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Optimal Power Flow, Sizing and Location of Thermal Generating Units Using Meta – Heuristic Soft Computing Algorithms

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Abstract

This paper presents an approach on stochastically approximated optimal power flow (OPF) in thermal generation system. It also considers the optimal sizing and location of thermal generation units for finding the optimal generator with minimal losses in distributed environment. The proposed hybrid approach optimizes the power flow using stochastic approximation technique with Flower Pollination Algorithm (FPA). With OPF as a key objective, the system chooses the optimal location and sizing of distributed thermal generators using Krill Herd Algorithm (KH). Here, the objective function for FPA is concerned with minimal cost, emission and voltage stability index. Likewise, KH algorithm is concerned with minimal loss and installation of thermal generators. Proposed hybrid system that combines optimal power flow, sizing and location is compared with conventional techniques to prove its effectiveness. The comparative analysis of proposed hybrid approach is implemented over standard IEEE 30-bus and IEEE 57-bus distribution system. Simulation results proved that the meta-heuristic hybrid approach performs well when compared with available conventional techniques.

Peer-review under responsibility of the Organizing Committee of ICCC 2016

***Keywords**:* Optimal Power Flow; Sizing and Location; Flower Pollination Algorithm; Krill Herd Algorithm; Fuel Cost; Emission; Voltage Stability Index.

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1. INTRODUCTION

In recent researches optimal power flow (OPF) is one of the essential factors for planning, operation and control factor for integrated and deregulated power industries like thermal distribution system [1]. Generally optimization is the process of selecting best solutions factor when limited number of resources is available in order to save energy, time, cost etc [2]. Distribution system is relatively smaller in size and provides power ranges from few kW to 100 MW since it is important for efficient utilization of available resources [8, 10]. Same like OPF problem optimal sizing and location of the thermal generation system is the important constraints. In the year of 2015 A.Y. Abdelaziz [3] stated that in distribution level distribution system subject to 13% ohmic losses due to misplacement of the distribution system it can be minimized by placing distribution system in appropriate position. For thermal distribution system it is necessary to maintain voltage stability with minimized reactive power loss [4]. To overcome OPF, optimal sizing and location numerous approaches are adopted like Particle Swan Optimization [5], Direct Search Algorithm [6], Teaching Learning Based Algorithm [7] and Evolutionary algorithm are developed for solving OPF and placing problem in thermal distribution system. Other than existing algorithm Krill Heard Algorithm (KHA) [2] provides effective convergence to particular solution.

In the last decade, several inspired algorithms are introduced and attempted for many engineering optimization problems. Some of the notable inspired algorithms are FPA (Flower Pollination Algorithm), krill herd algorithm, Particle Swan Optimization, Ant Colony Algorithm etc. By using existing algorithm as said above novel approach called stochastic approach which is recently evolved provides excellent solution to several challenges in thermal generation system [1]. Through stochastic approach uncertainties in thermal devices are optimized for efficient performance of the thermal system. In stochastic approach several random variables will be collected over time and consideration are taken to solve uncertainties in the thermal generation system [5]. While examining existing researches in the year of 2015, P.K Roy [9] analyzed about multi-objective OPF using KHA in various buses like IEEE 30-bus, IEEE 57-bus and IEEE 118-bus system. The OPF is examined for various parameters like fuel cost, voltage deviation minimization and voltage Stability improvisation. Obtained results of KHA are comparatively examined for various existing algorithm. From the comparative analyzes it is concluded that KHA outperforms rather than existing algorithms in terms of computation time, quality, convergence and robustness. Similarly in the year of 2014, Lenin [4] concentrates on minimizing economic dispatch problem using flower pollination algorithm. The FPA algorithm is tested with IEEE 30-bus system for minimizing real power loss and voltage stability. Simulation results demonstrate that FPA algorithm outperforms than existing algorithm in terms of voltage stability enhancement with voltage profile index. From the existing researches it is observed that KHA and FPA approach outperforms for solving OPF problem.

