WIDE AREA BACKUP PROTECTION SCHEME FOR POWER TRANSMISSION LINES USING PMU

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Abstract— *This paper presents wide area backup protection scheme in power transmission lines. In this paper deals with PMU based wide area backup protection scheme for transmission lines developed to identify the faulted line by with PMUs. After a fault arises in the transmission network, zero and positive sequence currents entering the faulted backup protection zone highly increase, and faulted backup protection zone can be determined. To overcome these problems the optimization model is developed to identify the faulted line by using the wide area data of WAMS. Here linear least squares method is used to determine the faulted line as well as the fault location by voltage and current phasors of the Backup Protection Zone (BPZ) with limited measurement points. The proposed method is executed for IEEE-9 bus system using MATLAB/Simulink software.*

Keywords—*Backup Protection Zone (BPZ), Phasor Measurement units (PMUs),Wide Area Measurement System (WAMS), IEEE 9-bus system.*

1. INTRODUCTION

The existing SCADA systems provide asynchronized measurements leading to inaccurate estimation of system states. Further, the slow data scan rate of about 2-10 seconds makes them inefficient to capture very short disturbances of the order of sub-seconds on the grid. These issues can be overcome by using the phasor measurement units, which utilize the global positioning system (GPS) receivers to accurately time-stamp each measurement. The capability of PMUs to measure 25 to 60 samples per second makes them suitable for analyzing the system under dynamic conditions. The deployment of PMU at each bus would facilitate direct measurement of all the states of the system. However, this is uneconomic and infeasible due to the higher installation cost of PMUs and limited communication facilities available. Thus, there is a need for strategic placement of PMUs across the power grid. A distance relay is designed to only operate

for faults occurring between the relay location and the selected reach point, and remains stable for all faults outside this region or zone.

The resistance of the fault arc takes the fault impedance outside the relay's tripping characteristic and, hence, it does not detect this condition. Alternatively, it is only picked up either by zone 2 or zone 3 in which case tripping will be unacceptably delayed [6]. The distance relays are based on standalone decision, while each relay operates independently according to three different one of operation [2]. The mal-operation or fail-to trip of protection is determined as one of the origins to raise and propagate major power system disturbances. A vast majority of relay mal-operations is unwanted trips and have been shown to propagate major disturbances. Backup protections in fault clearance system have the task to operate only when the primary protection fails to operate or when the primary protection is temporarily out of service [3]-[5]. The recent complexity and enlargement of power systems makes it difficult to coordinate operation times and reaches among relays.

In the areas of power system automation and substation automation, there are two different trends: centralization and decentralization. More and more dynamic functions are moving from local and regional control centres toward central or national control centres [7]. To ensure the fast responsibility of such a system to the emergent events, the communication requirements are discussed as well. Conclusively, the proposed system is designed by two ways. First, in substation, concentrate some conventional backup protection functions to an intelligent processing system; second, concentrate the coordinated and optimized processing and controlling arithmetic of all backup protection in a region into a regional processing unit. The communication of data among them is carried via optic-fiber networks. The relay decision is based on collected and shared data through communication network [8]. The suggested technique satisfies high degree of reliability and stability while it is based on shared decision rather than stand-alone decision [9].

In this paper an optimization model is developed to minimize the number of PMUs required for this scheme. This overcomes the problems of data storage, Limitations and requirements of extensive communication facilities and infrastructures. The suggested technique can see all the power system area and can deal with the transmission lines as unit protection. The primary purpose of these systems is to improve disturbance monitoring and system event analysis. These measurements have been sited to monitor large generating sites, major transmission paths, and significant control points. Synchronized phasor measurements provide all significant state measurements including voltage magnitude, voltage phase angle, and frequency.

In This paper, the fault detection and classification is discussed. Phasor and synchrohasor basics are covered in Section 2. Phasor Measurement Units 3. Wide Area Measurement System 4. Backup Protection Scheme 5. Simulation Results summarizes the key points presented in this paper.

