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Fire-Fly Algorithm Based ANN Classification of Power Transformer Faults

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Abstract*: Monitoring and estimating the states of the transformer during faulted phase condition is essential to continuity of supply. Varied techniques are proposed for faulted phase detection to improve condition assessment. In this paper, we propose a novel method to detect and classify power transformer faults using wavelet transform Multi Resolution Analysis (MRA) as feature extracted parameter vector and Fire-Fly Algorithm (FFA) based Artificial Neural network training as classification method. The observed Dissolved Gas Analysis (DGA) waveform data is analyzed with wavelet transforms (WT) to identify abnormalities which is supported by MRA. In MRA, the current, voltage and temperature of winding and oil are decomposed into high and low frequency components. The magnitude of components, signifies the feature vector, gives a detection criteria. After detecting feature vector, dominant coefficients of WT can be used to train the ANN with FFA based learning algorithm. Different types of faults are created on transformer such as Single Line-Ground (SLG), Line-Line (LL), Double Line-Ground LLG, Three phase fault (LLLG) for the analysis using WT and ANN. The detection and classification of the fault signal are executed and examined in different winding location and different fault conditions. Finally, the presented precise model recognizes the faults based on performance metrics with high classification accuracy for various classes.

Keywords: **Artificial Neural networks, Dissolved Gas Analysis, Fire-Fly Algorithm, Multi resolution Analysis.**

I. INTRODUCTION

Power Transformers are most significant and expensive equipment in a power system, which require consistent solutions for their safety to guarantee smooth process. If a power transformer undergoes a fault, it is required to take the transformer out of work as quickly as possible in order to prevent the damage minimization. The expenditure related to recovery of a deteriorated transformer may be very large, which leads to heavy burden on electric utilities economically [1].

The traditional diagnostic based methods are supposed to be influenced by transformer operating conditions and they are time consuming. Hence faulted phase identification is difficult through traditional approaches [2].

Wavelet analysis is an efficient signal processing tool for the recognition and analysis of faults in power transformer. Wavelets have been proposed in the technical literature in various fields of power systems, using the continuous wavelet transform (CWT), the discrete wavelet transform (DWT) and the wavelet packet transform (WPT). The choice of the mother wavelet function is one of the crucial process in the utilization of wavelets [3]. The Daubechies family is one of the mainly used wavelet transforms for feature extraction in the detection and analysis of faults [4-5]. The wavelet coefficients represent the feature vector, which is used as input to neural network.

The artificial neural networks (ANNs) present exceptionally attractive and helpful alternative solution to faulted phase classification because they can handle the majority by change in the system operating conditions. ANN is robust with parallel data processing tools, high computation rates and adaptive capability. With these characteristics it yields better accuracy by minimizing the error based on training including incorrect or missing data. In ANN training the coefficients(after optimization) corresponding to a fault is given as input matrix and by initializing the weighting coefficients with appropriate bias the ANN is trained algorithm is used till the target output is reached.

FFA has been incorporated with a variety of data driven modeling approaches such as neural networks, support vector machines to prove a noticeable development in model performances through training [9].

The objective of the present research is to investigate the potential of artificial neural network models together with firefly optimizer algorithm for modeling with MRA of wavelet transform. The FFA optimization technique is utilized for generating the optimal training dataset for training the ANN. In the Proposed model, FFA acts as a add-in Optimization tool in-order frame a precise model that recognizes the faults based on performance metrics. The obtained precise model performance is superior to various models based on applicability of ANN, Fuzzy Logic system and ANFIS with MRA of wavelet transform [6-8]. The rest of the paper is divided in to the following sections. Section II & III describes the proposed classification model and Wavelet analysis respectively. Section IV & V illustrates the Firefly algorithm and FFA Learning based neural network model. Finally Sections VI & VII gives case study of a power system, Results and conclusions respectively.

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II. PROPOSED CLASSIFICATION METHODOLOGY

The proposed power transformer fault detection and classification process is described in Fig. 1. The FFA optimization technique is utilized for generating the optimal training dataset for training the ANN. Finally the classification process is carried out with the help of ANN of the proposed power transformer signal.

