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Review on Artificial Intelligence Based Protection System of Transmission Line

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ABSTRACT: Contemporary power systems are associated with serious issues of faults on high voltage transmission lines. Instant isolation offault is necessary to maintain the system stability. Protective relay utilizes current and voltage signals to detect, classify, and locatethe fault in transmission line. A trip signalwill be sent by the relay to a circuit breaker with the purpose of disconnecting the faultedline from the rest of the system in case of a disturbance for maintaining the stability of the remaining healthy system.This review paperfocuses on the studies of fault detection, fault classification, fault location, fault phase selection, and fault direction discriminationby using artificial neural networks approach. Artificial neural networks are valuable for power system applications as they can betrained with offline data. Efforts have been made in this study to incorporate and review approximately all important techniquesand philosophies of transmission line. This comprehensive and exhaustive surveywill reduce the difficulty of new researchers to evaluate different ANN based techniques with a set of references of all concernedcontributions.

Keywords: ANN, Fault classification, Protection system, Relays, Transmission line.

I. INTRODUCTION

Transmission line is one of the power system components which have the highest fault incidence rate, since it is exposed to the environment. Line faults due to lightning, storms, vegetation fall, fog and salt spray on dirty insulators are beyond the control of human. The balanced faults in a transmission line are three phase shunt and three phase to ground fault. Single line to ground, line to line and double line to ground faults are unbalanced in nature. On a transmission line, the protective relay system is incorporated to detect the abnormal signals indicating the faults and to isolate the faulty part from the rest of the system with minimal disturbance and equipment damage.

There is no fault-free system and it is neither practical noreconomical to build a fault-free system.The various cases ofabnormal circumstances such as natural events, physical accidents,equipment failure, and misoperation generate faults inthe power system. The consequences of faults are traumaticamplification of current flow, increasing heat produced in theconductors leading to the major cause of damage.The actualmagnitude of fault depends on resistance to flow and variedimpedance between the fault and the source of power supply.Total impedance comprises of fault resistance, resistanceand reactance of line conductors, impedance of transformer,reactance of the circuit, and impedance of generating station.The conventional distance relay settings are based on a predeterminednetwork configuration with worst fault outcome. As theneural networkbasedalgorithmhasmore adaptabilityand is likely to be more accurate, various researchersused it for power system protection which is the main focusof this study. A number of prime purposes and applicationsof ANN are accessible in the literatures; those will assist torecognize the perception of accepting it as a tool for faultdetection, classification, and localization on transmission lineof the power systems[1].

The paper is organized as follows. In Sections 2 and 3, abrief introduction of power system faults and artificial neuralnetworks is provided, Section 4 is about distance protectionby ANN method; in Section 5, ANN and its application forprotecting transmission line are illustrated. Section 6 dealswith the conclusions drawn from this survey followed byacknowledgments and references.

II. FAULTS IN POWER SYSTEM

Fault is an unwanted short circuit condition that occurs eitherbetween two phases of wires or between a phase of wire andground. Short circuit is the riskiest fault type as flow ofheavy currents can cause overheating or create mechanicalforces which may damage equipment and other elements ofpower system[2].

2.1. Categories of Faults

Faults also can be classified into threetypes, that is, symmetrical faults, unsymmetrical faults, andopen circuit faults.

2.1.1. Symmetrical Faults

The fault that results in symmetricalfault currents (i.e., equal currents with 120 displacements)is known as a symmetrical fault. Three-phase fault is anexample of symmetrical fault where all three phases are shortcircuited with or without involving the ground.

2.1.2. Unsymmetrical Faults

Examples of different unsymmetricalfaults are single phase to ground, two phases toground, and phase to phase short circuits. The details of theseshunt fault types that can occur in transmission line aredescribed as follows [3].

(1) Single Phase to Ground (L-G) Fault

L-G is a short circuitbetween any one of phase conductors and earth (prevalenceis 70%–80%). It may be caused either by insulation failurebetween a phase conductor and earth or breaking and fallingof phase conductor to the ground.

(2) Two Phases to Ground (L-L-G) Fault

L-L-G is a shortcircuit between any two phases and earth (prevalence is 10%–17%).

(3) Phase to Phase (L-L) Fault

L-L is a short circuit betweenany two phases of the system (prevalence is 8%–10%).

(4) Three-Phase (L-L-L) Fault

L-L-L is a short circuit between any two phases of the system (prevalence is 2%-3%).

