Indian Grid

An overview

Source: Presentations by Mr Narasimhan, POSOCO and Mr Soonee, Advisor POSOCO

"Except for a few islands and some small isolated systems, the entire electric grid is really one big circuit.
The humble wall outlet is actually a gateway to one of the largest and most complex objects ever built. The grid encompasses billions of individual components, tens of millions of miles of wire and thousands of individual generators"

Thomas Overbye,
Re-engineering the Electric Grid, American Scientist, 2000, Vol. 88, Iss. 3.

Indian Grid…One of the World's Largest

Source: GO15

1 national synchronous grid

3 electricity generation
electricity consumption
installed generation capacity
transmission system

5 wind generation

6 solar generation

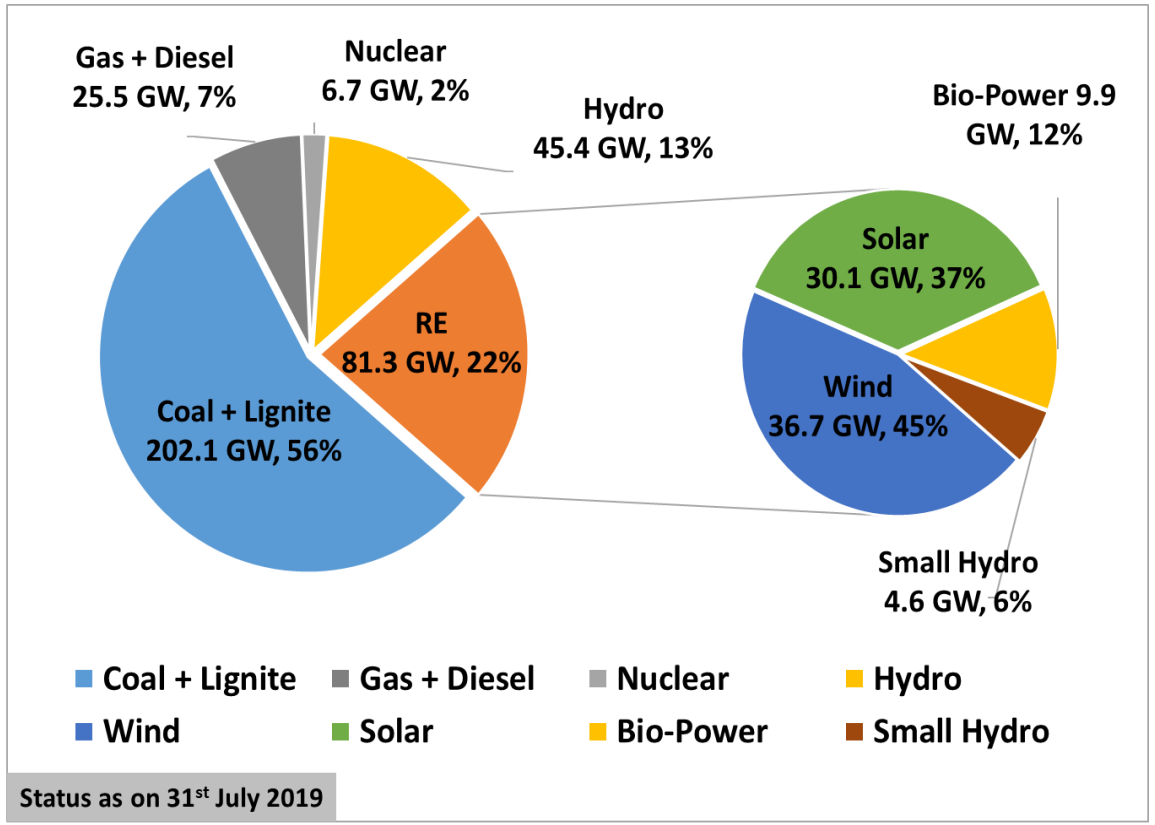
7 hydro generation

Source: IEA Key World Energy Statistics 2018 (2016 data)

Renewables in India – Present and Future

Present Total Installed Capacity – 360 GW

Present RE Installed Capacity – 81 GW



Future

Target of 175 GW RE by 2022

- 100 GW Solar
- 60 GW Wind

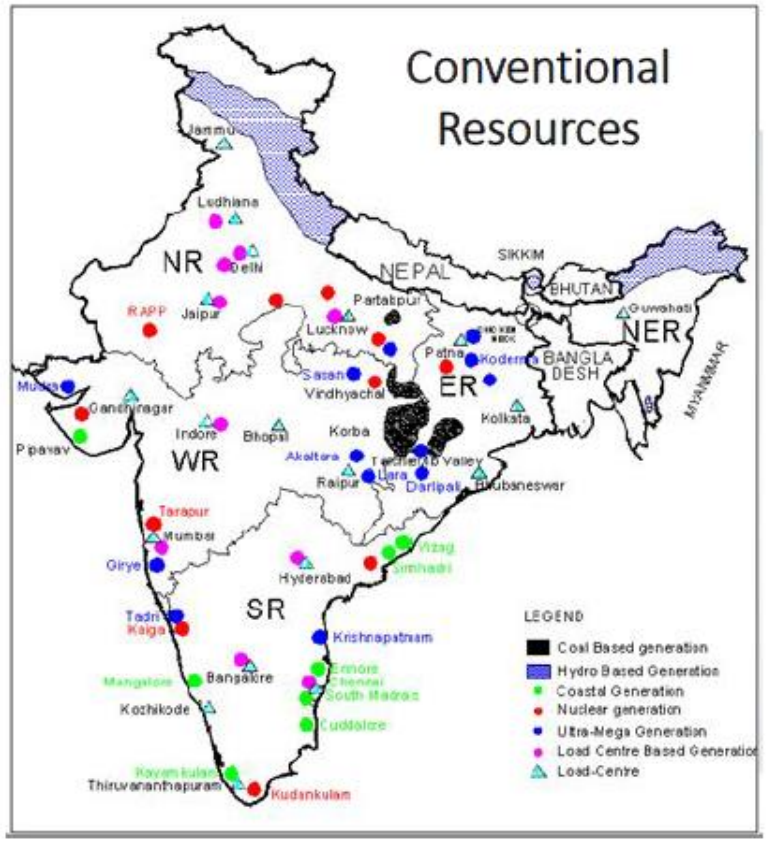
455 GW RE envisaged by 2029-30*

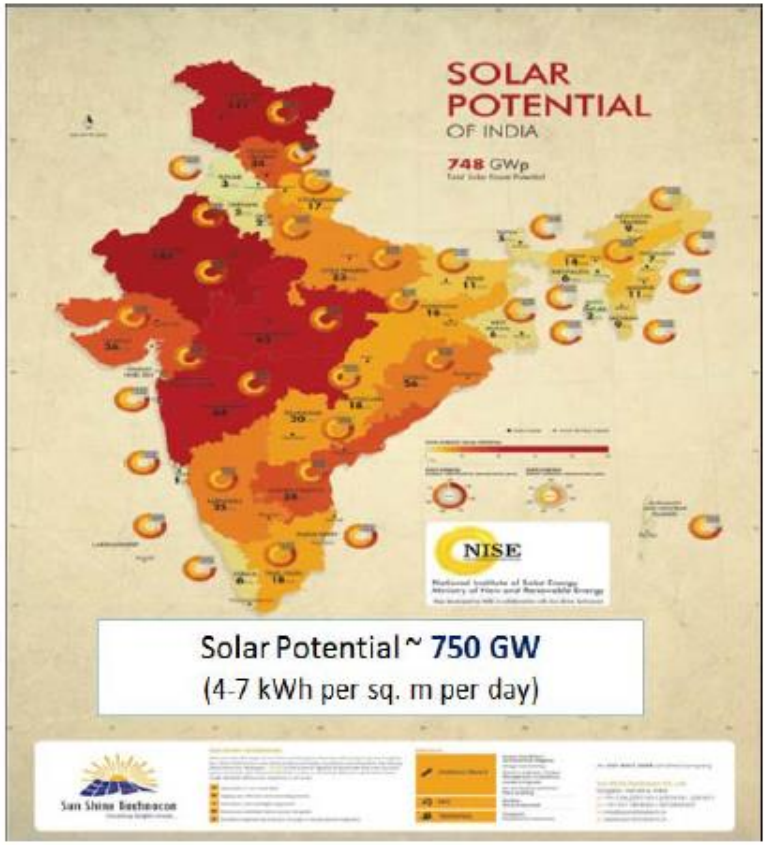
- 300 GW Solar
- 140 GW Wind
- 10 GW Bio-Power
- 5 GW Small Hydro

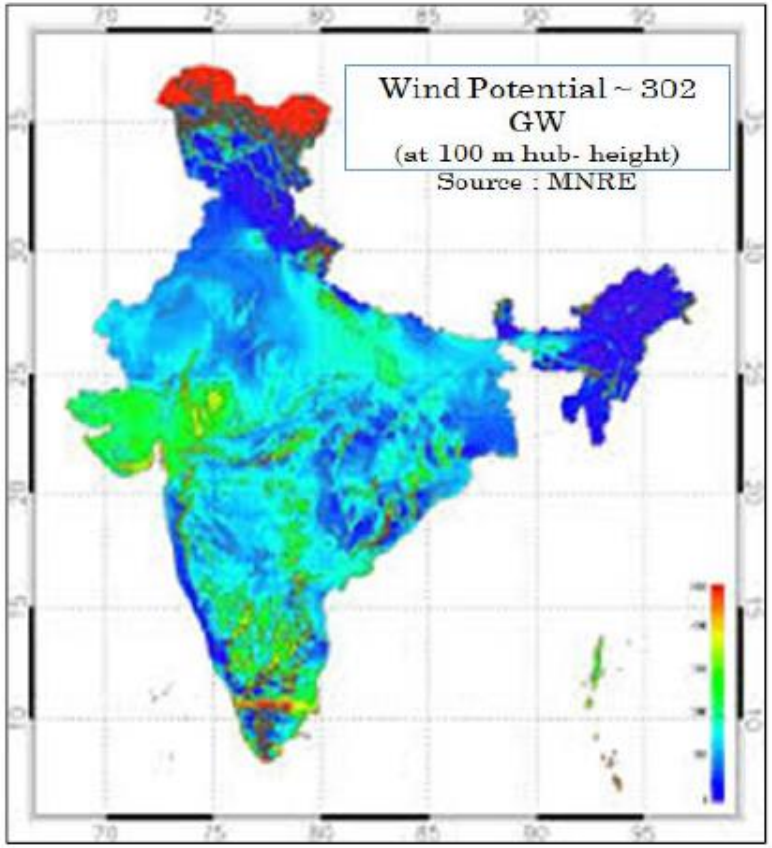
64.9% share of Non-fossil fuels in Installed Capacity envisaged by 2029-30*

* Source: CEA report on *"Optimal Generation Capacity Mix"* by 2029-30"

Diversity of Energy Resources



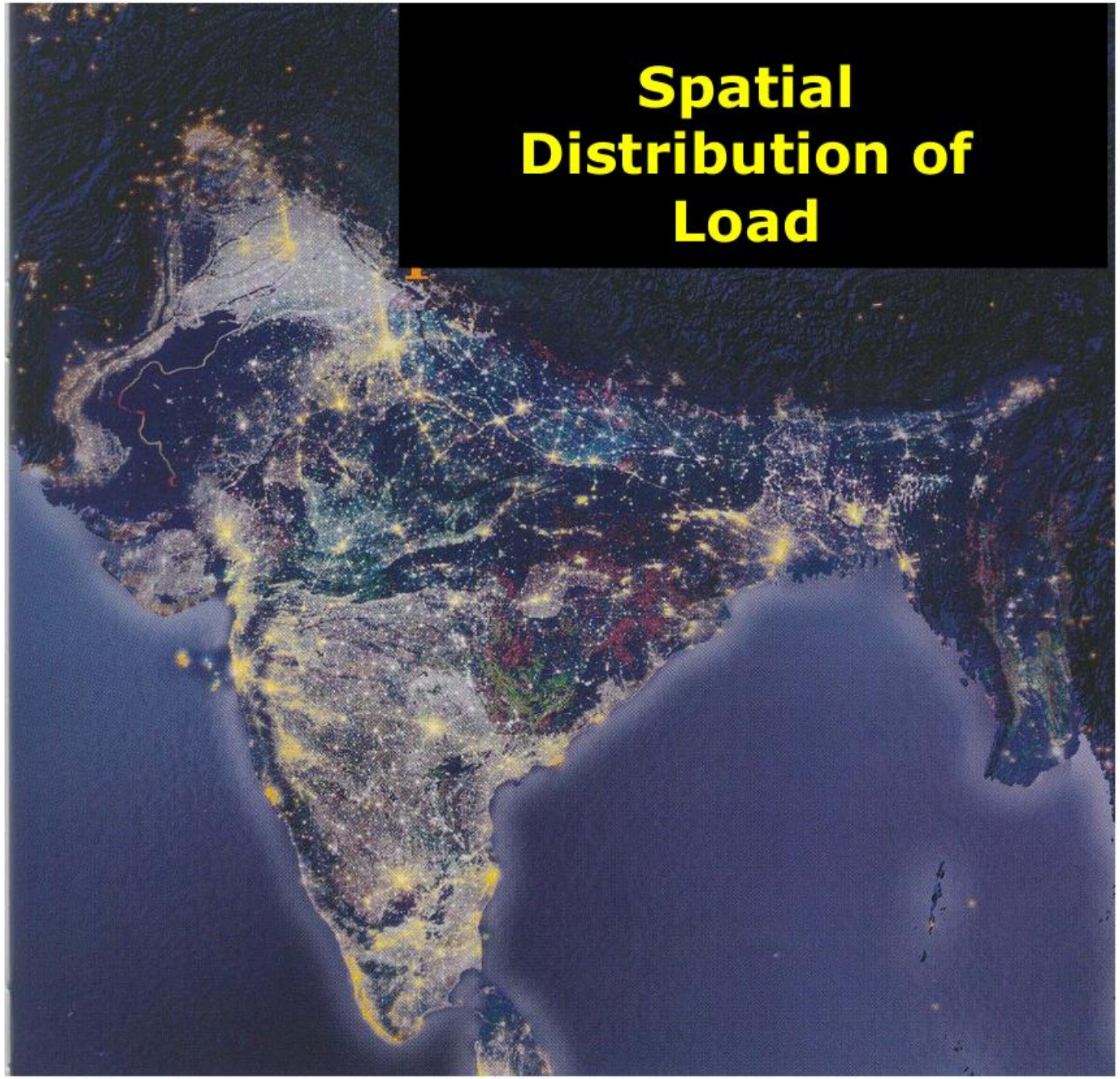




https://posoco.in/wp-content/uploads/2018/08/REC_REPORT_17082018_fPRINT.pdf

"Diversity: Key to happiness in the society"

