Pump Storage Plant, Modern technologies and large scale RE integration

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CMD-POSOCO, India

Indian Grid…One of the World's Largest

Source: GO15

1 national synchronous grid

3 electricity generation
electricity consumption
installed generation capacity
transmission system

4 wind generation
solar generation

6 hydro generation

9 pumped storage installed capacity

Source: IEA Key World Energy Statistics 2021 & IHA 2021 Hydro Status Report (2019 data, 2019 provisional data)

Dimensions

395 GW+
generation capacity

200 GW+
peak demand

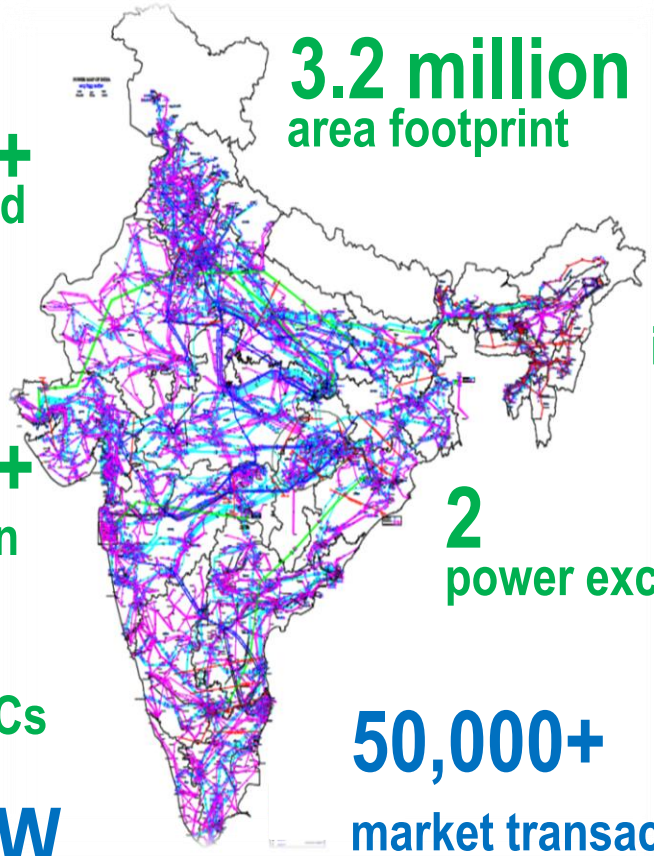
> 4 TWh
daily energy met

425,000 ckm+
EHV transmission

~152 GW
Renewables
(including large hydro)

10 +
HVDCs

~ 100 GW
inter-regional capacity



3.2 million km²
area footprint

1.3 Billion+
people served

4 GW+
international exchanges

120 TWh+
annual market trades

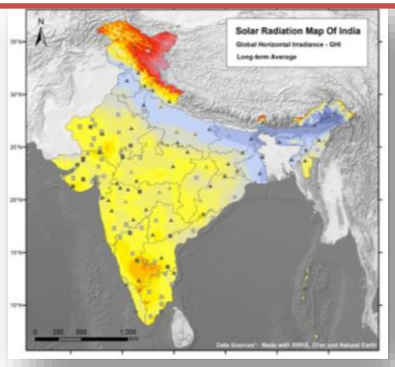
2
power exchanges

6000+
market participants

50,000+
market transactions

Clean Energy Transition in India

Solar Radiation Atlas



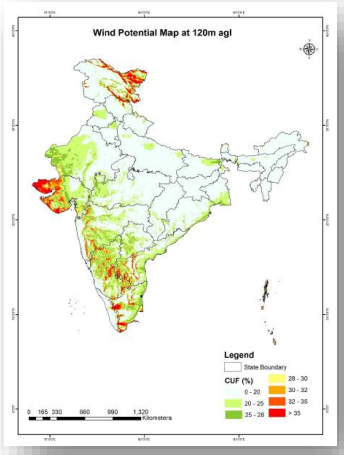
Present Total Installed Capacity – 395 GW

Present Renewable Installed Capacity ~ 105 GW

Solar Potential ~ 750 GW, Wind Potential @ 120 mtr agl ~ 700 GW

Off-shore wind potential ~ 70 GW (coast of Gujarat & Tamil Nadu)

Wind Atlas



Offshore Wind

2020-21 State	Annual RE Penetration	Maximum Daily RE Penetration	Maximum Instantaneous RE Penetration
Karnataka	30 %	72 %	115 %
Andhra Pradesh	20.3 %	51 %	71 %
Tamil Nadu	16.1 %	42 %	54 %
Telangana	9.8 %	16 %	46 %
Gujarat	12 %	39 %	49 %
Madhya Pradesh	7.5 %	30 %	45 %
Maharashtra	5.4 %	21 %	27 %
Rajasthan	13.9 %	35 %	68 %
Southern Region	18 %	33 %	51 %
Western Region	8.3 %	23 %	32 %
Northern Region	5.4 %	11 %	25 %
All India	8 %	16 %	27 %

Pumped Hydro Schemes in India

- 8 Nos. - 4.78 GW
  - 6 Nos. (3.30 GW) pump mode operational
  - 2 Nos. (1.44 GW) not operational
- 3 Nos. (1.58 GW) under construction
- 1 GW Turga scheme in West Bengal
  - DPR concurred by CEA
- 1.2 GW Pinnapuram scheme in Andhra Pradesh
  - Under examination by CEA
- 17 Nos. (16.77 GW) under survey & investigation

Schemes under construction

1. Tehri St.-II – Uttarakhand
2. Koyna Left bank – Maharashtra
3. Kundah pump storage - Tamilnadu

Schemes in DPR & Survey

West Bengal: Turga PSS (DPR),
Odisha: Upper Indravati, Upper Kolab, Balimela
Karnataka : Sharavathy, Saundatti
Tamilnadu : Kodayar, Silahalla , Sillahalla St.-I
Andhra Pradesh : Pinnapuram , Gandikota, OWK , Chitravathi, Kurukutti, Karrivalasa , Somasila , Yerravaram
Madhya Pradesh : MP30 Gandhi Sagar
Maharashtra : Warasgaon

