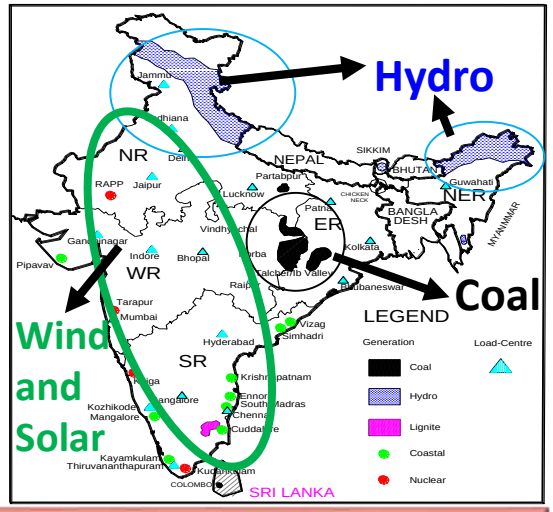
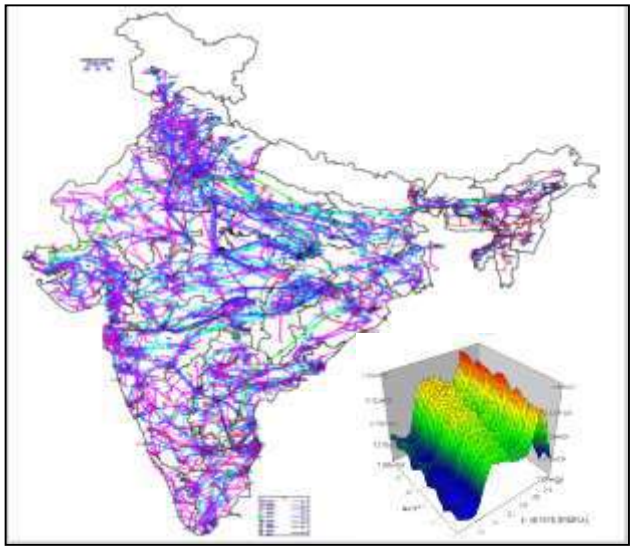
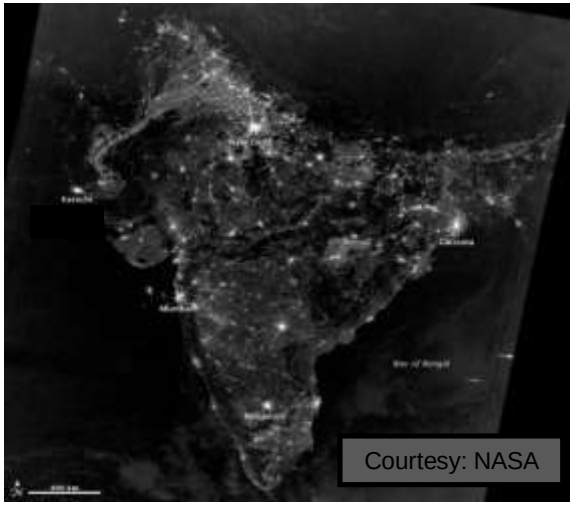
Flexibility Options in India

Indian Grid…Large Footprint







Indian Power System

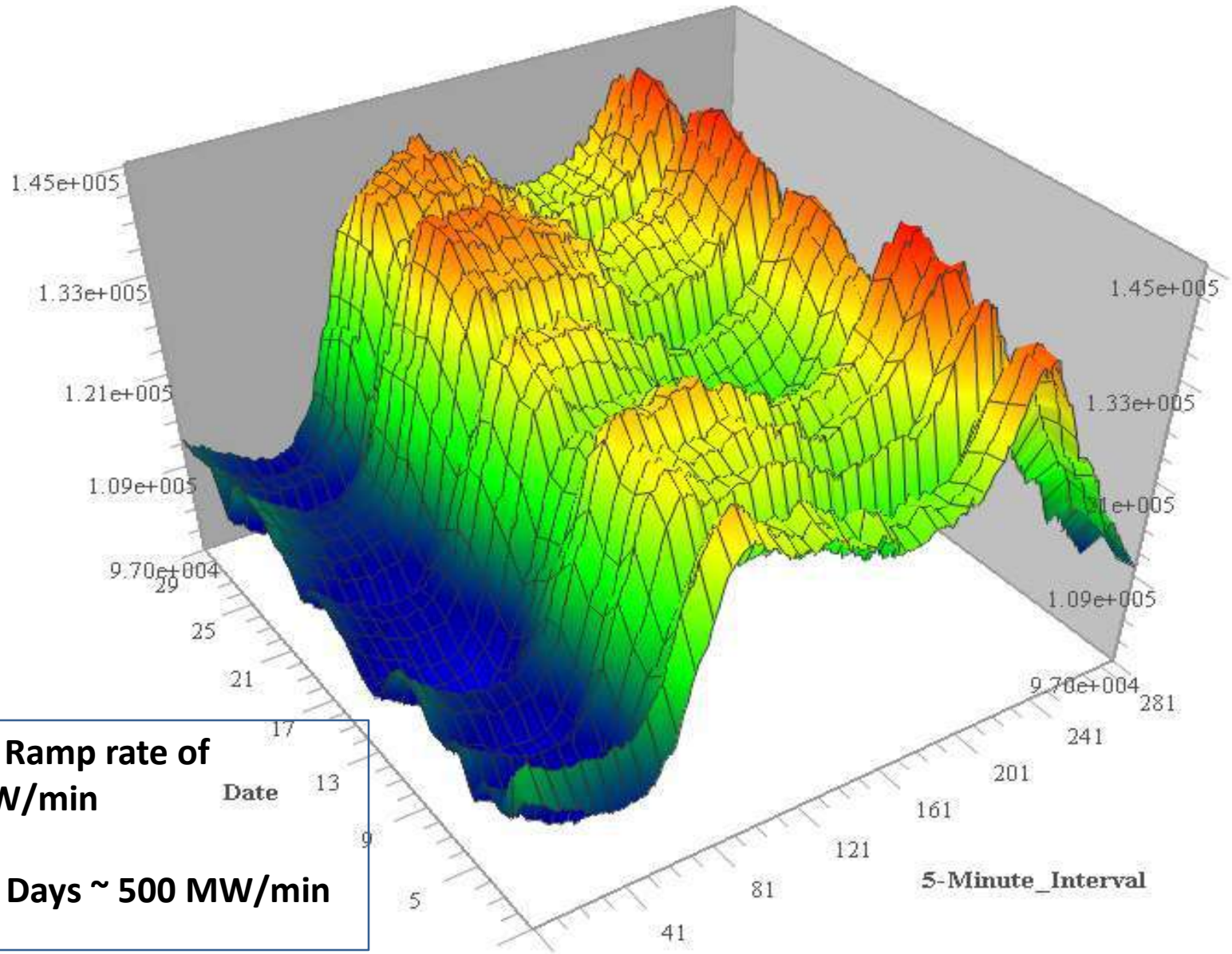
- Generating Stations > 900 Nos.
- Generating Units > 2200 Nos.
- > 7000 Sub-stations,
- > 3100 transformers
- 11 Nos. HVDC Bi-pole/BtB
- > 100 nos. 765 kV lines
- > 1300 nos. 400 kV lines,
- > 3200 nos. 220 kV lines

High growth

- **Demand met – 175590 MW on 18th Sep 2018**
- **Energy met – 3925 MU on 19th Sep 2018**
- **Hydro Generation – 741 MU on 31st Aug 2018**
- **Solar Generation – 116.8 MU on 28th Oct 2018**

