Multi-objective Modeling for Optimal Placement of Distributed Generation Resources in Electrical Railways of Azerbaijan District Using DAPSO Algorithm

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ABSTRACT: high volume of investment and increase of energy and equipment price caused designers of distribution networks to apply more accurate and more suitable methods for designing these networks. Emergence of distributed generation resources in distribution systems has allowed companies to design systems with lower cost while changing stages of operating these systems. To achieve this goal, stages of designing distribution systems should be revised. In this paper, a multi-objective model was presented for optimal placement of distributed generation resources in electrical railway network and the main goal is to optimize costs of investment, operation and improvement of the profile of voltage and losses.
Keywords: Distributed generation resources, Electrical Railway, DAPSO algorithm, optimal placement, Multi objective.

INTRODUCTION

Distributed generation resources are in fact the generation units with low capacity which are connected near the customers in distribution systems. Utilization of DG can lead to reduction of the system investment costs by postponing construction of new equipments, improving voltage and reducing losses of system. In addition, DG can be used to improve reliability of the Customers' service. On the other hand, the presence of DG in distribution systems increases complexity of design and development of these systems and makes use of the available methods inefficient for solving it. Therefore, problem of design and development of distribution systems should be reviewed in the presence of DG and this requires formulation of new models and methods for solving it.

Necessity of constructing distributed generation due to the presence of new technologies can have considerable effective on flexibility, reliability and emergency charge of the network and economic investment in power sale section in electrical railway. They can cause to lower losses of overhead transmission network, improve quality of power, speed and facility of decision making, and take action regarding operation of generators for feeding electrical line network. Fivefold increase of security of electricity industry against military attacks and reduction of need for construction of new capacities of transmission and distribution network are of other advantages which they have.

Considering public interest of metropolises of Iran for having subway, study of experiences of Tehran metropolis can be effective in design of power systems of other cities. Expansion of urban railway and subway lines and supplying its power through distributed generation is able to reduce load of power system and increase security of power supply of Azerbaijan electric railway and subway.

In paper (K. Nara , Y. Hayashi, 2001), Search algorithm method has been used for determination location and optimal capacity of DGs from the viewpoint of minimum losses. In other words, writer discusses about application of TS method for optimal allocation of DGs on demand side of a distribution system to reduce losses of distribution. It utilizes nested use of Tabu Search algorithm for determination location and optimal capacity of DGs.

To determine type, size, and optimal location of distributed generation, genetic algorithm based method has been used in paper (J.H. Teng, T.S. Luor, 2001) in order to increase reliability of system (reducing cost of power outage and power cost storage) and determine profit. Types of DGs used in this paper are mini gas turbine and fuel cell.

Paper (C. Tautiva , A. Cadena , 2009) has developed a heuristic method based on genetic algorithm for determining optimal location and size of distributed generation in order to maximize total profit., technical aspects such as energy losses, voltage level and reliability as well as economic aspects such as energy price, investment, operating costs of distributed generation, cost of losses and unsupplied energy are considered.

In paper (H. Falaghi, M.R. Haghifam, 2007) ACO-based algorithm has been used to find optimal size and location of distributed generation in a power distribution system in order to minimize investment cost and operating cost of the entire system. In the model presented in this paper, load fluctuation time model in a year as well as DG resources optimum operation strategy in the system is considered.

In paper (P. Prakomchai , 2010) , the aim is DG placement on power network using MPSO or multi objective algorithm for minimizing economic cost of distributed generation and environmental pollution emission in the network.

In paper (G. Celli, S. Mocci, 2005), a multi objective approach has been used for solving simultaneously insertion of different kinds of distributed generation and optimal allocation of distributed generation with environmental constraints. The used algorithm is based on genetic algorithm and the goal is to save energy for reducing greenhouse emission and the objective functions include network increasing cost, energy losses cost, unsupplied energy cost, daily load diagrams and environmental pressure of DG. In paper (T. Sutthibun and P. Bhasaputra, 2010), goal is optimal multi objective placement of distributed generations using simulated annealing which finds the optimal location and size of DGs with shorter computing time than GA and TS. Main goal of this paper is to minimize power losses and environmental pollution emission.

Paper (M. Sedighizadeh, A. Rezazadeh, 2008) has used intelligent genetic algorithm for optimal placement and sizing of distributed generation resources. Objective function of this paper is to minimize losses.

In paper (M. Lezama, A. Padilha , 2009), sizing and insertion of system in distribution networks have been studied to find optimal solution to perform two applied goals of social welfare maximization and profit maximization utilizing a method based on Locational Marginal Prices (LMP).

In paper (V. Reshmi, M. Ebenezer, 2010), sum of powers method has been studied based on theory of directed branches and direct relationship between losses and branches of network during injecting active and reactive powers has been considered.

Mathematical multi-objective modeling of DG placement problem objective function

The main aim in this section is to determine location, size, and type of distributed generation resources in electrical railway network to improve the following three goals: 1) profile of voltage 2) loss power, 3) total system cost function.

Each of these goals has been converted into an individual function using weighted coefficients. Generally our objective function is as follows:

$$Min\, f_T = a_1.F_{n.prof} + a_2.F_{n.loss} + a_3.F_{n.\cos t} \qquad (1)$$

Voltage profile objective function

$$Min\ f_T = a_1.F_{xprof}\,|V_{ref} - V_i| \qquad (2)$$

This part of objective function indicates voltage deviation of different buses of the network from its reference value and shows voltage loss in the network.

$$f_{n.prof} = \frac{f_{prof}}{f_{bprof}} \qquad (3)$$

f_{prof}: loss of base voltage of profile after installation of DG
f_{bprof}: loss of base voltage of profile before installation of DG
f_{nprof} :normalized value of voltage profile
V_{ref} :Root-mean-square (rms) voltage
V_i: bus voltage i

As observed above, we divide value of function by value of profile without DG to normalize the profile function which indicates that the voltage profile rate should be improved after installation of DG. It is necessary to note that this state holds true for losses and cost.

