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A Novel Strategic Approcah for Dg Location Considering Security Issues

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Abstract— **In this paper, a novel strategic approach is proposed to locate distributed generation (DG) in the primary distribution network under (N-1) line outage security criterion. The static voltage stability margin (VSM) using continuation power flow (CPF) is determined for each line outage condition and based on corresponding reduced VSM is considered as a criterion for line outage ranking. The critical bus is selected for DG location under worst line contingency condition. Using repeated power flow (RPF) approach, the DG value is increased up to network becomes normal state. At this stage, the TVAC-PSO algorithm is implemented to optimize system voltage profile and so loss minimization. The proposed approach is tested on standard IEEE test systems and is found to be very effective in identifying the suitable location and size of DG for voltage stability margin enhancement.**

Index Terms— **Continuation power flow, distributed generation, (N-1) line outage security criterion, repeated power flow, TVAC-PSO algorithm, voltage stability margin.**

I. INTRODUCTION

The demand of power is escalating in the world of electricity. This growth of demand triggers a need of more power generation. Distributed generation (DG) uses smaller-sized generators than does the typical central station plant. Distributed Generation (DG) also called as Dispersed Power (DP) or on-site generation or Distributed Resources (DR) or Distributed Energy Resources (DER) is defined as the electrical energy that is generated and distributed using small scale technologies closer to its end users. DG mainly depends upon renewable technologies like wind power, photovoltaic cells, geothermal energy and hydro power plants. These small scale technologies can yield power from 1KW to as much as 100MW [1].

A distributed generation (DG) unit with adequate generation capacity can be directly connected to a bulk consumer or integrated to the distribution grid of the utility at an appropriate location. The major technical and economical benefits of DG include: reduced line losses, voltage profile improvement, increased overall energy efficiency, enhanced system reliability and security, improved power system quality, relieved congestion, reduced operational & maintenance costs for some DG technologies, reduced fuel costs, reduced health care costs due to improved environment and low operating costs due to peak shaving. On the other hand, DG units may introduce few problems to the existing protection systems because of their short circuit current contributions. Some of the disadvantages of dg include: the distribution system needs adequate protection at the distributed generator to ensure safe and stable power exchange, large number of DG's may require complex signaling to facilitate stable power flows, initial costs may be very high for some dg technologies, misplacement of dg's leads to high losses in the system and chances of reverse power flow in some cases is high.

Generally, DG's are placed at the consumer level i.e. at the distribution side of the power system. There are many technical, economical and environmental benefits in placing DG. Improper placement of DG may lead to reverse effects which lead to increase in losses and also may introduce few problems to existing system. Hence, proper placement of DG is became an interesting research topic in the deregulation environment. From the literature, the primary objective of DG location and rating is loss minimization via voltage profile improvement. In [2], the node with low voltage collapse margin is identified in every iteration of multiple DG placement procedure based on the Voltage Collapse Index (VCI). The rating of DG unit at the identified location is determined by evaluating the multi-objective performance index using Genetic Algorithm (GA). In [3], the active power losses, reactive power losses and the cumulative voltage deviation are included in the fitness function and the optimization is obtained with GA. In [4], a new approach by the associate with artificial bee's colony algorithm (ABC) has been developed for finding the optimal locations and sizes of DGs for loss minimization. The stable node voltages referred as power stability index (PSI) is developed considering stable node voltages referred as power stability index (PSI) and a new analytical approach is adopted to visualize the impact of DG on system losses, voltage profile and voltage stability [5]. In [6], Particle Swarm Optimization (PSO) technique is proposed to find the optimal size and optimum location for the placement of DG in the radial distribution networks for active power compensation by reduction in real power losses and enhancement in voltage profile. Two strategies are proposed in [7]. Different DG placements are compared in terms of power loss, loadability and voltage stability index. To improve power transfer capacity, two line stability indices, the Fast Voltage Stability Index (FVSI) and Line Stability Factor (LQP) for voltage stability contingency analysis are compared. The sizing and placement of DG is based on single instantaneous demand at peak, where the losses are maximum values. In [8], the optimum location of DG units is specified by introducing the power losses and voltage profile as variables into the objective function. The optimization problem is solved using the Combination of Particle Swarm Optimization and Clonal Selection Algorithm (PCLONALG) to acquire superior solutions.

