International Conference on Innovative Applications of Computational Intelligence on Power, Energy and Controls with their Impact on Humanity (CIPECH14) 28 & 29 November 2014

Disaster Management of Distribution Line using Fixed and Switched Capacitors

Prof. Zaheeruddin
Dept.of Elect. Engg.
Jamia Milia Islamia
New Delhi, India
zaheeruddin@jmi.ac.in

Mayank Pande
Research Scholar, Dept. of Elect. Engg.
Jamia Milia Islamia
New Delhi, India
mayank1400@rediffmail.com

Abstract - **This papers proposes a plan of using fixed and switched capacitor for the during disaster condition of distribution system. The configuration of a distribution network is different from a transmission network. Distribution systems are typically radial: the loop power flow does not exist. Distribution systems include the inductive loads along with transformers and lines, which account for quite significant power loss due to lagging current.**

The introduction of strategically sized and placed shunt capacitors within the distribution system help to counteract the losses created due to an inductive system by, increasing the system capacity, reducing system losses and improving the voltage profile. The problem of capacitor allocation includes the location, type (fixed or switched), and size of capacitor. The sizing of capacitor is determined by a simple capacitor-sizing algorithm developed in MATLAB.

Keywords- Disaster Management, capacitor placement, reactive power

I. INTRODUCTION

Often distribution lines reach the limit of their power handling capacity and become overloaded under certain loading conditions. In some cases a new distribution line is necessary to supply the peak power required by the load [1]. In others, the problem is alleviated by capacitor placement, and the investment in a new line is postponed. This avoids the possibility of manmade disaster.

Power factor correction is considered to be the best economic option in networks with high reactive demand levels. Numerous technical and economical benefits can be realized through the implementation of correctly sized and placed shunt capacitors in a distribution network[2]. These benefits include (but are not limited to), power loss reduction, improved voltage profiles, reduced loading, increased transformer ratings and often a postponement in costly network upgrades. Other than the disaster management the capacitors allocation gives added advantages like power loss reduction are also fruitful outcome of the capacitor placement.

Correcting power factor reduces network losses, loss reduction occurs from the point in the network where the correction is performed, through to the source of generation. To maximize benefits, power factor correction should be implemented as close to the customer load as possible[3]. However, due to economies of scale, installation of capacitors at the LV level is very costly for a distribution company when compared against HV options. "Losses decline since the capacitor banks along the feeder and at the customer premise now supply the reactive demand of the load. Unlike zone substation capacitor installations, loss reductions are achieved in the HV distribution feeders and the LV network[4]. These reductions can be substantial".Table 1 demonstrates the potential loss savings that can be achieved by correcting power factor.

Table 1. Potential theoretical loss savings by correcting power factor to unity at the customer side.

PF	Potential Loss Saving
0.95	10 %
0.90	19 %
0.85	28 %
0.80	35 %

II IMPROVED VOLTAGE PROFILE

"Highly utilized feeders with high reactive demands have poor voltage profiles. Large voltage variations at the ends of feeders can occur as the load changes, particularly when loading levels change dramatically, as in the case with temperature sensitive loads."

Traditionally, line drop compensation or voltage regulators are required to address this problem. With the inclusion of distributed capacitors along a feeder, and by switching them according to the reactive power demand a "flatter" voltage profile can be achieved[5]. By attempting to keep the power factor close to unity along the section in question, the need for line drop compensation and expensive voltage regulators can be minimized or even eliminated in certain situations. to enhance the capability of substation informatics. Further this knowledge can be used by various utility groups for better overall management of the system[6]. Automation functions can also be increased and optimized if decision support tools are designed and integrated in the system using the knowledge obtained from the database. Such tools when integrated in substations will enhance the substation automation functionality

Objectives of the research are:

- To save the Distribution System from pre disaster voltage fluctuations which may turn to a disaster .
- To compensate the power system giving the reactive power with the help of fixed and switched capacitors
- To improve the voltage profile of the distribution system
- To design a classifier to analyze the unseen events like state of the system

