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Transmission Line Protection Using Artificial Neural Networks: A Review

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ABSTRACT

In today's era protection and reliability of the power system is a need for maintaining high standards of living. The power system components mainly the transmission lines suffer from unanticipated failures and thereby prone to faults. So, there is a need to protect the transmission lines by isolating the fault using distance protection schemes utilizing newer intelligent techniques of fault detection and classification using artificial neural networks. Fast isolation of fault is required to maintain system stability and reliability for obtaining desired level of efficiency. The protection relay mostly uses voltages and currents or other relevant parameters of power systems as inputs for fault diagnosis in power systems. Several methods have been employed for protection of power systems like prominent ones are based on wavelet theory, SVM (Support vector machine), Fuzzy logic, Genetic algorithm, artificial neural network (ANN) etc. The characteristics of neural networks such as adaptability, generalization, parallel processing, pattern recognition and classification make them pertinent for power system applications. In this paper, the ANN technique that has been used since long and is commonly used to protect transmission lines is reviewed.

Keywords: Distance Protection, Fault Detection, Fault Classification, Artificial Neural Networks, Adaptability

I. INTRODUCTION

Protection of transmission lines is the most important aspect of protective relaying. Majority of faults on power system (50% of total) are on the transmission lines since they are exposed to atmosphere. Transmission lines dissipate power from generating stations and also form a link in inter connected system operation for bidirectional flow of power. The faults are also due to atmospheric conditions like lightning hitting the line, resulting in overvoltage and flashover of insulators, falling of trees on lines, switching overvoltage, breaking of conductors etc. Fortunately, majority of faults are transient in nature. The conventional distance relays developed in the past were able to detect the fault but they posed a lot of problems and worst outcomes. So, an artificial neural network algorithm has been used in the present because of its adaptability which is found to be more accurate. So, a no of researchers used it for protection

of power system. Therefore this new intelligent technique is widely used as a powerful tool for detection, classification and location of faults on transmission lines.

In this paper, the ANN technique that has been used in the past and commonly used to protect three phase transmission line is reviewed. Research work in three phase transmission line protection of past works are highlighted in this paper. Hence, the scope of fault location and various other related issues involving distance protection in transmission lines using intelligent methods can be explored further. This paper is divided into five sections. Section I covers the introduction of protection of transmission lines. Section II describes the various types of power system faults commonly encountered. Section III describes the differences between conventional and new intelligent techniques of distance protection. Section IV describes applications of distance protection to ANN for fault detection and classification. Section V deals with the conclusions and references.

II. POWER SYSTEM FAULTS

The steady state operating mode of a power system is balanced 3-phase AC. Due to sudden external or internal changes in the system, this condition is disrupted. When the insulation of the system fails at one or more points or a conducting object comes in contact with a live wire, a short circuit or fault occurs. A fault generally causes a tremendous increase in current in the system. This high current may damage the power system components.

Mainly there are two types of faults which include shunt fault and series fault

A. Shunt Fault

Shunt fault constitute single line to ground (LG), line to line (LL) fault, double line to ground (LLG) fault. These are also called as unsymmetrical (Unbalanced) faults. Majority of faults are unsymmetrical.

B. Series Fault

Series fault constitute open conductor (one or two conductors open) fault. Broken conductors also constitute a series fault.

Faults can be single or combination of the above.

III. COMPARISON BETWEEN CONVENTIONAL AND NEW INTELLIGENT TECHNIQUES OF DISTANCE PROTECTION

Formerly, conventional over current distance, travelling wave, unit protection schemes have been employed for line protection against shunt faults which results in excessive current and must be cleared quickly to maintain synchronism of the system and for protection to lines, equipment's,etc.

There has been a remarkable progress in the development of protective relaying from conventional electromechanical [1] relays. Nowadays, static relays which include microprocessor [2] based numerical relays (computer based relaying) have been in use. Static relays are based on evaluation of magnitude or

phase of relaying quantities. The competency of computer based (Numerical) relays along with communication techniques has also been used.

The protection schemes have grown in sophistication with digital computer relaying with the use of communication and signal technology like optical fiber, satellite etc.

