

Performance Analysis of a Novel Hybrid Optimization Technique for Sizing and Placement of DG Units

S Bakshi^{1*}, T Thakur² and R Khanna³

Department of Electrical Engineering, PEC University of Technology, Chandigarh, India

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In today's scenario Distributed Generation (DG) resources have gained a lot of attention due to their positive impact on distribution system. Multisource hybrid power generation system with the utilization of Renewable Energy Resources (RES) is of greater concern considering environmental aspects. The considered resources are photovoltaic panels, wind turbine and battery storage. This paper attempts to solve this problem using a hybrid Modified Human Opinion Dynamics Gravitational search algorithm (MHODGSA) based Optimization algorithm and compares the solution of the stated multi-objective problem with that of (Gravitational search algorithm) GSA optimization techniques for 33 Bus Distribution System. The results of MHODGSA method is found to be moderately better than the GSA method in terms of accuracy while there is a significant improvement in terms of convergence.

Keywords: RES, Multi Objective Optimization, Optimization Techniques, Distributed Generation (DG)

Introduction

The hybrid system is defined as a way of organizing or doing something that is composed of element of two separate systems. It is the combination of two or more different things, aimed to achieve particular objective or goal. There are various advantages of hybrid systems like the strength of one resource can overcome the weakness of other during a certain period of time, construction of this type of power plant do not require grid expansion, and integration of two resources makes the system more stable and reliable throughout the year. Omalley *et al.*¹ proposed optimal Distributed Generation within the Irish system by employing affected approach of linear programming. The target of the planned methodology was to take advantage of the Distributed Generation. Kashem *et al.*² proposed a systematic method to work out the best Distributed Generation supported power loss sensitivity investigation The method used by them was supported as it minimized the power losses of distribution system. Acharya *et al.*⁴ proposed the progressive modification of the system power losses with relation to the modification of injected real power sensitivity issue. This issue was discussed to verify the bus and inflicting the losses to be best for hosting a Distributed Generation. Gravitational Search Algorithm (GSA) is an analytical algorithm for

optimization that has been becoming a popular area in research filed⁵⁻⁷. However, this technique is currently been condemned for not fully based on the law of gravity³. GSA was introduced by Rashedi *et al.* in 2009 and is intended to solve optimization problems. The population-based heuristic algorithm is based on the law of gravity and mass interactions¹⁴. Different researchers have performed various experiments in this area¹⁵⁻¹⁶. The Human Opinion Dynamics based Optimization technique is a novel meta-heuristic algorithm based on the group discussion behavior of humans. As the humans interact with each other, their opinion about any particular topic starts varying. MHOD model has been motivating research area and many researchers put their methods and theory to match the things in real life into mathematical model⁸⁻¹⁰. Human opinion dynamic model is employed to improve continuous opinion dynamics optimizer. The model has four basic fundamentals such as social structure arrangement, social impact, point view area and restore order. A new model is developed which is known as cellular automata model (CAM). This Cellular automata model is the one of the form of Moore's neighborhood in which all characters are involved¹¹⁻¹³.

Methodology of hybrid algorithm

A hybrid population-based algorithm (MHODGSA) is recommended along with the combination of Modified Human Opinion Dynamics (MHOD) and

*Author for Correspondence
E-mail: surbhi_pec@yahoo.com

Gravitational Search Algorithm (GSA). In this paper, the hybridization of MHOD is performed with GSA, to produce strength of both algorithms, using low-level co-evolutionary approach which is also heterogeneous.

In MHODGSA, initially, all opinions are randomly started. Each opinion is measured as a solution of candidate. After initialization, gravitational constant, gravitational force and resultant forces among opinions are calculated. Further, the accelerations of particles are mentioned. The social ranks of agents are considered which is calculated on the basis of mass of each agent. This rank is utilized for weighting the updation of each agent according to the formula given by gravitational search algorithm. Thus the local search capability of GSA and social influence of MHOD are utilized and the results are compared.

