Analysis and Modeling of High Impedance Fault

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ABSTRACT : *A high impedance fault (HIF) results when an energized primary conductor comes in contact with a quasiinsulating object such as a tree, structure or equipment, or falls to the ground. The significance of these previously undetectable faults is that they represent a serious public safety hazard as well as a risk of arcing ignition of fires. A high impedance fault is characterized by having impedance sufficiently high that it is not detected by conventional over current protection, such as fuses and over current relays. Unlike low impedance short circuits, which involve relatively large fault currents and are readily detectable by conventional over current protection, these HIFs represent little threat of damage to power system equipment. High impedance faults produce current levels in the 0 to 85 ampere range. Typically, an HIF exhibits arcing and flashing at the point of contact. In this paper, high impedance fault is analyzed and it is modeled using MATLAB Simulink tool for deploying proper protection scheme in distribution system.*

Keywords –*Distribution system, Fault detection, High Impedance Fault, HIF modeling, nonlinearity*

I. INTRODUCTION

A High Impedance Fault (HIF) on a distribution feeder is an abnormal circuit condition which results in energy being dissipated in a manner other than the serving of the intended load. Most faults can be detected and isolated in time, but high impedance faults and arcing faults are still difficult to detect in practice because the currents the faults produce are small and they mimic normal loads. Distribution feeder conductors are prone to physical contact with neighboring objects such as overgrown vegetation, building walls, asphalt, a high impedance object or surface, which limits current values for faults on distribution systems and prevents conventional overcurrent protection from operating. In the case of an arcing HIF, when an energized conductor contacts the ground, the electric contact is not solid. Due to the existence of air between ground and conductor, the high potential difference in such a short distance excites the appearance of the arc. High impedance faults (HIF) have characteristics in their transient and steady state regimes that make them identifiable. They also lead to arcing and it is the result of air gaps due to the poor contact made with the ground or grounded objects; it occurs when a conductor breaks and falls on a non-conducting surface such as asphalt road, sand, cement, grass or perhaps a tree limb, producing very little if any measurable current. The arcing that often results from HIFs can have deadly fire and electrocution consequences. A HIF may result in damage to the electrical system, loss of power to customers, public hazard, or possible unsafe conditions due to arcing and flashing and possible property fire.

This paper explains high impedance fault characteristics and modeling of this fault in MATLAB Simulink software using variable resistor, also clearance method of these fault types are discussed.

II. PHYSICAL PROCESSES IN ARC

By their nature all gases are normally good electrical insulators, but it is well known that the application of a sufficiently high electric filed may cause a breakdown of the insulating properties, after which current may pass through the gas as an electric discharge. The term arc is usually applied only to stable or quasi-stable discharges, and an arc may be regarded as the ultimate form of discharge; it is defined as a luminous electrical discharge flowing through a gas between two electrodes. Electric discharges are commonly known from natural phenomena like sparks whose lengths can vary. Discharges can occur not only in gases, but also in fluids or solids or in almost any matter that can turn from a state of low or vanishing conductivity to a state of high conductivity, when a sufficiently strong field is applied. According to [1-4], starting with a uniform distribution of ions when the current and voltage are zero, the increase in voltage will cause space charge sheaths to form next to the electrodes and, because the mobility of the electrons is much greater than that of positive ions, most of the applied voltage will be across the space charge sheath at the anode as seen in Figure 1. The current densities in this sheath are very small and in order to 'restrike' the arc, the space charge sheath must be broken down. If there are no ionizing agents, the breakdown must be ionization by collision; it will therefore require a minimum of several hundred volts. Under the action of the electric field strength, electrons are emitted from the cathode spot. These collide with neutral molecules, thereby ionizing them electrically. The ions in the arc column fly now under the effect of the field strength towards both electrodes and heat them by impact to high temperature. The negative electrons hit the anode, and the positive ions hit the cathode. In this way new electrons are liberated within the arc column and at the electrodes, and the process starts again. According to [7] the dynamic characteristics of arcs may be represented as in Figures 2 and 3.

