14-BUS LOAD FLOW PROBLEM SOLVING BY FIREFLY ALGORITHM

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Abstract

Many limitations started to be thinking about controlling the power transmission system. If these networks are not properly designed and arranged they can lead to operational problems such as excessive voltage drop, reduced voltage stability and increased losses that, in some cases, such as the critical loading conditions, especially in industrial areas and due to the lack of voltage stability index lead to sudden destruction. We applied a new bio-inspired meta-heuristic, called the Firefly Algorithm, to solve the problem. MATLAB/Simulink IEEE 14-bus benchmark system is implemented to show the validity of the proposed techniques. The performance of load bus power, voltage magnitude, and power loss were examined.
Keywords: *Electrical network, Power Flow, Firefly Algorithm, Optimisation.*

I. I.INTRODUCTION

Day to day life increase the demand of Electricity when the continuous growth of the population so nowadays the generations are not equal to the demand. Power system operations have the responsibility to ensure that sufficient power is delivered to the load reliably and economically, in order to ensure adequate delivery of power demand.
Due to the increased operations, which may cause power system to be in highly stressed Conditions? [1].

The load flow problem is one of the basic problems in power system engineering. Load flow studies are used to ensure that electrical power transfer from generators to consumers through the grid system is stable, reliable and economic. In 1956, Ward and Hale described the first successful computer program for solving load flow problems [2]. Since then, a considerable amount of research effort has been spent on developing very efficient and reliable load flow solution methods.

The main information obtained from the load flow or power flow analysis comprises magnitudes and phase angles of load bus voltages, reactive powers and voltage phase angles at generator buses, real and reactive power flows on transmission lines together with power at the reference bus; other variables being specified. The resulting equations in terms of power, known as the power flow equations become non-linear and must be solved by iterative techniques using numerical methods. Numerical methods are techniques by which mathematical problems are formulated so that they can be solved with arithmetic operations and they usually provide only approximate solution [3].

Apart from the above methods, another class of numerical techniques called evolutionary search algorithms such as genetic algorithm (GA), particle swarm optimization (PSO), frog leaping, harmony search optimization (HSO), artificial bee colony [4].

The aim of this study is to investigate the feasibility of Firefly Algorithm (FA) which is based on the social flashing behaviour of fireflies in obtaining load flow solutions. This technique is tested on the IEEE 14 bus system and executed using the MATLAB software package.

II. PROBLEM STATEMENT

Consider an interconnected power system where there are load buses, generator buses and one slack bus. The voltage magnitudes for load buses and voltage phase angles for load and generator buses must be determined in load flow analysis [5]. The load flow equations are:

$$P_i = \sum_{j=1}^{N} V_i V_j \left(\mathrm{G_{ij}} \cos\theta_{ij} + \beta_{ij} \sin\theta_{ij}\right) \qquad (1)$$

$$Q_i = \sum_{j=1}^{N} V_i V_j \left(\mathrm{G_{ij}} \cos\theta_{ij} - \beta_{ij} \sin\theta_{ij}\right) \qquad (2)$$

Where θij = θi −θ j. Pi and Qi are the active and reactive power injection at bus i. Vi and θi are the bus voltage magnitude and angle at bus i. Gij and Bij are the conductance and susceptance of the (i,j) element in the admittance matrix.

The objective functions are to minimize the active power loss using.

$$F_{obj} = min \sum_{i=1}^{NP} P_{Loss} \quad (3)$$

Where NL is number of lines in power system.

A. Equality Constraints:

The equality constraint is represented by the power balance equation that reduces the power system to a basic principle of equilibrium between total system generation and total system loads. Equilibrium is only met when the total system generation equals the total system load demand (P_D) plus system losses (P_L).

$$\sum_{i=1}^{NG} P_{gi} - P_D - P_L = 0 \quad (4)$$

Where, Pgi is a Real power generated at ith bus; NG is a Number of generator buses.

