Utilities

Purulia Pumped Storage Plant – An engineering marvel

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We recently visited the 900MW (4 x 225MW) pumped storage plant (PSP) of West Bengal State Electricity Distribution Co. (WBSEDCL) at Purulia, consequent to our recently released report 'Pumped storage: Back in the limelight' where we highlighted the importance of PSP in energy transition and emerging multi-billion dollar opportunities for utilities, EPC and capital good players over the coming decade. Purulia PSP is one of the largest, and the best, pump storage plants in the country. It is touted as one of the global success stories in PSP technology with 6-8 hours of storage capacity and overall plant efficiency of 77.80%. For large scale energy storage, PSP technology, developed over a century ago, is still the best on offer. The high maturity of the technology, relatively low-gestation period and bigger role for domestic industry players in it vis-à-vis BESS makes PSP attractive for policy makers as is evident from the power ministry's recent guidelines on pumped hydro storage.

- **Jewel in a deep forest:** We reached the Purulia PSP after traversing through deep forest for almost five hours at night. We were spellbound and enthralled by this hidden and under-recognised jewel in the country. For a long time since it was set up, the unit hardly attracted any visitors. But that has changed suddenly, with a host of visitors including EPC players, developers, policymakers and other industries making a beeline to the plant in recent months. This 900MW PSP is not only the largest project of its kind in India, it is one of the global beacons for what PSP technology can do. With maintenance of grid stability becoming a challenge due to the increasing share of renewables, and the resultant imperative to boost energy storage capabilities and capacities, people are happy to discover that a solution to these problems lies in their backyard. The PSP solution also has the added advantages of supporting 'Aatmanirbhar Bharat' (new plants can largely be done by Indian companies), technology maturity unlike in BESS, and EPC capability adjacencies (largely similar to a typical hydropower plant). For us, the visit was an eye-opener to the immense possibilities that lie ahead for players as energy transition initiatives kick into high gear. What was also heart-warming to see was the pride and confidence on the faces of the small team of young engineers, led by Mr Kalyan K Maiti, the Project site in-charge, who manage the project.
- **Purulia PSP:** The plant at Purulia is a closed-loop (reservoirs are separate from natural waterways) pumped storage hydroelectric power plant, located at Ayodhya Hills in Purulia, West Bengal. The plant is equipped with technology and main plant equipment from Toshiba, Japan. The main work on the project started in May'02 and it was commissioned in Dec'07. Larsen & Toubro Ltd was the sub-contractor for civil work for the plant. The total cost of the project in 2007 was INR 25bn and was funded by JICA.
- **Capital cost:** The capital cost for a typical closed-loop PSP project is ~INR 40-50mn/MW with a 5-year execution period and 40+ years of plant useful life. Civil and HM works (30%) and electro-mechanical works (50%) account for a majority (80%) of the capex to be incurred on setting up a PSP.
- **Upcoming projects of WBSEDCL:** WBSEDCL is developing two new projects in the same region - 4x250MW Turga pumped hydro storage project (project cost of INR 69bn) and 4x225MW Bandu PSP (project cost of INR 47bn). Pre-construction activities at Turga have begun. The selection of a developer for Bandu on DBFOT basis is in process.
- **Existing and projected capacities:** India has 4,746MW of PSPs under operation and 2,700MW are under construction. With Further, DPRs for 1,000MW projects have been concurred by CEA, and 25,630MW projects are under various stages of survey and investigation. It is estimated that PSP-based storage capacity of about 6.81GW/18.82GW with 46.65GWh/135GWh of storage is required by FY27/FY32. The government has already allocated projects of more than 73GW to various central utilities.
- **Likely beneficiaries:** We expect the entire value chain to benefit from the traction in PSP over the next few years. NHPC, SJVNL, NTPC, JSW Energy, Tata Power, Adani Green, and Greenko will likely be the key beneficiaries, going forward. EPC players such as L&T, and capital goods players such as Siemens and Voith will benefit greatly. We have a **BUY** rating on NTPC (TP – INR 205), and a **HOLD** rating on both JSW Energy (TP – 270) and Tata Power (TP – INR 220).

