REVIEW: DOUBLE CIRCUIT TRANSMISSION LINE PROTECTION TECHNIQUES

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ABSTRACT

Parallel transmission lines have been extensively utilized in modern power systems to enhance the reliability and security for the transmission of electrical energy. The different possible configurations of parallel lines combined with the effect of mutual coupling make their protection a challenging problem. This paper presents different types of protection and algorithms have been proposed in the past to overcome some of the performance related issues. In addition to the effect of mutual coupling, fault resistance and pre-fault loading consideration, as well as cross-country faults have to be considered in order to determine the protection response.

Keyword: - *Double circuit line, parallel line, line protection, ANN.*

1. INTRODUCTION

Double circuit transmission lines are being used more widespread as they increase the power transmission capacity and increase the reliability of the system. However, there is difficulty in classifying the fault types on such lines using conventional techniques, principally because a faulted phase(s) on one circuit has an effect on the phases of the healthy circuit due to mutual coupling between the two circuits. The positive and negative sequence coupling between the two feeders is usually less than 5–7 % and, hence, has negligible effect on protection. However the zero sequence coupling can be strong and its effect cannot be ignored. The mutual impedance can be as high as 50–70% of the self-impedance [5].

Thus mutual coupling particularly under earth faults, poses difficulties for conventional distance protection schemes. One principal cause is the presence of fault resistance which, depending upon the level of mutual coupling and/or source impedance, can cause the protection relay to either overreach or under-reach. The problem is compounded by the remote source in-feed to the faulted branch. Similarly, substantial errors in measurement can result from ignoring the capacitance influence especially for high resistance faults. The problem is compounded by the fact that this coupling is not constant in nature and is dependent upon a complex interplay amongst a number of variables. As a consequence, the coupled phase(s) on the healthy circuit may sometimes be wrongly diagnosed as being the faulted phase. It should be noted that the aforementioned problems are particularly endemic when there is earth fault in a fault. In this respect, the vast majority of faults (over 90%) are of the single phase earth type. The conventional classifiers based on logical comparison techniques or linear algorithms are not well suited for such circuits. Thus, it is vitally important to develop an alternative protection scheme, such as that based on the adaptive concept, for such systems. Very often, fault classification is part of an overall protection scheme. To a large extent, the majority of power system protection techniques are involved in defining the equipment states through identifying the pattern of the associated voltages and/or currents. This effectively means that the development of adaptive protection can be essentially treated as a problem of pattern recognition of the Artificial Neural Network. The conventional pattern recognition techniques find it difficult to map complex and highly nonlinear input–output patterns associated with faults on double-circuit lines due to the changing system conditions and many causes of faults,.

ANN is powerful in pattern recognition, classification and generalization. Consequently, various ANN-based algorithms have been investigated and implemented in power systems in recent years [1]. Neural Networks are useful for power system applications because they can be trained with off-line data.
The specialty of ANN based distance protection is that it does not explicitly use the impedance information as the basis of information rather it learns from the examples presented to it during training. ANNs possess excellent features such as generalization capability, noise immunity, robustness and fault tolerance. Therefore, the decision made by an ANN-based relay will not be seriously affected by variations in system parameters. ANN-based techniques have been used in power system protection and promising results are obtained as a basic relaying tool & as an alternative to existing schemes [2- 10].

2. DIFFERENT TECHNIQUES FOR DOUBLE CIRCUIT TRANSMISSION LINE PROTECTION

In some work described problems of fault diagnosis in complex multi-circuit transmission systems, in particular those arising due to mutual coupling between the two parallel circuits under different fault conditions; the problems are compounded by the fact that this mutual coupling is highly variable in nature. In this respect, artificial intelligence (AI) technique provides the ability to classify the faulted phase/phases by identifying different patterns of the associated voltages and currents. In this work [1], a Fuzzy ARTmap (Adaptive Resonance Theory) neural network is employed and is found to be well-suited for solving the complex fault classification problem under various system and fault conditions. Emphasis is placed on introducing the background of AI techniques as applied to the specific problem, followed by a description of the methodology adopted for training the Fuzzy ARTmap neural network, which is proving to be a very useful and powerful tool for power system engineers. Furthermore, this classification technique is compared with a Neural Network (NN) technique based on the error back-propagation (EBP) training algorithm, and it is shown that the former technique is better suited for solving the fault diagnosis problem in complex multi-circuit transmission systems.

