AN OPTIMAL AND CAPACITOR PLACEMENT FOR LOSS REDUCTION IN ELECTRICAL DISTRIBUTION SYSTEMS USING ETAP

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Abstract - *The distribution systems network takes electricity from the broadcast system and gives it to consumers. By disseminate the electricity at high voltage levels, this cut down the transmission line losses and yield the transmission line more efficient. Since transmission voltage levels cannot be used by consumers it required to step down the transmission voltage to more usable voltages. The analysis of a distribution feeder consists of a study of the feeder under normal steady state operating conditions. This paper presents a loss reduction technique for capacitor placement in spiral distribution feeders to diminish the reactive power loss.*

Different steps have been presented for the analysis of the feeder. First, the proposed of an IEEE 4 Node tests system for testing and evaluating of three phase delta grounded wye transformer connection. Second, implement with and without capacitor banks are added in distribution system to reduce the reactive power loss and also execute with solar panel is added in distribution system to reduce the actual power loss. Finally the proposed method for total loss reduction is tested on IEEE 4 Node test system and the results are obtained by ETAP Software.

Key Words: Distribution systems, capacitor placement, loss reduction, real power loss, reactive power loss, ETAP software.

1. INTRODUCTION

Power plants became bigger and bigger. Transmission lines converged the land forming bulk interconnected networks. In the previous half of the twentieth century the plan and operation of the generation and transmission components presented many challenges to working engineers and researchers. The operation of these large interconnected networks required the development of new analysis and operational techniques.there is not yet been developed multiple operational aspects [1]. Optimal Capacitor Placement [2] may not give in the best solution and it can also be impossible for large systems. [3]May be due to some practical unavoidable circumstances the capacitor can't be put on the selected bus still this approach gives a nearest solution. Distribution capacitors can also decrease system line losses and the system power factor is not forced into a foremost mode [4], [5]. [6]- [8] To evaluate the low voltage network. Drawback of this [9] is costly and produces undesirable operational conditions in distribution system. In this approach [10]-[12] Compensators have not only reduce losses but also increase the minimum voltage over desired limit. The proposed method does not consider the adjustable capacitors and a planning perspective consisting of many periods [13]. [14] This feeder becomes singular and it is not any solution achieved. The optimum capacitor placement solution is originate for the method of transformer and not for any individual feeder [15].The main objective of this paper to develop a 4 node test system for testing and evaluation of three phase transformer connection. To implement with and without capacitor banks are added in distribution system to reduce the reactive power loss. To execute with solar panel is added in distribution system to reduce real power loss.

2. PROBLEM FORMULATION

The current in branch (i, k) linking buses i and k is given by

$$I_{ik} = \frac{P_{ik} - jQ_{ik}}{V_i} \tag{1}$$

Where

I_{ik} -Current through branch (i, k)

P_{ik} -Total real power flow in the branch (i, k)

Q_{ik} -Total reactive power flow in the branch (i, k)

V_i - Voltage at node i

The Total Power Loss (TPL) in the transmission lines is:

$$TPL = \sum_{ik-1}^{n} \left| I_{ik} \right|^2 R_{ik}$$

Where

n -Current through branch (i, k)

R_{ik} -Resistance of branch (i, k)

A branch current has two components: active (Ia) and reactive (Ir).The total loss related with the real and reactive components of a branch current can be written as

$$TPL_a = \sum_{ik-1}^{n} \left| I_{ik}^{a} \right|^2 R_{ik} \quad TPL_r = \sum_{ik-1}^{n} \left| I_{ik}^{r} \right|^2 R_{ik}$$

The loss TPL a coupled with the active component of branch current cannot be decreased for a particular source spiral network because all real power must be supplied by the source at the root bus. However, giving part of the reactive power load in the neighborhood, the loss TPLr connected with the passive components of branch currents can be decreased. The capacitor draws a passive current Ic and for a spiral network it changes only the reactive component of current of branch set α. The current of other branches is unchanged by the capacitor. Thus the new passive current of the (i, k)th branch is given by

$$I_{rik}^{new} = I_{ik}^{r} + D_{ik} I_{ik}^{c} \tag{2}$$

Where

$$D_{ik} = 1, \text{ if branch } (i,k) \in \alpha$$

$$= 0, \text{ otherwise}$$

Here rIik is the passive current of branch in the unique system achieved from the load flow solution. The loss TPLrcom connected with the passive element of branch current in the alone system (when the capacitor is attached) can be written as

$$TPL_r^{com} = \sum_{ik-1}^{n} \left(I_{ik}^{r} + D_{ik} I_c \right)^2 R_{ik} \tag{3}$$