Source: CEA Feb 2022: Report on Pumped Storage Development in India

Why Need for PSP Plants

CIGRE TB 808 - Short-term flexibility Report

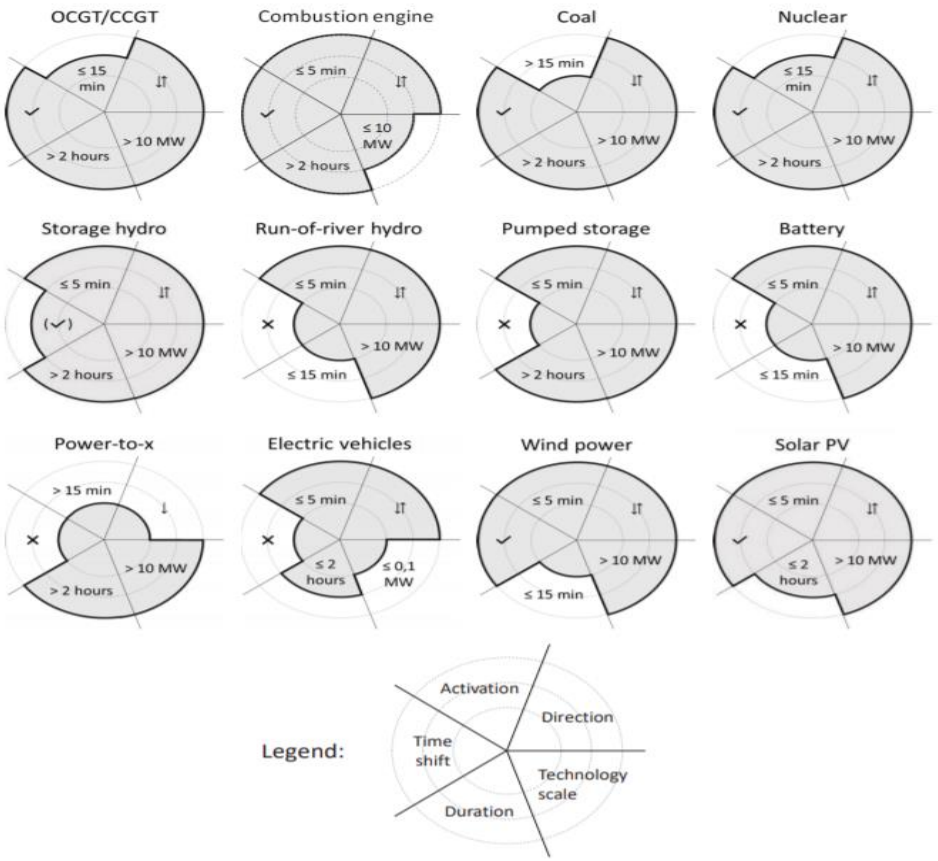
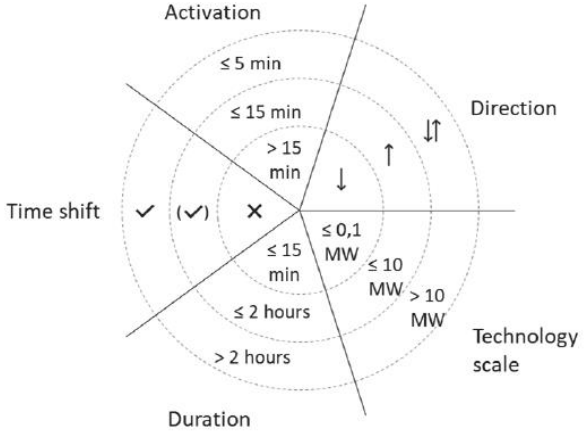


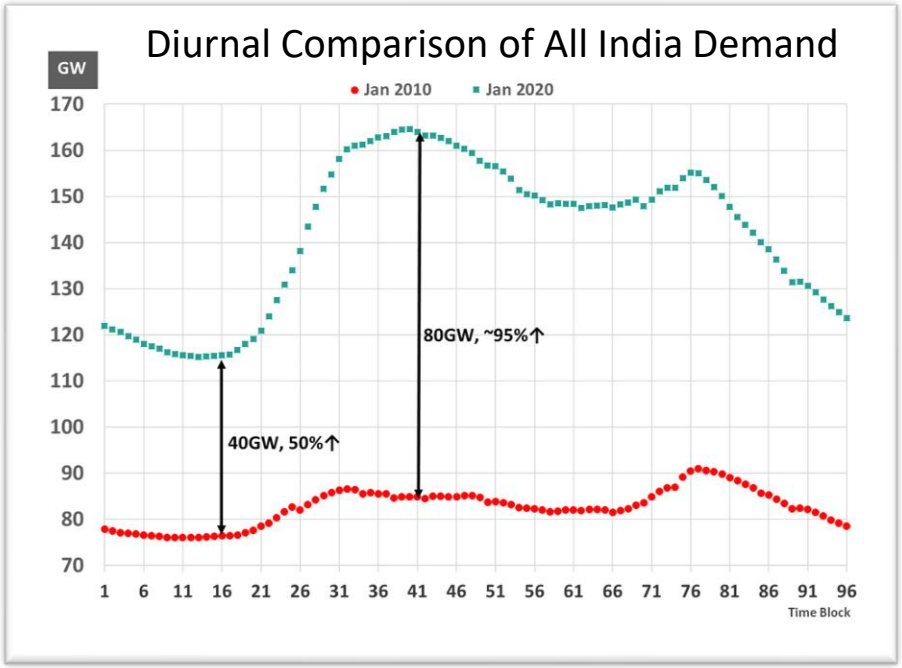
Figure 1: Overview over flexibility characteristics
(note that the bidirectional capabilities of wind and solar PV would require them to produce below potential output)

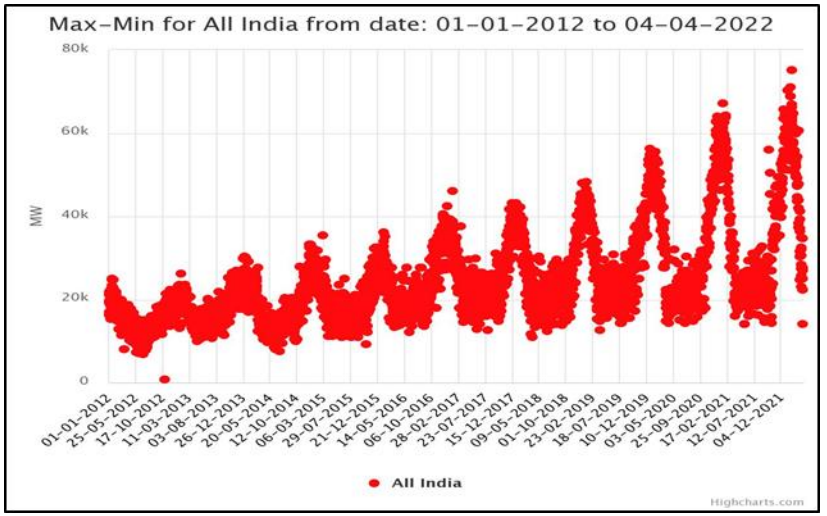


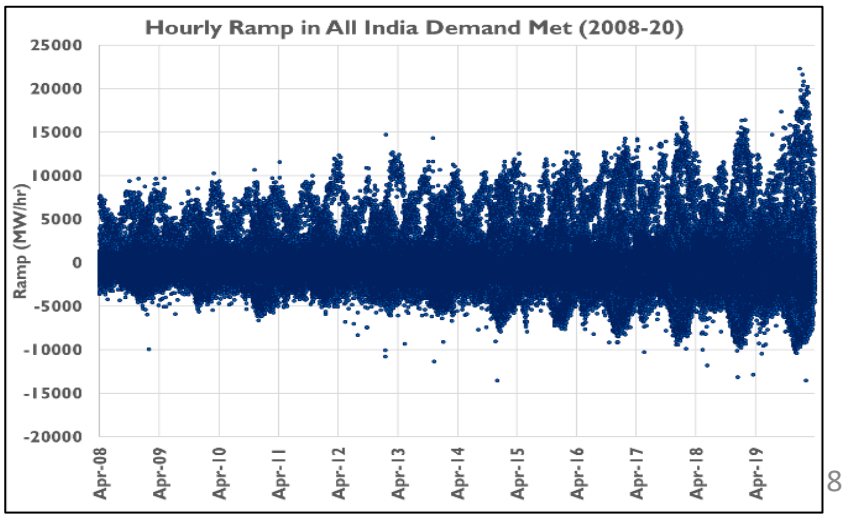
- Pumped hydro has good capabilities for delivering short-term flexibility.

