Fault Classification of Three-Phase Transmission Network using Genetic Algorithm

Majid Jamil, Sanjeev Kumar Sharma, D. K. Chaturvedi

***Abstract*—The present paper proposes a very simple method for fault sorting of three-phase transmission line, which is based upon the wavelet transform and Genetic Algorithm. Three phase currents of only one end are measured and features are extracted using discrete wavelet transform. These features are then used as inputs to the genetic algorithm. The training data set for genetic algorithm is obtained by simulating the ten different types of faults using various values of fault inception angles and fault resistances, so that the accurate results can be obtained. The proposed genetic algorithm employs twenty inputs and only one output for classifying the faults. The uniqueness of the proposed method is that all the features, inputs used in developing the algorithm are normalized, so that the method can be used for any system without any substantial changes. The simulation of the three-phase transmission line network and wavelet transform analysis are achieved in the tool boxes of MATLAB® and genetic algorithm codes are also written in MATLAB®.**

***Index Terms*—Wavelet transform, artificial neural network, feed forward, fault inception angle, normalize.**

I. Introduction

The reliability and security of any electrical power system is governed by the fastness of fault detection, classification and restoration/removal of faulty section. This not only affects the power quality of electricity provides to the consumer but also improves the transient stability of the power system. The invention of fast digital computers and large data storage devices has digitalized the entire power system. The methods of fault detection are changing from analog to digital; hence the algorithms for fault detection have to be changed accordingly. Some traditional methods which are based upon the power frequency components of three-phase voltage and current signals (*e.g.* over current, distance, under/over voltage, differential, *etc.*) are well known methods of fault detection. But these techniques are suffered from their inherent limitations and are system dependent. The process of fault detection and classification starts with the measurement of three phase voltages and/or currents. The proposed method uses the current of respective three phases at one point of transmission network. The next very important part is gathering of the information from the considered voltage/current samples. The following methods are generally used for this purpose: Fourier Transform [5], Wavelet Transform [5], [8], [9], S Transform [4] *etc.* The Fourier Transform analyzes the signals in time domain only, so the limited information can be extracted from this analysis tool. The localization of signal in Fourier Transform is also not possible, the accuracy of method is affected by this inability. The S transform is relatively new tool in electrical power system, the validity and reliability of this method is still a subject of study. The proposed research paper uses the Discrete Wavelet Transform (DWT) for the analysis of the measured signals, which is a well proven tool in power system and is in used for years. The DWT transform can analyze the signals not only in time but also in frequency domain. Since the localization of the signal is also possible by windowing function of the DWT, therefore required analysis can be done effectively.

The sampling of required signals generates large amount data and it is not possible to analyze this data without any soft computing technique. Several soft computing techniques (*e.g.* fuzzy logic, artificial neural network, generalized neural network, genetic algorithms) are available for analyzing the data and to declare the meaningful conclusion from the sampled data set. A lot of work on Artificial Neural Network (ANN) related to fault detection and classification has been reported in the literature [3], [6], [8]. The proposed research work adopted the genetic algorithm for fault detection and classification in three-phase transmission network. The performance of any genetic algorithm method network depends upon the training and testing of the developed genetic algorithm. The rigorous training and testing makes the use of genetic algorithm quite easy, efficient and reliable. The method is very easy and no rules are required for detection and classification of different types of faults. Besides this the system may be designed for any types of three-phase transmission line fault without any threshold value; the different problems related to the variations in electrical power system parameters are also dealt with.

This paper is classified into five parts: the first part contains the brief introduction of the related research work already done and introduction of the proposed method, in the second part discrete wavelet transform and in its application in fault classification is discussed. The third part is about the basic concepts of genetic algorithm, its training, in fourth part model under consideration and its results are discussed, the fifth part is conclusion. The total twenty inputs are used as inputs and one output is assigned in order to detection and classification of the faults by genetic algorithm. The results of simulation establish the validity of proposed method.

I. Signal Processing and Information Gathering

The first step in the process of fault classification of three phase transmission network is to acquire the appropriate electrical signal, which is used in the process of fault detection and classification. The knowledge acquired from the analysis

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form the signal is useful in declaring the type of fault. Any electrical Three-phase transmission network has only two signals that can be acquired and analyzed effectively. The first is voltage and second is current. In this paper the current of respective three phases of transmission network at bus one is measured *i.e.* the proposed method utilizes the signals of one location only.