International Interconnections

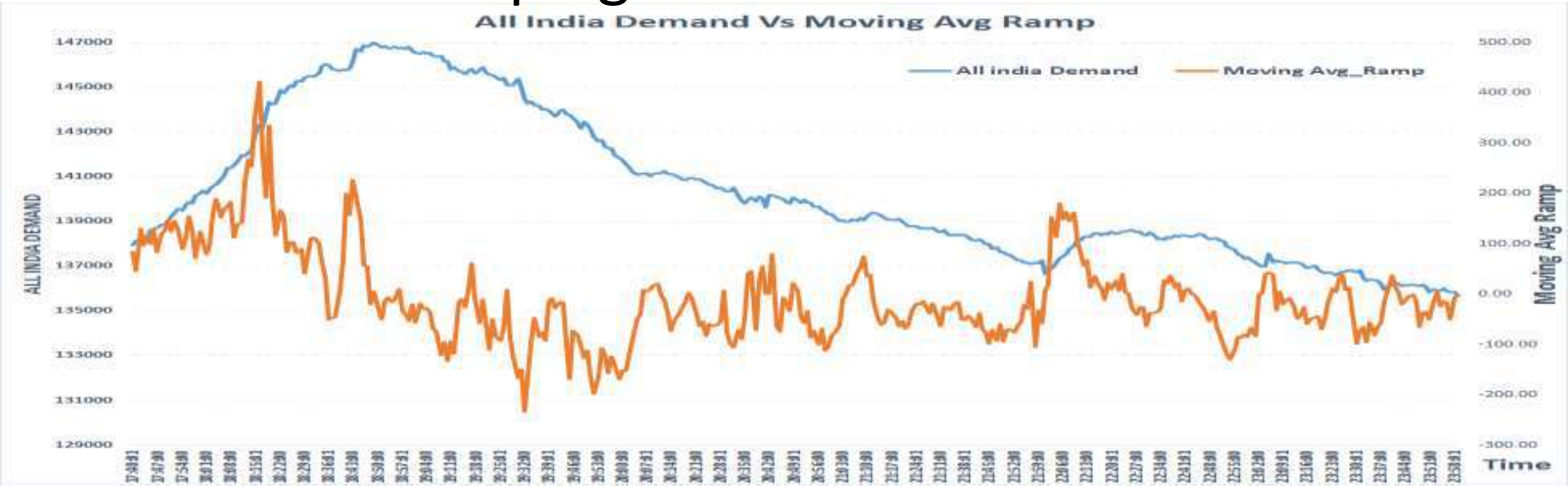
Typical All India Load Pattern

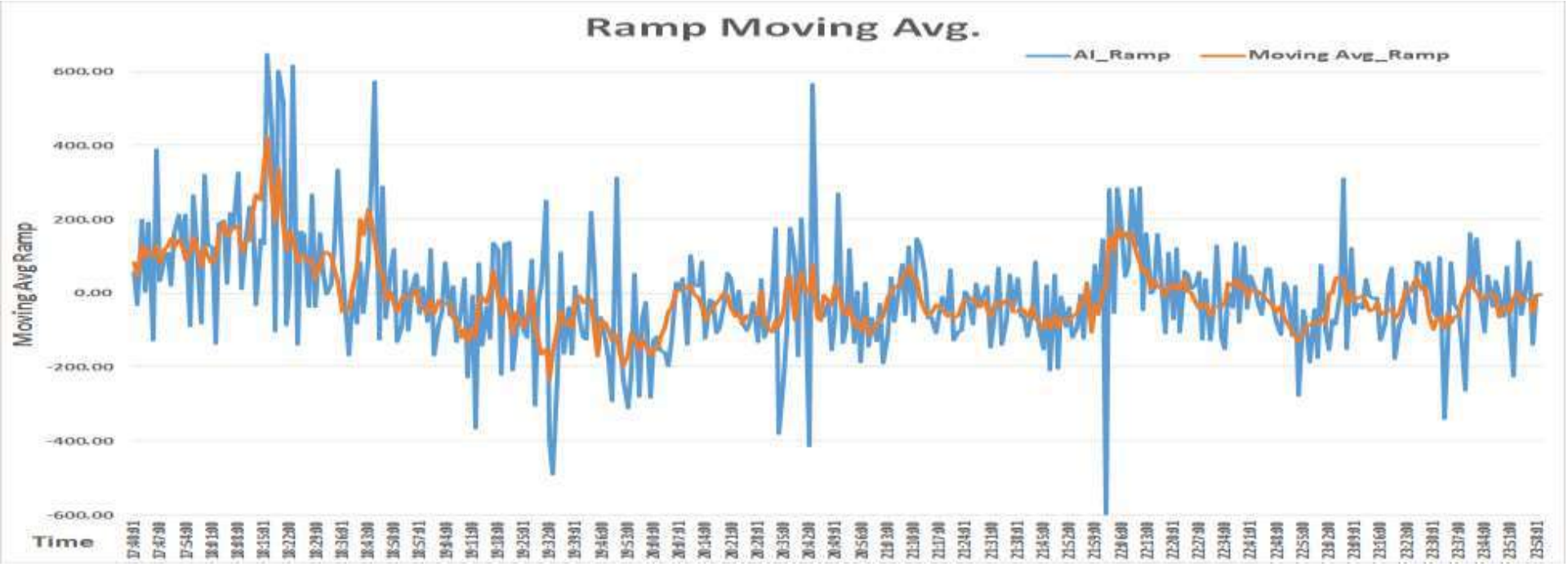


Typical Ramp rate of 250 MW/min

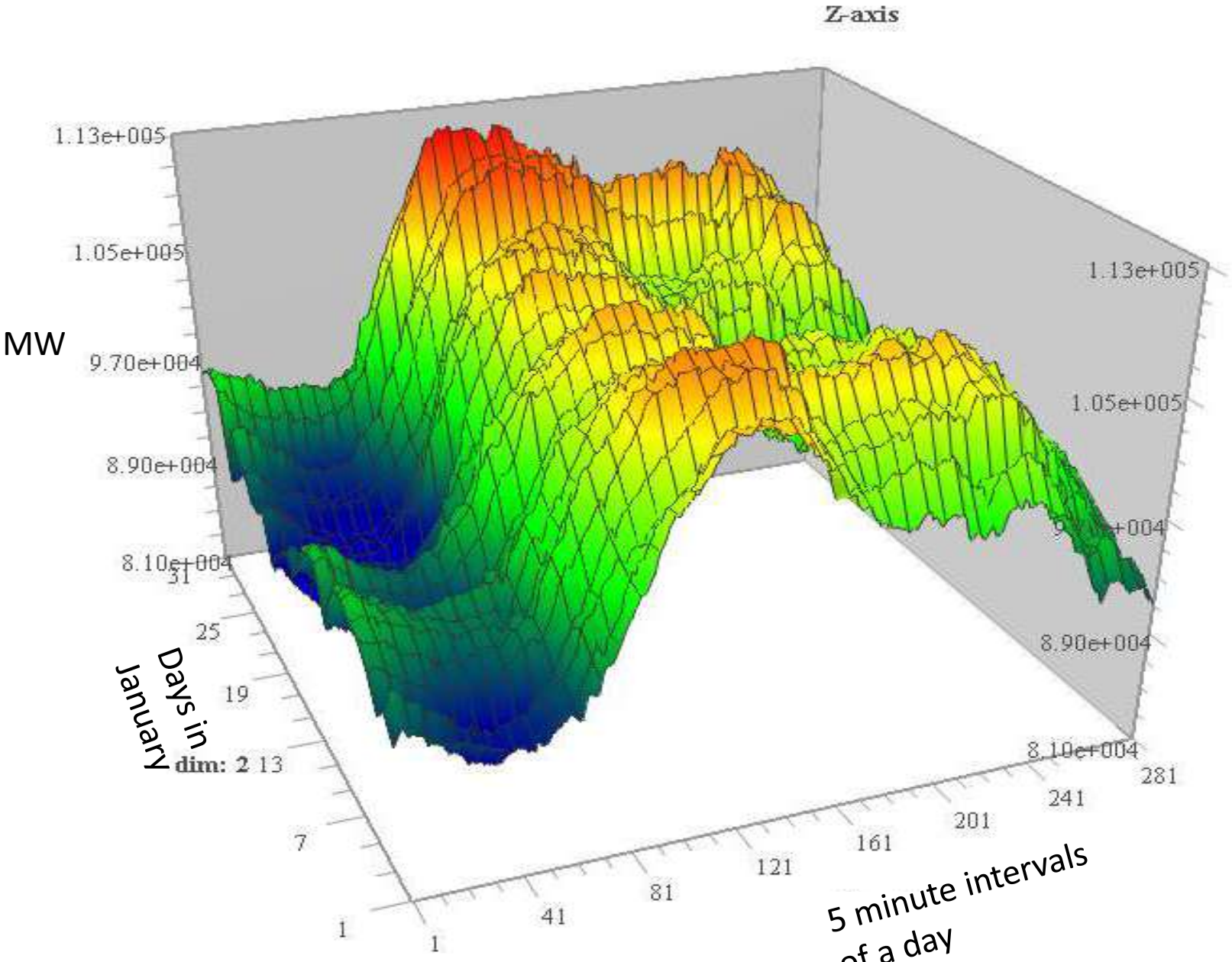
Special Days ~ 500 MW/min

Ramping in All India Demand

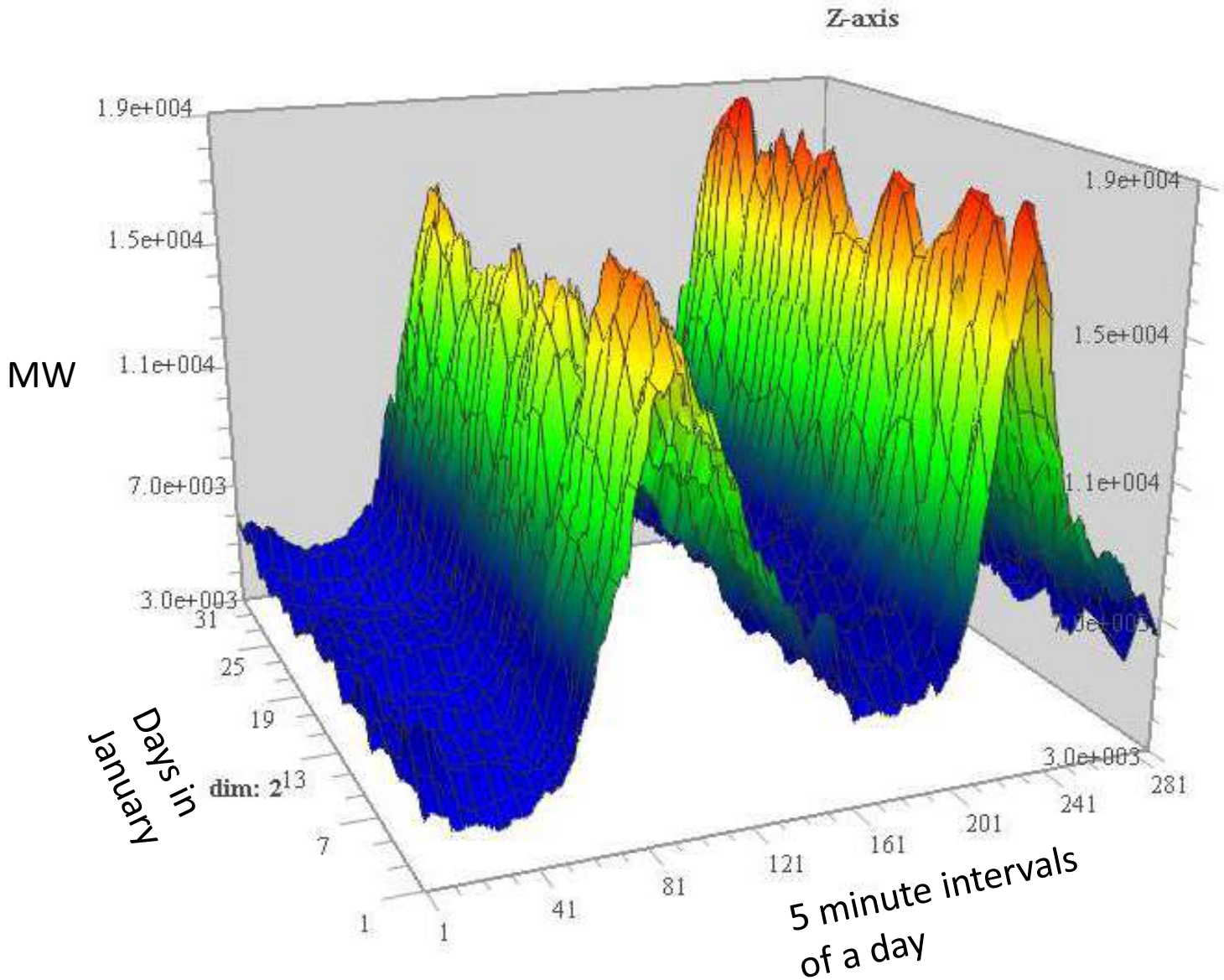




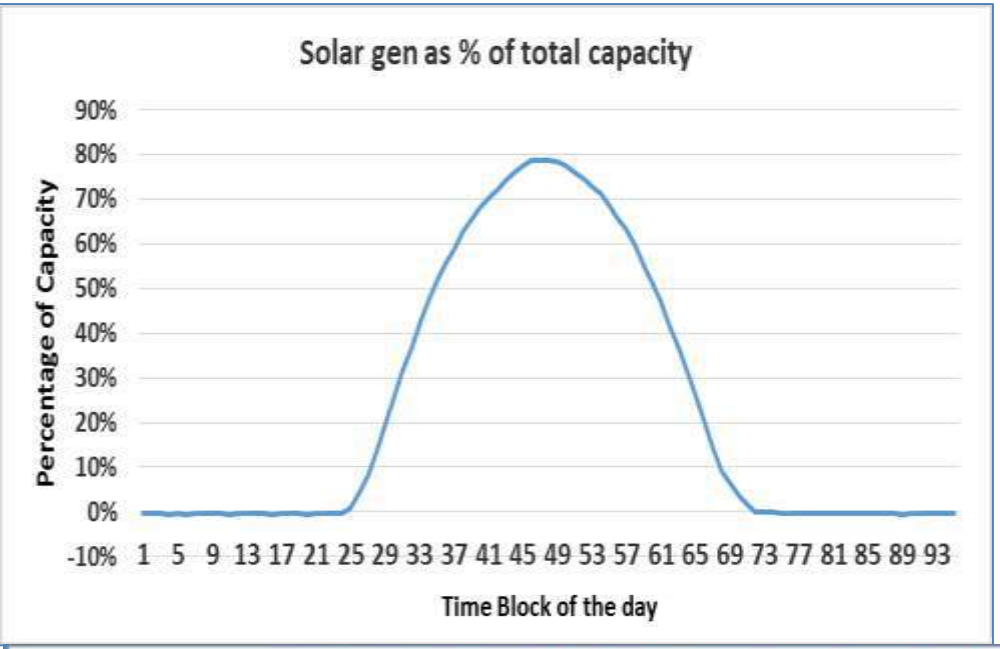
All India Thermal Generation