Source : CIGRE TB 808 - Short-term flexibility in power systems: drivers and solutions

Load shape changes necessitating resource flexibility





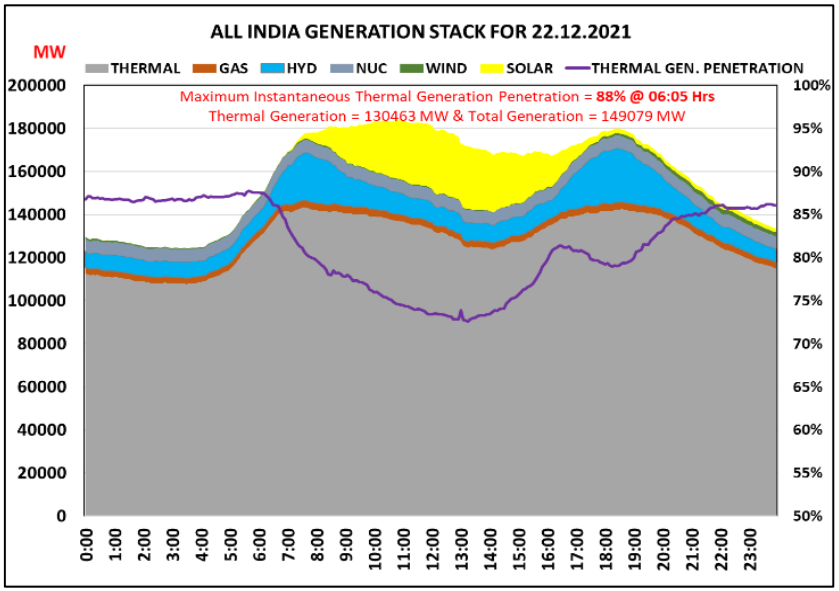


Minimal shortages leading to natural load shape

Agricultural load shifting to solar hours

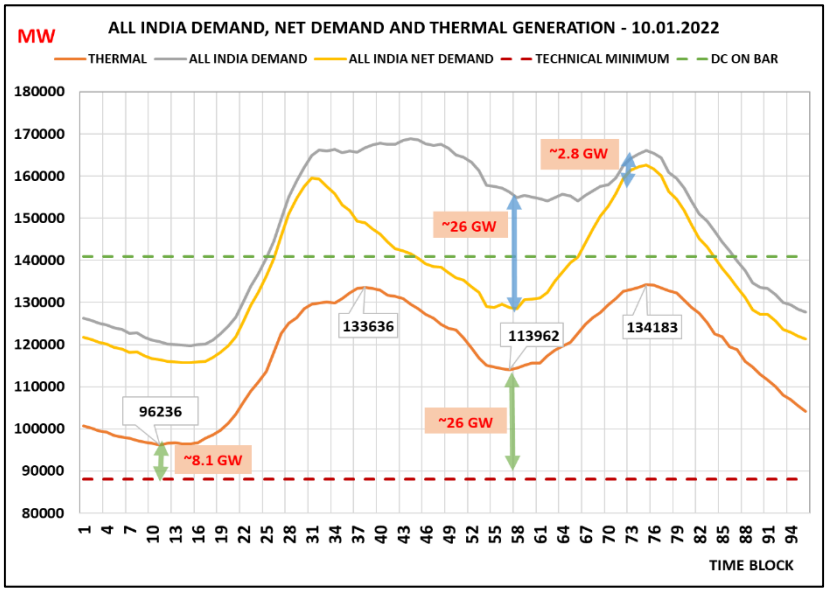
Induction cooking?

Resource Adequacy



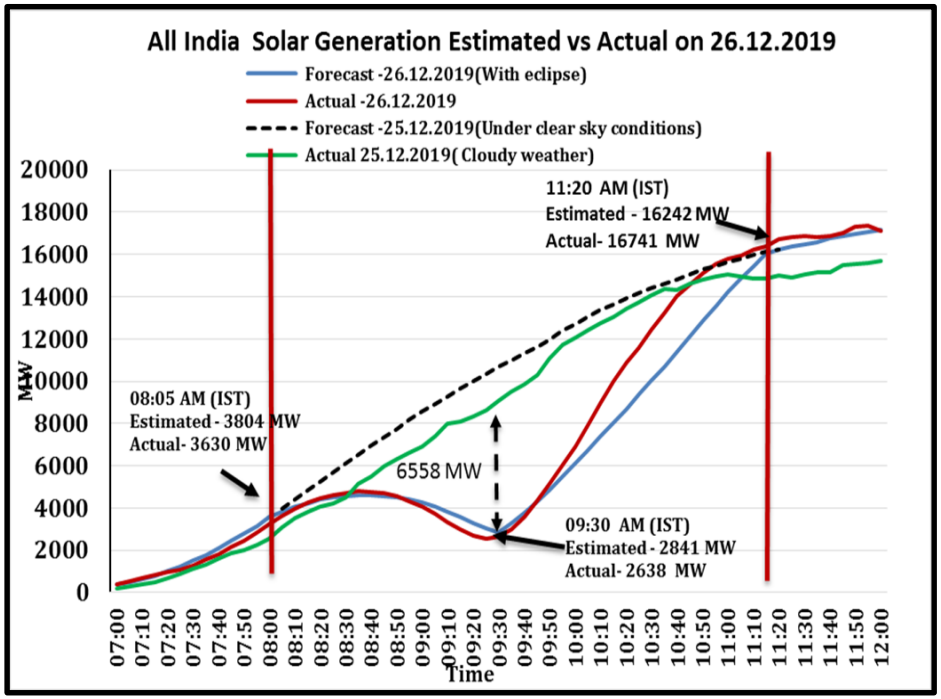
- Significant contribution of thermal generation, at present, in meeting peak demand
- Y-o-Y increase in Peak Demand
- Limited addition of Conventional Generation in future
- Separate time of occurrence of Peak Demand and Peak RE generation