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From all these works, the DG location can be identifying either in strategic approach or by using any heuristic algorithm. In this paper, we have defined reduced voltage stability margin (RVSM) for identifying critical line outage in the network using continuation power flow (CPF). Under this contingency, the value of DG is determined using repeated power flow (RPF). Finally the Time Varying Acceleration Coefficients - Particle Swarm Optimization (TVAC-PSO) is applied to optimize transmission losses via voltage profile improvement.

II. PROBLEM FORMULATION

By performing continuation power flow [9], the line rankings are determined. This work is similar to [10], in which the ranking is done based on reduced voltage stability margin for FACTS devices location. The (N-1) line outage contingency analysis is considered for static security assessment. All the lines may not be caused to insecure operation in system. The lines which are not cause to unsecured state treated as normal contingencies and remaining as credible contingencies. Under any line contingency, the loading level of remaining lines should be maintained at least at their rated MVA capacity. The Repeated Power Flow (RPF) [11] method is adopted to determine the required load curtailment or DG size. The mathematical models are briefed here.

$$LC_p = \left(P_{d,p} + jQ_{d,p}\right)\left(1-\lambda_c\right) \qquad (1)$$

where LC_p is the required load curtailment (MW) at bus p, $\lambda_c \left(0<\lambda_c<1\right)$ is the load curtailment factor and $P_{d,p}$ and $Q_{d,p}$ are the actual real and reactive power demands at bus p. As λ_c increases, the load curtailment increases and hence in optimization problem the location will optimize based on minimum λ_c value.

In case of DG integration at bus p, the λ_c set to zero and the output power of DG will determine as follows:

$$DG_p = \lambda_{DG} \times P_{d,p} \qquad (2)$$

where DG_p is the required real power generation (MW) by DG at bus p, $\lambda_{DG}\left(0<\lambda_{DG}<1\right)$ is the penetration level factor of DG and $P_{d,p}$ is the actual real power demand (MW) at bus p. As penetration level λ_{DG} increases, the DG output increases and so load will met locally. Since bus p is modeled as PV bus with specified voltage 1.0 p.u, the MVAr generation is undefined at first stage. By optimizing the λ_{DG} towards congestion relief, we will get MVAr generation and correspondingly the MVA rating of DG can determine finally.

III. ILLUSTRATIVE EXAMPLE

In order to understand clearly, we have illustrated the concept with an IEEE-6 bus system. The bus data and line data are given in Table 1 and Table 2 respectively. Base case simulation using PowerWorld® simulator is illustrated in Fig. 1 and validating its normal operating state with (8.4 MW – j1.2 MVAr) transmission loss. For convenience, the case studies are divided into two sections to evaluate the required load curtailment or DG rating for normal operating state under (N-1) line outage security criterion. The RPF is used to determine the load curtailment or DG rating as explained in Section II.

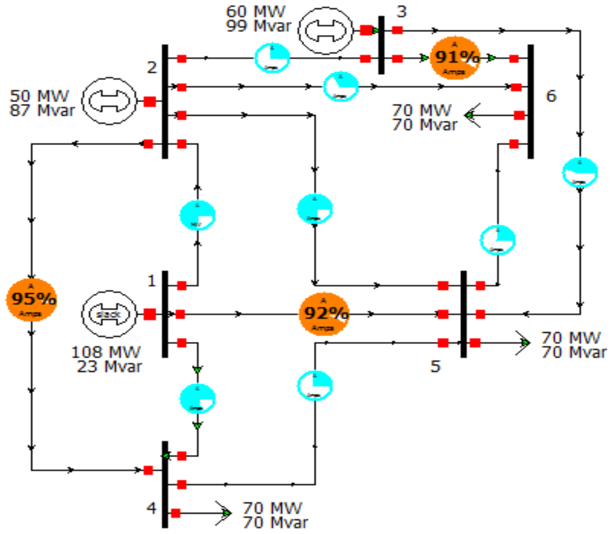

Fig.1 Simulation of base case.

