Modelling, Simulation and Fault Detection for a Transmission Lines by Synchronized Phasor Measurement

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Abstract—

This paper proposes a novel adaptive relaying scheme based on phasor measurement units (PMUs) for transmission lines. The proposed adaptive relaying scheme can provide an extremely accurate discrimination between in-zone and out-of zone faults. Two novel and composite fault discrimination indices in terms of Clarke components of synchronized voltage and current Phasors at two ends of a line are derived. A line parameter estimation algorithm is developed and built in the newly designed relay to solve the uncertainty problem of line parameters. The proposed relaying scheme is independent of fault types, fault locations, fault path resistance, fault inception angles, and the variations of source impedance. The tripping decision time of the designed relay is very fast and almost held well within 6 ms for most fault events.

Keywords— PMU, PDC, GPS, SCADA, DFT

I. INTRODUCTION

In this modern age of technological development demand of the electricity is increasing where generation and transmission capacity is not increasing at same rate. Calculation of stability is again complicated process, as this is based on the pre-collected data. This calculation does not allow us to use the transmission lines up to their stability limits. There is one important constraint in power systems i.e. protective system used for transmission line protection. A classical protection 'scheme is more dependable than secure, which creates problems of blackout, voltage collapse etc. In the developing countries the reliability of the supply is less, as their protective schemes are more dependable than secure. So there must be an adequate protective scheme, which has better coordination between dependability and security, as both are equal important properties of a protective scheme.

Latest technique developed, which uses the synchronized phasor measurement for fault location problem. The synchronized phasor measurement for protection, control and monitoring of electrical power system were collected.

II. OBJECTIVES OF PROPOSED MODEL

It was observed that base of this is wide area measurement. Following are the main objectives of the project.

A. To study first about classical protective system in the power system which is more dependable then secure and which creates problems of blackout, voltage collapse etc.

B. To improve classical system by using wide area measurement system and this provides real time data of various buses through GPS based satellite communication technology and by using phasor measurement unit.

C. To model the power system network drive by fault breaker by giving different faults as Line to Line, Line to round, Double Line to Ground, Three Phase Fault and simulate the model for getting the results.

III. PHASOR MEASUREMENT UNIT (PMU) FOR POWER SYSTEM &WIDE AREA MEASUREMENT SYSTEM

Electricity is the backbone of every country whether it is developed or developing countries. The recent blackouts in various countries show that the electric utilities are not so reliable and there must be improvement in the protection schemes. False and undesirable operations of the protective devices play an important role in initiating and propagating the cascading events. Effective monitoring of a large power system is a long and difficult process than the local area control. The communication channels which is available now are not able to give real time information regarding the on line status of load flow, system frequency, system voltage. So monitoring of a large system is not so easy and that's why we must have proper communication system. The wide area measurement transforms power system from a component to a system level.

A. *Necessity of Wide Area Protection and Control and its Benefits*

The outages in power system have to be avoided to ensure security and reliability. The following are the major factors that lead to enormous disturbances and restrictions in power supply [4].

- Blackout
- Voltage collapse
- Cascade tripping

- Insufficient power generation
- Restriction on transmission capacity
- Restriction in power system extension

Presently there is no single system which acts both dynamically and coordinated for preventing from wide area disturbances. Power utilities demand for wide area control, protection and optimization systems is increasing, which are filling gap between classical protection and SCADA/EMS systems as summarized in the figure 1.

