

# Unified Real Time Dynamic State Measurements (URTDSTM) Scheme – Smart Transmission

- System Operation & Challenges
- Synchrophasor Technology
- Real time measurements/events & control analytics
- URTDSTM Scheme for National Grid

*February 2013*

# System Operation

- Vast Transmission Expansion & its operation
- Open and growing electricity market & power trading
- Integration of large scale intermittent & variable renewable generation into grid
- Steady state view of Transmission Network
- No phase angle measurement in real time – critical parameter
- Presently high Latency(delay) and time skewed system data monitored through SCADA
- Coordination of protection settings
- Analysis based on the steady state information(SCADA)

**Necessitates Real time measurements and monitoring of Grid parameters to capture dynamic behavior for improved efficiency**

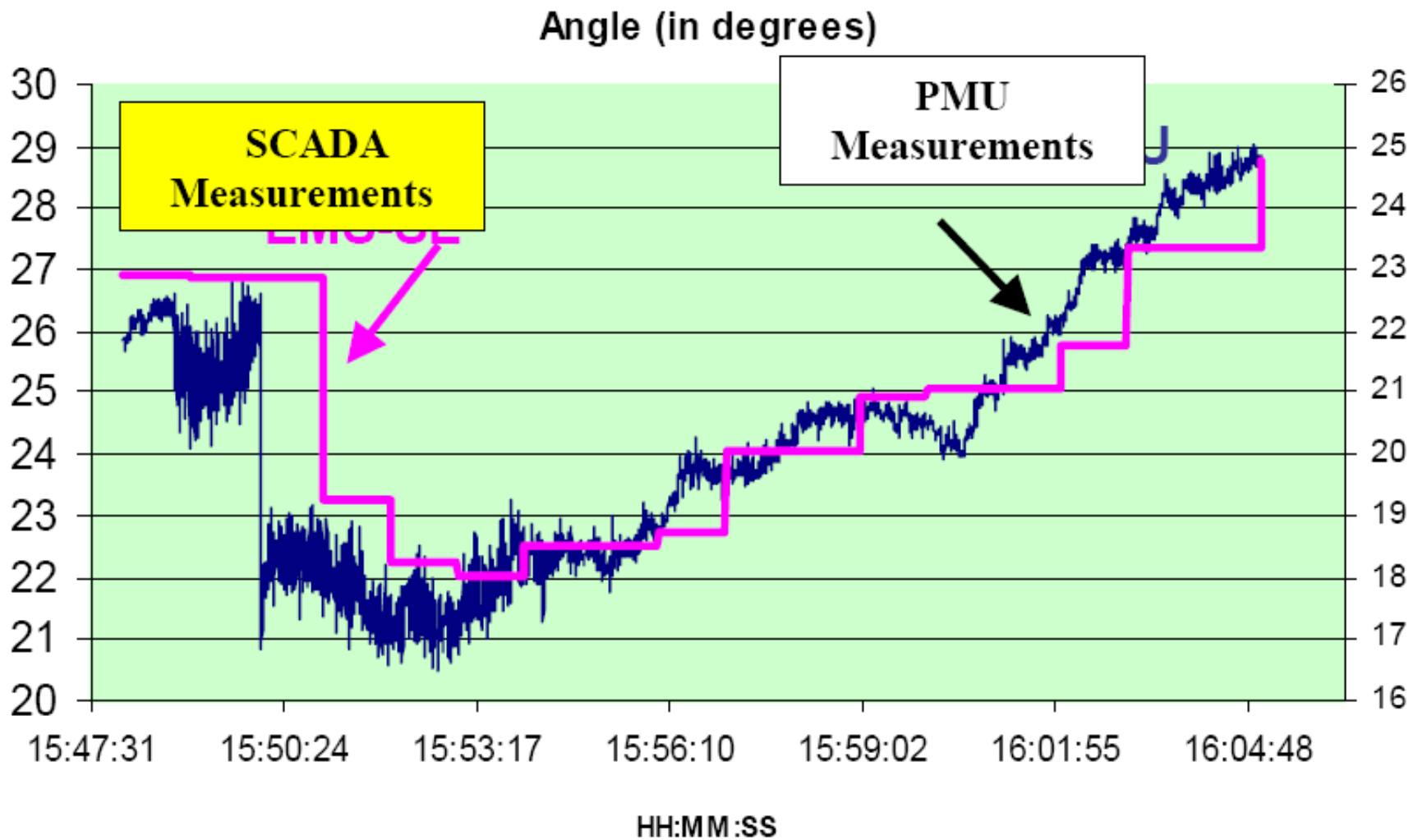
# Issues & Challenges

- How do we know what is going on in the grid where SCADA(10-15 sec) cannot monitor?
- Is the system really stressed? What are real-time margins?
- How to monitor system dynamics viz angle? How to improve grid security, quality & reliability ?
- How to address large scale integration of intermittent & variable Renewable Energy?
- Was there an Event? When, where, what kind, after-effects?
- Are there unstable oscillatory modes in the system?
- How to optimized system operation & how to enhance situational awareness ? Quick decision support tools to the operator. Self-healing action

# State-of-the-Art Technology (Synchrophasors)

- **Phasor Measurements Units (PMU)**
  - Measure states (Voltage/Current & Angle) and not estimates (20 - 40 milliseconds)
  - Dynamic system conditions via High Resolution Data (25 samples/sec)
  - Ability to compare due to Time Synchronized/stamped data(GPS) viz. voltage, current, angle etc.
- **Wide Area Measurement/Monitoring Systems(WAMS) with high bandwidth communication (OPGW)**
- **High resolution, time synchronized data, useful for calculation, dynamics monitoring & emergency control**
  - % damping (inter-area and local area oscillations)
  - Measured sensitivities, such as  $\Delta V/\Delta P$ ,  $\Delta\delta/\Delta P$
  - Angle Difference (between buses)
  - Transmission loadability
  - Avoid widespread disturbances

# Higher Resolution (typically 25 samples/second) Compared to 4 to 10 seconds/sample of SCADA

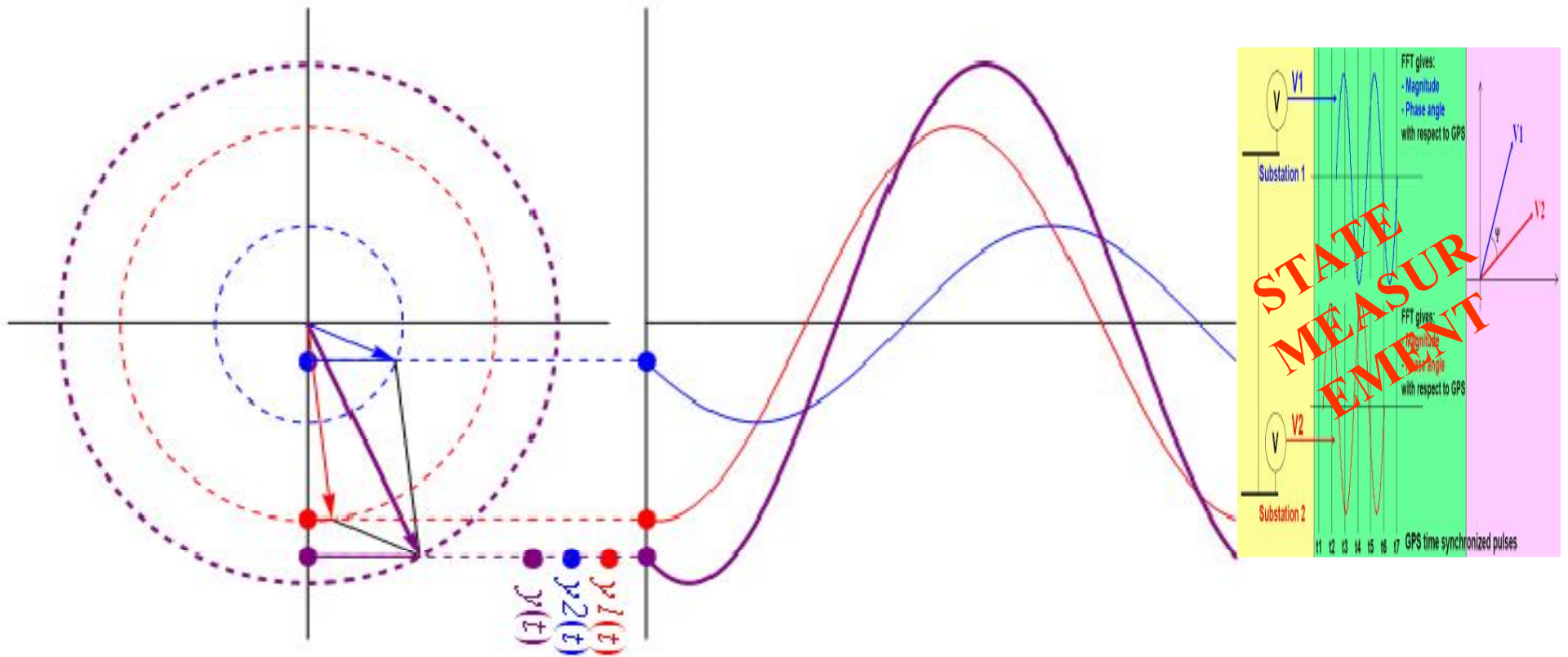


# Synchrophasor Technology

Enhanced Situational Awareness to Monitor & Control Health of the Grid

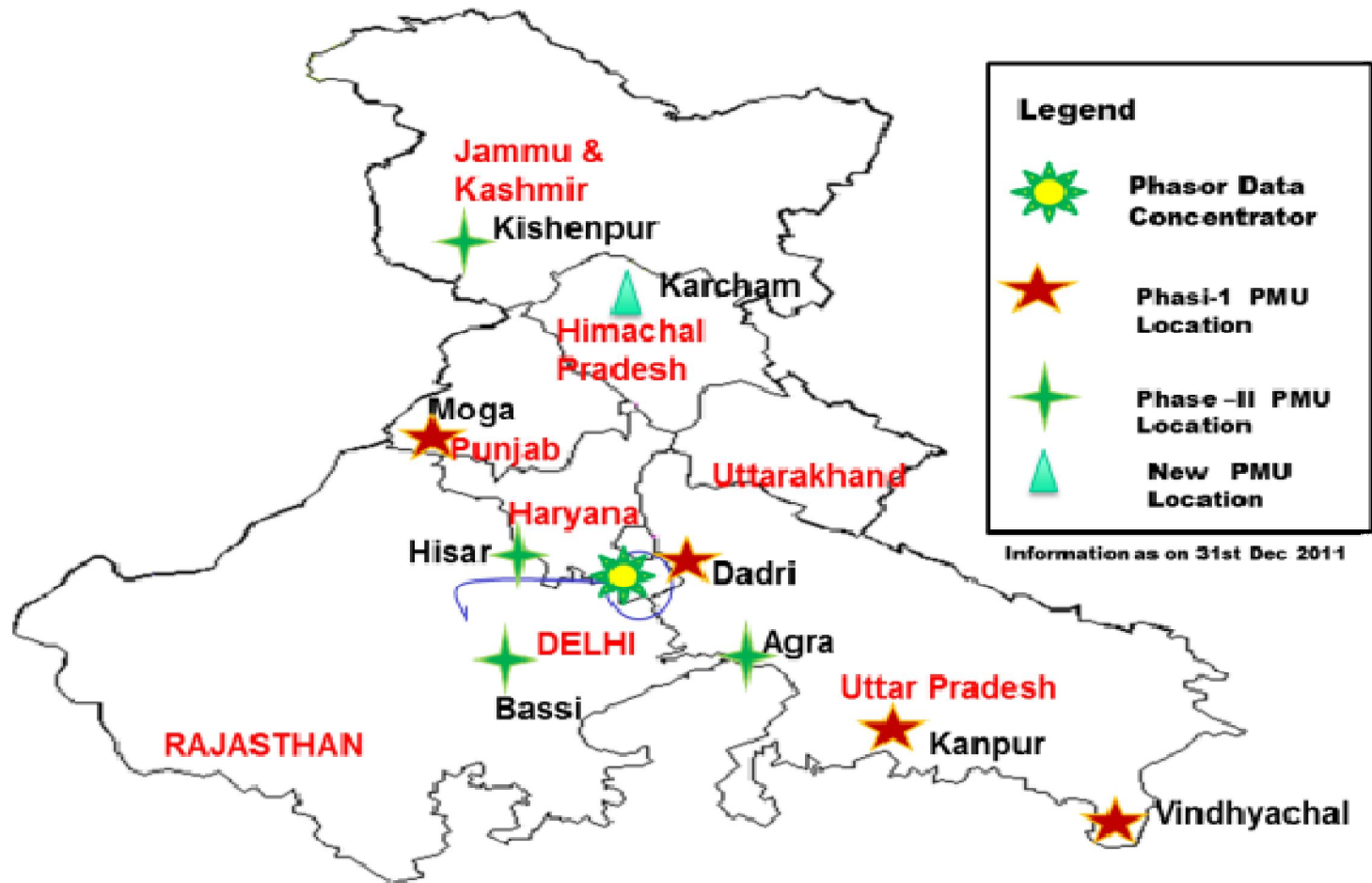
<b>Grid Stress</b>	Phase Angular Separation
<b>Grid Robustness</b>	Damping Status and Trend(s)
<b>Oscillations</b>	Sustained oscillations High Mode Energy
<b>Frequency Instability</b>	Frequency Variation Across Interconnection
<b>Voltage Stability</b>	Low Voltage Zones / Voltage Sensitivities
<b>Angular Stability</b>	Power-angle Sensitivities, stability
<b>Margin (s)</b>	“How far from the threshold value?”

