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Employing a New Combination of the Remaining Harmonics of the Current to Detect the High Impedance Fault in Electrical Distribution Networks

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Abstract- High Impedance Fault (HIF) in the distribution network occurs due to the contact of the conductor of a phase with a high resistance level, such as the earth, or falling a tree branch with high impedance over one of the phases. In this type of fault, the fault current is low and along with spark. The main purpose of detection the HIF is to save the human's lives exposed to contact with an energized conductor and prevention from fire accident.

HIF has always been a problem for the techniques of network protection such as distance relays. As the current resulting from HIF is at the level of load current or less than it, (in the relay of additional current, the low level of current resulting from HIF is less than the adjustments of relay sensitivity). The existing protective relays in the network such as the relays of additional current, fuses and relays of the earth connection in contact with these faults cannot show a proper performance and in fact, they cannot detach them from the capacitor switch, line and load.

So far, various methods have been presented to disclose the HIF's and of course each of them has some disadvantages. In this project, using the harmonic combination of odd and even and presenting a suitable index, efforts have been made to present a new method to identify and detect HIF with a less disadvantages as compared with the previous methods. Simulations made in EMTP Works also confirm this claim.

Keywords- *High Impedance Fault, Fault Current Harmonics, Distribution System, EMTP Works.*

I. Introduction

The HIF is defined in from of the electrical contact between an energized conductor and a non-conducting external object. [1-2[. The non-conducting objects, with regard to their types, show a high resistance against the passing current and only small quantities of the current cannot pass through them. So, such a fault is not considered as an abnormal condition for the protective equipment. Irrespective of the quality of contact, a leaking current flows from the energized conductor to the earth. This current passes through the contacted objects which now have a high potential and flows into the earth. This high potential can at least threaten the humans' life [6-3].

The various types of prevailing HIF occur when the conductors of the distribution system contact with the trees branches, concrete walls and the earth surface. The mentioned cases are usually near the conductors of feeding lines of the distribution system and in each time, they are exposed to these undesired contacts. Figure (1) shows a distribution system in which there is a possibility for the contact of conductors to a tree branch.

The main feature of HIF is their very difficult disclosure. Despite other faults which lead to very high faults, the fault current in HIF's is very slight.. For this very reason, the prevailing protective systems like the protection of high current will be unable to detect these faults. The lack of divulging the HIF's can impose many life damages or lead to fire accident [10-7].

Many researchers in recent years have presented different techniques to disclose HIF's. In general, out of these techniques, it is possible to refer to the low frequency energy components method [11], neural networks method [12-13], Kalman filtering method [14] , low rank harmonics current method [16-15] , fault current flicker and half-wave asymmetry [17] , and Fractal analyze method [18] and in most of these techniques, in order to disclose HIF, the singles being produced by arc is used. The Discrete Wavelet Transform (DWT) method which is a suitable tool to analyze the transit phenomena is employed in it [22-19].

Figure (1): The possibility of connection of the distribution system conductors to a tree branch

Most of the presented methods have not been so precise so far or their practical implementation has been difficult. So, in this article, a new method is presented to detect the HIF in distribution networks based on harmonic analysis of the current by using a new index. Various simulations made in EMTP Works software environment show that the suggested method in this article is not only simple and easy to implement, but also it enjoys a very high precision.

II. DYNAMIC MODEL OF HIF ELECTRICAL ARC

Figure (2) shows the current –voltage characteristic of a real HIF [23]. As it is observed, the arc behavior for the two half cycles of positive and negative is different. In [23] due to the difficulty of simulation, it has been assumed that the arc behavior in each two half cycles is similar to the positive half cycle, but in this article, a model is used in which the current-voltage characteristic arc in two cycles in compliance with the practical results is different.

A comprehensive model which has been used to describe the behavior of HIF arc in [23] is taken from the reference of [24]. In this model which is based on thermal equations, the following relation is used to determine the conductance of arc variable:

$$\frac{dg}{dt} = \frac{1}{\tau}(G - g) \tag{1}$$

Which in this relation, g is the flexible conductance with the arc time, G=|i| /Varch , the fixed conductance of arc , I is the absolute value of arc current , Varc is the fixed quantity of arc voltage and …. is the time fixed of the arc. The parameters of the above relation are determined such that its result could be in compliance with practical and lab results. In order to calculate these parameters, the characteristic shown in Figure (2) is used. In order to calculate τ the following relation is used:

$$\tau = Ae^{Bg} \tag{2}$$

which A and B are fixed quantities which like V arc in two half cycles of positive and negative of voltage and fault current have different quantities that can be calculated from the results obtained from this experiment. Reference [1] has stated the quantities of the positive half cycle in form of V arc=2520 v , A= 6.6E and B=41977 and the quantities for the negative half cycle in form of :V arc=2100v, A=2.0E-5 and B=85970.30.

