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Inter-Circuit Fault Classification in Parallel Incomplete Journey Transmission Lines Using Artificial Neural Networks: A MATLAB-Based Approach

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ABSTRACT

Transmission line is a main portion of power system owing to its capacity of increasing power in a power grid. Nonetheless, due to increasing complexity, faulty detection in power line has been always a potential issue. Parallel incomplete journey transmission lines (PIJTL) frequently subject a variety of technical issues in the view of power system protection. This study presents artificial neural networks (ANN) based inter circuit fault classification of PIJTL using MATLAB Software. Although different approaches have been addressed for ordinary shunt faults in PIJTL, nonetheless, determining the inter circuit faults in PIJTL hasn't been focused so far. When fault occurs in the PIJTL current waveforms are distorted due to transients and its pattern changes according to the fault type in the line. The ANN approach finds the inter circuit faults by means of currents. ANN takes a reduced set of feature inputs, i.e., the fundamental components of six phase currents of the two parallel lines at source of parallel incomplete journey only. The result performed that proposed ANN is capability of right tripping action then type of fault at high speed as a result can be applied in practical application. The main feature of ANN is that it acceptably estimates finds the inter circuit faults and also ordinary shunt faults, thus making it more accurate and reliable when compared to other approaches. Several fault case studies have conformed the effectiveness of ANN technique. Further, fuzzy based inter circuit fault locator and classifier for PIJTL we can design.

1. INTRODUCTION

The electricity and its management have an important role in various applications due to the rapid globalization in this new era. As an essential part of the electrical power system, the transmission line fault will affect the power grid. If the fault type cannot be determined in time, it leads to an unwanted power interruption as well as severe economic losses for utilities. The accuracy of the fault type in the transmission line will reduce the time, manpower and materials consumed by the transmission line inspection work [1]. However, classification of the transmission line is the challenging task for protection engineers, whereas parallel incomplete journey transmission line (PIJTL) is installed.

The detecting the faults in PIJTL is not a simple work owing to the long length line whose impedance value is very low and severe atmosphere situations. PIJTL uses different methods which has disadvantage viz. the requirement of communication link and both terminal measurement details. Hence, it is important to develop a method to classify the inter circuit faults with maximum accuracy in all testing cases. A considerable body of research work has hitherto proposed on the PIJTL [2-4]. In our previous work [5, 6], the fuzzy and mathematical system-based fault protection for PIJTL has been reported. At present, the main research on a power system protection mainly focuses on the fault classification method [7-9]. Some recent fault classification methods for single terminal transmission lines have been focused in the study [10, 11]. Naresh Kumar et al. [12] implemented a scheme of classification using supports vector machines. Several researchers illustrated different schemes for inter circuit fault classification [13-16]. Bejugam Srikanth et al. [17] used fault data collected from single bus to estimate the inter circuit faults. Swetapadma et al. [18, 19] developed optimum Naïve Bayes classifier structure for identifying the inter circuit faults.

In the recent study, ANN-based approach is employed for detecting faults also. It is found that artificial neural network (ANN) being non-linear is better in finding faults and can reduce error compared with their methods. Extensive literature survey on ANN for transmission lines protection. A few researchers have presented fault location using ANN algorithms such as Levenberg–Marquardt (LM) [20] and Back Propagation (BP) [21]. Furthermore, researchers have studied the ANN technique in the practical applications [22, 23].

In order to overcome the communication channel issues and to obtain the classification objectives, an ANN is introduced in the study [24]. The ANN does not require any complicated algorithm to enhance the classification accuracy. Jain et al. [25] developed an ANN based algorithm for parallel transmission lines inter fault classification. Nevertheless, no existing solution can reach sufficiently better results in inter circuit fault classification in PIJTL. The existing literature review on fault classification in PIJTL that none of the existing schemes have simultaneously focused all the following problems:

(i) Imparting immunity to the ANN against different conditions.
(ii) Performing both inter circuit and shunt under different conditions.
(iii) Inputs are only currents.
(iv) Accurate classification.

Considering demerits of existing approaches, a technique for locating inter circuit faults has been presented based on one end current using the ANN approach. In view of the above reported concerns, an effective inter circuit fault classification using the currents has been taken in the present research work.

The rest organization of this article is structured as follows: The first section is related work and problem statement, the second section explains about design of the in PIJTL, the third section mainly demonstrates the overall framework of the ANN, the fourth section gives the experimental study to verify the ANN and the last section is the conclusion part.