# Visualisation & Awareness



# **Snap-shots of Operational Events on WAMS Pilot project**

# PMU Locations-Northern Region (WAMS Pilot)



# Applications

- **Real-time : Enhancing Situational Awareness**
  - Magnitude & angle of all Voltage/Current phasors
  - Sequence components of Voltage/Current phasor
  - Frequency & frequency difference
  - Rate of change of frequency
  - Angular separation between pair of nodes
  - 1-phase auto-reclosing in transmission lines

# Applications

- **Forensic analysis of grid incidents: Detection of**
  - Grid event within/other regions
  - Type of fault viz. LG, LL, LLG, LLL, LLLG
  - Nature of fault (Dead short circuit or high resistance)
  - Time of the fault and sequence of events
  - Fault clearance time, summary of elements on fault
  - Voltage recovery post fault clearance
  - Possible protection operation/misoperation

# Applications

## ■ **Post-dispatch analysis of grid operation: Validation of**

- Network model
- Transfer capability declaration
- Simulated short circuit current
- Performance/utility of SPS
- Measurement cycle used in  $df/dt$  relay

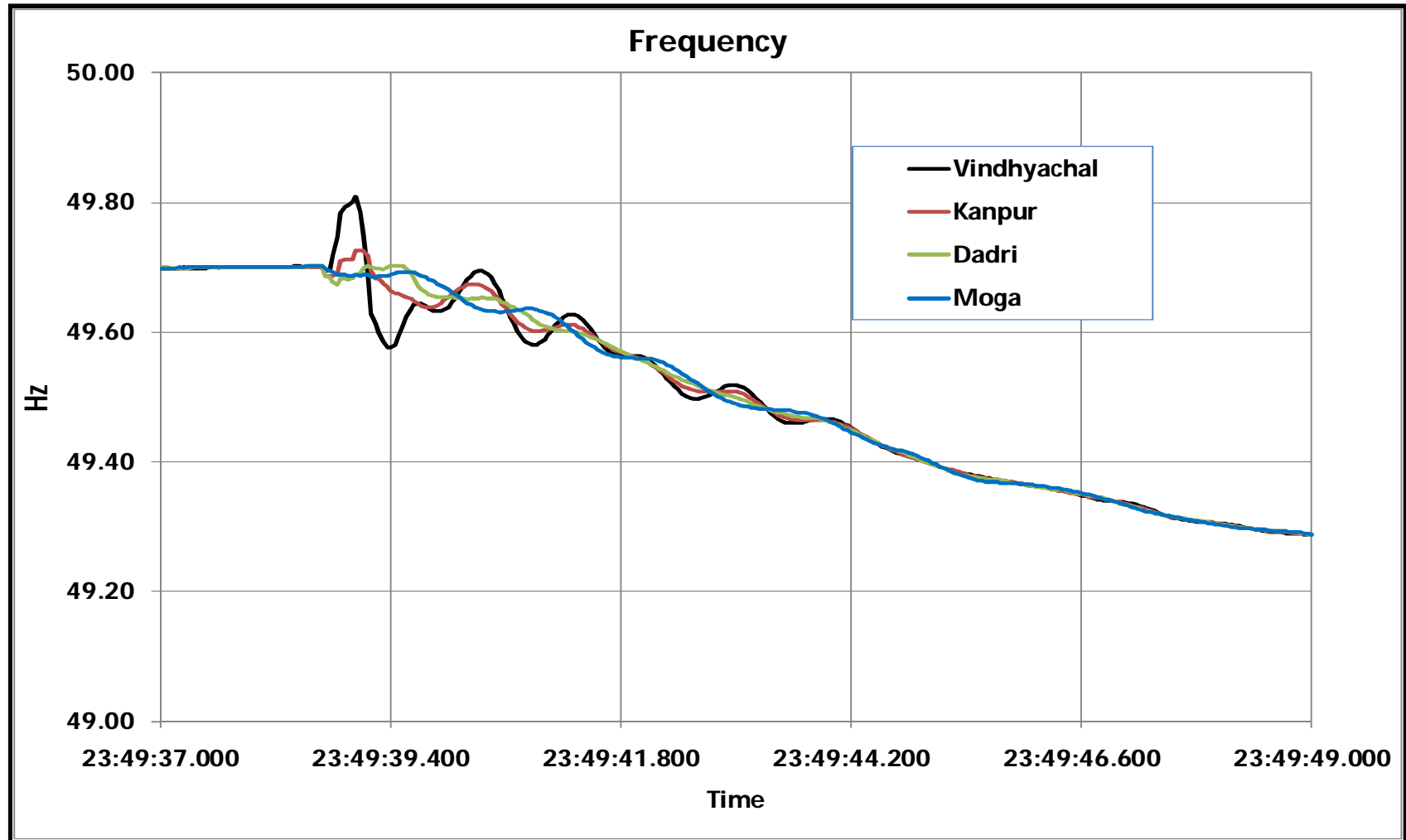
### **Computation of :**

- System inertia constant(H) using  $df/dt$
- Frequency Response Characteristics (MW/Hz)

## ■ **Detection & Analysis of Oscillations**

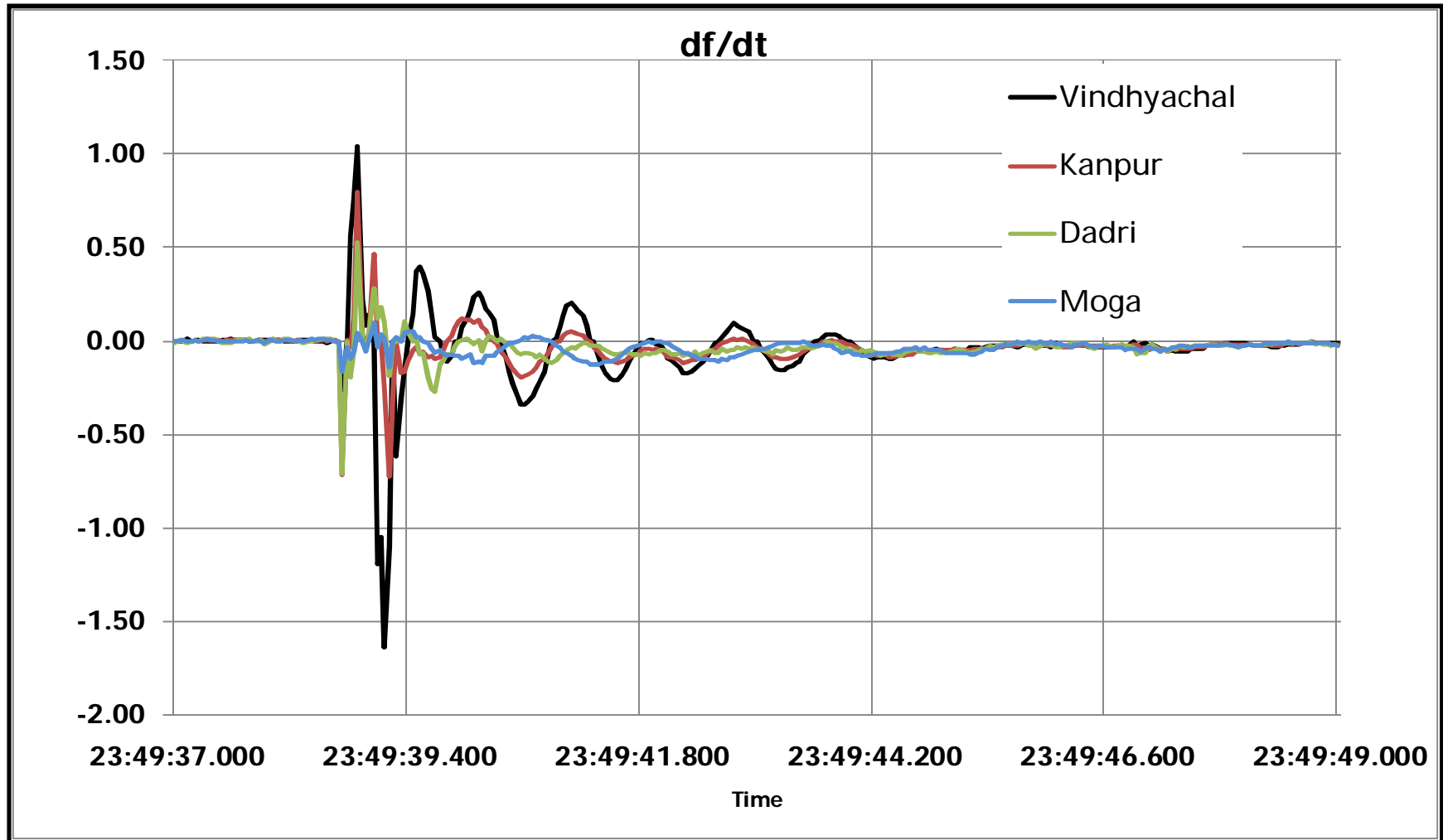
- Time, duration, amplitude, frequency of oscillations
- Type of oscillations viz, inter-area or local
- Nature of oscillations viz, damped or un-damped
- Modes present, their amplitude and damping factor

