

Low Frequency Local mode Oscillations in NER Grid, Validation using Model based analysis and Mitigation

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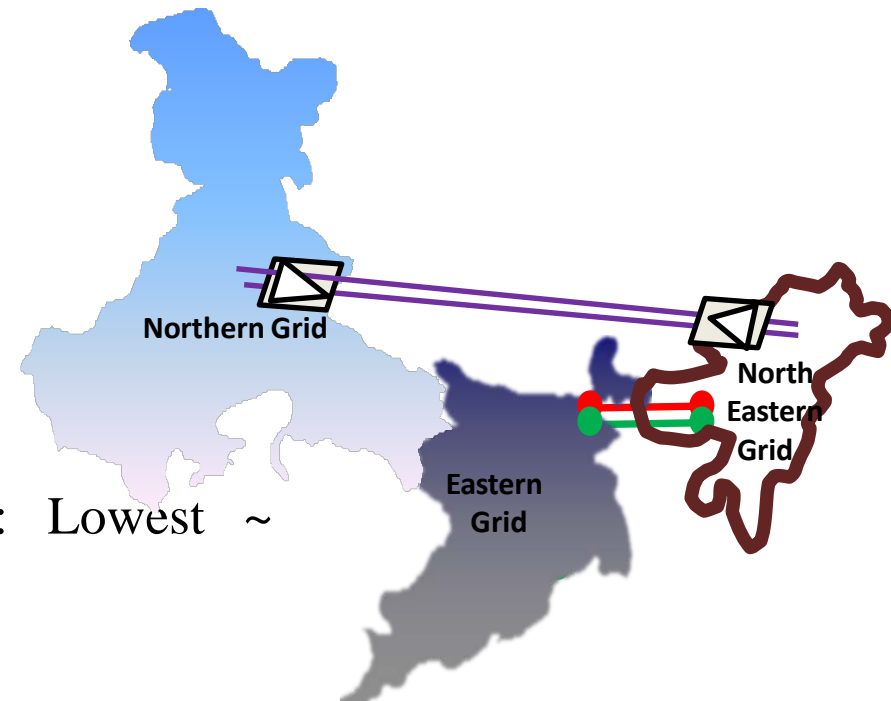
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Outline

- ☐ **Profile of North-Eastern Regional Grid**
- ☐ **WAMS usage in Control center in India**
- ☐ **Low Frequency Oscillations**
- ☐ **Case description (2)**
- ☐ **Preliminary analysis and Control center actions (3)**
- ☐ **Model based analysis and results (2)**
- ☐ **Corrective Action and Mitigation**
- ☐ **Summary**

North-Eastern Regional grid - Profile

- ❖ Smallest of the 5 regional Grids of India
- ❖ High growth rate; High Hydro potential
- ❖ Large unmet demand
- ❖ Thermal: Hydro: Solar Ratio- **60:39:1**
- ❖ Average Daily Energy Met: **40.72 MU**
- ❖ Peak Demand Met: **2548 MW**
- ❖ Very Low Per capita consumption : Lowest ~ 300kWH



Challenges:

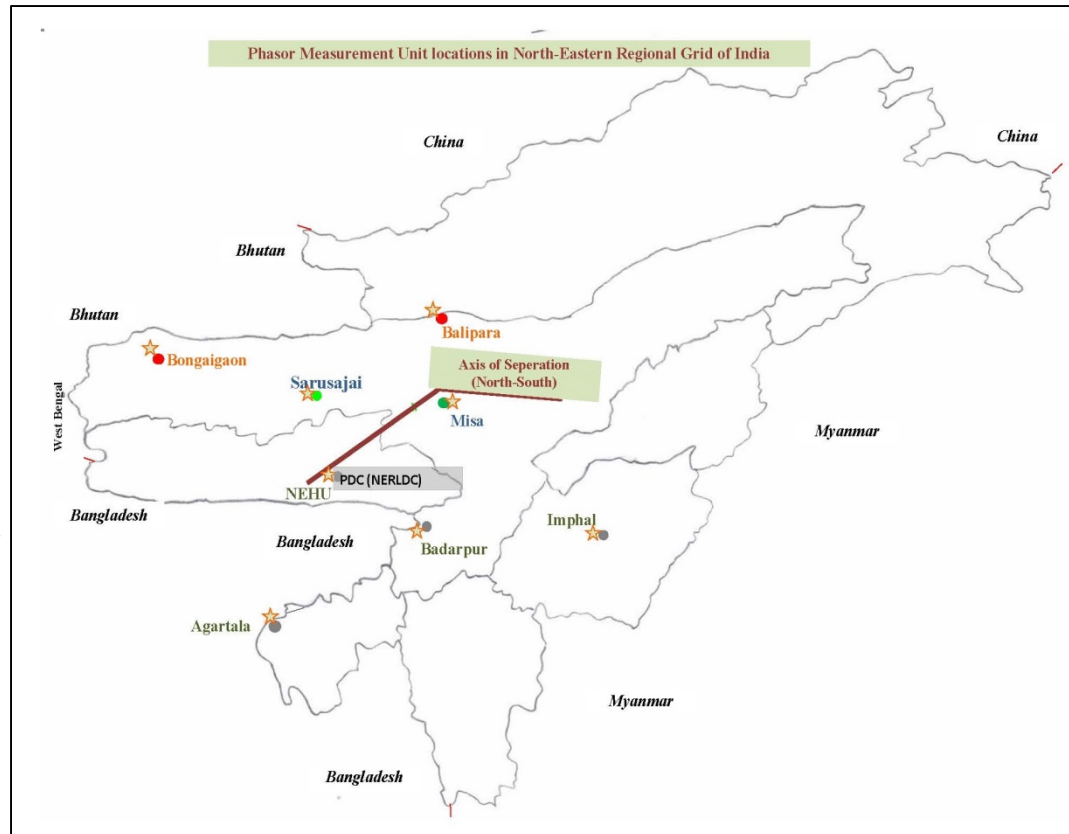
- Synchronous interconnection with Eastern Grid only, through *Chicken Neck area*
- Weak Grid with SCR~2, and Operation of +/-800 kV Biswanath Chariali (NER) – Agra (NR) MTDC (6000 MW capacity)

Usage of WAMS in NER Grid

- 8 PMUs installed at 132 kV, 220 kV and 400 kV levels
- PMUs installed as part of Pilot project of Synchrophasors in India
- Used in Control Center for monitoring purpose: 25 times better resolution than existing SCADA system

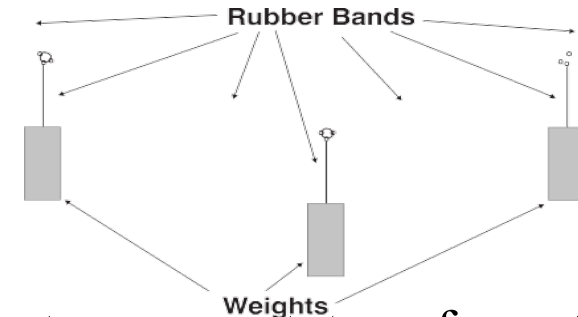
➤ Usage till now:

- Island synchronization in contingency cases
- Synchronization of HVDC link to NER Grid
- Monitoring of HVDC system operation and interaction with AC system
- Post-dispatch analysis
- Detection of Small signal instability : Low frequency oscillations



Low Frequency oscillations

- **Small Signal instability:** Insufficient damping torque leads to Low Frequency electro-mechanical oscillations
- **Trigger:** Small disturbances in system
- **Analysis methods:**
 1. Measurement based analysis (Instantaneous state of system): Signal processing techniques applied to high frequency measurement data
 2. Model based analysis (Estimated state of system): Eigen-analysis of power system models for mode identification, relative participation
- Observation at NERLDC in real-time using moving window Prony analysis
- Several cases of Inter-plant and Intra-plant oscillations observed
- High participation of NER Generators in Inter-area oscillations in Indian grid