A. *Load Curtailment Approach*

The simulation of line 1-2 outage contingency is given in Fig. 2. From this, it is evidencing that system is under unsecured mode with congestion in the network. In order to relieve congestion, the load is curtailed at each bus sequentially. The procedure is carried out for all transmission line outages and the corresponding results are given in Table 1.From the results, load curtailment is less at bus-5 when compared with bus-4 and bus-6. In other words, the required load curtailment at bus-5 can meet with DG integration. Similarly, some other situations are mentioned as ‘ineffective’ because the 100% load curtailment at that bus is also not relieved the congestion. For some situations, we mentioned as ‘NA’ because no lines are subjected to congestion.

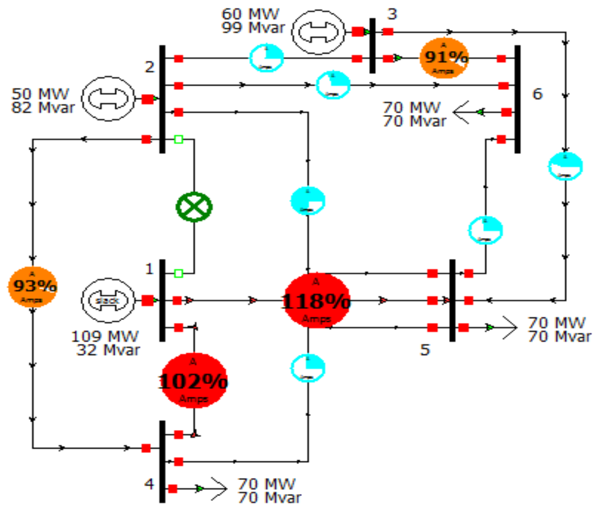

Fig.2 Simulation of line 1-2 outage

Table 1. Line Outages and Required Load Curtailment

S. No.	Outaged Line	No. lines Overloaded	Required Load Curtailment(MW + *j* MVAr)		
			Bus-4	Bus-5	Bus-6
1	1 - 2	2	21+j21	12+j12	16+j16
2	1 - 4	3	33+j33	----	----
3	1 - 5	3	----	17+j17	----
4	2 - 3	Nil	NA	NA	NA
5	2 - 4	2	25+j25	----	----
6	2 - 5	2	19+j19	6+j6	----
7	2 - 6	2	----	----	15+j15
8	3 - 5	4	----	14+j14	----
9	3 - 6	3	23+j23	4+j4	----
10	4 - 5	Nil	NA	NA	NA
11	5 - 6	Nil	NA	NA	NA

Note: ----- indicates ineffectiveness in that case.

A)DG Integration Approach

In this approach, a fictitious generator is added at bus-5 as a DG. The output power of DG is adjusted up to 11 MW and the situation of congestion relief is given in Fig. 4. As per load curtailment approach, we need to curtail 12 MW at bus-5 for normal operating state but when it is equipped with DG, only 11 MW power injection locally is relieved the congestion. The similar procedure is carried out sequentially for all transmission line outages and the corresponding results are given in Table 2.