## Frequency Profile during 2000 MW loss of Generation at Rihand-1<sup>st</sup> June-2010

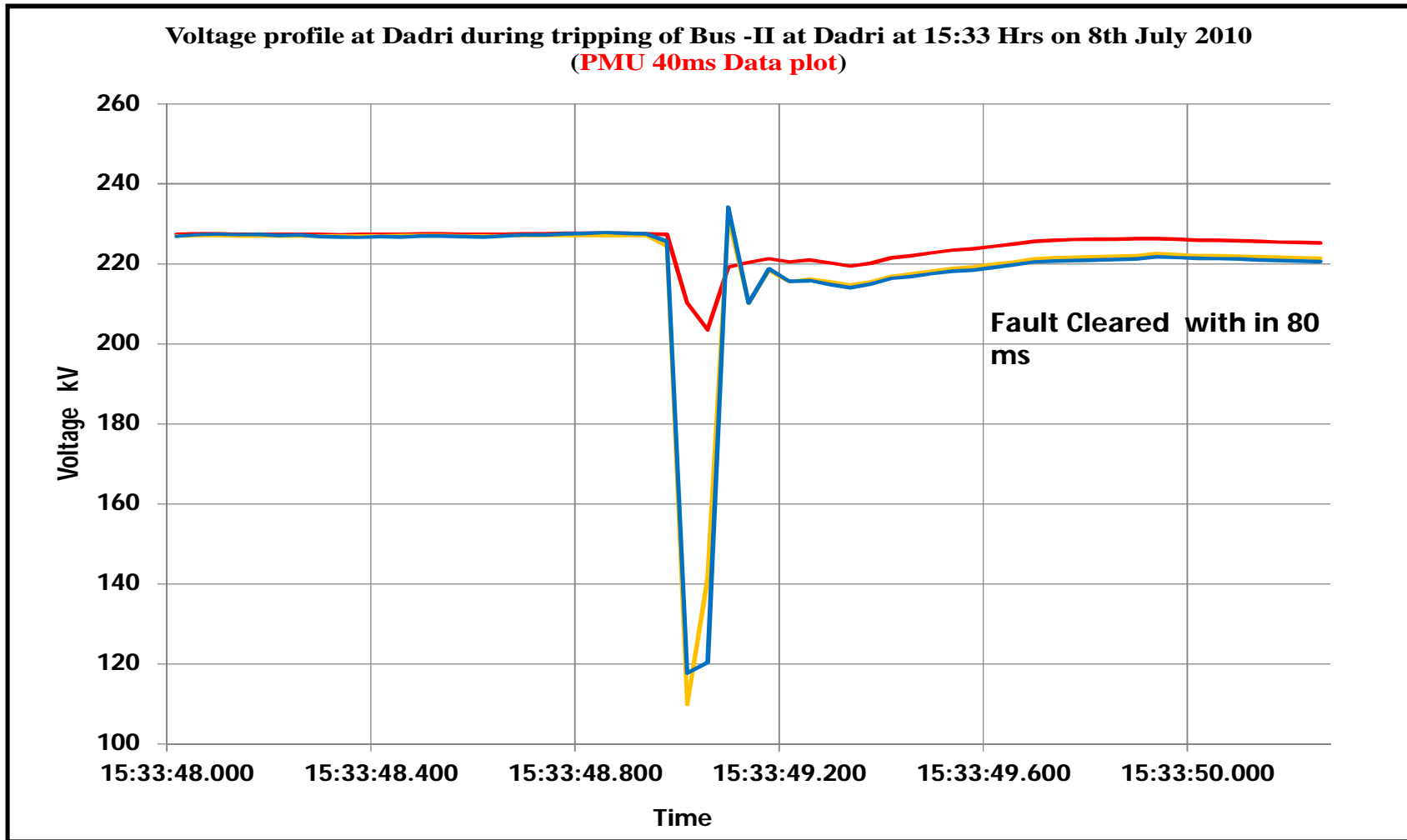


Frequency of different locations oscillates differently on tripping

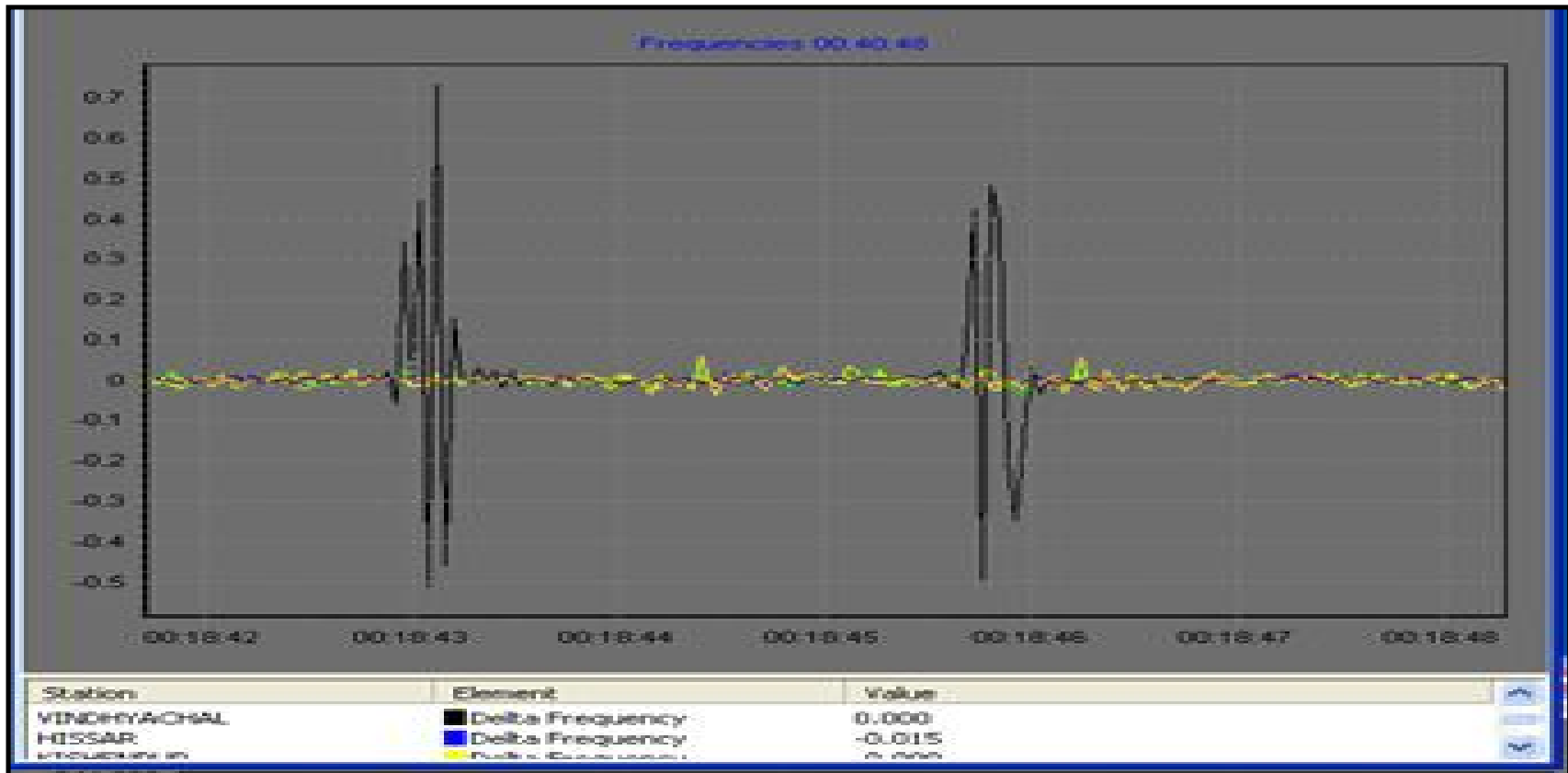
# df/dt Profile during 2000 MW loss of Generation at Rihand-1st June-2010