B. Inequality Constraints:

For static load flow equations solution to have practical significance, all the state and control variables must be within the specified limits. These limits are represented by specifications of power system hardware and operating constraints, and are described as follows:

- Limits on real power generation

$$P_{gi}^{min} \leq P_{gi} \leq P_{gi}^{max} \quad (5)$$

- Limits on reactive power

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \quad (6)$$

(i = 1, 2, …… NG)

- Limits on voltage magnitudes

$$V_i^{min} \leq V_i \leq V_i^{max} \quad (7)$$

(i = 1, 2, …… NB)

The limit arises due to the fact that power system equipments are designed to operate at fixed voltage within the allowable variations of + (5 – 10) % of rated values [6].

III. FIREFLY ALGORITHM

The Firefly Algorithm (FA) is a biologically inspired algorithm derived from the social behavior of fireflies Figure-1. Most firefly species produce short and rhythmic flashes by bioluminescence. Though the true functions of such signaling systems are still being debated, these flashes are primarily meant to attract mating partners. They can also attract potential prey or serve as a warning mechanism for the swarm.

Figure 1: The figure presents the one Firefly.

FA was designed by Xin-She Yang [7, 8] in 2009 and follows three idealized rules:

a) *Fireflies are considered to be unisex. So, a firefly will move towards the brighter members of the swarm, regardless of their sex.*

b) *The attractiveness between fireflies are proportional to their brightness. Given two fireflies, the one with lower light intensity will move towards the brighter one. The brightest firefly in a swarm will explore the search space randomly.*

c) *The brightness of a firefly will be determined by the fitness value of its location in the search space, obtained from the objective function for the optimization problem.*

The mathematical model of the Firefly Algorithm involves two main components: the variation of light intensity and the determination of attractiveness [7, 8].

For purposes of simplicity, it is assumed that the attractiveness of fireflies is dependent on their brightness, which in turn depends on the fitness values of the search space.

This means $I(x) \propto f(x)$ where $I(x)$ gives the light intensity of the firefly at the location x and f is the objective function. The attractiveness β, however, is not only dependent on the brightness of the firefly but also on the perception of that brightness by other fireflies, which is affected by the distance between the fireflies. So, it is imperative to take into consideration that light intensity $I(r)$ decreases with distance r according to the inverse square law as in equ. (8):

$$I(r) = {}^{I_0}/_{r^2} \qquad (8)$$

Where I_0 is the source intensity. Also, some light energy will be absorbed by the medium and the resulting intensity will vary with distance as given in (9):

$$I(r) = I_0 e^{\gamma r} \qquad (9)$$

Where γ is the fixed light absorption coefficient of the medium. The combined effect of inverse square law and absorption can be approximated as the Gaussian function shown in (10):

$$I(r) = I_0 e^{-\gamma r^2} \qquad (10)$$

Which helps to avoid the singularity at r = 0 in (8). Since a firefly's attractiveness is proportional to its brightness as perceived by other fireflies [9,10], the attractiveness β(r) of the source firefly to the observing firefly at a distance r the source can be defined as:

$$\beta = \beta_0 e^{-\gamma r^2} \qquad (11)$$

The Cartesian distance between two fireflies i and j at locations X_i and X_j respectively is given by

$$r_{i,j} = \|X_i - X_j\| = \sqrt{\sum_{k=1}^{d} (X_{i,k} - X_{j,k})^2} \qquad (12)$$

The movement of a firefly i attracted to a brighter firefly j is given by (13) as:

$$\boldsymbol{X_{i+1} = X_i + \beta_0 e^{-\gamma r_{i,j}^2}(X_j - X_i) + \alpha\varepsilon} \qquad (13)$$

The second term is due to attraction and the third term is a random component with α being the randomization parameter. ε is a random vector that follows the Gaussian distribution or uniform distribution. In this algorithm, ε is implemented by (*rand* -1/2) where *rand* is a random number generator uniformly distributed in [0,1] and the parameters $\beta_0 = 1$ and α ϵ [0,1] are used.