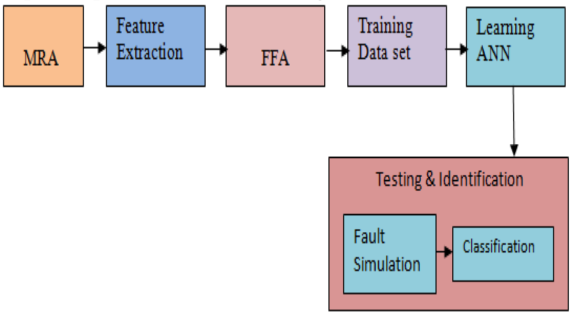

Fig. 1 The proposed classification methodology.

III. WAVELET ANALYSIS

Failure of Transformer can cause improper operation and control of power system. Even though DGA is better option of condition monitoring, it is basically offline method. Therefore GPRS is used to receive the currents, voltages and temperature of transformer which is at remote end .The information which can be drawn at the end of DGA can be drawn by using one of the signal processing tools such as Wavelet Transforms and is given to Personal Computer and the data is represented in the form of a signal in time domain

When the signal is analyzed by Wavelet Transform the abnormalities in the signal are identified as the Wavelet Transform supports Multi Resolution Analysis (MRA). In MRA, the current, voltage and temperature of winding and oil is decomposed into high and low frequency components in such a way that the wavelet transform is realized as successive low pass filter and high pass filter which is shown in Fig. 2.During MRA, by adjusting the scale factor different resolutions of the signal is obtained interms of approximate and detailed coefficients. The magnitude of the coefficients signifies the identification of fault.

The wavelet coefficients signify the data of a signal in the different frequency bands. The peak magnitude, the square magnitude, the mean value, the standard deviation, the energy distribution pattern or the entropy of coefficients are distinctive features for the detection and analysis in power transformer at the different resolution levels.

The steps of multi-wavelets are shown in Fig. 3. The steps are as follows

i. Pre-processing method is done to transform the one input signal into two subsequent signals
ii. The two subsequent signals are decomposed into two spectral components; each consists of approximation coefficients and several detail coefficients in different scales.
iii. The decomposed signals are separated into different sub-bands.
iv. The fault features are finally extracted for accurate fault diagnosis.As an illustration, the signal S that is temperature of winding and oil obtained through GPRS can be decomposed by considering the Daubechies wavelet as mother wavelet. As wavelet supports MRA, resolution of the signal is obtained interms of approximate and detail coefficients.

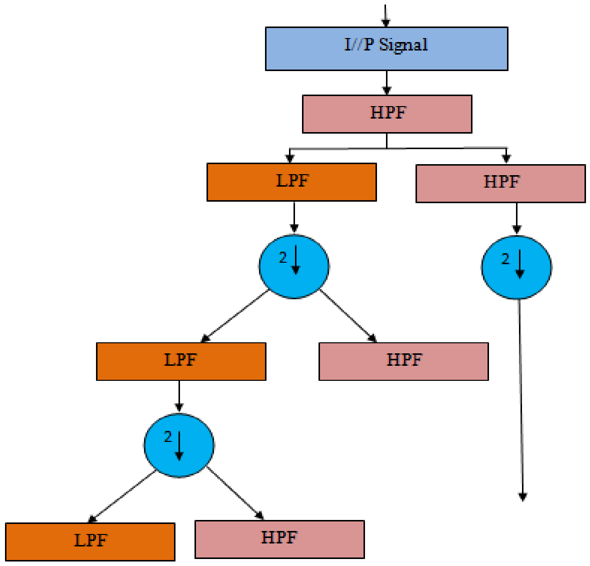

Fig. 2 Multi Resolution Analysis of Wavelet

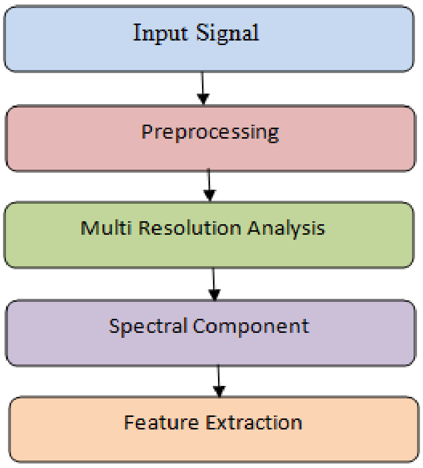

Fig. 3 The Implementation Steps for Multi-Wavelets

The detail and approximate coefficients after MRA is given in Table 1 and Table 2 refer to detailed and approximate coefficients of temperature of oil after using Daubechies wavelet. Similarly such type of data has been evaluated for I_R, I_Y, I_B, V_{RY}, V_{YB} and V_{BR}.