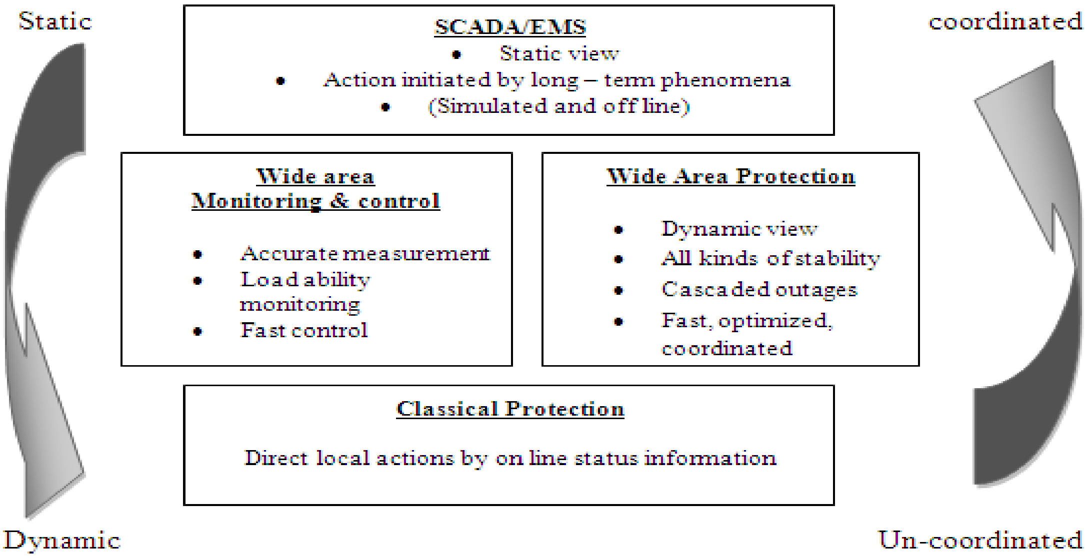


Fig 1 Wide Area Protection against Classical Protection and SCADA

Dependability being the measure of the relay equipments ability to correctly clear a fault while security is a measure of relaying equipment tendency not to trip incorrectly. By utilizing redundant relaying scheme, dependability and security can be controlled. Dependability and security are the function of type of protection scheme, construction of relay, application of relays. For a fixed or non-adaptive type-relaying scheme, once the relaying system is designed and installed, its security and dependability are fixed and cannot respond to changing system conditions. With the availability of rapidly developing computer and communication technologies,

The control and ·protection schemes for power system comprise mainly of two types of systems, which are working independently in most of the cases.

- **Local control and protection: -** This is acting locally to protect individual equipment such as transformers, generators, transmission line etc. This is acting dynamically but without any on-line co-ordination with other protection equipment and network management. This is operated locally with least reliability, which protects equipment to isolate faulty section within millisecond.

- **SCADA network control: -** This is static or quasi static, which can handle long term non-dynamic phenomena with other systems and equipment. But these are not considering any dynamics such as oscillation and momentary actions.

B. ***Basic concept of Wide Area Measurement***

The primary purpose this section is to discuss various facets of wide area measurement and adaptive protection schemes in order to generate thought-provoking ideas from protection engineers. The conceptual block diagram is as shown in the fig 2 to provide quick overview of the proposed concept.

The functional architecture of the proposed protection system is described. It explains the logical way in which all individual protective functions are organized and co-operate with each other. The corresponding functions, as they exist presently are also provided in this table for comparison.

The wide area platform for protection and control comprises of hardware:

- Phasor Measurement Unit (PMU)
- Communication Links
- Central Unit- Personal Computer
- Data Preprocessing Package
- Basic Services (BS)
- Specific Individual Applications
- Graphical User Interface
- Package containing model/data of the supervised power system and coordination with other software packages [4].

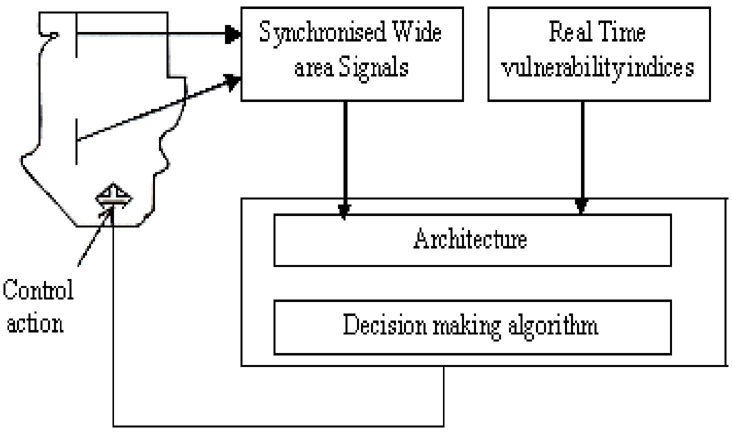


Fig 2 Conceptual Block Diagram of Wide Area Adaptive Protection

C. ***Phasor Measurement system***

The PDC also exports data from other utilities and then it wills uses for display, recording and controlling function. The PDC correlates the data by time tag to create a system wide measurement.

