Utilization of Synchrophasors during Synchronization and Operation of Large Grids - Experience of Indian Grid Operator

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14-15 October NASPI Work Group Meeting, Chicago,IL

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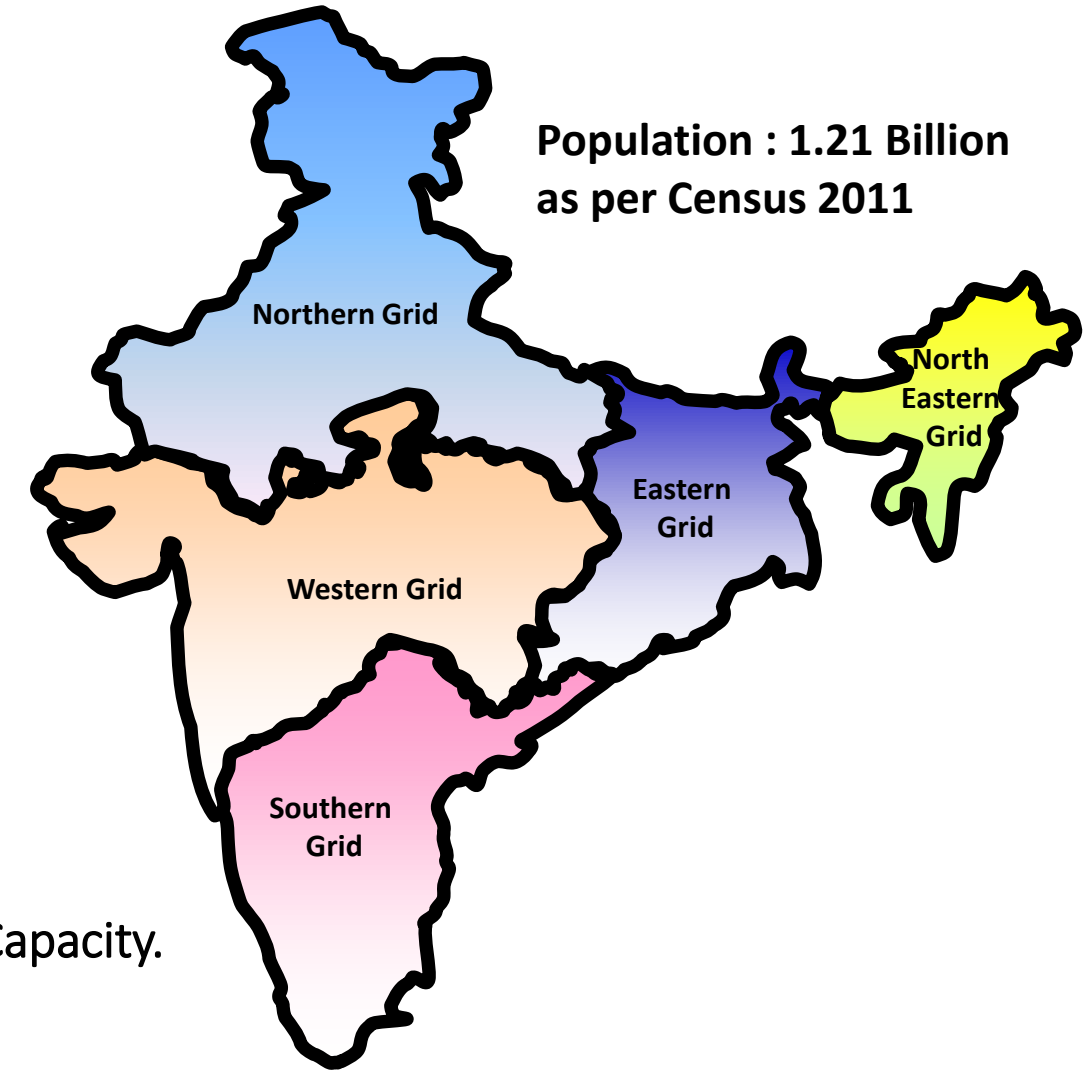
Indian Grid : Profile

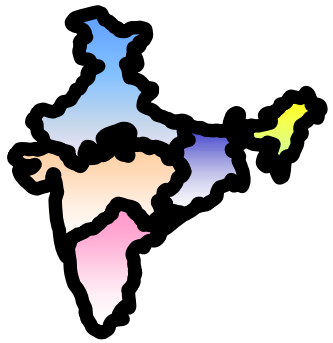
- Demarcated into Five Regional Grids
- Installed Capacity : 276.7 GW (as on 31st July 2015)
- Peak Demand : 147 **GW** (as on 31st Sept 2015)
- Average Energy Consumption : 3.3 TWhr/Day
- Large Generating Complexes of 4000 MW
- Renewable Generation : 36 GW
  - Wind : 23.7 GW, Solar : 4 GW (On increasing trend)
- Meshed Network of 765 kV and 400 kV Lines
- Rapid growth in Generation, Transmission and Distribution Capacity.

Population : 1.21 Billion as per Census 2011

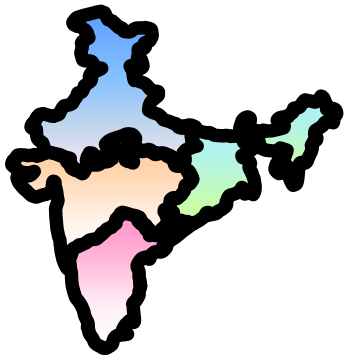


Indian Grid : Development

- Federal Structure of Governance.
- State Grids interconnected gradually to from 5 self-sufficient regional grids.
  - Northern, North Eastern, Eastern, Western and Southern Grid.
- Asynchronous interconnection among regional grids.
- Synchronous interconnection of regional grids

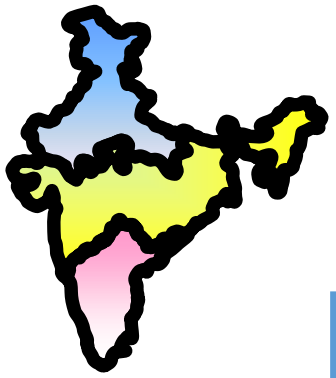


Pre 1991:
Five Regional Grids - Five Frequencies



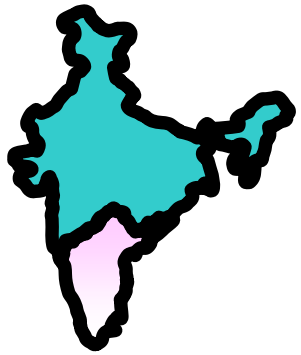
October 1991:
East and Northeast synchronized