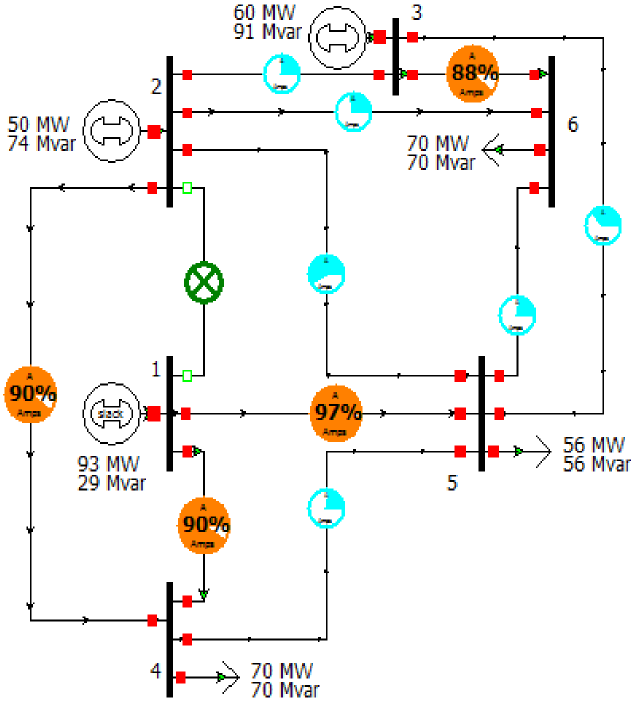

Fig.3 Congestion relief by load curtailment at bus-5 under line 1-2 outage.

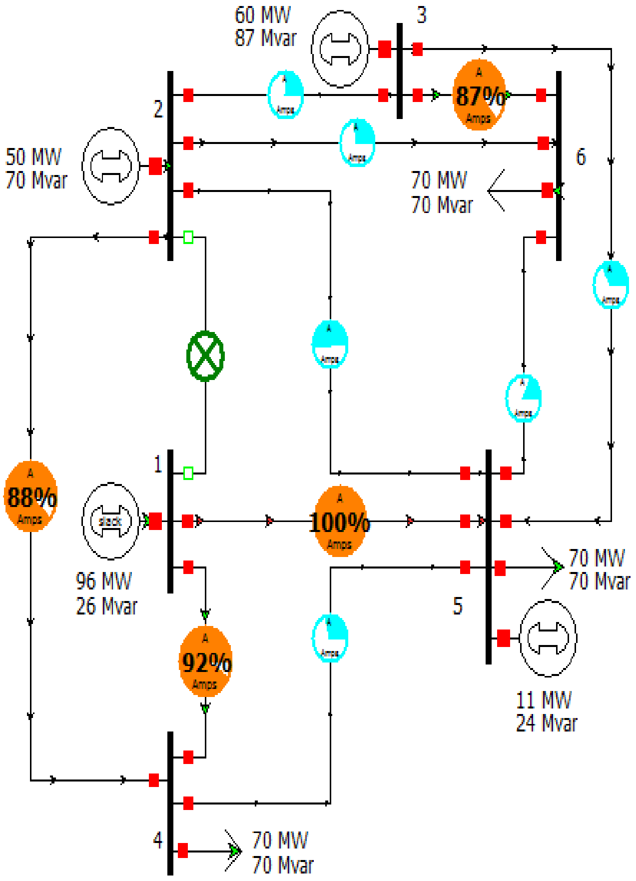

Fig.4 Congestion relief by DG integration at bus-5 under line 1-2 outage.

Table 2. Line Outages and Required DG Ratings

S. No.	Outaged Line	No. lines Overloaded	Required DG (MW + *j* MVAr)		
			Bus-4	Bus-5	Bus-6
1	1 - 2	2	-	11+j25	-
2	1 - 4	3	32+j41	-	-
3	1 - 5	3	-	15+j45	-
4	2 - 3	Nil	-	-	-
5	2 - 4	2	5+j67	-	-
6	2 - 5	2	-	0+j48	-
7	2 - 6	2	-	-	6+j20
8	3 - 5	4	-	0+j56	-
9	3 - 6	3	-	0+j66	-
10	4 - 5	Nil	NA	NA	NA
11	5 - 6	Nil	NA	NA	NA

With this illustrative case study, we are concluding that the location of DG and its rating can effectively improve the system performance and this is taken as an optimization problem. The entire solution in the form of flow-chart is given in Fig. 5.