Table 1 Detail Wavelet coefficients at different levels

S.No	Detail coefficients			
	Level 1	Level 2	Level 3	Level 4
1	0.15162	0.21132	0.22451	0.38412
2	0.00315	0.00120	-0.66111	0.39792
3	0.12545	1.00240	-0.00241	0.37891
4	0.22511	-0.03631	0.13531	0.37800
5	0.00324	-0.02181	0.03251	0.39111
6	0.00123	0.01786	0.03258	0.34197
7	0.01372	0.02464	0.03673	0.30011
8	0.01977	0.02460	0.03245	0.37842
9	0.08142	0.12791	0.03796	0.33641
10	0.11641	0.04699	0.28741	0.36379

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Table 2 Approximate Wavelet coefficients at different levels

S.No	Approximate Coefficients			
	Level 1	Level 2	Level 3	Level 4
1	0.2221	0.12138	0.87234	0.12901
2	-0.0834	0.32987	0.12985	0.21864
3	-0.0213	0.12765	0.54981	0.45821
4	0.28734	0,61823	0.55237	0.39613
5	0.19263	0.29812	0.56281	0.50912
6	0.98241	0.12987	0.23761	0.61920
7	0.37211	0.32985	0.38740	0.41952
8	0.45912	0.39214	0.27861	0.28710
9	0.54291	0.34818	0.29561	0.02783
10	0.67439	0.72192	0.39872	0.09173

IV. FIRE-FLY ALGORITHM

Fireflies use flash signals to attract other fireflies for potential mates. Based on the behavior, a meta-heuristic algorithm was developed by Xin-She Yang. All the fireflies are considered unisexual and their attraction is directly proportional to the intensity of their flash. Therefore, if a firefly particle had the choice of moving toward either of two fireflies, it will be more attracted toward the firefly with higher brightness and moves in that direction. If there are no fireflies nearby, the firefly will move in a random direction. In firefly algorithm, there are three rules given by

i. A firefly is attracted by other fireflies regardless of their sex.
ii. Attractiveness is proportional to their brightness and decreases with respect to distance.
iii. The landscape of the objective function determines the brightness of a firefly.

Firefly is a stochastic meta-heuristic algorithm. Due to its stochasticity nature, the algorithm is able to search a set of solutions through randomization.

In the implementation of the algorithm, the flashing light is formulated in such a way that it gets associated with the objective function to be optimized. Fireflies are characterized by their flashing light produced by biochemical process .For proper design of FA, two important issues need to be defined: the variation of light intensity (I) and the formulation of attractiveness (β). Initial population of fireflies in the attractiveness of a firefly is determined by equation 1 its light intensity and the brightness is associated with the objective function are determined by equations 2-3.

$$X_i = [X_1, X_2, \dots \dots X_n] \quad (1)$$

$$I(r) = I_0 \exp(-\gamma r^2) \quad (2)$$

$$\beta(r) = \beta_0 \exp(-\gamma r^2) \quad (3)$$

Where I(r) and I_0 are the light intensity at distance r and initial light intensity from a firefly, β(r) and β_0 are the attractiveness a distance r and γ is light absorption coefficient.

Updating the objective function fitness is based on the equations 4-5.

$$x_i^{i+1} = x_i + \Delta x_i \quad (4)$$

$$\Delta x_i = \beta_0 \, e^{-\gamma r^2}(x_j - x_i) + \alpha \epsilon_i \quad (5)$$

Where α is randomization coefficient whose value is between 0 and 1 and ϵ_i is the random number vector derived from a Gaussian distribution.

V. ANN BASED CLASSIFICATION

In the paper, the coefficients obtained by MRA after using Daubuchies Wavelets are used for training of the ANN. Here the data corresponding to the wavelet coefficients are huge and therefore the training of ANN may take time while using Back Propagation Algorithm. Therefore dominant coefficients of the wavelet transforms can be used to train the ANN instead of training the ample data corresponding to Wavelet coefficients. This will increase the speed of the training and the time to identify the faults is less.