The continuous wavelet transform (CWT) is a very commanding tool for analyzing any electrical signal. The CWT can analyze the signals in time domain as well in frequency domain, as it can decompose the signal into different frequency ranges by using fixed wavelet function known as mother wavelet with the help of translation and dilation property. A lot has been on the wavelet transform, still brief theory about CWT is presented here to make the proposed method easy for readers. The CWT of any signal *f(t)* is represented by

$$CWT(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

where, ψ (t) is mother wavelet, which basically is a windowing function, *t* is time, *a* and *b* are the dilation and translation parameters respectively. The parameters *a* and *b* both are continuous parameters with respect to time [11]. The practical applications of CWT are limited as available signals may vary in nature *e.g.* stationary to non stationary. Besides this the data provided by CWT is very large, which makes the analysis of data and decision making difficult.

The above problem is addressed with the Discrete Wavelet Transform (DWT), which a digitalized form of CWT and can be obtained easily. The DWT of any signal *x(t)* is represented by

$$DWT(m,k) = \frac{1}{\sqrt{a_0^m}} \sum_n x(t)\psi\left(\frac{k - nb_0 a_0{}^m}{a_0^m}\right) \qquad (2)$$

where $\psi(.)$ is the mother wavelet, a_0 is scaling parameter, b_0 is translation parameter, both a_0 and b_0 are functions of an integer m such that a = $a_0{}^m$ and b = $nb_0 a_0{}^m$, k is an integer that indicate to a number of a particular sample of an input signal[12].

The practical implementation of DWT is achieved by two stage filtering *i.e.* one filter is a high pass filter and second is filter low pass filter. The DWT break the acquired current signal into various frequency ranges and this is accomplished by down sampling course of procedure. The acquired current signal is passes through low pass filter and high pass filter simultaneously, hence broken into by high frequency part and low frequency part. This method is usually acknowledged as the Multi Resolution Analysis (MRA) *i.e.* analyzing the signal at various and different frequency levels. The analysis provides the approximate and detail coefficients. The approximate and detail coefficients achieved by down sampling course. These details and approximate coefficients contain useful information, based upon which the types of fault can be classified. The entire process can be under stood easily by Fig.1.

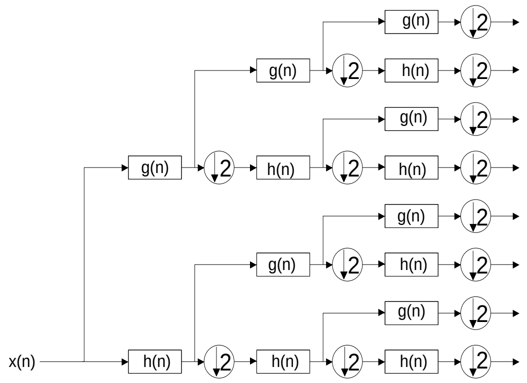

Fig.1 MRA of signal *i.e.* Multi Level Signal Decomposition

This paper has adopted the Daubechies mother wavelet of level four (Db4) for analysis of three phase current, because Db4 provides most accurate results for power system signals. The measured three phase respective current is analyzed up to the level of four for obtaining detail and approximate coefficients. The accuracy and performance depends upon the level of decomposition, the decomposition has done up to level four, which provides required accuracy.

The MRA coefficients are is used for developing the input data set for each types of fault *e.g.* faults involving one phase and ground (LG), faults involving two phases and ground (LLG), faults involving only any two phases (LL) and triple line (LLL) faults also known as symmetrical fault. The thorough and careful observation of these coefficients illustrate that the value of the detail coefficients is unique for a given type of fault. These values are different for ten different types of three phase transmission line faults [14]. The detail coefficients of level three and level four are sum up, to form the input data set. There are total three signals respective to the three phase currents, correspondingly there are total six detail coefficients three for level three and three for four level respectively. Total twenty different combinations ten for level three and ten for level four are formed based upon the detail coefficients of the three phase current signal. These twenty combinations of detailed coefficients of three phase currents are used to make the inputs data set. This data set is employs for developing the proposed algorithm.

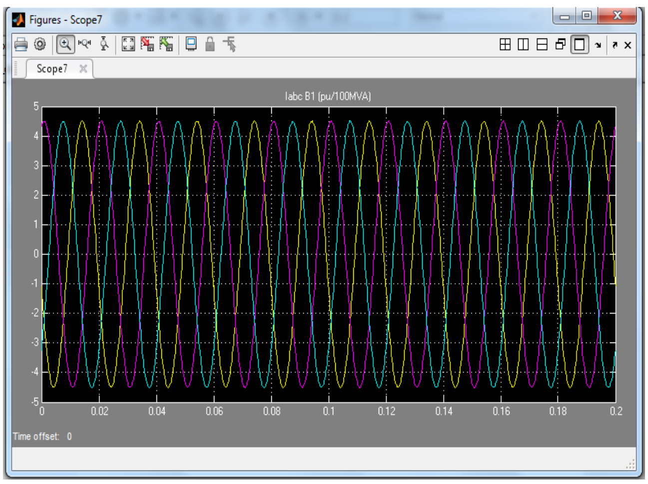

Fig. 2 Three Phase Transmission Network Line Currents under Normal Conditions

The Fig. 1.2 depicts acquired three phase currents for healthy system. The three currents are balanced and symmetric. Fig. 1.3 depicts the acquired three phase currents for line to ground fault on phase A, the distortion can be observed. These three phase distorted currents when analyzed with the help of DWT gives different values of approximate and detail coefficients.

