Shunt Capacitor Placement Techniques To Improve The Stability of Power Systems

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Abstract- *With increasing non-linear loads harmonic currents are created in the power system and distorted all of the voltage and current.The need of capacitor in electrical power system has many advantages that includes for correcting power factor, for voltage stability, for increasing the pick flow through electrical components, for loss reduction by controlling reactive voltage system power flow and so on.By decreasing the flow through cable the system load can be increased without adding any new cables.This application of shunt capacitor greatly depends up on how the capacitor is located in the system. It is necessary to minimize the power losses in the system the higher the losses result in limiting the line capacity as well as higher voltage drop. This problem is minimized by installing shunt capacitor at best location. This paper present different technique for capacitor placement and sizing problem and try to show how each techniques differ from one another and their focusing area the methods used for capacitor placement for loss reduction.*

Keywords- shunt capacitor, reactive power compensation, voltage stability, radial distribution systems.

I. INTRODUCTION

In the in the introduction I will discuss application of shunt capacitor in radial distribution system

Capacitor application

The need of capacitor in power system has different advantage that includes for power factor improvement, voltage stability, loss minimization and for improving power quality of the system, for adequate power transmission the above applications can be determined by how the capacitor is located in the entire power system. The capacitor unit is considered as the building block of shunt capacitor bank. The capacitor units are connected in parallel serious combination and form a single-phase capacitor bank. The series combination reduces the cost of dielectric while parallel combination increase the total capacitance of shunt capacitor.

It is necessary to minimize the power losses in the system the higher the losses result in limiting the line capacity as well as higher voltage drop. This problem is minimized by installing shunt capacitor at exact location with optimum size.Capacitors are mostly installed in distribution system operated as reactive power compensation have the capacity to improve efficiency of distribution system. These capacitor has are also used for voltage profile improvement and maximizing transmitting power flow through cables and transformer.

This important application is depends on controlling the operation of shunt capacitor, and planned placement of capacitor for changing the status of capacitor.

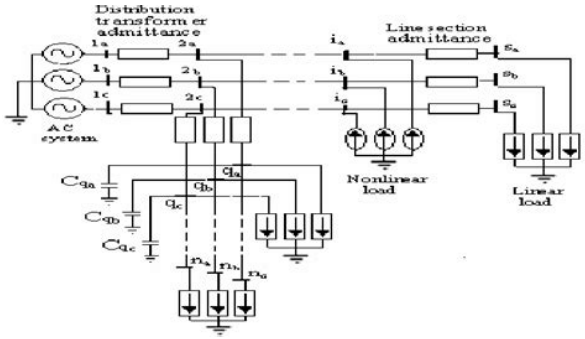

Fig.1. radial distribution feeder with shunt capacitor

II. IMPROVING THE DISTRIBUTION SYSTEM EFFICIENCY

Currently due to the increased of load demand has given a challenge task to a power system engineers in controlling reliability and securing the system operation effectively. The most dominant load at the distribution system is inductive load which require active and reactive power. The inductive nature of the load causes significant power losses due to lagging currents.Thus the distribution system is the highest power loss reduction relative to transmission and generation system.

With such a higher power losses in distribution system, it is necessary to reduce the line losses occurring in primary line as much as possible. The higher losses results in limiting the line capacity as well higher voltage limit in the power system. Now days manufacturer are bound to design

electrical equipment with higher efficiency with high power factor.

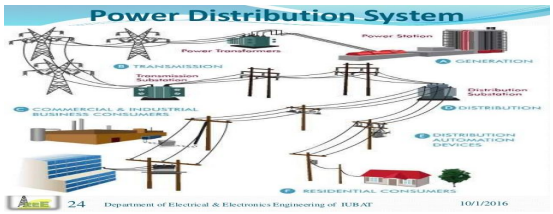

Fig.2. power distribution system

III. IMPORTANT OF REACTIVE POWER COMPENSATION IN DISTRIBUTION SYSTEM

Reactive power is essential to move active power through the transmission and distribution system to the customer and produced when the current wave forms leads the voltage or the current lags the voltage.

The control of voltage and reactive power is critical issue in power system operation for preventing electrical equipment from damage such as overheating of transformer, generator, and transmission line.Stability of voltage in electrical power system is achieved by controlling reactive power flow in the power system. The generation of the reactive power can affect the generation of power which is used by the electrical load. Shunt capacitor and reactor are deviceswhich used for these controlling mechanisms.They are either connected to the transmission and distribution or switched to improve voltage stability.so one primarily dilemma with reactive power is that a sufficient quantity of it is needed to provide the loads and losses in the network, but having too much reactive power flowing around in the network causes excess heating and undesirable voltage drops. The normal answer for such issue is to provide reactive power source (such as capacitor) in the electrical power system network. Thus importance of reactive power compensation has been increased due change in structure of power market. shunt capacitor bank with the low initial cost, no maintenance and no personal cost is the most effective solution for reactive power compensation.