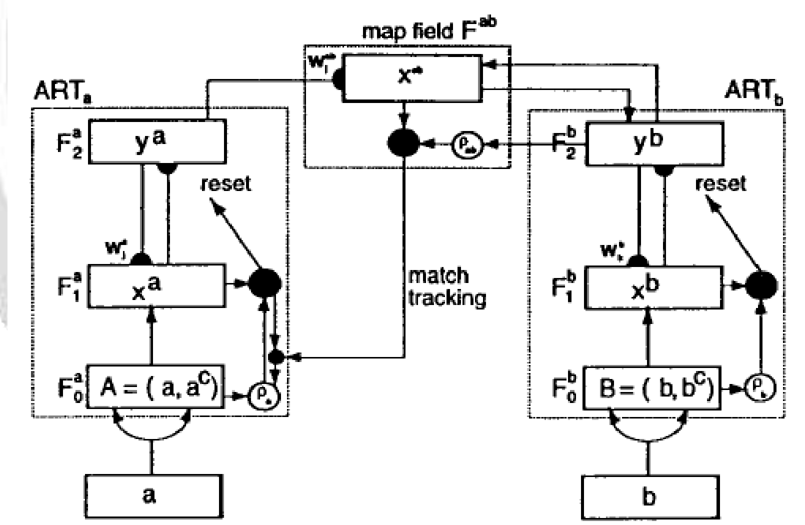

Fig.1:- A typical fuzzy ARTmap architecture [1].

The presence of series connected FACTS (flexiblc ac transmission system) devices like TCSC (thyristor controlled series capacitor), TCPST (thyristor controlled phase shifting transformer) and UPFC (unified power flow controller) etc. can drastically effect the performance of a distance relay in a two terminal system connected by a double-circuit transmission line. The control characteristics of the series connected FACTS devices, their locations on the transmission line, the fault resistance especially the higher ones make this problem more severe and complicated. The fault location with respect to the position of the FACTS devices also greatly influence the trip boundaries of the distance relay. For that problem, author presents apparent impedance calculations for relaying of double circuit transmission system [2] with varying parameters of the FACTS devices and location. The study reveals the adaptive nature of the protection scheme that necessities the use of an ANN based procedure for the generation of trip boundaries during fault conditions.

Parallel transmission lines often pose more difficult protection problems than single lines. In the case of parallel lines, a number of problems arise when using the distance protection. The author discusses problems associated with parallel line distance relaying schemes and presents a novel technique to overcome these problems. Two relays instead of four are proposed for the double lines [3]. One relay is located at the beginning and another one at the end. Each relay is fed by three voltage and six current signals from the two lines. The suggested technique is based on the comparison of the measured impedance of corresponding phases.
So, the complexity of the possible types of faults, high path fault resistance, mutual effects, current in-feed, inter-system faults are solved. Moreover, 100% of line is protected and the problem of balance-point locations is avoided. Alternative Transient Program models the power system and simulates different fault conditions.

