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DETERMINING PF THE FAULT LOCATION IN DISTRIBUTION SYSTEMS IN PRESENCE OF DISTRIBUTED GENERATION RESOURCES USING THE ORIGINAL POST PHASORS

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Purpose. In this paper a method for determining the fault location in distribution systems in presence of distributed generation resources is presented. **Methodology**. In presented method the section which has fault in distribution system gets identified and the distance of fault location from the original post gets calculated by recording the phasors of voltage and current in original post and analyzing the Circuits sequence of positive, negative and zero of system, the section which have fault in distribution system is determined and the distance of fault place from original post gets calculated. **Results**. The suggested method is applicable in distribution systems which have diffused generation source with high penetration level and the different values of fault resistance. In operating defense by the time of crisis and occurring fault in distribution system of the power of centers considering that for making the time of power outage minimum in sensitive centers the emergency generators are needed, also a quick trouble shooting system is needed to make the place of fault clear and start to repair it in least possible time and carefully. The obtained results of investigating the variety of faults over system in presence of distributed generation resources shows the efficiency of suggested method. **Originality**.

A novel fault location and protection scheme are presented to provide the distribution networks with distributed generation (DG). The suggested approach is able to determine the accurate type and location of faults in presence of distributed generation resources using the original post phasors. **Practical value.** Consequently, determining the accurate location of probable faults will be more important in distribution systems including DG. For simulating, the intended method over a sample distribution system is done by EMTP software. For processing and analyzing the information the MATLAB software is used.

Key words: distribution system, the voltage and current phasors, place of fault, distributed generation resource.

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1. INTRODUCTION

The case of determining the fault place in distribution systems always have been considered as an important problem by experts. The conditions like existing different branches, not fixed load and existing the influence of distributed generation sources in distribution system have made it difficult to determine the place of fault. These problems leads to requirement of designing the new protection systems for distribution systems (Das et al, 2014).

(Pourahmadi-Nakhli and Safavi, 2011), (Ramar and Ngu, 2010), and (Borghetti et al, 2011) presented several methods for positioning the fault. But these methods can be applied for distribution systems without presence of distributed generation resources. Recently several methods for considering the effect of presence of DG have been developed from which the methods based on impedance and measuring the phasors of voltage and current can be addressed.

These methods are divided to two categories. First category is based on measurement of voltages and currents in original post (Penkov et al, 2005) and (Nunes and Bretas, 2010). While the second category depends on measurement of both the original post and DG (Brahma, 2011) and (candena, et al, 2012).

Nunes and Bretas, 2010 and Penkov et al, 2005 have presented methods for fault determination but in these papers the resistance of fault is not considered.

In this paper a method is presented in which measuring the voltage and current only is done in original post. This is an advantage for suggested method. The obtained results confirms the validity of this method for using in distribution systems including the distributed generation resources. Following that the effect of distributed generation resources on accuracy of suggested method will be investigated. Then the fault of single phase and three phase short circuit is analyzed. Finally, the results of simulation and conclusion of paper is presented.

It has been shown that coordination between protective devices in distribution systems in the presence of significant DG will be disrupted (Javadian, et al., 2009; Senderovich and Diachenko, 2016; Yasin et al., 2017; Zayandehroodi, et al., 2011). Brahma (2011) described a general method to locate faults in this type of system, which used synchronized voltage and current measurements at the interconnection of DG units and was able to adapt to changes in the topology of the system.

Also, Zayandehroodi et al., (2011) proposed a new automated fault location method by using radial basis function neural network (RBFNN) for a distribution network with DGs. Their suggested approach was able to determine the accurate type and location of faults using RBF neural network. Several case studies have been made to verify the accuracy of the proposed method for fault diagnosis in a distribution system with DGs using a MATLAB based developed software and DIgSILENT Power Factory 14.0.523. Their findings revealed that the proposed method can accurately determine the location of faults in a distribution system with several DG units. Daryalal and Sarlak (2017) developed the application of a novel ultra-high speed scheme to release the distance relay to operate for a fault during a power swing in the series compensated line. They found that using the proposed scheme significantly speeded the fault detection, in comparison with the previous methods.