2.2. Open Circuit Faults

This type of fault is caused bybreaking of conducting path. Such fault occurs when one ormore phases of conductor break or a cable joint/jumper (atthe tension tower location) on an overhead line fails. Suchsituations may also arise when circuit breakers or isolatorsopen but fail to close in one ormore phases. During the opencircuit of one of the two phases, unbalanced current flowsin the system, thereby heating rotating machines. Protectiveschemes must be provided to deal with such abnormalconditions.[4]

III. ARTIFICIAL NEURAL NETWORK

Artificial neural network (ANN) has been equipped with distinctiveness of parallel processing, nonlinear mapping, associative memory, and offline and online learning abilities. The wide uses of ANN with its conquering outcomes make an effective diagnosticmean in electric power systems. Its versatility withmultitude applicability can be seen in other areas of science and engineering research [5]. It is a complex network of interconnected neurons where firing of electricalbpulses via its connections leads to information propagation. ANN is trained by using prior chosen fault samples as input and set of fault information as output for fault diagnosis application. Neural networks are comprised of primarily three basic learning algorithms such as supervised learning, unsupervised learning, and reinforced learning. Among these supervised learning is most commonly used and is also referred to as learning with a teacher. This is applied when the target is having identified value and is associated with each input in the training set [5]. Figure 1 represents the supervised architecture of ANN.

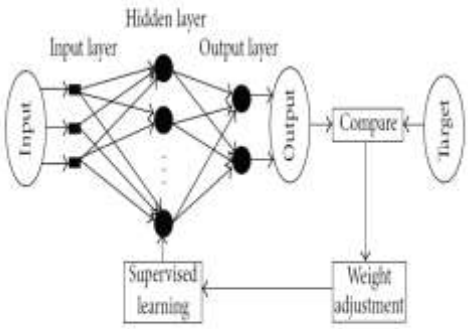

Fig. 1 Supervised architecture of ANN [5]

Error back propagation (BP) neural network was applied by Chan [6]for diagnosis of fault in power system. However slow speed training and the shortcomings of local optima lead to the introduction of additional momentum factor for problem solving. Radial basis function (RBF) neural network has a faster learning speed and the ability of arbitrary function approximation. Bi et al. presented a novel RBF neural network for estimating section of fault. Their simulation results of 4-bus test system shown that the capability of RBF neural networkin grid fault diagnosis was better than the conventionalBP neural net [6].For solving improper problems, neural network topologiesare tobe alteredand there isaneedtoretrain thenetwork.Cardoso et al. [7] used the true capacity of multilayerperception (MLP) and generalized regression neural network(GRNN) for fault estimation in electric power system.GRNNis having the advantage of faster learning, global optimum,and lower requirement of comprehensive sample. They fedthe failure information into MLP and the resultant outcomewas given as output toGRNN.They also comparedANNfaultdiagnosis methods with expert system diagnostic methodsand foundthatANNbasedmethodsmay evade the formationof expertise, expert heuristic knowledge, and expression andhence save tedious work.

IV. METHODOLOGY

1. Working principle of current protection:

According to the requirements of line faults for main and backup protection, there arethree types of current protection for transmission lines:

i) Untimed current instantaneous trip protection, referred to as the first stage of current protection .Its role is to ensure that only faults on this line are removed under anycircumstances.

ii) The setting value of its current measurement element must follow the following principles:The time-limit current quick-break protection can protect the entire length of the line(including the end of the line). To this end, the protection range must be extended to theadjacent lower ~ line.

iii) Time-limit overcurrent protection, referred to as the third stage of current protection,which is used as the backup of the main protection of this line ~ the backup protection ofthe line (or components), that is, the remote backup protection. The starting current of thecurrent protection is to avoid the maximum load [8]. Sections 1, 2, and 3 are collectivelyreferred to as three phase current protection for line short circuits. In the single-powerradiation network, the time-limited current quick-break protection at the circuit breaker.

The short-circuit current of the AB line when three-phase and two-phase short-circuitingshould be calculated first. Ignoring the resistance component of the line, the phase potential of the system equivalent power source at the circuit breaker 1QF is Es. The maximum short-circuitcurrent I_{kmax}^{3} when the three-phase short-circuit of the line, and the minimum short-circuit [9,10].

CurrentI_{kmin}^{3} when the two-phase short-circuit is:

$$I_{kmax}^{3} = \frac{E_{\varepsilon}}{X_{smin} + x_1 l} = f(l)$$

$$I_{kmin}^{2} = \frac{E_{\varepsilon}}{X_{smin} + x_1 l} * \frac{\sqrt{3}}{\sqrt{2}} = f(l)$$

2. Advantages and disadvantages of current protection:

In the case where the system operation mode varies greatly, when the 1QF current quickbreakprotection of the circuit breaker is set according to the selective requirements of protectionunder the maximum operation mode, there is no protection range under the minimumoperation mode [11].

