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Performance Assessment of Power System by Incorporating Distributed Generation and Static VAR Compensator

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***Abstract*—Due to the continuous increment of the load demand, identification of weaker buses, improvement of voltage profile and power losses in the context of the voltage stability problems has become one of the major concerns for the larger, complex, interconnected power systems. If the voltage profile of the weaker buses is improved, the voltage stability can be improved significantly. Because of the increasing importance of the stability, it is essential to analyze and improve the voltage profile, power losses in the context of steady state stability considering weak buses of the network. Static VAR Compensators (SVC) and Distributed Generators (DGs) can be installed at the identified weaker buses to improve voltage stability and power loss. This paper focuses on identification of weakest bus/area of the system by analyzing several voltage stability indices. The multi-objective PSO is used to find the optimal location and size of DG and SVC. The impact of the distributed generation (DG) unit installation on electric power losses, voltage profile and steady state voltage stability is thoroughly analyzed. The performance is also assessed by connecting static VAR compensator (SVC). Remarkable improvement in the system performance is observed by integrating SVC and DG in the test systems like IEEE 30 interconnected and 12 bus radial systems. By showing results, the performances of DG, SVC and their combined incorporation in the same test systems are analyzed and compared.**

***Keywords*—Distributed Generation; Static VAR Compensator; weaker buses; power loss; voltage stability**

I. INTRODUCTION

The demand of power system is growing exponentially which is a challenging issue for power utilities. The existing transmission line infrastructure is not capable of supporting such a huge power demand. These results in drop in voltage profile, increased system losses, poor system efficiency, instability and disturbance. The distribution companies try to provide power by proper designing and exploitation of the network.

The power quality related problems can be alleviated to some extent by using FACTS devices such as SVC. Introducing FACTS device such as SVC is the most effective way for the utilities to improve voltage profile and voltage stability margin of the system [1].

Under stressed condition, one of the effective ways to save the system from voltage collapse is to reduce the reactive power load or add additional reactive power sources by introducing sources of reactive power such as SVC [2]. The SVC has a positive impact on enhancing the system voltage profile, improving the power factor, voltage stability and reduction in power loss.

Distributed generator (DGs) can play a major role in distribution system planning. The DGs are not centrally placed but are directly connected to the load or near the load centre. Its capacity varies from few KW to few MW [3]. DGs have different types depending upon the type of energy sources utilized for production of electric energy such as renewable and non-renewable small energy sources. Presence of DG in electrical system can represent a significant impact on the operational characteristic of the network. The integration of DG into the system reduces overall energy loss and improves supply quality, reliability and voltage stability [4]. In [5], a set of indices has been proposed to assess some of the technical benefits in a quantitative manner. The indices proposed are voltage profile improvement index , line loss reduction index, environmental impact index and benefit index.

The optimal placement and sizing of the equipment have significant impact on the system parameters. The suitable location for the reactive power compensating device for improving the voltage profile and steady state voltage stability of the system is the weak bus [6]. The recent literature review reveals that various analytical tools had been proposed to predict voltage collapse [6]-[7]. These indices provide reliable information about proximity of voltage instability and weak bus, weak area or line in the system. Another method for the optimal placement of the FACTS device or compensating device was suggested which was based on local price method where devices were allocated in the vicinity of most congested line [6]. In [7], a multi-objective particle swarm optimization technique was proposed for FACTS device allocation. In [8], a novel global harmony search algorithm is used to determine optimal location and size of shunt reactive power compensator such as Shunt Capacitor, Static Var compensator and Static Synchronous Compensator in a transmission network.

The objective function here is to improve voltage profile, voltage stability, while minimizing cost.

Several techniques were suggested for the optimal placement of the DGs for the improvement of voltage profile, reduction of line loss and improvement of voltage stability. [9]-[16]. In [9], the quantum genetic algorithm (QGA) was suggested for the optimal placing and sizing of the DG. In [10], the optimal placement and sizing was determined by the new power stability indices. The DG unit placement and sizing was proposed using particle swarm optimization (PSO)[11]. In [12] , the optimal location of DG units is according to steady state voltage stability index. The AMPL software package is utilized for evaluating the size of DG units. In [13], genetic algorithm (GA) was used for concurrent placement of DG and capacitor in a distribution network. In [14], the sensitivity analysis was developed for the optimal placement of the DG and the capacitor and the heuristic technique was used for the optimal sizing of DG and the capacitor. In [15] , the strategic placement of DG units and shunt capacitors was proposed for overall voltage support and power loss reduction in a distribution feeder. Further PSO technique was used to minimize the investment cost of DG units and shunt capacitor. In [16], a static and dynamic var planning has been proposed based on the reactive power margin for enhancing dynamic voltage stability of distribution network with distributed wind generation. Further a cost effective combination of shunt capacitor bank and D-STATCOM was determined through static and dynamic analyses to ensure voltage stability of the system after a sudden disturbance for different wind penetration levels.