Key aspects

- The main structures involved in the project are: two rockfill dams (upper dam and lower dam) with central clay core for upper and lower reservoirs with a live storage of 13 million cu.m each, twin water conductor, an **underground power house** (157m long, 22.5m width, 48.7m height) to accommodate four reversible pump turbines (vertical Francis, rated head 177m, maximum power discharge : 150 cu.m/sec) of 225MW each, an **underground transformer** (280MVA of four nos. 16.5KV/400KV) cavern (119m long, 17m width, 17m height), an access tunnel to the power house, and 400KV **gas insulated substation** (GIS) linked through a cable tunnel. Two 400KV double circuit transmission lines connecting Durgapur and Arambagh sub-stations with the project have been developed to transmit and receive power.
- The plant is located in the highly stable Chotonagpur plateau and is primarily composed of archaeon rocks of granite and gneiss etc.
- Japanese companies Toshiba and Mitsubishi HI supplied two turbines each for the plant. These operate as pumps during the pumping operation and as turbines in the generation cycle.
- The reservoirs were filled initially, only once. The evaporation loss is less than 0.1%. The loss is compensated during monsoon rains. The excess water is regularly released into the neighbouring pond for maintaining the heads.
- Only one unit is taken up every year for overhauling, which requires 2.0-2.5 months. TPSC (India) Pvt Ltd, which is a wholly owned subsidiary of Toshiba Plant Systems & Services Corporation, Japan (TPSC), has been awarded the annual maintenance and other major contracts, being an OEM.
- The total length of penstocks (pressure vessels in the form of pipes that carry water from the reservoir to the turbines) is around 1.5km and are made of steel.
- The plant generates around 3MU/day. During FY23, it generated 1,578MU and consumed 2,038MU for pumping.
- The project employs around 100 people on fulltime basis against the norms of 0.225 numbers/MW.
- The normative O&M cost of the plant is INR 0.47mn/MW.
- WBSEDCL is in process of developing a grid connected solar PV power plant of 10MW (AC) capacity in the vicinity of the upper dam.
- For a typical PSP with both reservoirs naturally available, the capital cost breakup is:

Exhibit 1. Estimated breakup of capital cost components for a 1,200MW PSP project

Particulars	INR mn	% of total cost
Civil & HM works	15,000	30%
Electro-mechanical works	25,000	50%
Power evacuation	1,000	2%
Other costs	3,500	7%
Total cost (including FC)	44,500	89%
IDC	5,500	11%
Total cost	**50,000**	**100%**

Source: JM Financial, expert discussions

Exhibit 2. Project specifications

Particulars	Specification
Upper Reservoir	
High water level	Elevation (EL).516.00 m
Low water level	EL.494.00 m
Available draw down	22.0 m
Full water capacity	16,404,924 m3
Available capacity	13,371,025 m3
(used about 6 hour by 600m3/s)	
Lower Reservoir	
High water level	EL.337.00 m
Low water level	EL.300.00 m
Available draw down	37.0 m
Full water capacity	17,253,036 m3
Available capacity	14,475,571 m3
(used about 6 hour by 600m3/s)	
Headrace Intake Tunnel	7.70 m dia. x 2 nos.
Penstock	7.70 - 7.30 m dia. x 2 nos.
	4.30 m dia. x 4 nos
Tailrace	8.70 m dia. x 2 nos
	5.60 m dia. x 4 nos
Sedimentation rate	9.50 Cum/ SqKm ./Year

