Optimal Capacitor and DG Placement for Loss Less Distribution on 69- Bus System using KVS – Direct Search Algorithm

T. S. Sirish, G. V. Srihara Rao & K V S Ramachandra Murthy

Abstract: In this paper, a KVS- Direct Search Algorithm is implemented to determine the optimal sizes of Static Capacitors and Type -3 Distributed Generators (DGs) together with their optimal locations in 69 Bus Radial Distribution Systems so that maximum possible reduction in real power loss is obtained. The algorithm searches for all possible locations in the system for a particular size of capacitor or DG and places them at the bus which gives maximum reduction in active power loss. The optimal sizes of capacitors and DGs are chosen to be standard sizes that are available in the market i.e., discrete sizes of capacitors and DGs are considered. The algorithm is tested on standard 69 bus systems. The loss reduction obtained in this paper for the 69 Bus Test System is highest compared to the other technique as reported in the literature. The total active power load on this system is 3802.19 kW and reactive power load on this system is 2694.60 kVAr. Without placement of Capacitors and DGs the loss is 225 kW whereas after placement it is 7.27 kW. There is a reduction of 96.76% in the losses. Before placement of DGs and Capacitors, the power loss is 5.58% of the total power supplied by the slack bus. After optimal placement by the KVS- DSA algorithm, 7.27 kW is obtained, which is 0.19% of the total power supplied by the system. As the loss is less than 2%, the system is considered as Loss Less Distribution System. It is implemented using MATLAB/Simulink.

Keywords Loss Less Distribution, Capacitive compensation, Optimal DG placement, Distribution Systems.

I. INTRODUCTION

The computational methods used in the analysis and design of distribution systems are not as robust as they are in transmission systems. In particular, the design of compensation systems for radial distribution system has become very complex because, the system does not fit into the usual optimization methods used in transmission system. Several works have been reported on optimal capacitor placement for improving the voltage profile and reducing the power loss and optimal DG placement for reduction of active power loss and to improve the reliability of the system. Type -3 DG injects only active power into the system. Only one paper has addressed the concept of minimizing the active loss by placing both DGs and Capacitors at their optimal locations.

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This concept works well for the developing countries like India, where the 11KV rural distribution feeders are too long. The voltages at the far end of many such feeders are very low with very poor voltage regulation. The algorithm proposed in [1] is implemented in this work. This algorithm is an extension of Direct Search Algorithm for Capacitive compensation proposed by M. Ramalinga Raju et. al.[2].

Carpinelli et al. implemented [3] non-linear programming technique for capacitor placement on three phase unbalanced system. Wang et al. implemented [4] integer programming technique, and Tabu search was used by Huang et al. [5] for optimal capacitor placement. Grainger implemented equal area criterion [6] and genetic algorithm applied to capacitor placement by Dlfanti [7] for determining optimal sizes of capacitors. Das applied Fuzzy-GA method for capacitor placement problem [8]. Sydulu and Reddy applied Index Vector to capacitor placement problem [9], Prakash and Sydulu applied particle swarm optimization for optimal capacitor placement problem [10]. Safigianni and Salis presented optimum VAr control of radial primary power distribution networks by shunt capacitor installation [11]. Das implemented genetic algorithm [12], Hsiao implemented Fuzzy-genetic algorithm for [13] for optimal capacitor placement problem. Huang applied immune multi objective algorithm for capacitor placement problem [14]. Kannana et al. applied Fuzzy-Differential Algorithm [15], Srinivasa Rao et al. applied plant growth algorithm for optimal capacitor placement problem [16].

DGs are considered as small power generators that complement central power stations by providing incremental capacity to power system. DGs may never replace the central power stations. However, penetration and viability of DG at a particular location is influenced by technical as well as economic factors. The technical merits of DG implementation include voltage support, energy-loss reduction, release of system capacity, and improve utility system reliability [17]. By supplying power during peak load periods DG can best serve as a price hedging mechanism. Numerous techniques are proposed so far to address the viability of DGs in power system. Besides, several optimization tools, including artificial intelligence techniques, such as genetic algorithm (GA), Tabu search, etc., are also proposed for achieving the optimal placement of DG. An optimization approach using GA for minimizing the cost of network investment and losses for a defined planning horizon is presented in Ref. [18]. The method for optimal placement of DG for minimizing real power losses in power distribution system using GA is proposed in Ref.