- PMUs at substations make measurements.
- Data sent in real time to phasor data concentrator (PDC).
- PDC sends data for applications, stores disturbance data, manages measurement system.
- Applications include monitors, recorders, alarms, and controls.

D. ***Communication system***

Standard communications systems are adequate for most phasor data transmission. analog modems operating at 33.6 kbps are fast enough for most pmus sending data at 30 samples/sec. higher data rates and shorter delay times require digital communications at 56 kbps or higher. In addition to a data rate high enough to carry the data, low error rate and low latency are important. Data sent from the PMU is not re-transmitted, so the communication system must have error correction or a low error rate. 33.6 KBPS system includes optional error checking and recovery protocols. Even better is a system with inherently low error rates, such as SONET over fiber. Latency, the delay time between sending the data from the PMU and receiving it at the PDC, is critical to control applications. It is often the dominant factor in the overall control loop delay that limits the control frequency performance. Direct digital systems like fiber are much faster than analog systems with modems. Dial-up and Internet connections are not currently reliable enough for continuous, real-time systems, but may be used in the future.

E. ***Phasor Data Concentrator***

The Phasor Data Concentrator (PDC) brings together data from many sources including both PMUs and other PDCs and concentrates it into a single measurement set. It sends the full set or selected subsets of the correlated data out to other applications. It provides system management by monitoring all the input data for loss, errors and synchronization. It also can be used for data recording, continuous or only during disturbances.

IV. MATHEMATICAL MODELING OF THE PROPOSED SYSTEM

A. ***Precise calculation of frequency and phasor***

i.What is a phasor

Originally, phasors were introduced for the purpose of transforming electrical circuit differential equations. As an example in Fig 3 [12]

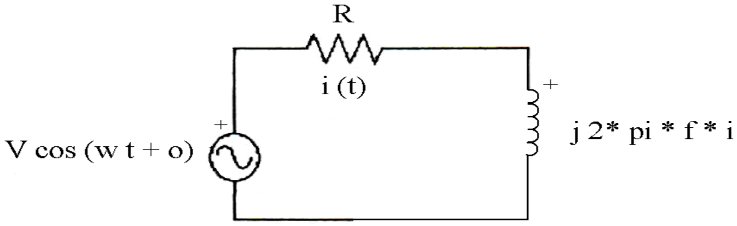


Fig: 3 RL electrical Circuit

The solution of flowing equation provides the solution of the circuit current.

$$v \cdot \cos(\omega \cdot t + \varphi) = Ri + L\frac{\partial i(t)}{\partial t} \quad (4.1)$$

If the circuit is linear, the solution for current is

$$i(t) = I \cdot \cos(\omega \cdot t + \theta) \quad (4.2)$$

Voltages and current phasors can be represented as complex number in exponential form as

$$\vec{V} = V \cdot e^{j\varphi} \text{ and } \vec{I} = I \cdot e^{J\theta} \tag{4.3}$$

Then appendix A shows that equation can be represented in algebraic form as follows:

$$V \cdot e^{j\varphi} = (R + j\omega L) I \cdot e^{J\theta} \tag{4.4}$$

The solution for the current is

$$I.e^{j\theta} = \frac{\mathrm{V.e}^{j\varphi}}{(R + j\omega.L)} \tag{4.5}$$

From this we can conclude that

- If phasor is a complex number associated with sinusoidal wave from, the phasor has the same magnitude as that of the sinusoidal waveform and has phase angle measured at t=0.
- Phasors are associated with nominal frequency only.
- There is no need to define a time scale or a time reference in theoretical steady-state studies, because the time dimension has been removed from the final phasor based equations when all parameters in the system are constant.(See Eq. 4 &5)
- When all the parameters are constant and the system frequency is constant, the phasor application in power system is easy. In the load flow studies or short-circuit studies we find that the system parameter are not constant. So there must be some precise method to calculate phasor at parameter variations.