A great α value encourages firefly to search unknown areas, while a small α value forces firefly to search locally [11]. The Flow chart of the firefly algorithm is shown in Figure 2. An initial swarm of fireflies is obtained by generating random values.

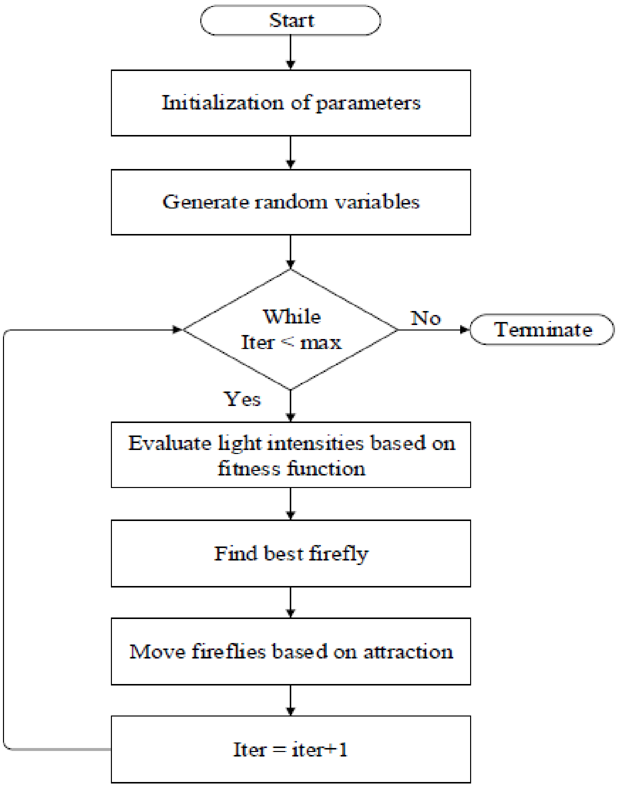

Figure 2: The figure presents the flow chart for FA based optimization.

IV. RESULTS AND DISCUSSIONS

In IEEE-14 bus system there are 14 buses and 20 lines which have been used to test the proposed methodology. The data for IEEE-14 bus system were taken and buses renumbered to make bus-1 as slack bus having pre specified voltage as $1.06\angle 0^0$ p.u.,

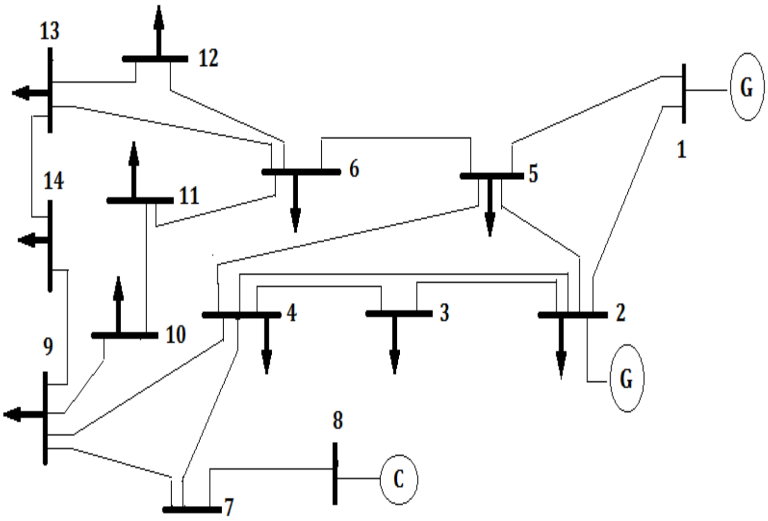

Figure 3 : the figure presents the structure Of IEEE 14Bus Bench Mark System.