Case description

- On 14th July'2016 during 13:16:28.440 Hrs to 13:20:05.840 Hrs, oscillation observed in Voltage and Frequency (Active Power)
- Duration: 4 minutes
- Relative participation:
Maximum oscillation at 132 kV Imphal
- Other oscillatory nodes: 220 kV Misa, 132 kV Badarpur

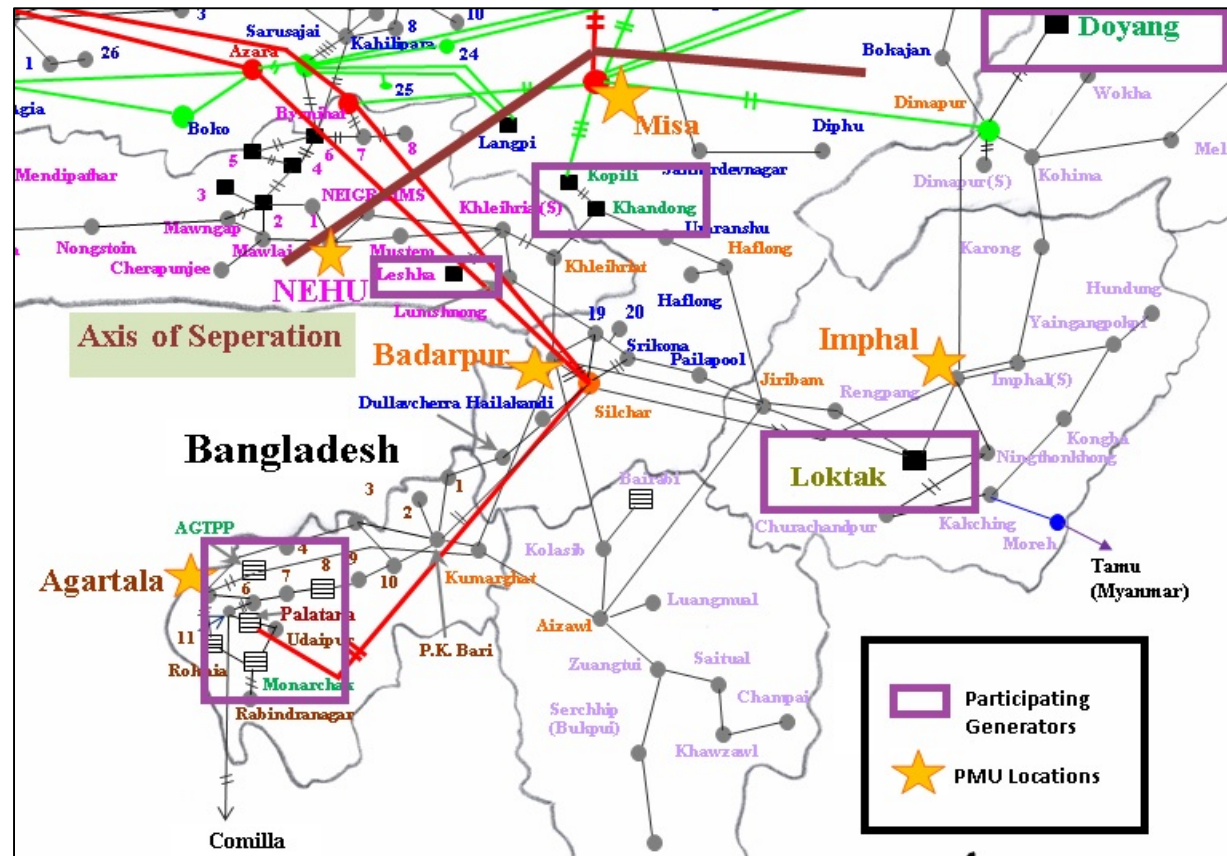


Fig: PMU Locations and participation generators

Case description – contd...

