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Type-2 DG Optimal Placement Using Direct Search Algorithm for 33 Bus Loss Less Distribution

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Abstract— In this paper, a new algorithm is proposed to determine the optimal sizes of Static Capacitors and Type - 2 Distributed Generators (DGs) together with their optimal locations in 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. Type 2 DG injects active power and consumes reactive power from the system. The power factor considered is 0.85 lagging. Discrete sizes of capacitors and DGs are considered. The algorithm is an extension of [1] with a little modification. The modification is required to compensate for additional reactive power required by Type-2 DG. The new algorithm consisting of 3-stages is tested on standard 33 bus systems. In the first stage, capacitive compensation is done. In stage 2, DGs are placed and in Stage-3, capacitive compensation is done for additional reactive power requirement of DGs.The loss reduction obtained in this paper for the 33Bus Test System is highest compared to the other technique as reported in the literature. Without placement of Capacitors and DGs, the active power loss is 211kW whereas after placement it is 19.28 kW. There is a reduction of 90.86% in the losses. Before placement of DGs and Capacitors, the power loss is 5.67% of the total power supplied by the slack bus. After optimal placement by the proposed algorithm, 19.28 kW is obtained, which is 0.51% of the total power supplied by the system. Hence, the system is termed as Loss Less Distribution System. The Modified DSA algorithm is implemented using MATLAB/Simulink. This paper also includes optimal cost analysis with and without placing capacitors and Type-2 DGs.

Keywords— Capacitive compensation, Distribution Systems, Loss Less Distribution, Optimal DG Placement

I. INTRODUCTION

Optimal capacitor placement is implemented for improving the voltage profile and reducing the power loss. Optimal DG placement is implemented for reduction of active power loss and to improve the reliability of the system. Very few papers have addressed the concept of minimizing the active loss by placing both DGs and Capacitors [1-3] at their optimal locations. 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. In India, all the 11 KV rural distribution are radial and too long. The voltages at the far ends of many such feeders are very low with very poor voltage regulation. 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. T. S. Sirish et. al[1] have used Direct Search Algorithm for placing Type-3 DG on 69 Bus Distribution System. In this work, the algorithm proposed is modified version of Direct Search Algorithm [2] according to the requirement of Type-2 DG. This algorithm is an extension of Direct Search Algorithm for Capacitive compensation proposed by M. Ramalinga Raju et. al. [3].

The technical merits of DG implementation include voltage support, energy-loss reduction, release of system capacity, and improve utility system reliability [4]. 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 [5]. The method for optimal placement of DG for minimizing real power losses in power distribution system using GA is proposed in [6]. The gradient and second order methods to determine the optimal location for the minimization of losses is employed in [7]. An iterative method that provides an approximation for the optimal placement of DG for loss minimization is demonstrated in [8]. Analytical methods for determining optimal location of DG with the aim of minimizing power loss are proposed in [9]. 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. [10].

Carpinelli et al. implemented [11] non-linear programming technique for capacitor placement on three phase unbalanced system.Wang et al. implemented [12] integer programming technique, and Tabu search was used by Huang et al. [13] for optimal capacitor placement. Grainger implemented equal area criterion [14] and genetic algorithm applied to capacitor placement by Dlfanti [15] for determining optimal sizes of capacitors.

Das applied Fuzzy- GA method for capacitor placement problem [16]. Sydulu and Reddy applied Index Vector to capacitor placement problem [17], Prakash and Sydulu applied particle swarm optimization for optimal capacitor placement problem [18]. Safigianni and Salis presented optimum VAr control of radial primary power distribution networks by shunt capacitor installation. Das implemented genetic algorithm, Hsiao implemented Fuzzy-genetic algorithm for optimal capacitor placement problem. Huang applied immune multi objective algorithm for capacitor placement problem. Kannana et al. applied Fuzzy- Differential Algorithm Srinivasa Rao et al. Applied plant growth algorithm for optimal capacitor placement problem.