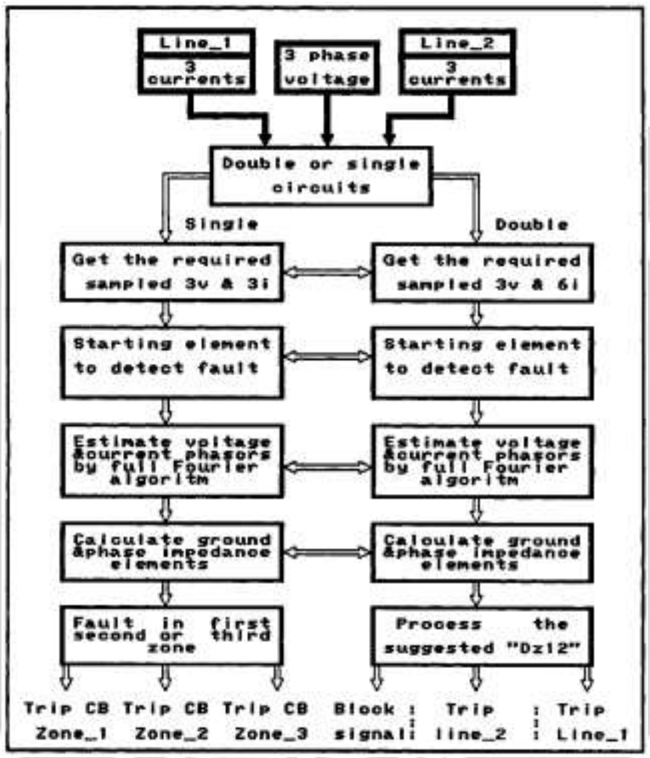

Fig. 2:- The main units used in the suggested technique [3].

The great development in computing power has allowed the implementation of artificial neural networks (ANNs) in the most diverse fields of technology. In one of article, author discuss how diverse ANN structures can be applied to the processes of fault classification and fault location in overhead two-terminal transmission lines, with single and double circuit [4]. The existence of a large group of valid ANN structures guarantees the applicability of ANNs in the fault classification and location processes. The selection of the best ANN structures for each process has been carried out by means of a software tool called SARENEUR.

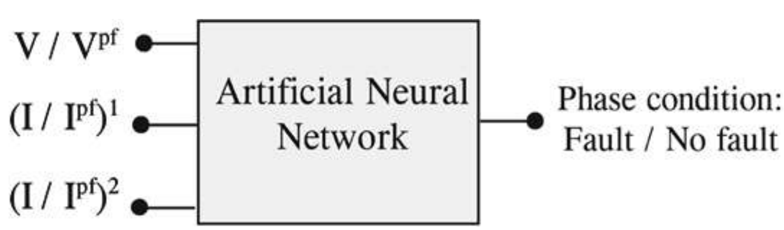

Fig 3:- Network structure for fault classification in double-circuit lines [4].

Convectional distance relay utilized for double circuit transmission line protection but due to mutual inductance effect cause problem in protection scheme. The problems arise principally as a result of the mutual coupling between the two circuits under different fault conditions; this mutual coupling is highly nonlinear in nature. An adaptive protection scheme is proposed for such lines based on application of artificial neural network (ANN). ANN has the ability to classify the nonlinear relationship between measured signals by identifying different patterns of the associated signals [5]. One of the key points of the present work is that only current signals measured at local end have been used to detect and classify the faults in the double circuit transmission line with double end infeed. The adaptive protection scheme is tested under a specific fault type, but varying fault location, fault resistance, fault inception angle and with remote end infeed. An improved performance is experienced once the neural network is trained adequately, which performs precisely when faced with different system parameters and conditions. The entire test results clearly show that the fault is detected and classified within a quarter cycle; thus the proposed adaptive protection technique is well suited for double circuit transmission line fault detection & classification.

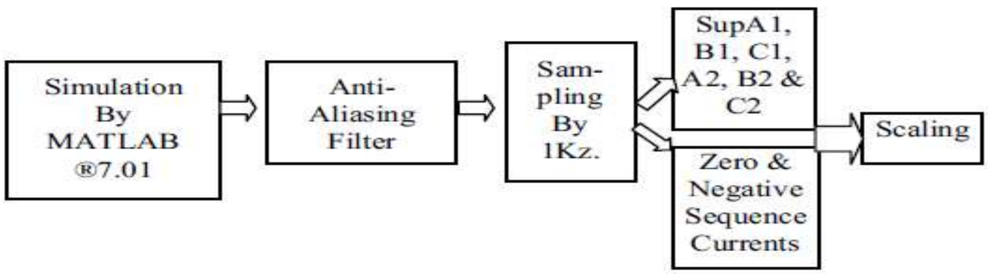

Fig.4:- training patterns generation process [5].