Merchant Power



March 2003:
Western Grid synchronized with East & Northeast

Electricity Act, 2003, Open Access



August 2006:
North synchronized with Central Grid forming NEW Grid

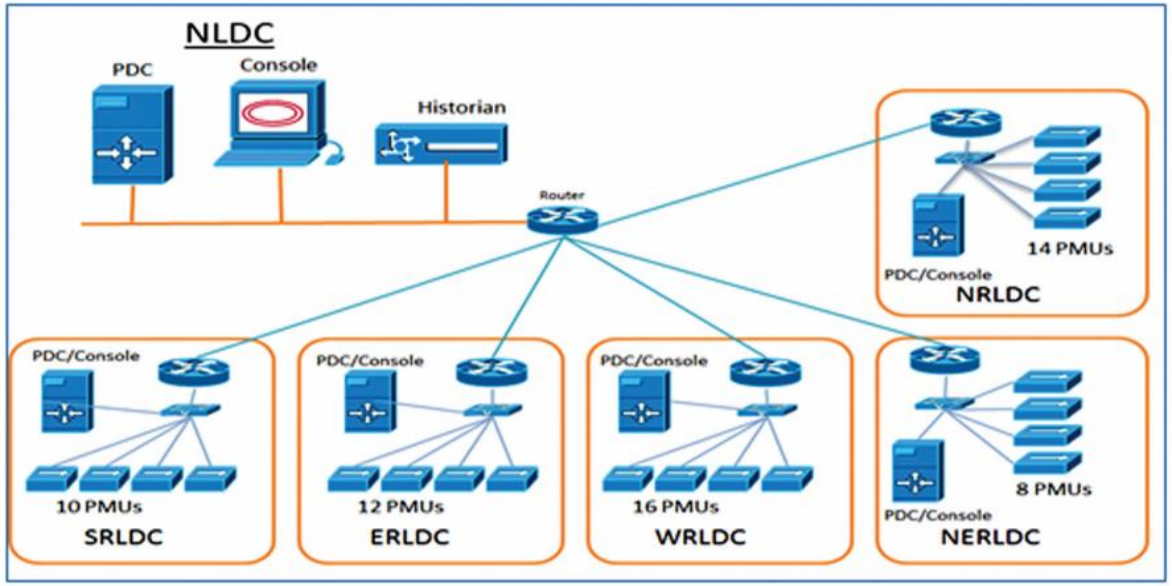
Merging of Markets, Power Exchanges

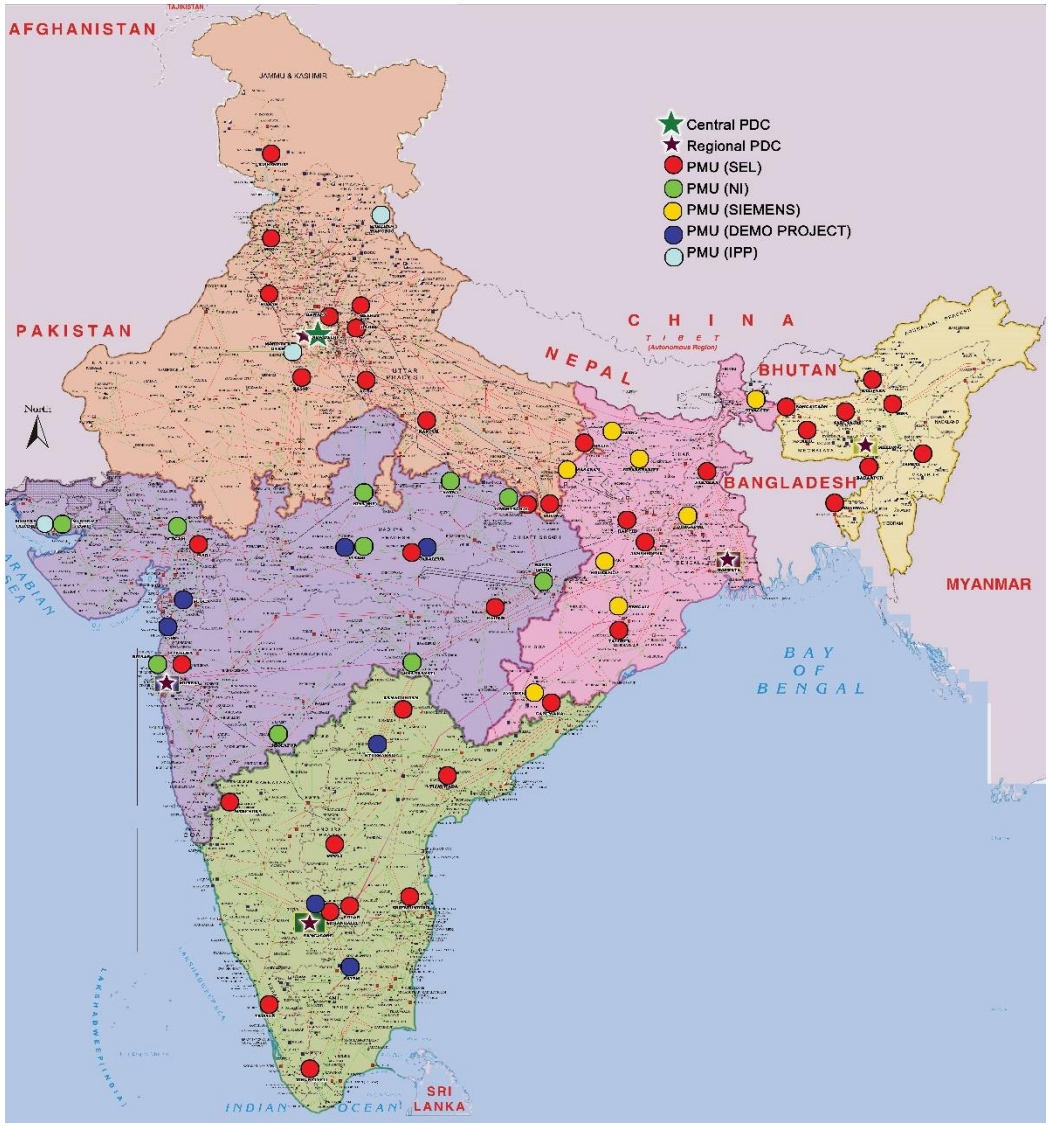
Dec 2013:
All India Synchronized Grid

Addition of large 500 MW & above gen. units and 765 kV transmission Lines, Ultra Mega Power Projects

Wide Area Measurement System in India

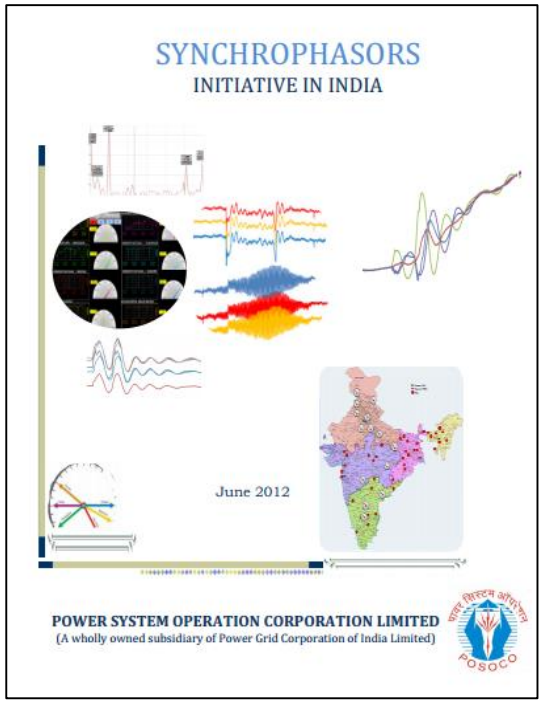
- Six Pilot projects on PMUs.
- 62 PMUs from 4 Vendors at 60 Locations.
- 11 PDCs of 3 Vendors
- Integrated at National level.
- Extensively used in real time and offline.