- **Phasor: -** A complex equivalent of a simple sine wave quantity such that complex modulus is the sine wave amplitude and the complex angle is the sine wave phase angle.

- **Synchronism:-** The state where connected alternating current systems, machines, or a combination operate at the same frequency and where the phase angle displacement between voltages in them are constant, or vary about steady and stable average value.

- **Synchronized phasor: -** A phasor calculated from data sampling using a standard time signal as the reference for the sampling process. In this case, the phasors form remote ends have a defined common phase relationship that is synchrophasor.

- **Phase lock: -** The state of synchronization between two ac signals in which they remain at the same frequency and with constant phase difference. This term is typically applied to a circuit that synchronizes a variable oscillator with an independent signal.

This standard definition is associated with the nominal frequency. Outside the rated frequency the standards are open to all manufacturers to manufacture their equipments. The standard has no requirement regarding phasor magnitude measurement accuracy outside the nominal frequency (50Hz or 60Hz). The instantaneous phase angle measurement remains constant at rated frequency when using the stat of the second phase reference. If the signal is at off nominal frequency, the instantaneous phase varies with time.

The IEEE Standard 1344-1995 defines a steady state waveform where the magnitude, frequency and the phase angle of the waveform do not change. This standard has no requirements regarding phasor measurement performance for a waveform in transient state. The synchronized phasor measurement is as shown in the fig 4

$$v = V \cdot \cos(\omega t + \Phi) \tag{4.6}$$

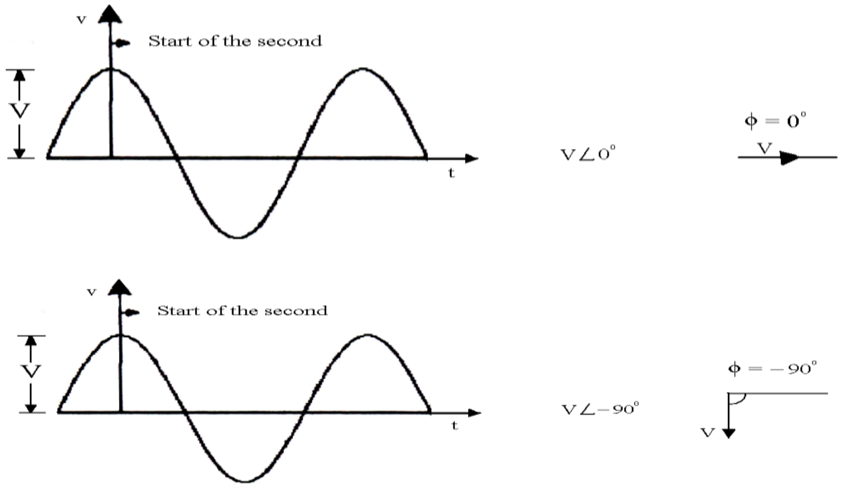


Fig 4 Synchronized Phasor Measurement Convention with respect to Time

V. MATLAB/ SIMULINK IMPLEMENTATION OF PROPESED SYSTEM

The given adaptive fault detection/location technique tested using data obtained from MATLAB. This section discusses about the effects of various factors different types of fault and different fault resistances are considered on the fault detection/location.

It is observed the absolute values of M and N will be held at zero before the occurrence of fault. This can be proved by substituting the measured data (Vs, Is) and (V_R, I_R) into the formula of M and N, respectively. Such all measured components satisfy the transmission line equation. As soon as, the post-fault data is inputted to algorithm through the moving data window, the computed absolute value of M and N abruptly deviate from zero, and hence fault location index D also quickly converges between 0 and 1 to some definite value. After the one or two cycle the index M and N are settled down to some constant value and index D take little time to settle down to final value. For this analysis, various faults were applied on the line of 200 km of two bus system shown. The results obtained from MATLAB programming are shown in the figure.

