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Location Detection of Downed or Broken Power Line Fault not Touching the Ground by Hybrid AD Method

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Abstract: Occurrence of open-circuit faults is common in power transmission and distribution system. Finding exact location of downed or broken power line fault not touching the ground in high voltage and low voltage is one of the most important issues in power system. Till now so many methods to finding location of power line open-circuit fault. In all that methods failed to find exact location because of impedance and reactance of transmission line and some of the methods are too costly to find exact location. By observing all these points, this paper proposes a new method to find exact location of downed or broken power line fault not touching the ground by hybrid AD method. The proposed method is economic and easily to find location of fault with simple formula.

Key words: PLG (Power Line Guardian), High Impedance Faults (HIF's), Current Transformer (CT), location, methods, transmission

INTRODUCTION

In power transmission and distribution system line faults are common issues. Finding fault and fault location is a critical issue for both transmission and distribution system. An efficient fault protection and fault location scheme required to protects the equipment as well as public from hazardous over voltages. Downed conductors or broken power lines not touch the ground are of major concern to electric utilities because they may result in public hazard. Finding fault location of down power lines not touching ground is big problem because finding this type of fault is big concern in power system.

Downed conductors may not contact a conductive object and, therefore, have good probability of remaining energized. It's not easy to find fault (Anonymous, 1989; O'Brien and Udren, 2015; Anonymous, 1989; Cook and Garg, 2013; Hou, 2006) and at present this fault comes under open-circuit fault. This study mainly concentrated on location detection of downed or broken power line Fault not touching the ground.

Transmission line faults and fault location finding is very important for power system. So, many methods using for finding open-circuit fault location. Currently travelling wave and impedance based methods used for finding open circuit fault location. In impedance bases method, phasor voltage and phasor current measured from either sides or single side of transmission line (Covington *et al*., 2017; Anderson, 1995; Deepika *et al*., 2017; Saha *et al*., 2002; Zimmerman and Costello, 2010; Roostaee *et al*., 2017; Goh *et al*., 2017; Dugan *et al*., 2012). As compare to impedance method, travelling wave method would give accurate results (Rohrig, 1931; Ando *et al*., 1985a, b; Krzysztof *et al*., 2011; Barburas *et al*., 2015; Bingyin *et al*., 2005; De Andrade and De Leao, 2012; Gale *et al*., 1997; Crossley *et al*., 1993; Bollen, 1989; Ma *et al*., 2016; Costa and Souza, 2011; Baseer, 2013; Papaleonidopoulos *et al*., 2013; Anonymous, 1997). The drawback of this method is depend upon system parameters and configuration of network (Idris *et al*., 2012; Kawady and Stenzel, 2002). Travelling waves measured by using current transformers (Aurangzeb *et al*., 2001; Redfern *et al*., 2004).

Power Line Guardian's (PLG's) is a latest technology used for increase or decrease power flow in a transmission line and as well as observe power line between pole to pole every time (Milioudis *et al*., 2012; Dolezilek and Schweitzer, 2011). It's used to find transmission line condition like voltage, current frequency, etc.

Harmonics are another problem for power system, but effect of harmonics on power system is low. In some cases effect of harmonics is more and harmonics will reduce power system realibility. The harmonics in power system generated by non-linear loads, if harmonics can control by conducting awareness of harmonics program for industries, so, it help to power system reliability and stability (Holey and Chandrakar, 2016; Ellis, 1996; Al-Duaij, 2015; Shah, 2013).

MATERIALS AND METHODS

Methods for finding open circuit fault location: Occurrences of high impedance faults are common in power distribution between substation to rural area and within rural area. High impedance faults detected based

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on fault current measured by fault detection devices but an important fault is the downed or broken power line fault not touching the ground cannot be detected when there is not enough faults current to work fault detection devices in over head power distribution. At present there are no electrical techniques to detect this fault with 100% accuracy with less cost. A person touching an energized power line conductor faces real risk, since, no detection device known today can react fast enough to prevent injury. The only available solution to this problem today is an alert and informed public (Anonymous, 1989a, b; O'Brien and Udren, 2015; Anonymous, 1989; Cook and Garg, 2013; Hou, 2006). Finding downed or broken power line fault not touching ground is very difficult and finding exact location distance of this fault also big problem.