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 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 33 Bus Standard Test System, for which the data is given in [19]. Type -2 DG injects active power into the system and consumes reactive power as mentioned in [20].

II THE MODIFIED DSA 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. **Stage -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. **Stage -2:** 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.
11. **Stage- 3:** In Stage-1 reactive power requirement is from the loads. But, in stage -3, capacitive compensation is required to meet the additional requirement of Type-2 DGs. Stage -1 is repeated for capacitor compensation. Calculate the additional $Q_{required}$ by DGs. Take a single capacitor whose magnitude is nearer to $Q_{required}$ by DGs. Step3-Step5 is repeated.

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

III COST FUNCTION

The objective function for optimization can be stated mathematically as given below. The first part of it is cost of energy loss and second part is the purchase cost of Capacitor and DG. The objective is to minimize the total cost, S:

$$\text{Minimum } S= (K_e \sum_{j=1}^{L} Tj\, Pj) + (\sum_{i=1}^{Ncap} KcQci + \frac{KgPgi}{Tg})$$

Where Ke is the energy cost per each kW h, Tj is the duration for which a jth load level operates. Generally three load levels are present for cost analysis. They are light, nominal and peak. But in this work, only nominal load level is considered for simplicity. Pj is the active power loss during jth load level. Qci is the size of the capacitor placed at ith bus. Different size capacitors would be suitable for different load levels at the optimal locations for minimizing the total cost function. Kc is the purchase cost of capacitor per kVAr. Number of candidate locations is indicated by 'ncap'. Kg is the purchase cost of DG per kW. Pci is the size of DG placed at ith bus. Tg indicates number of operating hours of DG.

Table 1 Load Level and Load Duration Time

Load level	Light(0.5)	Nominal(1)	Peak(1.6)
Duration(h)	2000	5260	1500

In this paper, Nominal load level is taken for the cost analysis, so from the table 1, it is clear that Tj= Tg = 5260h

IV RESULTS

The DSA Algorithm is implemented on 33 - Bus System. The total active and reactive power demand of the system is 3715 kW and 2300 kVAr respectively. The minimum active power loss obtained after making reactive power load demand (i.e., at all load buses, Q_{load} =0) is 138.05 kW. This is the minimum possible loss that should be aimed at. Minimum loss obtained by placing capacitors is 139.06 kW using the proposed algorithm. After placing both capacitors and Type-2 DGs the loss is 57.78 kW. After stage-3, of Modified KVS-DSA algorithm, the loss is 19.28 kW. Without placement of Capacitors and DGs the loss is 211 kW whereas after capacitor placement the loss is 139.06 kW. After complete capacitor and DG placement, the active power loss gets reduced to 19.28 kW. There is a reduction of 90.36% in the losses. Before placement of Capacitors and DGs, the power loss is 5.67 % of the total power supplied by the slack bus. After optimal placement by the DSA algorithm, 19.28 kW is obtained, which is 0.51% of the total power supplied by the system. Hence, the system is termed as Loss Less Distribution System.

Table 2: Capacitor placement on 33-bus system using Direct Search Algorithm

S.No.	Q kVAr Compensation	Min Loss Location	Active power loss after placing the capacitors in turn (kW)
1	300	32	185.07
2	300	30	167.24
3	300	14	153.29
4	300	30	145.6
5	300	25	142.09
6	300	6	139.81
7	150	24	139.4
8	150	21	139.18
9	150	4	139.06

