Impact of Heat Wave on Power System

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
- Solar Generation
- Wind Generation

6 Hydro Generation

10 Pumped Storage Installed Capacity

Source: IEA World Energy Outlook 2022 & IHA 2022 Hydro Status Report

Dimensions of Indian Power System

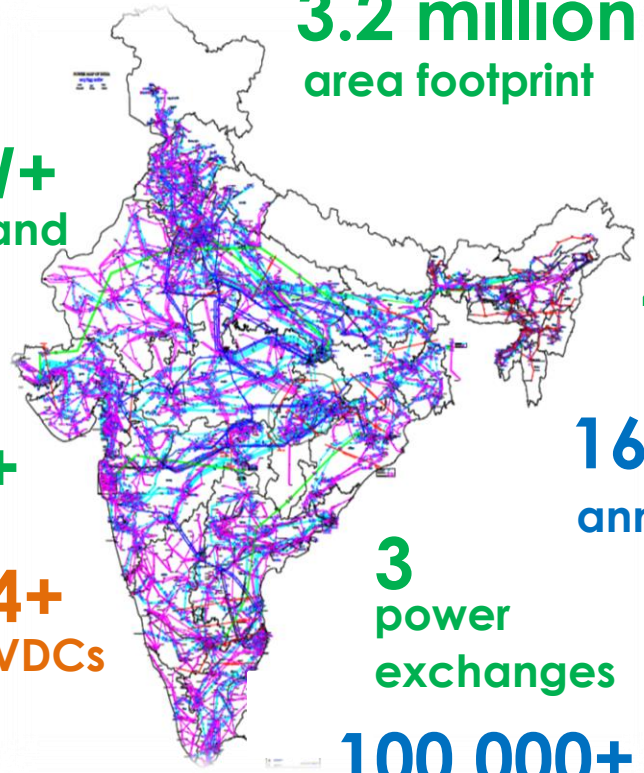
~424 GW
generation capacity

3.2 million km²
area footprint

1.4 Billion+
people served

239 GW+
peak demand

> 4.5 TWh
daily energy met



4 GW+
international exchanges

165 TWh+
annual market trades

468977 ckm+
EHV transmission

~174 GW
renewables
(including large Hydro)

14+
HVDCs

3
power exchanges

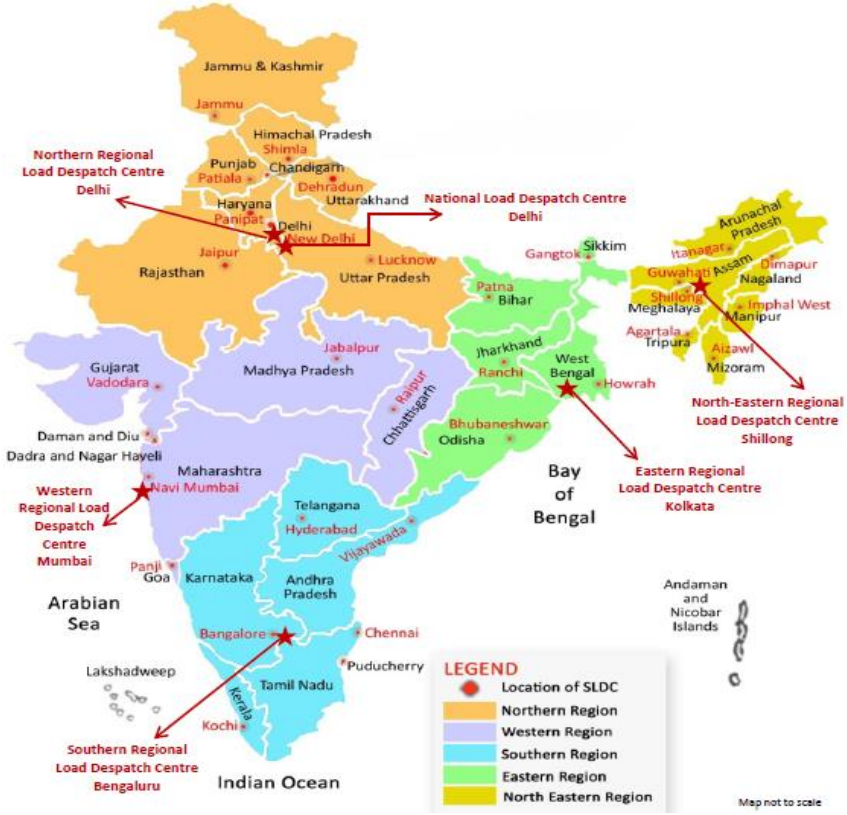
6000+
market participants

~ 112 GW
inter-regional capacity

100,000+
market transactions

Institutional Arrangements

Policy Making	Central Government	CEA	State Government
Regulators	Central Electricity Regulatory Commission	State Electricity Regulatory Commission	
System Operators	National Load Despatch Centre	Regional Load Despatch Centres	State Load Despatch Centres
Generation	Central Generating Stations	State Generating Stations	Private Sector Players
Transmission	Central Transmission Utility	State Transmission Utilities	Private Sector Players
Distribution	State Sector Distribution Licensee	Private Sector Distribution Licensee	
Markets	Trading Licensee	Power Exchanges	Bilateral Markets



