



IMPROVEMENT OF BUS VOLTAGES AND LINE LOSSES IN POWER SYSTEM NETWORK THROUGH THE PLACEMENT OF CAPACITOR AND DG USING PSO

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ABSTRACT

The optimum allocation of capacitor banks and distributed generation (DG) units are one of the challenges of power network planner and operators in transmission and distribution levels. Capacitors and DG are compensators that can help to power network to reduce the total power losses and improve the voltage profile, but non-optimal allocation of compensators can lead to inverse power flow. This can be caused to raise the voltage at busses out of the statutory limits as well as increasing the system losses due to reverse power flow. The capacitors in power system are generally utilized to supply real reactive power for reducing real power, then as the results improving the voltage profile. Therefore, the appropriate placement and sizing of capacitors are essential to ensure that system can mitigate power loss and improve the voltage profile with respect to all the technical constraints and limits which takes into account as penalty factor and added the objective function of optimum allocation of DG and capacitors. To minimize the obtained objective function, this paper has utilized Particle Swarm Optimization (PSO) technique to find the optimum location and the size of the units to ensure that can achieve minimum power losses and better voltage profile. The OpenDSS engine is utilized for performing power flow calculation in an iterative manner for PSO algorithm. The IEEE 14 bus system has been used as a case study in this paper for executing the proposed method and finding the optimum solution for DG and capacitor allocation. The results of this paper show that proposed method was successful to achieve the target of the objective function and allocate the DG and capacitors into the best optimum location with appropriate size. This paper highlighted that how the existing power network can be improved to be functional in future long-term load growth without the huge investments of the network reinforcement. The results show that by allocating the DG units and capacitors the existing network can supply the good power quality to the end receiving buses, even with a better voltage profile and less total power losses in the overall network.

Keywords: distributed generation, particle swarm optimization, OpenDSS engine, power loss reduction, voltage profile improvement.

1. INTRODUCTION

Distributed generation can be defined as the generation units that are connected at the distribution network level and close to end-users [1]. The main goal of power system production is to meet the demand at all the sites within the power grid as reliably and economically as possible. The conventional power system generator uses the traditional energy resources, like fossil fuels, Steam power, Gas energy, nuclear, etc. For electricity generation. The operation of such conventional power generation system is based on centralized control utility generators, transmission power during an extensive transmission and distribution system, to meet the given demands of vastly scattered users. Nowadays, the warrantable for the big central-station plants is weakening due to draining traditional resources, increased Distribution costs and transmission, heightened environmental concerns, and technical advancements. Power distribution system provides a final connect among the high voltage transmission system and delivers it to end-users [2].

Shunt compensation capacitor is among the first tools utilized in the distribution network; Shunt capacitor is also the tool that injects reactive power to a distribution grid in order to reduce the power losses and voltage profile improvement in order to improve the voltage profile. The

merits of shunt capacitors involve decreasing active power losses, reactive power losses, releasing capacity of lines and transformers, improving power factor and maintaining. The voltage was within the allowable range specified. To take merits of the Cases mentioned above, capacitors must be utilized at optimal locations and sizes. Optimal placement of the capacitor in the distribution network and its various methods have been presented [3].

One of the main issues facing distribution facilities is the combination of distributed generation units (DGs) into distribution networks. This paper proposes a population-based approach called particle optimization (PSO) to optimize the placement and size of different DG units in the distribution network, taking into account the different loading conditions. The main target of this implementation is power loss minimization and voltage profile improvement compared to the standard case IEEE 14 bus with incremental the loads [4]. In order to find the optimal location and size of Distribution Generation (DG) units. As well, the optimal locations and sizes of the DG units are determined in the areas of significant feeder load growth.



2. METHODOLOGY

This Methodology explained based on the scope are covered in this paper and it's divided into four major topics which are (i) network modeling, (ii) data collection and implementation of power flow engine (OpenDSS), (III) Load flow analysis using OpenDSS and (iv) Particle Swarm Optimization (PSO). All the essential topics referred based on the study from the related Literature review.

2.1 Network modeling

This paperwork proposes the use of a Particle Swarm Optimization (PSO) and OpenDSS engine for

selecting the optimum size and placement of (DG) units. The DG is considered located in the distribution network with the aim of reducing power losses and improving the voltage profile. This method has been examined on the standard IEEE-14 bus with incremental the loads 5%, 15% and 25% [4] distribution network using Particle Swarm Optimization (PSO). The IEEE14 Bus System with incremental the loads is shown in Figure-1 [4]. The system data were collected from IEEE database. The Bus System consists of 14 buses, five generators, 16 lines, 11 loads, one shunt and five transformers [4].

Table-1. Generator dispatch and controlled setting.

Generator dispatch				Generator controller settings			
Generator	Bus	P (MW)	Q (Mvar)	Bus Type	Voltage (P.u)	Minimum capability (MVA)	Maximum capability (MVA)
Gen 0001	Bus 0001	N.A.	N.A.	Slack	1.060	N.A.	N.A.
Gen 0002	Bus 0002	40.0	N.A.	PV	1.045	-40.0	50.0
Gen 0003	Bus 0003	0.0	N.A.	PV	1.010	0.0	40.0
Gen 0006	Bus 0006	0.0	N.A.	PV	1.070	-6.0	24.0
Gen 0008	Bus 0008	0.0	N.A.	PV	1.090	-6.0	24.0

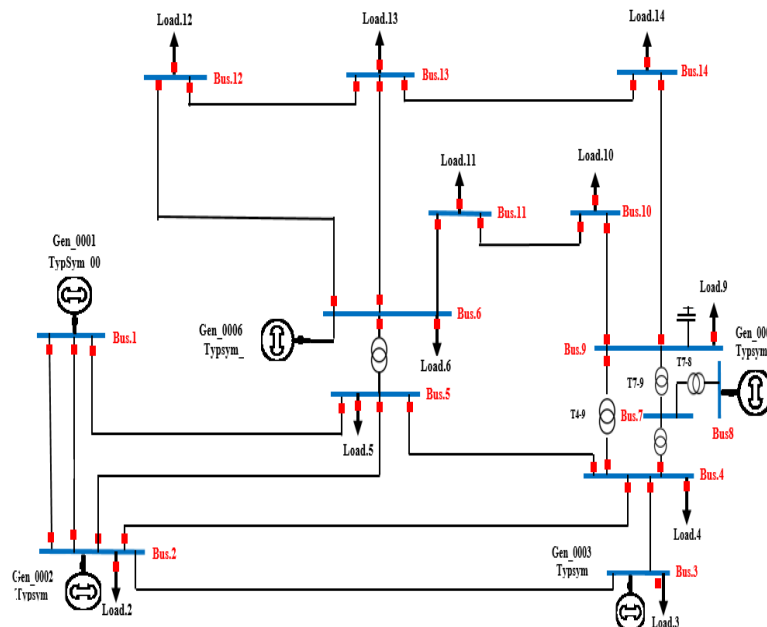


Figure-1. Single line diagram of a 14 - Bus system.

