JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

A Multi-Objective Hybrid Algorithm for Planning Electrical Distribution System

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Abstract: In the paper a multi-objective Gravitational Search Algorithm (GSA) and Tabu heuristic search for planning electrical distribution system is proposed. The GSA has been minimized the Distribution Generator (DG) investment cost, cost of distribution system losses, operation and maintenance cost of DG with the help of appropriate constraints. So the optimum sizing of DG is planned in the optimum location with reduced cost. Here, the Gravitational Search Algorithm (GSA) accelerates convergence speed with combination of the search strategy of Tabu heuristic search method. Then the proposed multi-objective hybrid algorithm for planning electrical distribution system is implemented in the MATLAB platform and the effectiveness is analyzed by comparing with the other techniques. The comparison results demonstrate the superiority of the proposed approach and confirm its potential to solve the problem.

Key words: GSA, Tabu search, DG, operation and maintenance cost, investment cost, cost of losses

1. INTRODUCTION

The onset of an aggressive electricity market coupled with hi-tech growth and ecological contaminations has triggered the progress of DG, especially the renewable energy resources [1]. No wonder, the electric power distribution system design has emerged as a very significant technology for power utilities [2] [3]. The main focus of the current power system economics is targeted at ensuring a distribution system with the least installation and process outlay [4]. The challenges facing the distribution system planning comprise various factors such as taking an appropriate decision on the optimum numbers and localities of the supply substations and the finest method of linking the load nodes to these substations by means of the inter-linking of feeders [5]. This calls for a proper planning which will, in the long run, usher in considerable reduction in costs without in any way compromising customer delight. As a result, distribution system planning has virtually become a multi-objective optimization issue [6] [7]. Conversely, one of the vital issues faced by distribution system planning models is that the number of optimal plans with least expenditure is limited to one only [8].

The central aim of the distribution system planning (DSP) issue is targeted at furnishing a reliable and cost effective service to clients simultaneously guaranteeing that voltages and power quality are maintained at the benchmark levels [9-11]. The cost reduction encompasses several factors including capital and overheads of recently established and the existing facilities, expenditure involved by the purchase of power from other electric enterprises, and the amount spent on account of electric system power losses [12]. The distribution power system planning technique involves two significant phases. The former phase is the preliminary system planning and the latter is the optimization planning for consistency [13]. The smart grid incorporation of dispatch able renewable DG units like biomass generators has become as one of the remarkable alternatives to satisfy the ever zooming load demands, at the same time radically improving customer reliability and decreasing the entire emissions [14].

Anyhow the reactive power planning for a distribution network is effortlessly carried out with the proper positioning of shunt capacitor banks [15]. The evolutionary calculation methods are employed as solution techniques in a lion's share of the Pareto-based multi-objective planning schemes fascinated by their multi-point exploration potency, facilitating the achievement of a set of non-dominated solutions [16-18]. The central targets of multi-objective algorithms are focused on inching closer to the set of optimal solutions which would lead to a set of diversified solutions. Hence it can be stated that the multi-objective algorithm sets its bar with the lofty motive of an instantaneous achievement of sterling convergence [19, 20].

In the paper a multi-objective Gravitational Search Algorithm (GSA) and Tabu heuristic search for planning electrical distribution system is proposed. The GSA has been minimized the Distribution Generator (DG) investment cost, cost of distribution system losses, operation and maintenance cost of DG with the help of appropriate constraints. So the optimum sizing of DG is planned in the optimum location with reduced cost. Here, the Gravitational Search Algorithm (GSA) accelerates convergence speed with combination of the search strategy of Tabu heuristic search method. The specified clarification of the proposed hybrid technique and the DSP model are discussed in section 3. Former to that, the present research works are presented in section 2. The results and the discussion are presented in section 4. In section 5 the paper is ends.

2. Recent Research Works: A Brief Review

Literature is flooded with innumerable investigations of relevance based on Distribution System planning with several objective types, a few of which are discussed below. Jose L. Rueda *et al.* [21] have judiciously brought out an all-inclusive technique to estimate an optimal transmission system expansion plan taking due account of the enrichment of small-signal solidity by means of wide-ranging deployment of the accessible and designed transmission system assets. The vibrant model of the transmission network operational planning (TNOP) was resolved in accordance with a blend of the Mean-Variance Mapping Optimization (MVMO), and the standard dynamic programming technique entrenched with a heuristic process. In addition, a probabilistic Eigen analysis-based recursive approach was launched to estimate the optimal control techniques that were significantly applicable to the augmentation of the system small-signal solidity excellence all through the planning perspective. Numerical outcomes recount the success stories of the perspective and the efficiency of the innovative technique in ushering in optimal strategies of least expenditure simultaneously tackling successfully the volatility risk linked to badly damped minimal frequency electromechanical oscillations.

With inherent genius, S. Ganguly *et al.* [22] have carved an innovative vibrant programming technique for multi-objective planning of electrical distribution systems. The proposed design envisions the estimation of the optimal feeder routes and branch conductor dimensions of a distribution system by concurrent optimization of expenditure and consistency. The multiple planning targets covered minimization of various facets encompassing establishment and running expenses along with reduction in overheads due to delay. The former objective task embraced several areas such as the establishment expenses of new feeder branches and substations, preservation overheads of the current and new feeder branches, and the payment towards loss of energy. On the contrary, the latter objective task estimates the consistency of the distribution network according to the related expenditure due to delay for the entire branches including which included the expenditure towards non-delivered energy, cost of maintenance, and the customer loss cost on account of delays. Thus, a dynamic programming based planning algorithm for optimization of the feeder routes and branch conductor sizes was launched.

Ehsan Naderi *et al.* [23] have effectively shaped a novel technique for considering DGs in the DSP issue. In the innovative model, an optimal power flow (OPF) was envisioned to minimize capital expenditure for system renovation, running and preservation expenses, and the payments towards damages in handling the load expansion for the design domain. The idea encapsulated in the term “dynamic” pointed to the planning for a definite interval which was envisaged in the innovative dynamic distribution system planning. Moreover, a customized genetic algorithm was also employed to hit upon the optimal topology solution.