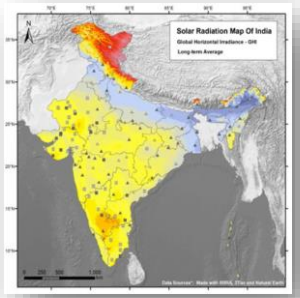
http://www.forumofregulators.gov.in/Data/Reports/FOR%20Report%20CABIL.pdf

Clean Energy Transition Underway in India

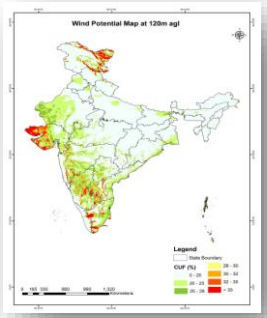
Present Total Installed Capacity ~424 GW
Present Renewable Installed Capacity ~ 172 GW
Present Solar + Wind Installed Capacity ~110 GW

Solar Potential ~ 750 GW, Wind Potential @ 120 mtr agl ~ 700 GW
Off-shore wind potential ~ 70 GW (coast of Gujarat & Tamil Nadu)

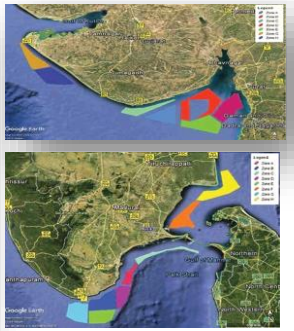
Solar Radiation Atlas



Wind Atlas



Offshore Wind



Region/State (FY 2022-23)	Annual VRE Penetration (Energy Terms)	Maximum Daily VRE* Penetration (Energy Terms)	Maximum Instantaneous VRE Penetration (Energy Terms)
Rajasthan	14.57	35.81	56.00
Northern Region	10.56	18.36	46.75
Gujarat	15.44	35.80	55.80
Madhya Pradesh	11.01	32.40	53.90
Maharashtra	10.10	23.00	37.21
Western Region	11.03	23.10	35.13
Karnataka	27.52	65.38	132.00
Andhra Pradesh	20.50	58.59	81.00
Tamil Nadu	18.42	50.08	77.00
Telangana	12.17	17.63	49.00
Southern Region	16.91	36.32	61.00
All India	11.01	20.40	31.80

*VRE:Wind and Solar only

Source: Ministry of New and Renewable Energy

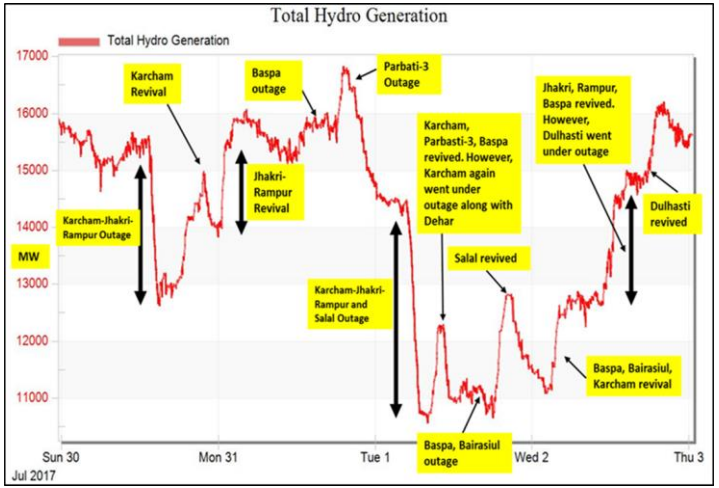
~ 66 GW
Wind + Solar capacity under implementation

~ 45 GW
Wind + Solar capacity tendered

Solar and wind accounted for **92%** of total capacity additions in 2022
Coal accounted for only **5%.**

Impact of Weather on Power System

- **Peak Summer Period(April-June)**
  - High Temperature – Increase in Demand
  - Dust-storms - Load crash, High voltage
- **Monsoon Period(July-Sept)**
  - Widespread rains- sudden load crash & high voltage
  - Sudden hydro generation outage - due to high silt content
- **Winter Period(Dec-Feb)**
  - Multiple element outage due to Fog/smog
- **Cyclones**
  - Power outages, damage to transmission & distribution network
- **Intermittent Renewable Generation**
  - Variation in Wind Speed and Wind Direction
  - Variation in Irradiance due to Cloud Cover, Fog ,Astronomical events



Hydro generation outage due to silt

Impact of Heat wave on Power System

- Impact on Load/Demand.
- Impact on Generation.
- Impact on Transmission Network.