In this paper, various voltage stability indices are represented so as to identify the weak bus or weak line in an area. The SVC and the DG are separately placed at the weak bus. The optimal size of the DG and the SVC is determined by multi objective particle swarm optimization technique. The performance of the SVC which is a shunt FACTS controller connected at the weakest bus is assessed by comparing voltage profile, steady state stability indices and line loss reduction. Similarly the performance of the DGs which are the active power source and which had been optimally placed in the weak bus is also assessed on the same performance parameters. Further the performance parameters are assessed by integrated placement of the SVC and the DG in the system. Standard IEEE 30-Bus and a radial 12 bus are considered as the test systems.

II. VOLTAGE STABILTY

The voltage stability is concerned with the ability of a power system to maintain acceptable voltage at all nodes in the system under normal condition and after being subjected to disturbance [17]. As the power system is becoming more complex and heavily loaded along with economic and environmental constraints, the voltage instability becomes an increasing serious problem. The voltage stability indices either reveal the weak bus or the critical lines which are on the verge of instability. The indices used to examine the system stability are briefly described in this section.

A. Fast voltage stability index (FVSI)

For a typical transmission line, the Fast voltage stability index is calculated by

$$\mathrm{FVSI_{ij}} = \frac{4Z^2 Q_j}{V_i^2 X} \qquad (1)$$

Where Z is the line impedance, X is the line reactance Q_j is the reactive power flow at the receiving end and V_i is the sending end voltage. To maintain secure condition the value of FVSI should be maintained less than 1.

B. Line stabilty index LQP

LQP index is as follows

$$\mathrm{LQP} = 4\left(\frac{X}{V_i^2}\right)\left(\frac{X}{V_i^2}P_i^2 + Q_j\right) \qquad (2)$$

Where X is the line reactance, Q_j is the reactive power flow at the receiving bus, V_i is the voltage on sending bus and P_i is the active power flow at the sending bus. To maintain secure condition, the value of LQP index should be maintained less than 1. The system stability and the system security will improve if the values of LQP index are lower .

III. STATIC VAR COMPENSATOR

The primary requirement to avoid voltage instability is that the power system should be capable of transferring reactive power from source to consumer during steady operating condition. Therefore, the planning for the SVC is the major concern for power utilities. The SVC is widely used in electric power system [13].

The SVC is a first generation FACTS device. It acts as a reactive power compensator but is not capable of exchanging the active power from the system. The SVC is a shunt device. It can be operated as both inductive and capacitive compensation.

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The susceptance (B) of SVC is controllable and directly used in power flow equation. A pair of thyristor which are connected in a back to back configuration is used to control the current through the SVC.

IV. Distributed Generation

The DG refers to small generating sources or units installed near the local loads or load centers. This avoids the need of network expansion. The DG can be defined in various ways. The electric power research institute defines a DG from a few KW to 50 MW [3]. The international energy agency (IEA) defines a DG as a generating plant serving customer onsite or providing support to a distributed network connected to grid at distribution level voltages. The international conference on large high voltage electric system defines DG as smaller than 50 -100 MW [3]. The DGs have many different types ranging from conventional fossil fuel based combustion to the renewable energy including wind, photovoltaic, micro turbines, small hydro turbines, CHP or hybrid. The word distributed generation is also subjective and changes with respect to region.

