OPTIMIZED NEURAL NETWORK RELAYING FOR EFFICIENT POWER TRANSFORMER PROTECTION

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ABSTRACT: *One of the most important devices in a power system is a Power transformer. However, the main issues in power transformers are stability and dependability. The automation system's transformer relaying protection is very important for operating transformers safely. So, it is imperative that continuity in the operation of transformers is required to ensure dependability of power. Any repair work that is not as per schedule more so in cases of faulty transformers being replaced it becomes time and money consuming. A milestone in the development of Fourier transform which is the Wavelet Transform (WT) has now gained a lot of popularity and is being successfully applied in the various fields. In solving engineering modeling problems, the Neural Network method (NN) is being successfully applied. When searching for parameters in any function for citing an optimal solution such a search is known as optimization in which all possible values and solutions are considered among which the one with the extreme value is accepted as the optimal solution. Firefly Algorithm (FA) is considered very effective and is producing good optimal solutions. In this work, the FA is duly hybridized along with hill climbing algorithm for improving the efficiency of NN for improved power transformed protection.*

KEY WORDS: *POWER TRANSFORMERS, WAVELET TRANSFORM (WT), NEURAL NETWORK (NN), FIREFLY ALGORITHM (FA) AND HILL CLIMBING.*

1. INTRODUCTION

Medium power transformers as well as large ones are very critical components of the power systems. Owing to its cost and need it has to be protected properly in a quick and reliable manner. Properly executed continuous checking and monitoring can evade major losses by giving an early warning of any failure thereby minimizing damages and enhancing reliability. Therefore, there are very high expectations placed on the power transformers and protective relays. These include reliability, speed of operation, security and above all stability. A principle known as referential relaying is made used of for protecting both large and medium power transformers. [1].

As power transformers are considered very important, the reliability and quickness of protection is needed to ensure the power system can be operated in the best possible manner. The protection scheme should be well suited, safe when tripping commands are made and have fast methods of fault clearing. Differential protection has been the main method for its protection for many years now. This should issue quick and efficient tripping commands in cases of internal faults and not issue them in cases of external faults as well as any magnetizing inrush conditions of crush and over-excitation.

Recently owing to the developments made in ANN or Artificial Neural Network and Wavelet analysis, the application the power transformer's protection is also becoming important. A developed ANN can increase the scope for the waveform identification approach. The ANN approach is much faster, and also easier and robust in its implementation than any of the conventional approaches. This is being used effectively in the power systems since the early nineties owing to its excellent ability of generalization and stability of learning in various topologies.

WT or the Wavelet Transform is a new and successful tool employed in analyzing the transient phenomena in various power systems. It can pull out information from the transient signals in domains of both time as well as frequency. WT can focus on short term intervals and also high frequency components and also optimize long intervals for frequency components that are low by employing oscillations and impulses that are localized. Therefore, wavelet decomposition is considered perfect for the study of transient signals and for procuring better characterization and dependability in the technique of discrimination [2]. WT was introduced instead of Fourier analysis and has been successfully getting interest in various fields such as voice communications, acoustics and seismic. This has also proved to be an effective mathematical tool for the analysis of signals and can be employed in a

varied range of applications like data compression wave propagation signal processing and pattern and speech recognition. Recently WT has also been used in detection of faults in the power system equipment that employ wavelet transforms which has the special feature of being able to translate the representation of time amplitude of any signal the representation of time frequency which is encapsulated as wavelet coefficients set..