2.2 Data collection and implementation of power flow engine (OpenDSS)

The standard IEEE-14 buses with incremental the loads 5%, 15% and 25% [4] are taken for the simulation of power flow, such as OpenDSS engine and Power World Simulator IEEE 14 BUS system is running under three cases, i.e., OpenDSS engine, Power world simulator and PSO technique. These three options are available in this

MATLAB software. The performance of the system network can observe for these three cases via using this MATLAB software. The system consists 11 loads in which total real load (P) is 259 MW, and reactive load (Q) is 73.5 Mvar of the standard case, and five generators are configured to control the P injection and voltage magnitudes at the connected with buses 1, 2, 3, 6 and eight



respectively [5]. The IEEE 14 Bus System is shown in Tables 1 and 2[4]

Table-2. Load demand with incremental the loads.

Load	Bus	Standard case (0%)		Load growth (5%)		Load growth (15%)		Load growth (25%)	
		P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
Load 0002	Bus 0002	21.7	12.7	22.79	13.335	24.955	14.605	27.13	15.88
Load 0003	Bus 0003	94.2	19.0	98.91	19.95	108.33	21.85	117.75	23.75
Load 0004	Bus 0004	47.8	-3.9	50.19	-4.10	54.97	-4.485	59.75	-4.875
Load 0005	Bus 0005	7.6	1.6	7.98	1.68	8.74	1.84	9.5	2
Load 0006	Bus 0006	11.2	7.5	11.76	7.88	12.88	8.625	14	9.375
Load 0009	Bus 0009	29.5	16.6	30.98	17.43	33.925	19.09	36.875	20.75
Load 0010	Bus 0010	9.0	5.8	9.45	6.09	10.35	6.67	11.25	7.25
Load 0011	Bus 0011	3.5	1.8	3.68	1.89	4.025	2.07	4.375	2.25
Load 0012	Bus 0012	6.1	1.6	6.41	1.68	7.015	1.84	7.625	2
Load 0013	Bus 0013	13.5	5.8	14.18	6.09	15.525	6.67	16.875	7.25
Load 0014	Bus 0014	14.9	5.0	15.65	5.25	17.135	5.75	18.625	6.25

Tables 3 and 4 [4] have a summary of the transmission lines and transformers. The transmission parameters have 16 lines. The line data are given in per unit (p.u) with base $S_b = 100\text{MVA}$ without data about the line length. The susceptance b in P.u which is taken as

one - half of the sum charging of lines and five transformer parameters involve the tap changers with the line data , i.e., Resistance (r) in p.u, reactance (x) in p.u and impedances (z) in ohms.

Table-3. Data of lines in the power factory model.

Line	From bus	To bus	Un (kV)	R (Ω)	X (Ω)	B (μS)
Line 0001 0002/1	1	2	132	6.7535	20.620	151.515
Line 0001 0002/2	1	2	132	6.7535	20.620	151.515
Line 0001 0005	1	5	132	9.4142	38.862	282.369
Line 0002 0003	2	3	132	8.1875	34.494	251.377
Line 0002 0004	2	4	132	10.1251	30.722	214.647
Line 0002 0005	2	5	132	9.9230	30.297	195.133
Line 0003 0004	3	4	132	11.6758	29.800	198.577
Line 0004 0005	4	5	132	2.3261	7.337	73.462
Line 0006 0011	6	11	33	1.0343	2.166	0.000
Line 0006 0012	6	12	33	1.3385	2.786	0.000
Line 0006 0013	6	13	33	0.7204	1.419	0.000
Line 0009 0010	9	10	33	0.3464	0.920	0.000
Line 0009 0014	9	14	33	1.3842	2.944	0.000
Line 0010 0011	10	11	33	0.8935	2.092	0.000
Line 0012 0013	12	13	33	2.4058	2.177	0.000
Line 0013 0014	13	14	33	1.8614	3.790	0.000



Table-4. Data of transformers given in based on 100 MVA, with rated voltages added to the power factory model.

Transformer	From bus	To bus	Ur HV in kV	Ur LV in kV	r in p.u.	x in p.u.	x Ohms	Transformer final turns ratio
Trf-0004-0007	4	7	132.0	1.0	0.0	0.20912	36.4371	0.978
Trf-0004-0009	4	9	132.0	33.0	0.0	0.55618	96.9088	0.969
Trf-0005-0006	5	6	132.0	33.0	0.0	0.25202	43.9170	0.932
Trf-0007-0008	7	8	11.0	1.0	0.0	0.17615	0.2131	0.000
Trf-0007-0009	7	9	33.0	1.0	0.0	0.11001	1.0900	0.000

2.3 Load flow analysis using OpenDSS

The Open Distribution System Simulator (OpenDSS) is an inclusive electrical system simulation tool for electric utility distribution networks. OpenDSS indicates the open source execution of the DSS. The Figure-2 block [6]. Diagram of OpenDSS model consists of the main Simulation Engine, User-written DLLs, Scripts results and computer (COM) Interface. The OpenDSS Engine are utilized for the development of IEEE Test feeder cases, distribution network Analysis of Unusual Transformer Configurations, System Planning and Analysis, distribution network Analysis of Unusual Transformer Configurations, (Daily and Yearly) Power Flow And others [6]. OpenDSS engine is a valuable tool to determine the optimum allocation (sizing and sitting) for both DG and Capacitor in the distribution system network; the OpenDSS engine was developed to provide a very flexible research Platform, and as a base for distribution analysis enforcement such as Distributed Generation (DG), the power flow analysis is required.