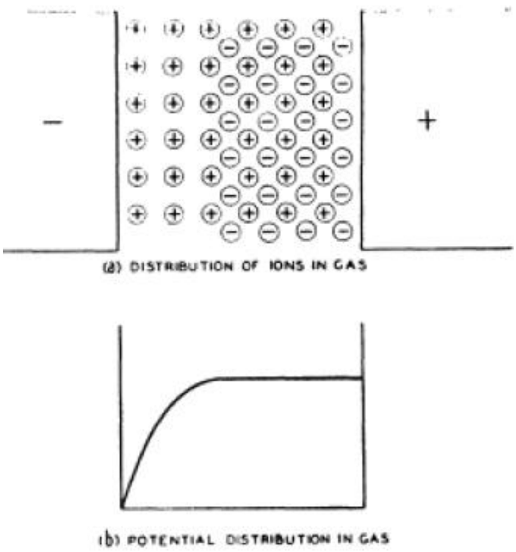

Figure 1: Ions and potential distribution in arc discharge through Gas

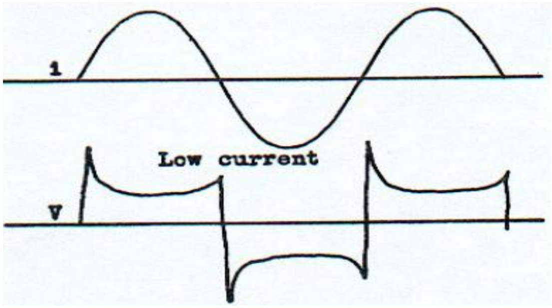

Figure 2: Voltage and current during electric arc

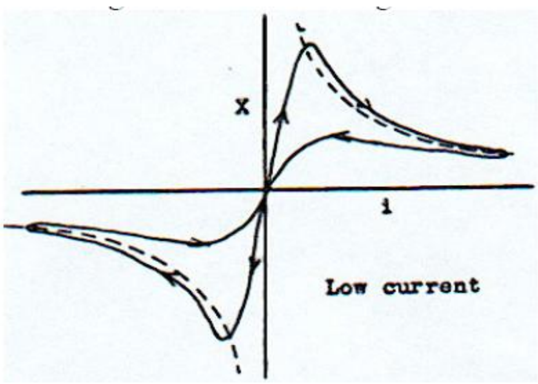

Figure 3 : V-I characteristics during arc

III. REVIEW OF HIF MODEL

The Arcing associated with the HIFs results in energy dissipation in the form of heat that turns the moisture in the soil into steam and burns the grass into smoke. In the arcing phenomenon associated with downed power lines, due to the existence of air between ground and conductor, the high potential difference in such a short distance excites the appearance of the arc. Also, arcing often accompanies these faults, which poses a fire hazard. Therefore, from both public safety and operational reliability viewpoints, detection of HIFs is critically important. High impedance fault is a difficult case to model because most HIF phenomena involve arcing, which has not been perfectly modeled so far. Some previous researchers have reached a consensus that HIFs are nonlinear and asymmetric, and that modeling should include random and dynamic qualities of arcing. Emanuel model is based on laboratory measurements and theoretical components [1] suggested two dc sources connected anti-parallel with two diodes to simulate zero periods of arcing and asymmetry as seen in Figure 4.

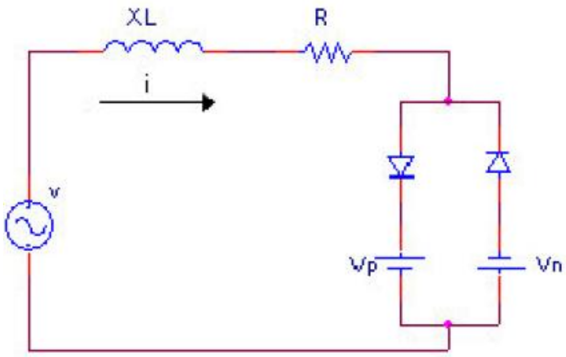

Figure 4: The Emanuel arc model

In [5] for consideration of nonlinearity in earth impedance the arcing high impedance fault was modeled as two sets (positive and negative) of diodes in series with a resistance and a dc source Figure 5 illustrates that model.

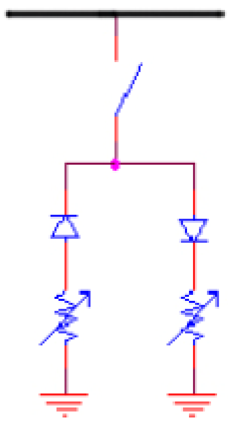

Figure 5 : HIF model introduced by [5]

A simplified Emanuel model was introduced in [7]. As shown in Figure 6 the model has two unequal resistances that represent asymmetric fault currents. The two resistances, *R*p and *R*n, represent the fault resistance: unequal values allow for asymmetric fault currents to be simulated.

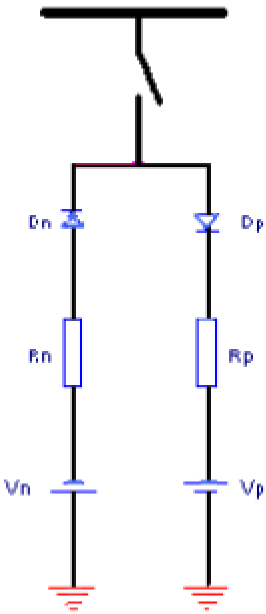

Figure 6: The Introduced HIF model in [7]

A simplified 2-diode HIF model was introduced in [8], as shown in Figure 8. This model consists of a nonlinear resistor, two diodes and two dc sources that change amplitudes randomly every half cycle.