Source: WBSEDCL. JM Financial

Different operating modes

- **Pumping mode:** The unit takes starting power (max 11.5MW) through static frequency controller (SFC) or back to back (BTB) operation and rotates in the clockwise direction when viewed from the top of the generator. After synchronisation with the grid, the turbine operates as a pump and the generator as a motor. The motor takes active and reactive power from the 400KV grid. Water in the lower reservoir is pumped up and stored in the upper reservoir as potential energy for use at peak demand in the 400KV grid by converting it into electrical energy. The guide vane (GV) of the turbine is controlled to its optimum opening position by the governor system for the entire water head of the upper reservoir (EL 516m - 494m) and the lower reservoir (EL 337m – 300m).
- **Generation mode:** The unit here is a reversible one. The same machine runs as a generator as well as a motor. The execution command is given from the central control room through the operator station (OPS). The unit starts as a generator by opening the main inlet valve (MIV) and GV, which allows the water to flow from the upper to the lower reservoir through the runner, and the runner rotates through water pressure and reaction forces. The runner is connected to the generator rotor. So, the rotor rotates and electrical energy is produced in the stator. The electrical energy so produced is fed to the 400KV feeder through the main transformer and the gas insulated switchgear (GIS).
- **Synchronous condenser mode:** The unit runs both in SCOG (Synchronous Condenser Operation in Generating Direction) and SCOP (Synchronous Condenser Operation in Pumping Direction) modes. In SCOG, the unit starts like it does in generation mode until it is synchronised with the grid. Once synchronised, water flow stops through closure of the GV and MIV, and water in the turbine section is depressed by pressurised air. The unit draws minimum power from the grid (4MW) to rotate freely. In SCOP, the unit starts like it does in pumping mode by using SFC until it is synchronised with the grid. After synchronisation, the unit draws minimum power (4MW) in water depressed condition. In both cases, the reactive power can be controlled fully and, when required, SCOG can be converted to generation mode and SCOP can be converted to pumping mode very quickly.

How fast is Purulia PSP?

- **Generation mode:**
  - Start: The unit takes only 5 minutes to run from standstill to full load
  - Stop: The unit takes a total of 11 minutes to stop (including stoppage of auxiliary equipment such as oil lifter)
- **Pumping mode:**
  - Start: The unit takes only 11 minutes to run from standstill to full load
  - Stop: The unit takes a total of 11 minutes to stop (including stoppage of auxiliary equipment such as oil lifter)

Upcoming projects of WBSEDCL

Encouraged by the favourable economics, market demand and favourable policy environment, WBSEDCL is developing the following new projects in the same region:

4x250 MW Turga pumped hydro storage project

- WBSEDCL is developing another 1,000MW PSP (5 hours daily peaking storage) at Ayodhya hills under Baghmundi Block in Purulia at an estimated cost of INR 69bn (2018 price level).
- The Turga PSP on Turga Nala is a closed loop type PSP located in Purulia district of West Bengal.
- The project envisages utilisation of rainfall in the catchment of the Turga Nala in Ayodhya hills for peak power generation through a pumped storage type project development. The project envisages construction of an upper dam (catchment area (C.A). 8.29 sq. km) across Turga Nala, a tributary of Subarnarekha river, a water conductor system with an underground power house downstream of the upper dam, and a lower dam having an intermediate catchment of 4.37 sq. km (total C.A. 12.66 sq. km).
- The project comprises four reversible pump-turbine units each of 250MW generating capacity installed in the underground power house. Two of these units will be fixed speed machines and the other two will be variable speed machines to absorb intermittent solar/ wind power, for efficient integration of renewable power into the grid.
- The total land required for the project is 292.0 ha.
- Pre-construction activity has begun.

