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Application of a Reliable Technique for Transmission Lines Protection

Ihedioha Ahmed C.
Enugu State University of Science and Technology Enugu, Nigeria.

Abstract – In this research, a protection of transmission lines using Global Positioning Systems (GPS) is presented. The proposed idea has the feature of unit protection relays to protect large power transmission grids based on phasor measurement units. The principle of the protection scheme depends on comparing positive sequence voltage magnitudes at each bus during fault conditions inside a system protection center to detect the nearest bus to the fault. Then the absolute differences of positive sequence current angles are compared for all lines connecting to this bus to detect the faulted line. The new technique depends on synchronized phasor measuring technology with high speed communication system and time transfer GPS system. The simulation of the interconnecting system was applied using Matlab Simulink. The new technique can successfully distinguish between internal and external faults for interconnected lines. The time of fault detection were estimated by 0.00345 msec for all fault conditions and the relay were also evaluated as a backup relay based on the communication speed for data transferring.

Index Terms – Protection, Transmission lines, Global Positioning Systems (GPS), Phasor.

1. INTRODUCTION

The on-going reforms in the Nigerian power sector incorporate among its numerous objectives, to produce radical expansion of the existing grid network. It is expected that in the next few years, a much superior, fortified and secure grid will replace the inadequate, unstable and delicate grid in Nigeria [1].

The rapid increase in the demand for electricity as a result of population growth, industrial development and rise in consumer electrical appliances have necessitated the stepping up of generation and transmission capabilities of the grid network to deliver quality power supply to the consumers. It becomes therefore necessary to fulfill the requirement of load without any fault in providing bulk power from sending end to receiving end in short duration of time. At such, there is need to effectively detect and manage the associated faults inevitable in all transmission lines.

Faults detection on transmission lines using conventional means can be very costly and inconclusive. In power transmission systems, accurate location of faults will not only save time but helps to optimally utilize resources available for electricity supply. Thus, power system operator needs accurate information transferred speedily in a form most suitable to communicate with field personnel [2].

The traditional method such as time graded over current protection, current graded over current protection, e.t.c have failed to deliver on accuracy in fault detection at specific time. To this, a more robust technology for fault detection on transmission lines has become therefore necessary.

There has been rapid advancement in the use of novel and more efficient technologies in management of transmission lines across the globe. These technologies reduce the high costs of emergency measures invoked to guard against the possible effects of a second or third fault in the same vicinity. There is also a prime economic driver to quickly isolate the faulted section, undertake repairs and return a network to normal operational status in the shortest possible time.

Now on the heels of a new revolution, one of the latest available technologies is Global Positioning System (GPS) which can help prescribe fault location on power transmission system within a transmission distance.

2. THE GLOBAL POSITIONING SYSTEM

The Global Positioning System (GPS) is a satellite-based navigation system made up of a network of 24 satellites placed into orbit. GPS was originally intended for military applications, but in the 1980s, the government made the system available for civilian use. GPS works in any weather conditions, anywhere in the world, 24 hours a day. GPS Technology allows precise determination of location, velocity, direction, and time. GPS are space-based radio positioning systems that provide time and three-dimensional position and velocity information to suitably equipped users anywhere on or near the surface of the earth (and sometimes off the earth). By combining GPS with current and future computer mapping techniques, we will be better able to identify and manage our natural resources [3]. Intelligent vehicle location and navigation systems will let us avoid congested freeways and more efficient routes to our destinations, saving millions of dollars in gasoline and tons of air pollution. Travel aboard ships and aircraft will be safer in all weather conditions. Businesses with large amounts of outside plant (railroads, utilities) will be able to manage their resources more efficiently, reducing consumer costs. GPS satellites circle the earth twice a day in a very precise orbit and transmit signal information to earth. GPS receivers take this information and use triangulation to calculate the user's exact location. Essentially, the GPS receiver compares the time a signal was transmitted by a satellite with the time it was received [4]. The time difference tells the GPS receiver how far away the satellite is. Now, with distance measurements from a few more satellites, the receiver can determine the user's position and display it on the unit's electronic map. By knowing the distance from another satellite, the possible positions of the location are narrowed down to two points (Two intersecting circles have two points in common). A GPS receiver must be locked on to the signal of at least three satellites to calculate a 2D position (latitude and longitude) and track movement. With four or more satellites in view, the receiver can determine the user's 3D position (latitude, longitude and altitude). Once the user's position has been determined, the GPS unit can calculate other information, such as speed, bearing, track, trip distance, distance to destination, sunrise and sunset time and more. Accurate 3-D measurements require four satellites. To achieve 3-D real time measurements, the receivers need at least four channels [5].