Samui *et al.* [24] have significantly ushered in an analysis on the function of consistency consideration in distribution system design and planning expenditure of radial distribution system. A direct investigation method was used for optimum planning envisaging only the significant reduction of planning outlay. Moreover, the idea of principle of optimality thesis enables the direct technique become highly effective in computation by bringing down the total numbers of radial paths. Reliability indices were determined to assess the consistency of systems with diverse feeder structures. The innovative technique was also experimented for optimal feeder routing by duly altering the number of substations, which furnished the data on swapping between optimality and dependability of the system structure.

A.M. Cossi *et al.* [25] have competently offered the planning paradox of primary distribution networks as a multi-objective mixed-integer non-linear programming model (MINLP). The objective tasks of the proposed model were the development and process investment expenditure of primary distribution networks in addition to the consistency costs of the in the unforeseen happening. The consistency expenses were estimated by calculating the non-supplied energy in view of the maintenance and switching processes in the distribution network performed to segregate and to reallocate loads in the affected segment by eternal errors. With a view to tackle the growth concerns of the primary network a Multi-objective Reactive Tabu Search algorithm (MO-RTS) was envisaged. The theories of dominance were applied to gather Pareto’s optimal frontier in the MO-RTS. The issue of positioning of sectionalizing switches to reinstate the distribution system and to cut back non-supplied energy expenditure during the incidence of eternal errors in the system was tackled concurrently with the network growth planning issue with the help of a committed genetic algorithm.

A multiyear dynamic model to the Transmission Expansion Planning, TEP, an intricacy to recognize the most suitable set of projects and their scheduling along the planning horizon, these were proposed by Manuel Costeira da Rocha *et al.* [26]. Using a fitness activity that includes operation and investment rate and a set of penalty terms, a candidate plans were determined. These provisions were correlated with the level of losses, non-zero values for the power not provided namely for the entire system and for $n - 1$ unexpected events, financial limits, more number of projects to execute in each year or all along the horizon and the potential to accommodate not only the expected demand, but also precarious disturbing the required forecasts. To carry out the distinct problem, an advanced algorithm is introduced namely PSO algorithm. This algorithm comprises a developmental embracing of the PSO regulation and further several corrections to assure that participative progression of each candidate key is technically possible given its distinct nature.

In a multi-objective optimization framework, a Multistage Distribution network Expansion Planning (MDEP) problem in the presence of Distributed Generations (DGs), it is presented by Mohsen Gitizadeh *et al.* [27]. These patterns combine two goals. To minimize the investment costs and operation costs as well as to maximize of reliability index. They also projected an updated model subject to AC power flow restrictions to acquire the finest configuration of feeders (adding and removing lines) contains the best size of branch conductor, alternate of conductor for reserve feeders, and created power of DGs. To determined the Energy-Not-Supplied (ENS) index a systematic approach on the basis of graph theory was executed as an extra objective purpose for the proposed MDEP reliability problem. A hybrid Particle Swarm Optimization (PSO) and Shuffled Frog Leaping (SFL) algorithm was executed to recognize Pareto optimal solutions of the multi-objective MDEP problem.

Normally the distribution system planning model is formulated with one objective function. The objective function is varied as minimization of installation cost, the cost of energy losses and maximization of profit. One of the significant features in the competitive power market is also considered as another objective for distribution system stability. The stability of distribution system is formed by the total cost of customer outage, customer interruption, and the contingency load loss index. Different approaches have been used for optimizing the objective function of cost and stability of the planning model. That approaches have been solved by single solution problem or multi-objective decision making problem. In this planning model, the main challenge is to formulate a solution strategy as the objective functions are typically nonlinear, non convex, and non differentiable by separate and continuous resultant variables. The complexity increases by means of advanced proportions that depend on the number of buses in the system. The complexity is overcome by two ways of solution strategies that are deterministic algorithms and optimization algorithms. The deterministic algorithms are depends on mathematical optimization procedure which can generate similar output for a certain input for all time. Hence, it would be solve the problem by only nonlinear, dynamic, and mixed type programming methods. But, the optimization algorithm is able to generate a feasible solution to a problem in many practical situations, but there solution is varied by randomly. The optimization algorithms are such as genetic algorithm, tabu search, artificial immune system, particle swarm optimization, honey bee mating optimization and etc. But, these algorithms have the convergence problem which is overcome by introduced new search techniques. The proposed multi-objective function is briefly explained in the following section 3.

3. Formulation of Multi-Objective Function

This section describes about the aim of our proposed work, which is formulated by multi-objective function. The objective function is formulated as minimization of DG installation cost, the cost of energy losses and maximization of profit. One of the significant features in the competitive power market is also considered as another objective for distribution system stability. The stability of distribution system is formed by the total cost of customer outage, customer interruption, and the contingency load loss index. Different approaches have been used for optimizing the objective function of cost and stability of the planning model. That approaches have been solved by single solution problem or multi-objective decision making problem. In this planning model, the main challenge is to formulate a solution strategy as the objective functions are typically nonlinear, non convex, and non differentiable by separate and continuous resultant variables. Here, the multi-objective model is developed for minimizing the cost of DG installation, cost of losses, cost of operation and maintenance. The required multi-objective function is described in the following equation (1).

$$Fitness = \Psi = Min\{f_1, f_2, f_3\} \tag{1}$$

Where, $f_1 = C_{DG}^{inv}$ is the DG investment cost; $f_2 = C_{DG}^{o\&m}$ is the operating and maintenance cost of DG and $f_3 = C_L$ is the cost of losses; the description about the multi-objective function is given in following equations (2), (3) and (4).

$$C_{DG}^{inv} = \sum_{i=1}^{N_b} C_i^{inv} \left\{ \frac{P_{DG\,i}^{\max}}{C_{annual} 8760} \right\} \tag{2}$$

With, $C_{annual} = \left[\frac{(1+r)^T - 1}{r(1+r)^T} \right]$ is the annualized factor; N_b is the total number of buses possible to connect DG; $P_{DG\,i}^{\max}$ is the total DG units capacity limit at bus $i\,(MVA)$; C_i^{inv} is the DG investment cost $(\$/MVA)$; d is the discount rate and T is the horizon planning period (year). The operating and maintenance cost equation is described by the following.

