

Analyzing of phasor oscillations in 500kV power system and using synchrophasors for control stability

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Abstract

To meet the requirements of the National Electrical System operation, the automatic control equipment, data collection and disturbance recorders are used more commonly. In this paper, the modelling and analyzing effect of phasor oscillation for the local 500kV power grid in both the state-steady and transient operation modes could certainly benefit from development and potential application phasor technology. The purpose is to increase the overall system efficiency and reliability for all power operation modes via significant dependence on wide area measurement system (WAMS) as distributed intelligence agents with improved monitoring, protection, and control capabilities of power networks.

Keywords: 500kV power grid; Inter-area power oscillations; Stability; Phasor measurement unit (PMU); State-steady and transient operation mode; Wide area measurement system (WAMS).

1. Introduction

The development of the Extra High Voltage network of 500kV [2]. and interconnections with regions play an important role in the unified power system operation safely and continuously. However, in the recent years, the continuous growth in electricity consumption need an optimization in power systems and higher complexity in their operation. In the different operating modes, the transmission networks often transmitted the large amount of capacity among regions and therefore they were limited by the risk of instability due to inter-area power oscillations [6][10].

New distributed instrumentation technology using accurate phasor measurement units (PMUs) has developed in recent years to become a powerful source of wide-area dynamic information. The recent advances in wide area measurement system (WAMS) technologies using PMUs can deliver synchronous phasors and control signals at a high speed [2].

This paper discusses a method to utilize data collection to check stability of power system networks. From the modelling results, the electrical system operators can give the relevant methods to enhance the stability and operation quality as well. In the first time, it achieved benefits through building pilot PMUs infrastructure communication network.

The performance of the overall proposed system is investigated through a Matlab simulation in a small disturbance scenario of power line on a 8-bus utility network with the associated communication network. This paper is organized as follows. In section 1, an introduction to the subject is presented. In Sections 2, 3 description and mathematical modeling of the system are introduced. In Section 4, test results are presented and discussed under different system conditions.

Section 5 presents some applications and development of synchrophasor technology. Finally, Section 6 presents some conclusions.

2. System description

The power grid is the interconnected power system operating with the synchronous operation at 50Hz and 525kV connecting to an 525kV equivalent source rated 30000MW. The type of the power plant consists of the hydro power plant (generator 1, generator 2) with max capacity 6*400MW, 8*240MW respectively and the thermal power plant (generator 3, generator 4) with max capacity 3*300MW, 560MW in order. The main transmission system is split into eight ACSR330 power lines connected to the buses B2, B3, B4, B5, B6, B7, B8.

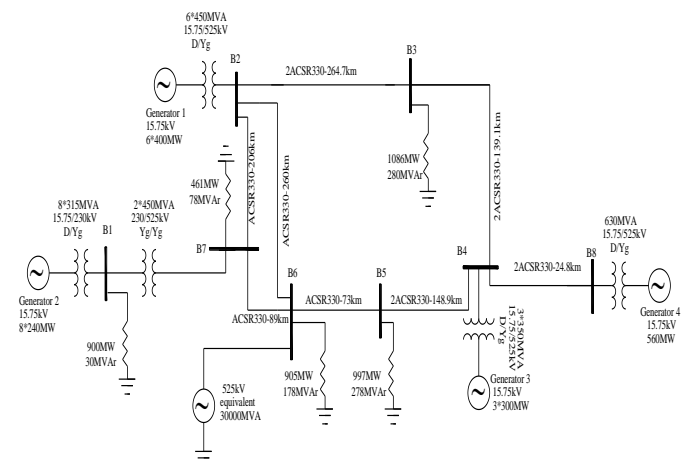


Figure 1. The 500kV transmission system

3. Matlab/Simulink implementation of proposed system

The modelling process of power system is based on Matlab/Simulink. The prospective short circuit current of a fault can be calculated for power systems. In power system, protective devices detect fault conditions and operate circuit breakers and other devices to limit the loss of service due to a failure.