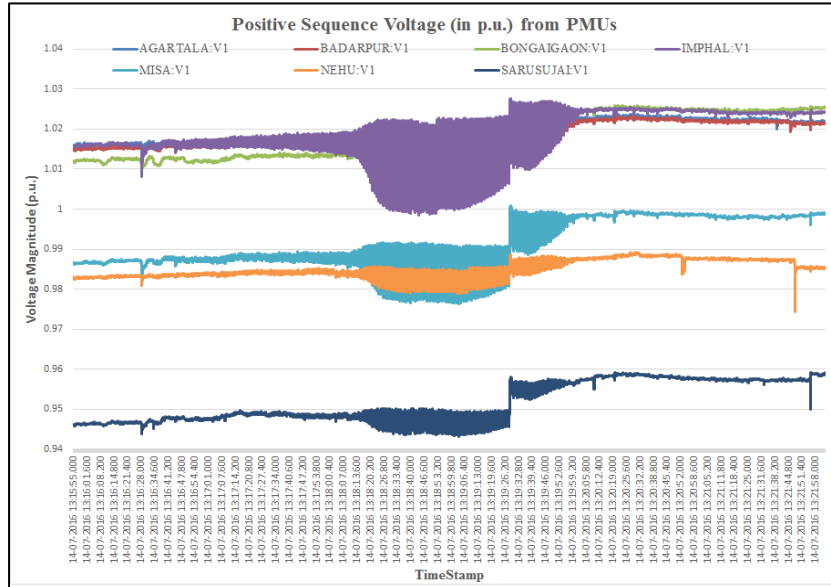


Fig: Positive sequence voltage (in p.u.)

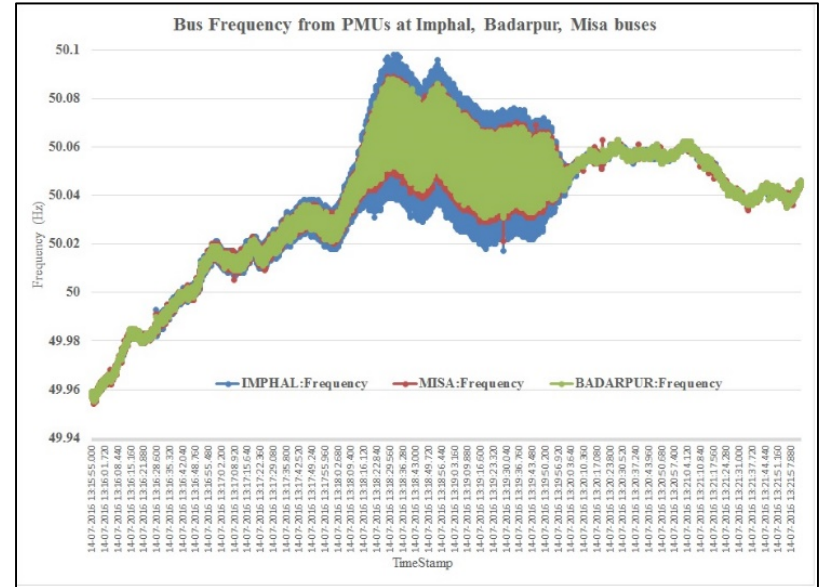


Fig: Bus Frequency (in Hz)

- Oscillatory mode from Prony analysis (OMS engine) : **0.98 Hz and 1.96 Hz (Harmonic)**
- Mode frequency indicates Local oscillations : Inter-plant and Intra-plant
- Oscillation not observed outside of NER Grid