Optimization [3] has been a functioning region of research for a very long while. Since most of the genuine optimization issues turns out to be more mind boggling, better streamlining calculations were required. In all optimization issues the objective is to locate the base or most extreme of the goal work. Throughout the most recent years, several numerical optimization systems have been utilized to enhance the effectiveness of the back propagation calculation including the conjugate gradient descent. On the other hand, one constraint of this method, which is a gradient-descent method, is that it needs a differentiable neuron exchange work. Additionally, as neural systems produce difficult blunder surfaces with numerous neighborhood minima, the BPNN fall into nearby minima rather than a global minimum. Evolutionary computation is frequently used to prepare the weights and parameters of neural systems. Lately, numerous enhanced learning algorithms have been projected to conquer the shortcoming of gradient-based procedures. These calculations incorporate global search method, for example, artificial bee colony algorithm, Particle Swarm Optimization (PSO), Differential Evolution (DE), ant colony back propagation algorithm, Genetic Algorithms (GA) and Cuckoo search (CS), Firefly (FF) Algorithm, etc., FA which is the Firefly Algorithm is an intelligence meta heuristic method which is newly being used for solving problems or optimization where the algorithm for search gets its inspiration from the behavior of fireflies and the bioluminescent communication phenomenon. The two important issues in FA [4] are the attractiveness formulation and light intensity modification. This algorithm makes an imitation of the behavioral pattern of the fireflies that fly in the summer sky in tropical regions. They communicate with each other, hunt for prey and also attract other fireflies of the opposite sex by means of bioluminescence and flashing methods. Different meta-heuristic algorithms can be successfully designed by imitating nature. [5]. The joining behavior and execution of the projected ANN training utilizing FA is investigated. Another local search method is hill-climbing which is used for the purpose of optimization. On comparing the values of the fitness function that exists between the current node and the neighbors a node which is superior than the current node can be identified.

In this work, firefly algorithm can be hybridized by means of a local search algorithm like the hill climbing method in order to derive an effective protection transformed by power. The literatures that relate to this work are enumerated in Section 2, the details of techniques employed in Section 3, the results obtained in Section 4 and finally the conclusion in Section 5.

2. RELATED WORKS

An examination of the outcome of renewable energy usage in generation of power with the energy system that is classical and the one which is managed by a method of intelligence for the minimization of cost and reduction of the emission of gas was done by Younes [6] The results of simulation on a given 10 units of the power system was able to prove that the efficiency of this method was able to confirm that it had the ability to solve the problem, of economic power dispatch in renewable energy.

A presentation by Özgönenel [7] was made for the development of another algorithm that was wavelet based which helped in differentiating the magnetizing inrush currents and the currents due to power system faults which was fast, dependable, sufficient and an efficient tool. This technique included a preprocessing unit which was based on DWT or Discrete Wavelet Transform which was combined with ANN for identifying and grouping all fault currents. The DWT worked in extracting any distinctive features in the signals of input in relay locations. The information was further fed into the ANN for the purpose of classification the fault and inrush condition magnetization. A laboratory transformer of 220/55/55 V, 50Hz is then connected to a power system of 380 V and simulated by using ATP-EMTP. The DWT is then implemented by means of Coiflet and Matlab mother wavelet for analyzing primary currents and for generating data for training. The results from simulation was then presented to prove that this proposed technique can differentiate between fault currents and magnetizing inrush in protection of transformer.

Another network known as Probabilistic Neural Network of PNN was identified by Tripathy et al [1] which was a core classifier for the discrimination between the internal fault of power transformers and the magnetizing inrush. In order to get an optimal smoothing factor for the PNN which is a very important parameter, the particle swarm optimization is utilized. Another algorithm from the conventional differential protection theme for the transformer was developed. This used the voltage to frequency ratio

and the differential current amplitude for finding out the condition of operation of the transformer. The heteroscedastic type PNN and its performance in comparison with the conventional one was investigated for neural network, Feed Forward Back Propagation which is FFBP and conventional harmonic method of restraint. For the purpose of evaluation of the algorithm that is developed various operating methods, their relaying signals, their internal and external faults are all taken by using modeling of the transformer in PSCAD/EMTDC and further implemented by using MATLAB

Another proposal by Liu et al [7] which proposed two accurate and fast digital Maximum Power Point Tracking (MPPT) methods for environments that were fast changing. Piecewise line segments were used for approximating the Maximum Power Point (MPP) locus and in certain cases high-speed, low-complexity MPPT techniques are developed. To make the PGS users, and Neural Network (NN)-based program easier some parameters of emulated MPP locus can be developed and later embedded into the system. The detailed procedure for design and the theoretical derivation are provided in this. This system has the advantage of high tracking speed, dynamic and static tracking efficiency and low requirement for computation. For the purpose of accuracy and efficiency validation of these methods results of experimenting with a 230 W PV system and simulation will also be given.