Lines losses objective function

This part of objective function includes the loss power on lines of the network.

$$\min f_{loss} = \sum_{i=1}^{n_b} \sum_{j=1}^{n_b} \alpha(i,j) \times z(i,j) \times I^2(i,j) \quad (4)$$

$\alpha(i,j)$: decision variable which indicates relationship or lack of relationship between buses.

$$f_{n.loss} = \frac{f_{loss}}{f_{bloss}} \quad (5)$$

n_b: the number of buses
$f_{loss:}$ value of losses objective function in the presence of DG
f_{bloss}: value of losses objective function in the absence of DG
$F_{n.loss}$: normalized losses objective function
Z(i,j): impedance of line between buses i and j
I(i,j): value of current which exists between two buses i and j.

Cost objective function

This part of objective function is divided into two parts. The first part relates to the fixed costs which includes primary investment costs which should be spent at the beginning of planning period. The second part relates to variable costs which include costs of maintenance and operation of DGs which are spent during planning period in the system.
In general, cost function includes three parts which is calculated according to the following formula:
Min $f_{cost} = IC_{DG} + OC_{DG} + OC_{SS}$ (6)

Installation cost of DG (IC_{DG})

This cost is of fixed type and is spent at the beginning of planning period and includes installation cost of each DG in distribution network which depends on its type and capacity.

$$IC_{DG} = \sum_{i=1}^{ndg} IC(\beta(i)) \quad (7)$$

β(i): indicates type and capacity of the selected DG which is a number between 0 and 5 considering hypotheses of the problem . Zero indicates that DG has not been installed in the desired place.
ndg: the number of candidate places for installation of DG
IC: cost of DG installation in candidate place which is determined considering its type.

Operation cost of distributed generation resources (DC_{DG})

This part of objective function is divided into two parts. The first part is relate to repair and maintenance cost of the distributed generation resources, which is equal to a definite value considering type and capacity of each DG, and the second part includes operation cost of DGs which is determined considering type of selected DG.

$$OC_{DG} = \sum_{t=1}^{nt} (f_{pw})^t \sum_{t=1}^{ndg} [Mc(\beta(i)) + CP_{DG}(\beta(i))] \times 8760 \quad (8)$$

$$f_{pw} = \frac{1 + Infr}{1 + Intr} \quad (9)$$

Nt: period of planning (year)
f_{pw}: economic coefficient for converting costs which are spent during the period into their current value
I_{ntr}: annual interest rate
I_{nfr}: annual inflation rate
Mc(B(i)): repair and maintenance cost which is specified by determining its type and size.
CPDG(B(i)): operation of DG(i) which depends on its power and type of DG which is operated.

Operation cost of overhead network

This section relates to cost of power received from overhead network for supplying loads of the network and lines losses which is calculated from the following relation:

$$OC_{ss} = \sum_{t=1}^{nt} (f_{pw})^t \times P_{ss} \times K_{ss} \times 8760 \quad (10)$$

$$P_{ss} = \sum_{i=1}^{nlp} P_l(i) + \sum_{j=1}^{nf} P_{loss}(j) - \sum_{k=1}^{ndg} P_{DG}(\beta(k)) \quad (11)$$

Constraints

Objective function along with a set of limitations forms general model for placement of distributed generation resources. Taking into account necessity of considering the network constraints and operation of equipments, it is essential to include the following constraints in the optimization model.

Power balance constraint

$$P_{slach} + \sum_{k=1}^{ndg} P_{DG}(k) = \sum_{i=1}^{ndg} p_L(i) + \sum_{j=1}^{ndg} P_{loss}(j) \qquad (12)$$

Constraints of active and reactive powers

$$Q_{DGi}^{\min} \le Q_{DGi} \le Q_{DGi}^{\max}$$

$$P_{DGi}^{\min} \le P_{DGi} \le P_{DGi}^{\max} \qquad (13)$$

Losses constraint

$$\sum P_{loss}(withDG) < \sum P_{loss}(withoutDG) \qquad (14)$$

Voltage profile constraint

$$F_{profil.Voltage}(withDG) > F_{profil.Voltage}(without\ DG) \qquad (15)$$

Buses voltage constraint

$$v_i^{\min} \le |v_i| \le v_i^{\max} \qquad (16)$$

Buses current constraint

$$|I_i| \le |I_i|^{\max} \qquad (17)$$

Cost constraint

$$Cost(with\ DG) < \cos t(without\ \ D) \qquad (18)$$

Final objective function

Considering objective function (F_T) and constraints of the problem (that here minimization of objective function considering constraints is desirable) and to insert constraints of the model, final objective function has been defined as follows:

$$\mathrm{Fit} = \mathrm{F_T} + \mathrm{C_p} .\ \mathrm{JAR} \qquad (19)$$

Where the second part indicates penalty of each element according to violation of constraints of the model.

$$d_i = \begin{cases} 0 & G_i \le b_i \\ (G_i - b_i)/b_i & otherwise \end{cases}$$

$$JAR = \sum_{iIc} di \qquad (20)$$

In this relation, JAR(i) is inactivity rate of particle and Cp is penalty coefficient (very large number). If the constraint of the problem, infeasibility of particle is obtained through the above relation. In this relation, is pass rate from the constraint and Ic is a set of constraints which have been violated by chromosome.