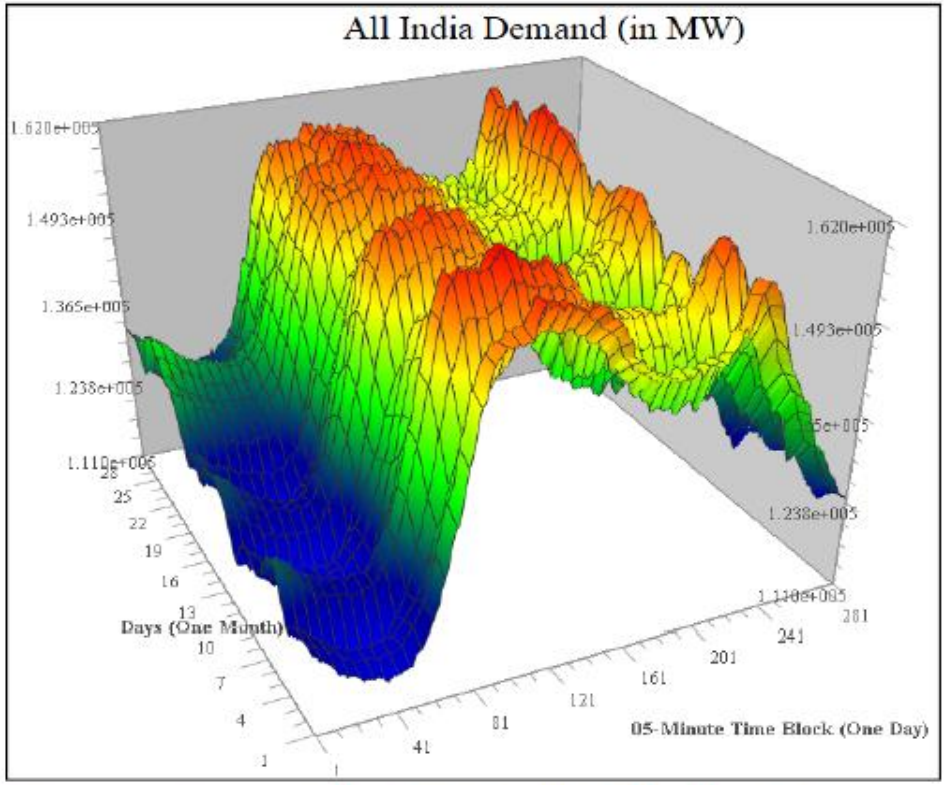
Spatial Distribution of Load



Source:

Powerline, Oct-2006

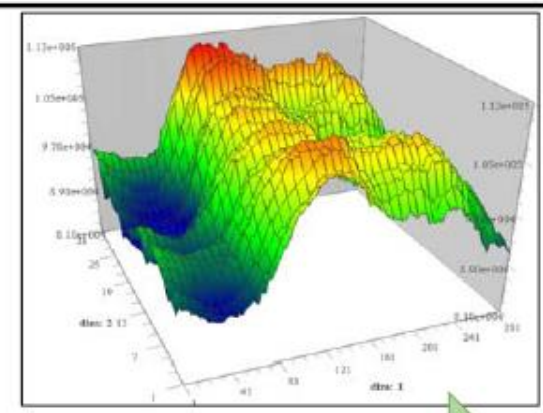
Diversity in Demand and Supply



Demand variability ~ 3-5 GW/block of 15 minutes

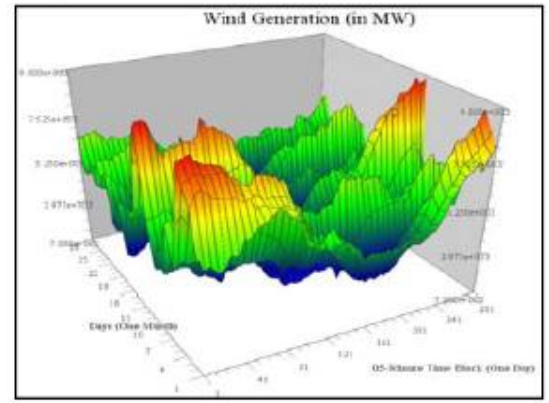
Typical Ramp Rate ~ 250 MW/min

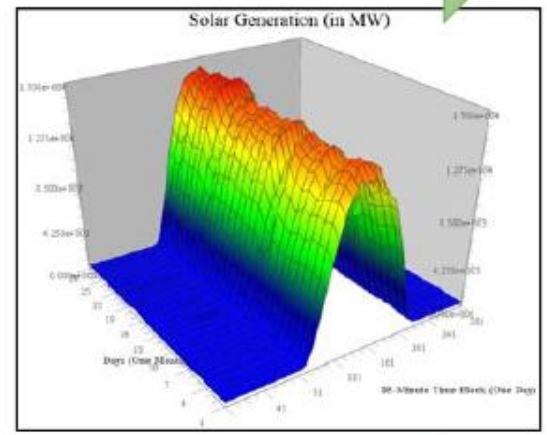
Special Days (Festivals…) ~ 500 MW/min



Thermal

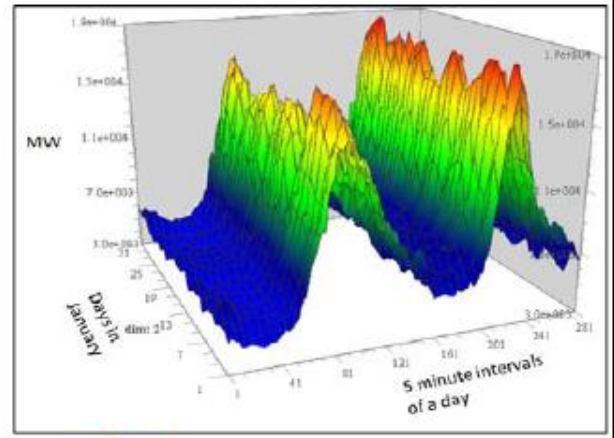
Wind





Solar

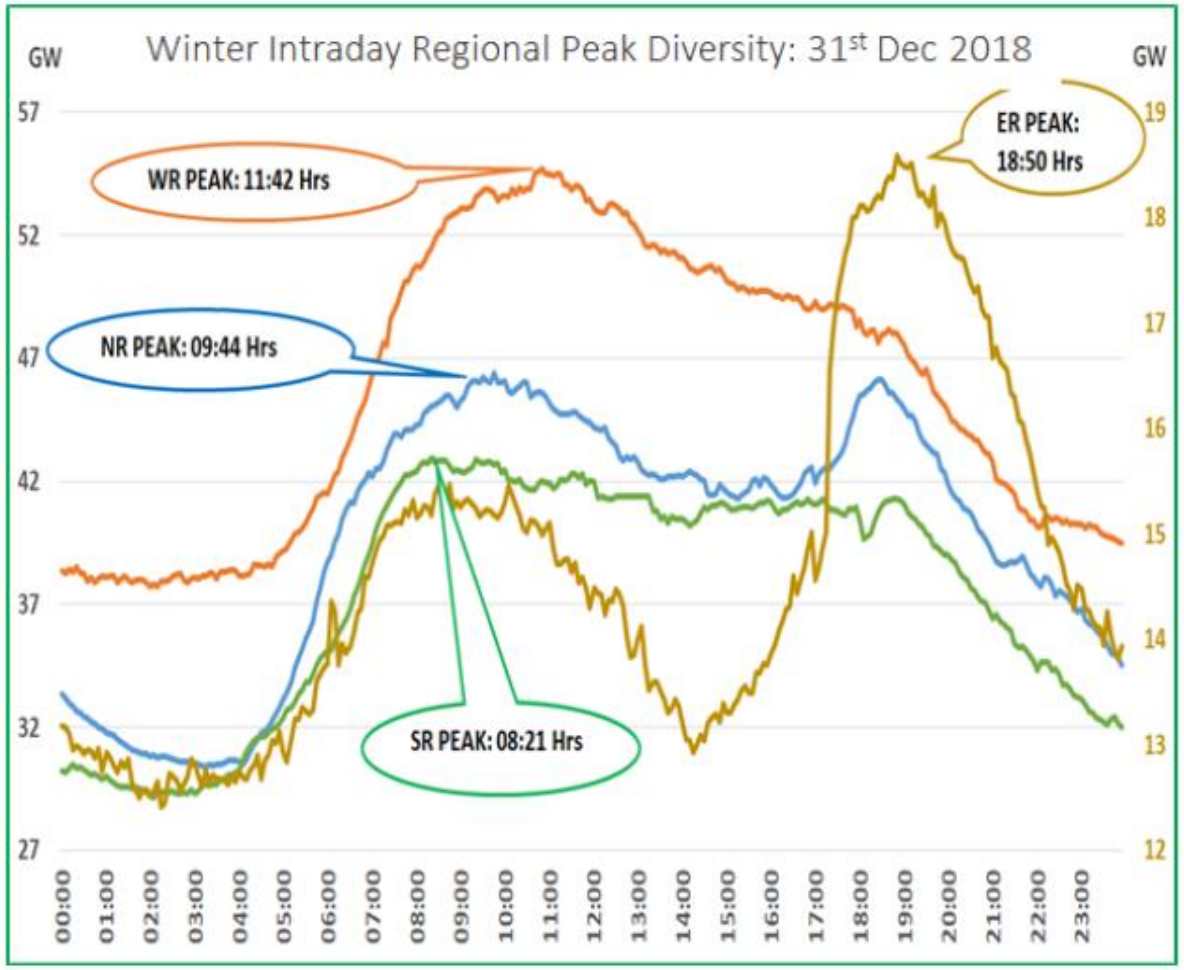
Hydro

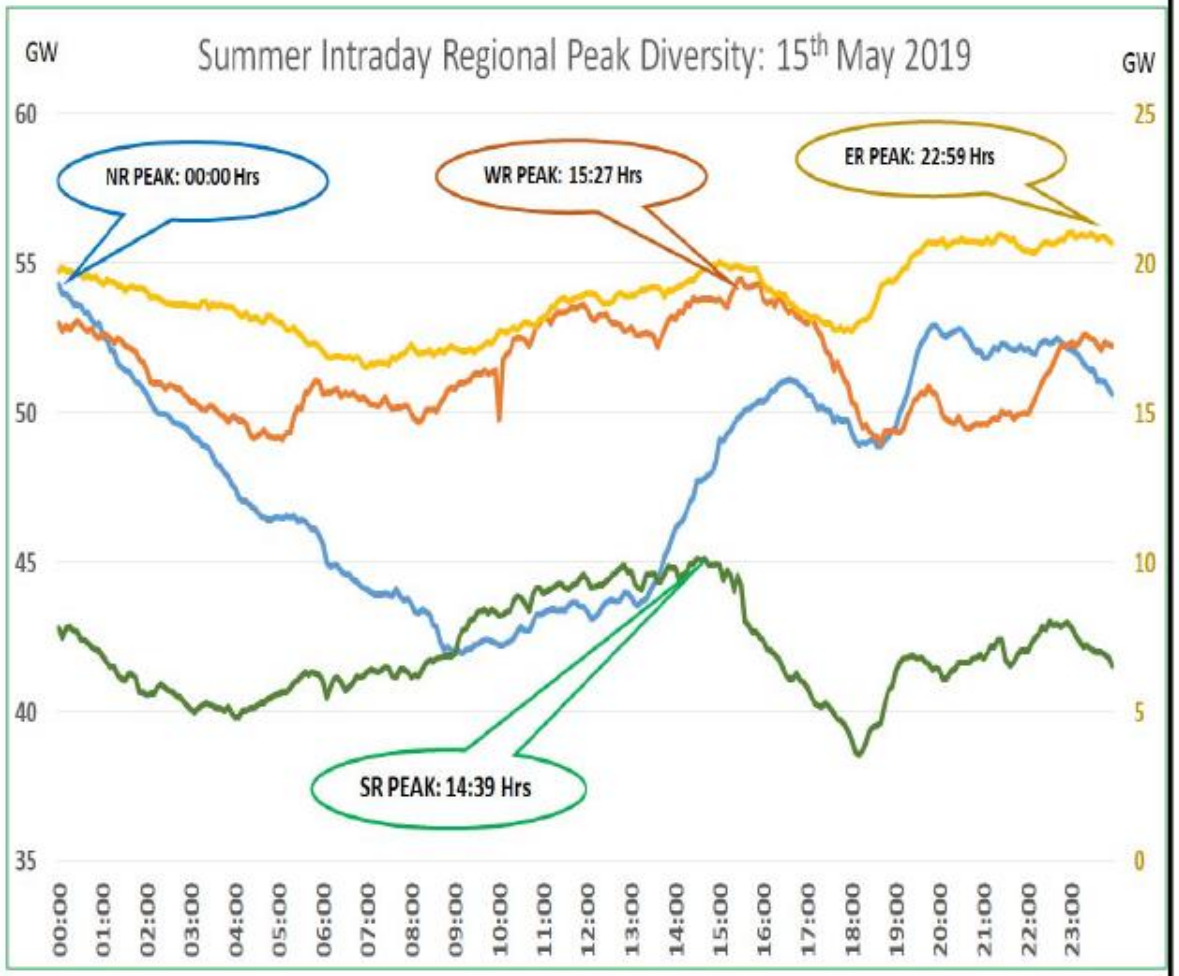


https://posoco.in/download/electricity-load-factor-in-india-power-system/?wpdmdl=709

