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ENHANCEMENT OF DIGITAL SUBSTATION USING WIDE AREA MONITORING SYSTEM WITH INTELLIGENT ELECTRONIC SYNCHROPHASOR

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Abstract: With the rapid development of new technologies this paper shows the growth of power system both in terms of geographical as well as technological advancement, it requires monitoring tools for dealing with system wide disturbances that may cause widespread blackouts in power system networks. Protective measures play a vital role to prevent further degradation of the system, restore the system back to the normal state, when major fault or disturbances occurs. The next evolutionary step in control centre technology may be the utilization of various kinds of sensors with digital concept and measurement instrument principle in general have promoted the advent of Phasor Measurement Unit [PMU].This paper discusses about the modelling and testing of phasor measurement units with the help of wide area monitoring protection and control using phasor measurement model. This model has been done through MATLAB/SIMULINK and the results are analyzed.

Index Terms: Global positioning system (GPS),Phasor Measurement units (PMUs), Smart grid, Wide area measurement system (WAMS).

I. INTRODUCTION

Innovation continues to modernize the electric grid. The development of information and communication technology (ICT) has transformed our world in many ways and these transformative technologies are now enabling power system design and operations to meet new challenges.

To meet our increasing demand of power and to reduce the emission of carbon dioxide, our power system networks need a way to manage these challenges in a reliable and economical way. To fulfil our requirements different technical selections are needed to design and operate the power system, referred as smart grid.

The incident of power outages in many power system networks has given a new impetus for large scale implementation of wide area monitoring system [1].The real time monitoring for control and protection as well as self-healing purposes, the delay is very crucial. Presently much better precision, at least 1µs, is obtained using satellite Global Positioning System [GPS]. WAMS have made continuous progress over the recent times in terms of performance, scalability, functionality and openness such that they plays an alternative ways in house development even for very demanding and complex control systems as those of physics experiments.

The accuracy of the GPS reference time of about 1 µs is good enough to measure AC phasors with a frequency of 60 Hz which is small enough with high accuracy from the point of view of phasor measurement.
Phasors are time stamped using the GPS, and synchrophasors are gathered from a widely distributed transmission network at a central point, in order to suitably evaluate them there, as a monitoring instrument.
Advanced wireless technologies are providing valueable techniques to prevent cyber crimes.There is a systematic approach which provides guidelines for smart grid wireless communications.It is based on the framework of Cyber-physical system(CPS)[2].
The technology component and phasor measurement units, Data Concentrators, Data Acquisition systems, Communication Systems, EMS/SCADA, Market Operations Systems which requires a platform to implement a WAMPAC which is already available in the market.
A rapid transformation is made in measurement techniques and telecommunication techniques , but there is a lack of WAP and WAC control algorithms even though the WAMPAC acts a barrier,its is based on use of phasors. . There has been a lot of research devoted to that problem but the state of knowledge cannot be regarded as satisfactory [3, 4].

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PMUs as the core of WAMS measures the parameters from buses and components but the existing commercial PMUs are sophisticated and expensive. It is also very difficult to modify the program of them and their PDC. In addition, coordinating and matching them is difficult because they are not open source. These difficulties and the cost of the component as well as training discourages the industry to facilitate their system with these PMUs.
In the detail and technical point of view, the part in PMUs that needs improvement is in developing applications, specifically the software that operates on the data provided by the PMUs. Although academia, vendors, utilities, and consultants have developed a large number of methods and algorithms and performed system analysis and studies to apply the technology, similar to any other advanced tool, PMUs are good only in the hands of trained users. In addition to the above problems, the cost of the present commercial PMUs are the main issue. The reason for high cost is GPS requirement, and communication infrastructure requirement.
This research paper represents modular analysis of PMUs. This is essential to determine the functioning of individual modules within a PMU. MATLAB Simulink model is extensively used to implement the idea.

II. OVERVIEW OF PMU TECHNOLOGY

PMUs plays a vital role in interlinking of power system through wide area measurement system. PMU measures the positive sequence voltages and currents,phase voltages and currents,local frequency,rate of change of frequency, the status of circuit breakers and switch.

