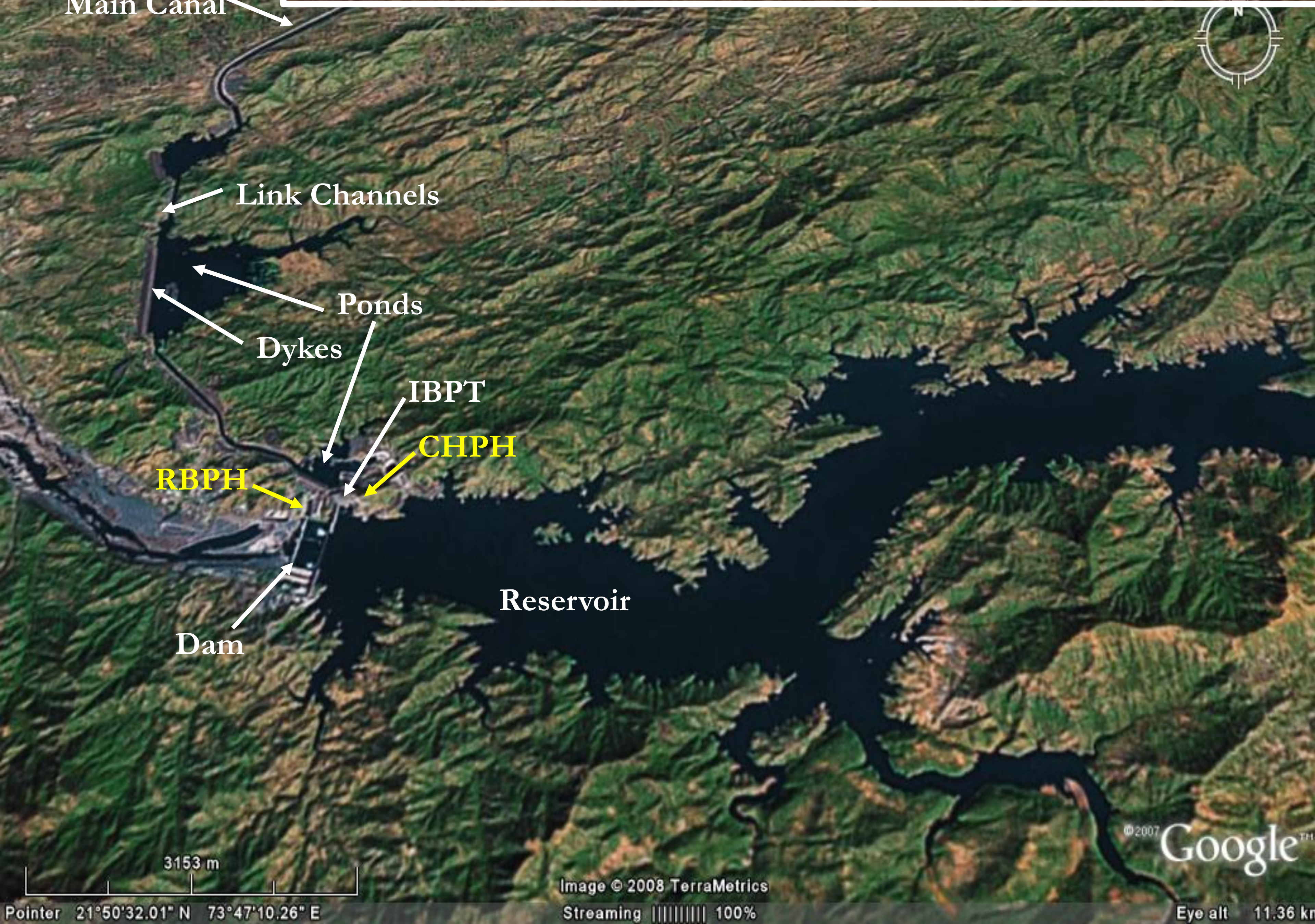
SCHEDULING OF HYDRO PLANT

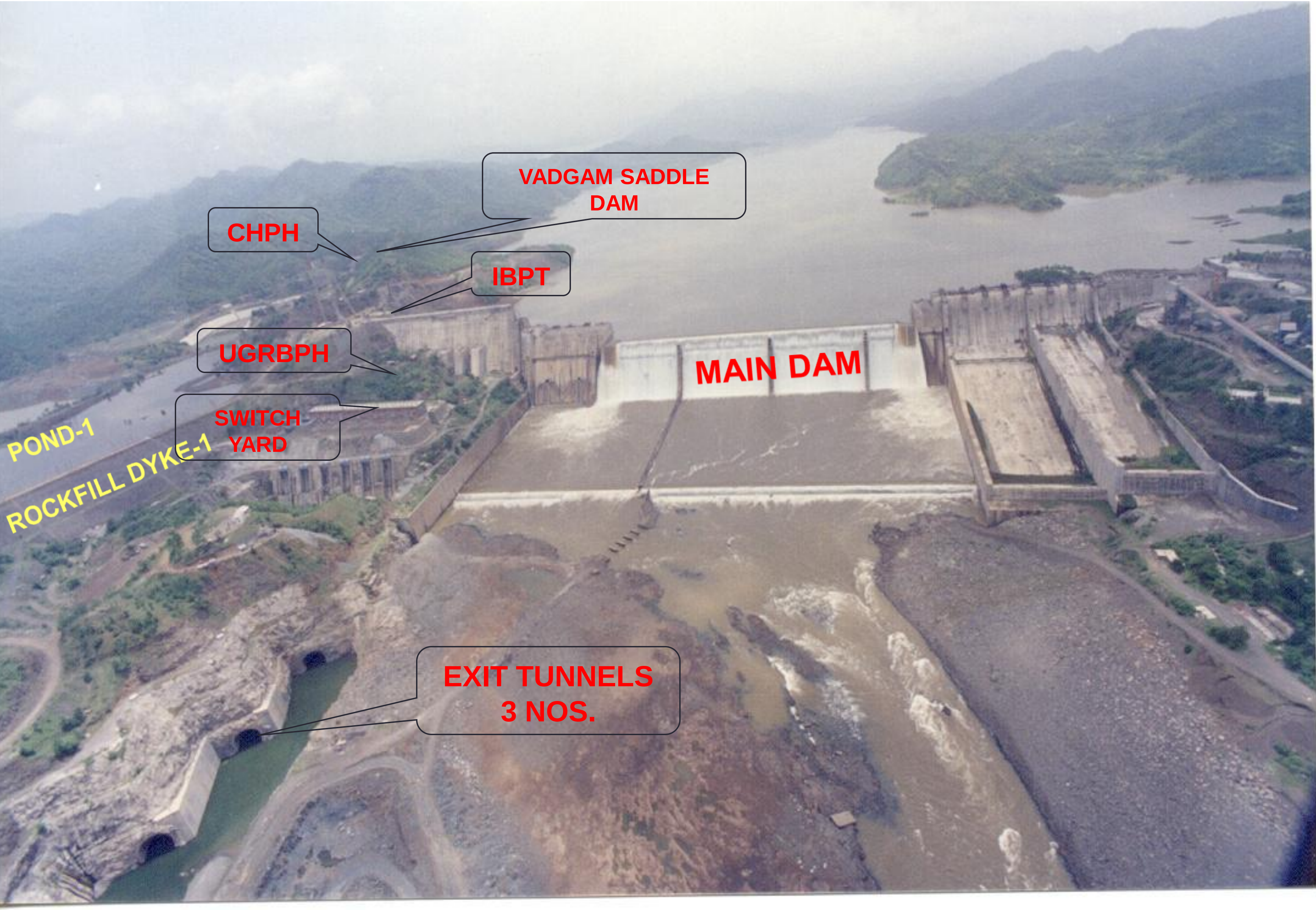
PUMPED STORAGE SCHEME
INTEGRATING RE
SSP EXPERIENCE

M A K P SINGH
Member Secretary, NRPC

Sardar Sarovar Dam - a Satellite View



Overview of Dam & Hydropower Complex



PRINCIPLES OF SOUND RESERVOIRS OPERATION

- Maximization of Irrigation.
- Maximization of power generation.
- Avoidance of floods.
- To hedge against poor/delayed monsoons during the ensuing year.
- ~~Peak~~ Power Management

Government Guarantee

- Subsequent to the successful negotiations with M/s Sumitomo Corporation of Japan, the loan agreement was signed by SSNNL with Sumitomo Corporation.
- The Government of Gujarat has given guarantee
- The counter-guarantee was given by Ministry of Finance Government of India.

OPERATION OF RESERVOIRS

- The reservoir operation is classified into two distinct periods viz.

  Filling Period' and the 'Depletion Period'.

  The 'Filling Period' (Monsoon-months):

  1st July to 30th November.

  The 'Depletion Period' (Non-Monsoon Months)

  1st Dec to 30th June

  Rule Curve to be followed: Reservoir operation Table (ROT) is finalized well in advance

SSP RESERVOIR

Length	214 Km
FRL	138.68 m (455 ft)
MDDL	110.63 m (363 ft)
Crest level	121.92 m (400 ft)
Gross storage	9500 Mcum (7.70 Maf)
Live storage	5800 Mcum (4.43 Maf)
Evaporation Loss	616 Mcum (0.5 Maf) Annual

Gates

Type	…	Radial
No. & size	…	30
7 Nos. auxiliary spillway		
		18.3 m x 18.3 m (60'x60')
23 Nos service spillway		
		18.3 m x 16.76 m (60'x55')
Discharge Capacity	…	84949 cumec (30 lakh cusec)

USE OF WATER

IRRIGATION

CCA	21.29 lakh ha.
Annual Irrigation	17.92 lakh ha. (Gujarat- 12 districts)
	73000 ha (Rajasthan) Jalore & Barmer Districts.

DRINKING WATER

Allocation … 1307 Mcum (1.06 Maf) in Gujarat

- 8 Mcum in Rajasthan.
- Industrial use in Gujarat 275 Mcum (0.21 Maf)
- Drinking water use in Gujarat 1032 Mcum (0.85 Maf)

Urban Centres benefitted 135

Villages benefitted … 8215

POWER

- Power benefits:

RBPH (River Bed Power House 6x200 MW Underground)

Firm 3635 Gwh reducing to Zero after 45 years.

Secondary 1431 Gwh reducing to 520 Gwh after 45 years.

CHPH (Canal Head Power House 5x50 MW)

Firm 213 Gwh increasing to 440 Gwh After 45 Yrs.

Secondary 190 Gwh increasing to 345 Gwh after 45 years.

POWER HOUSE OPERATION Constraints

Ten daily limit set by Reservoir Regulation Committee (Water Allocated in Ten daily)

Environmental Release

Demand of beneficiary State

Downstream water requirement- Festivals.

No sudden surge of water

Irrigation demand

Breach in canal

Maintenance in Canal

Afflux Bund

- The Afflux Bund is for protection of backwater affected villages.
- Construction of earthen embankments varying from 2m to 10m to be constructed on river side of affected villages with full pitching on river side slope and green turfing on village side slope.
- Proper arrangement for natural drainage through Sluices and Pumps
- Earthen embankment of masonry section is to be constructed in reaches with the objective of protecting households rather than agricultural land.
- The topographical monitoring to be done on regular basis.

Real Time Data Acquisition System

- Each Hydo Project should establish, maintain and operate an effective system of flood forecasting and flood control, including reporting of heavy precipitation, and telecommunication systems.

CANAL

Main Canal structures		590
Canal syphon	…	14
Drainage syphone	…	148
Canal crossing		25
Syphon aquaduct	…	5
Main Canal Level		
Regulator	…	42
Cross Regulator	…	39
Escapes	…	13
Super passage	…	6
Road bridge	…	280
Railway crossing	…	17
Lining	…	M-15 cement concrete

- 10 cm thick on bed and12.5 cm on sides.

NANGAL HYDEL CHANNEL

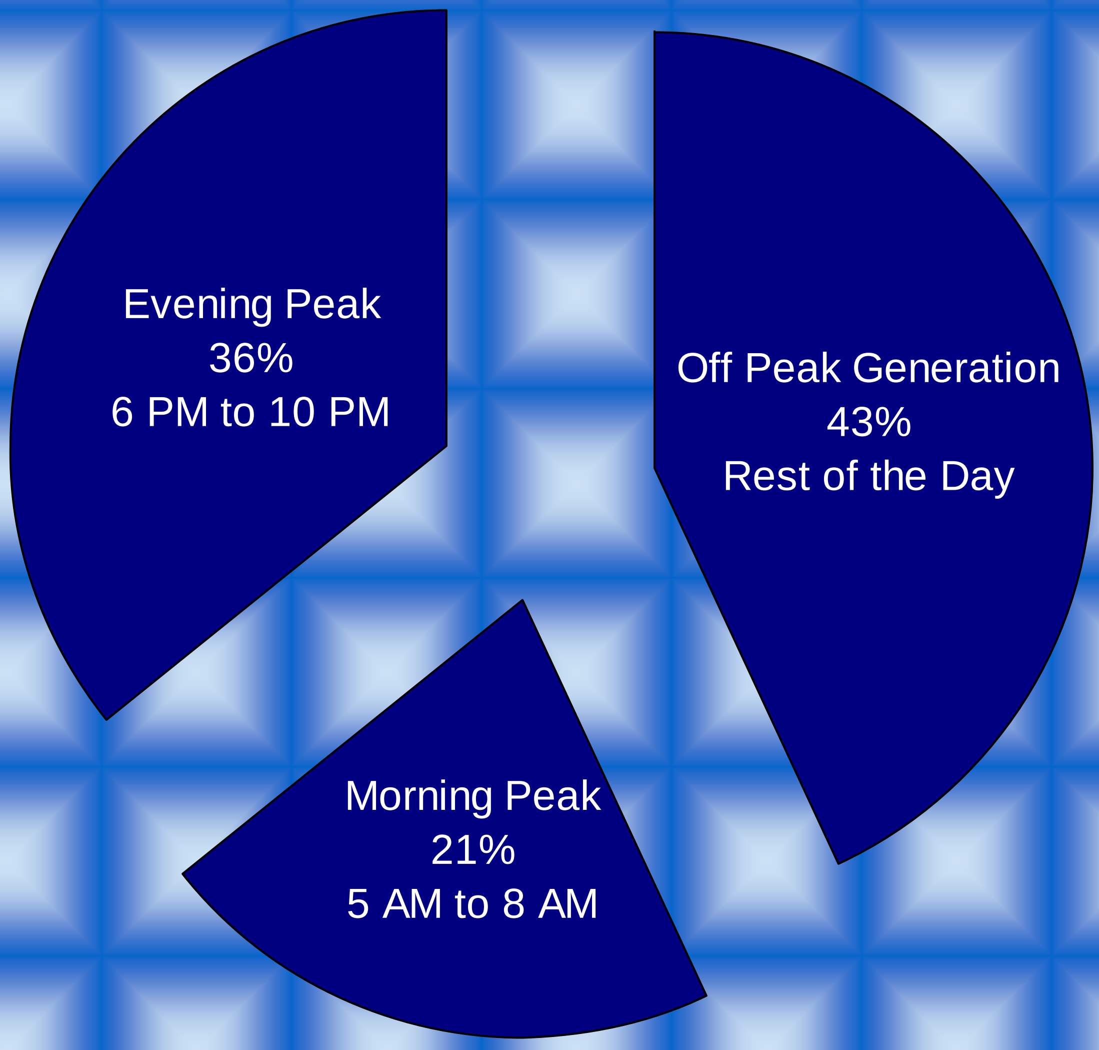
- Permissible Rate of Raising the water

Depth of Water	Rate per Hour
0 to 5.5 ft	5.5 ft/hr
5 to 16 ft	0.5 ft/hr
Above 16ft	0.25 ft/hr

- Permissible Rate of Lowering the water

Depth of Water	Rate per Hour
Above 16 ft	0.25 ft/hr
16 to 12 ft	0.20 ft/hr
12 to 5.5 ft	0.10 ft/hr

PEAK AND OFF PEAK GENERATION IN JAN 2005

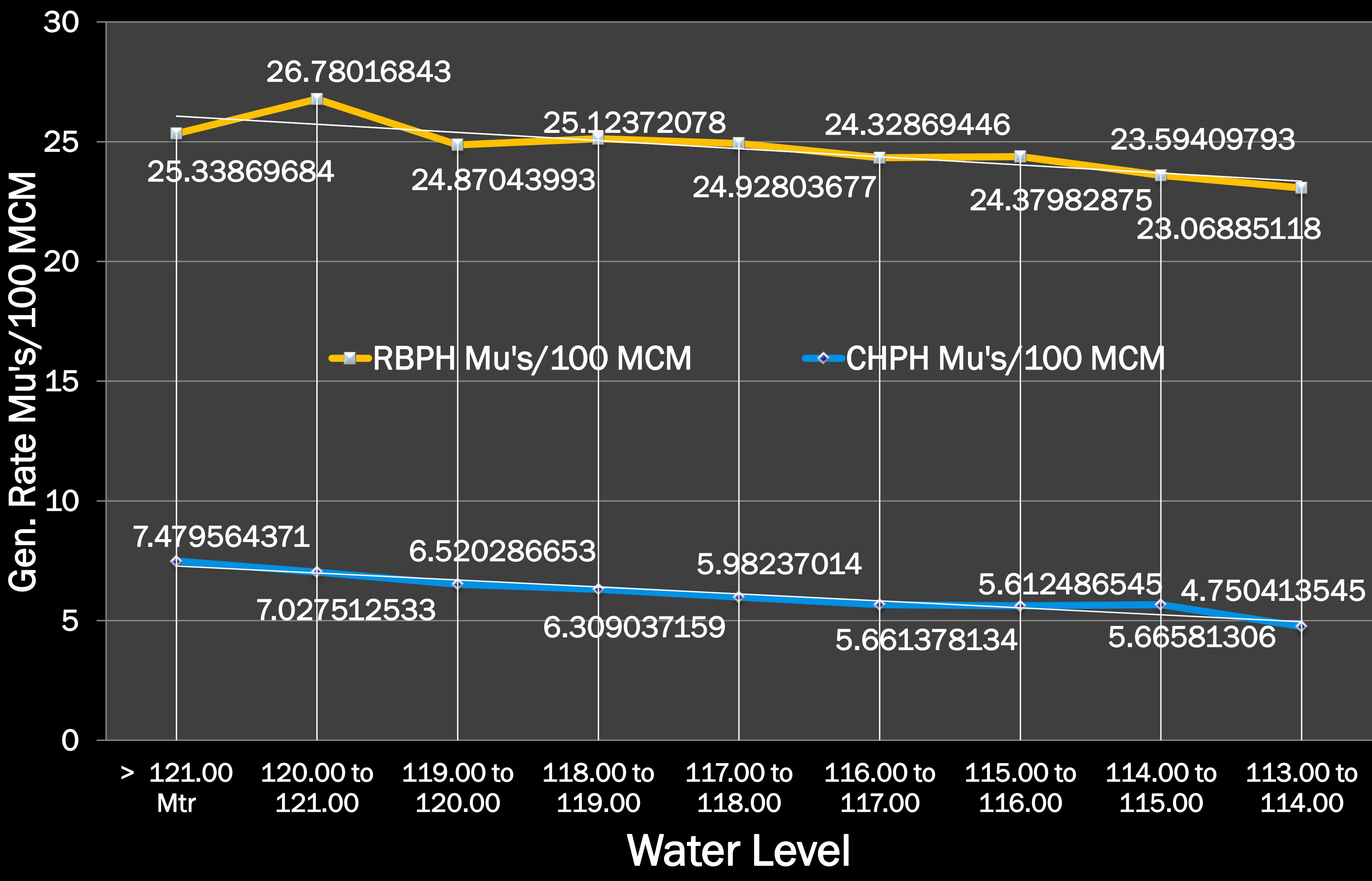


The Tribunal orders:

The power generated in the River Bed and Canal Power House at Navagam will be integrated in a common switchyard.

- Madhya Pradesh and Maharashtra will be entitled to get 57 percent and 27 percent respectively of the power available at bus bar in the switchyard after allowing for station auxiliaries.
- The above entitlement applies both to availability of machine capacity for peak loads and to the total energy produced in any day.
- The entitlement of power and energy for any day can be utilised fully or partly by the concerned States or sold to another participating State under mutual agreement. It cannot, however, be carried forward except under a separate agreement or working arrangement entered into among the affected parties.

SSP (RBPH+CHPH) GENERATION RATE MU'S/100 MCM



METHODOLOGY OF BEST FIT SCHEDULE OF SSP

Best Fit Schedule(BFS) Philosophy

The scheduling of the generation at SSP from its two Power Houses Viz: RBPH and CHPH (for irrigation) is being done BFS with following objectives:

- Demand of all beneficiary States in all time blocks is met to the maximum possible extent.
- Ten Daily target given by SSRRC is achieved.
- Prevent/minimize overflow at SSP Dam.
- Optimum utilization of water.
- Maximization of generation at SSP.
- Helps RLDC in Reliable and Stable Grid Operation.

Best fit schedule

- In consultation with WRLDC.
- As per the requirements of beneficiary States during different parts of the day
- As per the entitlement under NWDT Award.
- Schedule worked out will not be altered.
- Adjustment of shortfall/excess of power drawn to be settled at the earliest instance.

PROCEDURES

- Based on quantum of water allocated for RBPH in Ten Daily issued by SSRRC, NCA will inform total MW generation possible in each time block and m/c_hrs (Mus) for a given day in advance to each beneficiary states.

- During any time block the Max. sum of demand that can be met is equal to DC *Number of available RBPH M/Cs.

- Each beneficiary State to submit their demand set P1 time block-wise .

PROCEDURES Contd

- Additional set of demand(P2) if any to be indicated separately.

Where:

- T_d = Sum of demand given by all the three States in a 15 min time-block,

- T_{av} = Total no. of m/c available * DC in MW of each m/c as per DC

Situation I :

In a particular 15 mints time block if Td <= Tav , where Td= Total demand of all the three States, Tav = MW then scheduled power in that time block will be as per the demand of each State.

	BLOCK	GUJ	MP	MAH	Td	Tav
Entitlement	37	168	598.5	283.5		1050
Demand		175	350	175	700	
internal calculation		175	350	175	700	
		0	0	0	0	
		175	**350**	**175**	700	
		0	**0**	**0**	0	
Allocated share		**175**	**350**	**175**	700	

Situation II:

In case , 1 or 2 states having demand less than their entitlement, then their non-requisitioned share will be given to other party state having demand more than its share.

	BLOCK	GUJ	MP	MAH	Td	Tav
Entitlement	41	168	598.5	283.5		1050
Demand		175	350	875	1400	
internal calculation		260.47	350	439.53	1050	
		85.465	0	-435.5	85.465	
		175	**350**	**525**	1050	
		0	**0**	**0**	0	
Allocated Share		**175**	**350**	**525**	1050	

Situation III:

If Td > Tav & All the three states having demand more than their entitlement then Total MW will be distributed in 57: 27:16 as per their power share mentioned in NWDT award.

	BLOCK	GUJ	MP	MAH	Td	Tav
Entitlement	61	168	598.5	283.5		1050
Demand		175	700	875	1750	
internal calculation		168	598.5	283.5	1050	
		-7	-101.5	-591.5	0	
		168	**598.5**	**283.5**	1050	
		0	**0**	**0**	0	
Allocated Share		**168**	**598.5**	**283.5**	1050	

continued

Once a unit starts to generate it will not be withdrawn before minimum 3 hrs.

Except otherwise, for the reason of safety and security of WR grid, Best Fit Schedule will not be revised on Real Time Basis.

Unrequested Share (URS) MUs on any day by any state will be given to other states only on condition of Mutual Agreement between them and the copy of such agreement shall be made available to NCA as well as WRLDC.

State should consume SSP power on First Charge Basis.

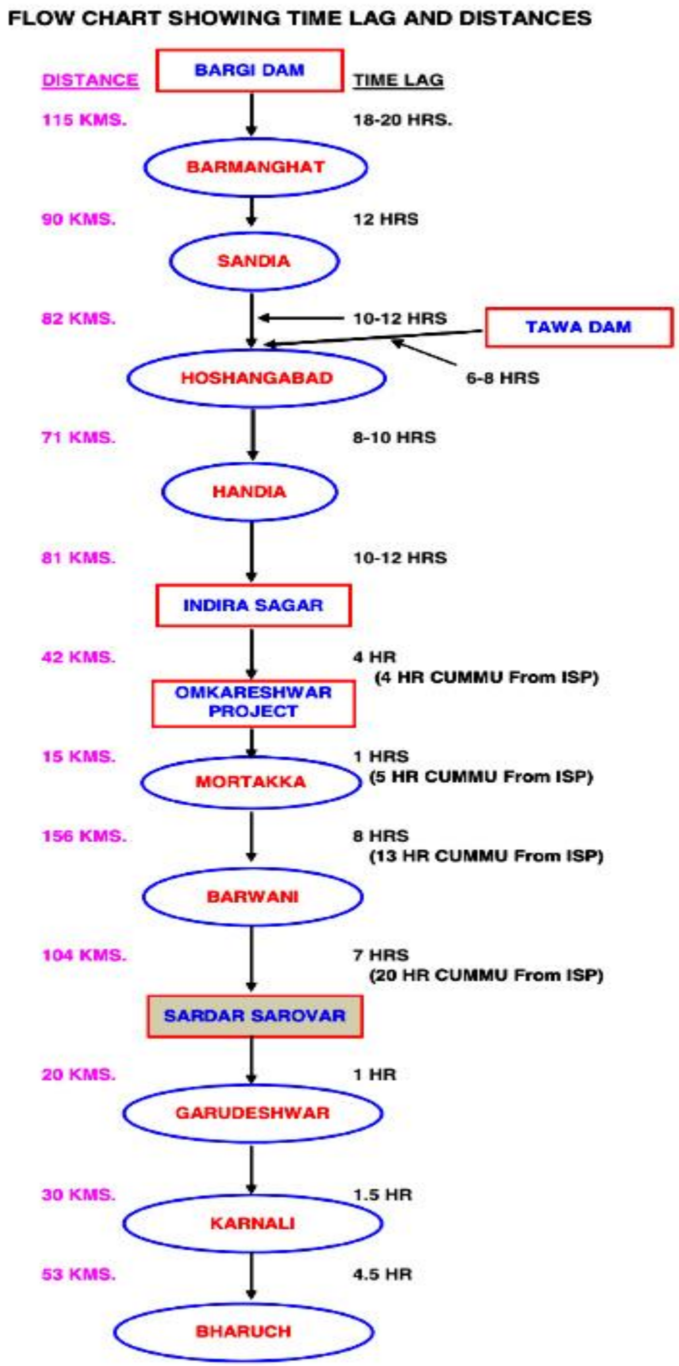
After finalizing the Best Fit Schedule, it will be revised under emergency situation (e.g. withdrawal / stoppage of Generation, line/corridor congestion) on Real Time Basis in consultation with WRLDC.

Pattern of Power generation from the power complex SSP (RBPH & CHPH) in the initial and intermediate stages

All figures in MUs

Stage	Year	Firm Energy		Average Energy		Seasonal Energy	
		RBPH	CHPH**	RBPH	CHPH	RBPH	CHPH
I*	10	3635	213	5066	403	1431	190
II A	20	1477	676	2438	787	961	111
II	30	517	676	1851	787	1334	111
III	45	-	440	520	785	520	345

*Year of full commissioning of the power component.
** Corresponding to design irrigation release/requirements.



FLOW CHART WITH LAG AND DISTANCE BETWEEN NARMADA PROJECTS

TARIFF OF THE PUMPED STORAGE SCHEME/PROJECTS
(Modified Amendments As Regulation 22a)

1. NET CAPACITY CHARGE

A. If actual Generation (monthly) >= 75 % of the Pumping Energy consumed for the month:

Monthly Payable Net Capacity Charge (inclusive of incentive) = ((AFC x NDM / NDY)- 0.75 x ECCm)

B. If actual Generation (monthly) < 75 % of the Pumping Energy consumed :

Monthly Payable Net Capacity Charge (inclusive of incentive) = ((AFC x NDM / NDY) x (Actual Generation during peak hours in a month / 75% of the Pumping Energy consumed by the station during the month)

Where,

AFC = Annual fixed cost specified for the year (Rupees) ,

NDM = Number of days in the month

NDY = Number of days in the year

ECCm = Energy charge Credits for the sale of power in excess of the Design energy + 75% of the energy utilized in pumping the water in that month(Rupees).

2. Energy Charge

Energy Charge payable by beneficiary is at a flat rate equal to the avg. energy charge @ 20 paise / kWh, excluding free energy.

Energy charge payable = 0.20 x {Scheduled energy (ex-bus) for the month(kWh) – (DEm+75% of the energy utilized in pumping for the month)} x (100 – FEHS) / 100.

Where,

DEm=Design energy for the month specified for the hydro station(MWh),

FEHS = Free energy for home State, in %, if any.

Provided further that

If Scheduled energy in a month < (DEm + 75% of the energy utilized in pumping, the energy charges payable by the beneficiaries need to be zero.

3. If without any valid reason, generator is not pumping water or not generating power to its potential or wasting natural flow of water, the capacity charges of the day is non-payable by the beneficiary on order of the Commission if any application made by any of the beneficiary.

For this purpose, outages of the unit(s)/station (planned and forced) up to the 15% in a year to be construed as the valid reason for not pumping water or not generating power.

In the event of total machine outages in a year >15%:

Total capacity charges (recovered during the year adjusted on prorata basis):
(ACC)adj = (ACC) R x (100- ATO)/85
Where,
(ACC)adj – Adjusted Annual capacity Charges
(ACC) R – Annual capacity Charges recovered
ATO - Total Outages in % for the year (forced and Planned)

Provided that the generating stations declare its machine availability daily on day ahead basis for 96 time blocks.

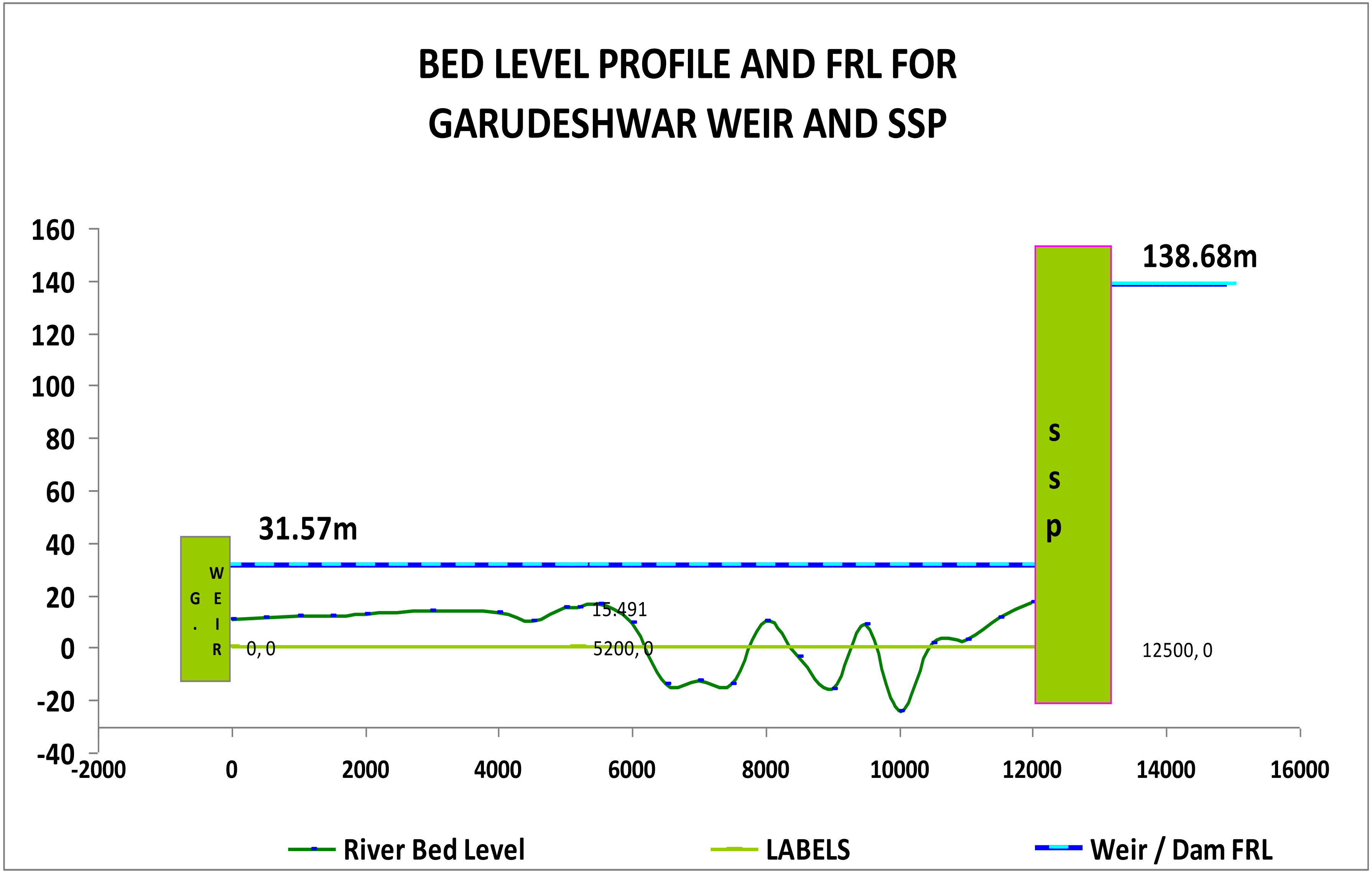
In view of Commission:

1. The power for pumping water to be arranged by the beneficiaries.
2. Commission also of view that O&M @ 2% of the capital cost is reasonable as increased cost of pumped storage scheme would take care of any additional O&M requirement.