In this paper, the effect of distributed generation resources on accuracy of suggested method is investigated. For this purpose, by the time a three phase fault with the resistance of R_F occur in a distance after the distributed generation resources, the post and distributed generation resources act parallel for feeding the fault. When the fault is after DG the appeared impedance from post proportional to fault impedance, because of existing the DG current, will have other amount of impedance beside it. Neglecting the DG current surely will decrease the accuracy of estimation of fault location. Fault occurrence in a point after DG increase the amount of fault impedance and consequently increase the impedance seen from the end of post (Z_{APP}). This causes that the method based on impedance estimate the fault location more than the real distance. By attention to figure (1), when the fault had the considerable resistance of R_F, the fault location method based on impedance is effected by an additional reactance fault. Since the short circuit current in the fault point (I_F) is obtained from the short circuit of power post (I_G) and the current of DG (I_{DG}), the phase angle of I_F and I_G are not equal. When the I_F leads to I_G the term (I_F/ I_G) R_F beside the equation (I_{DG}/ I_G)(m-d) Z_{L1} increase the emerged impedance of fault and lead to location determination algorithms considerably calculate the location of fault more than its real amount.

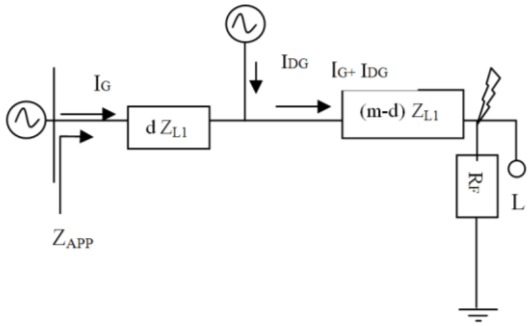

Figure 1 – the effect of DG current on impedance seen form the end of post

2.THE SUGGESTED METHOD IN DISTRIBUTION SYSTEM INCLUDING DISTRIBUTED GENERATION RESOURCES

In this section for presenting the suggested method, the single-line diagram of a feeder in a distribution network including distributed generation resources is shown in figure 2. For extending this method, it is assumed that feeder has different connections. The suggested method has used analyzing the positive, negative, and zero sequential circuits for determining the location of fault. Following that the sequential circuits of upward single phase fault (between the distributed generation resource and original post), sequential circuits of downward single phase fault (after distributed generation resources), and sequential circuits of three phase faults are analyzed respectively. Finally, using these analysis, a method for calculating the distance of resulted fault is presented.

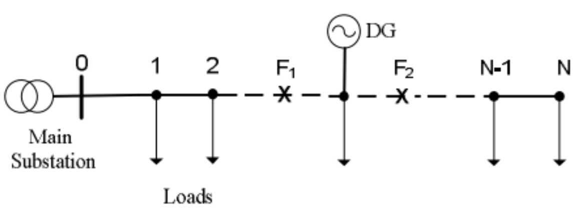

Figure 2. single linear curve for a distribution network including DG resources

3.UPWARD SINGLE PHASE CONNECTION TO THE GROUND FAULT

For ground single phase connection fault with R_F fault resistance which occur in point F_1 all of the positive, negative, and zero sequential circuits are included. The system which is upper than fault section is presented by Thevenin's equivalent circuit (Z_{th}, E_{th}). Moreover, the negative and zero sequential circuits decrease to equivalent Z_{m1} and Z_{m0} impedances respectively as it is shown in figure (3).