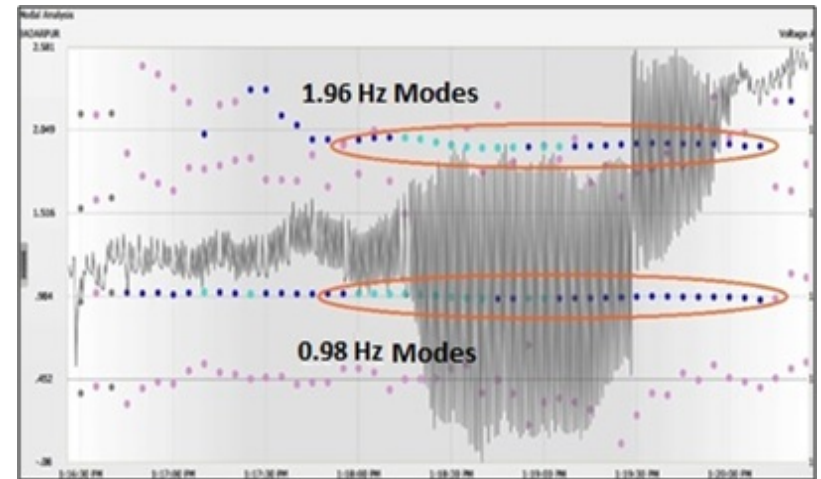


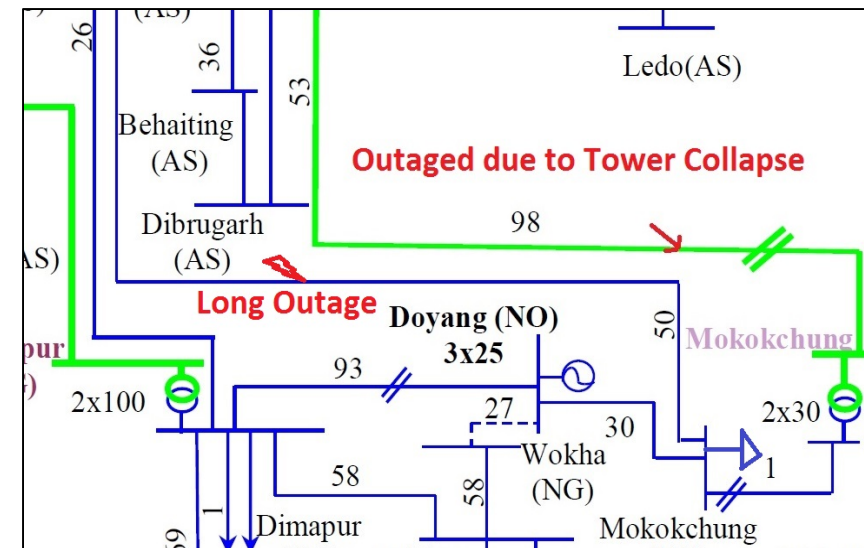
Fig: Modal Analysis (OMS engine)

Preliminary analysis and Control center actions

- Oscillations observed on multiple dates with similar duration till 25th July 2016
- Nearby generators:
 1. Doyang (Close to Misa/Imphal)
 2. Loktak (Close to Imphal)
 3. Khandong, Kopili (Close to Misa / Badarpur)
- Preliminary analysis for possible trigger cases:
 1. Nearby power system fault
 2. Loss of generation or load
 3. Change of network configuration
 4. Change of drawal schedule of Load Serving Entities
 5. Change of Injection schedule of generators

Preliminary analysis and Control center actions – contd...

- Units at Loktak HEP and Doyang HEP were suspected to have participated in oscillations based on their close proximity to 132 kV Imphal (PG) and 220 kV Misa (PG), respectively
 - Loktak HEP: Reported hunting in line currents on 14th July case**
 - Doyang HEP: Reported hunting in unit on multiple dates**
- Change of network configuration noted since 12th July'2016: 220 kV Mariani – Mokokchung D/C line out of service due to Tower collapse
- Reduced Inertia
- Change of scheduled injection pattern of Doyang HEP noted: Oscillations occur during generation near capability limits



Preliminary analysis and Control center actions – contd...