Optimization algorithm and decision variables coding (β(i))

To optimize the problem, DAPSO algorithm was used which has been presented in the following flowchart. To form the primary populations randomly, for starting optimization operations, decision variables are coded. Here, any population is based on number of candidate places of DG and any particle is a number between 0 and 5 that 0 indicates no installation of DG. According to the hypotheses which have been considered for types of DG in this paper, five capacities of DG have been considered as PQ bus which is synchronous and modular. Other numbers (1 to 5) indicates capacity of DG in the desired candidate place. This coding is as follows:

0-5	0-5	....	0-5	0-5

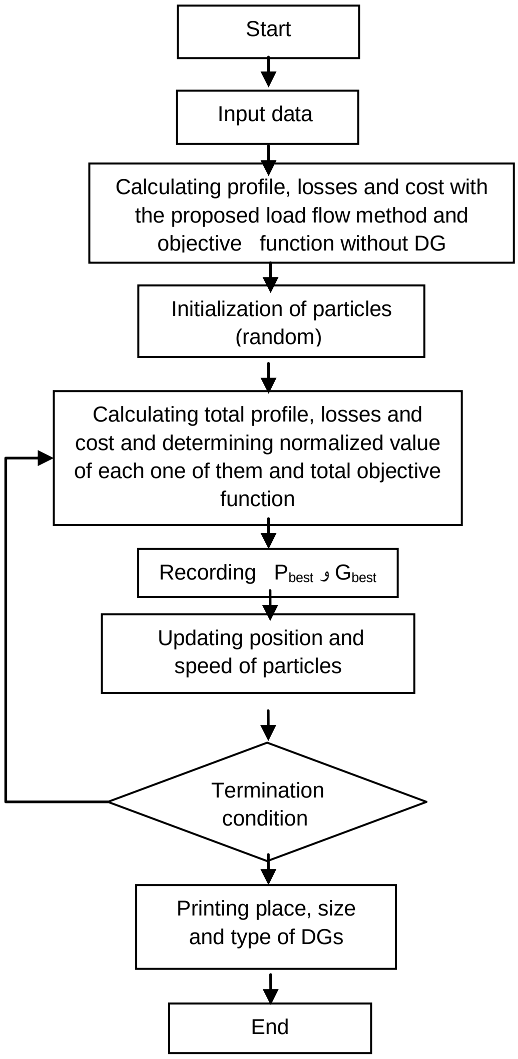

Figure 1. Flowchart of problem solving with PSO algorithm

Load flow algorithm

An important part of calculation of DG units relates to load flow of the network. According to radial structure, resistance and reactance of lines in distribution systems, it is not easily possible to apply conventional methods of load flow such as Newton raphson. For this reason, direct solving methods are used to solve load flow equations of these systems. In this research, a load flow based on back/forward sweep method has been used.

Generally, stages of load flow calculation in the presence of DG units are as follows:

Step 1: voltage is initialized in all nodes of the network as follows:

$$v_i = (1+0j) \qquad i = 1, 2 ,. .. ,NN \qquad (21)$$

In this relation, NN shows the number of the network nodes.

Step 2: Load equivalent current is calculated in each one of the network nodes by the following relation:

$$I_{Li} = \frac{(P_{Li} - P_{DGi}) - j(Q_{Li} - Q_{DGi})}{V^*} \qquad (22)$$

Where, P_{Li} and Q_{Li} are active power and reactive power of fuzzy load in the i-th node. P_{DG} and Q_{DG} show active power and reactive power of DG in the i-th node.

Step 3: current passing each line from end sections to distribution substation of railway is calculated by the following relation (Back/Forward Sweep).

For all line section:

$$I_{i,j} = I_{Lj} + \sum_{(j,k)\in SL} I_{j,k} \quad (23)$$

In this relation, $I_{j,k}$ is current passing section (j and k) and SL is set of sections which are connected to the j-th node (j and k).

Step 4: voltage of each node from distribution substation of railway to end of the network is calculated by the following relation (Back/Forward Sweep).

For all line nodes:

$$V_j = V_i - Z_{i,j} I_{i,j} \quad (24)$$

Where $Z_{i,j}$ is impedance of section (i and j) which connect two nodes i and j to each other.

Step 5: if difference between voltages calculated in step 4 and their previous values is larger than a specified limit, calculation is iterated from step 2 (convergence of calculation).

Step 6: representation of results which includes voltage of nodes, current passing lines, and losses.

Numerical Studies

To represent efficiency of the proposed algorithm, the problem has been implemented on a real network with 22 buses (Azerbaijan electrical railway) which is shown in figure 2 and its information is given in tables 6-1 and 6-2. Also in this section, 5 types of DG with specified capacities which are of microturbine type have been used and their information is given in table (6-3).

The problem has been solved in multi-objective case with and without installation of DG, and the obtained results have been discussed. The results obtained with Matlab software have been compared with results obtained from calculation in Digsilent software.

