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Demystifying returns in solar PV and storage plant

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With an increasing focus on firm and dispatchable renewable energy (FDRE), the combination of renewables and storage has been met with both curiosity and trepidation, existing somewhere between need for energy transition and optimal investment return expectations. India's first and largest utility-scale 20MW Solar PV plant/8 MWhr BESS system in Andaman and Nicobar islands (338MU/ 60MW energy/ peak demand during FY22), three years after commissioning enhances our understanding in respect of return profile and techno-commercial feasibility of operations. The plant was set up with a capital cost of INR 1,260mn and had the financial assistance of INR 447mn along with regulated RoE of 16.96%. Considering renewable projects along with storage without subsidy and regulated RoE, we arrive at RoE of 6.1%/ 10.7%/ 13.4% and IRR of 10.5%/ 13.7%/ 14.7% for the (tariff/ interest rate) of (INR 6.5/ 8.5%), (INR 8/ 9.5%), (INR 8.5/ 8.5%).

Key take aways from the project are:

- The total capital cost of the project was INR 1,257mn including the EPC cost of INR 1,129mn and battery equipment cost of INR 339mn.
- The Battery cells and modules were supplied by LG Chem, S.Korea and the Battery Energy Storage System (BESS) was integrated and supplied by L&T. The BESS has the Cycle life of 4,000 cycles. Considering one cycle per day, it works out to 11 years. The battery replacement is to be done after 11 years costing INR 310mn.
- The 20 MW Solar Power Plant achieved an all-time peak power of 15.56 MW on 2 Sep’22.
- The solar plant since commissioning was not operating at full capacity due to prevailing high frequency condition in the grid.
- The plant was able to achieve maximum of 12.91% CUF without BESS and 12.08% with BESS (battery energy storage system).
- Factors like adverse weather conditions, high grid voltage and frequent inverter tripping contribute to the inability to achieve the designed CUF.
- The instantaneous active power from plant was curtailed at the rate of 20% and 40% during the frequency range from 51.5Hz to 51.8Hz respectively.
- The reliability of the grid remains a challenge. In the absence of this, curtailment of RE generation leads to suboptimal returns.
- This renewable project along with storage gives RoE of 6.1%/ 10.7%/ 13.4% and IRR of 10.5%/ 13.7%/ 14.7% for the (tariff/ interest rate) of (INR 6.5/ 8.5%), (INR 8/ 9.5%), (INR 8.5/ 8.5%), after removing subsidy, regulated return and better operational efficiency.

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Introduction

Power generation and distribution in the Andaman and Nicobar islands is based on standalone systems, and each island has its own generation and distribution system. The energy and peak demand of the island were about 338MU and 60MW respectively in FY22.

A 2x10MW (AC) Solar PV Plant with 8 MWhr BESS was set up at Andaman & Nicobar Islands in 2020. Of the 20MW, 2.5MW Solar PV was commissioned on 31 Dec'18 and the remaining solar capacity including BESS was commissioned on 30 Jun'20. This was India's first and largest utility-scale BESS along with solar PV at that time.

The plant was given a subsidy of INR 447mn by Govt of India and a normative RoE of 14% grossed up by 17.5% for MAT, yielding pre-tax RoE of 17%.

We have considered the project without subsidy and regulated RoE to improve our understanding regarding the return profile of current firm and dispatchable renewable energy (FDRE), renewable projects with storage.

Specifics of the project

The capacity of the solar power plant is 20MW AC with solar modules of around 22MWp installed. Eight inverters of 2.5MW capacity each are connected to two 10.5MVA and 33KV transformers. Power evacuation is routed through the 33KV switchyard that is tied up with South Andaman DG grid.

The BESS of 2C rating and capacity of 16MW is connected with the point of common coupling along with 33KV solar feeders. Around eight LG Chem-JP3 model MWh battery modules are accommodated in nine battery containers. Each container has two battery banks along with its battery management system (BMS), ventilation, data connectivity etc. Each battery container is connected with an 18-Ingeteam power conversion system (PCS).

