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(Full length research article)

A new appproach for placement of Capacitor in radial distribution system for improvement of Voltage Profile and reduction of power loss

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Abstract

This paper presents a new and efficient approach for capacitor placement in radial distribution systems with an objective of improving the voltage profile and reduction of power loss. In this paper, our aim would be optimal distributed generation allocation for loss reduction in distribution network. The main purpose of this paper is to discuss the basic understanding of power quality in relation to the distributed generation. A New Search Algorithm (NSA) was used as solving tool. This algorithm is used to minimize an objective function. For applying NSA, a software is programmed under MATLAB software is prepared. This proposed NSA method is implemented on IEEE various Bus System, and the results may show that the proposed method is better than the other methods. The results prove the efficiency of the proposed method.

Keywords: *Radial distribution power flow, Element incidence matrix, Loss Reduction, Transmission loss, Distributed generation*

1. Introduction

The demand of power is escalating in the world of electricity. This growth of demand triggers a need of more power generation. Studies have indicated that inappropriate selection of location and size of DG, may lead to greater system losses than the losses without DG [1, 2]. Utilities already facing the problem of high power loss and poor voltage profile, especially, in the developing countries cannot tolerate any increase in losses. By optimum allocation, utilities take advantage of reduction in system losses; improve voltage regulation and improvement in reliability of supply [1–3]. It will also relieve capacity from transmission and distribution system and hence, defer new investments, which have a long lead-time, the distribution systems are characterized by their prevailing radial nature and high R/X ratio. Studies have indicated that as much as 13% of total power generated is wasted in the form of losses at the distribution level [4]. Capacitors are widely used in distribution systems for reactive power compensation to achieve power and energy loss reduction, voltage regulation, and system capacity release. The extent of these benefits will depend upon how the capacitors are placed on the system, to reduce these losses, shunt capacitor banks are installed on distribution primary feeders. The advantages with the addition of shunt capacitors banks are to improve the power factor, feeder voltage profile, Power loss reduction and increases available capacity of feeders. Therefore it is important to find optimal location of capacitors in the system to achieve the above mentioned objectives. Sundharajan and Pahwa [5] proposed the genetic algorithm approach to determine the optimal placement of capacitors based on the mechanism of natural selection. Many methods [6-13] have been developed and tested ranging from sweep methods, to conic programming formulation. The basis for the all the sweep methods is that they need an initial value (normally flat) for the voltages and the updating is done in forward and backward way implementing the Kirchhoff's equations. Expósito and Ramos [8] have proposed a radial load flow technique based on solving a system of equations in terms of new variables and using the Newton approach. In this paper, injection of reactive power is done for the purpose of improving the voltage profile as well as reducing the system loss for the given system.

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Notations:

N=Number of buses

P_i=Real power flows into the sending end of branch i+1 connecting bus i and i+1

Q_i=Reactive power flows into the sending end of branch i+1connecting bus i and i+1

P_{Li+1}= Real power loss at bus i+1

Q_{Li+1}=Reactive power loss at bus i+1

V_i=Bus Voltage magnitude at bus i

R_{i+1}=Resistance of branch, line, connecting bus I and bus i+1

X_{i+1}=Reactance of branch, line, connecting bus I and bus i+1

2. Problem Formulation

The objective of capacitor placement in the distribution system is to minimize the annual cost of the system, subjected to certain operating constraints and load pattern. For simplicity, the operation and maintenance cost of the capacitor placed in the distribution system is not taken into consideration. The voltage magnitude at each bus must be maintained within its limits and is expressed as:

$$V_{min=} \leq |Vi| \leq V_{max}$$

Where $|Vi|$ is the voltage magnitude of bus i, V_{min} and V_{max} are bus minimum and maximum voltage limits, respectively. The power flows are computed by the following set of simplified recursive equations derived from the single-line diagram depicted in Fig. 1.