Kurukshetra [8] implementation which was one of replacing operator in hill climbing empirically analyzes the rate of convergence of the hybrid algorithm with the use of algorithms that are simple and genetic. Both these find an optimal solution by using the complementary property of exploitation. A good performance of memetic algorithm is used to find an optimal result for difficult problems. This is in turn affected by the size of the population and the number of children generated. This work also makes an analysis of the rate of convergence of the memetic algorithm on De jong's function.

3. METHODOLOGY

The ANN method, FA-ANN, wavelet based ANN and hybrid FA-hill climbing methods are all elaborately explained in this work.

3.1 Artificial neural network (ANN):

Neural network is trained for the performance of various complex functions in different fields including identification of pattern, classification, vision, speech and control systems. Back propagation is normally used for this purpose. This tries to minimize mistakes by making adjustments for every value network which is in proportion to the error of that value which is derived which is called gradient descent. In learning of back propagation, the target values or error signals in comparison with actuals are compared layer by layer by updating accordingly the synaptic weights.

In the construction of ANN the choosing of the hidden layers and the neurons for every layer is the most critical of all problems. Usage of very few neurons in the layer that is hidden can prevent the process of training from converging when many neurons are used it can delay the training time and the generalization attribute may be lost. Many tests were done which were different hidden layers and also the different number of neurons in every hidden layer with complete connections between the neurons. The hidden layer that has two neurons was considered sufficient for the classification of eight outputs.

ANN can also be understood as a processing system that contains a huge number of widely connected but simple elements known as neurons. Today in ANN's use the unique paradigm is the multilayer perceptron architecture. The training of the networks take place with the data set that used back propagation algorithm to enable the capture of non-linear mapping that exists between the variables that are the input and the output quantities. At the time of training the weights of the network are adjusted according to the learning rule of back-propagation. In order to make a valuation of the efficiency of the training network, a training goal of mean square error is brought in. If the mean square error is small, it is an indication that the network is performing effectively and accurately [9]. This training of network includes the adjustment of the connection weights and also the correct mapping of the set vectors of the training without much error. The network duly learns what the training set teaches. The efficiency of the training set and the training algorithm makes it possible for an accurate estimate of the output be made even in cases where the inputs do not belong to the training set. This concept is known as generalization.

Therefore, if the neural network is applied to the problem of cognition it identifies two phases which are the training and the testing phase. At the time of the training phase an adaptation of network weights is made for the reflection of the domain of the problem and at the time of testing phase the weights are frozen and the presentation of data is completed with the prediction of the right output by the test data.

3.2 Firefly based ANN:

Based on the communication behavior of fireflies of tropical locations is the Firefly Algorithm or FA. This studies the tropical fireflies and their flashing patterns and their behaviors, by using three idealized rules for building the algorithm's mathematical model:

The fireflies get attracted to one and another irrespective of their sex as they are all unisex;

Attractiveness of the fireflies proportional to their brightness. So the less bright firefly will move towards the brighter firefly when flashing and attractiveness decreases if the distance between them increases;

The objective function's landscape determines the brightness of each firefly. (Therefore, in case of a problem of maximization the illumination of the firefly is relative to the objective function's value.)

Firefly algorithm with ANN with the Firefly algorithm made a proposal of multi-layered perceptrons which are Artificial Neural Networks. In this the multi-layered neural network consists of large volumes of neuron units that are linked among themselves in a connection pattern that are normally divided into three distinct classes:

Input units (that receive information that has to be processed)

Output units (which includes the results of the processing)

Hidden-units (that are between the input units and output units)

Feed-forward ANNs enables One-way transmission of signals which is from the input to the output is enabled by Feed Forward ANNs. First the network training is based on a combination of the data for mapping the input and the output. The weights given the association between the neurons and then arranged and then used for the identification of classification of the newly identified sets of data.

Entirely through this process of classifying time series the input unit signals are distributed through the net for establishing the initial values at every output unit. All inputs have initial values that indicate some external feature that belongs to the net. After this, every unit of input makes a transmission of its initial value and then signals are duly sent to the hidden units that are associated.