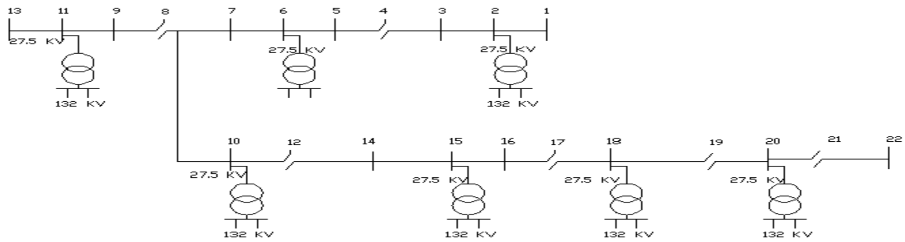

Figure 2. 22-bus network of Azerbaijan electrical railway

Table 1. Information of 22-bus network of Azerbaijan electrical railway

Bus number	P(KW)	Q(KW)	Line number	Start bus	End bus	Length of line (Km)
1	8.1	3.8	1	1	2	23
2	8.2	3.8	2	2	3	22
3	8.1	3.8	3	3	4	14.6
4	7.2	3.3	4	4	5	21
5	8.5	3.9	5	5	6	19
6	9.8	4.6	6	6	7	26
7	8.2	3.8	7	7	8	29
8	10.8	5	8	8	9	22
9	8.8	4.1	9	8	10	26
10	8.2	3.8	10	9	11	29
11	10.5	4.9	11	10	12	28
12	9	4.2	12	11	13	19
13	10	4.7	13	12	14	26
14	8.2	3.8	14	14	15	18.3
15	7.5	3.5	15	15	16	31.1
16	8.7	4	16	16	17	24
17	10.2	4.7	17	17	18	29
18	10.2	4.7	18	18	19	24
19	10.6	4.9	19	19	20	29
20	8.2	3.8	20	20	21	37
21	11.1	5.2	21	21	22	31
22	11.3	5.3				

Table 2. Information of distributed generation resources used in the study

DG No.	Type of DG	Generating Active power by DG (kw)	Installation cost of DG($)	Repair and maintenance cost of DG ($/Hour)	Operation cost of DG ($/Hour)
1	PQ	1000	282000	11630	45
2	PQ	2000	413120	21140	103

3	PQ	3000	682400	33230	143
4	PQ	4000	937440	42310	221
5	PQ	5000	1023453	48090	331

Also in this study, cost of purchasing power from overhead network is equal to 70[$/MWh], and impedance of the network per km is equal to 21+43j.

Test according to optimization algorithms

In this section, the problem optimization has been done using PSO, IPSO and DAPSO algorithms and considering weighted coefficients as a1=.333, a2=.333 and a3=.334 and results have been compared. In table 3, changes of different parts of the main objective function are shown and it is observed that the best results obtained after performing optimization operations relate to DAPSO algorithm. In tables 4 and 5, profile of voltage and losses of lines are given for all three algorithms and these results have been compared with each other as a diagram in Figures 3 and 4.

Table 3. Results of different parameters of DG placement objective function before and after installation of DG and comparison of results of different algorithms

Parameters	Before installation of DG	After installation of DG(using algorithms) DAPSO	PSO	IPSO
Normalized voltage profile function	1	0.3995	0.3995	.3995
Real value voltage profile function (per unit)	1.0932	0.4367	0.43678	0.43678
Normalized losses function	1	0.2792	0.2792	0.7292
Real value losses function	0.2856	0.07974	0.07974	0.079745
Normalized cost function	1	0.9492	0.9495	0.949
Real value cost function $	$1.5713*10^9$	$1.4912*10^9$	$1.4912*10^9$	$1.4912*10^9$
Normalized value of final objective function	1	0.5385	0.5420	0.5387
DGs' Installation locations	–	2,4,5,6,8,9,10,12,14,15, 16,17,18,19,20,21	2,4,5,6,8,9,10,12,14, 15,17,19,20,21	2,4,5,6,8,9,10,12,14,15, 16,17,18,19,20,21
Capacity of DG installed in each location	–	3,5,5,3,5,5,3,5,3,3,3,5,3 ,4,3,4	3,5,5,5,5,5,3,5,3,3,3, 3,3,3	3,5,5,3,5,5,3,5,3,4,3,5,3, 4,3,3

Table 4. Comparing profile of voltage before and after installation of DG for different algorithms

Bus Number	Before installation of DG	After installation of DG DAPSO	PSO	IPSO
1	.9764	.9754	.9754	.9754
2	1	1	1	1
3	.9775	.9766	.9766	.9766
4	.9642	.9777	.9777	.9777
5	.9797	.9987	.9987	.9987
6	1	1	1	1
7	.9727	.9715	.9715	.9715
8	.9297	.9576	.9576	.9576
9	.9668	.9966	.9966	.9966
10	1	1	1	1
11	1	1	1	1
12	.9673	.9960	.9960	.9960
13	.9759	.9749	.9749	.9749
14	.9812	.9921	.9921	.9921
15	1	1	1	1
16	.9647	.9836	.9627	.9836
17	.961	.9911	.9785	.9911
18	1	1	1	1
19	.9593	.9832	.9768	.9832
20	1	1	1	1
21	.9434	.9748	.9662	.9662
22	.9382	.9692	.9605	.9605

According to the following diagram, profile of voltage after installation of DG has been improved by all three algorithms compared with the case without DG and in DAPSO algorithm, this diagram has the best state compared with other algorithms, i.e. it has been optimized in fully standard limit (-5%-+5%) in DAPSO.

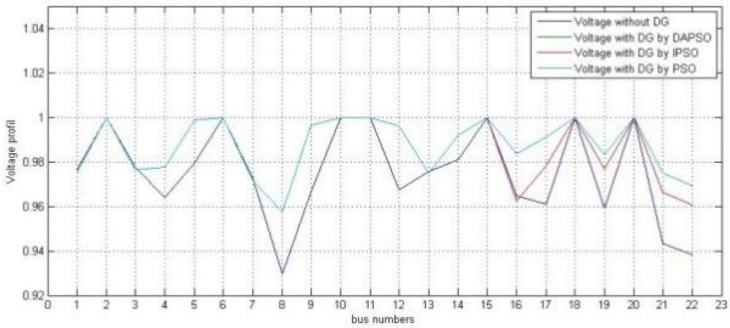

Figure 3. Comparing profile of voltage before and after installation of DG for different algorithms

As observed in the following figure, the best answer relates to DAPSO algorithm. Although values of voltage profile function are the minimum in PSO algorithm and the best results for losses have given by IPSO algorithm, but the most suitable, balanced and optimized answer for different parts of objective function relates to DAPSO algorithm, because, the main parameter for determination the answer is related to final objective function.