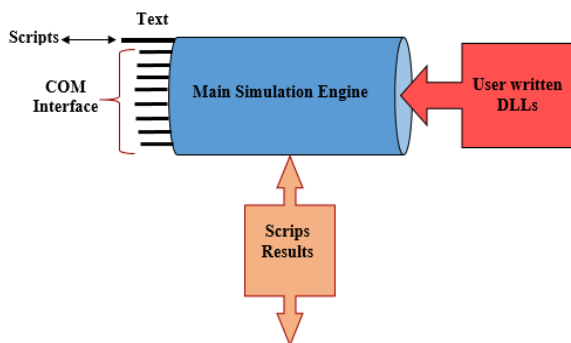


Figure-2. Block diagram of the OpenDSS model.

2.4 Particle swarm optimization (PSO)

The PSO algorithm is inspired by the social demeanor of some group of subject, for example, birds flock or fish school [7]. The general thought of this method can be described as follows. The search space has a set of points, and every point has its value, which is assigned via the evaluation function. The function is to find the optimal of this task. There is also a set of particles that are moving in the defined search space. The movement laws can be considered as interactions among objects. Using those movement laws, the objects should find the positions with best values or even optimal. The general picture of PSO particle movement is shown in

Figure-3 [8]. The optimal movement of every particle through particle movement based on best personal position, global position, and velocity of particles from the previous position to the next position. The related equation of PSO that can be elaborated from Figure-3 is shown in Equation 1 and Equation 2, respectively [8].

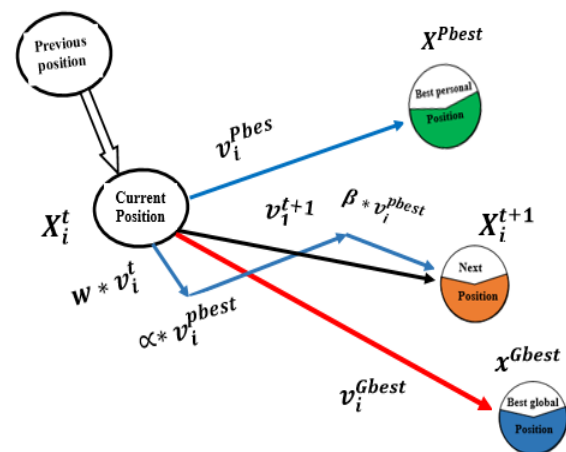


Figure-3. The structure of the particle swarm.

Optimization

$$V_i^{t+1} = (w * V_i^t) + \alpha (X^{Pbest} - X_i^t) + \beta (X^{Gbest} - X_i^t) \quad (1)$$

$$X_i^{t+1} = X_i^t + V_i^{t+1} \quad (2)$$

Where,

X_i^t Refers to the current position of the particle i at iteration t

X^{Pbest} Refers to the best personal position of the particle

$$X^{Pbest} = \begin{cases} X^{Pbest(i)} & \text{if } OF^{j+1} \geq OF^j \\ X_i^t & \text{if } OF^{j+1} \leq OF^j \end{cases} \quad (3)$$

X^{Gbest} Refers to the best global position of the particle



$$x^{Gbest} = \begin{cases} x^{Gbest(j)} & \text{if } OF^{j+1} \geq OF^j \\ x^{pbest(j+1)} & \text{if } OF^{j+1} \leq OF^j \end{cases} \quad (4)$$

V_i^t Refers to the velocity of particle i at iteration t
 V_i^{t+1} Refers to the velocity of particle i towards next position
 w Denote to the inertia weight factor
 α & β Refers to the Acceleration Coefficient
 OF Denote the Objective Function

where C_1 refers to the cognitive factor, C_2 refers to the social factor and r_1 & $r_2 \sim U(0,1)$ is the uniformly distributed random number[9].

3. PROPOSED ALGORITHM FOR CAPACITOR ALLOCATION

Particle swarm optimization (PSO) is an optimization method established via Kennedy and Eberhart in 1995, inspired via a social compartment of bird flocking or fish teaching [2]. Figure-4 gives a flow chart of Particle swarm optimization (PSO) which can be utilized in solving engineering problems. The flowchart has been found using the proposed algorithm for Optimum Capacitor placement and sizing steps for PSO implementation. The flowchart is very important to provide orientation for work. The PSO Algorithm for the general diagram is shown in Figure-4 and is explained with steps as following.

- Step 1:** In initialization, are included in the parameters of PSO such as bus data, a number of populations (n), line data, maximum iteration number, line data and load flow variables with the constraint.
- Step 2:** All data standard IEEE-14 buses with incremental the loads 5%, 15% and 25% [4] are sent to power flow solver.
- Step 3:** Solve the power flow by using the OpenDSS engine.
- Step 4:** Determine the top reactive power (Q) and fewer voltage Buses.
- Step 5:** Find the sensitive buses in order to select the capacitor placement.
- Step 6:** the process will evaluate the obtained results by solving the power flow during the Open DSS to determine two parameters, one of them the personal best and other global best.
- Step 7:** Updates, in this stage the two parameters will be updated; one of them is the personal best and others are the global best particles.
- Step 8:** PSO main loop, will be implemented after that until the end of the population loop in step (8). The PSO main loop starting in this step and updates of the position and velocity of particles is performed at this step. Also to find the optimal placement and bus in the power system as well as sizing of the DG [8]-[10].

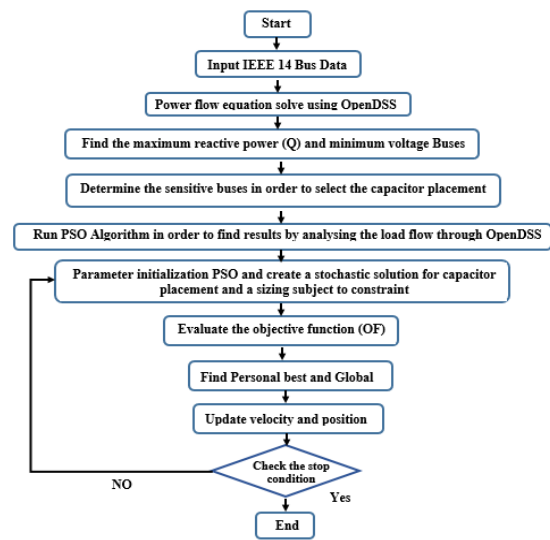


Figure-4. Flowchart for basic PSO algorithm.

