Wide Area Monitoring systems (WAMs)

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***Abstract*— Based on prediction, the penetration of renewable resources has been increased up to 40% of total power demand in India till 2022. The complexity of the network has been increased due to presence of renewable resources. In order to improve the performance and efficiency of the power system, implementation of WAMs is essential. In this study, need and basics of WAMs are presented. This paper presents the need and basics of WAMs. Moreover, conceptual lay out of WAMs is also elaborated. Further, the main components of WAMs and its superiority with Supervisory Control and Data Acquisition System (SCADA) has been shown. Furthermore, application of WAMs in real time power system network has been elaborated. In addition, conceptual lay out of Phasor Measurement Unit (PMU) and working of its different parts has been explained. At last, the different locations in India where PMUs are installed has been listed.**

***Index Terms*— Communication channels, Global positioning system, PMU, WAMs**

I. INTRODUCTION

Day by day, the awareness about green energy has been increased. It has been also noticed that innovative technologies are implemented to improve the performance of existing renewable resources [1], [2], [3]. Still today this subject motivates many researchers to do their research in this area. Due to the penetration of renewable energy sources in the existing grid, the complexity of the power system network has been increased [4], [5]. In order to maintain the reliability, performance and efficiency of the power system, it is required to do optimization of the complicated network. Subsequently, WAMs are used to take counter measures and its helps to perform optimal utilization of resources [6]. Many researchers have done work on WAMs for the optimal unit commitment [5]. Nowadays, adaptive protection is also one of the major advantages serves by WAMs [7], [8]. The basic terminology of WAMs and its basic models has been suggested in [5]. Further, this basic model has been modified and new model of WAMs involves many new components [9], [10], [11]. However, the western country had done lots of research about WAMs application but in India it is still in State of Art Phase [12], [13]. This paper presents some key factors about implementation of WAMs in Indian scenario.

II. NEED OF WAMS

Nowadays, global warming is one of the biggest threat on this earth. It disturb the cycle of the atmosphere and causes adverse effect to human health. Further, air pollution of industries and internal combustion vehicles contribute the major role [12]. However, preventive steps are taken by using innovative ways to minimize the level of air pollution, In case of electrical power generating plants, coal base conventional power stations are one of the main culprit for air pollution [14]. Subsequently, in order to reduce the level of pollution generated due to coal based power plant, renewable power generators are anticipated. The latest power generating scenario in India is shown in Table 1. It has been observed from Table 1 that the thermal power plant has highest contribution compare to other plants (i.e. 59%). The hydro and renewable sources occupies second and third place, respectively.

Table 1 Summary of generation with different electrical power resources in India

Sr. No	Mode of generation	Capacity (GW)	%age
1	Thermal power plant	195	59%
2	Hydro power plant	45	14%
3	Nuclear power plant	7	2.1%
4	Diesel power plant	0.85	0.2%
5	Gas power plant	25	7.69%
6	Renewable energy plant	57	17.4
	Total	330	

In order to promote the green energy concept the penetration of renewable sources should be increased. However, presence of renewable resources at distribution level makes bi directional flow of electrical power. Subsequently, the power system network becomes complicated [7]. Hence, in order to regulate the power, it is required to monitor power generation from different sources on continuous basis. In this case concept of WAMs helps the central power authority to regulate the power smoothly. WAMs collect data from global positioning system through satellite. In addition, the data are synchronized using satellite time clock. Due to this data analysis and interpretation becomes easy. Fig. 1 shows conceptual lay out of WAMs.