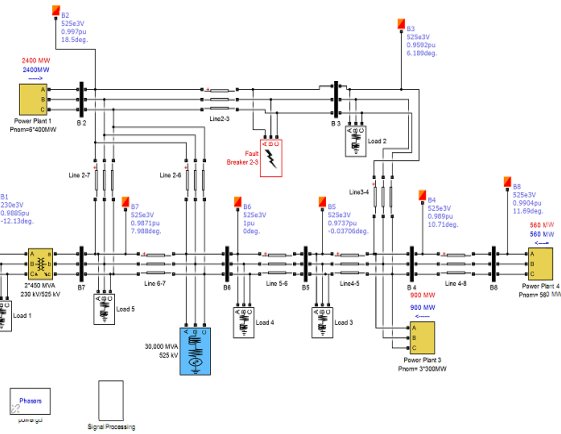


Figure 2. Matlab simulation diagram of fault on transmission line system

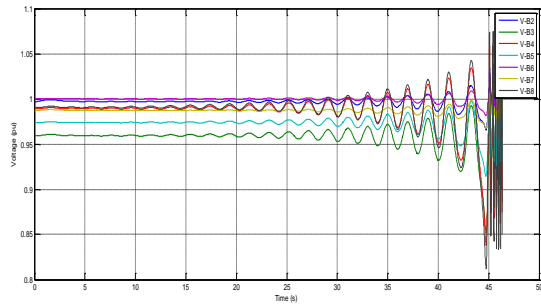


Figure 3. Voltage oscillation in nominal operating mode

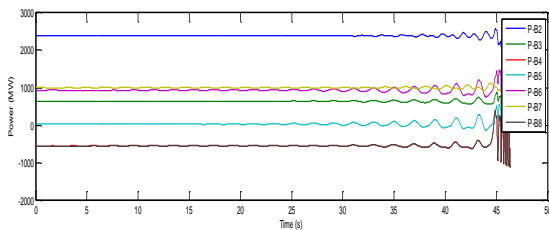


Figure 4. Power oscillation in nominal operating mode

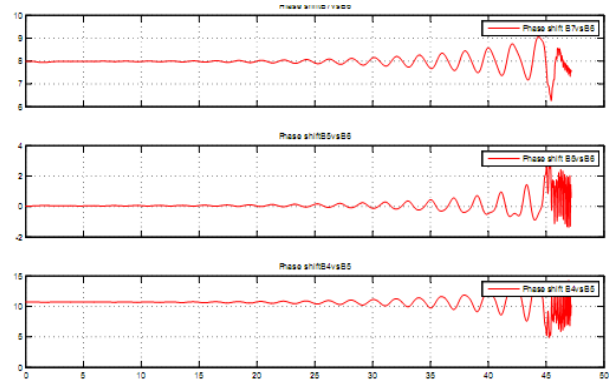


Figure 5. Phase angle difference between voltage buses in nominal operating mode

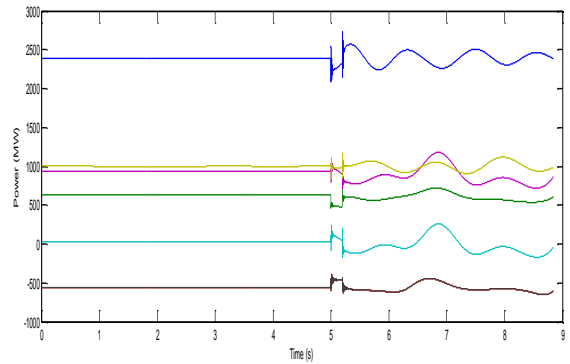


Figure 6. Power oscillation when ground fault phase A-Line 23

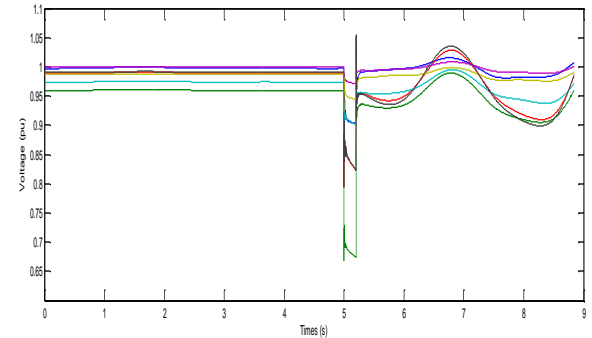


Figure 7. Voltage oscillation when ground fault phase A-Line 23

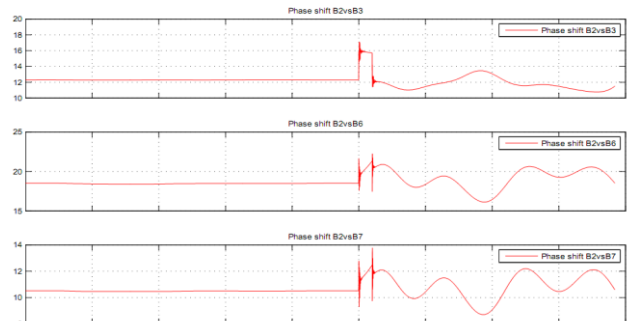


Figure 8. Phase angle difference between voltage buses when ground fault phase A-Line 23

4. Modelling result analysis

The experimental setup for testing different operation modes together with the proposed power swing, voltage oscillation, large voltage phasor angle difference using Simulink model is illustrated above. These issues, therefore, confirmed that in the power system needs more modern state estimated and fault defined technologies to help network operators giving fast resolves.

5. Synchronous technology

Synchrophasors are precise time-synchronized measurements of certain parameters on the electricity grid, now available from grid monitoring devices called phasor measurement units (PMUs). A phasor is a complex number that represents both the magnitude and phase angle of voltage and current sinusoidal waveforms (50Hz) at a specific point in time (shown in Figure 9).