Tariff

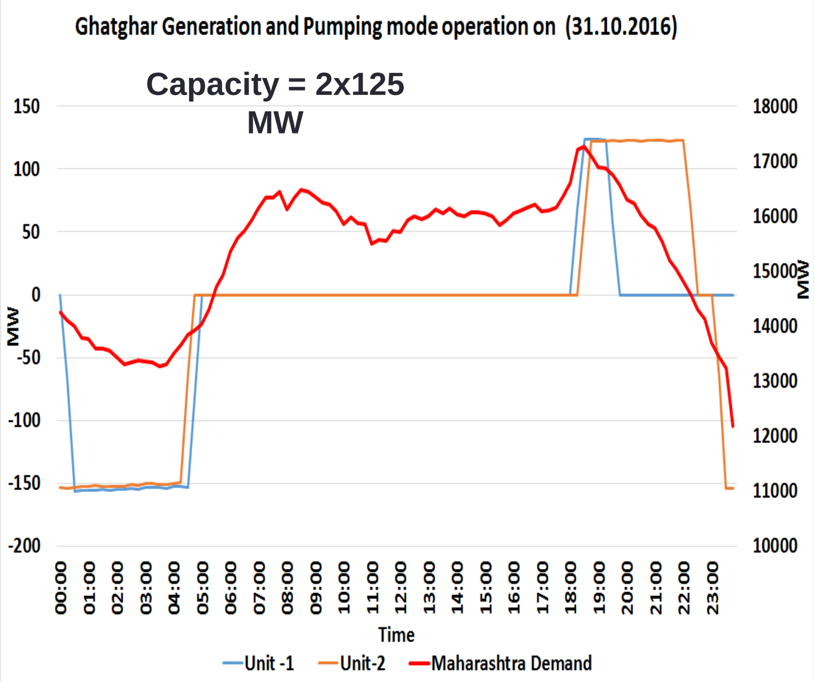
- Tariff Committee have decided most of the issues on the Tariff and Energy Accounting, except the cost of Pumping Power and it's distribution among the Party States. However, 7th meeting of the Tariff Committee recommended that
- "Energy consumed by SSP during Pumping mode should be distributed among beneficiary States in the ratio of their shares in SSP and added to their drawal from Central Sector generation while preparing the Regional Energy Accounting. Tariff for energy consumed for Pumping shall be the pooled Central Sector Tariff."

L-SECTION GARUDESHWAR WEIR

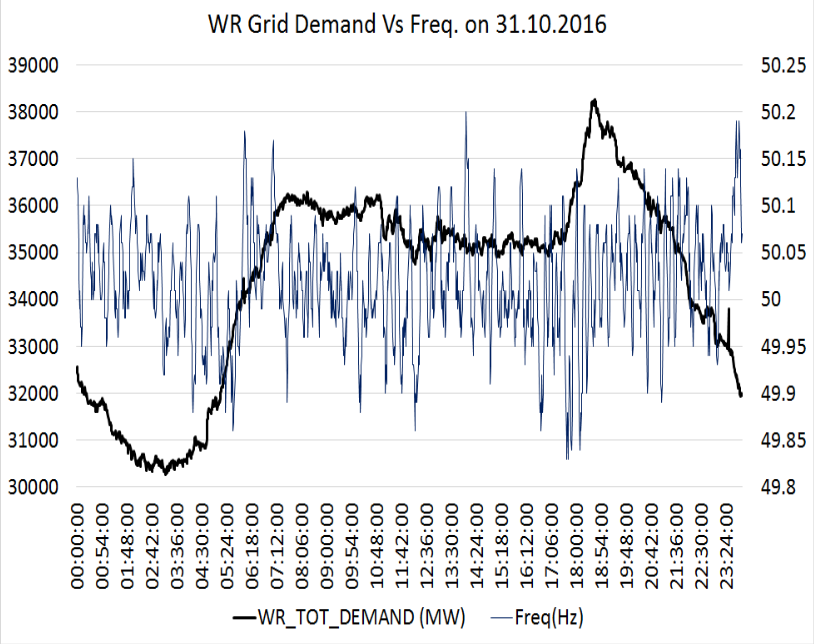


SALIENT FEATURES GARUDESHWAR WEIR

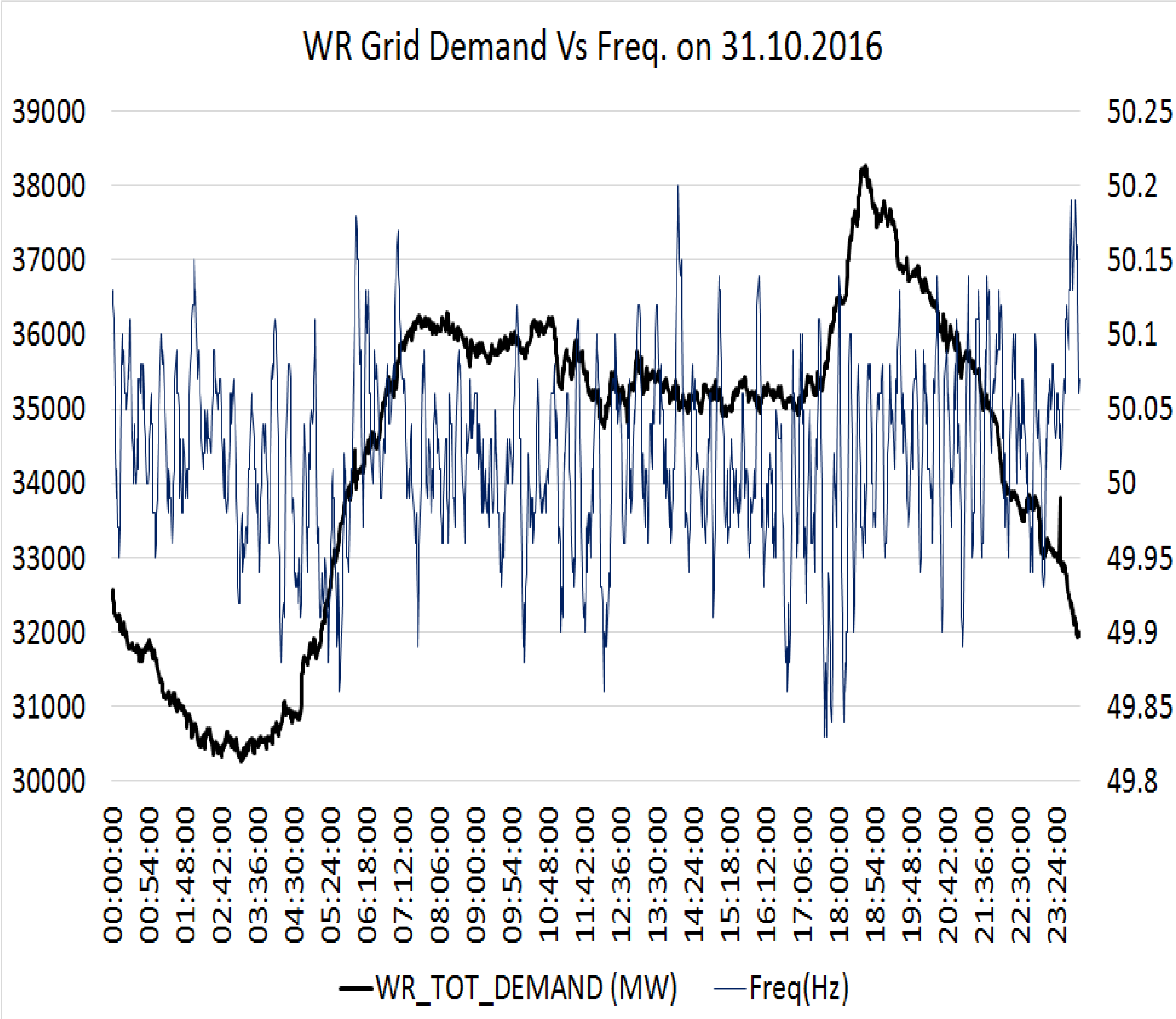
- **LOCATION : 12.10 km D/s of Sardar Sarovar dam**
- **Design discharge : 69385 Cumecs**
- **Full Reservoir Level : 31.57m**
- **Crest Level : 31.75m**
- **Normal Tail Water Level : 37.30m**
- **Gross Storage Capacity : 8720 HAM (70708 Aft)**
- **Dead Storage Capacity : 5422 HAM (43974 Aft)**
- **Live Storage Capacity : 3298 HAM (26734 Aft)**
- **Total length of Weir : 1137m**
- **The poundage : 34.36 MCM (27850 acre ft.).**
- **Operating levels : +27.33 m to 33.15 m.**
- **Storage : pumping mode operation of RBPH.**
- **Pumping for 8 hours**
- **RBPH : peaking station for 6 hours.**



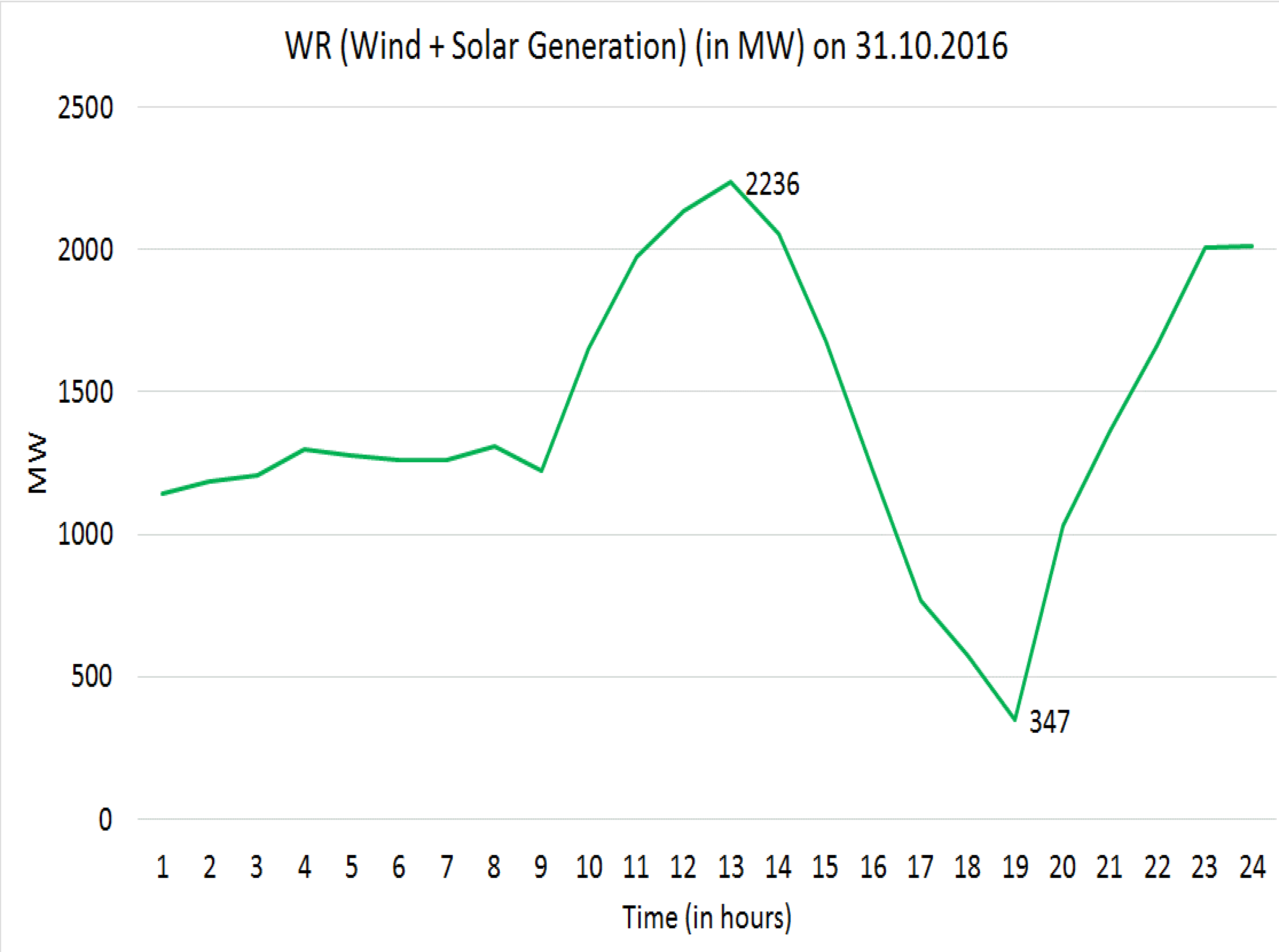
Ghatghar Generation and Pumping mode operation on (31.10.2016)
Capacity = 2x125 MW
150
100
50
0
-50
-100
-150
-200
MW
18000
17000
16000
15000
14000
13000
12000
11000
10000
MW
00:00
01:00
02:00
03:00
04:00
05:00
06:00
07:00
08:00
09:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time
Unit -1
Unit-2
Maharashtra Demand



WR Grid Demand Vs Freq. on 31.10.2016
39000
38000
37000
36000
35000
34000
33000
32000
31000
30000
50.25
50.2
50.15
50.1
50.05
50
49.95
49.9
49.85
49.8
00:00:00
00:54:00
01:48:00
02:42:00
03:36:00
04:30:00
05:24:00
06:18:00
07:12:00
08:06:00
09:00:00
09:54:00
10:48:00
11:42:00
12:36:00
13:30:00
14:24:00
15:18:00
16:12:00
17:06:00
18:00:00
18:54:00
19:48:00
20:42:00
21:36:00
22:30:00
23:24:00
WR_TOT_DEMAND (MW)
Freq(Hz)

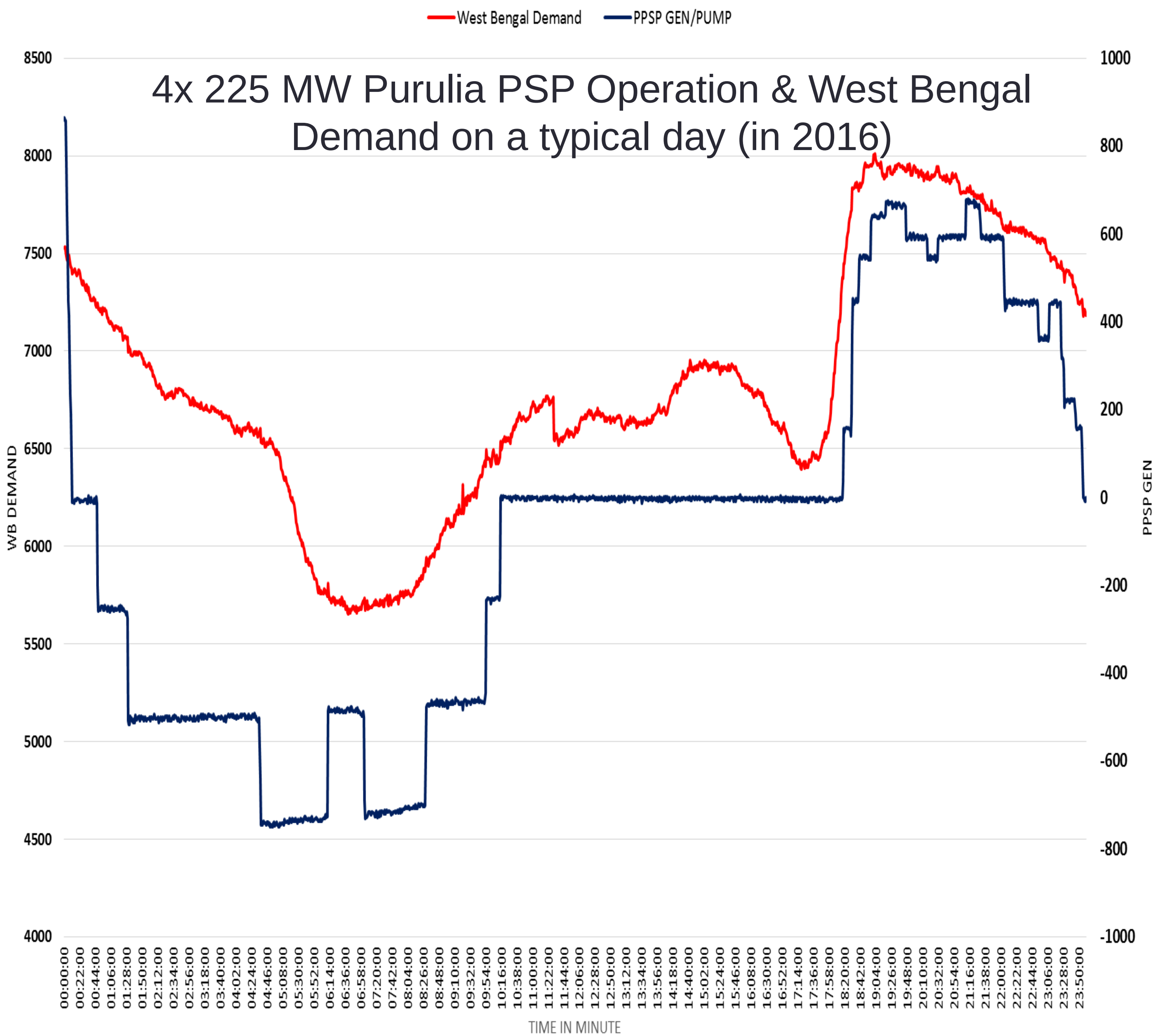


WR Grid Demand Vs Freq. on 31.10.2016
39000
38000
37000
36000
35000
34000
33000
32000
31000
30000
50.25
50.2
50.15
50.1
50.05
50
49.95
49.9
49.85
49.8
00:00:00
00:54:00
01:48:00
02:42:00
03:36:00
04:30:00
05:24:00
06:18:00
07:12:00
08:06:00
09:00:00
09:54:00
10:48:00
11:42:00
12:36:00
13:30:00
14:24:00
15:18:00
16:12:00
17:06:00
18:00:00
18:54:00
19:48:00
20:42:00
21:36:00
22:30:00
23:24:00
WR_TOT_DEMAND (MW)
Freq(Hz)



WR (Wind + Solar Generation) (in MW) on 31.10.2016
MW
Time (in hours)
2500
2000
1500
1000
500
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
2236
347

WB DEMAND VS PPSP GEN



RTO will depend on:

Pumping power made available by the beneficiary States.

Margin for RTO available during off peak hours.

Preference sequence:

i) PTGT

Pump today- generate today during peak hours.

ii) PTGL

Pump today-generate later at the earliest instance

iii) PTWS

Pumped today-water spill to be avoided

<table>
<tr><th rowspan="2">Time (hrs)</th><th colspan="4">Pumping Power</th></tr>
<tr><th colspan="2">Available</th><th colspan="2">Not Available</th></tr>
<tr><th></th><th>RTO</th><th>Generation</th><th>RTO</th><th>Generation</th></tr>
<tr><td>09:00-15:00</td><td>No</td><td>Yes
$W_{RTO} + W_{SSRRC} > 0$</td><td rowspan="4">No</td><td>Yes
$W_{RTO} + W_{SSRC} > 0$</td></tr>
<tr><td>15:00-18:00</td><td>Yes
$W_{SSRRC} = 0$</td><td>Yes
$W_{SSRRC} > 0$</td><td>Yes
$W_{SSRRC} > 0$</td></tr>
<tr><td>18:00-23:00</td><td>No</td><td>Yes
$W_{RTO} + W_{SSRRC} > 0$</td><td>Yes
$W_{RTO} + W_{SSRC} > 0$</td></tr>
<tr><td>23:00-09:00</td><td>Yes
$W_{SSRRC} = 0$</td><td>Yes
$W_{SSRRC} > 0$</td><td>Yes
$W_{SSRRC} > 0$</td></tr>
<tr><td colspan="5">Spill of W_{RTO} to be avoided
Here W_{RTO} and W_{SSRRC} means demand from W_{RTO} and W_{SSRRC} respectively.</td></tr>
</table>

Recommended:

Simultaneous Pumping and Straight generation not to be permitted.

Sharing of O&M expanses.(to be agreed apriori)

Separate energy account for Straight generation, Pumping Energy & generation from pumped water.

Separate water account to be maintained for pumped water and inflow water

Peak hours may be different for beneficiary States.

Generation from pumped water to be scheduled during low grid frequency in the grid only.

On similar line of RRAS Pumped Storage Scheme to be operated by NLDC

UP- Generation from Pumped water

Down –Reversible turbine operation


THANK YOU

Integrated Operation Philosophy of
Tehri Hydro Power Complex



By

THDC INDIA LTD.

An Overview

General

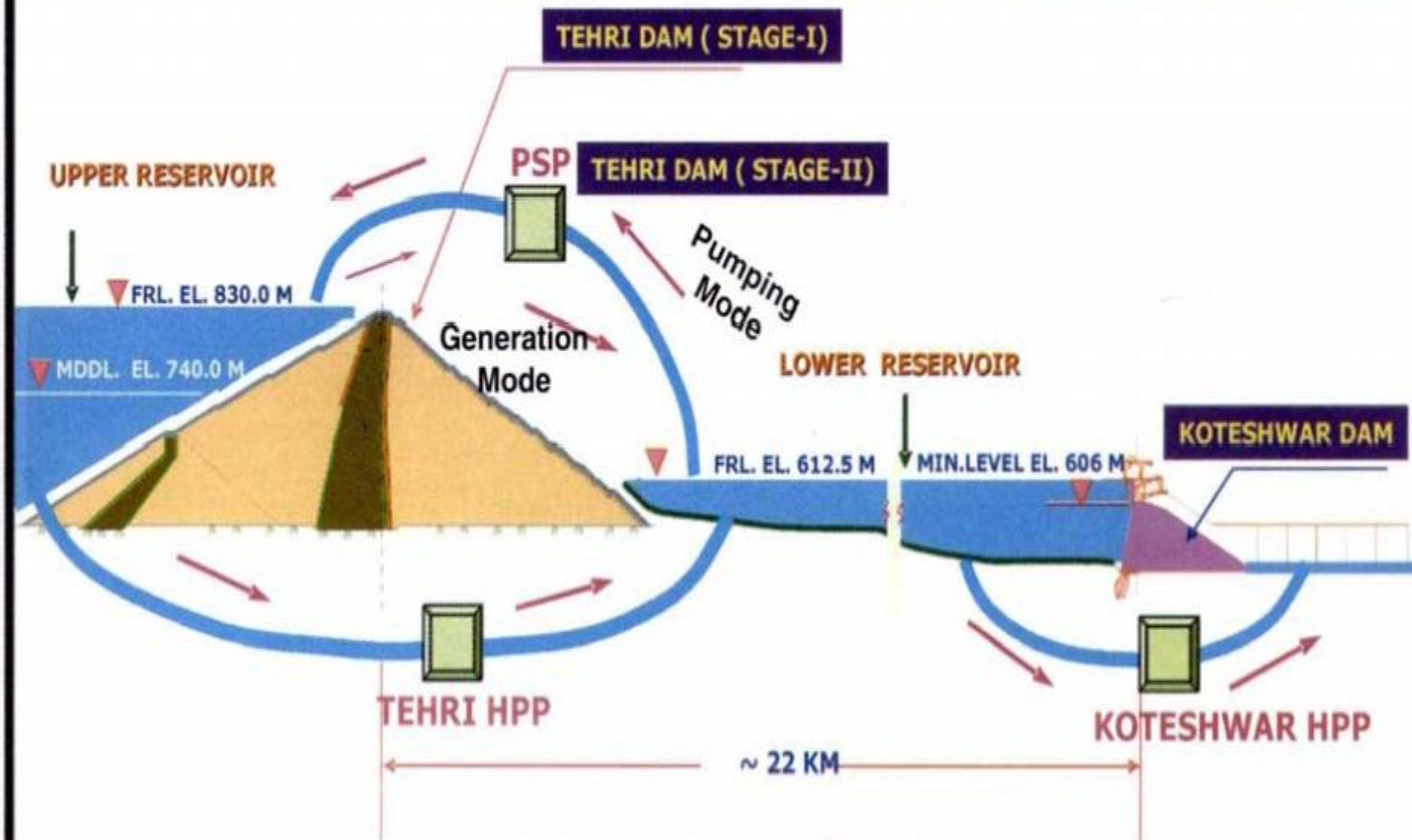
Tehri Hydro Power Complex (2400MW) is a multipurpose project conceived & designed to store surplus water of the river Bhagirathi during monsoon and releasing stored water after monsoon according to irrigation requirement of UP State and drinking water requirement of UP & Delhi States in addition to provide peaking support to Northern grid. Tehri Hydro Power Complex (HPC) comprises of :

- Tehri HPP (4x250 MW) - Under Operation.
- Koteshwar HEP (4x100 MW) - Under Operation.
- Tehri PSP (4x250 MW) - Under Construction

An Overview

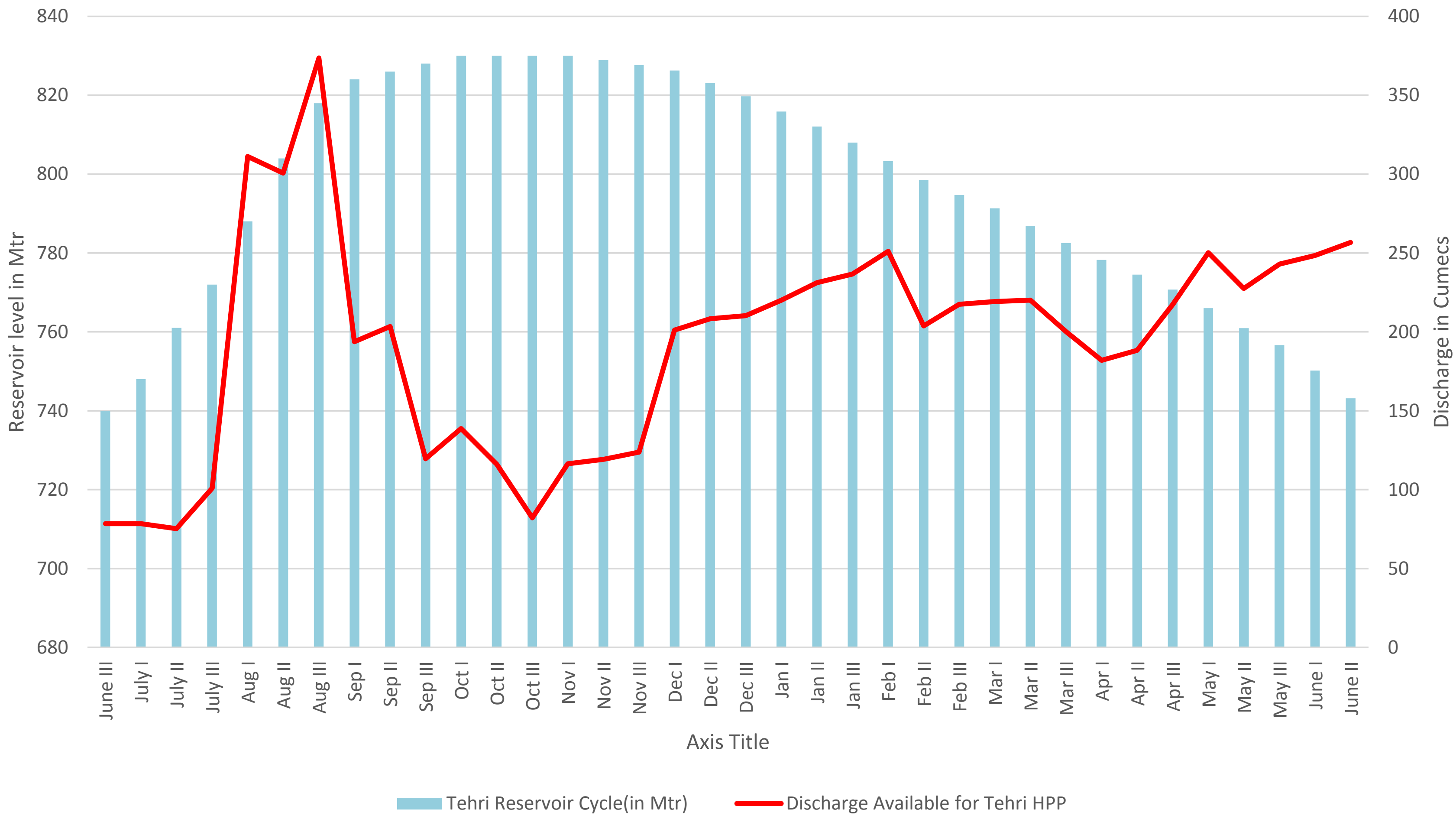
- Tehri Dam is an Earth and Rock fill type storage dam with live storage capacity of 2615MCM.
- Koteshwar Dam, located at about 22km downstream of Tehri Dam, is a Concrete dam with live storage capacity of 35MCM.
- Tehri reservoir stores excess water of River Bhagirathi during monsoon period whereas Koteshwar reservoir serves the purpose of daily regulation of water released from Tehri reservoir.
- After commissioning of Tehri PSP, Koteshwar reservoir will also function as lower reservoir for the Pump Storage Plant.

TEHRI HYDRO POWER COMPLEX



L-SECTION OF TEHRI HYDRO POWER COMPLEX
(UPPER AND LOWER RESERVOIRS)

Tehri Reservoir Cycle 10-Daily Basis During Year and Discharge Available for Machines (Based of 90% Dependable year data)



NOTE: Presently, maximum allowable filling of reservoir is EL 825.00Mtr

Hypothesis for Tehri PSP Operation

Non Monsoon Period (270 Days)	7 hours of pumping has been estimated during off peak hours while the volume of pumped water could be "turbined" during the peak hours of the day, with nominal power foreseen in turbine mode.
Monsoon Period (100 days)	Extra discharge due to rain falls, no pumping is needed.

