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A Novel Method for Determining Optimal Location and Capacity of DG and Capacitor in Radial Network Using Weight-Improved Particle Swarm Optimisation Algorithm (WIPSO)

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ABSTRACT: Active and Reactive power supplied by the distribution side components plays a significant role in maintaining the power supply during the peak load and excess load conditions. Compensating elements are excessively utilized to provide necessary power support (i.e active and reactive power) and to share the peak load demand. In this paper we have proposed optimal bus number where the capacitor to be placed and also its size. Placement of capacitors additionally will reduce the losses and will also maintain the required voltage profile within limits. This paper proposes Weight-Improved Particle Swarm Optimization Algorithm (WIPSO) for optimal location (siting)and sizing of compensating devices. This proposed method is tested in detail on various systems and comparative study is done before and after installation of distributed generators. Results illustrates improvement in network voltage profile, reduction in system real and reactive power loss and reduction in cost of service provided by these local devices.

KEYWORDS: Capacitor, Distribution Generation, WIPSO Technique, System Security.

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I.INTRODUCTION

Placement of capacitors in radialsystem has manyadvantages in order to reduce the reactive power and voltage problems in radial system. Majority of the loads in the radial systems are inductive loads such as motors (fans, pumps etc) and transformers which produce lagging power factor of the radialnetwork. This lagging power factor causes reduction in capacity, disturbance in voltages and increases the distribution losses. Optimal placement of capacitors in radial network provides the necessary reactive power support to minimize the reactive power losses and disturbances in voltage[1][19]. There are various capacitor allocation techniques and each technique has its own merits, demerits and useful guidelines for allocation of capacitors [2][20]. The effect of shunt capacitor in radial network provides the reactive power control, power factor correction, improve the voltage profile and also enhance the system security and reliability. A state-space method is used to evaluate the reliability index for the compensated and uncompensated networks [3]. The optimal placement and design of capacitor size using genetic algorithm is implemented to reduce the power and energy loss and the main objective is to reduce cost involved in capacitor installation and reactive power support [4]. Deterministic and genetic algorithm together involved in optimal location and sizing of capacitors to provide the necessary compensation and main objective is to minimize the investment required to satisfy suitable reactive constraints [5].

II. MOTIVATION

Distributed generation takes place on two-levels: the local level and the end-point level. Local level power generation plants often include renewable energy technologies that are site specific, such as wind turbines, geothermal energy production, solar systems (photovoltaic and combustion), and some hydro-thermal plants. These plants tend to be smaller and less centralized than the traditional model plants. They also are frequently more energy and cost efficient and more reliable. Since these local level DG producers often take into account the local context, the usually produce less environmentally damaging or disrupting energy than the larger central model plants. The main motivation for the studies involving integration of DG to the grid. The installation of DG in distribution network results in improvement of voltage profile and reduction of system losses. The general definition and various issues involving distributed generation have been provided. Distributed Generation is defined as electric power generation in distribution network or on the consumer side of the network[6].The various concepts and regulations related to DGs are understood through some important definitions and their operating constraints and also a brief idea about classification, types, technologies and applications related to DG are studied [7].The impact of DG on power system results in improved power quality, improved voltage profile, reduction in loss, transmission and distribution capacity release and improved utility system reliability [8][21]. The optimal placement and sizing of DG using a hybrid PSO & HBMO algorithm is implemented in the distribution network to minimize the total system loss and to improve the system voltage profile [9]. Genetic Algorithm is also used for optimal location and sizing of DG in order to provide necessary real and reactive power support in a distribution network and the main objective is to minimize system losses and to enhance system reliability and voltage profile [10][19].Optimal placement and sizing of DG and shunt capacitor together is one of the best option to minimize system loss and to improve system voltage effectively and the main objective of this integration of DG and shunt capacitor is to minimize the investment cost of these local devices using PSO technique [11]. DG and capacitor are integrated to compensate active and reactive power loss in the distribution network using PSO technique and optimal power factor is also evaluated [12]. Generalized Pattern Search and Genetic Algorithm are used together for optimal location and sizing of DG and capacitors in distribution network to enhance system reliability and voltage profile and also to minimize system losses and here the presence of DG together with capacitor results in better performance [13][19]. Binary Particle Swarm Optimization (BPSO) technique is used for siting and sizing of DG and capacitor in the radial system and here multi-objective is carried out, involving reliability index, active power loss index, DG's and capacitor's investment cost index and voltage profile index using BPSO technique [14][2].