3.1 Objective function for capacitor allocation

One of the main merits of using reactive power compensation and distributed generation within a network is to reduce power losses and voltage profile improvement in electrical energy as possible, considering parity and imparity constraints of the system. In another word, the issue can be stated as obtaining the location and size of shunt capacitor and DGs by maximum reduction of the active power loss (p). The utilized power flow method has been a direct impact on the accuracy and reliability of responses. In actuality, the major essence of the problem solving is the plan for power flow in the presence of shunt capacitor and DGs. Therefore, back and forward power flow were utilized in this work.

In capacitor placement and sizing, the total cost is included in the power losses and the capacitors costs. The objective function can be expressed as[11]:

$$\min OF = \sum_{i=1}^{nb} C_L \cdot p_{Loss}^i \quad (5)$$

Where OF refers to the total cost function, C_L Refers to the total capacitor which is provided in P_{Loss}^i [KW] which refers to the active power losses on bus; i at then nb refer to the number of buses.

$$P_{Loss}^i = \sum [V_i^2 + V_j^2 - 2V_i^2 \cdot V_j^2 \cos(\delta_i + \delta_j)] \cdot Y_{ij} \cos \theta_{ij} \quad (6)$$

Element voltages, magnitudes, and angles are referred to as V_i , δ_i , V_j and δ_j of bus i and j , element line admittance magnitude and the angle to referred as Y_{ij} and θ_{ij} between the buses i and j , respectively.

3.2 Placement and sizing of capacitor in the power network

The utilization of capacitors in power networks has several benefits of the power system that include voltage profile improvement and power losses minimized



due to the compensation of the reactive component of power flow. Maximum and minimum bus voltage is affected indirectly by capacitor size, which is one of the main constraint in finding the optimum capacitor placement, and sizing, that is taken into account as a penalty factor (PF).

3.3 Assumptions of capacitor

The following assumptions are considered in the development of the objective function (PF).

Standard case (STD)

- Total Capacitor size : 54000KVAR
- Shunt capacitors limits : $50 < \text{cap} < 8100$
- STD without Cap9 Bus 5 is 7349KW
- STD with Cap9 Bus 4 = 9661KW and Bus 7 = 9742KW

5% with incremental Load

- Without Cap9 Bus 7 = 10000 KW
- With Cap9 Bus 7 = 10000 KW
- With Cap9 Bus 4 = 10000 KW

25% with incremental Load

- Without Cap9 Bus 7 = 10000 KW
- With Cap9 Bus 4 = 10000 KW
- With Cap9 Bus 7 = 10000 K

4. PLACEMENT AND SIZING OF DG IN THE POWER NETWORK

Select the parameters such as the size of the swarm; number of iterations, acceleration coefficient and velocity that are to be optimized via using PSO. Here the parameters are the real (p) and reactive power (Q) that are injected through the Distributed Generation (DG) into a distributed network, i.e. the size of the Distributed Generation (DG) in order to minimize the power losses and improve voltage. The optimizing placement and sizing of DG in power networks are one of the significant issues of the power system. The optimizing placement and sizing of distributed generation can help to reduce the real and reactive power losses and improve the bus voltage profile in the system. In this paper, PSO technique is used to evaluate objective function for capacitor placement [2].

4.1 Objective function for DG allocation

The main objective function of DG allocation in this paper can be written as follows:

$$OF = \sum_{i=1}^{\text{buses}} P_{\text{losses}}^i + PF \quad (7)$$

Where OF is the objective function of DG allocation that needs to be minimized, P_{losses}^i are the power losses at bus i , and PF is the penalty factor of the

problem constraints that can be obtained from the violations of the following inequality constraints.

$$\sum_{i=1}^{\text{num}} DG_i < \text{MaxDG}_{\text{num}} \quad (8)$$

$$\sum_{i=1}^{\text{Size}} DG_i < \text{MaxDG}_{\text{size}} \quad (9)$$

$$\text{MinDG}_i < DG_i < \text{MaxDG}_i \quad (10)$$

$$V_i < 1.05 \quad (11)$$

4.2 Assumptions of DG

The following assumptions are considered in the development of the objective function (PF).

- Max DG numbers: 3
- Max total size of DG 100000 KW: 10% of total loading.
- DG unit size: $0 < DG < 100000$

5. RESULTS AND DISCUSSIONS

The proposed method is executed using program MATLAB that performed on IEEE-14 bus standard case with three incremental the loads scenarios which are 5%, 15% and 25% as was shown in Table-1. The network consists of swing/slack bus, generators at buses 3, 6, 8 and 14 transmission lines. There are loads in 11 nodes, which are nodes 2, 3, 4, 5, 6, 9, 10, 11, 12, 13 and 14. The following subsection shows the power flow calculation results for all of the scenarios after and before capacitor and DG allocation.

5.1 Power flow calculation using OpenDSS engine

All data are sent into the power flow calculation are carried out via the text file (DSS file) for generators, loads, transformers, and lines. All of the fields are executed in the OpenDSS engine through com interface with Mat lab to obtain the required parameters of power network such as power losses, voltage, current etc. Figure-5 shows a voltage comparison between OpenDSS and standard case as well as load growth cases with 5%, 15% and 25% load increment, respectively. The results show that the minimum voltage in the OpenDSS standard case is 1.009p.u. And the maximum voltage is 1.076. Figure-5 shows the significant voltage drop in cases with load growth. For instance, the minimum voltage is dropped at bus 14 in 0.935p.u. With 25% load increment case. Hence, the bus voltage is suggested in this paper to be improved by allocating the capacitors and DG units to maintain the voltage profile. Figure-6 shows the total power losses of all the scenarios. It indicates that by increasing the incremental load percentage, the total power losses of the network have been significantly increased which is the main reason of the voltage drop at end receiving buses. As discussed earlier in this paper, by optimally injection of the capacitors and DG into the certain buses, the voltages of the busses can be improved



and meanwhile the total power losses of the network can be reduced.