$$C_{DG}^{o\&m} = \sum_{i=1}^{N_b} C_i^{o\&m} P_{DG\,i} \tag{3}$$

Where, $C_i^{o\&m}$ is the DG operating cost at bus $i\,(\$/MVA)$ and $P_{DG\,i}$ is the DG's generated power at bus $i\,(MW)$. The cost of losses equation is described in the following.

$$C_L = loss\,C_p^i \tag{4}$$

Where, $loss = \sum_i \sum_j P_{ij}$; C_p^i is the active power price at bus $i\,(\$/MWh)$. In the above objective equations are used to planning the distribution system. During the whole planning period, the network must satisfy some security and configuration constraints. Here, it could be mentioned by power balance constraints, apparent power flow limit constraints, bus voltage constraints, distribution substation's capacity and cost constraints. In addition to the traditional system constraints, additional ones and modified existing traditional of them are introduced by the proposed integrated model as follows.

(a). Power balance constraints

The power balance constraint is most important constraint in the distribution system planning, which is nothing but the power production is must to meet the load demand and the losses. Here, the power balance constraint is used to find the stability of the distribution system with minimum cost. The power balance constraint is classified into two types like active power balance equations and reactive power balance equation. The active power balance equation is described in the following equation (5).

$$(P_{DG\,i} + P_{Gi}) - P_i^d - \sum_{j=1} P_{ij} = 0 \tag{5}$$

With, $P_{ij} = Y_{ij}\{V_i^2 \cos(\theta_{ij}) - V_i V_j \cos(\delta_j - \delta_i + \theta_{ij})\}$ is the power flow in feeder connecting bus i to j (MW); V_i is the bus voltage at bus i; V_j is the bus voltage at bus j; δ and θ are the load and admittance angle respectively; Y_{ij} is the admittance between the bus i to j and P_i^d is the total active power demand at bus i (MW). Then the reactive power balance equation is described in the following equation (6).

$$Q_{G\,i} - Q_i^d - \sum_{j=1} Q_{ij} = 0 \tag{6}$$

Where, Q_{Gi} is the reactive power dispatched from the transmission company number i (MW); Q_i^d is the total reactive power demand at bus i $(MVar)$; Q_{ij} is the reactive power flow in feeder connecting bus i to bus j $(MVar)$. The distribution substation's capacity constraint and the cost constraint are explained in the following section b.

(b). Distribution substation's capacity and cost constraints

The substation present in the distribution system contains specified capacity to satisfy the load demand; which is allocated with in a limit. Depending upon the capacity of the distribution system substation, the load buses dispatching has been determined. The violation of the distribution substation capacity makes the increasing of maintenance cost and instability. So the capacity limits are considered for the distribution system planning. Here, the active and the reactive power capacity limit are shown by the following equation (7) and (8).

$$Q_{Gi}^{\min} \le Q_{Gi} \le Q_{Gi}^{\max} \tag{7}$$

$$0 \le P_{DG\,i} \le P_{DG\,i}^{\max} \qquad \forall i = 1,2 \ldots N_b \tag{8}$$

Where, $Q_{Gi}^{\min}$ is the minimum reactive power dispatched from the transmission company number i $(MVar)$; $Q_{Gi}^{\max}$ is the maximum reactive power dispatched from the transmission company number i $(MVar)$ and $P_{DG\,i}^{\max}$ is the maximum active power dispatched from the transmission company i (MW). The above equations are mentioned the capacity limits of the DG resources, which should consider the financial constraints of the DG investment. This constraint imposes a limit on the DG capacity the distribution company can invest in.

$$\sum_{i=1}^{N_b} C_i^{inv} P_{DG\,i}^{\max} \leq DBL \quad (9)$$

Where, DBL is the distribution company budget capacity limit $(\$)$. The apparent power flow limit of the distribution system lines are explained in the following section c.

(c). Apparent power flow limit of lines

The distribution system apparent power flow limit is described in the following equation (10).

$$\left|S_{ij}\right| \leq S_{ij}^{\max} \quad (10)$$

Where, S_{ij} is the apparent power flow through line connected between i and j; $S_{ij}^{\max}$ is the maximum permissible line power flow capacity. The distribution system bus voltage limits are explained in the following section d.

(d). Bus voltage limits

The distribution system planning must know the bus voltage profile limits. In the bus voltage profile is maintained within the specified limit for improving the stability of the system. The voltage profile of the bus could be affected by the increasing of the load demand and some contingencies. During this condition the DG resources are need to allocate at the required capacity to minimize the investment cost and improve the stability. The required distribution system voltage limit is described in the following equation (11).

$$V_i^{\min} \leq V_i \leq V_i^{\max} \quad (11)$$

Where, $V_i^{\min}$ is the minimum permissible voltage at bus i (V) and $V_i^{\max}$ is the maximum permissible voltage at bus i (V). The above mentioned equations are used to optimize the multi-objective function (1). The best constraints to achieve the multi-objective function reflect distribution system cost reduction and stability. Then, the proposed technique to planning the distribution system is explained in the following section 3.1.