"In diversity, there is beauty and there is strength"

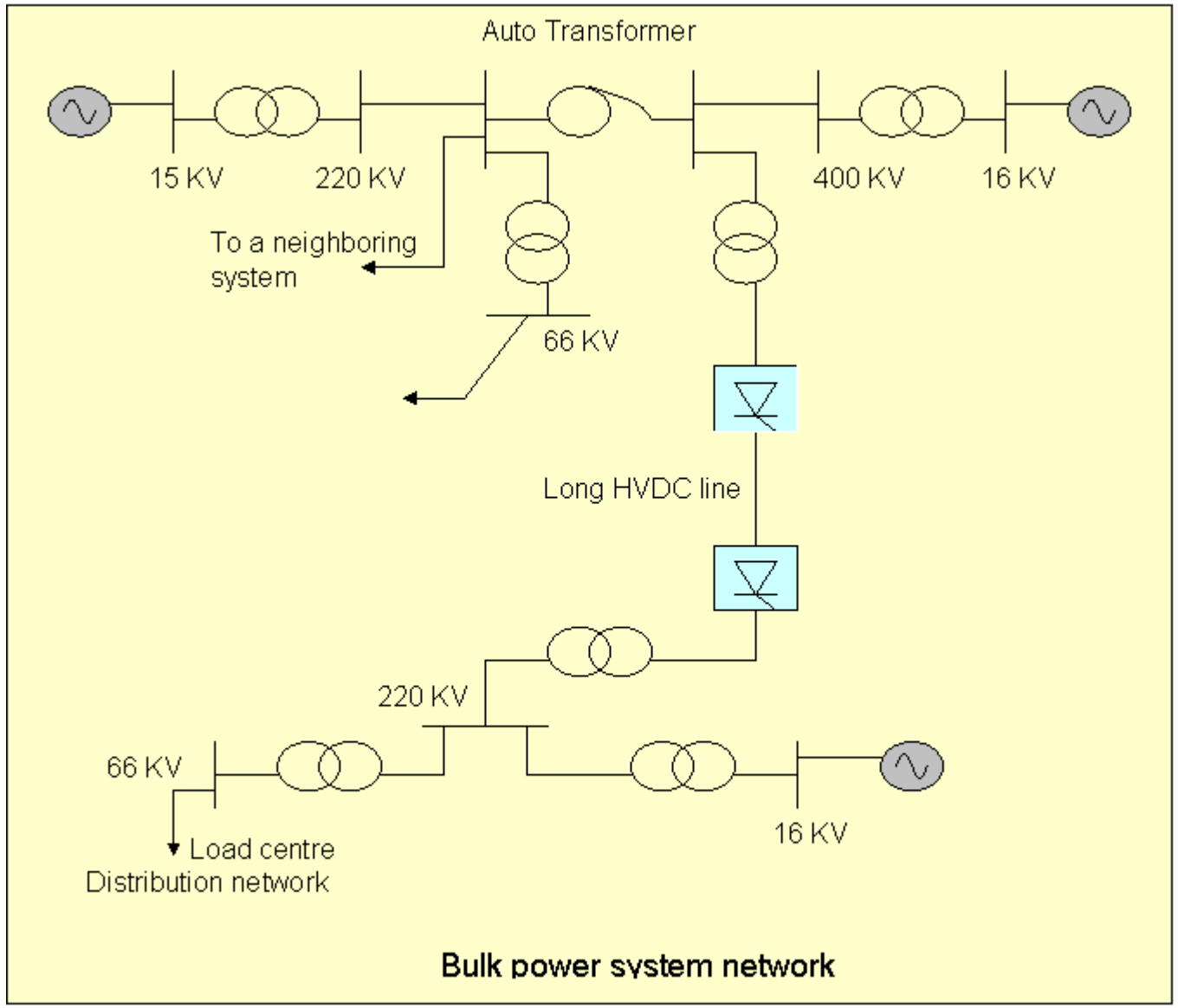
Diversity in Regional Peak Demand – Intra-day & Seasonal

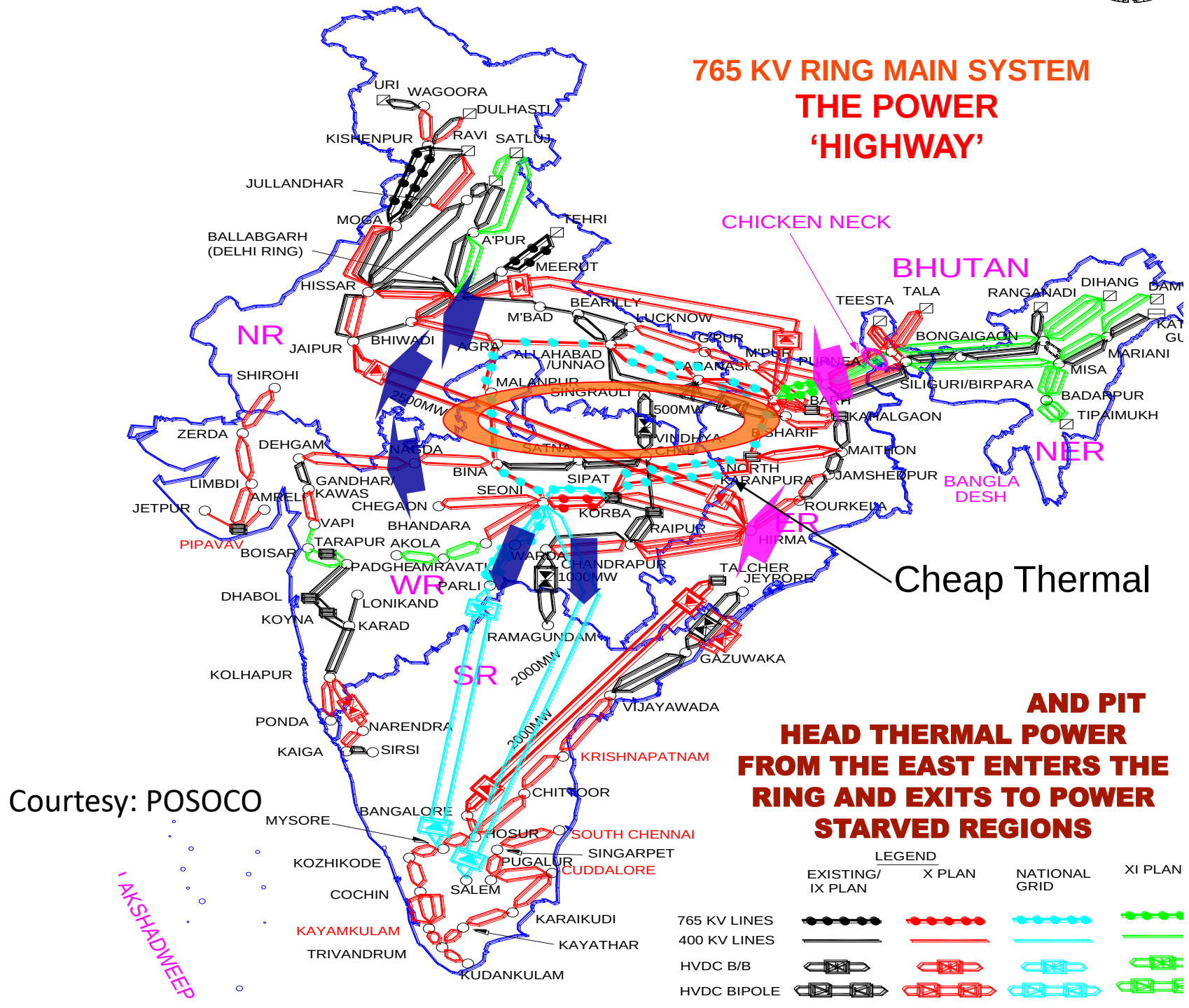




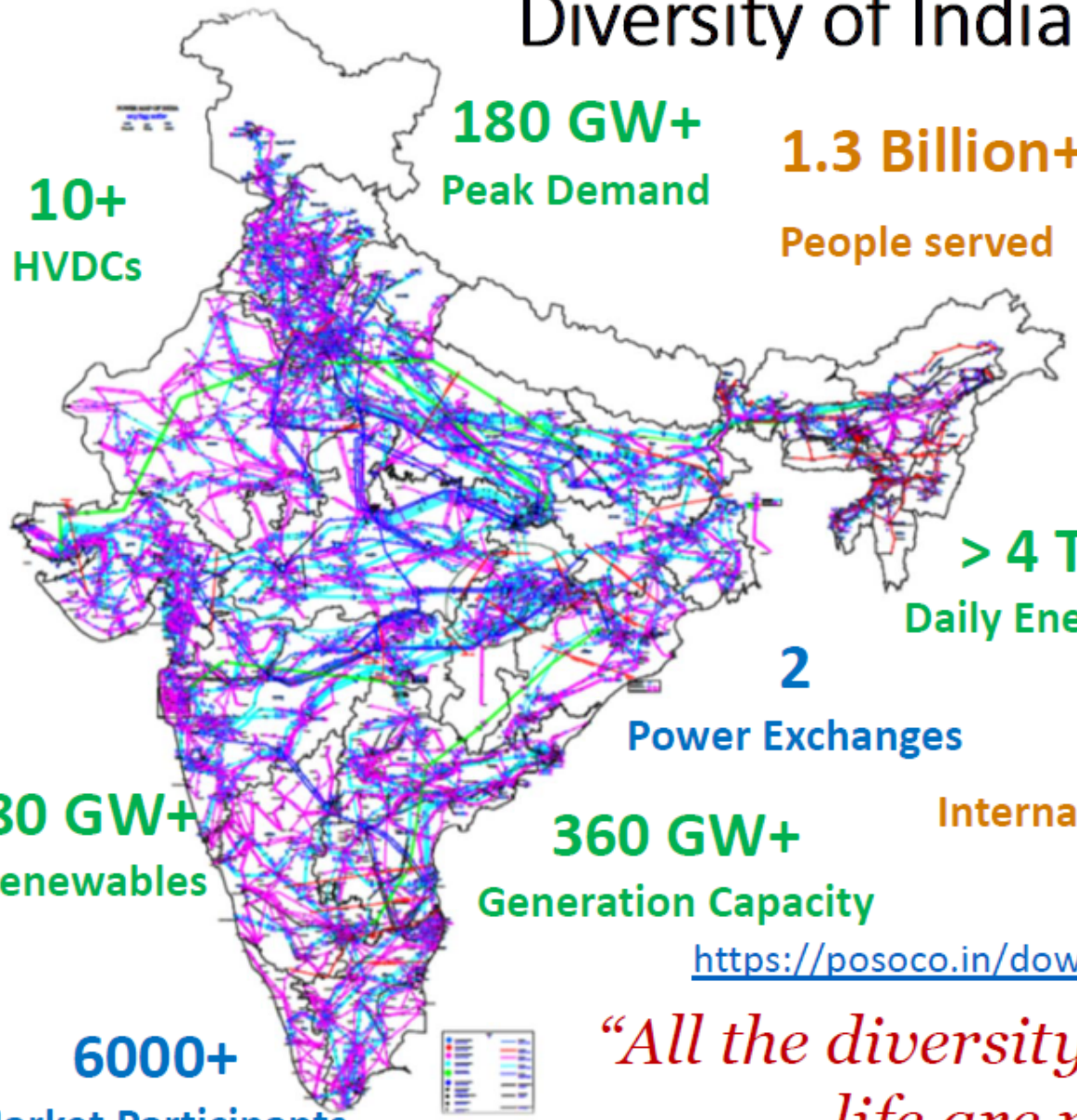
https://posoco.in/reports/electricity-demand-pattern-analysis/

"Diversity is about embracing one another's uniqueness"


Auto Transformer
15 KV
220 KV
400 KV
16 KV
To a neighboring system
66 KV
Long HVDC line
220 KV
66 KV
Load centre
Distribution network
16 KV
Bulk power system network