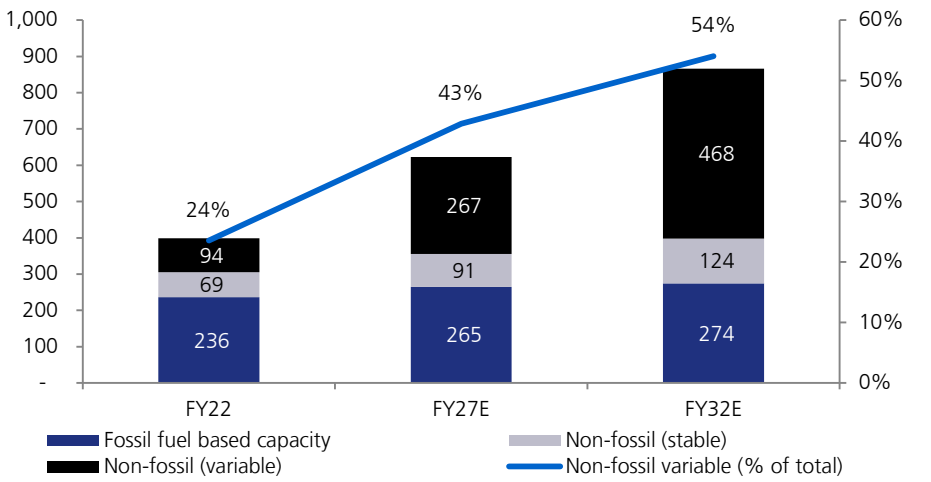
4x225 MW Bandu pumped storage project

- WBSEDCL is also developing a 900MW Bandu PSP near Ayodhya village in Purulia district of West Bengal through public private partnership.
- WBSEDCL will procure electricity from the Bandu PSP for a period of 35 years during peak hours of the day after 18:00 hours in the evening (PPA commitment). The project is located in the north-eastern fringe of the Ayodhya Hills near Ayodhya village in Purulia District, West Bengal.
- The project entails construction of a rockfill dam across Bandu Nala and a saddle rockfill dam at the higher reaches, a rockfill dam across Bandu Nala at the lower reaches, and an underground power house (UGPH) in between to generate 900MW peaking power.
- The Bandu project area will cover three dams including upper saddle dam and two reservoirs, UGPH, and water conductor system.
- The Department of Power, Government of West Bengal, is in the process of selecting a developer for the project on design, build, finance, operate and transfer (DBFOT) basis. The indicative cost of the project is INR 47bn with 49% civil works and rest electro-mechanical works.

Market potential

In India, as per National Electricity Plan 2022, the total non-fossil fuel-based capacity to meet the projected demand is 358GW in FY27 and 592GW in FY32, which includes 267GW and 467.4GW from variable renewable energy (VRE) respectively.

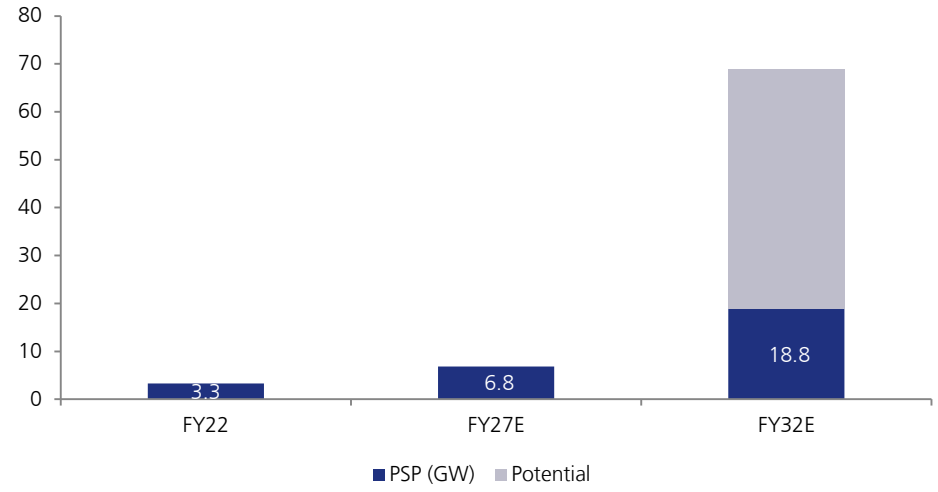
Exhibit 3. National Electricity Plan 2022, projected capacity addition (GW)