- State Load Despatch Center, Nagaland reported tripping of 132/66 kV transformer at Dimapur bus [close to Doyang HEP] and subsequent load loss
- All factors together: Doyang (3x25 MW) chosen to be candidate for investigation
- NERLDC action: Limit Doyang HEP injection about 10% below capability limit.
- Further analysis on PMU data => Signal Processing toolbox of MATLAB
- Highest participation found at **0.965 Hz** and **1.965 Hz** => Corroborates with OMS engine results

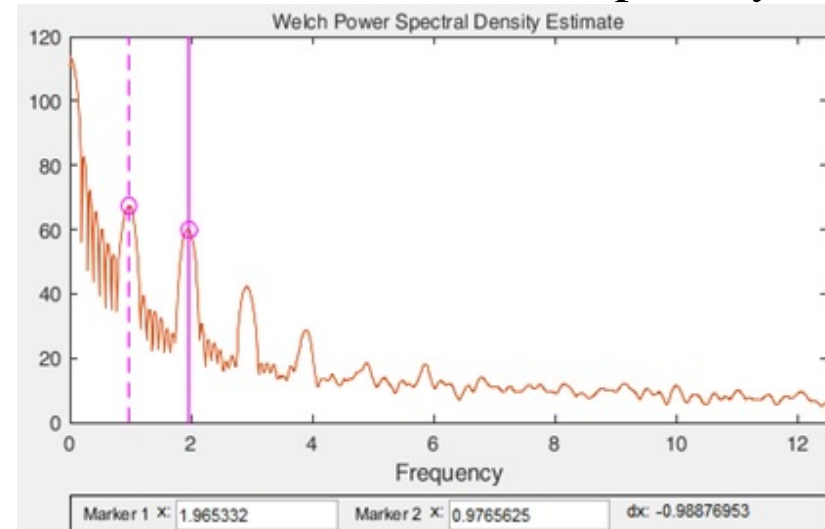


Fig: PSD estimate on measured PMU data

Model based analysis and results

- Reasons for going for Model based analysis:
 1. To identify effect of various grid conditions on oscillatory modes
 2. To identify mitigation actions based on participation
 3. Correlate the simulation models with field data
- Software used: PSSE + NEVA
- Studies on 3 different scenarios :
 1. **Case A:** With Grid network as on 14th July'16 during period of LFO, with Load-generation balance as actual on 14th July with Doyang HEP generation = 72 MW [Rated = 3x25 MW]
 2. **Case B:** With Grid network as on 14th July'16 during period of LFO, with Load-generation balance as actual, but with 220 kV Mariani(PG) – 220 kV Mokokchung(PG) – 132 kV Mokokchung (PG) – 132 kV Mokokchung (Nagaland) – 132 kV Doyang HEP closed
 3. **Case C:** With Grid network as on 14th July'16 during period of LFO, and with less generation at Doyang (44 MW instead of 70 MW , viz. 1 unit kept out of service)

Model based analysis and results – contd...

• Case-A:

1. About 70 oscillatory modes found
2. Modes of interest : 0.8 Hz to 2.0 Hz => Several modes near **1.1 Hz, 1.4 Hz, 1.9 Hz** with negative damping
3. From Mode shape (Normalized Right Eigenvector), oscillation between Units of Doyang observed viz. **Intra-plant oscillation with -5.2 percent damping**
4. Around **1.19 Hz**, Inter-plant oscillation with **-7.7 percent damping** was observed between units of Leshka HEP, Doyang HEP and Loktak HEP. **This mode corresponds to the Inter-plant mode as observed from PMU measurements**

