INTERPHASE AND GROUND FAULTS DETECTION FOR HIGH SPEED TRANSMISSION LINE PROTECTION USING ARTIFICIAL NEURAL NETWORK AND THE ONE-TERMINAL CURRENT DATA

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Abstract: This paper presents an application of an artificial neural network (ANN) to detect faults in a E.H.V. transmission line for high-speed protection. The proposed fault detector is based only on instantaneous current values and one terminal line to detect inter-phase faults and ground faults and to make decisions. A feed-forward neural network using the Back-Propagation Learning Algorithm has been used to realize an optimal fault detector. The ANN has been trained and tested with a number of simulation cases that simulate different fault conditions (fault types, fault locations and fault inception angles) in a selected network. Results show that the proposed ANN based fault detector is robust and able to offer both very high accuracy and speed fault detection.

I. INTRODUCTION

Fault need to be detected accurately and cleared as fast as possible. When a fault occurs on a transmission line, it is necessary to disconnect it from the main power system by the protection system. The aim of the fault detection function is to detect accurately the instant of fault inception and to start the protection function of the digital relay. Some approaches have been proposed to detect the faults in the literature. One method uses an off-line detector to detect the faulty line by injecting special frequency signals to the line. This method is neither safe nor convenient and is off-line. Other methods identifies the phase to ground fault according to the changes of the three phase voltages and currents [1] or the apparent impedance [2], but cannot properly distinguish the faulty line from healthy lines. Recently, with the advent of microprocessors, various analytical methods have been developed and tested to detect the faults. Unfortunately, these methods use digital signal processing which take time and do not have the ability to adapt dynamically to the system operating conditions. They are likely to make incorrect decisions if the signals are noisy. Artificial neural networks (ANNs) provide a promising alternative, because they can handle most situations which can not be defined sufficiently for finding a deterministic solution. The ANNs take into account their noise immunity, robustness, fault tolerance and generalization capabilities. Neural computing is now one of the most promising technologies in all fields of engineering, resulting in the development of a number of ANNs. The neural networks have the ability to learn the desired input-output mapping based on training examples, without looking for an exact mathematical model. Once an appropriate neural network is trained exactly, the weights of the ANN will contain a representation of the non-linearity of the desired mapping between the inputs and outputs.
In this paper a new application of ANN to detect faults in a H.V. transmission line for high-speed protection. The proposed fault detector is based only on instantaneous current values and one terminal to make decisions contrarily to some other methods who use current and voltage values [3]. One terminal fault detection is used to eliminate the communication links. The proposed fault detector is composed of two ANNs, the first ANN detects all fault types and the second detects if the fault is with ground or not. The ANNs have been trained and tested with a number of simulation cases that simulate different fault conditions (fault types, fault locations and fault inception angles) in a selected network. A feed-forward neural network using the Back-Propagation Learning Algorithm has been used to realize an optimal fault detector.

II. POWER SYSTEM UNDER CONSIDERATION

Figure 1 represents the system under study. It was chosen for the purpose of generating currents at the point S for different types and locations of faults in the transmission line. The transmission line is of 150 km and 400 kV, extending between two sources. A highly accurate digital simulation of the transmission line in a faulted condition based on the work of Johns and Aggarwal [4] was utilized to produce voltage and current waveforms for different types of faults. The transmission line is represented by distributed parameters and the frequency dependence of the line parameters are considered. The characteristics and the physical arrangement of conductors (Fig. 2) are also considered.

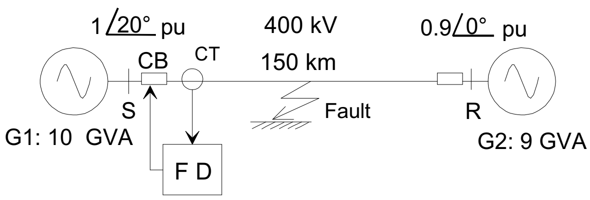

Fig. 1 System under study.
CT: Current Transformer. CB : Circuit Breaker.
FD: Fault Detector.

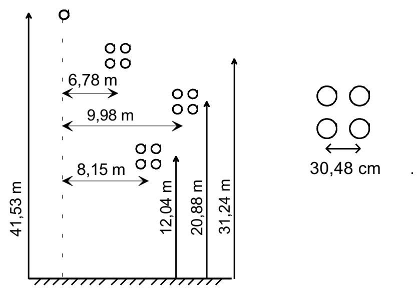

Fig. 2 Transmission line configuration.