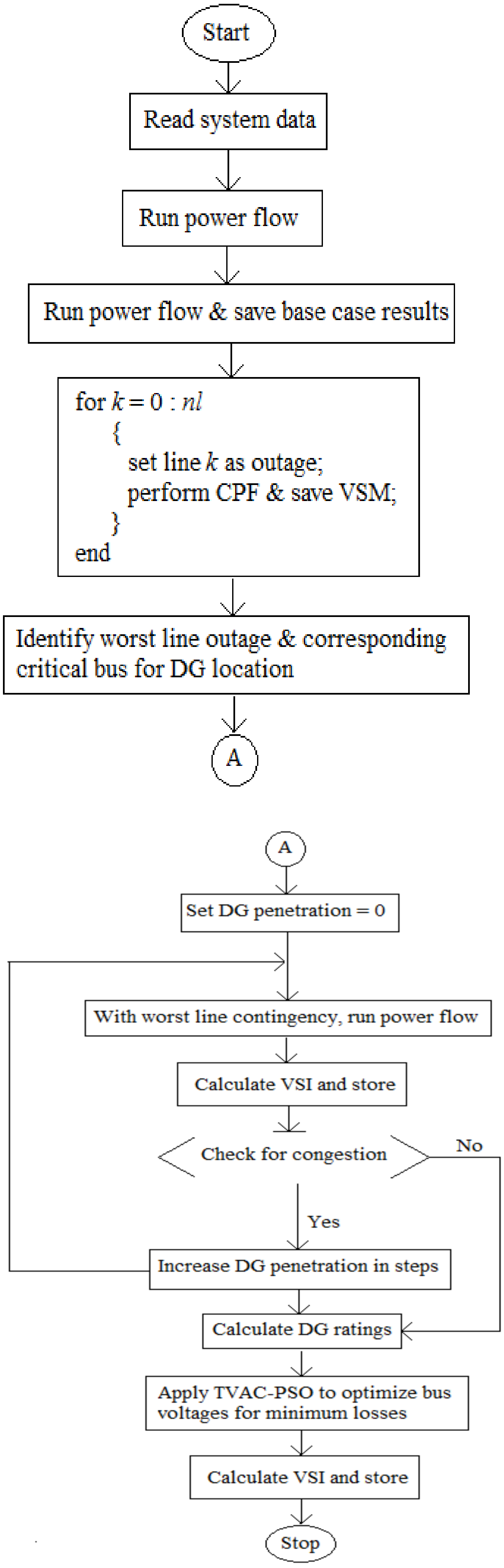

Fig. 5. Flow chart of the proposed approach

IV. TVAC-PSO ALGORITHM

In order to solve optimization problem, we have taken Time-Varying Acceleration Coefficients-Particle Swarm Optimization (TVAC-PSO) is implemented in [12, 13] to optimize voltage profile in the network. The major difference to standard PSO to TVAC-PSO is in acceleration of velocity and position vectors. The new acceleration and position vectors are given by:

$$V_i^{k+1} = \omega^k V_i^k + c_1^k \times rand_1 \times \left(P_{best,i}^k - X_i^k\right) + c_2^k \times rand_2 \times \left(P_{gbest,i}^k - X_i^k\right)$$

$$X_i^{k+1} = X_i^k + V_i^{k+1}$$

$$\omega^k = \omega_{\max} - \left(\frac{\omega_{\max} - \omega_{\min}}{k_{\max}}\right) \times k$$

$$c_i^k = c_{i,\max} - \left(\frac{c_{i,\max} - c_{i,\min}}{k_{\max}}\right) \times k \qquad i = 1,2$$

According to [26], the best parameters are: $\omega_{\max} = 0.4$, $\omega_{\min} = 0.9$; towards local best: $c_{1,\min} = 2$, $c_{1,\max} = 0.4$; and towards global best: $c_{1,\min} = 0.4$, $c_{1,\max} = 2$.

V. CASE STUDIES & SIMULATION RESULTS

The case studies are performed on standard IEEE 14 bus system. After performing CPF for every transmission line outage, the line contingencies are ranked as per maximum loading point (MLP). The base case loadability is 2.04 p.u. As per reduced loadability given in , line contingencies are ranked as given in Table 3. From the results, line 1-2 is severe line outage. Under this line outage, bus 4 is the critical bus. The corresponding PV curves for base case and line 1-2 outage are given in Fig. 6 and Fig. 7 respectively. Hence the best location for DG integration is bus-4.