An accurate fault classification algorithm for double end fed parallel transmission lines based on application of artificial neural networks is presented by author [6]. The proposed method uses the voltage and current available at only the local end of line. This method is virtually independent of the effects of remote end in-feed and is insensitive to the variation of fault inception angle and fault location. The Simulation results show that phase-to-phase faults can be correctly detected, classified and located within one cycle after the inception of fault. The proposed scheme allows the protection engineers to increase the reach setting i.e. greater portion of line length can be protected as compared to conventional techniques. The technique neither requires a communication link to retrieve the remote end data nor zero sequence current compensation for healthy phases.

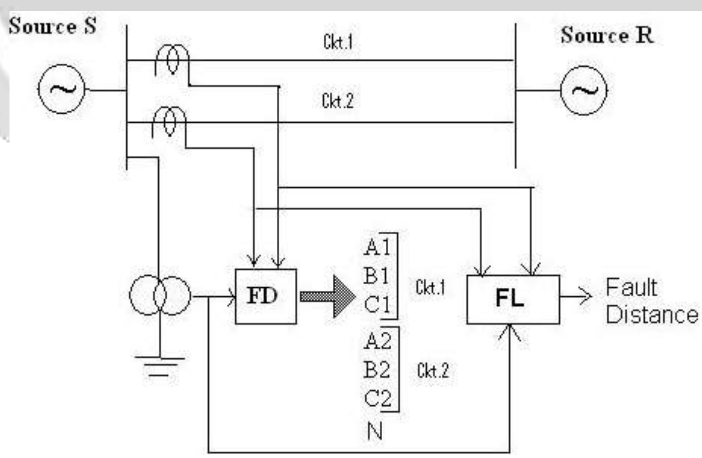

Fig.5:- Single line diagram of Power System under Study [6].

Distance relays used for protection of transmission lines have problems of under-reach, over-reach and mal-operation due to high impedance faults. Further the problem is compounded when the distance relays are used for protection of double circuit transmission lines due to effect of zero sequence mutual coupling. Different types of faults on a protected transmission line should be located correctly. Author presents a single neural network for fault distance location for all the ten types of faults (3 LG, 3 LLG, 3 LL, 1 LLL) in both the circuits of a double circuit transmission line fed from sources at both the end [7]. This technique uses only one end data and accurate fault distance location is achieved after one cycle from the inception of fault. The proposed Artificial Neural Network (ANN) based Fault Distance Locator uses fundamental components of three phase current signals of both the circuits & three phase voltage signals to learn the hidden relationship in the input patterns. An improved performance is obtained once the neural network is trained suitably, thus performing correctly when faced with different system parameters and conditions i.e. varying fault type, fault location, fault resistance, fault inception angle, presence of mutual coupling and remote source in-feed.

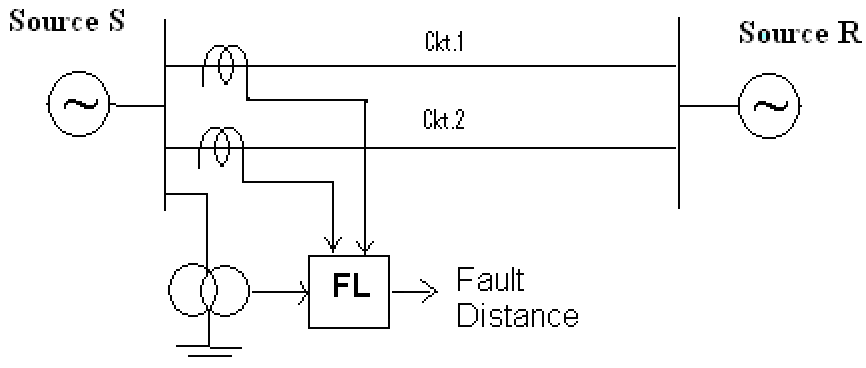

Fig.6:- Single line diagram of power system under study [7].