765 KV RING MAIN SYSTEM
THE POWER
'HIGHWAY'
CHICKEN NECK
BHUTAN
NR
WR
SR
ER
NER
BANGLA DESH
Cheap Thermal
AND PIT
HEAD THERMAL POWER
FROM THE EAST ENTERS THE
RING AND EXITS TO POWER
STARVED REGIONS
Courtesy: POSOCO
LEGEND
EXISTING/ IX PLAN
X PLAN
NATIONAL GRID
XI PLAN
765 KV LINES
400 KV LINES
HVDC B/B
HVDC BIPOLE
2500MW
500MW
1000MW
2000MW
2000MW
URI
WAGOORA
DULHASTI
KISHENPUR
RAVI
SATLUJ
JULLANDHAR
MOGA
TEHRI
BALLABGARH (DELHI RING)
A'PUR
MEERUT
HISSAR
BEARILLY
M'BAD
LUCKNOW
JAIPUR
BHIWADI
AGRA
ALLAHABAD
/UNNAO
G'PUR
M'PUR
VARANASI
PURNEA
SHIROHI
MALANPUR
SINGRAULI
BARH
ZERDA
DEHGAM
NAGDA
VINDHYA-
CHAL
SATNA
BISHARIF
MAITHON
BINA
NORTH
KARANPURA
JAMSHEDPUR
LIMBDI
GANDHAR/
KAWAS
SIPAT
SEONI
AMRELI
JETPUR
CHEGAON
KORBA
ROURKELA
VAPI
BHANDARA
RAIPUR
HIRMA
PIPAVAV
TARAPUR
AKOLA
BOISAR
WARDA
CHANDRAPUR
PADGHE
AMRAVATI
TALCHER
JEYPORE
PARLI
DHABOL
LONIKAND
KOYNA
KARAD
RAMAGUNDAM
GAZUWAKA
KOLHAPUR
VIJAYAWADA
PONDA
NARENDRA
KAIGA
SIRSI
KRISHNAPATNAM
CHITTOOR
MYSORE
BANGALORE
HOSUR
SOUTH CHENNAI
SINGARPET
KOZHIKODE
PUGALUR
CUDDALORE
COCHIN
SALEM
KARAIKUDI
KAYAMKULAM
KAYATHAR
TRIVANDRUM
KUDANKULAM
LAKSHADWEEP
TEESTA
TALA
RANGANADI
DIHANG
BONGAIGAON
MISA
MARIANI
SILIGURI/BIRPARA
BADARPUR
TIPAIMUKH
KAHALGAON
MAITHON

Diversity of Indian Electricity Grid



180 GW+
Peak Demand

1.3 Billion+
People served

10+
HVDCs

Voltage Level (kV)	No. of Lines	Circuit Kilometres
765	196	42857
400	1921	182608
220	5547	178374

> 4 TWh
Daily Energy Met

50000+
Market Transactions

2
Power Exchanges

3 GW+
International Exchanges

80 GW+
Renewables

360 GW+
Generation Capacity

120 TWh+
Annual Market Trades

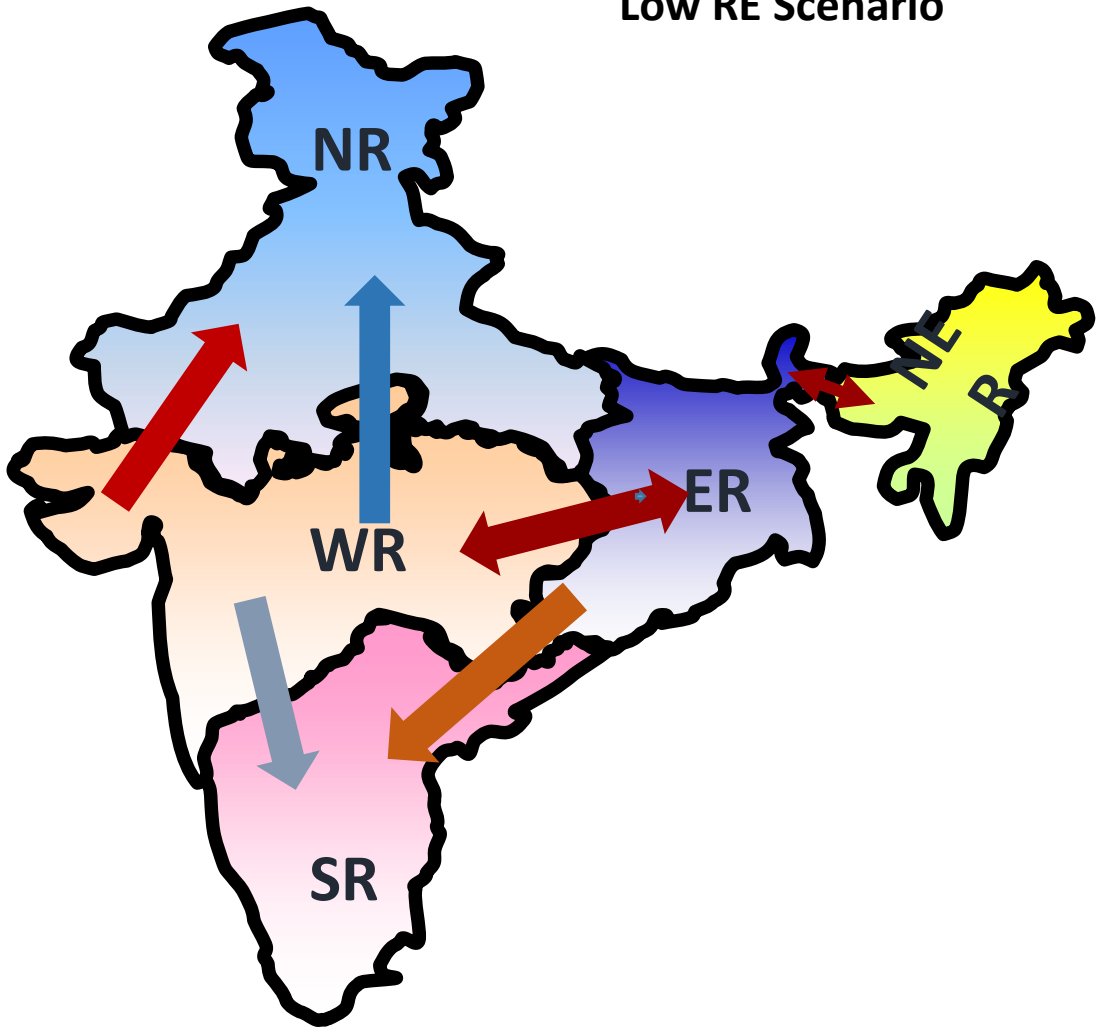
https://posoco.in/download/indian-electricity-market-data-analysis/?wpdmdl=10594

6000+
Market Participants

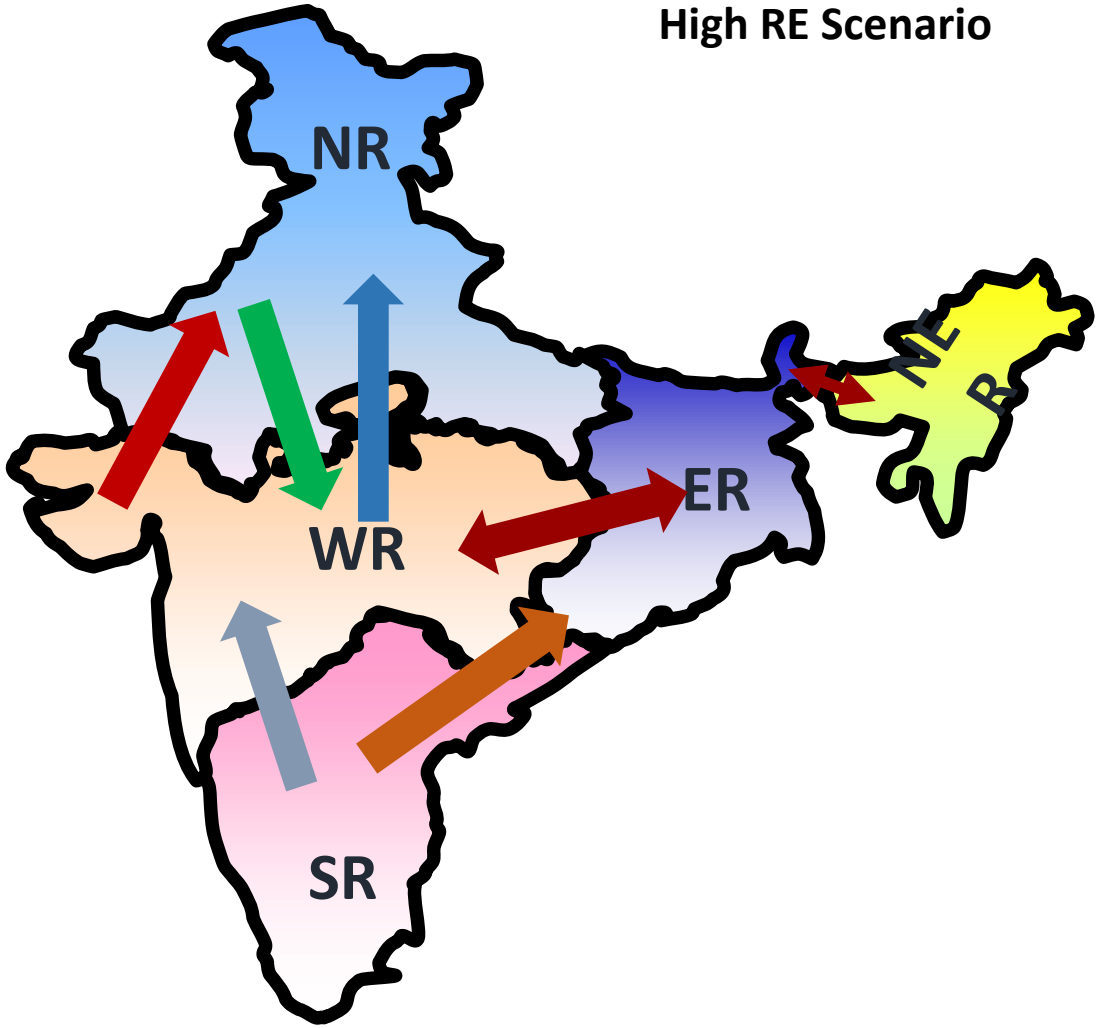
"All the diversity, all the charm, and all the beauty of life are made up of light and shade."