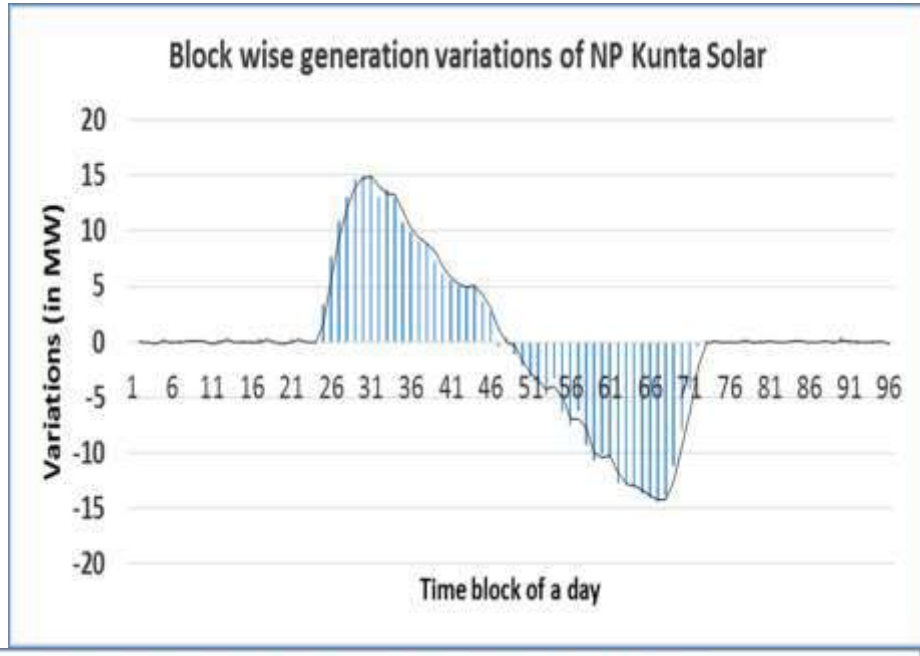


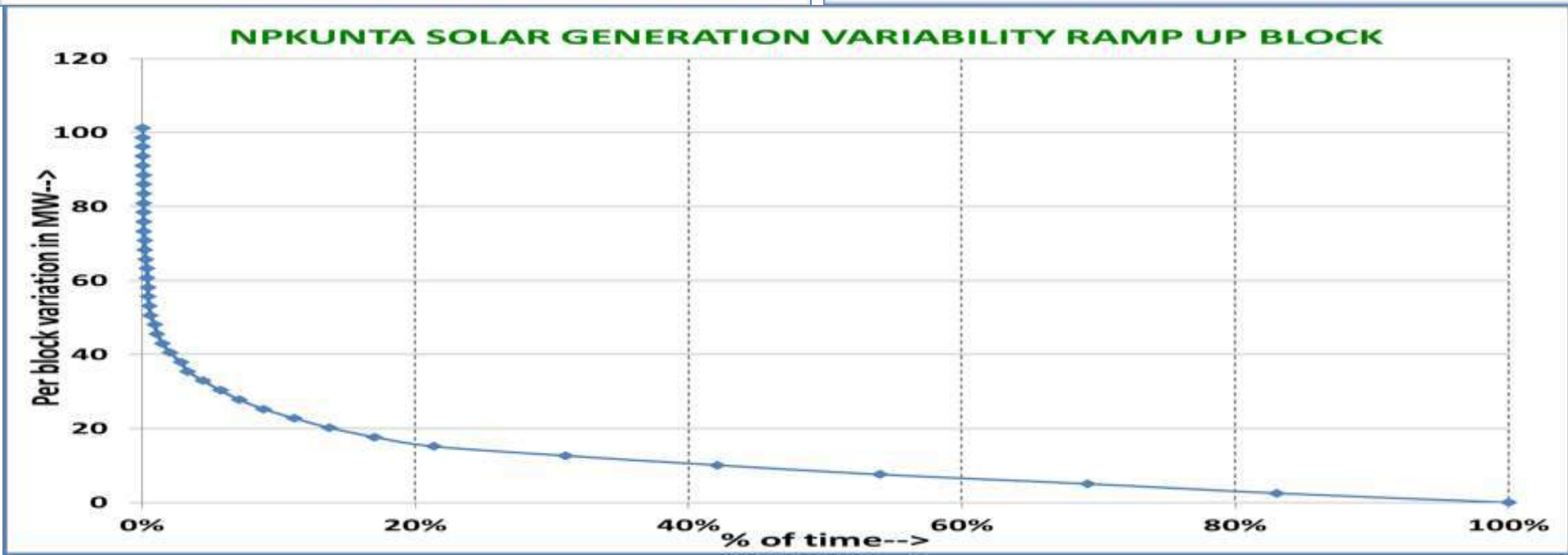
All India Hydro Generation



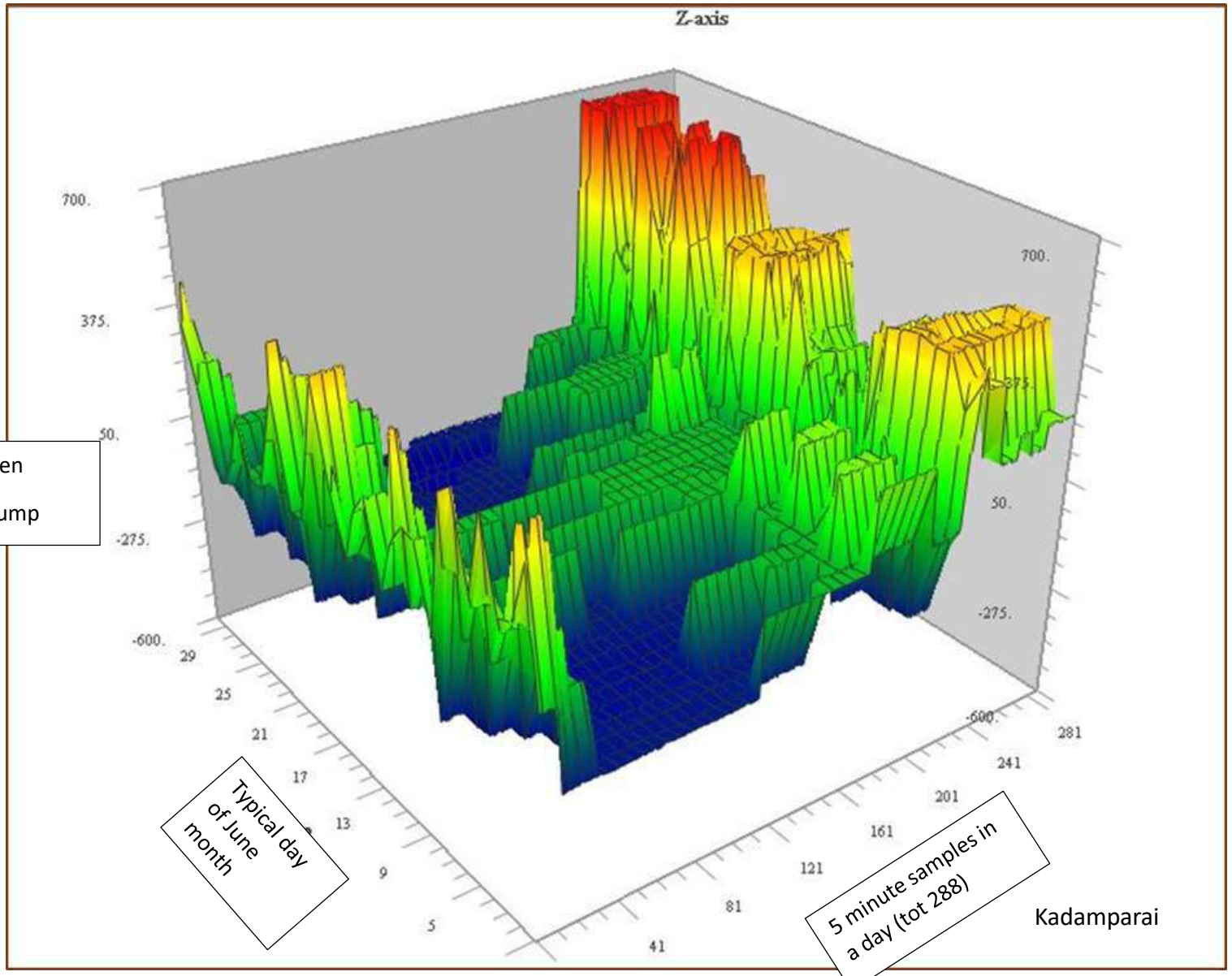
Solar Generation







Pumped Storage

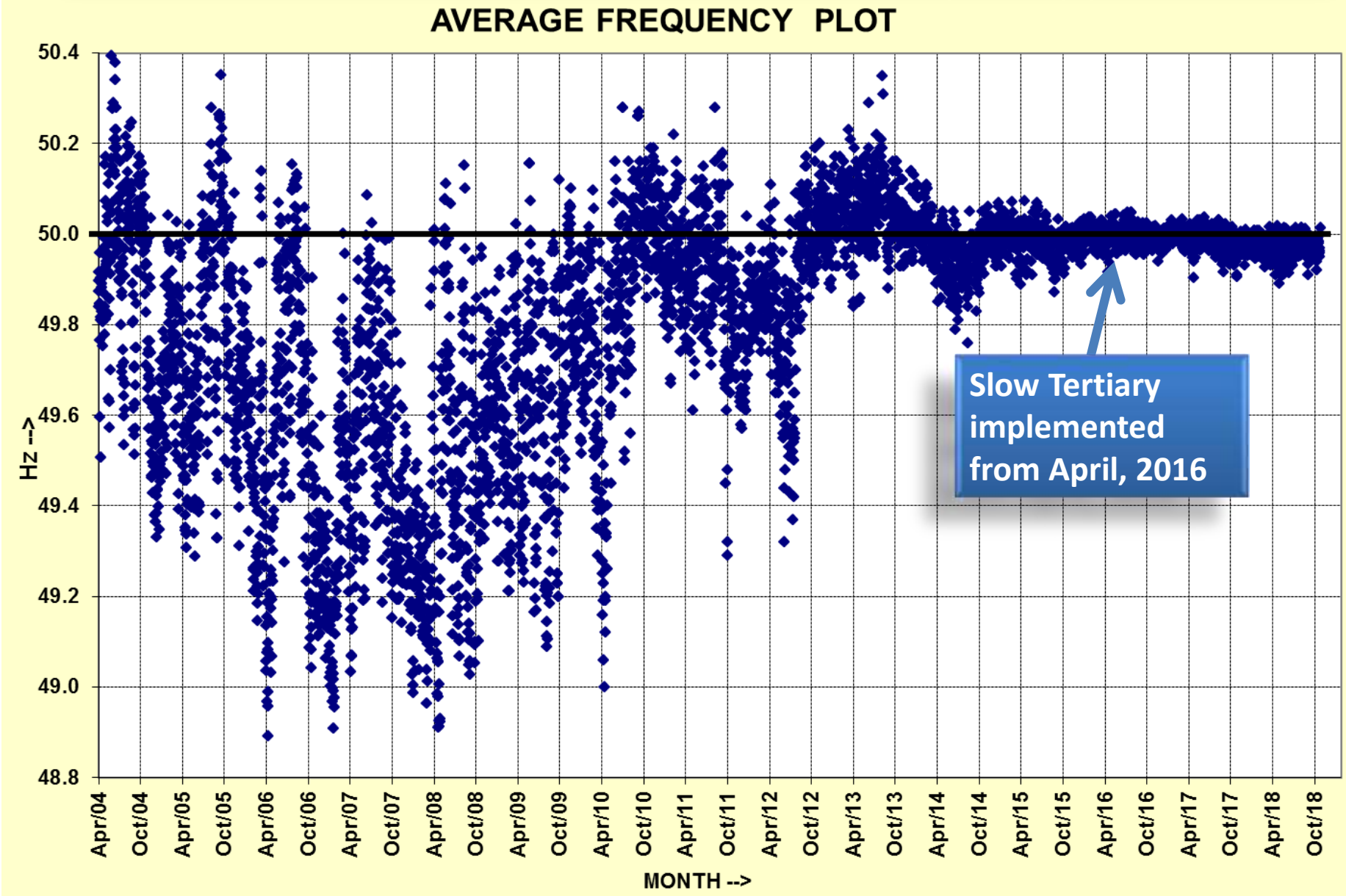


Pumped Storage Plants in India

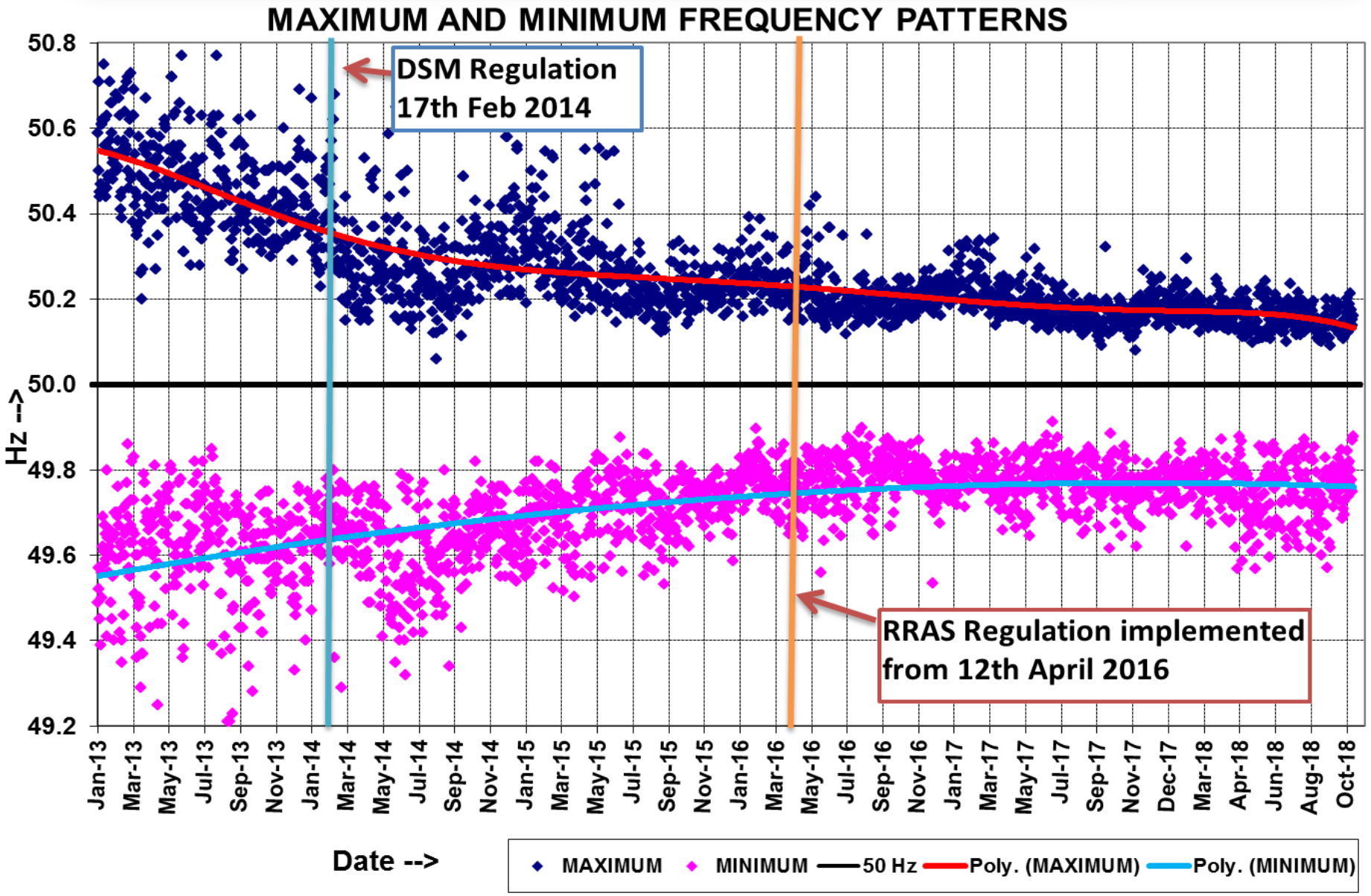
S. No.	Name of Project / State	Installed Capacity		Pumping Mode Operation	Reasons for not working in Pumping mode
		No. of units x MW	Total (MW)		
1	Kadana St. I&II Gujarat	2x60+2x60	240	Not working	Due to vibration problem
2	Nagarjuna Sagar Andhra Pradesh	7x100.80	705.60	Not working	Tail pool dam under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

Source: " Large scale integration of Renewable Energy Sources-Way forward" Report by CEA