II. METHODOLOGY OF CAPACITOR SIZING & IMPLEMENTATION

IEEE 30 bus system is taken for standard test case. After finding the Capacitor suitability index for different nodes using Fuzzy inference system, a capacitor sizing program is executed in MATLAB to obtain optimal size of the capacitor. The capacitor sizing algorithm described below was successfully implemented as a minor project using the real time data obtained from BSES .The sizing obtained using the newly developed algorithm was compared with the BSES capacitor placement algorithm and validated. Data from IEEE 30 bus system is taken for standard test case[5]. After finding the Capacitor suitability index for different nodes using Fuzzy inference system, a capacitor sizing programme in MATLAB is run by importing the real time inputs from excel data sheet using EXCELLINK function[7] By using the Input data simulations were performed in MATLAB to obtain the following:

The reactive power (Qreq) required.
The rounded off uncompensated reactive power.
The minimum numbers of fixed capacitors required.
The reactive power remaining after fixed capacitor placement.
Improved power factor after fixed capacitor placement.
The number of switched capacitor required
The total remaining reactive power after placement of fixed & switched capacitors.
The total power factor improved.
Check for overcompensation and correction.
Rise in the receiving end voltage.
Total saving per year and payback due to capacitor placement.
The obtained results were exported and stored in a excel datasheet.

To achieve this MATLAB program is developed to export the results.
To analyze the results graphs were plotted for input data i.e. input MW and PF when no compensation is done, taking X axis as real time[8].
Graphs were also plotted between results obtained and time.

B. Problem Formulation

The input data used for simulation in MATLAB programme is obtained from standard test case i.e. IEEE 30 bus system. The input data are as in results
Using the input data a formula is developed to obtain the Q required

$$Q_{req} = KW * \mathrm{Sqrt}\ \{(1-pf^2)/pf\} \qquad (1)$$

Where

Qreq= Reactive power required
KW = Max. Demand in KW
pf = Powerfactor before compensation

The above formulae is obtained by using the conventional basic formulae of Electrical engineering [10] & used as base for developing the programme.
After calculating the Qreq, Qcheck is compared with the KVAR rating of the capacitor module. Now if the Qcheck is greater than or equal to KVAR then the number of fixed capacitors required is determined by using the formulae,

$$N_f = Q_{uncompensated}/KVAR \qquad (2)$$

Where

Nf = No. of fixed capacitors required
Quncompensated = Min. of Reactive Power before Compensation
KVAR = Rating of capacitor module

Else it is inferred that there is no need of capacitor placement at that moment Improved power factor after placing the fixed capacitor is found by using the formula:

$$PF_{improved} = \cos(\tan^{-1}(Q_{rem}/KW)) \qquad (3)$$

Where

PFimproved = Powerfactor improved after placement of fixed capacitor
Qrem= Remaining required Reactive Power after placement of fixed Capacitor
KW = Max. Demand in KW

In the next step the Qrem is obtained in order to see that whether there is any need of switched capacitors. If Qrem is greater than zero than the number of switched capacitors is obtained by the formula:-

$$switch = Q_{rem}/KVAR \qquad (4)$$

Where

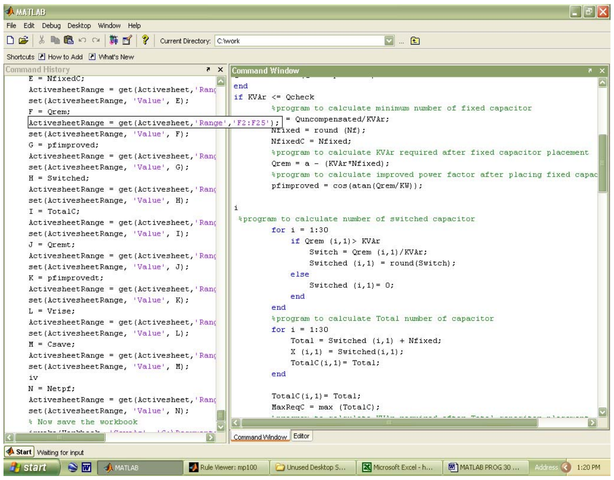
switch = No. of switched capacitor required
Qrem = Remaining required Reactive Power after placement of fixed Capacitor
KVAR = Rating of capacitor module

QremT is obtained by using the formulae:
QremT = Qreq-(KVAR*Total no of cap.)
Where
QremT = Reactive Power required after placement of both fixed and switched capacitors
KVAR = Rating of capacitor module

The overcompensation of the distribution line is checked by the condition QremT is smaller than zero then the number of switched capacitor is reduced by 1 to avoid overcompensation

The voltage rise is obtained due to total capacitor placement to analyze the effect of capacitor placement in performance of line.

