A BP Neural Network Based Technique for HIF Detection and Location on Distribution Systems With Distributed Generation

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Abstract. High Impedance Faults (HIF) are faults of difficult detection and location while using traditional digital relaying. In this article it is presented a new proposal for detection and location of HIF's in distribution systems with distributed generation (DG), based on artificial neural networks. The methodology inputs are the local measured voltage and current phase components, supplying as output the detection, classification and location of the fault, when it occurs. The basic characteristics, the algorithm and comparative tests with other detection and location methodologies are presented in this article. The proposed scheme was tested in a simulation platform of a distribution system with DG. The comparative results of the technique with usual fault detection and location schemes show the high efficiency and robustness of the method.

1 Introduction

The detection and location process of high impedance faults (HIF) in power distribution systems (PDS) are becoming one of the major problems for the protection systems of the electric power distribution companies. Besides presenting characteristics that can be confused with normal operations in the network, its low magnitude fault current inhibits the detection of this kind of failure when overcurrent relays are used.

The HIF's are faults caused by the contact of line cables with trees or ground [1], originating a situation with high danger to the population. Moreover, the fact that these faults are not usually detected puts also in risk the maintenance staff of the distribution companies.

A new difficulty managed by the protection systems of distribution companies nowadays is the new trend on the distribution systems, known as distributed generation (DG). DG is defined as the generation of power inside the PDS. But these new sources of power have impacts in the PDS.

The main consequences of the presence of the DG in PDS are the changes in magnitude, direction and duration of the fault currents, making necessary a reformulation of the planning of the PDS protection schemes.

With the intention to reduce the problems caused by the HIF occurrence, several studies were developed, in order to characterize HIF. Among the several characteristics observed, it could be cited: the measure of the imbalance between phases [1], the angle difference between the complex numbers representing the fundamental component of the voltage and the 3^{rd} harmonic of the current [2], [3], and the voltage and current harmonic content analysis [4], [5].

In opposition to the necessity of total reformulation of the distribution systems protection schemes and with the intention to reduce the problems caused by the HIF, the present work proposes a new method to detect and locate high impedance faults in distribution systems with DG. The above-mentioned method is based on artificial neural network (ANN).

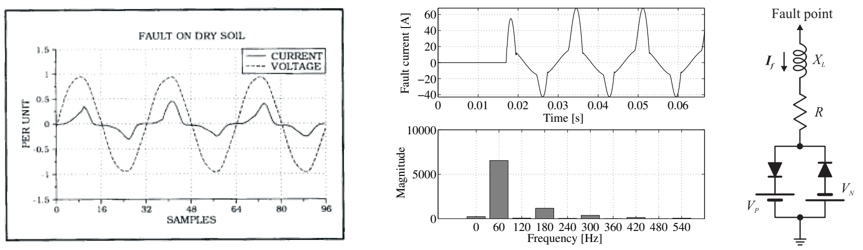
2 High Impedance Faults

The HIF are a special case of faults that can occur in power systems. Its low fault current magnitude and the presence of an electric arc make its detection, and also its modeling [6], difficult. The existence of an electric arc in the fault occurrence generates a non-linear characteristic, as can be seen in Figure 1(a).

The non-linear characteristic denotes to this phenomenon a unique harmonic content, as illustrated on Figure 1(b). This particular behavior is used to characterize HIF, according to the studies made and presented in [2], [3], [4], [5]. The modeling process of HIF in this work was based in the model proposed in [7]. This model is shown in Figure 1(c).

3 Distributed Generation Impacts

The addition of new generation units to the PDS has great consequences in the overall operation of these systems. The main change is the loss of the radial



(a) Current and voltage relation. (b) Harmonic content. (c) Model.

Fig. 1. High impedance faults.

characteristic of the PDS, changing the original power flow of the system. This makes necessary a modification in the protection systems parameters. In result of these facts, the reliability, the safety and the efficiency of the protection systems are affected by the DG. With this, the system capacity in maintain the electric power supply with minimum interruptions, with quality and without putting the system and the consumer in risk gets compromised, making necessary a new approach for PDS protection that considers the DG.

4 Artificial Neural Networks

As described in [8], mathematical models of the biological neurons and its interconnections were developed aiming to represent its processing properties, such as: learning, generalization, non-linearity, failure tolerance and answer to evidences. The ANN operates in two stages: the training and the test process. The training process trains the ANN so it outputs the correct results of the process. In this stage, different data, covering both faulty and non-faulty states of the system, are presented to the model. This work is done through different optimization algorithms and the one used in the present work is the backpropagation algorithm [8]. The test stage is the process where another data in presented to the trained ANN and the results are verified for the validation of the ANN performance.

5 Proposed Scheme

The proposed model to HIF detection and location in PDS with DG was developed based in ANN, having four different processes, as shown in Figure 2.

5.1 Data Acquisition

The first part of the scheme consists in the data acquisition for the ANN training and test processes. This data acquisition can be done through a digital fault recorder, a digital relay or even with computer simulations of the system model in which the method will be applied.