Algorithm for MHODGSA

Algorithm: optimal sizing and allocation of DG

Begin

Initialize opinions for size and bus numbers

Allocate size and bus number to opinion1 and opinion2

n: number of buses in system

l: number of transmission lines

lp: number of loops

np: number of particles d: the domain space

f(x): objective function as a function of voltage and losses

Define the objective function of f(x), where

$x = (x_1, \dots, x_d)$

Generate the initial population of particles or x_i

($i=1, 2, \dots, n$)

While ($i < lp$)

 For $j=1$ to np (all opinions)

Allocate bus number and size

Apply Newton Raphson and load flow

Calculate voltage at each bus and total line losses

Formulate cost function

Calculate the fitness corresponding to each particle and use HOD for social rank calculation

Convert Social Rank into Social Score based on cost function using MLE

End for

Store best individual to bfn

For $j=1$ to np (all opinions)

For $k=1$ to np (for all opinions)

If k not equal to j

Calculate social influence w_{jk}

End if

End for

Use Social influence as force between the particles and calculate force between each pair

Calculate acceleration using Force/mass

Calculate velocity and position

Calculate adaptive noise standard deviation

If j not equal to bfn

Update position of each particles using discussed equation

Convert particles of bus number to integer

End if

 If $error < threshold$

Break out of loop

End if

End while

End procedure

Problem formulation

Load flow problem

The problem of load flow in power system forms an example of classic engineering problems in power system. In most of the cases of circuit analyses, the network components are limited to known value of impedances with current and voltage source. But the load flow problem is different because instead of impedances, the known quantities are active and reactive powers at most network buses, because behavior of most of the load in a lot of cases are as constant power loads, assuming that voltages applied on them remains within acceptable ranges. The set of unknowns producing power balance at all of the specified buses in the system is solved by the load flow algorithm. Stated otherwise, the specified power at a particular bus must be same as that of the power flowing into the system. The power which is generated is taken as positive power, which makes it consistent with KCL equation $\sum YV = I$. Since two unknowns are present at every bus, the load flow problem is of the size $2N$, where N denotes the number of buses. So, there is a requirement of two additional equations at each bus. These are obtained from the KCL equations. The problem now is to find a set of bus voltages which satisfies these equations⁸ stated.

Optimal sizing problem

The use of Distributed Generation units is well known for solving load shedding problem and it has been shown to reduce the losses incurred in the transmission lines. The problem statement of this paper is to minimize this loss and improve the voltage stability by developing a novel meta-heuristic algorithm which would solve the problem of optimal sizing and allocation of the newly added DG unit. A multi-objective constraint optimization problem is formed using the voltage of buses and the losses in the transmission lines. The aim is to bring the voltage of each bus close to unity and also to minimize the total losses incurred in the transmission lines. The solution obtained is a pseudo-optimal solution and the weightage given to the losses or the voltage depends on the type of application. The objective function is represented by $f(x)$ as shown below.

$$f(X) = t_1 * \sum_{i=1}^n \text{loss}_i + t_2 * \sum_{i=1}^m (1 - V_i)^2 \quad \dots (1)$$

Where t_1 and t_2 are the weights assigned to the loss minimization and voltage stabilization. 'n' represents the number of transmission lines and 'm' represents the number of buses.

Selection of weights for the objective function

Although the selection of weights for the objective function is a task left to the user as it represents the importance of our proposed two objectives (loss minimization and voltage improvement), there is a need to give a thought to the selection depending on application. In our problem, we have taken the weights ' w_1 ' as 0.7 and ' w_2 ' as 0.3, assuming that loss minimization is our main objective. Hence the solution found in our method is not the optimal solution but a pseudo-optimal solution.