Source: CEA, JM Financial

It is estimated that PSP-based storage capacity of about 6.81GW with 46.65 GWh of storage is required by 2026-27 to fulfil the storage requirement of the grid. The storage capacity requirement increases to 70.38GW (18.82GW PSP and 51.56GW BESS) with storage of 392.78GWh (135 GWh from PSP and 257.78 GWh from BESS) by FY32. The government has already allocated projects of more than 73GW to various central utilities. The opportunities in PSP may further increase if the cost of BESS does not come down as expected and additional technology development in PSPs reduces the cost.

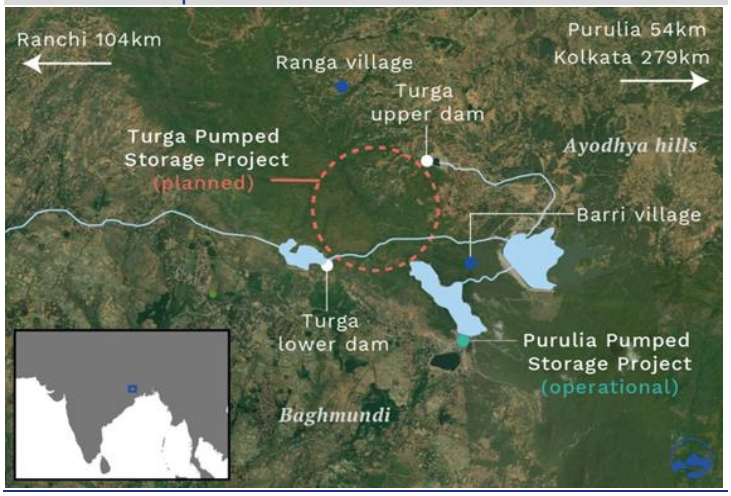
Exhibit 4. PSP targeted capacity (GW)