Finally saving per year and payback period for total capacitor placement is obtained.



```
E = NfixedC;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', E);
F = Qrem;
ActivesheetRange = get(Activesheet,'Range','F2:F25');
set(ActivesheetRange, 'Value', F);
G = pfimproved;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', G);
H = Switched;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', H);
I = TotalC;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', I);
J = Qremt;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', J);
K = pfimprovedt;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', K);
L = Vrise;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', L);
M = Csave;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', M);
iv
N = Netpf;
ActivesheetRange = get(Activesheet,'Rang
set(ActivesheetRange, 'Value', N);
% Now save the workbook
```

```
end
if KVAr <= Qcheck
        %program to calculate minimum number of fixed capacitor
             = Quncompensated/KVAr;
        Nfixed = round (Nf);
        NfixedC = Nfixed;
        %program to calculate KVAr required after fixed capacitor placement
        Qrem = a - (KVAr*Nfixed);
        %program to calculate improved power factor after placing fixed capac
        pfimproved = cos(atan(Qrem/KW));

i
 %program to calculate number of switched capacitor
        for i = 1:30
            if Qrem (i,1)> KVAr
                Switch = Qrem (i,1)/KVAr;
                Switched (i,1) = round(Switch);
            else
                Switched (i,1)= 0;
            end
        end
        %program to calculate Total number of capacitor
        for i = 1:30
            Total = Switched (i,1) + Nfixed;
            X (i,1) = Switched(i,1);
            TotalC(i,1)= Total;
        end

        TotalC(i,1)= Total;
        MaxReqC = max (TotalC);
```

Figure 1 – Program in Matlab for the implemented capacitor sizing

III RESULTS

The data is taken from IEEE 30 Bus standard test system. Load flow program is run to obtain Power loss indices. The Fuzzy Inference System is developed in which two inputs i.e. per unit voltage and PLI is chosen and output is Capacitor suitability indices[9]. The two highest CSI is found to be of node 7 and 8. The CSI of all the nodes are obtained. The results shows the justification of using the fixed and switched capacitor placement in the distribution line .The placement of the fixed capacitors in the distribution lines used in the past encountered the problem of overcompensation where when the reactive power demand reduces results in the overvoltage problem as the fixed capacitors are placed for a particular calculated load to give the line reactive power compensation for the existing load.

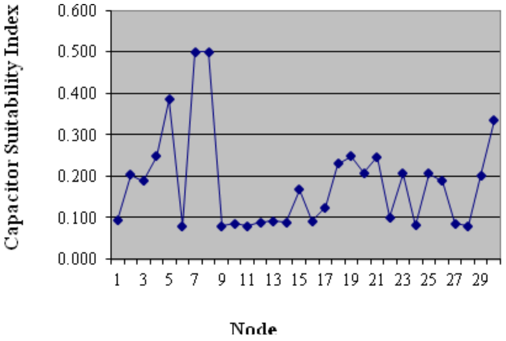


Fig 2.Graph 1- Capacitor Suitability index Vs Node

It is well obvious from the graph 1 that Highest CSI is of node 7 and 8.

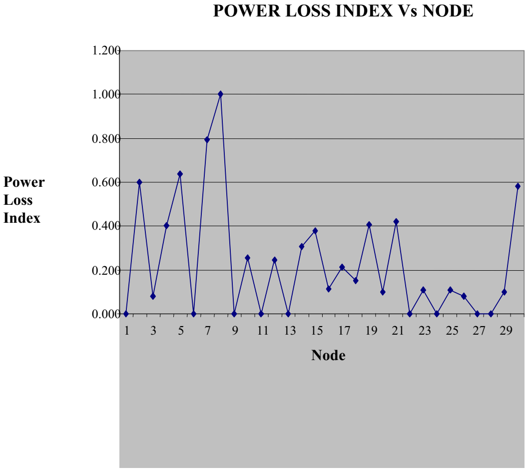


Fig 3 Graph 2- Power Loss index Vs Node

From Fig 3 graph 2 it is seen that Power Loss Index is also highest for node 7 and 8.