III. ANN-BASED FAULT DETECTOR

3.1. Proposed ANN fault detector

Many papers have been published describing the applications of ANNs in power systems protection by using the voltage and current data [3]. The proposed ANN-based fault detector in this paper is composed of two ANNs, the first ANN detects all fault types and the second detects if the fault is with ground or not. The occurrence of the fault is determined by identifying the state of the power system in direct way by using only instantaneous current data and one terminal line to make decisions. The design process of the ANN-based fault detector consisted of : (i) preparation of suitable training data, (ii) selection of a suitable ANN structures, (iii) training of the ANNs and (iv) evaluation the trained networks using test patterns.

3.2. Inputs and outputs

In order to build up a ANN, the inputs and outputs of the neural network have to be defined for pattern recognition. Inputs to the network should provide a true representation of the situation under consideration. The fault detector would indicate the presence or the absence of the fault and if the fault is with ground or not. The phase and zero current signals extracted from the simulation at the relay location are chosen in order to detect the inter-phase and ground faults. Samples of these current signals, at 1000 kHz are applied to digital processing to simulate a 2 kHz sampling process (40 samples per 50 Hz cycle). This sampling rate is compatible with the sampling rates presently used in digital relays are used as inputs to the ANN.
The phase and zero current signals sampling at 2 kHz are used as input data to the ANNs. One output is used for each ANN. For the first ANN (ANN1), the presence of fault is indicated by an output of "1" while the absence of the fault is indicated by "0". For the second ANN (ANN2), the ground fault is indicated by an output of "1" while the inter-phase by "0".
Figure 3 shows the basic functional blocs of the ANN fault detector on the transmission line.

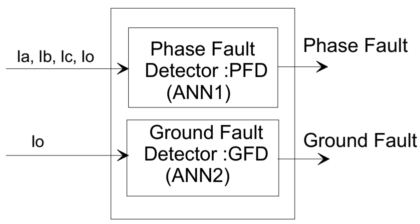

Fig. 3 Fault detector on the transmission line.

3.3. Structure and training of the ANNs fault detector

The fault detection task can be formulated as a pattern classification problem. A full-connected multi layer (input, hidden and output) feed-forward neural network (FFNN) has been used successfully to classify fault and non-fault. Number of the inputs to the network and number of neurons in the input and hidden layers are decided empirically by experimentation. Various network configurations are trained and tested in order to establish an appropriate network with satisfactory performance. This performance are the fault tolerance, time response and generalization capabilities. The three layer FFNN is selected to implement the algorithm for single ended fault detection using current data. Strings of seven consecutive samples of the three phase and zero current taken at 2 kHz are found to be appropriate inputs to the neural network. This represents a data of window of seven samples. Number of neurones in the hidden layer and one neurone in the output are used. A logistic sigmoid transfer function for the perceptrons and an error back-propagation method for training are used. It should be mentioned that the input current samples have to be normalized in order to reach the ANN input level (±1). In order construct a good neural network system, it is vitally important to train and test it correctly. Supervised learning ANN is trained from various input patterns corresponding to different fault types at various locations for different fault inception angles and fault resistances which are used as a training data.

Through a series of tests and modifications of the neuron and the layer numbers, it has been found that the three layer perceptron is used for each ANN and the structures of the ANN1 (Fig. 4) and the ANN2 (Fig. 5) provide the best performance. The ANN1 is with 28 inputs of the three phase currents and the zero current, one output and 50 neurons in the hidden layer. The ANN2 is with 7 inputs of the zero current, one output and 45 neurons in the hidden layer.

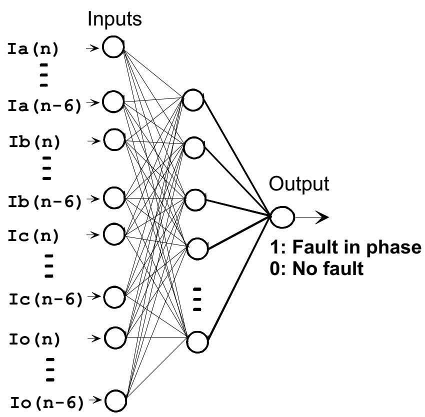

Fig. 4 ANN structure for phase fault detector (ANN1).