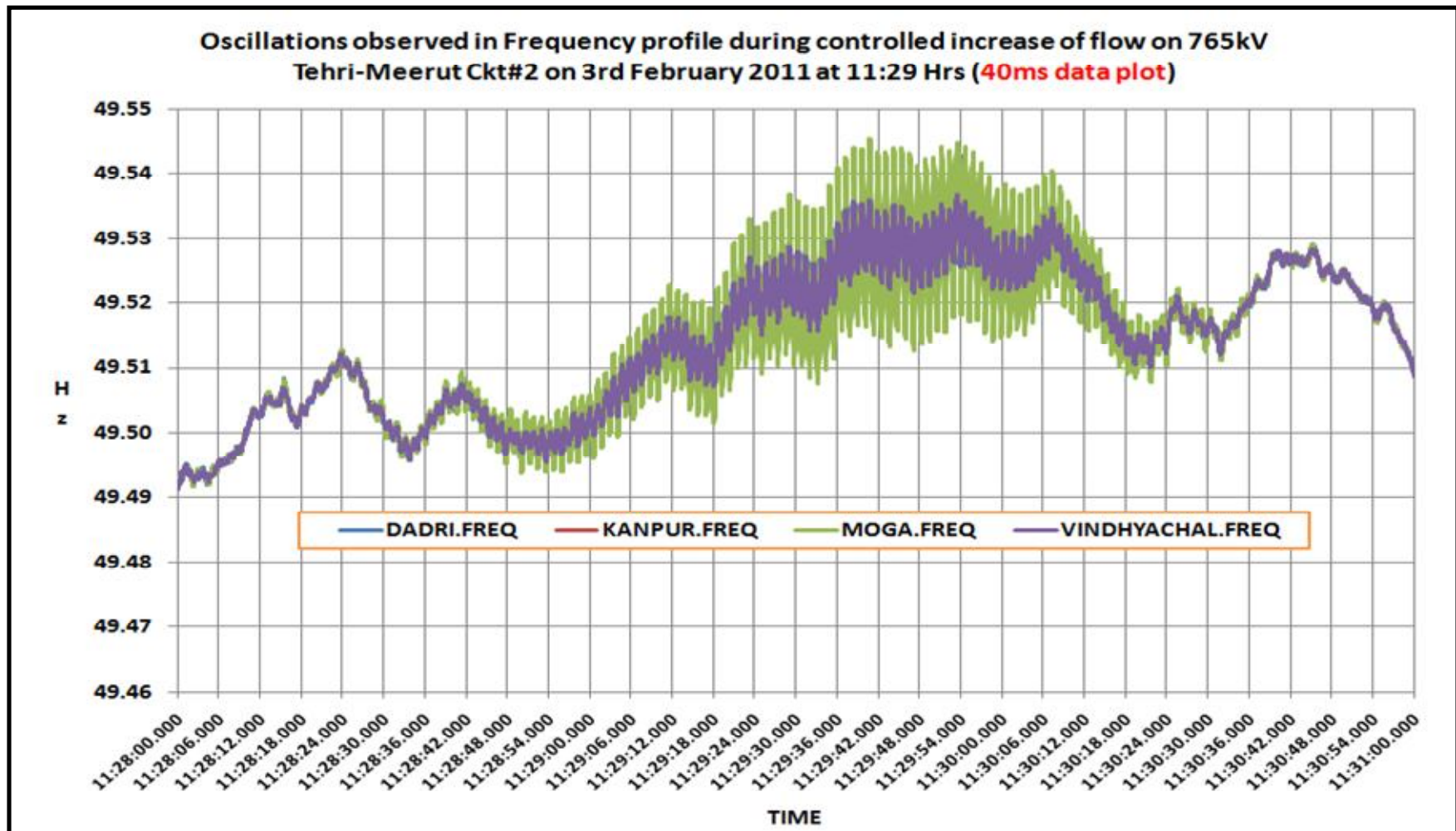
# Fault Clearing time



# df/dt : Indicating auto - reclosure on 400kV Bassi-Jaipur line

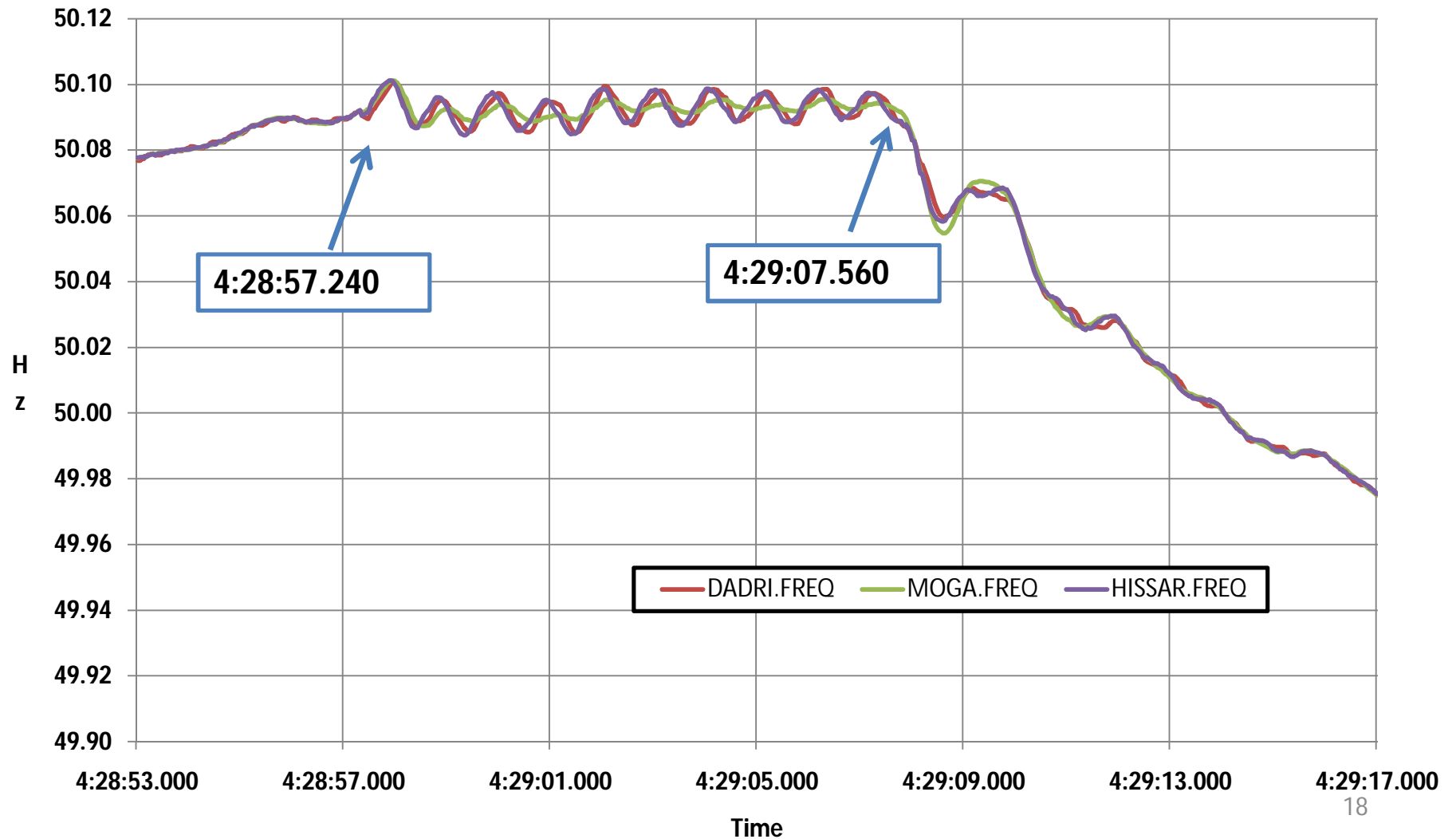


# Oscillations Monitoring



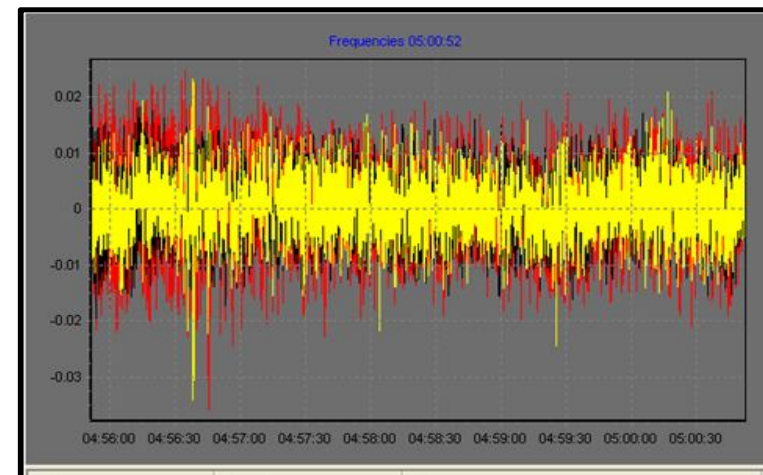
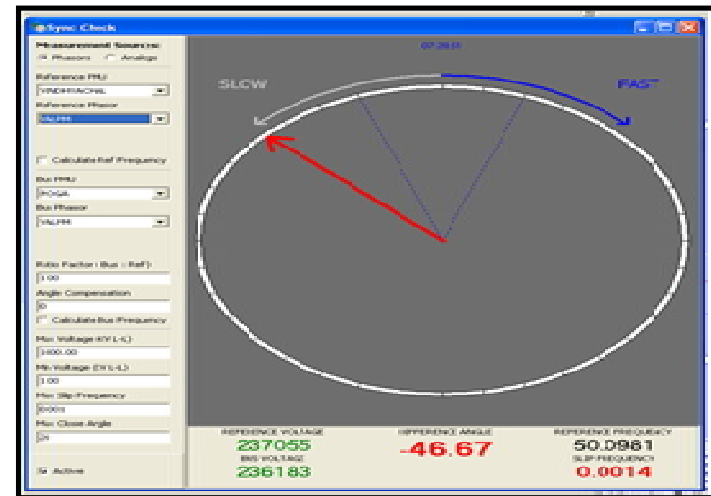
# Oscillations for 10 sec delayed SPS operation

Frequency profile on 16th July 2011 from 04:28 - 04:31 Hrs  
(40ms data plot)



# Visualization

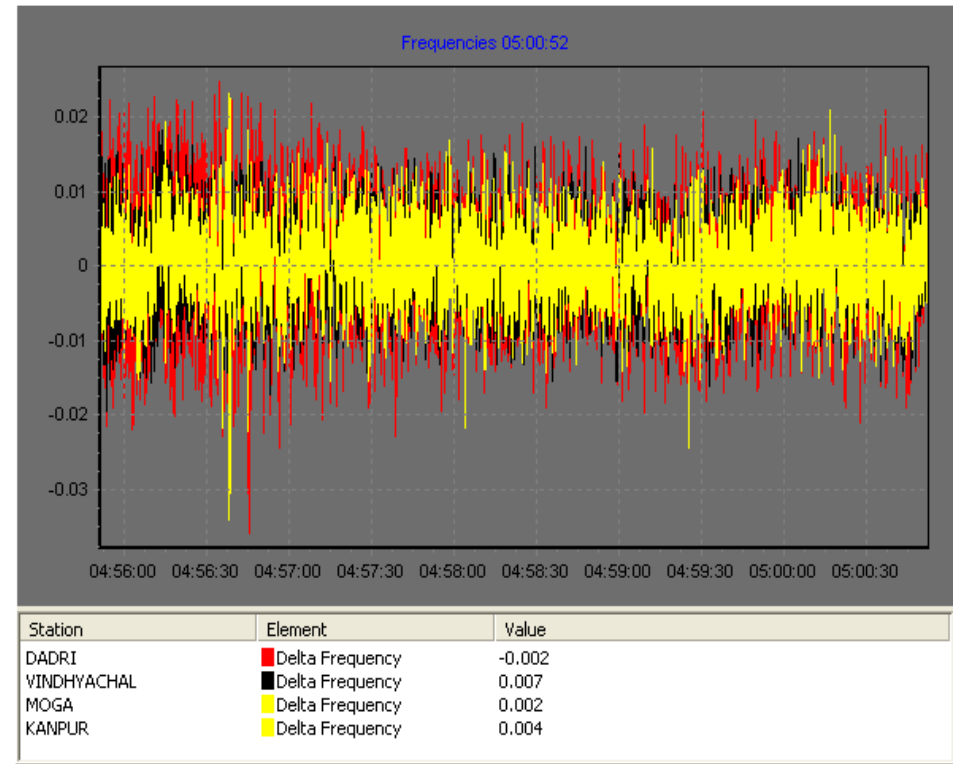
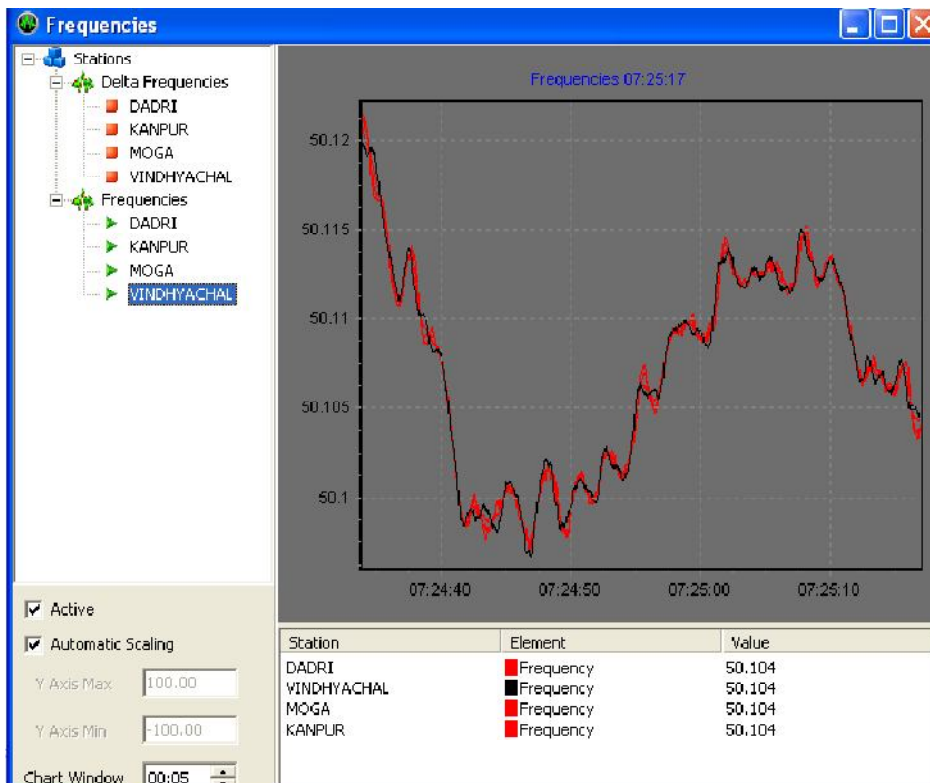
- Voltage & current phase angles (monitor angle-of-separation) – Dial, trend, tabular representation
- Voltage, angle Contour
- Frequency, rate-of-change (identify generation loss/load)
- % Damping - inter-area, local oscillations
- Frequency response characteristic (MW/Hz)



# Frequency Plot

Display of absolute frequency

Display of frequency difference

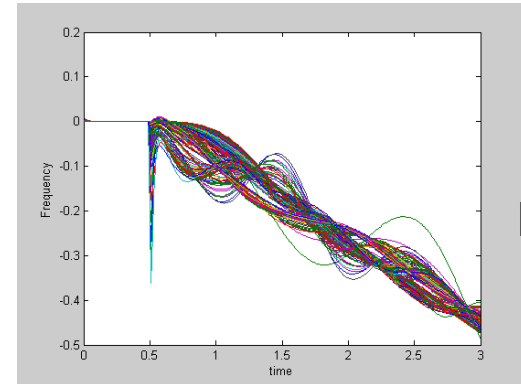


# Example

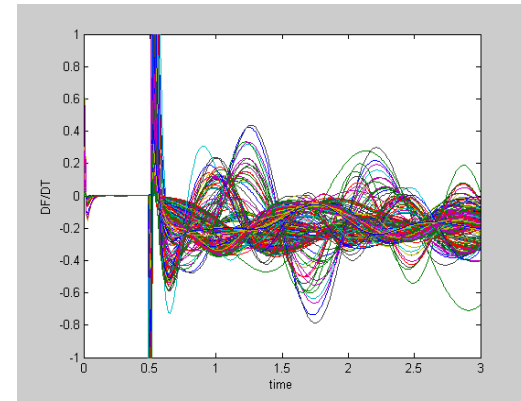
- **Frequency Control:**  
**Under Frequency Relaying:**  
Local frequency contaminated due to swings (1-2 Hz).  
df/dt should not trigger on swings but on “common” motion.