In this research proposed a stochastic approach for improving the performance of thermal generation system. This research is carried out by incorporating mete heuristic algorithm for solving OPF problem in thermal generation system for finding optimal size and location of the thermal generation system. For solving OPF in thermal generation system this research uses Flower Pollination Algorithm (FPA). By using FPA thermal generation system fuel cost, emission, loss and voltage stability index are comparatively analyzed. Since this research follows stochastic approach fuel cost and loss obtained from FPA algorithm are considered and utilized for finding optimal size and location of thermal generation system. For finding optimal sizing and location of the thermal generation system in this research uses Meta heuristic krill heard algorithm. Results of stochastic approach for finding OPF, size and location are obtained by stimulating Meta heuristic algorithm in IEEE 30-bus and IEEE 57-bus system. Results obtained by stochastic approach using Meta heuristic algorithm are comparatively examined with existing algorithm with both bus system.

2. Problem Formulation

The essential goal of OPF is to streamline the settings of control variables to meet certain destinations while fulfilling arrangement of uniformity and imbalance imperatives. The OPF issue can be scientifically communicated as takes after:

$$Minimize f(x,u) \tag{1}$$

Subject to,

$$g(x,u) = 0 \tag{2}$$

$$h(x,u) \leq 0 \tag{3}$$

Where, f is the objective function to be minimized, g is set of equality constraints representing nodal power injections and h is set of inequality constraints. The vector u consists of independent variables or control variables and vector x consists of dependent variables or state variables

2.1 Objective Function

Main objective of this research is through stochastic approach need to find OPF, optimal size and location of the thermal distribution system. Proposed stochastic approach utilizes mete heuristic algorithm like FPA and KHA. For finding optimal size and location minimum fuel cost and loss are considered as objective function. Objective function of the system is stated as follows,

$$f(a,k) = \sum_{i}^{N_a} f_i(a_i) + \sum_{i}^{N_k} f_i(k_i) \tag{4}$$

In objective f defined in equation (1) which is minimized one where $f_i(a_i)$ is the minimum cost function of the FPA algorithm, $f_i(k_i)$ is the minimized loss for FPA which is implemented in IEEE 30-bus and IEEE 57-bus.

2.2 Stochastic Equation

The main objective of this research is to propose a stochastic approach using Meta heuristic algorithm for solving OPF and optimal sizing and location of the thermal distribution system. The stochastic equation for the proposed system is stated below:

$$\min E[TC] = \int_{d_1}\int_{d_2}\cdots\int_{d_N}\sum_{t=1}^{N}(ad_t + h\max(I_t,0) + vQ_t) \times g_1(d_1)g_2(d_2).....g_N(d_N)d(d_1)d(d_2).....d(d_N) \tag{5}$$

Subject to, for $t = 1,2,.....N$

$$I_t = I_0 + \sum_{i=1}^{t}(Q_i - d_i) \tag{6}$$

$$d_t = 1, \text{ if } Q_t > 0 \tag{7a}$$

$$d_t = 0, Otherwise \tag{7b}$$

$$P_r\{I_r \geq 0\} \geq a \tag{8}$$

$$Q_t \geq 0, d_t \in \{0,1\} \tag{9}$$

Where δ_t represents requirement placed in the period of t, Qt shows the order quality placed in the period of t.

3. Research Methodology

This research proposes a stochastic approach for efficient utilization of thermal distribution system. Proposed approach uses Meta heuristic algorithms like FPA and KHA for finding optimal sizing and placement of the thermal distribution system. Methodology adopted for finding optimal sizing and location for thermal distribution system is graphically demonstrated in figure 1 as below which are all tested in IEEE 30-bus and IEEE 57-bus system.