3. Working principle of distance protection:

The working principle of distanceprotection is shown in Fig 2.As can be seen from Fig 2, the ratio of the input of the protective measuring elementinstalled at each circuit breaker is the bus voltage $U_m$and the current flowing through the lineI_m [12,13]. The measurement impedance $Z_m$protected here, i.e.

$$Z_m = \frac{U_m}{I_m}$$

Under normal working conditions, U_m=U_w(operating voltage of the bus), I_m =I_l(loadcurrent of the line), the measurement impedance of the protection measuring element is theload impedance, that is,

Z_m=Z_l

During normal operation, the working voltage U_ w of the bus is near the rated value.

Generally,the negative current $I_l$of the line is much smaller than the short-circuit current, so themeasured impedance Z_l value of the line under load is large, and its angle Load power factorangle. The line distance protection is similar to the current protection, and can also constitute athree-stage distance protection. The first and second sections of the distance protection are themain protection of the line, and the third section of the distance protection is the near-backupprotection and adjacent components of the main protection of the line far-backup protection [14].

4. Advantages and disadvantages of distance protection

Its main advantages and disadvantages are as follows:

1. In multi-supply networks and even in complex power networks, distance protection canbetter meet the selective requirements of the actions.

2. The first stage of the protection distanceis protection for instantaneous action to limit thedamage to the first protection zone. In a dual-supply network, if the first-stage protectionon both sides of the line has overlapping protection zones, both sides of the line mayremove errors in the overlay zone without delay, and the radiation network of a source inthe first stage protection zone of the line after the first step error and error non-

overlappingarea on both sides of the dual supply line, the action shall not be removed without delay.
3. The wiring of the components of composite resistance to distance protection is more complexand the relevant locking device must be added to make the device distance more complicated.Therefore, the reliability of the distance protection is lower than that of the currentprotection [16-18].
5. Decision-making process of protection system
The organic coating factor can be adjusted to the S3 stack substrate and other substratescommunicate with substation s3 via fibre optics. Within the Agent Agency, according to thenetwork wiring, corresponding circuit switches have been stored to form the same protectionfield. When the organisation agent receives the action message interrupted by the circuitbreaker, quickly considers that other switches within the protection range should be activatedand transmits this directive to the protection subsystems on all sides through the factor; coordination.

Any protection agent may use the current protection on the basis of a neural networkconsisting of two neural networks. The neural network 1 (ANN 1) is a positive-direction separatorand a failure type selector on adjacent lines. The neural network 2 (ANN 2) is a sub-networkfor instantaneous action when an error occurs within 85% of the protection zone. Whensub-network 1 and sub-network 2 operate simultaneously, the travel agent shall be activatedand the local protection switch shall be activated instantaneously; and that information shallbe transmitted to the Agency Agent at the same time. When Sub-Network 1 operates andreceives the travel order transmitted by the Agency Agent, the travel agent shall also activateand immediately activate the local protection switch [19,20].

V. DISTANCE PROTECTION BY ANN

The fundamental principle of distance protection is that theapparent impedance seen by the relay reduces considerably incase of line fault. A fault is indicated if the ratio of apparentimpedance to the positive sequence impedance is less thanunity. This scheme of protection is inherently directional andused by impedance and Mho relays. This paper focuses uponthe studies of distance protection scheme applying ANNapproach.

Adaptive relaying was introduced for widespread applicationsincluding incorrect or fault operations measurement.The learning capacity of ANN from input and output patternsextended its applicability in several adaptive protectionschemes. Khaparde et al. applied adaline neural networkmodel in offline mode for protective relaying operation oftransmission lines. They also proposed adaptive distanceprotection by using ANN [21].They have applied MLPmodelto reduce misoperation of a relay. Girgis et al. presenteda method for the computation of fault location in twoandthree-terminal high voltage lines which is based ondigital computation of the three-phase current and voltage60/50Hz phasors at the line terminals. For evaluation of theconvergence and distinctive solution, this method was testedby electromagnetic transient (EMPT) generated transientdata from a steady state fault analysis. Qi et al. proposedANN approach for distance protection of power system bytaking trained data fromsimulation of a simple power systemunder load and fault conditions [22-25]. According to them conventionaldistance relays might not function properly undercertain conditions such as nonlinear arc resistance, highimpedance fault, and variable source impedance. However, ifsuch relays are implemented with ANN, such issues can beaddressed. Khaparde again proposed an adaptive schemeof distance protection using an artificial neural network [26,27]. Lai implemented an adaptive protection scheme by ANNapproach for classification purpose. They have consideredconditionsofhighimpedance fault (harddetectionbecauseofminute fault current) and variable source impedance. Couryand Jorge proposed distance protection using ANN fortransmission lines utilizing the magnitudes of three-phasevoltage and current phasors as inputs. ANN based approachfor improving the speed of a differential equation baseddistance relaying algorithm was developed by Cho et al. Several researchers illustrated various methodologiesfor improvements in fault distance computation[28].