2. PHASOR MEASUREMENT UNITS

Synchronised Phasor Measurement Units (PMUs) were first introduced in early 1980s, and since then have become a mature technology with many applications which are currently under development around the world. The occurrence of major blackouts in many major power systems around the world has given a new impetus for large-scale implementation of Wide Area Measurement Systems (WAMS) using PMUs and Phasor Data Concentrators (PDCs) in a hierarchical structure [11]. Data provided by the PMUs are very accurate and enable system analysts to determine the exact sequence of events which have led to the blackouts, and help analyze the sequence of events which helps pinpoint the exact causes and malfunctions that may have contributed to the catastrophic failure of the power system. As experience with WAMS is gained, it is natural that other uses of phasor measurements will be found. In particular, significant literature already exists which deals with application of phasor measurements to system monitoring, protection, and control. A pure sinusoidal waveform can be represented by a unique complex number known as a phasor. The phasor representation are illustrated in Fig. 1

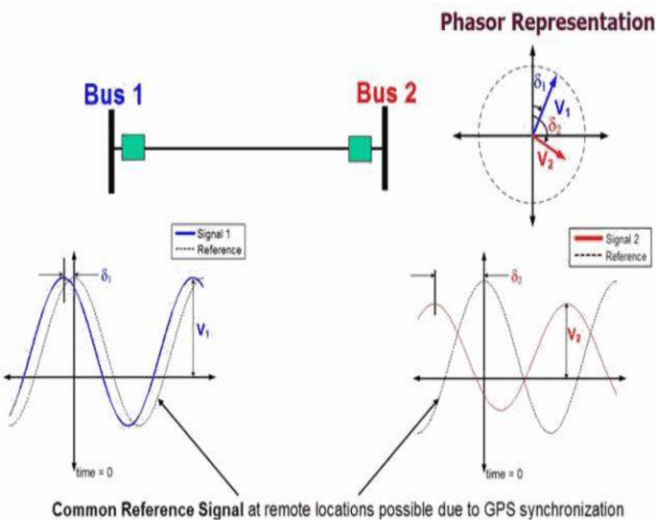

Fig.1 Phasor representation

3. WIDE AREA MEASUREMENT SYSTEM

In last two decades, power industries have been deregulated, restructured and decentralized in order to increase their efficiency, to reduce their operational cost and to free the consumers from their choices of electricity providers. As a result of these changes, in comparison with the traditional power systems, new competitive power industries face specific challenges that are related to their generation, operation and planning. As a consequence of these challenges, new intelligent systems should be introduced and established in the power systems in order to tackle such challenges. Wide Area Measurement Systems (WAMS) is a new term, which has been introduced to power system literatures in late 1980s. Recently, they are commercially available in power systems for purposes of monitoring, operation and control.

To be able to monitor, operate and control power systems in wide geographical area, WAMS combines the functions of metering devices (i.e. new and traditional) with the abilities of communication systems. The overall capability of this particular combination is that data of the entire system can be obtained at the same time and the same place i.e. the control center. This data, which are obtained from the entire system, can be used by many WAMS functions, effectively. These facts indicate that nowadays, WAMS has been a great opportunity to overcome power systems challenges related to the restructuring, deregulation and decentralization.

3.1 Communication Infrastructure of WAMS

The communication system of WAMS is responsible for data delivery from data resources to the control center(s) and from control center(s) to the system actuators. Indeed, the communication network of WAMS is similar to the neural network of humans. As in case of failure or mal-functioning of neural network paralyzed may happen, failure of communication network may cause huge problems in system operation and control, especially in operation of WAMS applications. Consequently, especial attention should be paid to communication infrastructure, which is as important as electrical infrastructure itself. These two infrastructures (communication and electrical) have become increasingly interdependent so that in the case of failure for each of them, another one may also become out of service.

New communication systems are designed based on Open System Interconnection (OSI) layer model. In this architecture, upper layers relay data, assuming that the lower layers work perfectly. In fact, this model is an effective architecture for explanation, designing, implementation, standardization and use of communications networks. The OSI reference model consists of seven layers: physical, data link, network, transport, session, presentation, and application.