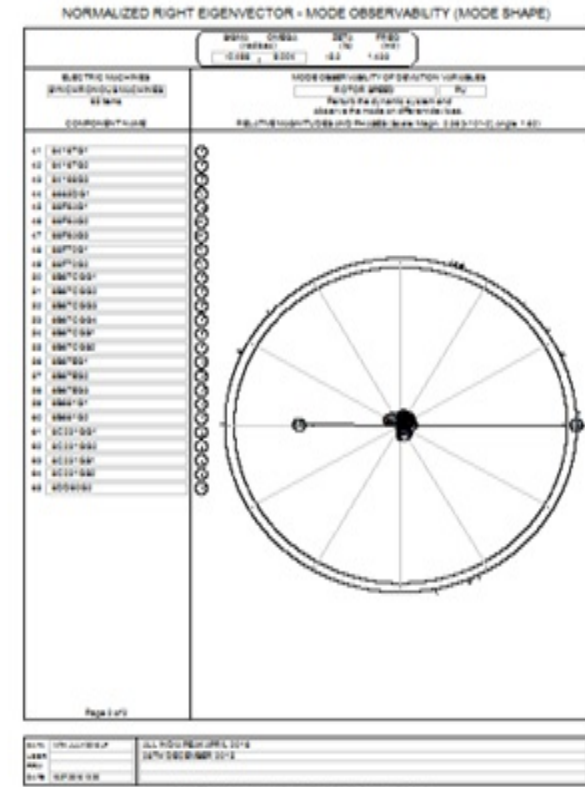
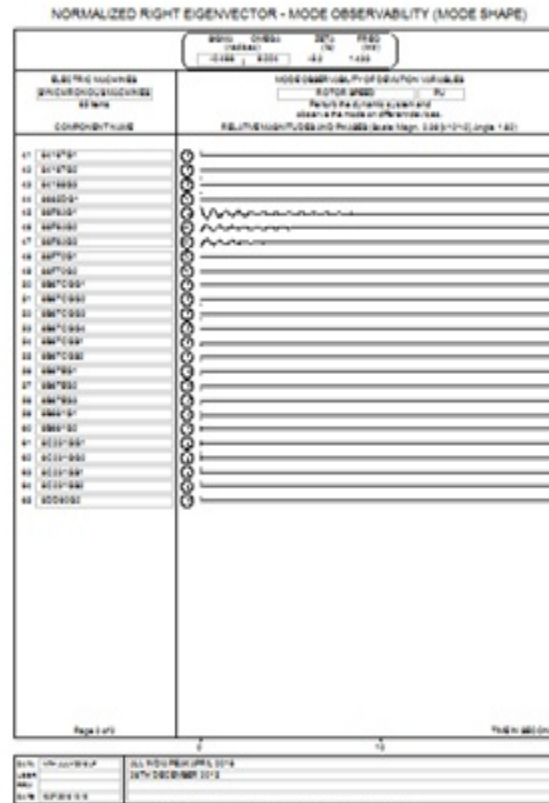


Figure: Oscillations at Doyang HEP (Mode Shape)

Model based analysis and results – contd...