Venkatesan and Balamurugan developed neural networksimulator for identifying the optimum ANN structurenecessary to train the data and implement the ANN inhardware. However, there is no precise rule for selection ofthe number of hidden layers and neurons per hidden layer.So, it is not certain whether or not the ANN based relaygives the optimum output, for maintaining the integrity ofthe boundaries of the relay characteristics. Pradhan et al.proposed a high speed distance relaying scheme basedon RBF neural network due to its capability of distinguishingfaults with data falling outside the training pattern. Asequential procedure for distance protection using a minimalRBF neural network for determining the optimum numberof neurons in the hidden layer without resorting to trial anderror was illustrated by Dash et al[24]. Authors trainedmultilayer feed-forward architecture with two inputs andthree-trip or no-trip output signals based approach and usedBP technique for three-zone distance protection of transmissionlines. The first output was used for main protection ofthe transmission line section, whereas the other two outputsprovide backup protection for the adjacent line sections. Theinput features extracted by discrete-Fourier transform fromthe fundamental frequency voltage and current magnitudes.Santos and Senger developed and implemented of aunique ANN based algorithm for transmission lines distanceprotection.Their algorithm can be used in any transmissionline despite of its configuration or voltage level and also doesnot require any topology adaptation or parameters adjustmentwhen applied to varied electrical systems [25]. Vaidya andVenikar illustrated an ANN based distance protectionscheme for long transmission lines by considering the effectof fault resistance of single line to ground fault type. Theyhave utilized the magnitudes of resistance and reactance asinputs for classifying unknown patterns. A novel distanceprotection approach for detection and classification stagesbased on cumulants and neural networks was developed byCarvalho et al[22].

VI. APPLICATION OF ANN ON TRANSMISSION LINE PROTECTION

This section presents the studies on application of ANN forfault detection, classification, location, direction discrimination,and faulty phase selection on transmission line[29].

6.1. Studies on "Fault Detection and Classification"

It is necessaryto identify the fault and classify its type with the aim ofestablishing safety and stability of the power system. LimandShoureshi developed ANN based monitoring system forhealth assessment of electric transmission lines. Their systemshowed satisfactory performance in fault classification byusing both MLP (multilayer perceptron) and ART (adaptiveresonance theory) classifiers.

6.2. Studies on "Fault Detection and Classification and Location"

It is extremely essential to identify and locate thetransmission line faults for maintaining the proficient andtrustworthy operation of power systems. For estimation ofthe fault location, there are a number of mathematical andintelligent methods accessible in the literature. However,the broad variations in operating conditions such as systemloading level, fault inception instance, fault resistance and dcoffset, and harmonics contents in the transient signal of thefaulty transmission line give rise to unsatisfactory results[16].

6.3. Studies on "Fault Direction Discrimination"

Fault directionestimation on transmission line is very crucial forenhancing the performance of power system. Advancementof huge generating stations and highly interconnected powersystems entails less fault clearing times.The approach ofANNhas been positively utilized for the improvement of manyof the standard functions that are operated in transmissionlines. The accuracy of an electromechanical, static, or amicroprocessor based distance relay is affected by differentfault conditions and network configuration changes. Hencethe direction of the fault should be discriminatedtomaintainthe normal operation of the power system.Dalstein et al. have used ANN method to estimatethefault location process by means of directional discrimination.They have proposed a neural network to estimatethe direction of the fault. Authors employedneural network for designing two different fault directiondiscrimination modules for high speed transmission lineand found that fault direction can be identified quickly andaccurately from their results[10].

6.4. Studies on "Faulty Phase Selection"

Fault phase selection,an imperative part of fault diagnosis, is carried out bymeasuring faulty line parameters. Different power systemfaults such as LG, LL, LLG, LLL, and LLLG on a protectedtransmission line should be detected, classified, and locatedand faulty phase should be selected swiftly for performing thenormal system operation[22].

VII. CONCLUSION

There are widespread applications of ANN in power systemprotection, but this paper intensively analyzed few of them.Novel tools and techniques are preferred to maintain powersystem reliability and security within a satisfactory level forimprovement of the performance of digital protective relays,renovation of power industry, and stability of the transmissionlines. ANN is found to be robust, accurate, and efficientapproach for transmission line fault detection,

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classification,localization, direction discrimination, and faulty phase selection.A comparative study of different schemes for faultdetection, fault classification, fault location, fault directionestimation, and faulty phase selection has been discussed indetail. An extensive review of the published studies on thesubject of ANN application to transmission line protection isspecified in this paper which will be beneficial for researchersfor further research and development in this field.

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