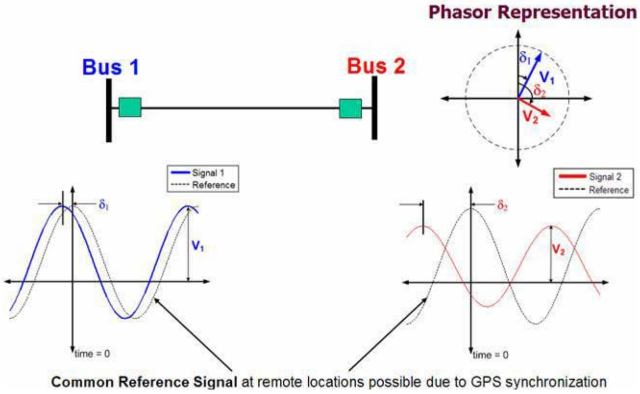

Figure 1. Phasor measurement at remote location

The WAMS employs synchronous data collection hierarchy with PMU which is used for real time monitoring of power system [5]. This is shown in Figure 1. The two PMUs at two buses provide time synchronized data. This helps for grading the currents and voltage signal using common reference signal obtained from GPS. A synchrophasor is a phasor which is time stamped, extremely precise and accurate using time reference signals.

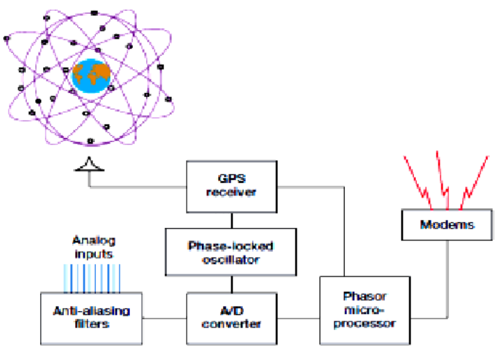

Figure 2. Fundamental representation of phasor measurement unit

The figure shown in Figure 2 is the fundamental representation of PMU. Here, Current and Voltages are coming from C.T and P.T. are going to the input channel block.PMU continuously measures the current and voltage phasors and other key parameters and it transmits the time stamped message,
A solid state relay is used with GPS clock and digital fault recorder along with it is placed.the resultant time tagged phasors receives information from control stations which can be transmitted to a local or remote receivers at a rates up to 60 samples per second.

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The real time monitoring system receives and transmits the information' s in less than one second time frame. The transmitted data will be collected and transmitted at high speed decisions of 100ms to 15 time frame .It also transmits at very high speed decisions of about 10 to 100ms time frame .The date collected is finally sent to the PMU.
The anti aliasing filters present in the input block of the PMU which produces the phase delay depends upon their characteristics. The anti aliasing delay is introduced by the filter after the sample data is taken because the task of the PMU is to compensate for this delay. A sampling clock which is phase-locked to the one – pulse- per second signal provided by a GPS receiver where the synchronization is achieved.
The output block is going to low pass filter for removing higher order harmonics from the inputs. Then analog to digital converter converts 22 vrms from the transformer to a 24Vdc. Compact Reconfigurable I/O will calculate the RMS value, frequency, phases with time stamped will take the help of GPS data, GPS pulse, and stepped down wall voltage. The measured voltages, currents and frequency are transmitted through GPS module and also could be saved in CPU. The output of the data will be saved as a text file.

III. FLOW CHART FOR SIMULATION MODEL OF PMU

In order to maintain accuracy in power system using PMU, an accurate model of PMU needs to be made. The simulation of a PMU is given in Figure 3.

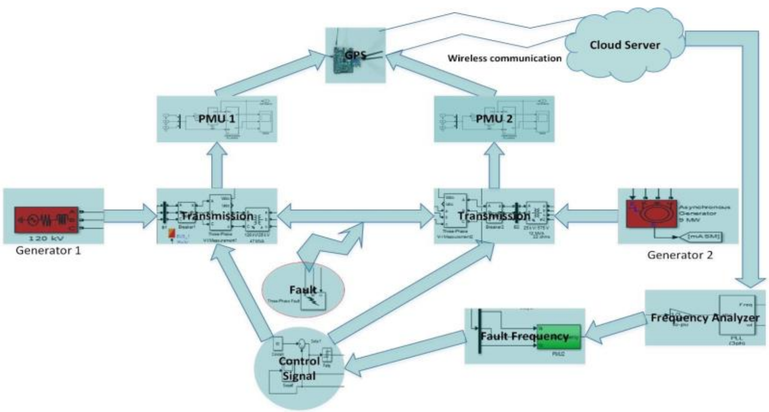

Figure 3. Simulation of a Phasor measurement Unit

WAMPAC are used in large scale,distributed management of critical infrastructure systems and its geographically dispersed.In a Power utility,the PMU with WAMS used for transmission and distribution of power.

The basic PMU Model configuration consists of supervisory control station and multi control station,either local or remote.The uses of control station is that the operators can monitor the status and issue commands to the appropriate devices at right time.The control stations consists of many devices that either collect the data or the effect of conrol of equipment.

