A New Protection Scheme for High Impedance Fault Detection using Wavelet Packet Transform

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***Abstract*—This paper proposed a novel technique to effectively discriminate between the HIF and the normal system operation events in distribution by combining a preprocessing module based on wavelet packet transform with an artificial neural network(ANN). Wavelet packet is firstly applied to extract of distinctive feature of current signals. Then this information is introduced to training ANN for identifying an HIF from the normal system operation events. The simulated results clearly show that the proposed technique can accurately identify the HIF in overhead distribution feeder.**

***Index Terms*— Artificial neural network, Distribution networks, Fault detection, High impedance fault, Wavelet packet.**

I. INTRODUCTION

HIFs are generally difficult or impossible to be detected with conventional over-current protection devices because the fault current may not be large enough to activate them.

HIF detection has been thoroughly studied in recent years. Several techniques to detect these faults have been proposed in the literature [1]-[10].

A method is introduced by [4], in this method with aid of extra equipment, the HIF is diverted to single phase to ground fault which is not economically proper due to price of extra equipment, in [5] for discrimination of HIF from switching introduced a method based on current variation, this method is not proper for fault current with low variation speed. In [6] and [7] methods are based on the half cycle currents asymmetry, but in some normal operation of power system, current waveform shows the same behavior as HIF current waveform which may consider as HIF by this detection method. In [8] feeder impulse response is used as a detection method, but by any change in the feeder configuration method will be acted incorrectly. Due to unsymmetrical behavior of HIF current, even harmonics are presented, In [9] the ratio of variance of power of even harmonics of HIF current to the variance of power of odd harmonics of HIF current is used, but this criteria can make a wrong decision because sometime in switching current higher harmonics are available that can be considered as HIF current. In [10] and [11] the low frequency current components performance is used, but this performance is dependent on the kind of soil and duration of arc, variation in energy of high frequency current components is used as a criterion by Christie et al [12], but for low amplitude currents or when high power capacitor banks with grounded neutral are used, HIF detection is very difficult.

Due to above mentioned difficulty, intelligent or combined methods are used for HIF detection by some researchers. In [13] fuzzy method is used to detect HIF in compensated neutral grounded MV distribution systems, they introduced a new algorithm for their job and Jota et al [14] used a fuzzy reasoning system to identify HIF, their method is based on the analysis of the feeder responses to impulse waves which are periodically injected at the feeder inlet. Neural nets and chaotic degree is used for detecting HIF [15], a back-propagation neural network is employed as a fault detector. Neural network and subband decomposition of current is used [16] in order to detect HIF. Nowadays wavelet transform method is used for detection HIF [17], [18], [19].

In this paper, a new approach based on the wavelet packet transform, is used to discriminate the HIF current from currents of capacitor switching, line and load switching and non-linear load currents that behave like HIF current.

The Model of HIF should show the random behavior of fault as well as the influence of earth resistance, fault location, on fault current. Model of this paper is based on model of [20].

II. WAVELET PACKET TRANSFORM

The wavelet Packet Transform (WPT) is a generalized version of the discrete wavelet transform. In wavelet analysis, a signal is split into approximation and detail coefficients by passing it through low-pass and high-pass filters, respectively, in the first level of decomposition. The approximation is then split into a second-level approximation and detail, and the process is repeated. In WPT, a signal is split into an approximation and a detail in the first level. Then in the second level both detail and approximation are decomposed further which forms binary tree.

Starting with the signal *f* with length *N*, the first level decomposition will produce d^1 and a^1 as any other wavelet transform. It should be noted that in the wavelet packet analysis, a^1 and d^1 are called node 1 and 2, respectively.

The second level decomposition will produce four sub-bands due to the decomposition of both d^1 and a^1 using the same set of filters used in the first level decomposition. These four sub-bands are aa^2, ad^2, da^2, and dd^2 which are called node 3, 4, 5 and 6, respectively [21,22]. Thus the ordinary wavelet decomposition is a sub-tree of the wavelet packet decomposition tree.

The main advantages of the WPT over other types of wavelet transforms are accurate and detailed representations of the decomposed signals. Also, wavelet packet basis functions are localized in time offering better signal approximation and decomposition.

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III. THE PROPOSED ALGORITHM

In this paper a novel technique is presented to detect high-impedance fault (HIF) by means of wavelet packet and artificial neural network.