Impact on Load/Demand

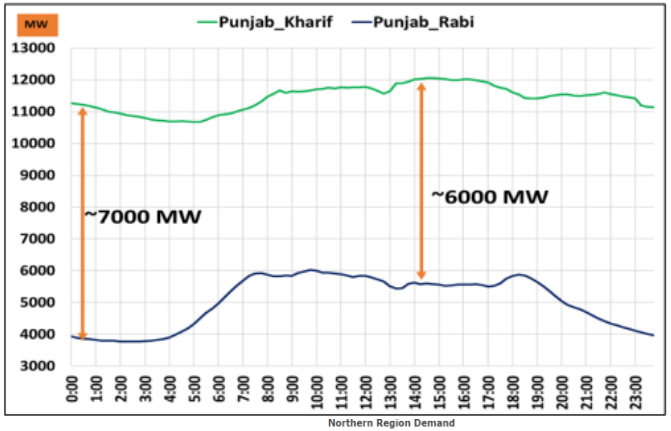
- Due to Heat wave and rise in ambient temperature:
  - ✓ Increase in Peak-demand.
  - ✓ High demand for long duration.
  - ✓ Increase in Energy consumption.
  - ✓ High power flow in Transmission line and Transformer (Overloading of Lines and Transformer resulting Congestion in system)
  - ✓ High Electricity market Price (less availability of Power in the market)

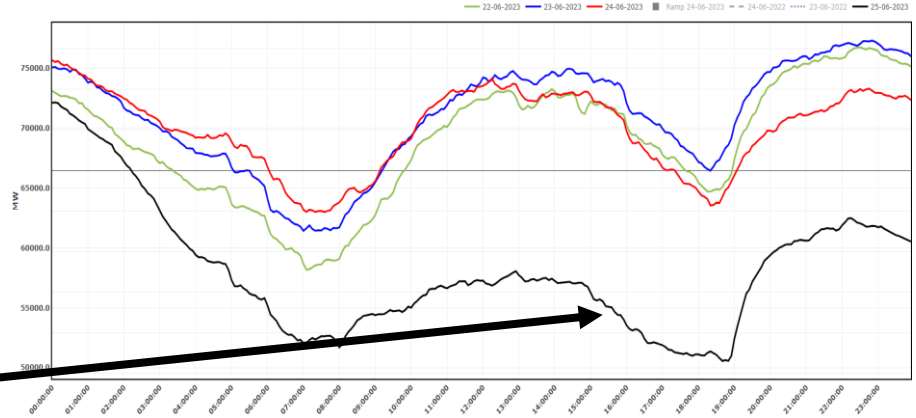
- On average, aggregate electricity demand in India increases by 11% or more at temperatures above 30 °C from demand at temperatures of 21–24 °C.

Power requirements for agricultural supply

- States having large share of agricultural load severely impacted due to heat wave

- Dependency of power demand on rainfall is significant especially in Punjab/Haryana during summer/monsoon.

