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Gravitational Search Algorithm based Real Power Loss Minimization using Ideal Region of Facts Devices

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Abstract
Major goal of power schemes is to give reliable power supply to the consumers with guaranteed quality. The voltage magnitude of buses in the power scheme maintained within the prescribed boundary, would aid in the maintenance of power quality. The transmission loss in the existing power system involves the tax income of power sector at a considerable level. Number of methods are prescribed to reduce transmission losses. The ideal region of FACTS devices like TCSC, STATCOM including UPFC is the prescribed methods to concentrate the losses and to improve the voltage magnitude. The proposed work gives the optimal arrangement of the region of STATCOM in the transmission scheme. The weak buses are distinguished as the locations of STATCOM. Load flow analysis has been borne out using the the Newton - Raphson method. After executing the Newton-Raphson analysis, weak buses are identified. The recognition of weak bus, in the large power system network is framed as an optimization problem. To identify the weak bus and for the placement of STATCOM device, an algorithm like the Gravitational search is proposed. The fitness function for a gravitational search algorithm is the main focus in this work. The results show the improvement of bus voltages after the placement of STATCOM in the power system which is having weak bus. The standard system for the proposed work is considered from IEEE 30 bus test case.

Keywords: *FACTS (Flexible AC transmission system), TCSC (Thyristor Controlled Series Compensator), STATCOM (Static Synchronous compensator) , UPFC (Unified power flow controller), GSA (Gravitational Search Algorithm).*

I. INTRODUCTION

Reliable power supply to consumers with guaranteed quality is to provide. To maintain power quality and voltage magnitude of buses in power scheme should be kept within the prescribed value. The revenue of the power sector is affected to a considerable extent by the transmission loss in the existing power system. Several techniques are available to reduce the transmission line losses [1]. The region of FACTS devices like TCSC, STATCOM and UPFC is the prescribed methods to concentrate the losses and to voltage magnitude improvement [2]. Generators, tap changing transformer, static capacitors and so on are the sources of reactive power.Reactive power which is generated and its flow path in the grid network is carried by real I^2R loss minimization, which plays vital role for reliable performance of power system in respect to their system and voltage stability. Real and reactive power flows and latent difference could be worked by introducing FACTS devices to resolution of congestions. The FACTS devices identical of TCSC and SVC which are used in the power system network along with the real

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time VAR generators, the transmission losses significantly reduces [10], it also improves the electric potential outline is observed in the whole power system under study. Hence, the method to be resolved is a VAR power optimization problem which controls the VAR generators

In this proposed work, the location of STATCOM in the transmission system are discussed. The weak buses were located at the locations of STATCOM. Load flow analysis has been supported out by the Newton - Raphson method. After executing the Newton-Raphson analysis, weak buses were identified. The recognition of weak bus, especially in the event of large power system network is an optimization problem.

GSA method is used for planning reactive power as an optimization method through FACTS devices[3]. In order to minimize the Watt power loss , deviation in bus voltage magnitude are planned with a single objective optimization problem. To find a solution to a large power system with various constraints with optimal reactive flow. GSA is used in this projected work. The implementation of the GSA - algorithm examinations on the IEEE 30 bus examination cases [5].

II. PROBLEM FORMULATION:

The fitness evaluation is estimated by Gravitational force and inertia masses and its current valuesare solved with equations (1),(2).A heavier mass which is more efficient agent, and the better agents have higher attractions and walk much slower. Considering that gravitational and inertia mass are identical and by using the map of fitness, the values of masses are calculated :

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - wort(t)}$$

$$m_i(t) = \frac{fit_i(t) - worst(t)}{best(t) - wort(t)} \qquad (1)(1)$$

$$M_i(t) = \frac{m_j(t)}{\sum_{j=1}^{N} m_{j(t)}} \qquad M_i(t) = \frac{m_j(t)}{\sum_{j=1}^{N} m_{j(t)}}$$

(2)(2)