The AC supply is connected to 33kV multi-winding transformers, which is in turn connected to the HT switchgear panel to connect to the switchyard.

The entire plant is automated with the installation of supervisory control and data acquisition (SCADA) with BMS, which also includes checking on battery system health at regular intervals.

Exhibit 1. Project details

Location	Attam Pahad and Dolly Gunj Sites at South Andaman
Capacity	22 MWp (DC)/ 20MW (AC) solar PV plant and 16 MW/8 MWhr BESS
BESS	LG Chem-JP3 model MWhr battery module with Ingeteam power Conversion System (PCS)
Land	41.252 Ha allocated by A&N administration
Capex	INR 1,328mn with Debt/Equity of 70:30
Subsidy	INR 452mn from MNRE, Govt of India
EPC cost	INR 1,187mn (excluding O&M)
EPC contractor	L&T with 17 months of execution time
Auxiliary consumption	0.25%
Project life	25 years
CUF	17.24% without BESS; 15.33% with BESS
Aux power consumption	8.51%
PPA	Signed with Electricity Department of Andaman & Nicobar
Salvage value	10 years

Source: CERC, JM Financial

Capital cost

The total capital cost of the project was INR 1,260mn including the EPC cost (inclusive of PV modules, module mounting structures, PCU, cables and transformers, civil & general works) of INR 1,130mn. The total cost of battery equipment was INR 339mn.

Generation & Auxiliary power consumption

The 20 MW Solar Power Plant achieved an all-time peak power of 15.56 MW on 2nd Sep'22. The complete system accounts for 25% of losses due to battery round trip efficiency, inverter discharge efficiency, BESS auxiliary losses and charging and discharging cycles of two per day, for 8MWHr capacity. This has led to an increase in auxiliary consumption to 8.51% against the design of 0.25%.

Battery life

The Battery cells and modules were supplied by LG Chem, South Korea and the BESS was integrated and supplied by L&T. The BESS has a cycle life of 4,000 cycles. Considering one cycle per day, the life of the battery works out to be 11 years. Hence, the battery has to be replaced in the 12th year.

Capacity Utilisation Factor (CUF)

The plant was able to achieve a maximum CUF of 12.91% without BESS and 12.08% with BESS.

Reasons for achieving less CUF

BESS solutions are meant to ensure a stable power supply and maintain must-run status. The plant has battery systems and BESS logic to smoothen power generation fluctuations due to cloud movement, using a 15-minute moving average for solar PV generation. The inability to achieve the designed CUF is due to factors like adverse weather conditions, high grid voltage, and frequent inverter tripping. Whenever the inverter trips due to frequency issues, the response time to restart as designed is ~3-5 minutes, thus causing the solar power plant to lose energy proportional to the Global Horizontal Irradiance (GHI) at that time, leading to lower CUF. The designed CUF could not be achieved due to power curtailment and inverter tripping at 52 Hz even after curtailment of 20% and 40% of plant output.

Challenges during operations

Since its commissioning, the solar plant was not operating at full capacity due to the prevailing high frequency condition in the grid. The BESS logic was redesigned to curtail active power export from the plant to control grid frequency as the DG sets were not regulated to match with grid frequency. After this modification the developer suffered loss of generation.

Curtailment

Curtailment relates to a phenomenon where the power-grid operator issues an instruction to limit the power output of specific generators. Curtailment is only permitted on grounds of maintaining grid stability and system safety, as per the Indian Electricity Code and the renewable energy power purchase agreements.

The A&N grid was subject to abrupt changes in frequency due to various factors, including feeder shutdowns, distribution feeder faults, changes in power export from other solar plants due to cloud cover, and fluctuations in demand. The instantaneous active power from plant was curtailed at 20% and 40% during a frequency range from 51.5Hz to 51.8Hz respectively.

