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FIRST STEPS TOWARDS SYNERGISING COMMUNICATION SYSTEM, WAMS AND SITUATIONAL AWARENESS SYSTEM

by

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SUMMARY

India faces major challenges both today and in near future for the growth and improvement in reliability of its electrical infrastructure alongwith bridging the gap between demand and supply. This is a gigantic task to accomplish involving multiple stakeholders. July-2012 grid disturbances in India highlighted the fact that, some of the important aspects needing attention in Indian Power Sector can be broadly listed as follows:

i. Various Technical issues involved in Generation, Transmission and Distribution sector from Planning to Commissioning, Grid Operation, Operation & Maintenance etc
ii. Grid discipline related issues,
iii. Commercial matters and Administrative issues,
iv. Skilled manpower related issues,
v. Proper planning and studies at Central and State level in coordinated manner considering the needs of various DISCOMS,GENCOS, Renewables etc.
vi. Timely execution of projects,
vii. Adoption to the proper guidelines regarding Grid operation, Operation and Maintenance at Centre and State level and following the same religiously,
viii. Complexities and ambiguities in regulatory processes,
ix. Proper co-ordination amongst various stakeholders at Centre, State level utilities and down below with private players, IPPs, CPPs, Renewable Energy Developers and Operators, etc.
x. Developing improved work culture amongst various stakeholders of power sector and creating awareness in society towards its role in developing this sector.

As far as proper operation, monitoring and control of the grid is concerned, it is important to adapt and adopt smarter technologies to achieve the goal of reliable, good quality power supply 24x7. Maharashtra State Electricity Transmission Company Limited (MSETCL) has realized the importance of Wide Area Measurement Systems (WAMS) and started the initial work towards developing WAMS system with a pilot project to experience the advantages of it.
This paper describes initiatives taken up by MSETCL in developing WAMS technology with due considerations to communication system requirements.

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The paper discuses in brief Maharashtra State Electricity Transmission Company Ltd. (MAHATRANSCO/MSETCL) experience in developing Wide Area Measurement Systems(WAMS) with due considerations to communication system requirements. Communication system architecture and related issues considering various real time and offline applications in MSETCL system like Supervisory Control And Data Acquisition (SCADA), Availability Based Tariff (ABT) mechanism, Enterprise Resource Planning (ERP) as well as WAMS along with tentative bandwidth requirement for these various applications. It briefly covers MSETCL experience in analyzing one of the occurrences in the grid with the help of synchrophasor system. This paper also focuses in brief on some of the initial integrational issues involved in first of its kind experience in India of integrating Synchrophasor System with Situational Awareness System for better operation, monitoring and control with improved observability of the grid.

KEYWORDS

Communication system, Bandwidth, SCADA, ABT, ERP, WAMS, Situational Awareness, SMARTGRID.

1. MSETCL INFRASTRUCTURE AND REQUIREMENT OF WIDE AREA MEASUREMENT SYSTEM.

MSETCL infrastructure comprises of 584 EHV substations, 99,716 MVA of transformation capacity and 41,390 CktKms of line as of 31st March 2013. It is the largest State Transmission Utility in India. MSETCL is the only State Transmission Utility in India which operates and maintains +/- 500kV HVDC system.

MSETCL/MAHATRANSCO is a part of synchronous North-East-NorthEast-West (N-E-W) grid, which is asynchronously connected to the Southern grid. MSETCL network is spread over seven zones across the State of Maharashtra.

Following are some of the important reasons to consider implementation of WAMS technology in MSETCL.

i) Majority of Geneartion that from the State owned utilities, IPPs is concentrated in the Eastern part of Maharashtra whereas major industrial development and major load centres are in Western part of Maharashtra. This emphasises the need of robust transmission network to carry power from one part of the State to the other part.

2)Generation capacity addition should be at least to meet electricity requirement for achieving GDP growth of 6-7%.Thus increase of generation demands development of corresponding evacuation and transmission capabilities.