Similarly the coefficients can be obtained for the remaining data which has been received by GPRS. These data can be used for training the ANN to identify the faults. In this paper the proposed technique is the combination of wavelet transform and AI technique by considering optimized data for training ANN.

The flashing manner of the fireflies is used to calculate the best possible weights of ANN, which consecutively progress classification accuracy of FFA-NN. The description of FFA learning based ANN is given through a flowchart shown in Fig.4.

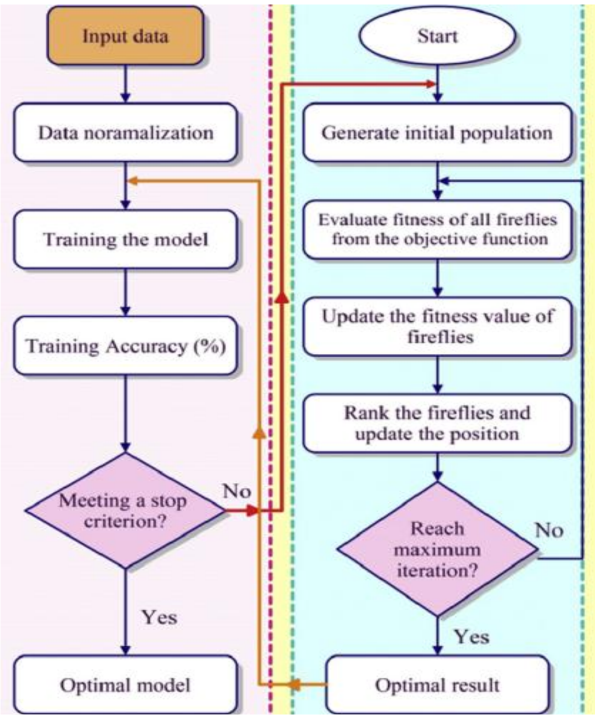

Fig.4 Description of FFA Learning based ANN

ANN Model description is as follows.

i) Learning algorithm*:* error back-propagation technique with adaptive learning rate and momentum.
ii) **Number of layers:** Three layer Feed forward network
iii) **Activation functions:** The network will have one hidden layer with tan-sigmoid neurons followed by an output layer with log-sigmoid neurons.
iv) **Inputs and outputs***:* Three phase current feature vector of detailed and approximate coefficients of different resolution levels of faults are provided as 20 inputs. The corresponding hidden neurons are 10 and one output neuron.

VI. TEST SYSTEM AND RESULTS

The Simulink diagram for the proposed system is shown in Fig. 5.By using the Simulink diagram various faults are created which are having same as that of currents and voltages received by GPRS system. During Normal operating conditions the three phase currents are shown in Fig. 6.

During Single line to ground fault conditions the Three-phase currents during single line to ground fault are shown in Fig. 7. During Line to line fault Three-phase currents during double line fault shown in Fig. 8. During Double line to ground fault Three-phase currents during double line to ground fault shown in Fig. 9. During Triple line to ground fault Three-phase currents during triple line to ground fault shown in Fig. 10.

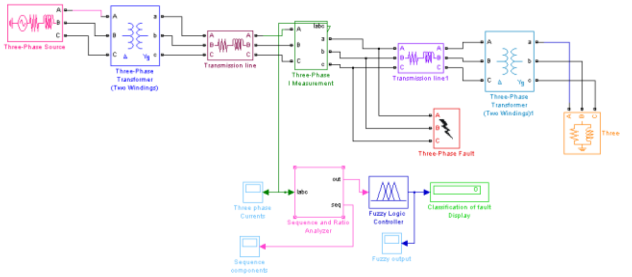

Fig. 5 Simulink diagram of Power System Model.