Present day trend is towards an altogether different protection in the form of artificial intelligence techniques.

Fuzzy logic and ANN are the main domains of AI techniques applied to power system widely. Neural networks or artificial neural networks (ANN) is a computer architecture inspired about the human brain. It is analogous to biological nervous system. Units called 'neurons' are used for interconnection to other neurons. ANN see pattern in the data condition presented to them, patterns of sound and fault condition, are different.

ANN require intelligence by learning from environment. They have the ability to generalize which imparts them 'adaptability". Adaptability allows ANN to adapt to changing system environment. Training of ANNs takes long time but once trained the output is instantaneous which is suitable for online applications. ANNs are fault tolerant means they are capable of giving a correct output even in the presence of noise, or corrupted data making them reliable. These are some techniques of future relaying.

IV. APPLICATIONS OF DISTANCE PROTECTION TO ANN FOR FAULT DETECTION AND CLASIFICATION

Distance protection is the basis of transmission line protection. It is a non-unit type of protection based on comparison of short circuit impedance. The basic principle behind impedance measuring is the division of voltage and current signals. The trip command is issued on the comparison of apparent impedance measured by the relay with known line impedance; if the measured impedance is smaller than settled line impedance, a trip occurs.

There are many protection schemes settled time to time by researchers using ANN. Below is a brief review presented.

Adaptive relaying [3, 4, 5, 6] technique has been widely used for distance protection. Khaparde et al [7] presented adaptive relaying using ANN by multi-layered perceptron (MLP) [8]. In this the ADALINE model was used where weights were trained off-line and stored on-line. Error- backpropogation algorithm was used along with simulation model of transmission lines. Dalstein et al [9] proposed a scheme for high speed protective relaying using ANN by digital signal processing for fault classification in real time by measuring three phase voltages and currents. Simulation was done using EMTP [10] program and NETOMAC [11, 12, 13] software by backpropogation learning algorithm. Sampling rate of 1 KHz was used for fault detection and classification. Results showed classification average in less than 6ms and detection of arcing and non-arcing fault in fast time. Qi et al [14] proposed ANN distance relay for detection of single line to ground fault with non-linear arcing resistance. Simulation and testing was done under load and fault conditions with different system conditions. According to them proposed relay

effectively works under conditions of non-linear resistance and variable source impedance where the conventional relays do not. Vazque et al [15] developed ANN based fault detector using feed forward ANN (FFNN). Simulation was done using MATLAB and EMTP. Sampling rate of 960Hz using a single hidden layer with several types of filters was used. Response time was found to be One-half cycle. Lai [16] proposed adaptive neural network scheme to be used for digital distance relaying considering high impedance and variable source impedance faults. It was mainly used for fault classification purposes. Chowdhury et al [17] developed modular methodology for fault detection and classification using different modules which can be model-based or model-free. Model free utilizes multilate filter banks. Also for classification purpose modified kohenon [18, 19] type neural network was proposed. Coury and Jorge [20] presented the use of ANN for distance protection as a pattern classifier by using the magnitudes of three phase voltage and current phasors as inputs [21]. Backpropogation algorithm has been used along with neural network toolbox from MATLAB to create ANN for testing, training and obtaining weights. Cho et al [22] presented an ANN based approach for improving the speed of a differential equation distance relaying algorithm without affecting the accuracy. The testing was done in three rates of 24, 48 and 96 in 345kV transmission line system and compared with conventional ANN regarding speed and accuracy. Results showed approach for improving speed of relaying algorithm. Zahara et al [23] presented transmission line relaying scheme using ANN and feed-forward neural network. It utilizes frequency spectrum of voltage and current for decision making. Testing using EMTP program for single line to ground fault (SLFG) and three phase fault.Relaying decision within a cycle was done accurately after fault inception. Simulation was done in MATLAB neural network toolbox [24] on a 160 miles line with a sampling frequency of 960Hz. Venkateshan and Balamurgan [25] presented optimum neural network structure with short training time using C++ language and developed a real time fault detector for distance protection using ANN. Simulation was done using MATLAB software and backpropogation algorithm. By this the hardware complexity was minimized with the elimination of external fault identifiers. Pradhan et al [26] presented a scheme for high speed distance relaying using newer version of RBFNN providing efficiency for training and computation. Cardoso [27] presented neural network modules for fault section estimation using general regression neural network and multilayer perceptron neural network by implementing protection schemes for 230kV transmission line. Sanaye et al [28] proposed neural network transmission line distance protection module by utilizing samples of voltage and current for learning hidden relationship by considering effect of fault resistance and source impedance. Simulation was done on a two machine three phase 230kV power system using EMTDC. Sampling rate was 20 samples per cycle. A comparison was made in backpropogation (BP) and Multi-layer (ML) and ML is chosen for different parameters. Results concluded pattern recognition and classification in ANN based relay immune to overreach and underreach extending to (80-90%). Bhalija et al [29] presented adaptive digital distance protection using radial basis function neural network providing more efficiency than conventional feed forward with backpropogation algorithm. Simulation was done using PSCAD/EMTDC [30] software for examining MCF (Modified compensation factor) on a 400kV, 128 km line. Results showed maximum