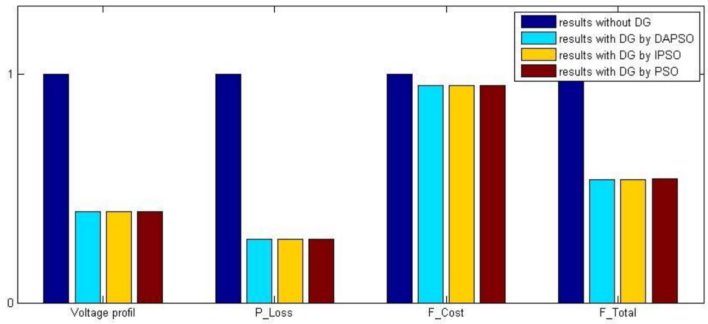

Figure 4. Comparing different parts of objective function before and after installation of DG for different algorithms

Considering the obtained results, as observed above, DAPSO has better results than other algorithms, which indicates optimization power of this algorithm.

Test according to different weighted coefficients

In this section, the problem has been optimized and studied in four states using DAPSO algorithm. In the first state, weighted coefficients are a1=.5, a2=.2 and a3=.3, in the second state, weighted coefficients are a1=.3, a2=.2 and a3=.5 and in the third state, weighted coefficients are a1=.2, a2=.5 and a3=.3. At the end, effect of each one of these coefficients on final answer and all parts of objective function has been compared.

RESULTS OF THE FIRST STATE: (A1=.5, A2=.2 AND A3=.3)

Table 5. Comparing profile of voltage before and after installation of DG for DAPSO algorithm

Bus number	Voltage profile before installation of DG	Voltage profile after installation of DG	Bus number	Voltage profile before installation of DG	Voltage profile after installation of DG
1	.9764	.9754	12	.9673	.9960
2	1	1	13	.9759	.9749
3	.9775	.9766	14	.9812	.9921
4	.9642	.9777	15	1	1
5	.9797	.9987	16	.9647	.9836
6	1	1	17	.961	.9785
7	.9727	.9715	18	1	1
8	.9297	.9576	19	.9593	.9768
9	.9668	.9966	20	1	1
10	1	1	21	.9434	.9748
11	1	1	22	.9382	.9692

Table 6. Results of different parameters of DG placement objective function before and after installation of DG using DAPSO algorithm

Parameters	Before installation of DG	After installation of DG
Normalized voltage profile function ($F_{n.prof}$)	1	0.3995
Real value voltage profile function (per unit) (F_{prof})	1.0932	0.43678
Normalized losses function ($F_{n.loss}$)	1	0.2792
Real value losses function kw (F_{loss})	0.2856	0.79745
Normalized cost function ($F_{n.cost}$)	1	0.0949
Real value cost function \$(F_{cost})	1.5713*109	1.501457*109
Normalized value of Final objective function (F_{fit})	1	0.5365
Locations of DG installation	_	2,4,5,6,8,9,10,12,14,16,17,18,19,20,21
Type of DG installed in each location	_	3,5,5,3,5,5,3,5,3,3,3,3,3,3,4

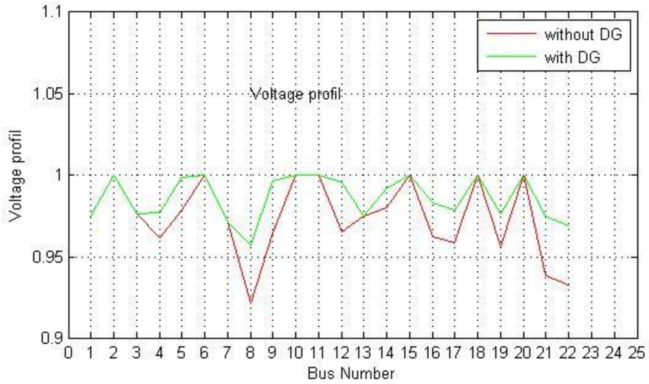

Figure 5. Comparing profile of voltage before and after installation of DG using DAPSO algorithm

As observed in the above figure, profile of voltage has considerably changed in different buses. In the above figure, loss of voltage was very high before installation of DG (voltage deviation about 0.1 per unit) while after installation of DG, voltage profile of all buses is acceptable and high in the studied network (the lowest profile of voltage is 0.9676).