V. Criterian For Measuring The Benefits Of DG Or SVC Placement

A. Voltage profile improvement index(VPII)

The voltage profile improvement can be calculated from the following index [19].

$$\mathrm{VPII} = \frac{\mathrm{VP_{W/DG}}}{\mathrm{VP_{Wo/DG}}} \qquad (3)$$

Where VP is given by

$$VP = \sum_{i=1}^{N} V_i L_i K_i \qquad (4)$$

V_i is the voltage magnitude, L_i is the load represented as complex power in per unit, K_i is the weighting factor, N is the total number of bus. $VP_{W/DG}$ and $VP_{Wo/DG}$ is the voltage profile with and without DG or SVC respectively.

VPII<1 Voltage profile of the system has decreased

VPII=1 No benefit

VPII>1 Improved voltage profile of the system

B. Line loss reduction index

Real and Reactive power loss indices (ILP and ILQ) are given by following equation [20]

$$ILP = \frac{[P_{LDG}]}{[P_L]} \qquad (5)$$

$$ILQ = \frac{[Q_{LDG}]}{[Q_L]} \qquad (6)$$

Where P_{LDG} is the real and Q_{LDG} is the reactive power line loss with DG or SVC. P_L and Q_L is the real and reactive power line loss respectively without DG or SVC.

ILP<1 Electrical line losses is reduced
ILP=1 Electrical line loss is not changed
ILP>1 Electrical line loss is increased

C. Voltage deviation index

$$IVD = max_{i=2\ to\ n}\left(\frac{|\overline{V_{nom}}| - |\overline{V_i}|}{|\overline{V_{nom}}|}\right) \qquad (7)$$

This index is used to find the voltage deviation from the nominal value, V_{nom}. The network performance will be improved if the index is closer to 0.

VI. Problem Formulation

In this section, problem formulation is made for optimum sizing and location of DG or SVC considering the three objectives: (i) minimizing the real power loss, (ii) minimizing the reactive power loss and (iii) minimizing the voltage deviation. Minimizing all the above parameters suggests improvement in system performance

The PSO based multi-objective function is given by

$$OF = W1.ILP + W2.ILQ + W3.IVD \qquad (8)$$

where $\sum_{i=1}^{3} W = 1$ (9)

TABLE 1
Different weight factors

INDICES	WEIGHT
W1	0.5
W2	0.25
W3	0.25

Weights are indicated to give importance to each index for penetration of DG or SVC.

As shown in Table 1, maximum importance is given to real power loss while calculating OF in equation (8) for finding the optimal size and location. This is due to the fact that real power loss reduction will in turn stabilize the frequency of the grid. As a result the system frequency deviation will be minimized. The multi-objective function is minimized subjected to various operational constants

1) Power balance constraints

$$\sum_{I=1}^{N} P_{DGi} = \sum_{i=1}^{n} P_{Di} + P_L \qquad (10)$$

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Where P_{DGi} is the real power generation by DG at bus i and P_{Di} is the power demand at bus i. P_L is the real power loss in the system.

2) Voltage constraints

$$|\overline{V}_i|^{min} \leq |\overline{V}_i| \leq |\overline{V}_i|^{max} \qquad (11)$$

3) The power flow should be

$$S_i \leq S_{imax} \qquad (12)$$

Where S_i is the power flow through the distribution line S_{imax} is the max allowable limit of power flow through the line.

4) Generator limits of generator capacity

$$P_{imin} \leq P_{Gi} \leq P_{imax} \qquad (13)$$

Where P_{imin} is the lower limit of generator capacity and P_{imax} is the upper limit.

VII. PATICLE SWARM OPTIMIZATION

In this paper PSO technique is utilized to solve the multi-objective problem of optimal location and optimal sizing of DG and SVC.

PSO is a population based stochastic optimization technique. It is an evolutionary computation technique. Dr Eberhart and Dr Kennedy developed PSO in 1995 [11]. In this technique a group of random particles are generated. According to fitness value the best solution is determined in the current iteration and also the best fitness value is stored. The best fitness solution is known as pbest. Another best fitness value is also tracked in the iteration obtained so far. The best fitness value is the global best and its corresponding particle is called gbest, as shown in Fig. 1.