2. PARALLEL INCOMPLETE JOURNEY TRANSMISSION LINES

The PIJTL is composed of two single circuits of 400KV transmission lines and the line lengths of each circuit are not equal. Each circuit ends are connected to two substations S1 and S2 respectively, so each of 100 km length and 150 km length Here, substation of 220MW is connected through a 100 km circuit-1. Afterward the energy is transmitted via 150 km circuit-2 to grid. This exists two single-circuit lines and adopts partially the same tower structure. Figure 1 shows the PIJTL model simulated in MATLAB® 7.01 Simulink Software.

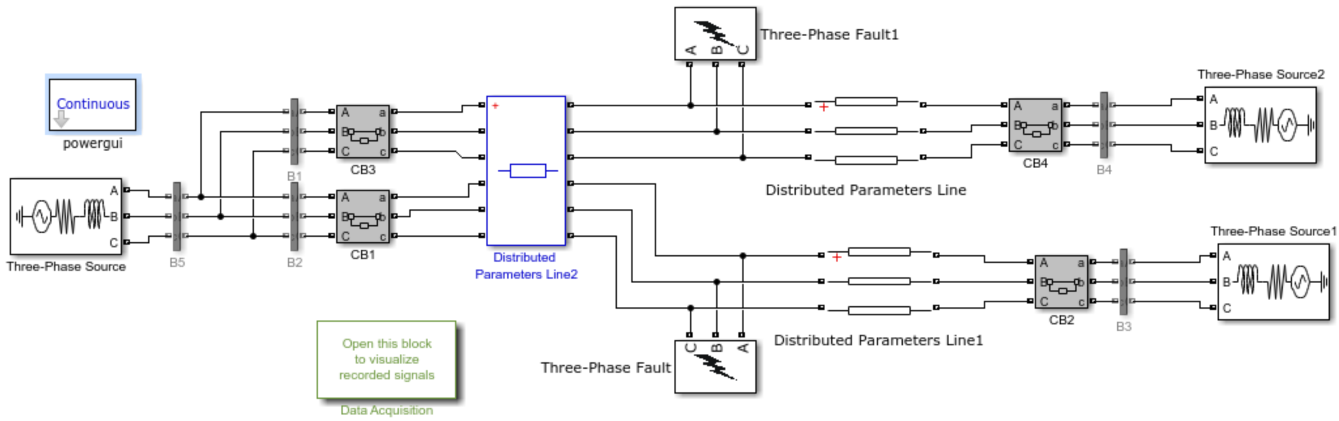

Figure 1. PIJTL model simulated in MATLAB® 7.01 simulink

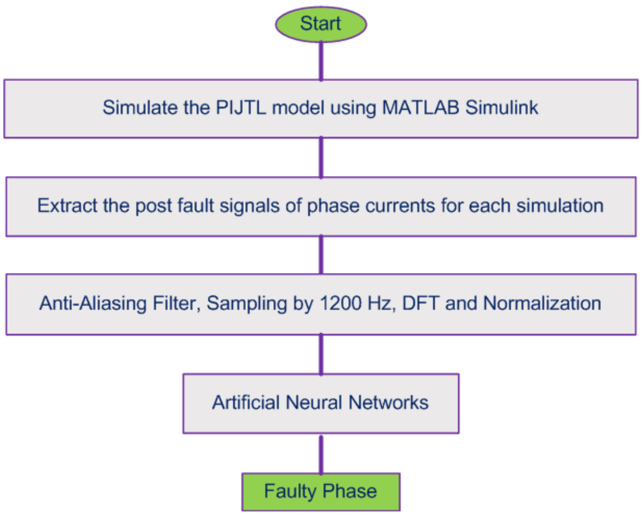

Figure 2. Flow diagram of work

Nominal Values of PIJTL parameters
Circuits in PIJTL-2
Phases in PIJTL-3
Circuit Lengths in PIJTL-100 km and 150 km
Frequency in PIJTL-50Hz
Source Voltage in PIJTL-400Kv

The two fault breakers are used to create inter circuit faults and varying the inception times and faulty resistances. The distributed line parameter block is selected to create PIJTL. The circuits are bifurcated into two parts to vary the faulty location. The incomplete-journey line partially adopts the same tower structure and exists two single-circuit lines. Therefore, the PIJTL cannot be considered as a two separate single-circuit lines or parallel circuit lines. The work flow of this article is depicted in Figure 2. Only one ANN is modeled for PIJTL total protection system. It explains simulation of PIJTL and normalization of current for ANN design.

