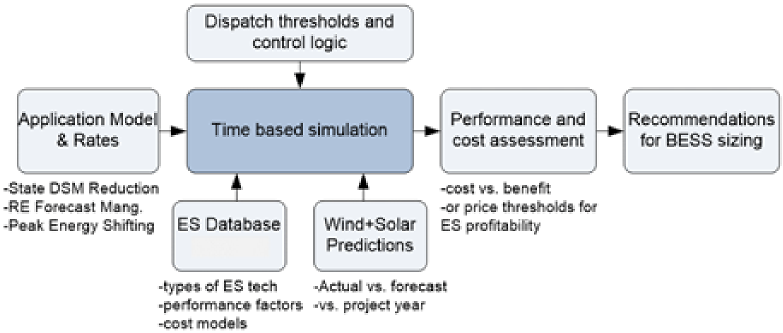

Figure 5. Methodology for assessing Energy Storage performance and costs for various applications, via time-based simulations

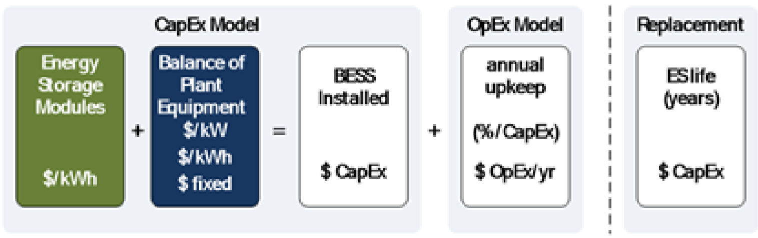

Figure 6 Components of the BESS cost estimate to serve the performance and cost assessment block (CapEx – Capital Cost, OpEx- Operation Cost)

Three primary applications and four secondary applications would be served with by BESS with rating of 10 MW/15 MWh (1.5-hour system) of moderate cycle life technology- Li-NMC (Lithium Nickel Manganese Cobalt).

Few other aspects of the BESS design:

- It is less profitable for the DSM fee reduction application and offers moderately higher energy rating to help with more energy intensive applications.
- BESS can support the less attractive, Peak Energy Shifting application with a 20% commitment level (of RE plant output rating) over the peak hours, with 90% compliance.
- It could serve the RE Plant Forecast Deviation Reduction if the RE rate structure tolerance band is less than +/- 8%. Additionally, BESS could also support the secondary applications of Ramp, Inertia, Frequency Support, with 10MW of power level.

VI. Financial Evaluation of BESS Integrated Hybrid Plant

This is the second step of BESS's value assessment. At this stage, financial evaluation is performed for estimating 'Levelized Tariff' and profitability over 25 years of operation life of the project [2]. For this case, the financial projections for the project were worked out in line with the Central Electricity Regulatory Commission's (CERC) methodology for computation of levelized tariff.

A. Assumptions for Analysis- (Costs basis – year 2015)

Key assumptions used for financial evaluation are indicated in TABLE II.

It is to be noted that:

- All the cost values are based in year 2015 as this case study was commenced in that year.
- Costs indicated in the 'cost summary' includes costs like land cost, communication device cost, project development cost, contingency, interest during construction, tax and duties etc. in addition to equipment cost.
- BESS design is finalized based on DSM saving and peak energy shifting application; however, DSM saving value indicated in assumption table is not considered for financial evaluation (profitability) since there was no regulatory framework available.
- The revenue stream of BESS is generated only with the sale of BESS power to the grid at Rs. 4.84 /kWh which is equivalent to wind and SPV generation's sale tariff.

TABLE II. ASSUMPTIONS FOR FINANCIAL EVALUATION

Installed Capacity		
Wind	MW	16
Solar PV	MW	25
BESS	MW/MWh	10/15
Capacity Factor		
Wind	%	25.50%
Solar PV	%	22.90%
BESS	%	N/A
Cost Summary		
Wind	Rs Crores	118
Solar PV	Rs Crores	148
BESS	Rs Crores	77
Total Cost	Rs Crores	343
BESS Details – (Cost assumptions are based on year 2015)		
Application	State DSM fee reduction + Peak Energy Shifting	
Power	MW	10
Energy	MWh	15
Technology		Li-NMC
Capital Cost – (Basic BESS)	Rs Crores	48
Capital Cost – (Basic BESS)	US $/kWh	478
Replacement Cost	Rs Crores	14.6
BESS Life	Years	19
Battery Efficiency	%	88%
DSM Saving – 1st Year	Rs Crores	2.61
Revenue Assumptions (Sale Tariff)		
Wind	Rs/kWh	4.84
Solar PV		
BESS		