**Solution: filter**, but filtering will involve delay.

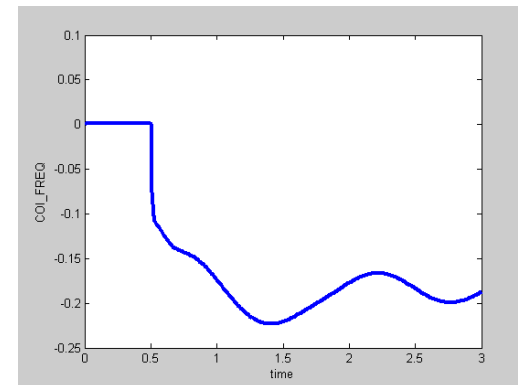
- Rate of Change of **Center of Inertia** Speed (NOT LOCAL)
- Reflects actual power deficiency. Need to know total inertias (will need to know whether islanded or not, which generators in island)



FREQ

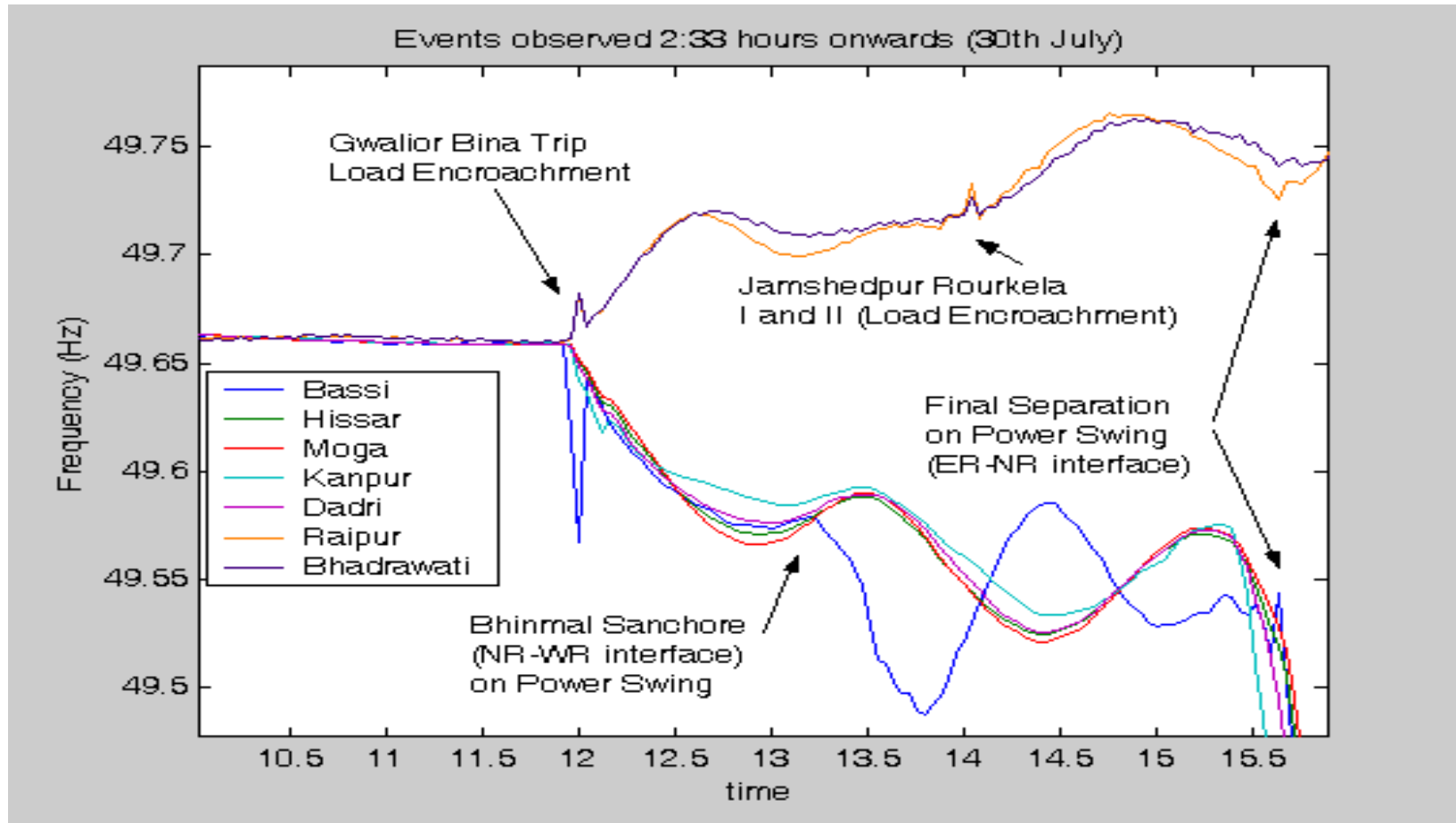


DF/DT



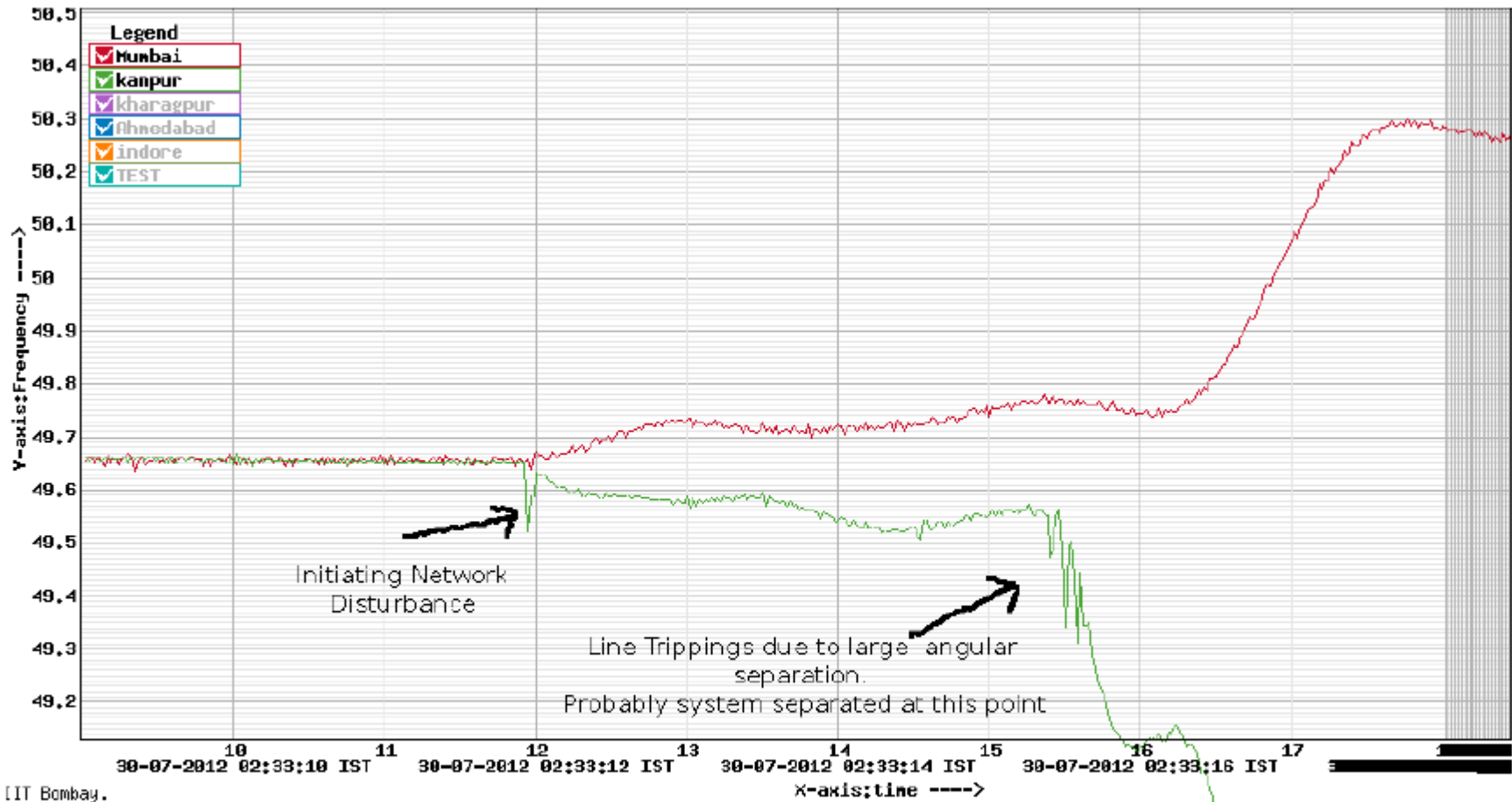
d/dt  
COI  
FREQ

# System Security- 30<sup>th</sup> July incident



After Bina-Gwalior tripped angle between the corridor was increasing. Separation took place in 3.5 secs. Such fast emergency schemes could analyse and actuate the load shedding or generation back down in desired area.

# Angular Separation between NR and NEW Grid – 30<sup>th</sup> July



IIT Bombay.

Fig 1: (source: Wide Area Frequency Measurement system developed by IIT-B, Mumbai.)

# Proposed Analytics

Linear  
State Estimator

Supervised  
Zone-3 protection to  
avoid unwanted tripping

Vulnerability  
Analysis  
of Distance Relays

On-line CVT  
Parameter  
Validation%

Emergency Control

Voltage  
Stability

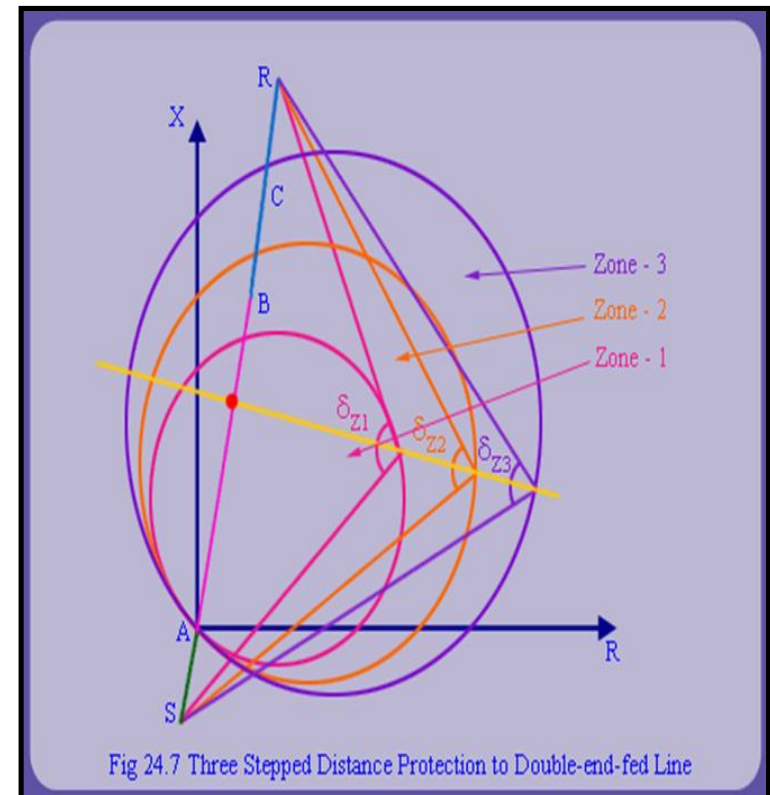
Frequency  
& Angular Stability

# Supervised Zone-3 Distance Protection

- **Distance relays can mal-operate on**

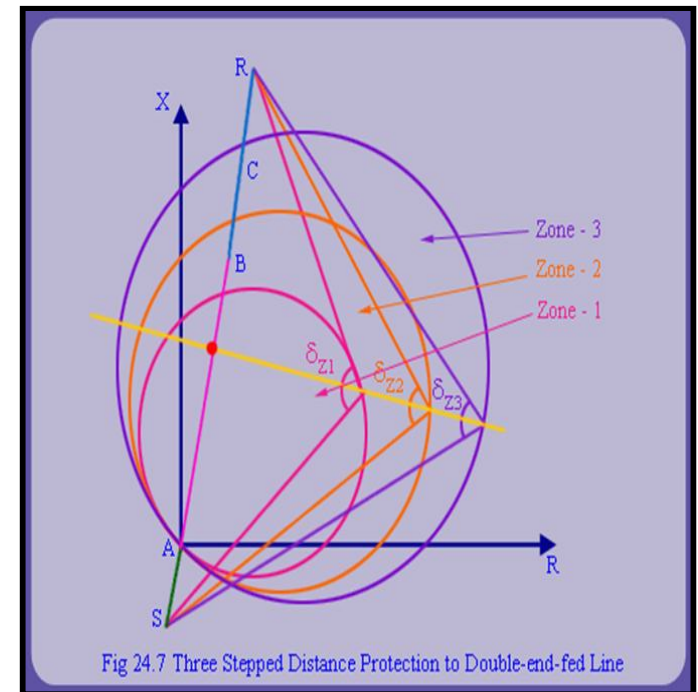
- Quasi Steady State condition- Load encroachment
- Electromechanical Oscillations - Power swing

**Analytics will identify the presence of persistent fault in the system and will generate control signal to block Zone-3, if there is no fault (i.e. Adaptive remote backup protection)**



# Online Vulnerability Analysis of Distance Relays

- **Distance relays can issue false trip signal due to:-**
  - Remote Fault
  - Under Stress
  - Low voltage scenario
  - Inappropriate relay settings
  - Changing network condition
- **Analytics will identify vulnerable relays (approaching threshold) using real-time data so that corrective measures can be taken in field**



# Instrument Transformer Performance Monitoring

- **CVT/CT performance deteriorates due to**
  - Ageing and failure of capacitor element
  - Drift in characteristics – results biased state estimation
- **Synchrophasor measurements enable evaluation of accuracy of these instruments by:**
  - Verification of measurement against benchmark CT/CVT
  - Using residual of linear state estimator
- **The errors shall be logged and reported to operator through alarm**

# Emergency Control Schemes for Improving System Security

- **Emergency Control involves automatic action taken in short time(2-3 secs)**
- **WAMS based emergency control schemes will continuously monitor the trajectories of key parameters (V,I) & analyses the stability/security of the system**
- **Based on the analysis, a decision on whether to take automatic control action, its quantum & location shall be taken by such schemes**
- **Examples of emergency control schemes are:**
  - Adaptive load tripping
  - Generation tripping
  - Utilization of capabilities of HVDC/FACTS
  - Controlled system separation

# Industry Experience with SPS schemes

## IEEE TPWRS, Vol. 11, No.3 1996

- Survey of SPS schemes mainly in USA, Canada, Europe, Japan, Australia
- 49 utilities, 17 countries and 111 schemes

# Types of Schemes

Type of SPS	Percentage
Generator Rejection	21.6
Load Rejection	10.8
Underfrequency Load Shedding	8.2
System Separation	6.3
Turbine Valve Control	6.3
Load & Generator Rejection	4.5
Stabilizers	4.5
HVDC Controls	3.6
Out-of-Step Relaying	2.7
Discrete Excitation Control	1.8
Dynamic Braking	1.8
Generator Runback	1.8
Var Compensation	1.8
Combination of Schemes	11.7
Others	12.6

# Linear State Estimator

- **Uses synchronously measured voltage & current phasor to determine state.**
- **Gives state of power system in millisecond.**
- **Identify topological error and detects island in the system.**
- **Power system condition can be played back along with topology and Power Flow**
- **Gives accurate base case for analysis and study**

**URTD SM**

# PMU Placement

All 220kV and above substation in State and Central grids

Generating stations at 220 kV level and above

HVDC terminals and important Inter-Regional and Inter-National tie lines

Both ends of all 220kV and above Transmission lines of State and ISTS grids .