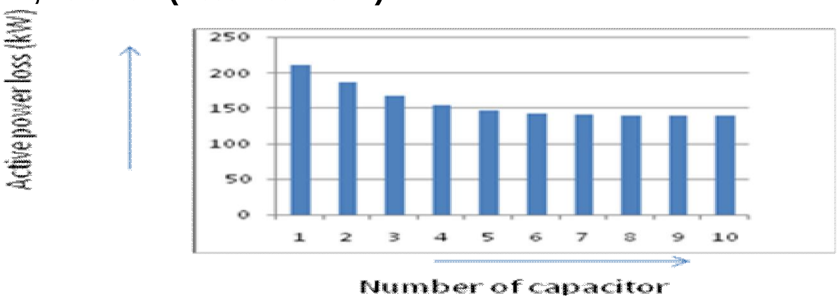

Fig 1 Reduction in Active Power Loss by Capacitor Placement

The Table 2 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 Table1 and Y-axis shows the corresponding active power loss reduction.
The Table 3 shows the best combination of Type-2 DGs with location for 33 bus system and fourth column shows active power loss after placing them and “fig” 2 shows the active power loss reduction by Type-2 DGs optimal placement. Table 4 shows the capacitive compensation used to meet the additional requirement of Type-2 DGs

Table 3: Type-2 DG Placement on 33-bus system using Direct Search Algorithm

S. No.	Active power Supplied By DG (kW)	Reactive power Consumed By DG (kVAr)	Min loss Location	Active Power Loss (kW)
1	1000	619.74	9	79.18
2	1000	619.74	29	64.52
3	500	309.87	25	58.34
4	300	185.92	21	57.78

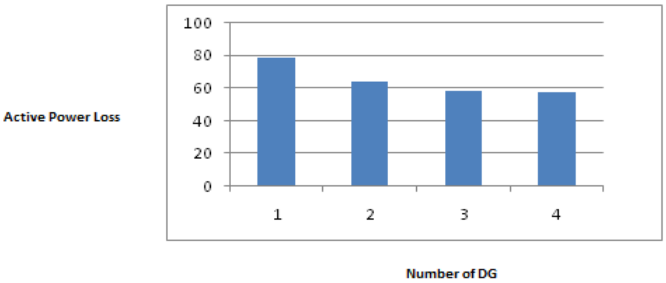

Fig. 2 Reduction in active power loss by Type-2 DG

Table 4: Capacitive Compensation to meet additional requirement of Type-2 DGs

S. No.	Q kVAr Compensation	Min Loss Location	Active power loss after placing the capacitors in turn(kW)
1	900	9	25.56
2	900	3	23.95
3	450	29	19.28

Cost Analysis

Detailed cost analysis is presented for 33 bus system. Energy cost is assumed as US $0.06 per kW h and purchase cost of capacitor is assumed as US $3.0 per kVAr. The Purchase Cost of Type-2 DG is assumed as US $4019 per kW.

Table 5: Cost Analysis

Description	Cost of Energy Loss	Purchase cost of Capacitor and Type-2 DG	Total Cost
Without Placement of Capacitors and Type-2 DG	$66512.700	___	$66512.700
With Placement of Capacitors and Type-2 DG	$6084.668	$15639.300	$21723.968

V Conclusions

In this paper, Modified Direct Search Algorithm is proposed to determine the optimal sizes of Static Capacitors and Distributed Generators (DGs) together with their optimal locations in 33 Bus Radial Distribution System so that maximum possible reduction in real power loss is obtained. The optimal sizes of capacitors and Type -2 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 33 bus systems. The loss reduction obtained in this paper for the 33 Bus Test System is highest compared to the other technique as reported in the literature. There is a reduction of 90.36% in the power loss. Before placement of DGs and Capacitors, the power loss is 5.67% of the total power supplied by the slack bus. After optimal placement by the proposed algorithm, 19.28 kW is obtained, which is 0.51% of the total power supplied by the system. Hence, the system is termed as Loss Less Distribution System. In this paper cost analysis is also presented as in table 5 in which the reduction in cost of energy loss is dominated by the purchase cost of capacitors and type-2 DGs and hence total cost with placement of capacitors and type-2 DGs is much more lesser than total cost without placement.

References

[1]. T. S. Sirish, G. V. Srihara Rao & K V S Ramachandra Murthy, "Optimal Capacitor and DG Placement for Loss Less Distribution on 69- Bus System using KVS – Direct search Algorithm", International Journal of Emerging Trends in Electrical and Electronics, May, 2013.