Battery replacement

The battery replacement cost is based on two sets of assumptions, viz., (i) the projected BESS cost (declining trend); and (ii) the foreign exchange rate variation (increasing trend). Firstly, the cost of battery in the 12th year after COD has been taken as USD 300/KWhr (which translates to a 46% decline in battery cost over a period of 12 years from commissioning). Secondly, the actual exchange rate has been considered for the first 4 years (Jan'20-Jan'23); after that the exchange rate is escalated at 5% YoY till the year of replacement. Replacement cost in the 12th year for 8 MW Battery System and modules works out to INR 310mn on the basis of the above assumptions of technological change and the escalation of exchange rate.

Contractual disputes

The plant has seen disputes between developer and discom regarding reasons for curtailment, less CUF and loss of revenue.

Financial Performance

The project is based on regulated equity model as per the CERC's Regulation 16 of the RE Tariff Regulations 2017. The normative RoE of 14% grossed up by 17.47% (effective MAT rate) yields the RoE of 16.96%. Considering renewable projects along with storage without subsidy and regulated RoE, we arrive at RoE of 6.1%/ 10.7%/ 13.4% and IRR of 10.5%/ 13.7%/ 14.7% for the (tariff/interest rate) of (INR 6.5/ 8.5%), (INR 8/ 9.5%), (INR 8.5/ 8.5%).

Exhibit 2. Sensitivity of IRR w.r.t. interest rate/ tariff (INR/Kwh)

Interest Rate → Tariff ↓	8.5%	9%	9.5%	10%	10.5%
6.5	11%	11%	11%	11%	11%
7.0	12%	12%	12%	12%	12%
7.5	13%	13%	13%	13%	13%
8.0	14%	14%	14%	14%	14%
8.5	15%	15%	15%	15%	15%

Source: CERC, JM Financial

Exhibit 3. Sensitivity of RoE w.r.t. interest rate/ tariff (INR/Kwh)

Interest Rate → Tariff ↓	8.5%	9%	9.5%	10%	10.5%
6.5	6%	5%	5%	4%	3%
7.0	8%	8%	7%	6%	6%
7.5	10%	9%	9%	8%	8%
8.0	12%	11%	11%	10%	10%
8.5	13%	13%	12%	12%	11%

Source: CERC, JM Financial

Exhibit 4. Financials (excluding subsidy & regulated RoE)

Particulars (INR mn)	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Operational Metrics										
Installed Capacity PV Modules (MW)	20	20	20	20	20	20	20	20	20	20
BESS (MWhr)	8	8	8	8	8	8	8	8	8	8
CUF (%)	17.3%	16.8%	16.7%	16.5%	16.3%	16.2%	16.0%	15.8%	15.7%	15.5%
Power generated (MU)	30	29	29	29	29	28	28	28	27	27
Auxiliary Consumption (MU), 8.5%	2.6	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.3	2.3
Power sold post Degradation (MU)	27	27	26	26	26	26	25	25	25	25
Tariff (INR)	7.5	7.7	7.8	8.0	8.1	8.3	8.4	8.6	8.8	9.0
Financial Metrics										
Revenue	202	204	206	208	210	212	214	216	218	221
EBITDA	194	181	183	184	186	187	189	190	192	193
Margin (%)	96%	89%	89%	89%	88%	88%	88%	88%	88%	88%
EBIT	134	122	123	125	126	128	129	131	132	133
PBT	62	53	60	67	74	81	89	96	103	110
PAT	44	37	42	47	53	58	63	68	73	78
Margin (%)	22%	18%	21%	23%	25%	27%	29%	31%	33%	35%
RoE (%)	10%	8%	8%	8%	8%	8%	8%	8%	8%	8%

Source: CERC, JM Financial

Exhibit 5. Assumptions

Particulars	Amount
Cost of Debt Kd	8.5%
Cost of Equity Ke (Post tax)	12%
Discount Rate (WACC)	7.8%
Debt	70%
Equity	30%
Investment (INR mn)	809
Debt (INR mn)	566
Equity (INR mn)	243

Source: CERC, JM Financial

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