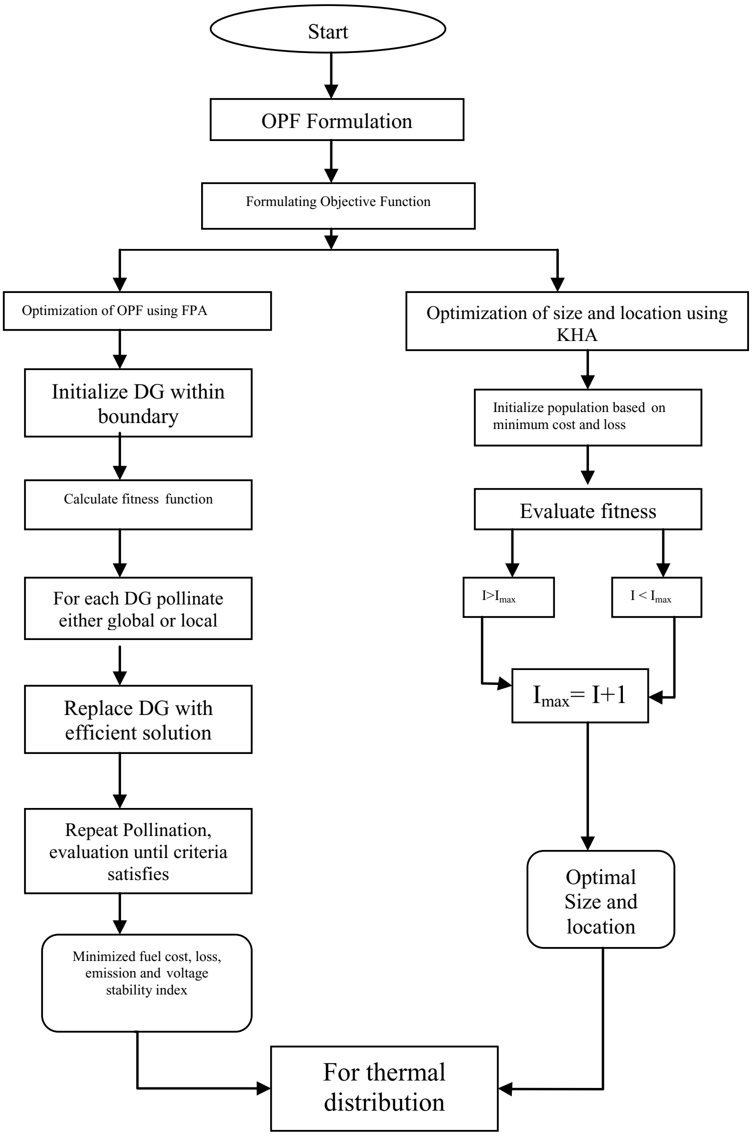

Figure 1. Flow Chart of Stochastic Approach

The above figure 1 demonstrates methodology adopted for finding OPF and optimal sizing and location of the thermal distribution system using IEEE 30-bus and IEEE 57-bus system.

4. Results and Discussions

For solving optimal power flow problem in this research applied FPA the obtained results are comparatively examined with existing approaches. For optimal sizing and location KHA is used with objective function using minimized cost and loss obtained from the FPA approach both algorithms are tested in both IEEE 30-bus and IEEE 57-bus system. Results of the approach are comparatively analyzed and stated as below. OPF is examined in both bus system by considering the factors like fuel cost, loss, emission and voltage stability index which are described followed by results obtained by implementing KHA for optimal size and location.

4.1 OPF Factors

4.1.1 Fuel Cost

For optimal power flow problem flower pollination algorithm is applied in this research. From the comparative analysis of the FPA algorithm with existing algorithm it is observed that FPA efficiently reduces fuel cost of the thermal distribution system.