[19]. The gradient and second order methods to determine the optimal location for the minimization of losses is employed in [20]. An iterative method that provides an approximation for the optimal placement of DG for loss minimization is demonstrated in [21]. Analytical methods for determining optimal location of DG with the aim of minimizing power loss is proposed in [22]. Optimal placement of DG with Langrangian based approach using traditional pool based Optimal Power Flow and voltage stability constrained Optimal Power Flow formulations is proposed in Ref. [23].

The KVS-DSA algorithm proposed, with a possible expert interaction yields optimal locations with suitable sizes of Capacitors and DGs results in minimum active power loss. The algorithm is implemented on 69 Bus Standard Test System, for which the data is given in [24]. Type -3 DG injects only active power into the system as mentioned in [25].

II. THE KVS-DIRECT SEARCH ALGORITHM

The algorithm proposed is for radial distribution system with source bus as slack bus and all other load buses as PQ buses. The algorithm proposed is described in following steps for deciding the optimal sizes of the capacitors in terms of standard sizes available in the market and their locations (only load buses). The algorithm is proposed in the following steps:

1. Base case load flow study is conducted and distribution line losses are determined. This uncompensated loss is considered to be maximum loss in the system.

2. All the load buses are fully compensated with all reactive powers set to zeros and load flow study is conducted and total line loss is determined. This is considered as minimum possible loss to be aimed at for determining optimal sizes of capacitors and locations.

3. To determine the optimal sizes of capacitors, a number of options having group of various capacitor sizes are to be tried. A tolerance index is chosen i.e., modulus of difference between losses under any option and minimum loss should be a very small value. All possible options may be enlisted.

4. Let m(k) be the number of capacitors in the k^{th} option, k ranging from 1 to n where 'n' is the total number of options. m(1) , the first option is with single capacitor, the Q of which is nearest to the total KVAR placed at all load buses, in turn, and load flow study is conducted. The line losses are determined. If the lowest loss satisfies the tolerance criterion, the process can be terminated. The size and location are considered as the optimal solution.

5. In one set of capacitors m(k), the first capacitor is kept at all load buses in turn, and the location for which losses are the lowest is considered as the optimal location for that capacitor. Placing this capacitor at that load bus, the procedure is repeated for placing the second capacitor at all load buses in turn and deciding the optimal location for the second capacitor. This procedure is repeated for all capacitors.

6. The options m(2) to m(n) are sequenced taking more and more number of capacitors of smaller size such that the total compensation is nearest to the total KVAR of the system. System losses are found out for each combination and checked for tolerance. If the tolerance is acceptable, process can be terminated.

7. Observe the total active power load in the system. To determine the optimal sizes of DGs, a number of options having group of various DG sizes are to be tried. A tolerance index is chosen. Losses under any option should be less than the tolerance index for convergence. All possible options may be enlisted.

8. Let a(t) be the number of DGs t^{th} option, t ranging from 1 to d where 'd' is the total number of options. a(1) , the first option is with single DG, the P (active power) of which is nearest to the total KW load, placed at all load buses, in turn, and load flow study is conducted. The line losses are determined. If the lowest loss satisfies the tolerance criterion, the process can be terminated. The size and location of DG are considered as the optimal solution.

9. In one set of DGs a(t), the first DG is kept at all load buses in turn, and the location for which losses are the lowest is considered as the optimal location for that DG. Placing this DG at that load bus, the procedure is repeated for placing the second DG at all load buses in turn and deciding the optimal location for the second DG. This procedure is repeated for all DGs.

10. The options a(2) to a(d) are sequenced taking more and more number of DGs of smaller size such that the total DG capacity is nearest to the total KW of the system. System losses are found out for each combination and checked for tolerance. If the tolerance is acceptable, process can be terminated.

Similar to the capacitor placement, DG placement also tried with number of groups of DGs which are going to inject only active power in to the system.

III. RESULTS

The KVS-DSA Algorithm is implemented on 69 - Bus System. The total active and reactive power demand of the system is 3802.19 kW and 2694.60 kVAr respectively. The minimum active power loss obtained after making reactive power load demand (i.e., at all load buses, Q_{load} =0) is 145.12 kW. This is the minimum possible loss that should be aimed at. Minimum loss obtained by placing capacitors is 145.92 kW using the proposed algorithm. After placing both capacitors and DGs with KVS-DSA algorithm, the loss is 7.27 kW.