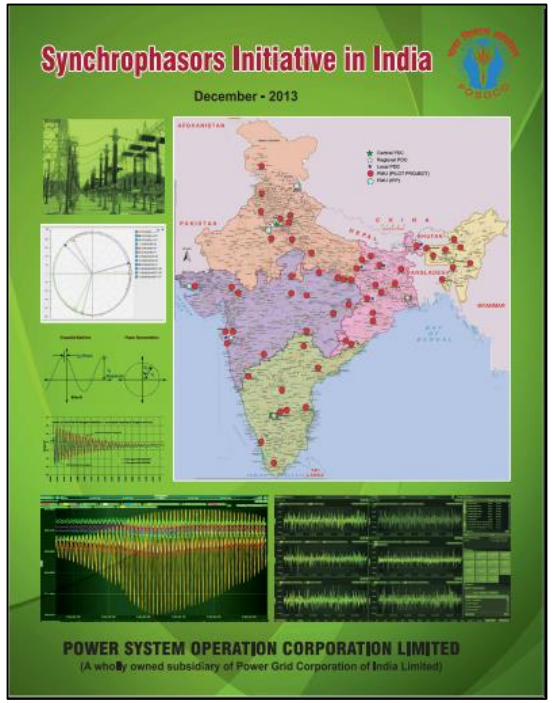


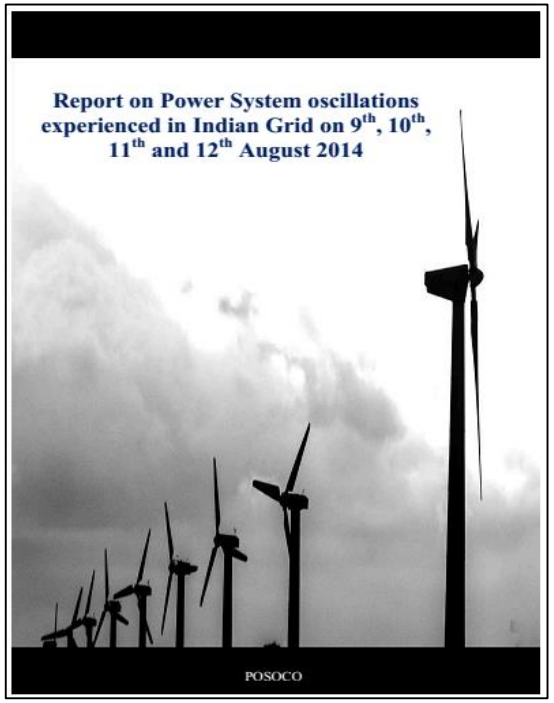


http://indiwams.posoco.in/

- **POSOCO publishes annual report based on its experience in the field of Synchophasor technology.**
- **POSOCO Reports are made public for the benefit of Power system Community.**
- **The second report on “Synchrophasor Initiative in India ” was launched in Dec’2013.**
- **The third Report on “Low Frequency Oscillation” has also been published in Sept-2014.**
- **Report links are : http://posoco.in/2013-03-12-10-34-42/synchrophasors**