3.1. Hybrid Technique based DG Planning

A major of meta-heuristic optimization algorithms searching the best solution due to the balance of two related concepts like exploration and exploitation [28]. Exploration seeks to understand the connectivity relationship of the search space, which is helpful to the global optimal solution; exploration hunts for better optimal solutions in adjacent area of the visited domain, which can strengthen the convergence capability of local search. So an excellent algorithm should improve the exploration ability in the first stage and then enhance the exploitation ability in the second stage with the iterations increasing. In the standard GSA, the movement direction of each agent is determined by the total force that other better agents act on it and lacking of communications between the agents. Hence, the GSA algorithm is hybridized with the Tabu search algorithm. Because the Tabu heuristic search algorithm contains major merits like restricts some search of neighboring solutions, aspiration allows exception and accessible solutions. Here, the GSA updated agents positions were checked out beyond the boundary or not, which is beyond the boundary means Tabu heuristic process is invoked or else the normal process is performed. Finally the best solution is judged through both the methods results. The process of proposed hybrid technique is briefly explained in the following. The hybrid technique input parameters are IEEE distribution system bus voltage and the power loss, which is explained in the following equation (12).

$$X_i = [(V_1, P_{L1})^1, (V_2, P_{L2})^2, (V_3, P_{L3})^3 \ldots (V_n, P_{Ln})^n] \quad (12)$$

Where, $(V_i, P_{Li})^d = X_i^d$ defines the position of the i^{th} agent at d^{th} dimension. From the agents optimum location is determined by the following relation (1). According to the Newton gravitational theory the total force acts on the agent is described in the following equation (13).

$$force_i^d(t) = \sum_{j \neq i} rand_j \left(force_{ij}^d(t) \right) \quad (13)$$

Where, $force_{ij}^d(t) = G(t) \dfrac{M_{pi}(t) * M_{aj}(t)}{R_{ij} + \varepsilon} * \left(X_j^d(t) - X_i^d(t) \right)$ with,

$R_{ij} = \left\| X_i(t), X_j(t) \right\|_2$ is the Euclidian distance between two agents i and j, $rand_j$ is the random values, i.e., [0, 1], ε is a small constant, M_{aj} and M_{pi} active and passive gravitational mass related to agent i and j .Here, the acceleration of the i^{th} agent can be determined by the following equation (17).

$$Acceleration\ a_i^d(t) = \frac{force_i^d(t)}{M_i(t)}$$

Updating the agent's position, using the following velocity equation (14).

$$V_i^d(t+1) = rand_i.[V_i^d] + a_i^d(t) \qquad (14)$$

The above velocity function is used to develop the new agents, which can be described in the following equation (19).

$$X_i^d(t+1) = X_i^d(t) + V_i^d(t+1) \qquad (15)$$

Where, $V_i^d(t)$ and $X_i^d(t)$ are the velocity and position of an agent at t time and d dimension, $rand_i$ is the random number in the interval [0, 1]. The position of the new agent is evaluated using the following condition.

If $X_i^d(t+1) > U_b(d)$; $X_i^d(t+1) = U_b(d)$ or

If $X_i^d(t+1) < L_b(d)$; $X_i^d(t+1) = L_b(d)$

Where, $U_b(d)$ and $L_b(d)$ are the upper and lower limit in the d^{th} dimension. All off-boundary agents are gathered in the boundary after such processing, which will generate a huge force compelling other agents to move forward boundary in accordance with law of gravity and the uniform distribution of agents is disrupted, which is great harmful to the global exploration, especially when there are local optimums around the boundary. Therefore, a new treatment named Tabu heuristic search strategy is used in this paper. This strategy helps to improve the searching ability of the agents; so the new agents building in the Tabu heuristic search method is described in the following relation (16).

$$X_{New}^d(t+1) = \begin{cases} X_{TS}^{11}(t+1) \\ X_{TS}^{21}(t+1) \\ \vdots \\ X_{TS}^{N1}(t+1) \end{cases} \qquad (16)$$

The steps for planning the DG in the distribution system using proposed hybrid technique are briefly explained in the following.

(a). Steps for planning DG in distribution system

Step 1: In the first step, the input agents are randomly generated at N dimensions. Here, the bus voltage and the line losses are selected as the agents.

Step 2: Apply load flow solution and then, evaluate the fitness values of the randomnumber of agents.

Step 3: In the high mass, agents are selected as the best solutions and the corresponding load flow is analyzed.

Step 4: The best solutions are separated into two groups, the first groups have the minimum best solutions and another group has maximum best solutions.

Step 5: For each best solution groups, the agent's positions and velocity is modified.

Step 6: Run load flow analysis and evaluate the new agents. Select the best agent from each group.

Step 7: Check whether the new position of the agent beyond the limit. If the new position of the agent is beyond the limit, the Tabu heuristic search is invoked or else goes to step 9.

Step 8: Evaluate the fitness of the each agent's new position. If it is accessible means replace the current agent's position or otherwise find the second best agent's position and check the accessibility again until find the optimum accessible agent's position.

Step 9: To judge the best agent while comparing both the GSA and Tabu heuristic search.

Step 10: Find the voltage, real and reactive power flow and power loss.

Step 11: Check the termination criterion. If it is satisfied terminate or else go to step 12.

Step 12: Generate the new agents to generate new solutions. Go to Step 2.

Once the process gets finished, the system is ready to give the optimum location and capacity of DG planning in the radial distribution system according to the demand growth. The above explained process has been explained in the following figure 1. Also the Tabu heuristic searching process structure is explained in the figure 2. Then the proposed hybrid technique is tested in the IEEE standard radial distribution system and the effectiveness is discussed through the following section 4.