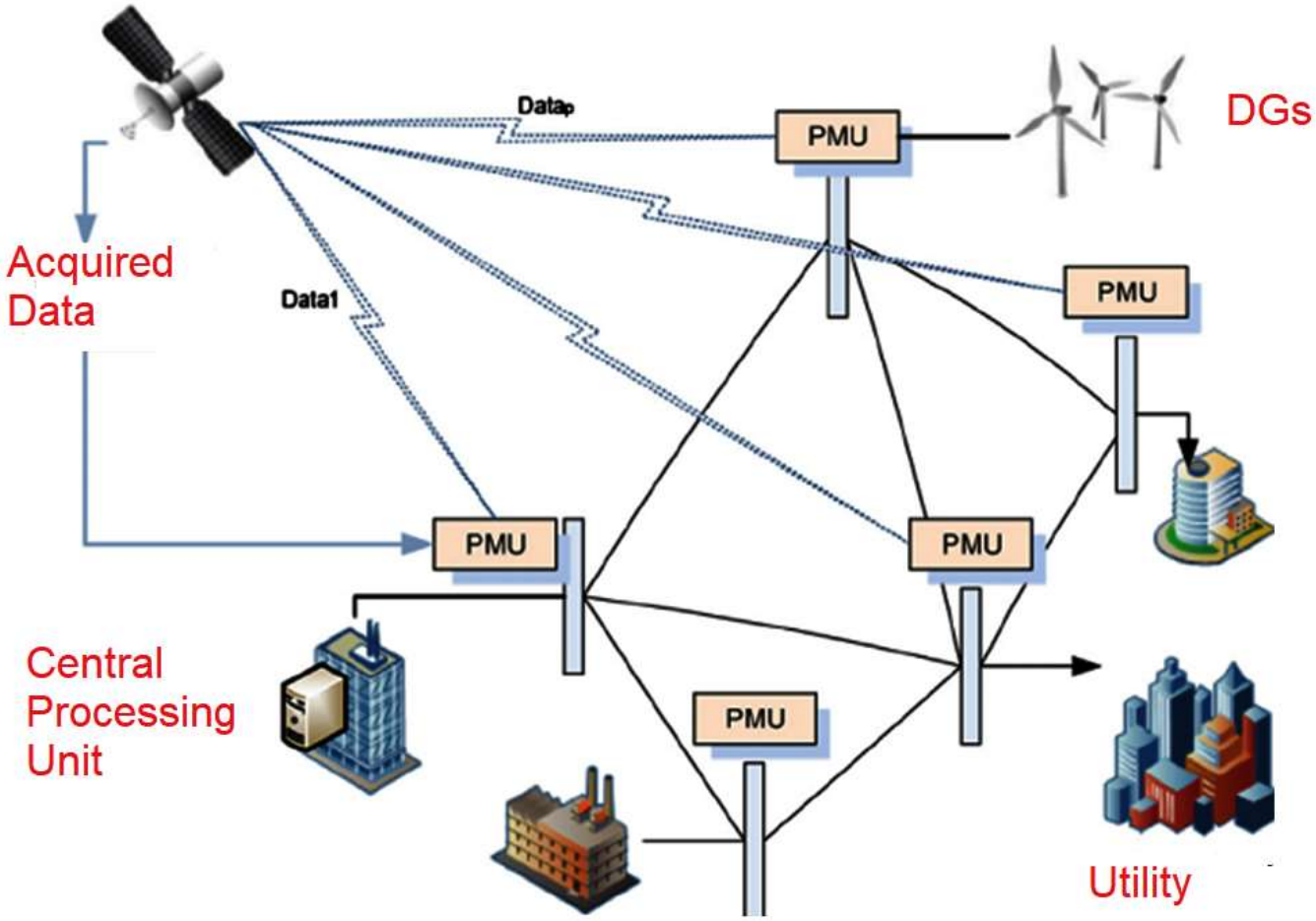

Fig. 1 Conceptual layout of WAMs

It has been observed from Fig. 1 that Phasor Measurement Units (PMUs) are located at different places to acquire the data from various places. In order to maintain the observability of entire power system network, the location of PMUs are selected. All the data which are collected from different PMUs are supplied to Central Processing Unit. In literature, Central Processing Unit may define as a Control Unit [9]. This data are separated by month wise, season wise and day wise. Unit. Based on these recorded data the load forecasting has been done. Moreover, the amount of power generation by different conventional plants (utility) and other Distributed Generators (DGs) are determined. Based on IEEE, WAMs is a corrective technology to monitor power system dynamics in real time, analyze system stability and helps to take immediate counter measures. The main benefits of WAMS are as follows

a) It improves system reliability and it is east to analyze pre and post disturbance condition.
b) It provides real time monitoring of entire network.
c) It makes system restoration easy.
d) It helps to provide adaptive protection to the network components.
e) It provides ease to identify sequence of event in case of outage.

The comparative evaluation of WAMs technology (PMU) with Supervisory Control And Data Acquisition (SCADA) is shown in Table 2. It has been observed from Table 2 that WAMs technology measures magnitude and phase angle both. Further, it provided synchronized clock based data which means it does not suffer with time scaling problems. Moreover, one unit of PMU has 16 digital and 16 Analog channel for input and output interference. Hence, this system can be used for wide area measurement. It is far more superior that SCADA technology.

Table 2 Comparative evaluation between SCADA and WAMs technology (PMU)

Parameter	SCADA technology	WAMS technology
Resolution	20-30 samples per minute	600-3600 samples per minute
Measured technology	Magnitude only	Magnitude and phase angle both
Time synchronization	Not available	Available
Input and Output channel	100 plus analog and few digital channels	10 Phasor, 16 analog, and 16 digital
Focus	Local monitoring control	Wide area measurement

III. BASIC OF WAMS TECHNOLOGY

3.1 WAMs network

WAMs consist of following components

a) Global Positioning System (GPS)
b) Communication channels
c) PMU
d) Phasor data concentrator
e) Visualization and analysis tool
f) Wide area situational awareness system
g) Wide area protection system

WAMs process includes three different subsystems, namely data acquisition, data transmitting, and data processing. Global positioning network is required for synchronization of phasors. GPS, PMU, phasor data concentrator, and communication channels form data acquisition and transmission system which collect the data from the real field and transmit to control room. Thereafter visualization and analysis tools are used to detect the health of the network. This gives awareness about the real time condition of the network[11]. In case of emergency, the wide area situational awareness system provides alarm or emergency signal to indicate the abnormality of the system. Moreover, analysis of the acquired data helps to provide adaptive protection for the apparatus of the network. Moreover, measurement system and energy management system helps to improve the optimal usage and increase the overall efficiency of the system.