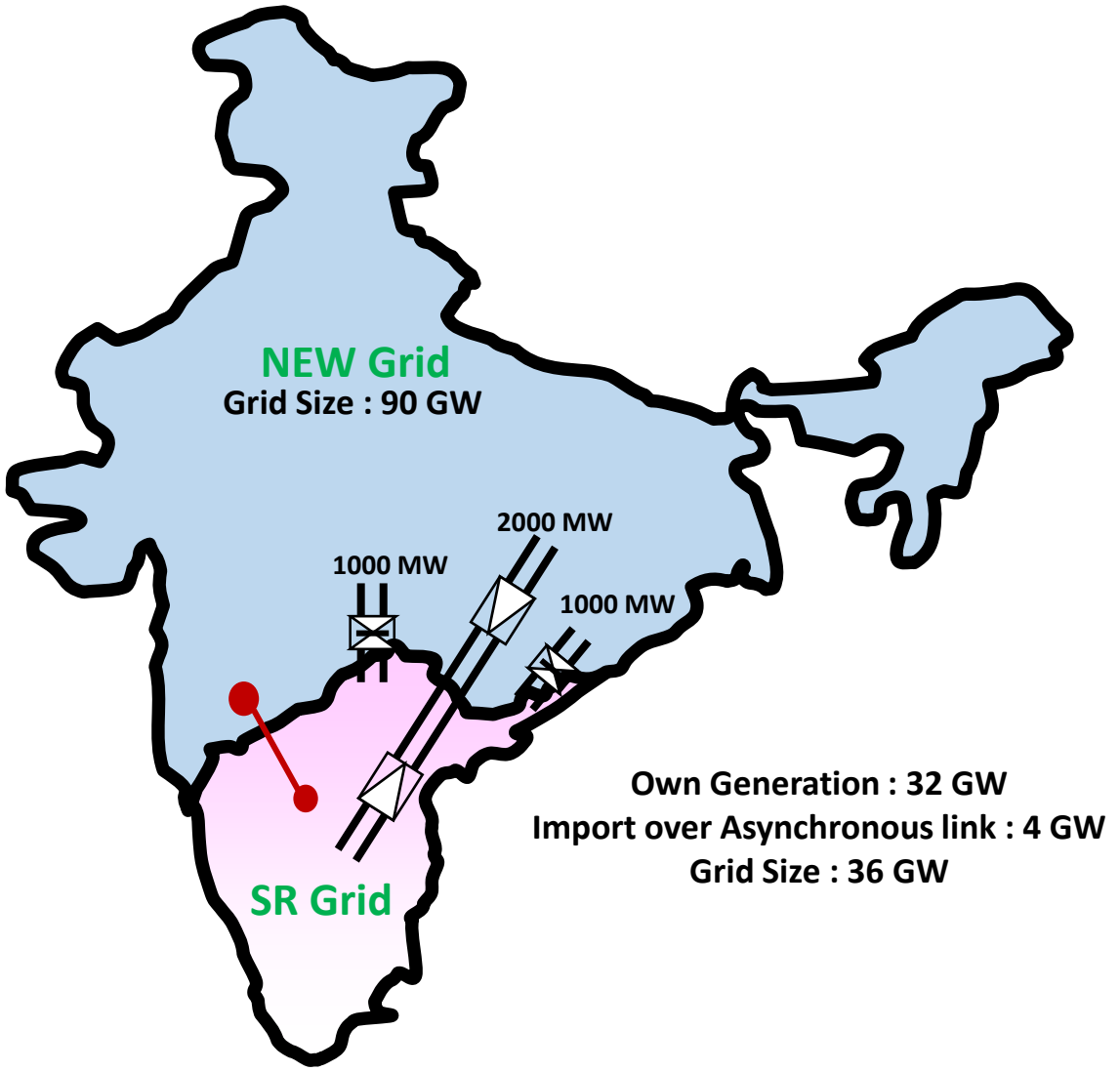


Synchronization and Operation of Large Grids

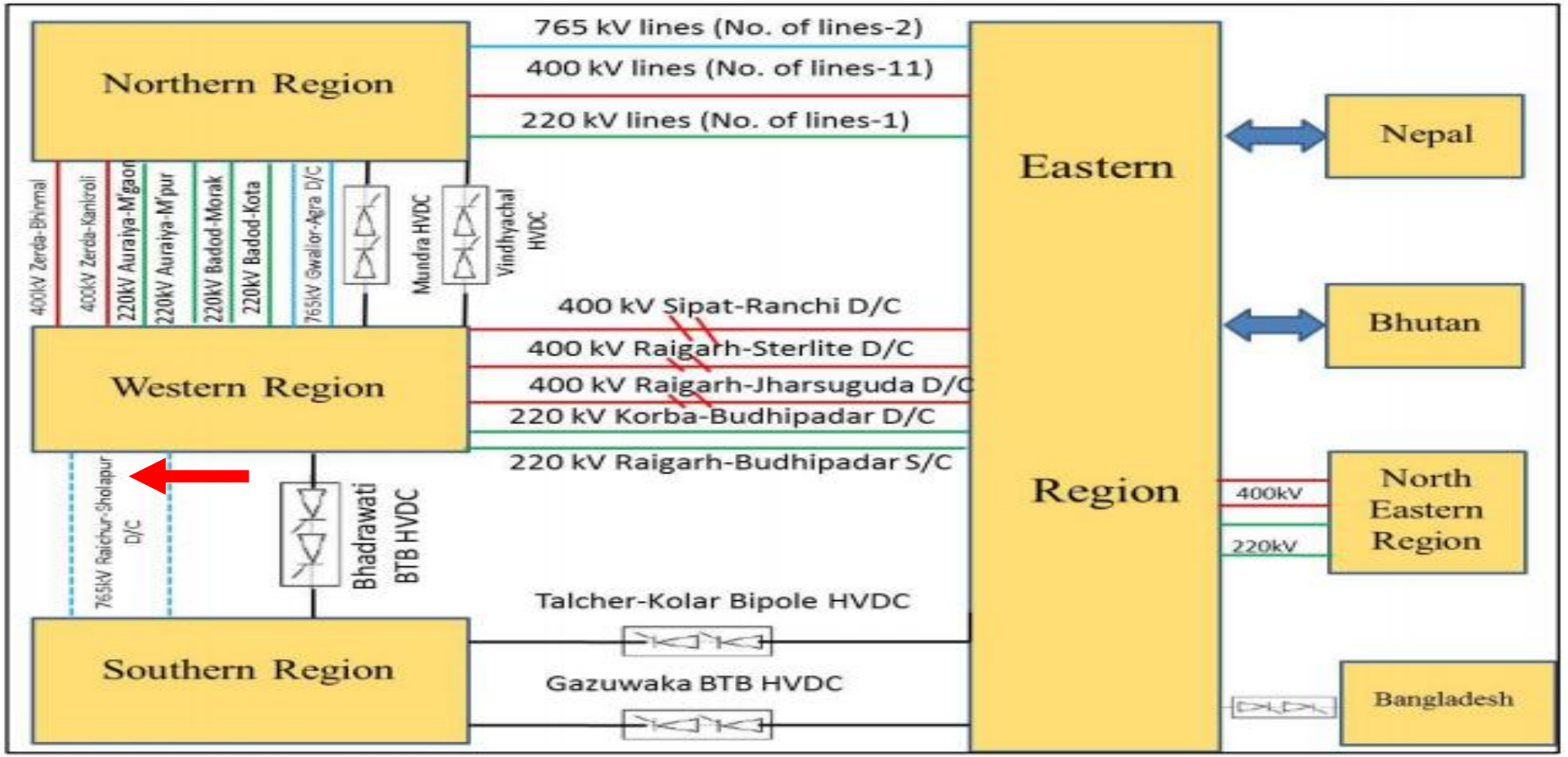
Case Studies

Case Study 1 : Synchronization of Large Grids on 31st December 2013

- Asynchronous interconnection between NEW Grid and SR grid :
  - +/- 500 kV, 2 x 1000 MW HVDC Talcher-Kolar bipole.
  - 2 x 500 MW HVDC back-to-back station at Gazuwaka
  - 2 x 500 MW HVDC back-to-back station at Bhadrawati
- Synchronization of NEW Grid and SR grid : 765 kV Solapur-Raichur circuit S/C (208 km line, Quad Bersimis)



Regional Grid Interconnection status as on 31st Dec 2013



Synchronization Aspects

Field Setting for Auto-Synchronization
Phase angle difference $\Delta\delta < 5^o$
Voltage difference ΔV <25 kV
Frequency difference Δf <0.1 Hz
Same Phase Sequence

SPS Envisaged for Secure Operation
Power Flow based SPS
Safe Isolation SPS
Rate of Change of Power SPS
Contingency based SPS