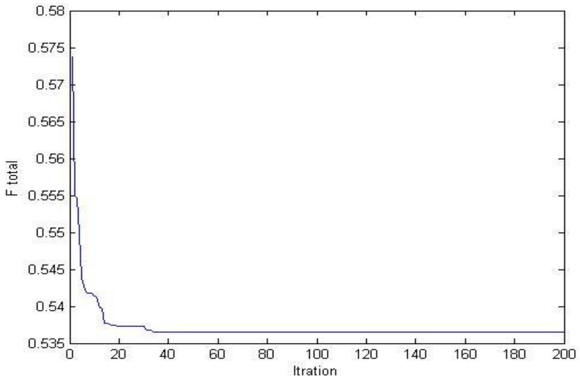

Figure 6. Optimization problem convergence route using DAPSO algorithm

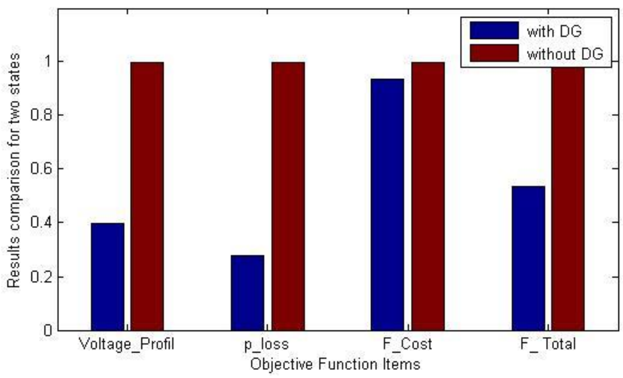

Figure 7. Comparing different parts of objective function before and after installation of DG for DAPSO algorithm

In the above figure, a comparison is made between different states of design (with and without DG) for different parts of objective function and it is observed that different items of objective function have considerably decreased.

RESULTS OF THE SECOND STATE: A1=.3, A2=.2 AND A3=.5

Table 7. Comparing profile of voltage before and after installation of DG for DAPSO algorithm

Bus number	Voltage profile before installation of DG	Voltage profile after installation of DG	Bus number	Voltage profile before installation of DG	Voltage profile after installation of DG
1	.9764	.9673	12	.9754	.9960
2	1	.9759	13	1	.9749
3	.9775	.9812	14	.9766	.9921
4	.9642	1	15	.9777	1
5	.9797	.9647	16	.9987	.9836
6	1	.961	17	1	.9749
7	.9727	1	18	.9715	1
8	.9297	.9593	19	.9576	.9832
9	.9668	1	20	.9966	1
10	1	.9434	21	1	.9662
11	1	.9382	22	1	.9605

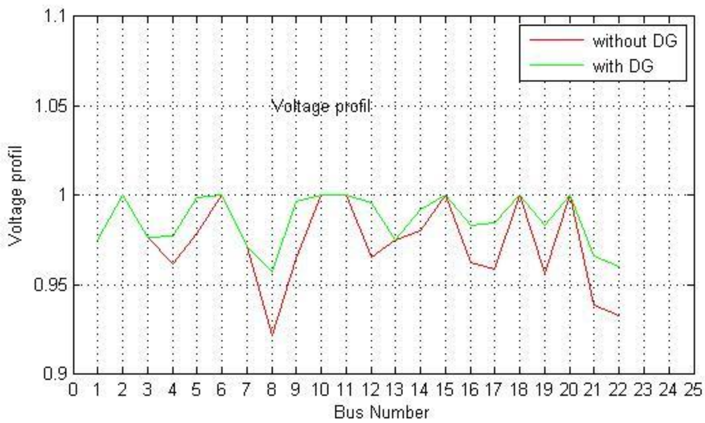

Figure 8. Comparing profile of voltage before and after installation of DG using DAPSO algorithm

As observed in the above figure, profile of voltage has considerably changed in different buses. In the above figure, loss of voltage was very high before installation of DG (voltage deviation about 0.07 per unit) while after installation of DG, voltage profile of all buses is acceptable and high in the studied network (the lowest profile of voltage is 0.9658).

Table 8. Results of different parameters of DG placement objective function before and after installation of DG using DAPSO algorithm

Parameters	Before installation of DG	After installation of DG
Normalized voltage profile function ($F_{n.prof}$)	1	0.3995
Real value voltage profile function (per unit) (F_{prof})	1.0932	0.43678
Normalized losses function ($F_{n.loss}$)	1	0.2792
Real value losses function kw (F_{loss})	0.2856	0.079745
Normalized cost function ($F_{n.cost}$)	1	0.9487
Real value cost function $($F_{cost}$)	1.5713*109	1.490708*109
Normalized value of Final objective function (F_{fit})	1	0.64311
Locations of DG installation	_	2,4,5,6,8,9,10,12,14,15,16,17,18,19,20,21
Type of DG installed in each location	_	3,3,4,2,4,3,3,3,5,3,5,5,3,5,5,3

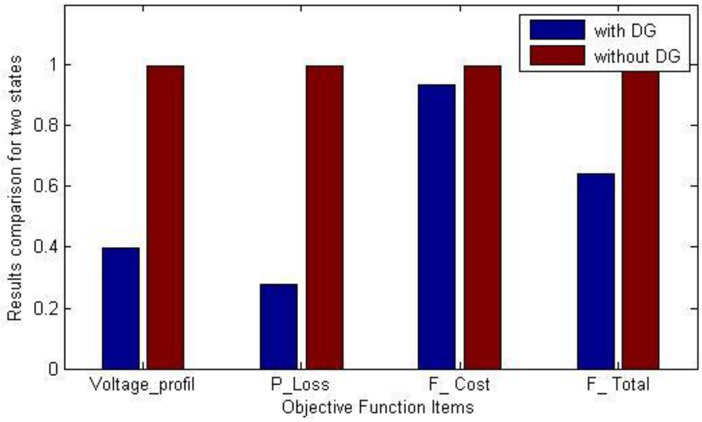

Figure 9. Comparing different parts of objective function before and after installation of DG for DAPSO algorithm

In the above figure, a comparison is made between different states of design (with and without DG) for different parts of objective function and it is observed that different items of objective function have considerably decreased.