RE Transmission Planning – Insights

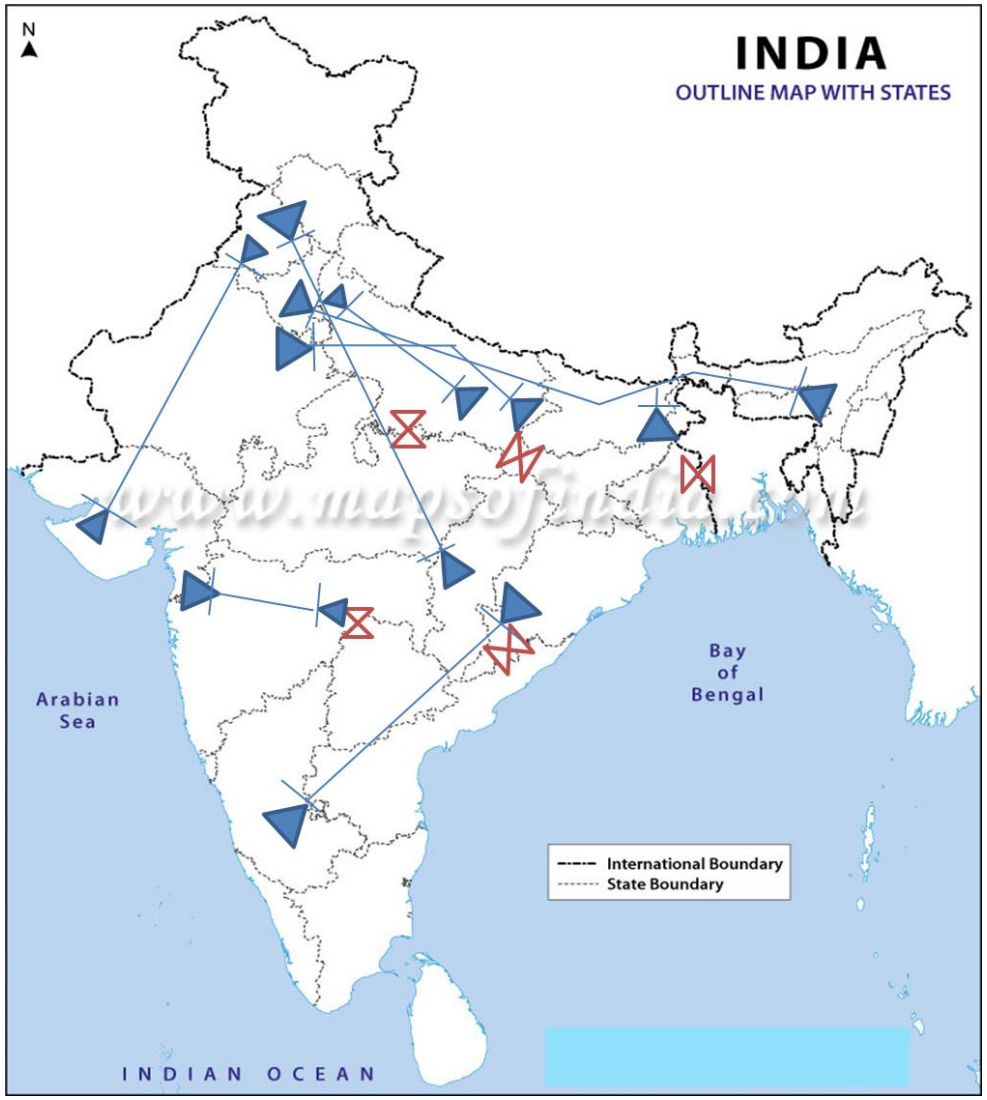
Low RE Scenario



High RE Scenario

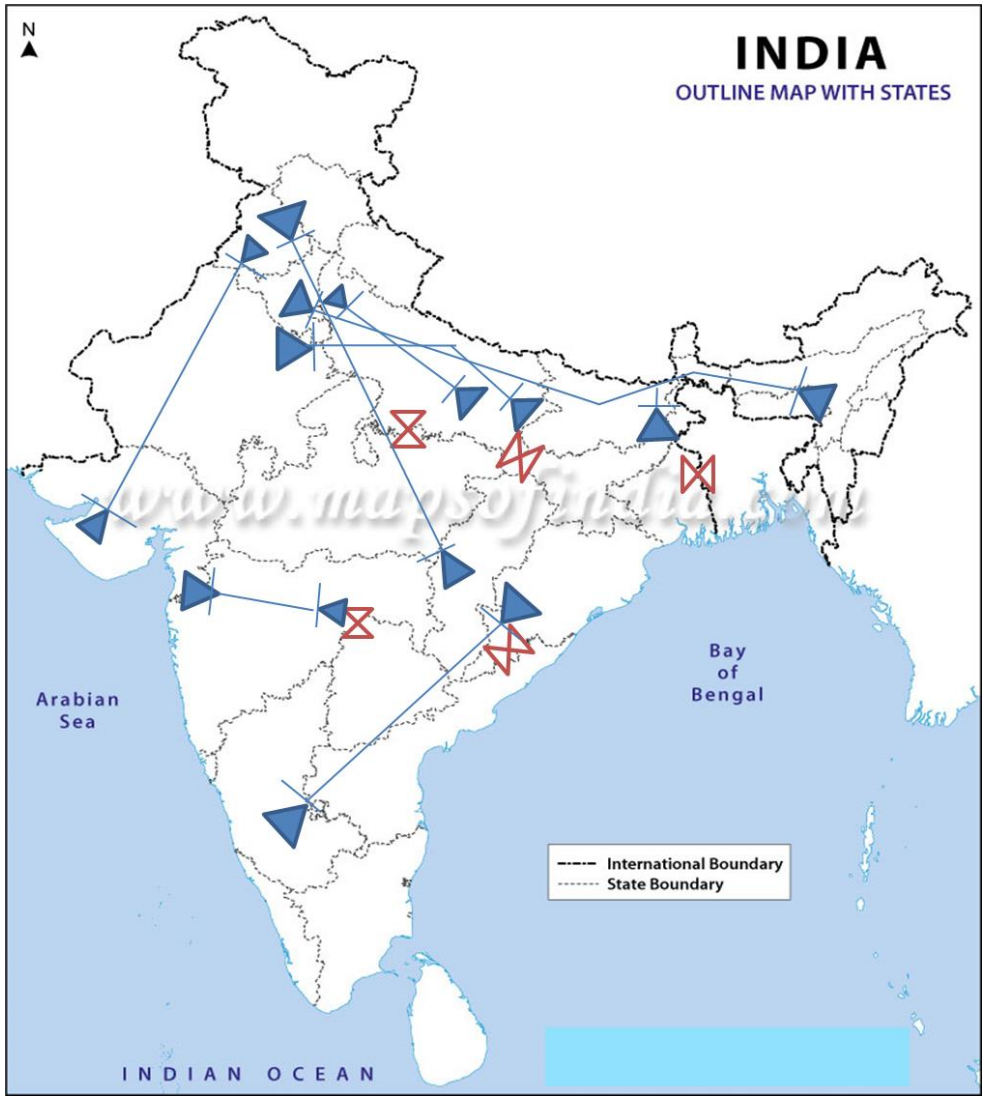


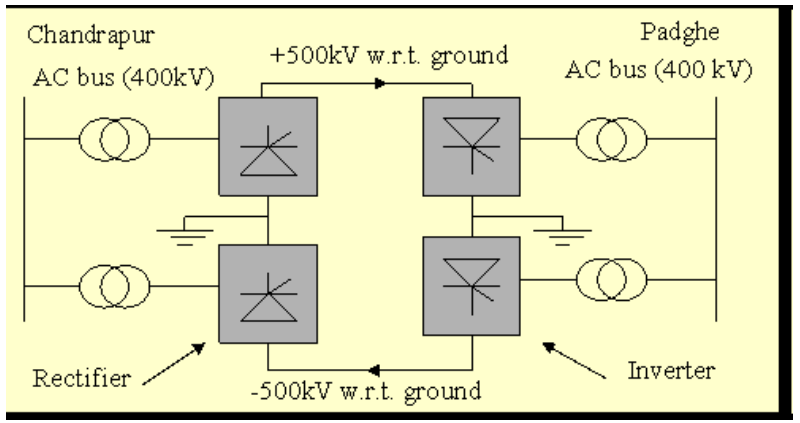
HVDC– Flexible Transmission



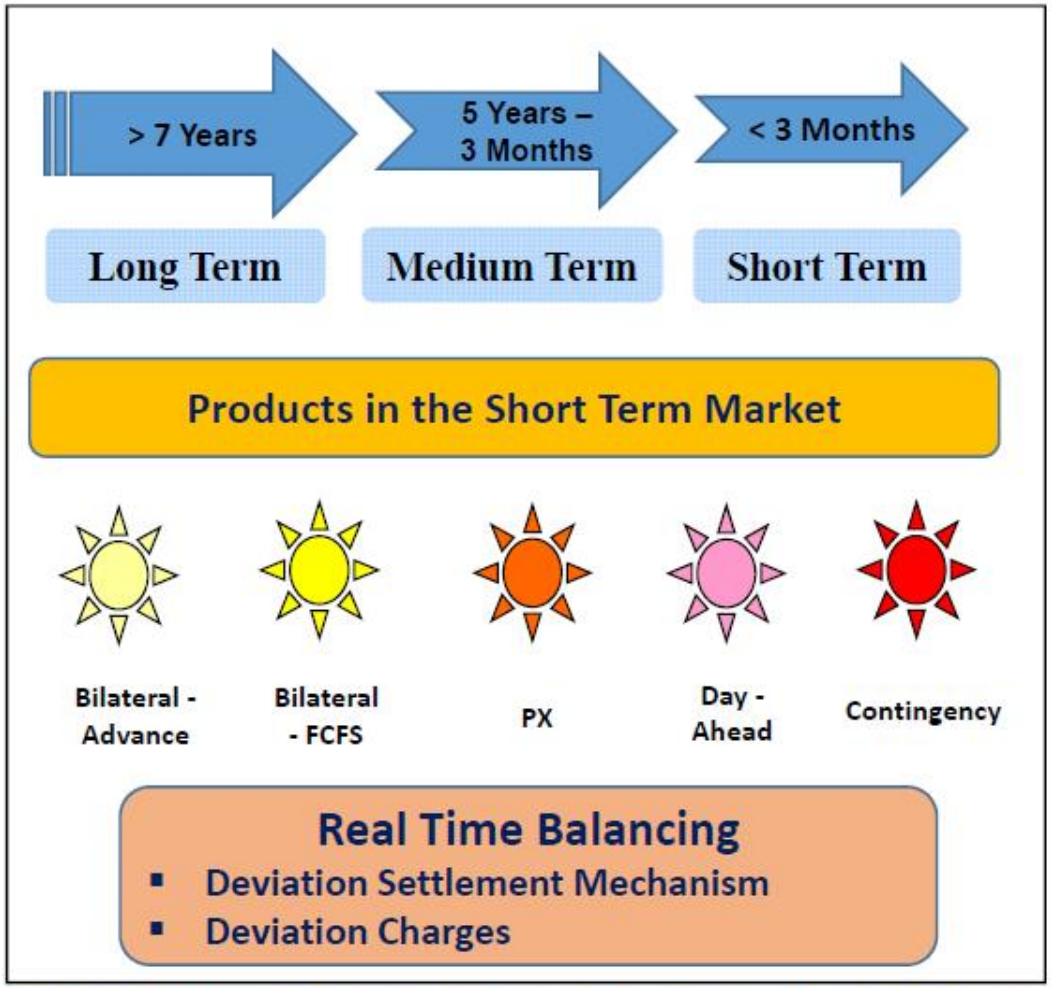
- HVDC Back to Back - 4 Stations
- HVDC Bi-pole - 6 Links
- HVDC Multi Terminal - 1 Link
  - Connecting 3 Regions (NER, ER & NR)
- International HVDC: India-Bangladesh Link
- Under Construction – 2 HVDC Links
- Toggling of HVDC Set-points

