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Optimal Planning using WOA for the Capacitor Placement in the Presence of PV Systems in Distribution Networks

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***Abstract:** The distributed photovoltaic (PV) generation can have an impact on the voltage regulation of distribution feeder as the PV systems have the ability to inject reactive power into the network. Over the decades, the penetration level of solar PV is rising into the distribution network because of the increase in distributed PV generation. So, the different criteria presented in this paper are the optimal capacitor placement and sizing in the presence of PV systems at different penetration levels during the hours of day and night and then the impact of penetration levels on the voltage profile and power loss in the distribution network. A Whale Optimization Algorithm (WOA), recently introduced multi-objective optimization technique is employed in this paper for the optimal planning. The proposed algorithm is applied to IEEE 33-bus radial distribution network. Finally, the simulation results show the impact of the reactive power injection of PV inverters into the grids on the power loss and voltage profile and thus, are compared with the existing algorithm which demonstrates that the proposed algorithm is more effective, reduces the network loss and improves the voltage profile.*

***Keywords:** Optimal Capacitor Placement, Photovoltaic System (PV), Penetration Level (PL), Optimal Power Factor, Radial Distribution Network, Whale Optimization Algorithm (WOA).*

I. INTRODUCTION

At distribution level, the load profile will be extremely fluctuating in nature because of different kinds of loads like industrial, commercial and domestic loads, which causes imbalance in the power flow leading to power loss. Therefore, power loss reduction in distribution systems is an important aspect. It is indicated in the studies that around 13% of total power generated is wasted in the form of losses at the distribution networks [1]. The power loss in distribution networks can be effectively reduced by the generation of active and reactive power in proper amounts at strategic locations. This is achieved by placing capacitor banks for the reactive power compensation at the required locations which also improves the voltage profile.

Optimal capacitor placement is most effectively used method for reducing the losses and improving the voltage profile within the prescribed limits. As the optimal capacitor placement includes optimization of location and size, it is referred as a combinatorial optimization problem which has been investigated over decades. Different methods have been proposed for the optimization of losses and voltages in the distribution networks which differs in the techniques proposed. A survey of capacitor allocation approaches has been presented in [1]-[4], which includes optimization techniques like mixed integer nonlinear programming, Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Self - Adaptive Harmony Search (SAHS). In these works, power loss has been efficiently reduced, but allowable voltage profile range ($0.95 < |V_{p.u}| < 1.05$) [5] is not considered.

In recent years, the fast development of distributed generations (DGs) led to compensation of both active and reactive power improving the voltage profile majorly. By employing different optimization techniques in [6-11], the optimal locations and sizes have been analyzed, assuming power factor of DGs to be definite values.

Of all the renewable generations, Photovoltaic (PV) is the only viable option at the distribution scale. The PV generation will reach to a significant percentage out of all new distributed generations in next decades. PV systems not only generate active power but can also inject or absorb the reactive power [12]. Because of this bidirectional flows, utility system operators and regulators have generally treated distributed PV generation as a variable negative load. Considering distributed PV generation as a negative load not only ignores the voltage impacts, but also limits the amount of PV capacity that can be interconnected to the grid without ceding power quality and grid reliability. If the distributed PV inverters are required or allowed to participate in voltage control and reactive power management, utility operators can accommodate higher PV penetration levels [13]-[14]. It is mentioned in [14] that some of PV inverters are capable of working in the range of 0.8 lagging to 0.8 leading power factor (PF).

PV inverters already supply leading and lagging reactive power at any time during regular feed-in operation. However, with the development of reactive power (Q) at night hours, the devices can now provide Q even when feed-in operation is not in progress (at night) some are assumed to inject reactive power up to 30% of their nominal apparent power at night time [15]

PV systems can supply both active and reactive power demands in the case of non-unity power factor operation. Therefore, the impact of PV systems on voltage control, power loss reduction and capacitor placement need to be studied. As the generation of the distributed PV generators depends on solar irradiance, they are different from other distributed generations and can inject active power only during certain hours of the day. So, the optimal capacitor placement in the presence of PV systems shall be performed by considering the hourly load data, PV generation curve, PV penetration levels and PV systems optimal power factor [16]-[18].