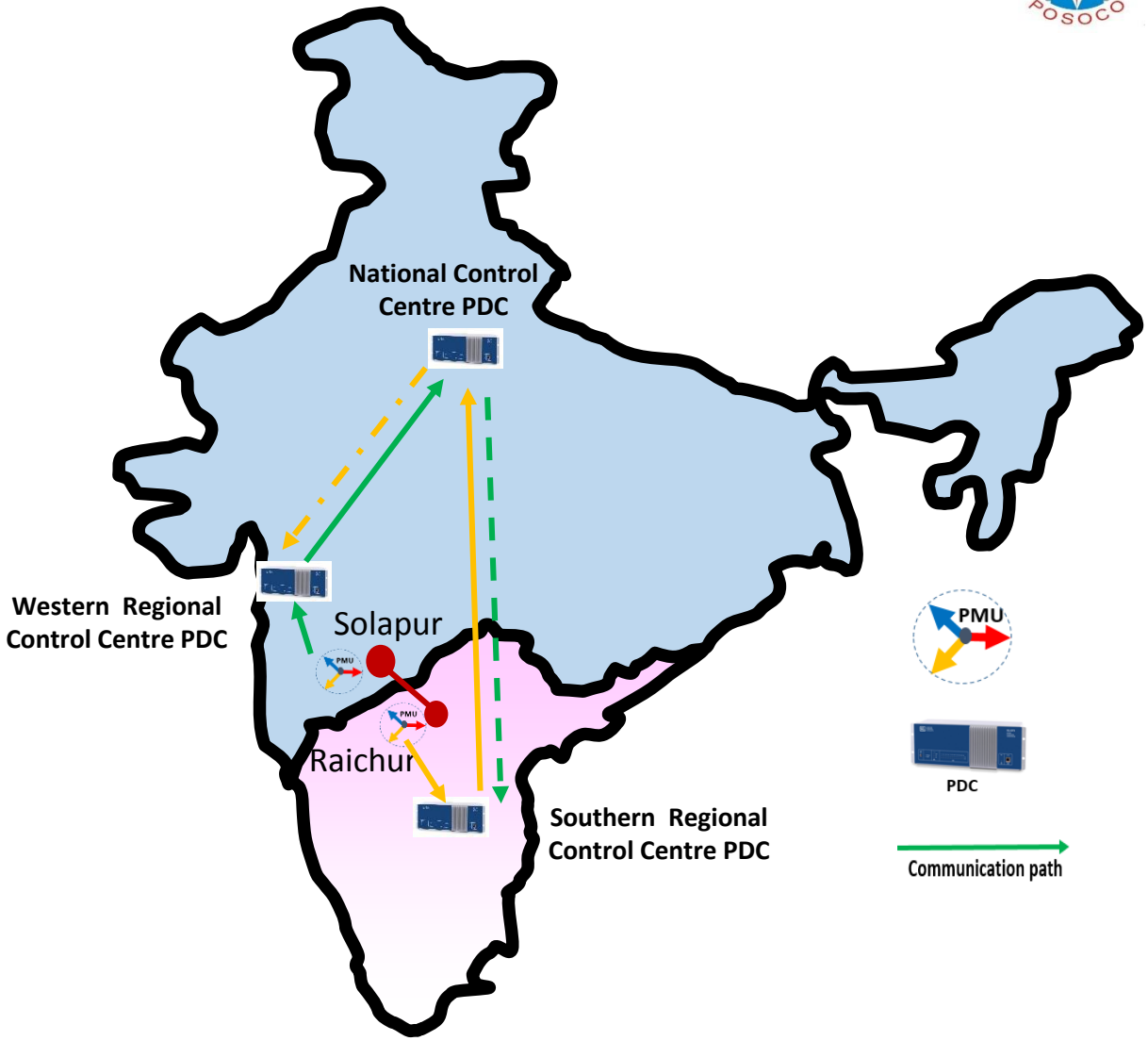
Synchronization Display in Field

Source : Holland-Controls QuickSync

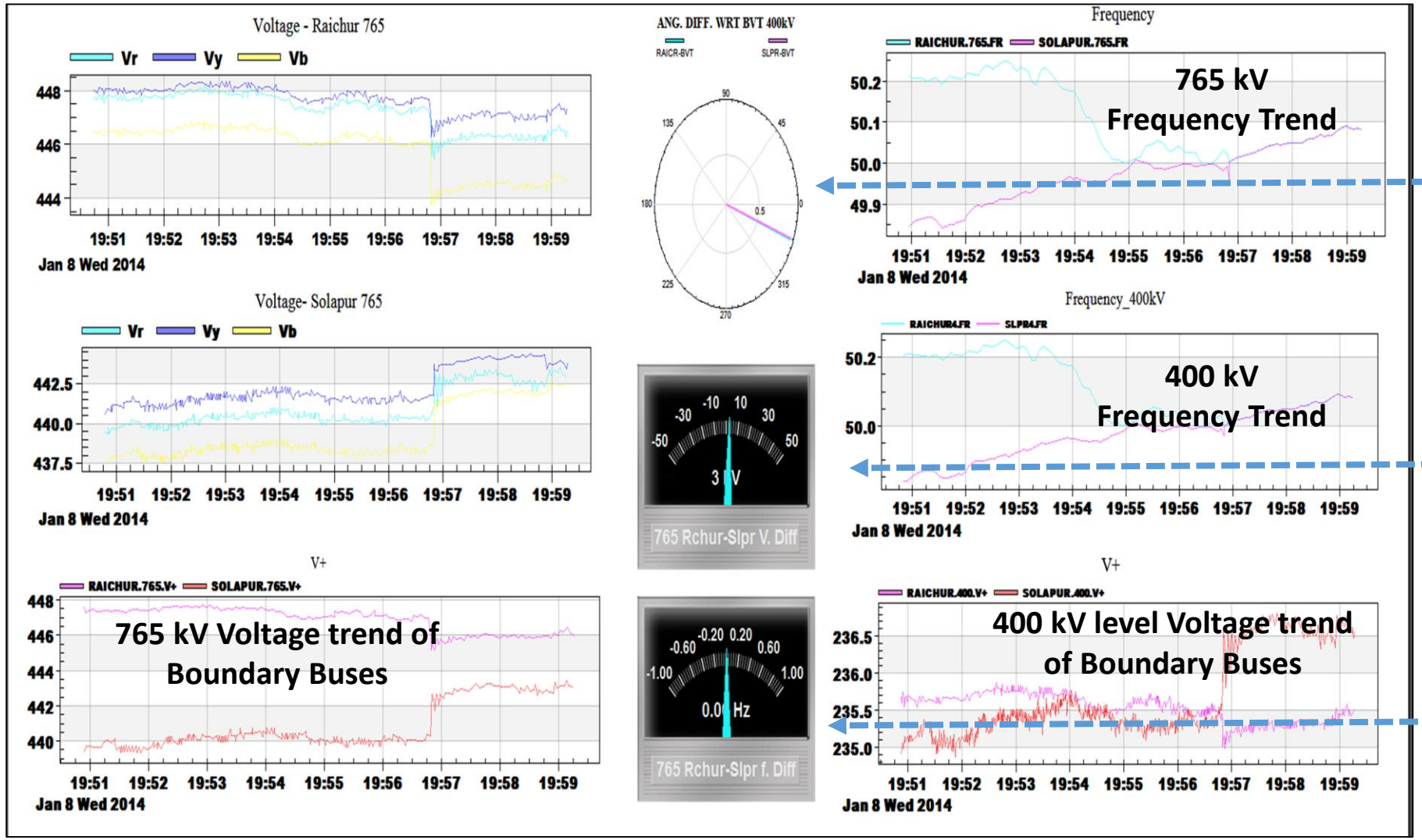
Synchronization Display at Control Centre

Remote Synchroscope for Control Centre using Synchrophasors

- PMU installed on both ends of the Tie Line
- Bus PT and Line CT given as input to PMUs
- Optical fiber communication between PMU to Regional Control Center.
- Displays for visualization / decision making
  - Frequency Control
  - Voltage Control
- Real-time view at Regional/National Control Centre
- Instruction for activation of auto-synchronization at sub-station issued from Control Centre