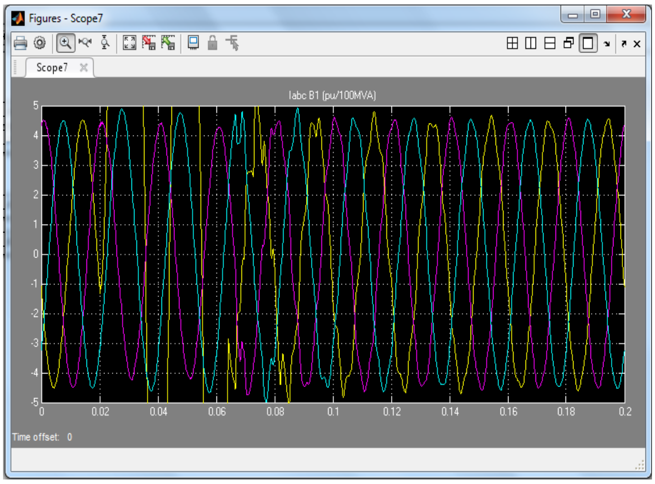

Fig. 3 Three Phase Transmission Network Line for Line to Ground Fault on Phase A

III. GENETIC ALGORITHM

The generated data from the simulation of three phase transmission network contain lots of information about the fault and the data cannot be analyzed without any suitable artificial intelligent technique. Genetic Algorithm can be applied for fault classification effectively, because it is a programming technique applicable to the problems where the information available in huge, vague, redundant, distorted and cannot sorted out by any linear programming method. In the problems of fault classification they are effectively applicable because of:

- ✓ They can be trained by off line data and further can be used on line
- ✓ There are several factors which affects the fault classification e.g. fault impedance, fault inception angle, distance from the relaying points etc.
- ✓ The results of genetic algorithm are very fast, reliable and accurate, if it is trained properly and can be retrained easily.
- ✓ The weights can be modified easily, even in during the training process.

The basic Genetic Algorithm network has four basic tools in performing its complete task:

- ✓ Selection of population- means the input data set which can become better parents
- ✓ Cross over from the selected population- reaching near to better solution i.e. from the parents of last step production of new and better off springs
- ✓ Mutations of off-springs- removal of similar solutions i.e. on similar off-springs is used in further selection
- ✓ Survival of mightiest and fittest-the final solution i.e. the best results are to sustain and utilized.

The performance of any genetic algorithm depends upon the training of network. The proposed method has adopted dynamic weights method so that the algorithm can be conversed easily and quickly.

A. Basic Concepts of Genetic Algorithm and Modeling of the Genetic Algorithm

The presented paper has adopted two basis functions for developing the Genetic Algorithm. The first one is Sigmoid function and the second is Gaussian function. The combination of both provides the ability to deal with the nonlinearity involved in the problem of fault detection and classification. The typical developed genetic algorithm model processes the output by taking the sum of the output of Sigmoid function and Gaussian function. Hence, the proposed model is named as summation type model.

The final output of the genetic algorithm is a function of two outputs O_Σ and O_π, where Σ is summation function and π is aggregation function. The output of summation part is given by

$$O_\Sigma = \frac{1}{1+e^{-\lambda s * s\_net}} \qquad (3)$$

where, $s\_net = \sum W_i X_i + X_{o\Sigma}$

The output of the product aggregation part can be represented as

$$O_\Pi = e^{-\lambda p * pi\_net^2} \qquad (4)$$

where, $p\_net = \prod W_i X_i * X_{o\Pi}$ and the final output of the GA is given by (5).

$$GA - output = O_\Sigma * W + O_\Pi * (1 - W) \qquad (5)$$

B. Error minimization in GA

The output of the genetic algorithm certainly will contain error, and this error is calculated and minimized by comparing it with the desired output. Basically the sum squared error for convergence of model is used. The sum squared error *Ep* is given by

$$E_p = \sum E_i^{\ 2} \qquad (6)$$

where, E_i is error *i.e.* $E_i^{\ 2} = (Y_i - O_i)$ between input Y_i and output O_i.