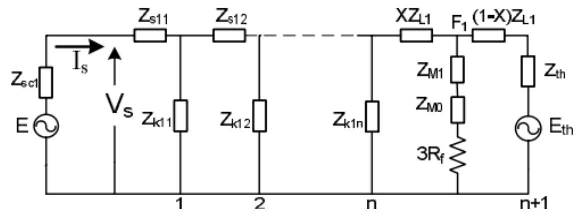

Figure 3. The sequential circuit for upward single phase connection to ground

In which:

(1) $Z_{M1} = \frac{-Z_{L1}^2 X^2 + L_1 X + M_1}{Z_{n1}}$

(2) $L_1 = Z_{L1}^2 - Z_{L1} Z_{P1} + Z_{L1}$

(3) $M_1 = Z_{L1} Z_{P1} + Z_{P1} Z_{u1}$

(4) $Z_{n1} = Z_{L1} + Z_{P1} + Z_{u1}$

Z_{u1}: equivalent impedance from the node (n+1) upward up to end of feed

Z_{P1}: equivalent impedance from the node (N) up to post

Z_{L1}: the sequence of positive impedance for faulty power sector

X : faulty sector in each unit of fault section

Similarly, the Z_{M0} using the equation 1 will be calculated after alternating all the positive sequence values with corresponding values form zero sequence.

For calculating the voltage in node (n) and the current from the node (n) to fault using the following equations the voltages and currents are measured and used in post:

(5) $I_{L(k+1)} = Y_{L(k+1)} V_{K+1}$

(6) $V_{K+1} = V_K - Z_{s1(K+1)} I_K$

(7) $I_{K+1} = I_K - I_{L(k+1)}$

V_K : the positive sequence voltage in node (k)

I_K : the current of positive sequence from node (k) to node (k+1)

$I_{L(k+1)}$: the current of charge in node (k+1)

$Z_{s1(K+1)}$: the impedance of positive sequence of feed section

$Y_{L(k+1)}$:the admittance of the charged which is connected to node (k+1)

In k=0, $V_0 = V_s$, $I_0 = I_s$

Therefore equivaleny circuit decreases in form of the circuit shown in figure 4.

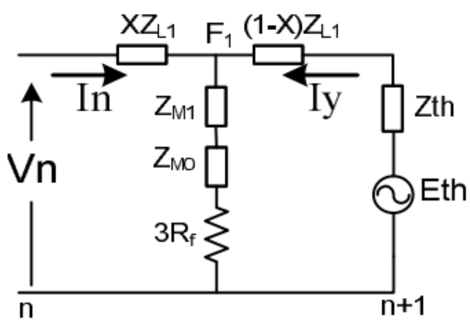

Figure 4. The equivaleny circuit for upward single phase connection to earth fault

By analyzing this circuit the following equations is obtained:

(8) $V_n - XZ_{L1}I_n = E_{th} - ((1-X)Z_{L1} + Z_{th})I_y$

(9) $V_n - XZ_{L1}I_n = (3R_f + Z_{m1} + Z_{m0})(I_n + I_y)$

By simplification, the following equation is resulted:

(10) $AX^2 - BX + C = 3R_f$

In which:

(11) $A = \frac{Z_{L1}^2}{H} + \frac{Z_{L1}^2}{Z_{n1}} + \frac{Z_{L0}^2}{Z_{n0}}$

(12) $B = \frac{Z_{n1}(Z_t + Z_{L1} + Z_{th})}{H} + \frac{L_1}{Z_{n1}} + \frac{L_0}{Z_{n0}}$

(13) $C = \frac{Z_t(Z_{th} + Z_{L1})}{H} - \frac{M_1}{Z_{n1}} + \frac{M_0}{Z_{n0}}$

(14) $H = \frac{E_{th}}{I_n} + Z_{L1} + Z_{th} - Z_t$

(15) $Z_t = \frac{V_n}{I_n}$

In a condition that the resistance of fault be a little bit real, we have:

(16) $imag(R_f) = 0$

(17) $A_i X^2 - B_i X + C_i = 0$

In which:

(18) $A_i = imag(A)$

(19) $B_i = imag(B)$

(20) $C_i = imag(C)$

The distance of each fault (x) from the node (n) is calculated by solving the (17) equation, which is a second degree equation. The two possible method is presented in (21). In this equation only one answer is acceptable and the other ones are unacceptable values.