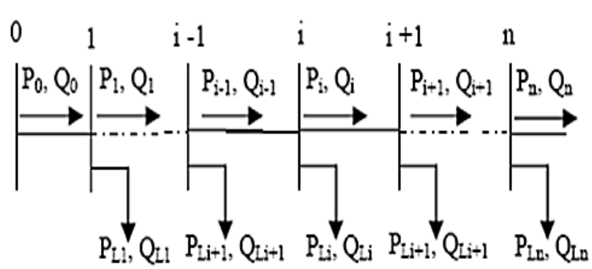

Fig.1 Single-line diagram of a main feeder

$$P_{i+1=}P_i - P_{Li+1-}R_{j,i+1}.\frac{P_i^2+Q_i^2}{|V_i|^2} \quad (1)$$

$$Q_{i+1=}Q_i - Q_{Li+1-}X_{j,i+1}.\frac{P_i^2+Q_i^2}{|V_i|^2} \quad (2)$$

$$V_{i+1}^2 = V_i^2 - 2(R_{j,i+1}.P_i + X_{j,i+1}.Q_i) + (R_{i,i+1}^2 + X_{i,i+1}^2).\frac{P_i^2+Q_i^2}{|V_i|^2} \quad (3)$$

Where

P_i and Q_i are the real and reactive powers flowing out of bus i, and

P_{Li} and Q_{Li} are the real and reactive load powers at bus i. The resistance and reactance of the line section between buses i and i+1 are denoted by $R_{i,i+1.}$ and$X_{i,i+1.}$, respectively. The power loss of the line section connecting buses i and i+1 may be computed as

$$P_{loss}(i, i+1)=R_{i,i+1.}\frac{(Pi^2+qi^2)}{|V_i|^2} \quad (4)$$

The total power loss of the feeder$P_{T,Loss}$, may then be determined by summing up the losses of all line sections of the feeder, which is given as

$$P_{T,Loss} = \sum_{i=o}^{n-1} P_{loss}(i, i+1) \quad (5)$$

Consider a distribution line with an impedance R+jX and a load of P_{eff} + jQ_{eff} connected between 'p' and 'q' bus as shown in fig.2

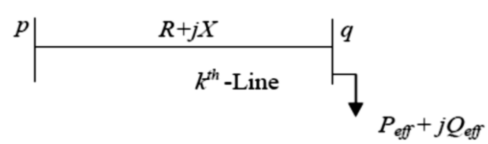

Fig. 2 Distribution line

Active power loss in the k^{th} line is given by, $|[I_K^2] * R[k]|$ which can be expressed as,

$$P_{lineloss}[q] = \frac{(P_{eff}^2[q]+Q_{eff}^2[q])R[k]}{|V[q]|^2} \quad (6)$$

Similarly the reactive power loss in the k^{th} line is given by

$$Q_{lineloss}[q] = \frac{(P_{eff}^2[q]+Q_{eff}^2[q])X[k]}{|V[q]|^2} \quad (7)$$

Where, P_{eff}[q]= Total effective active power supplied beyond the node '*q*'.

Q_{eff}[q]= Total effective reactive power supplied beyond the node '*q*'

Table 1 Load and line data of a 9-bus system

Line No	From Bus, i	To Bus, i+1	Ri,i+1(Ω)	Xi,i+1(Ω)	P_L (kW)	Q_L(KVAR)
1	0	1	0.1233	0.4127	1840	460
2	1	2	0.014	0.6057	980	340
3	2	3	0.7463	1.205	1790	446
4	3	4	0.6984	0.6084	1598	1840
5	4	5	1.9831	1.7276	1610	600
6	5	6	0.9053	0.7886	780	110
7	6	7	2.0552	1.164	1150	60
8	7	8	4.7953	2.716	980	130
9	8	9	5.3434	3.0264	1640	200

Table 2 Percentage increase of Voltage Profile after Injecting Reactive Power at Various Buses

Bus	Bus 4&5		Bus 5&6		Bus 6&7		Bus 7&8		Bus 8&9		Bus 9&10	
No	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%	50%	70%
1	1.13	1.14	1.11	1.12	1.11	1.11	1.11	1.11	1.11	1.11	1.11	1.11
2	2.93	2.97	2.9	2.91	2.89	2.89	2.89	2.89	2.89	2.89	2.89	2.9
3	3.43	3.5	3.36	3.39	3.33	3.33	3.33	3.34	3.34	3.34	3.34	3.35
4	4.27	4.36	4.18	4.21	4.14	4.14	4.14	4.14	4.15	4.15	4.15	4.16
5	4.11	4.2	4.05	4.09	3.98	3.98	3.98	3.99	3.99	4	4	4.02
6	4.63	4.72	4.57	4.61	4.5	4.5	4.5	4.51	4.51	4.53	4.52	4.54
7	4.16	4.25	4.1	4.15	4.03	4.03	4.04	4.04	4.05	4.06	4.06	4.08
8	3.01	3.1	2.94	2.99	2.87	2.87	2.88	2.88	2.9	2.92	2.92	2.95
9	2.2	2.29	2.13	2.18	2.06	2.07	2.07	2.08	2.09	2.11	2.12	2.17