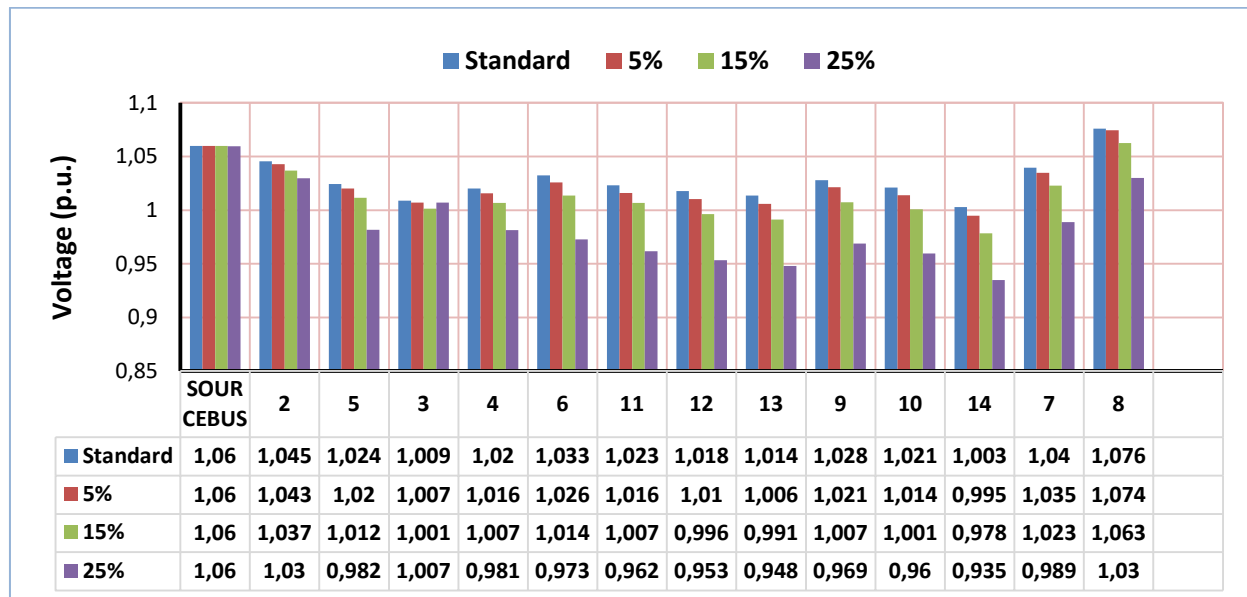


Figure-5. The voltage profile before optimum solution.

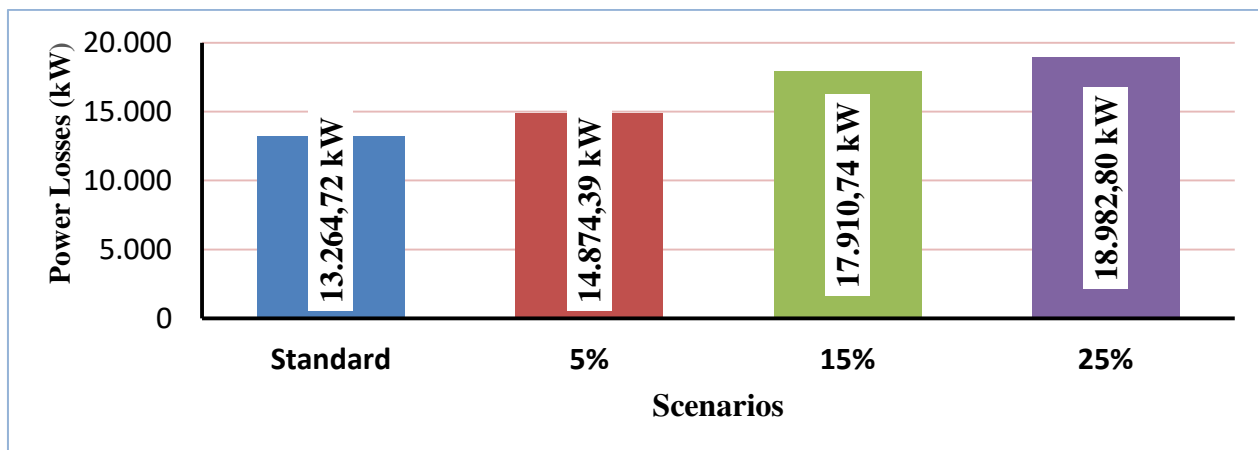


Figure-6. Total power losses per scenarios.