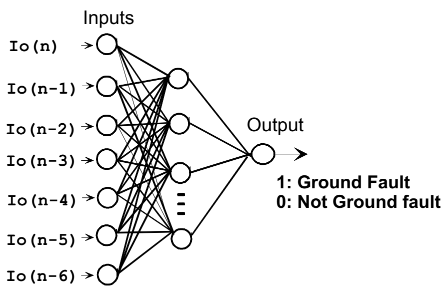

Fig. 5 ANN structure for ground fault detector (ANN2).

IV. TESTS AND RESULTS

The only means of verifying the performance of a trained neural network is to perform extensive testing. After training, the ANNs are then extensively tested using an independent data set consisting of fault simulations previously unseen by the ANNs. The trained ANNs are tested by using patterns set containing approximately 1500 different patterns included all types of transmission line faults. The test of the ANNs reveal that the networks are able to generalize the situation from the provided patterns and correctly indicates the presence or the absence of the fault and if the fault is to ground or not. Figures 6 to 12 show some simulation current waveforms and the response of the proposed ANN fault detector to different types of faults, indifferent locations and various inception angles.

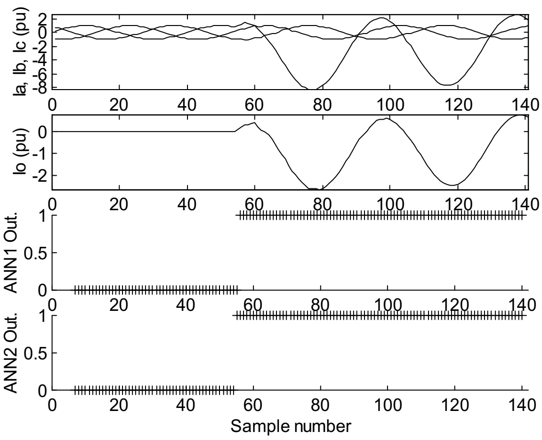

Fig. 6 Currents and ANN outputs of phase "c" to ground fault at 3 km from S and inception angle of 30°.

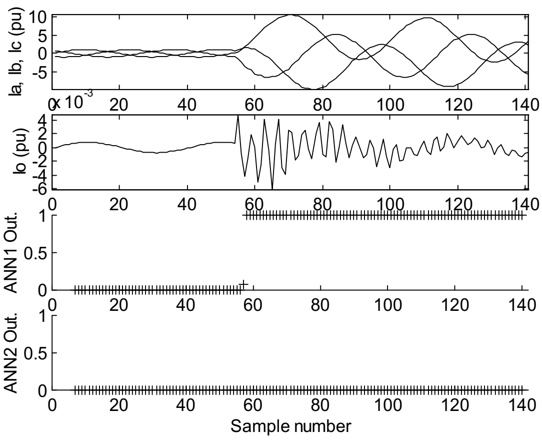

Fig. 7 Currents and ANN outputs of phase "a", "b" and "c" fault without ground at 3 km from S and inception angle of 30°.

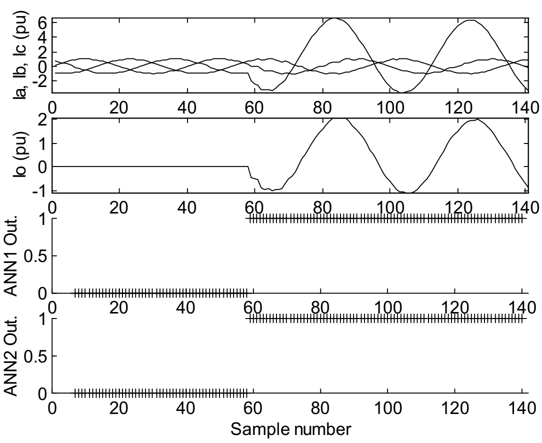

Fig. 8 Currents and ANN outputs of phase "b" to ground fault at 50 km from S and inception angle of 60°.