The loss saving TLS is the difference between equation (2) and (3) and is given by

$$T_{LS} = TPL_r - TPL_{rcom}$$

$$\sum_{ik-1}^{n} \left(I_{ik}^{r} \right)^2 R_{ik} - \sum_{ik-1}^{n} \left(I_{ik}^{r} + D_{ik} I_{ik}^{c} \right)^2 R_{ik}$$

$$\sum_{ik-1}^{n} \left(2D_{ik} I_{ik}^{r} + D_{ik} I_c^2 \right) R_{ik}$$

$$\sum_{ik-1}^{n} \left(D_{ik} I_{ik}^{r} + D_{ik} I_c \right) R_{ik}$$

The capacitor current Ic that provides maximum loss saving can be obtained from dS/dIc= 0.Thus the capacitor current form loss saving is given by

$$I_c = \frac{- \sum_{ik \in \alpha} I_{ik}^{r} R_{ik}}{\sum_{ik \in \alpha} R_{ik}}$$

The proposed technique can also be repeatedly employed to further optimizing saving of cost of energy by identifying sequence of buses to be remunerated for extra loss reduction by optimal placement of capacitor.

2.1 The Test System

In transformer model the system to be used is shown in Fig 1 below. The procession segment on the load side [ZeqL] and source side [ZeqS] of the transformer bank utilize the pole spacing's as shown in Figure 2.

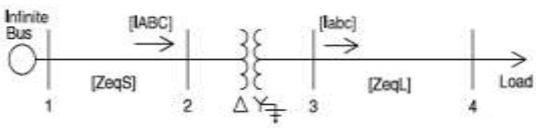

Fig. 1 Transformer Model Test System

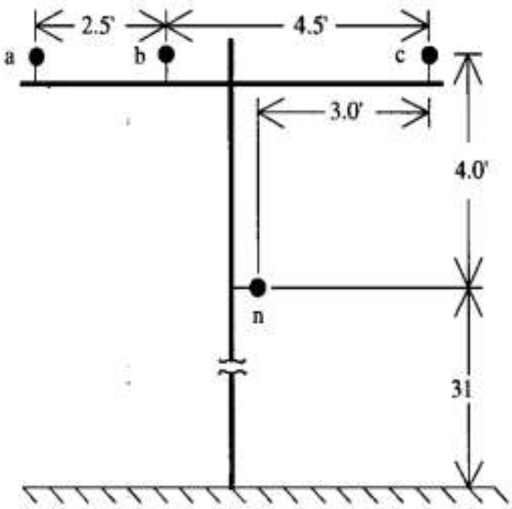

Fig. 2 Pole Spacing

The conductors used in Figure **2** are:

Phase Conductors: 336,400 26/7 ACSR

Neutral Conductor: 4/0 ACSR

The voltage levels for the system shown in Fig 1 :

Source: 12,470 volts line to line

Load: 4,160 volts line to line

The loads used for *11k* system I Figure 1 are:

Unbalanced 1500 kVA,0.85 PF (a-b), 2000 kVA,0.9 PF (b-c),2500 kVA, 0.95 PF (c-a).

Using the pole spacing's the four wire wye line segment is in Figure 2 and the phase and earth conductors as given. The four-wire wye impedances are used for the impedances of windings while the three wire delta impedances are used for a line segment associated to wye connected transformer the impedances of a line connected to delta connected transformer windings.

3. SOTWARE SIMULATION

ETAP software offers the most inclusive and incorporated suite of power system enterprise solution that spans from modelling to operation. The ETAP Software contribute a good crossing point for performing accurate analysis on electrical power systems and is one of the best in Electrical Transient analysis software. Its integration to Microsoft Excel is also one of its many amazing features. The ETAP Software provides an easy to use, user sociable environment along with a widespread user guide that helps user through any problem come across during simulation.

A power grid is represented with its Thevenin equivalent, a constant voltage source subsequent to a short-circuit impedance. Info page allows specifying the utility ID, connected Bus ID, In/Out of Service, Equipment Name and Description, and the power grid Type as shown in Fig 3 below.