The first layer of OSI model, referred to the physical layer, is a kind of medium that establishes the physical connection between transmitter and receiver. The characteristics of the communication systems will become seriously influenced by the characteristics of their media. Therefore, it can be concluded that the characteristics of the transmission media play an important role in communication infrastructure of WAMS. Some major characteristics of a medium are as follows: cost, bandwidth, propagation delay, security and reliability.

Transmission media, as described below, can be classified as guided and unguided ones. Guided media guides the waves through a solid medium. Twisted pair, coaxial cable, power transmission/distribution line and optical fiber are some examples of guided media. In the case of guided media, the media itself has the most important role in characterizing the limitations of transmission.

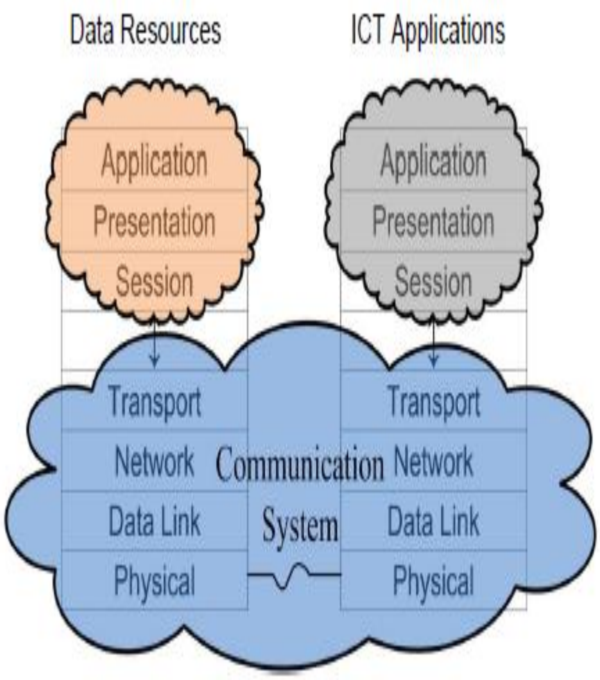

Fig.2 Layering in WAMS based on OSI reference model

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4. BACKUP PROTECTION ZONE

The primary objective of back-up protection is to open all sources of generation to a cleared fault on the system. To accomplish this objective, an adequate back-up protective system must meet the following functional requirements:

1.It must recognize the existence of all faults which occur within its prescribed zone of protection.

2. It must detect the failure of the primary protection to clear any fault as planned.

3. In clearing the fault from the system, it must

a. Initiate the tripping of the minimum number of circuit breakers.

b. Operate fast enough (consistent with coordination requirements) to maintain System stability, prevents excessive equipment damage, and maintain a prescribed degree of service continuity.

In the discussion which follows, a local back-up system is presented which meets all of the above requirements and which closely approaches ideal back-up relaying. This proposed scheme is designed so that no single failure in either the ac circuits, the relays or in the dc control and trip circuits (except station battery failure) can nullify all protection. In essence, the proposed local back-up system provides two separate back-up functions: it provides relay backup with an entirely separate group of relays from that used for front-line protection, and it provides breaker backup with the necessary time delay and auxiliary relay components. The basic plan of the proposed scheme is the same for any breaker position, regardless of the bus arrangement being used. Only the details of the breaker back-up protection are changed for different bus arrangements. BPZs are formed on the basis of the PMU placement and network topology. Each BPZ consists of the lines and buses that are surrounded by PMU-equipped buses.

5. SIMULATION RESULTS

The IEEE 9-bus is utilized to demonstrate the effectiveness of the adaptive wide area backup protection scheme. In IEEE-9 bus system there are three generators and loads. The Figure 3 shows the single line diagram for IEEE-9 bus system with phasor measurement units.