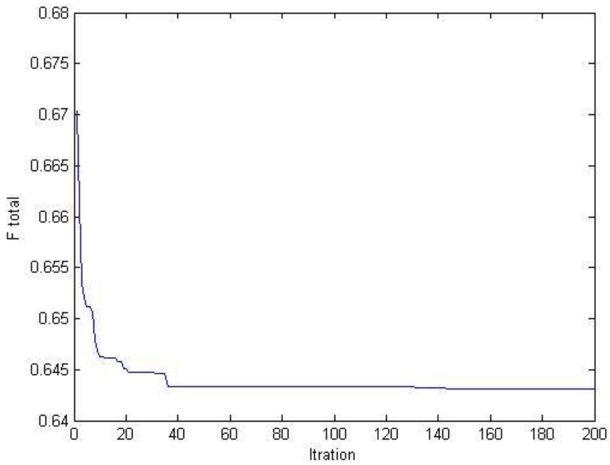

Figure 10. Optimization problem convergence route using DAPSO algorithm

RESULTS OF THE THIRD STATE: A1=.2, A2=.5 AND A3=.3

Table 9. Comparing profile of voltage before and after installation of DG for DAPSO algorithm

Bus number	Voltage profile before installation of DG	Voltage profile after installation of DG	Bus number	Voltage profile before installation of DG	Voltage profile after installation of DG
1	.9764	.9754	12	.9673	.9960
2	1	1	13	.9759	.9749
3	.9775	.9766	14	.9812	.9921
4	.9642	.9777	15	1	1
5	.9797	.9987	16	.9647	.9836
6	1	1	17	.961	.9785
7	.9727	.9715	18	1	1
8	.9297	.9576	19	.9593	.9768
9	.9668	.9966	20	1	1
10	1	1	21	.9434	.9662
11	1	1	22	.9382	.9605

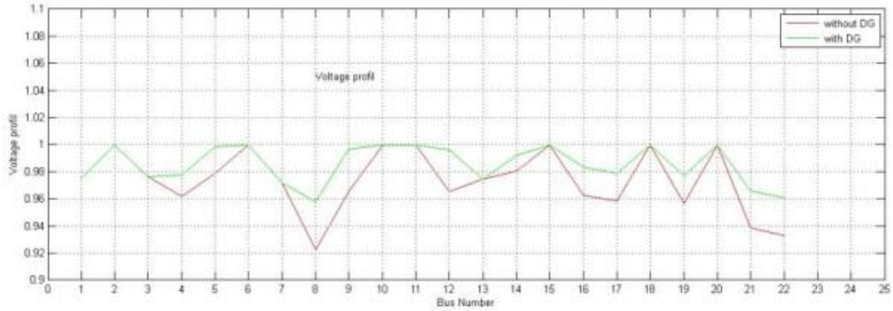

Figure 11. Comparing profile of voltage before and after installation of DG using DAPSO algorithm

As observed in the above figure, profile of voltage has considerably changed in different buses. In the above figure, loss of voltage was very high before installation of DG (voltage deviation about 0.1 per unit) while after installation of DG in the studied network, voltage profile of all buses is acceptable and high (the lowest profile of voltage is 0.96). Considering the obtained results, it is observed that losses have considerably changed in different lines.

Table 10. Results of different parameters of DG placement objective function before and after installation of DG using DAPSO algorithm

Parameters	Before installation of DG	After installation of DG
Normalized voltage profile function ($F_{n.prof}$)	1	0.3995
Real value voltage profile function (per unit) (F_{prof})	1.0932	0.4367811
Normalized losses function ($F_{n.loss}$)	1	0.2792
Real value losses function kw (F_{loss})	0.2856	0.79745
Normalized cost function ($F_{n.cost}$)	1	0.9452
Real value cost function $($F_{cost}$)	$1.5713*10^9$	$1.4852*10^9$
Normalized value of Final objective function (F_{fit})	1	0.50039
Locations of DG installation	_	2,4,5,6,8,9,10,12,14,15,16,17,18,19,20,21
Type of DG installed in each location	_	3,3,3,3,3,3,3,3,5,3,5,5,5,5,5,3

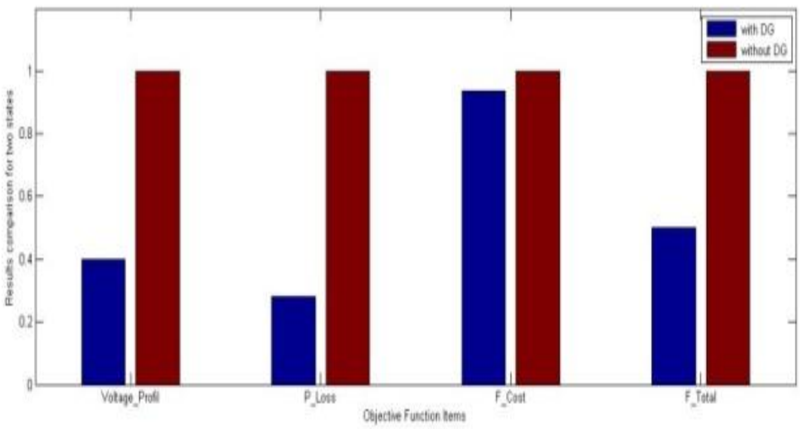

Figure 12. Comparing different parts of objective function before and after installation of DG for DAPSO algorithm

In the above figure, a comparison is made between different states of design (with and without DG) for different parts of objective function and it is observed that different items of objective function have considerably decreased.