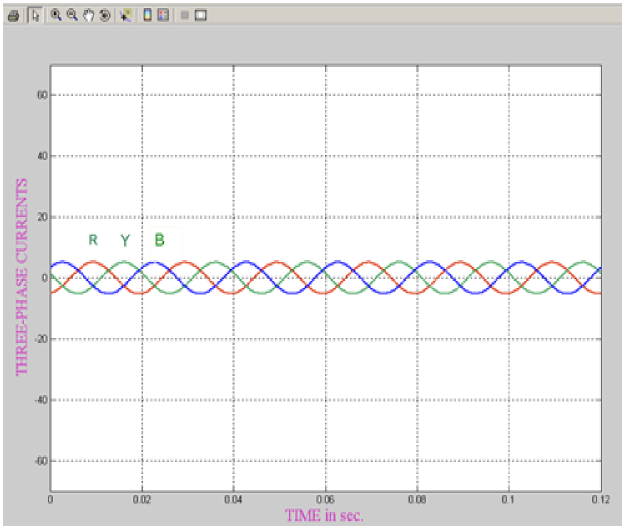

Fig. 6 Three-phase currents during normal condition.

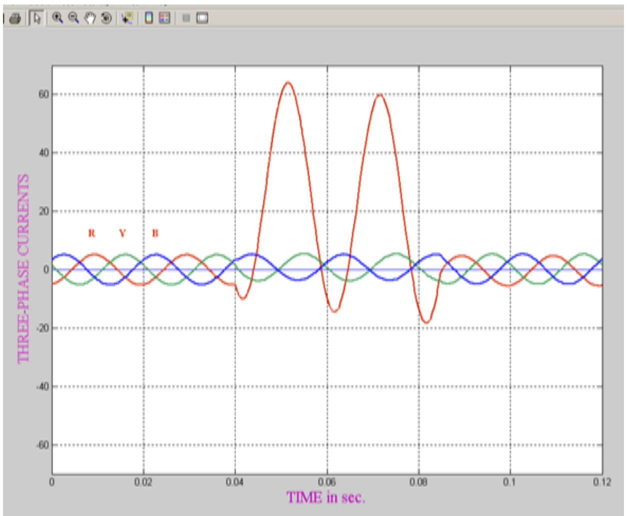

Fig. 7 Three-phase currents during SLG fault

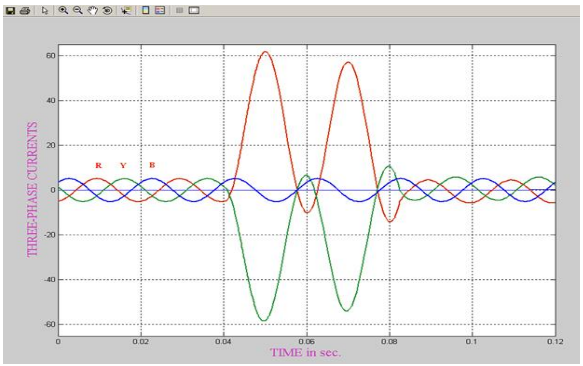

Fig. 8 Three-phase currents during LL fault

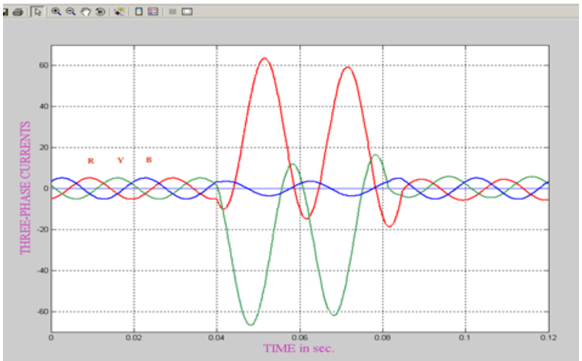

Fig. 9 Three-phase currents during LLG fault.

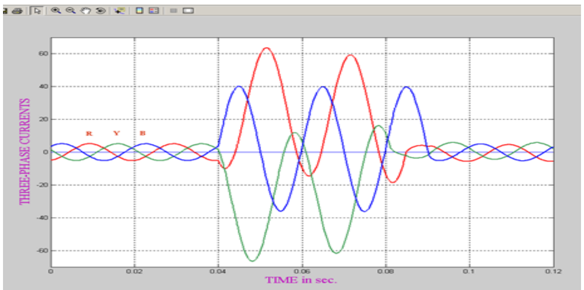

Fig. 10 Three-phase currents during LLLG fault.