Table 3. Contingency Ranking based on MLP

Line Outage	MLP	Line Outage	MLP
1--2	0.229	9--14	1.8
2--3	0.848	10--11	1.855
5--6	0.898	4--5	1.969
7--9	1.297	4--9	1.978
6--13	1.515	3--4	1.979
2--4	1.535	6--12	2.002
13--14	1.537	9--10	2.02
2--5	1.631	12--13	2.034
6--11	1.722	1--5	9.951
4--7	1.754		

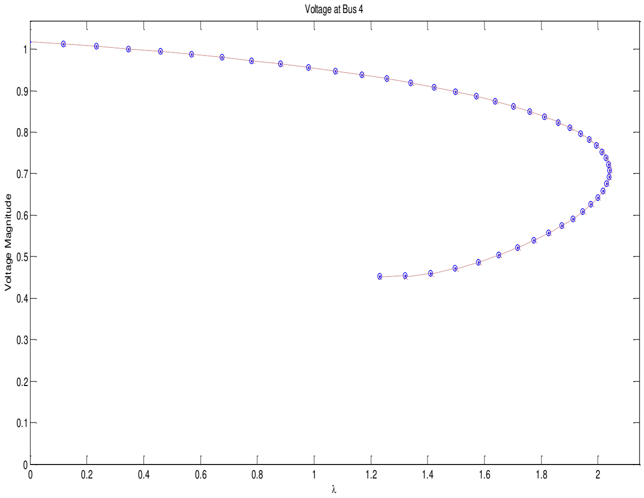

Fig. 6. PV curve at base case

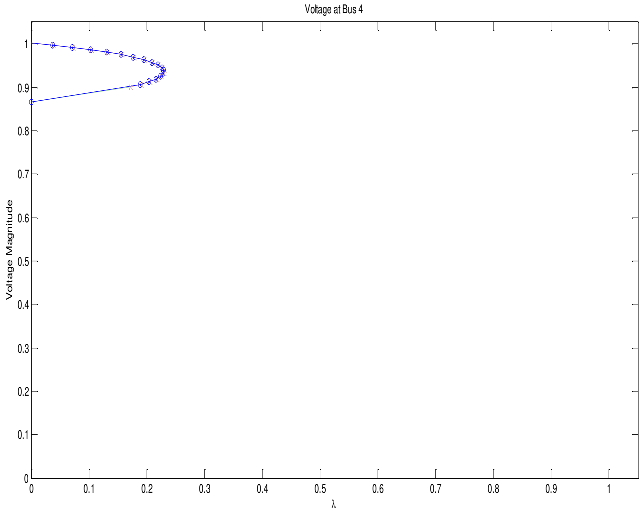

Fig. 7. PV curve under line 1-2 outage

After placing DG at bus 4, the system performance is illustrated in Fig. 8 and Fig. 9.

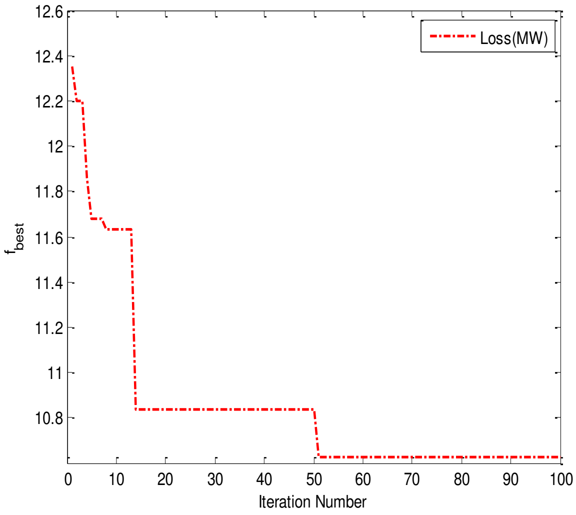

Fig. 8. TVAC-PSO Convergence characteristics.