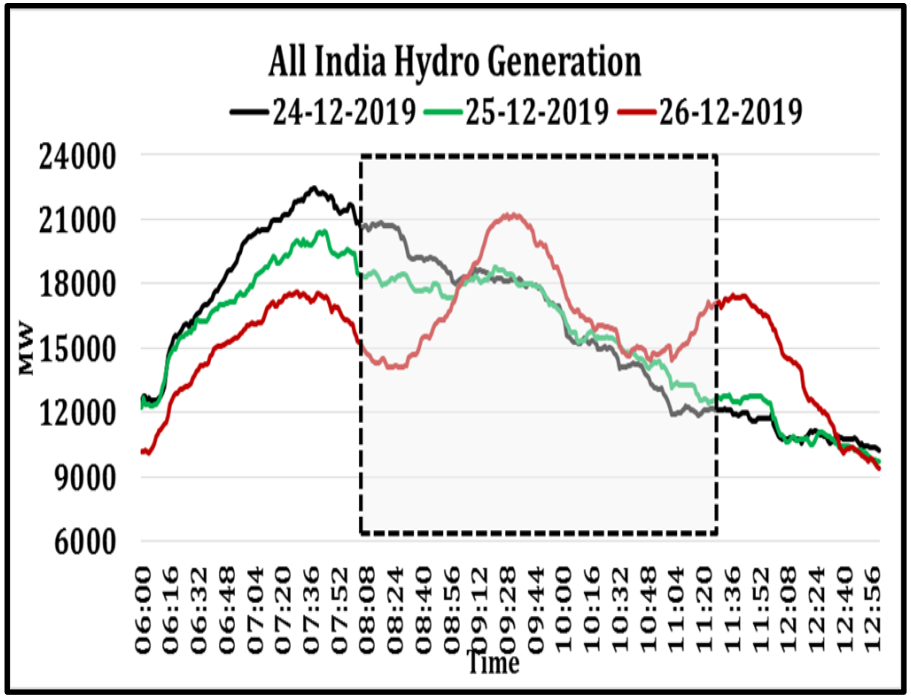
Flexibility



- **Increasing "Duck Curve" Belly**
- **Increasing difference b/w Max. and Min Demand**
- **Issues in absorbing additional RE (solar) beyond a certain quantum**
- **Technical Minimum operation issues in both inter & intra state coal-fired plants**

Events requiring Flexibility
Solar Eclipse 26 Dec 2019





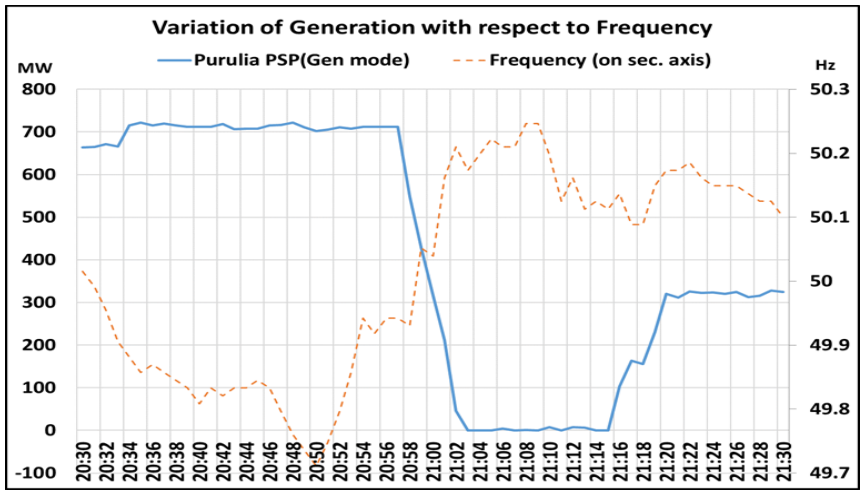
Generation variation during Solar eclipse

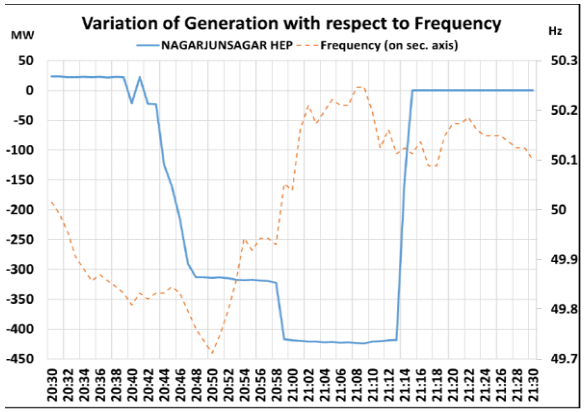
Hydro generation = 6000 MW - Thermal generation =2000 MW - Gas based generation =1000 MW

- Approximately 60 – 70 % solar generation was handled by Hydro based generating units.
- No significant variation in frequency during the eclipse period.

Events requiring Flexibility
05th April lights switch-off event (32 GW load reduction)

- Purulia PSP kept in generation mode and modulated with change in grid frequency
- Nagarjunsagar & Kadamparai started in pumping mode @ 2030 hrs & reached peak by 2100 hrs
- Total relief of around 650 MW
- Flexibility provided as per advisory
- Instant changeover to pump mode might take time
  - Phase sequence change
  - Stoppage of rotor
  - Start of SFC and synchronizing to grid
- Smooth control ~ 60 - 100 %





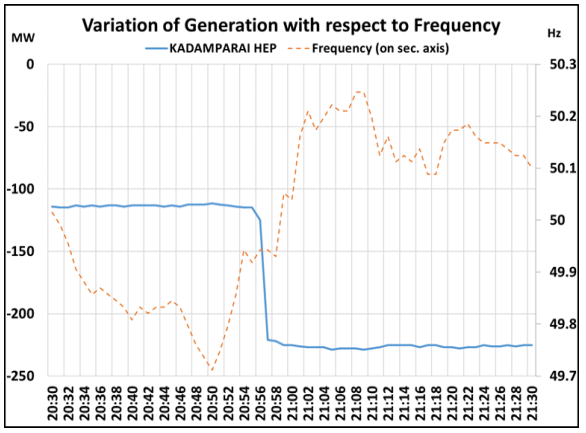
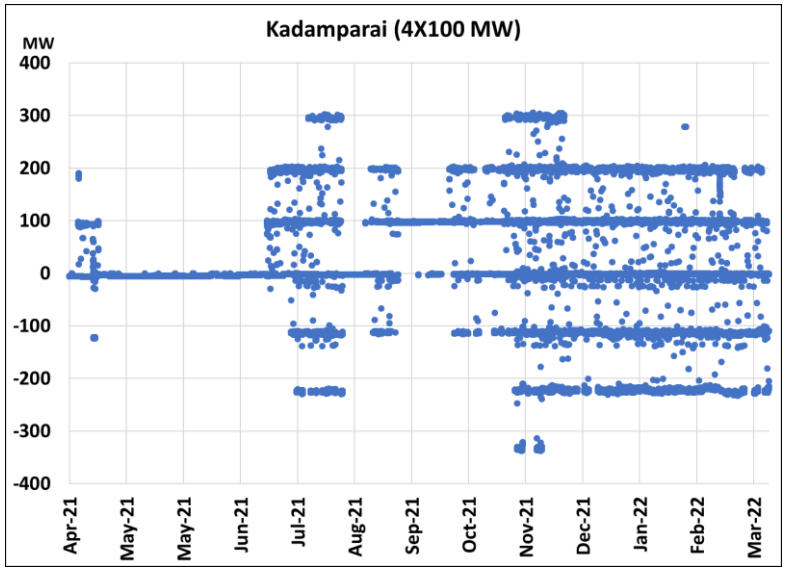