Each particle updates its position and velocity according to the following equation:

$$V_i^{k+1} = wv_i^k + c_1 rand \times (p_{best\,i}^k - s_i^k) + c_2 rand \times (g_{best\,i}^k - s_i^k) \qquad (14)$$

where s_i^k= current position of the i[th] particle.

v_i^k= current velocity of the i[th] particle

p_{besti}^k= pbest of i[th] particle for the k[th] generation

g_{besti}^k = gbest of the i[th] particle considering the whole iteration that is up to k[th] generation

V_i^{k+1} = updated velocity of the i[th] particle

w=inertia weight of the i[th] particle

$$w = 0.5 + \frac{rand}{2} \qquad (15)$$

$c_1 \& c_2$= Constriction factor

$rand()$= Random number between 0 and 1

$c_1 \& c_2$=1.5

The current searching point can be updated by the following equation

$$x_i^{k+1} = x_i^k + v_i^{k+1} \qquad (16)$$

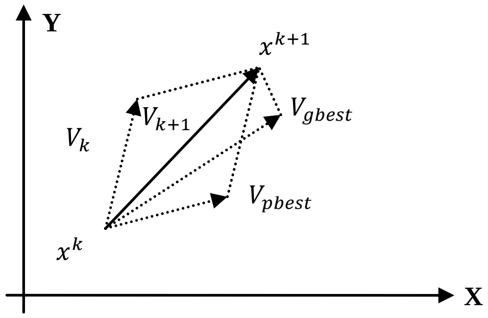

Fig. 1. Searching Point by PSO

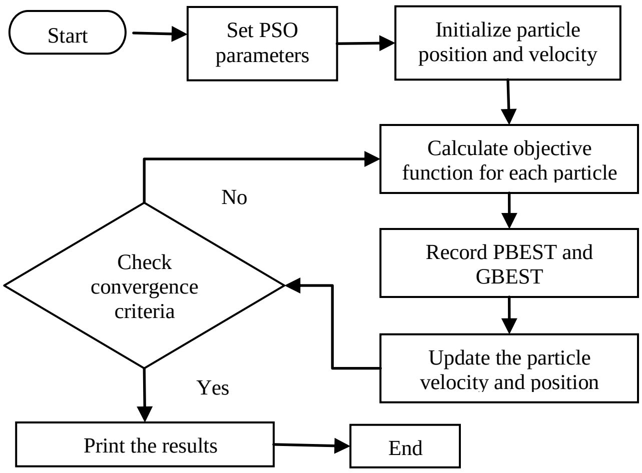

Fig. 2. Flowchart of PSO.

VIII. PROPOSED ALGORITHM

PSO procedure is given in the following steps:-

STEP 1: Input line and bus data of the network.

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STEP 2: Set the upper and lower limits of voltage magnitude, phase angle, line power, reactive power generation of generator bus (except slack bus) and active power generation of DG.

STEP 3: Set maximum number of iteration.

STEP 4: Initialize power flow variables (voltage magnitude and phase angles) within their corresponding limits randomly.

STEP 5: Apply constrained power flow using PSO at base load and 150% of base load.

STEP 6: Update power flow variables using PSO.

STEP 7: Check convergence criteria, if not converges then go to step 5, otherwise go to next step.

STEP 8: Evaluate voltage stability index and obtain weakest bus according to it.

STEP 9: Install DG or SVC or combination of two.

STEP 10: Initialize the size(s) of the device(s) randomly within the corresponding limits.

STEP 11: Calculate the objective function considering ILP, ILQ and IVD.

STEP 12: Apply PSO as shown in Fig. 2.

STEP13: Update the size of the device.

STEP 14: Check the objective function for the convergence criteria.

STEP 15: If it is converged show results, otherwise go to step 12.

IX. Simulation Result And Discussion

PSO parameter taken for optimal size and location is as follows: population size=30, maximum iteration=50. Maximum number of DG or SVC is one for each system. The proposed algorithm has been tested on 2 test systems, IEEE 30 bus system [22] and radial 12 bus system [21]. To demonstrate effectiveness of the proposed algorithm, four different cases are introduced for each test system.

Base Case- System without DG or SVC

Case 1- SVC is placed at the optimal location

Case 2-DG is placed at the optimal location

Case 3-Combined DG and SVC placed at optimal location

The PSO Technique with multi objective function is used for each of these cases i.e. Case1, Case2 and Case 3. All results are compared with the Base Case system. The result analysis in determination of optimal location and size of DG, SVC and DG with SVC is explained.

Weak bus is identified as a node where poor voltage profile is observed. Voltage stability index FVSI and LQP is chosen for the stability analysis. The lines which have high values of stability index are identified as weak (critical) lines. For 30 bus system, line numbers 5, 8, 15 are identified as weak line as shown in Table 2. In 12 bus system, line numbers 7 and 8 are identified as weak lines as shown in Table 3.