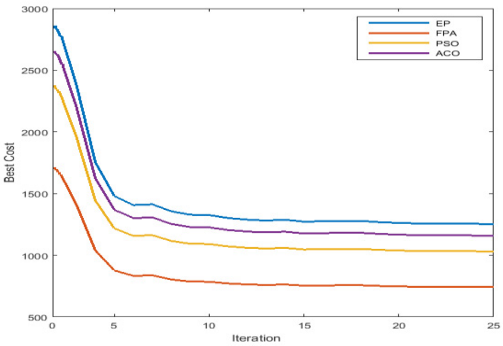

Figure 2 Fuel Cost tested in IEEE 30 bus

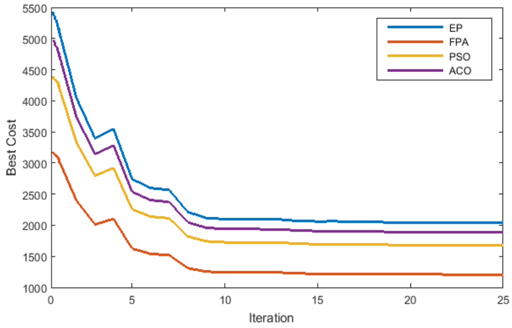

Figure 3 Fuel Cost tested in IEEE 57 bus

The above figure 2 and figure 3 describes the fuel cost obtained from FPA implemented in IEEE 30 and IEEE 57 bus system respectively. Also the figure 2 and 3 shows that FPA algorithm efficiently reduces fuel cost below 700$/hr where other existing algorithm are higher fuel cost than FPA algorithm. For IEEE 57-bus system FPA provides fuel cost of 1400$/hr which is lower than existing algorithm like Particle Swam Optimization (PSO), Ant Colony Optimization (ACO) and EP algorithm.

4.1.2 Loss

The loss obtained by implementing FPA in IEEE 30 bus system are shown in figure 4 and figure 5 shows the simulated loss obtained in IEEE 57-bus system.

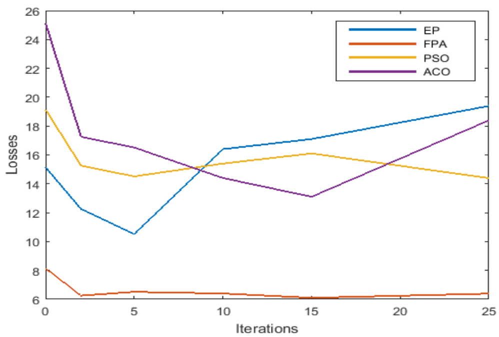

Figure 4 Simulated Loss for IEEE 30 bus system

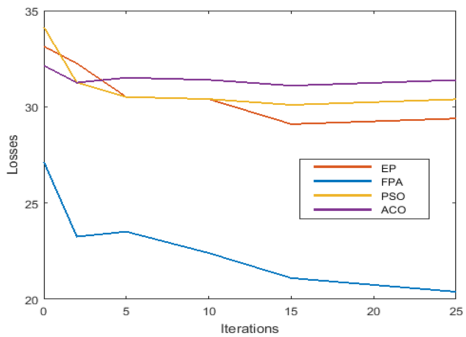

Figure 5 Simulated Loss for IEEE 57 bus system

For IEEE 30-bus system FPA provides the loss in the rate of 0.001 whereas other existing algorithm provides the loss in the range of greater than 12. Same as IEEE 30 bus in IEEE 57-bus system provides loss at the rate of 0.002.

4.1.3 Emission

The figure 6 and figure 7 describes the emission obtained for FPA algorithm in IEEE 30-bus and IEEE 57-bus system for thermal distribution system.