In this paper, distribution load flow [21] followed by a recently developed algorithm [22]-[27] is employed for the analysis of the effect of PV systems on voltage control, loss reduction and optimal capacitor placement. In this approach, the optimal capacitor locations and sizes are determined simultaneously considering hourly load profile and PV output data, for a typical IEEE 33-bus radial test system. The impact of PV inverters capability of injecting reactive power during night hours for different penetration levels has been studied. The results of minimized losses and improved voltages at different cases are compared with the existing algorithm [20] and conclude that proposed algorithm is effective comparatively.

II. MATHEMATICAL CALCULATION

The optimal placement and sizing of capacitors play a vital role for the improvement of voltage profile and reduction of power losses. Therefore, the problem is to determine the optimal location and size of a capacitor to be placed. As the PV systems installed in the distribution network can supply both active and reactive power demands at non-unity power factors, the contribution percentage of each PV system in supplying power demand depending on its penetration level is illustrated in later sections. The optimal power factor (PF) will also be described and assigned to each PV system and then reduction of losses and voltage profile improvement is observed. The mathematical description of the objective function and the constraints to be followed by the problem are as follows.

A. *Objective Function and Constraints:*

The objective function for the optimization is formulated as a weighted combination of three indices as:

$$OF = \alpha_1 \frac{VPI}{VPI_b} + \alpha_2 \frac{PLI}{PLI_b} + \alpha_3 \frac{CCI}{CCI_b} \qquad \text{..........} (1)$$

Where, VPI is voltage profile index

PLI is power loss index

CCI is capacitor cost index

b refers to the base values for normalization

α_1, α_2 and α_3 are weighted normalized factors based on importance of each index.

1) Voltage Profile Index: This index is used to show an acceptable performance for voltage profile in 24 hours and represented as:

$$VPI = \sum_{h=1}^{24} \sum_{i=1}^{N} (V_{i,h} - V_{i,set})^2 \qquad \text{..........} (2)$$

$$V_{i,set} = \begin{cases} 1,0; i \in PQbuses \\ V_{set-po\,\mathrm{int}}; i \in PQbuses \end{cases}$$

The voltage magnitude for PQ buses practically lies in the range 0.95-1.05 p.u. [19]. $V_{i,h}$ is the voltage magnitude of bus i at hour h and $V_{i,set}$ is the reference voltage of bus i . 'N' is the total number of buses in the network.

2) Power Loss Index: The power loss of the branch connecting buses i and j of a balanced distribution system can be mathematically written as:

$$P_{Loss}(i, j) = R_{i,j} \frac{(P_i^2 + Q_i^2)}{|V|^2} \qquad \text{..........} (3)$$

where, P_i and Q_i are active and reactive powers flowing out of bus i and $R_{i,j}$ is the resistance of the branch between the buses i and *j*.

To minimize the network power loss over 24 hours, the following index is used.

$$PLI = \sum_{h=1}^{24} \sum_{i=1}^{N-1} P_{Loss}^{h}(i, j) \qquad \text{...........} (4)$$

where, $P_{Loss}^{h}(i,j)$ is the power loss of the branch connecting buses i and j at hour 'h' and 'N' is the number of system buses.

3) Capacitor Cost Index: The installation cost of capacitor is described with the index as follows:

$$CCI = \sum_{i=1}^{N_c} C_{fi} + C_{vi} Q_i \qquad \text{..........} (5)$$

where, C_{fi} and C_{vi} are the annual fixed and variable costs of the installed capacitor at bus i in \$ and \$/KVAR respectively. 'N_c' is the total number buses at which a capacitor is installed and Q_i is the capacitor size at bus i , represented as,

$$Q_i = lQ_0, l = 1, 2, 3, ..., k \qquad \text{..........} (6)$$

where, l is the multiplication factor for practical capacitors whose smallest standard size is Q_0 and k is the maximum practical value of *l*.

4) Constraints: The limitation of the instantaneous reactive power capability of the PV inverters is based on its fixed apparent power, S and variable active power generation, *p(g)* and to describe this mathematically, a model of PV inverters which is considered previously [16]. Here the range of allowable reactive power generation is

$$q(g) \le \sqrt{S^2 - p(g)^2} = q_{\max} \qquad \text{..........} (7)$$

The voltage magnitude at each PQ bus must be within acceptable limit which is expressed as:

$$0.95 < \left|V_{i,h}^{p.u}\right| < 1.05, i = 1, 2, ...N \qquad ……….\ (8)$$

where, $\left|V_{i,h}^{p.u}\right|$ is per unit value of the voltage magnitude of bus ‘ i ’ at an hour ‘ h ’ and N is the total number of buses in the network.