Source: DPR of Tehri PSP

Integrated Operation Calculation

A. Capacity of balancing Reservoir for Tehri PSP (Operating range EL 606m to 612m)

i) Reservoir Capacity = 612-606 m = 6 mtr

ii) Capacity of reservoir / mtr = 2.6 MCM

iii) Gross Capacity Available = 15.6 MCM

Integrated Operation Calculation

B. Pumping Mode

Pumping Discharge Data of Tehri PSP/Machine = 110 Cumecs (109.5 at nominal net Head)

Discharge Data of Koteshwar HEP/Machine = 155 Cumecs (157.93 As per Design)

Time Required for emptying balancing reservoir while 04 Machines of PSP in Pumping mode and 01 unit of KHEP in Generating mode :

Let the time required is 'T'

Volume of water pumped back by Tehri PSP= Tx(4x110x3600)/10^6 =T x 1.584 MCM

Volume of water release by KHEP = Tx(1x155x3600)/10^6 = Tx 0.558 MCM

Net volume of Water evacuated from balancing reservoir = Tx(1.584+0.558) MCM

= Tx 2.142

Time Required to evacuate = Tx2.142=15.6 MCM

T = 7:16:58 hrs

Integrated Operation Calculation

C. Generating Mode

Discharge Data of Tehri HPP/Machine =150 Cumecs (146 As per Design)
Discharge Data of Tehri PSP/Machine =150 Cumecs(146.9 As per Design)
Discharge Data of Koteshwar HEP/machine = 155 Cumecs (157.93 As per Design)

Time Required to refill balancing reservoir while all 08 Machines of Tehri HPP & PSP and 01 unit of KHEP in Generating Mode :

Let the time required is 't',

Volume of Water Release in t hrs from Tehri HPP and PSP = tx(8x150x3600)/10^6 = t x 4.32MCM

Volume of Water Release in t hrs from Koteshwar HEP = tx(1x155x3600)10^6 =t x 0.558 MCM

Net Volume=tx(4.32-0.558) = tx3.762 MCM

Time Required=tx3.762 =15.6

t = 4:08:48 hrs

Integrated Operation Calculation

C(i). Generating Mode to increase Peaking Time:

Time Required to refill balancing reservoir while all 08 Machines of Tehri HPP & PSP and 04 unit of KHEP in Generating Mode :

Let the time required is t',

Volume of Water Release in t' hrs from Tehri HPP and PSP = t'x(8x150x3600)/10^6 = t' x 4.32MCM

Volume of Water Release in t' hrs from Koteshwar HEP = t'x(4x155x3600)10^6 =t'x 2.232 MCM

Net Volume=t'x(4.32-2.232) = t'x2.088MCM

Time Required=t'x2.088 =15.6

t' = 7:28:17 hrs

Outcome

For Integrated operation of Tehri PSP,HPP and Koteshwar HEP:

Total time required in one cycle = T+t = 7:16:58 + 4:08:48 hrs

=11:25:47 hrs

(i.e 1.75 hrs. Pumping ≈ 1 hr. Generation)

Note: i) Pumping mode considered for Nominal Net Head of 188 Mtr consuming 205 MW in above calculations.

ii) For the purpose of Energy calculation for RE integration, an average of two cycles of Pumping per Day for approx. 300 Days (off monsoon) in a Year might be supported by Tehri PSP. However, planned outages for maintenance are not taken into consideration.

iii) Micro level planning for Koteshwar scheduling will be required to achieve desired Plant Utilisation Factor.

Issues & Challenges in O&M of Tehri PSP

Sr.No	Issues/Challenges	Proposed Suggestions
01	Tariff calculation & COD was first time introduced in Tariff regulation 2009-14 in detail with generalized approach	IEGC should also be revised considering present scenario of power system and projects constraints.
02	Generating station shall be required to declare its machine availability daily on day ahead basis for all the time blocks of the day in line with the scheduling procedure of Grid Code	However, scheduling shall be entirely depend on margin available in balancing reservoir, hence, provision for flexible scheduling shall be devise in IEGC for PSP
03	Tariff regulation 2014-19 Chapter – 7 Computation of Capacity Charges and Energy Charges Clause 32(5) detailed regarding inflow and its utilization.	case of Common reservoir, accounting of inflow and operation of PSP is entirely different, such scenario shall also be included. Accordingly NRLDC should incorporate necessary provision exclusively for multipurpose hydro projects . Also flexible scheduling shall be devised for such Power Complex .

Issues & Challenges in O&M of Tehri PSP

Sr.No	Issues/Challenges	Proposed Suggestions
04	Central Electricity Regulatory Commission (Indian Electricity Grid Code) (Fifth Amendment) Regulations, 2017. Regulation 5.2 (h) of Part 5 of the Principal Regulations	This amendment restricts the maximum capacity utilization of Generating stations and same will also increase the generating mode operation of Tehri PSP for generating the same MU, hence cycle time for the PSP operation may get affected.

Thank You

Meeting on operationalization of existing pump storage plants (PSPs)
NRPC, New Delhi – 28th June 2017

ECONOMIC VALUE OF PUMPED STORAGE IN A POWER SYSTEM WITH SOLAR PV

Anoop Singh, Kalpana Singh & Parul Mathuria
Dept. of Industrial and Management Engineering
Indian Institute of Technology Kanpur

ISSUES WITH GROWTH OF RENEWABLE ENERGY SOURCES

- Variable renewable energy (VRE) sources like wind and solar are variable and intermittent
- Lack of coincidence with the demand pattern
- Location specific

HOW TO ADDRESS THIS

i. Better RE forecasting

ii. Better load forecasting

iii. Load shifting

iv. Energy Storage

- Energy storage systems (ESS) store the surplus generation, utilize it during times of low or no generation

LITERATURE SURVEY

i. **Black and Strbac (2007)** – quantified storage value, determined fuel costs for conventional and wind generation systems

ii. **Brown and Lopes et al (2008)** – value of pump quantified as the reduction it causes in fuel costs and dynamic reserves it provides

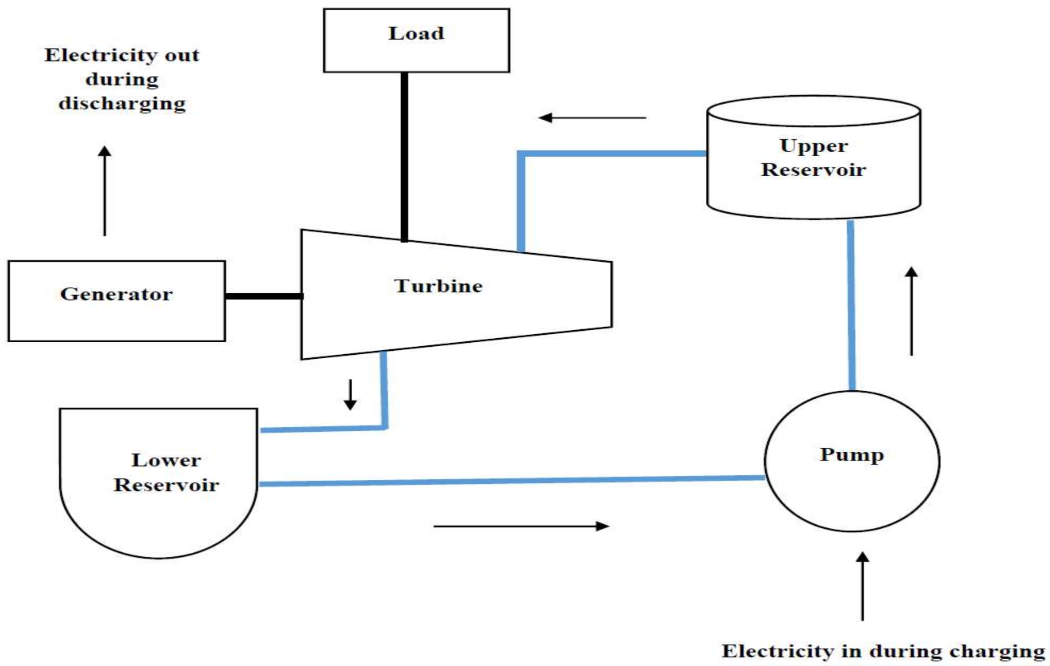
iii. **Schill and Kemfert et al (2011)** – game theoretical model in an imperfect market setting

iv. **Takaagi Masaaki et al (2013)** – marginal value of storage system in an optimal generation mix model

v. **Denholm Paul et al (2013)** – overall system operations cost with and without storage

vi. **De Siaternes et al (2016)** – storage value quantified in terms of reduction in CO_2 emissions

PUMPED HYDRO ENERGY STORAGE



A pumped hydro storage unit

PUMPED HYDRO ENERGY STORAGE (PHES) SYSTEMS

- Well established commercially available storage technology
- Stores and produces electricity from a hydroelectric plant
- Water discharge from upper to lower reservoir during generation
- Water pumped back to upper reservoir from lower to store electricity
- Quick start up and shut down with tighter ramping capabilities
- Ability to track load changes and adapt

Major Pumped Storage Plants in India

Location	State	Capacity (MW)	Year of Commissioning	Upper reservoir capacity (m^3)	Lower reservoir capacity (m^3)
Srisailam	Andhra Pradesh	6 X 150	2001-2003	6.16×10^9	5.44×10^9
Sardar Sarobar	Gujarat	6 X 200	2002-2006	5.8×10^9	5×10^9
Parulia	West Bengal	4 X 225	2007-2008	16.5×10^6	16×10^6
Ghatghar	Maharashtra	2 X 125	2008	5.87×10^6	3.80×10^6
Tehri	Uttarakhand	1000	2006	4×10^9	$.89 \times 10^9$

OBJECTIVES

1. To evaluate the economic value of ESS like Pumped Energy Storage System in a PV dominated power system
2. A unit commitment power system model is setup to analyse the impact of ESS for VRE source dominated power system.
3. Apply to a 6-bus test case and 30-bus IEEE system

METHODOLOGY

- Security Constrained Unit Commitment (SCUC) model determines optimal order of operation of power generators with the objective of cost minimization while maintaining certain constraints.
- Mixed integer non-linear problem (MINLP) formulated in GAMS
- A model characterizing a power system with PV generating unit, thermal units and pumped hydro energy storage (PHES) unit with two scenarios,

i. without pumping action of pumped hydro unit

ii. with pumping action of pumped hydro unit

METHODOLOGY

- SCUC model developed with following constraints:

i. Power balance

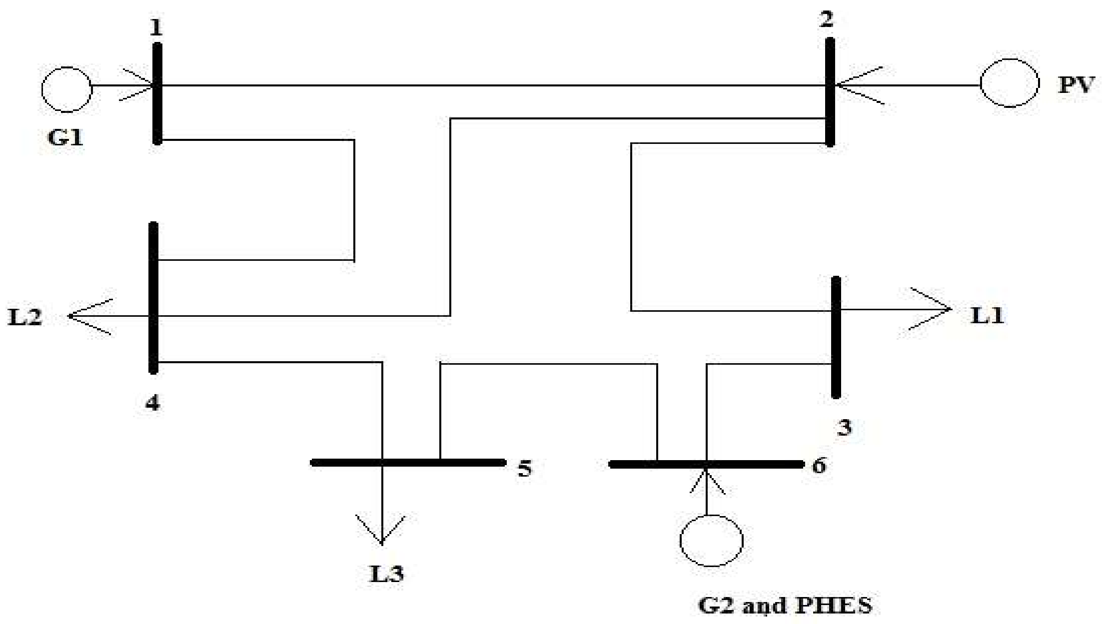
ii. Power generation capability limits of units

iii. Ramp rate limits

iv. Minimum up-time and down-time constraints

v. Transmission flow limits of lines

CASE STUDY – 6-bus test system

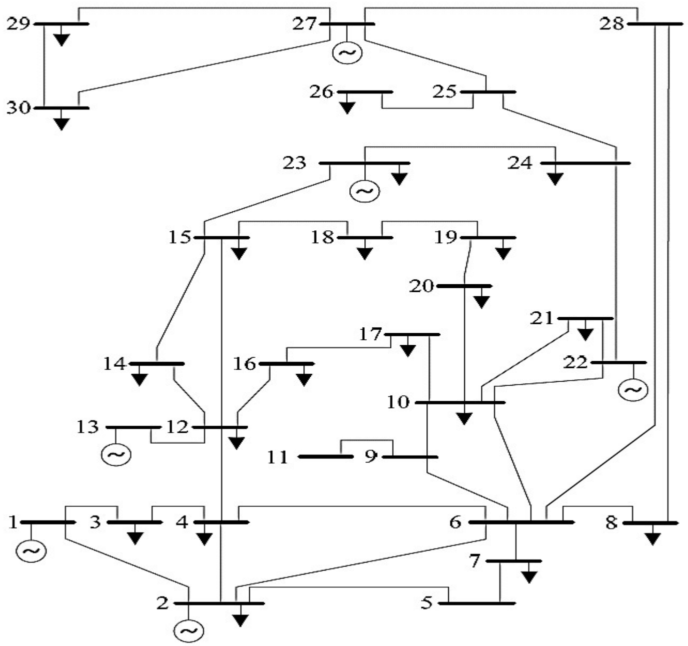


Line diagram of 6-bus test system

SYSTEM CHARACTERISTICS OF 6-BUS TEST MODEL

- The 6-bus test system has :
- 2 thermal units – one coal fired and one gas fired
- 1 PV generating unit
- 1 PHES unit
- Seven transmission lines

30-bus IEEE standard system



Line diagram of 30-bus standard IEEE system

System characteristics of 30-bus IEEE standard system

- It has 6 generators
- 3 thermal generators – 2 coal based and one gas based
- 2 PV generators
- 1 PHES unit
- 41 transmission lines

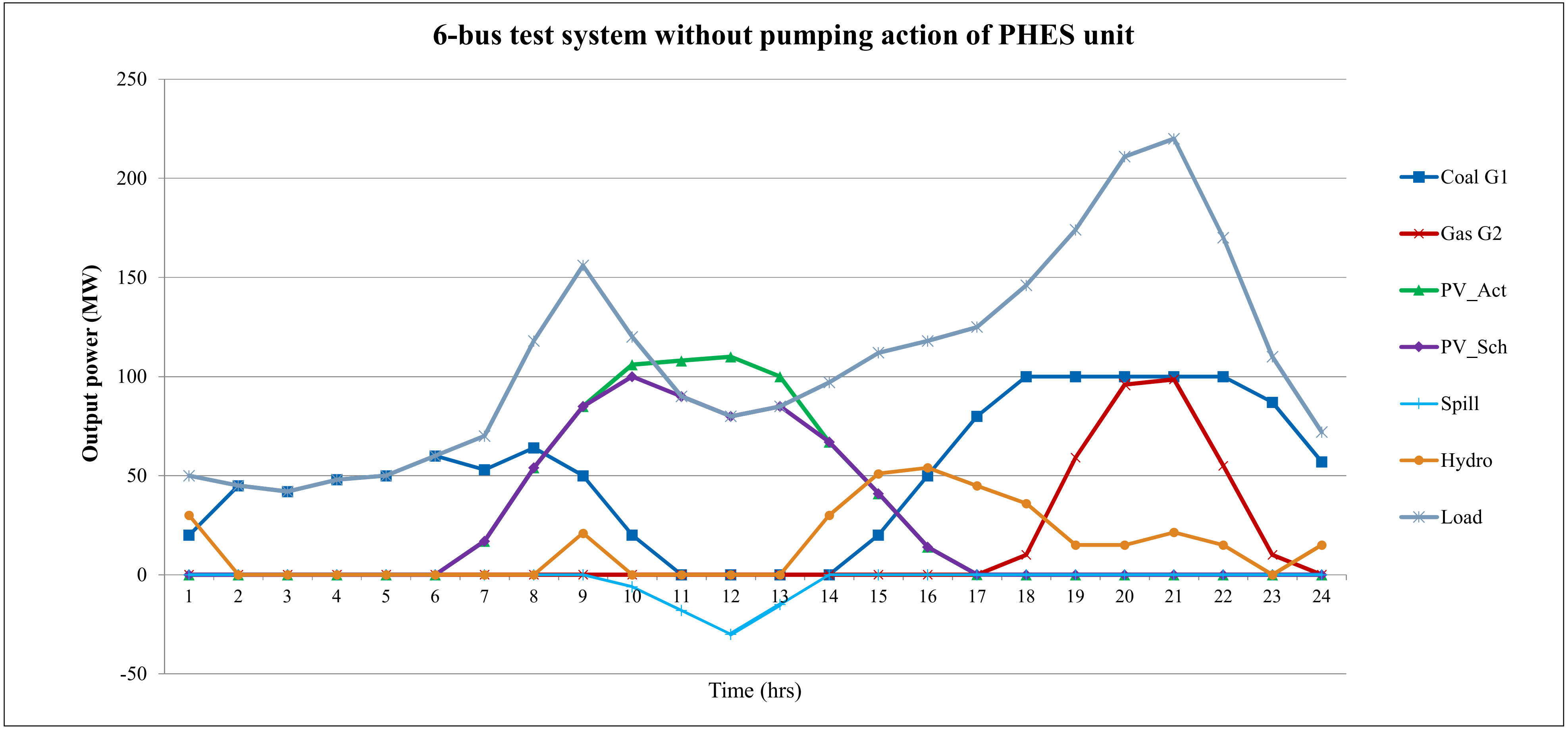
RESULTS

- The short term SCUC analysis for a 24-hour duration is carried on the 6-bus test system and 30-bus standard system
- Model formulated was setup in GAMS , solved using SBB solver
- The results compared two actions of PHES unit:

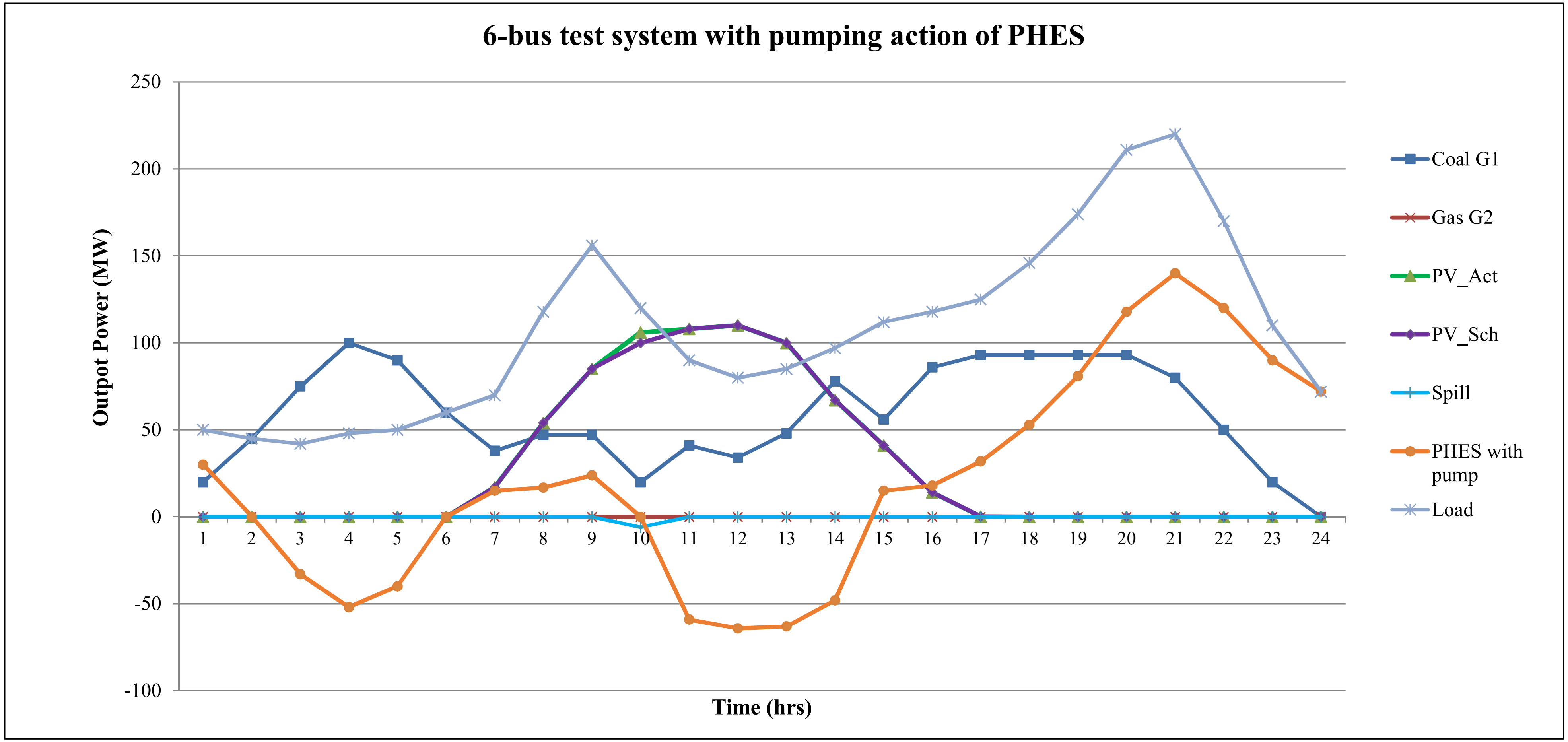
I. Without pumping mode of PHES

II. With the pumping action of PHES

6-bus system without pump



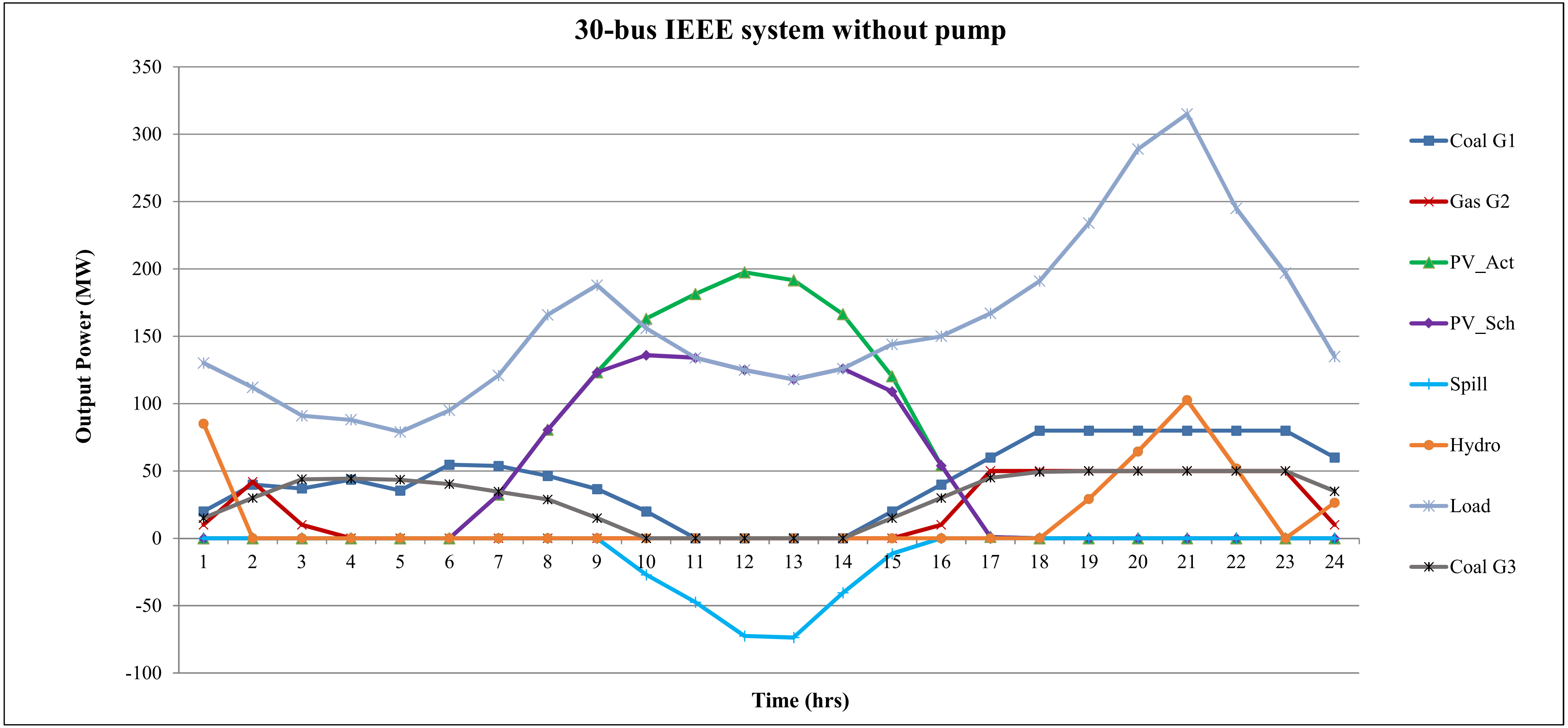
6-bus system with pump



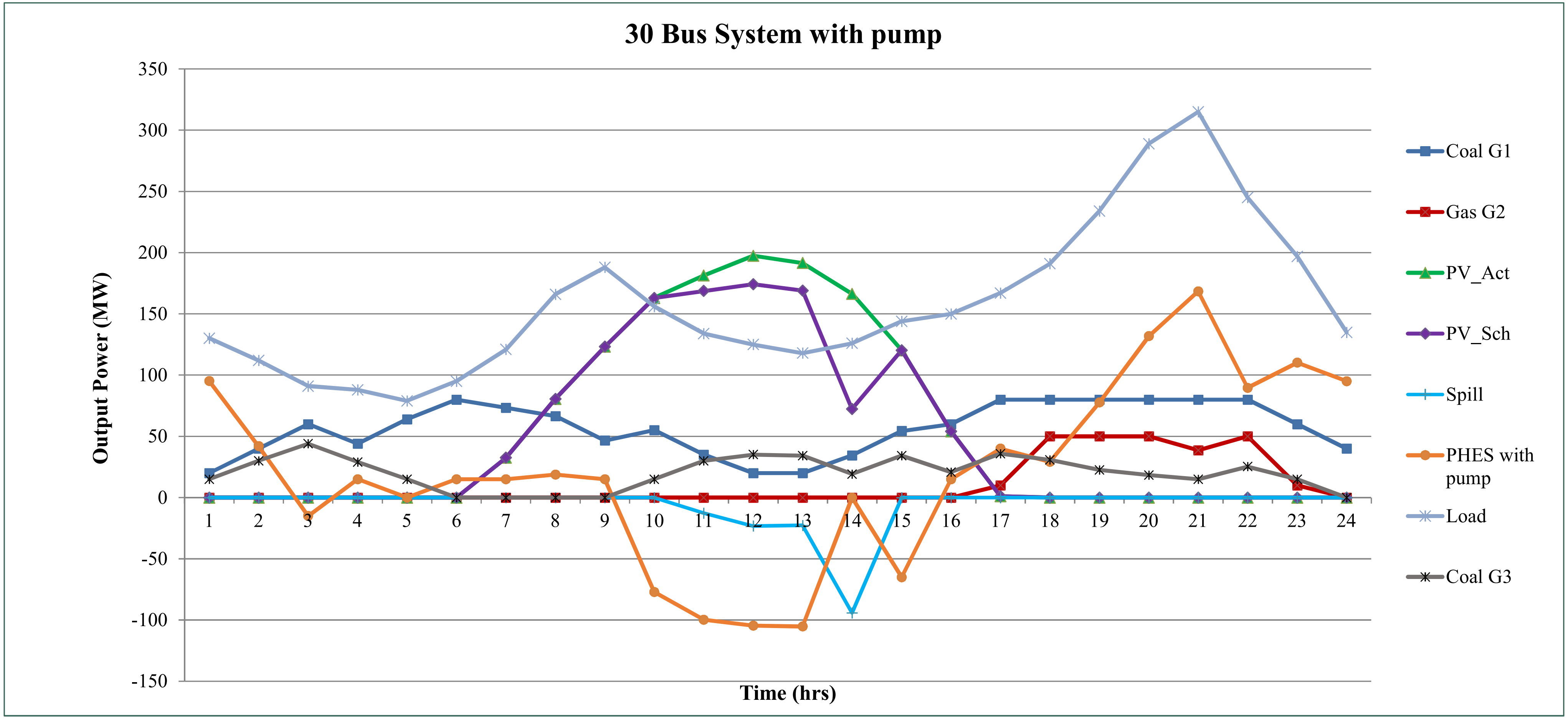
Output results for 6-bus test system

		Without pump	With pump
Total cost of operation (million Rs.)		2.87	2.11
Total generation from thermal units	Coal Unit G1 (MU)	1246	1407
	Gas Unit G2 (MU)	328.5	0
Total Cost of generation from thermal units	Coal Unit G1 (million Rs.)	1.86	2.11
	Gas Unit G2 (million Rs.)	0.88	0
Total load shed (MU)		13	0
Cost of load shedding (million Rs.)		130	0
Per unit cost of system operation (Rs./MWh)		1120	822.4
Per unit cost of energy served (Rs./MWh)		1074.8	822.4

30-bus IEEE STANDARD SYSTEM WITHOUT PUMP



30-Bus IEEE standard system with pump



Output results for 30-bus IEEE STANDARD system

		Without pump	With pump
Total cost of operation (million Rs.)		5.57	3.72
Total generation from thermal units	Coal Unit G1 (MU)	1047	1353
	Gas Unit G2 (MU)	432	258
	Coal Unit G3 (MU)	720	484
Total Cost of generation from thermal units	Coal Unit G1 (million Rs.)	1.55	1.9
	Gas Unit G2 (million Rs.)	1.1	0.66
	Coal Unit G3 (million Rs.)	1.14	0.8
Total load shed (MU)		170	33
Cost of load shedding (million Rs.)		1700	330
Per unit cost of system operation (Rs./MWh)		1468	980.4
Per unit cost of energy served (Rs/MWh)		1068.5	901.3

ECONOMIC VALUE OF PUMPED STORAGE

- Assessment of the economic value of pumped storage in the defined power systems
- Assumptions : same SCUC operation and same demand pattern throughout the year
- Life of PHES unit – 30 years
- Discount rate – 15%

6-bus test system	Overall system operation cost without penalty		Overall system operation cost with penalty	
Daily cost of operation (million Rs.)	Without pump	With pump	Without pump	With pump
	2.74	2.11	2.87	2.11
Savings / year (million Rs.)	231		279	
Present value (million Rs.)	1748		2107	
Value of pump facility (million Rs./MW)	8		9.6	

Thus the pumping facility of a hydro unit adds a value equivalent to 9.6 million Rs/MW and 8 million Rs/MW excluding the penalty costs

30-bus IEEE system	Overall system operation cost without penalty		Overall system operation cost with penalty	
Daily cost of operation (million Rs.)	Without pump	With pump	Without pump	With pump
	3.87	3.4	5.57	3.72
Savings / year (million Rs.)	176		676	
Present value (million Rs.)	1330		5107	
Value of pump facility (million Rs./MW)	6		23	

Thus the pumping facility of a hydro unit adds a value equivalent to 23 million Rs/MW and 6 million Rs/MW excluding the penalty costs

CONCLUSIONS

- Spillage reduced by 91% in 6-bus test system, by 44% in 30-bus IEEE standard system
- In a 6-bus test system, presence of pump reduced cost by 26.5 % and by 23.48% excluding the penalty cost
- Translates to present value of Rs. 9.6 million /MW including and Rs. 8 million/MW without the cost of unserved energy
- In a 30-bus test overall reduction of 33.24% in the cost of system operations (with pump) and 15.6% without the penalty costs
- The present value of pumped storage facility is Rs. 23.2 million /MW and Rs. 6 million /MW without the penalties.
- Study highlights that power system (society) is loosing economic benefit of investments made in PHES.
- PHES can help assist Greater penetration for VRE.

Thank You

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Selected Readings

- "Power Sector Reform in India: Current Issues and Prospects", Energy Policy, Elsevier, Volume 34, Issue 16, November 2006.
- http://dx.doi.org enter the following doi:10.1016/j.enpol.2004.08.013
- "Towards a Competitive Market for Electricity and Consumer Choice in Indian Power Sector", Energy Policy Vol. 38 4196-4208, 2010. (Elsevier)
- http://dx.doi.org enter the following doi:10.1016/j.enpol.2010.03.047

Selected Readings

- Anoop Singh, Tooraj Jamasb, Rabindra Nepal, and Michael Toman, Cross-Border Electricity Cooperation in South Asia, World Bank Policy Research Working Paper (PRWP), #WPS7328, 2015.
- Anoop Singh, Jyoti Parikh, K.K. Agrawal, Dipti Khare, Rajiv Ratna Panda and Pallavi Mohla, "Prospects for Regional Cooperation on Cross-Border Electricity Trade in South Asia", 2013, IRADe, New Delhi
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- "Power Sector Reform in India: Current Issues and Prospects", Energy Policy, Elsevier, Volume 34, Issue 16, November 2006.