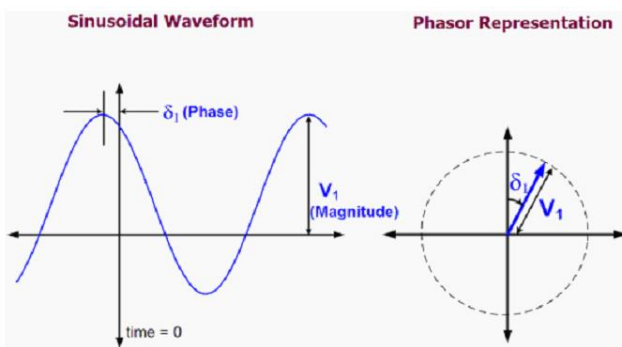


Figure 9. Sinusoidal Waveform and Phasor Representation

Synchrophasors can be used for a wide variety of applications that help maintain power grid reliability. These applications include wide-area monitoring, real-time operations, forensic analysis, and smart grid operations.

The historical development of the heart of synchrophasor technology, the Phasor Measurement Unit (PMU), which evolved after developments of transmission relaying applications, supports the fact that the first uses of the synchrophasor technology were at the transmission level [2].

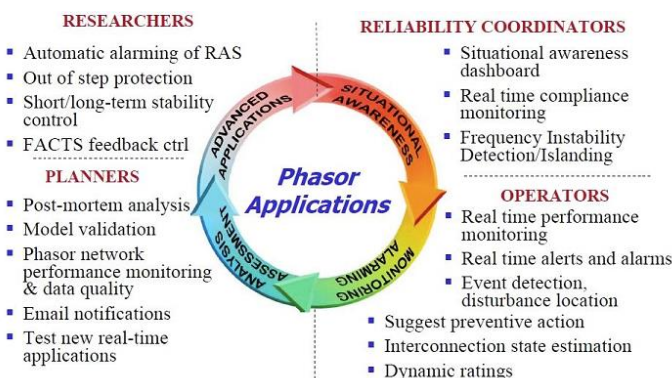


Figure 10. Phasor applications taxonomy

5.1 Phasor measurement units (PMUs)

The effective operation of power systems in the present and the future depends to a large extent on how well the emerging challenges are met today. Power systems continue to be stressed as they are operated in many instances at or near their full capacities. In order to keep power systems operating securely and economically, it is necessary to further improve power and control system protection. Synchronized phasor measurements-also known as phasor measurement units (PMUs)-are ideal for monitoring and controlling dynamic power system performance, especially during high-stress operating conditions [2].

