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# СОВРЕМЕННЫЕ АЛГОРИТМЫ ОПТИМИЗАЦИИ ОЦЕНКИ МЕСТОПОЛОЖЕНИЯ СБОЕВ В ЭНЕРГОСИСТЕМАХ

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# MODERN OPTIMIZATION ALGORITHMS FOR FAULT LOCATION ESTIMATION IN POWER SYSTEMS

**АННОТАЦИЯ.** В этом тексте представлен подход оценки местоположения сбоя в двух терминальных линиях передачи с использованием метода оптимизации на основе обучения (TLBO) и метода гармонического поиска (HS). Были обсуждены предыдущие методы, такие как генетический алгоритм (GA), искусственная «пчелиная колония» (ABC), искусственные нейронные сети (ANN) и Cause & Effect (C&E) с обсуждением преимуществ и недостатков всех методов. Моделирование было выполнено на SIMULINK путем извлечения исходных входов от SIMULINK до MATLAB, где целевая функция задает местоположение ошибки с очень высокой точностью и за очень короткое время. Обсуждаются будущие работы, показывающие преимущества использования Дифференциального обучения TLBO (DLTLBO)

**КЛЮЧЕВЫЕ СЛОВА:** робототехника, алгоритм оптимизации, автоматизация.

**ABSTRACT.** This text presents a fault location estimation approach in two terminal transmission lines using Teaching Learning Based Optimization (TLBO) technique, and Harmony Search (HS) technique. Previous methods were discussed such as Genetic Algorithm (GA), Artificial Bee Colony (ABC), Artificial neural networks (ANN) and Cause & Effect (C&E) with discussing advantages and disadvantages of all methods. Simulation of the model was performed on SIMULINK by extracting initial inputs from SIMULINK to MATLAB, where the objective function specifies the fault location with a very high accuracy, precision and within a very short time. Future works are discussed showing the benefit when using the Differential Learning TLBO (DLTLBO)

**KEY WORDS**: robotics, optimization algorithm, automation.

Nowadays, it becomes so critical and crucial to supply different customers by stable, sustainable, reliable and continuous electricity, which by return is enhancing the investment capabilities. Transmission lines are exposed to faults, which are caused by

many reasons such as storms, snow, insulation breakdown and short circuit for any reason. Specially, those transmission line faults are the reason for most of faults within the grid. So, special dedication should be applied to transmission line system protection and service reliability. The ability of maintenance crew to detect a fault location quickly will help them to clear the fault as fast as possible, and will not cause long duration of outages on the customer side. Different techniques discuss the calculations needed to find the exact fault location on transmission lines explained in which used travelling wave-based fault location for two and three terminal networks and it was concluded that the method is unaffected by noise or spurious changes in line because it used a time average integral function. It also achieved an error of 3.2%. Besides, a microprocessor fault locator is described which is used to improve accuracy. The main feature of the used method is that it considers the effect of remote-end infeed of the lines, while in an accurate method of series compensated transmission-line was proposed. This method takes the advantage of only half cycle of post fault currents and voltages. The results calculated errors were almost 0.5% which is not good and will affect the fault detection and will have a bad effect on the maintenance team ability to know the fault location along the line. Also, in impedance-based fault location method was discussed which proved to be simple and of low cost, while it is affected by several sources of errors and will have bad accuracy with different types of transmission lines and different models and is affected also by the line length which reduces the accuracy and mislead the maintenance team. It was shown that fault resistance, fault location, source impedance and the transmission line model can negatively affect the performance one terminal impedance-based method which will increase the cost of fault detection because more time will be needed to know the exact location. On the other hand, it was shown that if the source impedance is available because of techniques of adaptive protection, a fault location method free from current transformer errors can be developed, but this method depends on many parameters that will take more time to get to the exact location which affect the fault clearance process and will lead to more damage to equipment and ultimately will lead to more cost to fix that damaged equipment. This method is valid for un-transposed lines, not for transposed ones which

is a disadvantage as the lines will be affected by the mutual field between phases. It is proved that if redundant measurements are available, it's feasible to design an approach for the fault location detection. It was concluded that a two-terminal approach for fault location estimation using un-synchronized post-fault phasors, while a new accurate technique for locating faults was discussed and two-terminal line case has been considered. In a fault location approach using ‘‘phasor matching" is based on genetic algorithm, but it takes a long time which cause a problem in detecting the fault in a proper time and also cause a problem that can damage more equipment within the grid. While an accurate method is used for two terminal transmission lines based on time-domain distributed model, genetic algorithm was used in fault location; the method is based on digital measurement of short circuit current which can sometimes mislead and cause inaccuracy which lead to locating a wrong fault position along the line. The fault location method applies present Field Programmable Gate Array (FPGA) using Artificial Neural Networks (ANN) theory. This method was developed as generic as possible with the aim of using it to develop similar applications. While in some useful features extracted from Single-Line-to-Ground (SLG) using harmonic spectrum of one-end voltage. This method was conducted on the un-transposed transmission line. In another fault location method was discussed; this method takes loads into effect. This method also eliminated problems of conventional methods. As if the load behaves as constant impedance, fault location can be determined from the pre-fault data. While for a variable impedance load, the fault location requires prior knowledge of the load model which is not available all the time, and this causes inaccurate results and mislead the team and lead to a wrong location estimation. This method results are three fault locations for three fault types and then choose the most appropriate distance or distance. While in showed an expert system in fault section identification, it also showed that combination of numeric and data base algorithms is essential to many developments in expert system application for power systems. It concluded that expert system offers good promise for many applications in utility. While at this era, the use of expert system wasn't mature enough and may cause some issues and has cost associated activities. Those methods are different, especially in the below points:

Power system protection is designed originally to detect faults, and isolate only the faulted zones without disturbing the performance of other functioning zones. Some of other advanced methods investigated in recent decades use voltages and currents measured from both ends of transmission line. It utilizes measurements from local terminal only and illuminates the need for data transfer between both local and remote terminals, but unfortunately those methods have major drawback, as they are affected by fault resistance and source impedance. Other methods were used in utilizing measurements of both ends. Those methods are more accurate in locating the fault location due to the larger data amount available in those methods. Recently, more intelligent methods have been utilized in this aspect to detect fault location in transmission system where fault location is not achieved directly from equations linking currents and voltages. Also, optimization techniques such as Genetic Algorithm (GA) have joined recently this field of study adding more intelligence.

Genetic Algorithms are the heuristic search and optimization techniques that mimic the process of natural evolution. This introduces three main definitions within GA:

1) Selection: This process determines which solutions should be preserved and allowed to reproduce and which solutions deserve to decay. Select the best solutions and discard the rest.
2) Crossover: This is used to create new solutions from existing available solutions after applying selection operator.
3) Mutation: This is the occasional introduction of new features into the solution string to maintain diversity in the population.

It shows classes of search techniques, and allocate GA among those techniques. Recent researches proved that GA has many advantages. It doesn't need a continuous search space as it jumps from point to point in search space; this allows it to escape from the local optima in which other algorithms may fall. Another advantage is that GA deals with nonlinear function without linearization. This is to find the location of the fault by solving optimization problem defined based on objective function derived from the mathematical system representation. Artificial Bee Colony (ABC) is well

known for this methodology. An iterative method for fault location in transmission system that utilizes only post-fault measurements was proposed. This method was only valid for asymmetric faults and used short line model to locate the fault location.

Artificial Bee colony is an optimization technique that is based on the natural phenomena to reach an optimal solution. A metaheuristic technique based on swarm intelligence was mentioned. It has no centralized controller and self organizing techniques. In BCO, bees use Path Integration and use a direct path to come back to hive instead of back tracking their original route. Bee colony optimization algorithm is very efficient as it takes less number of steps when finding and collecting food. BCO algorithm requires less computation time to complete task so it is more scalable.

Also, one of the important techniques used to tackle this issue is Artificial neural network (ANN). ANNs can be considered as a black box performing a job of fault location; the simulation results obtained for this technique prove that satisfactory performance has been achieved by all of the proposed neural networks in general. As further illustrated, depending on the application of the neural network and the size of the training data set, the size of the ANN (the number of hidden layers and number of neurons per hidden layer) keeps varying. Some important conclusions that can be drawn from simulation are:

1) Neural Networks are indeed a reliable and attractive scheme.
2) Back Propagation neural networks are very efficient.

Another method was used before. It is Cause-Effect principle. This approach can deal with fault sections for single and multiple faults, even subject to malfunction devices. The proposed method has the following features:

1) Fast inference speed.
2) Concise knowledge representation.
3) Systematic inference procedures.
4) Feasible to utilities.

This method focuses on the causality between faults and actions of protective devices. Cause and effect relationships analysis gives fault diagnosis approach and the proposed method was of much benefit to the operators in analyzing fault situations and

as a double-check of operator's decision. Two other methods went into details in this area as explained, one of those methods was only valid for asymmetric faults while another one assumed that fault resistance is zero. This paper discusses the issue of fault location estimation in power system using modern optimization algorithms based on post-fault voltages and currents from both ends utilizing the modernized equipment that link both sides together, this enables a very fast and accurate fault clearance.

**Optimization techniques used**

In this paper, different optimization algorithms are discussed to get the exact fault location from the above-mentioned objective function. The most important factors for any method are the time taken to get the fault location and error % in fault location result. The error percentage in the calculated location (EFL) and error in calculating line parameters (Ep) can be achieved by equations

Genetic Algorithms are the heuristic search and optimization techniques that mimic the process of natural evolution. This introduces three main definitions within GA. To get the optimum solution using the GA it takes up to 10 min if settings were used. While if we are going to use the Newton optimization technique, it takes up to 22 h to get the optimum solution for the same computer used for GA. This can reduce time needed for the Newton method to be almost 22 min, which is still more than time needed for the GA. The harmony search algorithm was originally proposed and it was applied to solve optimization problems. When musicians compose harmony, they try many possible combinations of music pitches from their memory to find the best harmony. This was inspired from explicit principles of the harmony improvisation. A modified HS method is used to handle non-convex economic load dispatch in power system. TLBO algorithm is a population based algorithm inspired from the learning process in a class room. It consists of two phases, a teacher phase and a learner phase. In the teacher phase, learners get knowledge from a teacher and from classmates in the learner phase. In this phase, the best solution is the teacher solution, and the teacher tries to enhance the results of learners by increasing mean results towards the teacher result. In the second phase, the learner tries to increase their information by interacting with other learners. So, individuals learn new knowledge if others have more

knowledge than him. If the new solution is better, it will be accepted. The algorithm continues till the termination condition is met.

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