Courses, Workshops and Conferences

- Short Term Course “Challenges and Implementation Issues post Electricity Act 2003: Regulatory, Policy & Technical Solutions”, 10-14 April, 2004
- International Conference on “Power Market Development in India: Reflections from International Experience”, 19-21 April, 2005
- National Workshop on “Project Financing for Energy and Infrastructure Sector”, April 19-22, 2007
- 2nd National Workshop on “Project Financing for Energy and Infrastructure Sector”, April 24-27, 2008
- Capacity Building Programme for Officers of Electricity Regulatory Commissions, 30th June - 5th July, 2008

Courses, Workshops and Conferences (contd.)

- 2nd Capacity Building Programme for Officers of Electricity Regulatory Commissions, 3-8 August, 2009
- 3rd Capacity Building Programme for Officers of Electricity Regulatory Commissions, 23-28 August, 2010
- Energy Conclave 2010, 8-15 Jan. 2010
- 4th Capacity Building Programme for Officers of Electricity Regulatory Commissions, 18-23 July, 2011
- 5th Capacity Building Programme for Officers of Electricity Regulatory Commissions, 18-23 Oct., 2012

Further Readings

- "Analysing Efficiency of Electric Distribution Utilities in India: a Data Envelopment Analysis" (with Dilip Kumar Pandey), IAEE International Conference, Stockholm 19-23 June, 2011.
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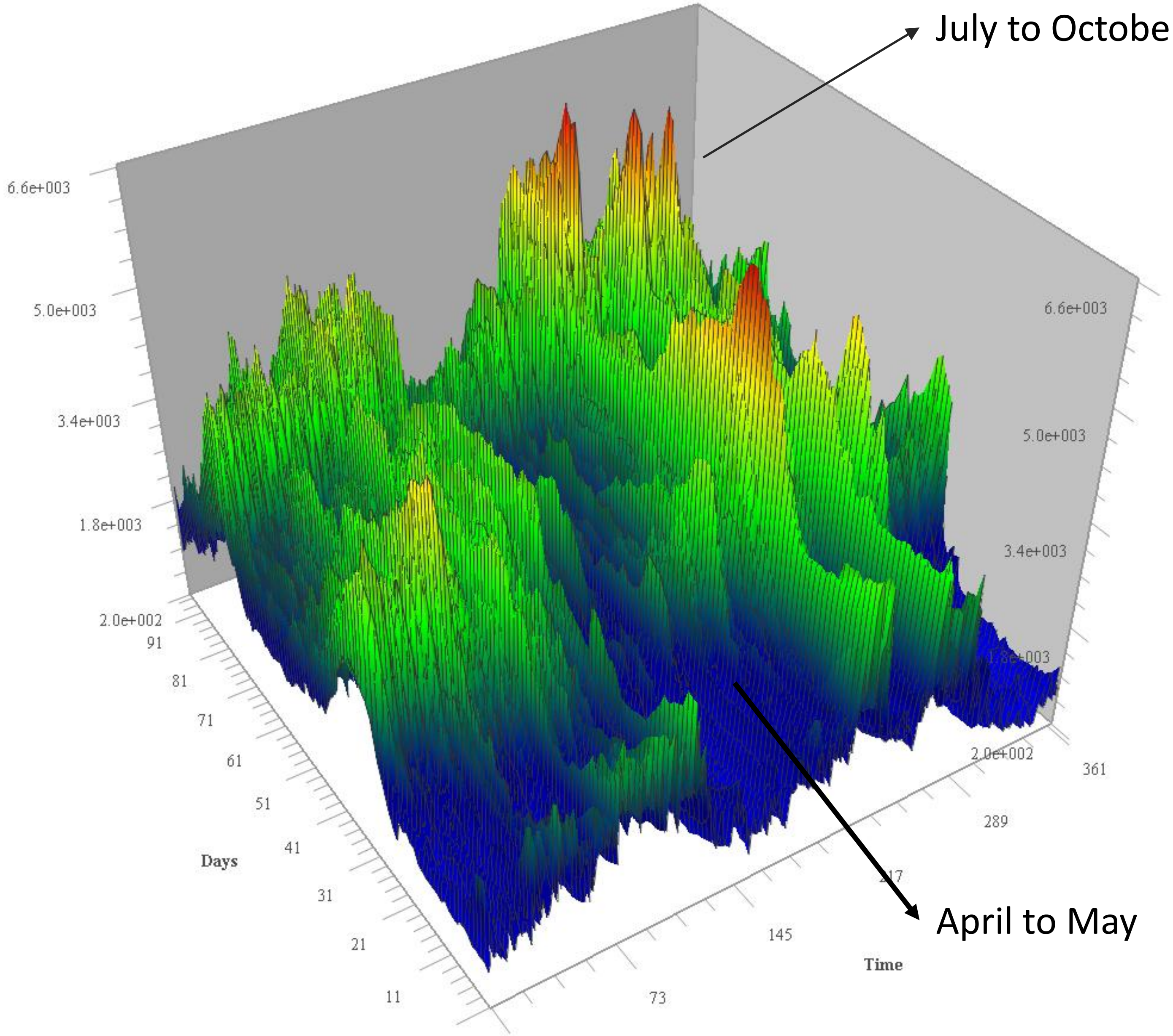
For ppts of above programs, visit

www.iitk.ac.in/ime/anoops

PUMPED STORAGE PLANTS
IN
SOUTHERN REGION

SR Hydro Jan 2016 to Dec 2016

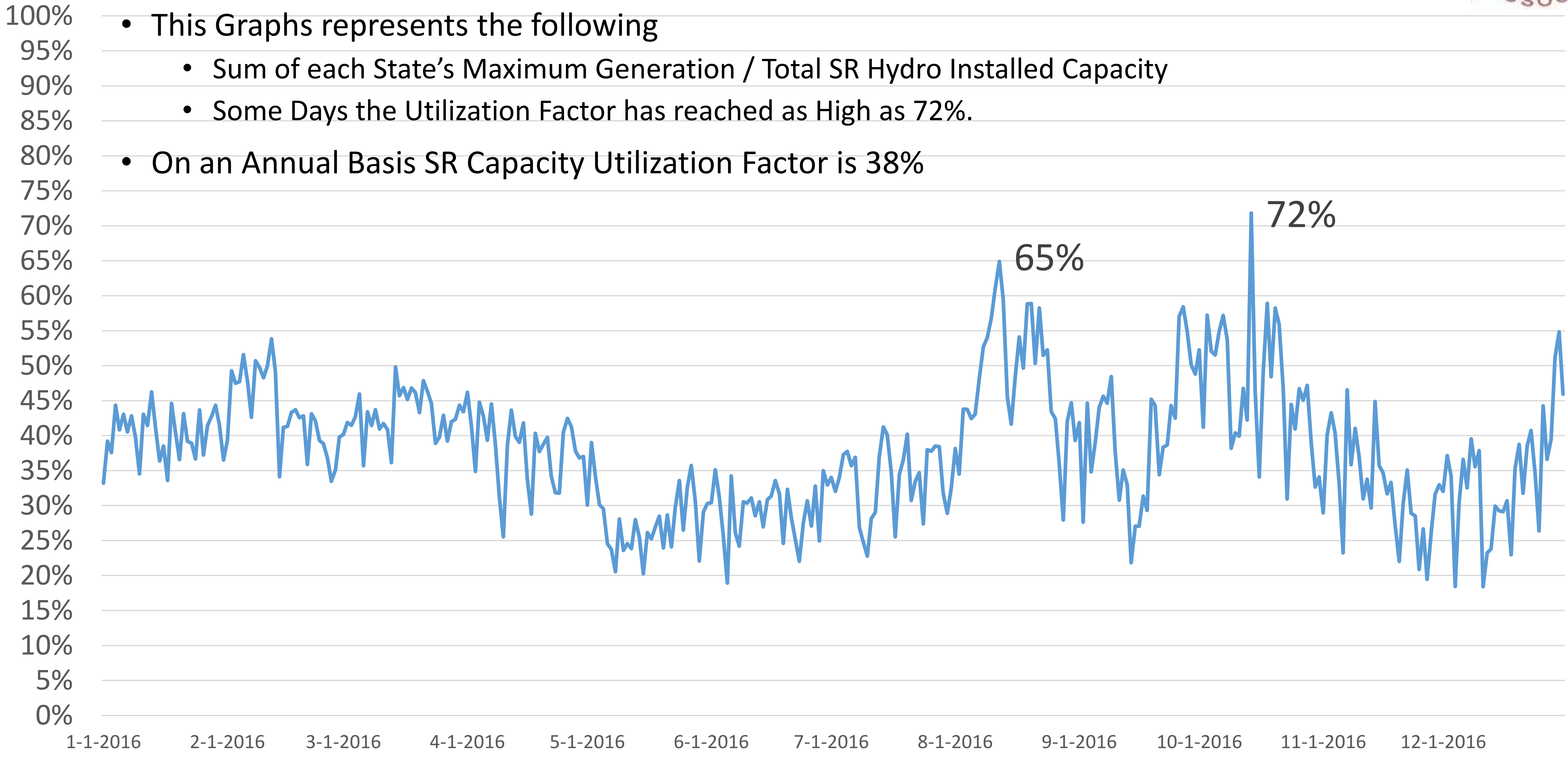


- Southern Regional Hydro is Highly Monsoon Dependent
- Hydro is Mostly utilized for the morning and the Evening Ramps
- During Summer due to depletion of Reservoir Levels less generation
- During Monsoon higher generation to avoid spillage

- MAXIMUM GENERATION: 6681 MW

Hydro Maximum VS Installed Capacity

- This Graphs represents the following
  - Sum of each State’s Maximum Generation / Total SR Hydro Installed Capacity
  - Some Days the Utilization Factor has reached as High as 72%.
- On an Annual Basis SR Capacity Utilization Factor is 38%

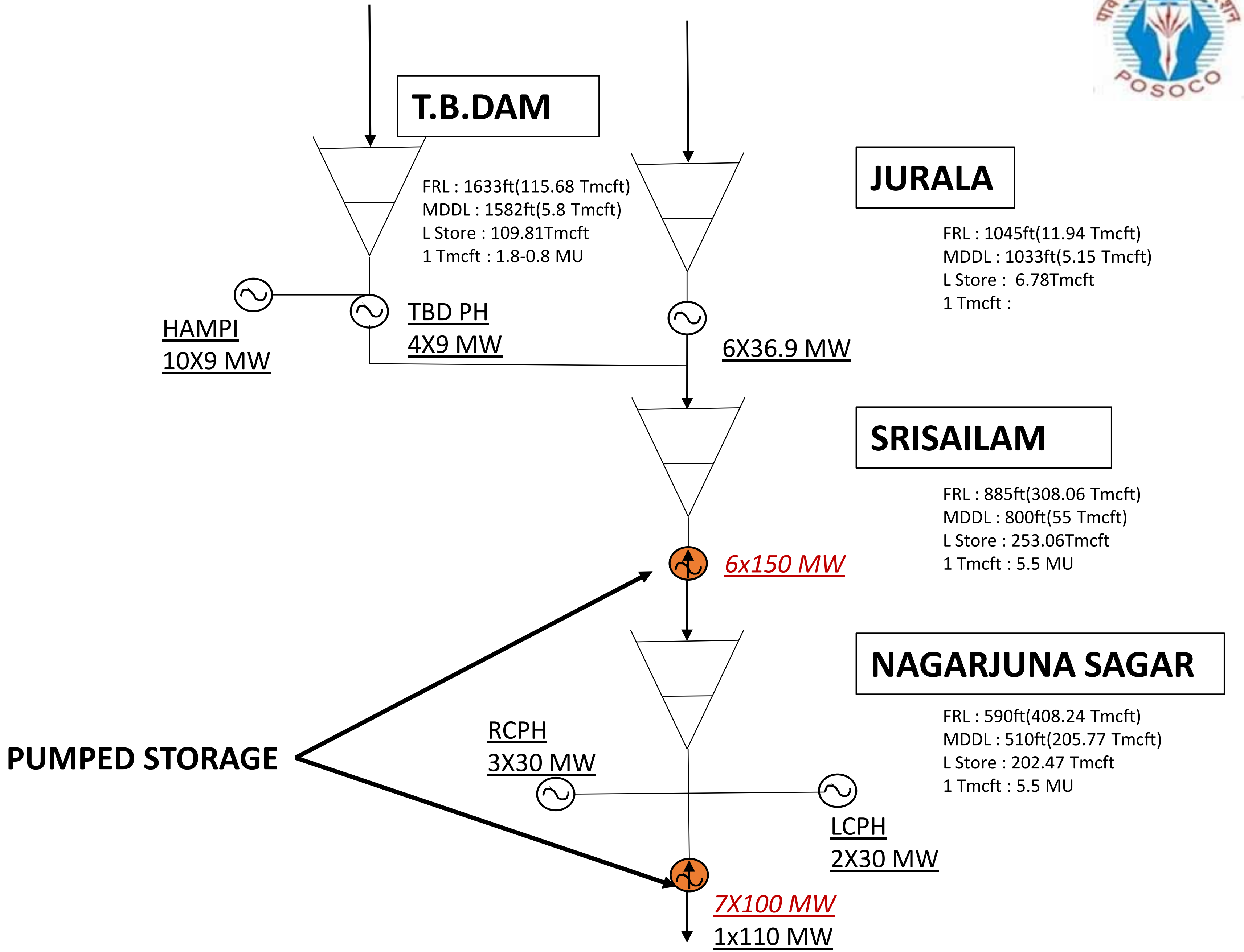


PUMPED STORAGE INSTALLED CAPACITY IN SR

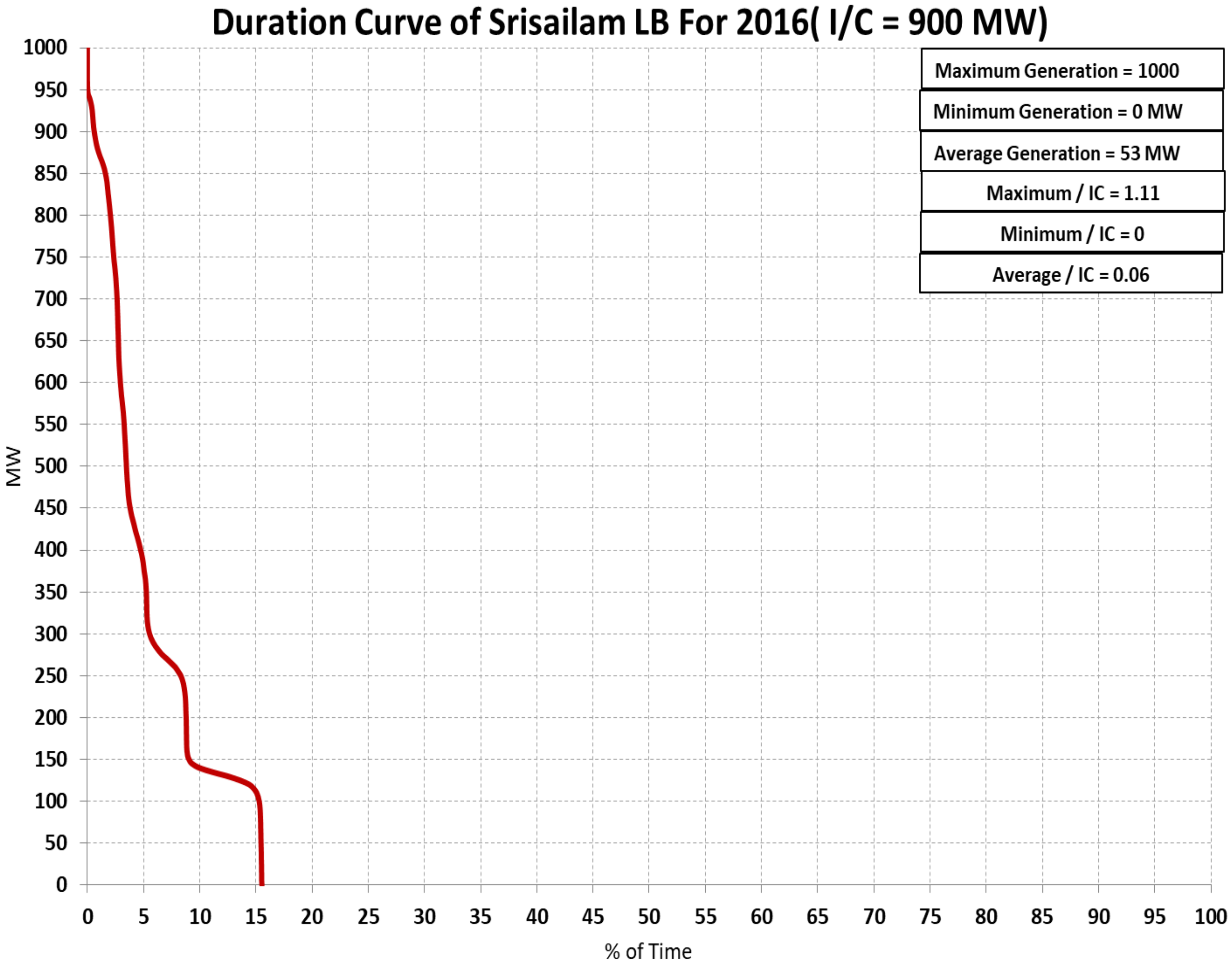
- SRISAILAM LB :
  - Krishna River , Telangana
  - 900 MW (6 X 150 MW)
- NAGARJUNSAGAR :
  - Krishna River , Telangana
  - 705.6 (7 X 100.8 MW)
- KADAMPARAI :
  - Kadamparai River, Tamil Nadu
  - 400 MW (4 X 100 MW)

- TOTAL SR CAPACITY : 2005 MW

KRISHNA BASIN HYDRO MAP



SRISAILAM LB



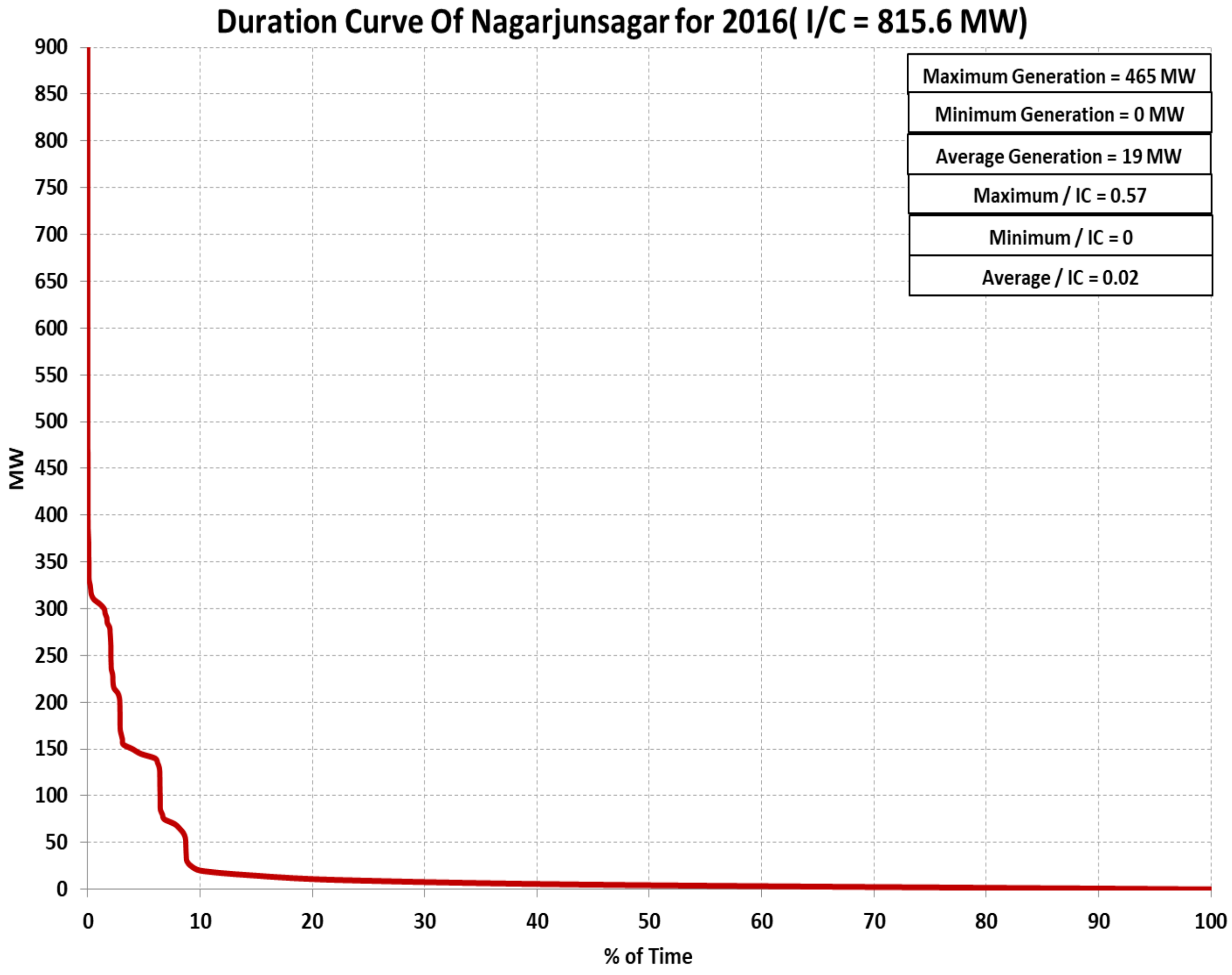
- **Turbine Type** : Francis Turbine
  - All Machines can be run in Condenser mode.
    - Time Taken – 3 to 4 Hours with 45 Min. Gap
  - No hurdles faced due to Upstream flow, Balancing reservoir, etc.
- **Irrigation Requirement** : Usually During Summers on the request 3.5 MU/ Day is being scheduled
- **Transmission Constraint** : No Transmission Constraints
- **Generation Constraint :**
  - Dam is under the control of Krishna Irrigation Dept. In case of additional requirement due to grid conditions, special permission is to be obtained.
  - Cannot be Operated less than 110 MW due to Vibration
  - Pump Operation dependent on Nagarjunsagar Dam Level as Srisailam Tail Race WEIR is under repair
  - No specified limitations on no. of start - stops

Constraints in Operation at Srisailam LB

- 540 ft level was required at Nagarjunasagar for pump mode operation at Srisailam LB. Generally, water is above this level for about 2-3 months in a year.
- There is a weir between Srisailam Reservoir and Nagarjunasagar Reservoir which is used for pumping operation. The weir was not operational since last two years. Attempts to repair the weir have not been successful. Issue had been taken up with CEA/CWC also.

Source: Special Meeting AP & TS on 28.04.2017

Nagarjunsagar HEP (1x110 + 7 x 100 MW)



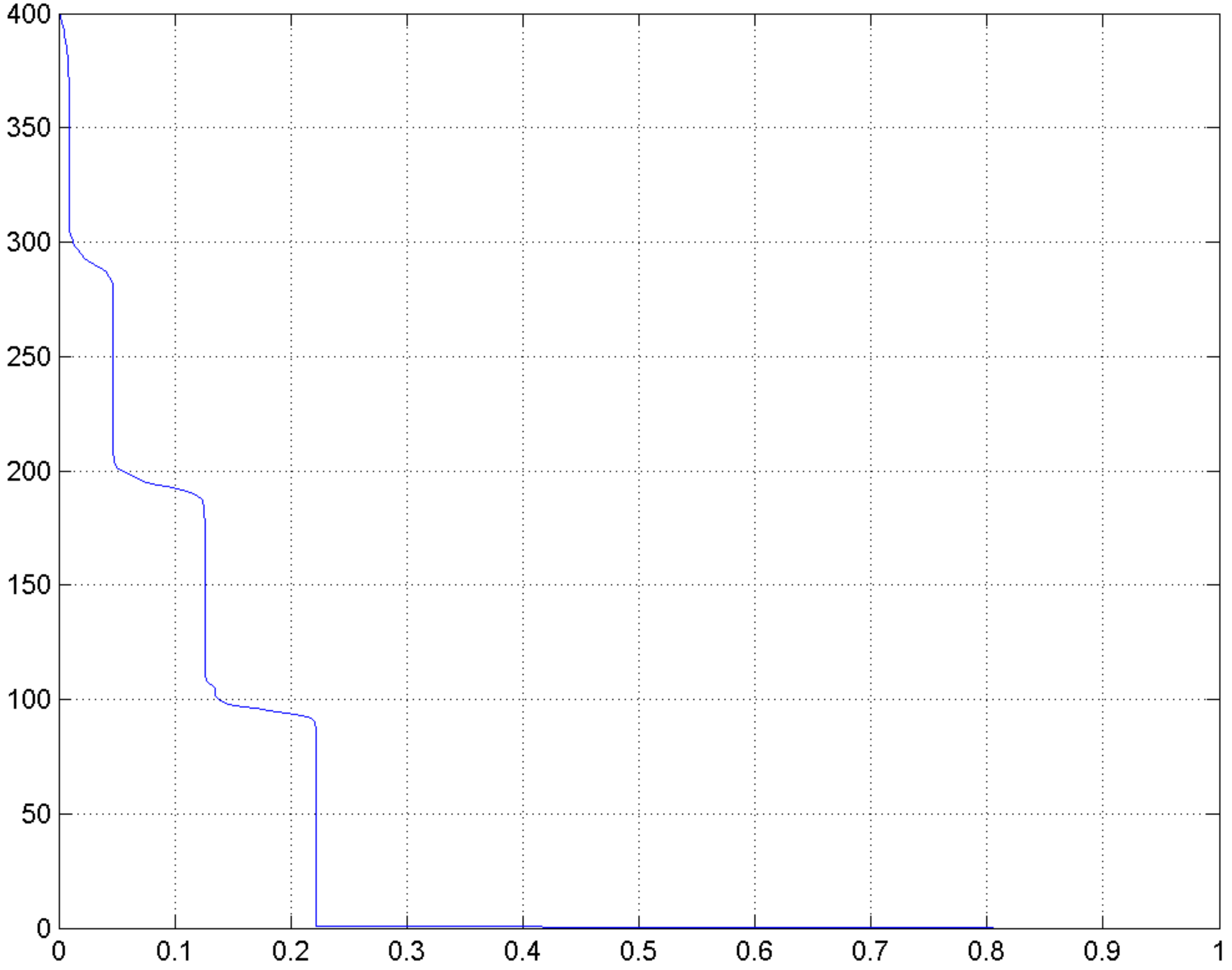
- **Turbine Type** : Francis Turbine
  - All Machines can be run in Condenser mode except U#1.
    - Time Taken –4 min for starting and 8 min for full load
  - No hurdles faced due to Upstream flow, Balancing reservoir, etc.
- **Transmission Constraint** : No Transmission Constraints
- **Generation Constraint :**
  - Dam is under the control of Krishna Irrigation Dept. In case of additional requirement due to grid conditions, special permission is to be obtained.
  - Vibration observed when generation is less than 65 MW for Unit#1 &55 MW for Unit#2 to 8.
  - No specified limitations on no. of of start/stops operations

Constraints in Operation at Nagarjunsagar

- Shifting of lift irrigation pumps to avoid possible submergence
- 7 TMC of water is required in the Tail Pond Reservoir for pumping operation, out of which, 6 TMC was dead storage while one TMC could be utilized for pumping operation
- It was noted that for pumping mode, the level required in Tail Pond Reservoir was higher than the MDDL for 2x25 MW generating station. Further Tail Pond generating station to operate its unit when water level is above the level required for pump mode and whenever discharge was there from main Nagarjunasagar Reservoir
- Each unit takes around 20 – 30 minutes from stand – still to pumping mode.

Source: Special Meeting AP & TS on 28.04.2017

KADAMPARAI HEP (4 X 100 MW)



- **Turbine Type** : Reversible Francis Turbine
- **Irrigation Requirement** :
  - No Irrigation Requirement.
- **Transmission Constraint** :
  - Low Voltage Issues
- **Generation Constraint :**
  - Availability of water

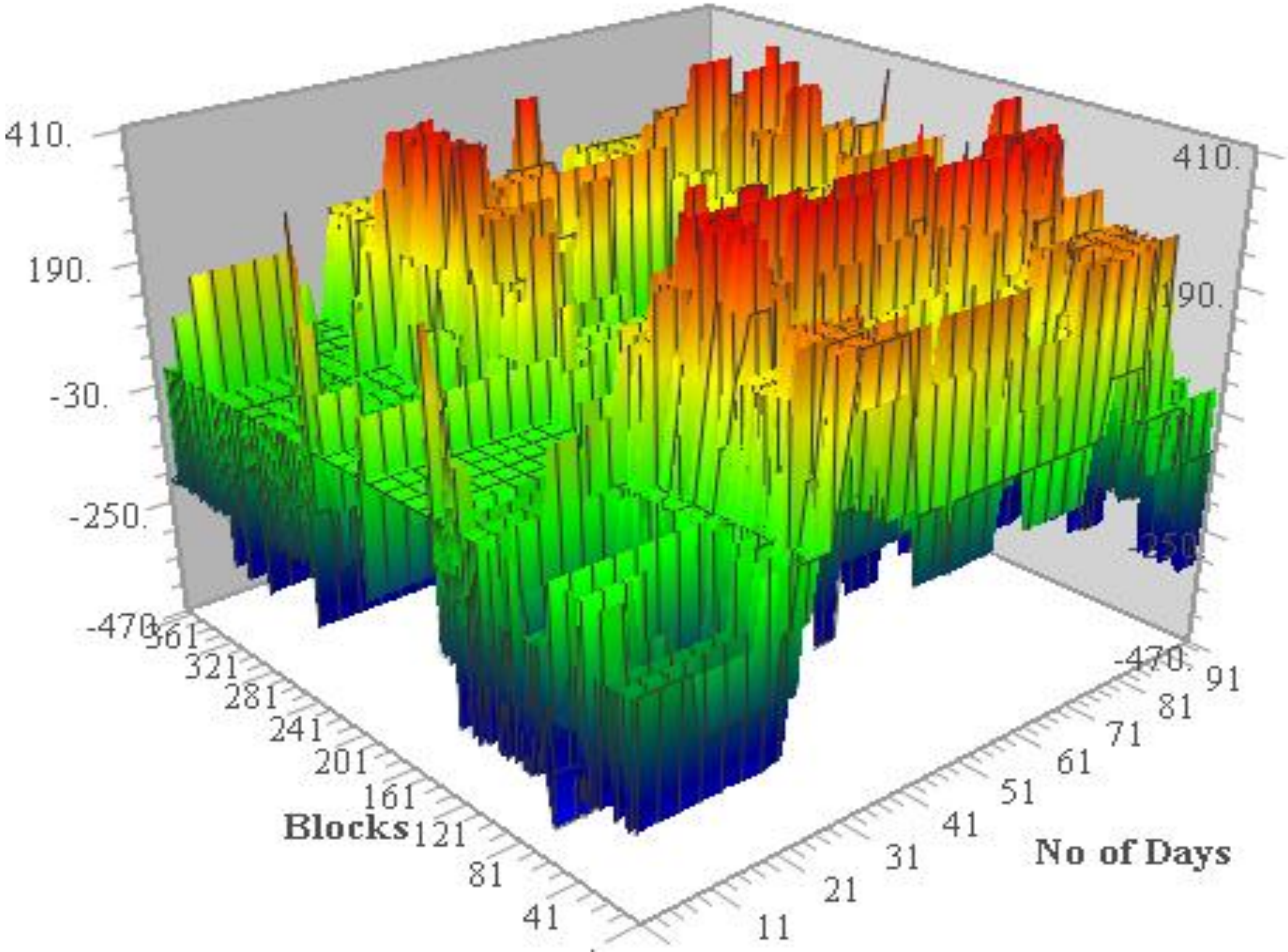
Mode	Condition	Response Time
Generator	Stand still to on-line	5 min
Generator	On-line to full load	Few seconds
Motor	Stand still to Synchronous condenser	9 min
Motor	Synchronous condenser to Pump	1 min

Kadamparai Pumped Storage

- Kadamparai hydroelectric pumped storage plant is located in Anamalai hills in Coimbatore district of Tamil Nadu in Southern Region (SR). Upper reservoir of the plant is Kadamparai dam and Lower reservoir of the plant is lower Aliyar dam
- The power house is located underground with 4 no's of reversible Francis Turbine units each having a generating capacity 100 MW. Index plan of Kadamparai project is shown in