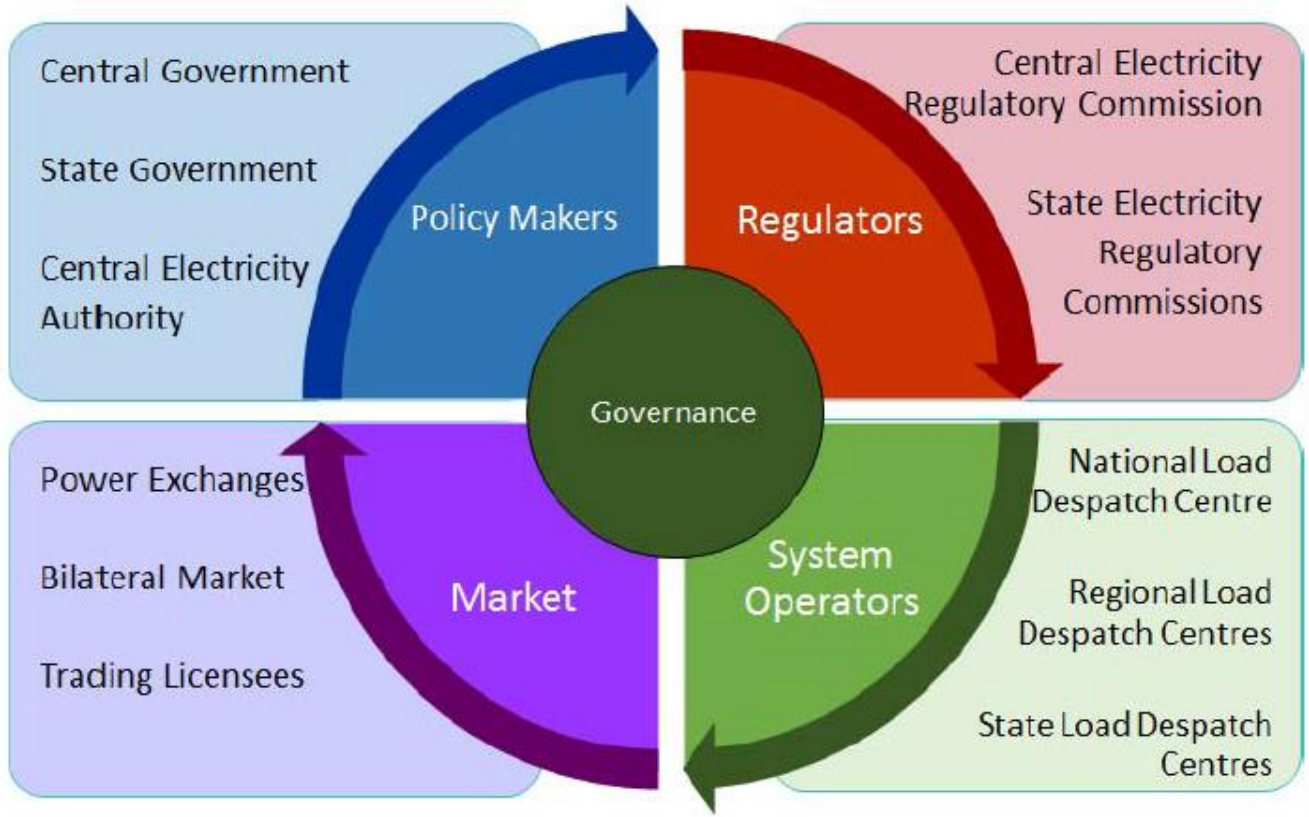
HVDC– Flexible Transmission





Diversity in Market Design and Governance

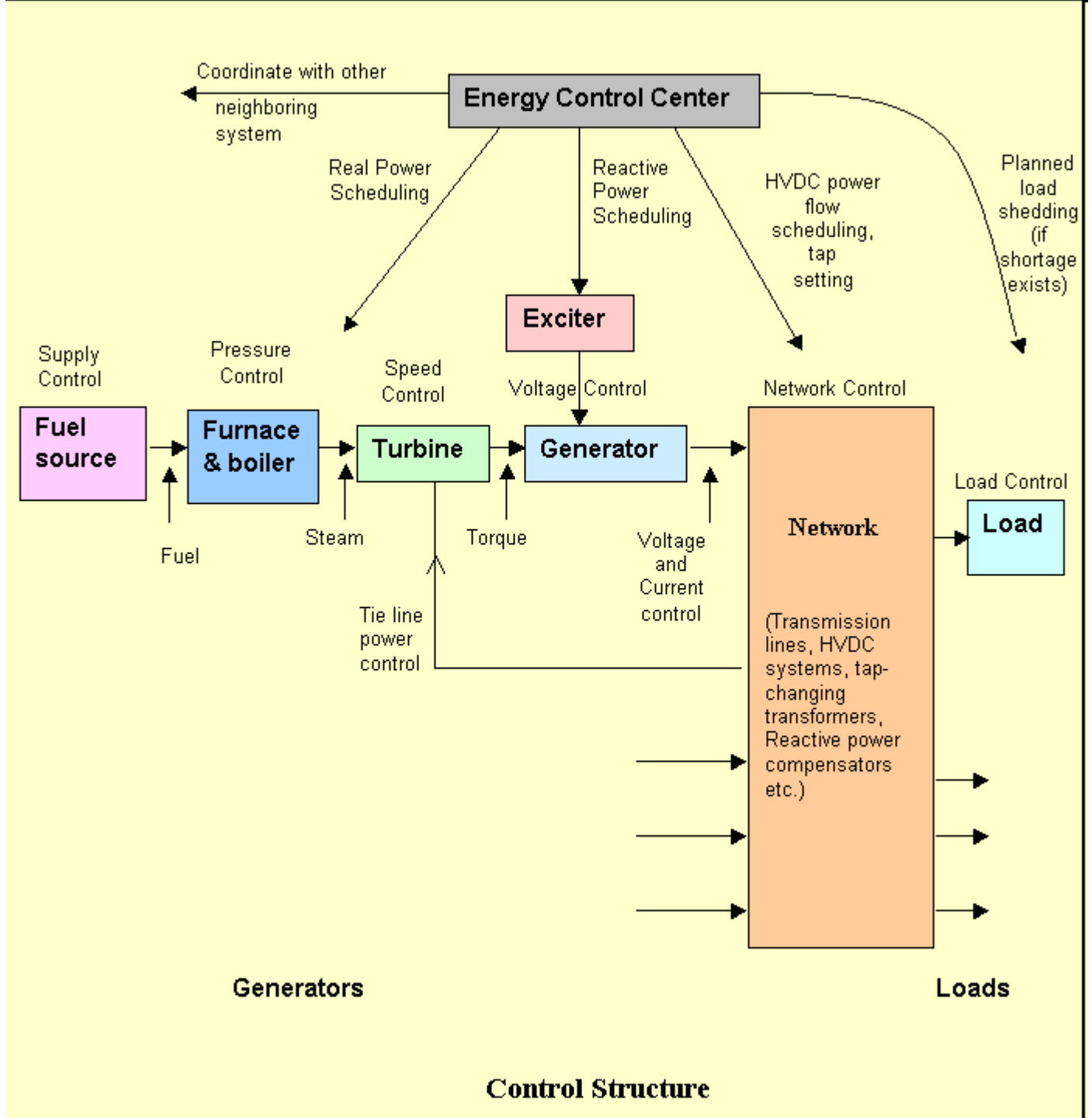




https://forumofld.in/download/capacity-building-of-indian-load-despatch-centres-cabil/?wpdmdl=904

http://www.forumofregulators.gov.in/Data/WhatsNew/SAMAST.pdf

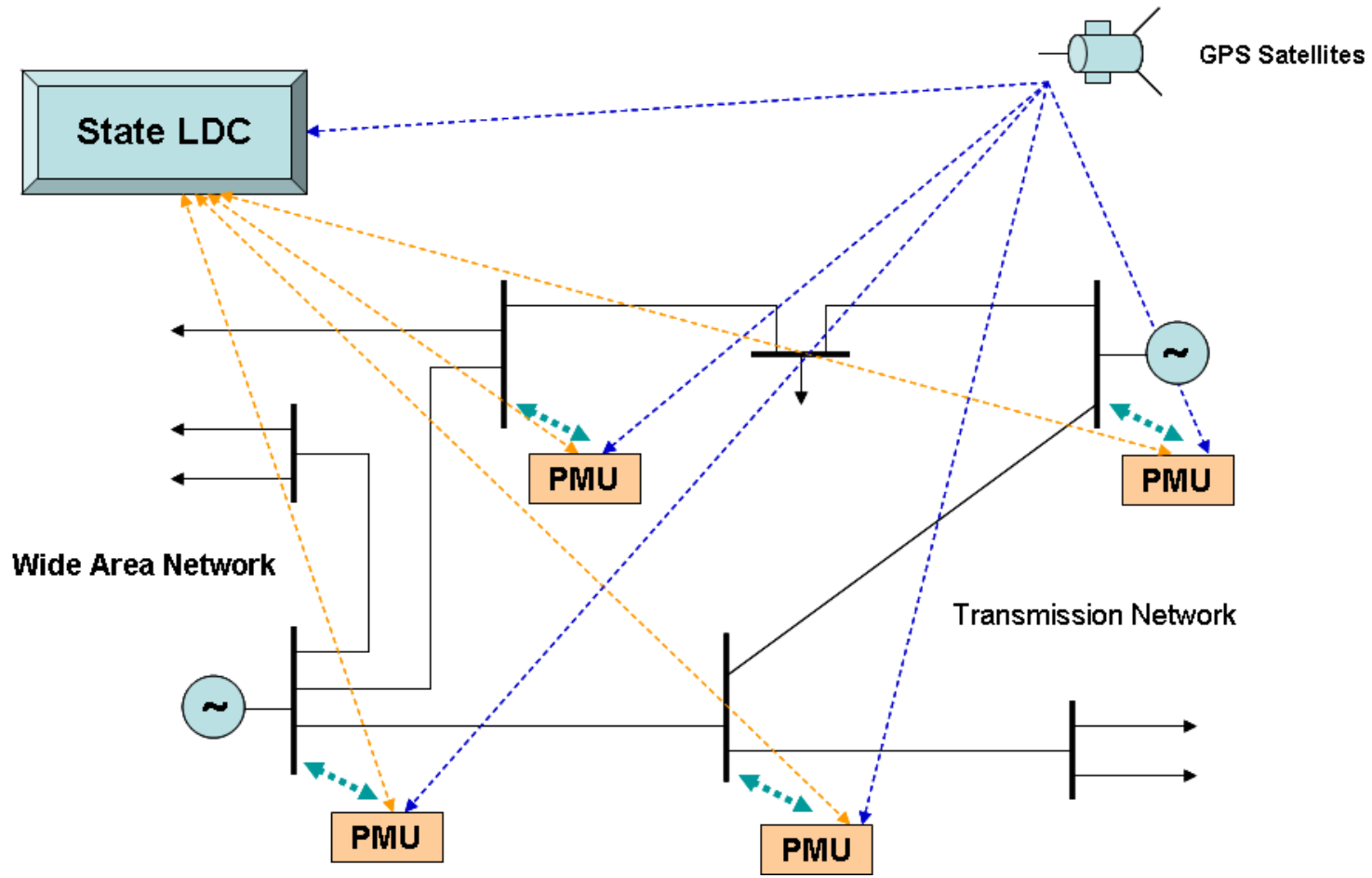
"If you want to go fast, go alone; if you want to go far, go together"



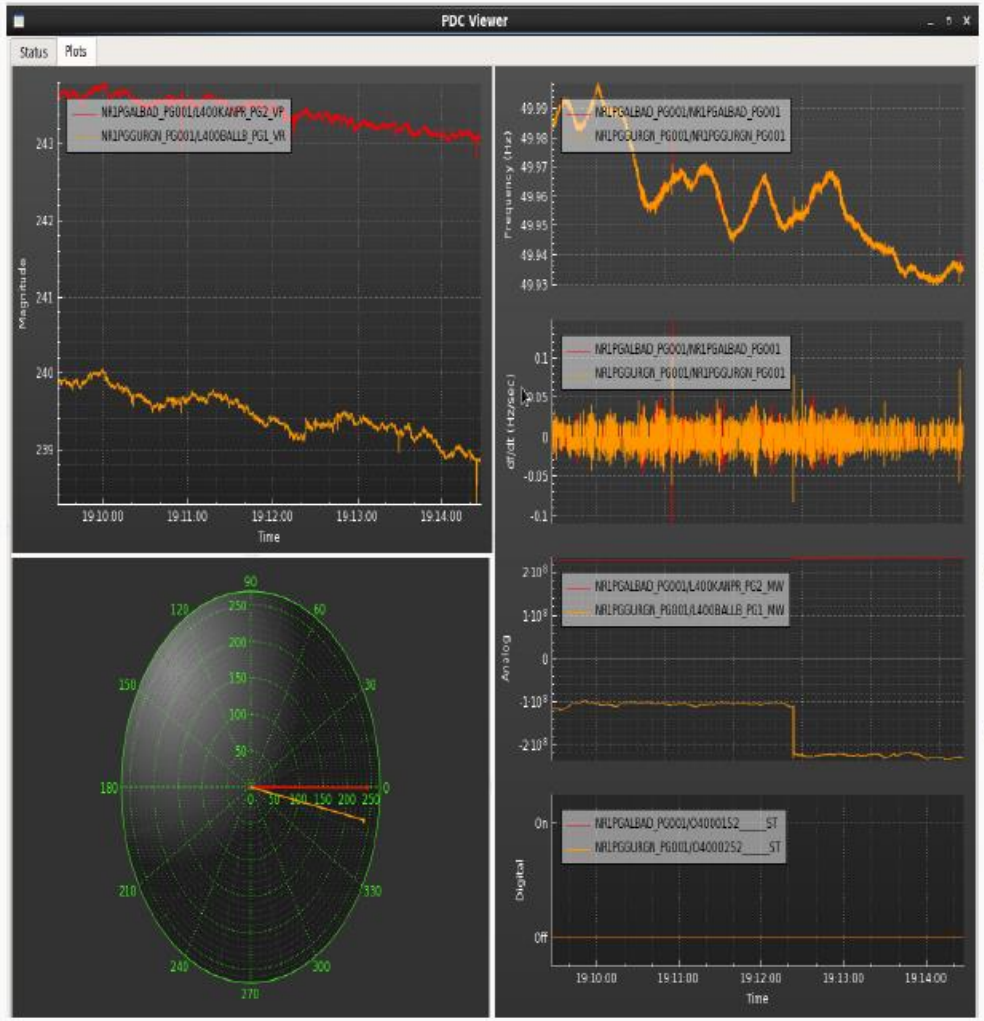
Control Structure

Control Centre

WAMS


GPS Satellites
State LDC
PMU
PMU
Wide Area Network
Transmission Network
PMU
PMU

Phasor Measurement Units (PMUs)

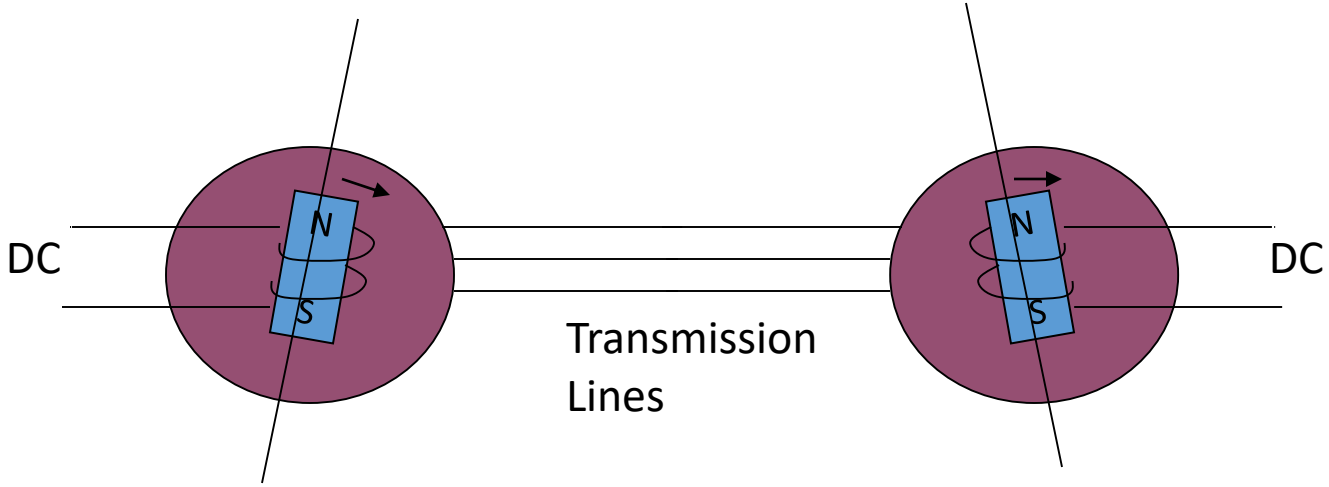


- 3-Φ resolution.
- Data streamed every 20 ms/40 ms to Energy Control Center.
- Digital status of switchgear.
- MRI scan of the system.