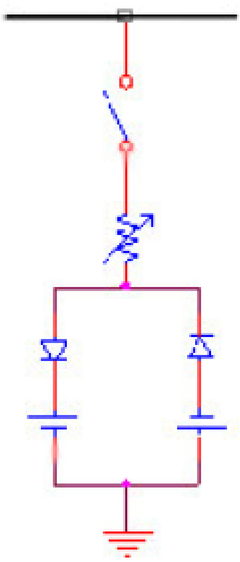

Figure 7: The HIF model proposed by [8]

IV. THE PROPOSED MODEL OF AN ARCING HIF

The high impedance fault model proposed by this paper shown in Figure 8 includes two DC sources, DC1 and DC2 with voltages, Vp and Vn, which represent the arcing voltage of air in soil and/or between trees and the distribution line; two resistances, Rp and Rn, between diodes which represent the resistance of trees and/or the earth resistance, and since most observed arcs occur in highly inductive circuits [9] two inductances, Lp and Ln were added to the circuit. The effect of the inductances leads to the nonlinearity loop shape in the V-I curve and the desired asymmetrical shape for the HIF current. When the line voltage is greater than the positive DC voltage Vp, the fault current starts flowing towards the ground. The fault current reverses backward from the ground when the line voltage is less than the negative DC voltage Vn. In the case when the line voltage is in between Vp and Vn, the line voltage is counter-balanced by Vp or Vn so that no fault current flows.

The characteristics shown by HIF are studied and are reproduced using MATLAB Simulink blocks. For studying HIF characteristics a sample distribution system is taken into consideration and HIF is simulated on this system as shown in Fig 8.

The Emanuel model proposed is used as a basic model and variable resistor is obtained using MATLAB Simulink block. As given in Ref [5], resistance ranges are brought in table 1. It can be seen from table 1 that average varying resistance is 250ohm. Thus in matlab model for HIF, resistance is varied up to 10% of original value. Fault is initiated at instant of time of 0.2 sec.

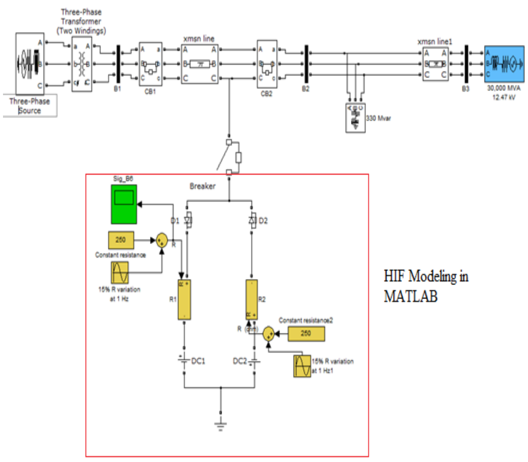

Figure 8: Model of HIF in Matlab

	R_p	R_n
1	208	212
2	215	223
3	235	225
4	244	227
5	245	245
6	247	271
7	255	280
8	267	286
9	269	289
10	272	290

Table 1: Value of Emanuel model parameter

V. Simulation Results and Discussion

The problem with conventional detection schemes is that it monitors only low-impedance faults (LIFs that result in instantaneous and large increments of current due to a low-impedance path to ground (short circuit). A HIF seems invisible to such detection methods because it presents only a small increment in line current and appears to be a normal load increment.

As depicted in figure 8, HIF is simulated on sample distribution system and fault current is measured at breaker. Waveforms obtained are shown in fig 9. It can be seen that there is phase shift occurred in HIF waveforms; this phase shift is used to find a reliable protection scheme for HIF in distribution system.

As discussed conventional protection scheme id insufficient to detect such faults hence a new method to protect distribution system for these faults is essential. A numerical relay can be designed in such a way that it will detect presence of these patterns and isolate system. A novel method of differential protection with numerical relay can be used to protect system against all types of faults.

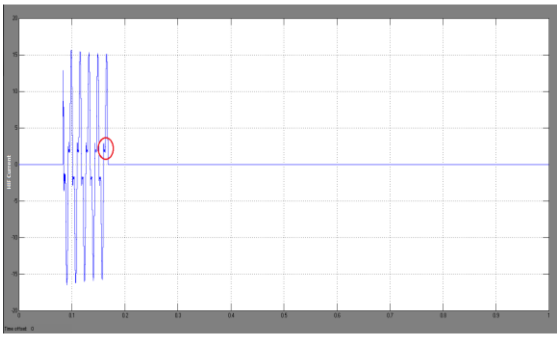

Figure 9 : HIF waveform from HIF MATLAB model.

VI. Conclusion

The aim of this paper is to develop a model that represents and predicts all important high impedance fault characteristics, including nonlinearity, asymmetry and harmonic content. The physical processes occurring in an arc result in a unique characteristic signature. Accordingly, a new model for a high impedance fault has been proposed and tested, containing active as well as passive elements (voltage sources, diodes, resistances and inductances), giving a very satisfactory representation of the arc characteristics. The new model preserves the unique shape of the high impedance fault voltage and current, and it also has the harmonics content, as well as the angle shift of the 3rd harmonic, consistent with experimentally observed behavior. Thus the proposed model can be considered an appropriate and physically well justified representation of high impedance fault characteristics and can be harnessed to generate various data necessary for developing more reliable HIF detecting algorithms.

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