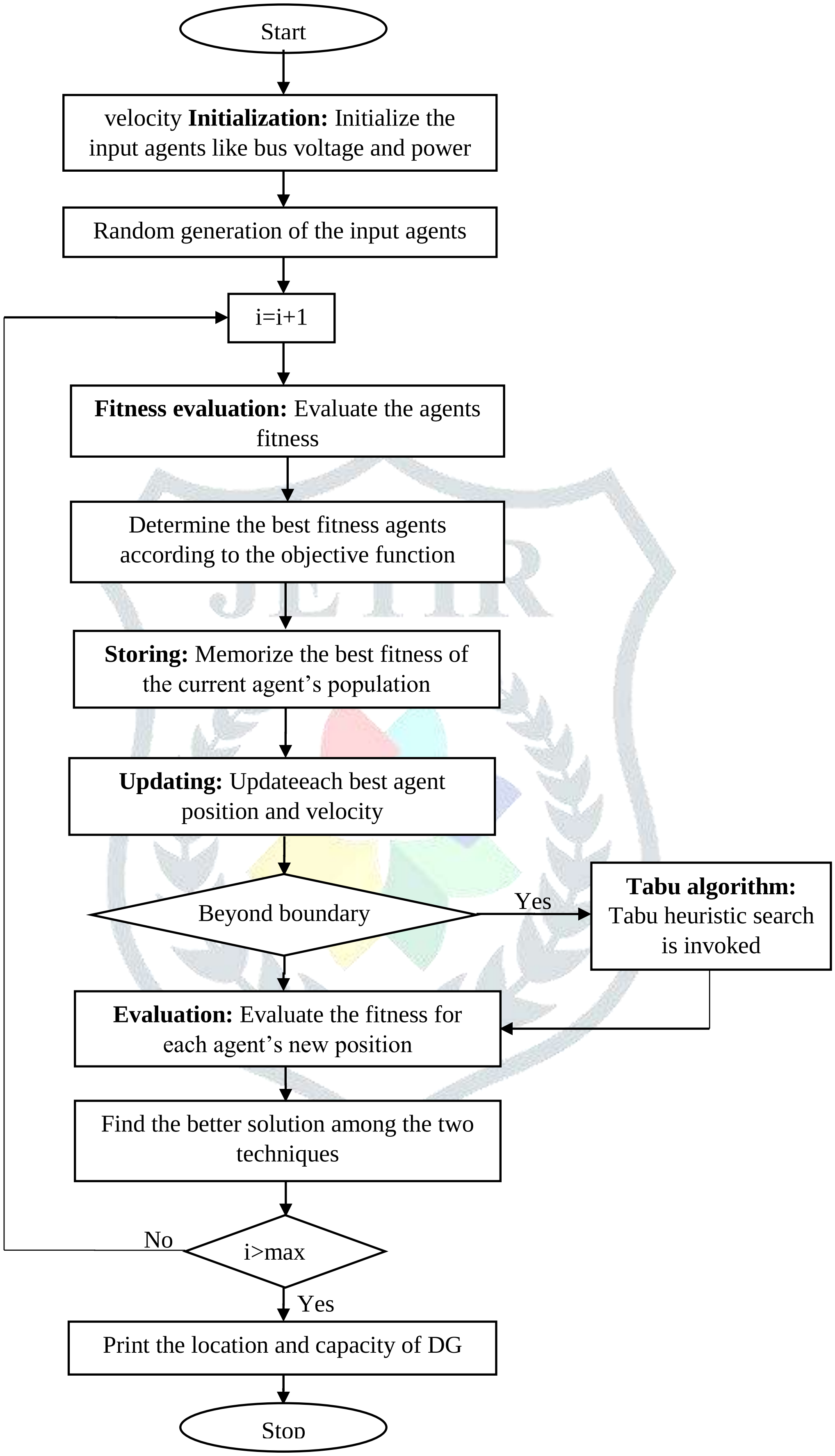

Figure.1: structure of the proposed hybrid technique

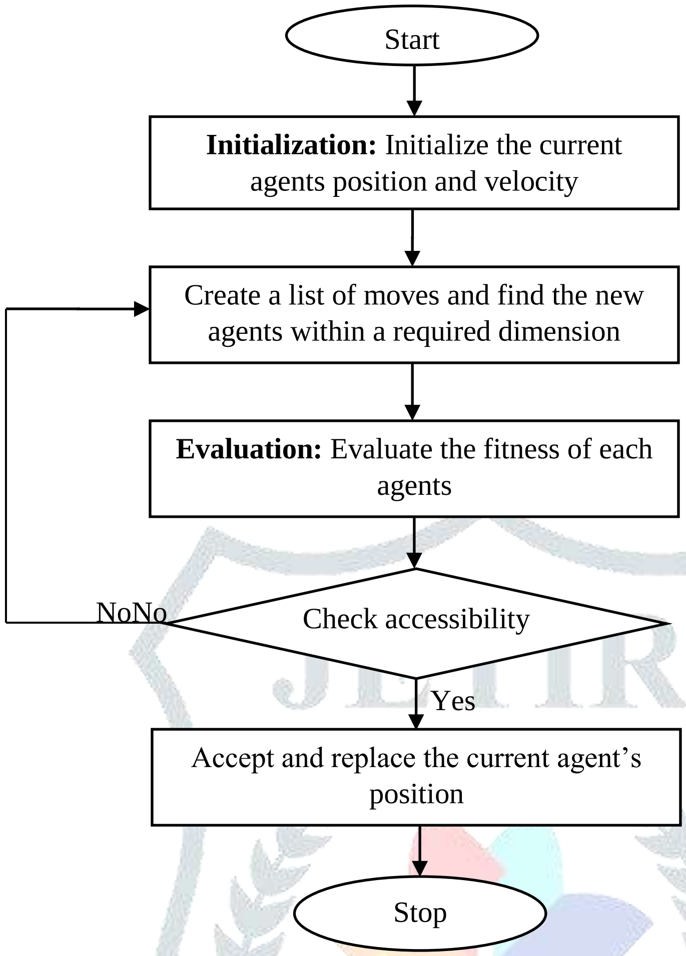

Figure.2: Structure of the Tabu search algorithm

4. Results and Discussions

The proposed mutual method is implemented in MATLAB (R2015) platform, 4GB RAM and Intel(R) core(TM) i5. Here, the minimization of DG investment cost, cost of losses operation and maintenance cost of DG are considered as the objective function. The proposed technique finds the optimum location and sizing of the DG depending on the objective function, which were enhancing the planning of DG in the distribution system. The IEEE standard bench mark system like 33 bus radial distribution is utilized for the planning the DG in the distribution system. The effectiveness of the proposed hybrid technique is identified by using the comparative analysis with the GSA technique. The IEEE 33 bus radial distribution system structure is described in the following figure 3.