Where $fit_i(t) fit_i(t)$ characterise the fitness value of I *th* agent at *t* time, and also the minimization and maximization problem with respect to worst (t) and best(t) can be identified and discussed by the subsequent equations (3),(4) and (5),(6) :

$$best(t) = \min_{j \epsilon (1....N)} fit_j(t)$$

$$best(t) = \min_{j \epsilon (1....N)} fit_j(t) \qquad (3)$$

$$worst(t) = \max_{j \epsilon (1....N)} fit_j(t)$$

$$worst(t) = \max_{j \epsilon (1....N)} fit_j(t) \qquad (4)$$

$$best(t) = \max_{j \epsilon (1...N)} fit_j(t)$$

$$best(t) = \max_{j \epsilon (1...N)} fit_j(t) \qquad (5)$$

$$worst(t) = \min_{j \epsilon (1...N)} fit_j(t)$$

$$worst(t) = \min_{j \epsilon (1...N)} fit_j(t) \qquad (6)$$

III. OBJECTIVE FUNCTION:

The real function of exploration in this problem is to minimize the real power I^2R loss and voltage deviation which can be discovered by the rating shunt for compensating devices as well as the optimal settings of VAR power management variables. Hence, the following function can be considered as main objective function:

$$F = \min \{w P_L + (1-W)VD\} \qquad (7)$$

In the equation weighing for active power loss (w) and voltage deviation can be considered as 0.7.

REAL POWER LOSS MINIMIOZATION (PL):

The following can be given for the Overall real power calculation of the system

$$P_L = \sum_{K=1}^{N_L} G_K[V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_1 - \delta_2]$$

$$P_L = \sum_{K=1}^{N_L} G_K[V_i^2 + V_j^2 - 2V_iV_j\cos(\delta_1 - \delta_2] \qquad (8)$$

The aggregate quantity of lines(N_L) in system(G_k); also conductance of line („k”); scales of the sending end of the line and receiving end voltages (V_i and V_j).

The voltage angles at both ends will be $\delta\delta_i$ and $\delta\delta_j$

MINIMIZATION OF LOAD BUS DEVIATION IN VOLTAGE (VD):

In order to confirm the service quality, bus voltage magnitude in the acceptable range should be maintained. Also by minimizing the deviance between the load bus voltage within the reference value (it is taken as 1.0 p.u.), the voltage profile can be enhanced.

$$VD = \sum_{K=1}^{N_{PQ}} |V_K - V_{ref}|$$

$$VD = \sum_{K=1}^{N_{PQ}} |V_K - V_{ref}| \quad (9)$$

The followings are the equality constraints and inequality constraints of the minimization:

Equality Constraint (POWER TO THE LOAD FLOW CONSTRAINTS)

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_B} V_i V_j Y_{ij} cos(\delta_{ij} + \gamma_j - \gamma_i) = 0$$

$$P_{Gi} - P_{Di} - \sum_{j=1}^{N_B} V_i V_j Y_{ij} cos(\delta_{ij} + \gamma_j - \gamma_i) = 0 \quad (10)$$

Inequality Constraints (VAR PRODUCING LIMITS OF SVCS):

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max} ; i \in N_{SVC}$$

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max} ; i \in N_{SVC} \quad (11)$$

VOLTAGE CONSTRAINTS :

$$V_{Ci}^{min} \leq V_{Ci} \leq V_i^{max} ; i \in N_B$$

$$V_{Ci}^{min} \leq V_{Ci} \leq V_i^{max} ; i \in N_B \quad (12)$$

GRID NETWORK LIMITATIONS OF FLOW

$$S_i \leq S_i^{max} ; i \in N_l$$

$$S_i \leq S_i^{max} ; i \in N_l \quad (13)$$

CONSTRAINTS IN TAP POSITION :

$$T_{Pi}^{min} \leq T_{Pi} \leq T_{Pi}^{max} ; i \in N_T$$

$$T_{Pi}^{min} \leq T_{Pi} \leq T_{Pi}^{max} ; i \in N_T \quad (14)$$

IV. GSA ALGORITM

GSA could be figured as a group of candidate solutions whose (agents) masses are proportionate to their meaning of functional (fitness) performance and move with one another by the law of gravitation and motion of Newton. Through the generations (iterations), all masses attract one another by the gravitative forces between them and this gravitative force makes a global movement of all lighter masses objects towards the objects with heavier masses. A bigger mass has the larger attraction force. Thus, the heavier masses gives nearer to the global optimum attract the other lighter masses which is proportional to their lengths [9]. Hence a direct type of communication is employed by the masses, through gravitation. The significant masses correspond to smart solutions and move a lot of slow and conversely light-weight masses represent to poor solutions and move towards significant masses abundant quicker. Thus the rule based on an algorithm can be guaranteed by the exploitation step. After calculating acceleration of every element,the velocity of every element is updated with the changed rate. The location of the mass corresponds answer to the problem of optimisation and the fitness function can be represented by its mass.