In Phasor Data Concentrator[PDC] the informations are aligned in the the reference of the time.The incoming PMU messages from multiple measuring devices.PDC in a single steam sends out the aggregated synchronized data .It saves the data and information and create it as a record.PDCs exchange the records at other locations.

There are some testing procedures which is required for a perfect simulation of the system.First of all we require a wall outlet of sinusoidal wave with 120 Vrms.This can be verified using a voltage probe and an oscilloscope.Then the GPS must accurately generate a square wave with a rising edge of 1µs each second.

The pulse has a value of 5+-0.6 Vdc.The accuracy will takes a effect in the rise time.The GPS signal will be tested using a oscilloscope. The resulting waveform is ploted.the RMS value is calculated, which must be within 48Mv of the wall voltage.The frequency of the voltage wave is calculated by setting a code form.

The resulting frequency must be same as the frequency of the wave displayed on the oscilloscope. The will be sampled at each point which will be time stamped with the help of GPS signal .It transmits the data to the web server. Creating a code for transmitting the data and to transfer the data to the store line.

Check the data stored successfully in the web server. Make sure to check the web server whether no data is stored with the GPS signal missing. Remove the GPS signal by introducing an error .In the web server the data to be received from the CRIO continuously.

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The CRIO and GPS unit are powered by the wall voltage of 112 Vrms with the help of AC to DC converter .The oscilloscope measures the converter DC voltage.

The voltage and the current with its ripple is measured using the oscilloscope. Power the GPS by the CRIO USB port.and verify the pulse signal presented. We want to make sure the components should not melt or hot while the system is operating for a long span of time.

Date	Time	Phase	Vrms	Frequency
04/22/13	07:08:15 PM	225.91	123.48	59.9964
04/22/13	07:08:15 PM	225.78	123.52	59.9929
04/22/13	07:08:21 PM	225.56	123.50	59.9937
04/22/13	07:08:21 PM	225.83	123.49	59.9917
04/22/13	07:08:21 PM	225.98	123.56	59.9955
04/22/13	07:08:21 PM	226.20	123.53	59.9969
04/22/13	07:08:21 PM	226.04	123.59	59.9956
04/22/13	07:08:21 PM	225.90	123.59	59.9966
04/22/13	07:08:22 PM	225.72	123.55	59.9958
04/22/13	07:08:22 PM	225.63	123.54	59.9929
04/22/13	07:08:22 PM	225.40	123.54	59.9971
04/22/13	07:08:22 PM	225.67	123.48	59.9964
04/22/13	07:08:22 PM	225.52	123.53	59.9965
04/22/13	07:08:22 PM	225.37	123.56	59.9962
04/22/13	07:08:22 PM	225.27	123.57	59.9940
04/22/13	07:08:22 PM	225.10	123.54	59.9950
04/22/13	07:08:22 PM	225.38	123.58	59.9969
04/22/13	07:08:22 PM	225.27	123.59	59.9964

Figure 4. Web server Snapshot

IV. SIMULATION RESULT AND DISCUSSION

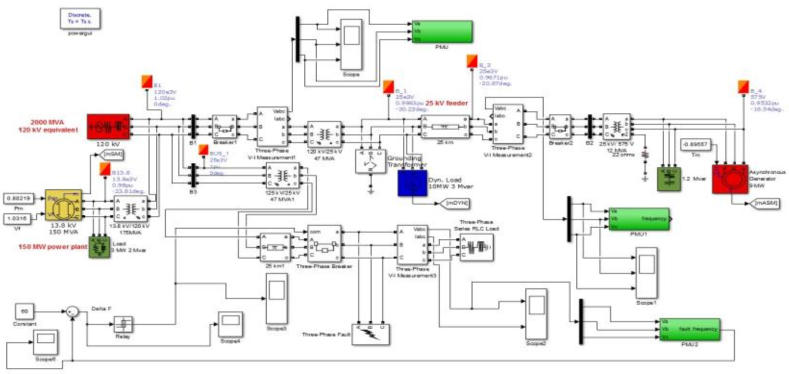

Figure 5. Simulation model for three bus system with PMU

A Simulink model of doubly fed two bus system is developed with PMUs and the network parameters are as follows.
Network Parameters Voltage Rating: 120k
System Frequency: 60Hz
Line Constant:
Positive Sequence Resistance: 0.1153;
Zero Sequence Resistance: 0.413; (ohm/km)
Positive Sequence Inductance:1.05e-3;
Zero Sequence Inductance: 3.32e-3; (H/km)
Positive Sequence Capacitance: 11.33e-009;
Zero Sequence Capacitance: 5.01e-009; (F/km)
Transmission Line length: 25km