Unit #	Date of Commissioning
1	17.10.1987
2	26.02.1988
3	12.04.1989
4	16.12.1988

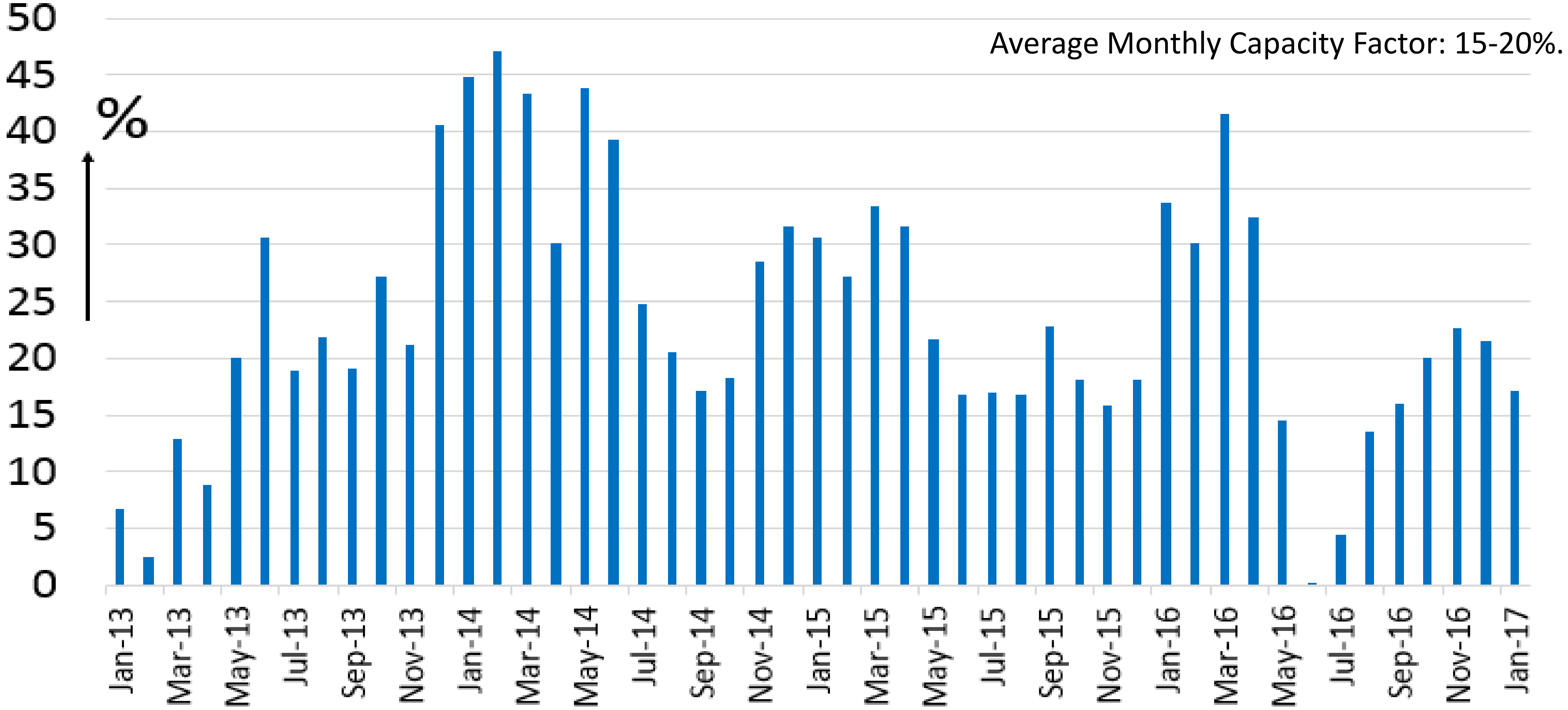
3D Plot of Kadamparai Generation and Pump Operation during 2016

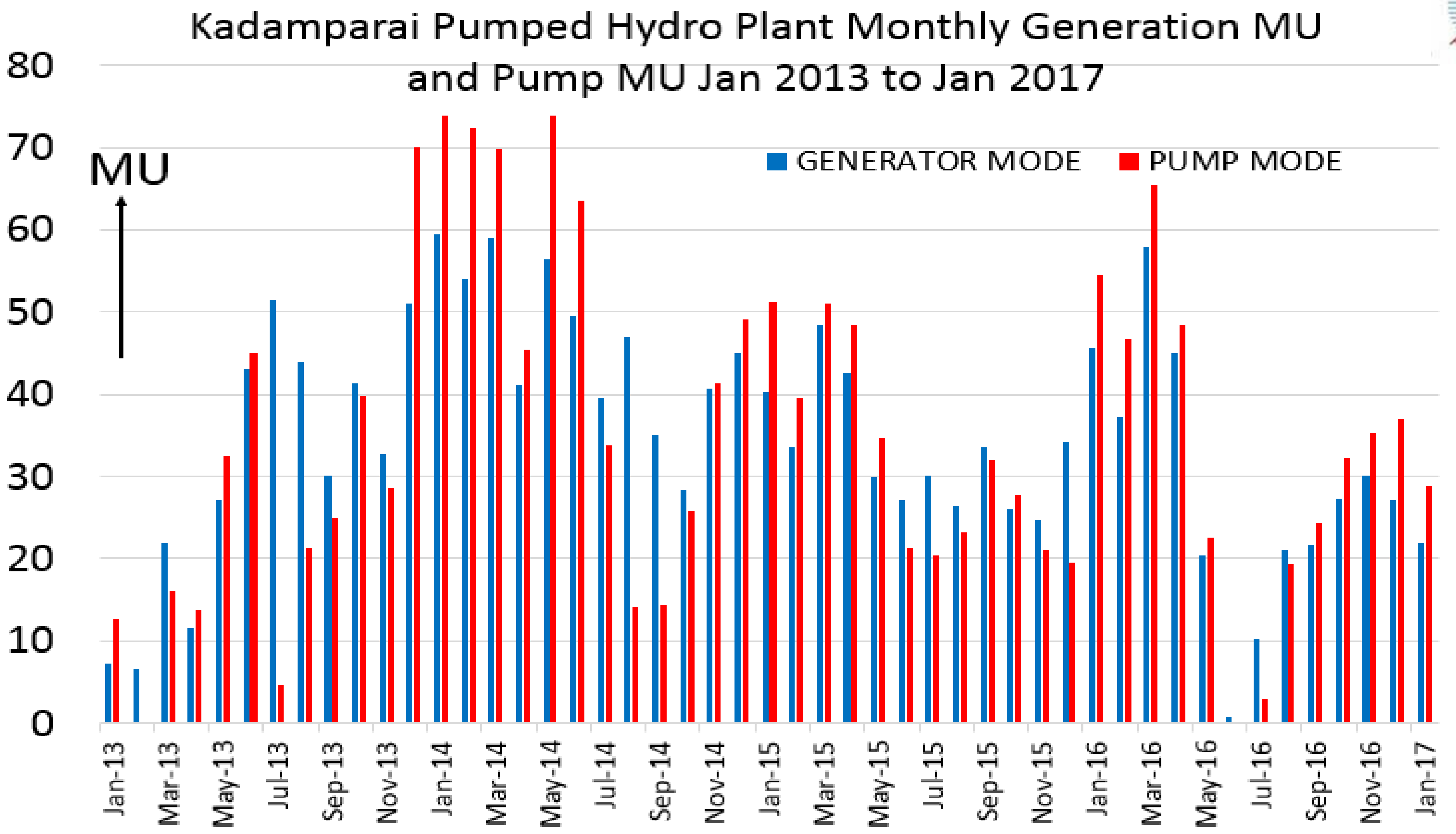


Constraints in Operation at Kadamparai

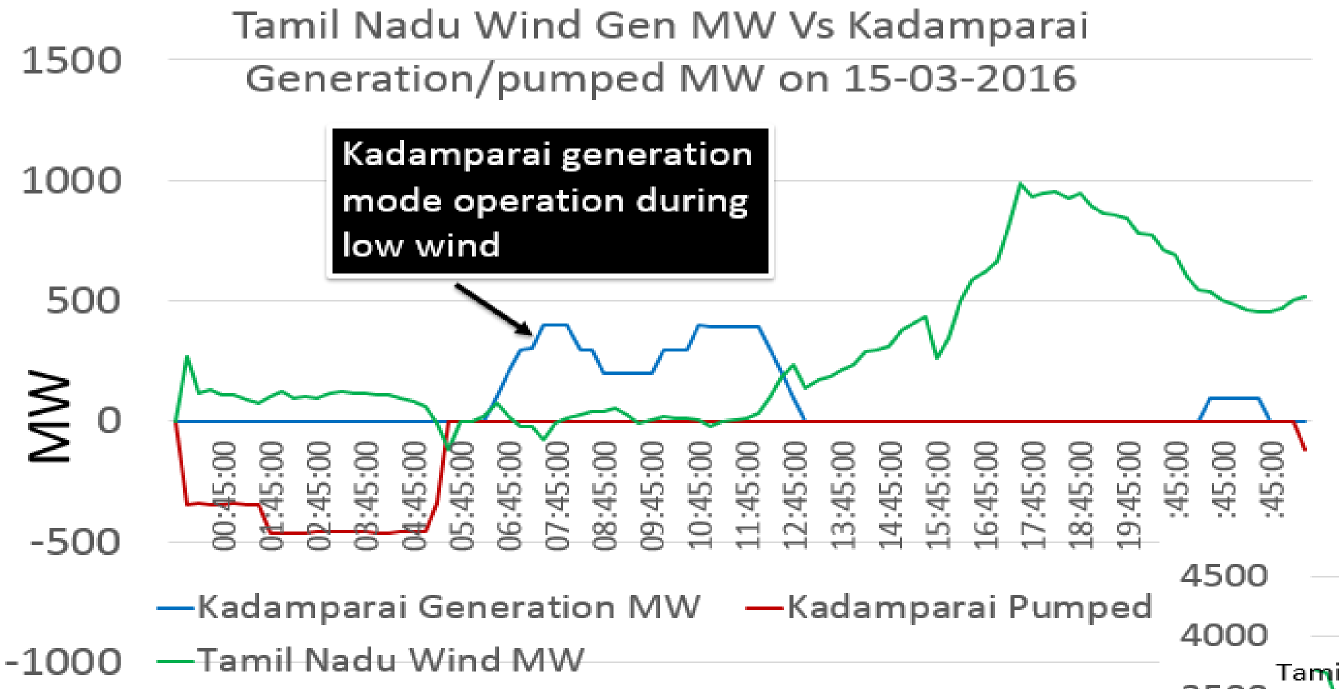
- Low voltage problem in Kadamparai
  - Due to low voltage, stator of the motor draws more current which may cause damage to the windings.
  - ICT Tap Change was facilitated by SRLDC at Udumalpet SS to maintain the voltages at Kadamparai SS.
  - Reactive power shortage at 230 kV and below of Kadamparai substation.
- Water availability due to monsoon.

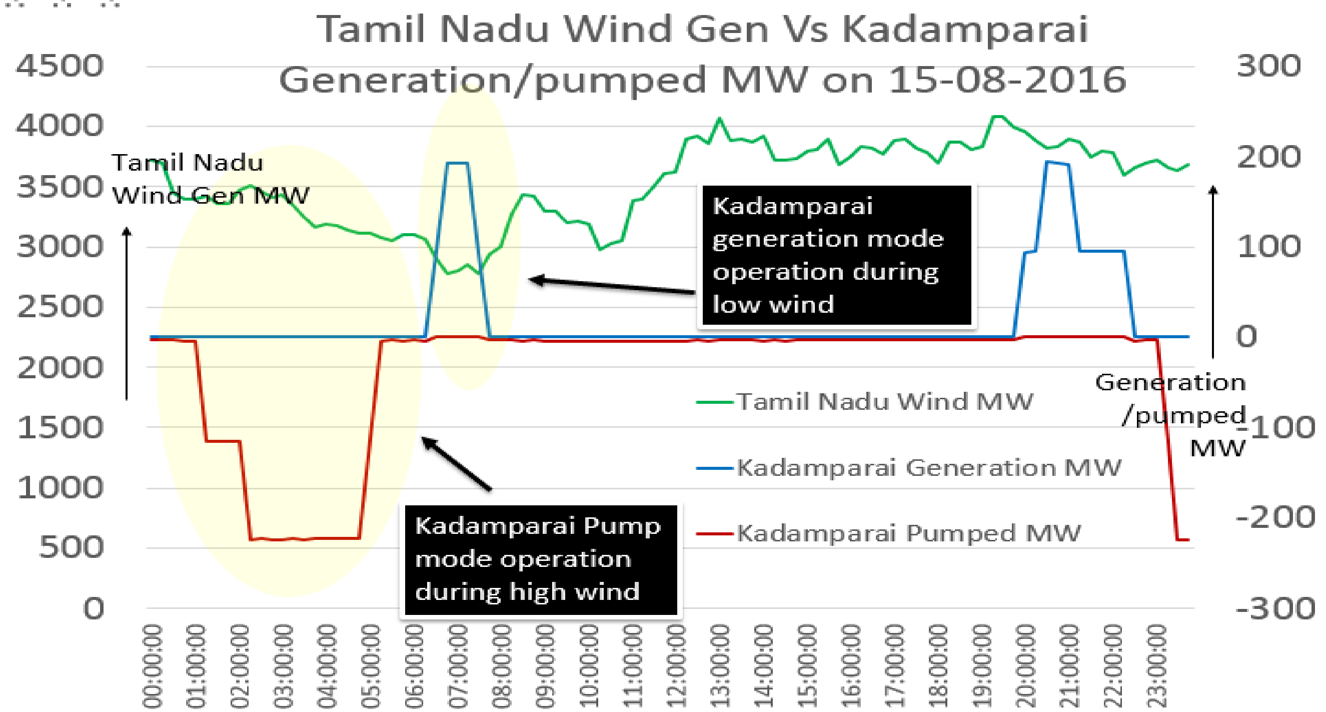
Kadamparai Pumped Hydro Plant Monthly CF %
Jan 2013 to Jan 2017



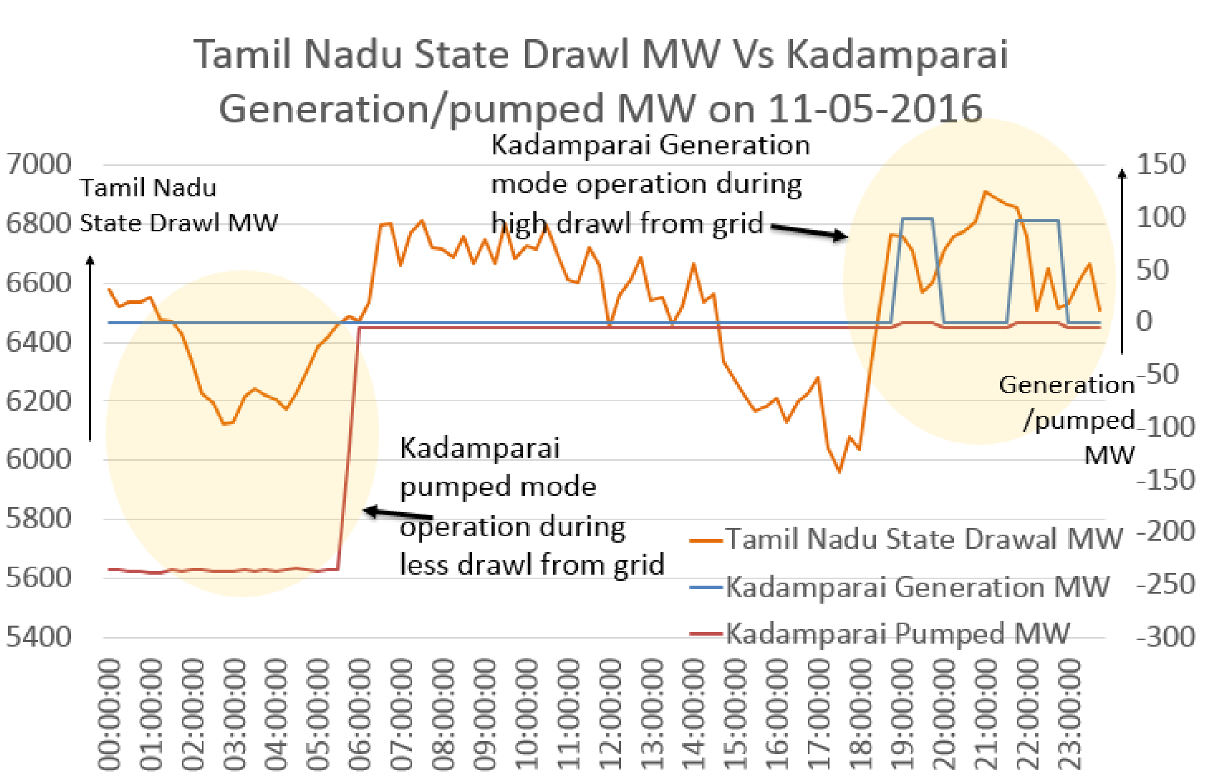

Kadamparai Pumped Hydro Plant Monthly Generation MU and Pump MU Jan 2013 to Jan 2017
MU
GENERATOR MODE
PUMP MODE
0
10
20
30
40
50
60
70
80
Jan-13
Mar-13
May-13
Jul-13
Sep-13
Nov-13
Jan-14
Mar-14
May-14
Jul-14
Sep-14
Nov-14
Jan-15
Mar-15
May-15
Jul-15
Sep-15
Nov-15
Jan-16
Mar-16
May-16
Jul-16
Sep-16
Nov-16
Jan-17
POSOCO

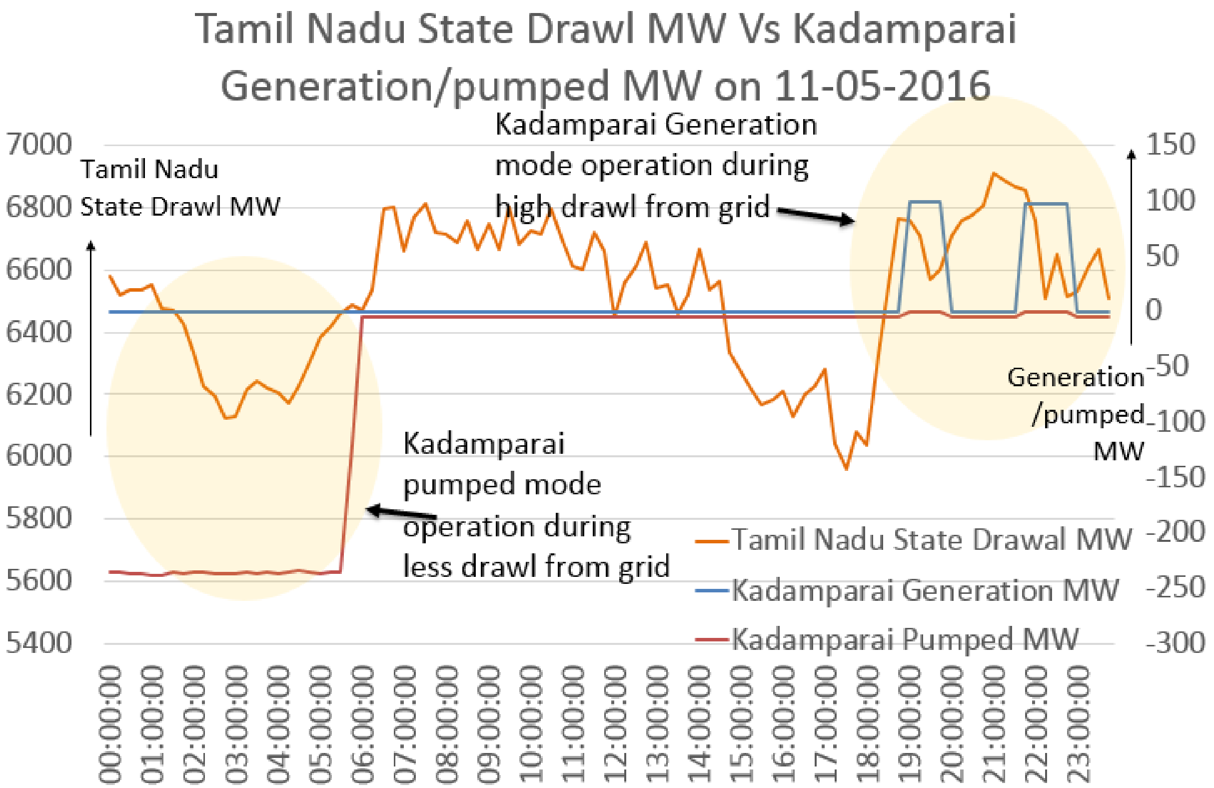
CASE : Kadamparai Generation/Pump during Wind Season

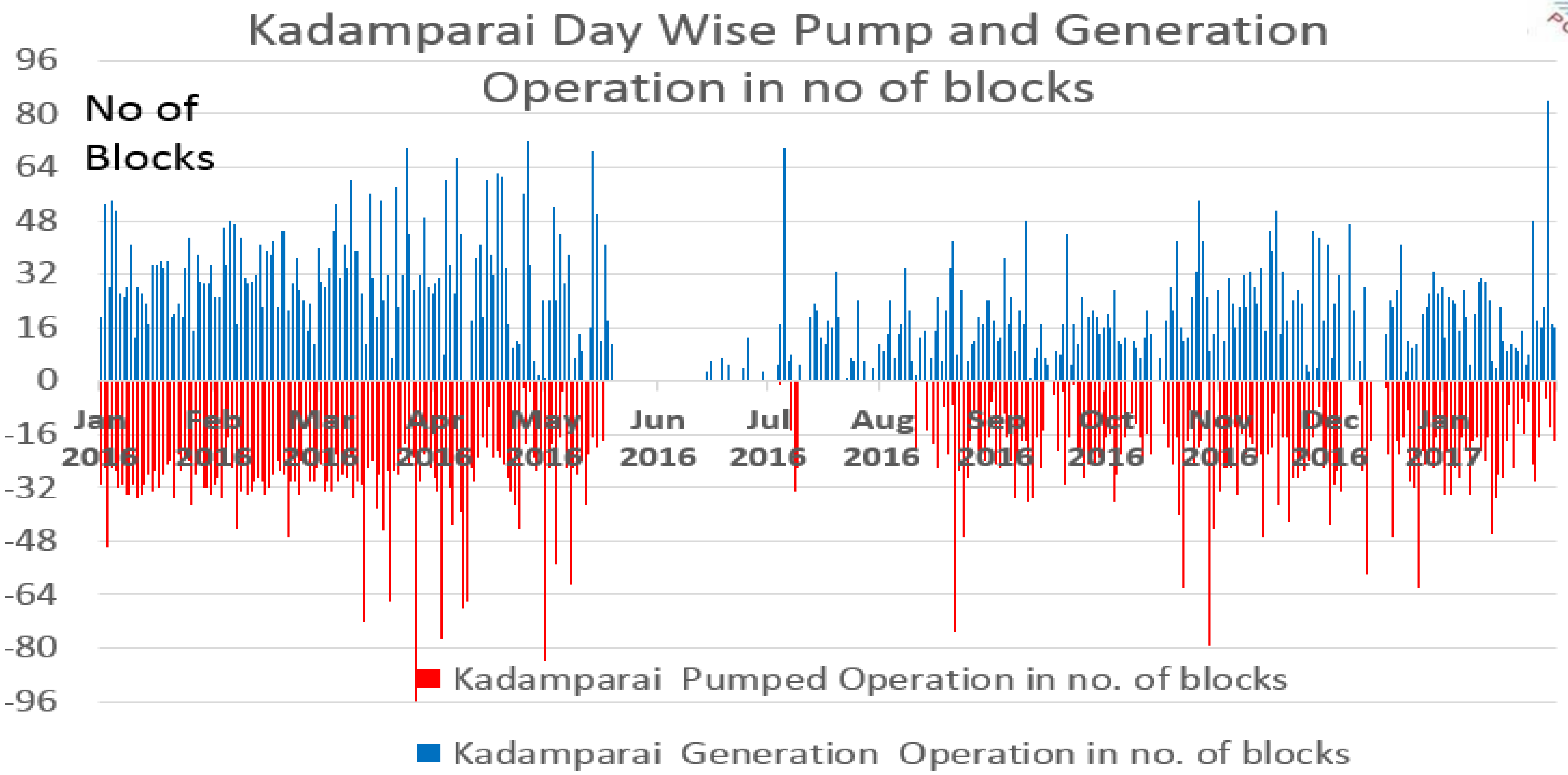




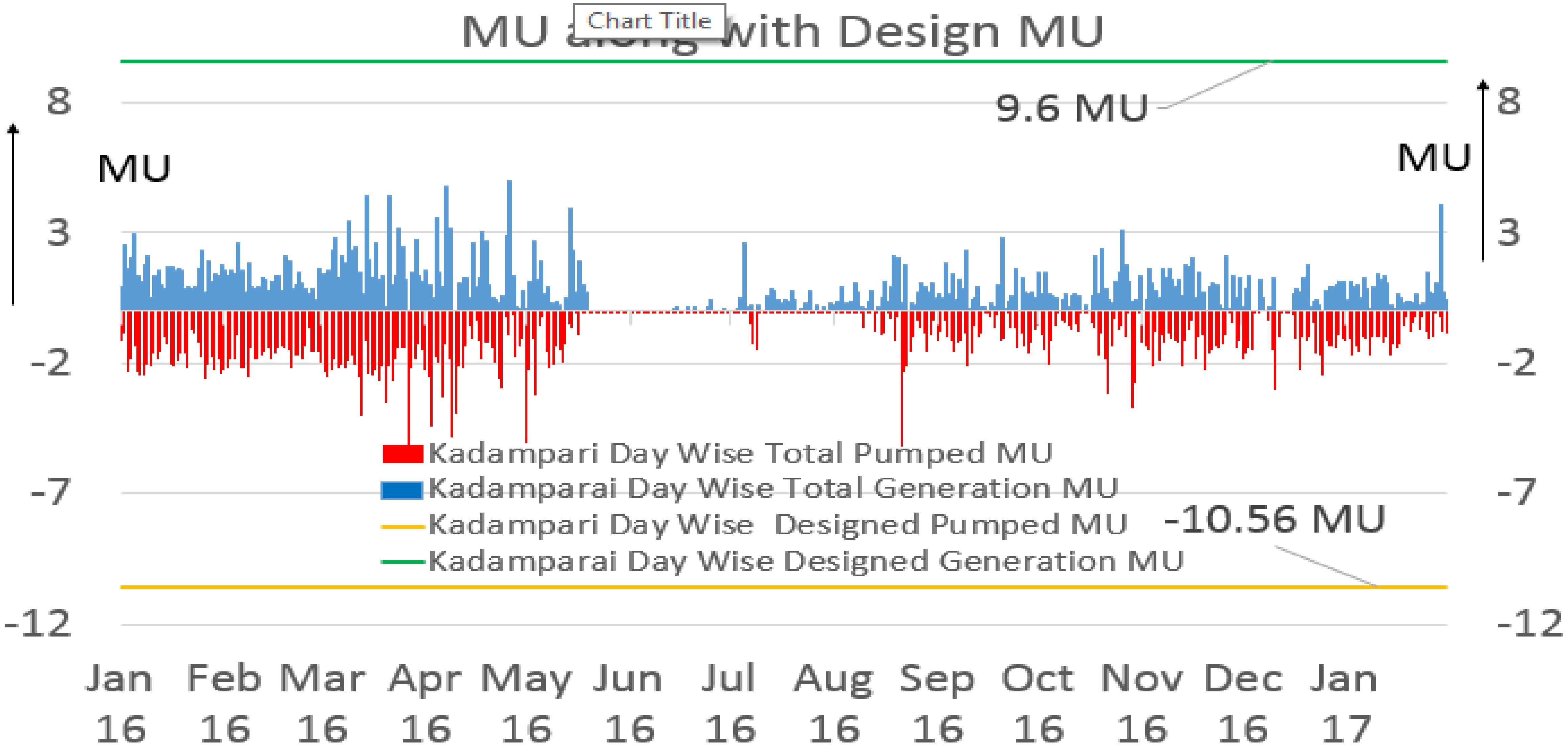
CASE : Kadamparai Generation/Pump and TN Drawl






Kadamparai Day Wise Pump and Generation Operation in no of blocks
No of Blocks
96
80
64
48
32
16
0
-16
-32
-48
-64
-80
-96
Jan 2016
Feb 2016
Mar 2016
Apr 2016
May 2016
Jun 2016
Jul 2016
Aug 2016
Sep 2016
Oct 2016
Nov 2016
Dec 2016
Jan 2017
Kadamparai Pumped Operation in no. of blocks
Kadamparai Generation Operation in no. of blocks

Kadamparai Day Wise Generation and Pumping in MU along with Design MU



Pump Mode Operationalisation
Points to Ponder

SRPC

28.06.2017

(Status update as informed in the Special Meeting convened at Hyderabad on 28.04.2017 to discuss TS-AP issues)

PSPs existing in SR

- **TSTRANSCO**: Nagarjunasagar(1x110+7x100.08) MW
- Pump mode operation possible: 7x100.08= **705.6 MW**
- **TSTRANSCO**: Srisailam LBPH(6x150) MW
- Pump mode operation possible: 6x150= **900 MW**
- **TANTRANSCO:** Kadamparai (4x100) MW
- Pump mode operation possible: (4x100) = **400 MW**

Out of Total Capacity of 2005 MW 1300 MW is operational. (Srisailam and Kadamparai)

1. Pump mode Operation of Nagarjunasagar

- APGENCO had informed that the tail pond reservoir would be handed over to TSGENCO shortly
- APGENCO said there are no lift irrigation pumps to be elevated
- TSGENCO informed that there were certain legal issues (on account of submergence) which were being addressed and likely to be resolved in 4-5 months. TSGENCO said there were two lift irrigation pump schemes which were required to be elevated(will be done after issues on account of submergence are addressed)
- 7 TMC of water is required in the Tail Pond reservoir for pump mode(6 TMC for dead storage + 1 TMC could be used for Pump Mode Op.)
- Unit-I(110 MW) can be used in generation mode. Other 7 units(100.8 MW each) can be used in both generation + pumping modes. It could take around 20 to 30 minutes for pumping operation for each of the unit.

- Units need to be tested in pump mode through their OEM M/s Hitachi

- It was noted that for pumping mode, the level required in Tail Pond Reservoir was higher than the MDDL for 2x25 MW generating station under APGENCO. TSGENCO had suggested that APGENCO station may operate its unit when level is above the level required for pump mode and whenever discharge was there from main Nagarjunasagar Reservoir. Tail Pond Reservoir was constructed for the purpose of pump mode operation which needs to be met. APSLDC/APTRANSCO had stated that generation would be based as per AP’s grid requirement/stipulated discharges.
- TSSLDC had stated that the water being pumped back should be at the disposal of TSSLDC

RECOMMENDATIONS

- TSGENCO to address all issues for filling up the Tail Pond Reservoir ie legal issues, elevating the lift irrigation schemes etc. TSGENCO to test the pump mode operation through their OEM M/s Hitachi.
- It was felt that the issue of the discharges (quantum/time duration) / mechanism for enabling pump mode operation/utilization of the water pumped back could be referred to CEA /MoP for further guidance and suitable directions. This would help in utilization of Nagarjunasagar units in pump mode in optimal manner especially with the higher renewable integration.

2. Srisailam Pumps

- TSGENCO had informed that 540 ft level was required at Nagarjunasagar for pump mode operation at Srisailam LB. Generally, water is above this level for about 2-3 months in a year.
- On a query, TSGENCO informed that there was a weir after Srisailam units and before Nagarjunasagar Reservoir which was used for pumping operation. The weir was not operational since last two years. Attempts to repair the weir had not been successful. Issue had been taken up with CEA/CWC also.
- Options were with regard to reconstruction of weir with advanced technology, diversion of water for reconstruction, relocation etc. Since, project was capital intensive assistance from PSDF could be sought. It could take 2 years once the project is approved.
- TSSLDC stated that the water being pumped back should be at the disposal of TSSLDC.

RECOMMENDATIONS

- It was felt that the issue of weir could be taken up with CEA /MoP for further advice/guidance/funding. Though it could take 2-3 years for completion but in perspective plan with high targets of renewables, this would be useful in pump mode operation at Srisailam and balancing of RE.
- It was felt that issue regarding discharges (quantum/time duration) / mechanism for enabling pump mode operation/utilization of the water pumped back could be referred to CEA /MoP for further guidance and suitable directions. This would help in utilization of Srisailam units in pump mode in optimal manner especially with the higher renewable integration.