zone relaying for high resistance faults with reduced training data and RBFNN is suitable for real time. Martin et al [31] proposed digital relay for double circuit line protection consisting of time based frequency module in combination with ANN. Simulation was done on PSCAD software along with implementation of wavelet transform with ANN in MATLAB. Daubechies 6 pre-processor is used for providing reliability and efficiency readily. Results showed approach is unaffected by oscillations, magnetic coupling etc. best for classification purposes. Tayeb et al [32] designed an ANN utilizing backpropogation neural network algorithm as alternative method for fault detection and classification. In the proposed work, pi model 110kV transmission line of length 145 km was used. Simulation was done using MATLAB and Neuroshell 2 software applying levenberg-marquardt algorithm [33]. Results demonstrated backpropogation neural network architecture to be highly satisfactory resistant to errors with fast evaluation. Santos and Sengar [34] presented and implemented a unique ANN based algorithm for transmission line distance protection. This algorithm can be used in a transmission line inspite of configuration and voltage levels. The algorithm does not require topology adaptation and parameter adjustment in different electrical systems. Abdel et al [35] proposed a scheme for high impedance fault detection and classification using an adaptive neuro fuzzy inference system. Vaidya et al [36] implemented ANN based distance protection relay for long transmission lines considering the effect of fault resistances based on pattern classification and recognition ability utilizing the inputs of magnitudes of resistance and reactance. Simulation was done in MATLAB environment on a 400 kV line system with series compensation along with ANN toolbox using backpropogation neural network and feed forward neural network. Ben hessine [37] proposed a new approach based on ANN for fault detection and classification in real time to EHV for digital protection. The proposed work was based on measured V and I values of each phase. MATLAB software has been utilized along with ANN toolbox on a 400kV, 50Hz and 100km long line. The test concluded ANN output for fault type indication with various parameters at a high speed. Altaie et al [38] proposed fault detection and classification technique for the EHV lines. Detection includes combining three types of relays using differential, overcurrent and distance method. Classification is by recorded data using DSP and ANN. A feed forward ANN using RMS values of phase voltage, phase current and phase voltage angle. Simulation was done in MATLAB software on a 600 km long transmission line sampled at 20000 samples per second (333.333 samples per cycle). Jamid et al [39] proposed a technique of fault detection and classification in transmission lines using ANN with voltage and currents as inputs employing feed forward neural network along with BPNN. Simulation was done on 400kV line system of length 300km with different fault resistances in MATLAB environment. Sampling rate was 20 samples per cycle. Results showed ANN architecture to be robust and reliable method.

V. CONCLUSIONS

There are numerous applications of ANN in protection of power system, but in this paper only a few of them are examined. Several new tools and techniques have been proposed and discovered in the recent

times for maintaining power system stability, reliability and security for effective operation and performance improvement of the digital protection distance relays in real time. A newer intelligent technique of artificial neural network (ANN) provides better capability of fault detection and classification as compared to conventional techniques developed. The inherent capability of pattern recognition and classification has been utilized in the schemes. ANN architecture is robust, reliable, effective and accurate for distance protection. A brief review of applications of ANN to transmission line protection has been specified in this paper.

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