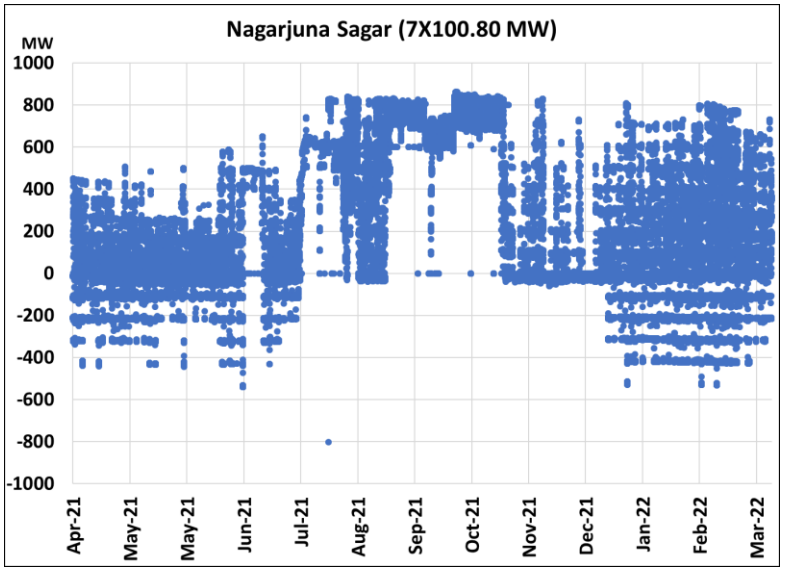
Figure 30: Nagarjunasgar PSP Generation during the event

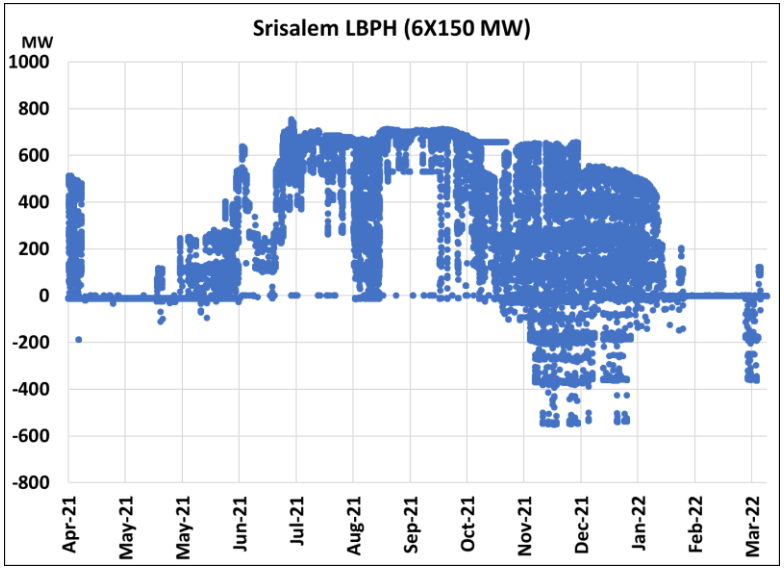
https://posoco.in/wp-content/uploads/2020/05/Report-on-Pan-India-Lights-Off-Event-9-PM-9-Minutes-on-5th-April-2020-1.pdf

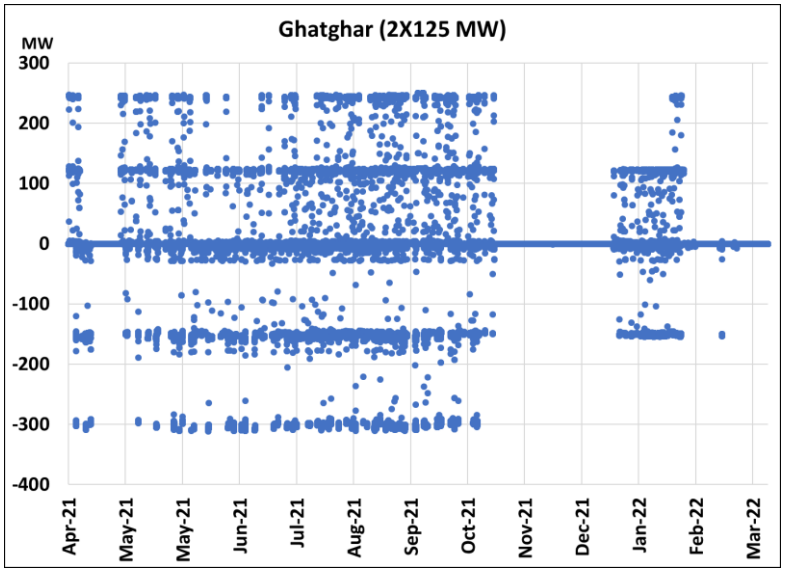
Pumped Storage Plants Generation (2021-22)

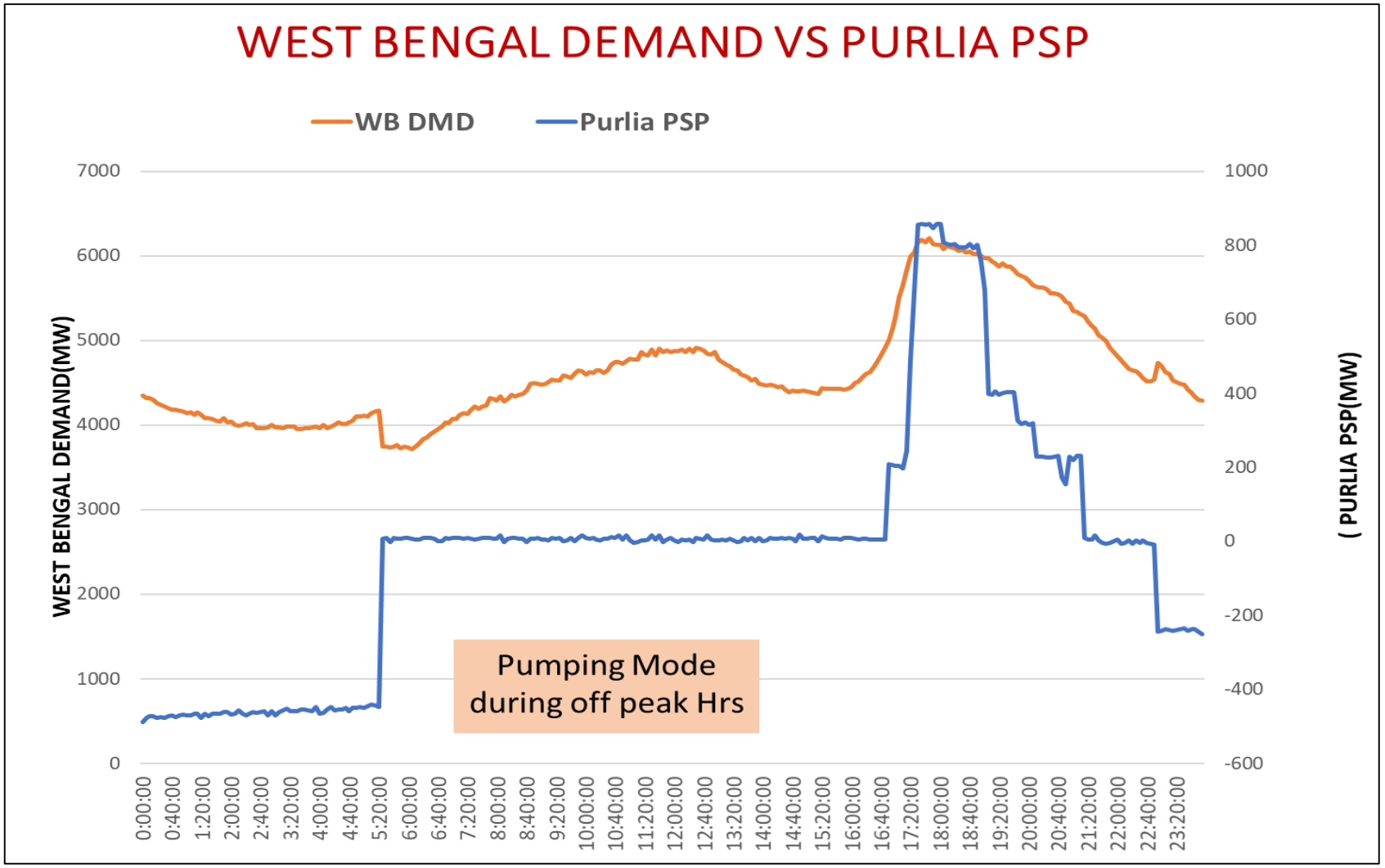
Note: Positive means Generating Mode and Negative means Pumping Mode