Load flow

Different types of load flow buses are classified in tabular form provided below (Table 1). The set of unknowns producing power balance at all of the specified buses in the system is solved by the load flow algorithm. The power balance equation is given by equation,

$$P_i^{\text{given}} + jQ_i^{\text{given}} = P_i^{\text{comp}} + jQ_i^{\text{comp}} \quad \dots (2)$$

Where, $P_i^{\text{comp}} + jQ_i^{\text{comp}} = V_i I_i^*$, Stated otherwise, the specified power at a particular bus must be same as that of the power flowing into the system. The power which is generated is taken as positive power,

which makes it consistent with KCL equation $\sum V = I$. Since two unknowns are present at every bus, the load flow problem is of the size $2N$, where N denotes the number of buses. So, there is a requirement of two additional equations at each bus. These are obtained from the KCL equations as given below:

$$P_i^{\text{given}} + jQ_i^{\text{given}} = P_i^{\text{comp}} + jQ_i^{\text{comp}} = V_i I_i^* = V_i \left[\sum_{j=1}^N y_{i,j} V_j \right]^*$$

The above stated equation is then separated into real and imaginary components as shown:

$$P_i^{\text{given}} = P_i^{\text{comp}} = \sum_{k=1}^N |V_k| |y_{k,i}| |V_i| \cos(\delta_k - \delta_i - \theta_{k,i})$$

$$Q_i^{\text{given}} = \sum_{k=1}^N |V_k| |y_{k,i}| |V_i| \sin(\delta_k - \delta_i - \theta_{k,i}) \quad \dots (3)$$

Where, $V_k = |V_k| \angle \delta_k, V_i = |V_i| \angle \delta_i, y_{k,i} = |y_{k,i}| \angle \theta_{k,i}$. The problem now is to find a set of bus voltages which satisfies these equations stated above.

Results and Discussions

Table 2 is showing the comparison among results of 33 bus systems of hybrid system and GSA technique based on various simulation parameters. Table 3 represents the bus voltages for both the applied techniques. The voltage values can be seen as varying slightly with respect to the GSA based tuning of DG unit. Figure 1 and 2 represents the movement of the particles as with iterations. Initially the objects are distributed randomly and as the iterations increases the objects start to converge towards common points. The convergence represents that our algorithm gives us a unique solution. In our case these objects are bus number and size of the DG unit.

Table 1-Different types of Load Flow Buses

Classification	Known Parameter	Unknown Parameter
Load Bus or PQ bus	P, Q	V, δ
Generator Bus or PV bus	P, V	Q, δ
Swing or V, δ bus	V, δ	P, Q

Table 2-Comparison among results of 33 bus system of Hybrid system and GSA

	MHODGSA	GSA
Bus System	33	33
Optimal Bus No	22	19
Loss(MW) without DG	9.0235	10.645
Loss (MW)With DG	7.4058	9.2854
Optimal Size (kW)	72.9764	47.4070

Table 3-Output with DG value of voltage (33 Bus)

Bus no.	Voltage (MHODGSA)	Voltage (GSA)
1	1.0400	1.022
2	1.0400	1.027
3	1.0350	1.029
4	1.0399	1.0200
5	1.0383	1.0250
6	1.0300	1.023
7	1.0439	1.029
8	1.0350	1.030
9	1.0300	1.030
10	1.0701	1.0504
11	1.0565	1.0485
12	1.0650	1.0450
13	1.0619	1.0488
14	1.0639	1.0499
15	1.0546	1.0447
16	1.0643	1.0489
17	1.0597	1.0510
18	1.0919	1.0859
19	1.1263	1.1151
20	1.1372	1.1228
21	1.1931	1.1625
22	1.1935	1.1755
23	1.1947	1.1185
24	1.2016	1.1192
25	1.2320	1.0919
26	1.1499	1.1158
27	1.1196	1.0986
28	1.1029	1.0876
29	1.0897	1.0773
30	1.2497	1.1100
31	1.2764	1.1484
32	1.2779	1.2010
33	1.2827	1.2028