Financial Assumptions		
Evaluation Term	Years	25
Discounting Rate	%	10.7%
Exchange Rate- INR to USD		67
Return on Equity - Expected	Assumptions as per CERC tariff guidelines	
Depreciation		
Working Capital		
Corporate Tax		
Minimum Alternate Tax (MAT)		
Debt	%	70%
Equity	%	30%
Domestic Loan	%	100%
Foreign Loan	%	0%
Operation and Maintenance (O&M) Assumptions (Year 2015)		
Wind O&M	Rs/Lakhs/MW/Year	11.5
Solar PV O&M	Rs/Lakhs/MW/Year	5.75
BESS	Rs Lakh/Year	90.8
O&M Escalation	%/Year	5.72%

B. Levelized Tariff for Hybrid RE + BESS plant

The levelized tariff projections had been calculated in line with CERC assumptions. The levelized tariff is calculated by carrying out levelisation for 'useful life' for each technology considering a discount factor for time value of money.

The levelized tariff estimated with year 2015 cost assumptions (BESS costs at 457 US$/kWh) is Rs. 6.78/kWh for the BESS Integrated Hybrid plant. It includes the levelized fixed charge of Rs. 5.97/kWh and levelized O&M charge of 0.81/kWh. The break-down of levelized tariff between the various components of the project is as shown in "Figure 7". The energy production from the integrated plant is considered as the basis for this chart and it indicates the impact of every sub-system in the project on the overall tariff.

TABLE III compares levelized tariff of the integrated project based on the cost of BESS in year 2015 (457 $/kWh) and year 2019 (at assumed price level of 250 $/kWh). All other costs (wind and SPV) are considered un-changed. As observed from the table, total contribution of BESS in the project cost is less than 25% (in years 2015 and 2019); as a result, 45% reduction in BESS costs lowered the total levelized charge by 8% (from Rs. 6.78/kWh to Rs. 6.22/kWh).

TABLE III. COMPARISON OF LEVELIZED TARIFF BASED ON BESS COSTS IN YEAR 2015 AND 2019

Final Costs				
Project Module	**Year 2015**		**Year 2019**	
	Rs. Crores	**% of Total Cost**	**Rs. Crores**	**% of Total Cost**
Wind	118	34%	117	38%
Solar PV	148	43%	146	47%
BESS	77	23%	48	16%
Total Cost	**343**	**100%**	**311**	**100%**
Levelized Tariffs (Rs/kWh)				
Tariff Component	**Year 2015**		**Year 2019**	
Levelized Fixed Charge	5.97		5.42	
Levelized O&M Charge	0.81		0.80	
Levelized Total Charge	**6.78**		**6.22**	

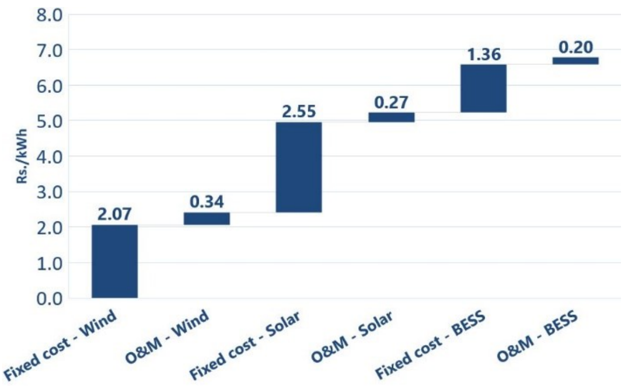

Figure 7. Levelized Tariff breakup for BESS Integrated Hybrid plant (estimated based on 2015 costs)

C. *Profitability of the Plant*

Equity IRR (EIRR) is the investment performance parameter considered here as an indicator of the profitability of the project. The IRR is the indicator used in financing as a measure of profitability of the business. The equity IRR addresses this from an equity investor perspective. The benchmark (target) EIRR for this case was assumed to be 16%. However, as per the cost and revenue assumptions, EIRR was estimated to be 5.3% (lower than target EIRR of 16%) which indicates the BESS integrated project was not financially viable.

Wind and SPV technologies are mature and well proven in numerous projects in India; BESS is still evolving and hence there might be a perception of higher risk from a lender's perspective regarding financing BESS. Recovery of capital cost (fixed cost) may be an issue due to reluctance of financial institutions for financing comparatively newer technology (of BESS). Financial institutions may not want to completely finance the capital cost for BESS technology. In this situation, alternative financing arrangements would be required.