B. *Optimal Load Flow Calculation:*

The distribution systems possess low line X/R ratios, because of which the distribution networks will be ill-conditioned for the calculation of voltage and currents of each bus and branch using conventional load flow methods. Moreover, the load flow method of distribution system should have time efficient and robust characteristics. Therefore, backward-forward sweep method is employed as distribution load flow technique to calculate currents of each branch (I_{br}) [21].

1) Backward Propagation: The backward sweep starts at the extreme end node and proceeds towards source node. The voltage (V_b) values obtained in the forward path are held constant during the backward propagation and power flows (S_b) at each branch updated are transmitted backward using backward path along the feeder. The current at each bus is computed as,

$$i_b^k(b) = \frac{S_b^k(b)}{V_b^k(b)} \qquad ……….\ (9)$$

The current of each branch is then calculated as the current difference between last branch and last bus from the end node i.e.,

$$i_{br}^k(br) = i_{br}^k(br-1) - i_b^k(b) \qquad ……….(10)$$

2) Forward propagation: The voltage at each node starting from the source node of feeder is calculated in the forward sweep. Here, the effective power in each branch is held constant to the obtained value in the backward sweep. Voltage at each bus is calculated as voltage difference between last bus and last branch from the starting node to the last one.

$$V_b^k(b+1) = V_b^k(b) - Z_{br}(br) i_{br}^k(br) \qquad ……….\ (11)$$

Z_{br} (br) represents the impedance of each branch.

The voltages calculated in the previous and present iterations are compared for the convergence criteria. ‘k’ here in all equations is the iteration count. The procedure is repeated until the voltage of each bus is converged i.e., $\Delta V_b^k(b) \le \varepsilon(tolerance)$ is satisfied in

$$\Delta V_b^k(b) = V_b^k(b) - V_b^{k-1}(b) \qquad ………..\ (12)$$

C. *Assumptions:*

The smallest standard size of capacitors Q_0 is assumed to be 50 KVAr and their maximum allowable size is to 750 KVAr. Therefore, the value of ‘k’ will be equal to 750/50 = 15. The values of C_{fi} and C_{vi} are assumed as 500 $ and 4.9 $/KVAr, respectively.

III. PROPOSED ALGORITHM

Recently developed technique, whale optimization algorithm (WOA) is proposed in this paper which is a meta-heuristic optimization algorithm that imitates the natural hunting mechanism of humpback whales. These whales search their food in a special behavior called bubble-net feeding method which is based on creating distinctive bubbles along a circle or through ‘9’-shaped path [22-27].

The modeling of this algorithm follows three phases as explained below.

A. *Searching and Prey Encircling:*

The whale algorithm starts with an initial best search agent in this first phase. After the best search agent is defined, the other search agents try to update their positions towards the best search agent. This behavior is mathematically represented as follows:

$$D = \left|C.X^*(t) - X(t)\right| \qquad ……….\ (13)$$

$$X(t+1) = X^*(t) - A.D \qquad ……….\ (14)$$

where, t is the current iteration count, X^* is the position vector of the best solution obtained so far and A and C are coefficient vectors and can be calculated as,

$$A = 2.a.r - a \qquad ……….\ (15)$$

$$C = 2.r \qquad ……….\ (16)$$

‘ a ’is linearly decreased from 2 to 0 over the number of iterations and ‘ r ’is random vector in range [0, 1].