The prospective short circuit current of a fault can be calculated for power systems. In power systems, protective devices detect fault conditions and operate circuit breakers and other devices to limit the loss of service due to a failure.

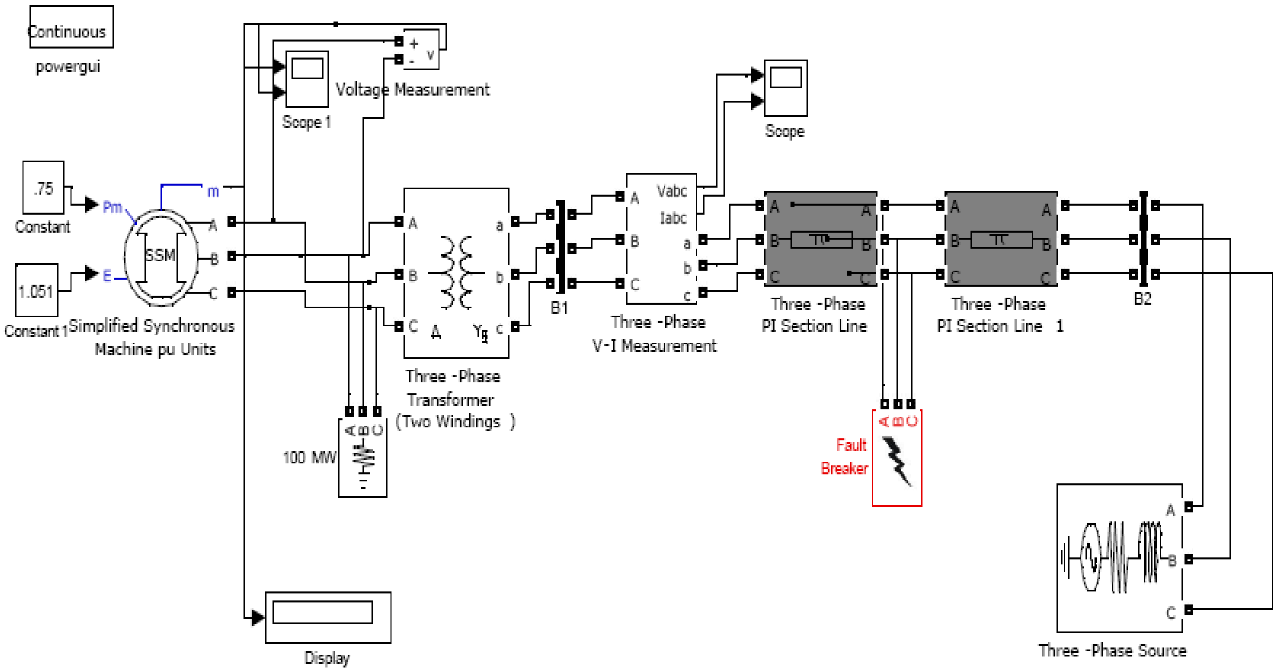
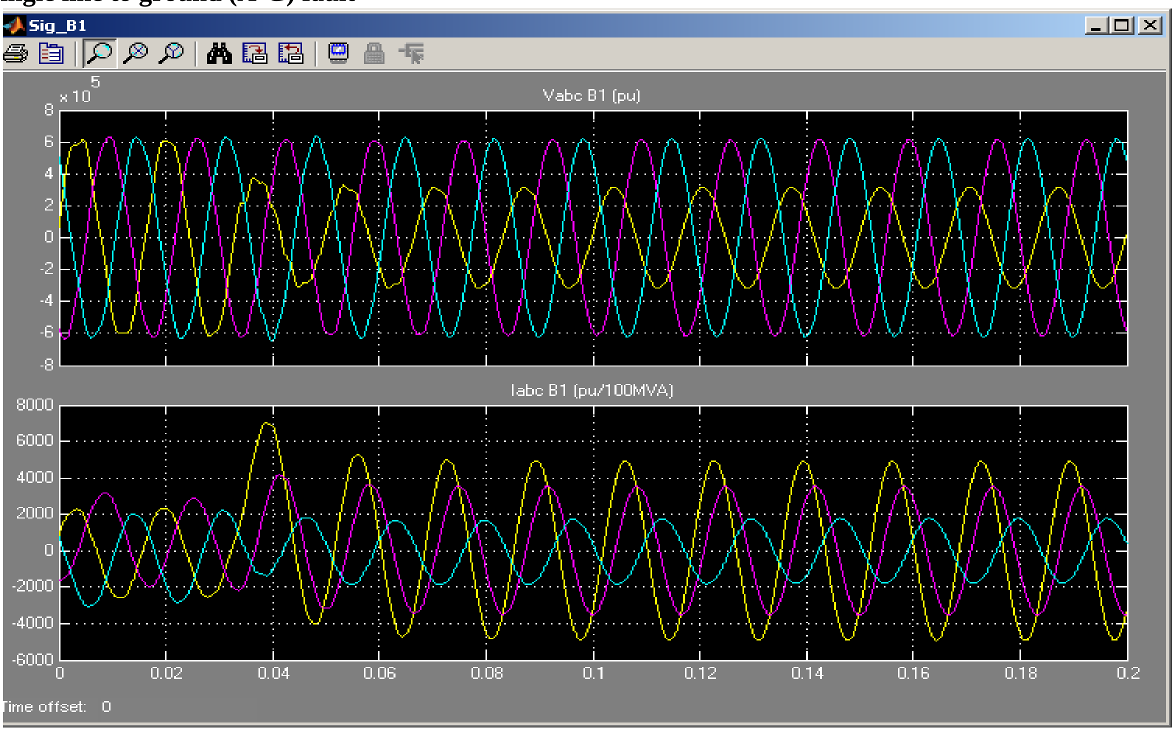