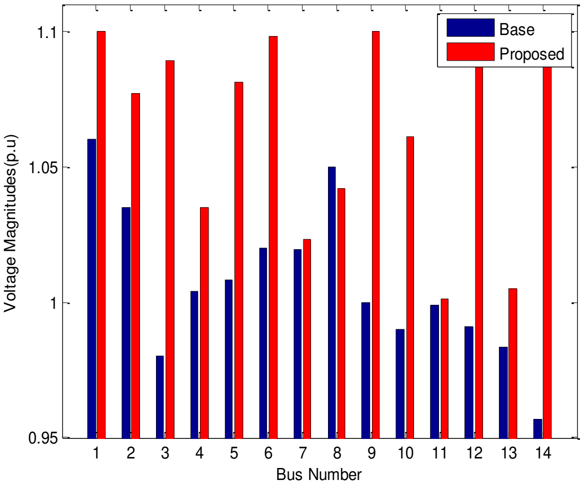

Fig. 9. Change in voltage profile

VI. CONCLUSION

In this paper, the location and size of Distributed Generation (DG) is optimized using Repeated Power Flow (RPF) method. To prevent congestion in the network, the required load curtailment or DG size is determined. Based on (N-1) line security criterion, the minimum and maximum size of DG is determined.

REFERENCES

[1]. Ackermann, Thomas, Göran Andersson, and Lennart Söder. "Distributed generation: a definition." *Electric power systems research* 57.3 (2001): 195-204.

[2]. Vinothkumar, K.; Selvan, M.P., "DG planning method for enhancement of voltage stability margin in distribution system," *Proceedings of 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES),* pp.1-6, 16-19 Dec. 2012

[3]. Kotb, M. F., et al. "Genetic algorithm for optimum siting and sizing of distributed generation." *Proceedings of the 14th International Middle East Power Systems Conference (MEPCON'10)*, Cairo University, Egypt, December 19-21, 2010.

[4]. Linh, Nguyen Tung, and Dam Xuan Dong. "Optimal Location and Size of Distributed Generation in Distribution System by Artificial Bees Colony Algorithm." *International Journal of Information and Electronics Engineering,* vol. 3, no. 1, pp. 63-67, January 2013.

[5]. Aman, M. M., et al. "Optimal placement and sizing of a DG based on a new power stability index and line losses." *International Journal of Electrical Power & Energy Systems* vol. 43, no. 1, pp. 1296-1304, 2012

[6]. Kansal, Satish, et al. "Optimal placement of distributed generation in distribution networks." *International Journal of Engineering, Science and Technology*, vol. 3, no. 3, pp. 47-55, 2011.

[7]. Parizad, A., A. Khazali, and M. Kalantar. "Optimal placement of distributed generation with sensitivity factors considering voltage stability and losses indices." *Proceedings of 18th Iranian Conference on Electrical Engineering (ICEE),* May 11-13, 2010.

[8]. M. Sedighizadeh2, M. Fallahnejad1, M. R. Alemi1, M. Omidvaran1, D. Arzaghi-haris, "Optimal placement of distributed generation using combination of PSO and clonal algorithm." *Proceedings of 2010 IEEE International Conference on Power and Energy (PECon*2010), Nov 29-Dec 1, 2010, Kuala Lumpur, Malaysia.

[9].Ajjarapu, Venkataramana, and Colin Christy. "The continuation power flow: a tool for steady state voltage stability analysis." *IEEE Transactions on Power Systems,* vol. 7, no.1, pp. 416-423, 1992.

[10]. J. Varaprasad, and K. Chandra Sekhar. "Optimal allocation of FACTS controllers for critical loading margin enhancement." *Proceedings of 2013 International Conference on Power, Energy and Control (ICPEC), 2013*, pp. 86 – 91, 6-8 Feb. 2013, Sri Rangalatchum Dindigul, India.

[11]. Rong-fu Sun; Yue Fan; Yong-hua Song; Yuan-zhang Sun, "Development and Application of Software for ATC Calculation,"

Proceedings of IEEE International Conference on Power System Technology (PowerCon2006), pp.1-5, 22-26 Oct. 2006.

[12]. C. Achayuthakan and W. Ongsakul, "TVAC-PSO based optimal reactive power dispatch for reactive power cost allocation under deregulated environment," *IEEE Conference on Power & Energy Society General Meeting*, 26–30 July 2009.

[13]. Weerakorn Ongsakul and Dieu Ngoc Vo, "*Artificial Intelligence in Power System Optimization*", CRC Press, Taylor & Francis Group, 2013.