In this paper optimal placement and capacity of DG and capacitor in radial network is carried out using Weight-Improved Particle Swarm Optimization (WIPSO) technique. The main objective is to minimize the cost of service provided by these compensating devices and thereby reducing system loss and improves system voltage profile.

III.LITERATURE REVIEW

The main aim is to find the exact location and sizing of DG and capacitor which minimizes the distribution power loss and maintains the voltage stability of DGs and capacitors and specific total capacity of the DGs and capacitors. Therefore, the following assumptions are employed in this formulation.

1. Objective function:

Objective function is defined as cost over profit [9]. Cost includes charge of real and reactive power production and advantage is obtained from reduction of loss and variance of voltage (i.e. in other words, improvement in voltage profile, in order to maintain system voltage within desired range).

$$Min(f(x)) = \frac{[kpg(P_{DG} + P_{loss}) + kq(Q_{cap} + Q_{loss})]}{[kps(P_{lossold} - P_{loss}) + kq(Q_{lossold} - Q_{loss}) + kv(V_{costold} - V_{cost})]} \quad (1)$$

WhereKq is the reactive power production price. kpg is the real power production price.$P_{loss\ old}$ is the active power loss before installation of DG and capacitorand P_{loss} is the active power loss in presence of DG and capacitor. Q_{loss} is the reactive power loss in presence of DG and capacitor and $Q_{lossold}$ is the reactive power loss before installation of DG and capacitor. P_{DG} is the active power production of DG. Q_{cap} is the reactive power supplied by the capacitor. $V_{costold}$ is the voltage variation from ideal condition before installation of DG and capacitor. The price of DG power is considered to be 319 ryal/kW. Direct effect of reactive power on voltage profile kv factor can be held equal to kq. kps factor is the price of real power which is referred to 359ryal/kw.

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2. Constraints:
The constraints are listed as follows:

1. Absolute power limits:

$$\left| P_{ij}^{line} \right| \leq P_{ij,max}^{line} \qquad (2)$$

P_{ij}^{line}, $P_{ij,max}^{line}$ are the absolute power and its corresponding maximum allowable value flowing over the distribution line between the nodes i and j, respectively.

2. Voltage limits of Bus:

$$V_{min} \leq V_i \leq V_{max} \qquad (3)$$

Where V_{min} and V_{max} are the minimum and maximum values of bus voltage amplitudes, respectively.

Power limits of DG and capacitor:

$$P_{DGI}^{min} \leq P_{DGI} \leq P_{DGI}^{max} \qquad (4)$$

Where P_{DGI} and Q_{DGI} are the injected active and reactive power of DG and capacitor components at the i^{th} bus.

3. Power balance constraints:

$$\sum_{k=1}^{N_{sc}} P_{DGi} = \sum_{k=1}^{N_{sc}} P_{DGi} + P_L \qquad (5)$$

Where N_{SC} is the total number of sections. P_L is the real power loss in the system. P_{DGi} is the real power generation at bus i. P_{DGi} is the power demand at bus i.

3. Load Flow:
Owing to some inherent features of distribution system which includes radial structure, unbalanced distributed loads, large number of nodes, and a wide range of R/X ratios results in failure of conventional load flow technique developed for transmission system to perform distribution load flow. Hence, the conventional load flow technique developed for transmission system generally fails on the determination of optimal location and sizing of DG and capacitors. An algorithm for radial distribution power flow in complex mode including voltage controlled buses is used in this paper to perform distribution load flow efficiently [17][2].

4. Optimal Sizing of DG and Capacitor:
Here the active and reactive power compensation is obtained through DG and capacitor respectively [12]. The real power injection from DG placed at node i, is expressed as

$$P_{Di} = P_{Di} - \frac{1}{\alpha_{ii}} \left[\sum_{\substack{j=1 \\ j \neq i}}^{N} (\alpha_{ij} P_j - \beta_{ij} Q_j) \right] \qquad (6)$$

Similarly for reactive power injection,

$$Q_{capi} = Q_{Di} - \frac{1}{\alpha_{ii}} \left[\sum_{\substack{j=1 \\ j \neq i}}^{N} (\alpha_{ij} Q_j - \beta_{ij} P_j) \right] \qquad (7)$$

The equation (6) gives the size of DG and the equation (7) gives the size of capacitor for each bus i, for the loss to be minimum. Any other size of DG and capacitor apart from P_{DGi} and Q_{DGi} placed at bus i will lead to higher loss. The optimal size of DG and Capacitor can be determined by satisfying the system constraints.