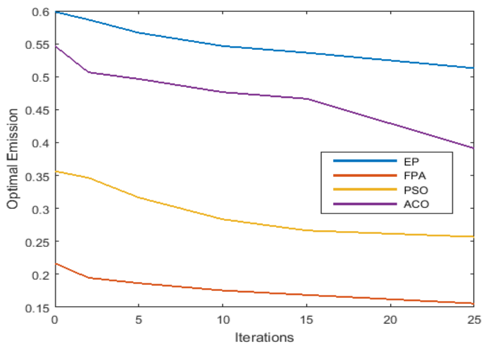

Figure 6 Emission tested in IEEE 30 bus

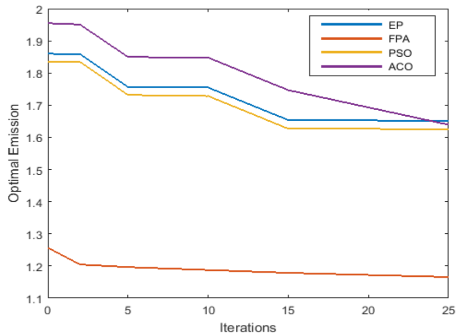

Figure 7 Emission tested in IEEE 30 bus

The graph 6 and 7 demonstrate that FPA significantly reduces the emission rate of OPF in both test system when compared with other algorithms.

4.1.4 Voltage Stability Index

For the FPA algorithm in IEEE 30 bus and 57 buses produces voltage stability index with value of 1 for numerous number of iteration.

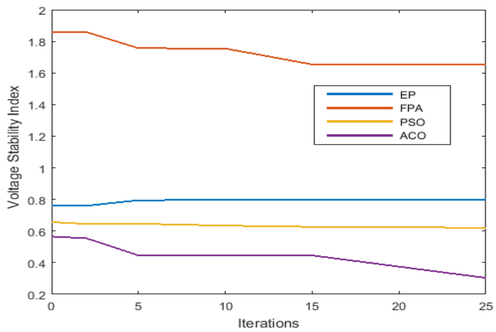

Figure 8 Voltage Stability Index in 30 bus

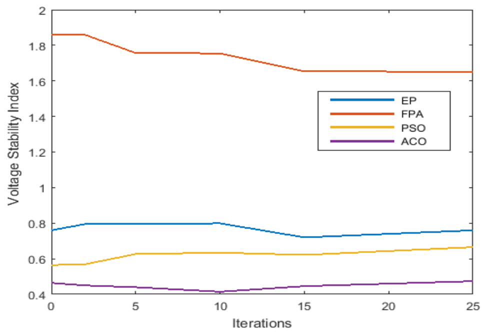

Figure 9 Voltage Stability Index in 57 bus

The above figure 8 and figure 9 shows the voltage stability index for the FPA algorithm in IEEE 30-bus system and IEEE 57 bus system. For both bus system voltage stability index is at the rate of 1.8.

Parameters	IEEE 30-bus System				IEEE 57-bus System			
	ACO	PSO	EP	FPA	ACO	PSO	EP	FPA
Fuel Cost	1600	1300	1000	700	2470	1900	2450	1400
Loss	0.0014	0.0015	0.0011	0.007	0.032	0.026	0.30	0.0025
Emission	0.5	0.35	0.6	0.2	1.9	1.77	1.68	1.2
Voltage Stability Index	0.4	0.7	0.8	1.21	0.4	0.5	0.7	1.82

Table 1. Summary of tested results in bus system

The table 1 demonstrate comparative results of stochastic algorithm tested in IEEE 30-bus and IEEE 57-bus system. The parameters like fuel cost, loss, emission and voltage stability index are implemented using FPA and optimal size and location are implemented using KHA.

4.2 Optimal Size and Location

Similar like FPA algorithm for OPF in thermal distribution system KHA is used for finding optimal size and location of the thermal distribution system. For finding size and location of thermal system minimum cost and loss obtained from OPF are considered as an objective function for stochastic approach and tested in IEEE 30-bus and IEEE 57-bus system. To determine the optimal location of installed wind turbines, probability of active bus states are added up, and if they obtained number is more than 0.5, the bus is regarded as an active bus.