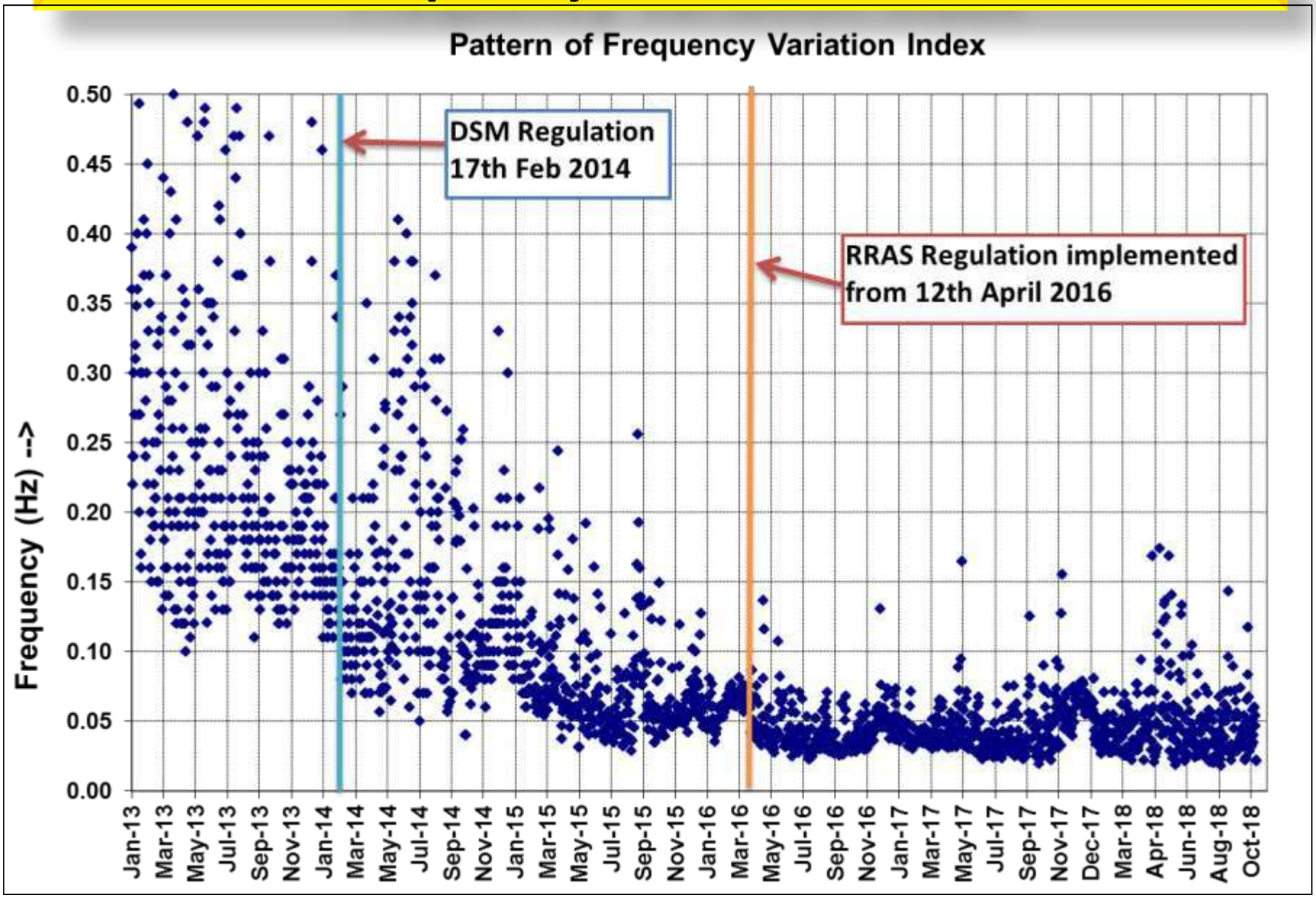
Frequency Profile over the years…



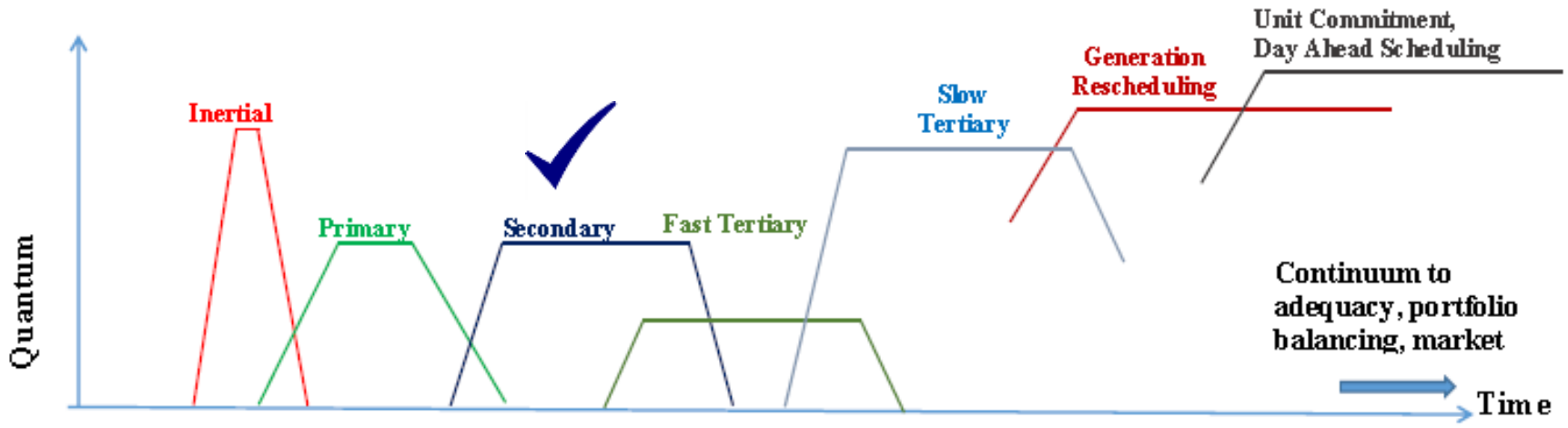
Maximum and Minimum Frequency patterns



Frequency Variation Index

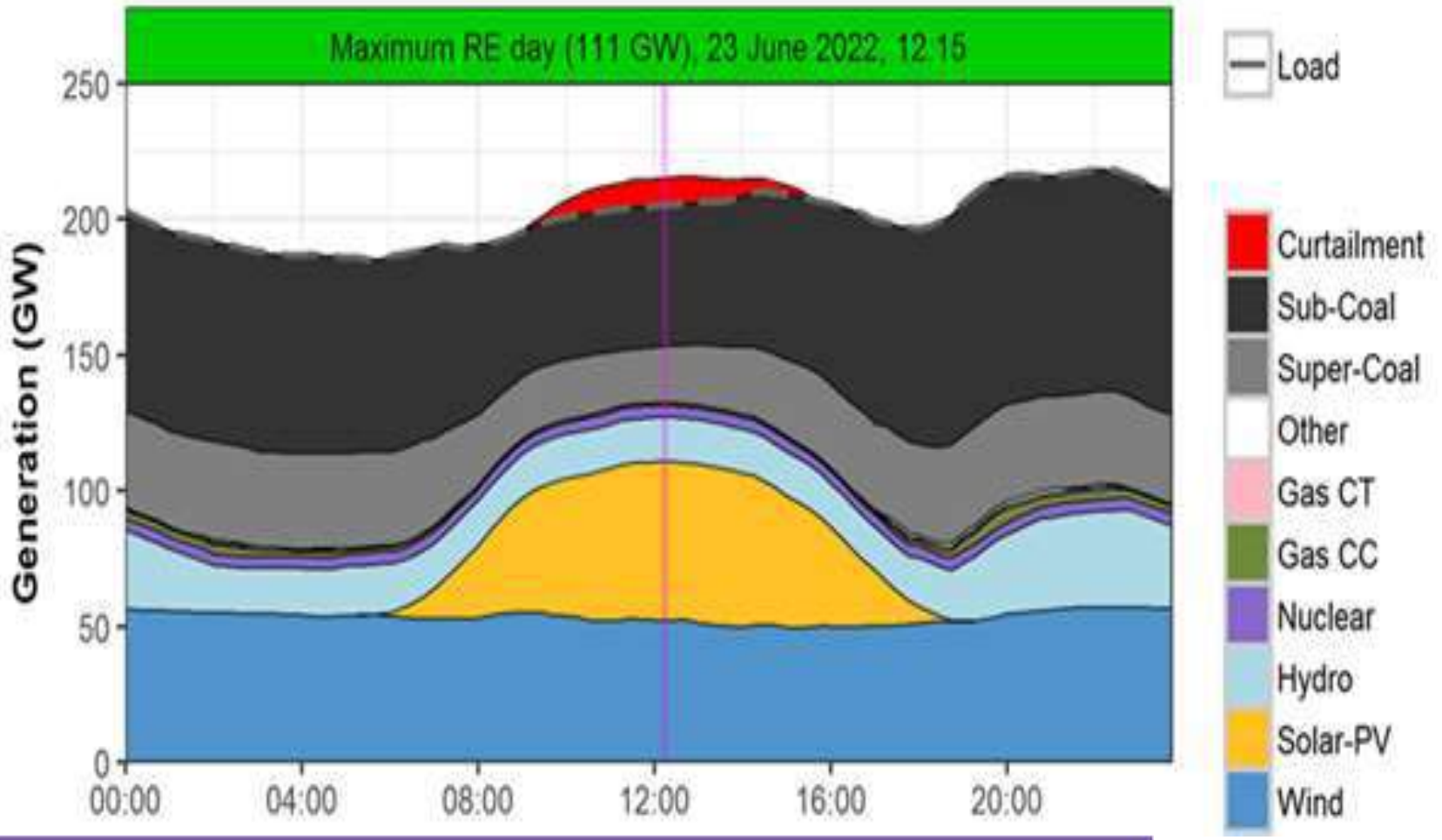


Frequency Control Continuum in India



Response → Attribute	Inertial	Primary	Secondary	Fast Tertiary	Slow Tertiary	Generation Rescheduling/Market	Unit Commitment
Time	First few secs	Few sec - 5 min	30 s – 15 min	5 - 30 min	> 15 – 60 min	> 60 min	Hours/ day-ahead
Quantum	~ 10000 MW/Hz	~ 4000 MW	~ 4000 MW	~ 1000 MW	~ 8000-9000 MW	Load Generation Balance	Load Generation Balance
Local / LDC	Local	Local	NLDC / RLDC	NLDC	NLDC / SLDC	RLDC / SLDC	RLDC / SLDC
Manual / Automatic	Automatic	Automatic	Automatic	Manual	Manual	Manual	Manual
Centralized / Decentralized	Decentralized	Decentralized	Centralized	Centralized	Centralized/ Decentralized	Decentralized	Decentralized
Code / Order	IEGC / CEA Standard (?)	IEGC / CEA Standard	Roadmap on Reserves	Ancillary Regulations	Ancillary Regulations	IEGC	IEGC
Paid / Mandated	Mandated	Mandated	Paid	Paid	Paid	Paid	Paid
Regulated / Market	Regulated	Regulated	Regulated	Regulated	Regulated / Market	Regulated / Market	Regulated / Market
Implementation	Existing	Partly Existing	Pilot	Yet to start	Existing	Existing	Existing