3)Interregional power transfer is also on rise year by year and MSETCL being one of the largest transmission utility in the country large amount of power would also flow through its network. Apart from this, MSETCL as a STU has a responsibility of transferring power within the state of Maharashtra once it is made available through CTU network.

4) Necessity to monitor dynamic behaviour of the grid

5) Multiple power exchanges working in the country influence pattern of powerflows considering "Market" as one of the factors deciding these powerflows.

6)Necessity to adopt advanced technologies to Operate, Monitor and Control the grid to maintain it intact and comply with the grid code regulations and grid Standards as specified by Maharashtra Electricity Regulatory Commission (MERC) and Central Electricity Regulatory Commission (CERC).

2. IMPORTANCE OF COMMUNICATION SYSTEM IN TRANSMISSION SECTOR

Today's power system functioning has become complex and interdisciplinary in nature that requires working in integrated manner with due considerations to Telecommunication and Information Technology (IT). This section discusses in brief some of the important aspects related to communication technologies to be considered while developing different applications in transmission field.

There are various applications in transmission system like RTU-SCADA system, Availability Based Tariff (ABT) system, Enterprise Resource Planning (ERP) system and Management Information System (MIS), Substation SCADA, VOIP, Video Conferencing, Wide Area Measurement system (WAMS) etc those depend on communication system for proper data transfer / communication from remote sites to central location as well as for satisfactory functioning of these applications.

Following are some of the important communication system considerations requiring attention while developing various applications in Transmission system:

As establishing communication media for data transfer from various applications involves cost, due consideration needs to be given for bandwidth requirements of different applications being used in transmission system. Following are some of the important points associated in its considerations.

a) Application, application parameters and its standard

b)Criticality of application whether real time or Offline

c) Latency of application and various Quality of Service (QoS) parameters linked to it

d) Type of communication media envisaged

3. COMMUNICATION SYSTEM ARCHITECTURE IN MSETCL

Currently MSETCL uses leased lines as well as optical fibres at selected locations for communication purpose. As shown in fig.1, substation data for the different applications like RTU -SCADA, ERP, ABT, and VOIP are connected to an 8 port layer-2 LAN switch. The LAN switch is connected to Cisco make MPLS router for communicating with the external world. There are different types of last mile connectivity in use like RF, VSAT and optic fibre at different locations in MSETCL. Fig.1 shows communication system architecture in MSETCL.

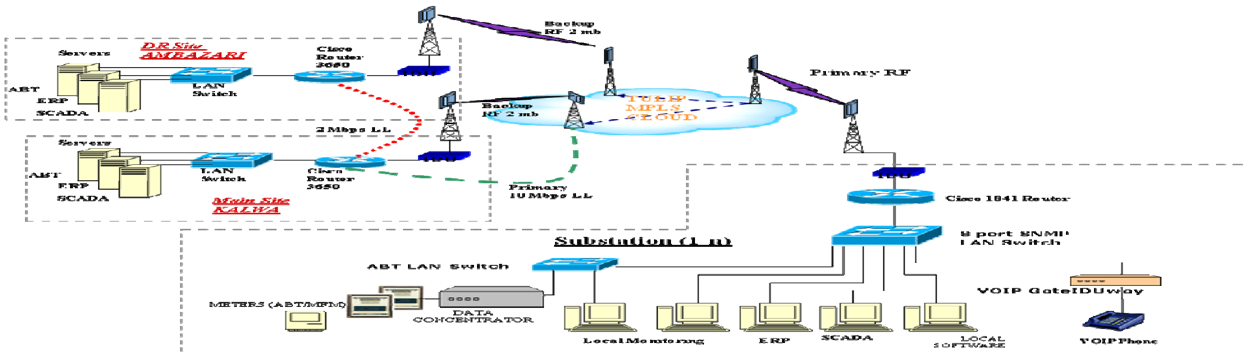

Fig.1: Communication System architecture in MSETCL .

4. CONSIDERATION S TO BANDWIDTH UTILISATION OF VARIOUS APPLICATIONS IN MSETCL

This section discusses in brief bandwidth utilisation for different applications in MSETCL with 400kV Dhule substation as an illustration. It covers applications like RTU-SCADA, ERP, ABT, VOIP and WAMS for this purpose.