In Table 4, the optimal DG and SVC size and the corresponding location is shown. Selection of optimal size and location is done by PSO technique. The selection is done in such a way that the objective function given in (8) is minimized. As shown in Fig. 3 the value of the objective function reached the global minimum and stayed there till the end of the iteration. This satisfies the convergence criterion of maximum no of iteration.

Table 2
Stability Index Of 30 Bus System

Line No	FVSI	LQP
1	0.0294	0.0265
2	0.0085	0.0081
3	0.0115	0.0154
4	0.0026	0.00223
5	**0.149**	**0.1475**
6	0	0.0051
7	0	0
8	**0.0579**	**0.0967***
9	0.0379	0.0343
10	0.0522	0.0483
11	0	0
12	0.0426	0.0426
13	0	0
14	0.0079	0.0079
15	**0.073**	**0.0743**
16	0	0.0008
17	0.0181	0.0173
18	0.0147	0.0124
19	0.0157	0.0144
20	0.0409	0.0189
21	0.009	0.041
22	0	0.0084
23	0.0206	0.0166
24	0.0022	0.0019
25	0.0063	0.0058
26	0.0203	0.0178

27	0.0063	0.0304
28	0.0369	0.0002
29	0	0.0001
30	0.0149	0.0129
31	0.0526	0.0443
32	0.0644	0.0584
33	0	0.0029
34	0.048	0.0331
35	0	0
36	0	0.0007
37	0.0181	0.0141
38	0.0554	0.0432
39	0.0433	0.0342
40	0	0.0131
41	0	0
42	0	0

*The values of stability index for weaker lines are represented in bold

Table 3.
Stability Index Of 12 Bus System

Line No	FVSI	LQP
1	0.0074	0.0011
2	0.004	0.0006
3	0.0013	0.0002
4	0.0113	0.0017
5	0.002	0.0003
6	0.0061	0.0011
7	**0.0336**	**0.0024**
8	**0.0382**	**0.0028**
9	0.015	0.0011
10	0.0079	0.0006
11	0.0032	0.0002

Table 4.
Optimal Dg And Svc Sizes

30 BUS			12 BUS		
BUS NO	*DG MW*	*SVC MVAR*	*BUS NO*	*DG MW*	*SVC MVAR*
4	42.45	10.51	8	0.22	.017
7	43.51	12.52	9	0.23	.018

Table 5.
Loss Reduction And Voltage Profile Improvement Comparison For 4 Different Cases

Case	30 bus		12 bus	
	MW loss	*VPII*	*MW loss*	*VPII*
Base Case	7.04		0.021	
Case 1	7	1.013	0.015	1.005
Case 2	5.08	1.001	0.007	1.03
Case 3	5.07	1.014	0.006	1.04

For comparison of results, 4 different cases are chosen for each test system. The location chosen is as follows, for 30 bus system bus no 4 and 7 is identified as weak bus and is chosen for DG and SVC placement. For 12 bus system, optimal location chosen for DG and SVC placement is bus no 8 and 9. From Table 5, it is observed that for 30 bus system, the reduction of power loss by placing DG is around 27.84%, by placing the SVC it is around 1% and by putting DG and SVC it is around 29%. For 12 bus radial systems, it is observed that placing DG in the optimum location, the reduction of power loss is around 65%, by placing SVC it is around 28% and by putting both DG and SVC it is around 70%. Best results are obtained by combined allocation of DG and SVC. The contribution of the DG in reduction of power loss is more as compared to the SVC. This is evident from the results shown in Table 5.

Further it is observed that both DG and SVC has got a major role in voltage profile improvement of the system.

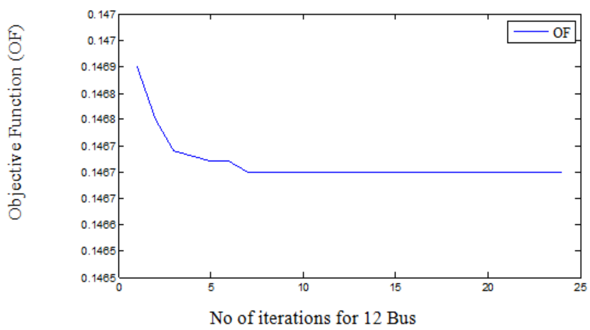

Fig. 3. Convergence characteristic of Radial 12 bus distribution system.