3. Test Result

The proposed method has been programmed using MATLAB and run on an Intel(R) Core(TM) 2 Duo CPU, 3-GHz personal computer with 1.93 GB RAM. The effectiveness of the proposed method for loss reduction by capacitor placement is tested on 9 bus and 28 bus radial distribution systems. The results obtained in these methods are explained in the following sections. The first test case for the proposed method is a 9-bus, single feeder, radial distribution system [14] shown in fig. (a). This system has zero laterals. The rated line voltage of the system is 23 kV. The details of the feeder and the load characteristics are given in Table 1.

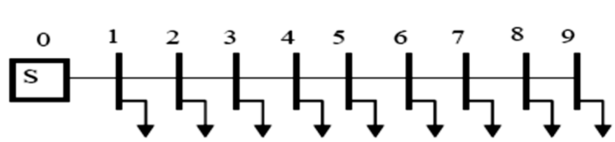

Fig. 3-9 Section Feeder

For a 9 bus test system, reactive power between two arbitrary buses injected from 50% to 70%,as a result voltage profile of the system improves from its initial position and it is also notice that reactive power injection between bus 4 and bus 5 give the best result compare to any other bus location. From fig. 6, 7, 8 & 9 increased injected reactive power at different buses results in increased loss reduction in real power as well as reactive power in the system. However it has more effect at corresponding bus.

4. Conclusion

In this paper, a new search technique for load flow analysis is proposed which is simple to implement and efficient in computation. The new voltage profile, active power loss and reactive power loss has been tasted using IEEE-9 bus and IEEE- 28 bus radial distribution networks. The total active and reactive power is also calculated and compared. It can be concluded that the new search technique give improved result and minimization of different bus power losses of load flow analysis of radial flow distribution network.