PDC Viewer developed at PowerAnser Labs (PAL), IITB

Synchronous Links

- Synchronous Grid:
  - Synchronous machines interconnected with AC lines



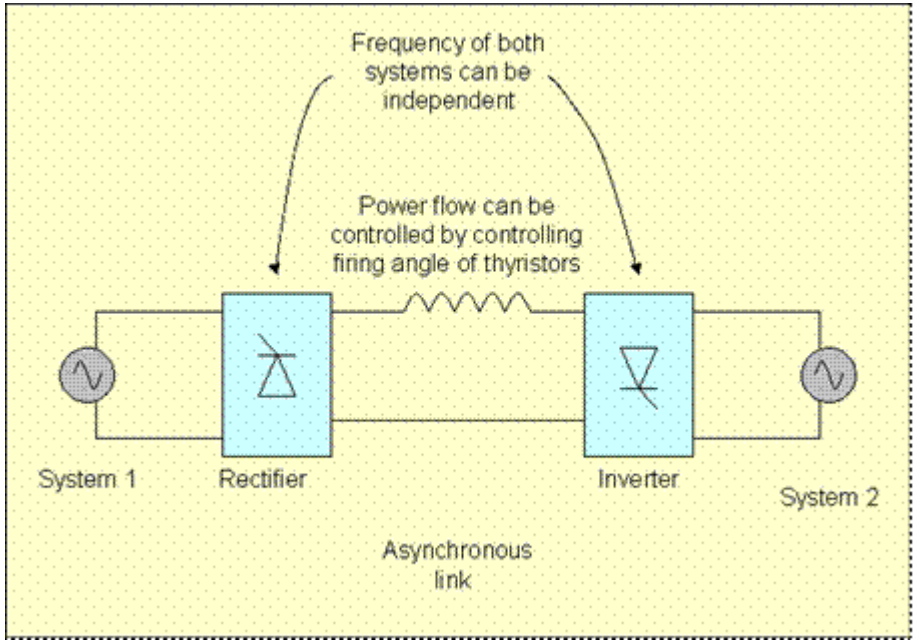
Induction Generators ?

Synchronous Links

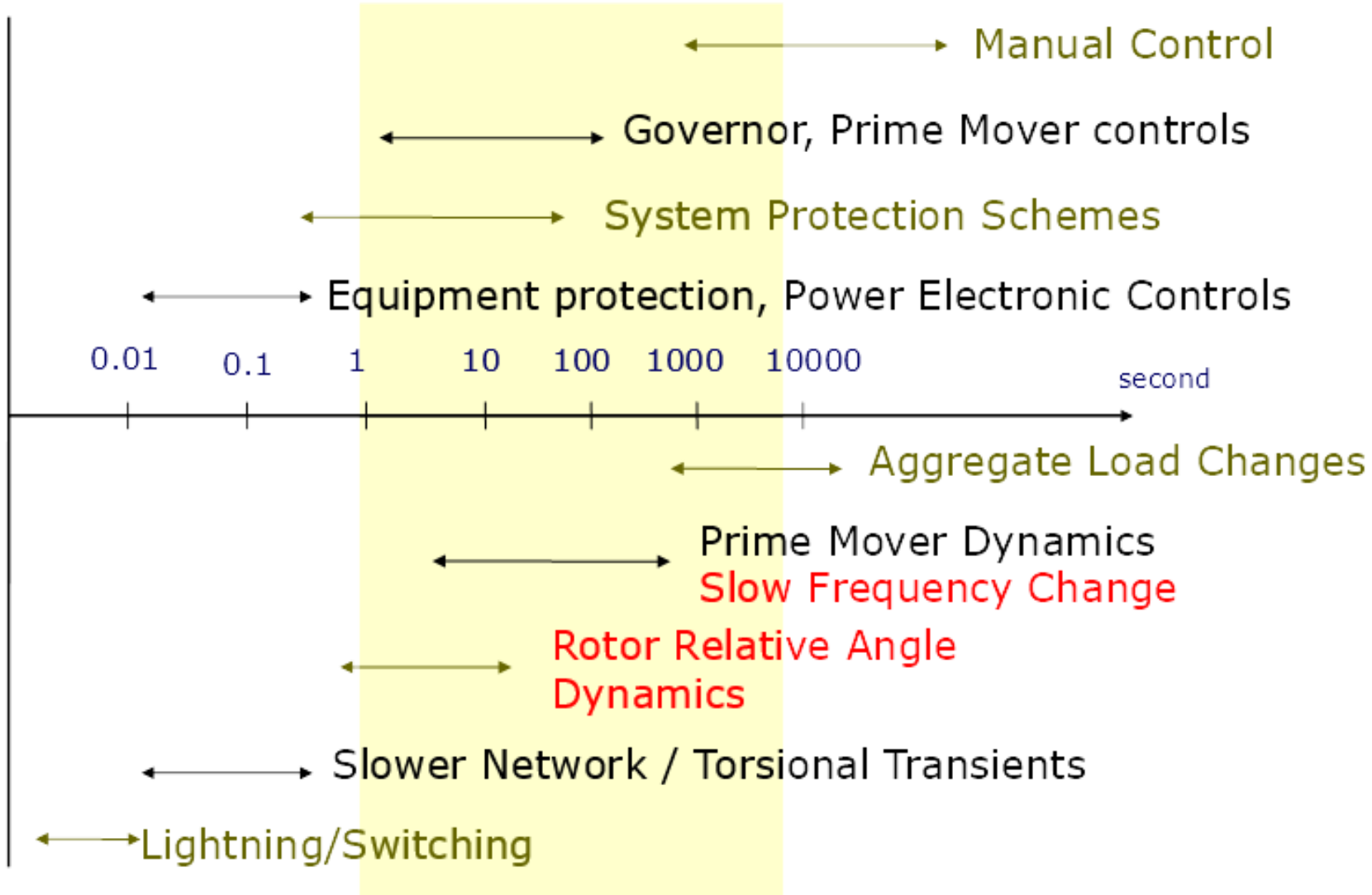
- Synchronous Grid:
  - Synchronous machines interconnected with AC lines
  - Power Flow in AC lines - function of Voltage phase Angle Difference (determined by the relative rotor position in synchronous machines)
  - Frequency throughout grid is the same in steady state (why ?)

Asynchronous Links

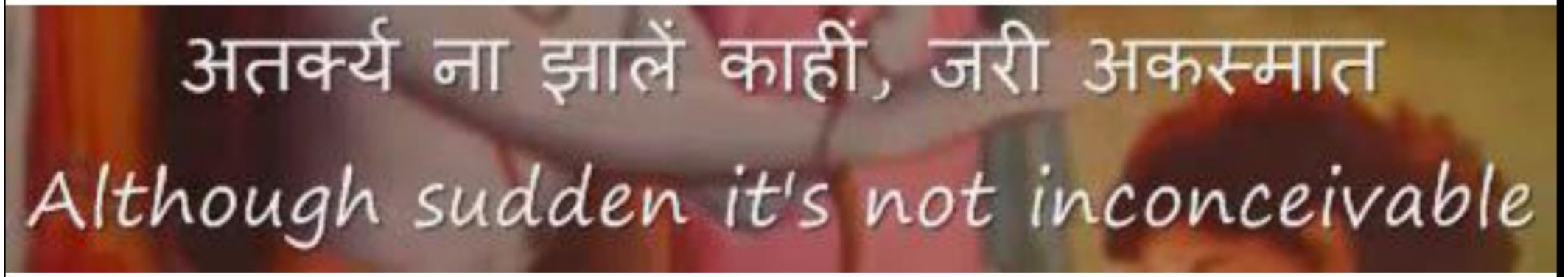
- Asynchronous Interconnects
  - HVDC links: Power flows not a function of Phase Angle Difference
  - Frequencies of connected regions could “happily” be different



Power Transient and Control "Spectrum"

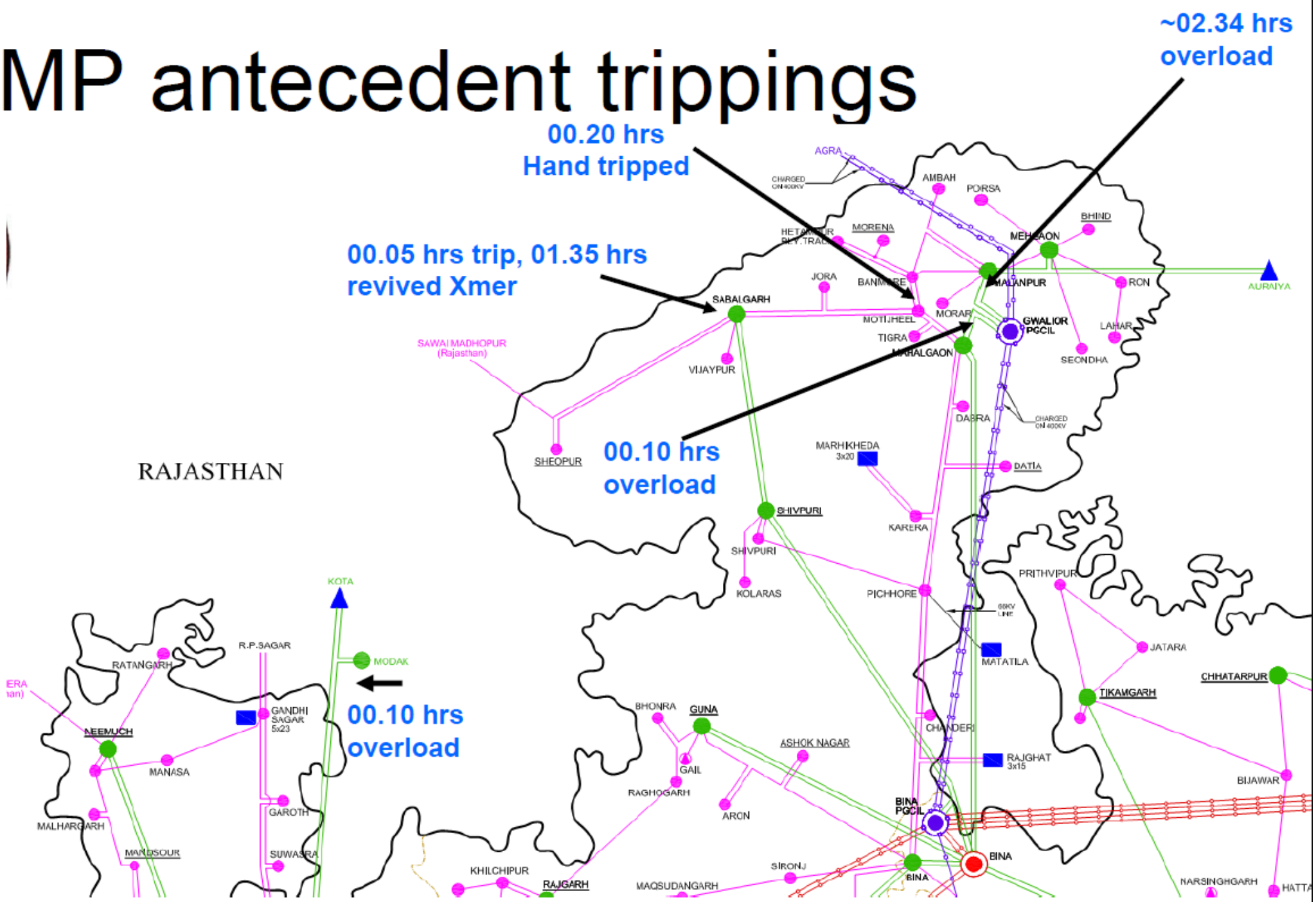


The Grid Collapse of 30th July 2012



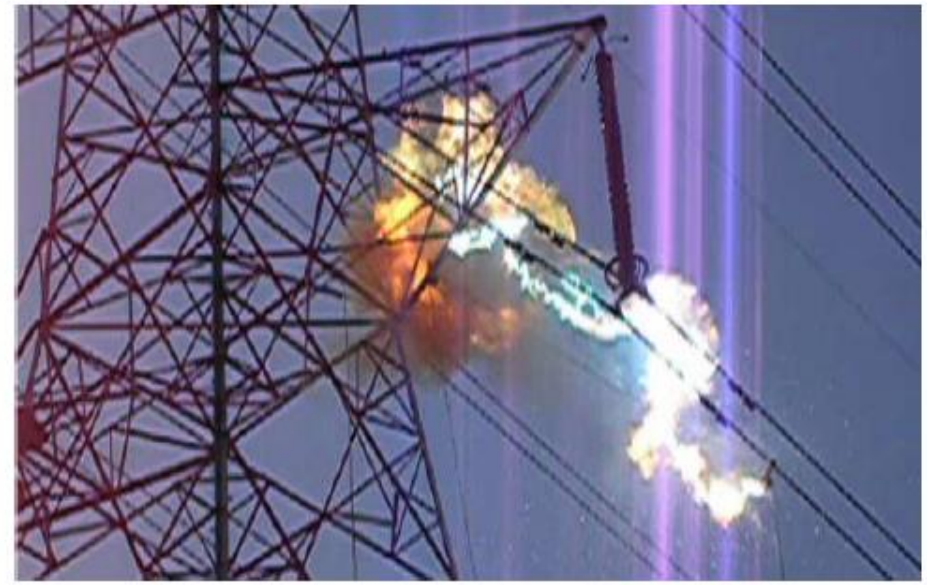
From Geet Ramayana (G.D.Madgulkar)