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In Fig. 4 and Fig. 5, voltage profile of 30 bus interconnected and 12 bus radial distribution is shown for 4 different cases. Improvement in voltage profile is observed in both the systems by the use of DG as well as SVC. Further the voltage profile has improved marginally in interconnected system and significantly in radial system. Since in the interconnected system the number of generator buses is more, the voltage profile of the system is within the limit.

Therefore the usage of DG or SVC does not add any significant benefit to the system at base load.

In radial system since there is only one power source (generator), the improvement in the voltage profile is very high by using DG or SVC in the weak buses. Further results in Fig. 5 state that in the radial system the improvement is remarkable if DG is placed in the system as compared to SVC. Best results are observed if both DG and SVC is simultaneously placed in a line.

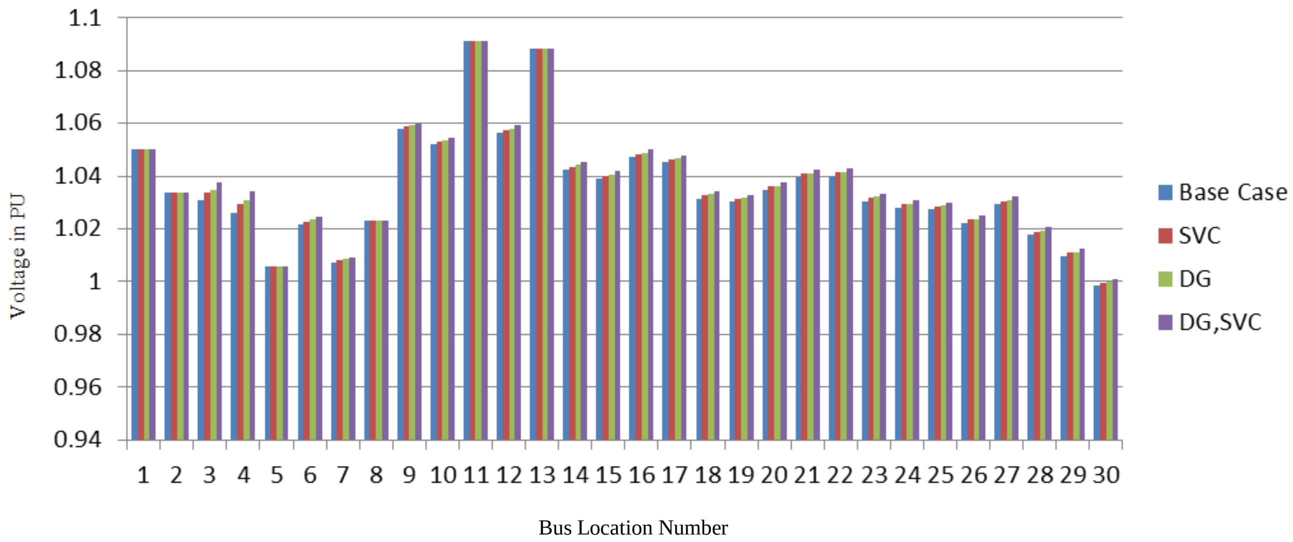

Fig. 4. Voltage profile of 30 Bus system

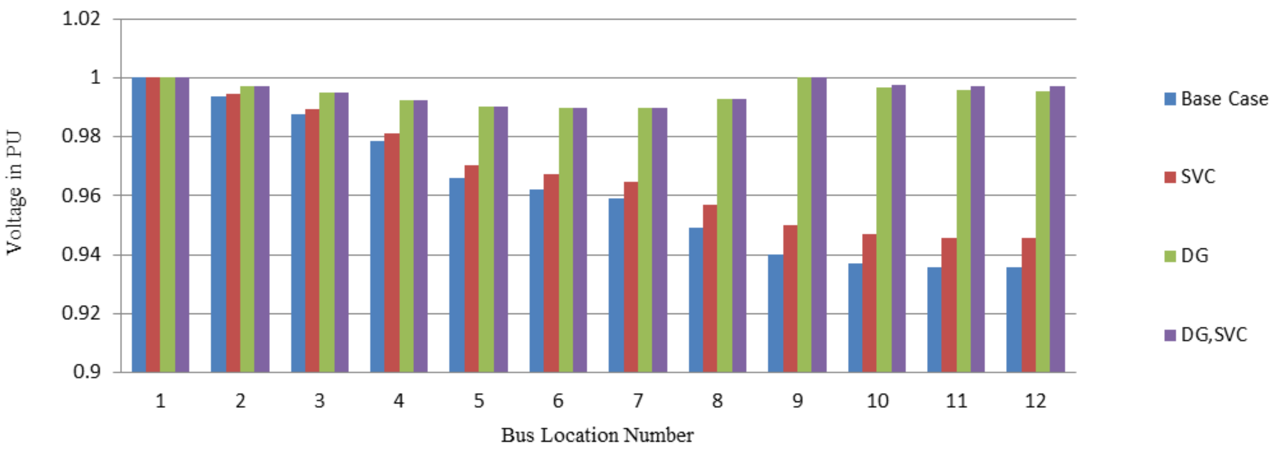

Fig. 5. Voltage profile of 12 Bus system

In Table 6 & 7, voltage stability analyses are again shown for 4 different cases. FVSI and LQP indices are chosen for line stability analysis. Weak bus /area is identified by solving voltage stability analysis equations of Fast voltage stability index (FVSI) and line stability analysis (LQP).

Line stability analysis is done by taking weak bus/area into consideration. As shown in Table 6, line numbers 5, 8 and 15 has been identified as weak area. For clarity of results voltage stability analysis has been done in 30 bus system by putting 150% load. The results clearly show that there is a significant improvement in terms of voltage stability. Lower the index or closer the index is to zero, better is the network performance in terms of stability.

Best results are observed by combined allocation of DG and SVC in the system.