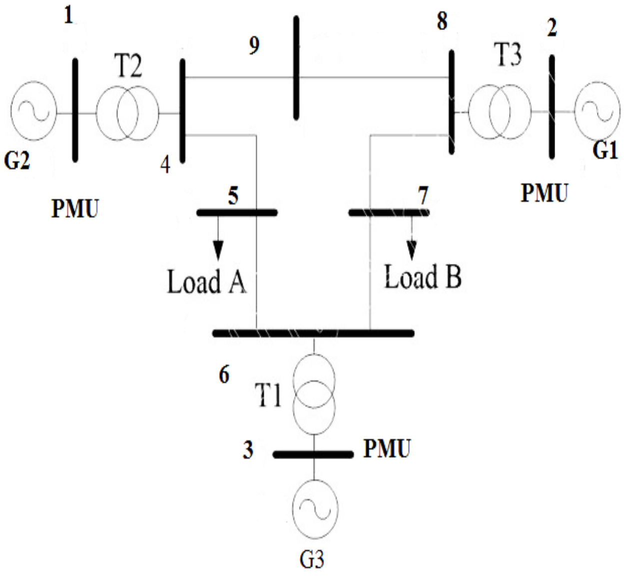

Fig.3 Single Line Diagram for IEEE9 Bus System with PMU

The Figure.4 describes the Simulink diagram for IEEE-9 bus system using PMU and it contains three sources three loads. In this PMU is connected at bus4 and the voltage and current obtained. In this PMU is connected at bus4 and the voltage and current obtained. In Figure.5 Simulink model of PMU with the data from transmission line voltage and current. The output of PMU is given to the circuit breaker and depending on the fault current the Circuit Breaker is opened, PMU extract the fundamental components of input signals in four stages which are modeled in MATLAB environment. First the input signals are passed through a second-order Butterworth anti-aliasing filter with a cut-off frequency of 350 Hz, which removes high frequency harmonics of input signals. In the second stage, the output signal of Butterworth filter is sampled at 4800 Hz which is equal to 96 samples per cycle. In the third stage, a digital mimic filter is used to eliminate the decaying dc offset. In the last stage, the fundamental components of input signals are obtained by using full-cycle Fourier transform. MATLAB software is used to construct the bus impedance matrix Z^0 for all BPZs. Wide area backup protection schemes have been carried out for the standard IEEE-9 bus system. MATLAB solver has been used for this purpose. The simulation result has been shown that the faulted line and fault location. The simulation results of identification of faulted line and location are illustrated below.