The resistances and reactances of network test are given in Table 1, the state variables are the load buses (PQ buses) voltages, angles, the generator powers.

In this simulation, the values of the control parameters are: $\alpha = 0.2$, $\gamma = 1$, $\beta_0 = 1$. The above table's 1&2 present's steady state of active and reactive powers voltage at different buses calculated by FA method.

Table 1: The table presents the network parameter's.

From Bus	To Bus	Resistance (p.u.)	Reactance (p.u.)
1	2	0,01938	0,05917
2	3	0,04699	0,19797
2	4	0,05811	0,17632
1	5	0,05403	0,22304
2	5	0,05695	0,17388
3	4	0,06701	0,17103
4	5	0,01335	0,04211
5	6	0	0,25202
4	7	0	0,20912
7	8	0	0,17615
4	9	0	0,55618
7	9	0	0,11001
9	10	0,03181	0,0845
6	11	0,09498	0,1989
6	12	0,12291	0,25581
6	13	0,06615	0,13027
9	14	0,12711	0,27038
10	11	0,08205	0,19207
12	13	0,22092	0,19988
13	14	0,17093	0,34802

Table 2: The table presents the steady state active power.

Node	PLaod(MW)	PGenerator (MW)
1	0,000	465,102
2	43,400	80,000
3	188,400	0,000
4	95,600	0,000
5	15,200	0,000
6	22,400	0,000
7	0,000	0,000
8	0,000	0,000
9	59,000	0,000
10	18,000	0,000
11	7,000	0,000
12	12,200	0,000
13	27,000	0,000
14	29,800	0,000
∑P(MW)	518,000	545,102

TABLE 3: the table presents the steady state Reactive Power.

Node	QLaod(MVAR)	QGenerator (MVAR)
1	0,000	-31,058
2	25,400	93,842
3	38,000	54,272
4	-7,800	0,000
5	3,200	0,000
6	15,000	43,208
7	0,000	0,000
8	0,000	36,364
9	33,200	0,000
10	11,600	0,000
11	3,600	0,000
12	3,200	0,000
13	11,600	0,000
14	10,000	0,000
∑Q(MVAR)	147,000	196,628

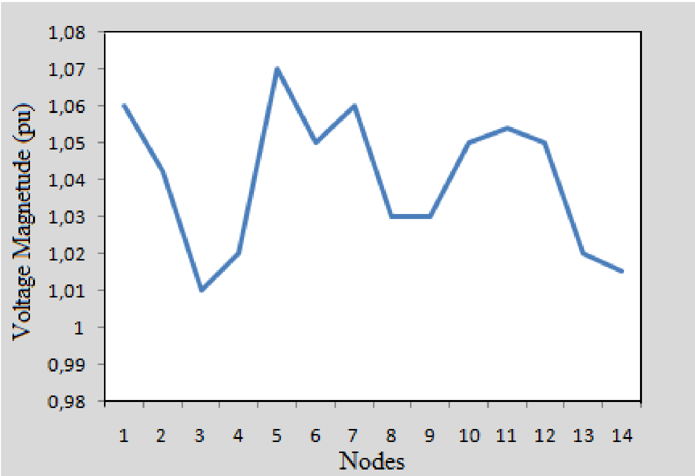

Figure 4: The figure showed the bus Voltage Magnitudes produced by FA.

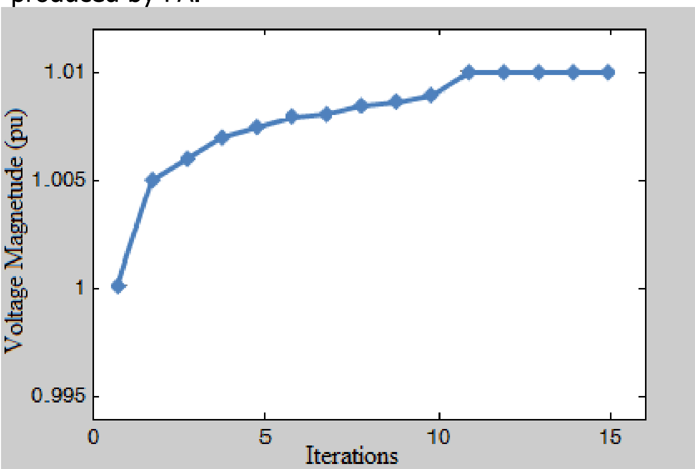

Figure 5: The figure showed the bus-3 Magnitude evolution.