Source: CEA, JM Financial

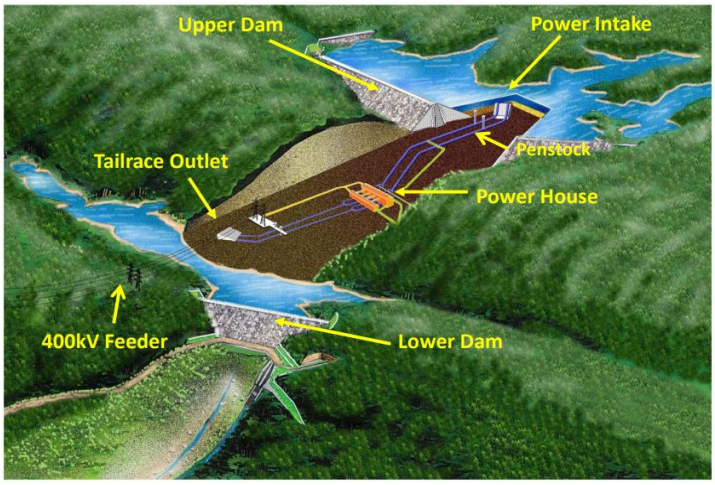
Snapshots of the visit

Exhibit 5. Purulia plant location



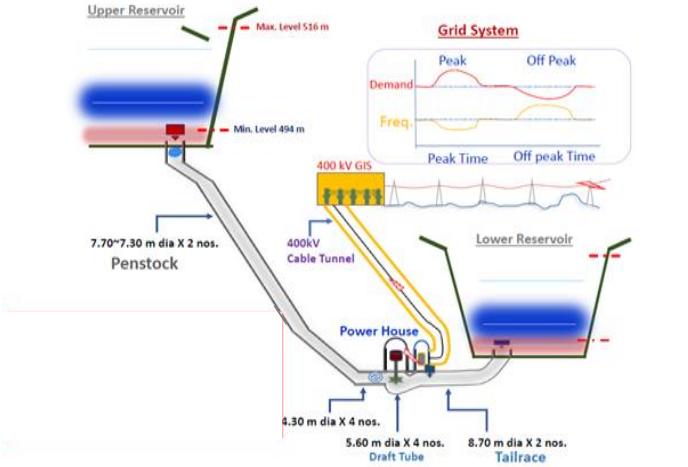
Source: WBSEDCL, JM Financial

Exhibit 6. Purulia PSP plant



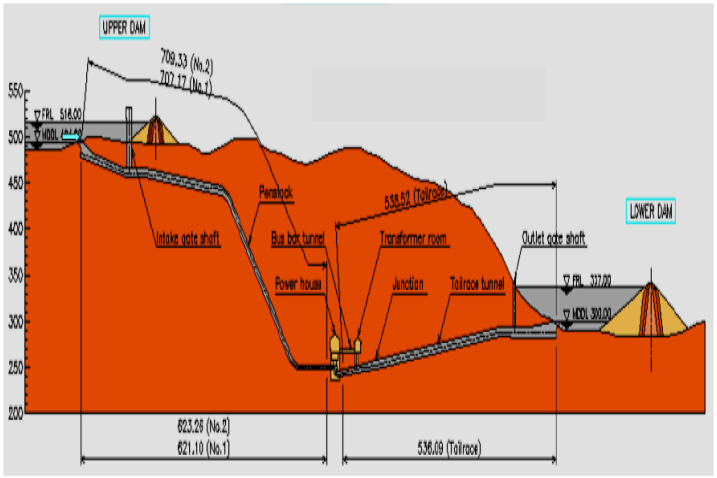
Source: WBSEDCL, JM Financial

Exhibit 7. General idea on PPSP



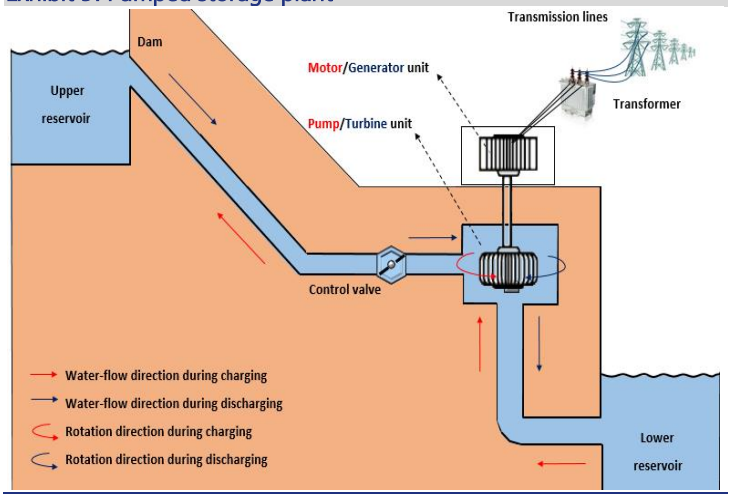
Source: WBSEDCL, JM Financial

Exhibit 8. Water way of PPSP



Source: WBSEDCL, JM Financial

Exhibit 9. Pumped storage plant



Source: WBSEDCL, JM Financial

Exhibit 10. Generator room

Source: WBSEDCL, JM Financial

Exhibit 11. Upper and lower dam

Source: WBSEDCL, JM Financial

Exhibit 12. Lower dam

Source: WBSEDCL, JM Financial

Exhibit 13. Upper dam

Source: WBSEDCL, JM Financial

Exhibit 14. Dedication to the Nation

Source: WBSEDCL, JM Financial

Exhibit 15. 1000 steps cable tunnel

Source: WBSEDCL, JM Financial

APPENDIX I

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