In generally, three methods are used for finding of fault location, they are impedance based technique, traveling wave technique and knowledge based technique. In below paragraphs explain how these two methods (impedance based technique and traveling wave technique) to find location of fault.

In impedance based method uses the fundamental frequency components like phasor voltage and phasor current. In this method phasor voltage and current measured from one side or two side of transmission line. Two side measurement would give more accurate results as compare to single side measurement because of its not depend upon fault resistance and reactance. Phasor voltage and currents are measured by PMU (Phasor Measurement Unit) and collection of data send to data center via. GPS (Covington *et al*., 2017; Anderson, 1995; Deepika *et al*., 2017). According to measurement, line impedance per unit length is calculated and fault location distance also calculated. In single end measurement depending upon reactance and resistance of transmission line, it may not give correct fault location. In case of grounded fault, fault resistance will be high and it will affect the fault location (Saha *et al*., 2002; Zimmerman and Costello, 2010; Roostaee *et al*., 2017; Goh *et al*., 2017). This method having some errors they are measuring voltage and current insufficiently, positive sequence impedance and zero sequence impedance calculated depend on parameters like size of conductors, distance between conductors etc. (Dugan *et al*., 2012).

Transmission line fault location by travelling waves first proposed by Rohrig (1931). Travelling wave method is most accurate and famous method to find fault location. In this method when fault occurred on transmission line, travelling wave generated from fault point and travelling wave travelled towards both sides and travelling wave returned (reflected wave) from both sides, depending upon reflected wave, fault location calculated.

In this method, we have single-side measurement algorithm and two-side measurement algorithm. In single-side algorithm or 2 side algorithm calculation of fault location depending upon first generated traveling wave travel or first generated two consecutive waves from fault point to end of transmission line and same wave reflected back to fault point (Ando *et al*., 1985). And for double-side algorithm use some GPS to get data from both sides of transmission line (Ando *et al*., 1985). The two side algorithm is costly and complex because of using GPS technology.

Depending upon fault locator, there are five types to find fault location. They are A-E (Krzysztof *et al*., 2011; Barburas *et al*., 2015; Bingyin *et al*., 2005; Gale *et al*., 1997; Crossley *et al*., 1993; Bollen, 1989; Ma *et al*., 2016; Costa and Souza, 2011; Baseer, 2013; Papaleonidopoulos *et al*., 2013; Anonymous, 1997). Here, we are discussed only Type A, D and E.

Type-A: This method measument only on one side of transmission line. Equation 1 used to find location of fault (Ando *et al*., 1985b; Krzysztof *et al*., 2011):

$$D = \frac{T_3 - T_1}{2}.V \tag{1}$$

Where:

- D = Fault location distance (m)
- T_1 = Time when first wave generated at fault location arrives at source station (sec)
- T_3 = Time when first wave reflected from fault location arrives at source station (sec)
- V = Wave velocity (m/sec)

Type-D: Type D locator measurements on both ends of the line. Suppose if two sub-stations A and B are there, if fault occurred in between Two sub stations. Travelling wave generated at fault point and travel towards station A and B within few micro seconds. Equation 2 used to find location of fault (Barburas *et al*., 2015; Bingyin *et al*., 2005):

$$D = \frac{(L + T_2 - T_1).V}{2} \tag{2}$$

Where:

- T_1 = Time when the first wave generated at fault location arrives at station A (sec)
- T_2 = Time when the first wave generated at fault location arrives at station B (sec)
- L = Length of line (m)
- V = Wave Velocity (m/sec)
- D = Fault location distance (m)

Type-E: Type E locator performs measurements on one end of the transmission line. Type E locator use wave generated by closing circuit breaker on transmission line. For finding fault location distance calculated by difference

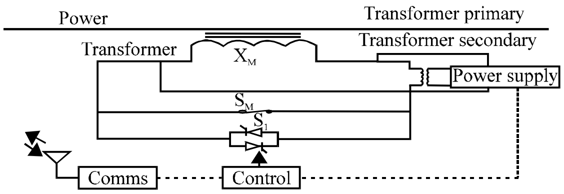

Fig. 1: Schematic diagram of Power Line Guardians ("PLG")

between timing of wave generated by closing a circuit breaker and a reflected wave from the fault (Gale *et al*., 1997; Crossley *et al*., 1993; Bollen, 1989). Equation 3 used to find location of fault:

$$D = \frac{T_2 - T_1}{2}.V \quad (3)$$

Where:

- D = Distance to fault location (m)
- T_1 = The time when wave is generated by closing a circuit breaker (sec)
- T_2 = The time when reflected wave reaches a substation (sec)
- V = Wave velocity (m/sec)

The drawback of this method is its completely depend upon system parameters, network configuration and one more major drawback of this method is if fault occurred near zero voltage inception angle, not able to detect fault location (Kawady and Stenzel, 2002). At present current transformer's are using for measuring travelling wave (Aurangzeb *et al*., 2001; Redfern *et al*., 2004).