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IV.PROPOSED OPTIMISATION TECHNIQUE

1. Basic PSO Algorithm:

Particle swarm optimization (PSO) is an evolutionary computation method. It is an iterative optimization algorithm created by Dr.Eberhart and Dr.Kennedy in 1995. PSO is a population based Optimization algorithm, originally derived from predation on the behaviour of the animals such as bird flocking and fish schooling. More than a decade, many researchers from various countries have been attracted towards this algorithm and its application in various fields. The algorithm has greater impact in intelligent optimization techniques such as pattern recognition, neural network training and other areas. The algorithm used the particle-velocity search model. The optimization problem has N-dimensional search space termed as 'bird', the algorithm called 'particles' for each and every possible solution. The fitness value decides the pros and cons of each particle which is none other than pros and cons of solution and each particle determines its moving direction and distance next step based on its speed parameter. In the search process of the optimal solution, in each round of iteration, the particles need to update two extremes. One is individual extreme and the other one is global extreme in which individual extreme is the accumulation of particles own experience of the individual and global extreme is the accumulation of particles group experience.

As mentioned earlier, in the basic PSO algorithm the candidate solution for the optimization problem is acquired through swarm of particles and each particle adjust its position according to its own experience, and the experience of its neighbouring particles [18]. The position and velocity of the i-th particle in the N-dimensional search space are represented as $X_i = (x_{i1}, ... , x_{in})$ and $V_i = (v_{i1}, ... , x_{in})$, respectively. The particles best position achieved during the search process is recorded and denoted by $Pbest_i = (x_{i1}^{Pbest}, ... , x_{in}^{Pbest})$.The best particle among all the particles in the population is denoted by $Gbest_i = (x_{i1}^{Gbest}, ... x_{in}^{Gbest})$. The velocity and position update of each particle in the (k+1) next step can be calculated by the following formulae of (4) and (5) as

$$X_i^{k+1} = X_i^k + V_i^{k+1} \qquad (8)$$

Where, the velocity of individual i at iteration k+1 is given by

$$V_i^{k+1} = wV_1^k + C_1 rand_1\left(Pbest_i^k - X_i^k\right) + C_2 rand_2\left(Gbest^k - X_i^k\right) \quad (9)$$

X_i^k : position of individual i at iteration k, X_i^{k+1} : position of individual i at iteration k+1, V_i^k : velocity of individual i at iteration k, w : weight parameter, c_1 : cognitive factors, c_2 : social factors, $Pbest_i^k$: the best position of individual i until iteration k, $Qbest^k$: the best position of the group until iteration k, $rand_1$, $rand_2$: random numbers between 0 and 1.

2.Weight-Improved Particle Swarm Optimization algorithm (WIPSO):

In this section, in order to obtain better global solution, the traditional PSO algorithm is enhanced by the improvement of weight parameters, cognitive and social factors [18]. Based on (9), the velocity of individual i of WIPSO algorithm is rewritten as,

$$V_i^{k+1} = wV_1^k + C_1 rand_1\left(Pbest_i^k - X_i^k\right) + C_2 rand_2\left(Gbest^k - X_i^k\right) (10)$$

Where,

$$w = w_{max} - \frac{w_{max} - w_{min}}{Iter_{max}} \times Iter \qquad (11)$$

$$w_{new} = w_{min} + w \times rand_3 \qquad (12)$$

$$C_1 = C_{1max} - \frac{C_{1max} - C_{1min}}{Iter_{max}} \times Iter \qquad (13)$$

$$C_2 = C_{2max} - \frac{C_{2max} - C_{2min}}{Iter_{max}} \times Iter \qquad (14)$$

w_{min} , w_{max} : initial and final weights, c_{1min} , c_{1max} : initial and final cognitive factors, c_{2min} , c_{2max} : initial and final social factors, $Iter_{max}$: maximum iteration number, Iter : current iteration number, $rand_3$: random numbers between 0 and 1.

3.WIPSO procedure for optimal placement and sizing of Distributed generators and Capacitors:

The algorithm for the proposed WIPSO for solving optimal location and sizing of DG and capacitor is obtained as follows:

Step 1: Initialize radial system data, load type, number of DG, number of capacitor, capacity and limits.

Step 2: Initialize PSO parameters like n, c_{1min} , c_{1max} , c_{2min} ,c_{2max}, w_{min} , w_{max} etc..