In Table 7, stability analysis is being shown on 12 bus radial distribution systems. The analysis is being done on base load condition. Again weak bus/area is identified by FVSI and LQP. Line numbers 8 and 9 are identified as the weakest line, as here the values of line stability index FVSI and LQP are highest. DG, SVC is separately placed in each line and voltage stability analysis is being done. Significant improvement is observed in each case. Again the best results were obtained when both DG and SVC were put at a time in the system. Thus it is beneficial to place them in this system.

TABLE 6.
STABILITY INDEX OF 30 BUSES AT 150% OVERLOADING

Line No	Without DG		With DG		With SVC		With DG and SVC	
	FVSI	*LQP*	*FVSI*	*LQP*	*FVSI*	*LQP*	*FVSI*	*LQP*
5	0.25	0.348	0.17	0.21	0.247	0.297	0.166	0.208
8	0.09	0.807	0.06	0.47	0.085	0.803	0.065	0.426
15	0.12	0.143	0.09	0.10	0.112	0.132	0.087	0.099

TABLE 7.
STABILTY INDEX OF 12 BUS SYSTEM BASE LOAD

Line No	Without DG		With DG		With SVC		With DG and SVC	
	FVSI	*LQP*	*FVSI*	*LQP*	*FVSI*	*LQP*	*FVSI*	*LQP*
7	0.0336	0.0024	0.0316	0.002	0.0318	0.002	0.0302	0.002
8	0.0382	0.0028	0.0349	0.00260	0.0356	0.00262	0.0331	0.0025

X. CONCLUSION

The above study reveals that there is a significant improvement in the performance of the system by optimal placement of DG or SVC while satisfying constraint. In this paper various voltage stability indices has been solved so as to identify the weak bus. The multi-objective PSO Algorithm has been solved to identify the optimal size and location of the devices. It is revealed that when DG is placed in a compensated system there is a significant improvement in system performance in terms of voltage profile improvement, line loss reduction and voltage stability improvement. From the results, it can be concluded that DG has more role in loss reduction as compared to SVC. Further it is observed that the improvement is more apparent if DG and SVC is placed in a radial system instead of an interconnected system.