Power Line Guardians ("PLG"): One of the important technologies is Power Line Guardian's (PLG's). Figure 1 shows the schematic diagram of PLG. The PLG's are mounted directly on the transmission line. The operating power for PLG is drawn from the conductor and PLG connected in series with the transmission line. The PLG system consists of hardware and software components. Hardware is used for the impedance change on overhead line and software is used for controlling the power flow (Milioudis *et al*., 2012; Dolezilek and Schweitzer, 2011) werline guardian had current transformer, transmission line act as a primary winding of current transformer, PLG measure all conditions of transmission line like current, voltage, frequency and etc., send observations to data center.

Harmonics in power system: Power system harmonics play big role in power system reliability and stability. Harmonics produced because of non-linear load like motors, heaters and etc. Two type of harmonics present in power system, they are even harmonics and odd harmonics. Even harmonics like (2nd, 4th, 6th, 8th, etc.,)

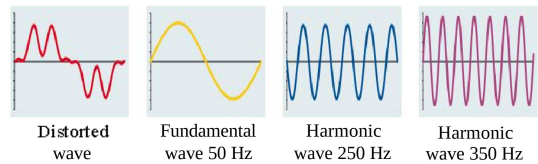

Fig. 2: Decomposition of a distorted wave form

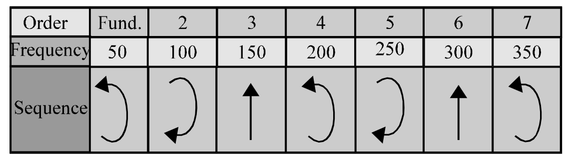

Fig. 3: Order and behavior of harmonics

and odd harmonics like (3rd, 5th, 7th, 9th, etc.,). Suppose if any odd or even harmonic produced in power system, these harmonic voltage and current multiply with fundamental frequency (Holey and Chandrakar, 2016; Ellis, 1996; Al-duaij, 2015; Shah, 2013). For example fundamental frequency is 50 Hz, if 2nd harmonic produced, 2nd harmonic frequency is 100 Hz. How fundamental wave affected with harmonic distorted wave explained in Fig. 2 and harmonic order and behavior explained in Fig. 3.

Hybrid AD method: In above sections explained about travelling wave method for finding open-circuit location, Power Line Guardian (PLG) for power flow control, harmonics in power system (2nd harmonic). Using travelling wave method, power line guardian and 2nd harmonic, we are going to propose new method to find location of downed or broken power line fault not touching the ground. The proposed method is very simple and less cost and it will give exact location. In this method PLG (Power Line Guardian) would play big role and using 2nd harmonic travelling wave, we are going to find location of downed or broken power line Fault not touching the ground. PLG having current transformer and it will measure high frequency ranges (travelling wave frequency). To find distance of fault please follow as operation of hybrid AD method.

Operation of hybrid AD method: Please follow below steps how to detect location of downed power line conductors fault between two sub stations.

Precondition:

- First calculate distance between two sub-stations (distance D)
- PLG connected between equal distance (at Pont P) (Fig. 4) from two sub-stations A and B. Please follow below cases how hybrid AD method help to detect location of fault

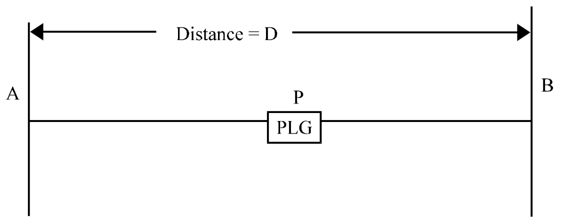

Fig. 4: PLG between two substations

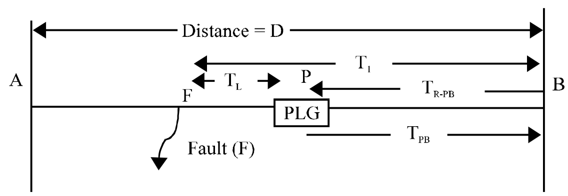

Fig. 5: Type AD method for fault near to station B

Case 1: Fault occurred between station a and PLG

Step 1: When downed or broken power line fault not touching the ground occurred (at Point F) (Fig. 5) at that point 2nd harmonic first travelling wave generated and travelled towards station A and station B (Fig. 5).