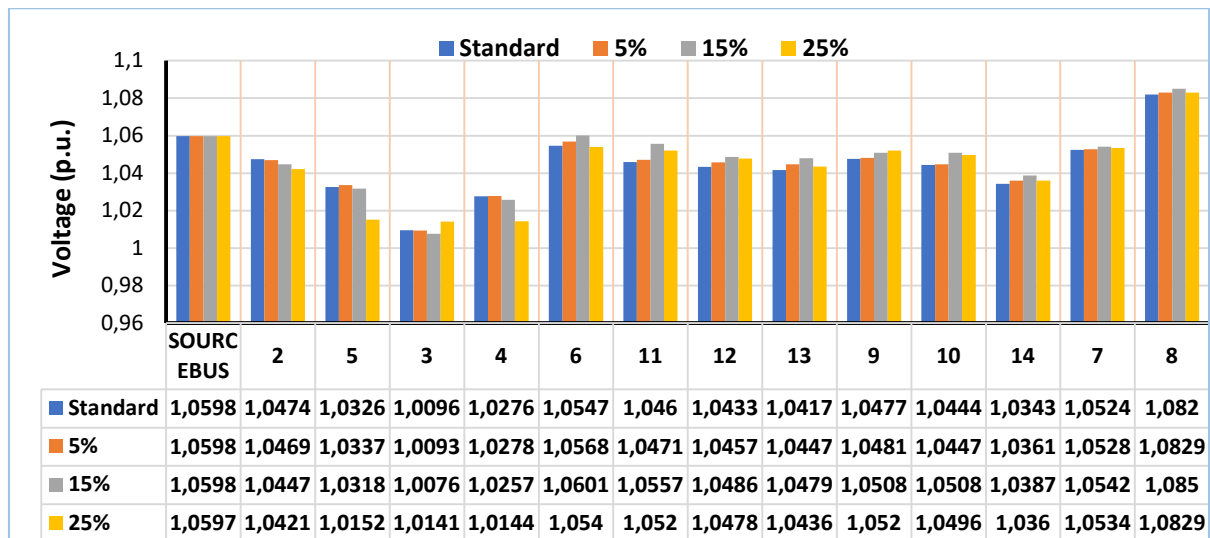
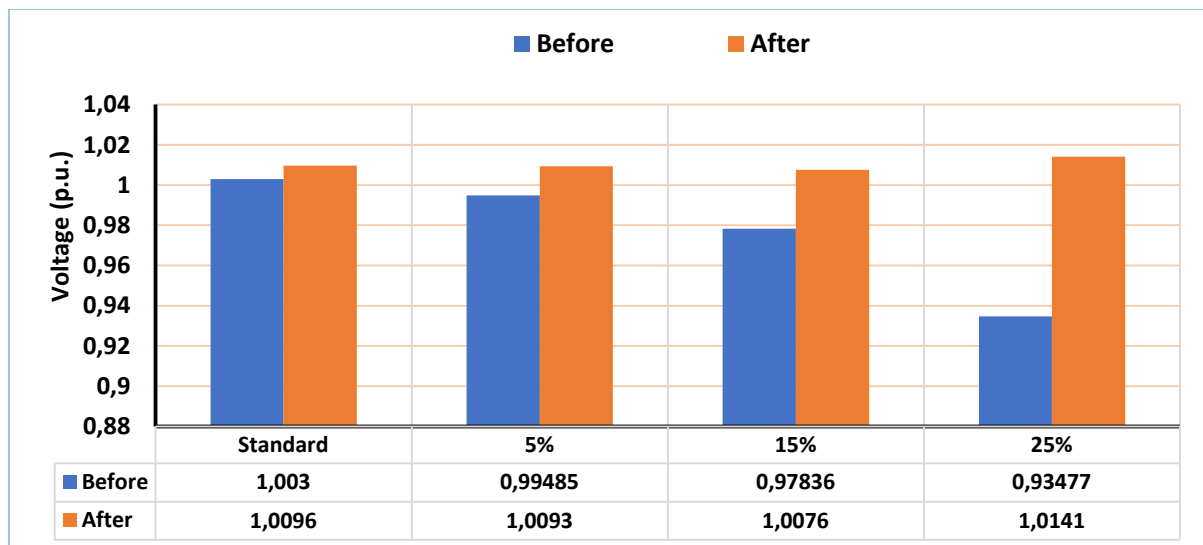
5.2 Results of optimum capacitor allocation

Implementation of PSO algorithm to determine the optimum capacitor placement and sizing on IEEE14 bus test system with incremental loads of 5%, 15% and 25% has been performed in this session. The capacitors location and sizes after optimum allocation are shown in Table-5. It illustrates the total capacitor installed 19, 42.65, 49.3 and 68.6 Mvar for standard case, 5% incremental loads, 15% incremental loads and 25% incremental loads, respectively. Figure-6 shows the voltage comparison results after optimum capacitor placement and sizing. It indicates that by installing capacitors at the optimum locations, the buses voltage is acceptable and within the statutory voltage range and even some of busses are improved. For instance, at bus 14, the voltage that was violated before capacitor installation with 0.935p.u. as Figure-5 has improved to 1.036 p.u. as shown in Figure-7. In general the minimum voltages of the

network busses for all scenarios are compared as shown Figure-8. It indicates that by installing the optimum capacitor, the significant voltages drop in case of long term load growth up to 25%, can be covered and reinforced. In other words, the voltage drop problem at receiving end busses has been increased by installing adequate size and location of capacitor. Moreover, the total power losses of the network have been also reduced after installing the capacitor into power system to obtain the best possible power quality delivery. Figure-9 shows the total power losses per scenarios for before and after capacitor installation. It can be observed from the figure that total power losses has been reduced after capacitor installation on top of minimum voltage improvement. For instance, in scenario of 25% incremental load, approximately 750Kvar power losses reduction has been achieved.

**Table-5.** Capacitor location and sizes after optimum allocation for all scenarios.

Buses Scenarios	Capacitor size (Mvar)														Total size (Mvar)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Standard	-	-	-	-	-	-	-	-	19	-	-	-	-	-	19
5%	-	-	-	0.05	8	-	0.05	-	19	4.05	-	-	6.15	5.35	42.65
15%	-	-	-	0.05	8.1	-	-	-	19	7.5	0.6	-	7.75	6.3	49.3
25%	-	-	-	-	8.1	-	4.35	-	19+ 7.45	6.7	4.25	4.1	8.1	6.55	68.6

**Figure-7.** Voltage profile after optimum capacitor allocation.**Figure-8.** Minimum voltage buses comparison before and after capacitor allocation.

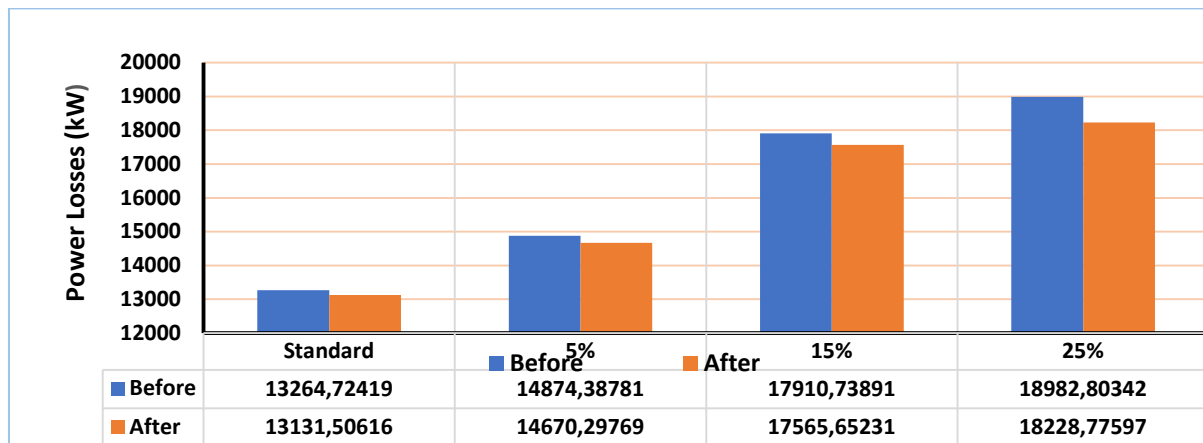


Figure-9. Total power losses comparison before and after optimum capacitor allocation.