3. ARTIFICIAL NEURAL NETWORKS

ANN is an important tool employed in the machine learning. It is brain inspired system, as “neural” portion of its name suggests, which objects to simulate way the people can learn. ANN consisting of input layer and output layer and a hidden layers of unit that converts the input into something which the output layers can employ. It is an excellent tool for detecting complex patterns. Recent years, it has become a main part of the artificial intelligence.

An artificial neural network is a nonlinear system, which is consisting of different computing units. It replicates the data storage, processing, and retrieval the neural system functions in the human's brain neural network. It is a type of abstraction, simplification and simulation of the human's brain neural system. Most of the works have seen the role of neural systems in machine translation, image recognition, medical diagnosis and speech recognition. The only difference between a traditional parameter model and ANN is that it does not require making any type of prior assumptions in the problem approaches. The resulting ANN structure is very simple, efficient and presents robust even for different conditions. Input matrix size pattern is given in Figure 3. In this, three inception angles (0, 90 and 180), eight fault resistances in ohms (8, 18, 28, 38, 48, 58, 68, 78), Leven fault locations in km (2, 12, 22, 32, 42, 52, 62, 72, 92, 102, 112) and ninety types of inter circuit faults. input matrix size pattern is 23760. A typical ANN is shown in Figure 4.

The ANN was coded in MATLAB software, using "trainlim" based on tansig activation function. Its training was conducted on an Intel i3-115G4 (3.00 GHz) CPU. In this experiment, the LM algorithm is selected to solve the fault location. For the LM algorithm, the learning constant was set to 0.001 and error is set to 0.5. The iterations were set to 50000 for the LM algorithm. Trial and error method neurons are varied. During the training procedure various numbers of hidden layers and their neurons were examined, but only 2 hidden layer and 23 neurons in first hidden layer and 21 in neurons in second hidden layer satisfactory results were obtained. Figure 5 gives the mean squared error (MSE) and loss curve of the ANN. As seen from Figure 5, MSE and loss values can rapidly decrease with increasing training steps, and in 38 epochs all finally in 38 epochs tends to 8.9225e-005, showing that the ANN has high stability, fast convergence speed, and high prediction precision. The ANN has a superior training procedure. Different hyper parameter combinations are chosen for comparison, and the test results obtained. Among them, the test case has the better accuracy under the hyper parameter combination of 23-21-6. The 23-21-6 refers to the layer output dimensions of the fully connected layer as 23, 21, and 6 in turn.

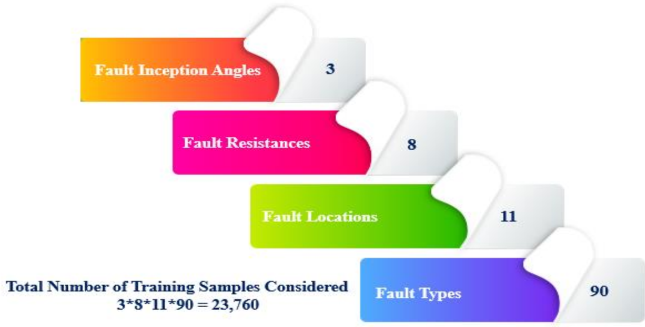

Figure 3. Training samples generation for ANN

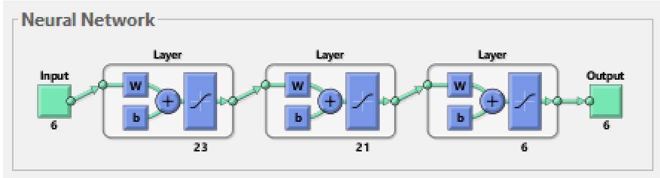

Figure 4. ANN structure

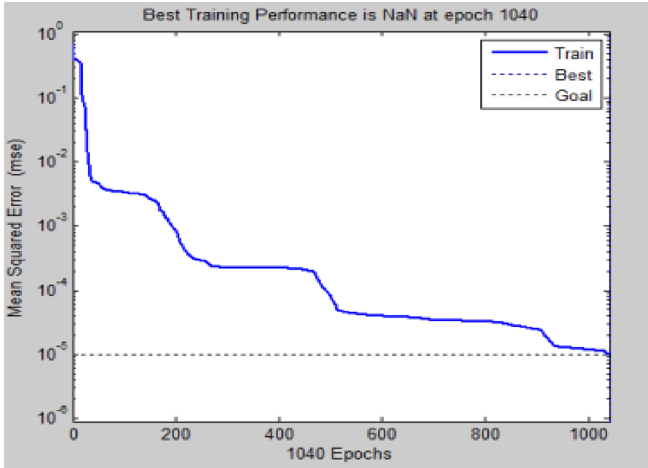

Figure 5. Training curve

4. PERFORMANCE EVALUATION

The effectiveness of the suggested ANN has been validated under diverse faulty operating conditions involving with change in fault parameters (fault location, inception angle and resistance) and no-fault scenario. The performance of ANN, dedicated to achieve the task of fault classification has been analyzed. The simulation results confirmed that the proposed ANN method works efficiently under several fault conditions.