In one case, the finding of the best locations and management for power system facility and security indexes, whether or not the power system facility is safe or not.Validation of the proposed work is presented as follows:

Best allocation and sizing of FACTS devices is projected by GSA methodology and implemented in the MATLAB platform. It generates a different variety of locations for locating the FACTS devices with totally random size values initially. Then, for generating every combination of placements and sizes of FACTS devices: the power flow method of the system is performed. From the power studies, bus voltages, line flow, total power losses are determined. From these determinations, fitness function of every combination is computed, on the fitness values of every combination, GSA proceeds for optimizing and determines the best positions and sizes of all FACTS devices.

To analyze the placement of FACTS devices can be tested with the standard IEEE 30 bus test cases by GSA methodology, the subsequent

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assumption is done: the type of FACTS devices to be set are selected first, Then the range of every FACTS device (for each type) should be selected.

The validation of the proposed work is carried as five totally different scenarios. They are taken in a sequence as without FACTs device installation, one UPFC, one TCSC [5] and one SVC..Here, power system under the first scenario is that the normal procedure of the network without plugging in no matter variety of types of FACTS device within the system. Other cases are based on the type of FACTS device considered for improving the power system security. For the mentioned three FACTS device allocation cases, GSA algorithm determines the optimal position.

The rule of algorithm experiments with a group of information, that move with one another through through the gravitative strength. The information of data are represented as objects and the object performance is quantified by their masses. A global movement caused by the gravity force wherever all the lighter objects move towards different objects with heavier masses. The slow movement of heavier masses corresponds to good solutions where it guarantees the exploitation step of the rule.

The GSA is the optimization rule supported the law of gravitation and also supports mass interactions. This rule is established on the Newton gravity. “Every particle within the universe attracts each different particle with a force that’s directly proportional to the product of their masses and inversely proportional to the square of the distance between them”. There is an isolated system of masses in GSA. Using the force (gravitational), each object’s mass within the system would take the place of different masses. This gravitation is a way of transmitting information through totally different masses. Agents are as objects and their execution is evaluated by their masses in GSA. These objects will attract one another by a gravity force, and this force features a motion of all lighter mass objects globally towards the objects with heavier masses. These significant masses correspond to solutions of the problem. The status of the objects corresponds to a resolution of the problem, and using a fitness function,the object's volume is specified. By masses and lapse of time are attracted by the heaviest mass,in the search space which would ideally present a best result. GSA could be represented as an isolated system of masses. It is like a short artificial world of masses which obey the Newtonian laws of gravity and motion [4]

The masses obeying the law of gravity as shown in Equation (15) and also the law of motion in Equation (16).

$$F = (G(M1M2 \backslash R2) \qquad (15)$$

$$a = F\backslash M \qquad (16)$$

As per Equation (15), the scale of gravitation(F), gravitation constant(G), M1 is the lot of the first objects and M2 is the lot of second objects and the length between the two targets (R). Gravitational Search Algorithm law of gravity as per Equation(1), The gravitation between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between the objects. As per eqution (2), Newton’s second law indicates that once a force, F, is applied to an object, its acceleration, (a), depends on the force and its mass(M). The agent has four parameters which are position of the mass represented the result of the problem and using fitness function the gravitative and mechanical phenomenon masses are defined. The rule is navigated by varying the gravitational and inertial masses, whereas all the masses presents a solution. Lighter masses are attracted by the significant heavy mass. Hence within the search area, the heaviest mass presents an optimum solution.

The carrying out of GSA technique has been conformed to the optimization of parameters, defining cost, strategies, power dispatch and also voltage control is shown better solution.