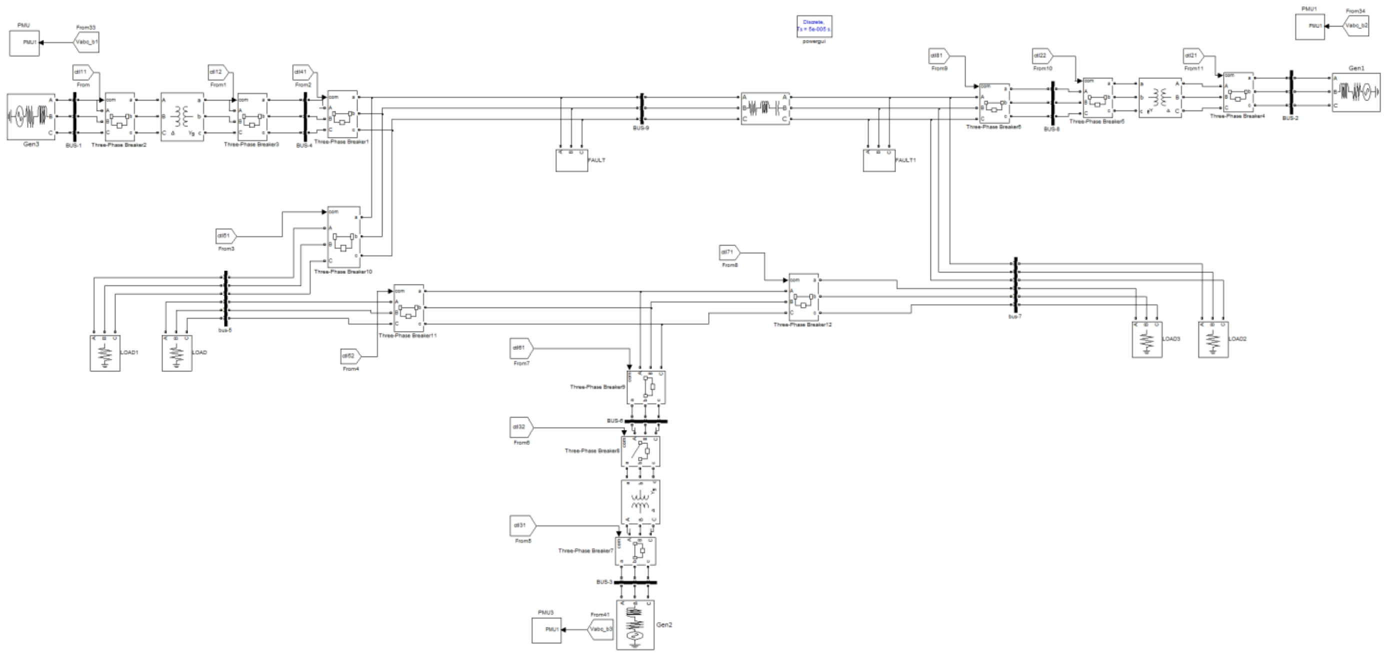

Fig.4 IEEE-9 Bus System Using PMU

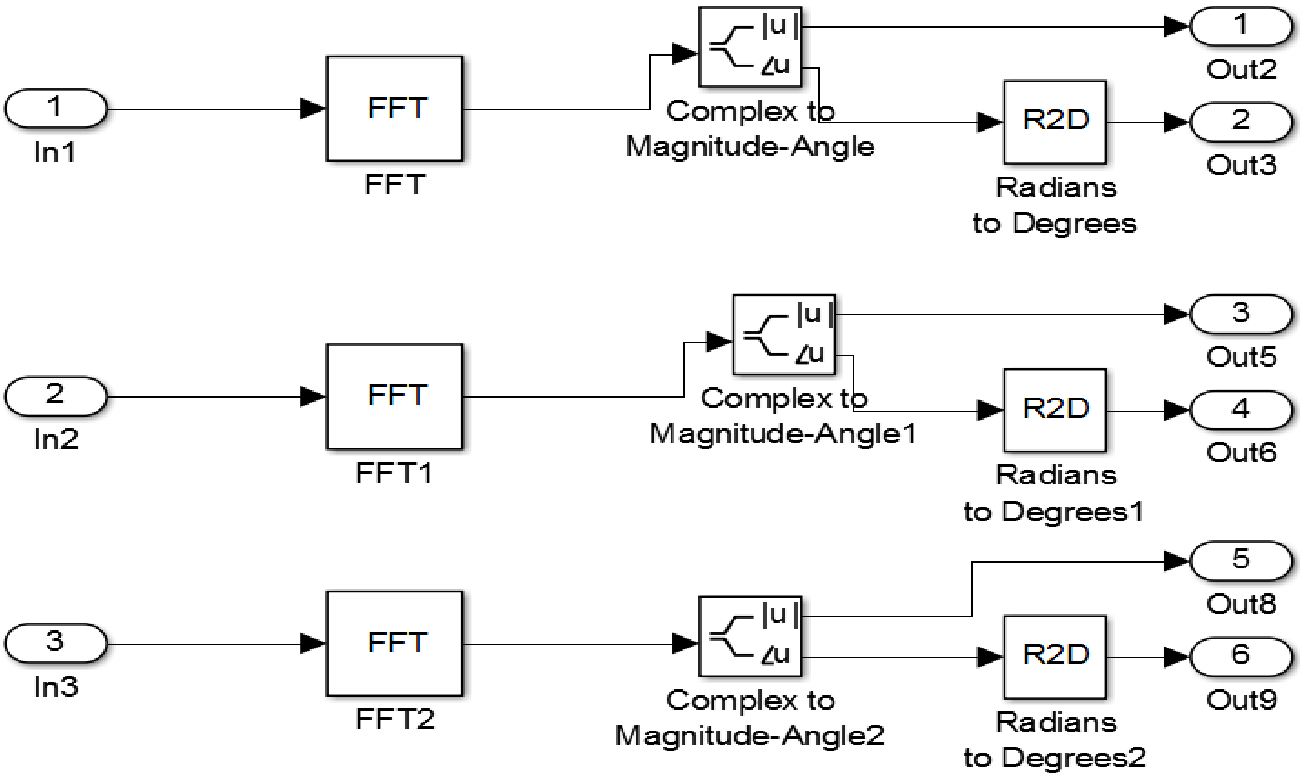

Fig.5 Simulink Model of PMU

PMU is located at the bus 1, 2 &3 respectively and the fault is occurred at the bus 2. The PMU gives the three phase voltage and current values and depending on the values of current, it gives trip command to the circuit breaker. At normal operation current flows from the source to load but during fault, the fault current flows in the direction opposite to the normal current flow and that is from the fault point to the source. In the analysis the fault is being occurred in bus 2 at the time instant of 0.2s.