3.2 Data resources

Normally the data resources used in WAMs acquires two types of data, namely, operational data and non-operational data. The details of operational and non-operational data is mentioned as below.

a) Operational data: It is continuous stream of data. Measurement of voltages, currents and bracker status lies under this category. Intelligent Electronic Devises (IEDs) are used for this purpose. It has been carried out using Synchronized Phasor Measurement Unit (SPMU).
b) Non-operational data: This data is available after specific time interval. Records of fault events, power swing events and any abnormality of the system lies under this category.

SPMU provides string of data for voltages and currents at different buses of the system and angle between them. SPMU consist of three main parts

a) PMU
b) Communication channels
c) Phasor data concentrator

PMU is microprocessor based electronic device which takes 20-40 samples in a cycle. These measured data are tagged with time stamp by GPS and transmitted to phasor data concentrator. PMU communicates with other devices using internet protocol. In order to establish communication between phasor data concentrator and PMU initially configuration frame is sent from phasor data concentrator to PMU after receiving the frame, again the configuration frame is sent to phasor data concentrator. Both side authentication has been done and afterwards the communication between these two established. Further. Phasor data concentrator is bi directional communicating device [13]. It collects the data from PMUs are make time stamp on it. Thereafter, this data has been stored. Moreover, communication links will also performed secured bi-directional communication. It maintains bi directional flow of data at a fast rate.

3.3 Application of WAMs

WAMs collects raw data from different points of the network and extracts useful information from the data about abnormality, power swing, and all the major and minor event occurred different location of the network. Different applications of the WAMs are listed as below

a) Generator Side: WAMs provides current operating status of the generator with its transient stability status
b) Transmission network: It provides data and calculate state estimation, load flow, optimal dispatch, and frequency control. It also do load forecasting
c) Distribution network: It provides data and calculate load flow for distribution network. It also give information about system side, consumer side and substation side automation. Moreover, it gives data regarding system restoration, black outs, and line drop compensation

In addition, WAMs also provides data about voltage stability monitoring, loss of line, local oscillations, reactive power shortage, congestion of the transmission line, heavy load and loss of synchronization.

IV. PMU BLOCK DIAGRAM AND ITS SCENARIO IN INDIA

Fig. 2 shows block diagram of PMU. It has been observed that GPS receiver collects data from the different location and synchronized with global clock. Each data collected by GPS receiver or analog input are provided with time stamped. This thing improves validity of the data and during analysis exact consequences can be determined. In order to transmit the collected data wired or wireless communication channels are established.