Step 3: Conduct distribution load flow for the system without DG and capacitor [17][2].
Step 4: Initialize Random value for DG and capacitor, Size using equations (6) and (7) and location randomly set within their boundary limits.
Step 5: Set iteration counter k=1 and particle i=1.
Step 6: Conduct load flow with DG and Capacitor [17][2]
Step 7: Evaluate the solution fitness for each particle according to the objective function (1) and corresponding constraints (2), (3), (4) and (5).
Step 8: Compare evaluated particle's fitness with its $Pbest_i$. If current value is better than $Pbest_i$, then $Pbest_i$ will be set to the current value. Obtain Gbest by identifying the particle in the neighbourhood with the best success so far and assign its index to Gbest.
Step 9: According to (10) update velocity by using the global best and individual best of each particle.
Step 10: Update position by using the updated velocities. The position of each particle is changed as (8).
Step 11: If the stopping criteria are not satisfied, set k=k+1 and return to Step 4. Otherwise Stop.

V.SIMULATION RESULTS AND DISCUSSION

1. Test System:

The proposed methodology as described in section (II) and (III) has been tested on 13-bus test system [9] as shown in Fig. 1. The sizing of DG and capacitor is obtained through equations (6) and (7) and optimal location of DG and capacitor is obtained through WIPSO algorithm. A computer software program has been developed in MATLAB environment to calculated the optimal location and capacity of DG and Capacitor in the test system and also to achieve the required objective function.

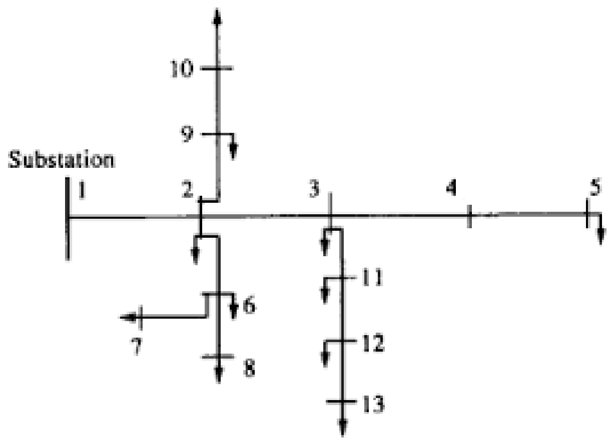

Fig. 1. The 13 bus radial distribution system

2. Results:

Table-I shows the simulation results of active and reactive power losses for base case (i.e. without DG and capacitor) is 237.78 and 186.88 respectively and the voltage variance is 0.4188 p.u. When DG alone is installed inthe test system with optimal location and optimal sizing, then power losses gets minimized when Compared to the base case, but it violates the voltage limits. So, in order to improve the system voltage profile both DG and capacitor are installed in the test radial system and the real and reactive power losses are minimized to a greater extent when compared to DG alone installed in the test system. Here both DG and capacitor are installed in the test system with optimal location and sizing. The minimization of the cost and power losses in the radial system by providing necessary real and reactive power support by the compensating devices is clearly understood from Table-I. There is significant reduction in loss and cost required to provide the necessary compensation when DG and capacitor are placed at same optimal location. The reduction in loss and cost is more important when DG and capacitor are placed at different

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optimal locations.

	No of DG	No of capacitor	Optimal Location (Bus)	Optimal DG (size) (MW)	Optimal Capacitor (size) (MVAR)	P_L (KW)	Q_L (KVAR)	Voltage Variance (p.u.)	Cost (ryal/KW)
Without DG	0	0	0	0	0	237.78	186.88	0.4188	0
WIPSO (with DG)	1	0	5	2.3656	0	222.51	174.75	0.4075	88.31
WIPSO (with DG and capacitor at same location)	1	1	5	2.3656	1.7177	217.87	172.19	0.4008	83.16
WIPSO (with DG and capacitor at different location)	1	1	5(DG), 6(Capacitor)	2.3656	5.3883	202.88	158.28	0.3811	74.08

Table-I

The reduction in active and reactive power losses are 217.87 and 171.19 and the voltage variance is 0.4008 p.u. when both DG and capacitor are placed at same optimal location, but when DG and capacitor are placed at different optimal locations the real and reactive power losses are 202.88 and 158.28 respectively and the voltage variance is 0.3811, for the test system used in this paper.