Step 2: Measure 2nd harmonic first forward travelling wave timing between fault point "F" to PLG Point "P".

Step 3: Measure 2nd harmonic first forward travelling wave from fault point "F" to station B.

Step 4: Measure first reflected travelling wave from station B to fault point (at point F).

Step 5: Measure first reflected travelling wave from station B to at Point P:

$$T_x = \left(\frac{T_{PB}+T_{R\text{-}PB}}{2} + T_L\right)/10$$

Where:

D = Total distance between station A and station B (m)
D_X = Fault location distance from station B (m)
F = Fault point location, P = Power line guardian arranged on transmission line
T_L = First forward travelling wave time between Fault point (F) and PLG point (P) (sec)
T_{PB} = First forward travelling wave time between PLG point (P) and station B (sec)
$T_{R\text{-}PB}$ = First reflected travelling wave time between PLG Point (P) and station B (sec)
T_1 = First forward travelling wave time between Fault point (F) and station B (sec)
PLG = Power line guardian, V = wave velocity (m/sec), T_x = Total travelling time (sce)

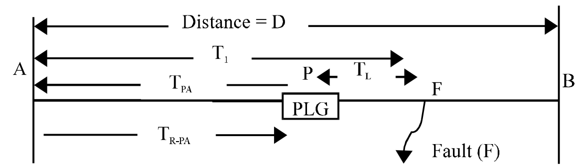

Fig. 6: Type AD method for fault near to station A

Fault location distance from Station $D_x = T_x$. V.

Case 2: Fault occurred between station B and PLG

Step 1: When downed or broken power line fault not touching the ground occurred (at Point F) (Fig. 6) at that point 2nd harmonic first travelling wave generated and travelled towards station A and station B (Fig. 6).

Step 2: Measure 2nd harmonic first forward travelling wave timing between fault point "F" to PLG Point "P".

Step 3: Measure 2nd harmonic first forward travelling wave from fault point "F" to station A.

Step 4: Measure first reflected travelling wave from station A to fault point (at point F).

Step 5: Measure first reflected travelling wave from station A to at Point P:

$$T_x = \left(\frac{T_{PA}+T_{R\text{-}PA}}{2} + T_L\right)/10$$

Where:

D = Total distance between A and station B (m)
D_X = Fault location distance from Station B (m)
F = Fault point location
P = Power line guardian arranged on transmission line
T_L = First forward travelling wave time between Fault point (F) and PLG point (P) (sec)
T_{PA} = First forward travelling wave time between PLG point (P) and Station A (sec)
$T_{R\text{-}PA}$ = First reflected travelling wave time between PLG point (P) and station A (sec)
T_1 = First forward travelling wave time between Fault point (F) and station A (sec)
PLG = Power line guardian, V = wave velocity (m/sec), T_x = Total travelling time (sec)

Fault location distance from station $D_x = T_x$. V.

RESULTS AND DISCUSSION

We used PSCAD V4.2 for this simulation results. If we apply in theoretical calculation to simulation for case