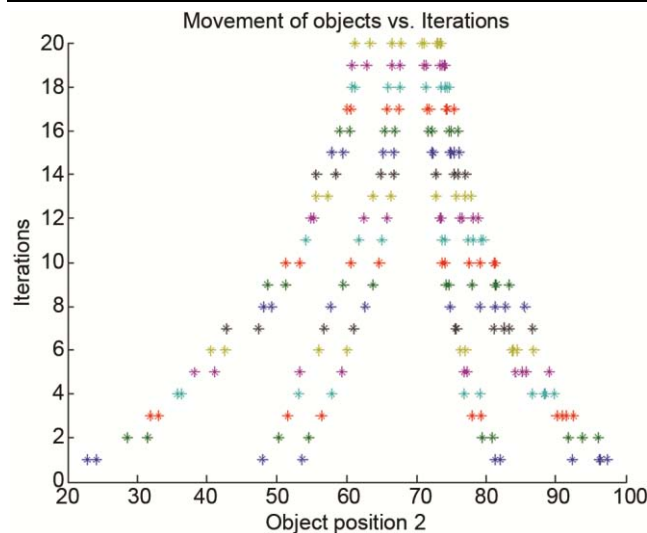


Fig.1-Convergence graph for object position 2

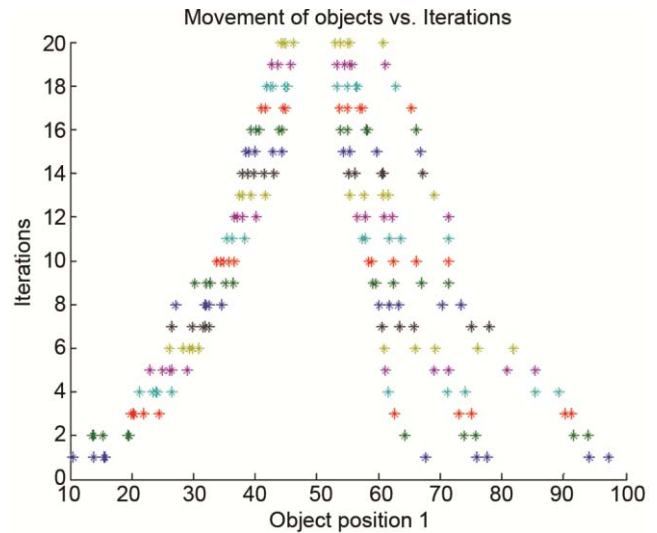


Fig.2-Convergence graph of GSA

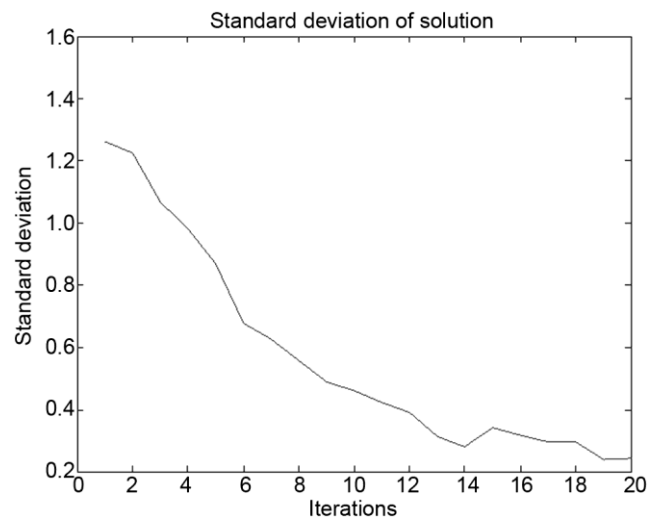


Fig.3-Deviation plot of MHODGSA algorithm

The bus number only changes its values according to integer values. Figure 3 represents the deviation plot of our hybrid algorithm. The deviation plot represents the standard deviation values of each column of the particles movement and since the deviation is high initially hence it must converge to lower values. As shown our hybrid algorithm converges faster i.e. the standard deviation values converge faster in comparison to the GSA algorithm.

Conclusion and future scope

The research implements a novel hybrid opinion dynamics based Gravitational Search algorithm for optimal sizing and placement problem in Distributed Generation in IEEE 33 bus system. The algorithm was

developed using a concept of opinion dynamics into traditional GSA algorithm. The traditional GSA algorithm performs better in case of local search while opinion dynamics increases the explorability. The results are compared and it is found that our algorithm performs better than traditional both in terms of convergence time and losses of the bus system.

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