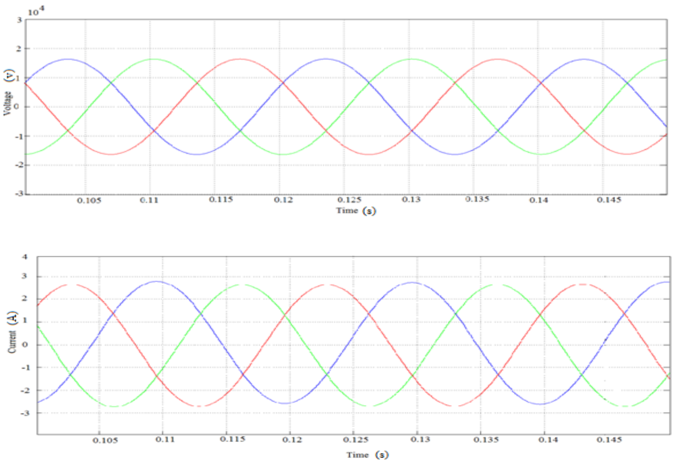

Fig. 6 System Bus Voltage And Current Before Fault

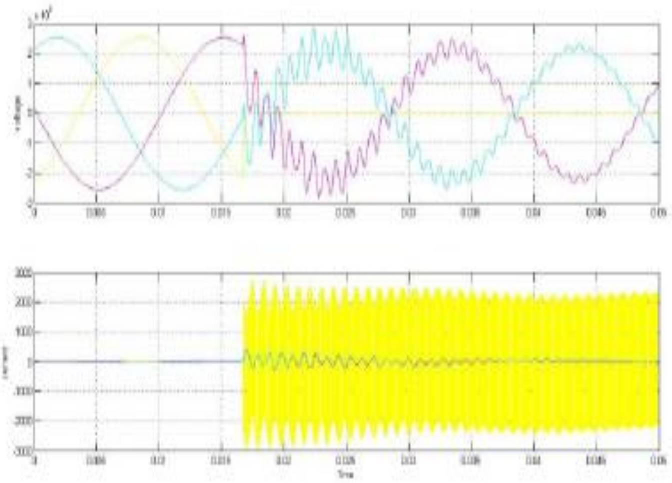

Fig. 7 System Bus Voltage And Current Under LG Fault

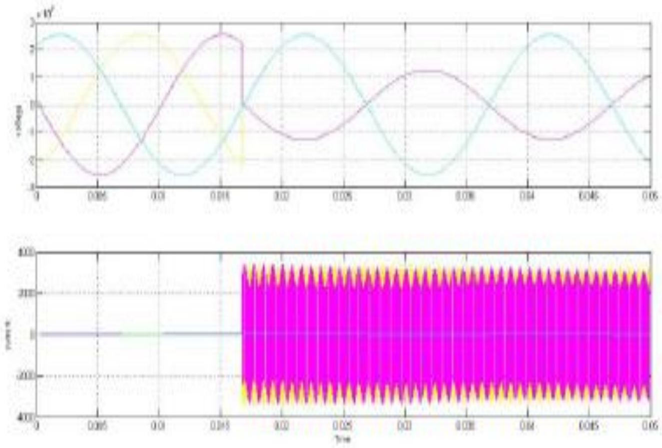

Fig.8 System Bus Voltage And Current Under Line To Line Fault

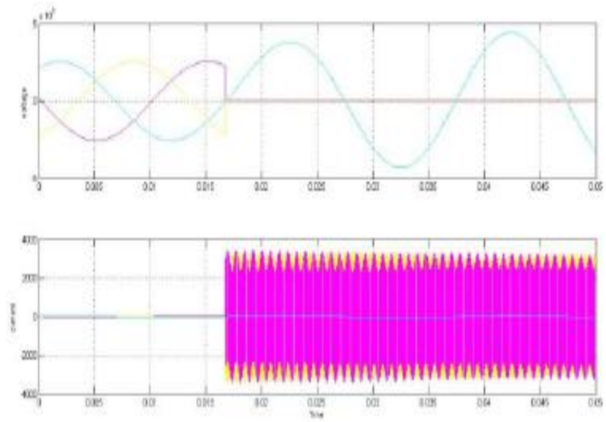

Fig.9 System Bus Voltage and Current Under Double Line To Ground Fault

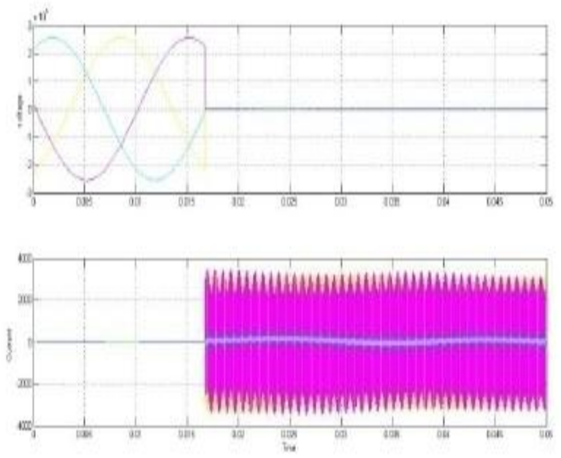

Fig.10 System Bus Voltage And Current Under Symmetrical Fault

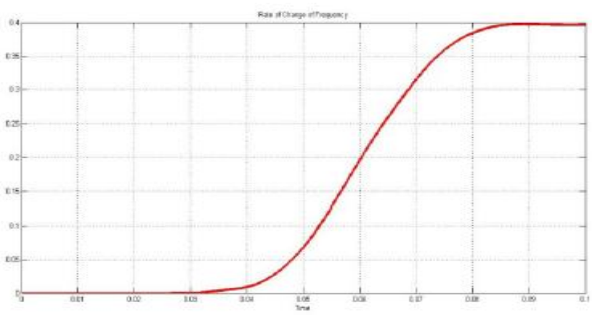

Fig.11 Rate Of Change Of Frequency

Fig.6. Shows the system voltage and current at the bus2 before fault. In Fig 7.. shows the system voltage and current under line to ground fault. In Fig. 8. Shows the System bus Voltage and Current under Line To Line Fault. System Bus Voltage and Current under Double line to ground fault is shown in Fig. 9. In Fig .10. System Bus Voltage and Current under Three Fault. Fig.11. Shows the rate of change of frequency is reduced in during the fault period. The symmetrical fault current is greater than unsymmetrical fault current. The manifestation of unsymmetrical fault is more than the symmetrical fault but the symmetrical fault is very severe in nature. In this proposed methodology the PMU is installed in the IEEE-9 bus system and the fault analysis is carried out. The various types of fault analysis are conceded and the waveform is obtained.

6. CONCLUSION

This paper proposes a new protection technique for transmission grids using phasor measurement units in a wide area system. Wide area backup protection scheme for transmission lines has been proposed. It utilizes wide area data of Wide Area Measurement System. This protection scheme, in comparison with other PMU based protection schemes and it is measured by a lesser number of PMUs. Moreover, this backup protection scheme acclimates its characteristics to the power system conditions. The IEEE 9-bus test system power network has been utilized to demonstrate the effectiveness of the proposed backup protection scheme. Various analyses indicate vigour of the proposed method against different fault locations, altered fault types, high impedance faults and measurement errors. It has also been observed that even if the faulted line is not equipped with any PMUs, the proposed method performs successfully and detects the faulted line and fault location quickly. By development of the communication infrastructures and wide area measurement systems (WAMS) the proposed scheme can be recognized in smart transmission grids.

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