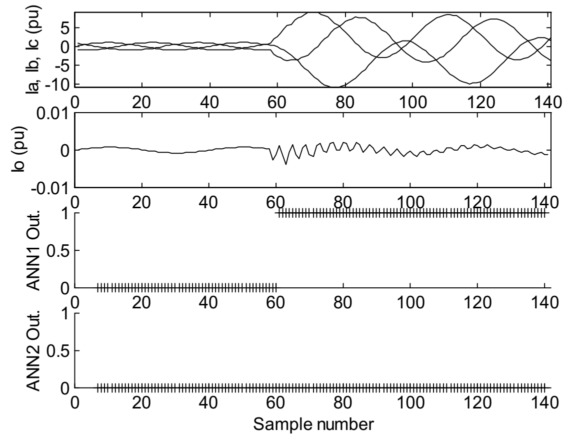

Fig. 9 Currents and ANN outputs of phase “a”, “b” and “c” fault without ground at 50 km from S and inception angle of 60°.

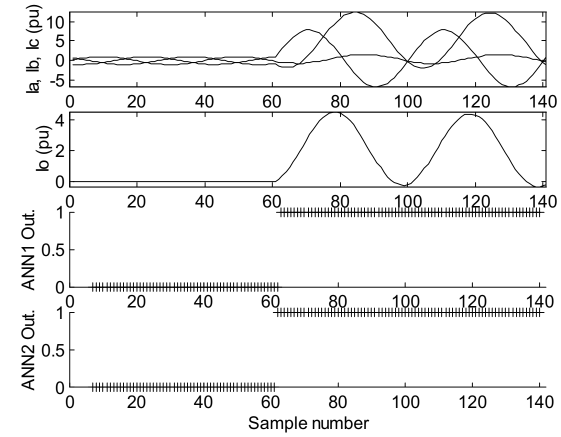

Fig. 10 Currents and ANN outputs of phase “a” and “b” to ground fault at 10 km from S and inception angle of 60°.

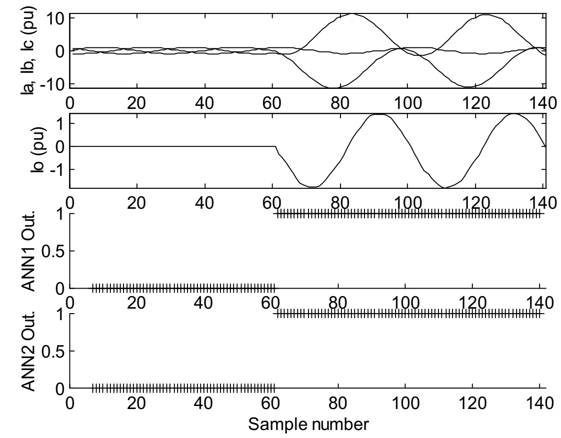

Fig. 11 Currents and ANN outputs of phase “b” and “c” to ground fault at 50 km from S and inception angle of 90°.

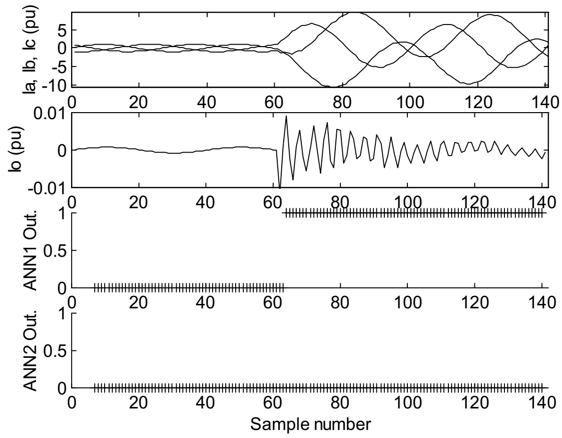

Fig. 12 Currents and ANN outputs of phase “a”, “b” and “c” fault without ground at 50 km from S and inception angle of 90°.

V. CONCLUSION

This paper has described a new application of ANN to detect a fault in a E.H.V. transmission line for high-speed protection. The proposed fault detector is based only on instantaneous current values and one terminal to detect inter-phase faults and ground faults and to make decisions. The fault detector was tested extensively by using simulated and field recorded data. Test results showing the performance of the fault detector are included. The fault detector is not affected by the type of the fault, location of the fault and fault inception angles, it can be used as a good protective relay.

VI. REFERENCES

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