Review Paper on Optimal Capacitor Placement and Sizing in Distribution System using Optimization Techniques

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***Abstract*— As the number of users corresponding to distribution system has been increasing but it also gives birth to various problems like capacitor placement in the network, reducing the power loss, balancing the voltage level. Capacitor is a device which is used for transferring the reactive power and the main focus or aim is to reduce the loss and to improve the voltage profile. In order to solve all these problems there is a requirement of proper planning regarding installation of distributed system. The problem of capacitor placement in electrical energy distribution system involves determining the number, position, type and size of capacitors located on the distribution feeder, the total cost of system installation and operation, system load. This study provides an overview to the distributed power system along with its basic concepts.**

***Keywords*—Distributed power system, Capacitor placement, Load Flow**

I. INTRODUCTION

Power distribution network is a collection of radial feeders which are inter-connected or grouped with each other by using various tie-switches and tie-lines. The critical issue of electric distribution system is power loss reduction in the grid system. Various methods are used optimal reconfiguration and capacitor placement is one of these techniques.

Normally in all electrical distribution industries there are two types of loads resistive and inductive respectively. Resistive loads emit light as a result of being heated. In case of pure resistive load the parameters such as voltage (defined as V), resistance (defined as R), and current (defined as I) are linearly related to each other as follows:

$$V = (I \times R) \qquad (1)$$

$$Power(kW) = (V \times I) \qquad (2)$$

The inductive load is a type of A.C., motors, furnace, transformers and blast lights. The inductive load requires two types of power active and reactive power. Active power is used for processing and the reactive power is used for generating and maintaining the electro-magnetic fields in the system. The term used for measuring the active power is (kW) kilo Watts. Reactive power is measured in the terms of (kVar) kilo Volt-Amperes Reactive. In order to calculate the total used power the amount of active power used is added to the amount of reactive power used. Then the total power is used for performing the assigned task. The measure used for calculating the total power is (kVA) kilo Volts-Amperes. The following figure1 is drawn for the purpose of representing the relationship between these power types. The combination of these powers generates the apparent power which is denoted by S in the power system.

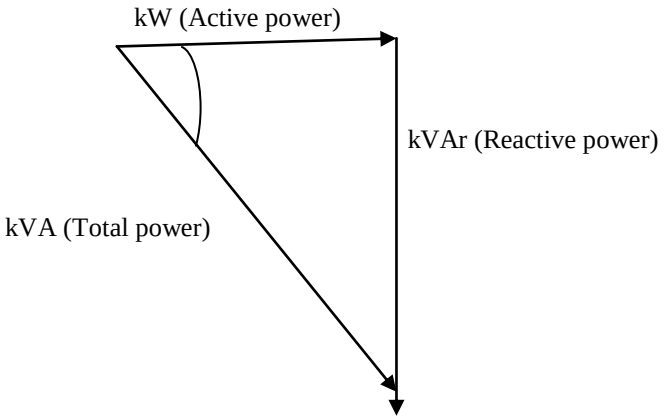

Figure 1 kW, kVAr and kVA Vector

In above figure the active power is needed in kW and similarly reactive power is needed in kVAr. The reactive power is at the distance of 90°in the pure inductive circuit. The active power is treated as pure or true power in the circuit. Both of the powers are added in order to generate the apparent power. The apparent power shows the total sum of actual electrical load on the system.

The capacitor is a device which is used for recovering the reactive power in distributed network. Capacitors are used for multi-purpose such as for reducing the voltage profile, for improving the voltage profiles etc. the main advantage of reducing or recovering the reactive power is based on the allocation or size of the capacitors.

The process to handle the flow of distributed system underlying the various operating conditions with respect to constant power model covers the following aspects:

- *Equivalent current injection:*

As the name depicts, this method works upon the basis of equivalent current injection. In this system the following formulation is composed for evaluating the current injection to the ith bus at kth iteration.

$$S_i = (P_i + jQ_i) \quad i = 1,2, \dots \dots N$$
$$I_i^k = I_i^r\left(V_i^k\right) + jI_i^k\left(V_i^k\right) = \left(\frac{P_{i+j}Q_i}{V_i^k}\right) \quad (3)$$

In above equation, S_i depicts the amount of complex power at ith bus;

P_i, stands for representing the amount of actual power at ith bus;

Q_i, represents the reactive power at ith bus;

I_i^k , defines the equivalent current injection for ith bus at kth iteration;

V_i^k, shows the bus voltage with respect to the kth iteration at ith bus;

DISTRIBUTION LOAD FLOW

Distribution load flow is an important part of capacitor placements because it provides the solution for placement related problems. Normally the distribution networks are radial in nature and R/X ratio is quite high. Generally distribution network are of ill-natured. Hence the methods or techniques like Newton Raphson (NR) and Fast Decoupled Load Flow are not (FDLF) are not suitable for such kind of networks. Following is the description of load flow algorithm.