3. Kadamparai Pump mode Operation

- 3 out of 4 pumps are available for operation
- Commercial framework and an incentive scheme is to be designed – for Regional balancing
- TANTRANSCO stated that the issue was under examination and they may come up with some proposal

PROPOSAL/STUDIES FOR PUMPED STORAGE OPERATION

ANDHRA PRADESH

- AP is preparing DPR for Pumped Storage Scheme at Upper Sileru(New Scheme). DPR 1000 MW is at finalisation stage.

KPCL

- KPCL has placed LOA no. LOT/PSP/Sharavathy/3230 dated 06.01.2017 on M/s WAPCOS Ltd for preparation of detailed project report on Sharavathy Pumped Storage Scheme. As a part of the assignment, M/s WAPCOS has submitted the Draft PFR on 05.05.2017 wherein an installed capacity of 2000 MW has been proposed. Draft PFR has been submitted to MoEF for first stage clearance of ToR and for obtaining prior Environmental clearance for conducting CEIA study on 14.06.2017.
- The PFR for Varahi Pumped storage scheme is being prepared by KPCL.Topographical survey has been done across Varahi River on the downstream of tailrace. PFR is under preparation for VarahiPumped Storage scheme.

KSEB

- Feasibility studies are under progress attached to Idukki and Pallivasal Generating Stations. At Idukki preliminary study is for around 750 MW

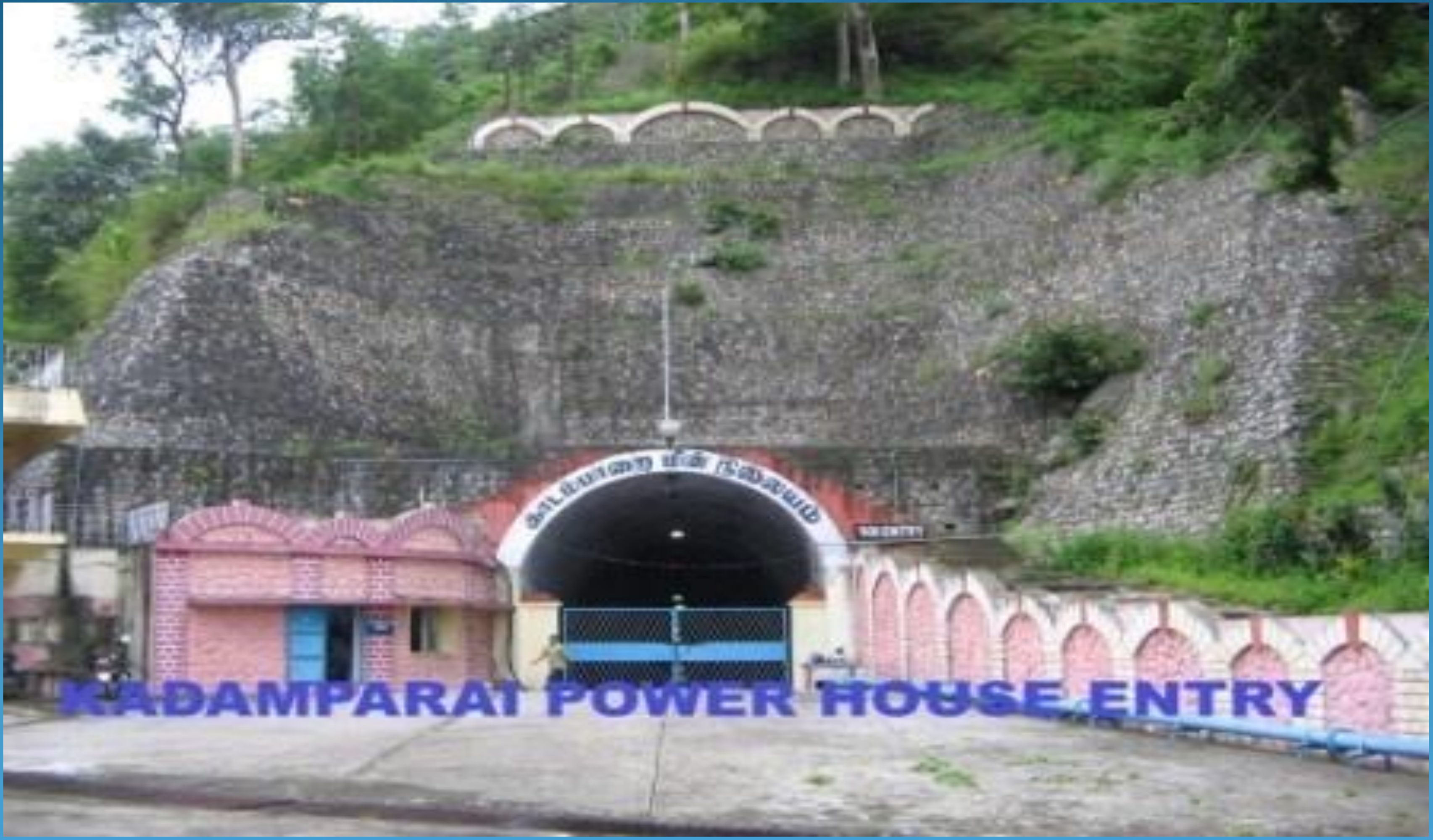
TAMIL NADU

- For MW approached for Environmental Clearance

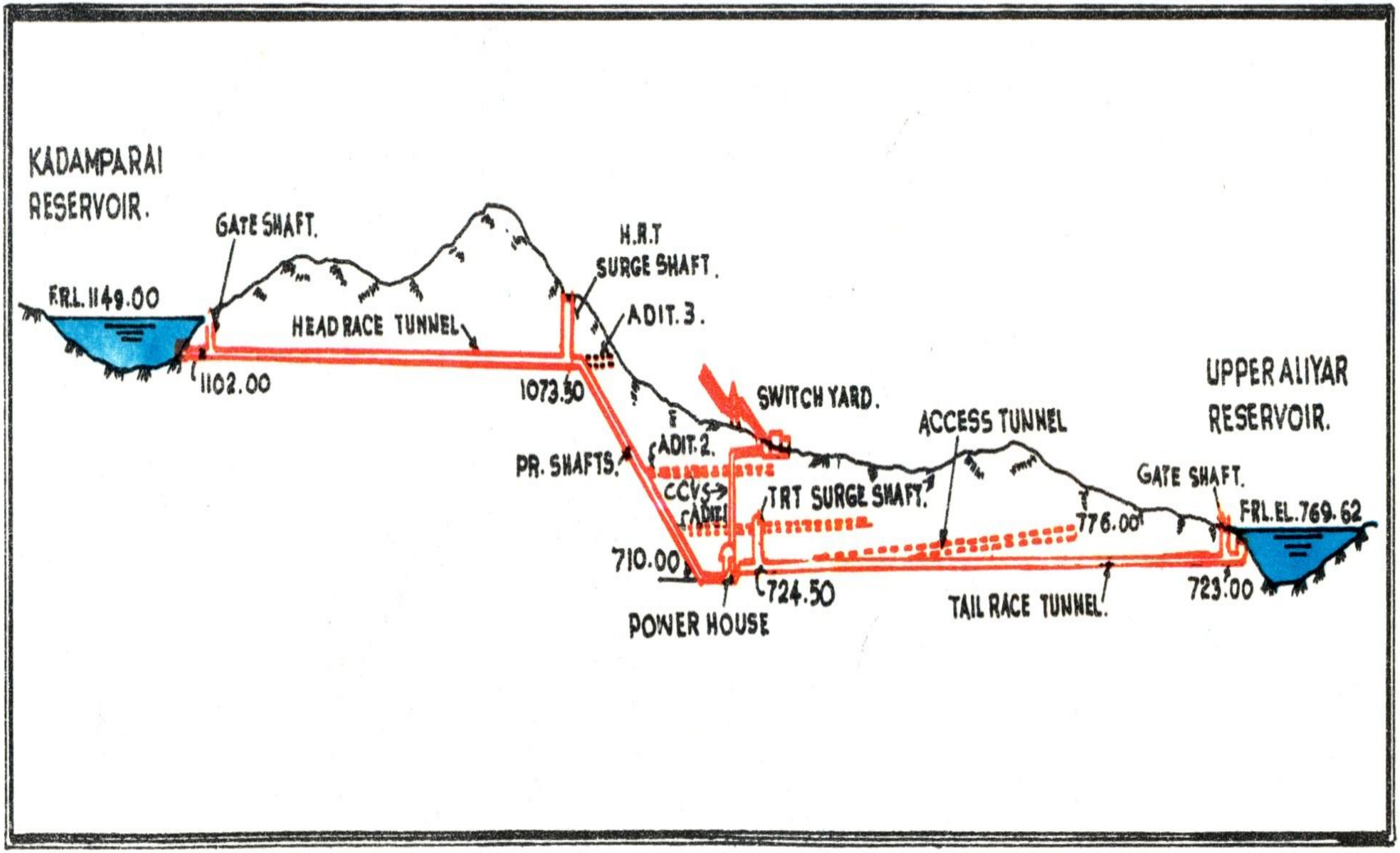
Kadampai Pumped Storage Scheme
by

SLDC, Chennai

welcome to kadamparai pumped storage

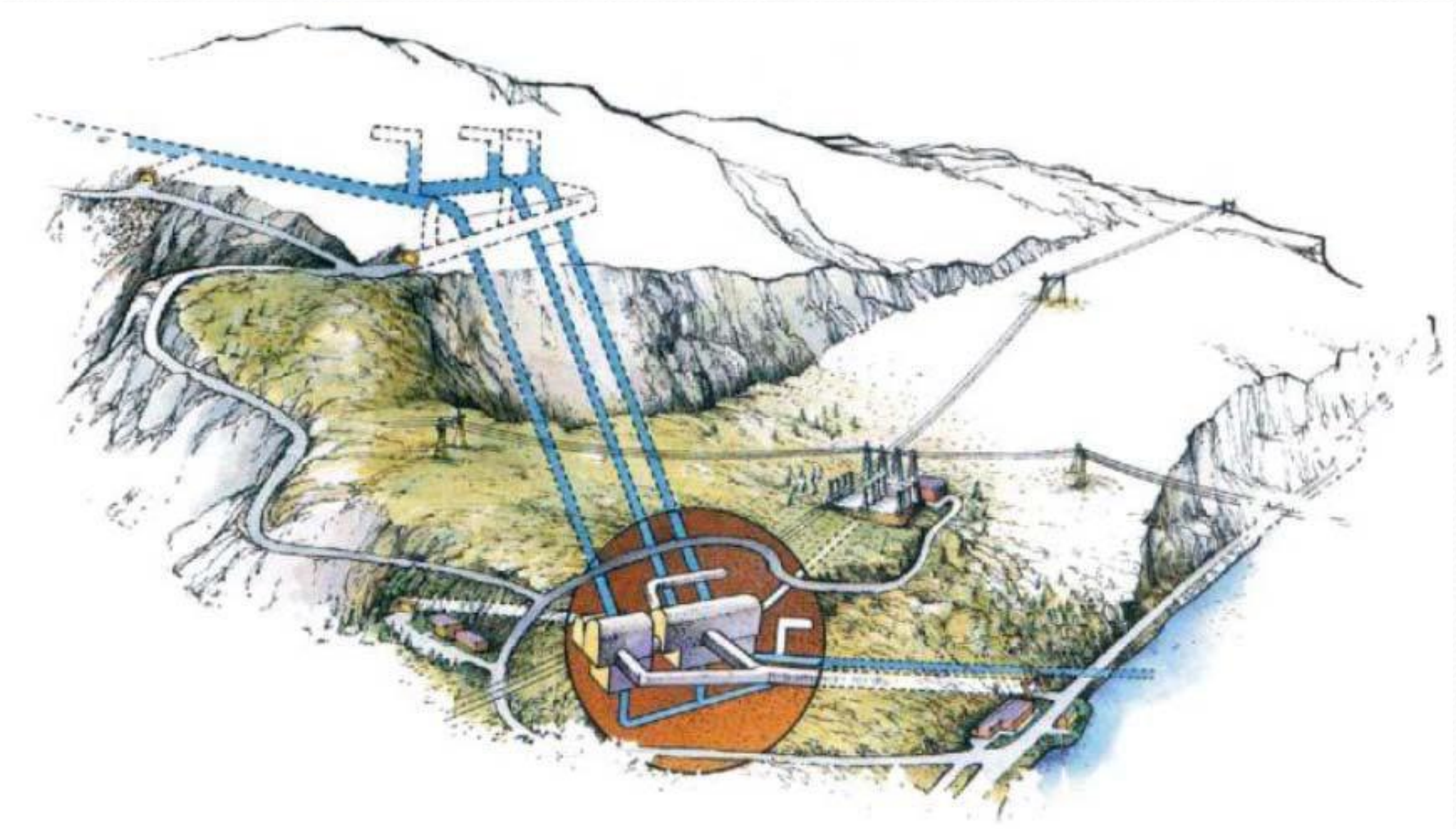


cavern view



KADAMPARAI TO UPPER ALIYAR RESERVOIR – PROFILE

3D view of pumped storage



kadamparai -"A boon for power availability in the southern grid".

view of outdoor end termination after erection.

Kadamparai pumped storage.

- In the Kadamparai Power House (capacity 4x100 MW), the water for power generation is taken from Kadamparai Dam and delivered to Upper Aliyar Dam.

- During non peak hour, the water in Upper Aliyar Dam is pumped to Kadamparai dam by pumping operation.

POWERHOUSE Commissioning Particulars

Number & Capacity of the Machine	**4 X 100 MW**
Date of commissioning of Units	1) 17.10.1987
	2) 26.02.1988
	3) 12.04.1989
	4) 16.12.1988

Turbine Operating Parameters

Make of Generator / Turbine	
	UNIT 1 GEC BOVING UNITED KINGDOM
	UNIT 2,3&4 BHEL INDIA
Type of Turbine	Francis Reaction Reversible
HEAD for each Power House	
a)Maximum	1) 395 mts (GENERATOR MODE)
	2) 413 mts (PUMP MODE)
b)Minimum	1) 323 mts (GENERATOR MODE)
	2) 341 mts (PUMP MODE)
Speed of Machine	500 rpm

Generation Capacity of one UNIT

Generation Details	Generation in Lakh Unit	Water discharge in Mcft
Per Unit /Hour Generation @full load (100 MW)	1 Lakh Units	3.7 Mcft
All the four Units run between 18.00 Hrs to 22.00 Hrs (i.e. 04 Hours)	16.00 L.U	59.2 Mcft.
Equivalent water Pumped Details	**Consumption in Lakh Unit**	**Water Stored**
Per Unit/ hour consumption and water stored	1.1 Lakh Units.	3.00 Mcft
If four Units are run as PUMP mode the time required for the above discharge (59.2 Mcft) Pump Running Hours 05 Hrs	22 L.U.	59.2 Mcft

Kadamparai Dam Particulars (Upper Reservoir)

Height of dam in Ft.	221.45
FRL in Ft.	3770
Storage in Mcft.	1089
MDDL in feet	3648
Dead storage in Mcft	140.57

Upper Aliyar Dam (Bottom Reservoir) Particulars

Height of the Dam	**265**
Full Reservoir level in feet	**2525**
Storage in MCft	**937.89**
Dead Storage in MCft	**23.1**
Minimum Draw Down Level for pump operation at 2445 feet and dead storage is 209 Mcft at Upper Aliyar Dam	

Grid frequency prior to 2002

- Grid was operated at lower frequency (i.e between 48.5Hz & 49.0Hz) for more times till 2002 and less surplus power was available during off peak time.
- Surplus power was available in the grid during National holidays,& on Sundays by which time two or three units were utilized as pump at Kadamparai.

Frequency limitation for pump operation at Kadamparai.

- Frequency for pump operation at Kadamparai is designed between 49.5Hz and 50.5Hz .
- The motor input required is about 110 MW at rated speed.
- If all the four units are operated as pump, then the power input required at station end is about 440 MW.
- First time, on 12-02-2003 only, all the four units were put on pump mode though the station was commissioned in 1989.

Pump performance-contd

2010-11	--	612 MU
2011-12	--	532 MU
2012-13	--	335 MU
2013-14	--	493 MU
2014-15	--	511 MU
2015-16	--	414 MU
2016-17	--	330 MU
2017-18	--	9 MU only (upto 26.06.17)

The present status of Kadamparai PSS as a Spinning Reserve

- Due to failure of monsoon in the year 2016-17 and the monsoon has not set in 2017-18 which leads to very poor storage in Kadamparai Dam i.e. only 158 Mcft excluding silt level.

- With this Alarming present level, Kadamparai PSS can not be used as generating mode. During sudden withdrawal of wind, this 400 MW of generation can not be utilized due to acute storage. Hence Kadamparai can not be used as a spinning reserve.

Contd ….

- Due to failure of monsoon in the year 2016-17 and the monsoon has not set in 2017-18 which leads to very poor storage in Upper Aliyar am i.e. only 125 Mcft excluding silt.

- With this Alarming present level, Kadamparai PSS can not be used as Pump mode. During this high wind season, the Kadamparai cannot be put into pump mode operation which draws consumption from 110 MW to 440 MW from the grid.

- This leads to difficulty in absorption of RE power to the quantum of 440 MW during this wind season.

Role of Hydro Power Generating sources in balancing power requirement due to high RE generation

- The Hydro generation:
- 2006-07 : 6292 MU
- 2007-08 : 6455 MU
- 2008-09 : 5386 MU
- 2009-10 : 5640 MU
- 2010-11 : 5105 MU
- 2011-12 : 5354 MU
- 2012-13 : 2905 MU
- 2013-14 : 5085 MU
- 2014-15 : 5186 MU
- 2015-16 : 4633 MU
- 2016-17 : 2505 MU

Contd…

- The present nett storage in pykara and kundha group is 2400 mcft only against the nett storage of 16600 mcft which is corresponding to 14% only.
- Since Tamil Nadu is deprived of hydro potential very much, role of hydro power generating sources in balancing power requirement in view of the increased generation from renewable energy sources is very much deplete.
- Tamil Nadu has to judiciously operate the hydro generation to meet out the summer demand till the onset of next monsoon.

Conclusion

- Because of less hydro storage due to failure of monsoon, the cheapest hydro sources are used as peaking station only to meet out the Tamil Nadu grid demand judiciously.

- Thank You

KADANA HYDRO ELECTRIC PROJECT

GUJRAT STATE ELECTRICITY COPRORATION LIMITED

GSECL

COMMISSOINING DATE OF UNIT NO. 1,2,3 &4

Unit No.	Date Of Commissioning	Make
Unit No. 1	31/01/1990	CKD Blansko
Unit no. 2	28/08/1990	CKD Blansko
Unit no . 3	02/01/1998	BHEL (CKD Blansko)
Unit No. 4	08/07/1998	BHEL (CKD Blansko)

KADANA HYDRO POWER STATION

Sr. No.	Description	Date
1	Kadana HPS commissioned[4x60 MW]	1991-98
2	Machines operated in generation mode only	1991-2004
3	Trial for pump mode operation taken	2004
4	Pump mode operation machine Hrs.130 [7.955MUs]	2004-05
5	Pump mode operation machine Hrs.34 [2.112 MUs]	2005-06

OBSERVETION DURING PUMP MODE

- KHEP has initiated to put one by one unit into pump mode operation as demanded/requirement by CEA/SLDC. Previously in year 2004-05 unit were run into pump mode but machine was not operated smoothly.
- **During operation of PMO following observation noticed**.

1. High eddy current drawn in reactor.
2. Frequent rotor earth fault observed resulting puncture of slip ring insulated bolts.
3. Vibration observed at the dam and penstock area.
4. Rise of TGB temperature and machine vibration.

OPERATION STATUS OF UNIT NO.1,2,3 &4 ON PUMP MODE

Sr No	Description	Unit 1	Unit 2	Unit 3	Unit 4	Remarks
1	First Trial Date	10.03.04	02.03.04	12.03.04	07.03.04	
2	Last Trial Date	16.06.04	11.06.04	06.06.04	06.06.04	
3	No of Trials					
	(a) less than 1 Hr	9	10	14	17	
	(b) between 1 hr & 3 hrs	11	1	1	6	
	(c) More than 3 hrs	NIL	1	NIL	1	
4	Max Running hours achieved in a trial	0.55 hrs on 15.06.04	4.55 hrs on 05.04.04	01.34 hrs on 06.04.04	4.3 hrs on 04.04.04	
5	Up to date running of machine on trial basis	05.39 hrs	08.44 hrs	03.10 hrs	17.58 hrs	
	(a) Step by Step local (Manual)	9	10	14	17	
	(b) Step by Step from Control Room (UCR)	Nil	2	1	3	
	(c) C/R Auto	Nil	Nil	Nil	Nil	Not desirable
6	Major Observations / Problems	Maximum Vibrations (Horizontal) at turbine guide bearing & temperature: 4.32 Microns, Max temperature less than 40 ^{0}C	Maximum Vibrations (Horizontal) at turbine guide bearing & temperature: 8.44 Microns, Max temperature less than 60 ^{0}C	Maximum Vibrations (Horizontal) at turbine guide bearing & temperature: 44.7 Microns, Max temperature less than 69.4 ^{0}C	Maximum Vibrations (Horizontal) at turbine guide bearing & temperature: 18.4 Microns, Max temperature less than 66.2 ^{0}C	Temperature setting has been increased by BHEL up to 72 ^{0}C (Minutes for increasing in setting of temp is drawn on date 12.06.04). BHEL has recommended max vibrations at bearing (horizontal) 50 Microns

Effort for the restoration of pump mode operation .

- Meeting held on Dt: 6/08/2015 with M/s BHEL at Bhopal regarding feasibility of pump mode operation of KHEP units . The detail discussed regarding problem faced during pump mode trial of KHEP unit during 2005 .

Conclusion of Meeting :

- M/s BHEL Bhopal opinion that the looking to the past record machines should not be operated in pump mode operation.
- As per requirement of SLDC letter dtd. 9/10/2015 ,KHEP again asked to M/s. BHEL and OEM M/s CKD Balnsko or the budgetary offer for the pump mode operation of KHEP units.
- M/s CKD Blansko had visited during march 2016 and submitted their proposal During may 2016 for the refurbishment and up gradation of unit no 1 for the pump mode operation at the cost of Rs:63.69 croers .

- KHEP is also requested to M/s Voith Hydro Noida to submit budgetary offer for to operate KHEP units on PMO vide Email Dt: 23/1/2017. In response M/s Voith Hydro Noida had visited KHEP site on Dt:13/14/2/2017. study in detail. Brief presentation displayed at CO on Dt :15/2/2017 and assured that they will submit their offer in short and KHEP are awaiting offer from M/s Voith.
- Also ,KHEP requested to M/s BHEL Bhopal to visit CO for the discussion on the feasibility of pump mode operation of KHEP. M/s BHEL Bhopal had visited CO on Dt: 12/4/2017 and discussed regarding past issue during PMO of KHEP units. M/s BHEL had suggested to carried ABC of units and run unit on generation mode. The data of generation mode to be collected and after analysis of generation mode operational data M/S BHEL will suggest about the feasibility of KHEP units on PMO.
- For ABC analysis checking the healthiness turbine for pump mode operation the principal approval received from C.O and tender under progress.

- Moreover, OEM M/s CKD Balnsko had plan to visit KHEP during 11/7/2017 to 20/7/2017 for the Pump mode operation of KHEP units.
- During visit of expert team of CKD Balsnko the BHEL and member of (Hydro) / CE(HEPR) remains present it was discussion and decided during the review meeting of committee was held 18/05/2017 at NPMC hall 2nd Floor Sharm Shakti Bhavan New Delhi.

Thank You



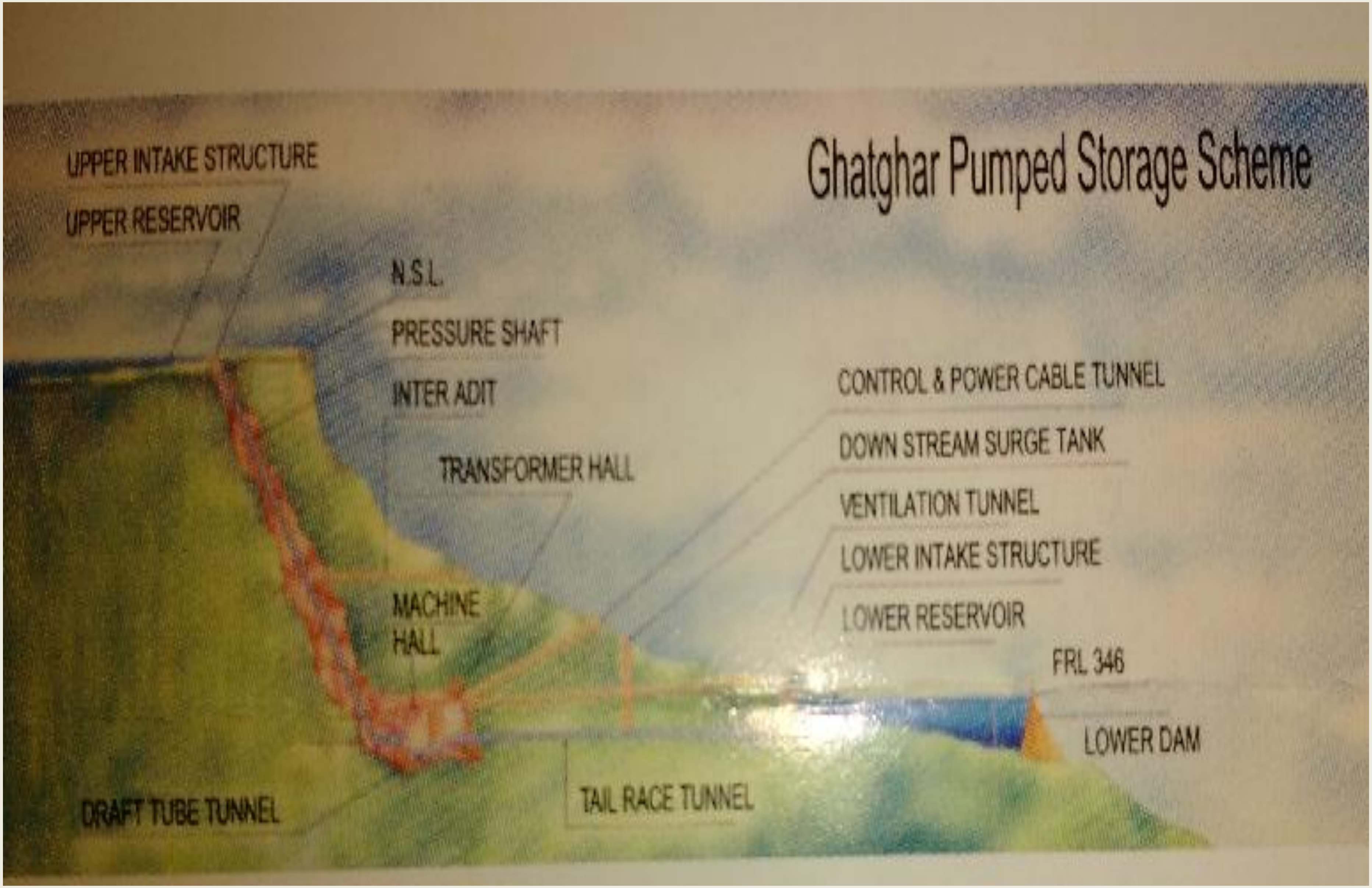
Operation of Ghatghar, Paithan & Bhira Hydro Pumped Storage Plants in Maharastra

Presentation by

State Load Despatch Centre, Airoli

28th June-2017

Ghatghar Layout



Ghatghar Pump Storage Operation

- **A. Plant details::-**
- Unit 1 (125MW) Commissioned on 08.04.2008
- Unit 2 (125MW) Commissioned on 21.06.2008

- 1) Capacity : 2 units (250 MW) Reversible Francis Turbine Pumps & Generator
- 2) Rated Head : 410 m (Generation Mode) & 430 m (Pumping Mode)
- 3) Rated Discharge 37.40 m3/sec
- 4) Daily hours of Generation : 6 hours
- 5) Daily hours of Pumping : 7 hours.
- 6) Max yearly generation possible : 469.5 Mus
  (Running 2X125MW , Daily 6 hrs for 313 day for year)
- 7) Max yearly energy required for pumping : 645.372 Mus.
- 8) Power House Type : Under Ground
- 9) Black start facility : 2 x 1250 KVA, 11 KV Diesel Generating sets.
- 10)Generator speed:- 500 R.P.M.

B. Hydrology	Upper Dam	Lower Dam
District	Ahemadnagar	Thane
River	Pravara	Shai Nalla
Catchment Area Storage	18.43 sq. km.	2.50 sq. km
Dead Storage	0.66 mm^3	0.08 mm^3
Live Storage	6.05 mm^3	3.57 mm^3
MDDL	750.25 m	310.00 m
MWL	756.25 m	347.00 m

C. Grid connectivity:-

- Bus configuration : 1 main + 1 Auxiliary Bus
- Lines connected
- 220 KV Ghatghar-Nasik
- 220 KV Ghatghar-Bapgaon-Kalwa
- 220 KV Ghatghar-Vashala-Raymond-Nasik
- 220 KV Ghatghar-Jindal steel- Padghe

D.Black start Facility:-

- Both units can be black started with help of DG sets in case of Black out.

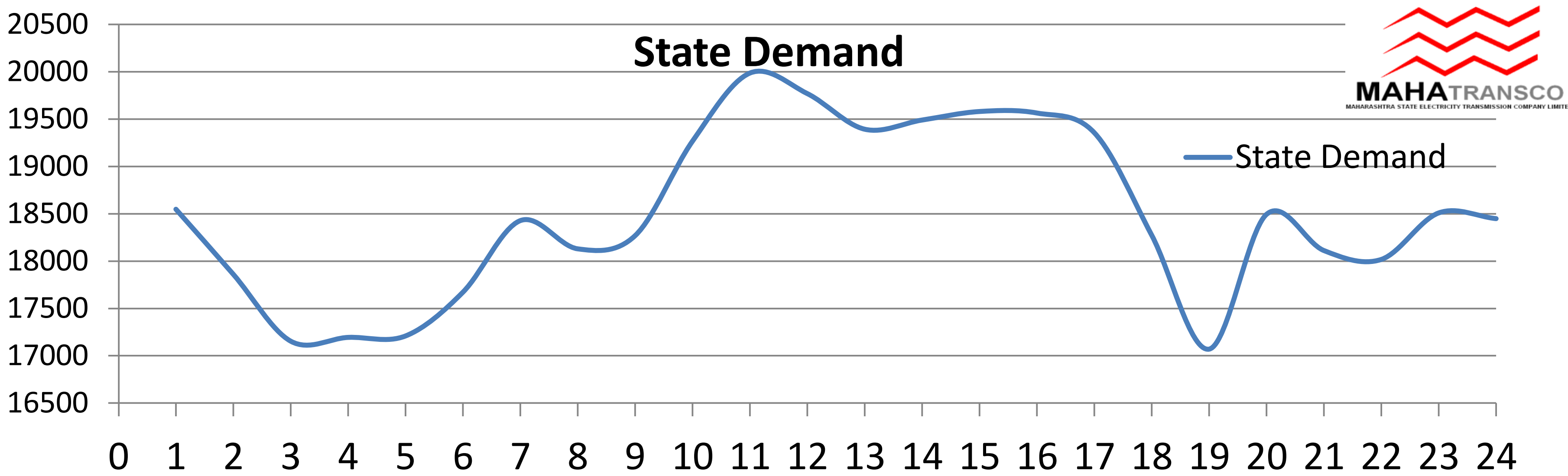
E . Day-to-Day routine operation.