2.1. How GPS Works

According to The Aerospace Corporation and Trimble, GPS technology can be described in terms of three segments:

a. Space Segment: Consists of twenty-four satellites orbiting 11,000 nautical miles above the earth.

b. Control Segment: Consists of 5 ground stations around the globe that manage the operational health of the satellites by transmitting orbital corrections and clock updates.

c. User Segment: Consists of various types of GPS receivers that can vary in complexity and sophistication. This segment is what most people are familiar with; examples include the navigation system in a car, or the GPS device in a cell phone.

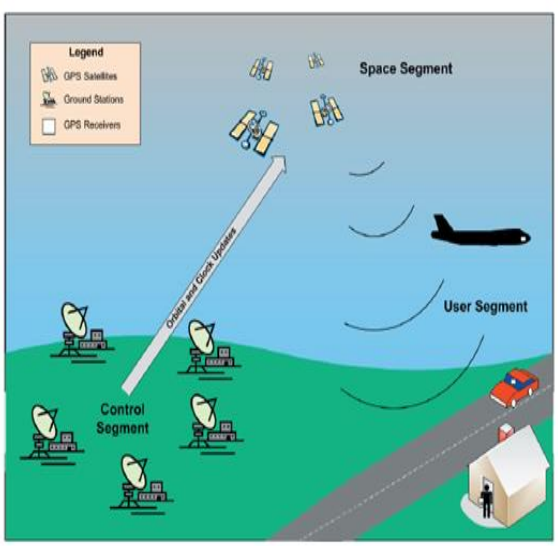

Fig.1: GPS Segments [6]

GPS receivers are able to identify their location when three GPS satellites triangulate and measure the distance to the receiver and compare the measurements. A fourth satellite measures the time to the receiver. The information from all four satellites is compiled to determine the location. The sophistication of a GPS receiver impacts the reliability and accuracy of the GPS data received.

2.2. Benefits of GPS in protection of transmission systems

The use of GPS in protection of transmission systems is beneficial with respect to;

1. Value regarding programmatic goals: more reliable monitoring using GPS related technologies.

2. Technical merit: New fault location algorithm based on new input data.

3. Emphasis on transfer of technology: CCET partnership aimed at commercialization.

4. Overall performance: On time, with all goals met so far.

2.3. Transmission system

Electric power transmission, a process in the delivery of electricity to consumers, is the bulk transfer of electrical power. Typically, power transmission is between the power plant and a substation near a populated area. Electricity distribution is the delivery from the substation to the consumers. Electric power transmission allows distant energy sources (such as hydroelectric power plants) to be connected to consumers in population centers, and may allow exploitation of low-grade fuel resources that would otherwise be too costly to transport to generating facilities. Due to the large amount of power involved, transmission normally takes place at high voltage (110 kV or above) [7]. Electricity is usually transmitted over long distance through overhead power transmission lines. Underground power transmission is used only in densely populated areas due to its high cost of installation and maintenance, and because the high reactive power produces large charging currents and difficulties in voltage management. A power transmission system is sometimes referred to colloquially as a "grid"; however, for reasons of economy, the network is not a mathematical grid. Redundant paths and lines are provided so that power can be routed from any power plant to any load center, through a variety of routes, based on the economics of the transmission path and the cost of power. Much analysis is done by transmission companies to determine the maximum reliable capacity of each line, which, due to system stability considerations, may be less than the physical or thermal limit of the line.

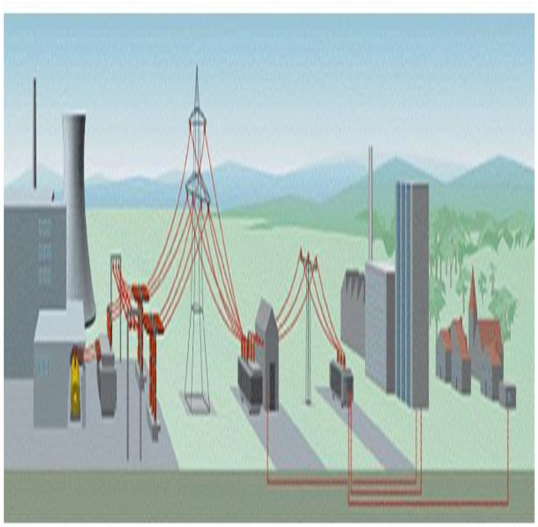

Fig.2: Description of a Transmission System [8]