Fig 5 Matlab simulation diagram of fault on transmission line system

- **Single line to ground (A-G) fault**



- **Three phase (A-B-C) fault**

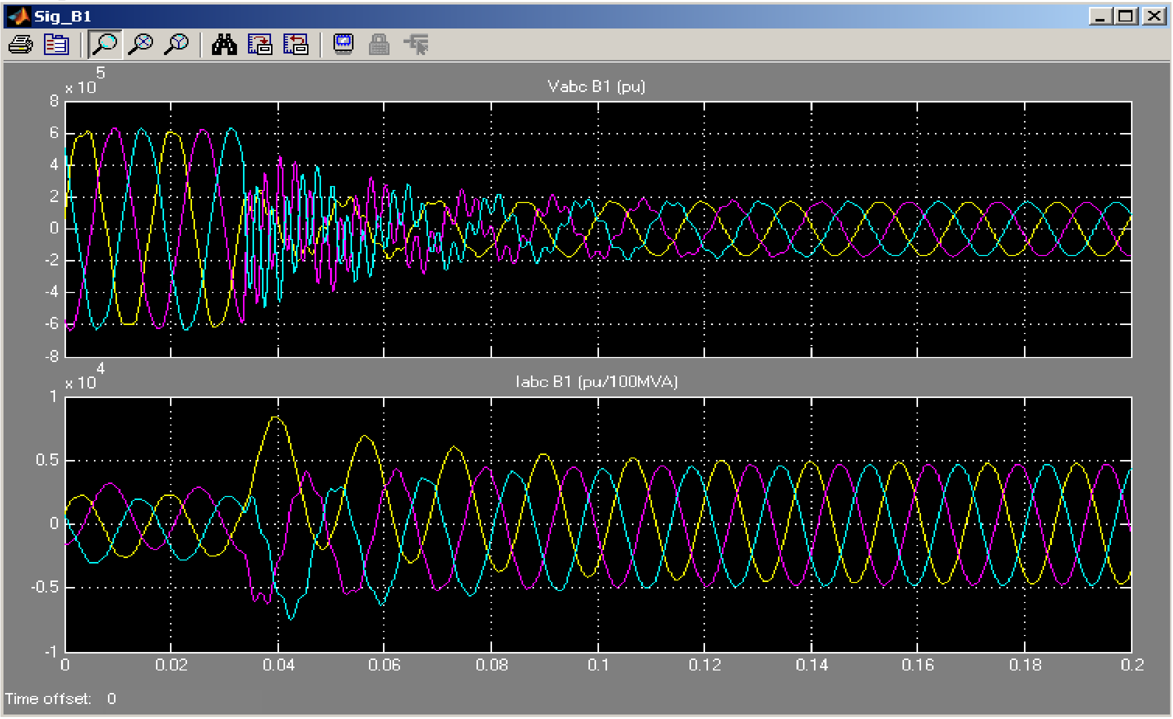


Fig 6 Magnitudes of Synchronized Phasors of Voltages and Currents for a-b-c Fault

VI. CONCLUSIONS

The advent of satellite-based time-keeping systems and advances in the computer technology has made it possible to take the samples of system parameters within l microsecond accuracy. These can provide synchronized measurements that eliminate the need of having different devices for protection, control and analysis of electrical power systems for wide area application. System wide applications have different sampling and the signal processing requirements than do have traditional protection application. The additional synchrophasor measurement in protective relay result in increased power system reliability and provides easier disturbance analysis, protection, fault distance calculations and control.

The extraction of the phasor from samples is an easier and fast process by DFT (Discrete Fourier Transform) and SDFT (Smart Discrete Fourier Transforms). The SDFT gives accurate results in the presence of frequency variation or deviation and in the presence harmonics also. The DFT and SDFT are acting as the filtering devices. Though this system gave accurate results, better reliability, fast system monitoring and decision-making facility, this system is not wide spread because they it is relatively too expensive and so it is used only in critical conditions.

In this report, an overview of fault location techniques for power transmission lines is presented. Fault-location techniques are used in power systems for accurate pinpointing of the fault position in order to allow fast repair to restore service to consumers. Fault location can be achieved by either impedance-based fault locators or through the use of high frequency traveling waves. The report discusses in depth the impedance-based techniques that use voltage and current phasors. Distinctive features of different fault location algorithms for the impedance-based techniques are presented.