It can be concluded that from Table 1 for fault classification has max accuracy for all tests. For inter circuit faults changing, length changing, inception changing and resistance changing overall accuracy is 99.3%, 99.1%, 99.4% and 99.15% respectively for all cases. For all test cases, the ANN is found to give the required response in minimum of time. The proficiency of ANN portrays detecting faults the significant situations.

The ANN fault identification scheme has these benefits:

1. Its fault accuracy above 99.91%.
2. The proposed method has sampling frequency of 1 kHz.
3. Its reach setting is 99.8%.
4. Need not to use communication channel.
5. It is easy, simple, reliable and robust.

Table 1. Testing results

Parameters	Faults	Lengths (km)	Inception (º)	Resistances (Ω)	A1	B1	C1	A2	B2	C2
Inter circuit faults changing	A1B2	62	20	15	1	0	0	0	1	0
	B1B2C2	62	20	15	0	1	0	0	1	1
	C1A2B2C2	62	20	15	0	0	1	1	1	1
	A1C2	62	20	15	1	0	0	0	0	1
	A1B1A2	62	20	15	1	1	0	1	0	0
	B1C1A2C2	62	20	15	0	1	1	1	0	1
	A1C1A2B2C2	62	20	15	1	0	1	1	1	1
	A1B1C1A2B2C2	62	20	15	1	1	1	1	1	1

	C1B2C2	13	40	25	0	0	1	0	1	1
	C1B2C2	27	40	25	0	0	1	0	1	1
	C1B2C2	35	40	25	0	0	1	0	1	1
	C1B2C2	57	40	25	0	0	1	0	1	1
Length is changing	C1B2C2	62	40	25	0	0	1	0	1	1
	C1B2C2	76	40	25	0	0	1	0	1	1
	C1B2C2	87	40	25	0	0	1	0	1	1
	C1B2C2	89	40	25	0	0	1	0	1	1
	C1B2C2	94	40	25	0	0	1	0	1	1
	B1C2	51	10	40	0	1	0	0	0	1
	B1C2	51	40	40	0	1	0	0	0	1
	B1C2	51	70	40	0	1	0	0	0	1
	B1C2	51	100	40	0	1	0	0	0	1
Inception is changing	B1C2	51	130	40	0	1	0	0	0	1
	B1C2	51	160	40	0	1	0	0	0	1
	B1C2	51	190	40	0	1	0	0	0	1
	B1C2	51	210	40	0	1	0	0	0	1
	B1C2	51	250	40	0	1	0	0	0	1
	B1C1A2B2C2	95	325	10	0	1	1	1	1	1
	B1C1A2B2C2	95	325	25	0	1	1	1	1	1
	B1C1A2B2C2	95	325	40	0	1	1	1	1	1
	B1C1A2B2C2	95	325	55	0	1	1	1	1	1
Resistance is changing	B1C1A2B2C2	95	325	70	0	1	1	1	1	1
	B1C1A2B2C2	95	325	85	0	1	1	1	1	1
	B1C1A2B2C2	95	325	105	0	1	1	1	1	1
	B1C1A2B2C2	95	325	110	0	1	1	1	1	1
	B1C1A2B2C2	95	325	115	0	1	1	1	1	1

5. CONCLUSIONS

This paper proposes a novel configuration of ANN to improve both location and classification in PIJTL effectively. The inputs are normalized with its pre-fault current values only. The ANN studied here taken the LM neural network architecture. The major aim of the ANN is that it classified the fault types (both inter circuit and shunt) accurately. The LM algorithm can detect in the presence of an inter circuit fault within one half power cycle. Next, the performance assessments are carried out by the comparing various metric which is accuracy. The solution has been examined showing that the ANN is beneficial in terms of location and classification in performance compared to the other schemes. Comparing all existing papers, ANN can be chosen over traditional techniques for built the modern transmission lines where the communication links are available. The system can determine if there is a fault or not, can classify the faults and detect the faulty location. In future we can design an ANN inter circuit fault locator for PIJTL and further fuzzy inter circuit fault locator for PIJTL.

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