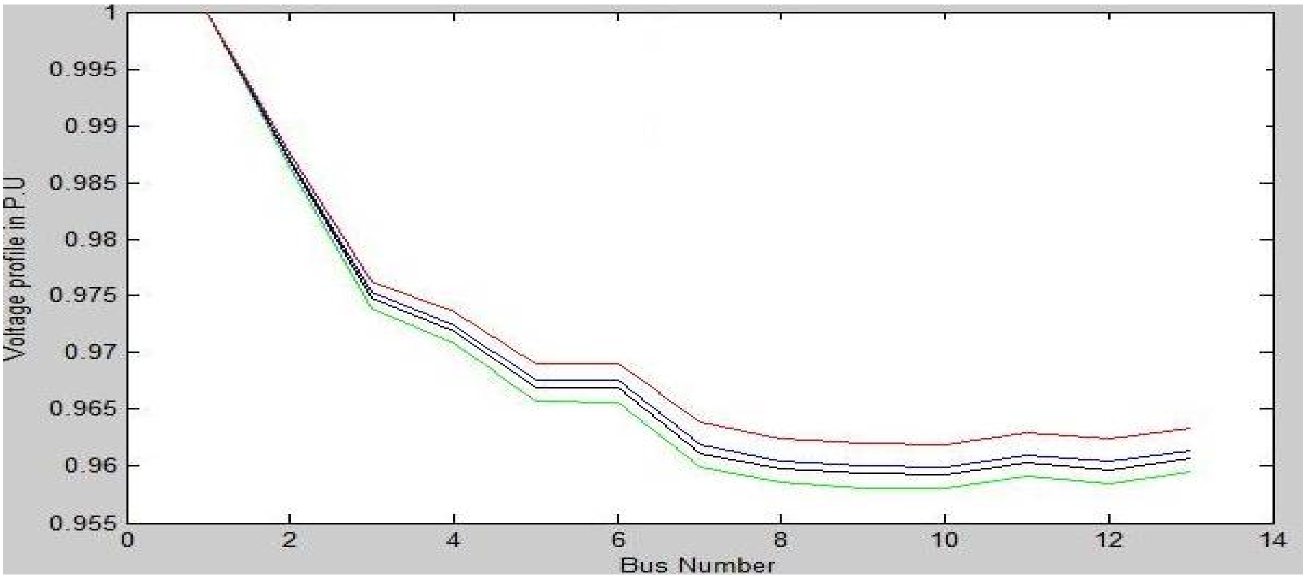

Fig. 2. Variation of voltage profile without DG, with DG, DG&Capacitor at same bus and at different bus

Fig.2 shows the improvement and comparison in voltage profile before and after installation of DG and capacitor at same and different locations in the test radial system. Green line indicate without DG, Purple colour line indicate with DG, Blue line indicate with DG and Capacitor at same bus and red line indicate with DG and Capacitor at different bus

VI.CONCLUSION

This paper is essentially concerned with the analysing and improvement of voltage stability, power factor corrections of radial power systems. Weight-Improved Particle Swarm Optimization algorithm is proposed for optimal location and capacity of DG and capacitor in a test radial system. This method efficiently minimizes the system real and reactive power losses and voltage variations in radial system. This methodology is accurate in determining the capacity and location of DG and capacitor. The cost of real and reactive power support incurred by the compensating devices gets reduced by suitable location and sizing of compensating devices.

REFERENCES

[1] R. A. Gallego, A. J. Monticelli, and R. Romero, "Optimal capacitor placement in radial distribution networks", IEEE Trans. on Power Systems, vol. 16, Issue 4, pp. 630- 637, 2001.

[2] R.. Arulraj; N.Kumarappa; T. Vigneysh; "Optimal location and sizing of DG and capacitor in distribution network using Weight-Improved Particle Swarm Optimization Algorithm(WIPSO), IEEEAutomation, Computing, Communication, Control and Compressed Sensing (iMac4s), 2013 International Multi-Conference on22-23 March 2013.

[3] H. N. Ng, M. M. A. Salama, and A. Y. Chikhani, "Classification of capacitor allocation techniques", IEEE Trans. on Power Delivery,vol. 15, pp. 387-392, 2000.

[3] Abdel hay A. Sallam, Mohamed Desouky and Hussien Desouky, "Shunt Capacitor Effect on Electrical Distribution System Reliability" IEEE Trans on Reliability, Vol. 43, Issue 1, pp. 170-176, March 1994.

[4] Srinivasan Sundhararajan and Ani1 Pahwa, "Optimal Selection of Capacitors for Radial Distribution Systems using a Genetic Algorithm" IEEE Transactions on Power Systems, Vol. 9, Issue. 3, pp. 1499-1507, August 1994.