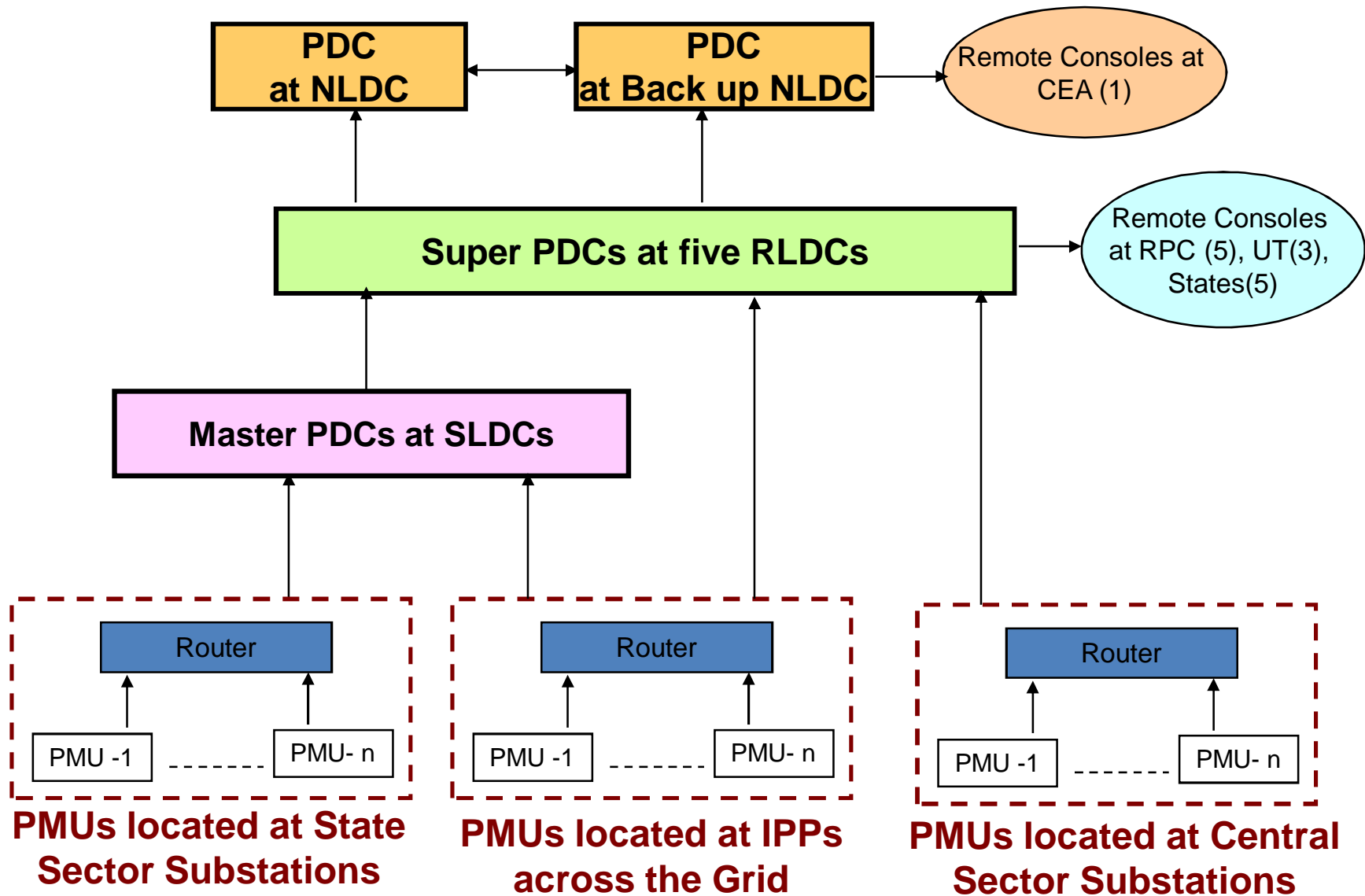
# PDC Placement

Master PDC at SLDC will collect data from PMUs and Time align the data.

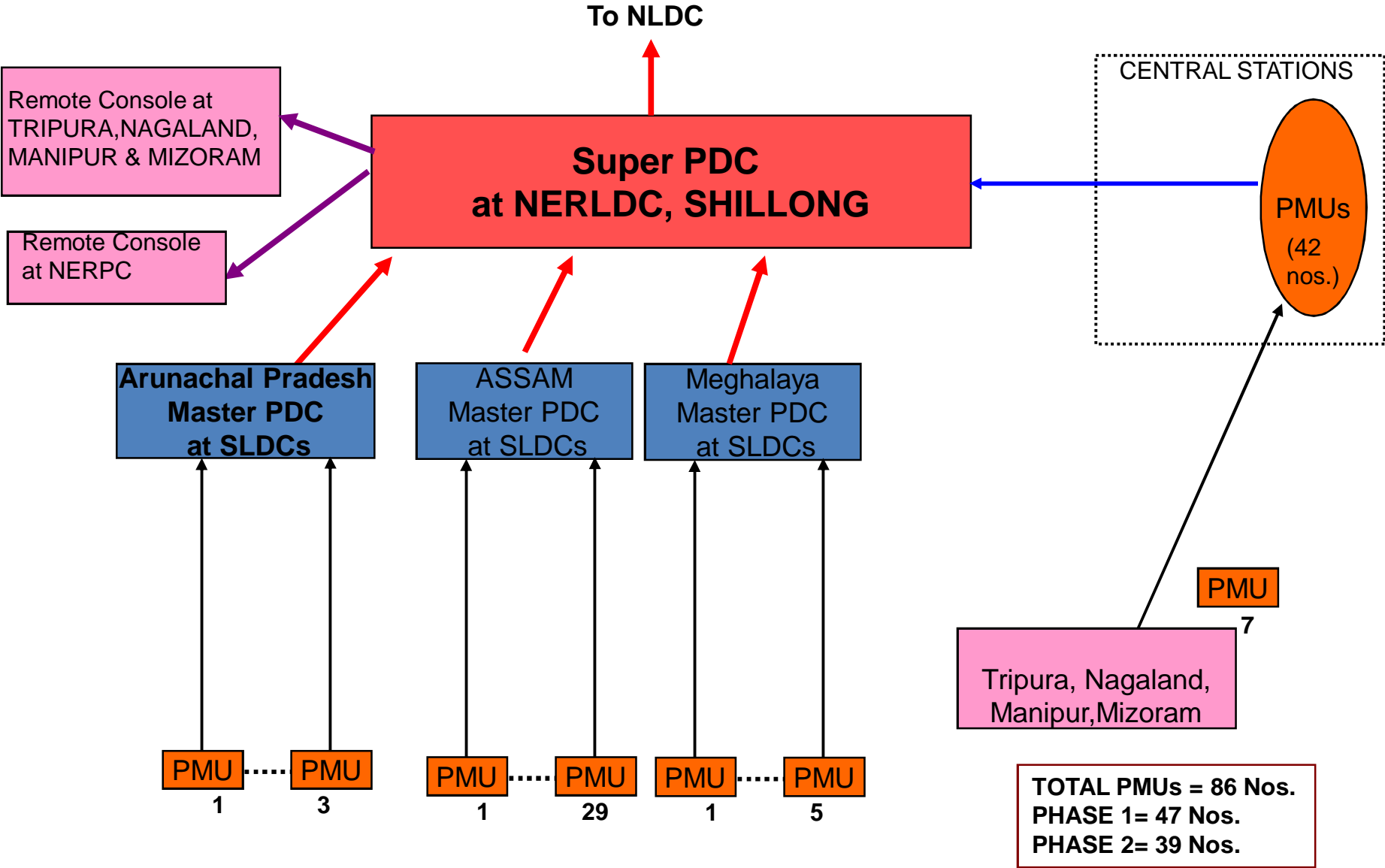
Super PDCs at RLDCs will collect the Data from all Master PDCs in the regions and Time align the data.

PDC at NLDC will collect the data from all the PDCs at RLDCs and Time align the data.

# URTDSM System Hierarchy



# URTDISM HIERARCHY – NORTH EASTERN REGION



# Region wise list of Substations & Lines by 2014-15

Region	Sub-stations			No of feeders			PMU			MPDC	SPDC	Main & B/U NLDC
	ISTS	IPP	STU	ISTS	IPP	STU	ISTS	IPP	STU			
NR	83	13	96	434	20	435	227	13	231	18	2	
WR	60	29	76	520	45	415	267	29	216	8	2	
ER	51	19	44	395	26	199	202	19	105	10	2	
SR	60	9	71	348	12	289	183	9	152	8	2	
<b>NER</b>	<b>14</b>	<b>*</b>	<b>25</b>	<b>81</b>	<b>*</b>	<b>81</b>	<b>42</b>	<b>*</b>	<b>44</b>	<b>6</b>	<b>2</b>	
<b>Total</b>	258	70	312	1778	103	1419	921	70	748	50	10	
	<b>570+70 = 640</b>			<b>3197+103 = 3300</b>			<b>1669+70 = 1739</b>					<b>4</b>

# NORTH EAST REGION (PMU & PDC)

NER-PH-I				NER-Ph-II			PDC	
	S/St	Feeders	PMU	S/st	Feeders	PMU	MPDC	SPDC
ARUNACHAL PRADESH	0	0	0	2	6	3	2	
ASSAM	4	20	11	11	35	18	2	
TRIPURA	0	0	0	1	2	1		
MEGHALAYA	0	0	0	3	9	5	2	
NAGALAND	0	0	0	1	2	1		
MANIPUR	0	0	0	2	6	4		
MIZORAM	0	0	0	1	1	1		
CENTRAL	9	69	36	5	12	6		1
<b>Grand Total</b>	<b>13</b>	<b>89</b>	<b>47</b>	<b>26</b>	<b>73</b>	<b>39</b>	<b>6</b>	<b>1</b>

# Implementation Plan

- **Location with OPGW available/being available**
  - PMU Location = 1186
  - Master PDC (Main & Stand By) = 50
  - Super PDC (Main & Stand By) = 14
  - Implementation Period-2014-15
- **Locations with OPGW link to be implemented**
  - PMU Location = 553
  - Optical Fiber = 11000Km

# URTDSM Scheme

- URTDSM scheme was deliberated & agreed for implementation in the Joint Meeting of all the Regional Standing Committees on Power System Planning held on 5<sup>th</sup> Mar'12.
- The scheme was deliberated and agreed by other RPCs for its implementation.
- As decided, POWERGRID filed a petition to CERC for regulatory approval.
- The deployment of WAMS also recommended in the Enquiry Committee report on the Grid disturbances held on 30th & 31st July 2012.