WEST BENGAL DEMAND VS PURLIA PSP
WB DMD
Purlia PSP
WEST BENGAL DEMAND(MW)
(PURLIA PSP(MW)
7000
6000
5000
4000
3000
2000
1000
0
1000
800
600
400
200
0
-200
-400
-600
0:00:00
0:40:00
1:20:00
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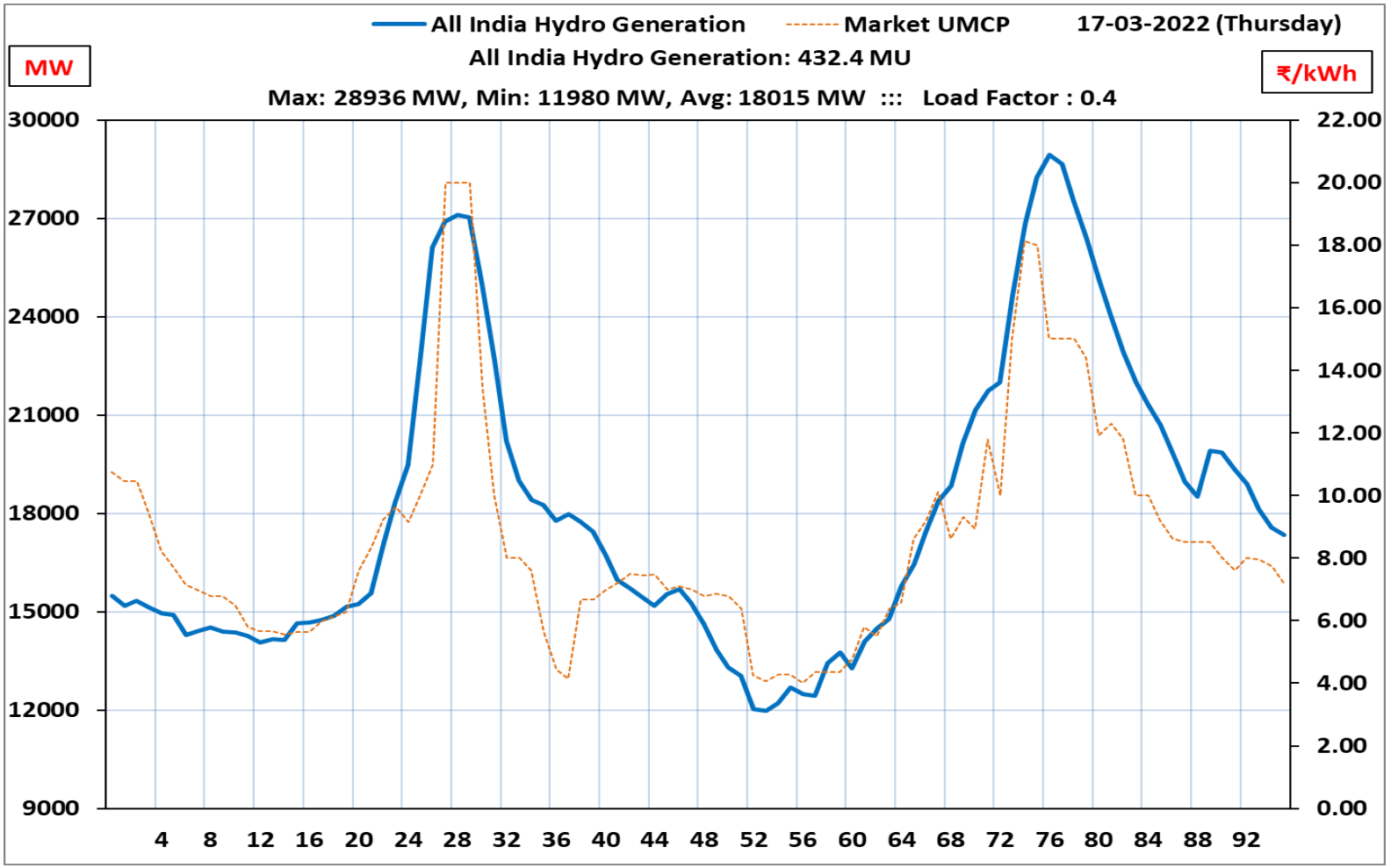
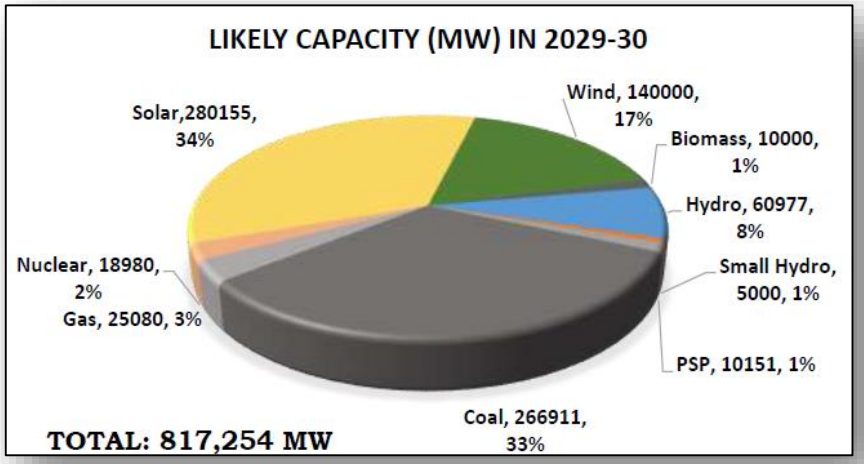
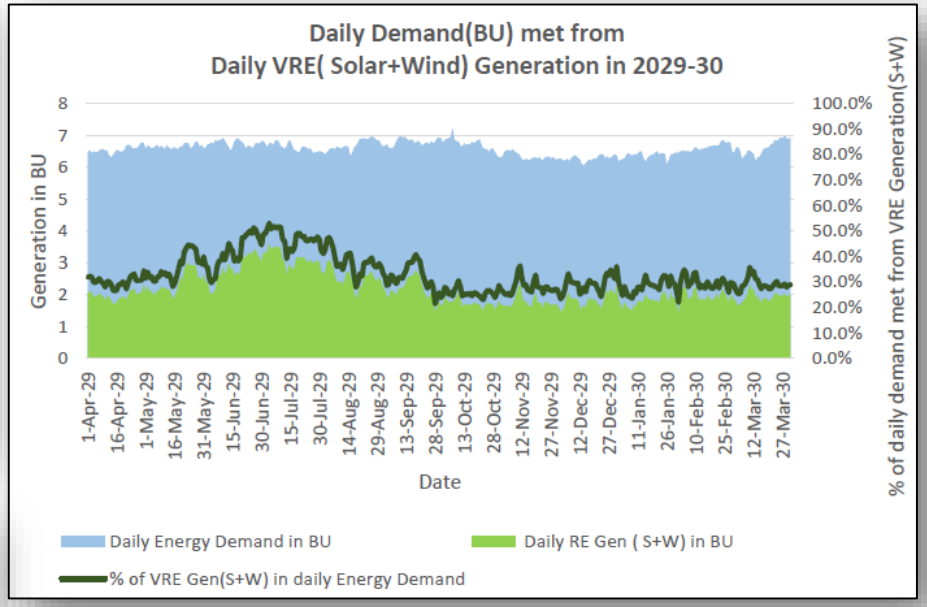
23:20:00
Pumping Mode during off peak Hrs