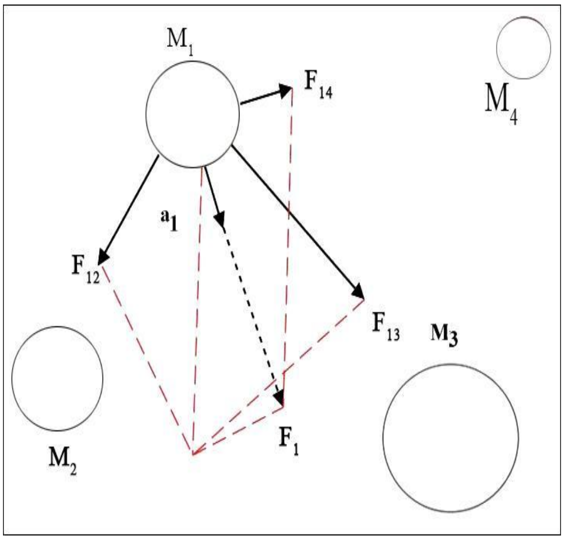

Figure 1. Gravitational Search Algorithm.

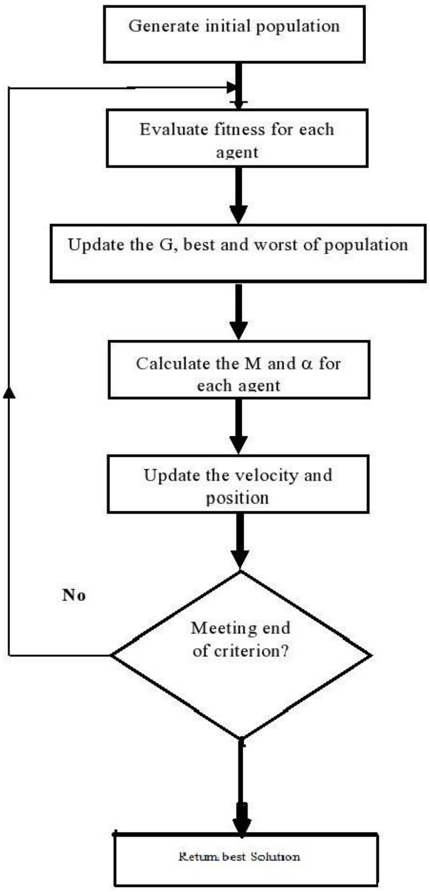

Figure 2. Flow Chart (GS Algorithm)

ALGORITHM FOR OPTIMAL FACTS DEVICE PLACEMENT USING GSA:

i) The input information including the location of FACTS devices, range of FACTS devices are defined.

ii) Generate an initial population (position of an agent in the search space) and an initial velocity and set iteration t=0.

iii) select the agent in the population.

iv) compute the fitness function

In this measure, load flow of the system is studied for that FACTS location and contents. From that, bus voltages and line power flows are defined. Using the bus voltages, line powers, power losses, installation costs; fitness function is computed utilizing the equation.

v) Parameters like the gravitational constant, nest fitness, worst fitness and mass of the agent is updated by using equation (14).

vi) The force of attraction on each agent due to another agent attractions is computed using equation (15).

vii) Compute the acceleration of each agent

In this measure, the acceleration of each factor is computed using equation (16) based on the force of attraction on it and self-mass of the agent.

viii) Each agent position is updated using equation (1). Here first, the velocity of the each is updated and using that next position of the agent is determined.

ix) If all agents are selected, go to the next step. Otherwise iteration counts (t=t+1) and proceed back to Step iii).

x) check the stopping criteria. If the stopping criteria satisfied finish the algorithm and provide the optimal placement & size of FACTS devices, else proceed to Step (iii) until the convergence criteria met.

