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Behavioral Dynamics of High Impedance Fault Under Different Line Parameters

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ABSTRACT- Predominantly the impedance faults can be classified as Low Impedance Faults (LIF) and High Impedance Faults (HIF). The LIF can be detected and protected by a conventional protective device. However, if High impedance fault occurs in the system, it is difficult to detect because of the low magnitude current. The overcurrent relay, which smartly detects the Low impedance faults, fails to detect the High impedance faults. This research work is organized as two components. In the first component some literatures regrading high impedance fault have been reviewed. In the second component classical modified several Emmanuel arc model is taken as the test system. Feeder number four is taken as the candidate feeder for testing the high impedance faults. The simulation is done through MATLAB and the results are obtained. From the results certain investigations are proposed.

Keywords: High Impedance Fault, Low magnitude current, HIF characteristics.

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1. INTRODUCTION

Normally, the faults occur in the power system network are identified by conventional methods like protective devices. But all the faults are not detected by protective devices because some faults have low magnitude current as high impedance fault (HIF) [1-4]. When conductor breaks-down or in contact with the devices which has high impedance may result in HIF. For detection of HIF, even though protective equipment's are available there are certain practical difficulties in implementation of such devices, because before the protective devices starts its role to prevent a fatal failure, there emerges some transient issues in the power system, due to the occurrences of HIF [5,6]. This hinders the protective devices to play its role. This results in a huge energy loss in the line and also fatal failures. This creates huge equipment failures in some cases fire hazards due to arcing created during HIF. Thus, high impedance faults alter the system impedance in such a way that, the impedance becomes so large and the fault currents are not identified. That's being so, it is necessary to model and develop the unique protective device in electrical networks. High impedance fault current is the one which occurs predominantly during the momentary open circuit condition. The open circuit condition can be as under - Line in contact with the object. Objects can be categories into two broad categories in below *Table 1*.

Table 1: Objects categories

Object A (Dry sand or Asphalt <1 ampere)	Object B (Dry Grass/ Wet Grass/ Dry Sod/ Reinforced concrete 25-75 ampere)
When the line is in contact with these kind of object, particularly dry sand or asphalt it does not allow the power system to sense the fault current which creates power system emergencies – Fatal accidents	Under these categories during the open fault due to the nature of the object, the power system parameters are so shuffled that the impedance shoots enormously which grabs or takes the entire fault current and makes the line to a low circulating current which unable for the relay to sense and to trip the circuit breaker.

1.1 Complexity in Detection of High Impedance Fault

The failure in the diagnosis of High Impedance Fault in an electrical network is the misconception in understanding the complete behavior and operation of the protective devices. In the following paragraph the types of misconceptions among the power engineers in understanding the behavior of the high impedance fault and the relative protective devices to suppress the fault has been discussed elaborately. It can be categorized into four broad types that has been dealt as below.

1.1.1 Type I: In general, protective relays manufactures design and test their protective relays for high current and the other extreme is for low current. Protective relays are so designed to cut off the circuit in their pre-settled values. But in the case of high impedance fault the current value is so minimum in the order such a way that even the experienced power system engineers are unable to predict the lower minimum value during the high impedance fault. This is the main challenge in designing the protective relay as well as in avoiding the HIF [7,8].

1.1.2 Type II: In general, the sensitive earth fault relays are tuned in such a way that it senses and operates the circuit breaker for any category of earth/ground fault. But in the case of high impedance fault, the fault current is in the order of very low value it escapes even the lowest setting point of the relay and the fault occurs which possess a big challenge for power system engineers [9-12].

1.1.3 Type III: In general, protective devices such as relay will enhance its protection mechanism on sensitizing the over current due to a fault. In high impedance fault category, the greatest challenge for the power system engineers is that the impedance rises enormously at fault condition due to which the current values fall sharply, which creates the big challenge for the protective devices to sense it and to disengage the fault circuit quickly. As a result, creates big fire hazards and loss of energy [9-12].