The dynamic model of HIF electrical arc is shown in Figure (3) in form of a diagram block.

The CTR control signal which has been used in Figure (3) for the control of controllable integrating element is shown in Figure (4). In fact, this part of the model shows the abrupt extinction of the arc while passing from the zero current. The output of this integrating is calculated with the integrating from the main entrance as far as the controlling signal is high. However, when the controlling signal becomes low, the output of integral will be equal to RES signal. The RES signal in fact gives us the resistance of the arc at the extinction moment whose quantity based on the results of the test in the first Ims after the arc extinction will be a flexible function with time and with the slope of 0.5MΩ/ms and after Ims a flexible function with time and with the slope of 4M Ω/ms.

Thereby, using CTR single, it is possible to simulate the abrupt extinctions and turn on of the arc at the moment of passing from zero fault current.

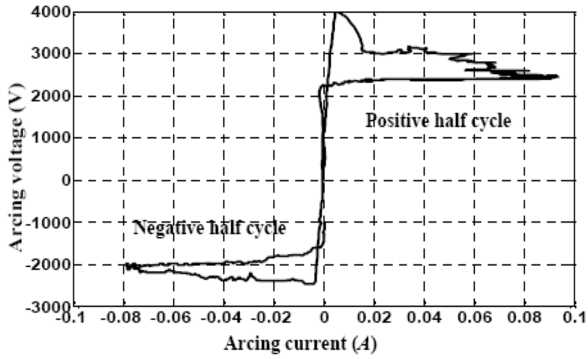

Figure 2. Lab Characteristic of Current Voltage of High Impedance [23]

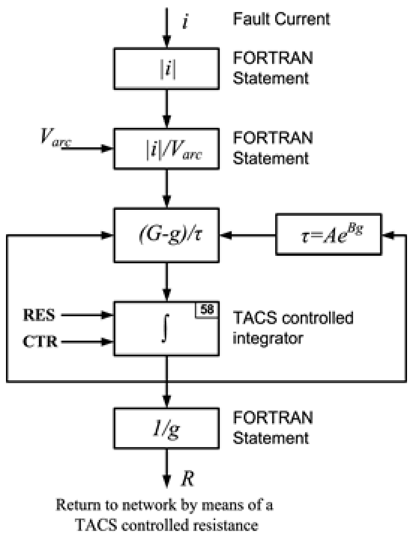

Figure 3. Arc model in HIF

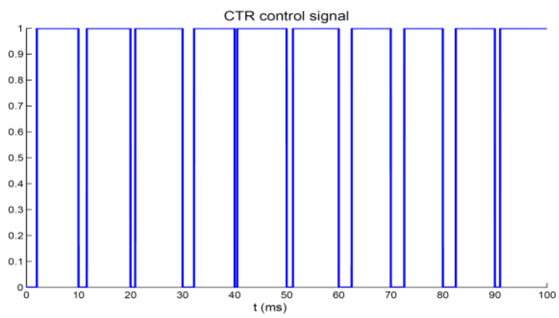

Figure 4. Controlling signal to simulate arc extinctions and its abrupt turn on

III. SYSTEM OF POWER DISTRIBUTION UNDER STUDY BY ALGORITHM

The diagram of not- connected 20Kv single line for the simulated distribution system in EMTP Work is shown in Figure (5).The frequency of the line dependent on model in EMTP Work has been intentionally selected for the asymmetrical faults. When the fault system and model are combined in a project, it is possible to study the behavior of the network during this fault. In these researches, the main transformation null is insulated in fixed and unconnected to the earth form. Also this system has been unconnected to the earth intentionally and connected to the earth capacitance capacity by null. So, the current of fault phase which is so low will help with further durability of services.