3. FAULT LOCATION TECHNIQUE

Fig.3 shows a single-circuit transposed transmission line. In Fig.3, total line length between buses S and R is assumed to be L, and the synchronized voltage and current phasors measured and the synchronized voltage and current phasors measured S and R are Vs, Is, VR and IR, respectively. Using symmetrical components transformation to decouple three-phase quantities and to consider only the variation of a distance variable x (km), the relation between the voltages and currents at a distance x away from bus R can be expressed by the following sequence equations:

$$\frac{dV_{012}}{dx} = Z_{012}I_{012} \qquad 1$$

$$\frac{dI_{012}}{dx} = Y_{012}V_{012} \qquad 2$$

Where Z_{012} and Y_{012} are the per-unit length sequence impedance (Ohm/km) and admittance (Mho/km) of the transmission line, respectively. The matrices of Z_{012} and Y_{012} are all diagonal matrices, and the diagonal entries of matrices Z_{012} and Y_{012} are (Z_0,Z_1,Z_2) and (Y_0,Y_1,Y_2), respectively. Furthermore, $I_{012} = [I_0\ I_2\ I_3]^T$ and $V_{012} = [V_0\ V_2\ V_3]^T$. The variables with the subscripts 0, 1, 2 denote the zero-, positive-, and negative-sequence variables, respectively. The solutions of voltages and currents of the three decoupled sequence systems can be written as.

$$Vxi = A_i\exp(\Gamma_i\, x) + B_i\exp(-\Gamma_i\, x) \qquad 3$$

$$Ixi = \frac{1}{z_{ci}}\,[A_i\exp(\Gamma_i\, x) - B_i\exp(-\Gamma_i\, x)] \qquad 4$$

Where the subscript i denotes 0, 1, and 2 sequence variables, $\frac{1}{z_{ci}} = \sqrt{\frac{Z_i}{Y_i}}$ denotes the characteristic impedance, and $\Gamma_i = \sqrt{Z_iY_i}$ is the propagation constant. The constants A_i and B_i can be obtained by the boundary conditions of voltages and currents measured at bus R and bus S respectively. Therefore, voltage (3) can be further rewritten as

$$V_{xi,}R = \frac{V_{i,R+}Z_{Ci}I_{i,R}}{2}e^{\Gamma_i x} + \frac{V_{i,R-}Z_{Ci}I_{i,R}}{2}e^{-\Gamma_i x} \qquad 5$$

$$V_{xi,}S = \frac{1}{2}e^{-\Gamma_i L}(V_{i,S} + Z_{Ci,}I_{i,S})e^{\Gamma_i x} + \frac{1}{2}e^{\Gamma_i L}(V_{i,S} - Z_{Ci,}I_{i,S})e^{-\Gamma_i x} \qquad 6$$

Equations (5) and (6) represent the voltages at point x, which are expressed in terms of the two data sets (Vi,R, Ii,R) and (Vi,s, Ii,s) measured at the receiving end R and sending end S of the line, respectively.

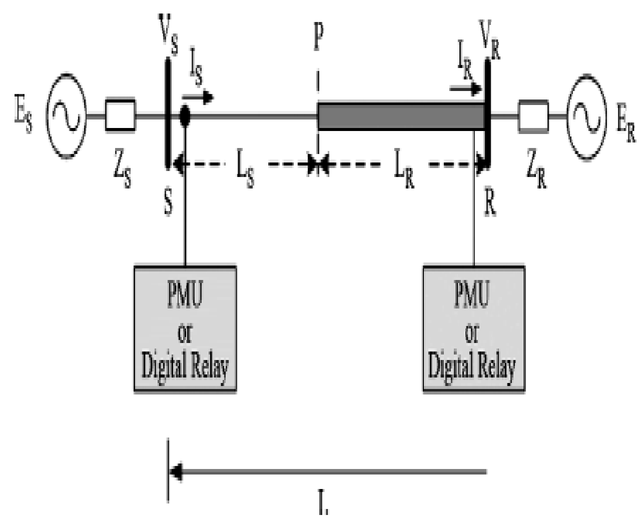

Fig. 3: One line diagram of a two-section compound transmission line

4. RESULTS AND DISCUSSION

4.1. Results

In this research, Matlab simulator is adopted to evaluate the performance of the proposed scheme. Fig. 4 depicts the response of the simulated system.