The proposed technique is used to classify the faulty signal measured from the transformer primary and secondary windings. The fault current of the secondary winding is illustrated in Fig. 6 to 9, which shows the different phase faults. Each and every phase should be classified for evaluating the performance of the proposed technique. Each of the fault is analyzed in Wavelet tool box for their decomposition supported by MRA. In wavelet tool box Daubuchies wavelet is used as mother wavelet and the wavelet coefficients are evaluated for training of ANN.

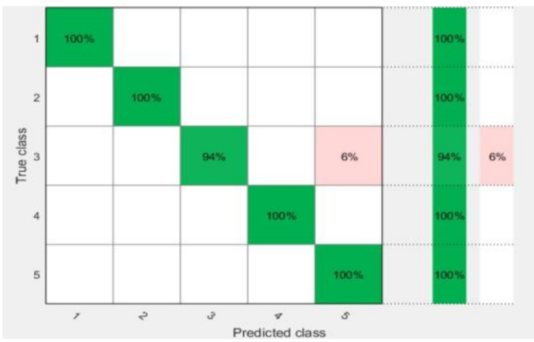

Fig.11 Confusion matrix of positive and negative rates

In ANN training the coefficients(after optimization) corresponding to a fault is given as input matrix and by initializing

the weighting coefficients with appropriate bias the ANN is trained algorithm is used till the target output is reached. From the confusion matrix shown in Fig 11, It can be observed that the proposed technique is providing the classification accuracy of 94% for various classes by considering dominant coefficients for the training. Performance metric of faulted phase classification is accuracy.

$$Accuracy = \frac{\Sigma \text{ True positive} + \Sigma \text{ True negative}}{Total\ number\ of\ population} \quad (6)$$

VII. CONCLUSION

Proposed FFA based ANN algorithm was utilized for diagnosing the internal faults conditions in power transformers. The proposed technique was worked with MWT and ANN based FFA optimization technique. Initially, the normal signals were analyzed at the particular time instant. After that, the faults were investigated in the power transformer with the help of the proposed technique. The proposed technique was utilized for detection and classification of the current signals in the power transformer. The extracted features of the current signal were given to the FFA. The FFA was selected with the optimized training dataset for training the ANN. After that, the ANN testing process was evaluated for the signal and classified the fault signal type. Proposed FFA-ANN methodology used dominant wavelet coefficients as optimized parameter vector to get improved percentage accuracy.

REFERENCES

1. Y. Sekine, Y. Akimoto, M. Kunugi, C. Fukui, S. Fukui, Fault diagnosis of power systems, Proc. IEEE 80 (May (5)) (1992) 673–683.W.-K. Chen, Linear Networks and Systems (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
2. J.H.Brunke, K.J.Frohlich, Elimination of Transformer Inrush Currents By Controlled Switching .IEEE transactions on power delivery, vol. 16, NO. 2, April 2001 p. 281-285.
3. G.J.Raju, Discrimination Between Internal Faults and Inrush Currents In Power Transformers Using The Wavelet Transform, International Journal of Advancements in Technology, Vol 2, No 2,April 2011.
4. Daubechies, I. (1990) “The wavelet transforms time/frequency location and signal analysis. IEEE Transactions on Information Theory”, 36, 961-1005.
5. Rioul, O. and M. Vetterli (1991) “Wavelets and signal processing. IEEE Signal Processing Magazine”, 14-38.
6. L. M. Peilin, R.K. Aggarwal, A Novel, Approach to the Classification of the Transient Phenomena in Power Transformers Using Combined Wavelet Transform and Neural Network, IEEE Transactions on Power Delivery, Vol. 16, No. 4, October, 2002.
7. J. P. Lee, D. J. Lee, P. S. Ji, J. Y. Lim, and S. S. Kim, “Diagnosis of power transformer using fuzzy clustering and radial basis function neural network,” in Proc. Int. Joint Conf. Neural Networks, Vancouver, BC, Canada, 2006, pp. 1398–1404.
8. A.P. Chen and C.C. Lin, “Fuzzy approaches for fault diagnosis of transformers,” Fuzzy Sets Syst. 118, pp. 139–151, 2001.
9. IztokFister, Xin-She Yang and Janez Brest, "A comprehensive review of firefly algorithms", Swarm and Evolutionary Computation, Vol.13, pp.34–46, 2013.

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