Automatic Fault Detection and Fault Solving using Travelling Wave

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Abstract:
In power system fault is abnormal condition may that is due to power loss, harmonic. Short circuit line, open circuit line ,L-L fault , due to L-G fault and L-L-G fault, due to Transient .Transient in power system is occurs due to high voltage spreading in power system that makes system faulty and unstable .This paper shows how these transients can be measured in a protective relay and used to find its fault locating. This approach provides accurate fault location estimation for transmission lines automatically within a couple of seconds after the fault. The travelling wave fault locator within the relay uses conventional current transformer measurements and does not require any additional wiring or special installation considerations. These relays detect internal line faults and use travelling wave and impedance-based algorithms to optimize the estimation and reporting of the fault location. The travelling wave and impedance based algorithms complement each other to provide accurate fault location estimation for all internal faults, independent of the fault incidence angle. This paper provides a tutorial on travelling wave fault location and describes a travelling wave fault locating algorithm that uses time-synchronized measurements of the travelling currents at the line terminals to determine the fault location.. The paper presents the details and experiences of a field application of these relays on a high-voltage transmission line.

Keywords: Automatic fault detection - High voltage protection – Wave propagation - Transient Fault.

I. INTRODUCTION
Due to recent development in power it is must be necessary to provide protection to transmission line. Extra high voltage transmission line protections are areas for new developments today. Transmission line protection using travelling waves generated at the time of fault are used as trip signals of a travelling wave relay. Relay tripping based on steady state component of voltage requires tripping time of few cycles and therefore does not give fast isolation. Fast fourier transform, Discrete transform, wavelet transform are based on sampling comparators and have inherent drawback of boiling down to computation based on steady state components for trip signals. The accuracy of computation and in turn isolation are need of the hour as part of fast tripping, to reduce the overall period to micro seconds. With speed of light. 0,α and β components are used to get relay trip signals df and dr. Proposed work has also calculated distance, relay trip signals from steady state post fault voltages and currents respectively. Thus proposed work has designed trip signals for travelling wave relay and distance relay from post fault voltages and currents respectively. Automated fault locating system that used microwave communications to send the TW arrival information to the remote terminal for fault location estimation. the development and field evaluation of the performance of a digital fault locator for high-voltage direct current (HVDC) lines that uses voltage and current measurements from one line terminal to estimate the fault location. Using voltage and current measurements, we can calculate incident and reflected waves. Applications based on incident waves are immune to the effects caused by termination impedances. Numerical protective relays include fault location estimation algorithms based on the line impedance and voltage and current measurements. In most applications, these relays only use measurements from the local terminal. Some relays also use information from the remote terminal to estimate the fault location. Using information from the local and remote terminals minimizes errors due to mutual coupling with adjacent lines, system nonhomogeneity, and fault resistance. In some applications, such as series-compensated lines, the impedance-based fault locating methods are challenged and utilities require more accurate. Therefore tripping schemes based on high frequency signals and not based on steady state components are desirable today. Also trip signals generated should be part of the post fault voltages of current and voltage. Also some kind of back up protection is required incase the main tripping schemes are susceptible to fail. Described protection of transmission line based on post fault voltages evaluated and detected by correlation output of the comparator. Proposed work has developed tripping schemes based on relay trip signals obtained from 0,α and β components using clark’s transformation. Post fault voltages are resolved in to forward waves and backward waves which travel on transmission lines Different fault distances and fault inception angles, are considered in the paper.

II. PROBLEM SUMMARY
At present power system engineers are mainly concerned with power system stability because of the interconnected networks in the deregulated power supply system. Since fault can destabilize the power system, they must be isolated quickly. There is therefore a need for ultra high speed clearing of the fault, which improves the transient stability of the power system. The need of the hour is to devise faster tripping schemes where trip time is not in cycles but in few milli second. Moreover finding the accurate location of a fault has always been a challenge for electric utility. Conventional method of fault location is to use
the voltage and current data measured at one or more points along the power networks. Knowing the line impedance per unit length, the fault distance can be approximated from the calculated impedance obtained from voltage and current data. This impedance method, however, is subjected to errors caused by e.g. high resistance ground faults, teed circuits topologies, and the interconnection to multiple sources. While technique based on travelling waves helps in determining the location of fault accurately. Moreover it is undoubtedly the quickest possible scheme for fault detection as it utilizes the high frequency components.