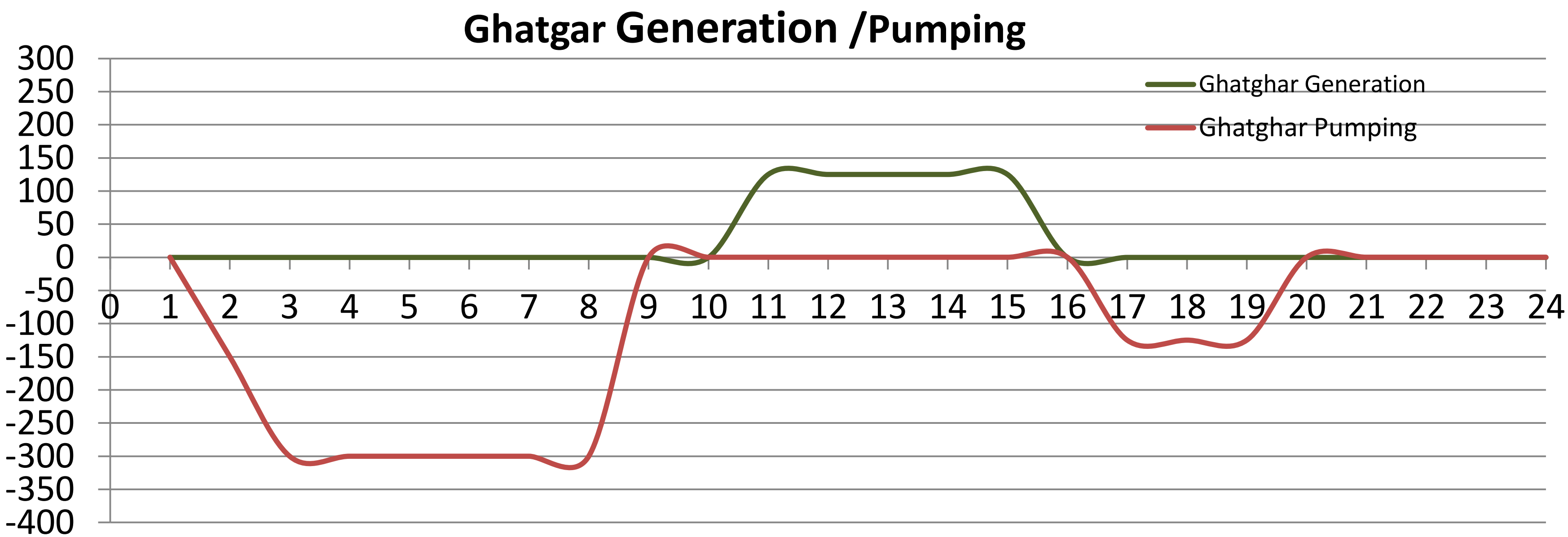
1.) Generation mode operation in the following conditions

- Morning peak hours and Evening peak hours (2 x 125 MW) or whenever required
- To reduce over drawl from central grid at low frequency.
- Units are available within 15 min from giving instruction
- Once taken as generator unit is operated for minimum 1 hour.
- Injection supporting to Nasik and Padghe Bus.

2.) Pumping mode operation in the following conditions

- Generally during night off peak hours or between reduction of day demand and before evening peak
- The pumping demand is 2X150 MW
- Pumping operation to reduce under drawl from Central grid at high frequency.
- Pumping /generation mode is also taken for controlling network loading in adjacent area.
- Once taken as Pump unit is operated for minimum 1 hour





Date:- 14 April 2016

MAHATRANSCO
MAHARASHTRA STATE ELECTRICITY TRANSMISSION COMPANY LIMITED

Month	Max Demand (MW)	Corresponding Min. Demand (MW)	Difference
Apr-15	20204	16731	3473
May-15	20367	16079	4288
Jun-15	19761	16537	3224
Jul-15	20141	16502	3639
Aug-15	18982	15174	3808
Sep-15	19681	15662	4019
Oct-15	21414	17421	3993
Nov-15	20760	15837	4923
Dec-15	19554	15291	4263
Jan-16	18647	13340	5307
Feb-16	19458	14178	5280
Mar-16	19866	16133	3733
Apr-16	20522	17749	2773
May-16	20451	16659	3792
Jun-16	20318	16940	3378

Energy injected by Ghatghar PSP in Maharashtra Grid

MAHATRANSCO
MAHARASHTRA STATE ELECTRICITY TRANSMISSION COMPANY LIMITED

Sr.No.	Year Month	2013-14	2014-15	2015-16
1	April	17.338	18.724	21.654
2	May	18.610	27.413	20.815
3	June	34.409	29.625	22.827
4	July	26.616	35.371	21.932
5	August	20.116	24.079	27.520
6	September	14.354	18.487	27.782
7	October	17.592	23.040	21.055
8	November	24.174	17.180	38.905
9	December	59.799	31.809	37.622
10	January	60.508	22.627	29.534
11	February	51.483	33.439	14.849
12	March	38.915	29.787	12.839
Total for the year (Mus)		***383.914***	***311.581***	***297.334***

Installed Capacxity in MW :-- 2x125 MW Units

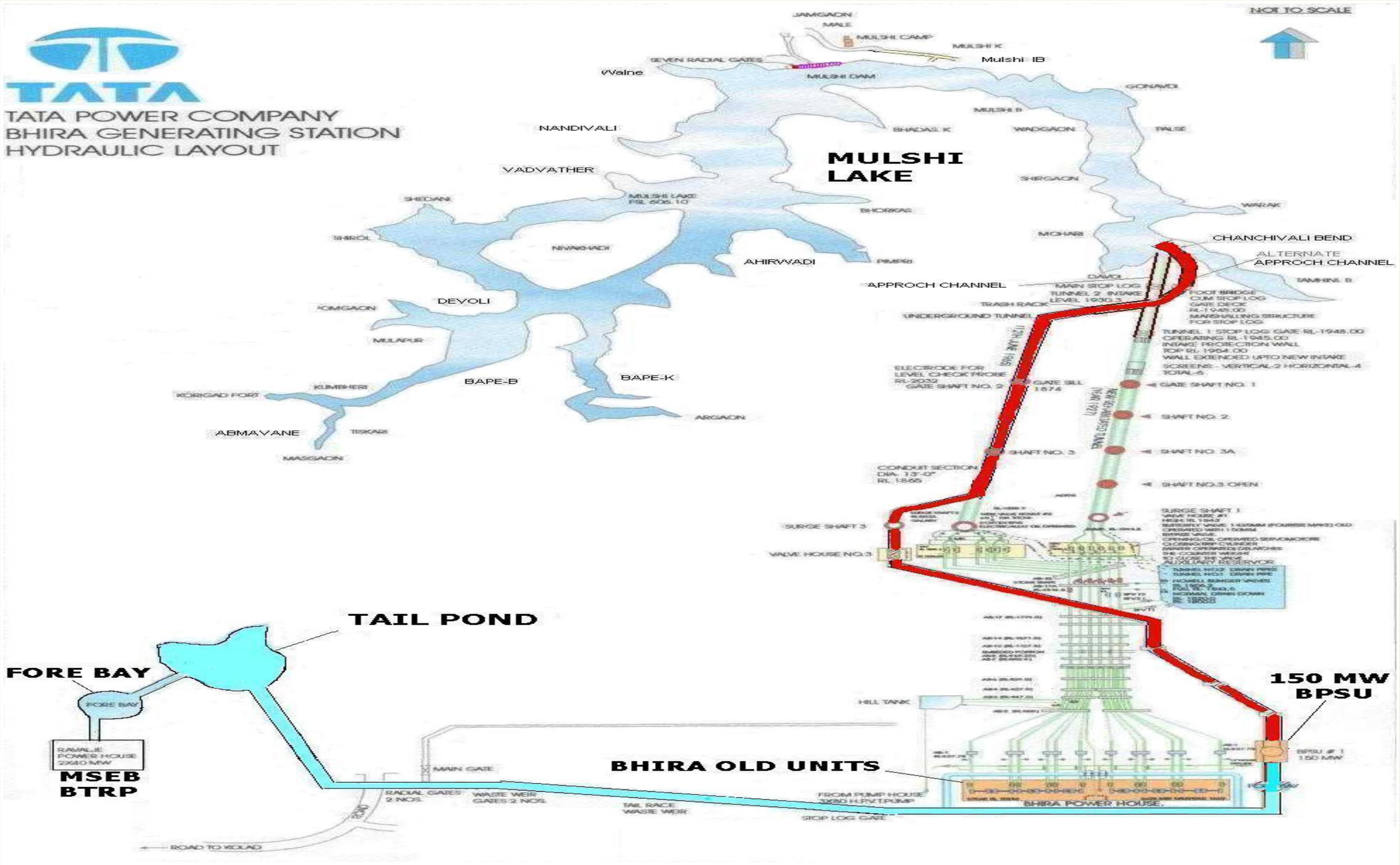
GENERATION & PUMPING DATA for FY 2015-16

Date	GENERATION				PUMPING			
	UNIT-1		UNIT-2		UNIT-1		UNIT-2	
	Gen. ABT Meter Mus.	Generation Service Hrs	Gen. ABT Meter Mus.	Gen. Service Hrs	Pumping Consumption ABT Meter Mus.	Pumping Service Hrs	Pumping Consumption ABT Meter Mus.	Pumping Service Hrs
Apr-15	13.048	103:10	9.222	69:58	15.247	102:55	14.578	102:00:00
May-15	11.524	93:10	9.290	75:38	7.026	45:25	18.852	124:10:00
Jun-15	13.001	105:30	9.827	80:20	13.947	91:14	17.816	117:58:00
Jul-15	11.320	91:40	10.612	86:35	11.386	74:15	22.497	148:25
Aug-15	17.389	142:05	10.131	81:50	17.53	115:00	20.914	138:45
Sep-15	15.156	122:50	12.625	103:00	15.873	103:30	20.668	133:45
Oct-15	10.845	87:45	10.211	83:23	16.138	104:33	12.54	82:15
Nov-15	20.015	162:10	18.202	148:30	25.665	168:20	23.846	159:45
Dec-15	18.161	150:27	18.824	153:17	27.539	181:10	20.996	139:30
Jan-16	17.352	141:20	11.736	96:02	21.805	142:32	17.995	119:45
Feb-16	8.713	70:50	6.041	49:20	11.475	74:30	6.523	42:10
Mar-16	3.432	27:58	9.336	76.21	5.625	36:10	12.633	81:47

Conclusion

- Even though the capacity of Ghatghar PSP is 2x125=250 MW is small compared to Maharashtra State Demand which is more than 22,000 MW, it is supporting to cater peak demand and consume power in surplus scenario.
- Ghatghar PSP proved useful in reliving congestion or constraints in case of line or unit tripping or disturbance.
- Ghatghar PSP can be modeled as an example for operation to support grid in generator and pumping mode as well.
- Ghatghar PSP is also used as a black start in case of grid failure
- Black Start Mock is regularly carried out, latest on 18.11.2016

Bhira Hydraulic Layout



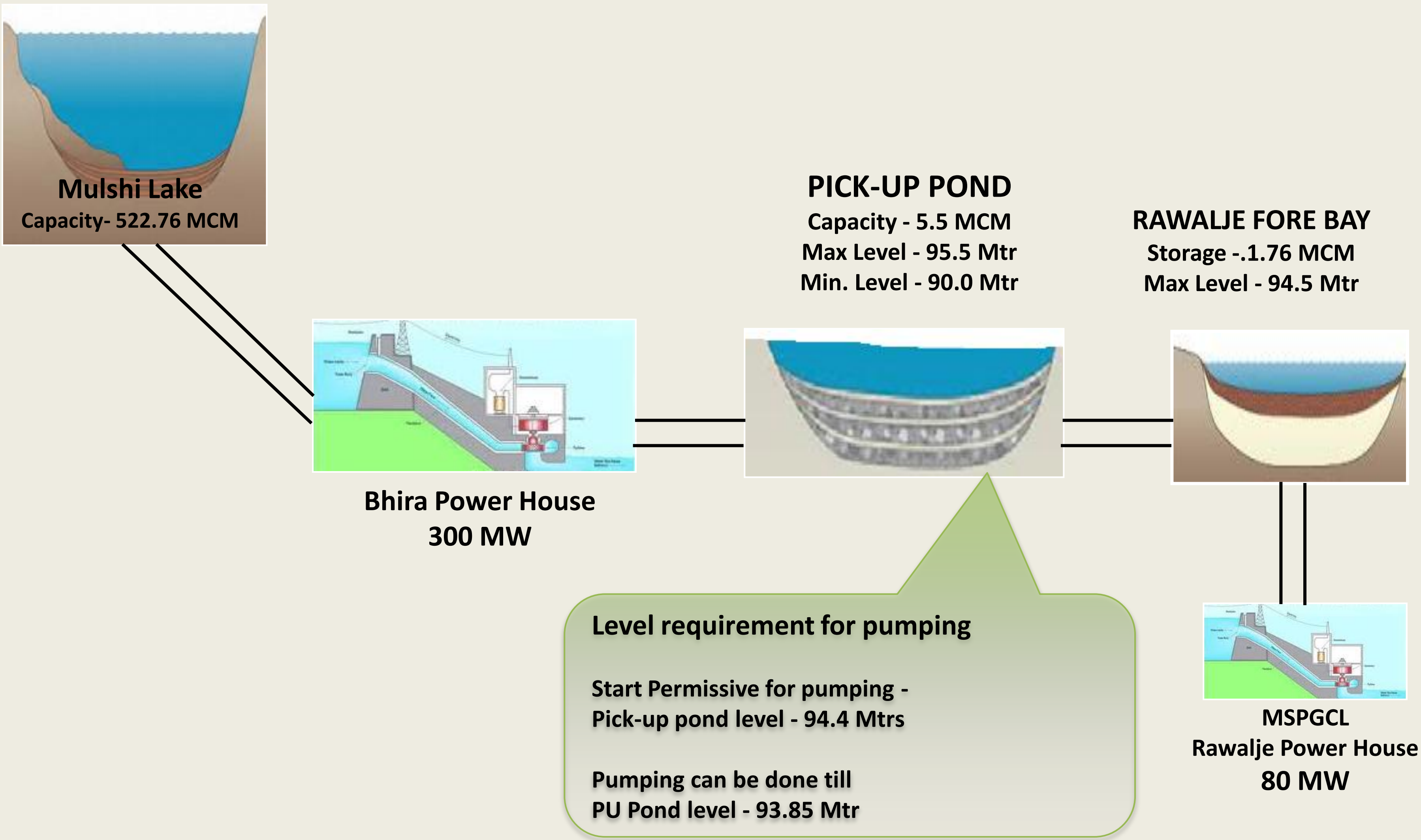
Brief Details of BPSU, Bhira – Mulshi Lake & Generation

- TPC commissioned 150 MW pumped storage unit at Bhira (BPSU) in 1997
- Scheme is designed to pump water from Bhira tail race pickup pond to Mulshi lake.
- Lake capacity – 522.76 MCM
- Average Inflow – 920 MCM
- Possible generation with the Inflow- 989 MU
- Dry period generation – 562 MU
- Average per day generation during dry season – 2.5 MU
- Pick up pond pond capacity – 5.5 MCM
- Pick up pond operating level – 90 – 95 Mtr
- Minimum Pick up pond Level required for pumping – 94.4 Mtr

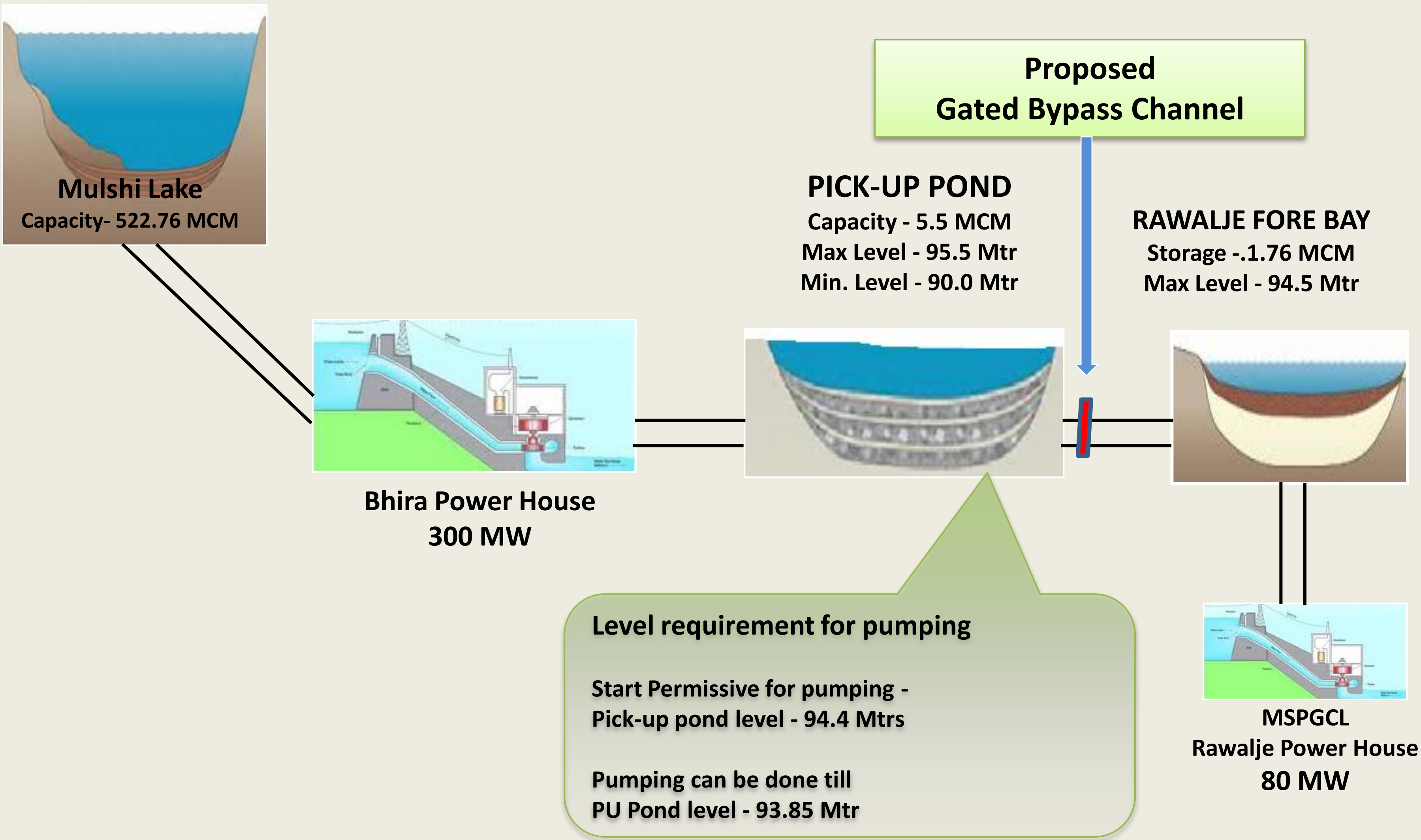
BPSU Pumping – Existing Operational Constraints

- Pumping would be possible only during off peak hours and when Bhira Old Power House and Rawalje Power House is not generating.
- The system frequency should be between 49.5Hz and 51.5 Hz and there shall be cheap power available for pumping.
- The Rawalje pickup pond level should be minimum 94.4 m during starting & more than 93.85 m through out the pumping operation.
- Interconnecting tunnel of BTRP & Forebay has no regulating gate & transfer of water from pick up pond to Forebay is continuous. Because of this, Pick up pond level remains at around 93 m during night time, so pumping is not feasible.

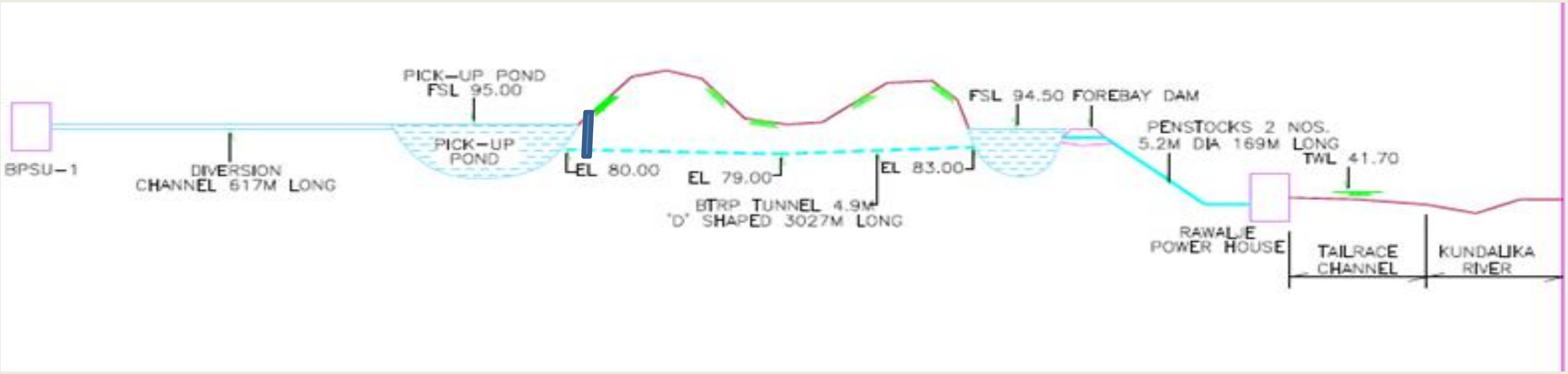
Operational Constraints of Pumping → Required Tail Race Level



Operational Constraints of Pumping → Required Tail Race Level



Proposed Measure to Mitigate Constraint of Tail Race Level



- Gate has to be provided between Pick up pond & Forebay to control the water level in Pick –up pond.
- NOC has been received from MSPGCL for the project. Agreement has been made with Central Design Organization, Nashik for Design of gated bypass channel and coffer dam for BTRP project. Design is in progress.
- After design of gated bypass channel and coffer dam for BTRP, approval from Chief Engineer, WRD-Konkan would be required for the project.
- MERC approval will be required for the project. On MERC approval for the project, estimated project cost will be deposited with Irrigation Department for project implementation.

Paithan Pump Storage Unit

1. Generator Installed Capacity (MW)	:12.0 MW
2. Pumping Capacity (MW)	:13.5 MW
3. Upper Dam Level (Godavari Dam)	:463.90 mtr.(Full Reservoir Level)
4. Lower Dam Level (Chankawadi Dam)	:435.96 mtr (Full Reservoir Level)
5. Daily average generation time	: 09:00 to 12:00 hrs : 18:00 to 21:00 hrs
6. Daily average generation energy(MUs)	: 0.05 Mus
7. Daily average pumping time	: 22:00 to 06:00 hrs
8. Daily average pumping energy	: 0.09 Mus
9. Manufacture	: M/S FUJI ELECTRIC. JAPAN

ISO 9001 CERTIFIED VINÇOTTE
An ISO 9001-2008 certified office

GOVERNMENT OF MAHARASHTRA
WATER RESOURCES DEPARTMENT
OFFICE OF THE CHIEF ENGINEER (ELECTRICAL),
HYDRO PROJECTS
HSBC BUILDING, 4TH FLOOR, M.G.ROAD, FORT, MUMBAI-400001
Tel. : 022-22674867/22670074/22678638 Fax : 022 22674867
E-mail: cehp_mumbai@wrd.maharashtra.gov.in / ceehpwrd@gmail.com

सत्यमेव जयते

Urgent By e-mail

No.CE(E)/HP/D-9/T-2/PSS/ 668 Date: - 15 MAR 2016

To,
Chief Engineer,
S.L.D.C.
Thane Belapur Road, P.O. Airoli,
Navi Mumbai 400708
Email: cesldc@mahasldc.in or mahatransco.in, seop8000@mahatransco.in, eeop8000@mahatransco.in

Sub.:- Availability of off peak energy for Pumped Storage Hydro Electric Projects in Maharashtra.

Dear Sir,

We are planning to undertake following Pumped Storage Hydro Electric Projects in Maharashtra.

Sr. No.	Name of Project	Installed capacity	Probable date of commissioning
1.	Malshej Ghat Pumped Storage Scheme	2 x 350 MW	2022-23 and beyond
2.	Panshet Pumped Storage Scheme	4 x 400 MW	2022-23 and beyond
3.	Warasgaon Pumped Storage Scheme	4 x 300 MW	2022-23 and beyond
4.	Varandhghat Pumped Storage Scheme	2 x 400 MW	2022-23 and beyond
5.	Muthkhel Pumped Storage Scheme	1 x 110 MW	2022-23 and beyond
6.	Koyna Hydro Electric Project Stage VI	2 x 200 MW	2022-23 and beyond
7.	Atvan Pumped Storage Scheme	3 x 400 MW	2022-23 and beyond

These Projects are expected to be commissioned in 2022-23 and beyond.

In view of above, it is requested to confirm whether off peak energy will be available by MSEDCL for the above projects. It is also requested to inform the duration of daily available off peak power (MW), so that capacity of pumped storage projects can be planned. Necessary action regarding stage wise development will be taken after receipt of your confirmation regarding availability of off peak energy.

It is requested to provide the required information in the matter immediately.

Thanking you,

Yours faithfully,

Ankush

(V.A. Ankush)
Chief Engineer (Electrical)
Hydro Projects, Mumbai-01

Thank
YOU

OPERATIONALIZATION OF EXISTING PUMP STORAGE PLANTS

Saswati Mukhopadyay, Chief Engineer
Dipak kumar Paul, Addl. Chief Engineer
Purulia Pumped Storage Project

BACKGROUND OF SETTING UP PURULIA PUMPED STORAGE PROJECT (PPSP):

- The State of West Bengal and the Eastern Region is having predominantly thermal power generation and it faces a serious system stabilization problem.
- In order to achieve a better hydro thermal generation mix and more efficient electrical energy management in the region, development of such Pumped Storage Scheme was undertaken and finally PPSP is now under operational condition.

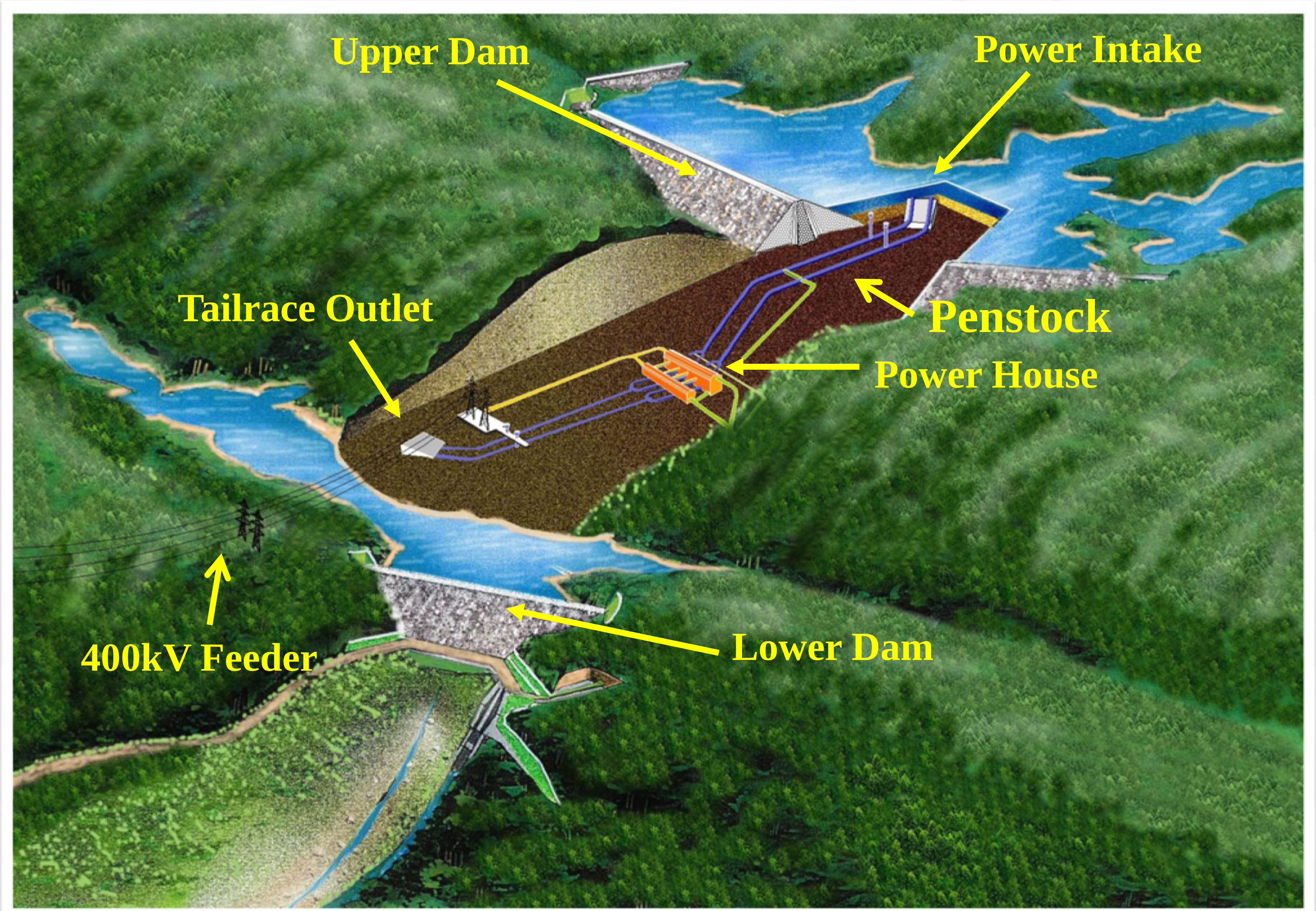
RENEWABLE ENERGY GROWTH - DRIVING THE NEED FOR ENERGY STORAGE

RENEWABLE ENERGY GROWTH - DRIVING THE NEED FOR ENERGY STORAGE

- India aims to increase the proportion of energy generation from Renewable source such as wind and solar. This can present new challenges for grid reliability and stability.
- The power output for these plants can fluctuate widely as weather patterns change and the magnitude of renewable energy generation ramps can be challenging to grid operators when renewable energy resources are a large component of generation portfolio.

- This variable output can lead to frequency and voltage fluctuations, which adversely affect grid stability.
- In geographic regions without a significant hydroelectric generation base, this variability is most commonly managed with fossil fuel-based thermal generation.
- Developing additional pumped storage hydro, particularly in area with increased wind and solar capacity, would significantly improve grid reliability with handling of green power.