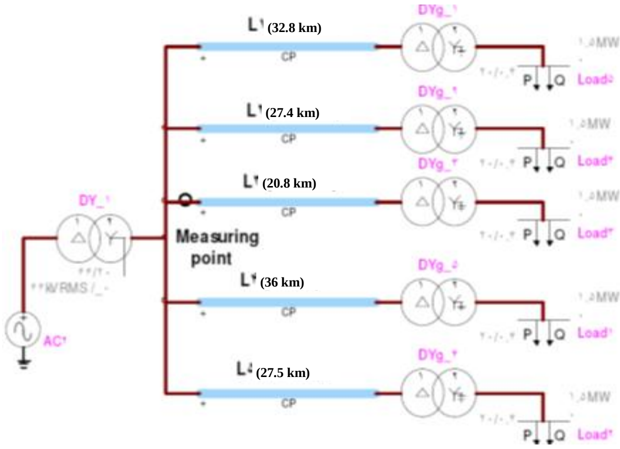

Figure 5. Network of power distribution under consideration in EMTP Works software

IV. A SUGGESTED METHOD TO DETECT HIF

Consider the Figure (5). A HIF is established at the middle of L4 line. The measurements are at the beginning of the line and fault starts at t=50 ms moment. Figure (6) shows the waves of voltage and current at fault location. This figure shows well the characteristics of HIF's. The shape of voltage wave has not had a noticeable change before and after the fault , however , the shape of wave of the current , as it is clear , is a shape of a periodic wave and like a sinus wave shape , with this difference that in each passing from zero , the created arc extinct and turns off again.

It must be pointed out that the voltage and current which is accessible in practice, is not the voltage and current at fault place, but it is the voltage and current which is obtained at the beginning of the line by measurement equipment. For this purpose, the Figure (7) shows the shape of voltage wave and current in the beginning of L4 line when the HIF occurs at t=50ms moment at the middle of L4 line. This shape of weaves shows that none of these shapes of waves have had a noticeable change before and after the fault, so that they are not suitable for detecting these types of faults.

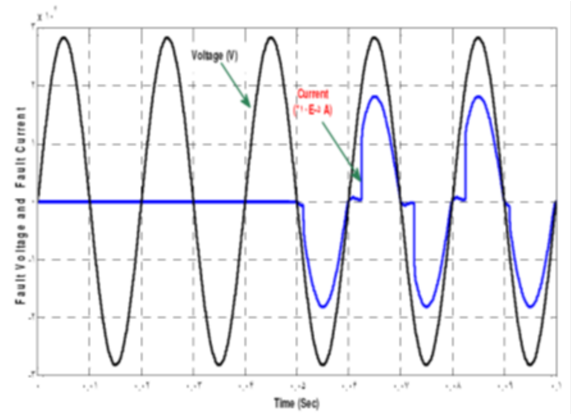

Figure 6. Shape of the waves of voltage and current at fault location

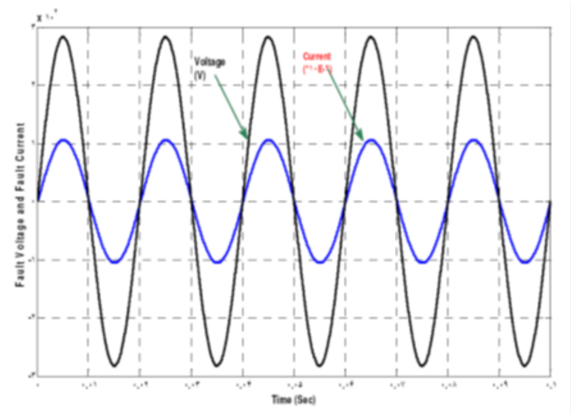

Figure 7. Shape of the waves of voltage and current at the beginning of L4 line

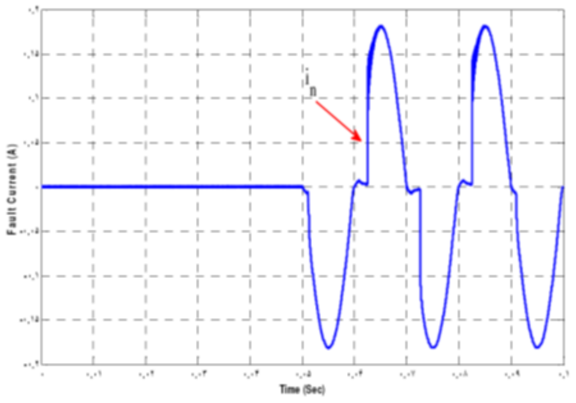

Figure 8. Shape of the wave of in current in the beginning of L4 line

As the shape of voltage wave in HIF does not have outstanding faults, so in order to detect the HIF, it is necessary to use the shape of current wave. So, in this article, irrespective of the fact that in which phase a fault has happened, the shape of ia current wave is constantly used which:

$$i_n = i_a + i_b + i_c \tag{3}$$

In which I_n is the total current of a, b and c phases in place of the line beginning. Figure (8) shows the shape of I_n wave once again for a state in which HIF has taken place at the middle of L4 line. Considering the Figure, it is clear that this time in the beginning of the line, i_n has a behavior similar to the current of HIF at the fault place.