Allocating reactive power source (capacitor) in the power system requires careful consideration. That means Effective use of capacitor in the power system is determined by how it is allocated in the network to get the desired output. These require selecting best capacitor placement in the network and effective technique and adequate controlling mechanism. By decreasing the flow through cables, the systems' loads can be increased without adding any new cables or overloading the existing cables. However these benefits greatly depend on how capacitors are placed in the system.

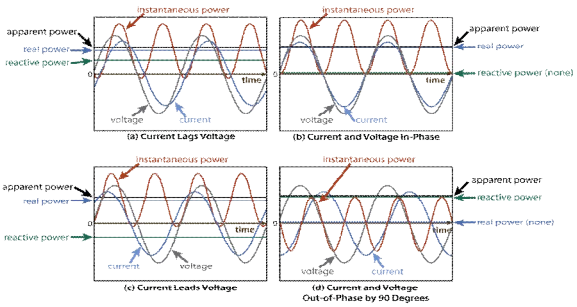

Fig.3. lagging and leading of current over voltage

IV. OVERVIEW OF OPTIMUM SHUNT CAPACITOR TECHNIQUES

In the previous day shunt capacitor is placed close to the substation for reactive power compensation it helps to improve the power factor, however to get the maximum benefit placing shunt capacitor close to the load is better. Now days the trend has changed the capacitor banks are placed on primary distribution lines as well.

Placing capacitor in the power system was varied from time to time depends on its desired output. Capacitors were placed near to the substation to the late 50's it helps to improve of power factor and minimization of power losses. Placing capacitors on such places were not effective way to get the maximum desired output. The capacitor placement problem from the different literature as follows.

Analytical method

The analytical methods were used in earlier time when advanced computing resource were expensive. The initial work has been carried out by Neagle[1] in 1956.For single and multiple capacitorbank in case of uniform and non-uniform distribution load. He suggest that in uniformly distributed load the capacitor bank must be placed at 1-1/2(capacitor kvar/system kvar) distance from the main substation. This indicate that a capacitor of known rating be placed where the ckva of the capacitor is twice the kvar flowing at that location along the feeder.

From these method two important factorsiscited: 1) the emergency of voltage rise and 2)added loss reduction. They derived a system of general application curves selecting location size of single capacitor to achieve loss reduction.Previous work for theanalytical methods for capacitor allocation includes:

Cook[2]worked on the same but more practical algorithm for fixed the optimum location of shunt capacitor must be 2/3(reactive load factor)and enhance his work and

also to include switched capacitor. He considered the reduction in energy loss, taking into account a periodic load cycle. He observed the reduction of loss can be achieved by not placing all multiple capacitor but with only one capacitor. He also investigates multiple capacitors, fixed and switched.Schimil [3] extend the work of cook equations are given for sizing and placement of capacitor on a uniform feeder with a uniformly distributed load. And the necessary condition for sizing and placement of the capacitor is presented.

This method is considered as simple method andlacks to consider different scenario, and modeling of the capacitor placement location and size as continuous size

Numerical programming technique

In this technique mathematical problem are formulated and they can be solved with arithmetic operation.it is an iterative technique which used to maximize or minimize an objective function of decision variable's. Due to increase of the occurring of fast computing the utilization of the numerical methods in the power system has increased [4]

Duran[4] used this approach and improved the work of Schimilwork uniformly and randomly distributed load to find the optimum capacitor placement the formulation is simple and only consider the energy lose reduction and account for desecrate capacitor sizes. Fawzi [5] extend the work of Duran[6] and includes the released kva into the saving function.

Dynamic programming

Until the work of Duran [6**]** the methods involved the use of performance curve and calculus to solve. Duran develops a return function which is summation of the difference between the total cost saving due to loss reduction and installed capacitor.

The above method examined the use of performance curve and calculus to solve for the extremum of an analytical function. Duran recognized the problem as one of dynamic programming and utilize a multistage maximization process and suitable for computer programing.Duran develops a return function which is a summation of difference between, the total cost saving due to loss reduction, and the cost of installed capacitors. He also try to investigate relationship between capacitor costs and installed capacity.