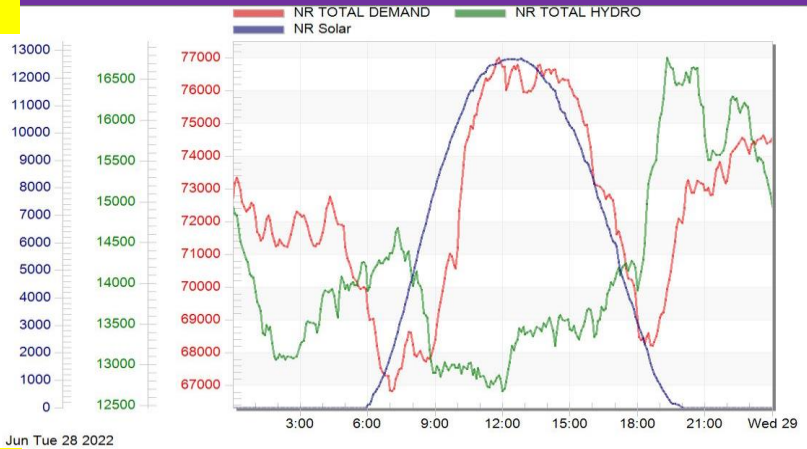




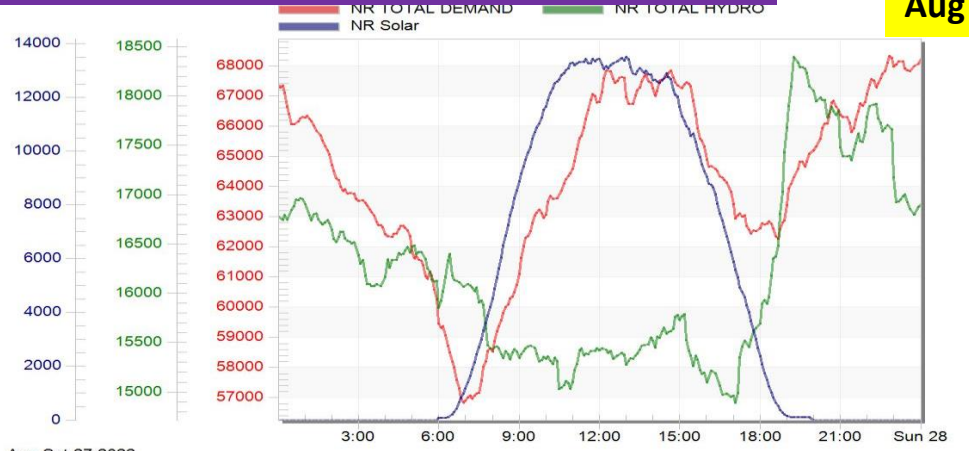
NR Demand crash in June due to rain

Seasonal and Diurnal Variation of Hydro, Solar Generation in Northern Region

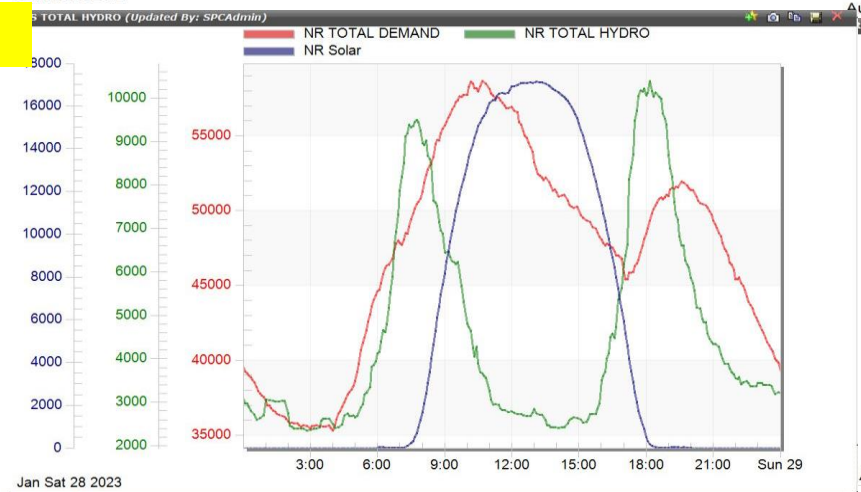
June



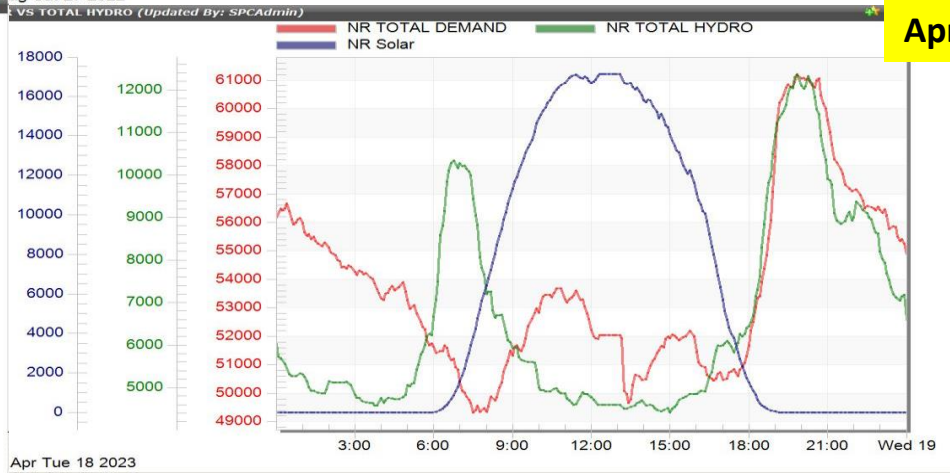
Aug



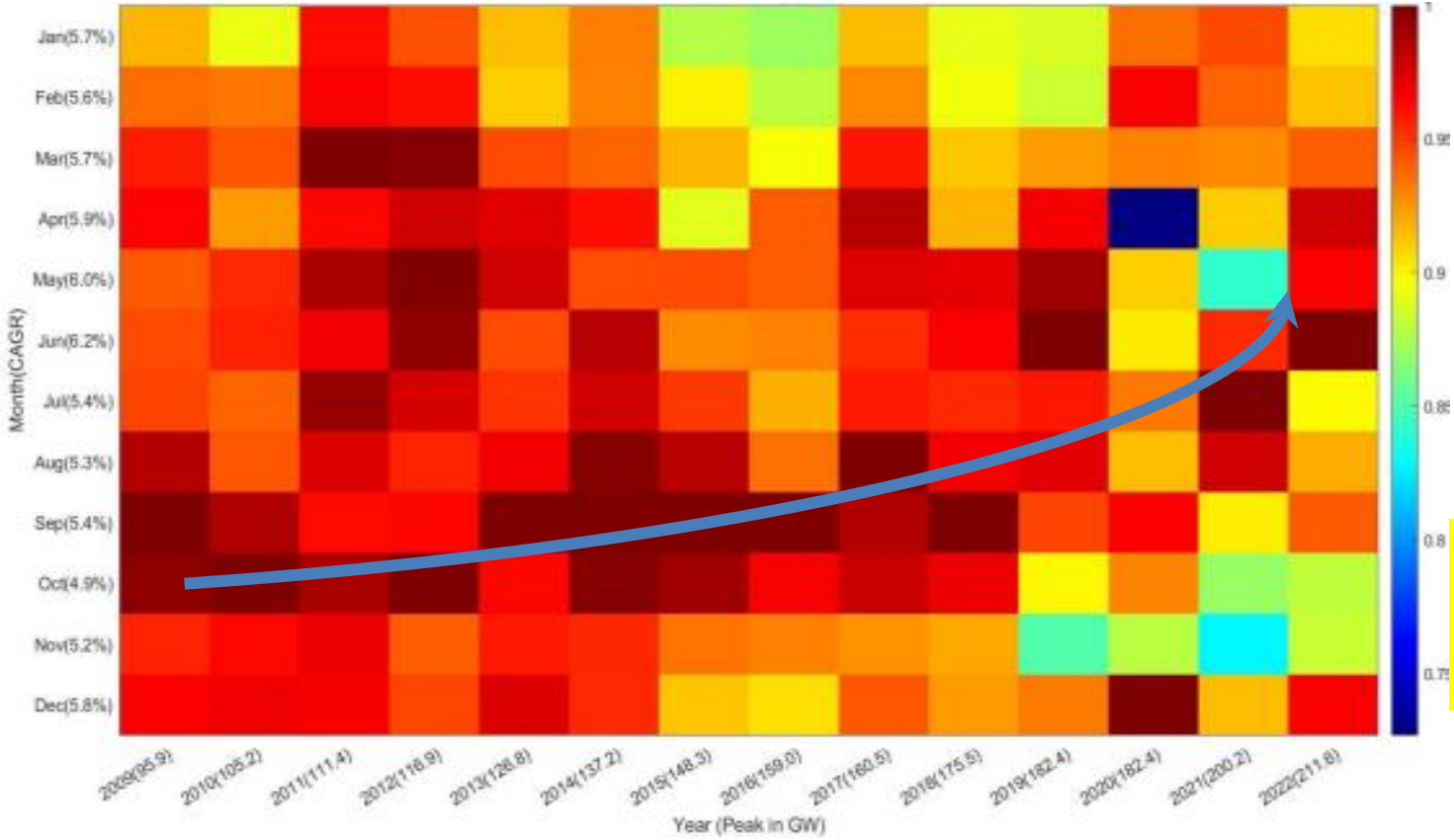
Jan



Apr

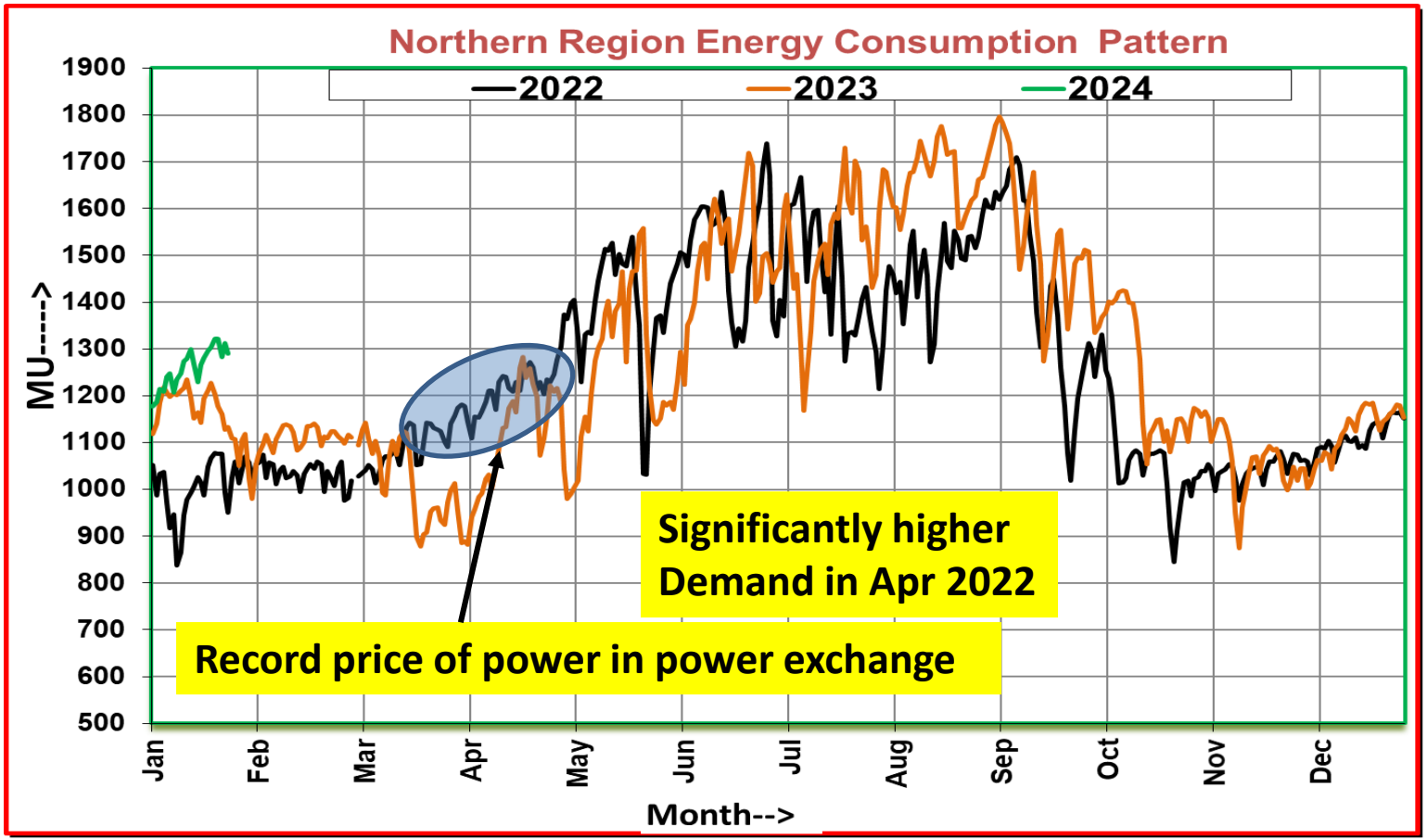


Normalised peak demand with corresponding maximum demand for All India



Maximum demand period shifting from Aug-Sep to Apr-Jun months

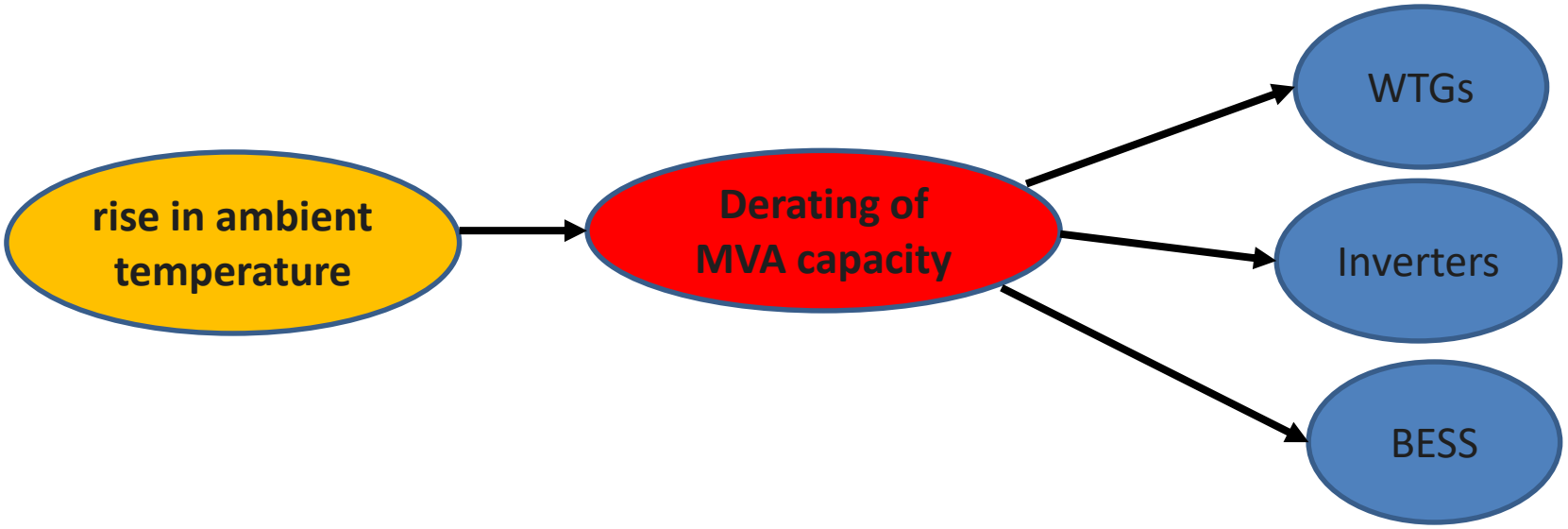
space cooling requirements and agricultural load


Northern Region Energy Consumption Pattern
2022
2023
2024
MU---->