B. *Exploitation Phase*

This phase is also known as the bubble-net attacking which includes two mechanisms. They are shrinking encircling mechanism and spiral updating position mechanism from where the distance between the whale and the prey location is calculated and the helix shaped movement of humpback whale is created using the following equation. ‘p’ is a random number in [0,1].

$$X(t+1) = \begin{cases} X^*(t) - A.D; p < 0.5 \\ D^{'}.e^{bl}.\cos(2\pi l) + X^*(t); p \ge 0.5 \end{cases}$$

……….(17,18)

C. *Exploration Phase:*

The prey will be searched in this phase according to fig.1 and the global optimization will be achieved. By randomly choosing an agent, the position of the search agent is being updated here and this allows WOA to perform global search. This mechanism is mathematically expressed as follows:

$$D = \left| C.X_{rand}(t) - X(t) \right| \qquad \text{……….} \; (19)$$

$$X(t+1) = X_{rand}(t) - A.D \qquad \text{……….} \; (20)$$

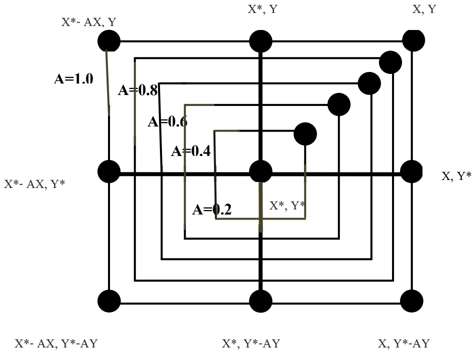

Fig. 1 Bubble Net Searching Mechanism in WOA

IV. PV SYSTEM PRESUMPTIONS

A. *PV Systems Location and Power Factor Range:*

Due to the changes in the sunlight throughout the day, it is assumed that with the increasing and decreasing of output active power of the PV systems, the reactive power output also changes accordingly. It is also assumed that the PV systems are already installed at all the buses in the network, except slack bus and their penetration level is only selected not their location. Since the electric power system was not designed to take into account distributed generation and bidirectional flows, the distributed PV generation is assumed as a variable negative load.

PV inverters are generally designed to operate at unity power factor as at this condition they just provide active power and energy. This is reported based on the IEEE.2-2003 standard [14]. But, according to Australian standard [17], the power factor of PV inverters shall range from 0.8 leading to 0.95 lagging and by this many inverters will be capable of producing reactive power in addition to active power. In this work, the capability of working of the PV inverters is assumed to be in the range from 0.7 leading to unity power factor and can be used to inject reactive power up to 30% of their nominal apparent power at night [15], based on the requirement. It is also assumed further, that the PV inverters are not capable of changing their power factor at different hours of the day, therefore, the optimal capacitor placement and PV systems' PF determination is performed at the hour with the worst voltage profile condition.

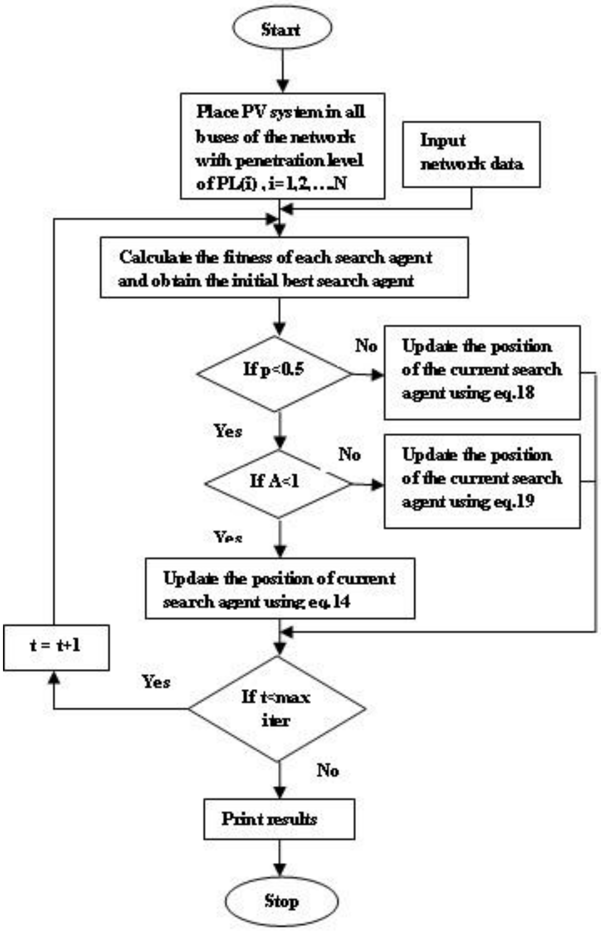

Fig.2 Flowchart for WOA

B. *Penetration level of PV systems:*

The most commonly used definition [18] is considered for the penetration level as follows,

$$PL = \frac{DG\ Power\ Capacity}{Peak\ load\ of\ line\ section\ or\ feeder} \times 100 \text{……….} \; (21)$$

For the analysis of impact of the penetration level on the power loss reduction and the voltage profile improvement, five values of penetration level, 15%, 25%, 35%, 45% and 60%, are considered at *PL(i)*, in fig 2.

C. *Hourly Load Data and PV System Generation:*

The daily load profile for 24 hours' analysis is considered in such a way that it includes 3 levels of loads: base load, intermediate load and peak load. Simultaneously, along with the load data, the daily generation profile of the PV system is assumed in Fig-3 and both the profiles are normalized based on their maximum value.

V. RESULTS AND DISCUSSION

The proposed methodology is implemented on a typical 33 bus radial distribution network. The network daily energy loss obtained by considering the above mentioned hourly load data as shown in fig.3 is 3378.5 KWh. The simulation results obtained are compared with the existing algorithm results from [20].

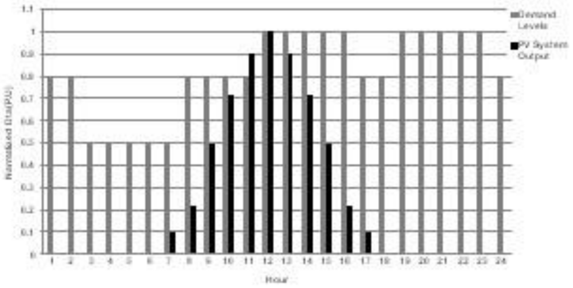

Fig. 3. Normalized Daily Load and PV Output Profile

A. *Optimal Capacitor Placement without PV System:*

Primarily, the network with zero penetration level is assumed i.e., no PV system is installed in the network. After the compensation in this case, the total size of the capacitors and the energy loss values are compared in the table-I for the proposed algorithm and the existing algorithm.

In the fig.4, the voltage profiles of the network before and after compensation are shown. However, it can be seen that the network voltage profile after compensation falls in the allowed voltage range of *ANSI C84.1*($0.95 < |V_{p.u}| < 1.05$), for the proposed configuration.

B. *Optimal Capacitor Placement in the Presence of PV System:*

According to [20], the optimal capacitor placement in the presence of PV systems is carried out for two different cases: (i) at the daylight hours and (ii) at night hours

1) At the Daylight Hours: According to fig.3, the daylight hours considered are from 7:00 to 17:00. Among all the hours, at 16:00, the PV system output is decreased to 23% of its nominal power due to reduced sunlight which results in obtaining the maximum sizes of capacitor. Therefore, the results mentioned in table-II refer to the capacitor sizes obtained at this hour for different penetration levels, at unity power factor. Also, PLI and VPI values are mentioned in the table-II.

2) At Night Hours: In this case, the maximum resulting sizes of capacitors are obtained at 19:00 to 23:00 at which the load level is high. At this time, it is assumed that PV inverters inject reactive power equal to 30% of its nominal power into the network. The capacitor sizes obtained during these hours for different penetration levels is given in table-III and their impact on voltage profile and losses are described. The results obtained by employing the proposed algorithm are compared with the existing algorithm.

Table I. Capacitor Configuration and Sizes without Pv System in the Network

Approach	**Bus Locations** **Capacitor Size (KVAr)**	**Total Capacitor Sizes (KVAr)**	**PLI (KWh)**
WOA	14 17 30 32	1500	2394.2
	250 350 350 550		
GA[20]	15 17 30 32	1550	2716.6
	300 300 350 600		

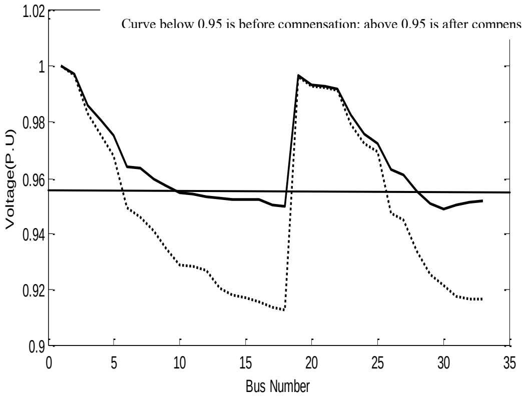

Fig. 4. Network Voltage Profile at Peak Load Hours before and after Compensation using Proposed Algorithm

C. *Optimal Planning with PV Systems at Non-Unity Power Factor:*

In the installation of PV systems, the power factor has prior importance. Therefore, the optimum power factor of PV systems is determined using the proposed algorithm to reduce the power loss of the network. Firstly, at 15% penetration level, with no capacitors, it is assumed that all the PV systems have the same power factors and then the power loss index (PLI) values are determined for power factors ranging from 0.7 leading to 1 as shown in fig 5.The least PLI value (3042.5 KWh) is obtained by setting all the PV systems at 0.82 PF as shown.

Table II. Optimal Planning at the Daylight Hours with PV Systems having Unity Power Factor

	Proposed Algorithm				**Existing Algorithm [20]**			
	Capacitor Size	**Total**			**Capacitor Size**	**Total**		

PL(i)	(KVAr)	Size (KVAr)	PLI (KWh)	VPI	(KVAr)	Size (KVAr)	PLI (KWh)	VPI
	Bus Locations				Bus Locations			
	14 17 30 32				15 17 30 32			
15%	250 200 300 550	1300	1922.8	0.63284	250 350 200 650	1450	2276.5	0.6242
25%	200 200 350 500	1250	1817.3	0.64109	250 300 200 600	1350	2076.7	0.6268
35%	200 200 400 400	1200	1735.5	0.65430	250 250 200 550	1250	1913.1	0.6363
45%	150 200 250 500	1100	1689	0.66016	250 200 200 450	1150	1785.5	0.652
60%	200 150 150 500	1000	1627.4	0.68346	200 200 150 450	1000	1681	0.6757

Table III. Optimal Planning at the Night Hours with PV Systems Injecting Reactive Power Equal to 30% of their Nominal Power

	Proposed Algorithm				Existing Algorithm [20]			
PL(i)	Capacitor Size (KVAr)	Total Size (KVAr)	PLI (KWh)	VPI	Capacitor Size (KVAr)	Total Size (KVAr)	PLI (KWh)	VPI
	Bus Locations				Bus Locations			
	14 17 30 32				15 17 30 32			
15%	150 250 450 450	1300	1901.4	0.58323	250 300 300 600	1450	2268.1	0.5705
25%	200 250 150 600	1200	1853.5	0.57625	250 250 300 550	1350	2059.3	0.5632
35%	100 250 200 450	1100	1763	0.54513	250 250 250 500	1250	1927.3	0.5289
45%	150 200 250 450	1050	1683.9	0.51268	200 250 200 550	1200	1815.5	0.4913
60%	100 200 150 500	950	1617.3	0.48903	200 200 150 500	1050	1665.6	0.4737

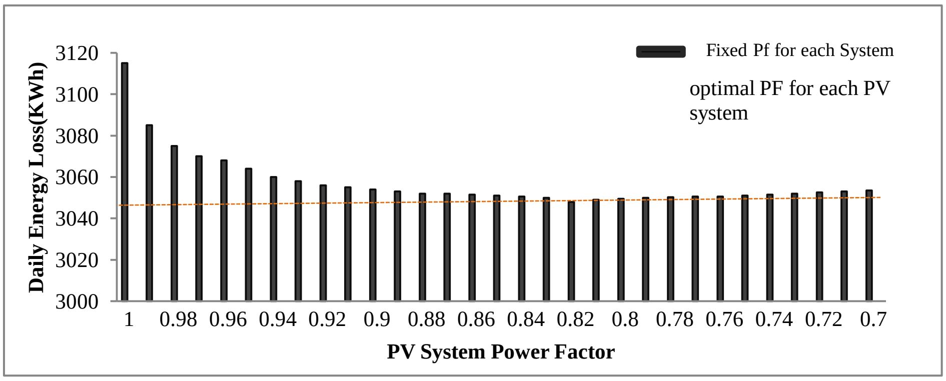

Fig. 5. Network Daily Power Loss Index (PLI) for a Fixed Power Factor for all PV Systems ranging from 0.7 leading to 1

Table IV. Optimal Planning at Daylight Hours with PV Systems having Optimal Power Factor

	Proposed Algorithm				Existing Algorithm [20]			
PL(i)	Capacitor Size (KVAr)	Total Size (KVAr)	PLI (KWh)	VPI	Capacitor Size (KVAr)	Total Size (KVAr)	PLI (KWh)	VPI
	Bus Locations				Bus Locations			
	14 17 30 32				15 17 30 32			
15%	150 300 250 550	1250	1934.9	0.65693	250 300 250 600	1400	2223.3	0.645
25%	250 200 250 500	1200	1825.9	0.67551	250 250 250 550	1300	2032.6	0.64
35%	100 250 400 350	1100	1728.9	0.68259	250 200 200 500	1150	1884.7	0.6663
45%	100 200 350 350	1000	1665.1	0.69394	250 200 200 450	1100	1782.2	0.6663
60%	150 150 200 400	900	1600.6	0.72563	150 200 100 450	900	1672.5	0.6979

Comparing table II and IV, it can be observed that the power factor optimization of PV systems reduces the amount of required capacitors up to 100 KVAr for the voltage profile modification. It also shows that the increase in penetration level reduces the power loss index and improves the voltage profile. Further, the results show that the proposed algorithm gives more optimized results when compared to the existing algorithm.

From tables III and IV, it can be seen that although VPI has been effectively improved by injecting reactive power at night hours, the PLI has been increased, which is because of increasing power loss due to excessive reactive power injection at low load level hours.

VI. CONCLUSION

In this paper, whale optimization algorithm (WOA) has been employed as an optimization technique for the placement and sizing of capacitors and voltage control in the distribution network under the presence of photovoltaic systems over 24 hours. For validation of method, different scenarios were considered and the numerical results of the voltage and loss indices of the test system confirm the effectiveness and dominancy of the proposed approach over other established algorithm. The analysis reveals that for each case, the reduction in losses obtained by using WOA method is approximately 2-3% more compared to existing algorithm results. The losses obtained by employing WOA were reduced by 41.1% of its losses obtained without capacitor compensation, whereas for genetic algorithm the reduction obtained was 39.8%. Therefore, WOA algorithm exhibits a higher capability in finding optimum size and location of capacitors in radial distribution system.

VII. REFERENCES

[1] Sayyad Nojavan, Mehdi Jalali and Kazem Zare, “Optimal allocation of capacitors in radial/mesh distribution systems using mixed integer nonlinear programming approach,” Electric Power Systems Research 107 (2014) pp.119– 124.

[2] Sattianadan. D, Sudhkaran. M, Vijayakumar. K and Vidyasagar. S, "Optimal placement of capacitor in radial distribution system using PSO," Sustainable Energy and Intelligent Systems (SEISCON 2011), International Conference on, vol. no., pp.326,331, 20-22 July 2011.

[3] Sethi, Naveen and Sanjay Kumar Jain. "Optimal Capacitor Placement in Radial Distribution System using Genetic Algorithm,” MSc Thesis, Thapar University, India, July 2009.

[4] Rani. D.S, Subrahmanyam. N and Sydulu. M, "Self adaptive harmony search algorithm for optimal capacitor placement on radial distribution systems," Energy Efficient Technologies for Sustainability (TCEETS),2013 International Conference on, vol. no., pp.1330,1335, 10-12 April2013.

[5] ANSI C84.1-2006, American National Standard for Electrical Power Systems and Equipment-Voltage Ratings (60 Hertz).

[6] Kalantari M. and Kazemi A., "Placement of distributed generation unit and capacitor allocation in distribution systems using genetic algorithm, "Environment and Electrical Engineering (EEEIC), 2011 10thInternational Conference on, vol. no., pp.1,5, 8-11 May 2011.

[7] Baghipour, Reza and Seyyed Mehdi Hosseini, “Placement of DG and Capacitor for Loss Reduction, Reliability and Voltage Improvement in Distribution Networks Using BPSO,” International Journal of Intelligent Systems and Applications (IJISA) 4.12 2012.

[8] El-Fergany A.A., and Abdelaziz A.Y., “Capacitor Allocations in Radial Distribution Networks Using Cuckoo Search Algorithm,” IET General Transmission Distribution, 2014, 8, (2), pp.223-232.

[9] Reddy, P., and Dinakara Prasad. "Sensitivity based capacitor placement using cuckoo search algorithm for maximum annual savings." IOSR Journal of Engineering 4.4 (2014): 6.

[10] Reddy, P. Dinakara Prasad, VC Veera Reddy, and T. Gowri Manohar. "Application of flower pollination algorithm for optimal placement and sizing of distributed generation in distribution systems." Journal of Electrical Systems and Information Technology 3.1 (2016): 14-22.

[11] Reddy, P. DinakaraPrasasd, VC Veera Reddy, and T. Gowri Manohar. "Ant Lion optimization algorithm for optimal sizing of renewable energy resources for loss reduction in distribution systems." Journal of Electrical Systems and Information Technology (2017).

[12] Turitsyn Konstantin, Su1c P., Backhaus Scott and Chertkov Michael, "Options for Control of Reactive Power by Distributed Photovoltaic Generators," Proceedings of the IEEE, vol.99, no.6, pp.1063,1073, June2011.

[13] Dave Click and Bob Reedy, “PV Generation and its Effect on Utilities” [online]. Available: https://solarprofessional.com/articles/design-installation/pv-generation-and-its-effect-on-utilities/

[14] IEEE Application Guide for IEEE Std 1547, "IEEE Standard for Interconnecting Distributed

Resources with Electric Power Systems," IEEE Std 1547.2-2008.

[15] “Profitable Night Shift for SMA Inverters,” [online]. Available: http://www.sma.de/en/solutionS/knowledgebase/profitable-night-shiftfor-inverters.html.

[16] Liu, Ellen and Jovan Bebic, "Distribution system voltage performance analysis for high-penetration photovoltaic," National Renewable Energy Laboratory, 2008.

[17] Australian Standard™ AS 4 777, "Grid connection of energy systems via inverters," Part 2: Inverter requirements, AS 4 777.2-2005.

[18] Ellis, Abraham, "Grid Operations and High Penetration PV," National Renewable Energy Laboratory, 2010.

[19] Hossein Seifi and Mohammad Sadegh Sepasian, "Electric Power System Planning: Issues, Algorithms and Solutions," Springer, Berlin, 2011,pp.174-183.

[20] Reza Nejad Soleimani, Mostafa Rajabi Mashhadi and Hashem Mortazavi, “Voltage Control and Optimal Capacitor Placement in the Presence of Photovoltaic Systems in Distribution Networks,” the 19th Electrical Power Distribution Conference (EPDC2014), 6-7 May, 2014, Niroo Research Institute.

[21] E. Bompard, E. Carpaneto, G. Chicco, and R. Napoli, “Convergence of the backward/forward sweep method for the load-flow analysis of radial distribution systems,” Int. J. Elect. Power Energy Syst., vol. 22,no. 7, pp. 521–530, 2000.

[22] Seyedali Mirjalili and Andrew Lewis, “The Whale Optimization Algorithm,” Adv. Eng. Softw. 95 (2016) 51–67.

[23] D.B. Prakash and C. Lakshminarayana, “Optimal sititng of Capacitors in Radial Distribution Using Whale Optimization Algorithm,” School of Electrical Engineering, BMSCE, Alexandria Engineering Journal 2016.

[24] Reddy, Dinakara Prasad P., VC Veera Reddy, and T. Gowri Manohar. "Renewable energy resources placement in distribution systems by whale optimization algorithm." International Journal of Computer Science and Information Security 14.12 (2016): 489.

[25] A.Marimuthu, Dr. K. Gnanambal and R.Priyanka, “Optimal Allocation and Sizing of DG in a Radial Distribution Network using Whale Optimization Algorithm,” IEEE international Conference on Innovations in Green Energy and Healthcare Technologies (ICIGEHT’17).

[26] Reddy, P. Dinakara Prasad, VC Veera Reddy, and T. Gowri Manohar. "Whale optimization algorithm for optimal sizing of renewable resources for loss reduction in distribution systems." Renewables: Wind, Water, and Solar 4.1 (2017): 3.

[27] Reddy, VC Veera, and T. Gowri Manohar. "Optimal renewable resources placement in distribution networks by combined power loss index and Whale optimization algorithms." Journal of Electrical Systems and Information Technology (2017).