Dashboard at Operator Console in Regional/National Control Centre

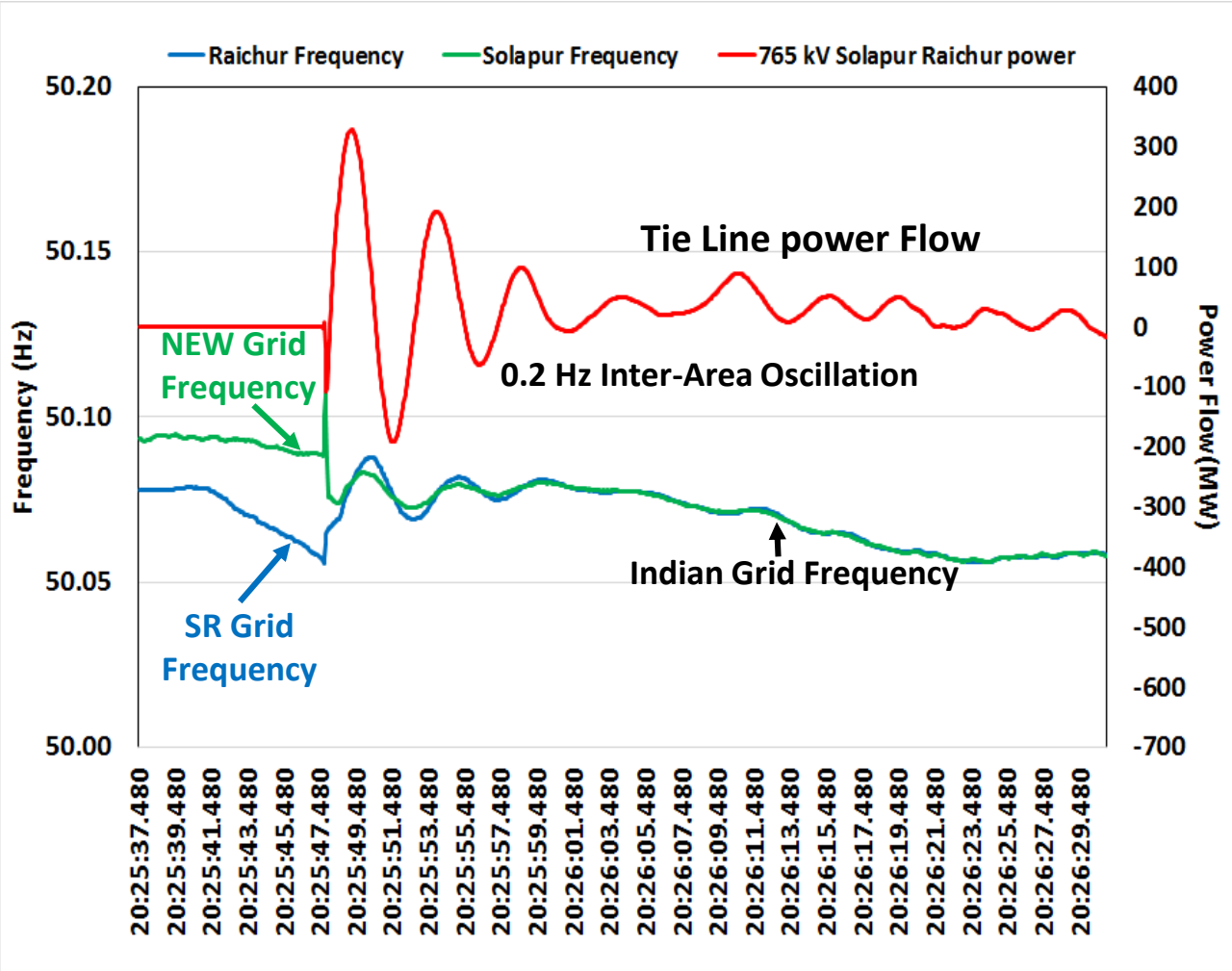


Phase Angle difference Scope

Voltage Magnitude difference Dial

Frequency difference Dial

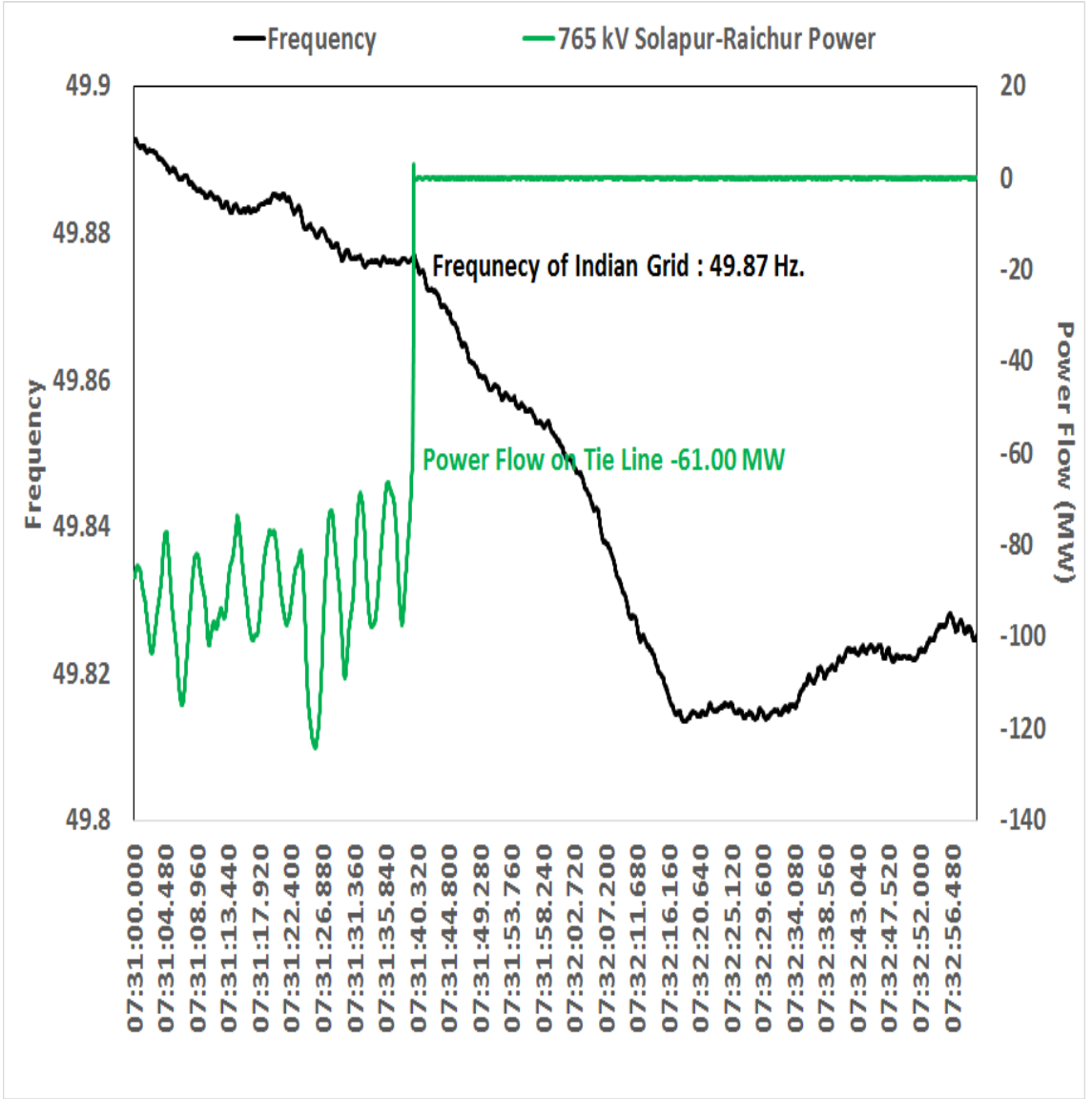
First Synchronization



- Frequency of NEW Grid higher than SR Grid.
- Δf = NEW-SR = 0.039 Hz
- Max Power flow in First swing : 328 MW export from NEW Grid to SR Grid.
- Inter-Area Oscillation Mode detected : 0.2 Hz
- Oscillation damped out time : 16 sec.
- Synchronization Tool reused subsequently at 14 times.

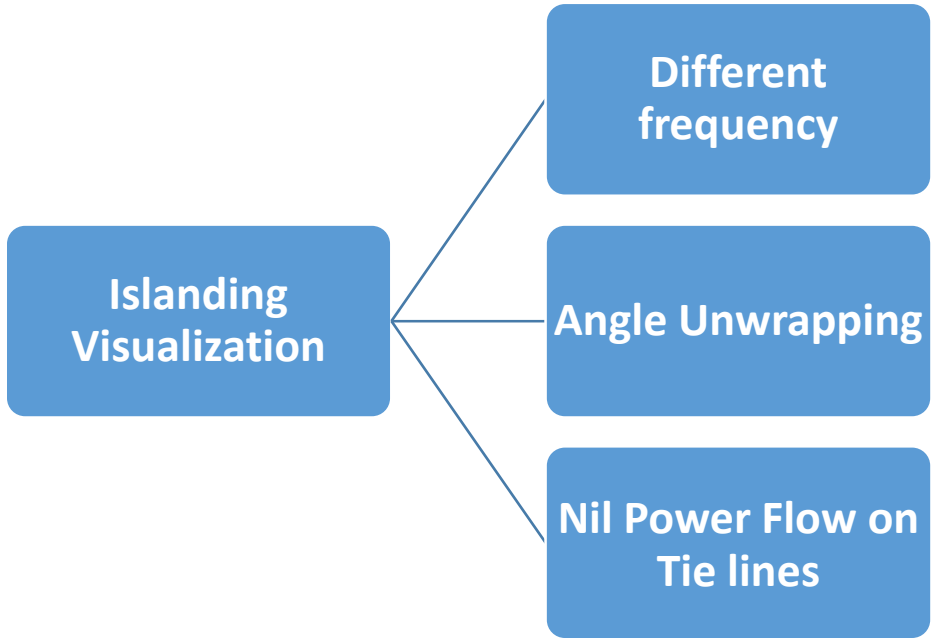
Case Study 2 : Controlled Separation of Large Grids on 10th October 2013

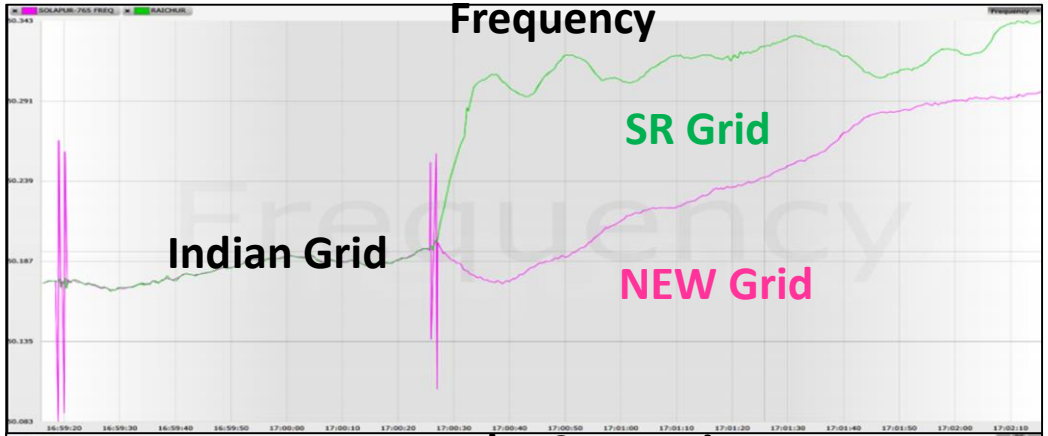
- Controlled separation required for facilitating maintenance or changing of SPS scheme or testing of SPS scheme
- Decision to issue instructions to open the CB at Boundary sub-station taken by Control Centre Operator with the help of Synchrophasor.
- Decision Criteria :
  - Nominal Frequency
  - Tie Line flow ≈ 0 MW.
- Tie line Flow regulation through HVDC tie
- Planned separation carried out for facilitating Planned Outage on 2x1000 MW HVDC Talcher Kolar Bipole.