Heuristics methods

This methods are 'hints' that are developed through intuition, experience aand judgment. This techniques is proposed by Abdel-Salem [7]are based on identifying the sensitive node and placing such capacitor bank to the greatest loss reduction due to capacitor placement problem.

The above methods mainly focused for selection of location and size of the capacitor, but there is a related problem of controlling and dispatching when switched capacitor are used. Hsu and kuo [8] investigate the problem of controlling or dispatch of capacitor rather than from a distribution system planning point of view. The approach determines the switching schedules of existing capacitor in a real time, to facilitate optimal application so that feeder losses are minimized.

The main advantage of the above method was that it systematically decided the locations and size of capacitors to realize the optimum sizable reduction in active power loss and significant improvement in voltage profile. The method placed capacitors at a fewer number of locations with optimum sizes and offered much saving in initial investment and regular maintenance. The disadvantage of that algorithm was that the capacitor sizes were considered as continuous variables, then the capacitor sizes were rounded off to the nearest available capacitor value. In this paper, an enhancement to that algorithm is proposed.

Loss sensitivity factor and Particle swarm optimization technique

Azim and Swarup [9] in presented a GA-based approach to determine the optimum locations and sizes of capacitors for a distribution system. This new method for optimum capacitor placement technique is known as particle swarm optimization. This technique uses Loss sensitivity factors to identify the buses requiring compensation and a discrete particle swarm optimization algorithm isused to determine the sizes of the capacitors.This method uses discrete variable and gets desired output among other techniques.

Cuckoo search optimization- based approach

Cuckoo[10} search optimization-based approach has been applied to allocate static shunt capacitor along radial distribution network. This approach identifies optimal sizing and placement and takes the final decision for optimum location within the number of buses nominated with a minimum number of effective location and with fewer injected VARs. The overall accuracy and performance of the proposed approach have been validated and tested on 33-and 69- bus

radial distribution system. The numerical result are compared with recent heuristic method, and statistical analysis proved that the problem-solving better than heuristic methods.

V. CAPACITOR PLACEMENT AND SIZING PROBLEM FORMULATION USING PSO

The aim of proper placement and sizing of the capacitor is for two purposes: to minimize total annual cost function and to minimize power losses which is given by:

$$K^{p}P_{LOSS} + \sum_{J=1}^{J} KCJ_{Q^{C}_{J}} \quad (1)$$

Where $k^{p}$is the annual cost, $p_{loss}$is the total power losses $k^{c}_{j}$is the total annual cost and $Q^{j}c$ is the shunt capacitor size.

Constraint that that need to be satisfied for this technique is listed below

- Shunt capacitor limit
- Bus bar voltage limit
- Line flow limit
- By assuming a distribution line connected two buses find the value of active power losses and loss sensitivity factor. The active power losses in the line is given by:

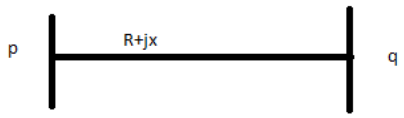

Fig.4.4 A distribution line between p and q

The active power losses in the k_{th} line is given by

$$P_{loss} = I^{2}_{Pq} R_{PQ} = \frac{S2PQ}{V2PQ} R_{pq} \quad (2)$$

now the load senstivity factor is given by

$$\frac{\partial y}{\partial x} \frac{ploss}{Qpq} = \frac{2Qpq}{vp2} R_{pq}(3)$$

- The load sensitive factor able to determine which bus is required for voltage compensation and which are not required.
- Using the discrete particle swarm optimization iteration methoddetermine the size of the capacitor to be installed

VI. CONCLUSION

This short summery has presented overview of different optimum shunt capacitor bank placement technique. In the literature Overview of Analytical method, Numerical programming, Dynamic programing, Heuristic, Coukoo approach and the new approach which is called loss sensitivity factor and Particle Swarm Optimization (PSO)methods are mentioned. All technique uses different algorithm to minimize active power loss and to minimize annual cost function. All except particle Swarm optimization technique and cuckoo approach uses continuous capacitor variables. PSO uses discrete capacitor variables which were to be placed on the buses such that they reduced the losses of the distribution system to a minimum.Optimum shunt capacitor placement in distribution system is very critical issue for minimizing active power losses and minimizing annual cost function in distribution system. This paper shows different ways to install capacitor as long as the size do not exceed the original inductive reactive power of the system. But it is very difficult to easily determine the best location size of the capacitor, moreover the unbalance nature of distribution system make to the placement more complicated. it is better to use discrete control variables.

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