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month-->
Significantly higher Demand in Apr 2022
Record price of power in power exchange

Impact on Generation.

Impact of Solar/Wind/BESS Generation:

- ✓ With Ambient temperature > 25°C, Solar modules efficiency gets reduced (Less DC generation with rise in Temperature).



Temperature de-rating curve of X make inverter

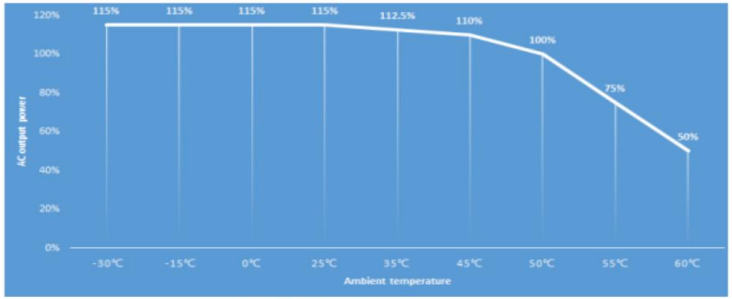


Fig- [redacted] derating curve vs temperature

The [redacted] inverter rated output power is 3125kW, max output power(+25℃) is 3594kW. From -30~25℃, the inverter AC output power is 115% of the rated output power, no derating up to 50℃.

At 25 ℃ ambient temperature, Max. output power : 3594kW,115% overloading
At 45 ℃ ambient temperature, Max. output power : 3438kW.110% overloading
At 50 ℃ ambient temperature, Max. output power : 3125kW.No derating.
At 55 ℃ ambient temperature, Max. output power : 2344kW.75% loading

Temperature de-rating curve of Wind Turbine generator

5. DERATING IN [redacted] WIND TURBINE

Ventilation and cooling systems are designed to allow the WTG operation at rated power up to a certain ambient temperature (nominal temperature) and a certain altitude. For sites located beyond 1000m above the sea level, the air density reduction affects the WTG components ventilation, reducing the maximum operational temperature at rated power.