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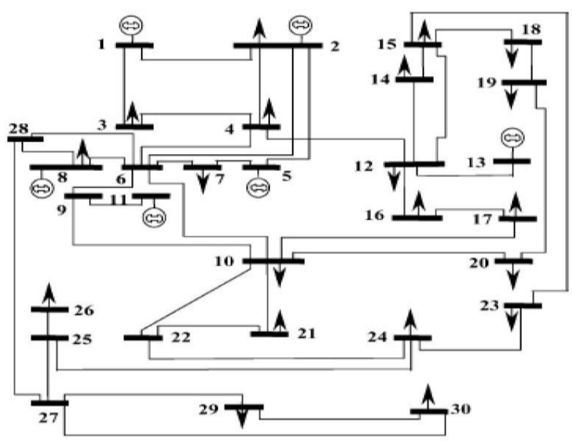

Figure.3. 30 Bus (IEEE) system single line diagram representation

The test system consists of generating units(six) connected to buses 2,5,8,11,12 and 13 and four r transformers for regulation are interconnected between bus numbers 27-28, 4-12, 6-9 and 6-10. With the bus numbers 10 and 24, two shunt compensators are connected. Also by 41 transmission lines the overall system is interconnected. Here generator's voltages tap changer position of the regulating transformers which regulates and VAR production of shunt capacitors are control variables.

V. POWER FLOW ANALYSIS OVERVIEW

Power Flow Analysis plays an important tool for the considering of new networks for future development to meet the increasing grid demand. The phase angles and nodal voltage magnitude and so the power injection at all the buses and the power flows through interconnecting power channels are given by this power flow analysis. It regulates the bus voltage. At certain buses,the voltage level must be maintained by closest acceptances is analyzed by using Newton-Raphson, Gauss Seidal method [8]

As per the analysis,the line should not operate closer to their thermal limits or stability and it should not be overloaded.

Under steady state condition, the analyze of the generator, transmission lines and transformer for the operation is carried out. Analysis is implemented by using MATLAB.

INPUT DATA

Table 1. Input Data

From Bus	To Bus	R (pu)	X (pu)	B/2 (pu)	X' (pu)
1	2	0.0192	0.0575	0.0264	1
1	3	0.0452	0.1652	0.0204	1
2	4	0.057	0.1737	0.0184	1
3	4	0.0132	0.0379	0.0042	1
2	5	0.0472	0.1983	0.0209	1
2	6	0.0581	0.1763	0.0187	1
4	6	0.0119	0.0414	0.0045	1
5	7	0.046	0.116	0.0102	1
6	7	0.0267	0.082	0.0085	1
6	8	0.012	0.042	0.0045	1
6	9	0	0.208	0	0.978
6	10	0	0.042	0	0.969
9	11	0	0.208	0	1
9	10	0	0.11	0	1
4	12	0	0.256	0	0.932
12	13	0	0.14	0	1
12	14	0.1231	0.2559	0	1
12	15	0.0662	0.1304	0	1
12	16	0.0945	0.1987	0	1
14	15	0.221	0.1997	0	1
16	17	0.0824	0.1923	0	1
15	18	0.1073	0.2185	0	1
18	19	0.0639	0.1292	0	1
19	20	0.034	0.068	0	1
10	20	0.0936	0.209	0	1
10	17	0.0324	0.0845	0	1
10	21	0.0348	0.0749	0	1
10	22	0.0727	0.1499	0	1
21	23	0.0116	0.0236	0	1

IEEE 30 bus test system will carry out the Load flow analysis. voltage angle values and output voltage magnitude from for IEEE 30 bus system. All data are calculated in per unit.

The voltage magnitude and angles of a IEEE30 bus test case were mentioned for the different values of the reactance loading and the

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results have been given. It can be concluded that there will be an increase in voltage regulation for any increased reactance loading from the results.