A new fault location algorithm for double-circuit transmission lines with availability of complete measurements from two anti-parallel end of the line is presented [8]. Sequence voltage and current phasors from these ends are taken as inputs and no synchronization between them is needed. Using the pre-fault data, the synchronization angles between measurements at the reference and the anti-parallel ends are obtained. Using the fault data, the faulted circuit is determined and the sequence voltages and currents at the fault point are calculated as a function of the fault distance. Finally, using the fault boundary conditions that exist for a given fault type, the fault location is derived and solved by an iterative method. Owing to zero-sequence mutual coupling, it is not straightforward to express the zero-sequence voltage and current at the fault point as a function of the zero-sequence voltages and currents at the two measuring ends and the distance to fault. To overcome this problem, a modal transformation matrix is introduced to obtain the modal networks, which are decoupled and can be analyzed independently. Based on distributed parameter line model, the proposed algorithm fully considers the effects of shunt capacitances and thus achieves superior locating accuracy, especially for long lines. Mutual coupling between circuits, source impedances and fault resistance do not influence the locating accuracy of the algorithm.

One of the author present a novel algorithm for locating faults on double-circuit transmission lines using two-end unsynchronized current measurements [9]. The algorithm does not require line parameters, which is a radical step forward compared to existing approaches, which require this information, so it can be considered as a settings-free algorithm. Only the positive-sequence current phasors during the fault are processed for determining the sought distance to fault and the synchronization angle, limiting thus the amount of data needed to be transferred from each line terminal. The proposed algorithm is derived by applying the Kirchhoff's voltage law around the parallel circuits loops during the fault. The algorithm is applicable for both transposed and un-transposed double-circuit lines and is independent of the fault type.

One of the methods proposed an artificial neural network-based protection scheme for double circuit transmission line with improved first zone reach setting up to 99% of line length [10]. The proposed scheme involves three stages. The first stage makes the discrimination among normal condition and faults. The second stage identifies the zone/section of the fault from the relay location. If a forward fault is detected in its first zone then the third stage is activated, which classifies the fault type and identifies the faulty phase. The three-phase currents and voltages measured at only one end of the double circuit line are used to calculate discreet Fourier coefficients. Thus, this technique does not require any communication link. The simulation results show that all types of shunt faults (forward as well as reverse), its zone/section and faulty phase can be correctly identified within a half cycle time. This method is adaptive to the variation of fault type, fault inception angle, fault location, fault resistance, single circuit operation and CT saturation. The main advantage of the proposed scheme is that it offers primary protection to total line length using single end data only and back up protection for the adjacent forward and reverse line section also.

3. CONCLUSION

The application of protection systems to double circuit lines requires careful consideration of fault scenarios under various network topology conditions. Complex analysis is required for phenomena such as mutual coupling, un-transposed lines and cross-country faults as it may have adverse effects on relay performance.

Line differential protection is obviously the first choice, since it provides instantaneous operation for faults anywhere on the protected line. However, it requires high-speed communications that are not always available. Unit protection schemes also do not provide remote backup which is typically required. That is why the effects of double circuit lines on non-communications based protection relays or systems are analyzed in the paper.

Distance protection performance is especially affected by the state of the parallel circuit and the mutual coupling. The application of adaptive protection principles is useful to improve the relay performance.

Back-up ground overcurrent relays are also affected under the zero sequence coupling conditions and the pick-up settings have to be calculated considering different operating conditions. Adaptive settings also provide advantages compared to fixed settings.

Various methodologies have been implemented in modern relays to assist the user in dealing with the uncertainties in double circuit applications. Advanced functions include mutual compensation, multiple setting group selection, high-performance communications based protection schemes and improved back-up protection functionality.

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