The control system, regarding the defined WTG type and altitude above sea level, will dynamically adjust the maximum allowed power as a function of the ambient temperature.

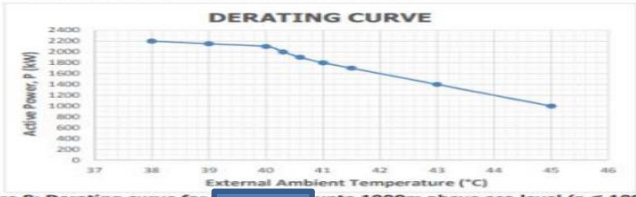
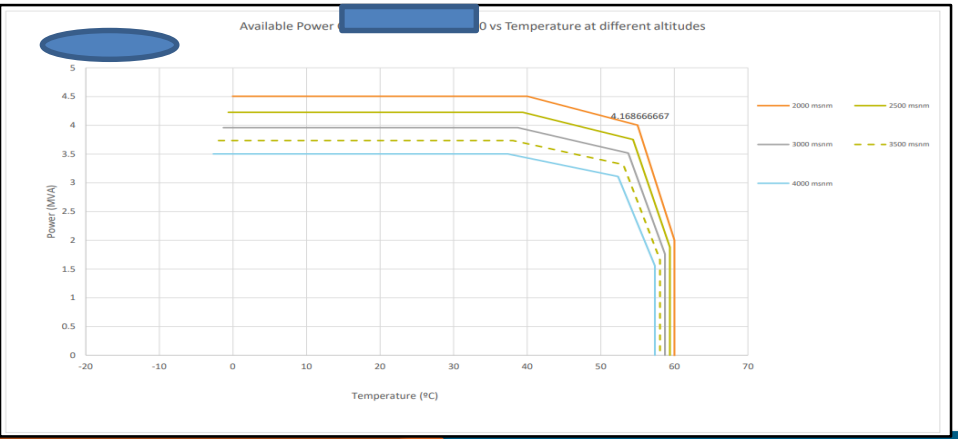


Figure 8: Derating curve for [redacted] upto 1000m above sea level (z ≤ 1000m)

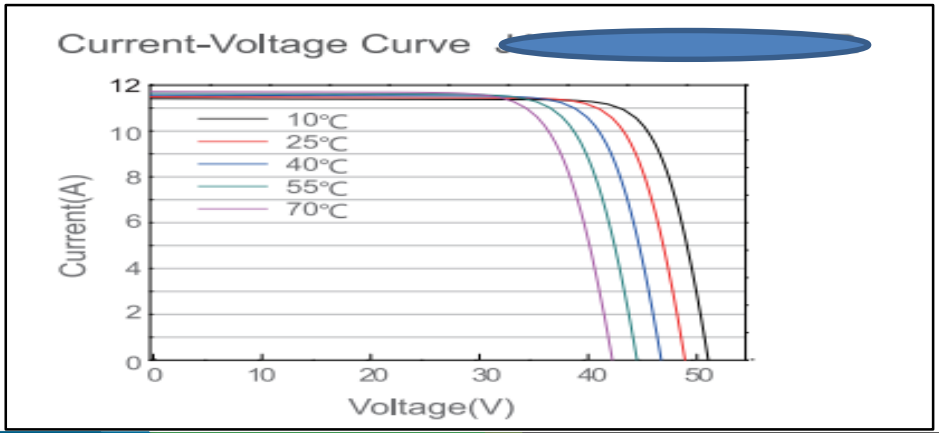
Temperature (°C)	Power (kW)
38	2200
39	2150
40	2100
40.3	2000
40.6	1900
41	1800
41.5	1700
43	1400
45	1000

Table 8: [redacted] values of Power vs Temperature at sea level (z ≤ 1000m)

Temperature de-rating curve of BESS



Solar Module de-rating w.r.t temperature



Impact in Generation.

Impact in Gas based generation:

- increased air temperature also causes derating effects, i.e., reduced capacity and efficiency of gas-turbine (GT) and combine-cycle gas turbines (CCGT)

Increased boiler tube leakage related outages in thermal plants

Impact on Transmission

- Higher ambient temperatures reduces thermal capacity of transmission lines.
- Possibility of tripping increased due to increased sag
- Increased forced outage due to hotspots
- Frequent maintenance requirement (emergency outage)
- Possibility of tripping on high OTI/WTI
- Difficult to work on transmission lines during High temperature