II. MATHEMATICAL REPRESENTATION OF TRAVELLING WAVE

A fault on a transmission line generates TWs that propagate from the fault location to the line terminals with a propagation velocity that depends on the inductance and capacitance of the line. Fig. 1 shows the equivalent circuit of a segment with length $\Delta x$ of a two-conductor transmission line. The circuit includes the resistance $R$, inductance $L$, conductance $G$, and capacitance $C$ of the line in per unit of the total line length. We use Kirchhoff’s voltage law, shown in (1), and Kirchhoff’s current law, shown in (2), to relate the voltages and currents at locations $x$ and $z + \Delta z$.

$$V(z, t) = R \cdot \Delta z \cdot I(z, t) + L \Delta z \frac{\partial I(z, t)}{\partial t} + v(z + \Delta z, t).$$  
**equ. (1)**

$$I(z, t) = G \cdot \Delta z \cdot v(z + \Delta z, t) + C \cdot \Delta z \cdot +$$  
**equ. (2)**

Equations (3) and (4) determine the voltage and current as a function of $x$ and time for the two-conductor transmission line in the time domain as the length of the segment $\Delta x$ approaches zero.

$$\frac{\partial v(z, t)}{\partial z} = -R \cdot I(z, t) - L \frac{\partial I(z, t)}{\partial t}.$$  
**equ. (3)**

$$\frac{\partial I(z, t)}{\partial t} = -G \frac{\partial v(z, t)}{\partial t} - C \frac{\partial v(z, t)}{\partial t}.$$  
**equ. (4)**

Current waves at 50, 150, 300, and 450 kilometers traveling on a 400 kV line for a nominal voltage step change at the sending end, where A-phase is green, B-phase is blue, and C-phase is red.

IV. TWO TERMINAL LINE FAULT LOCATION ANALYSIS USING TRAVELLING WAVE REPRESENTATION

TW-based fault location provides better accuracy relative to impedance-based fault locating methods. Single end (Type A) and double end (Type D) are the two most common methods for computing fault location using TWs. Type A uses the time difference between the first arrived wave and the successive reflections from the fault location to compute the fault location. This method is appealing because it only depends on local information; therefore, it does not require a communications channel. However, identifying the reflections is a major challenge. The reflections can arrive from the fault location, from the remote terminal, or from behind the local terminal. Accurately identifying the reflection from the fault location poses a challenge for single-end TW-based fault location, especially on ac transmission lines. The double-end method overcomes the challenge of identifying the reflections from the fault but requires the TW information from the remote terminal. This Type D method uses the time difference between the first arrived TWs captured at both terminals along with the line length and the wave propagation velocity to compute the fault location. Fig. shows the waves propagating to Terminals A and B following a fault condition on a transmission line.

![Figure 1. Wave Propogation](http://ijesc.org/)
Measurement devices at the line terminals detect the TWs and accurately time-stamp the arrival of the wave using a common time reference (e.g., IRIG-B or IEEE 1588). The typical time-stamping accuracy is better than 1 microsecond. The TW-based fault location is computed using. Where TWFL is the TW-based fault location, LL is the line length. TwaveA is the TW arrival time recorded at Terminal A. TwaveB is the TW arrival time recorded at Terminal B. c is the speed of light. LPVEL is the propagation velocity of the TW in per unit of the speed of light. The TW propagation velocity is a key parameter in the fault location calculation and is typically obtained from line parameter estimation programs. Typical installations have communications between the substation and the control center, where computer-based analysis tools retrieve the TW information captured at the line terminals and compute the fault location. In this paper, we discuss installations where protective relays exchange TW information obtained from the phase currents and automatically calculate the fault location at the line terminals within a couple of seconds after the fault.

V. TRAVELLING WAVE FAULT LOCATION RELAY

- **Benefit:** Numerical protective relays have included fault location estimation based on voltage and current measurements and line impedance since 1982 [1]. These relays use voltage and current measurements acquired at the local terminal and report the fault location estimation results at the substation and the control center through auto messaging right after the occurrence of a fault. While this approach provides estimations within 2 percent of the line length, there are cases where mutual coupling, fault resistance, and system nonhomogeneity can cause large errors. In these cases, the impedance-based fault locating methods in protective relays can be improved using local and remote (double-end) measurements. Impedance-based fault location estimation requires the presence of the fault for a couple of cycles to provide accurate results. While this requirement is not an issue in sub transmission network applications, it can be an issue in EHV and ultra-high voltage (UHV) applications where faults are sometimes cleared in less than two cycles. Furthermore, these impedance-based estimation methods might not be applicable to lines with series compensation or lines close to series compensation due to sub synchronous oscillations, voltage inversion, and so on. Protective relays that include both impedance-based and TW-based fault location have the advantage of providing fault location even in cases where the TW amplitude is too low for reliable detection (e.g., faults that occur at voltage zero). In these cases, the relays estimate the fault location using line impedance and local and remote voltage and current measurements. If the remote measurements are not available, the relay estimates the fault location using local measurements.

- **Relay to real communication:** The relay discussed in this paper uses a 64 kbps channel that exchanges currents for differential protection purposes. The relay takes advantage of this bandwidth and includes TW information within the data packet without affecting the performance of the differential element.

**Figure 2. Relay Communication**

The relays exchange the times of arrival of the TWs (see Fig.) and use this information to estimate the fault location, make the results available at the relay location, and send the results to the control center within a couple of seconds after the occurrence of the fault.