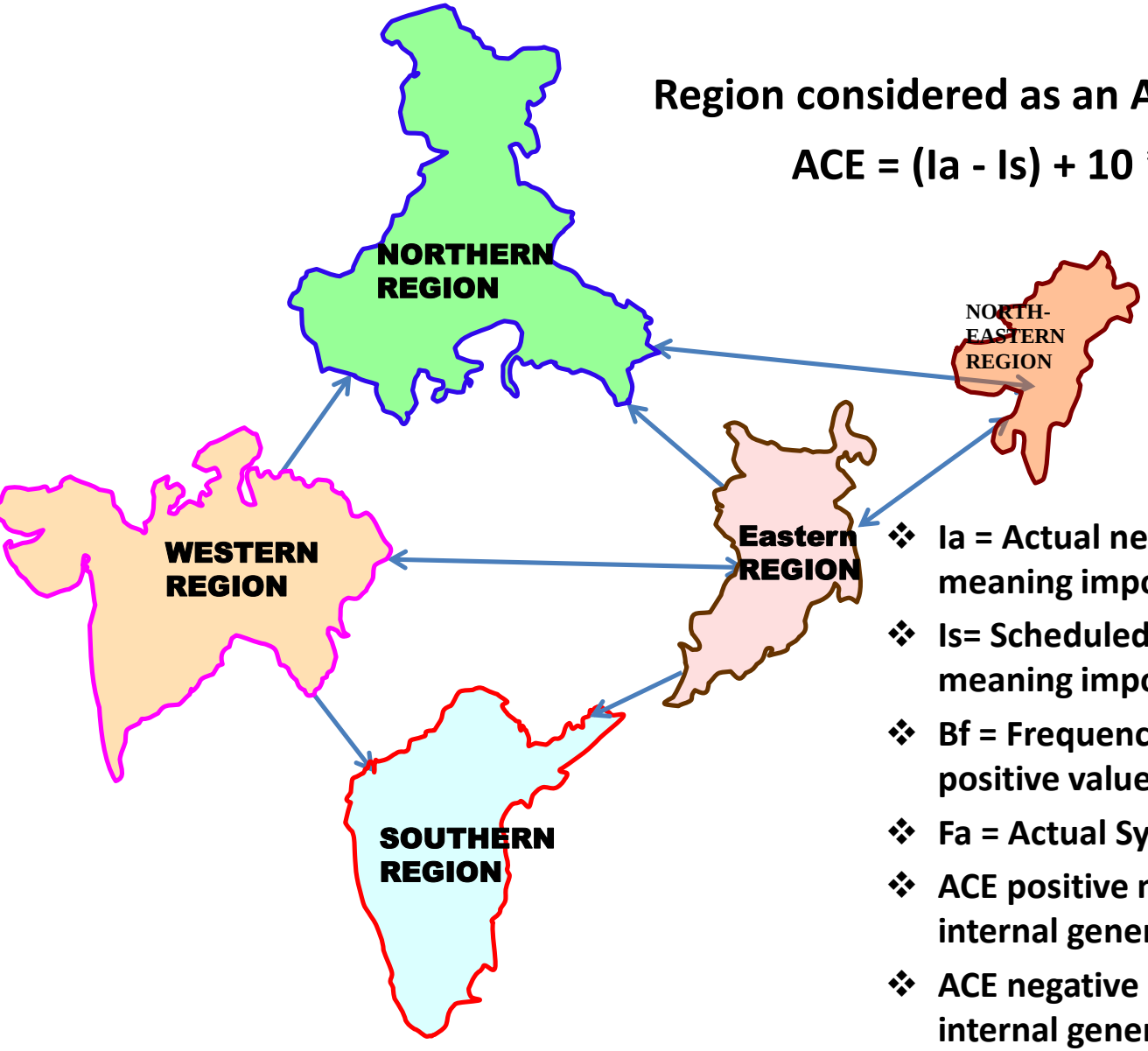
Future Ready AGC for 175 GW of RE by 2022



- Forecasting of Load & RE
- Use of Pumped Storage Plants
- Automatic controls

Region considered as an Area for secondary control

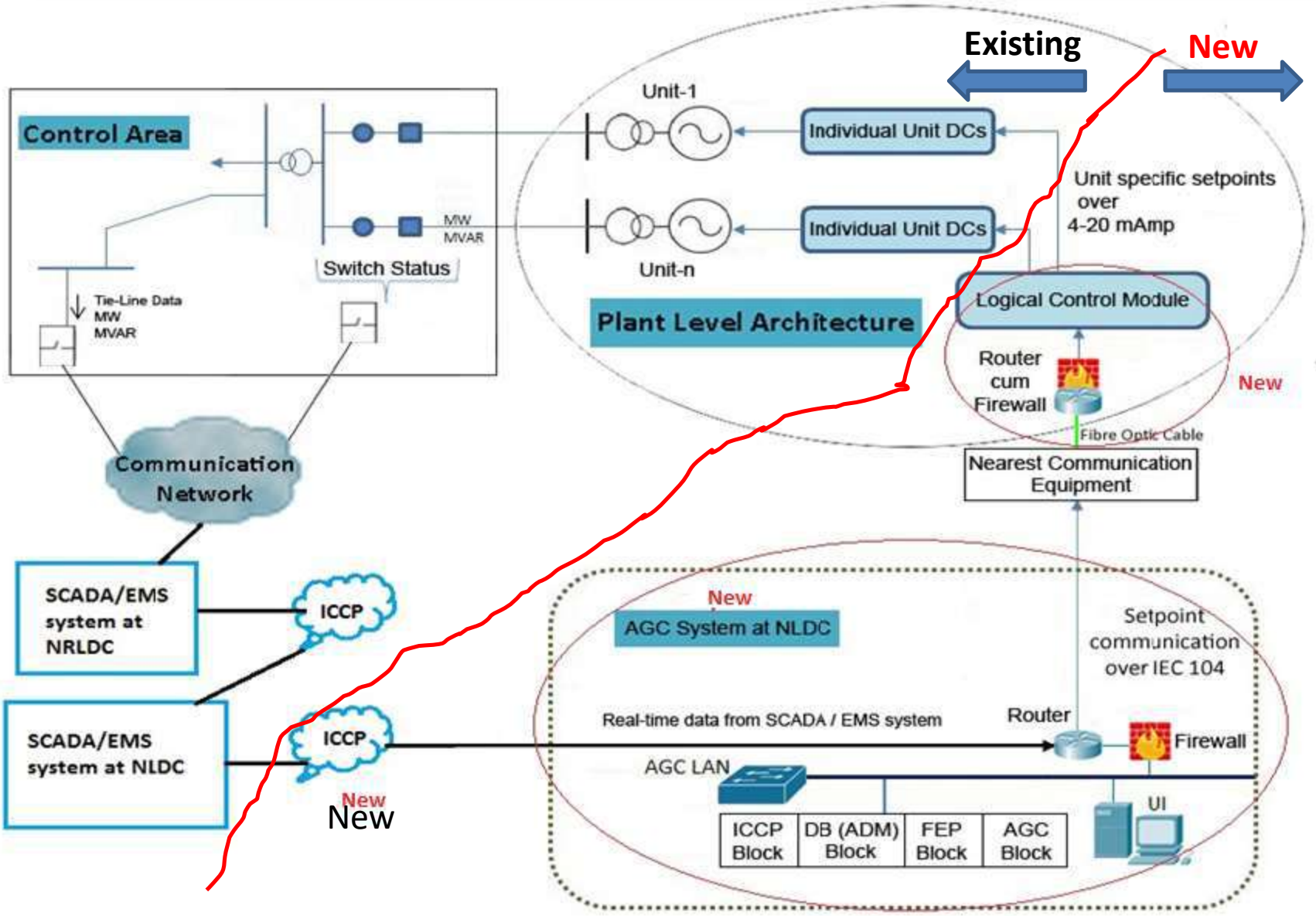
ACE = (Ia - Is) + 10 * Bf * (Fa - 50)



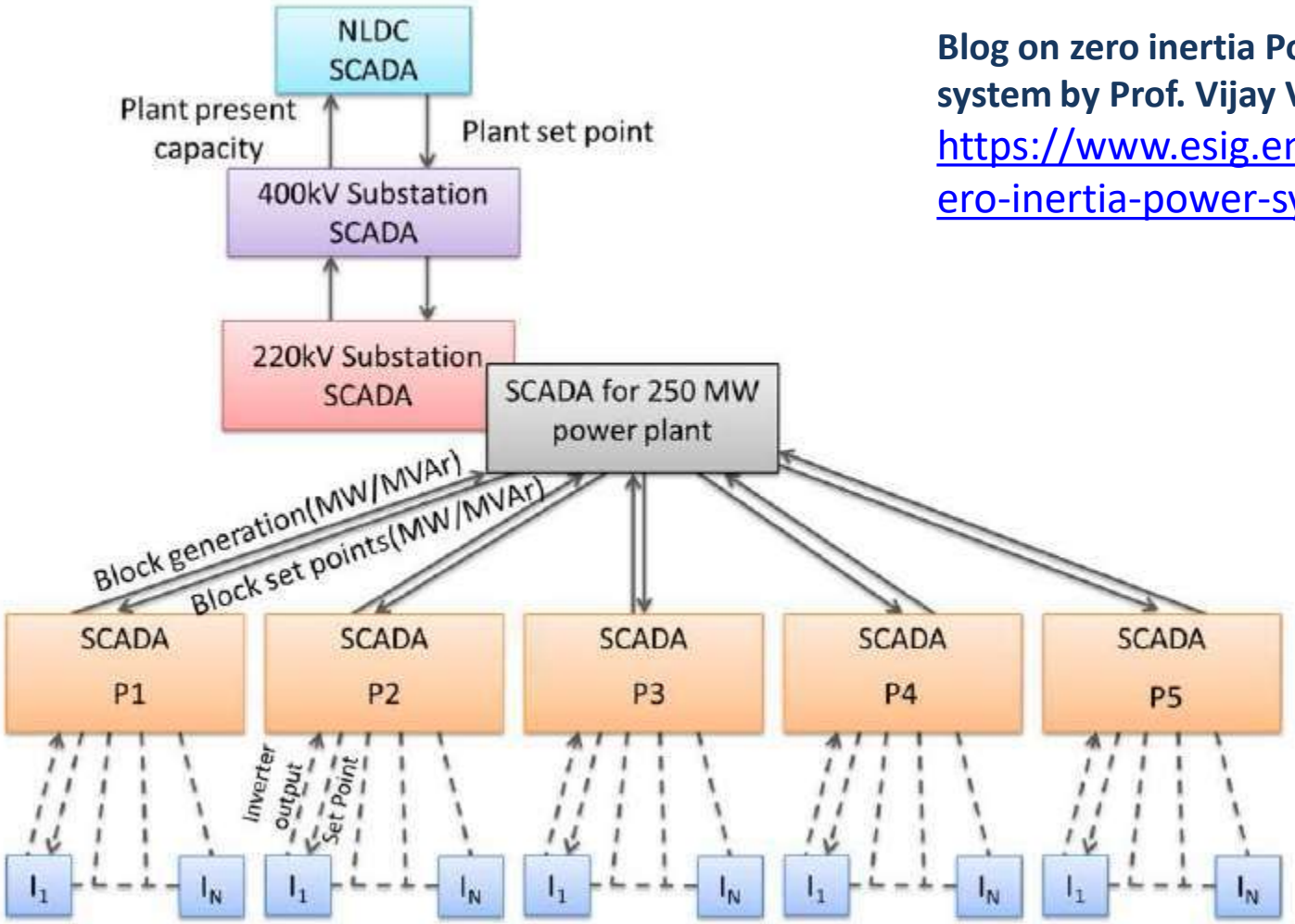
- Ia = Actual net interchange, negative for NR meaning import by NR
- Is= Scheduled net interchange, negative for NR meaning import by NR
- Bf = Frequency Bias Coefficient in MW/0.1 Hz, positive value
- Fa = Actual System Frequency
- ACE positive means NR is surplus and NR internal generation has to back down
- ACE negative means NR is deficit and NR internal generation has to increase