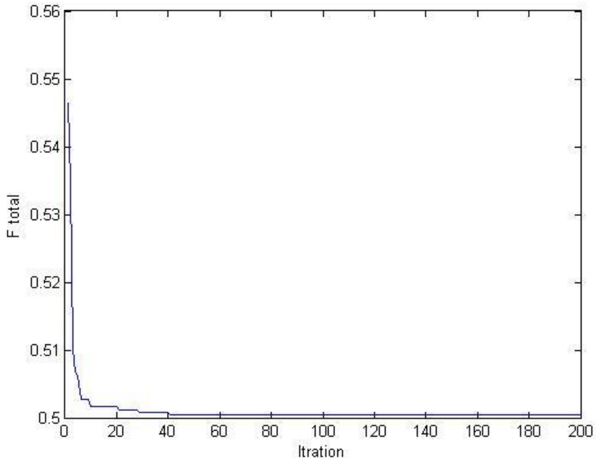

Figure 13. Optimization problem convergence route using DAPSO algorithm

Considering general comparison which was made between results of different tests for each one of the objective functions and as referred before, this problem has been designed using weighted coefficients as multi-objective model so that designer can perform optimization using weighted coefficients according to importance of each part of objective function. As referred above, improvement of voltage was the most important for designer in the first test and in this case, it is observed that the reference voltage deviation was mostly reduced in this test which is due to considering high value for weighted coefficient of voltage profile. In the third test which is the most important part of design relating to losses, it is observed that there were the minimum losses in this test and finally in the second test which the most important part of design related to cost function, it was observed that there was the lowest cost in this test.

COMPARING RESULTS WITH DIGSILENT SOFTWARE

In this section, the obtained results for section 5-1 using DAPSO algorithm have also calculated by Digsilent software and a review of results shows that voltage and losses are at equal levels.

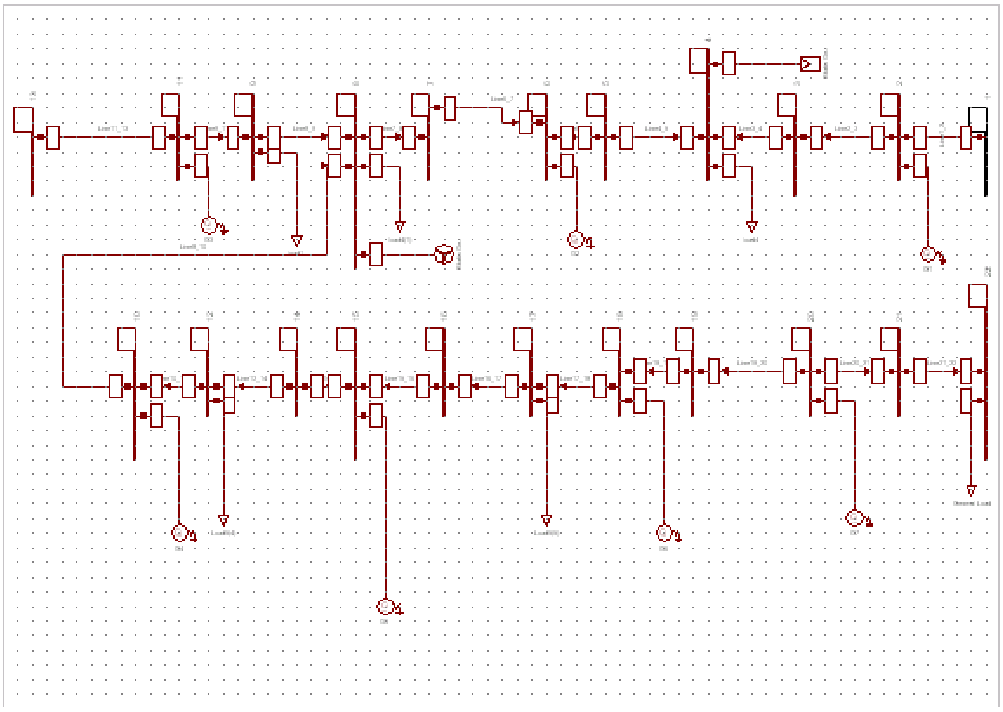

Figure 14. Diagram of system in Digsilent software

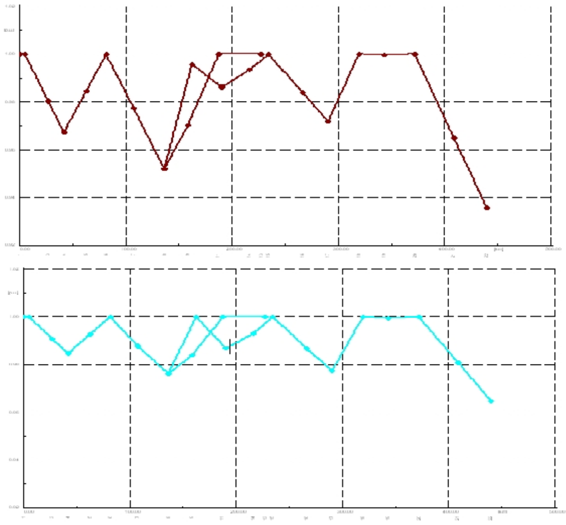

Figure 15. Results of buses voltages: 1) without DG and 2) with DG

CONCLUSION

In this paper, multi-objective modeling was presented from the viewpoint of private sector for optimal placement of distributed generation resources in Azerbaijan electrical railway network and the main goal here was to optimize profile of voltage and losses of system and cost. First, the problem was implemented and optimized using different algorithms and finally, it was observed that DAPSO algorithm was the best and the most powerful algorithm for optimization of this problem. Then, the problem was implemented for different weighted coefficients and then effect of change of each coefficient on final answer was studied and finally the obtained results were compared with the obtained results in Digsilent.

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