General view of the Purulia project



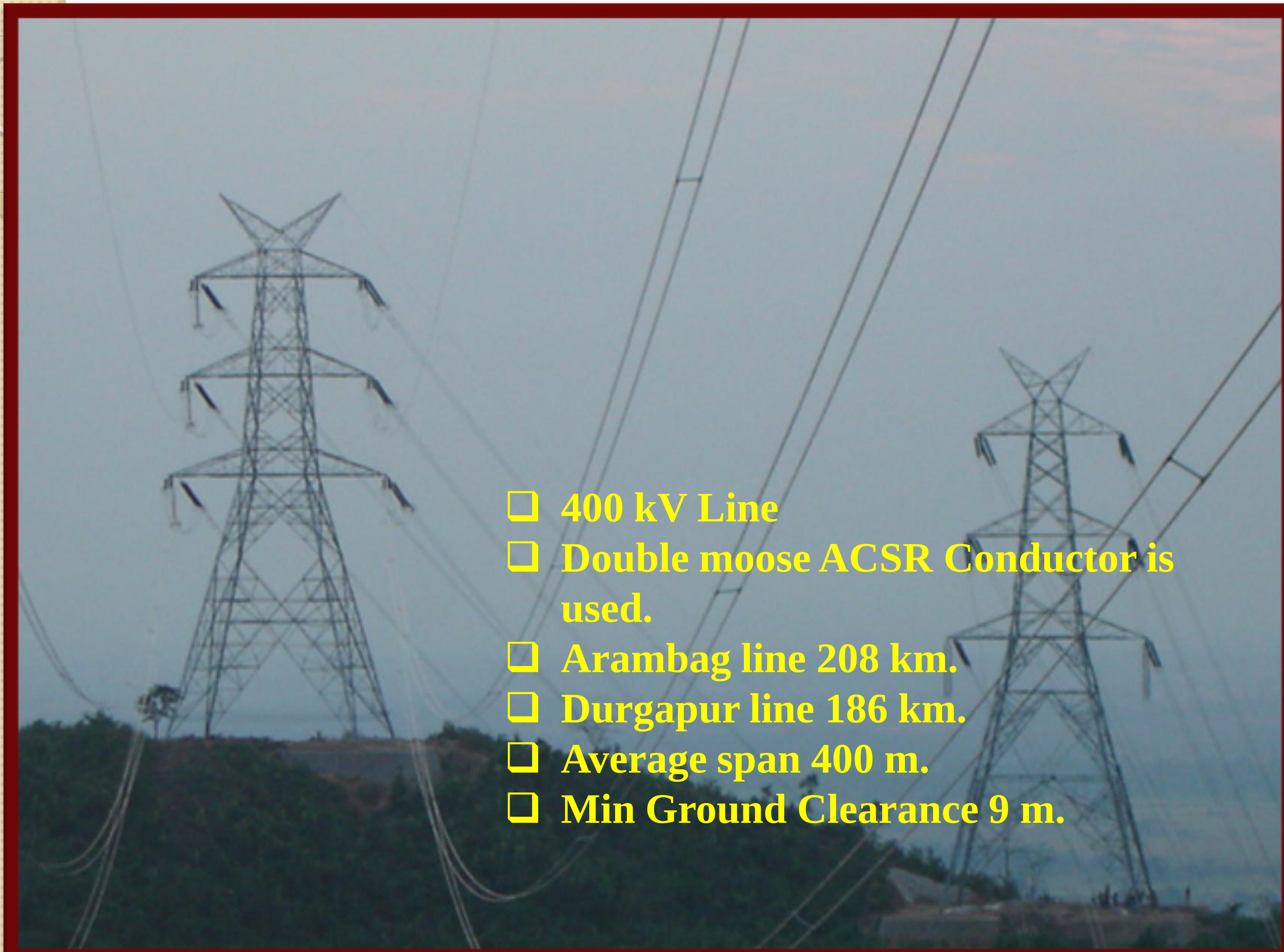
GENERATOR - MOTOR

➢ No of Unit	:4
➢ No of pole at each generator	:24
➢ No of pole winding turn	: 25
➢ Generator	:250 MVA (0.9pf lag)
➢ Motor	:255 MW(0.95 pf lead)
➢ Rated Voltage	:16.5 kV
➢ Armature Current (in P-mode)	:9546 Amp
➢ Armature Current (in G-mode)	:8748 Amp
➢ Excitation Current (G-Mode)	:2060 Amp
➢ Excitation Current (P-Mode)	:2040 Amp
➢ Excitation Voltage	:305 Volt
➢ Rated Speed	:250 RPM

PUMP-TURBINE

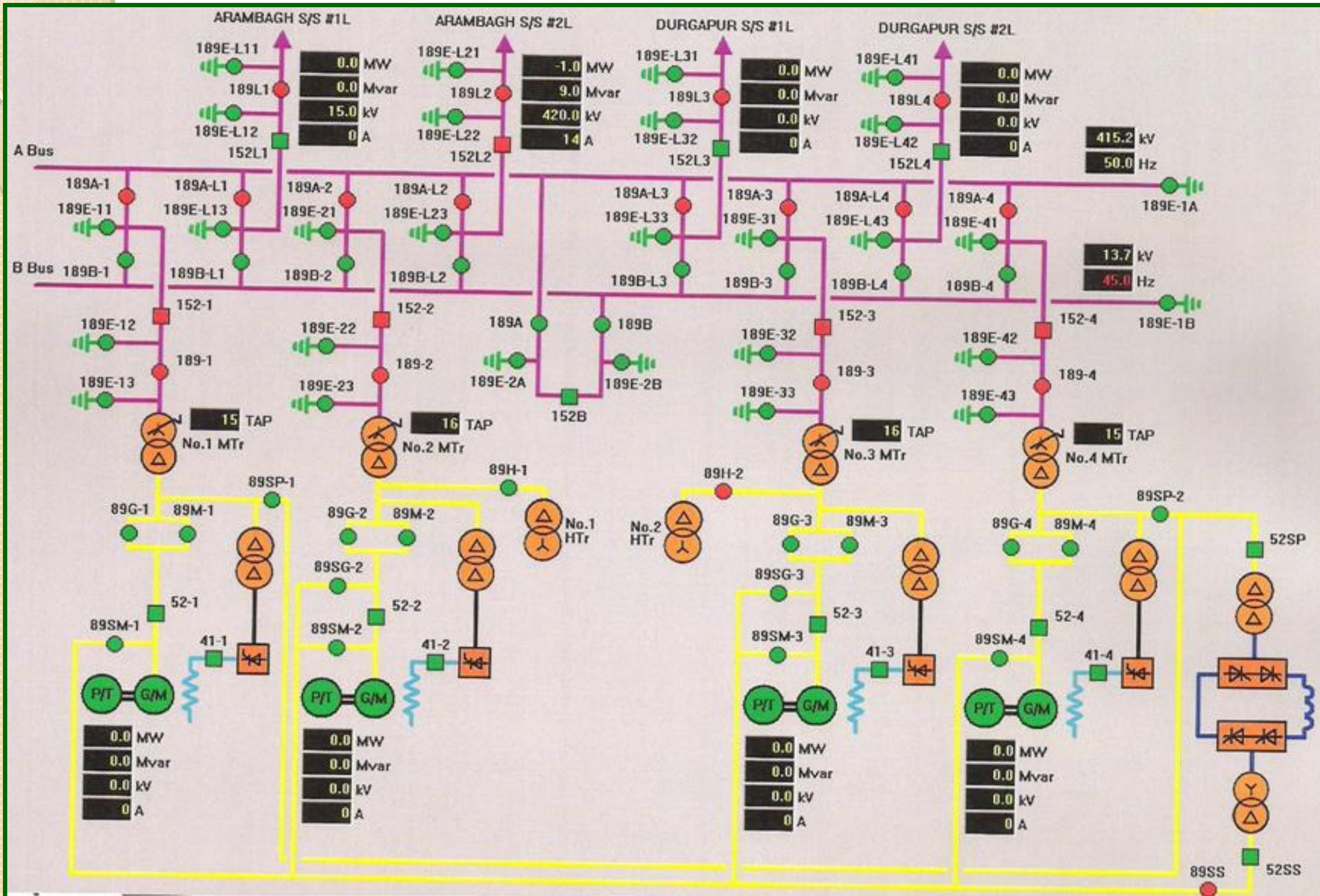
NO OF UNITS	:4
TYPE	:Vertical shaft, Francis Type reversible pump turbine
NORMAL NET HEAD	:177 M
MAX/ MIN NET HEAD	:214.5 M / 149.5 M
RATED TURBINE O/P	:230 MW
RUNNER WEIGHT	:59 TONE
MAX. PUMP I/P	:250 MW
NO OF GUIDE VANE	:20
SERVO OIL PRESSURE	:6.94 MPA
RATED SPEED	:250 RPM
MAX. DISCHARGE	
TURBINE	:150.0 Cum / sec

400 KV TRANSMISSION LINES



- 400 kV Line
- Double moose ACSR Conductor is used.
- Arambag line 208 km.
- Durgapur line 186 km.
- Average span 400 m.
- Min Ground Clearance 9 m.

STATION OVERVIEW

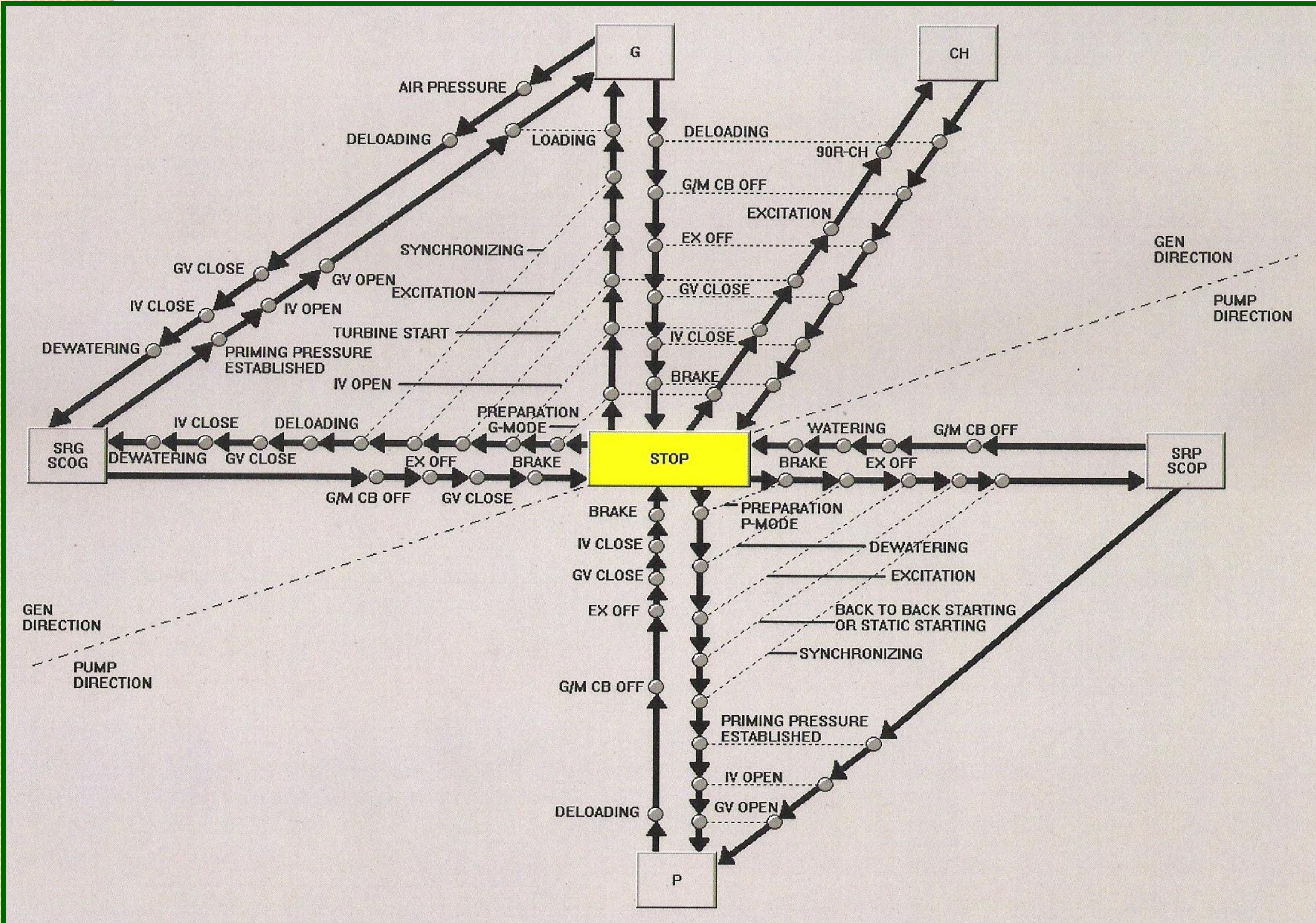


Now we are looking at a glance various mode of operations of PPSP Units in next few slides.

OPERATING MODE AND MODE CHANGING OPERATION:

- This power station has following five modes of operation.
- Generating Operation (G)
- Pumping Operation (P)
- Synchronous Condenser Operation in Generating Direction (SCOG)
- Synchronous Condenser Operation in Pumping Direction (SCOP)
- Line Charging Operation (CH)

VARIOUS MODE OF OPERATION OF PPSP UNITS



BENEFITS FROM THE PROJECT

- Peaking output : 900 MW
- No of peaking hrs : 6 hrs.
- Energy benefit : 5.4 mu / day
- Peak demand can be met instantly
- Plant load factor of thermal power station can be improved.
- Provide grid stabilisation services
- Utilizes surplus grid power to pump water from lower reservoir to upper reservoir at lean hours

- Ability to store large quantities of energy
- Load balancing
- Provide backup power & is instrumental for emergency preparedness

Generation and Pumping Data For Last 3 years:

Year	Energy Generated (MU)	Pumping Power (MU)	Plant availability factor (%)	Cycle efficiency (%)
2014-15	1416	1829	91.98	77.4
2015-16	1055	1357	76.72	77.7
2016-17	1106	1416	79.34	78.1
2017-18 Up to May 17	152	198	99.99	76.7

Purulia Pumped Storage Project :

Capacity 4x225MW = 900MW

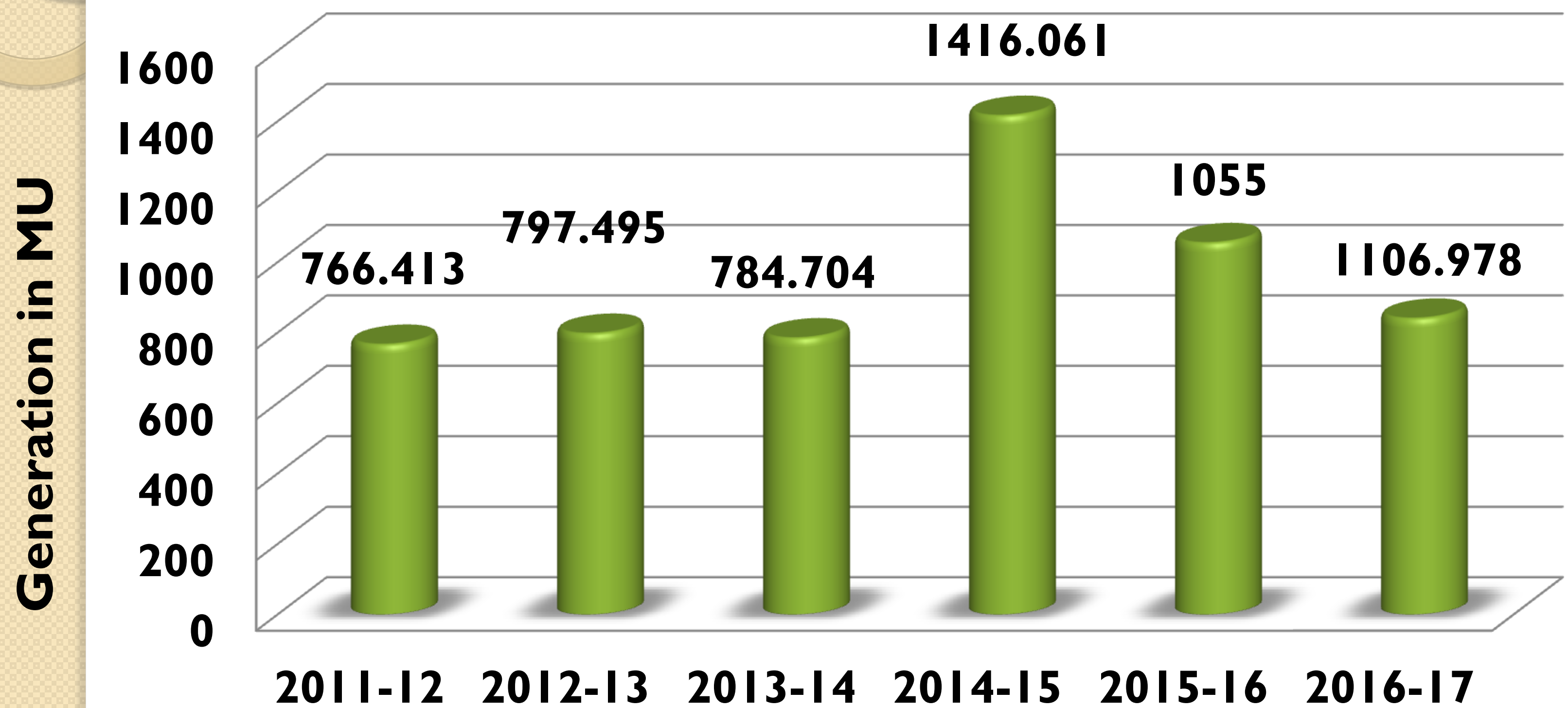
Designed Yearly generation = 1897 MU;

Designed Cycle efficiency =75.5%

Purpose :

1. **To cater peaking load demand**
2. **Grid balancing**
3. **To enhance plant load factor and efficiency of thermal units in the State**

PPSP Yearly Generation (MU)



Hydro Power Station of WBSEDCL

Name of the Power Station	Installed capacity	Remarks
Rammam Hydel Project	51 MW	
Teesta Canal Fall Hydel Project	67.5 MW	
Jaldhaka HEP	44 MW	
Massanjore HEP	4 MW	Small Hydel Project
Little Rangit HEP	2 MW	Small Hydel Project
Rinchington HEP	2 MW	Small Hydel Project
Mungpo-Kalikhola HEP	3 MW	Small Hydel Project
Fazi HEP	1.2 MW	Small Hydel Project
Sidrapong HEP	600 KW	Small Hydel Project
TOTAL (Hydel)	175.3 MW	

CONCLUSION:

- ❖ For grid stability, reliable supply and providing quality power, peak load plant to base load plant mix ratio should be 40:60. This can be achieved by installing pumped storage scheme.
- ❖ With rising levels of intermittent renewable energy generation by wind and solar system, clean energy pumped storage solution are being pursued.
- ❖ Pump storage can contribute to a future of sustainable energy.

- Bulk energy storage could promote the development of new variable energy because it would be able to shift renewable energy from low demand period to higher demand periods, thereby maximising the value of these green power projects.
- Regulatory Policy work can contribute to the development of valuable facilities, by assigning an actual value and compensation practices for the benefits of faster ramping resources & other ancillary services provided by pumped storage plants.

- Incentivizing the Pumped Storage Projects in a proper way. If the loss due to cycle efficiency is compensated by way of grant of 15 % of project cost, the cost of generation and tariff of the project may become reasonable.
- Arrangement of Viability Gap Funding under National Clean Energy Fund for developing Pumped Storage Project, so that it can support large scale renewable powers to be integrated in the grid effectively.

Thank You!

Pumped Storage Schemes (PSS)

Maharatna Company

Hydro Business Group

Presentation Outline

- Contribution of BHEL in Hydro
- Engineering & Manufacturing Capabilities
- Why Pumped Storage Schemes (PSS)
- BHEL association in earlier PSS
- Qualification Issues

Contribution of BHEL in Hydro

- First Hydro Generating Set commissioned : 3X33 MW Obra HEP in 1970
- BHEL hydro sets account for 44.62% of total installed hydro capacity in the country
- Experience of supplying and commissioning of more than 500 sets in India and abroad
- BHEL has contracted 5877 MW of pumps for various lift Irrigation Schemes. Largest pump is of 145 MW unit rating.
- Manufacturing capacity of 2500 MW per annum at Bhopal works, can be supplemented by Hardwar unit
- State of Art turbine model testing Laboratory at Bhopal : only hydro equipment manufacturer in India having a model test lab

Engineering & Manufacturing Capabilities

	Unit Rating (MW)	Head (m)	Runner Dia. (mm)
PELTON			
Capacity	1.5 to 300	200 to 1500	1000 to 5000
Actual	1.5 to 200	200 to 1100	Upto 3500
FRANCIS			
Capacity	5 to 400	30 to 600	1000 to 8000
Actual	Upto 200	Upto 500	Upto 5680
KAPLAN			
Capacity	2 to 150	10 to 80	1200 to 8500
Actual	Upto 75	Upto 50	Upto 5650

Engineering & Manufacturing Capabilities

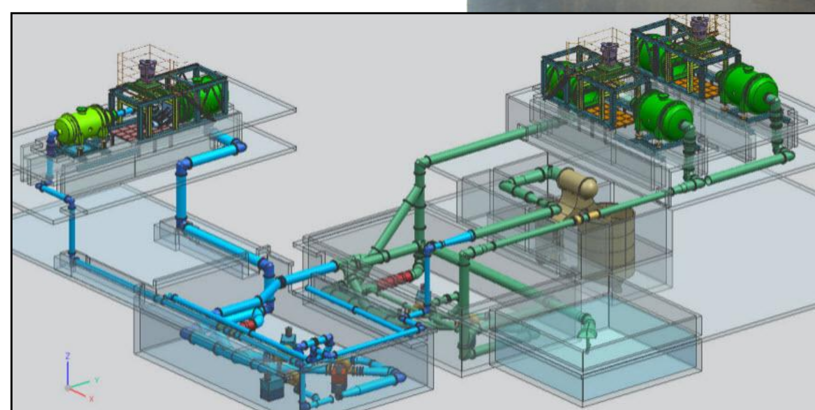
Model Development & Testing Facility - Bhopal

- **Recognized by the Department of Scientific & Industrial Research (DSIR), Government of India as in-house R & D group for Hydraulic Design & Development of Hydro Turbines.**

- **Accredited by NABL as per ISO / IEC 17025 :2005 in the field of Fluid Flow Testing.**

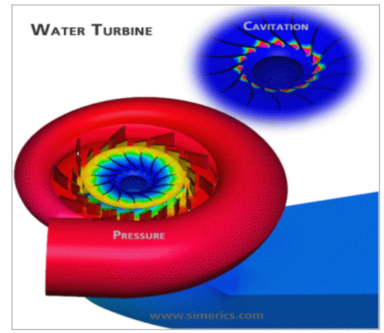
- **Fully automated Model Test Facility with 3 Universal test-beds for all types of turbines, pumps and reversible pump-turbines fulfilling IEC-60193 recommendations.**

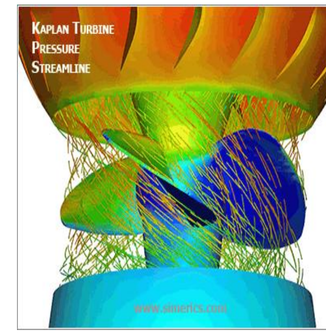
- **Dedicated Workshop with CNC Machines (5-axis and 3-axis) for accurate Model manufacturing.**

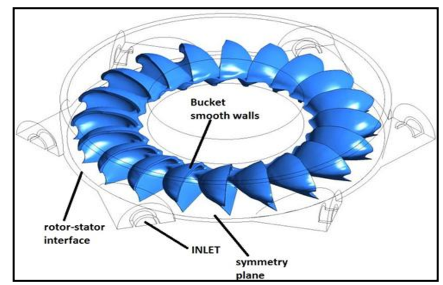


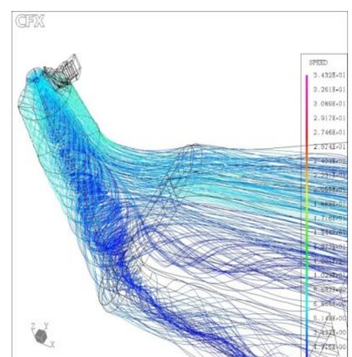
CFD Centre – Bhopal

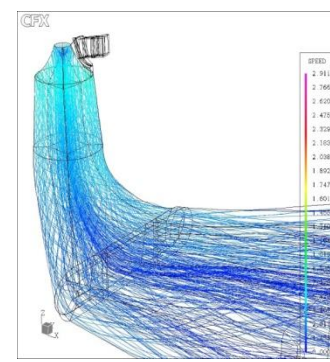
- **Equipped by a dedicated CFD laboratory which forms the basic back-bone of Hydraulic design and optimization of Hydraulic profiles.**
- **Dedicated High Performance Cluster for CFD Analysis.**
- **Capability of Hydraulic design and optimization of full range of Francis, Kaplan, Pelton turbines & pumps.**
- **Advance Research undertaken in the field of hydraulic machinery.**











Engineering & Manufacturing Capabilities at BHEL Bhopal

- **Total Dedicated Engineering strength of 200 Engineers.**
- **Hydraulic design capability for all types of turbines.**
- **Strength calculations for all components using latest CAD /CAE tools.**
- **Use of F.E.M for all major components for turbine & generator**
- **3-D Visualization of different assemblies by 3D Solid Modeling**
- **Designing done through Knowledge Based Engineering system.**
- **Designs developed for longer life, easy maintenance and cost reduction.**

Dimensional details of large size Hydro Turbines

Project	Runner Max Dia (mm)	Turbine Shaft Dia (mm)	Head Cover Dia (mm)	Pivot / Bottom Ring Dia (mm)	Stay Ring Dia (mm)
Ranjit Sagar (4 x 150 MW)	4550	1050	5580	5200	7060
Sardar Sarovar RPT (6 x 200 MW)	7000	1220	9520	8980	10880
Srisailam RPT (7 x 110 MW)	6680	1168	9180	8591	10530
Indira Sagar (8 x 125 MW)	5681	1120	7300	7020	8560
Koldam (4 x 200 MW)	4900	1168	6200	6000	7500
Nagarjun Sagar RPT (7 x 100 MW)	4500	965	7760	7230	8450

Milestones in Hydro Generators

Sl. No.	Description	Rating
1	Highest capacity vertical - JV	6x305 MVA, 300 RPM for Naptha Jhakri power house in India
2	Biggest in physical size	6x165 MVA, 136 RPM for Srisailam power house in India with a frame diameter of 13.4 m
3	Heaviest thrust bearing load	1800 tons for 4x84 MVA, 150 RPM for Ukai power house in Gujarat
4	Highest speed machine	1x24 MVA, 750 RPM for Kundah 'V' power house in Tamilnadu
5	Highest capacity (vertical) generator / motor - JV	6x222 MVA, 136 RPM for Sardar Sarovar Dam
6	Largest Bulb generators	2 x 9 MW, 125 RPM for Mukerian HEP

Higher Rating Generating Sets (150 MW & Above) - Supplied & Commissioned

Project	Customer	Rating	Type Of Turbine	Head (m)	Speed (Rpm)	Year of Commg 1st Unit
Nathpa Jhakri	SJVN	6 x 250	Francis	428	300	2003
S. Sarovar	SSNNL	6 x 200	R. Francis	116.6	136.4	2006
Kol Dam	NTPC	4 x 200	Francis	131.2	166.6	2015
Tala	Bhutan	6 x 170	Pelton	819	375	2006
Dehar	BBMB	6 x 165	Francis	282	300	1977
Srisailam	APSEB	6 x 150	R. Francis	82.8	136.4	2003
Ranjit Sagar	PSEB	4 x 150	Francis	100	166.7	2000

Higher Rating Generating Sets Under Execution

Project	Customer	Rating MW	Type Of Turbine	Head (m)	Speed (rpm)
Parbati-II	NHPC	4 x 200	Pelton	789	375
Punatsangchhu - I	PHPA Bhutan	6 x 200	Francis	338	250
Mangdechhu HEP	MHPA Bhutan	4 x180	Pelton	692	375
Punatsangchhu - II	PHPA Bhutan	6 x 170	Francis	241	250
Kameng	NEEPCO	4 x 150	Francis	504	428.6
Tapovan Vishnugarh	NTPC	4 x 130	Pelton	483	300
Vishnugad Pipalkoti	THDC	4x111	Francis	212.46	250

Higher Rating Pump Sets

Name of the Project / Scheme	No. x Rating in MW	Total MW
AMRP Lift Irrigation Scheme (Sri Sailam LBC)	4 x 18 MW	72
Mahatma Gandhi Kalwakurthy Stage-I LIS	5 x 30 MW	150
Jawahar Nettempadu Stage-I LIS	4 x 17 MW	68
Jawahar Nettempadu Stage-II LIS	3 x 17 MW	51
Koilsagar Stage-I LIS	2 x 7.5 MW	15
Koilsagar Stage-II LIS	2 x 7.5 MW	15
Mahatma Gandhi Kalwakurthy Stage-III LIS	5 x 30 MW	150
Pranahitha Chevella LIS Package - 6	7 x 116 MW	812
Pranahitha Chevella LIS Package - 8	7 x 139 MW	973
Pranahitha Chevella LIS Package - 10	4 x 106 MW	424
Pranahitha Chevella LIS Package - 11	4 x 134 MW	536
Palamuru Rangareddy LIS Stage - 2	9 x 145 MW	1305
Palamuru Rangareddy LIS Stage - 3	9 x 145 MW	1305
	Total	5877

	No of Sets	Total MW
Total Commissioned projects	**22**	**431**
Total under execution projects	**43**	**5446**

Why Pumped Storage Schemes (PSS)

- Government of India has set an ambitious program for increase in Renewable Energy Generation. Wind and solar plants are subject to daily cyclic natural fluctuations, as well as seasonal fluctuations leading to grid instability.

- Hydro pumped storage systems shall play an important role in providing storage of power and maintaining grid stability -- most of the developed countries are following this route.

- Hydro pump storage system is the only long term technically proven solution without any restriction of Unit capacity, is cost-effective, highly efficient and provides operationally flexible energy storage on a large scale and is available on short notice.

- In India the first pumped storage plant was taken up at Nagarjunasagar in Andhra Pradesh in the year 1970 with installed capacity of 700 MW. The project got commissioned during 1980-1985.

BHEL association in earlier PSS

Out of 4786 MW of PSS capacity in India, BHEL has been associated in the following schemes as partner with foreign manufacturers

Project	Collaborator	Rating	Rated Head	Rated Speed	Year of commng
Kadamparai (Tamilnadu)	Boving (T) AEI (G)	4 x 100 MW	341m (T) 381m (P)	500 rpm	Oct 87 till Dec 88
Nagarjun Sagar (AP)	Hitachi (T) MELCO (G)	7 x 100 MW	93m (T) 97m (P)	157.8 rpm	Oct 84 till Dec 85
Srisailam (AP)	Hitachi (T) MELCO (G)	6 x 150 MW	82.8m	136.4 rpm	Mar 01 till Sep 01
Sardar Sarovar (Gujarat)	Hitachi (T) Toshiba (G)	6 x 200 MW	100m (T) 96m (P)	136.4 rpm	Mar 06 till Jun 06
Ghatghar (Maharashtra)	Fuji (T&G)	2 x 125 MW	410m (T) 430 m (P)	500 rpm	Apr 08
Kadana (Gujarat)	Skoda	4 x 60 MW	43.5 (T) 47 (P)	142.8 rpm	May 98

BHEL's concern in PSS

- **While BHEL has been associated in Six PSS projects, BHEL does not possess the qualification requirements as orders were placed on foreign manufactures, with BHEL as partner**
- **BHEL over the years has developed its own technology and is capable of supplying PSS schemes**
- **BHEL is already a leader in design, engineering & supply of large size pumps for Lift Irrigation Schemes**
- **In view of forthcoming requirement of PSS, It would be in the interest of all stakeholders to qualify BHEL for future PSS tenders**

Qualification Issues

Concerns regarding PQ and suggested way forward

- **E & M package to be a stand alone Package (excluding any civil works); Alternatively E & M works vendor can be a nominated sub-vendor to the civil party**

- **Options for qualification should be available to companies like BHEL who have earlier executed reversible Pump-Turbine sets in India in association with established Pump-Turbine manufacturers**

Proposed Qualification criteria

A. General Experience: Prime contractor/ lead partner/ JV partner/ EPC contractor having experience of having executed E & M pkg. for a hydro project, valued at 50% of E&M estimated value in last 20 Years

B. Specific Experience:

i. Designed, engineered, manufactured, tested, erected/ supervised erection and commissioning/ supervised commissioning of at least one (1) no. reversible Pump Turbine of minimum 50% MW unit capacity OR one (1) no. of Pump of minimum 50% MW unit capacity in last 20 years in India and should be in successful operation.

Cont…

Proposed Qualification criteria

AND

ii. **Designed, engineered, manufactured, tested, erected/ supervised erection and commissioned/ supervised commissioning of at least one (1) no. hydro turbine generator set of not less then 50% MW unit capacity in last 20 years in India and should be in successful operation.**

AND

iii. **Designed, engineered, manufactured, tested, erected/ supervised erection and commissioned/ supervised commissioning of at least one (1) no. Generator of not less then 50% MW (equivalent MVA) unit capacity in last 20 years in India and should be in successful operation.**

Methods of achieving the qualification

Qualification

General Experience

- Prime Contractor, or
- Lead Partner, or
- JV Partner, or
- EPC Contractor meeting the criteria

Specific Experience

Alt I

- Bidder meeting all the specific criteria (i, ii & iii)

Alt II

- Bidder meeting specific Experience under any one/two of the criteria (i, ii & iii) can associate with a firm meeting balance two/ one of the criteria
- Bidder & associate jointly & severally responsible.
- JDU to be submitted with the bid (as per format)

Alt III

- Bidder shall be a joint venture of firms (Max 3 Nos)
- Firms of JV should together meet criteria (i, ii & iii) JV will identify a lead partner.
- JV agreement to be submitted with bid (as per format) along with Division of Work (DOW)

THANK YOU

9 PSS (4785.6 MW) under operation

S.No.	Name of Project/State	Installed Capacity		Pumping Mode Operation	Reasons for not working in Pumping mode
		No. of units	Total (MW)		
1.	Kadamparai, Tamil Nadu	4x100	400	Working	
2.	Bhira, Maharashtra	1x150	150	Working	
3.	Srisailam LBPH, Andhra Pradesh	6x150	900	Working	
4.	Ghatgar, Maharashtra	2x125	250	Working	
5.	Purlia PSS, West Bengal	4x225	900	Working	
6.	Panchet Hill-DVC	1x40	40	Not Working	Tail pool Dam not constructed
7.	Sardar Sarovar Gujarat	6x200	1200	Not Working	Tail pool Dam under construction
8.	Kadana St.I & II Gujarat	2x60+2x60	240	Not Working	Due to vibration problem
9.	Nagarjuna Sagar, Andhra Pradesh	7x100.80	705.60	Not Working	Tail pool Dam constructed but not yet operational
		Total	**4785.60**		