Without placement of Capacitors and DGs the loss is 225 kW whereas after capacitor placement the loss is 145.92 kW. After DG placement, the active power loss gets reduced to 7.27 kW. There is a reduction of 96.76% in the losses. Before placement of Capacitors and DGs, the power loss is 5.58 % of the total power supplied by the slack bus.

Table 1: Capacitive Compensation on 69- bus system using KVS- Direct Search Algorithm

S. No.	Q kVAr Compensation	Min Loss Location	Active power loss after placing the capacitors in turn(kW)
1	900	61	159.42
2	450	15	151.92
3	450	60	147.00
4	300	50	146.35
5	150	11	146.10
6	150	49	145.97
7	150	49	145.93
8	150	38	145.92

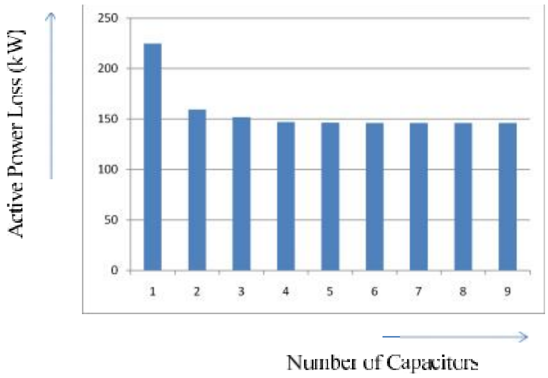

Fig. 1 Reduction in active power loss by capacitive compensation

After optimal placement by the KVS – DSA algorithm, 7.27 kW is obtained, which is 0.19% of the total power supplied by the system. Hence, the system is termed as Loss Less Distribution System. The Table 1 shows the best combination of capacitors with location and third column shows active power loss after placing capacitors in turn. Fig. 1 shows the reduction in active power loss by optimal placement of Capacitors. X-axis shows the number of capacitor bank mentioned in the order of Table 1.

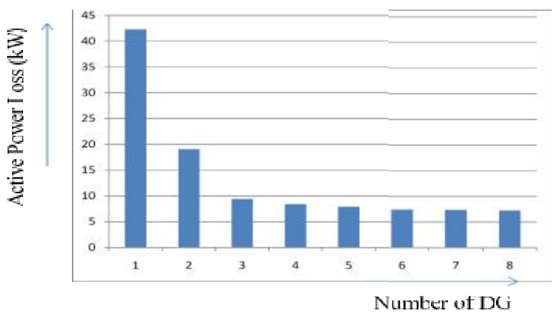

Fig. 2 Reduction in active power loss by DG placement

Table 2 shows best combination of DGs with location and active power loss after placing DGs in turn along with capacitors. Fig. 2 shows the reduction in active power loss by optimal placement of DGs. X-axis shows the number of DG mentioned in the order of Table 2.

Table 2: Type -3 DG placement on 69- bus system using Direct Search Algorithm

S. No.	DG size (kW)	Min Loss Location	Active power loss after placing the DGs in turn (kW)
1	1000	61	42.34
2	1000	61	19.04
3	500	18	9.44
4	300	50	8.45
5	300	11	7.91
6	300	49	7.43
7	200	49	7.35
8	100	45	7.27

IV. CONCLUSIONS

In this paper, a KVS – DSA algorithm is implemented to determine the optimal sizes of Static Capacitors and Distributed Generators (DGs) together with their optimal locations in 69 Bus Radial Distribution System so that maximum possible reduction in real power loss is obtained. The optimal sizes of capacitors and Type -3 DGs are chosen to be standard sizes that are available in the market i.e., discrete sizes of capacitors and DGs are considered. The algorithm is tested on standard 69 bus systems. The loss reduction obtained in this paper for the 69 Bus Test System is highest compared to the other technique as reported in the literature. There is a reduction of 96.76% in the power loss. Before placement of DGs and Capacitors, the power loss is 5.58% of the total power supplied by the slack bus. After optimal placement by the proposed algorithm, 7.27 kW is obtained, which is 0.19% of the total power supplied by the system. Hence, the system is termed as Loss Less Distribution System. Using the same KVS-DSA algorithm Type -2 DG and capacitor placement can be carried out for designing loss less distribution as future work.

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