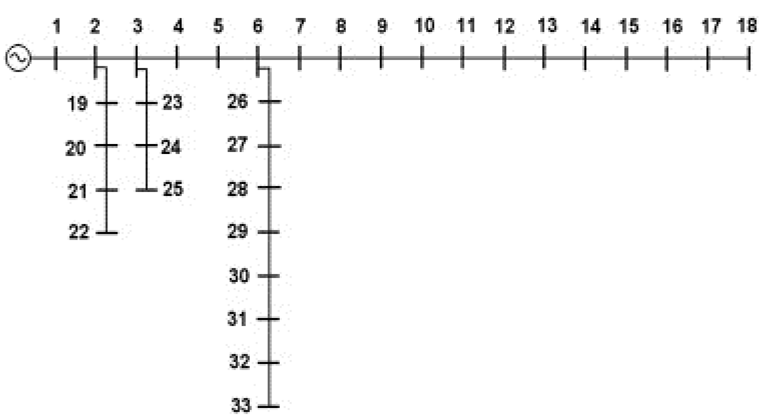

Figure.3: Structure of the IEEE 33 bus distribution system

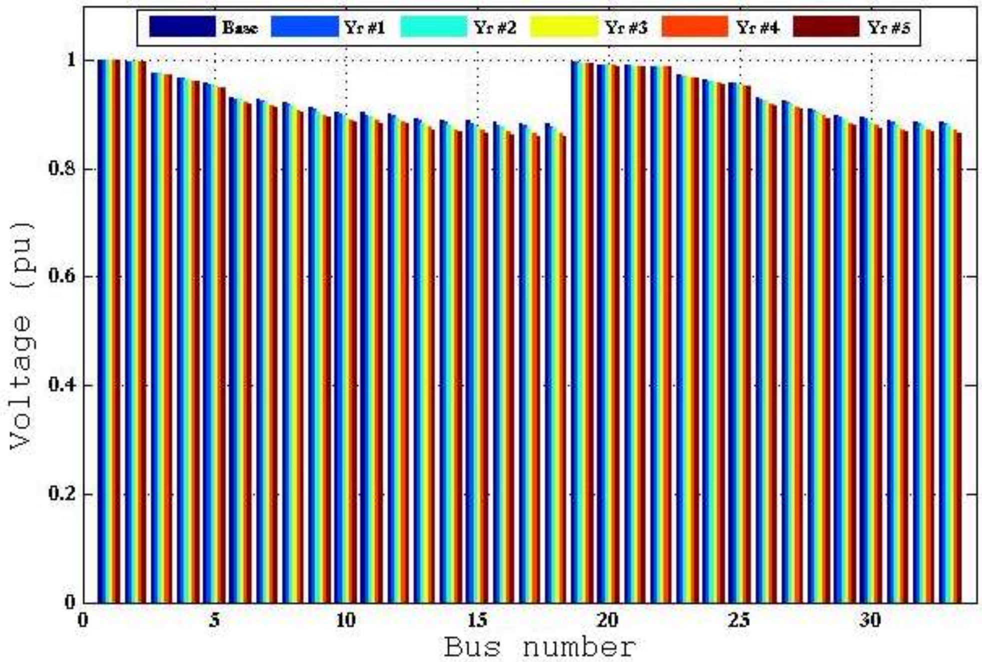

Figure.4: Distribution system voltage profile at each year

The IEEE 33 bus radial distribution system consists of 33 nodes. The voltage profile of all the nodes while the whole planning period is explained in the figure 4. Here, the 5 years of distribution system planning voltage profile with the base year has been explained. It was seen that the voltage profile in base case maintains the normal voltage limit, which has been violated during the change of load demand in every year.

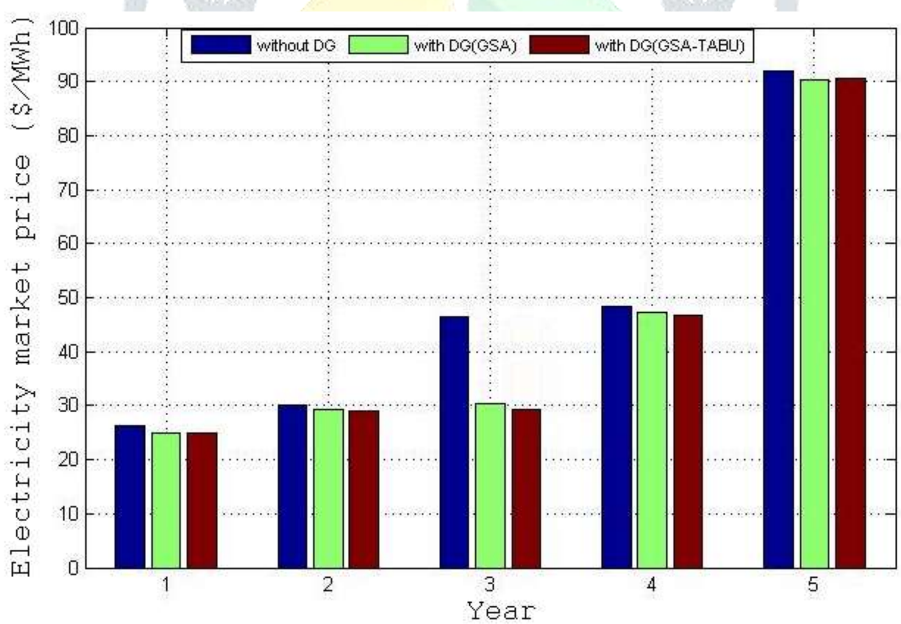

Figure.5: Electricity market price after DG installation at each year

The figure 5 describes the electricity market price after the DG installation at each year. Here the electricity market price has been analyzed for 5 years with different techniques such as IEEE 33 radial distribution system without DG, using GSA optimizing technique and proposed hybrid technique. In the whole period of analysis explained the effective planning of DG in the distribution system. During the planning of DG considers the increasing amount of load demand at each year. The electricity market price at whole planning period without DG have high amount of cost, which average is 49.2%. By using the GSA technique the electricity market price is slightly reduced at 44.4%. The market electricity price is 42.8% by using the proposed hybrid method at 5 years.