[2]. K. V. S. Ramachandra Murthy, Mamta Karayat, G. V. Srihara Rao, P. K. Das and A. Ravi Shankar, Loss Less Distribution using Optimal Capacitor and Type-3 DG Placement on Radial Distribution System, International Journal of Emerging Trends in Electrical and Electronics, May, 2013.

[3]. M. Ramalinga Raju, K. V. S. Ramachandra Murthy, K. Ravindra , Direct Search Algorithm for Capacitive Compensation in Radial Distribution systems, International Journal of Electrical Power and Energy Systems, Volume 42, March, 2012, Page: 24 –30.

[4]. P.P. Barker, Determining the impact of distributed generation on power systems: Part 1 -radial distribution systems, in: Proceedings of IEEE Power Engineering Society Summer Meeting, 2000, pp. 1645–1656.

[5]. G. Celli, F. Pilo, Optimal distributed generation allocation in MV distribution networks, in: 22nd IEEE PES International Conference on Power Industry Computer Applications PICA 2001, Sydney, Australia, May 2001, pp. 81–86.

[6]. N. Mithulananthan, Than Oo, LeVan Phu, Distributed generator placement technique in power distribution system using genetic algorithm to reduce losses, Thammasat Int. J. Sci. Tech. 9 (September (3)) (2004) 56–62.

[7]. N.S. Rau,Y.H.Wan, Optimum location of resources in distributed planning, IEEE Trans. Power Syst. 9 (4) (1994) 2014–2020.

[8]. T. Griffin, K. Tomsovic, D. Secrest, A. Law, Placement of dispersed generations systems for reduced losses, in: Proceedings of the 33rd Hawaii International Conference on System Sciences, Hawaii, 2000.

[9]. C.Wang, M. Hashem Nehrir, Analytical approaches for optimal placement of distributed generation sources in power systems, IEEE Trans. Power Syst. 19; November (4); 2004; 2068–2076.

[10]. W. Rosehart, Optimal placement of distributed generation, in: Nowicki (Ed.), 14th PSCC, Sevilla, 24–28 June 2002.

[11]. Carpinelli G, Varilone P, Di Vito V, Abur A. Capacitor placement in three-phase distribution systems with nonlinear and unbalanced loads. IEE Proc Generation Transmission Distribution 2005;152(1):47–52.

[12]. Wang J, Chiang H, Nanminu K, Darling G. Capacitor placement and real time control in large-scale un-balanced distribution systems: Part I and II. IEEE Trans Power Delivery 1997;12:953–64.

[13]. Huang YC, Yang HT, Huang CL. Solving the capacitor placement problem in a radial distribution system using Tabu search application. IEEE Trans Power System 1996; 11:1868–73

[14]. Grainger JJ, Lee SH. Optimum size and location of shunt capacitors for reduction of losses on distribution feeders. IEEE Trans Power App System 1981;100:1105–18.
[15]. Dlfanti M, Granelli GP, Maranninio P. Optimal capacitor placement using deterministic and genetic algorithm. IEEE Trans Power System 2000;15: 1041–6.
[16]. Das D. Optimal placement of capacitors in radial distribution system using Fuzzy-GA method. J Electr Power Energy Syst 2008;30: 361–7.
[17]. Sydulu M, Reddy VVK. Index and GA based optimal location and sizing of distribution system capacitors. In: Power engineering society general meeting, Tampa, FL; 2007. p. 1–4.
[18]. Prakash K, Sydulu M. Particle swarm optimization based capacitor placement on radial distribution systems. Power Eng Soc Gen Meet 2007: 1–5.
[19]. D. Das, Optimal placement of capacitors in radial distribution system using a Fuzzy-GA method, International Journal of Electrical Power and Energy Systems 30 (2008) 361–367
[20]. Duong Quoc Hung, Nadarajah Mithulananthan, Multiple Distributed Generator Placement in Primary Distribution Networks for Loss Reduction IEEE Transactions on Industrial Electronics, Vol. 60, NO. 4, April 2013, pp. 1700-1708