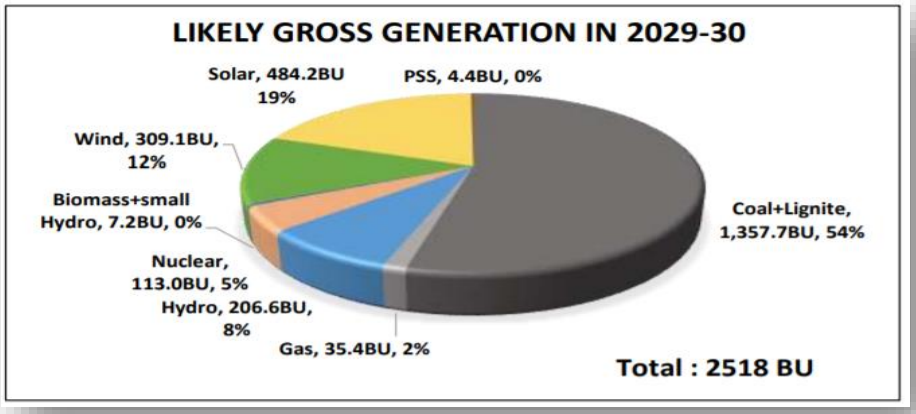
Flexibility of Hydro Plants During The Day



Future of Indian Power System Operations





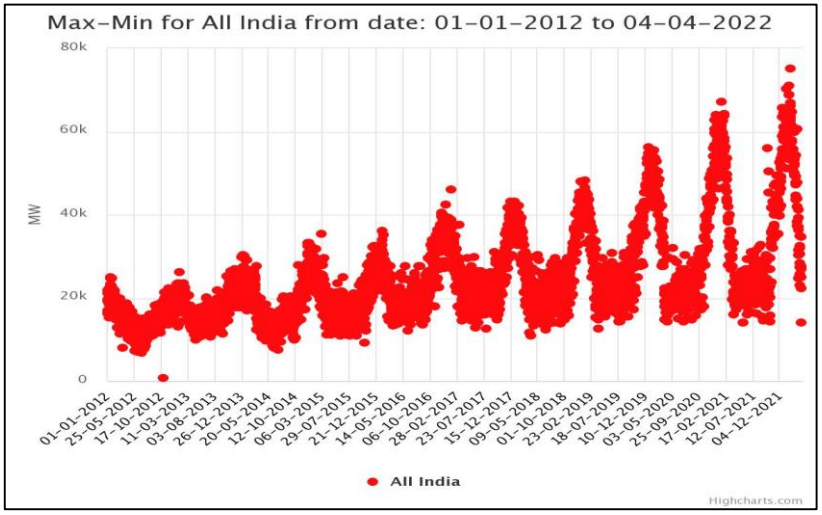


In 2029-30, it is projected that on all India basis, Renewables may contribute at least 20 – 30 % on daily basis with maximum reaching upto 50 % at certain periods

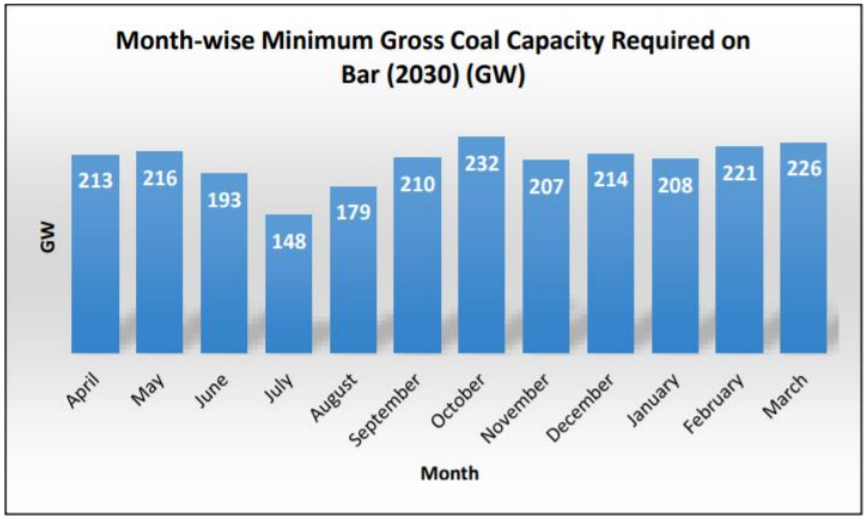
Source: CEA Report On Optimal Generation Capacity Mix for 2029-30
https://cea.nic.in/old/reports/others/planning/irp/Optimal_mix_report_2029-30_FINAL.pdf

Prospects and Plans for Energy Storage

- Resource Adequacy and Generation Flexibility to be an issue with increase in RE Capacity
- Development of new thermal plants is highly uncertain due to environmental concerns
- Hydro generation and thus flexibility provided by the same is highly seasonal
- Gas generation is affected by availability of domestic gas
- Necessary to explore new avenues to ascertain Resource Adequacy and Generation Flexibility