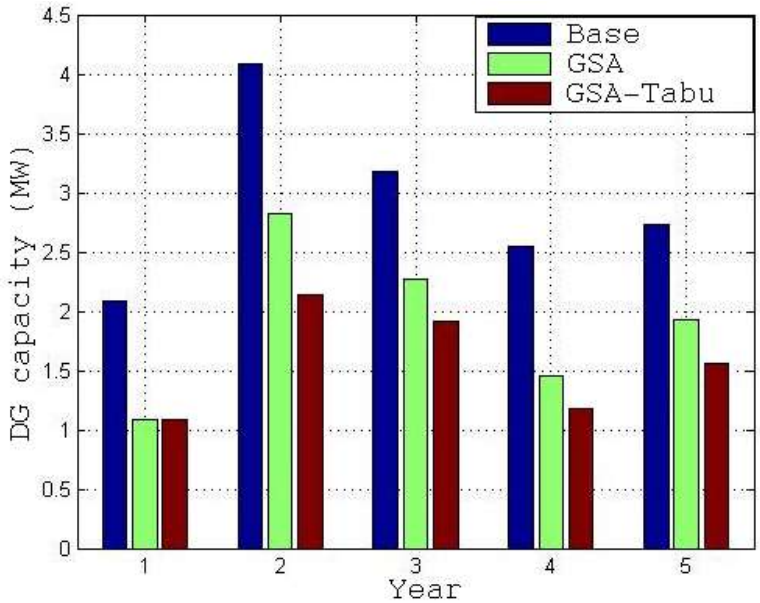

Figure.6: Optimum location and sizing of DG for different techniques

The figure 6 describes the optimum capacity of the DG installation at each year. Here the optimum capacity of the DG has been analyzed for 5 years with different techniques such as IEEE 33 radial distribution system normal condition, using GSA optimizing technique and proposed hybrid technique. In the whole period of analysis explained the effective planning of DG in the distribution system with optimum capacity. During the planning of DG considers the increasing amount of load demand at each year. In the starting year the load demand is increased at 5% of the total demand, in which the DG planning in the distribution system at normal condition is 2.1MW and the GSA chosen 1.2MW is the optimum DG capacity. But the proposed hybrid method optimizes 1.1MW DG is enough to manage the load demand. The second year IEEE 33 bus distribution system load demand is increased at 10% of the total demand. During the period 4.1MW DG is needed for the normal condition; the GSA optimizes 2.8 MW DG size and the proposed method identifies 2.1MW DG is enough rectifies the increasing load demand. The 15% of load demand is increased in the third year. During the year of planning normal condition has 3.2MW, GSA optimized 2.4MW and proposed method predicted 1.8MW DG size. The fourth year of DG planning mainly depends on the 20% of load demand increasing. During the fourth year planning 2.6MW capacity DG is selected in the normal condition; 1.4MW DG is optimized by using the GSA technique; the proposed method identifies 1.2MW DG size. The fifth year of planning faces the growth of 25% load demand. In the situation the normal condition identifies 2.7MW; GSA has 1.8MW capacity DG but the proposed hybrid method identifies 1.6MW DG size is required to solve the growth of the fifth year load demand.

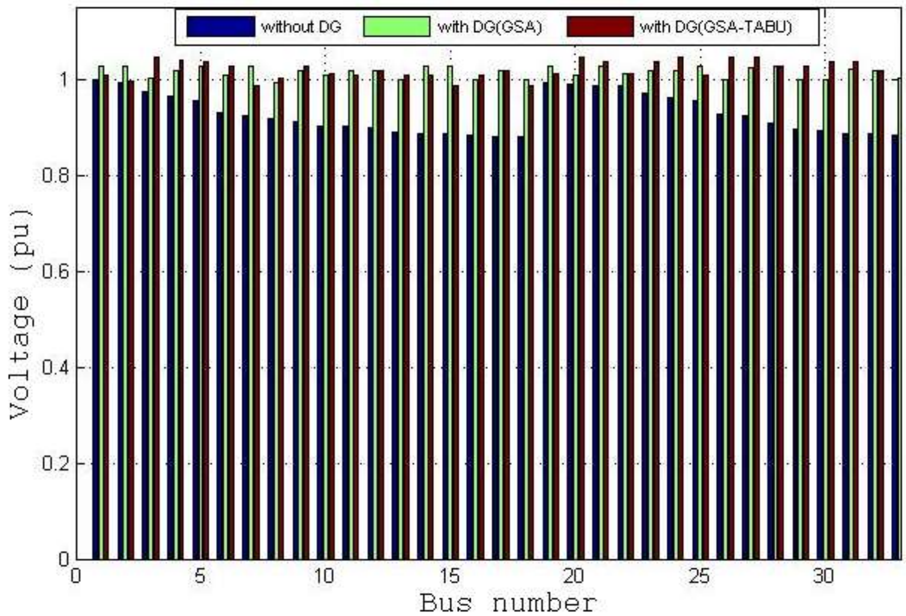

Figure.7: Optimum location and sizing of DG for different techniques

The optimum location and sizing of DG using different techniques are explained in the figure 7. Here, the voltage profile is analyzed by using different techniques like IEEE 33 radial distribution system normal condition, using GSA optimizing technique and proposed hybrid technique. From the figure the voltage profile of the radial distribution system at normal condition has stable condition. Then the voltage profile of the distribution system is violated due to the load demand at 5 years. In the situation the effectiveness of the proposed method is compared with the GSA technique. It was seen that from the figure the proposed method is effectively manages the voltage profile of the distribution system.