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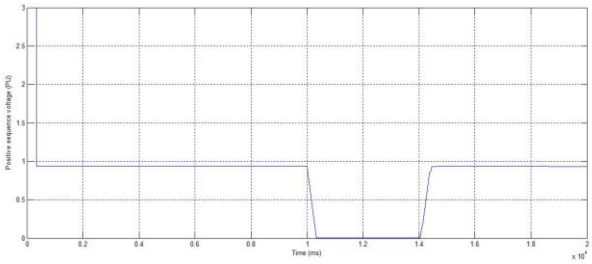

Figure 6. Positive sequence voltage

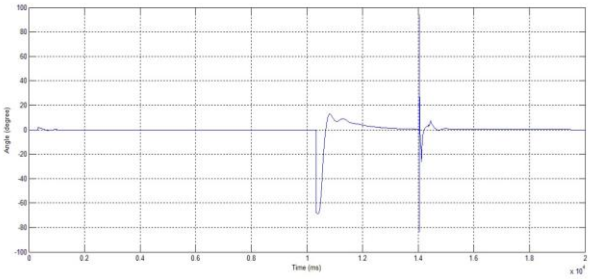

Figure 7. Positivesequence angle

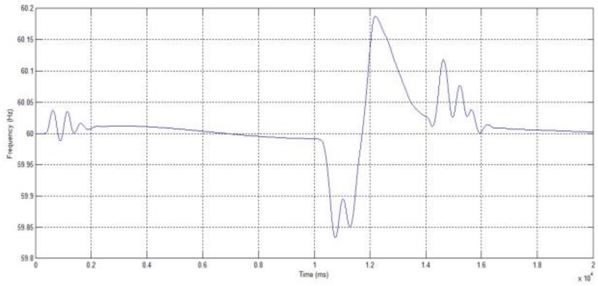

Figure 8. Frequency during before after and clearing fault

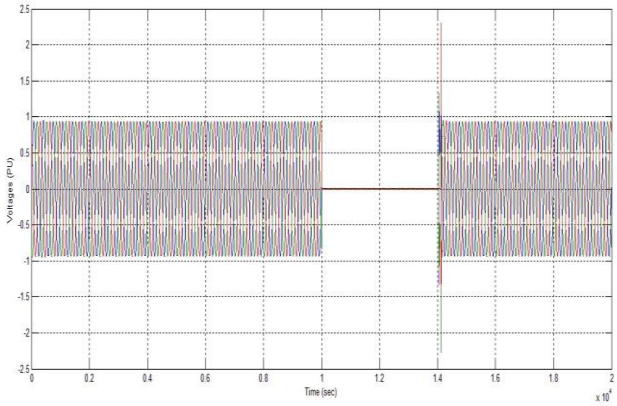

Figure 9. Voltage output after fault clearing using frequency feedback from PMU

Consider a sample of the GPS is 1 pulse per second signal is there in our system.The signal value is set as low value is 0V and High value is 5V.The pulses starting at each second accurate up to 1µs.There is an association NMEA which has a standard sentence of ‘ GPRMC’ which provides the exact date and time stamp.The GPS data sentence for date is(ddmmyy)and time is(hhmmss).

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The operation procees is when the PMU is first plugged into the wall,the PMU will wait for the GPS pulse which is 1 pulse per second signal is transmitted.If the pulse is observed ,the CRIO which collects the voltage data and inserts the data in a FIFO,which is the order for the sytem that helps to store the data in an particular order.
After the process for every 0.1 second,the data collected is extracted from the data storage structure and then we got a voltage waveform.From the waveform we can calculate the frequency,phase and RMS voltage is calculated and saved it as a data.Then the data is uploaded to the web server.
Individual modules of PMUs are modeled to determine module wise output. The result of the output of both the PMUs are compared to analyze process. Simulink model includes various power system components which can be utilized for modeling of all kinds of power system network simulations.
The three phase input voltages are measured after each bus. These three phase voltage are given to the PMU and PMU gives us the positive, negative and zero sequence voltages and also the Angle.
Figure 9 illustrates clearing fault with feedback frequency from PMU that is compared with constant frequency 60 Hz and error signal is used to operate relay. The relay is used to switch on and off the three phase breaker.
In designing the PMU, the dynamic of the system is considered, as the transient after fault is visible in the figure. Moreover, the 3-phase voltage then measured by V-I measurement block and feed to the PMU block.
PMU block is shown, where the voltage feed into the Phase Locked Loop (PLL) and then sequence analyzer. That is how the three sequence voltage is built. Frequency can be measured through PLL. Figure 9 shows positive sequence voltage before, during and after fault. Figure 7 shows positive sequence angle at the same time frame.