OUTPUT DATA

Table .2. Output Data

From Bus	To Bus	Voltage Value without STATCOM	Voltage Value with STATCOM
1	2	0.9927	1.0920
1	3	1.0208	1.1229
2	4	1.0336	1.1369
3	4	0.9863	1.0849
3	5	1.0230	1.1253
3	6	1.0347	1.1382
4	6	0.9849	1.0833
5	7	1.0217	1.1238
6	7	1.0008	1.1009
6	8	0.9850	1.0835
6	9	0.9720	1.0692
6	10	0.9720	1.0692
9	11	0.9720	1.0692
9	10	0.9720	1.0692
4	12	0.9720	1.0692
12	13	0.9720	1.0692
12	14	0.1329	0.1462
12	15	1.0435	1.1478
12	16	1.0741	1.1815
14	15	0.2387	0.2625
16	17	1.0610	1.1671
15	18	0.1159	0.1275
18	19	1.0410	1.1451
19	20	1.0087	1.1096
10	20	1.0731	1.1804
10	17	1.0070	1.1077
10	21	1.0096	1.1105
10	22	1.0505	1.1556
21	23	0.9845	1.0830
15	23	0.1080	0.1188
22	24	0.1242	0.1366
23	24	0.1426	0.1568
24	25	0.2036	0.2239
25	26	0.2748	0.302
25	27	0.1180	0.1298
28	27	0.9720	1.0692
27	29	0.2374	0.2611
27	30	0.3458	0.3804
29	30	0.2591	0.285
8	28	1.0407	1.1448
6	28	0.9903	1.0893

Voltage Magnitude:

The analytical quantities inferred from table 2 gives the values of voltage in various buses of the system under study. It is observed that if the loads that are free from voltage influence, the values of voltages is lower than that of the voltage dependent loads on comparison. Taking the primary case, the production of active power is highly pronounced in the event of the values of voltages is higher than 1 p.u. unification of voltage dependent loads proves a ripple less flat voltage profile, which shows that the load flow has ramped up effect on the values of voltages below 1 p.u and decreases those higher than 1 p.u [7].

Swing bus Active power:

Taking both the kind of loads the swing bus real power has a variance of 2.5% , which is very significant quantity, and one of the reasons for a total drop in the power output and hence the drop in cost of generation of active(real)power. The real power variance is correlated with power factor and voltage. And it is highly impracticable to forecast from the conventional load flow analysis without taking the integration of the loads which is dependent on voltages

Load Active power:

Taking the references from the Table 2 it gives the gives evidence regarding the load of the real powers at various buses that are available. The active power used on the load in various buses taking the item of voltage dependent and independent loads is dissimilar. Considering of the voltage loads which are dependent, the active power consumed is lower when associated with the voltage independent loads. The lowering of the Decrease real power consumption guarantees lowers the loss and improved security and stability of the power system.

Load Reactive power:

Taking the instances of different buses with its reactive component it doesn't have the

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following up any particular similarity in its configuration [4]. Taking the instances of some buses they have elevated values for voltage reliant loads and at some point, they have lesser values. But principally the variation is in-between 0.6% to 4.2 %.

Comparison of all the instances

It has been resulting from the overall assessment that, in the instant of load modelling for the above cited magnitudes have a lesser value as linked to that of conventional load flow. There is a borderline decline in generation cost and total losses.

VI. CONCLUSION AND FUTURE SCOPE:

A GSA algorithm, for the optimal positioning of FACTS devices (STATCOM) was presented in this proposal. The optimization of these devices was done based on the factors such as voltage stability and limited line power flow and reduction of power losses in economic operation and cost of the device. The validation of the proposed GSA method was performed on IEEE 30 bus test system. The inference of simulation, it was established that the recommended GSA method had placed the FACTS devices in optimal locations which enhanced the security indexes and thereby enhancing the security of the power system.

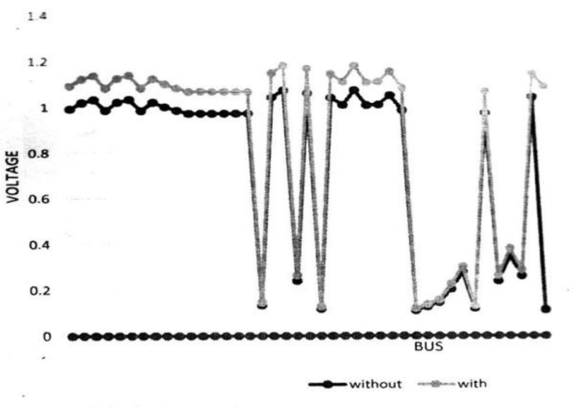

Figure. 4.Comparison results with and without SCATCOM

VII. FUTURE SCOPE:

For almost all optimization problems, GSA offers an effective, highly precise and high-quality solution. The algorithm has solved various optimization problems and also applied in various applications such as, controller design,in the power system, network routing, software design, sensor networks, antenna and micro grids.

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