A. Communication bandwidth usage for RTU-SCADA at 400kV Dhule Substation

At 400kV Dhule data from downstream RTUs is sent to RTU-DC at 400KV Dhule substation and from here data is sent to State Load Despatch Centre (SLDC)-Kalwa and Area Load Despatch Centre(ALDC)-Ambazari which is a back up control centre. 400KV Dhule substation is having last mile connectivity as RF. The RTU is communicating with the central SCADA in the standard IEC 60870-5-104 protocol. The total bandwidth usage by the RTU for remote communication depends on the number of signal points that the RTU need to share. Below table shows some configuration parameters in the protocol drivé of the RTU that will affect the communication bandwidth.

Data Type	Update rate	ASDU type
Single point information with 56 Bit time stamp	Upon change	30
Double point information with 56 Bit time stamp	Upon change	31
Measured value, short floating point value	Upon change	13

Table1 : Signal Update rate in Dhule Substation

Configuration data	Value
COT size in Octets	2
Common Address of ASDU Size in octets	2
IOA size in octets	3

Table-2: Protocol configuration Parameters in Dhule Substation

IEC60870-5-104 communication protocol has defined the packet size of each OSI layer as per the standard layers that supports. As per the standard the application layer packet size depends on the configuration data mentioned in the above tables. The below table shows the bandwidth required for a RTU with some of the typical signal count. The table shows physical layer data bandwidth size .

	ASDU type		
Number of signals from RTU for 10 number of substations to RTU-DC at Dhule	**30**	**31**	**13**
Total	**633**	**459**	**337**

Table3 : RTU to RTU-DC Number of signals at 400kV Dhule Substation
The bandwidth required for this communication depends on the type of signal as each ASDU type of data is having different packet size.
The RTU-DC communicates with the SLDC as well as backup control center and update all the data collected from the RTUs and the local substation data .The number of signals fetched from the Local substation is mentioned as below:

- Single point information with 56 Bit time stamp-96
- Double point information with 56 Bit time stamp-86
- Measured value, short floating point value-56

Signal type	Total Number of Signals	Update all signals in 1 sec (Kbps)
Single point information with 56 Bit time stamp	633	59.736
Double point information with 56 Bit time stamp	459	43.576

Measured value, short floating point value	337	23.488
	Total	**126.8**

Table 4: Bandwidth utilization for RTU at Dhule for fetching the RTU data

Signal type	Total Number of Signals	Update all signals in 1 sec (Kbps)
Single point information with 56 Bit time stamp	710	67.36
Double point information with 56 Bit time stamp	525	50.232
Measured value, short floating point value	380	26.24
	Total	**143.83**

Table 5: Bandwidth utilization for RTU-DC at Dhule for SLDC communication

Signal type	Total Number of Signals	Update all signals in 1 sec (Kbps)
Single point information with 56 Bit time stamp	710	67.36
Double point information with 56 Bit time stamp	525	50.232
Measured value, short floating point value	380	26.24
	Total	**143.83**

Table 6: Bandwidth utilization for RTU-DC at Dhule for backup control center communication

Communication with	Update all signals in 1 sec (Kbps)
Bandwidth utilization for RTU at Dhule for fetching the RTU data	**126.8**
Bandwidth utilization for RTU-DC at Dhule for SLDC communication	**143.83**
Bandwidth utilization for RTU-DC at Dhule for backup control center communication	**143.83**
Total Bandwidth utilization for RTU-DC at 400 kV Dhule substation	**414.46**

Table 7: Total bandwidth utilization for RTU-SCADA in Dhule Substation

B. ERP Bandwidth utilisation at 400kV Dhule Substation

The ERP system bandwidth requirement depends on the number of users of the ERP system and the modules that each user is using. Each ERP module requires different communication bandwidth.

Following two assumptions are made while calculating bandwidth for ERP-SAP requirements at Dhule substation

- Based on the ERP usage at Dhule substation in MSETCL it is assumed that, only 50% of the users are using the modules at the same time.