Arc current at each half-cycle during HIF produces high frequency components. These components can be used to extract criteria for discriminating line current during HIF from those currents that are similar to HIF current.

In this paper wavelet packet db4 is chosen and line current sampling frequency is F = 24 kHz.

The back propagation artificial neural networks (BP-ANN) are powerful for pattern recognition. With proper training, ANN can acquire HIF detection ability. The goal of the ANN is to diagnose an HIF and distinguish it from normal system operation events.

The size of the networks needed by the proposed application to solve a particular problem remains a topic of discussion; Three independent layers (two hidden layers) could be the best choice for complex systems [23]. The sizes of the input and output layers is determined by the nature of the application. Furthermore, the number of hidden layer neurons is not defined. More neurons in the hidden layer normally result in divergence; fewer nodes may be used in the hidden layer with reference to overall system performance [24].

Directly inputting the wavelet signals to ANN is impractical, incur the number of inputs to the ANN will be excessive, increasing the difficulty of ANN convergence. Fortunately, the energy of coefficient nodes can be used to overcome this problem.

Therefore ten cycles of current are selected and by applying db4 wavelet packet, the energy of coefficient nodes for the 5-level decomposition of the current signal are obtained. Then energy of coefficient nodes 23, 24, 52, 54, 55 to 62 are used as given inputs for learning the ANN. 5-level decomposition scheme of the selected wavelet packet analysis is shown in Fig. 1.

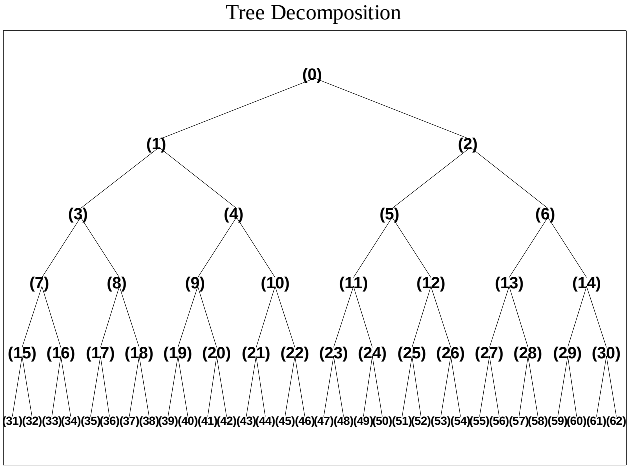

Fig. 1. Tree decomposition of the proposed wavelet packet analysis.

The ANN topology is composed of three independent layers of feed forward networks, with nine neurons in the first hidden layer, six neurons in the second hidden layer, twelve neurons in the input layer and one neuron in the output layer. In this ANN sigmoid function is used as the activation function of the hidden layer neurons and linear function is used for the output layer.

Output of ANN is a binary output: (1 means HIF has been occurred and 0 means other case has been occurred)

In order to train the ANN, seventy patterns are used for HIF, fifty patterns are used for switching, and eighty patterns are used for nonlinear loads.

For discriminating the HIF current from other currents that have similarity with HIF current, the simulated circuit shown in Fig. 2 is used.

This figure shows a radial distribution network with two feeders. This network is simulated using EMTP software. The power system frequency is 50 Hz. In the network, power is supplied at 63 kV from a 30 MVA transformer. This transformer has a wye (grounded)/delta configuration. The lines parameters are shown in Fig. 2. The HIF model is applied to bus 4 and 7 to simulate the HIFs occurred on different earth types (such as sand, wet soil, dry soil, asphalt, lawn). Since the nonlinear characteristics of HIFs may be similar to some nonlinear loads and switching operations, it must be ensured that these normal events do not confound the HIF recognition. Thus these event models (linear load switching, line switching, capacitor switching and non-linear loads that behave similar to HIF current such as adjustable speed driver, fluorescent lamp, dimmer and PC) are applied to other buses. Different cases (fault cases and non-fault cases) are simulated with various parameter values.

According to above mentioned methodology the perceptron ANN is trained with aid of different kinds of mother wavelet packets. Some of the results of these wavelet packets are showed in Table I to XII.