V. FUTURE WORK

PMUs have been instrumental for interlinking of power system through wide area measurement system

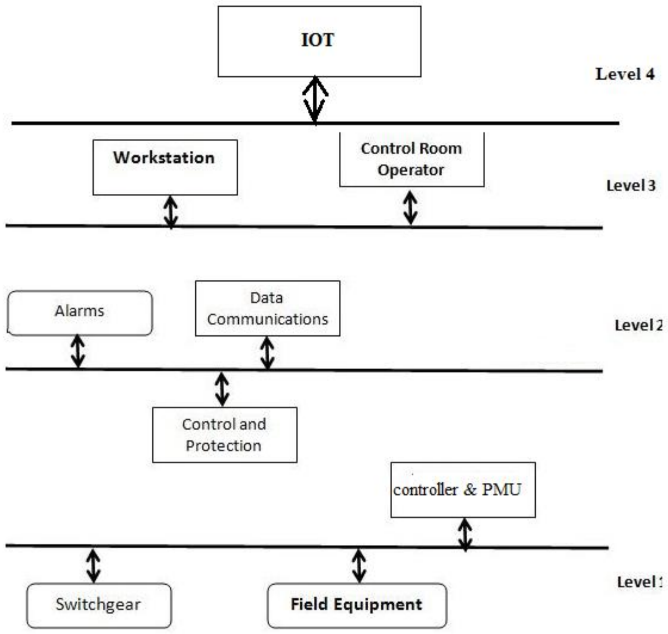

Figure 8. Architecture of power system.

It is very flexible and easy mode of accessing the system. It is the most important function of automation to protect the devices and supervisors and to prevent damage in case of fault.
Phasor Measurement involves electrical measurements such as power factor, current, voltage and harmonics
The proposed idea uses the feature of unit protection relays to protect the large power transmission grids with the help of PMU.
The principle of the protection scheme depends on the comparing positive sequence voltage magnitudes at each bus during fault conditions inside a system protection center to detect the nearest bus to the fault.
.Most of the substations are designed to meet our society' s electrical systems such as efficiency, performance and accuracy of the system. Here we introduced a new technology IoT which is very useful to operate the power system equipment' s (switching operation) from any part of the world

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Analog measurements and disturbance recordings for fault analysis. This information about the station is obtained from the control room or central database. This prevents the operator/engineer from going to the station to obtain information thus assisting in worker safety and work is reduced.

The information obtained can help in network studies, preventing faults and disturbances which cause large amount of losses. This can help in locating the fault and take preventive measures. Without data communication, power system automation cannot function. This can help to locate the fault and take preventive measures.In digital substation we are using Intelligent Electronic Devices[IED].

- The PMU with WAMS can be widely used in the application of Fault detection and location of the power systems.
- It is also used for security and protection of power systems from faults.
- It can be processed with the help of FACT controllers.
- It is used in state estimation of power system.
- Power system oscillation with the help of PMU.
- Harmonic Measurement in power system with the PMU.
- Real time monitoring of power system.
- Power system operation, planning and controlling.

VI .COMPARISON OF PMU VS SCADA

DESCRIPTION	SCADA	PMU(WAMS)
DATA UPTADE	2-10s(slow)	Once in 20ms fast
STATE DETECTION	Steady state	Steady and Dynamic State
MEASUREMENT VALUES	Magnitude only	Magnitude and phasor angle
TIME STAMP	At Substation (or) EMS arrival	GPS Time stamped at measurement location
STATE ESTIMATION	Non-linear, Numerical Calculation	Linear Calculation
STABILITY	Small Signal Stability	Oscillation Monitoring
ISLANDING	Island Management	Island Detection & Resynchronisation
RESOLUTION	Sample every(2-4)sec	10-60 Samples per sec
TIME SYNCHRONIZATION	No(optional)	Yes
TOTAL INPUT / OUTPUT CHANNELS	100+Anlog & Digital	~10 phasors 16+Digital 16+Analog
FOCUS	Local Monitoring and Control	Wide Area Monitoring and Control

CONCLUSIONS

This simulation and verification of the design are implemented using MATLAB and Simulink. Based on the complexity and the structure of design, some tasks will be implemented on processing system (ARM) and some will be implemented on programming logic (FPGA).Therefore, it has the FPGA programming logic and also a ble to be programmed through python for communication. The simulation was designed in the way to consider the transient of the system during and after clearing the fault. This avoids problems for protection as well as measurement components.

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