**Thank You**

# Estimated Cost

- **Location with OPGW available/being available**
  - Estimated Cost = Rs. 279 Cr
- **Locations with OPGW link to be implemented**
  - Estimated Cost = Rs. 377 Cr

# NER Details

# North East Region DPR Cost

Sl. No.	Description	Amount
A	Supply	
i	WAMS	15.91
ii	OPGW cable & accessories	11.34
iii	SDH, MUX & NMS Equipments	2.27
iv	Auxiliary Power supply	7.74
	Sub- Total A(i to iv)	36.76
B	PMU Test Lab	0.00
C	Training charges	0.25
D	Erection, Testing and Commissioning	4.91
E	Inland Freight and Insurance (@ 4%)	1.26
F	Consultancy for WAMS System through Panel of Experts	0.00
G	Taxes and Duties	
i	Custom Duty (@22.853 %)	included
ii	Excise Duty(@ 12.36 % )	included
iii	CST (@ 2% )	included
iv	Entry Tax	0.41
	Total (A to G)	43.60
H	Overheads (Engg. & Administration etc.) (@ 5%)#	2.18
I	Contingency (@ 3%)#	0.72
	Total (A to I)	46.50
J	Interest During Construction (IDC)	4.27
	Grand Total	50.77

# North East Region Ph-I Cost

Sl. No.	Description	Amount
	(URTDSM Phase-I)	
i	WAMS	12.25
ii	Auxiliary Power supply	6.52
	Sub- Total A(i to ii)	<b>18.77</b>
B	PMU Test Lab	
C	Training charges	0.25
D	Erection, Testing and Commissioning	1.37
E	Inland Freight and Insurance (@ 4%)	0.66
F	Consultancy for WAMS System through Panel of Experts	0.00
G	Taxes and Duties	
i	Custom Duty (@22.853 %)	included
ii	Excise Duty(@ 12.36 % )	included
iii	CST (@ 2% )	included
iv	Entry Tax	0.17
	Total (A to G)	<b>21.21</b>
H	Overheads (Engg. & Administration etc.) (@ 5%)	1.06
I	Contingency (@ 3%)	0.05
	Total (A to I)	<b>22.32</b>
J	Interest During Construction (IDC)	1.91
	Grand Total	<b>24.23</b>

# North East Region Ph-II Cost

Sl. No.	Description	Amount
	(URTDSM Phase-II)	
A i	WAMS	3.65
ii	OPGW cable & accessories	11.34
iii	SDH, MUX & NMS Equipment	2.27
iv	Auxiliary Power supply	0.72
	<b>Sub- Total A(i to iv)</b>	<b>17.99</b>
B	Training charges	0.01
C	Erection, Testing and Commissioning	3.54
D	Inland Freight and Insurance (@ 4%)	0.60
E	Taxes and Duties	
i	Custom Duty (@22.853 %)	included
ii	Excise Duty(@ 12.36 % )	included
iii	CST (@ 2% )	included
iv	Entry Tax	0.25
	<b>Total (A to E)</b>	<b>22.39</b>
F	Overheads (Engg. & Administration etc.) (@ 5%)	1.12
G	Contingency (@ 3%)	0.67
	<b>Total (A to G)</b>	<b>24.18</b>
H	Interest During Construction (IDC)	2.36
	<b>Grand Total</b>	<b>26.54</b>

## NORTH EAST REGION- Ph I

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
<b>ASSAM</b>						
<b>220 kV SEB S/S</b>						
1	Mariani	NER	4	Kaithalguri , Misa, Samaguri 1 &2	2	MW repal
2	Samaguri	NER	9	Sarusajai , Misa PG 1&2, Balipara, Mariani 1&2, 220kV tejpur 1&2, J.Nagar	5	MW repal
3	Agia	NER	4	BTPS 1&2, Azara, Boko	2	MW repal
4	Tinsukia	NER	3	Behiting 1&2, Makum	2	MW repal
		<b>Total</b>	<b>20</b>		<b>11</b>	

**Contd...**

## NORTH EAST REGION- Ph I

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
<b>CENTRAL</b>						
<b>400 kV S/S</b>						
1	BALIPARA PG	NER	12	Misa PG 1&2,B'Charyali 1,2,3&4 Bongaigaon PG 1,2,3&4, Kameng 1&2	6	Existing
2	BONGAIGAON	NER	14	BTPS 1&2,Balipara PG 12,3&4, Binaguri 1&2, 400kV Azara 1&2, 400kV Alipur 1&2, 220kV Birpara 1&2	7	Existing
3	Bishwanath	NER	12	Subansiri 1,2,3&4,Alipurdwar HVDC 1&2,Balipara 1,2,3&4, Ranganadi 1&2	6	Proposed
4	Silchar	NER	4	Azara, Pallatana 1&2, 400kV Byrnihat	2	MW Replac
5	MISA	NER	11	Balipara PG 1&2, 220kV Mariani, 220kV Mariani (N), 220kV Dimapur, 220kV KOPILI 1,2,&3,220kV Byrnihat 1&2, N.Kohima	6	Existing
<b>220 kV S/S</b>						
6	KOPILI	NER	3	Misa 1,2&3	2	Existing
7	Birpara		7	Siliguri 1&2, Chukha 1,2&3, Bongaigaon 1&2	4	MW repal
8	220kVMariani (New)	NER	4	200kV Kathalguri, 220Kv Misa, 220kV Mockochung 1&2	2	MW repal
9	Dimapur	NER	2	Misa, N.Kohima	1	Existing
		<b>Total</b>	<b>69</b>		<b>36</b>	

## NORTH EAST REGION-Ph II

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
<b>ARUNACHAL PRADESH</b>						
<b>400 kV SEB S/S</b>						
1	Subansiri(Lower)	NER	4	B'Charyali 1,2,3&4	2	No
<b>220 kV SEB S/S</b>						
2	Deomali	NER	2	Kathalguri, Miao	1	No
		<b>Total</b>	<b>6</b>		<b>3</b>	
<b>ASSAM</b>						
<b>400 kV SEB S/S</b>						
3	AZARA	NER	8	400kV Silichar, 400kV Bongigaon 1&2, 400kV Azara, 220kV Agai 1&2, 220kV Sarusajai, 220kV BOKO	4	No
<b>220 kV SEB S/S</b>						
4	Tejpur	NER	4	Balipara 1&2, Samaguri 1&2	2	No
5	Sarusajai	NER	6	Azara, Samaguri , boko, Langpi 1&2, J.nagar	3	No
6	Boko	NER	2	Azara, Sarsusajai	1	No
7	Longpi	NER	2	Sarusajai 1&2	1	No
8	Behiating	NER	2	Tinsukia 1&2	1	No
9	Amingaon	NER	2	Rangia 1&2	1	No
10	Makum	NER	2	Kathalguri, Tinsukia	1	No
11	RANGIA	NER	3	Amingaon 1&2, Bornagar	2	No
12	Bornagar	NER	2	BTPS, Bornagar	1	No
13	J.NAGAR	NER	2	Samaguri, sarsujai	1	No
		<b>Total</b>	<b>35</b>		<b>18</b>	

## NORTH EAST REGION-Ph II

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
<b>MEGHALAYA</b>						
<b>400 kV SEB S/S</b>						
14	Byrnihat	NER	3	400kV Silchar, 400kV Azara, 220kV Mawngap	2	No
<b>220 kV SEB S/S</b>						
15	N.shilong	NER	2	Mawngap 1&2	1	No
16	Mawngap(planned for 220kv, Charged at 132kv)	NER	4	N.SHILONG 1&2, Byrnihath 1&2	2	No
		<b>Total</b>	<b>9</b>		<b>5</b>	
<b>NAGALAND</b>						
<b>220 kV SEB S/S</b>						
17	N.KOHIMA	NER	<b>2</b>	Dimapur , Misa	<b>1</b>	No
<b>TRIPURA</b>						
18	PK Bari(Planned for 400kv,charged at 132kv)	NER	<b>2</b>	Silchar, Palatana	<b>1</b>	No
<b>MANIPUR</b>						
19	Loktak (132 kv)	NER	3	Jiribam 1,2, Churachandpur	2	No
20	Jiribam(132 kv)	NER	3	Loktak1, 2,Panchgram	2	No
		<b>Total</b>	<b>6</b>		<b>4</b>	
<b>MIZORAM</b>						
21	Aizwal(132 kv)	NER	<b>1</b>	Aizwal	<b>1</b>	No

**Contd...**

## NORTH EAST REGION-Ph II

S.No.	Name of Station	Region	Number of Feeders	Name of Feeder	No. of PMU	Fibre Optic Availability
<b>CENTRAL</b>						
<b>400 kV S/S</b>						
1	KATHALGURI(400 kv,Charged at 220 kv)	NER	2	220kV Mariani (New),220kVMariani, 220kV Mukum	1	No
2	RANGANADI	NER	2	B'Charyali 1&2	1	No
3	Pallatana	NER	2	Silchar, PKBARI	1	No
4	BTPS	NER	4	Salakati 1&2, Agia 1&2,	2	No
<b>220 kV S/S</b>						
5	Mockochung	NER	2	220kV Mariani (New) 1&2	1	No
		<b>Total</b>	<b>12</b>		<b>6</b>	

# Updated Cost

- Updated cost due to increased scope:
  - As part of unification, installation of PMUs in IPP generation switchyard considered. Increase in PMU, OPGW and communication equipment
  - Cost for developing of analytics
  - Increase in unit cost of Phasor Data Concentrator(PDC) & Data Archiving Hardware
  - Provision for auxiliary power supply at control centres(SLDC/RLDC/NLDC)
  - Erection, testing & commissioning for communication infrastructure



# Cost Benefit Analysis

- Presently corridor transfer capability(TTC) calculation is through offline software.
- May sometime lead to unused transfer capability & lost opportunity cost.
- WAMS measurement will allow precise measurement of TTC based on actual measurement.
- This will increase effective capacity of congested lines ,increase transmission asset utilization & effective capacity of congested line.

# Cost Benefit Analysis

S.No.	Description	Unit	Value
<b>A</b>	Cumulative transmission capacity of Inter-Regional corridor	MW	28000
<b>B</b>	Transfer capability in the month of Mar'2012 for inter-regional corridor	MW	8500
<b>C</b>	Monthly Increase in Transfer capability after implementation of WAMS (say 10% of B)	MW	850
<b>D</b>	Annual increase in transfer of power in inter-regional corridor terms of energy $(850 \times 0.40 \times 8760) / 10^3$	MU	2978
<b>F</b>	Increase in Revenue due to increased TTC/ATC (Assuming 1kWhr = Rs. 2)	Rs. cr	595