REFERENCES

[1] A.R Phadke,S.K .Bansal K.R Niazi ,“ A comparision of voltage stability indices for placing shunt FACT controller”. IEEE International conference on emerging trends in engineering and technology, pp. 939-944,2008

[2] Faisal B.Alhasawi and jovica V.Milanvic”Tecno economic contribution of FACT devices to the operation of power system with high level of wind power intregration.”,IEEE transaction on power system, vol.27 no.3 ,August 2012

[3] Thomas Ackermnn,Goren Andersson and Lennart Soder,”Distributed generation:a definition,” Electrical power system research, vol. 57, pp.195-204,2001

[4] V.V.S.N.Murthy,Ashwani Kumar,”Comparision of optimal DG allocation method in radial distribution systems based on sensitivity approaches”, Electrical power and energy systems, vol.53 , pp. 450-467,2013

[5] P.Chiradeja, R.Ramakumar," An approach to Quantify the technical benefits of Distributed Generation",IEEE Transactions on Energy Conversion ,vol .19,No 4,December 2004

[6] J.D.Finney, H.A.Othman and W.L Rutz,"Evaluating transmission congestion constraints in systemplanning,"IEEE transaction power system,vol.12 ,pp. 1143-1150,Aug 1997

[7] Rony Seto Wibowo,Naoto Yorino,Mehdi Eghbal,Yoshifumi zoka Yutaka Sasaki,"Fact device allocation for congestion management by means of MOPSO", IEEE T&D Asia, 2009

[8] Reza Sirjani,Azah Mohamed Hussain Shareef ,"Optimal allocation of shunt var compensator in power system using a novel global harmony search algorithm", Electric Power and Energy system, vol 43, pp. 562-572,2012

[9] Niketut Aryani,Muhammad Abdillah,Adi Soeprijanto,"optimal placement and sizing of distributed generation using Quantum genetic algorithm for reducing loss and improving voltage profile,IEEE TENCON, June 2011

[10] M.M Aman ,G.B Jasmon,H Makhlis,A.H.A Bakar ,"Optimal placement and sizing of DG based on new power stability index and line losses" ,Electric power and energy system ,vol43,pp. 1296-1304,2012

[11] Seyed Mohammad Hossain ,Nabavi Mohammad, A.SMasoum."Placement and sizing of distributed generation units for congestion management and improvement of voltage profile using PSO", 2011 IEEE

[12] M.Abdel-Akher,A.A.Ali,A.M Eid,H.El-Kishky,"Optimal size and location of Distributed Generation unit for voltage stabilty enhancement",2011IEEE

[13] Sayyid Mohssen.Sajjad Mahmoud,Reza Haghifan,Javed Salehi" "Simultaneous placement of distributed generator and capacitor in distribution network considering voltage stability index",Electric power and energy sytem,vol.46, pp. 366-375,2013

[14] S.Gopiya Naik,D.k.Khatod ,M.PSharma, "Optimum allocation of combined DG and capacitor for real power loss minimization in distribution network ",Electric power and energy system,vol.53, pp. 967-973,2013

[15] Kai Zou,A.P.Agalgaonakar,K.M .Muttaqui,S.Perera,"Voltage support by Distributed Generator units and shunt capacitor in distribution system",2009 IEEE

[16] N.K.Roy H.R.Pota,M.J.Hossain,"Reactive power managment of distribution networks with wind generation for improving voltage stability"vol.58 pp. 85-94,2013

[17] Claudia Reis F.p.Macial Barbosa, "A comparision of voltage stability indices " IEEE MELCON Spain, pp. 10007-1010,2006

[18] J.S Huang ,Z.H Jiang ,M.Negnavitsky,"Loadabilty of power system and optimal SVC placement" .Electric power and energy system, pp. 167-174,2013

[19] P-Ajay-D-Vimal Raj ,S.Santhilkumar J.Raja "Optimization of distributed generation capacity for line loss reduction and voltage profile improvement using PSO" Electrika, Vol 10 , pp. 41-48,2008

[20] Amany M,EL-Zonkoly," Optimal placement of multiDG units including different load models using PSO" Scientific research Smart grid and renewable energy system , pp. 160-171,2010

[21] D.DasH.S Negi D.P.kothari," Novel method for solving radial distribution network"in proc. IEE Generation Transmission Distribution vol141,pp. 291-298,july1994

[22] T.Nagaskar .M.Sukhija "Power System Analysis":Oxford Publication

[23] S.Ghosh D.das, "Method for load flow solution of radial distribution network" in Proc.IEE Generation transmission and distribution, vol146, November 1999