To demonstrate the robustness of the protection scheme, the simulations are conducted with respect to various system and fault conditions. In figure 5, fault inception time, fault-detection time, and tripping decision time, are shown respectively.

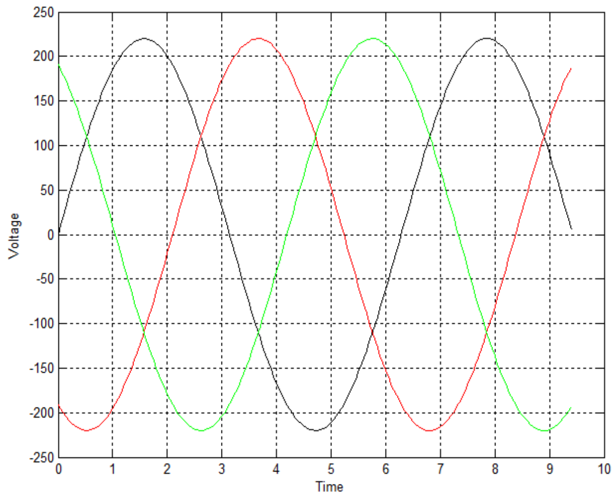

Fig.4: The response of the simulated system

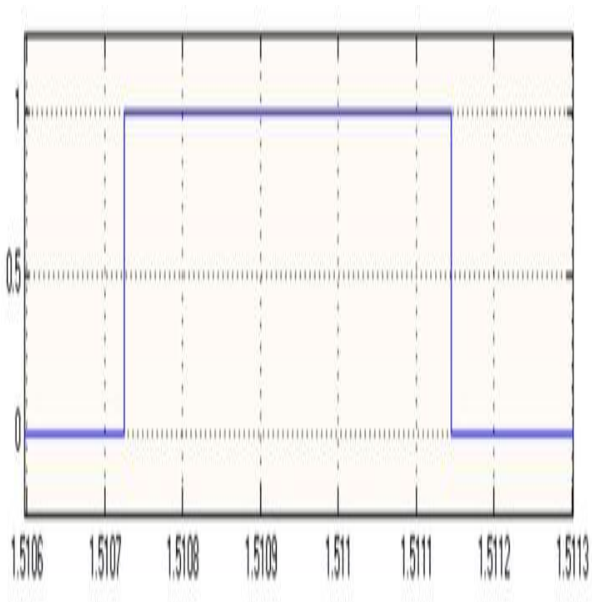

Fig. 5: Fault inception time

4.2. Discussion

The fault-on response curves of the proposed fault location indices for a phase to ground fault on the line is shown in Fig. 4. The fault position is set at 6.6 km away from bus S, the fault resistance is 1 Ohm and the fault inception angle is zero degree with respect to phase-voltage waveform at bus S. Fig. 4 obviously shows that all of the indices do not converge. It also shows the fault-on response curves of the proposed fault location indices for a phase to ground fault on the internal fault. The fault resistance is 10 Ohm and the fault inception angle is zero degree with respect to phase- voltage. In Fig. 5, the time taken to reach the threshold voltage is about 1.510760 ms, while the time taken to reach the threshold angle is also 1.511109 ms, then the fault can be detected in about 0.000349 ms.

5. CONCLUSION

The positional protection using GPS is a high speed protection system and offers a high accuracy in fault location. The protection system monitors the network to which it is connected and is not limited to individual unit plant as in traditional protection scheme.

The proposed scheme only uses a composite index to achieve high-speed relaying tasks including fault detection, direction discrimination, and classification. The scheme also provides accurate fault location.

Extensive simulation studies demonstrate that the complete protection scheme is not significantly affected by various system situations, fault events, and line configurations. The tripping decision time of the scheme is very fast and stable, whose value on average is well within half a cycle.

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Author

Ihedioha Chukwudi Ahmed is a PhD scholar in the department of Electrical and Electronics Engineering (Control option), Enugu State University of Technology, Enugu Nigeria. He holds a Master's degree (M.Eng) in Electrical/Electronics Engineering. Ihedioha Chukwudi Ahmed is also a member of the following; Council for the Regulation of Engineering in Nigeria, [COREN], Nigerian Society of Engineers, [NSE], Nigeria Association of Technologist in Engineering, [NATE], IEEE. His research interests are in the fields of Power systems, high-tech engineering intelligence systems, systems stability control, etc.