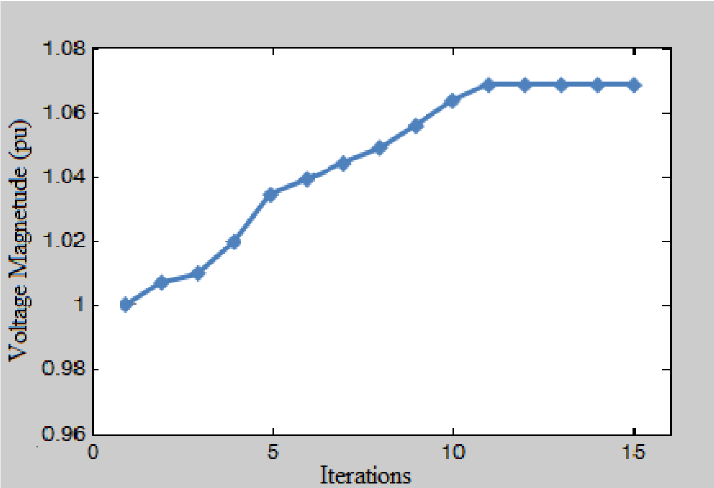

Figure 6: The figure showed the bus-5 Magnitude evolution.

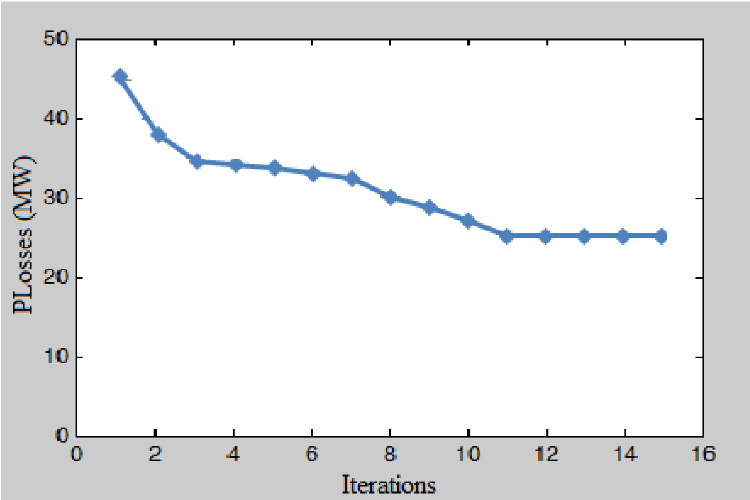

Figure 7: The figure showed convergence characteristic of the Power Losses.

Voltage deviations Figure 4, finals values is maintained in an appreciable margin of each buses. Figure 5 and Figure 6 views of voltages evolutions at bus-3 and bus-5 specify. In Figure 7 the absciss represents number of iterations and ordinate represents power loss, it shoud be that considerably reduction of this, and the number of iteration is very less as compared to the other methods. Simulation results show clearly convergence tendency is better.

5. CONCLUSION

This work has been focused on solve non-linear multi constraint power flow problem by Firefly algorithm tested on IEEE 14-bus system. The real power losses are reduced and grid system is stable by controlling voltage in appropriate boundaries. There are a number of issues that can be addressed in the future works such as to take into account the effect of renewable energy sources. Note That disadvantage of FA is the parameters of FA are invariable over time. To solve the practical problem, it is must adjustment α, β and γ.

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