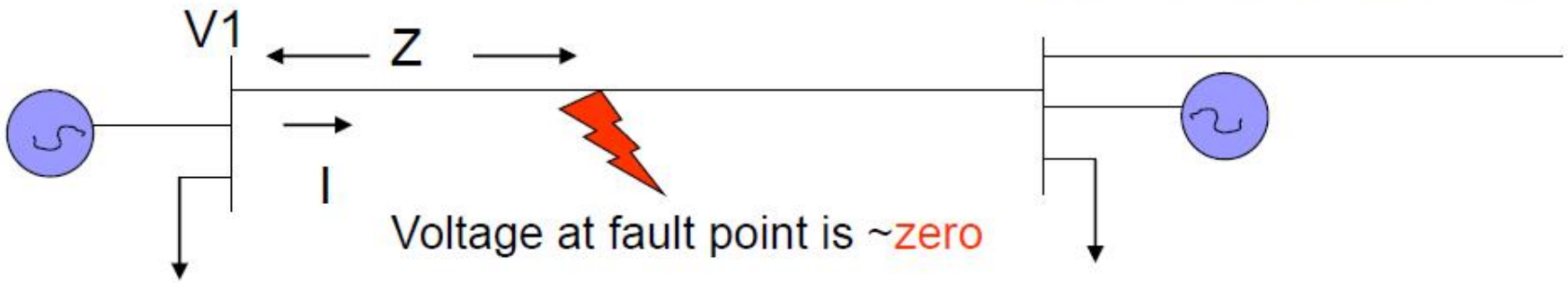
MP antecedent trippings



Distance Protection

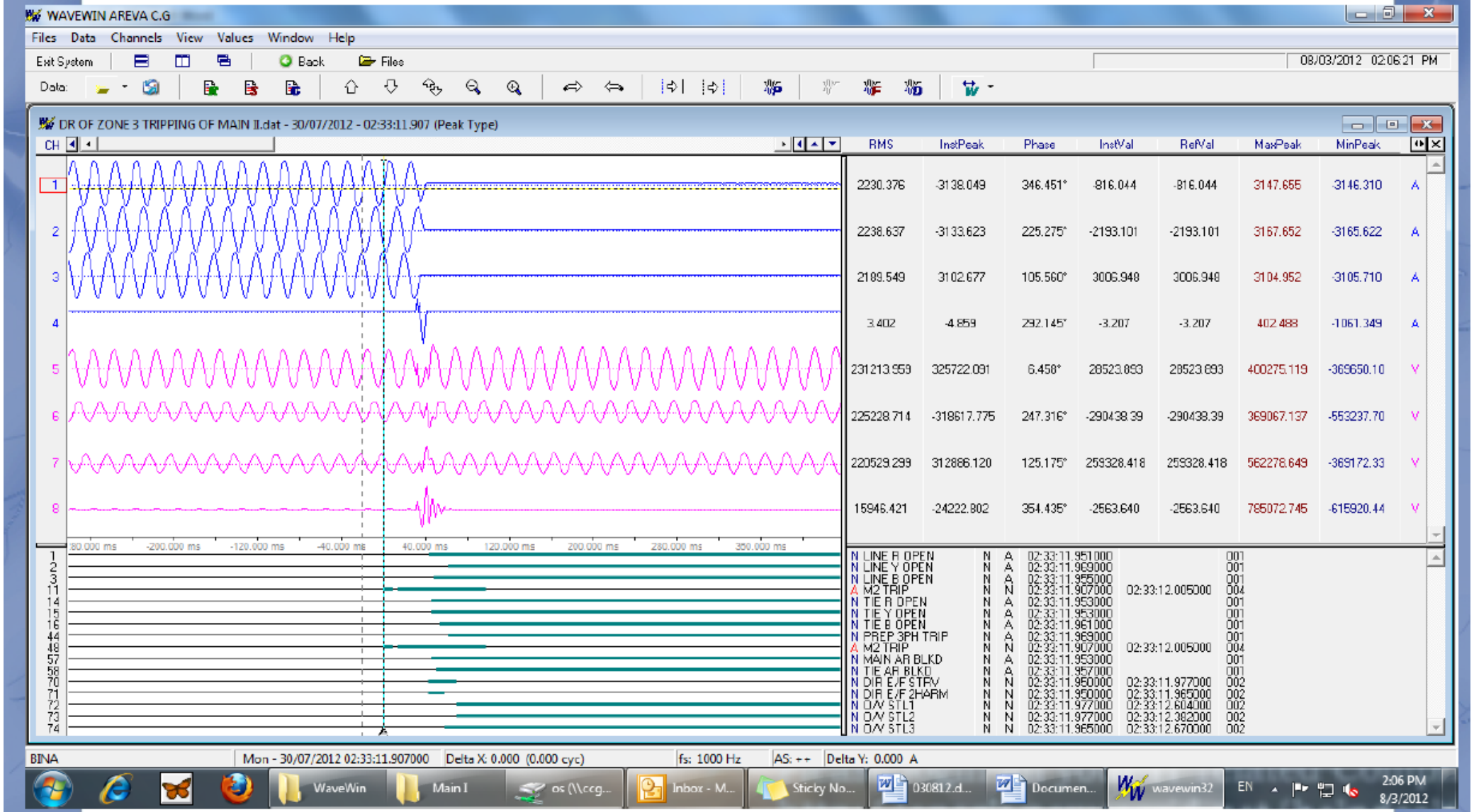
Fault →



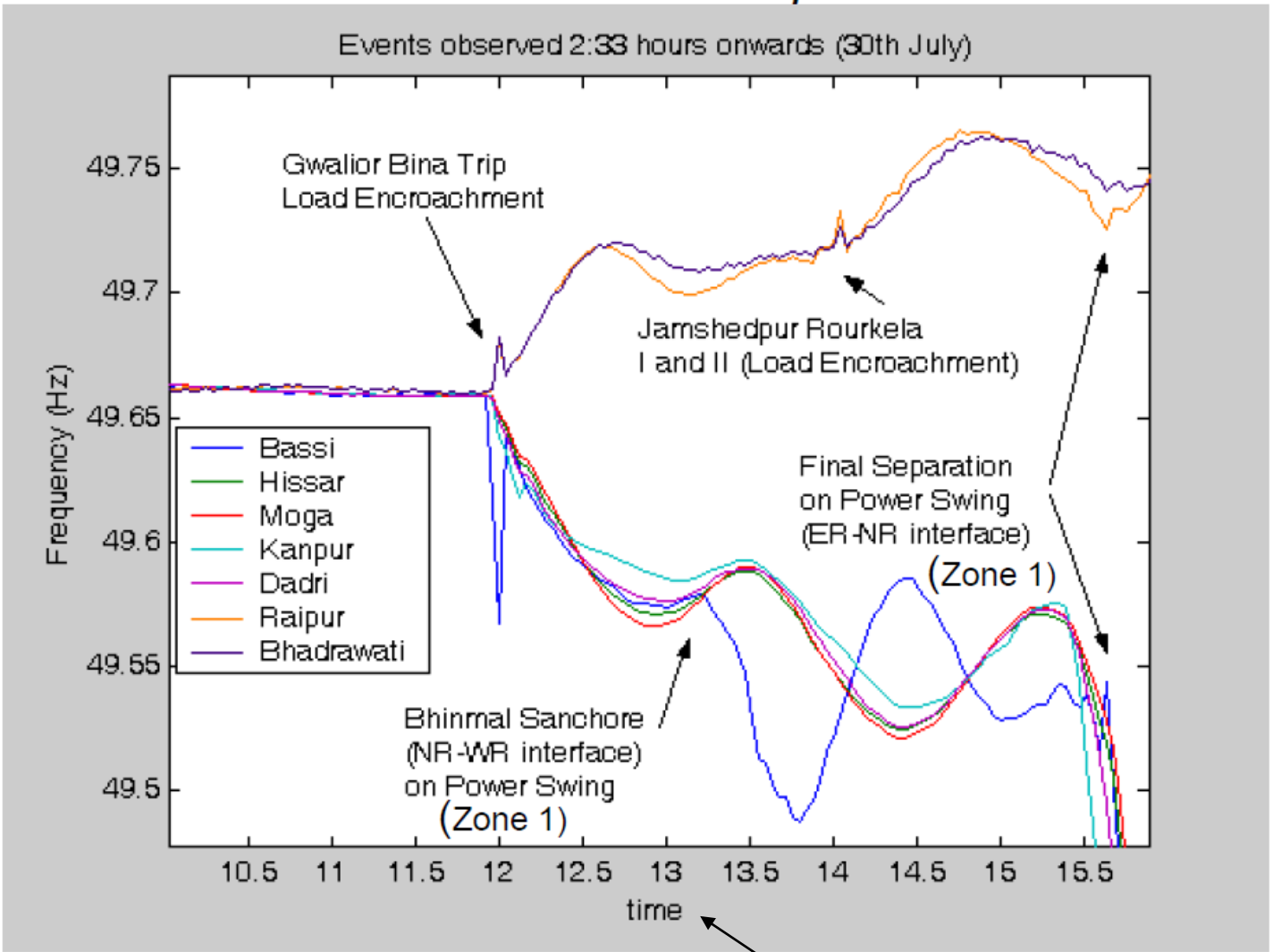


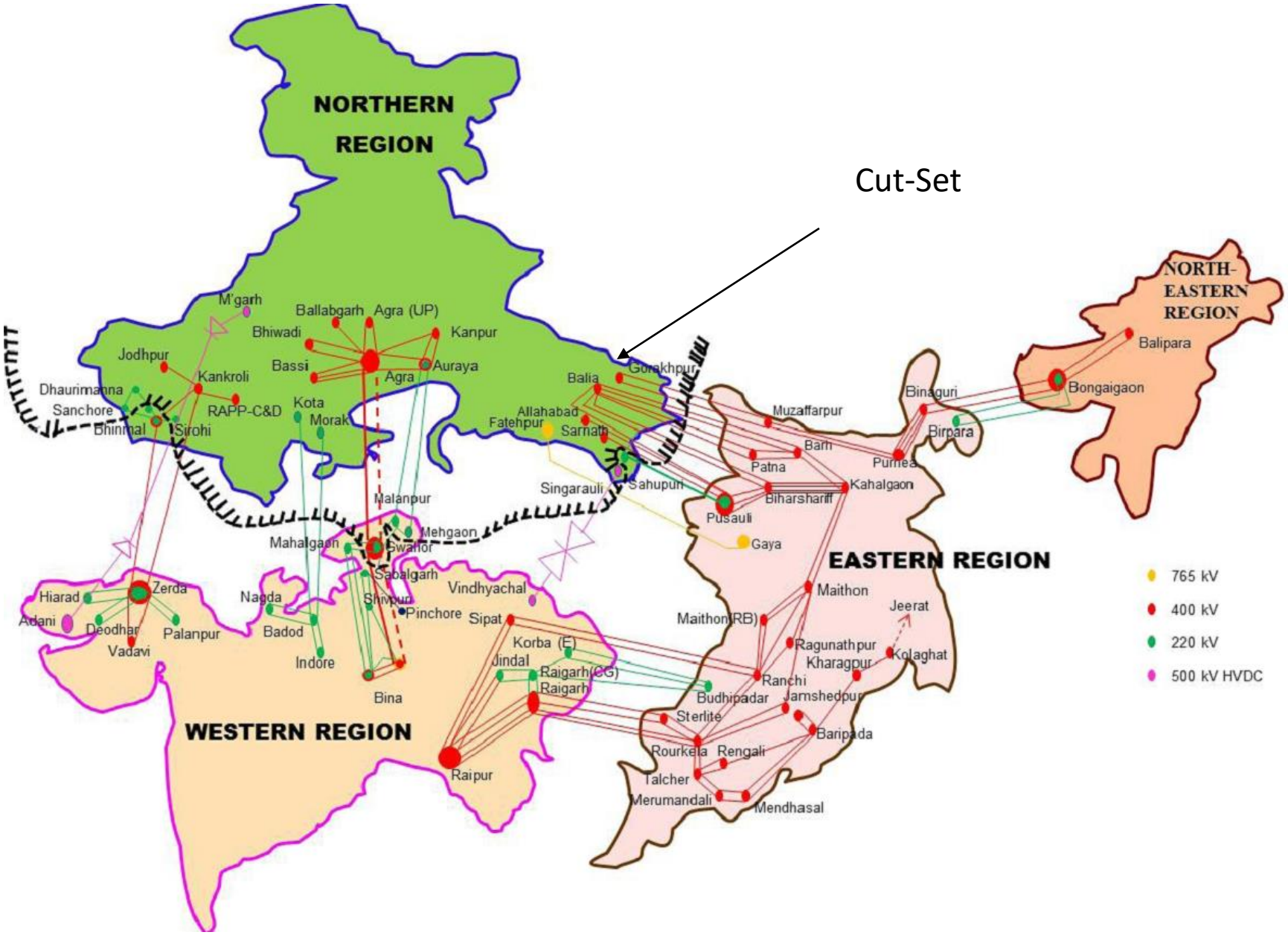
Zone3 tripping

DR of Bina-Gwalior



PMU data 30-7-2007, 2:33 hours




Cut-Set
NORTHERN REGION
NORTH-EASTERN REGION
WESTERN REGION
EASTERN REGION
M'garh
Ballabgarh
Agra (UP)
Bhiwadi
Kanpur
Jodhpur
Bassi
Auraya
Agra
Kankroli
Dhaurimanna
Sanchore
Bhinmal
Sirohi
RAPP-C&D
Kota
Morak
Malanpur
Mehgaon
Gwalior
Mahalgaon
Sabalgarh
Zerda
Hiarad
Adani
Deodhar
Palanpur
Vadavi
Nagda
Badod
Indore
Shujpur
Pinchore
Bina
Vindhyachal
Sipat
Korba (E)
Jindal
Raigarh(CG)
Raigarh
Raipur
Balia
Gorakhpur
Allahabad
Fatehpur
Sarnath
Singarauli
Sahupuri
Pusauli
Gaya
Muzaffarpur
Barh
Patna
Purnea
Binaguri
Birpara
Balipara
Bongaigaon
Kahalgaon
Biharsharif
Maithon
Maithon(RB)
Jeerat
Ragunathpur
Kharagpur
Kolaghat
Ranchi
Jamshedpur
Budhipadar
Sterlite
Baripada
Rourkela
Rengali
Talcher
Merumandali
Mendhasal
765 kV
400 kV
220 kV
500 kV HVDC

States of a Power System