LOAD FLOW ALGORITHM

Distribution system supports following two characteristics as compare to the transmission system as:

1. Radial construction
2. High ratio of r/x

Above characteristics can lead to the incomplete network in the distributed system. Hence system load flow algorithm does not suit such networks of distributed system. If in any case theses algorithms are used, then the load flow will be diverged. Hence other algorithms like forward and backward method are preferred in such conditions. The steps of Load flow algorithm is as follows:

1. Read the database of the system by using following equation:
$$Q_{T,loss} = \sum_{i=1}^{n} Q_{ij(loss)} \quad (4)$$
2. Go away to Slack bus.
3. Initialize the following parameters:
$$P_{acc} = 0$$
$$Q_{acc} = 0$$
4. Find out or calculate the value corresponding to P and Q for all buses.
5. Now calculate the value of V_j and δ_j for all buses.
6. Evaluate P_{loss} and Q_{loss} for all lines
7. Update the value of P_{acc} and Q_{acc} by using the following equation:
$$P_{acc} = P_{loss} + P_j$$
$$Q_{acc} = Q_{loss} + Q_j \quad (5)$$
8. Go to next bus and repeat the step from 4 to 8 till the last bus is reached.
9. Check for convergence and print the result else Go to step 2.

II. RELATED WORK

Fitriana Suhartati(2014)[1] total active power loss and improve power factor can be reduced by adding shunt capacitors in the distributed systems. But the harmonics distortion level will be amplified with the installation of shunt capacitors in distributed systems in case there is not proper placement with harmonic consideration. Consequently, this paper proposed a technique to determine capacitors placement and its sizing in distorted distribution systems. Technique proposed in this paper is named as direct search algorithm which helped in determined the placement of the capacitors and sizing. In order to search the proper location harmonic power flow had been connected with the algorithm and size of shunt capacitors. By using such method total active power was decreased and power factor can be increased. Moreover, total harmonic distortion did not exceed the actual allowable at each bus. Experiments had done on the 13-bus and 34-bus radial distribution system along with harmonic current injection in the order 5, 7, 11, 13 and 17.

A.H Etemadi(2008)[2] Distributed system is used for the purpose of facilitating the high voltage data transmission among various nodes or links. Hence in such a system while data transmission lot of energy is consumed by the nodes. This can leave an impact on overall system. The energy consumption depends upon the performance of the system collectively. Hence the author proposes a technique which implements the enhanced binary PSO for reducing the power loss in distributed system and optimal capacitor placement in the network. In this work a binary string is used for representing the state of the switches and capacitors in the network. A 16 and 33 bus IEEE test system is used for the purpose of testing and simulation of proposed work.

Ali Hassan(2003)[3] developed technique in order to solve the problem of optimal capacitor placement. The main focus of this work is to solve the problem that is formulated after studying the traditional research work. The problems are how to find out the best suitable location for capacitor placement in

distributed system, what should be size and type of the capacitor, how to reduce the objective function along with the load constraints or operational constraints (voltage profile). The author develops the technique which is the combination of SA i.e. Simulating Annealing, GA i.e. genetic Algorithm, TS i.e. Tabu Search and combination of GA-SA. For implementation 69 bus power system has been used in this.

Anwar Shahzad Siddiqui (2010)[4] shunt capacitors are used for enhancing the performance of distributed system which leads to the energy efficient distributed system. The main issue is that how to place the capacitor at an optimal location so that the reduction in energy to peak power loss can be achieved. In this work a 10 bus radial system is considered for implementing the proposed work. MATLAB simulation platform is used for implementing the load flow program. The proposed work is based on the combination of load flow data and fuzzy technique. The idea bhind using the fuzzy technique is that it is quite simple and contains less complex calculations.

M.Damodar Reddy (2008)[5] proposed a new method named as fuzzy and real coded Genetic Algorithm i.e. (RCGA). Thus proposed method had been used to place the capacitors on the primary feeders of the radial distribution systems. It was supportive in reduction of power losses as well as to improve the voltage profile. In such method two stage methodology had been introduced to solve the capacitor placement problem. In the first stage of the approach, fuzzy had used in order to find the optimal location of the capacitor whereas real coded genetic algorithm had used in the second stage. It helped in finding the size of the capacitors. The sizes of the capacitors corresponding to maximum annual savings are determined. The proposed method is tested on 15-bus, 34-bus and 69-bus test systems and the results are presented.

N. Ganesankaran (2015)[6] the proposed energy efficient model is capable to reduce the power loss and to balance the voltage profile of the system. This is achieved by installing the shunt capacitor at optimal location in a radial distributed network. The proposed works first of all use the loss sensitivity factor in order to find out the optimal location for installing the shunt capacitor. After finding the optimal location it implements the Ant Bee Colony optimization algorithm which selects the suitable size and type of the shunt capacity. On the basis of maximum cost saving large number of buses has been searched. The results section represents the performance level of the proposed work and also compared with traditional work.

M. Varmohamaddi(2012)[8]the proposed work is a hybrid approach which uses two techniques such as PSO and HBMO i.e. Honey Bee Mating Optimization. This technique efficiently selects the optimal location for capacitor placement in the network along with the number of shunt capacitors in order to reduce the power loss and control the voltage profile of power system. First of all the technique determines the number and size of the shunt capacitor which is going to place in a network then it uses the hybrid technique which is a combination of PSO and HBMO in order to evaluate the number optimal bus capacitors at the optimal sizes. The main reason behind using this hybrid approach is less complexity and simplicity of the technique. The implementation of the technique is done by using 14 bus IEEE transmission systems. After simulation it is observed that the proposed system provides a quality solution as compare to existing techniques.

III. CONCLUSION

The concept of capacitor placement and sizing is an interesting topic to the researchers. Since lot of research work is going on under this topic. The paper shows the study of various research works that had been done in this field. The study shows various parameters which effects the performance of the system in which capacitor is placed. This study provides a survey over various research works that has been done in the field of capacitor placement in power grid systems. From the related work it is concluded that more advanced technique such as Newton Raphson can be used for optimal capacitor placement by using any optimization techniques such as PSO, GA, State Transition

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