- **Case-B:**

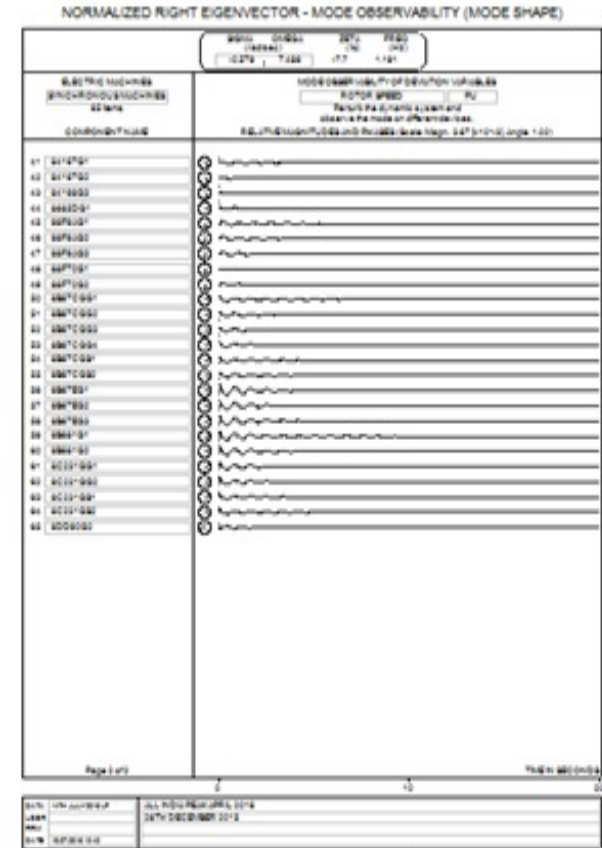
1. Oscillatory modes found near **1.1 Hz, 1.4 Hz, 1.9 Hz** with poor damping were still observed
2. Improved Damping factor
3. Indicates outage of the feeder section to Doyang HEP made the system more prone to oscillatory instability, and their mere presence contributed to improved system damping

- **Case-C:**

1. Number of oscillatory modes had reduced, as the generation quantum was reduced from close to rated
2. Oscillation in the 1.19 Hz mode has disappeared, indicating small signal stability problem was reduced

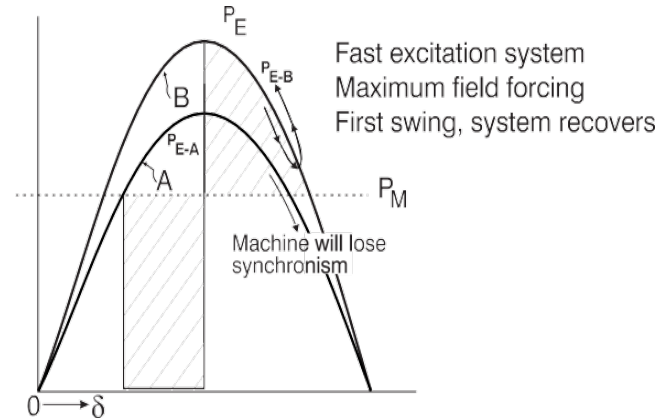
Conclusion:

- On account of maximization of generation at Doyang HEP to match with it's injection schedule, oscillations could have occurred
- Ill-tuned AVR of the small hydro generators together with low inertia of the Southern Part of NER Grid contributed to growth of these oscillations



Corrective Action and Mitigation

- Interaction between the Power-Angle curve and rotary inertia of generator \Rightarrow Hunting of generators
- Local mode oscillations \Rightarrow Common in case of AVR of generating units acting with high output and feeding into a weak network (Negative damping contribution by Excitation System)



- Improvement of Damping \Rightarrow supplementary controls to AVR's through PSS
- Doyang HEP had disabled their PSS in all units following a maintenance exercise
- Corrective action: PSS in all units of Doyang was enabled. Controlled test run displayed no presence of further oscillations
- Further action: Tuning of the PSS at generators of NER after baselining of oscillation cases

Summary

- All states of NER have international boundary: Large number of interconnections with Bangladesh, Bhutan, Myanmar expected in future
- Very low per capita consumption: 292 kWh (Compared to 1010 kWh) for All India
- High potential for growth in NER
- Potential in Renewables (Solar / Wind): Solar parks planned in Arunachal Pradesh, Assam, Meghalaya, Nagaland
- Need for Better visibility => URTDSM (Unified Real-Time Dynamic State Measurement) scheme is under implementation
- Number of PMUs expected in NER Grid under URTDSM = **86 numbers**
- System Protection system implementation based on WAMS: movement to WACS
- Tuning of generators controls using remote bus signals using PMUs
- Power system model validation using PMUs

Thank You !

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