- SAP Modules(SAP R/3,Portal,ESS,Reports),MS mail and DMS will not be used by the ERP users at the same time

Following table gives total bandwidth requirement of ERP users at 400kV Dhule substation.

Number Of Users	**4**	**4**	**4**	**4**	**4**	**4**
Modules	SAP R/3	Portal	ESS	Reports	MS Mail	DMS
Bandwidth required for single user in Kbps	56	80	20	50	128	128
Total bandwidth required in Kbps	224	320	80	200	0	0
Total bandwidth For ERP in Kbps at 400 kV Dhule Substation	**824**					

Table 8: Bandwidth utilization for ERP in Dhule Substation

C. ABT Bandwidth utilisation at 400kV Dhule Substation

This section discusses in brief requirement of bandwidth for transferring Availability Based Tariff (ABT) metering data for energy accounting purpose from Dhule substation to SLDC. As per ABT mechanism in Maharashtra data is updated at SLDC at the interval of 5 minutes and energy accounting is carried out in 15 minutes block. The DCU installed in the substation uses the leased line to transfer the data file that contains the meter data to SLDC. The file size in the DCU is around 6 KB. As per the FTP standard the transfer of 6KB file to remote FTP client passes around 10KB data through the communication channel. In Dhule Substation there is only one DCU installed for the ABT purpose. Considring this,bandwidth requirement for ABT system at Dhule is as shown in table-9.

DCU file size	6KB
Number of DCUs	1
Number of FTP servers	1
Total data transfer in FTP for each DCU	10KB
Total data transfer in ABT system	10KB
Total bandwidth in kbps	**5.33**

Table 9: ABT bandwidth utilization in Dhule Substation

D. VOIP Bandwidth utilization at 400kV Dhule Substation

There is a VOIP gateway and one Phone installed in Dhule substation. The VOIP gateway is connected to the substation LAN and the same is connected to the Phone .This VIOP is also communicating with the same leased line. The gateway used for VOIP is MG3000-A2 FXS VoIP Gateway (ATA). As the voice code is G.711A the bandwidth required for VOIP gateway is around 87.2 Kbps.

E. WAMS bandwidth at 400kV Dhule Substation :

As per synchrophasor standard of C37.118, while calculating bandwidth requirement for WAMS application at 400kV Dhule substation following data and procedure is adopted.

Planned Data Set for PoC	No.of Data	Data Format
Number of Phasors	6	Floating Point
Number of Analog	4	Floating Point
Number of Digital	16	Digital
Total frame/Sec	25	
Calculations:		
Field	Size (Bytes)	
SYNC	2	
FRAMESIZE	2	
IDCODE	2	
SOC	4	
FRACSEC	4	
STAT	2	
PHASORS	48	
FREQ	4	
DFREQ	4	
ANALOG	16	
DIGITAL	2	
CHK	2	
Total Data Frame Size	92	
Total Bits/PMU Data	**736**	
Overhead		
UDP	8	
IP	20	
Ethernet headers	18	
Total/Overhead/Frame	46	
Total Bits	**368**	
Total bits/Frame	**1104**	
Total bits/Second	27600	
Minimum bandwidth required at PMU with 6 phasors	26.953125	kbps

Table 10: Bandwidth requirement for WAMS application at 400kV Dhule substation

Thus minimum bandwidth requirement is 26.95kbps,say 27kbps.Considering future synchrophasor based application need bandwidth is assumed on higher side for WAMS application and it is assumed to utilise 128 kbps at 400kV Dhule.

Following table gives total communication bandwidth utilisation at 400kV Dhule substation for various applications like RTU-SCADA, ERP, ABT, VOIP and WAMS which comes out to be 1.47Mbps.