- Tie line bias mode and Frequency bias only mode both possible

Architecture of the Project



Solar Plant AGC signal hierarchy

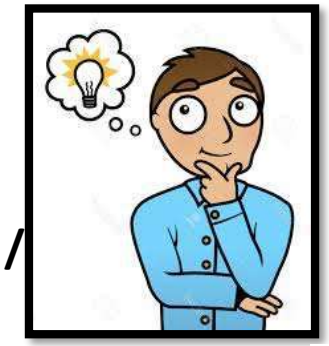


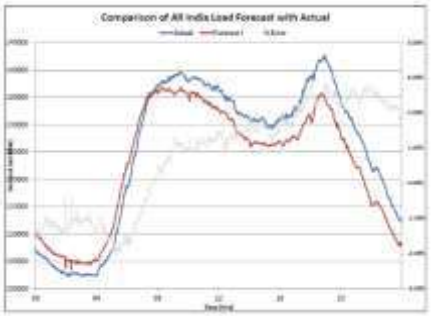
Blog on zero inertia Power system by Prof. Vijay Vittal
https://www.esig.energy/zero-inertia-power-systems/

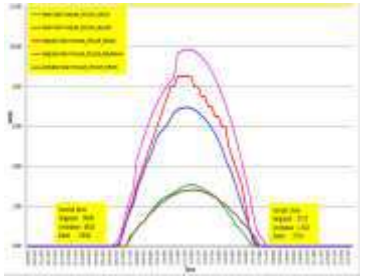
Tertiary Control

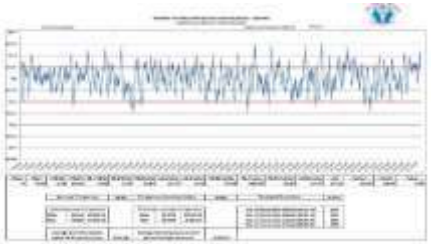
Cues for System Operator

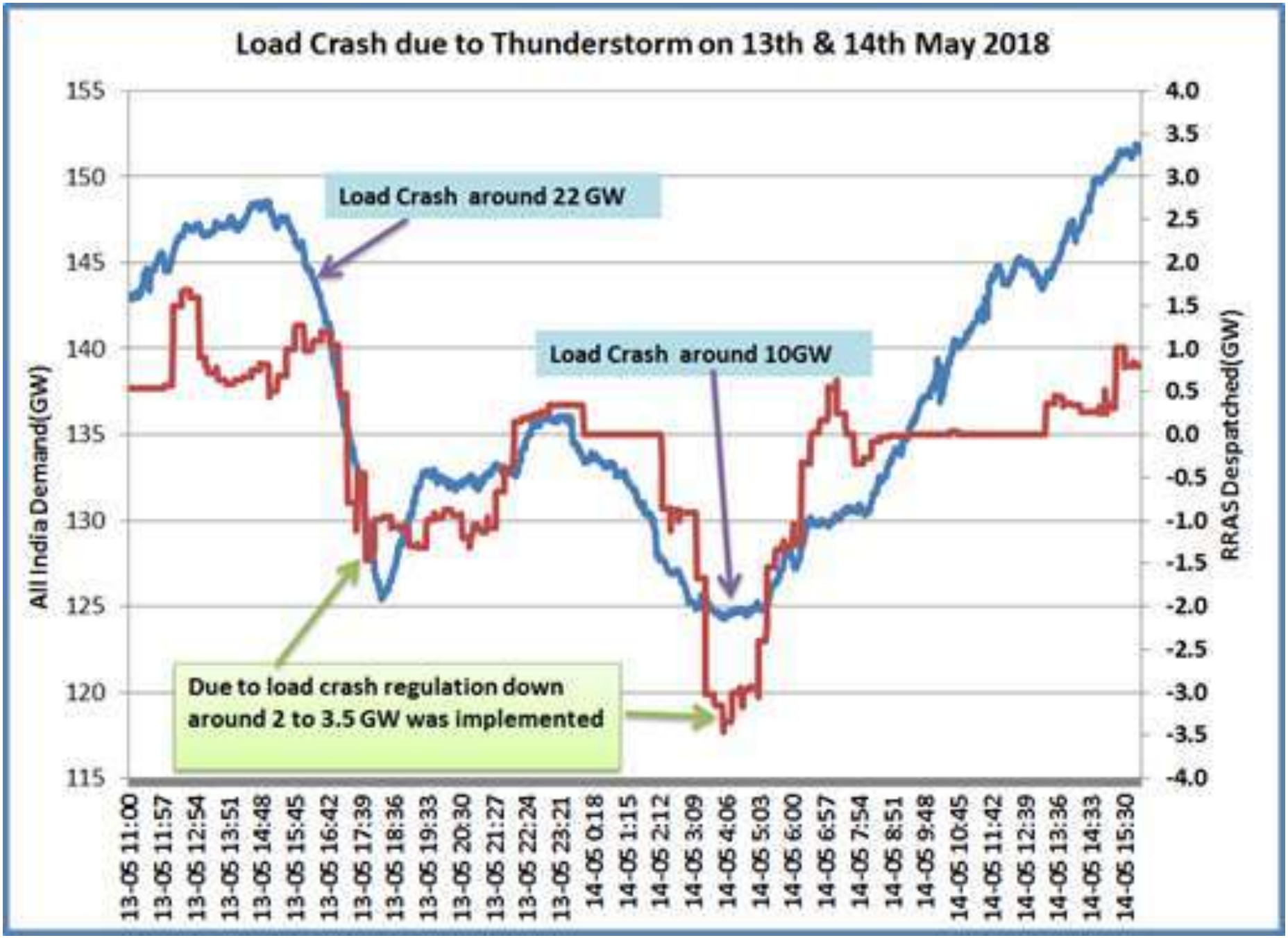
- Weather Forecast
- Load Forecast
- Availability of Reserves
- Monitoring of Renewables
- Outages of Transmission Lines / Generating units
- Anticipated Congestion
- Monitoring of Area Control Error (ACE)
- SCADA Visualization in Real Time







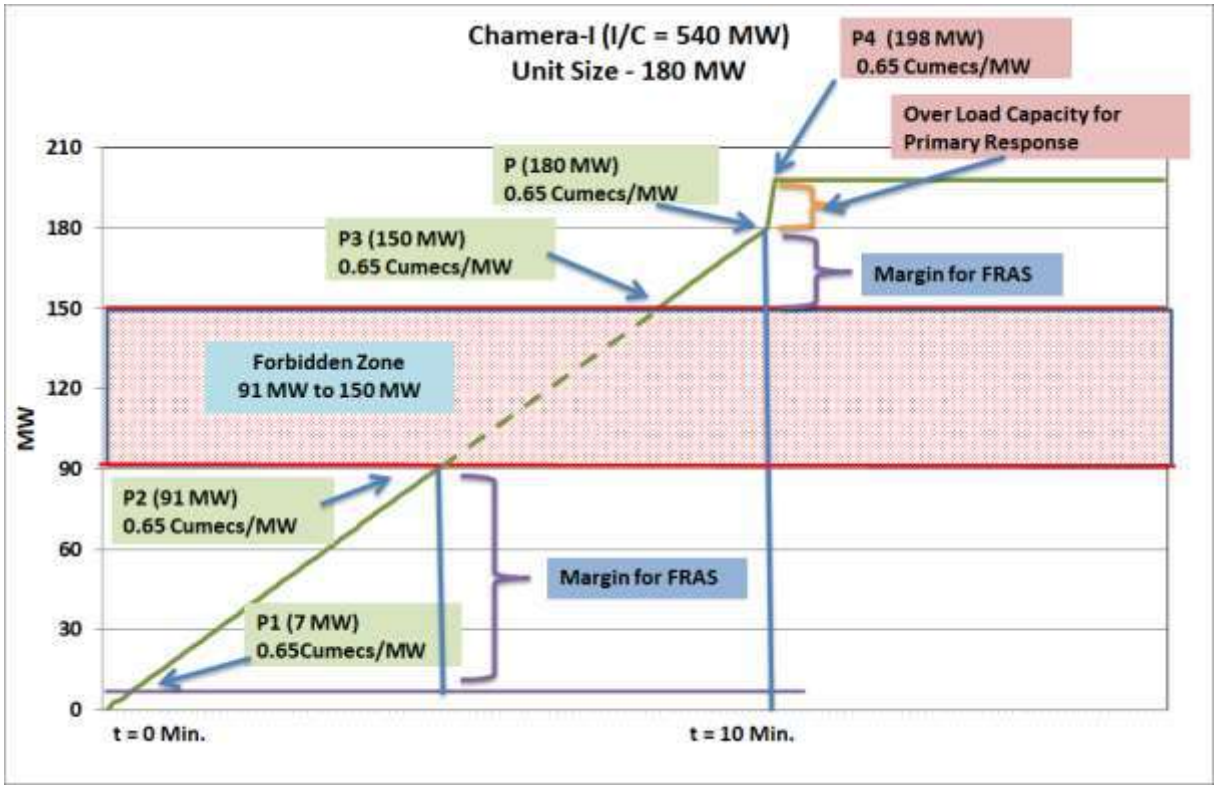



Load Crash due to Thunderstorm on 13th & 14th May 2018
Load Crash around 22 GW
Load Crash around 10GW
Due to load crash regulation down around 2 to 3.5 GW was implemented
All India Demand(GW)
RRAS Despatched(GW)
155
150
145
140
135
130
125
120
115
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
13-05 11:00
13-05 11:57
13-05 12:54
13-05 13:51
13-05 14:48
13-05 15:45
13-05 16:42
13-05 17:39
13-05 18:36
13-05 19:33
13-05 20:30
13-05 21:27
13-05 22:24
13-05 23:21
14-05 0:18
14-05 1:15
14-05 2:12
14-05 3:09
14-05 4:06
14-05 5:03
14-05 6:00
14-05 6:57
14-05 7:54
14-05 8:51
14-05 9:48
14-05 10:45
14-05 11:42
14-05 12:39
14-05 13:36
14-05 14:33
14-05 15:30