D. *Viability Gap Funding (VGF) Estimation*

As name suggests, funding or support required to bridge the viability gap of the project is termed as 'Viability Gap Funding'. Viability criteria for the project under consideration was based on minimum 'Internal rate of Return for the Equity shareholders (EIRR)'. EIRR is pre-decided by developer during project assessment and termed as 'expected EIRR'. 'Expected EIRR' may not always be equal to 'calculated EIRR' due to several reasons including project performance shortfall, higher capital cost or limited financing support. Following tools and methodology of VGF were used to equalize 'expected EIRR' and 'calculated EIRR':

- *Financial Support (Grant):* Base case calculated EIRR was raised to expected level by considering a financial grant in the financing plan of the project
- *Higher Sale Tariff (Generation Based Incentive, GBI):* GBI offers higher sale tariff for units generated by the RE plant for certain years. This increases the revenue and helps the EIRR to reach the desired target level.

Based on the year 2015 cost of BESS, BESS Integrated Hybrid project would achieve the target EIRR of 16% if a grant of Rs. 76 Crore. (equivalent to BESS cost) and a generation-based incentive of Rs. 0.67/kWh for 10 years is provided concurrently. The total VGF on a present value basis is Rs. 112 Crore.

E. *Recognizing DSM revenue for BESS application*

Initial analysis did not consider additional revenue from the DSM application of the BESS even though as per simulation results under BESS design, an annual revenue of Rs. 2.61 Cr. was realizable as the state DSM savings. An alternate (optimistic) case with this revenue was also simulated and the results are indicated in TABLE IV. As seen from the result, recognizing the revenues from DSM application had a significant impact on the VGF requirement, reducing the total VGF support in present value terms from Rs.112 Crores. to Rs. 92 Crores.

TABLE IV. IMPACT OF DSM REVENUE RECOGNITION ON BESS INTEGRATED PROJECT'S PROFITABILITY

Scenario	EIRR	VGF Requirement for 16% EIRR		Total VGF IN PRESENT VALUE TERMS (RS. Crores)
		Grant (Rs. Crores)	GBI for 10 Years (Rs/kWh)	
Base Case	5.30%	76	0.67	112
Scenario#1 Annual DSM revenue @ 2.61Cr. escalated @5% annual rate (Optimistic case)	7.5%	76	0.30	92

VII. KEY FINDINGS

Value assessment of BESS is a complex process as business models need to be developed for justification of investment in BESS. Business model should take into consideration the potential BESS's services offered to hybrid plant and to the grid. Viability of BESS integrated hybrid plant depends largely on the regulatory framework of the region as possible recognition of revenue generated by BESS services are at the core of revenue model. The first step towards value assessment would be identification of BESS applications followed by technology selection and sizing which will yield maximum profit. Different benefits of BESS Integrated Hybrid plant were qualitatively discussed in this paper. Quantitative analysis suggested that viability gap funding would be required if the project is not financially viable which would be in the form of grant and/or generation-based incentive. Levelized tariff of the plant is sensitive to BESS investment and it would reduce with the reduction in BESS costs. Thorough feasibility study with sound financial evaluation would be required to correctly ascertain BESS value.

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Dr. Segal is a Senior Member of IEEE, life member of Institution of Engineers, a chartered engineer and has authored 14 technical papers. Dr. Segal is a member of IEEE task force committee to develop technical standards on Low Voltage DC (LVDC) for homes. Dr. Segal received TATA RAO Medal for a paper published in journal of Institution of Engineers (India).

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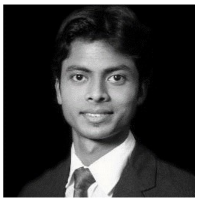
Mr. Unni is a University Gold Medalist (Delhi University) during his BE (Electrical, Instrumentation and Control Engineering). He has co-authored 5 papers published recently in several conferences.



Mr. Partha Deb is working as Senior Engineer at Power Economics team of GE Energy Consulting group in India since 2014. Mr. Deb holds B.Tech (Electrical Engineering) from the West Bengal University of Technology and MBA (Energy Management) from Great Lakes Institute of Management, India.

Mr. Deb specializes in sophisticated technical analysis of electrical power markets including production-simulation modeling, evaluation of identified design alternatives, system optimization, asset valuation, and competitive power-markets analysis. He has been actively involved in various renewable integration and power market studies for India & other South-East Asian countries including Laos, Cambodia, Malaysia, Indonesia etc.

Mr. Deb is a Rio+20 Sustainability Specialist, affiliated with the United Nations Conference on Sustainable Development (UNCSD).