1.1.4 Type IV: In general, power engineers have strong opinion that by clearly providing a rugged protection scheme like automated relay control mechanism fault can be prevented thoroughly [17]. But in reality, due to high impedance fault the localized circulating currents even though small in their magnitude creates an arcing in the power system network due to which not only the power system apparatus but also the personnel’s working in the power system is subjected to fatal risks. By considering the complexity in the detection of HIF and the challenges in the protection mechanisms, power engineers have done many models to detect and to understand the high impedance fault in the power system [13-16].

From the above, the complexities involved in the identification of high impedance faults are elaborately discussed. It is highly necessary that there are to be strong, intelligent mechanisms to negotiate and to eradicate the high impedance faults are necessary.

In this research, using the classical Emmanuel arc model, a fault condition is created and its effects are analyzed in detail. In the further research process many intelligent protective mechanisms to detect High impedance fault and to protect the power system are in the pipeline, to underscore certain protection mechanisms it can be highlighted.

a) Discrete wavelet transform methodology are implemented to detect the high impedance faults.
b) Intelligent techniques like deep learning and fuzzy logic (to address the non-linearity during the fault conditions) are to be devised and tested to detect and to intelligently protect the power system from high impedance faults.

2. LITERATURE SURVEY ON HIF TECHNIQUES

In the power system network, reliability and security are the most important criteria. During the undetected high impedance fault emerges the risk of public, huge energy losses in the system and in some cases fire hazards. In-order to mitigate the above risks several researchers have elaborately studied and analyzed the nature of HIF, its detection methodology and to mitigate it smoothly. The below literature survey has analyzed the same.

A.R. Sedighi *et al.* [15,18,19,25] has compared real value of HIF current with simulation models by applying Bonferroni confidence interval with EMPT tool as well as they have created various switching pattens in order to study the random behavior of HIF current. In their research work they have framed five new models based on the Emmanuel method has their reference. They further extended their studies by applying fuzzy logic to explore the non-linear behavior of the power system network. Further, they have applied Fast Fourier Transform (FFT) tool and proposed a new methodology. They have tested their new methodology in different models. Also, they have obtained real data from 20KV radial feeder in Iran, Qeshm with the total feeder length of 19.5Km. The fault location of HIF is 8.5Km from the source end. From this real data set they applied and tested for seven types of conduction medium at two different locations and analyzed and obtained field fault study results. From their seven types of conduction medium, they conducted three tests on each conducting medium and obtained 42 sets of data for HIF current at each location. Muthubalaji *et.al*. [26] in their literature works have demonstrated certain models in improving the performance of long distance tuned AC transmission system.

3. METHODOLOGY AND PROCEDURE

Kavaskar *et al.* [20-24] has underwent many studies in their research work with high impedance fault events like switching of load at linear and non-linear states, switching of capacitance, inrush current of transformers in their studies.

In their work, they have taken Emmanuel arc model and they have modified and taken several results and have clearly postulated that for the feeder system having five or six feeders, even if one feeder is slightly opened for even a minimum period of time switching currents have developed in healthy feeder. This switching current is very fatal for the power apparatus and in some cases even for personnel. It has to be understood from their research contributions that the compared to the candidate feeder (the feeder which has open circuited for the very short time and closed again and as it behaves has healthy feeder- this is the matter of high concern). This candidate feeder is the root cause for the switching currents to happen in the healthy feeders.

In this research work, the above lead is taken as the research problem. In the following *figure 1*.

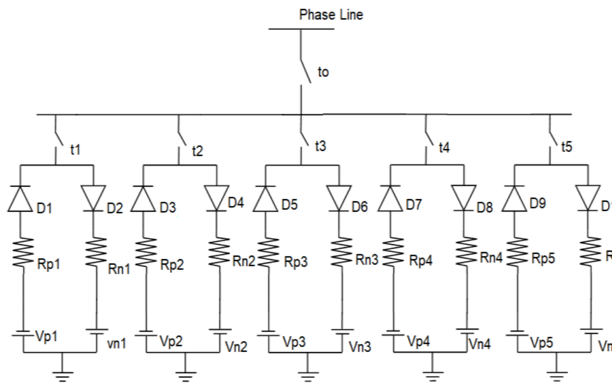

Figure 1: Modified several Emmanuel arc model

Feeder number four is taken has the candidate feeder and open circuit condition is created. The state parameters of the above power circuit network (*Figure 1*) is shown below *Table 2*.