Bandwidth for RTU data Communication	**414.46Kbps**
Bandwidth for ERP data Communication	**824Kbps**
Bandwidth for ABT data Communication	**5.33 Kbps**
Bandwidth for VOIP data Communication	**87.2Kbps**
Bandwidth for WAMS data communication	**128.0**
Total bandwidth requirement	**1479.53 Kbps (1.47Mbps)**

Table 11: Total bandwidth requirement for various applications in use at 400kV Dhule substation

5. MSETCL INITIAL EXPERIENCE WITH WAMS AND SITUATIONAL AWARENESS SYSTEM

MSETCL has installed 15 numbers of PMUs across the Maharashtra network covering major generating stations, critical 400kV substations and important grid substations even of 220kV level in the system, such that proper observability of State as well as Regional grid is achieved. Fig.2 shows the architecture of WAMS infrastructure in MSETCL.

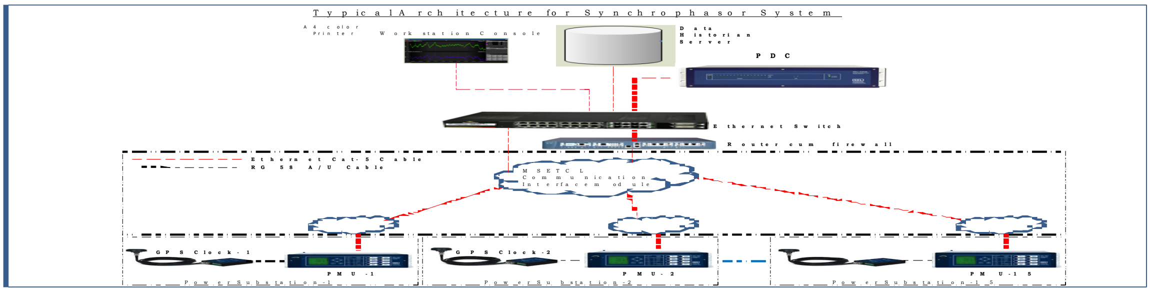

Fig.2: Architecture of WAMS infrastructure in MSETCL.

A. Occurrence at 400kV Deepnagar Substation and calculation of H

400kV Deepnagar is a generation attached substation in Maharashtra system. On 22.05.2013, at 22 :48 :22 :200 Hrs, it is observed that, R phase Bus-1 CT of GT-5 bay failed and burst resulting into operation of busbar protection of main Bus-I. The bursting of CT further caused consequential damages to adjacent equipment like other CTs, Bus Post Insulator, Synchronizing CVT, isolator, insulator etc. At the same time, B phase pole of main CB of 400 kV Khadka Circuit-2 failed and burst. The bus bar protection for Main bus-2 also operated. Thus, both the 400 kV buses became dead resulting into failure of supply at 400kV Deepnagar substation. This occurrence has also resulted into generation loss of 531MW in the state grid.
Fig.3 shows frequency and df/dt variations as sensed by PMUs in Maharashtra grid. In this case rate of change of frequency (df/dt) recorded by PMU's is utilised to calculate inertia constant for Maharashtra system as follows.

$H = (\Delta P / P) * f_0 / (2 * df/dt)$

Here ΔP - Generation loss during occurrence

P - Total Generation in Maharashtra on 22.05.2013

f_0 - Frequency before the disturbance

$H = (531) / (15973) * 50.02 / [2 * (-0.119)]$

H = -6.25 Sec.

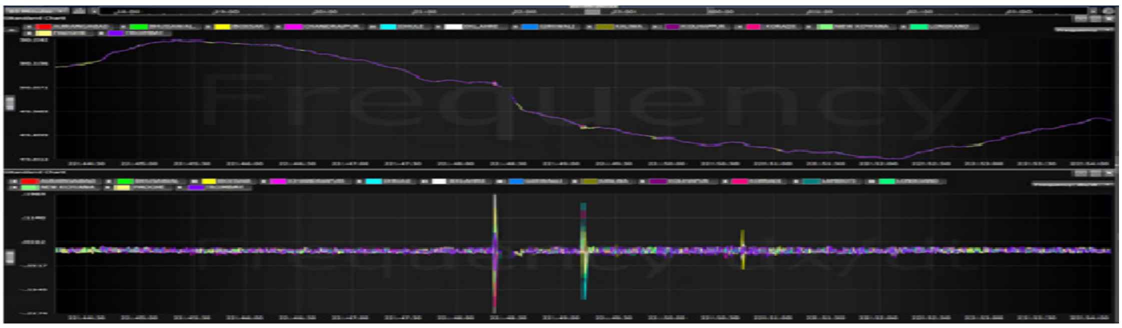

Fig.3: Frequency and df/dt variation during occurrence of 22.05.2013 at 400kV Deepnagar.