PMUs can enhance grid reliability for both real-time operations and off-line planning applications and they are used for the wide area monitoring systems (WAMS) at the control centre of the national grid, and they are the direct source of the dynamic information for the post-disturbance analysis. Disturbed with the small-signal, the power system exposed the dynamic performance of the oscillation such as the inter-area oscillation mode, the local oscillation mode. These dynamic performances data recorded in the PMUs are the motivation for the post-disturbance analysis. The power system oscillation assessments can use the event data from the PMUs consisting of the phasor voltage, the phasor current, the frequency, and the rate of change of frequency. The power system oscillations were evaluated from the actual system disturbances data, for example, the switching of the transmission line, the loss of the generation and the switching of the transformer [1] [6][10].

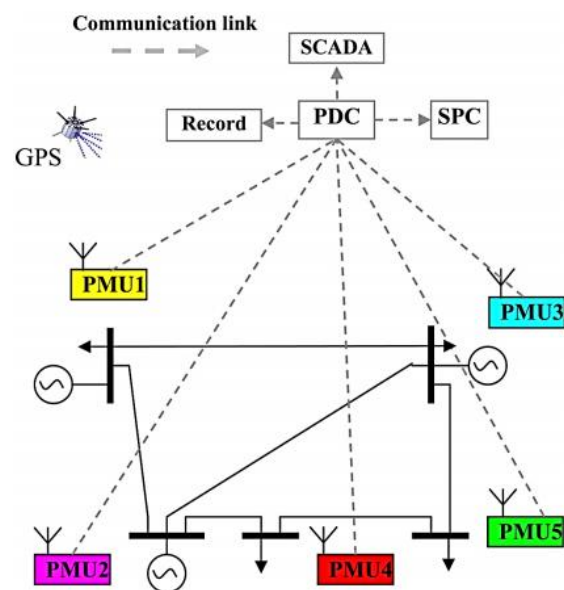


Figure.11. The PMUs arrangement with phasor data concentration and system protection center

The PMU-based technology is raised to solve the problems of the conventional technology. The PMUs are installed in the substations and acted as the distributed backup protection system. The computation and

communication capabilities of PMU allow the implementation and concentration of novel sophisticated protection principles [2]. One example of this technology is shown in Figure 11. The transmission network is divided into 5 areas, and 500 kV lines area are selected. PMUs are installed at substations and send real-time data to a Phasor Data Concentrator (PDC). The measurements are correlated and exported to System protection center (SPC) for protection as well as Supervisory Control and Data Acquisition (SCADA) for system analysis and monitor. Data of PMUs are synchronized by GPS and time stamped.

5.2 Synchrophasor (PMUs) System Deployment in the world

5.2.1 North America [2].

03/2013			
Project	Estimated PMUs	Real PMUs	Voltage level
11	>800	826	230kV 500kV