Table 2: State- arc parameter at five different conditions

State	Arc parameters	1	2	3	4	5
State 1 $t_0 = 0$*	t (s)	0.0625*	0.076*	0.105*	0.116*	0.083*
	R_P (Ω)	1200	3010	2900	3730	1000
	R_N (Ω)	1000	2500	2500	3000	1200
	V_P (V)	4060	8020	7560	10010	5000
	V_N (V)	4500	8100	7680	10500	5200
State 2 $t_0 = 0$*	t (s)	0.051*	0.0625*, 0.1@	0.12*	0.085*	0.108*
	R_P (Ω)	1200	3010	2900	3730	1000
	R_N (Ω)	500	2850	2000	2100	300
	V_P (V)	1800	3000	4000	10000	2000
	V_N (V)	1920	3500	4500	10500	2500
State 3 $t_0 = 0$* 0.12@ 0.16*	t (s)	0.06*, 0.1@	0.08*, 0.12@	0.1*, 0.14@	0.16*	0.16*
	R_P (Ω)	4500	11000	7500	7800	10000
	R_N (Ω)	4600	11100	7300	7500	10100
	V_P (V)	10000	9900	10200	9200	8900
	V_N (V)	10500	9800	10000	9800	9100
State 4 $t_0 = 0$*	t (s)	0.05*	0.07*	0.083*	0.104*	0.124*
	R_P (Ω)	200	200	290	165	180
	R_N (Ω)	220	250	270	185	150
	V_P (V)	6550	7500	9100	9100	9500
	V_N (V)	6300	7800	9000	9000	8800
State 5 $t_0 = 0$*	t (s)	0.05*	0.08*	0.15*	0.12*	0.14*
	R_P (Ω)	4250	9000	7520	5800	10000
	R_N (Ω)	4150	9600	8510	6500	10500
	V_P (V)	8100	7900	9200	9100	8900
	V_N (V)	8000	8200	9500	9000	8700

*Switch is closed at that instant, @ switch is opened at that instant.

The above *table* represents the five different states, their timings of closing and conditional opening (this research is narrowing in the conditional opening or creating a high impedance and associated fault due to open circuit conditions) and also the values of phase resistance (R_P), neural resistance (R_N), phase voltage (V_P), neural voltage (V_N) under running conditions. This research work is formulated in such a way that feeder four is conditionally opened for research analysis at the time of 0.0625 sec and closed at 0.1 sec and it is mentioned by the special character @ and it is clearly indicated in the above *Table 1*.

4. RESULTS AND INTERPRETATIONS

As highlighted in the abstract this research work has two components. One is the literature survey what is discussed elaborately in the above headings and the second component is the test and the research carried out in the classical modified Emmanuel arc model which is taken as the test system. In the Emmanuel arc model, which is taken as the test system, feeder number four is taken as the candidate feeder. The test procedure and its associated results are as follows.

The time duration for the open circuit condition is set as 0.0375 sec which is very minimal and it is auto recloses after the time period. In this open circuit condition of 0.0375 sec, the impedance values of the candidate feeder (faulty feeder – open circuited feeder) has enormously risen to 3730Ω, due to this huge rise in impedance the switching currents are not clearly identified in the candidate feeder number four and the feeder behaves as a normal feeder due to which the relay fails to identify the open circuit and to trip the feeder number four. This is a big lacuna in the protection mechanism. Due to the above the other healthy feeders which are running in their normal impedance values suffers huge switching currents which are shown below.