5.2 Characteristics Extraction

With the data obtained in the above mentioned process, the characteristics extraction process begins. In this process the filtering of the information obtained

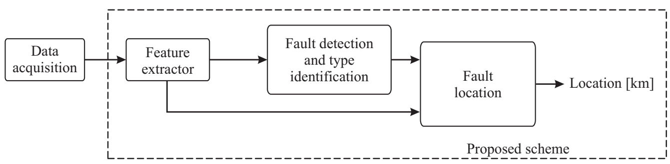


Fig. 2. Proposed scheme.

in the data acquisition is done. This process was developed with the philosophy of detect and locate HIF.

As described in [2] and [3], the angle difference between the complex numbers representing the fundamental voltage phasor and the 3^{rd} harmonic current phasor is a good track of HIF occurrence. Thus, this relation is used to detect and locate faults in the proposed methodology. The fault type classification, in turn, is done with the symmetrical components unbalance analysis of the current, present in the system.

The subroutine has a Fourier Filter, with the addition of the algorithm proposed and described in [9], for voltage and current data DC component elimination. This filter extracts the 2^{nd}, 3^{rd} and 5^{th} harmonic components that, in addition to the voltage and current fundamental phasors, are the extraction process output data.

5.3 Fault Detection and Identification

The fault detection is based in the 1^{st}, 2^{nd}, 3^{rd} and 5^{th} harmonics of the symmetrical components of the current phasors measured at the local terminal. In one time samples intervals, these components are calculated, using a one-cycle sampling window (fundamental frequency) in the algorithm described on section 5.2, and the fault state is identified, with the output vector of this ANN representing the type of fault and the phases involved. If a fault state is identified for more than 10 consecutive samples, a fault state is detected and the incidence point is determined.

5.4 Fault Location

Once the fault detection and identification process is complete, the fault location process starts. This routine is based in two different ANN: one is trained for phase faults and the other for ground faults. The input vector of these ANN are based in the phases involved in the fault, and contains the fundamental voltage and current components ($\left|V^{1h}\right|, \left|I^{1h}\right|$), the angle difference between them ($\Delta\theta^{1h}$) and the angle difference between the complex numbers representing the voltage fundamental phasor and the 3^{rd} harmonic current phasor ($\Delta\theta^{3h}$), as illustrated in Equation 1.

$$X = \left[\left|V^{1h}\right|, \left|I^{1h}\right|, \left|I^{3h}\right|, \Delta\theta^{1h}, \Delta\theta^{3h}\right] \ . \tag{1}$$

6 Tests and Results

The proposed scheme was tested in the modified system from [10]. A 3.2MVA/440V distributed generation facility was added to this system, in order to validate the methodology. The distribution feeder is illustrated on Figure 3.

Different types of faults were simulated: Phase-to-ground, double-phase, double phase-to-ground and three-phase. A total of 67 fault points were simulated

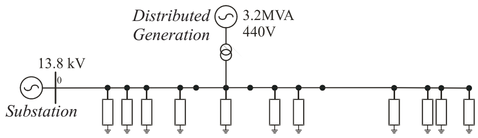


Fig. 3. Distribution feeder model.

for each type of fault, and for each point, high impedance faults, faults with linear resistance of $R_{fault} = 0, 10, 20, 50, 100\ \Omega$ and even non-fault cases were simulated. The faults were simulated using the ATP/EMTP Software [11].

These data was used for the training and validation processes. After the ANN training, the methodology was tested and the results are shown above.

6.1 Fault detection results

The results obtained with the proposed methodology for fault detection are shown on Table 1. The methodology was compared for the same fault cases with an overcurrent relay scheme (set with a detecting current of two times the maximum load current) and achieved 100% of correctness for all fault types and resistances (including HIF) and fault distance, showing its robustness for these parameters.

6.2 Fault location results

The methodology performance analysis was accomplished based on the percentage of the fault locating error in respect to the total line length. The methodology was tested and compared with a classical fault location method, presented in [12], for the same fault cases.

The maximum error obtained with the proposed fault location methodology for ground faults and 100% load was approximately 7%. Parameters like fault resistance, fault distance and HIF have few influence in the proposed scheme, not affecting its performance. For the same cases, the classic method obtained results with severe influence of the same parameters. For fault resistances higher than 50 Ω or HIF, the classic algorithm did not converged.

Phase faults have a lower maximum error with the proposed algorithm, around 4%. The same happened for the classic method, but it still suffers great influence from fault distance and its resistance.

	R_{fault}	0 Ω	10 Ω	20 Ω	50 Ω	100 Ω	HIF
Ground	OR	47.76%	0%	0%	0%	0%	0%
Faults	ANN	100%	100%	100%	100%	100%	100%
Phase	OR	46.27%	13.43%	0%	0%	0%	0%
Faults	ANN	100%	100%	100%	100%	100%	100%

Table 1. Correct detection values for Overcurrent Relay and ANN techniques.

7 Conclusions

In this article a new HIF detection and location methodology for PDS with DG is proposed. The algorithm and its theoretical basement are also shown in this work. The results had shown the robustness of the scheme for fault parameters such as: fault resistance, fault distance and HIF. The DG does not affect the algorithm performance. Comparing to classic methods, the quality of the results obtained is verified. The results of this work also show that the methodology is worthy of continued research aiming real time applications.

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