B. Initial Integrational experience of Synchrophasor system with Situational Awareness system

This section discuses in brief MSETCL initial experience in integration of Synchrophasor system with Situational Awareness system. Fig.4 shows dataflow from PMUs to Situational Awareness system in MSETCL. In this case data from PMUs at different locations in MSETCL system is sent to PDC located at SLDC-Kalwa. This data is further sent to Situational Awareness System through converter.

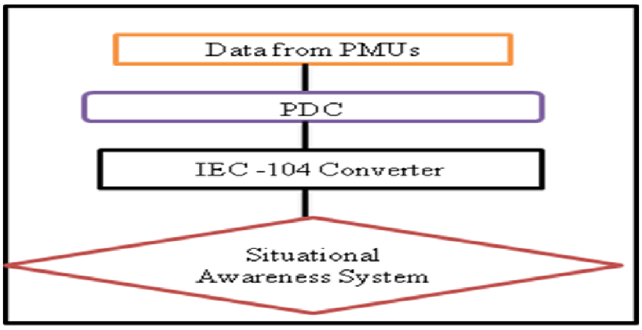

Fig.4: Dataflow from PMUs to Situational Awareness system

Fig.5 indicates status of data being sent properly from converter to Situational Awareness system

	Server	Connection State	Missing Data	Sent Data Frames
	VISUALIZATION(Primary)	Not Connected		0
	VISUALIZATION(Secondary)	Sending Data	Yes	7770709
	IEC-104	Sending Data	Yes	3123234

Fig.5 : Status of data being sent from Converter to Situational Awareness system

Fig.6 shows that, converter is not communicating with Situational awareness system.

Fig.6 : Converter not communicating with Situational Awareness system

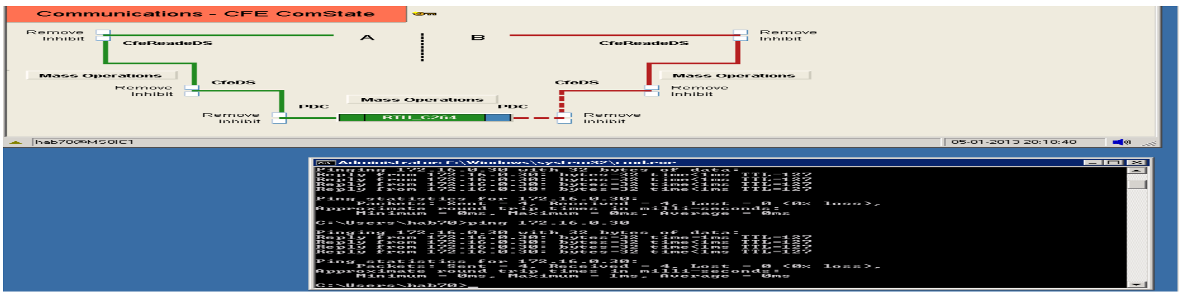

Fig.7 : Status of data transfer through Converter to Situational Awareness system

Fig.7 shows data being sent satisfactorily from PDC to Converter and further to Situational awareness system resulting in successful integration of Synchrophasor system with Situational awareness system.

6. CONCLUSION

This paper discuses in brief role of communication system in transmission sector, bandwidth utilisation for different application in transmission including WAMS. It also discusses in brief MSETCL initial experience with Synchrophasor system alongwith brief information on initial integration related issues between Synchrophasor system and Situational awareness system.

7. ACKNOWLEDGEMENT

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8. BIOGRAPHIES

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