Single-terminal data fault-location method and issues related to its accuracy are presented. The two-terminal data fault location method based on non-synchronized and synchronized measurements is considered. Two-terminal impedance-based fault location methods can improve the accuracy compared to that of single-terminal method. The synchronized double-end approach using DFRs enhanced with efficient data acquisition interfaced to GPS receivers to synchronize the data located at the two ends of a transmission line. Since this approach adds extra cost to the system, its use is restricted to critical lines in the power network.

The synchronised phasor measurement provides fairly good accuracy for measurement of phase angles. The angle difference of the PSV (Positive Sequence phasor) of the voltage phasors between the generator and infinite bus is the reflection of transient stability of the system. So by considering the angle difference between PSV phasors can help to determine the transient stability of the system with good accuracy. It will help to us to apply the remedies depending upon the contingencies.

Use of synchronised sampling in fault location algorithm provides following benefits.

- Fault location, type and incidence angle have very little effect on accuracy.
- Synchronized sampling at two ends of a line makes the algorithm transparent to the model characteristic and operating conditions of the rest of the power system.
- The algorithm can easily cope up with any level of mutual coupling, and it is applicable to multi-terminal lines.
- The algorithm can operate accurately on both transposed and un-transposed lines for any conditions.
- Although fault impedance may contain an inductive component and the fault resistance may be variable in time, the algorithm can still preserve the high accuracy.

- The algorithm is based on the direct solution of differential equations. Therefore it can be applicable to any type of the line as long as the model of interested transmission line is available.
- The algorithm is extremely fast. It responds only in one or one and half cycle with moving data window. As soon as the post fault measured data is entered into the moving data window, it detects and locates the fault.
- As this algorithm is useful both for detection and location of the faults, this gives the option for the distance relay.

The-reliability, security and dependability of this relaying scheme are high.

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