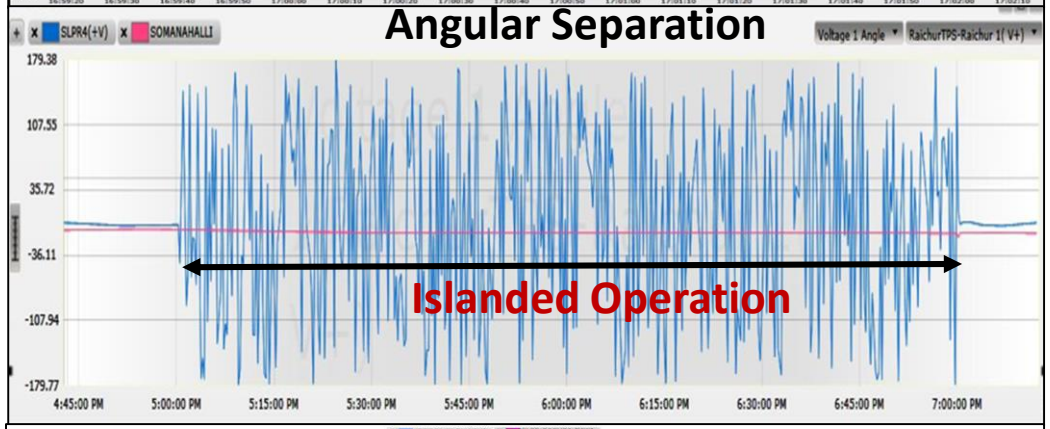


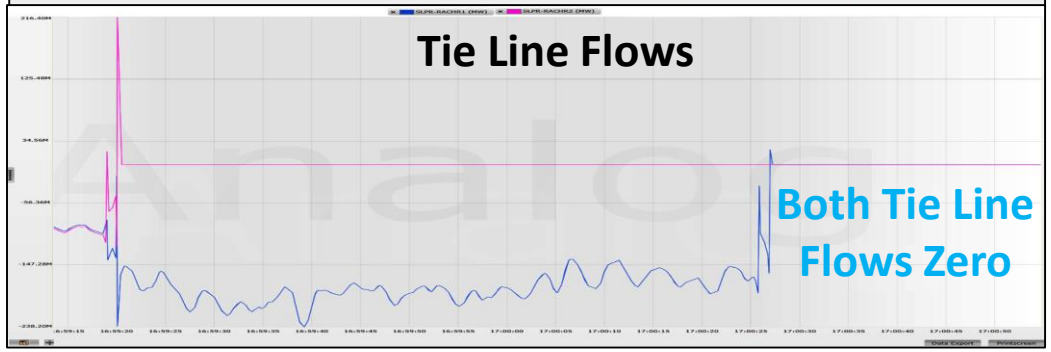
Case Study 3 : Islanding Detection and resynchronization

- In one case, both Lines tripped on transient fault within few seconds causing system isolation.









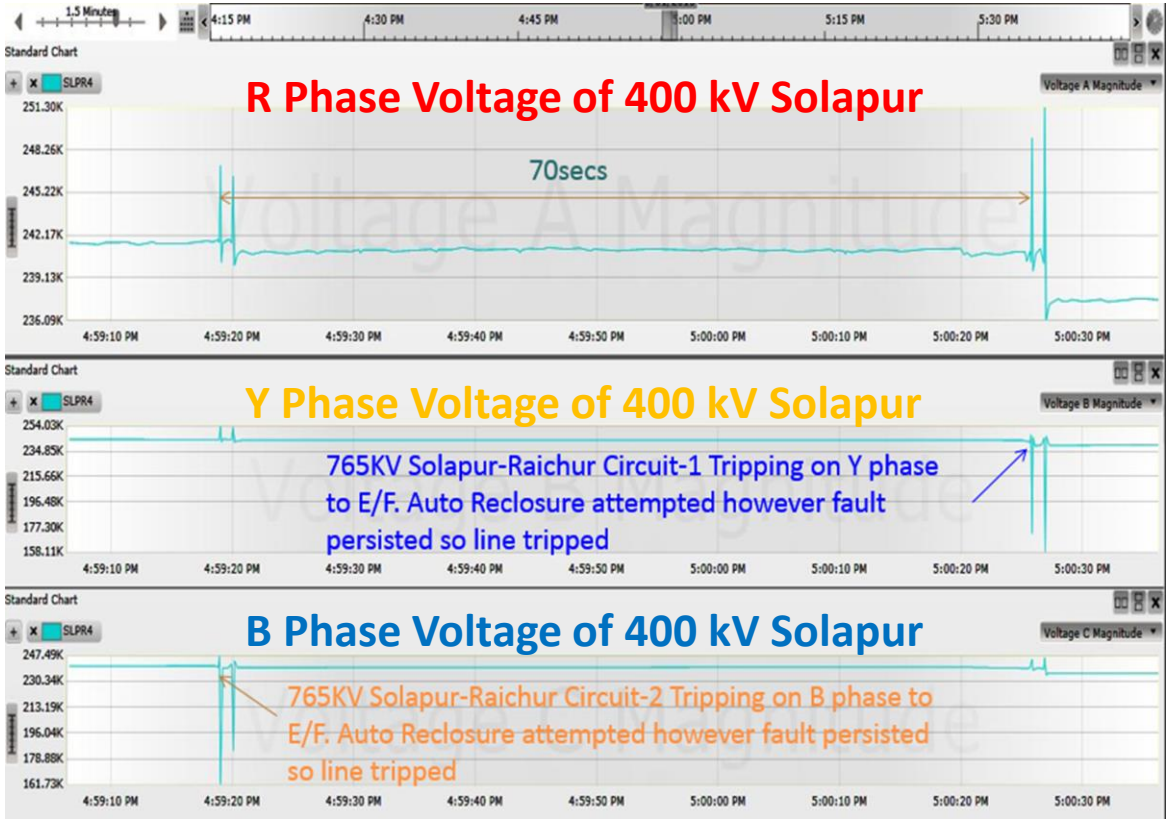
Confirmation/Validation Through SCADA SOE

05/31/2015 17:00:36	RACHR_CS CB G_D2_2 STTS OPEN	1	RACHR_CS	400KV	S024
05/31/2015 17:00:32	RACHR_CS CB G_D2_3 (SOLAPUR-1) STTS OPEN	1	RACHR_CS	400KV	S024
05/31/2015 17:00:32	HARSH_DV CB E_11 STTS CLOSED	1	HARSH_DV	400KV	S002
05/31/2015 17:00:21	LUDHIANA CB F_5 STTS CLOSED	1	LDHNA_PG	400KV	S002
05/31/2015 17:00:02	LUDHIANA CB F_4 (KOLDAM-2) STTS CLOSED	1	LDHNA_PG	400KV	S002
05/31/2015 16:59:27	RACHR_CS CB G_D1_3 (SOLAPUR-2) STTS OPEN	1	RACHR_CS	400KV	S024
05/31/2015 16:59:27	RACHR_CS CB G_D1_2 STTS OPEN	1	RACHR_CS	400KV	S024