[5] Maurizio Delfanti, Gianpietro P. Granelli, Paolo Marannino and Mario Montagna, "Optimal Capacitor Placement Using Deterministic and Genetic Algorithms" IEEE Transactions on power systems, VOL. 15, Issue. 3, pp. 1041-1046 August 2000.

[6] T. Ackermann, G. Anderson, L. Soder, "Distributed generation: a definition" Electric Power Systems Research, Volume 57, Issue 3, Pages 195-20420, April 2001.

[7] El-Khattam and M.M.A. Salama, "Distributed generation technologies, definitions and benefits" Electric Power Systems Research, Volume 71, Issue 2, Pages 119-128, October 2004.

[8] P. P. Barker, R. W. de Mello, "Determining the Impact of Distributed Generation on Power Systems: Part 1 - Radial Distribution System" IEEE Power Engineering Society Summer Meeting, vol. 3, pp. 1645-1656, 2000.

[9] M. Afzalan, M. A.Taghikhani, "DG Placement and Sizing in Radial Distribution Network Using PSO&HBMO Algorithms", Electrical

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Power Distribution Networks (EPDC), 2012 Proceedings of 17th Conference on , vol., no., pp.1-6, 2-3 May 2012.

[10] Carmen L.T. Borges, Djalma M. Falcao, "Optimal distributed generation allocation for reliability, losses, and voltage improvement", International Journal of Electrical Power & Energy Systems, Volume 28, Issue 6, Pages 413-420, July 2006.

[11] Kai Zou, A. P. Agalgaonkar, K. M. Muttaqi and S. Perera, "Voltage Support by Distributed Generation Units and Shunt Capacitors in Distribution Systems" Power & Energy Society General Meeting, 2009. PES '09. IEEE, vol., no., pp.1-8, 26-30 July 2009.

[12] Satish Kansal, Vishal Kumar, Barjeev Tyagi "Composite Active and Reactive Power Compensation of Distribution Networks", Industrial and Information Systems (ICIIS), 2012 7th IEEE International Conference on, vol., no., pp.1-6, 6-9 Aug. 2012.

[13] Kazem Haghdar, Heidar Ali Shayanfar, "Optimal Placement and Sizing of DG and Capacitor for the Loss Reduction via Methods of Generalized Pattern Search and Genetic Algorithm", Power and Energy Engineering Conference (APPEEC), 2010 Asia-Pacific , vol., no., pp.1-4, 28-31 March 2010.

[14] Reza Baghipour, Seyyed Mehdi Hosseini, "Placement of DG and Capacitor for Loss Reduction, Reliability and Voltage Improvement in Distribution Networks Using BPSO**"** I.J. Intelligent Systems and Applications, Vol.12, pp. 57-64, 2012.

[15] Xiuhua Wu,Zailin Piao,Yongliang Liu and Haiyan Luo, "Reactive Power and Voltage Control Based on Improved Particle Swarm Optimization in Power System", Intelligent Control and Automation (WCICA), 2010 8th World Congress on , vol., no., pp.5291-5295, 7-9 July 2010.

[16] Hao Wang, Huilan Jiang, Ke Xu, Guodong Li, "Reactive Power Optimization of Power System based on Improved Particle Swarm Optimization" Electric Utility Deregulation and Restructuring and Power Technologies (DRPT), 2011 4th International -609, 6-9 Conference on , vol., no., pp.606July 2011.

[17] R M Saloman Danaraj, Shankarappa F Kodad, Tulsi Ram Das, " An algorithm for radial distribution power flow in Complex mode including voltage controlled buses" Indian Journal of Science and Technology, Vol.1 , Issue.2 , Dec. 2007.

[18] PhanTu Vu; DinhLuong Le; NgocDieu Vo; Tlusty, Josef; , "A novel weight-improved particle swarm optimization algorithm for optimal power flow and economic load dispatch problems," Transmission and Distribution Conference and Exposition, 2010 IEEE PES, vol., no., pp.1-7, 19-22 April 2010

[19] B Mahipal; P Venugopal Rao; T Swetha; G Babu Naik; Ch Naresh Kumar;, " A New Technique to find the effect of Active Power Loading on Voltage Stability and Algorithm to improve Voltage Stability of Radial and Meshed Power Systems. Journal of Information Engineering and Applications, Vol.3, No.5, 2013.

[20] Mahipal Bhukya; Ch Naresh Kumar; Text book on Power System Voltage Stability : For Radial and Meshed Power Systems(ISBN 978-3-659-22276-4,LAP LAMBERT Academic Publishing, Germany).2014.

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