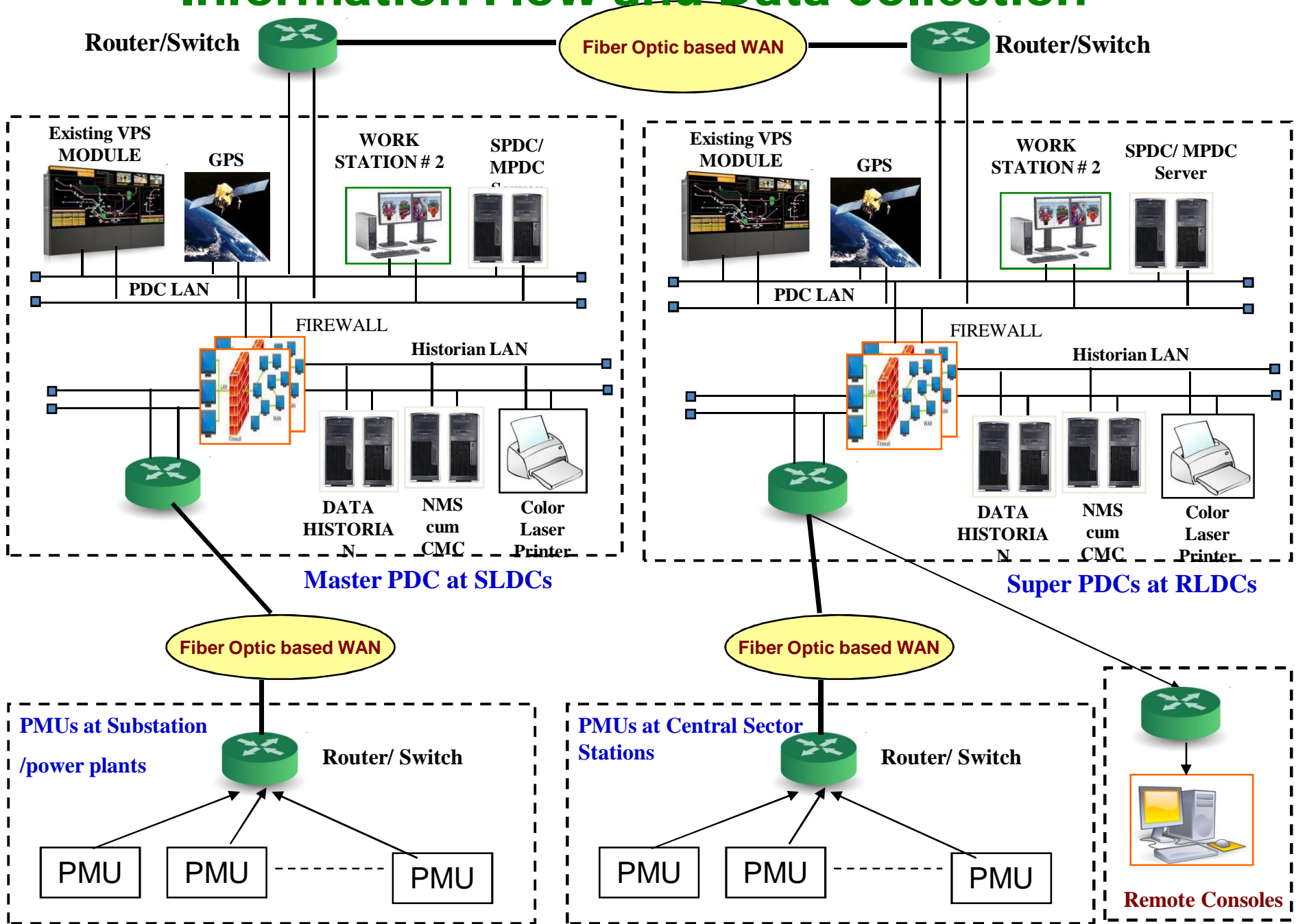
# Benefits

- With real time information on angular separation between buses, voltages/currents, transmission system loadability may be improved. This would result in better utilization of resources
- Early detection of critical conditions in the grid would facilitate timely and corrective actions to avert grid disturbance. This would avoid financial losses (in case of blackout)
- System oscillations may damage various equipment and reduces its life. Detecting such oscillations on real time and taking actions would enable healthy operation of the machines for a longer period, and thus optimizes their performance
- Would enable improvement of knowledge of the power system real time conditions to facilitate operator at the control centers to take corrective control actions (viz. avoiding unnecessary load shedding)

# Benefits

- Would enable development of back up control & protection schemes for emergent grid conditions
- With the better visibility and situational awareness of the operators at the control centres about system dynamics, defense Plan/ Islanding scheme(s) can be designed and made operational to avert grid collapse
- Objectives of secure, safe, reliable and smart grid operation will be achievable through WAMS
- Economically, if the above technical and operational benefits are translated into cost, it would avoid substantial financial losses and also enable to make optimal investment for transmission system planning & development

# Information Flow and Data Collection



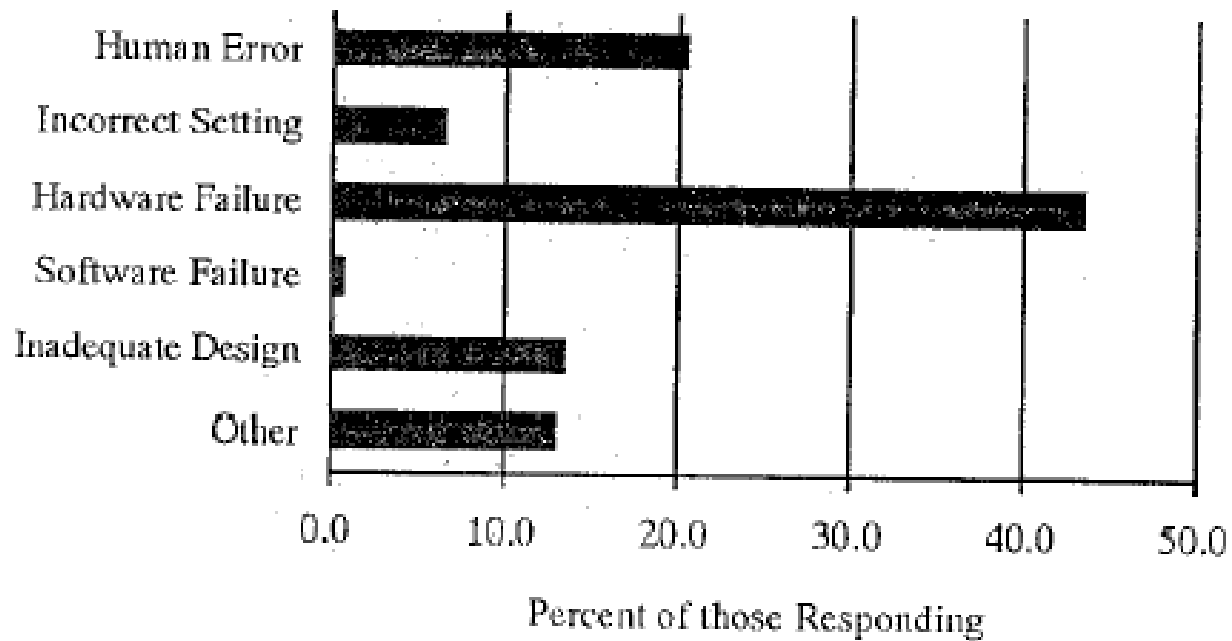


Figure 3 Dominant Causes of SPS Failure

This is before the advent of WAMS

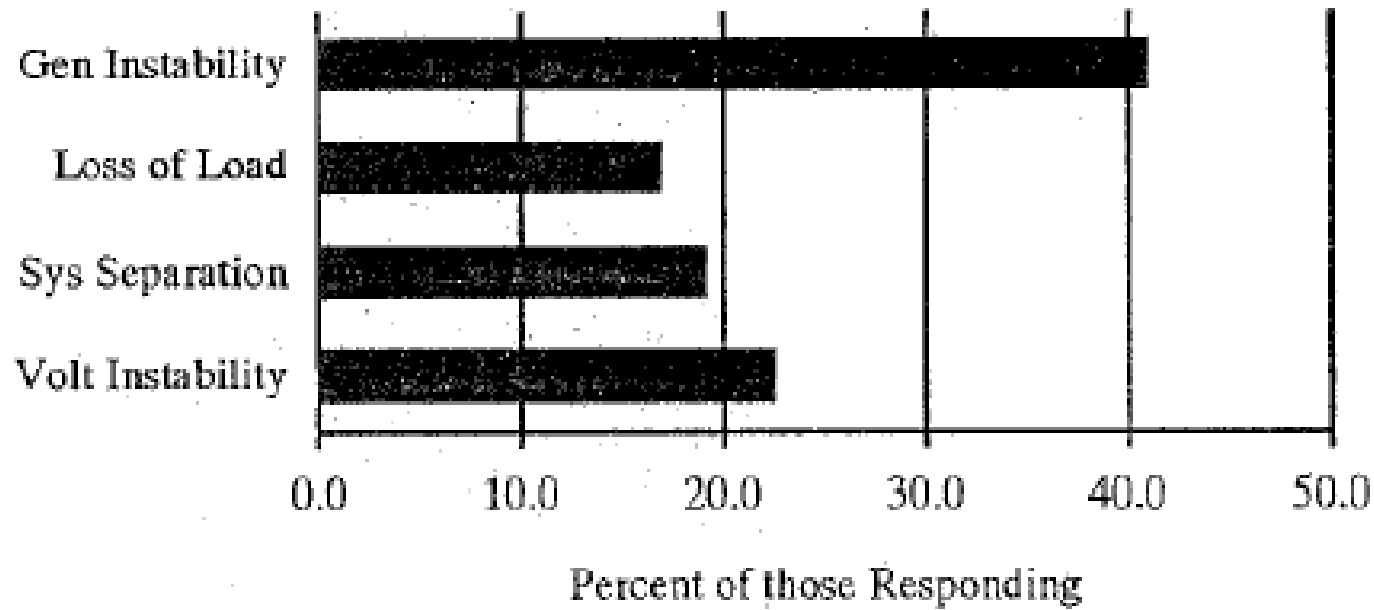


Figure 4 Primary Effects of SPS Failure

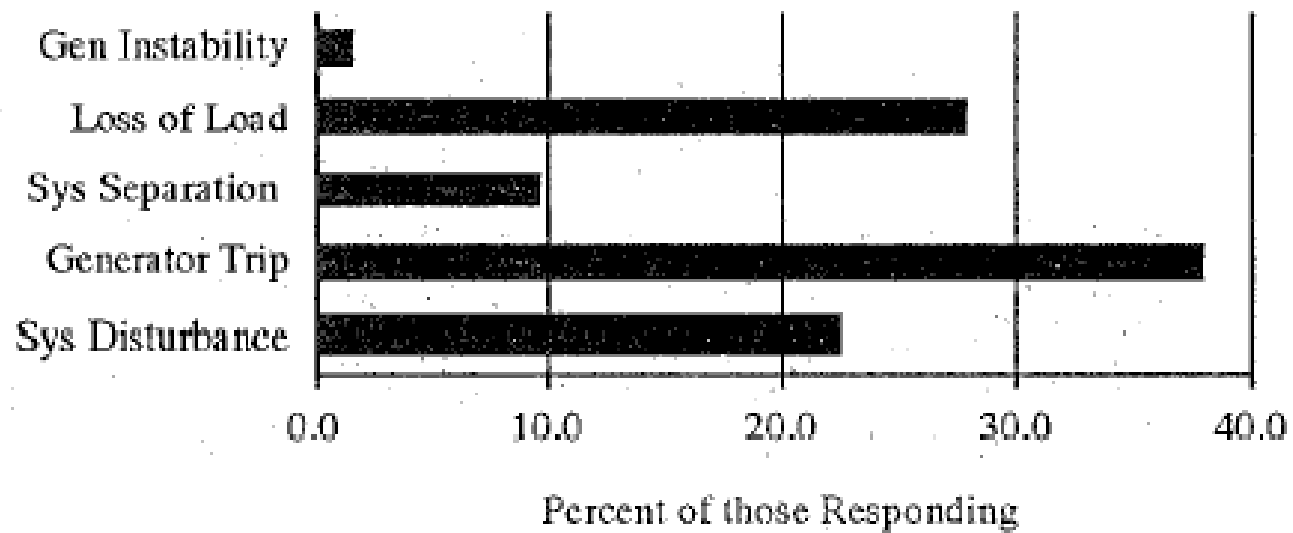


Figure 6 Effect of SPS Unnecessary Operation

This is before the advent of WAMS

# Operational Statistics

- Summary over 1986-1992
  - Successful Operations : 1093
  - Failures : 36
  - Un-successful operations : 20
  - Unnecessary operations : 306

This is before the advent of WAMS

# IEEE PSRC Report on Global Industry Experiences with System Integrity Protection Schemes (SIPS)

- Adaptive Load Mitigation
- Out-of-Step Tripping
- System Separation
- Shunt Capacitor Switching
- Tap-Changer Control
- SVC/STATCOM Control
- Turbine Valve Control
- HVDC Controls
- Power System Stabilizer Control
- Discrete Excitation
- Dynamic Breaking
- Generator Runback
- Bypassing Series Capacitor
- Black-Start or Gas-Turbine Start-Up
- AGC Actions
- Busbar Splitting

# URTDISM Scheme Cost

<b>S.No</b>	<b>Description</b>	<b>Earlier-</b>	<b>Present</b>	<b>Earlier Cost-Cr</b>	<b>Present Cost-Cr</b>
1	PMU & Phasor Data Concentrator	1669+59	1739+64	8.85	18
2	FO & Communication Interface	5000 Km	10600 Km	100	175
3	STM & SDH Eqpt.	230	300	16	21
4	Analytical Software			0	35
5	Spares & Auxiliary supply		32(Control Centre)	0	16
6	Erection Testing & Commissioning OPGW & others	10%		17	92
7	IDC				55