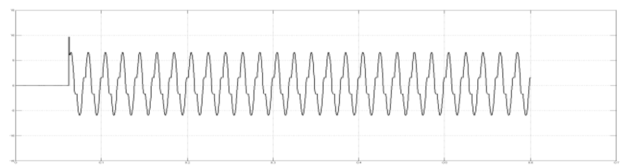

Figure 2: Feeder number one

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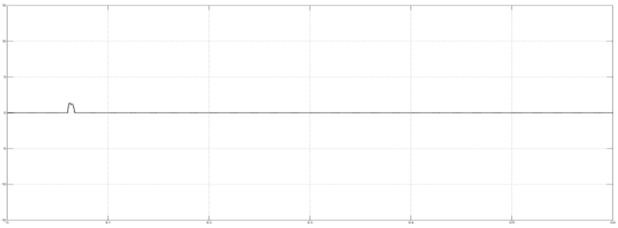

Figure 3: Feeder number Two

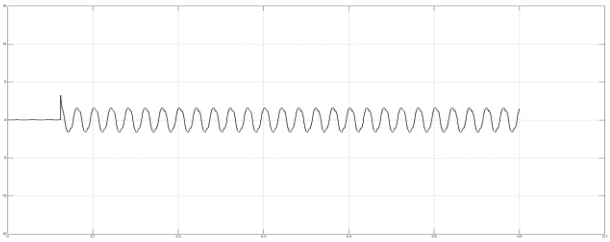

Figure 4: Feeder number Three

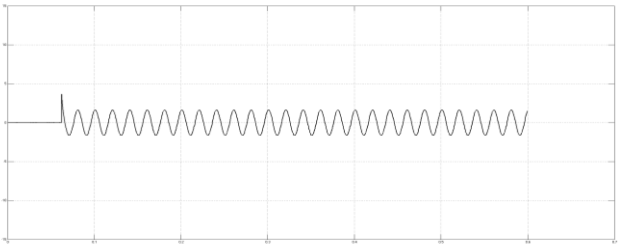

Figure 5: Feeder number Four

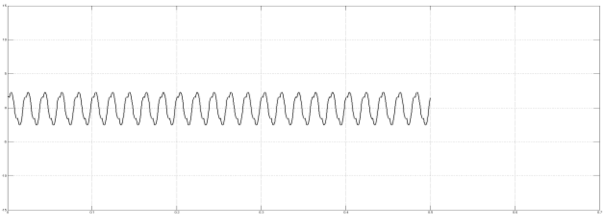

Figure 6: Feeder number Five

From the *Figure 2* for which the normal operating impedance is 1200Ω for feeder one and it is very clear the switching behavior are definitely seen. From the *Figure 3* for which the operating impedance is 3010Ω for feeder two which is relatively high the switching behavior is been hidden and not apparently seen as the *Figure 1*. From the *Figure 4*, the switching currents are partially noticed for the reason that, it is having an impedance value of 2900Ω which is relatively high compared to the feeder number one. From the *Figure 6* it is noticed that the switching currents are so obviously noticed due to the impedance value of 850Ω which is low compared to all other feeders.

Interpretations: From the above research and associated results it can be clearly understood that, the peculiar behavior of the high impedance as an open circuit fault 0.0375 sec in feeder number four as clearly cheated the conventional protection system due to which rest of the feeders suffers huge switching currents. Also, to be noted that the natural impedance of the feeder is having a big correlation in exhibiting the switching/arcing nature of the currents in the respective healthy feeders. It has to be understood that more the impedance value of the feeders lesser the switching currents are exhibited. Lesser the impedance value the switching currents are exhibited very clearly as shown in *Figure 6*.

5. CONCLUSION

From the above research work it can be summarized that the high impedance faults is having very unique behavior that due to momentary open circuit condition the faulty feeder is not exhibiting its true fault nature so that the protection mechanism cannot function properly or otherwise it has been fooled. The resulting healthy feeder's exhibits huge switching currents if properly not checked and arrested will collapse the power apparatus due to the arcing behavior and damages the entire power apparatus, which is quite costly for the utility providers to replace it. Also, it is fatal for the personnel working with the unit. Intelligent techniques [27, 28] have to be devised in order to investigate the nature of the momentary high impedance and HIF currents and to enhance the protection mechanism. In the future research process, due importance will be given to the intelligent techniques and how it can be applied in sensing the fault and making the protection mechanism more rugged.

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