Despite the fact that different methods have been presented to detect HIF based on harmonics analyses of current and most of these methods have only used the odd and even harmonics, but in this Article , new indexes have been used which are based on joint use of odd and even harmonics as follows where H_1, H_2, H_3 and H_4 are the first , second, third and fourth harmonics respectively and DFHIF is the standard of detection.

$$\mathrm{DFHIF} = \frac{H_1 + H_3}{H_2 + H_4} \tag{4}$$

Figure (9) shows the index of DFHIF corresponding with the shape of I_n current wave in Figure (8). As it is specified on the figure, whenever the index of DFHIF moves higher than 1.3 quantity, it shows the occurrence of HIF. This quantity is obtained based on many simulations.

V. ALGORITHM FOR THE DETECTION OF HIF

The suggested algorithm in order to detect HIF in this Article is in this form that the current of each three phases is detected in the beginning of the concerned line. Then , the total current of each three phases is calculated under the title of I_n . At the following stage, the harmonics of I_n current is extracted by using FFT method or any other methods. In the next step , the index of DFHIF is calculated and if its quantity is greater than the specified threshold level of 1.3, it shows the occurrence of HIF. Figure (10) shows the flowchart of the suggested method well.

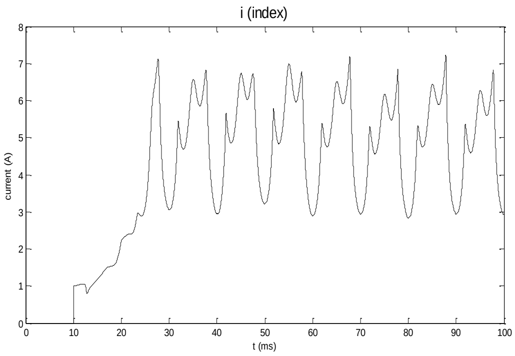

Figure 9. Index of DFHIF corresponding with the shape of In current wave related to Figure No. 6

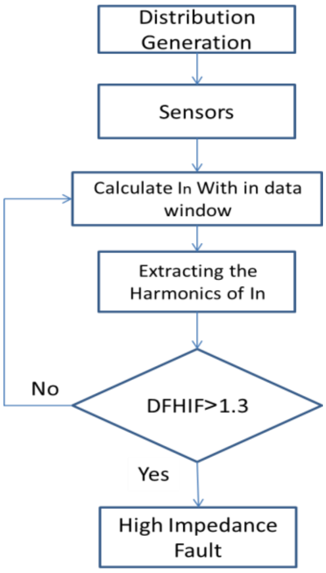

Figure 10. Diagram block of suggested method to detect HIF fault Identify the Headings

VI. SIMULATION RESULTS

In order to study the correctness of the suggested method in this article, many other different states have been considered to study whether or not this new method is able to detect HIF from other similar states. For this purpose, 5 different states are considered as follow:

A- Inserting the capacitor bank into the network

B- Exiting the capacitor bank from the network

C- Inserting the consuming load into the network

D- Switching Full Load Trans

E- HIF

Each of these states are included at the end of L3 line. Figure (11) shows the shape of the current wave of HIF along with DFHIF index for these 5 different states.

With regard to the Figure (11), it is clear that only in a state where HIF occurs, the index of DFHIF moves higher than the specified threshold limit. This means that this index shows a very good performance against other similar behaviors. This method not only enjoys high speed and precision , but also it enjoys a specific simplicity which makes its practical implementation easier , thus it can be noticed by the users of distribution networks.