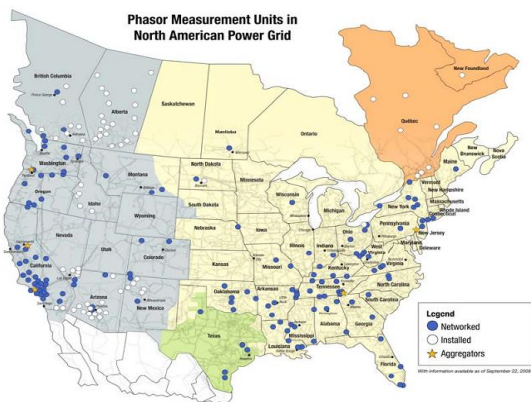


Figure 12. The PMUs locations

APPLICATIONS	AREAS						
	WESTERN	MIDWEST	CAROLINAS	PIM	AMERICAN	NEW YORK	
WAIM	Real-time Situational Visualization	✓	✓	✓	✓	✓	✓
	Oscillation Monitoring	✓	✓		✓		
	Voltage Monitoring	✓	✓				✓
	Voltage Stability Monitoring						✓
	Event and Alarm Processing	✓	✓		✓		
WAC	Voltage Control						✓
	Voltage Stability Control						✓
	System Separation Control						✓
OFF-LINE	Post-event Analysis	✓	✓			✓	✓
	State Estimation			✓	✓	✓	✓
	Congestion Management	✓	✓		✓	✓	✓
	Protection System Analysis	✓	✓				
System Model Validation	✓					✓	

Figure 13. Synchrophasor technology applications

5.2.2 China

05/2013			
Project	Estimated PMUs	Real PMUs	Voltage level
25	all	2500	700kV, 500kV, 330kV, 220kV, Generators



Figure 14. The PMUs locations

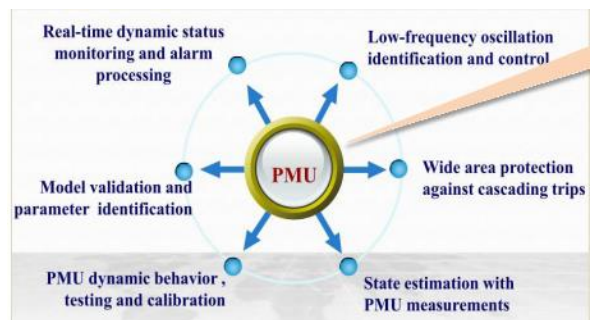


Figure 15. Synchrophasor technology applications

5.2.3 India

06/2012			
Project	Estimated PMUs	Real PMUs	Voltage level
05	59	40	400kV

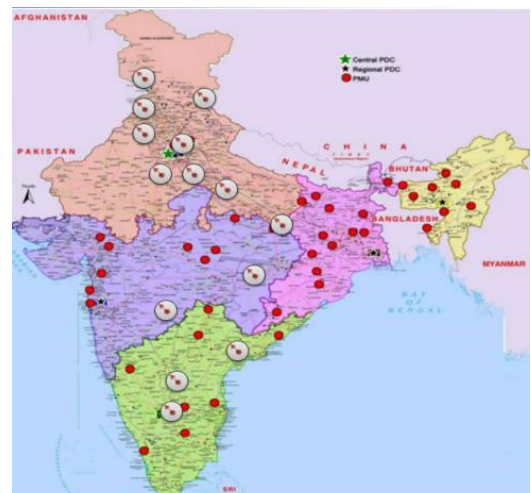


Figure 16. The PMUs locations

APPLICATIONS		Northern Region	Western Region	Eastern Region	Southern Region	North Eastern Region
REAL-TIME	Real-time Situational Visualization	✓	✓	✓	✓	
	Voltage Monitoring	✓	✓	✓	✓	
	Oscillation Monitoring	✓	✓	✓	✓	
	Event and Alarm Processing	✓	✓	✓	✓	
OFF-LINE	Post-event Analysis	✓	✓	✓	✓	
	Forensic analysis of faults/grid incidents	✓	✓	✓	✓	
	Detection and analysis of oscillations	✓	✓	✓	✓	
	System Model Validation	✓	✓	✓	✓	

Figure 17. Synchrophasor technology applications

6. CONCLUSION

This paper focused on analyzing effects of phasor oscillation for high voltage power system. The significant oscillation improvement can be achieved by utilizing synchronized measurement technology. Synchrophasor technology has the potential to greatly improve operators' ability to conduct real time grid operations and detect and respond to potential disturbances. It was demonstrated by developing and implementing significantly PMUs in some typical countries in the world.

7. Acknowledgment

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