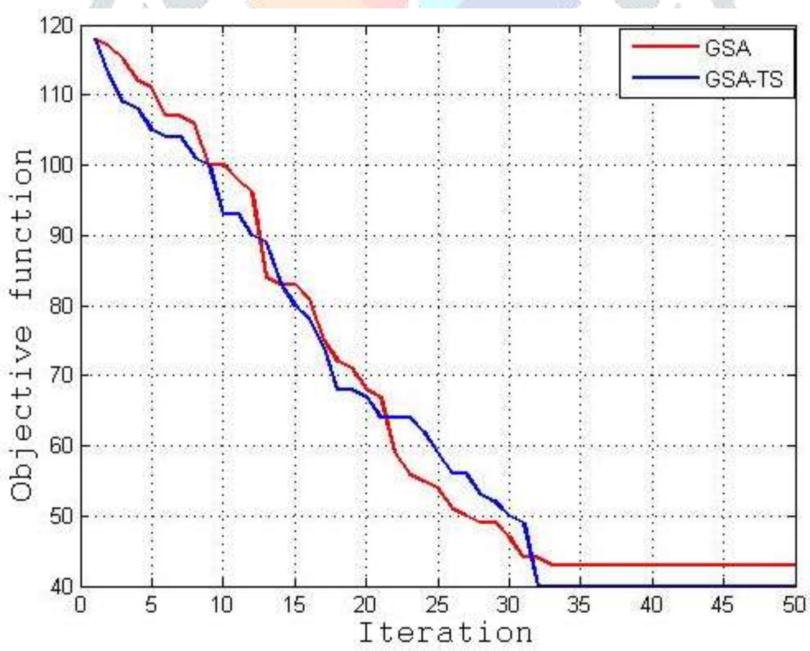

Figure.8: Comparison of convergence characteristic of objective function

The figure 8 describes the convergence characteristic of multi-objective function comparison, which takes 50 numbers of iteration for all techniques. It shows that the multi-objective function evaluation by using the proposed hybrid technique and GSA method. From the figure we observe that the GSA makes high values during the iterations, which starts from 120 and finishes at 45. Because, it minimized the Distribution Generator (DG) investment cost, cost of distribution system losses, operation and maintenance cost at inefficient manner. But the proposed hybrid technique takes accelerates the convergence characteristics with the combination of Tabu heuristic search, so it determines the multi-objective function effectively, i.e., initial iteration condition the objective function is 120; it is gradually reduced according to the variation of the number of iterations and at the end of the 50 iteration the objective function is 40.

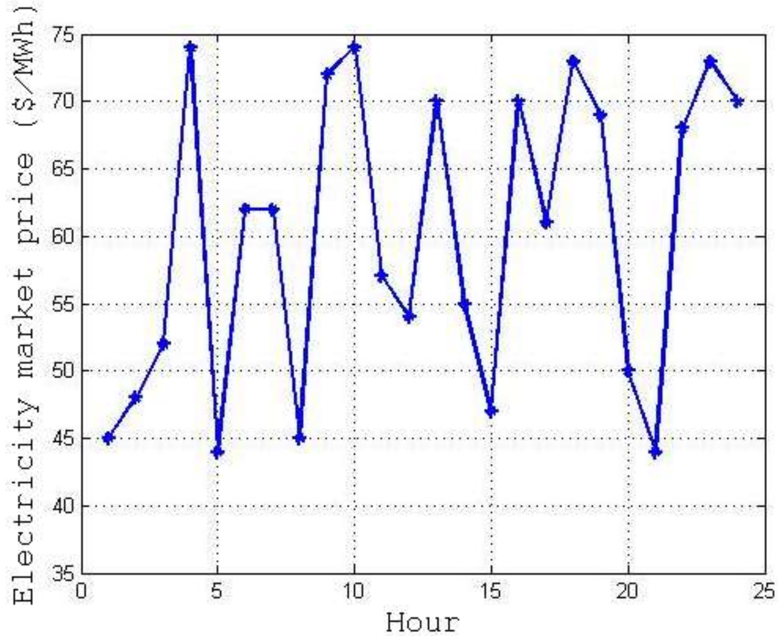

Figure.9: Variable electricity market price of hourly curve

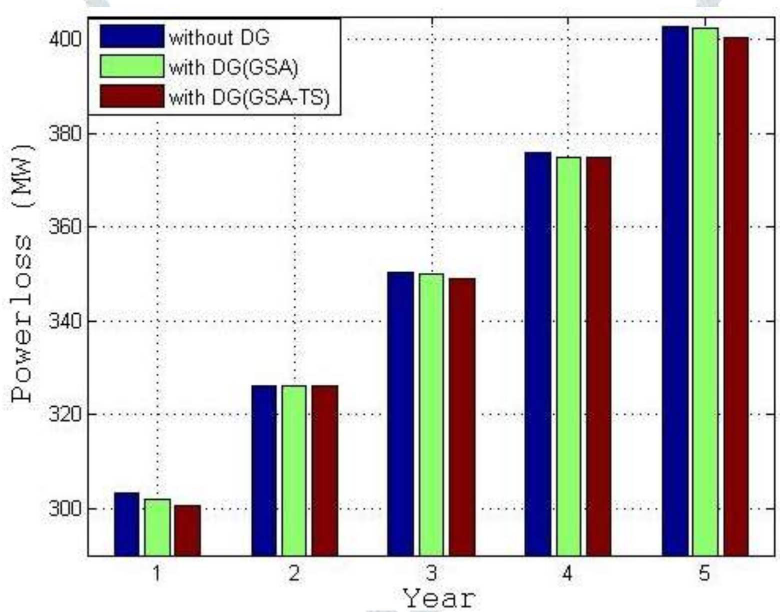

Figure.10: Comparison of convergence characteristic of objective function

The figure 9 explains the variable electricity market price of hourly curve for the distribution. From the figure, we obtained that the 24 hours electricity market price. Then the power loss of the IEEE 33 bus radial distribution system using different techniques like without DG, GSA and proposed method is explained in the figure 10 for 5 year planning period. In the whole period of analysis explained the effective planning of DG in the distribution system. During the planning of DG considers the bus power loss, because of load demand at each year. The power losses at whole planning period without DG have high losses, which has 10% high from the GSA technique. The GSA contains 5% high losses compare to the proposed hybrid method. Finally the comparison result shows that the effectiveness of the proposed method.

5. Conclusion

This paper proposed a multi-objective hybrid algorithm for planning electrical distribution system. Here the electrical distribution system planning is done by the combined GSA and tabu heuristic search method. The GSA actively minimized the investment cost of DG, cost of losses, operation and maintenance cost of DG, which is used to optimally locate the DG with optimum capacity. The Gravitational Search Algorithm (GSA) accelerates convergence speed with combination of the search strategy of Tabu heuristic search method. The proposed method is tested in the IEEE 33 bus radial distribution system and the performance was analyzed with different techniques like mentioned distribution system without DG and GSA. The comparison results were taken for the radial distribution system power loss, voltage at various conditions and cost. From the comparison results we finalized that the proposed method is the well effective technique to planning the electrical distribution system, which is competent over the other techniques.

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