5.3 Results of optimum DG allocation

Optimum DG unit integration in power networks using the PSO technique on IEEE 14 bus test system has been performed in this section. The long-term load growth strategy as similar as previous section with 5%, 15 and 25% incremental loads have studied in order to propose the best possible solution to avoid network collapse and avoid huge investments of network reinforcement to deliver good power quality to end receiving buses.

Hence, the main aim of this section is to determine the optimum allocation (sizing and sitting) of DG units in IEEE 14 buses test case. The results show the total power loss of the network has been reduced after installing the DG on top of the significant voltage profile improvement more especially in minimum voltage buses. The performance evaluation of PSO model was carried out by showing the best optimize number of the DG units installed on network per scenarios of load growth (standard case, 5%, 15% and 25%). As discussed in methodology of this paper the voltage limits at buses were considered as $v_{min} = 0.95$ p.u. And $v_{max} = 1.09$ p.u. as shown in the Figure-10. It indicates that all the busses are still within the statutory limit of voltage after injecting the DG units into optimum locations with adequate sizes. The

PSO approach was able to allocate the DG units at best possible location and sizes to obtain the best voltage profile as well as reduce total power losses. Table-6 shows the integrated DG units per scenarios after optimum allocation using PSO. It shows that by increasing the load growth percentage the total allocated DG sizes are increased as well to compensate the power losses of the network and improve the voltage drops during the network operation with existing network structure. Figure-11 shows the total power losses of the network for all the scenarios after optimum allocation of DG. It illustrates minimum voltage improvement more especially in scenario of high load increment, the functionality of optimum DG allocation to prevent network reinforcement. In other words, this paper highlights that the existing network can supply good power quality at end receiving buses if be facilitated with adequate DG units at weak buses. Moreover, the losses minimization is another advantage of the DG unit's integration. Figure-12 shows the results of the total power losses minimization before and after DG units' integration. It indicates the huge power losses reduction in case of 25% incremental loads from 18982kW to 4832kW which is about approximately 75% total power losses reduction.

Table-6. DG location and sizes after optimum allocation for all scenarios.

Buses Scenarios	DG units (MW)			Total size (MW)
	4	5	7	
Standard	63.70	-	19.02	82.72
5%	70.02	-	20.06	90.08
15%	91.05	-	21.23	112.28
25%	82.88	62.78	-	145.66

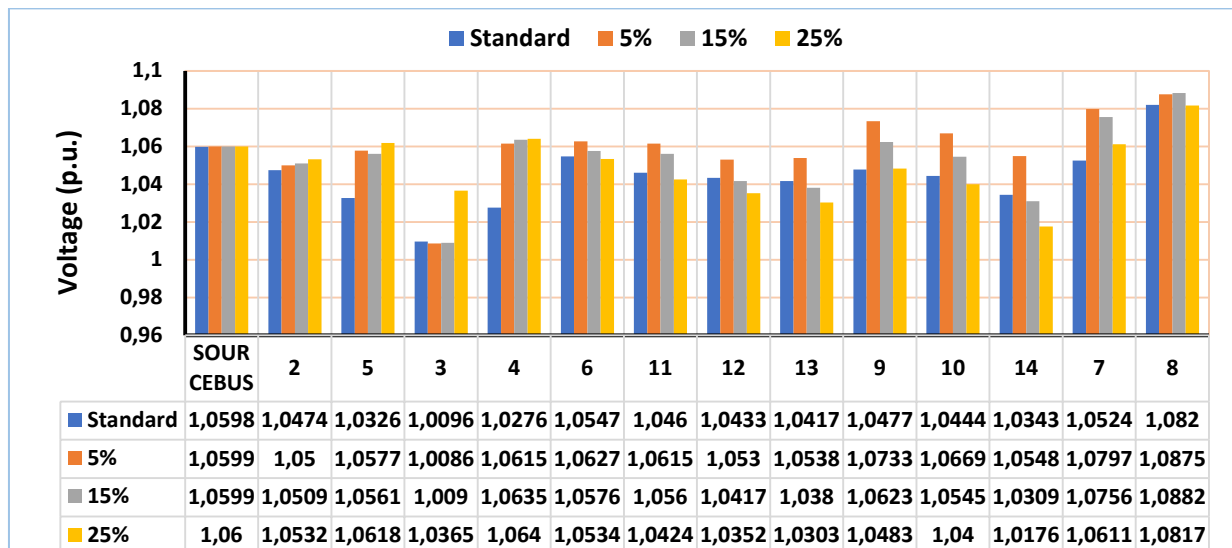


Figure-10. The voltage profile before optimum solution of DG allocation.

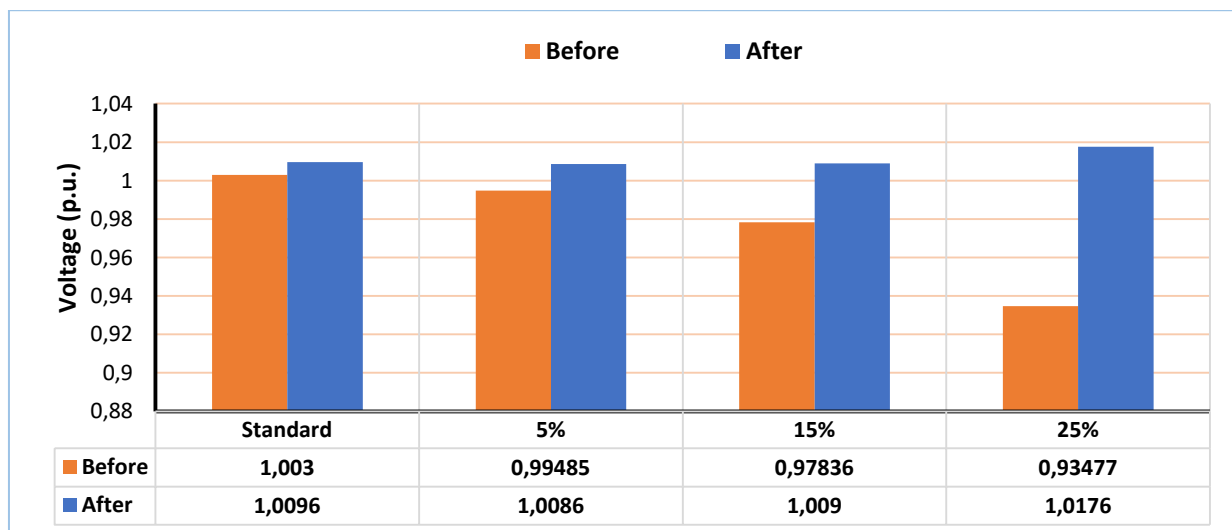


Figure-11. Minimum voltage buses comparison before and after DG allocation.