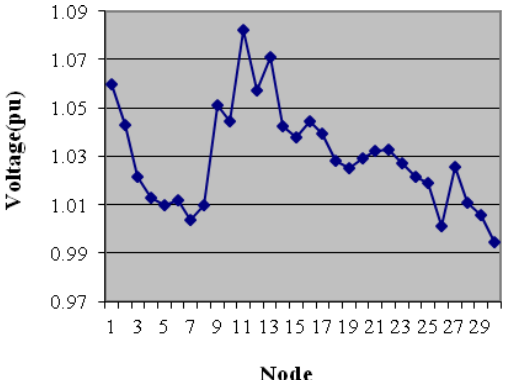


Fig 4 Graph 3- Power Loss index Vs Node

From Fig 4 graph 3 it is evident that V PU is lowest at node 7 and 8. The twenty five IF-THEN rules are fired to get the above values of CSIs. The location of capacitor placement is decided by analyzing the CSI of individual loads.

The result of capacitor sizing algorithm is given in tabular form .The analysis of graph between reactive power demand and node justifies the necessity of Fixed and Switched capacitors to be placed in radial distribution system. The cost and maintenance of fixed capacitor is less than that of switched and if the minimum requirement of the nodes is met by fixed capacitor

Graph 4-6 is plotted for input active power, Power factor & Reactive power before compensation.

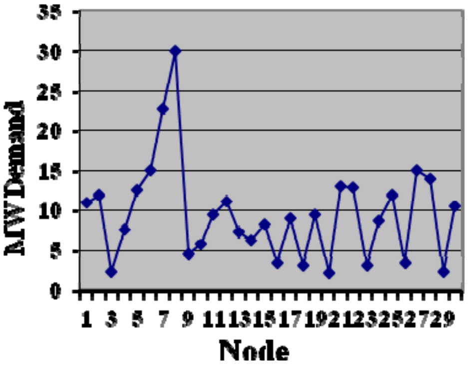


Fig 5 Graph 4- MW demand Vs Node

From Fig 5graph 4 it is observed that there is a continuous variation in active power required. Hence the need for compensation is justified

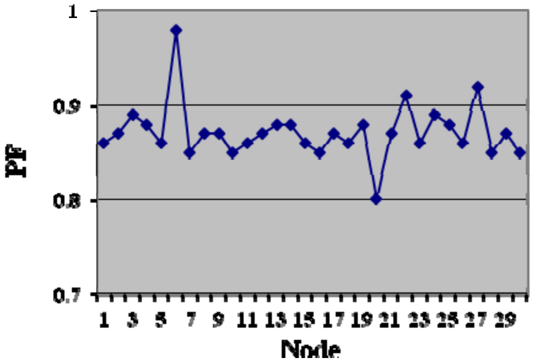


Fig 6 Graph 5- PF before Compensation Vs Node

From Fig 6graph 5 it is seen that without compensation the power factor of the distribution line is low & varies over a wide range, which means that the power quality is poor and the conventional method of using only fixed capacitor bank for compensation will not be economical and efficient. Therefore we require a mix of both fixed as well as switched capacitor bank in order to improve the power quality.

The Man made disaster in distribution system is due to excessive demand of rective power which if not met by the distribution companies leads to the collapse of the power distribution system

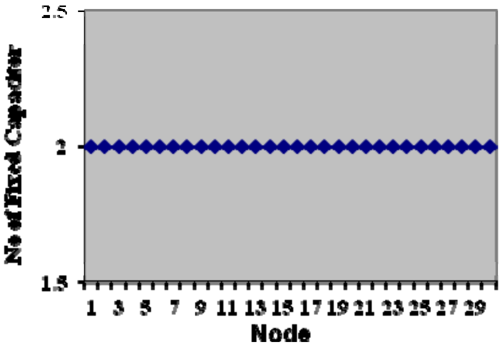


Fig 7 Graph 6- No. of Fixed capacitor Vs Node

From Fig 7 graph 6 shows that 2 fixed capacitors are required for the minimum of the reactive power requirement for 30 nodes.

The program is run in MATLAB and data exported to spread sheet is taken for analysis. The results for .75 MVAR are given in Appendix D. The results so obtained were compared with the actual results of capacitor placements of BSES and were found quite comparable with their costly software for placement of fixed & switched capacitors.

The analysis of the result obtained by the Fuzzy Inference system and Capacitor Sizing Algorithm agrees with the benefits of capacitor placement and justifies the concept of using Fixed and Switched capacitors in radial Distribution System.

The data is taken from IEEE 30 Bus standard test system. Load flow program is run to obtain Power loss indices. The Fuzzy Inference System is developed in which two inputs i.e. per unit voltage and PLI is chosen and output is Capacitor suitability indices. The two highest CSI is found to be of node 7 and 8. The CSI of all the nodes are obtained.

VI CONCLUSION

For managing the disaster due to reactive power demand capacitor placement is done in radial distribution line which also yields benefits due to peak power loss reduction, energy loss reduction, and benefits due to released generation, increased transmission and substation capacity and increased revenue due to voltage improvements and power factor correction.

By analyzing the results it can be concluded that the minimum reactive power requirement can be met by fixed capacitor placement, which is cheaper in cost and has less maintenance as compared to the switched capacitors.

Using modules of lower KVAR rating the cost of capacitor placement increases although the control and improvement of power quality is much better.

Using a single fixed capacitor module rather than using a large numbers of fixed capacitors of smaller ratings can reduce the cost factor.

Communication is very fast & cheap therefore the input & output can be very easily communicated through a high speed channel in excel sheet form. In SCADA the implementation of the project work can be effectively done.

It is observed that the investment on fixed and switched capacitors leads to annual saving with less payback period which implies that the capital cost of capacitor placement is fully justified with the improvement of Power factor, Voltage profile and Power quality.

The present work was discussed with BSES and NDPL DISCOMS in Delhi India for implementation in their SCADA system as the MATLAB program developed is very simple & incorporates the basics of power system with least input required. Using SCADA for optimal and most effective solution will solve the capacitor placement problem.

VI. References

[1] Attia A. El-Fergany1, Almoataz Y. Abdelaziz2." Efficient heuristic-based approach for multi-objective capacitor allocation in radial distribution networks" IET GT&D 2013, IET Gener. Transm. Distrib., 2014, Vol. 8, Iss. 1, pp. 70–80 79 doi: 10.1049/iet-gtd.2013.0213

[2] Benemar Alencar de Souza, Helton do Nascimento Alves, and Helvio Alves Ferreira "Microgenetic Algorithms and Fuzzy Logic Applied to the Optimal Placement of Capacitor Banks in Distribution Networks", IEEE Trans. on Power systems, VOL. 19, No. 2, MAY 2004

[3] C.S.Chen, C.T.Hsu, Y.H.Yan, "Optimal Distribution Feeder Capacitor Placement Considering Mutual Coupling Effect of Conductors", IEEE Tran. on Power Delivery, Apr. 1995, pp. 987-994.

[4] D.Jiang, R.Baldick, "Optimal Electric Distribution System Switch Reconfiguration and Capacitor Control",IEEE Tran. on Power Systems, May 1996, pp. 890-897.

[5] Hadi 1994, Publication Marcel Dekker, Inc Newyork Saadat, "Power System Analysis" Edition 2002, Publication Tata McGraw-Hill

[6] H.N. Ng, M.M.A. Salama and A.Y. Chikhani, "Capacitor Allocation by Approximate Reasoning: Fuzzy Capacitor Placement:"
IEEE Trans. on Power Delivery, vol. 15, no.1, January 2000.

[7] J.Balakumaran Dr.K.Thanuskodi. "Loss reduction in radial distribution systems by capacitor placement: fuzzy technique"IEEE Trans. 2004

[8] J.C.Carlisle, A.A.El-Keib, D.Boyd, K.Nolan, "Reactive Power Compensation on Distribution Feeders", Proceedings of the 29th Symposium on System Theory,Mar. 9-11, 1997, Cookeville, Tennessee.

[9] J. C. Carlisle and A. A. El-Keib, "A Graph Search Algorithm for Optimal Placement of Fixed and Switched Capacitors on Radial Distribution Systems" IEEE Trans. on Power Delivery, VOL. 15, No. 1, JANUARY 2000, pp. 423-428.

[10] Z.Gu, D.T.Rizy, "Neural Networks for Combined Control of Capacitor Banks and Voltage Regulators in Distribution Systems", IEEE Tran. on Power Delivery, VOL. 11, NO. 4, October 1996, pp. 1921-1928.