SCADA SOE confirming Breakers Opening

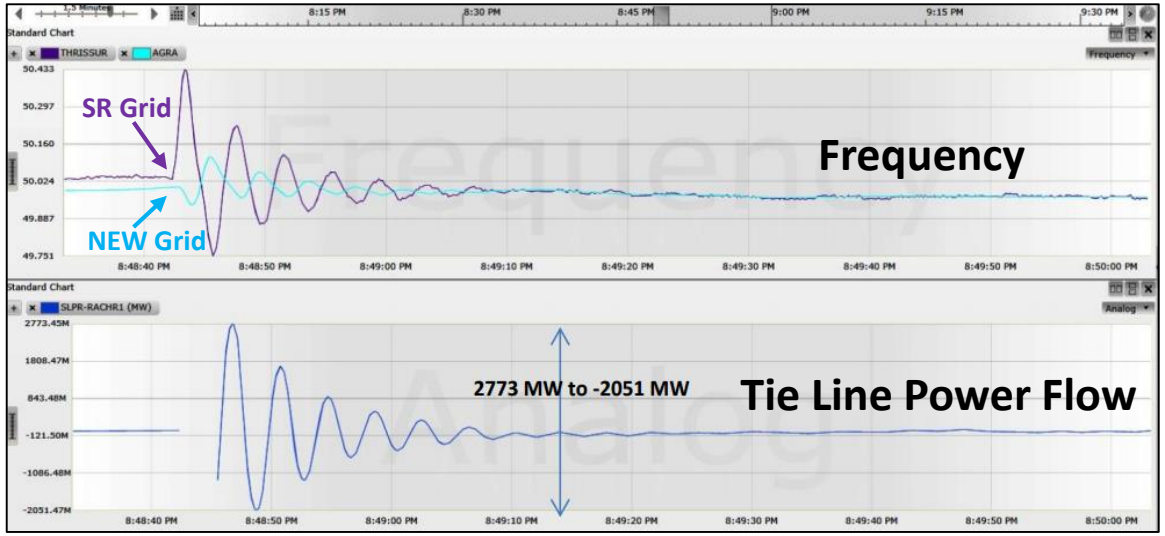
Fault Analysis in Real Time

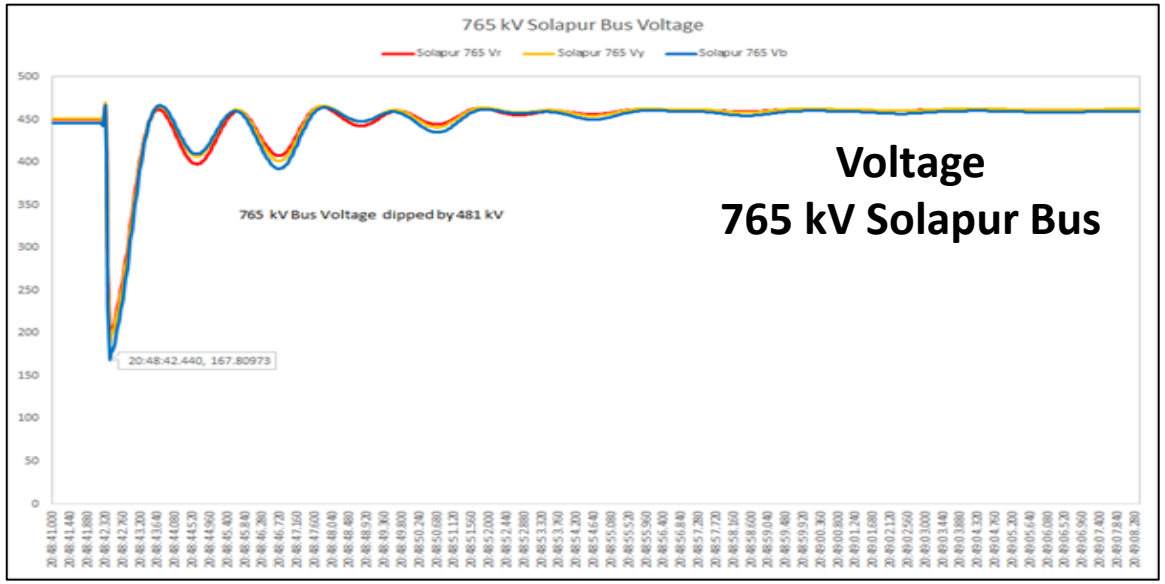
- **Reason for tripping of tie line was found based on voltage and current .**
- **One line tripped on B phase and other on Y phase.**
- **Unsuccessful auto-reclosure attempt due to persisting fault**
- **Resynchronization was completed within 2 hours.**



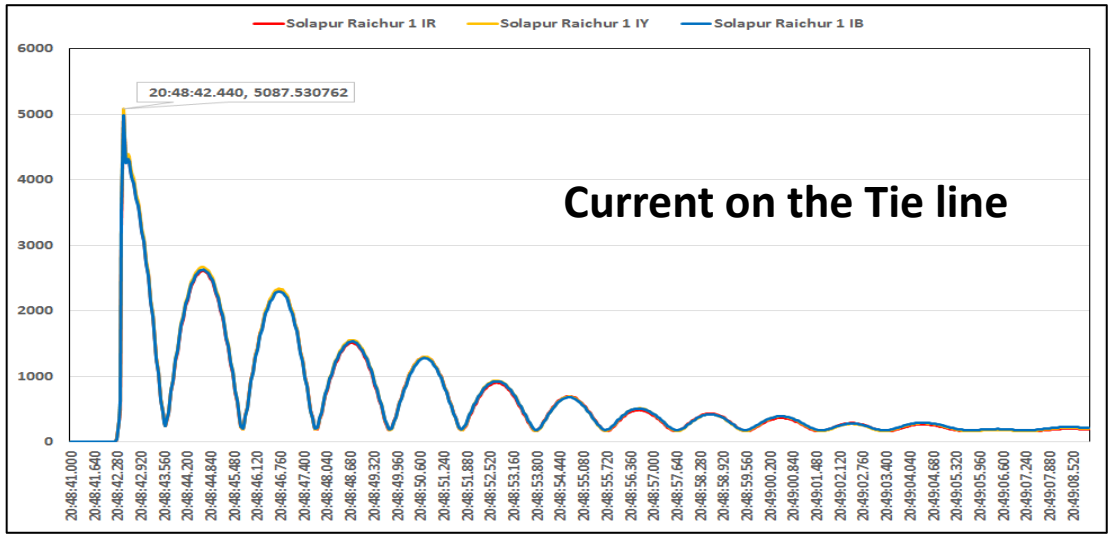
Case Study 4 : Healthiness of Auto-Synchronization on 24th May 2015

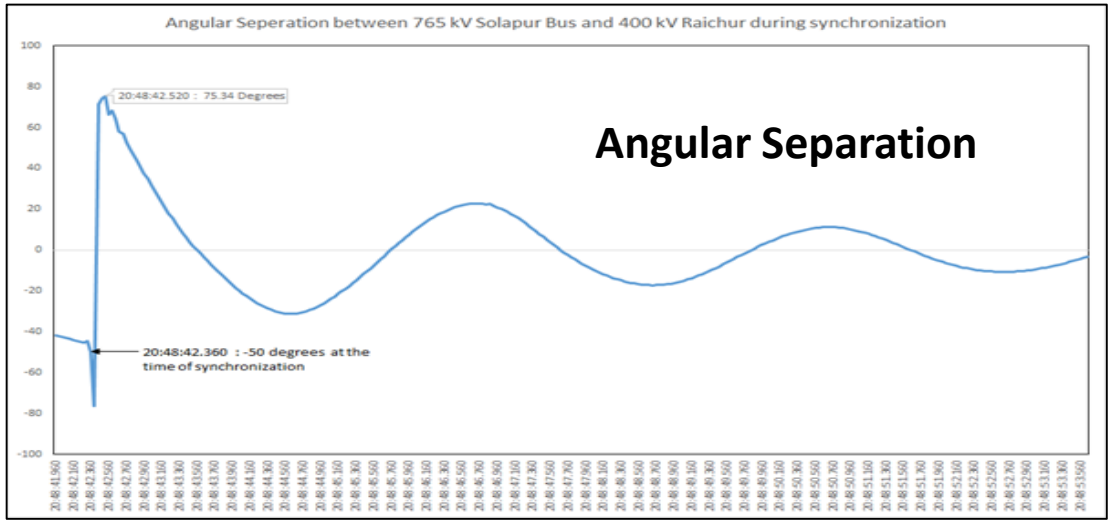
- Healthiness of Auto-synchronization facility at Sub-station need to be checked periodically.
- In one case of large grids synchronization, large swings were observed.
  - High oscillation in Frequency after synchronization.
  - High power swing on Tie line power flow
  - large current in the circuit
  - Large dip in voltage.





- **Parameters used for synchronization checked at Control centres using synchrophasr data from both ends of tie lines.**
  - **Frequency was Δf ~ 0.033 Hz**
  - **Voltage within acceptable limits**
  - **Phase sequence was correct**
  - **Phase angle difference Δδ > 50°**
- **Feedback given to Utility for checking auto-synchronization Relay.**





Summary

- **Synchrophasor aided Real-time Operation in India**
  - **Synchronization of two Large Grids**
  - **Safe separation of two Large Grids**
  - **Enhanced situational awareness and better decision making**
  - **Fault detection, localization and Characterization**
  - **Oscillation monitoring**
  - **Angular stability monitoring**
- **Utilization in Offline**
  - **Improving the SPS design**
  - **Feedback to Utilities, Planners and Regulators.**

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