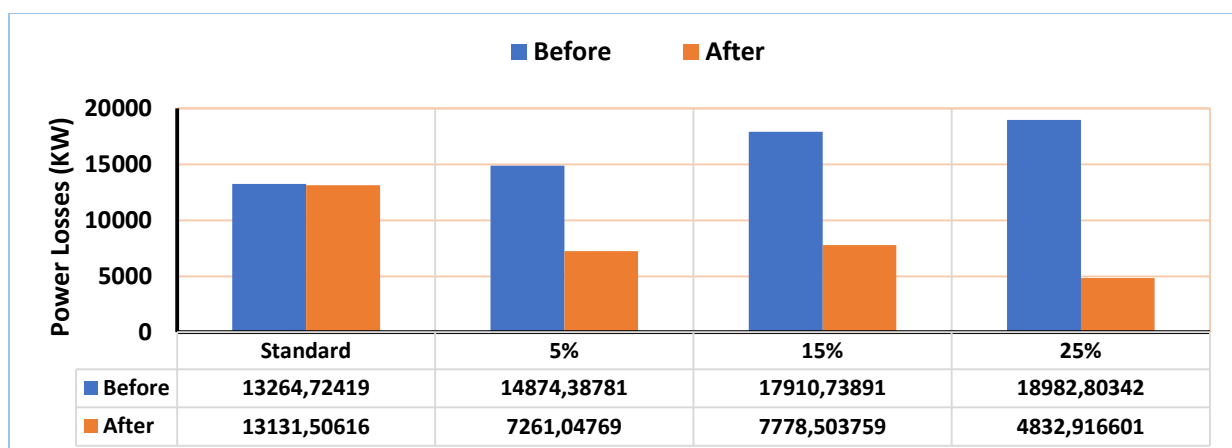


Figure-12. Total power losses comparison before and after optimum DG allocation.



6. CONCLUSIONS

This paper aims to highlight the benefits of optimum allocation of capacitor banks and DG units into power system with considering long-term load

Growth scenarios to evaluate the functionality of proposed method on the existing power networks. In this regard, this paper performed an optimization

Method by using PSO algorithm to solve the optimum allocation of capacitor and DG problem by minimization approach to reduce losses and improve busses voltage profile with subject to technical limits. The IEEE 14 buses test case has been utilized as case study to be evaluated before and after optimization in this paper. The OpenDSS power

Flow engine has been utilized to perform optimum power flow calculation. The results of this paper Show that the proposed method for optimum allocation of capacitors and DG was success to increase the network performance by improving the voltage profile and reducing the total power losses.

As seen from the obtained results, the PSO algorithm obtained the best possible voltages for the busses by allocation DG and capacitors with minimum losses for all the performed scenarios with long-term load growth of 5%, 15% and 25% load incremental. The reduction in the real power loss up to 75% in case of 25% load growth is one the significant results that highlighted in this paper as well as the minimum voltage improvement from 0.93p.u. to 1.01p.u. After optimum allocation. In general, the voltage profile has improved, and total power losses have reduced. The PSO approach was successful to find the best location and size of the DG units and capacitor banks on existing power network with long-term planning and load growth to avoid network huge investment of network reinforcement by allocating the compensators near the end receiving busses instead of increasing the size of main generators.

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REFERENCES

- [1] M. Z. B. M. RADZI. 2013. Optimal Allocation and Sizing of Distributed Generation Using Particle Swarm Optimization in Distribution System. No. June.
- [2] J. K. Charles. 2011. System Loss Reduction and Voltage Profile Improvement by Optimal Placement and Sizing of Distributed Generation (Dg) Using A Hybrid of Genetic Algorithm (Ga) and Improved Particle Swarm Optimization (Ips) By. pp. 1-122.
- [3] A. Mahari and A. Mahari. 2014. Optimal DG and capacitor allocation in distribution systems using DICA. J. Eng. Sci. Technol. 9(5): 641-656.
- [4] D. Power factory. 2015. 14 Bus System. Dig Silent Power Factory. pp. 1-9.
- [5] R. B. S. B. E, M. E and E. P. S. Email-rajendrasadafalesitrcorg. Optimal power flow of IEEE 14 bus system using FACTS device with voltage constraints. Int. J. Adv. Electr. Electron. Eng., no. ISSN: 2319-1112, pp. 113-118.
- [6] R. C. Dugan. Reference Guide: The Open Distribution System Simulator (OpenDSS). Electr. Power Res. Institute, Inc., no. November, pp. 1-199.
- [7] M. Spichakova. 2016. Modified particle swarm optimization algorithm based on gravitational field interactions Margarita. Proc. Est. Acad. Sci. 65(1): 15-27.
- [8] M. Shamshiri, C. K. Gan, K. Jusoff, I. J. Hasan, M. Ruddin, M. Yusoff, E. Engineering, M. Utem, H. T. Jaya, D. Tunggal, T. Jaya and D. Tunggal. 2013. Using Particle Swarm Optimization Algorithm in the Distribution System Planning. 7(3): 85-92.
- [9] M. H. 2015. A Review of Particle Swarm Optimization (PSO) Algorithms for Optimal Distributed Generation Placement. Int. J. Energy Power Eng. 4(4): 232.
- [10] M. Ashari and A. Soeprijanto. 2012. Optimal Distributed Generation (DG) Allocation for Losses Reduction Using Improved Particle Swarm Optimization (IPSO) Method. 2(7): 7016-7023.
- [11] I. J. Hasan, C. K. Gan, M. Shamshiri, I. Bin Bugis and M. R. Ab Ghani. 2013. Losses reduction and voltage improvement using optimum capacitor allocation by PSO in power distribution networks. Int. Rev. Model. Simulations. 6(4): 1219-1226.