Computation of its own initial value is done by all the hidden units and then signals are sent to the respective output units. Each receiving unit's initial value is also computed according to the function of simple activation and the contributions of the sending units are chunked by the function and the weight of the connection that exists between the receiving and sending unit is identified multiplied using the sending unit's initial value. [11]. Normally this value is then Furthermore a customization of this value is done by the modification of the initial sum to any value between 0 and 1 and also by the establishment of the initial value of this unit to 0 till such time a threshold level of this sum is obtained.

The ANN relies upon There are three basic aspects upon which ANN relies, which is the input and the functions of activation of the unit, the architecture of the network and the input connection's weight. If two of the first aspects are set the ANN's performance can be characterized by the value of the present samples.

A training of the weights belonging to the net is fixed originally to any arbitrary value and is revealed to the net. The input sample's value is entered and then compared to that of the preferred sample of output of every sample. After this the weights in the net are modified marginally for providing the net's output values that are close enough to the preferred value's output.

There are many multi-layered perceptrons algorithms that are available, for the purpose of training networks. The light intensity of all fireflies are calculated and the best candidate which is the most attractive firefly is identified. After this the attractiveness as well as the distance for each firefly for moving towards the other in the search space is measured. Lastly the most attractive firefly makes random movement within the search space. A repetition of this process takes place until a maximum number of generations is achieved.

To take in the ideal values of parameters or weights of the system that best suitable with the preparation information is an optimization issue. Along these lines, to enhance the parameters of a framework, firefly algorithm is used to limit the blunder or fitness function.

In Firefly Algorithm, every firefly is relates to an answer in search space and it travels approaching more illumination. Accordingly, from algorithmic perspective we can state that for a minimization issue, the intensity of light is basically inversely proportional to the value of the fitness function or squared error. Presently the pseudo code of the Firefly neural system can be given.

1. Objective function f(x)=E (Squared Error)
2. Create preliminary population of fireflies positions xi=[wi] (for i = 1, 2, ..., n) by means of proper range
3. Light intensity LIi at xi= 1/f(xi)
4. Describe light absorption coefficient
5. while (t <MaxGeneration)
6. for i = 1 : n all n fireflies
7. for j = 1 : i all n fireflies
8. if (LIj >L Ii), Shift firefly i close to j in d-dimension
9. end if
10. Attractiveness changes with respect to distance r via exp[– γr]
11. Calculate new solutions by changing the value of = [wi] by altering alpha with delta and renew equivalent light intensity
12. end for j
13. end for i
14. Grade the fireflies and discover the

Neural network has drawback such as it include its "black box" nature, greater computational burden, proneness to over fitting, and the empirical nature of model development.

3.3 Hill Climbing:

Hill climbing is one of the most widely used fields of artificial intelligence in achieving goals from starting nodes. It is normally used in the availability of good heuristic functions and in the absence of other useful knowledge. It can often beget much better results than the other algorithms especially when the case involves limited time for the search performance as in most real-time systems.

A problem of optimization is usually capable of being modelled as a search problem as searching for optimal solutions within the solution space may be quite challenging. With the assumption that the optimization problems that are proposed belong to the maximization category and without incurring any loss in its generality, this can be the search technique of hill climbing:

- Starting is done with the starting point or the initial solution and the current point is set in it.
- A move to the next solution known as the move of operation is made.
- Such a move being good, a new point at the current point is duly sent and (2) is repeated. In case it is a bad move the operation is terminated. The optimum solution is nothing but the final current solution. [12].

3.4 Firefly with Hill Climbing:

The main motivation for the hybridization of different algorithmic concepts has been to obtain better performing systems that combine advantages of the individual algorithm strategies. Hybrid FA usually includes FA in combination with a local search for solving general problems or a heuristic search for problem dependent solutions. On evaluation of the fitness of fireflies, FA makes use of Hill Climbing results based on a corresponding initial guess where running which is in parallel as the fireflies are with the population.