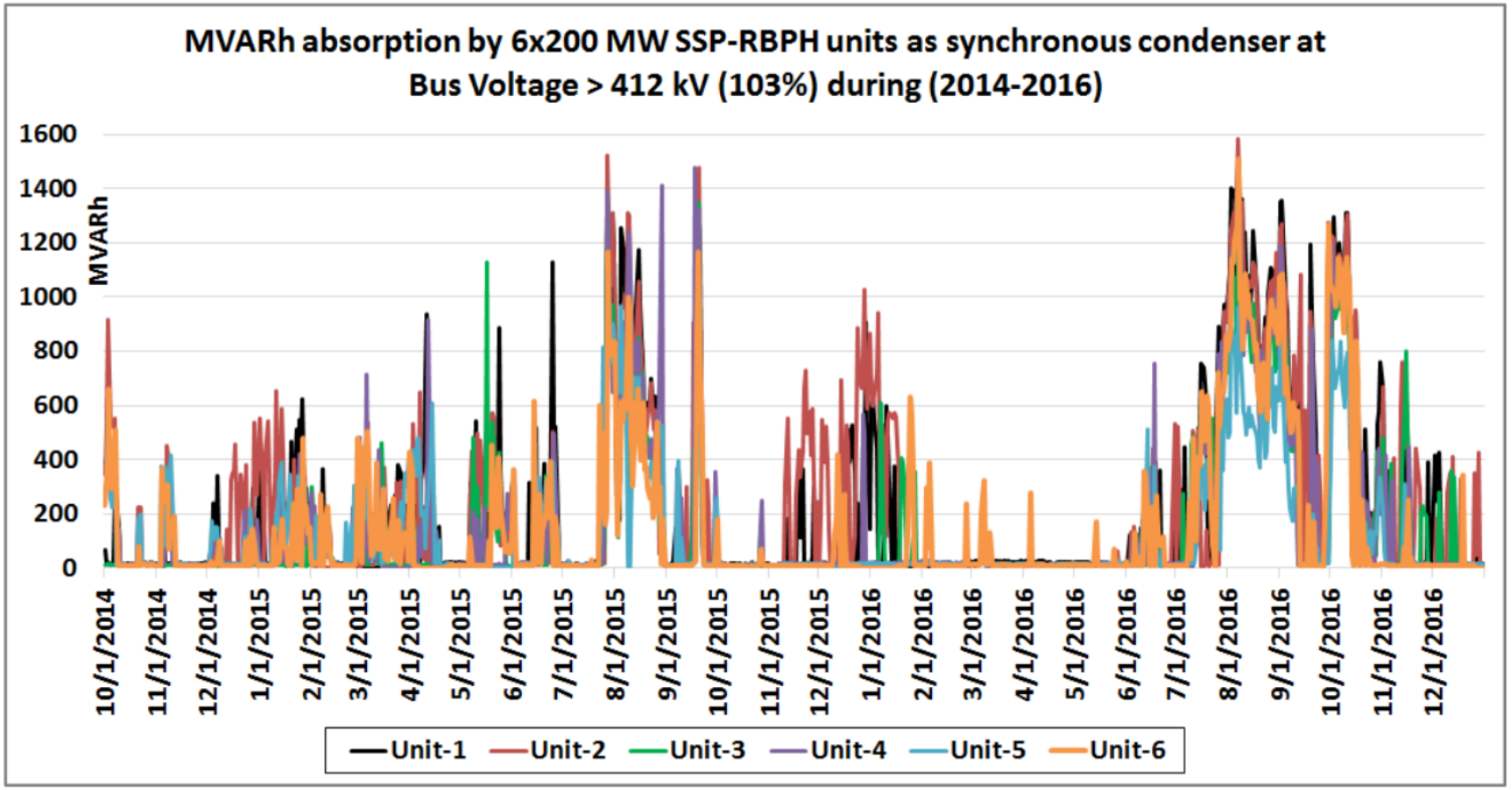


Source: NLDC SCADA Data



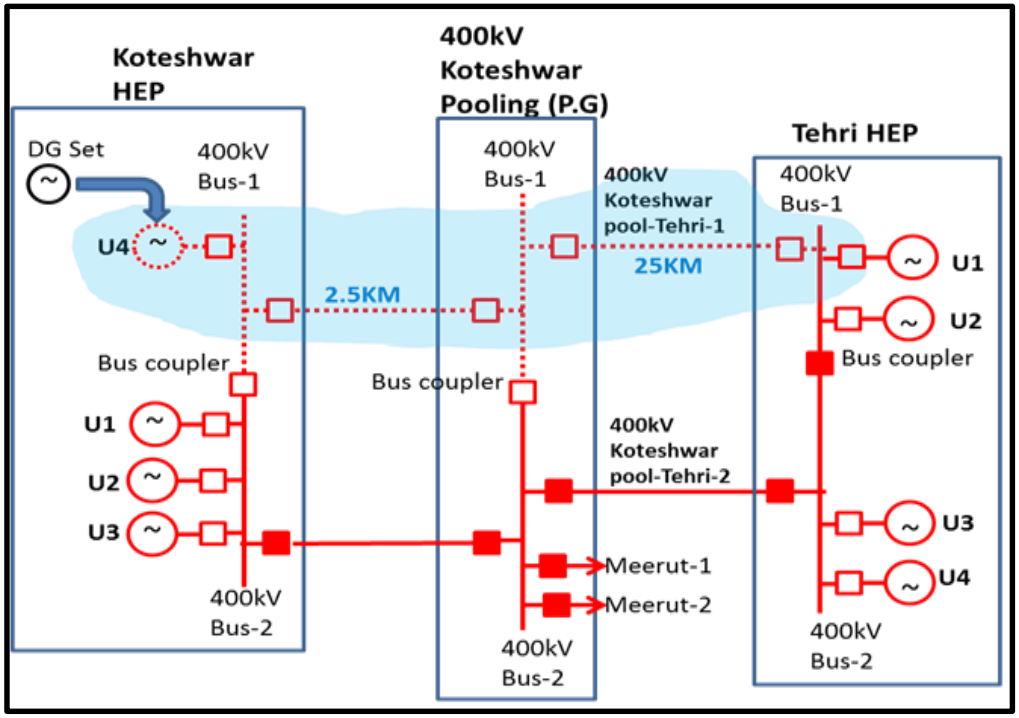
Source: CEA Optimal Capacity Generation Mix - 2030 Report

Sardar Sarovar Hydro Power Station : Condenser Mode



Proven Black Start Capability

Region	Number of stations with black-start capability
ER	13
NER	9
NR	16
SR	33
WR	16
All India	87



- **19 GW of hydro stations identified for black-start !**
- **Routinely Black start testing carried out in all hydro stations**

Way Forward

Need for Reassessment studies

- Earlier carried out by CEA during 1978-87; Need for national and international collaboration

Need for SAMAST implementation at state-level

- Kadamparai and Purulia can be included in SCED & RRAS

Create market products that allow flexible resources such as PSP to provide critical capacity during key energy need periods.

Establish an alternative, streamlined licensing process for low-impact pumped storage hydropower, such as off-channel or closed-loop projects.

Facilitate an energy market structure where transmission providers benefit from long-term agreements with energy storage facility developers.


धन्यवाद