There are only ten types of fault, which can occur on a transmission line. The output matrix can be formed easily because of this, as only ten elements are sufficient for representing the all possible faults on a three phase transmission line. The genetic algorithm model is trained and tested again and again in order to minimize the training time with increase in accuracy and performance. The coding of genetic algorithm is done in MATLAB.

IV. INTRODUCTION OF THE SIMULATED MODEL

A three phase transmission line is developed in the SimPowerSystem tool box of MATLAB for studying the different types of faults. The single line diagram of developed model is shown in the Fig. 4. Two generators are connected at the both the ends of the transmission line. The respective three phase currents are measured at the relay location as shown in the Fig. 4. The value of fault resistance for all three phases is varied from 15 Ω to 60 Ω for ground faults and 0.10 Ω to 0.75 Ω for the line to line faults for generating the training patters respectively. The fault beginning angle plays very important role in magnitude of fault current, which affects the fault current patterns. The value of fault beginning angle is also varied from 0^0 to 90^0 so that all the possible situations can be taken into account. The sampling time is 80e-6 s, which cover all the signals of interests.

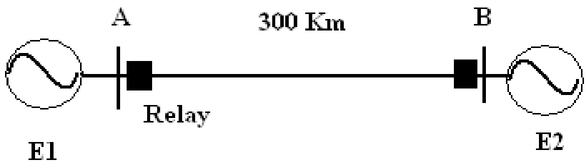

Fig. 4 Single line diagram of three phase transmission line

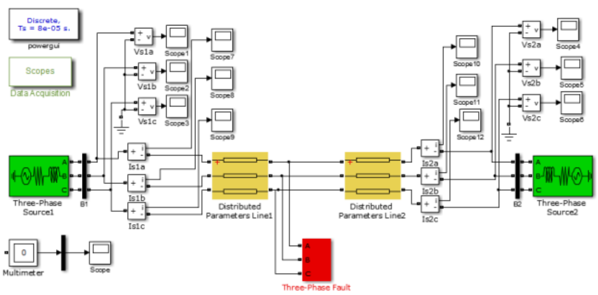

Fig. 5 Simulink model of the three phase transmission network in MATLAB

Fig. 5 shows the complete Matlab model, which is simulated for the proposed study. The fault resistances and fault beginning angle are varied accordingly and the model is simulated again and again for extensive study of the fault patterns. The accuracy of the genetic algorithm depends upon the size of the training patterns, more is size of training patterns more is the accuracy. The model is simulated for all possible ten types of fault for different parameters to generate the data set.

V. RESULTS AND DISCUSSION

After training, the proposed genetic algorithm based method of fault classification is tested with 90 new fault conditions for each type of fault. These conditions included different fault locations, different inception angles from 0 degrees to 90 degrees and different fault resistances 0 Ω to 100 Ω. The graph in Fig. 6 depicts fitness of the developed genetic algorithm, which is quite satisfactory.

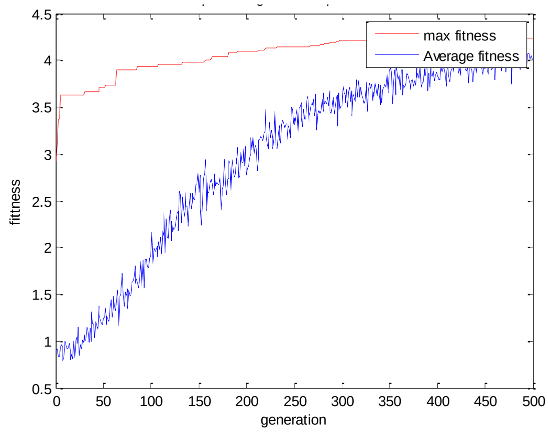

Fig. 6 Graph representing GA training

VI. CONCLUSION

This paper has proposed a new simplified technique for fault classification on a three phase transmission line network. The paper has utilized the DWT and genetic algorithm effectively for classification and detection of faults on a three phase transmission network. The paper has used the current samples at one end of the transmission line for fault classification, it makes the practical implementation of the scheme easy. The accuracy of the presented method has been increased by increasing the training data set of genetic algorithm for different operating conditions *e.g.* fault inception angle, fault resistance and ten different types of faults. The scheme is validated again and again by testing the algorithm for different data set. The time taken for train the ANN is very less and occupies less memory space of the system. The results shown in the given figure supports that the presented method is very effective and robust in classification of the fault type. All efforts have been made in the modelling of the three phase transmission line to match with the real life transmission line. The mean of all errors of fault classification is less than 7% for the system under study.

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