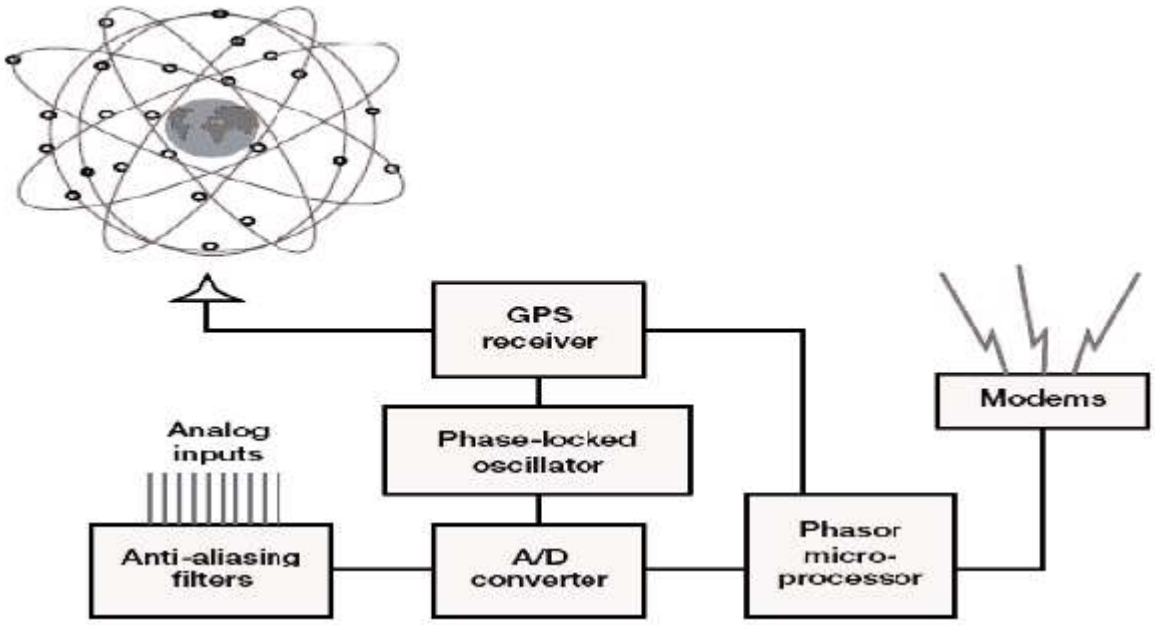

Fig. 2 Block diagram of PMU

There are 57 PMUs are installed across the India and three more by independent private players. Moreover, one phasor data concentrator has been installed at national regional center, New Delhi.

Table 3 Different locations of PMUs in eastern region

Sr.No	Location of substation	Line	Sr.No	Location of substation	Line
1	Rangali	Talcher-Baripada	7	Bina puri	Punea-Tala
2	Sasaram	Biharsharif-Allahbad	8	Bihar sharif	Balia-Khahalgaon
3	Farakka	Durgapur-Khalgaon	9	Raurkela	Balia-Barh
4	Talcher	Rengili-Meramuddani	10	Patna	Raigarh-Talcher
5	Ranch	Sipat-Mithon	11	Jeypore	Bolagir-Indravati
6	Jamshed pur	Raoukela-Maithon	12	Durgapur	Mithon- Jamshedpur

Table 4 Different locations of PMUs for north-east region.

Sr.No	Location of substation	Line	Sr.No	Location of substation	Line
1	Agartala	BJ nagar-RC nagar	5	Balipara	Misa-Benaigaon
2	Nehu	Sumer- Khelrighat	6	Sarusajal	Samaguri-Alga
3	Benaigaon	Balipara1-Balipara2	7	Badhapur	Khumaghal-Khelrighat
4	Misa	Dimapur-Koppi	8	Imphal	Dimapur-Lokwada

Table 5 Different locations of PMUs for northen region.

Sr.No	Location of substation	Line	Sr.No	Location of substation	Line
1	Dadri	Interconnecting lines Dadri A.C. to HVDC	8	K'wangtoo	Abdulpur1, Abdilpur2
2	Nagpur	Ballagrah1	9	Kishenpur	Moga1, Moga2
3	Moga	Bhivadi1	10	Meerut	Mozaffernagar, Koteshwar
4	Agra	Agra1	11	Balia	Interconnected HVDC line-2
5	Vidhyanchal	Singrul	12	Rihand	Interconnected HVDC line-2
6	Essar	Bawana	13	Bawana	Mandola -Mahendragrah
7	Bassi	Agra1, Agra2	14	Mohandergh	Bhandola1-Biwani1

Table 6 Different locations of PMUs for southern region.

Sr.No	Location of substation	Line	Sr.No	Location of substation	Line
1	Gooty	Raichur-Nelmangala	6	Ramagundan	Nagarjunsagar1-chandanpur1
2	Tirunlelveli	Trivendram-Udamapat	7	Somanhali	Saleem-Gooty
3	Kolar	Gooty-Sriparumbtoor	8	Narendra	Guttur-Kaigga
4	Trichur	Palakkad extention line1	9	Vijaywada	Nellor-VTPS
5	Gazua	Vijaywada-simadri	10	Sriperubudur	Chitoor-Kolar

Table 7 Different locations of PMUs for Western region.

Sr.No	Location of substation	Line	Sr.No	Location of substation	Line
1	Mudra	Dehgam2-Hadala	9	Boisar	Pharage-thirapur
2	Bina MP	Bina-Bhopal	10	Dehgam	Gandhar-Pirana
3	Korba	Bharatpur-GT6	11	Bhadrawati	Raipur1-Raipur2
4	Vidhyachal	Jabalpur-Kolba	12	Solapur	Kohlapur-Parli
5	CGPL Mudra	Limdi2	13	Itarasi	Jabalpur-Indore
6	Lab PMU	Jabalpur WRLDC	14	Satna	Bina3-Vidyachal3
7	Kalwa	Phalge-Khalhar	15	Raipur	Korba3-raigarh1
8	Asoj	Indore1	16	Jabalpur	Itarasi-Vidhyachal2

V. CONCLUSION

Based on prediction, there will be around 40% total power demand of India will be supplied by renewable sources. This penetration of renewable resources increases the complexity of the power network. In order to handle the power under such scenario, WAMs is an ultimate option. In this paper recent scenario of WAMs has been discussed. Moreover the basic concept of WAMs and different locations of PMUs are also discussed. Further, the comparison of WAMs technology with SCADA proves superiority of WAMs over other technology.

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