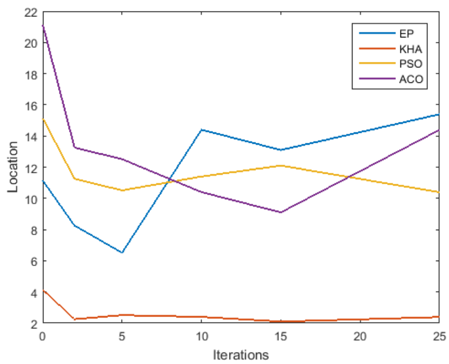

Figure 10. Optimal Location for IEEE 30 bus

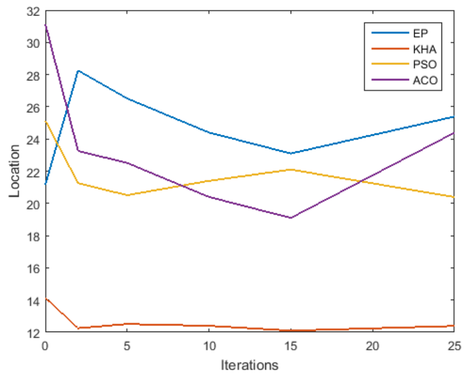

Figure 11. Optimal Location for IEEE 57 bus

The figure 10 demonstrate that 4 is the optimal location of the thermal generator in IEEE 30 bus for IEEE 57 bus 14 is the best optimal location of thermal distribution system.

In order to determine the optimal size of thermal distribution system the effect of each bus sizing are discussed in figure 12 and figure 13. The resource with a higher effect is determined as an appropriate resource and in order to specify the optimal location for placing thermal distribution system, locating is accomplished applying hybrid algorithm the sites with the occurrence probability more than 0.5 are selected as the optimal locations.

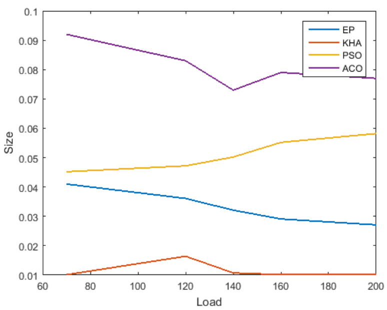

Figure 12. Optimal size using IEEE 30 bus

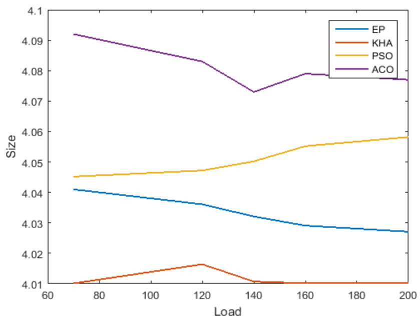

Figure 13. Optimal Size using IEEE 57 bus

Parameters	IEEE 30-bus System	IEEE 57-bus System
Optimal Size	100KW	120KW
Optimal Location	4	14

Table 2. Optimal Size and Location obtained for both bus systems

From table 2 it is concluded that for IEEE 30-bus system 4 is the optimal placement location of thermal system similarly for 57 bus system 14 is the optimal placement location of thermal distribution system. Similarly for optimal size IEEE 30 bus provides 100KW is the optimal size for IEEE 57 bus 120 KW as an optimal size.

Conclusion

Optimal power flow problem is the one of the important research area in the field of electrical power generation system for efficient function. Similarly same as OPF optimal placement and sizing of the thermal distribution system is important factor for efficient functioning. In this research proposed a stochastic approach using Meta heuristic algorithm for finding optimal size and location for the thermal distribution system and tested in IEEE 30-bus and IEEE 57-bus system. OPF factors are examined using FPA and tested in both bus systems from the obtained results of OPF with minimized cost and loss objective function for KHA algorithm is implemented for finding optimal location and size of thermal distribution system. Results obtained from FPA and KHA implemented IEEE 30-bus system and IEEE 57-bus systems are comparatively examined in both bus systems with existing heuristic algorithm.

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