- **Measurement of travelling wave:** High-frequency transients created by power system faults propagate at speeds that are close to the speed of light. However, high-voltage transmission lines are optimized to operate at nominal power system frequency with standard values of 50 or 60 Hz, and some of them are dc lines. Significant engineering effort is made in reducing the transmission line losses at these frequencies, with no attempt to consider their behavior at the high frequencies. Fortunately, the physics associated with the construction of efficient high-voltage transmission lines aid with the TW propagation. For various economic, operational, and environmental reasons, high-voltage transmission lines are built as regular structures, with uniform distances among phase conductors, uniform dielectric (air), constant conductor cross section, and regular transmission tower support, as illustrated in Fig. 3.

**Figure 3. High voltage transmission line**

Arrival of the TWs at the substations with sufficient energy is only the initial prerequisite for successful TW-based fault location. Once the waves arrive, they must be measured (extracted from the current and/or voltage measurements) and delivered to the fault location estimation algorithm. Currents and voltages on the transmission line are measured using standard CTs and voltage transformers (VTs). The responses of the CTs and VTs have been optimized for nominal frequency operation. TW signals can be measured using specialized high-frequency transducers similar to those used in high-voltage laboratories, but the high cost and custom nature of these devices make this approach impractical for wide-scale utility applications.
VL CALCULATION

The proposed methodology has been tested by implementing it on a 500 kV test system with different types of faults at different locations on a transmission line. The results obtained using proposed method, have been compared with the reference Pre-fault voltages and currents of all phases are as shown in figure.

Figure 4. Pre fault voltage and current waveform for 500kV line

When 3-ph to ground fault occurs at a distance of 525 km away from the relay location at an inception angle $90^\circ$, the results obtained using MATLAB programming are as below Post-fault phase voltages and currents for all phases are shown in figure.

Figure 5. Post Fault Voltage

High frequency forward backward voltage travelling wave

Figure 6. Post Fault Current

Figure 7. Voltage travelling wave
High frequency forward backward current travelling wave

And distance to the fault = 525 km (Estimated)

Mho relay characteristics

As shown in above method we can also getting different characteristic at different location like 525km, 220 km, 220 km, 195 km

VII RESULT ANALYSIS:

Result using MATLAB Programing show in this table

<table>
<thead>
<tr>
<th>Type of fault</th>
<th>Z</th>
<th>$z_{tw}$</th>
<th>$\tau$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 phase to ground</td>
<td>525</td>
<td>524.99</td>
<td>1.737</td>
</tr>
<tr>
<td>B – g</td>
<td>25</td>
<td>25.01</td>
<td>0.082</td>
</tr>
<tr>
<td>A – g</td>
<td>220</td>
<td>220.006</td>
<td>0.7279</td>
</tr>
<tr>
<td>C - g</td>
<td>195</td>
<td>194.99</td>
<td>0.6452</td>
</tr>
</tbody>
</table>

Where $z$ = Distance of fault in km

$z_{tw}$ = Distance calculated using proposed method

$\tau$ = Time at which relay identify travelling wave in msec

As seen from the relay signals in all above cases, $dr$ picks up before $df$. Hence in all cases fault is in forward direction. Moreover distance to the fault calculated in all cases are within the zone of protection as travelling wave relay is provided to protect the full 537 km length. Although theoretically $dr$ picks up first in case of B-g fault at 25 km, travelling wave relay will not trip for this fault as it is a close-up fault which is a limitation of travelling wave relay. Travelling wave relay will operate for all cases mentioned above except for the close-up fault. In case of 3-ph to ground fault at 525 km, Mho relay cannot operate as fault is out of its reach (relay reach is considered as 80% of the
length of line). For all other faults, Mho relay can operate. Mho relay provides comparatively faster protection in case of close-up fault. Hence if hybrid protection scheme is implemented, the limitation of travelling wave relay will be overcome by Mho relay. 3-ph to ground fault at 525 km is the case where Mho cannot operate while travelling wave relay operates and provides faster protection too. And for the cases where both relays can operate, travelling wave relay provides primary protection and Mho relay provides backup protection.

VIII. CONCLUSION
The methodology based on travelling wave for EHV transmission line protection was developed. Proposed methodology was tested on 500 kV transmission line systems. Post-fault voltages and currents, travelling wave components and fault location were calculated. Relaying signals were obtained. Studies show that the scheme is insensitive to fault type, fault resistance and fault position on the cable. Studies also show that the wavelet technique is able to offer a very high accuracy in fault detection and fault location on transmission line. Comparison of proposed method was done with correlation technique shown in Ref. paper for 500 kV test system. Post-fault voltages, post-fault currents and relaying signals were compared with the Ref. paper. The proposed method has also offered hybrid relay tripping signals.

IX. REFERENCES:


