

Optimized Power Distribution Planning A Review

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Abstract—Distribution system planning is extremely important for the end consumers of electricity; it is indeed become necessity to explore the area of real term planning of distribution system. The practical planning of distribution system incorporates the selection of optimal conductor size selection and capacitor placement in radial distribution network in distribution system. The load flow needs to carry out on the distributed system for power flow calculation at each node subjected to various system constraints to minimize total energy losses as well as cost. The capacitor placement includes the voltage constraint and load variation. Reactive power status needs to be investigated for the voltage profile on the feeder. In this paper, different techniques for distribution system planning have been presented based on previous literature to anticipate the future requirement and new hybrid techniques can be developed to enhance the current distribution system with the incorporation of more system constraints.

Index Terms—Distribution System (DS), Capacitor Allocation (CA), Voltage Stability (VS)

I. INTRODUCTION

Capacitor banks are extensively used in distribution systems for reactive power compensation to achieve power and energy loss reduction, optimum voltage profile and enhance voltage stability. The limit of these positive scenarios depends on the location, size, type and number of the capacitors subjected to different constraints. The capacitor allocation (CA) problem is a well-explored topic in literature for distribution system planning. The necessity to find a global solution for real distribution systems along with growth in digital system invites a new generation of methods and techniques based on computer applications. These methods suggested a global solution for the optimization of distribution system planning. Different conventional methods have been used for load flow calculations and to find optimum capacitor allocation problem. In the present scenario, extended distribution systems are radial in nature and produce very low voltages at the different load buses situated at long

from the sub-station. These minute voltages at the load points results in huge power losses and reduce the power factor lower than expected. In addition, the contemporary distribution systems are being faced with an exponentially growing load demand and experience sudden variations in load levels every day; and hence are operated in the region of their steady state power transfer limit. During peak load, even a small change in the load pattern may threaten the voltage stability (VS) of the system. The process of voltage instability is generally triggered by some form of disturbance or change in operating conditions that create an increased demand for reactive power, which is in excess of what the system is capable of supplying. The problem of voltage instability has thus become a matter of great concern to the utilities in view of its prediction, prevention and necessary corrections to ensure stable operation .

II. PROBLEM FORMULATION

Capacitor sizes and locations for allocation are inherent variables for distribution system planning for voltage profile and stability; this subjected the capacitor placement problem as a multi-objective and multi-decision combinatorial optimization nature .

$$\text{Min } Z = \sum_{k=1}^n T^k P^k \quad (1)$$

$$\text{Min } Z = \sum_{k=1}^n x^k T^k P^k \quad (2)$$

$$\text{Min } Z = \sum_{k=1}^n x^k T^k P^k + C \quad (3)$$

$$\text{Min } Z = \sum_{k=1}^n x^k T^k P^k + C + y P^p \quad (4)$$

Z = the value of the desired objective function

n = number of load levels

T^k = time duration for the k-th load level

P^k = power loss at the k-th load level

x^k = per unit cost of energy loss at the k-th load level

C = investment cost of capacitor

y = per unit cost of peak power loss

P^p = power loss at peak load level

III. OPTIMIZATION TECHNIQUES

There are many methods proposed in literature for distribution system planning. Below are some conventional and advanced methods for distribution system planning -

A. Traditional Techniques

- Newton Raphson
- Fast Decoupled
- Gauss Seidal
- Branch Bound
- Dynamic Programming
- Lagrange Algorithm

B. Advanced Techniques

- Branch Exchange
- Neural Network
- Honey Bee Optimization
- Shuffled Frog Leaping
- B Snake
- Dijkstra Algorithm
- Harmony Search
- Greedy Snake
- Tabu Search
- Pattern Search
- Meta Heuristic
- Ant Colony
- Differential Evolution
- Biogeography Based Optimization
- Cuckoo Search
- Ant Bee
- Plant Growth
- Ladder Method
- Fire Fly
- Bee Hive
- Fuzzy Logic
- Genetic Algorithm
- Particle Swarm Optimization

IV. LITERATURE BACKGROUND

G. Mohan and P. Aravindbabu [1] proposed an algorithm for VS enhancement based on voltage stability index. A line losses and voltage profile have been investigated for optimal size and location of capacitor bank at different nodes for 33 and 69 node distribution system. A fixed and switched capacitor banks has been evaluated for reactive power compensation at different load pattern. Test results reveal the effectiveness of proposed algorithm in terms of voltage profile, losses and voltage stability. G. Mohan and P. Aravindbabu [2] proposed a technique for optimal location and sizing of capacitor to improve voltage stability, voltage profile and minimize losses. This technique is tested on 33 and 69 node distribution system. Voltage stability index is chosen as the criteria to evaluate the performance of proposed algorithm. Different switched and shunt capacitor s have been employed to compensate for the reactive power at different nodes as suggested by the investigation of proposed techniques on different nodes.

This method is quite suitable to test on any system. T. Pavan Kumar and A. Lakshmi Devi [3] developed a novel method to find the location of TCSC in single line contingency mode using evolutionary technique called particle swarm optimization. A proposed method is tested on IEEE 6 and 14 bus test system. Test results reflect that TCSC is the good option for series compensation to minimize line overloads against contingency as well as to locate the size and parameter of TCSC. S. Bouri *et al.* [4] coined a new method based on artificial intelligence technique ant colony for the optimum CA in distribution system planning subjected to capacitor switching constraints. In the proposed technique, solution is obtained for system of feeders, not for individual feeders. Constraints based on capacitor switching transients are considered as they are imperative for pole mounted and station capacitor bank. System capacity release and reduction in losses are obtained. Proposed algorithm is investigated on Algerian company of electricity and gas systems incorporate 9 distribution systems. Srividya. V *et al.* [5] presents new efficient approach based on Dijkstra algorithm to determine the optimum location and size of capacitor banks to improve the voltage profile and minimize losses. Loss sensitivity factors determine the location of candidates for capacitor placements and Dijkstra algorithm is used to find the size of capacitor on that location. Proposed technique does not need any control variable and it treats system constraints separately. Proposed method is tested on 33 and 69 radial distribution system and comparison study is investigated which reveals that the proposed method is optimum as compared to others. Sandeep Chakravorty and Smarajit Ghosh[6] suggested a technique for distribution planning based on Analytical Hierarchy Process (AHP) .They considered various aspects of reliability such as miles of conductor, feeder failures, customer interruption, maximum interruption, estimated relative cost. In investigation, cost of constructing substation is minimized and long range distribution planning expenses are also optimized by achieving optimum feeder path. Test system of thirteen load point is considered to check the effectiveness of proposed algorithm. S. Auchariyamet and N. Rugthaicharoencheep [7] presented different review techniques investigated in optimal location of capacitor in distribution feeder. Application of artificial intelligence like fuzzy logic, Tabu search, genetic algorithm, simulated annealing, particle swarm optimization, harmony search algorithm in distribution system planning have been presented. Anwar S Siddiqui and Md. Farrukh Rahman [8] presented a technique based on fuzzy logic for the suitable location of capacitor bank. Test case of 10 bus radial distribution is considered to investigate the effectiveness of proposed algorithm. Shunt capacitor banks for reactive power injection at different buses have been evaluated. A load flow has been performed on the test system using fuzzy logic due to fast computation and simple formulation. Sandeep Chakravorty and Smarajit Ghosh[9] proposed a novel approach based on genetic algorithm and analytical Hierarchy process for distribution planning. Here factor

of cost related to conductor layout, capacity of substations and distance of load from substation is considered. Test result reveals the location of substation from load point which is minimum and further connection of load point based on conductor has been achieved. G. Rajender and Basavaraja Banakara [10] suggested a technique based on new sensitivity matrix L-index. It is used to locate the bus which is short of reactive power. Proposed technique is tested on IEEE-14 bus system. This is useful for radial and meshed system. Sandeep Chakravorty and Smarajit Ghosh [11] developed a hybrid method for distribution system planning. A hybrid technique based on Taguchi and Analytical Hierarchical process with consideration of reliability parameters like feeder failure, customer interruption. Investigation of proposed technique results into optimum feeder path, substation construction Costs. Taher and H.S Hosseini [12] implemented a for optimal placement of capacitor for non-linear load based on harmonic source detection. Genetic algorithm is used for optimization. Proposed method is tested on IEEE-30 bus system. Test results reflect in saving taking into consideration full harmonics. C. W Taylor [13] has introduced different criteria for voltage stability index which is helpful for voltage stability assessment. Ching-Tzong su et al [14] developed a technique based on fuzzy logic and genetic algorithm for distribution system. Capacitor allocation (CA) is utilized for change in voltage on bus to reduce losses against different load pattern. Proposed method is tested on 23 KV nine section feeder and 30 bus system. Fuzzy reasoning is used for the location of capacitor and genetic algorithm is used for optimal compensation. J. Tibin *et al.* [15] proposed a technique based on particle swarm optimization to improve the performance distribution system by using FACT devices. Proposed algorithm is tested on IEEE 14 bus system. With the help of PSO, parameter setting and location of SVC based FACT is utilized to enhance the voltage stability and active power losses are minimized. K. Dhananjaya babu *et al.* [16] suggested a hybrid algorithm integrating fuzzy and pso for the optimal placement of svc. IEEE 14 bus system is taken as a case study under different loading conditions to secure the optimal voltage profile, to limit the real power losses with tolerable zone. Fuzzy is utilized for location and PSO is applied for rating of SVC. R. Muthukumar and Dr. K. Thanushkodi [17] implemented a technique based on opposition differential evolution for capacitor placement in radial distribution system. Loss reduction using capacitor banks is preferred over distribution system configuration for better performance and improvement of voltage profile. Suggested technique is evaluated on IEEE 10, 33, 34 and 85 bus radial system and results are compared with other techniques. It gives promising results as compare to other methods. Dinu Calin Secui [18] presented an application of ant colony algorithm for capacitor bank placements. A fitness function based on cost is chosen as benchmark to evaluate the solution subjected to equality and inequality constraints. Case study of 35 nodes is considered and results shown

reflected the optimum voltage level, reduced losses and cost. Divya M and Bindu R [19] successfully applied ACO in distribution network with reduction in losses and system reconfiguration. System comprises 14 buses and 3 feeders is used for evaluation. Test result shows that proposed approach is more useful when applied jointly rather than on individual cases. M.C Piementel Filho *et al.* [20] applied ant colony algorithm and gradient for optimal placement of capacitor in distribution system planning. Gradient method has been integrated with ACO to enhance the speed of the solution. Test system comprises of 12, 25, 43 nodes has been chosen to evaluate the proposed technique. Fast computation time with reduced losses has been revealed with the suggested algorithm. Nasim Ali Khan *et al.* [21] developed a new technique based on BPSO algorithm for siting and size of shunt capacitors in radial distribution system. Suggested technique leads to global solution with minimization of losses, voltage deviation and leads to stable voltage profile. It is tested on IEEE 10 and 69 benchmarks. Investigating results reflecting optimumness in solution. Dae-Ho Chang *et al.* [22] suggested Modified Ant Colony Optimization for Optimum Design in Nonlinear Problems. Reliable and stable topology has been achieved and results are compared with solid isotropic material with penalization (SIMP) and bi-directional evolutionary structural optimization (BESO). R. Srinivasa Rao [23] proposed a technique built on Artificial Bee Colony (ABC) Algorithm to reduce losses in distribution system. ABC technique does not require any external parameter to control the solution. Results are compared with PSO for IEEE 69 bus system. This technique has given optimum results in terms of cost, losses. R. Srinivasa Rao [24] suggested a technique based on plant growth algorithm for distribution system optimization. Proposed method is applied to 9, 34, 85 bus system. Results are compared with fuzzy, PSO. Suggested algorithm outperformed other techniques in terms of speed, losses, cost and voltage profile. Reza Sirjani *et al.* [25] presented a optimization techniques for capacitor placement on radial distribution system. Tabu search, genetic algorithm, harmony search, ant colony optimization, simulated annealing, neural network and other hybrid techniques. A complete review has been presented for distribution system planning. Comparison study has been presented in the paper.

V. CONCLUSION

This paper benchmarks a literature survey of the research published on the application of different heuristic optimization techniques to solve the optimal capacitor problem in power distribution systems. Different advanced optimization techniques that are used to address the problem are summarized. The objective of the paper will serve as references for the research on optimal capacitor placement and sizing. Enhanced hybrid techniques need to be developed for further optimization of distribution system planning.

REFERENCES

- [1] G. Mohan and P. Aravindbabu, "A novel placement algorithm for voltage stability enhancement in distribution system," *International Journal of Electronics Engineering*, vol. 1, no. 1, pp. 83-87, 2009.
- [2] G. Mohan and P. Aravindbabu, "Optimal locations and sizing of capacitors for voltage stability enhancement in distribution system," *International Journals of Computer Applications*, vol. 1, no. 4, pp. 47-52, 2010.
- [3] T. P. Kumar and A. L. Devi, "Optimal location and parameter settings of TCSC under single line contingency using PSO," *International Journal of Advanced Engineering Research and Studies*, vol. 1, no. 1, pp. 30-34, 2011.
- [4] S. Bouri *et al.*, "Ant colony optimization to shunt capacitor allocation in radial distribution system," *Acta Electrotechnica et Informatica*, vol. 5, no. 4, pp. 1-10.
- [5] V. Srividya, *et al.*, "Optimal capacitor placement in radial distribution system using dijkstra algorithm," *Methods Enriching Power and Energy Developments*, pp. 1-9, April, 2013.
- [6] S. Chakravorty and S. Ghosh, "Distribution planning based on reliability and contingency criteria," *International Journal of Computer and Electrical Engineering*, vol. 1, no. 2, pp. 148-153, 2009.
- [7] S. Auchariyamet and N. Rugthaicharoencheep, "Optimal capacitor placements in distribution feeder," *World Academy of Science, Engineering and Research* 64, pp. 292-296, 2012.
- [8] H. P. Anwar, S Siddiqui, and Md. F. Rahman, "Optimal capacitor placement to reduce losses in distribution system," *WSEAS Transactions on Power Systems*, vol. 7, no. 1, pp. 12-17, Jan. 2012.
- [9] S. Chakravorty and S. Ghosh, "A novel approach to distribution planning in an unstructured environment," *International Journal of Computer and Electrical Engineering*, vol. 1, no. 3, pp. 350-355, August 2009.
- [10] G Rajendar and B. Banakara, "A novel algorithm for capacitor placement to improve voltage stability of radial and meshed power systems," *Journal of Information Engineering and Applications*, vol. 2, no.11, pp. 47-58, 2012.
- [11] S. Chakravorty and S. Ghosh, "A hybrid model for distribution planning," *International Journal of Computer and Electrical Engineering*, vol. 1, no. 4, pp. 356-361, August 2009.
- [12] S. A. Taher and S. A. Hosseini, "A novel technique for optimal capacitor placement and sizing in distribution system with non-linear loads based on harmonic source identification," *IUST International Journal of Engineering Science*, vol. 19, no. 5-2, pp. 99-106, 2008.
- [13] C. W. Taylor, *Power System Voltage Stability*, McGraw-Hill, Inc., 1994.
- [14] C. T. Su *et al.*, "Optimal capacitor allocation using fuzzy reasoning and genetic algorithms for distribution system," *Mathematical and Computer Modeling* 33, pp. 745-757, 2001.
- [15] J. Tibin, *et al.*, "PSO based optimal placement and setting of FACT devices for improving the performance of power distribution system," *Bonfring International Journal of Power Systems and Integrated Circuits*, vol. 1, Special Issue, Dec 2011.
- [16] K. D. Babu and M. D. Reddy, "Optimal placement of SVC using fuzzy and PSO algorithm," *International Journal of Engineering Research and Applications*, vol. 3, no. 1, pp. 485-490, 2013.
- [17] R. Muthukumar and K. Thanushkodi, "Opposition based differential evolution algorithm for capacitor placement on radial distribution system," *Journal of Electrical Engineering Technology*, vol. 8, no. 9, pp. 742-748, 2013.
- [18] D. C. Secui, *et al.*, "An ACO algorithm for optimal capacitor bank placement in power distribution networks," *Studies in Informatics and Control*, vol. 18, no. 4, pp. 305-314, 2009.
- [19] M. Divya and R. Bindu, "Simultaneous network reconfiguration and capacitor placement for loss reduction of distribution systems by ant colony optimization algorithm," *International Journal of Advances in Electrical and Electronics Engineering*, vol. 1, no. 2, pp. 211-220.
- [20] M. C. P. Filho, *et al.* "Capacitor placement using ant colony optimization and gradient," *Intelligent Systems Applications to Power System*, pp. 1-4, 2009.
- [21] N. A. Khan, *et al.*, "Optimum siting and sizing of shunt capacitor in radial distribution system using novel BPSO algorithm," *International Journal of Emerging Technology and Advanced Technology*, vol. 3, no. 2, pp. 220-225, Feb 2013.
- [22] D. H. Chang, *et al.* "Optimum design for non linear problems using modified ant colony algorithm," in *Proc. International Conference on Software and Computer Applications*, 2012.
- [23] R. S. Rao, "Capacitor placement in radial distribution system for loss reduction using artificial bee colony algorithm," *International Journal of Engineering and Natural Sciences* 4:2, pp. 84-88, 2010.
- [24] R. S. Rao and S. V. L. Narasimham, "Optimal capacitor placement in a radial distribution system using plant growth simulation algorithm," *International Journal of Electrical and Electronics Engineering* 2:10, pp. 651-658, 2008.
- [25] R. Sirjani, *et al.*, "Heuristic optimization techniques to determine optimal capacitor placement and sizing in radial distribution networks: A comprehensive review," *PRZEGLĄD ELEKTROTECHNICZNY(ElectricalReview)*, pp. 1-7, 2012.

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