Algorithm 1 Pseudo-code for the standard FA algorithm

Objective function $f(x), x = (x_1, \cdots, x_D)^T$
Initialize a population of fireflies x_i $(i = 1, 2, \cdots n)$
Compute the light intensity I_i at x_i by $f(x_i)$
Describe light absorption coefficient γ
While (t < MaxGeneration)
for i = 1:n all n fireflies
for j = 1:n all n fireflies
Compute the distance r between x_i and x_j by means of Cartesian distance equation
if $(I_j > I_i)$
Attractiveness changes with respect to distance r via $\beta_0 e^{-\gamma r^2}$
Shift firefly i close to j in all d dimensions
end if
Estimate new solutions and renew light intensity
end for j
end for i

Algorithm 2 – Local Hill Climbing algorithm

```
Begin    currentNode = startNode;
     loop do
     L = NEIGHBORS(currentNode);
     nextEval = 0;
     nextNode = NULL;
     for all x in L
     if (EVAL(x) < nextEval)
     nextNode = x;
     nextEval = EVAL(x);
     if nextEval >= EVAL(currentNode)
//Restore present node as no better neighbors be present
     return currentNode;
     currentNode = nextNode;
     End
```

A random solution is arrived at by the initiation of the population and the intensity of the light of the fireflies. They are then ranked according to their best solutions and when new solutions are arrived at for the intensity of light they are updated accordingly. The best among them are selected on the basis of the hill climbing algorithm.

4. RESULTS AND DISCUSSION

Figure 1 and 2 shows the Fitness and Mean Squared Error of FF-ANN and FA-HC-ANN respectively.

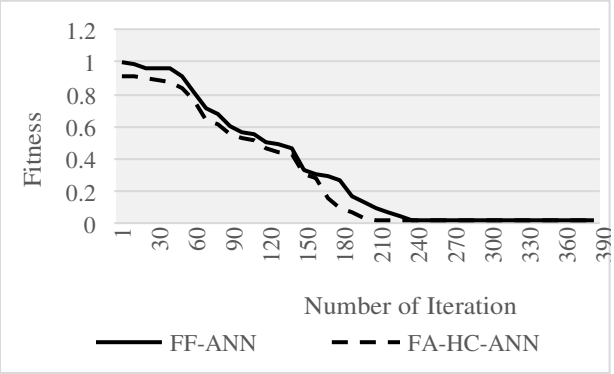

Figure 1 Fitness of Proposed FA-HC-ANN

It is observed from figure 1 that the fitness of proposed FA-HC-ANN performs better than FF-ANN. Convergence occurred for FA-HC-ANN at iteration number 230 where for FF-ANN it occurs at iteration number 240.

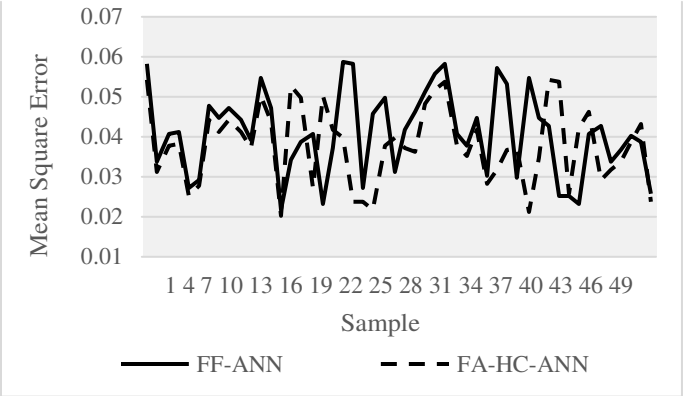

Figure 2 Mean Squared Error of Proposed FA-HC-ANN

It is observed from figure 2 that the Mean Squared Error of Proposed FA-HC-ANN reduced error and performs better by 7.3% than FF-ANN.

5. CONCLUSION

Various devices for protection are used to keep the power equipment and the lines of transmission safe from damages and overloads. So quick switch off of short circuits and faults with earth has to be done and endangered parts have to be isolated. This is very critical in maintaining the power system's stability. The principle of hill-climbing is rightly considered faster than the stochastic optimization as well as the many combinatorial problems of optimization especially when it involves a simplification of the reality of the actual problem of the function that has to be optimized. Here the hybrid firefly algorithm when working with hill climbing local search algorithm has been proposed obtaining a power transformed protection that is both efficient and effective. Results show that the Mean Squared Error of Proposed FA-HC-ANN reduced error and performs better by 7.3% than FF-ANN. Also the fitness of proposed FA-HC-ANN performs better than FF-ANN. Convergence occurred for FA-HC-ANN at iteration number 230 where for FF-ANN it occurs at iteration number 240.

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