(21) $X_1 = \frac{B_i + \sqrt{Bi^2 - 4A_iC_i}}{2A_i}$

(22) $X_2 = \frac{B_i - \sqrt{B_{i^2} - 4A_iC_i}}{2A_i}$

Finally, the distance of fault from the original post is calculated based on (23) equation:

(23) $fault \quad dis\tan ce = XD_M \sum_{r=1}^{r=m-1} D_r$

In this equation:

D_r : the length of feeding section R_{th}

M: the number of fault section

4.DOWNWARD SINGLE PHASE CONNECTION TO THE GROUND FAULT

Figure 5 shows the equivaleny circuit of fault of single phase connection to the ground with resistance of R_F which have occurred in point F_2.

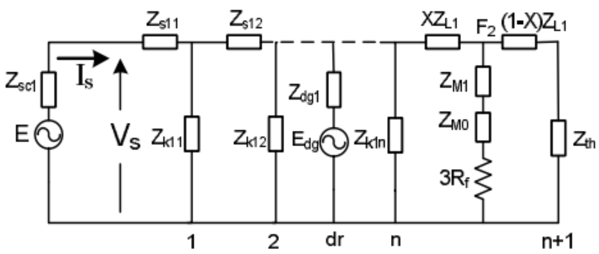

Figure 5: the equivaleny circuit for single phase connection to the earth

The DG current is calculated using the equation (24) considering that the inner DG voltage is constant along the fault. The current in a section upper than DG is calculated using the equation (25). Therefore, the equivaleny circuit decrease in form of figure 6.

$$(24)\quad I_{dg} = \frac{E_{dg} - V_{dr}}{Z_{dg1}}$$

$$(25)\quad I_{K+1} = I_K - I_{L(k+1)} + I_{dg}$$

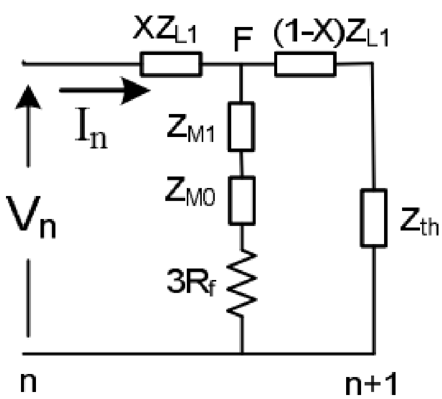

Figure 6. the equivaleny circuit for single phase connection to the ground fault

5.THREE PHASE FAULT

For a three phase fault, the R_f fault resistance in both states downward and upward, only the positive sequence of circuit is used. The calculation for three phase fault is like the equation used for single phase connection to the ground fault. Therefore, the used equations for localization of fault are based on regulation of Z_{M1} and Z_{M0} conditions over zero.

6.SIMULATION RESULTS

The suggested distribution system in this paper is a real system which is consist of a 11 KW feeder with 27 nodes (Kersting, 2007). The measured information with the stability in original post is done by EMTP software. This information are in form of CSV file as the input of MATLAB software. The distributed generation resources are simulated in form of a resource in behind of the impedance connected to node 9. (variety of faults for fault resistance of 50 ohm are done). The linear curve of distribution system is illustrated in figure (8).

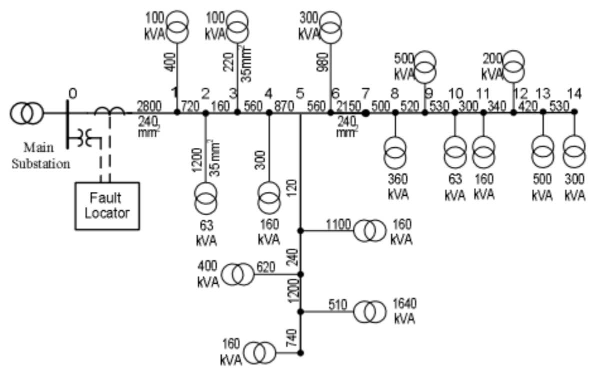

Figure 8. the distribution system used for investigating the suggested method

7.THE TYPES OF THREE PHASE AND SINGLE PHASE FAULTS

For evaluating the accuracy of the suggested method for determining the distance of single phase and three phase fault the four type of fault got experimented as following:

A : single phase fault in 6 Km distance (between DG and original post)

B : single phase fault in 4 km distance (down the DG)

C : three phase fault (between DG and original post)

D : three phase fault (down the DG)

The percentage of fault is calculated four all of the four conditions using the equation (26). In the equations (27-30), the percentages of fault for A, B, C, and D faults is calculated respectively.

$$(26)\quad \%\text{Error} = \frac{(D_{est} - D_{act})}{(\text{Total feeder length})} \times 100$$

$$(27)\quad \%\text{Error} = \frac{(6016 - 6000)}{(9000)} \times 100 = 0.177\%$$

$$(28)\ \ \%Error = \frac{(5000 - 5224)}{(9000)} \times 100 = 0.248\%$$

$$(29)\ \ \%Error = \frac{(1496 - 1520)}{(9000)} \times 100 = 0.26\%$$

$$(30)\ \ \%Error = \frac{(2930 - 2940)}{(9000)} \times 100 = 0.13\%$$

The obtained results based on the presented method for three above fault is shown in table (1).

Table 1.The simulation results

State of fault	Type of fault	Location of fault	Real distance	Determined distance	Percentage of fault
A	Single phase	upward	km 1.52	km 1.49	0.26٪
B	Single phase	downward	km 5.28	km 5.22	0.248٪
C	three phase	upward	km 2.93	km 2.94	0.13٪
D	three phase	downward	km 6	km 6.016	0.177٪

Investigating the effect of distance of fault location on the accuracy of method

The figures (9) and (10) indicate the percentage of error of suggested method for single phase and three phase fault. By attention to figure (10) it can be seen that the percentage of error of method for three phase is the highest and is changing in the 4 t 6 km distance and in domain from 0.12 to 0.2.

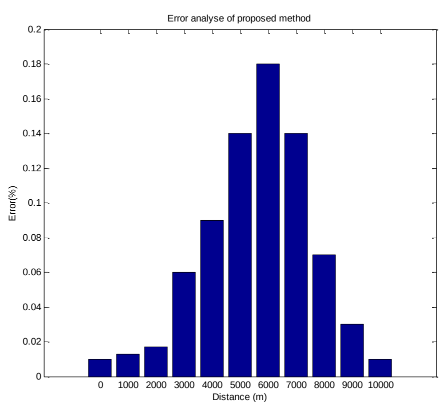

Figure 10. The percentage of error of suggested method in different distances from the beginning of the feeder for three phase fault

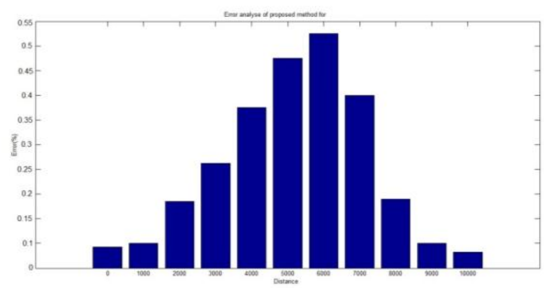

Figure 11. The percentage of suggested method in different distances for the beginning of feeder for single phase fault

8.CONCLUSION

In this paper an effective and new method for determining the fault location in distribution system using the recorded information in the beginning of feeder with presence of distributed generation resources is presented. This fault location finder only by the main stable current and voltage information presents the exact location of fault with high accuracy. From the advantages of the this suggested method is that the measurement of voltage and current only is done in original post. It is observed that the percentage of fault for single phase to earth and three phase respectively are changing between (0, 0-53, 67) and (0, 0-12, 2). This is a guarantee for truth and accuracy of suggested method.

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