Fast Response Ancillary Services (FRAS)

- CERC order in Petition No. 07/SM/2018 (Suo-Motu) dtd. 16 Jul'18
  - Pilot on 05-Minute Scheduling, Metering, Accounting and Settlement for Thermal/Hydro
  - **26th Nov'18- Pilot on Hydro as Fast Response Ancillary Services (FRAS)**
  - **In house Software**

Sample Hydro Station Data

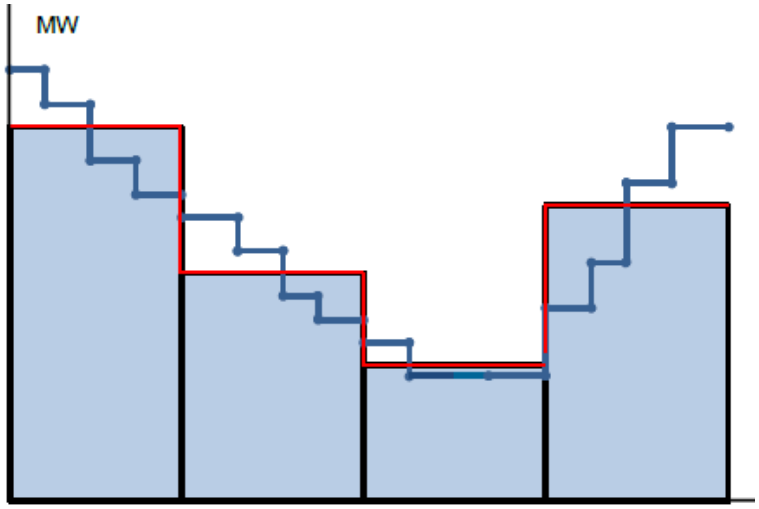


Provisions Regarding Ramping

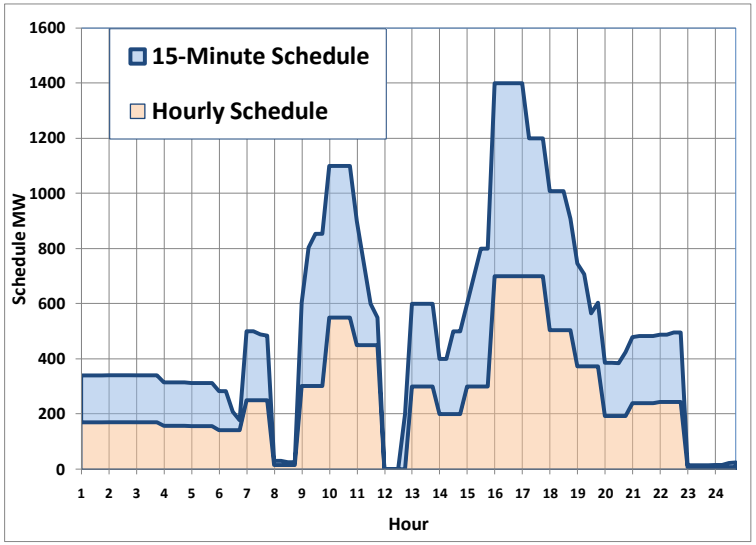
- **Provisions in the Indian Electricity Grid Code (IEGC):**
  - Operating Code (Section 5.2):
    - System Security Aspects - Ramping of
      - All thermal units greater than 200 MW.
      - All Hydro units greater than 10 MW
    - Sudden change in generation / load by the utilities of more than 100 MW without prior intimation to and consent of the RLDC.
  - Scheduling and Despatch Code (Section 6.4)
    - Generators to declare rate of ramping up / ramping down in a 15 minute block.
    - Acceptable ramping rate – 200 MW/Hour (in NER 50 MW/Hour)
- **CEA Standard Technical Features of Super-Critical Units**
  - Ramp rate: + 3% per minute (above 30% loading)
  - Technical minimum load of super critical units – 40%
  - Two shift operation mandated

Increasing granularity of Despatch Interval

- 5-minutes scheduling:
  - Reduced the steep ramps
  - Eliminates sharp discreet changes
  - Reduced frequency fluctuations
  - Facilitates better load management
  - Facilitates integration of renewables



Quarter-hour vs Hourly Schedules



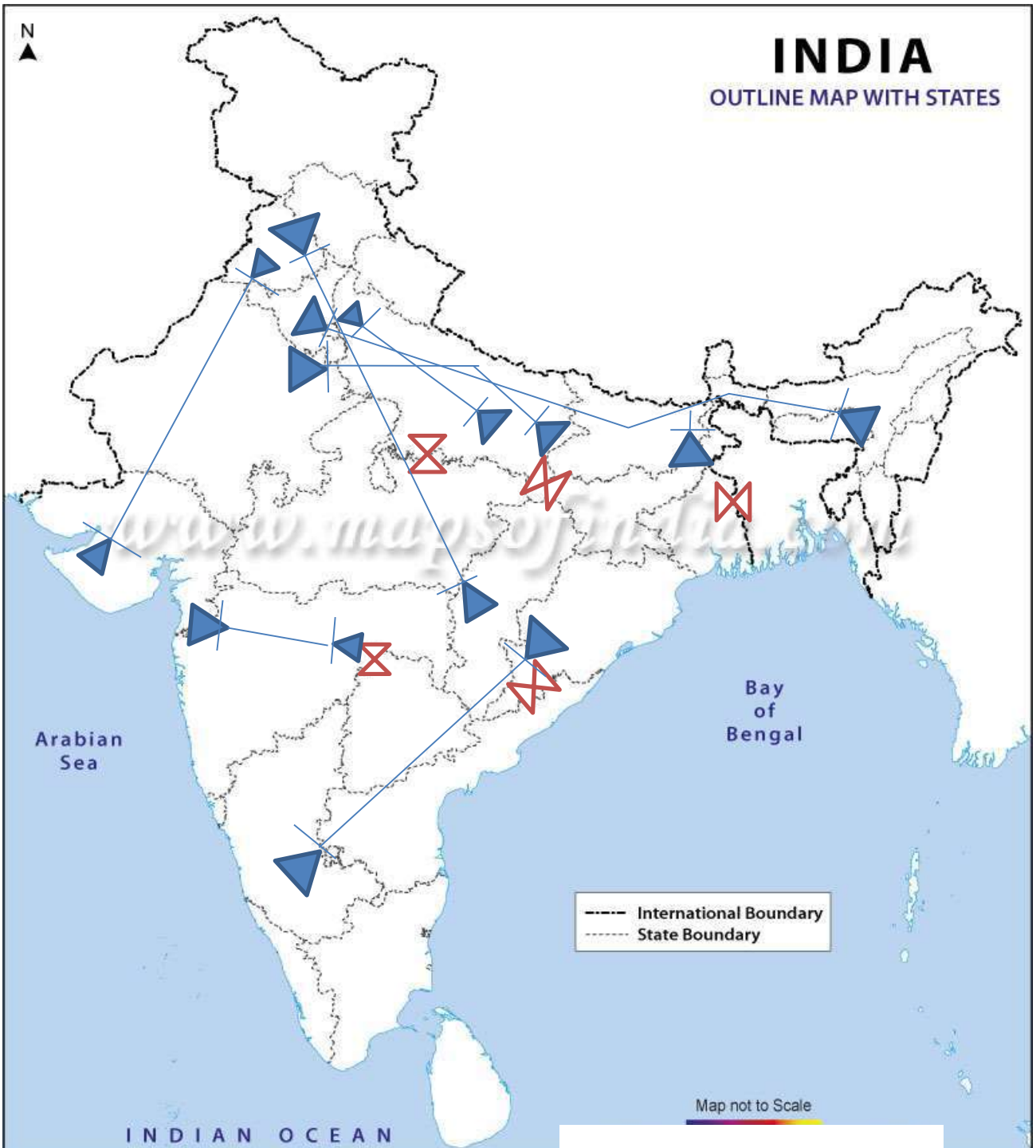
Typical Hourly & 15-Minute Schedules

Flexible Generation

- **Hydro**
  - Plan and implement more pumped storage
  - High head stations; **Pelton** vs Francis turbine
  - Operational norms to incentivize flexibility

- **Thermal**
  - Grid Code clauses on flexibility (ramp rate, minimum)
  - Incentives for flexible generation
  - Two-shift operation of thermal plants
  - Primary, Secondary and Tertiary Controls

- **Renewables**
  - Low Voltage Ride Through (LVRT)
  - Draft CEA standards notified



Flexible Transmission

- **HVDCs in India**
  - **5 back to back HVDCs**
  - **6 bipole HVDC links**
  - **1 MTDC**
  - **1 more planned**

- **CEA Transmission Planning Criterion (Section 18)**
  - More than 2000 MW over long distance more than 700 km.
  - Corridors of AC lines carrying heavy power flows (total more than 5000 MW)

Signs of Inflexibility

- Difficulty in balancing demand and supply
  - Frequency excursions
- Renewable curtailment
  - Inability to balance
- Area Balance Violations (Deviations)
- Electricity Markets
  - Price volatility

Source: Cochran, J. et al. (2012), "Flexibility in 21st Century Power Systems, A 21st Century Power Partnership Report". Golden, CO: National Renewable Energy Laboratory.
http://www.nrel.gov/docs/fy14osti/61721.pdf

Way Forward

- **Power systems are already flexible, designed to accommodate variable and uncertain load.**
  - New actors RE, distributed generation, storage etc. to be accommodated
- **Need for 'Flexible' Systems**
  - **Flexible Generation**
  - **Flexible Transmission** – FACTs, HVDC
  - **Flexible Distribution** – Price responsive demand
  - **Flexible Markets -**
    - More Frequent market operation, Ancillary services, Demand response
- **Policy / Regulatory Framework for Flexibility**
  - Measuring Flexibility
  - Metrics for performance
  - Incentivizing and paying for flexibility
  - Policy support to anticipate flexibility needs and support system flexibility
  - Flexibility considerations can be integrated into the design of procurement policies

Thank You