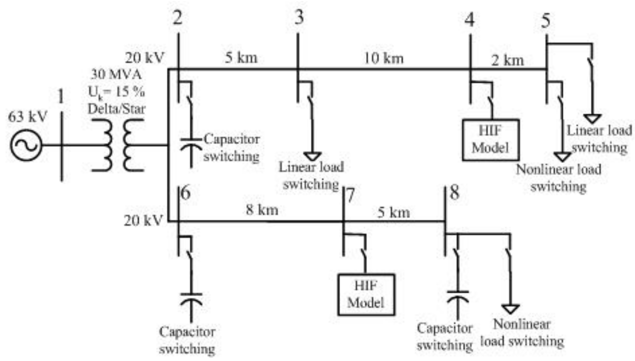

Fig. 2. Schematic diagram of the simulated power system network.

TABLE I
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF HAAR WAVELET PACKET

haar Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	28	2
Switching	30	30	0
Nonlinear Load	40	37	3

TABLE II
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF COIF2 WAVELET PACKET

coif2 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	28	2
Switching	30	30	0

Nonlinear Load	40	38	2

TABLE III
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF COIF4 WAVELET PACKET

coif4 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	29	1
Switching	30	30	0
Nonlinear Load	40	38	2

TABLE IV
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF DMEY WAVELET PACKET

dmay Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	28	2
Switching	30	30	0
Nonlinear Load	40	39	1

TABLE V
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF RBIO1.3 WAVELET PACKET

rbio1.3 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	28	2
Switching	30	30	0
Nonlinear Load	40	38	2

TABLE VI
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF RBIO3.9 WAVELET PACKET

rbio3.9 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	29	1
Switching	30	30	0
Nonlinear Load	40	39	1

TABLE VII
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF SYM3 WAVELET PACKET

sym3 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	29	1
Switching	30	30	0
Nonlinear Load	40	38	2

TABLE VIII
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF SYM5 WAVELET PACKET

sym5 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	29	1
Switching	30	30	0
Nonlinear Load	40	39	1

TABLE IX
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF BIOR2.4 WAVELET PACKET

bior2.4 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	28	2
Switching	30	30	0
Nonlinear Load	40	39	1

TABLE X
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF BIOR5.5 WAVELET PACKET

bior5.5 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	29	1
Switching	30	30	0
Nonlinear Load	40	39	1

TABLE XI
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF DB7 WAVELET PACKET

db7 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	28	2
Switching	30	30	0
Nonlinear Load	40	40	0

TABLE XII
RESULTS OF OUTPUT OF ANN WHICH IS TRAIND WITH AID OF DB4 WAVELET PACKET

db4 Pattern	Number of test patterns	Correct patterns	Incorrect patterns
High impedance fault	30	29	1
Switching	30	30	0
Nonlinear Load	40	40	0

These results show that db4 gives the better results; therefore db4 is used for detecting HIF.

IV. RESULTS

Table XIII provides some of the test results HIF and normal operation events. All the results meet the requirements of intelligent devices with general protection and HIF detection capability.

TABLE XIII
RESULTS

Pattern	Description	ANN Output	
		Actual Value	Desired Value
High impedance fault	Connection point: asphalt at bus 4	1.0028	1
High impedance fault	Connection point: sand at bus 4	1.0047	1
High impedance fault	Connection point: sand at bus 7	1.0016	1
High impedance fault	Connection point: dry soil at bus 7	1.0065	1
High impedance fault	Connection point: wet soil at bus 4	1.0017	1
High impedance fault	Connection point: wet soil at bus 7	1.0023	1
High impedance fault	Connection point: lawn at bus 4	1.0043	1
High impedance fault	Connection point: lawn at bus 7	1.0004	1
Capacitor Bank Switching	Capacitor bank connection at bus 2	0.0001	0
Capacitor Bank Switching	Capacitor bank connection at bus 6	0.0001	0
Capacitor Bank Switching	Capacitor bank connection at bus 8	0.0002	0
Load Switching	Load disconnection at bus 3	0.0001	0
Load Switching	Load connection at bus 3	0.0001	0
Load Switching	Load disconnection at bus 5	0.0001	0
Load Switching	Load connection at bus 5	0.0001	0
Nonlinear Load	disconnection at bus 5	0.00018	0
Nonlinear Load	connection at bus 5	0.00034	0
Nonlinear Load	disconnection at bus 8	0.00016	0
Nonlinear Load	connection at bus 8	0.00031	0

V. CONCLUSION

A new detection method has been proposed based on wavelet packet analysis of the feeder current signal. The detection scheme is based on the using db4 wavelet packet. The results show a high success rate of this procedure to detect HIF.

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