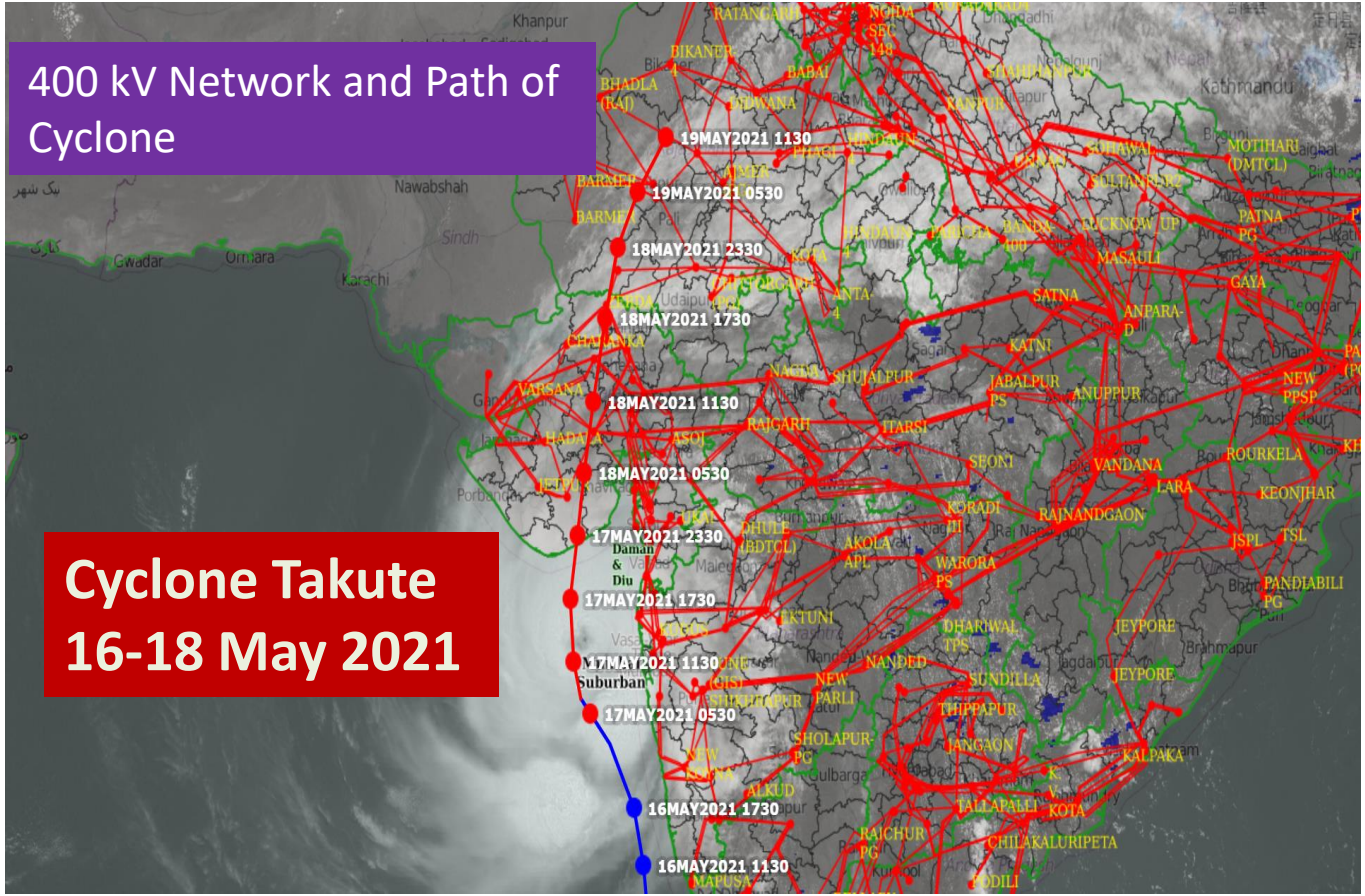
Thermal Loading Limits for ACSR Moose equivalent Conductors:

Name of Conductor	Stranding/wire diameter (mm)		Ambient Temperature (°C)	Ampacity for Maximum Conductor Temperature (°C)			
	Al/Al alloy wire	steel wire		65 ° C	75 ° C	85 ° C	95 ° C
ACSR Moose	54/3.53	7/3.53	40	501	707	858	NA
			45	354	614	787	NA
			48	222	551	740	NA
			50	NA	504	707	NA
AAAC	61/3.55	NA	40	512	724	881	1010
			45	361	629	808	948
			48	225	565	760	909
			50	NA	517	726	882
AL59	61/3.52	NA	40	534	754	916	1049
			45	377	655	840	985
			48	237	588	790	944
			50	NA	538	755	916
AL59	61/3.31	NA	40	503	703	852	975
			45	362	613	782	916
			48	239	552	736	878
			50	88	507	704	852

Measures:

- ***Defining Temperature Zone of the Country based on past data and anticipating future rise in Temperature***.
- **Designing of Solar/Wind/BESS plants as per temperature zone to optimize the overall cost.**
- Additional DC capacity and Inverter/WTG MVA capacity for high temperature zone.
- Generation planning considering heat wave/High Temperature .
- Adequate reserve to meet peak-demand and High energy consumption (Resource adequacy) .
- Adequate Transmission/Distribution infra to meet uninterrupted Power supply.


धन्यवाद
Thank you



Likely 220 kV Substations to be affected : 220 kV Kasod, 220 kV Otha, 220 kV Visavadar 220 kV Jetpur, … 400 kV lines likely to be affected 400 kV Amreli-Jetpur, 400 kV Jetpur-CGPL 400 kV Amreli-Chorania, 400 kV Amreli-Hadala S/C