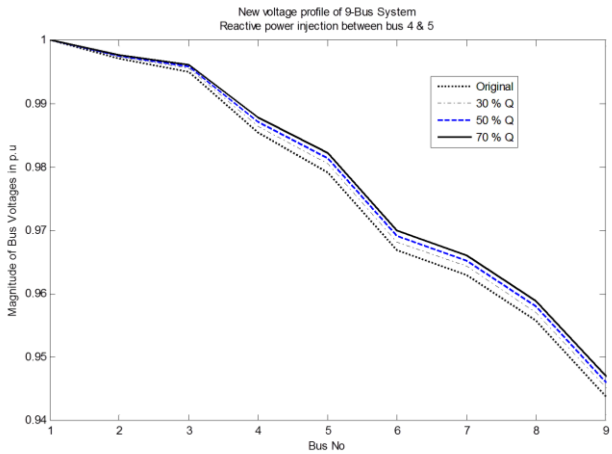

Fig. 4 Improved Voltage Profile for 9 bus Radial System

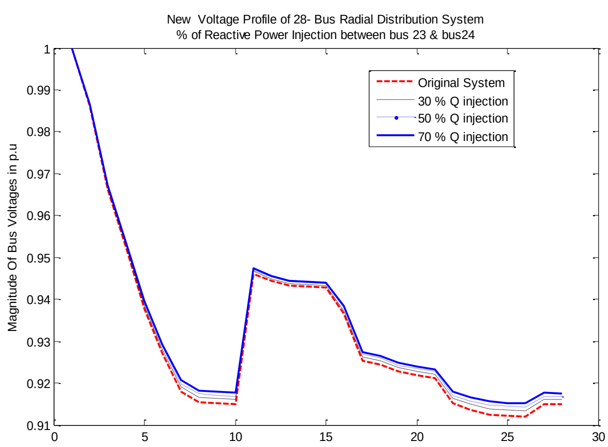

Fig.5 Improved Voltage Profile for 28 Bus Radial System

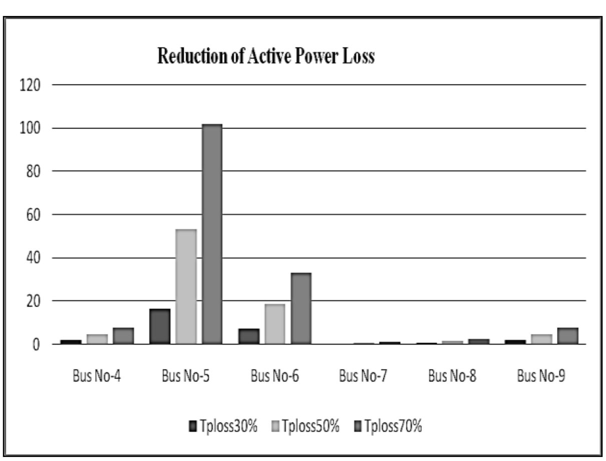

Fig. 6 Reduction of Active power loss for 9bus Radial System

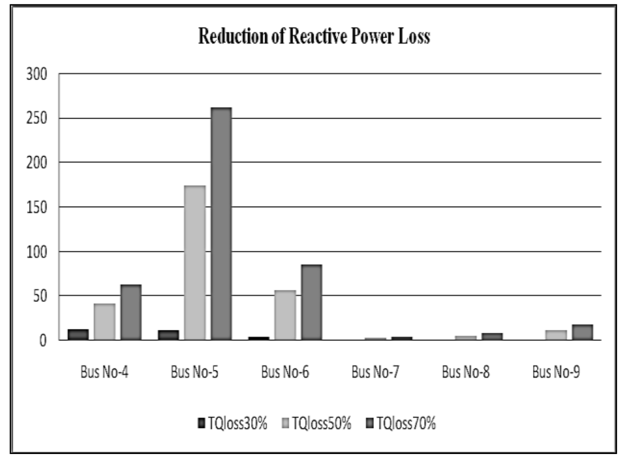

Fig.7 Reduction of Reactive power loss for 9bus Radial System

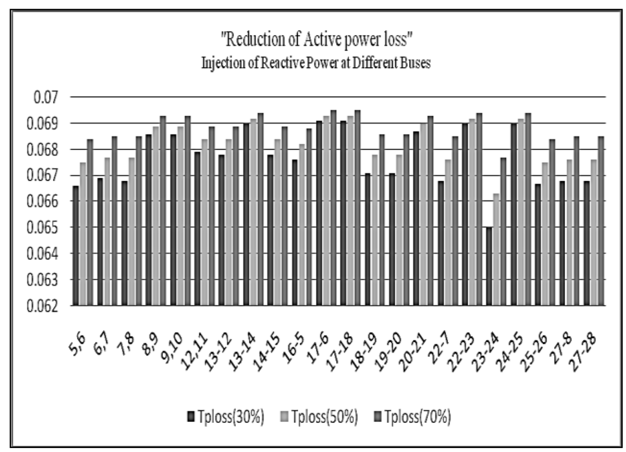

Fig. 8Reduction of Active power loss for 28bus Radial System

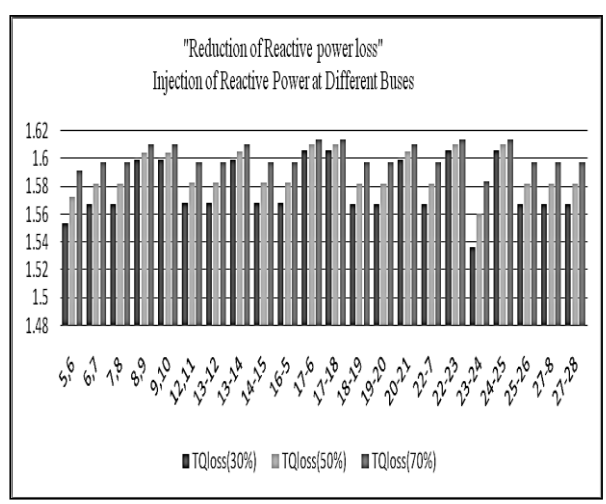

Fig. 9 Reduction of Reactive power loss for 28bus Radial System

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