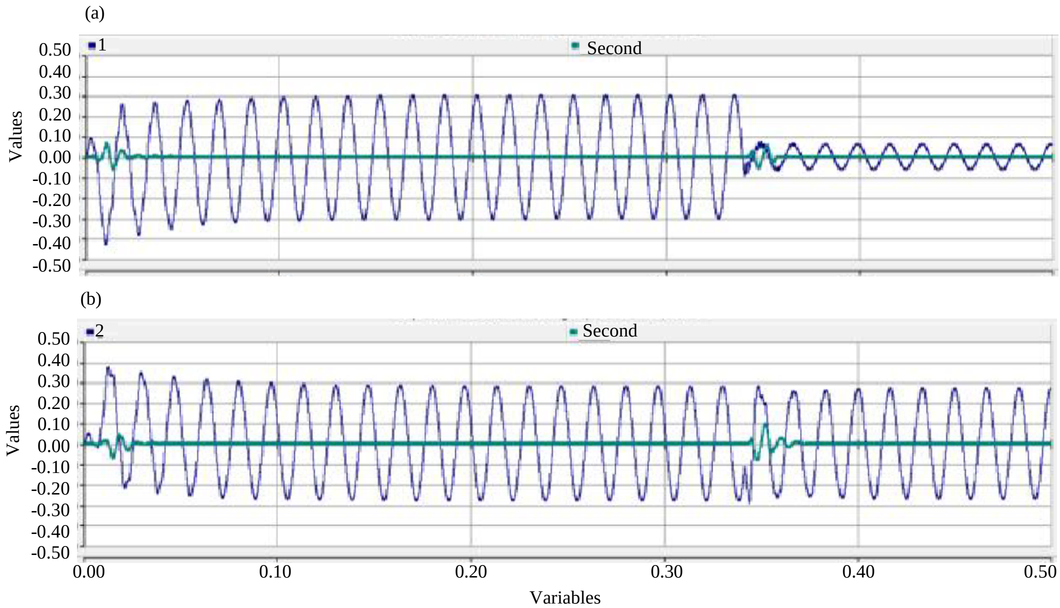

Fig. 7: 2nd harmonic wave generated at fault point: a) Graphs of currant waveform at sending source, second harmonic at breaker and b) Graphs of currant waveform at receiving and second harmonic at breaker

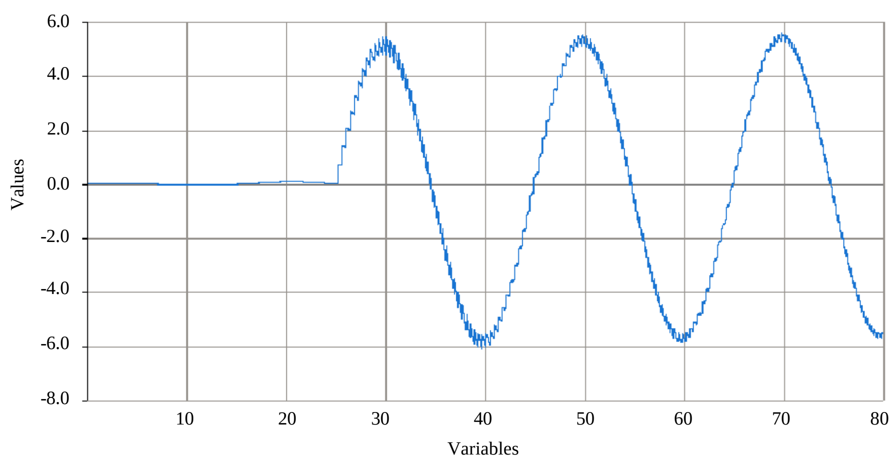

Fig. 8: First forward travelling wave travelling towards station B

1, distance between station A and B is 100 km. If downed or broken power line fault not touching the ground occurred at 25 km from station Fig. 7 and 8. Explains how 2nd harmonic generated at fault point and fault travelling wave travelling towards station B. From simulation results, T_{PB} = 0.188, $T_{P\text{-}PB}$ = 0.376, T_L = 0.6837 msec:

$$T_x = \left(\frac{T_{PB}+T_{R\text{-}PB}}{2} + T_L\right)/10$$

Fault location distance from Station B $D_X = T_x.V$ = 28.97 km. Final value near to fault location.

CONCLUSION

In smart grid, fault location finding methods using travelling wave concept but all methods measuring travelling wave at end of source or destination. As compare to all that methods, my proposed hybrid AD method measure travelling wave at middle of transmission line length. At present very few methods for finding exact location of downed power lines fault without touching ground. As compare to all of that's methods and process, the proposed solution will give better solution, economic and with in less time. I hope it will give almost 100% accurate solution for finding exact location detect downed power lines fault without touching ground. This study provides solution used for between two substations. Further research work will be finding exact location of downed power lines fault without touching ground between substations to rural area.

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LIST OF SYMBOLS

- D_X: distance to the fault location (m)
- V: Wave velocity (m/sec)
- D: Total distance between station A and station B (m)

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