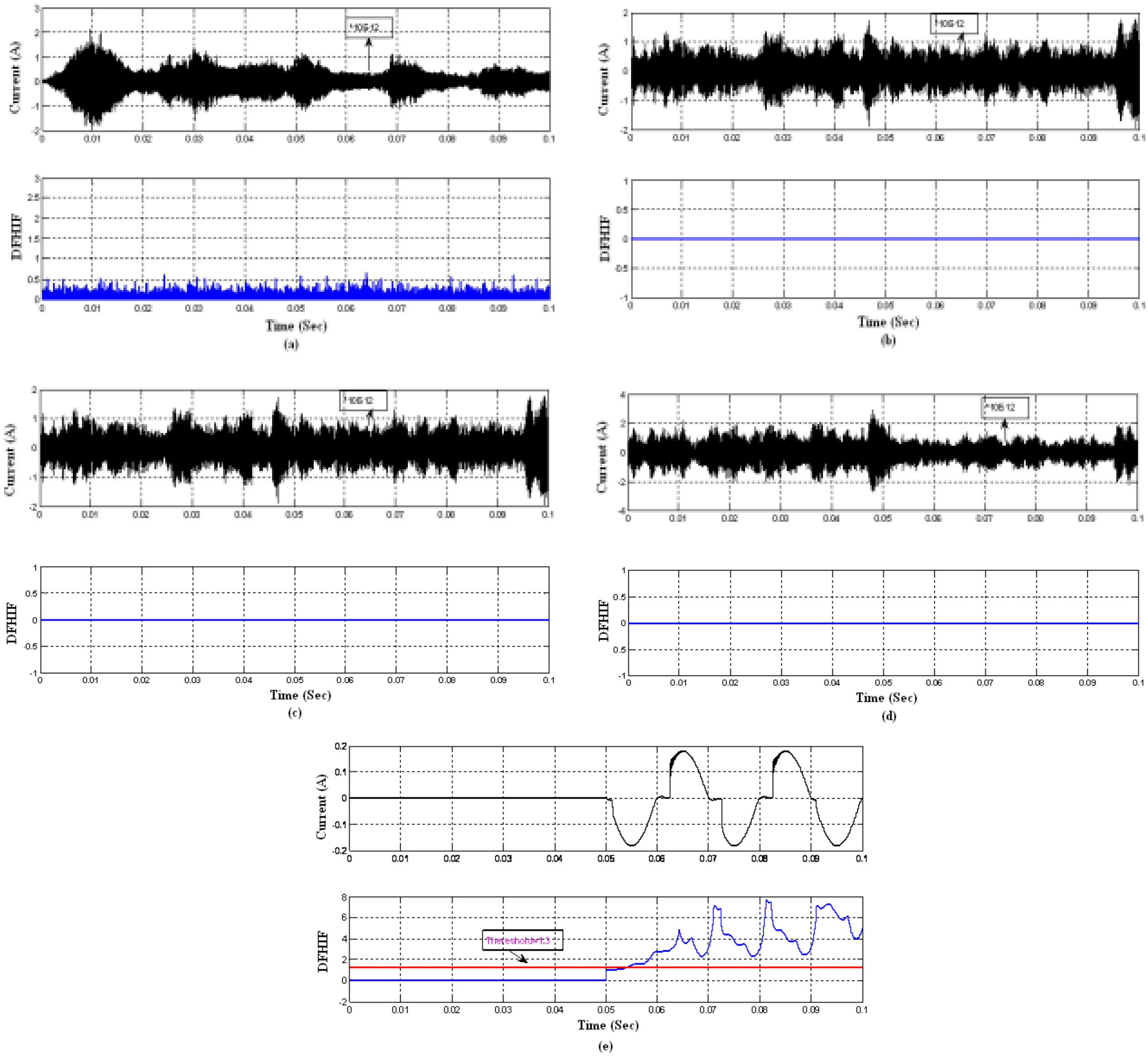

Figure 11. Shape of the waves of fault current and index of DFHIF for 5 different states

a)Inserting the capacitor bank into the network of b) exiting the capacitor bank from the network c) Inserting the consuming load into the network d) Full Load Trans Switching e) High Impedance Fault

VII. CONCLUSION

As the main characteristic of HIF is its very difficult disclosure , so despite other faults which leads to very high fault currents , the fault current in HIF's is very slight. So, the prevailing protective systems such as high current protection are unable to detect these types of faults. The lack of disclosure of HIF's can cause life damages or lead fire accident.

So, in this Article, a new method is presented to detect HIF's in distribution networks based on current harmonic analyses. Various simulation performed in EMTPWorks software environment shows that the suggested method not only is simple and its implementation is easy , but also it enjoys a high precision. Consequently, using the suggested method, it is possible to detect these types of faults in the least period of time and in a high precision and increase the system safety.

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