Fig.3 Power Grid

The rated voltage of the power grid is used by ETAP to convert the utility short-circuit MVA to percent short-circuit. This value is also used as the power grid base kV.The properties connected with a shunt capacitor can be entered in this editor. Specify the capacitor ID, connected Bus ID, In/Out of Service, Equipment (feeder) Tag, Name and Description, load Priority, Data Type, Phase connection, load Priority, Demand Factor and within the Info page as shown in Fig 4.

Fig.4 Bus Editor

If the bus nominal kV is 4.16 and this capacitor is connected between phase A and phase B (AB), then the rated voltage of the capacitor must be in the neighborhood of 4.16 kV shown in Fig 5. ETAP calculates and displays the amps and straight current by semiconductors and then to electric power through inverters. ETAP PV Array is used to correspond individual panels linked in series and parallel combinations with a grid tied inverter and represents blocks of PV power as shown in Fig 6.ETAP repeatedly assigns a single ID to each PV array. The assigned IDs consist of the default PVA plus a numeral, starting with the number one and rising as the number of PV arrays increase.

Fig.5 Capacitor Placement

4. RESULTS AND DISCUSSION

For this paper IEEE 4 bus system is selected to implement optimal capacitor placement. ETAP has different module for consistency and optimal capacitor placement and solar panel. This paper is drifting out for ETAP based capacitor allocation for IEEE 4 bus. Adding Kvar during capacitor placement can/may develop voltage profile, adjust power factor, decrease losses, improve reliability indices, decrease cost associated to reliability and lot of benefits. Most importantly capacitor placement should be profit oriented in addition to above benefits. All above parameters which modifies as number of capacitor increases while placing capacitor is evaluated. All these parameters are then compared with the results when no capacitor and solar panel is placed. This relationship is required to take decision whether to place a capacitor or not.

4.1 RESULTS FOR IEEE 4 BUS SYSTEM AT BALANCED CONDITION

Distribution systems have a relatively balanced nature, which results from a single phase network components, including balanced loads with capacitor and solar panel. The ETAP balanced load flow analysis program reducing the real power loss for all three phases throughout the electric power system.

4.1.1 LOSS REDUCTION FOR IEEE 4 BUS SYSTEM WITHOUT CAPACITOR PLACEMENT

The table 4.1 shows power losses in IEEE 4 bus at balanced load flow analysis of radial distribution system without capacitor placement.

Table 4.1 Balanced Load flow Analysis of IEEE 4 Bus system without capacitor placement

ID	Losses		%Vdrop in Vmag
	Kw	Kvar	
Line 1	39.2	79.6	1.07
T1	87.7	526.1	4.94
Line 2	440.6	902.5	11.28
Total Losses	567.5	1508.5	-

4.1.2 LOSS REDUCTION FOR IEEE 4 BUS SYSTEM WITH CAPACITOR PLACEMENT

The table 4.2 shows power losses in IEEE 4 bus at balanced load flow analysis of radial distribution system with capacitor placement.

Table 4.2 Balanced Load flow Analysis of IEEE 4 Bus system with capacitor placement

ID	Losses		%Vdrop in Vmag
	Kw	Kvar	
Line 1	35.5	72.7	0.98
T1	79.3	475.7	4.35
Line 2	398.4	816.0	10.20
Total Losses	513.2	1508.5	-

4.1.3 LOSS REDUCTION FOR IEEE 4 BUS SYSTEM WITH SOLAR PANEL PLACEMENT

The table 4.3 shows power losses in IEEE 4 bus at balanced load flow analysis of radial distribution system with solar panel placement.

Table 4.3 Balanced Load flow Analysis of IEEE 4 Bus system with solar panel placement

ID	Losses		%Vdrop in Vmag
	Kw	Kvar	
Line 1	29.7	60.5	0.91
T1	66.5	399.0	4.06
Line 2	334.1	684.4	9.53
Total Losses	430.4	1143.9	-

4.2 RESULTS FOR IEEE 4 BUS SYSTEM AT UNBALANCED CONDITION

The ETAP unbalanced load flow analysis program reducing the reactive power loss for individual phases throughout the electric power system. The module allows for swing, voltage regulated and unregulated power sources with power grid utility and transformer connections. It handles both radial and loop systems.

4.2.1 LOSS REDUCTION FOR IEEE 4 BUS SYSTEM WITHOUT CAPACITOR PLACEMENT

The table 4.4 shows power losses in IEEE 4 bus at unbalanced load flow analysis of radial distribution system without capacitor placement.

Table 4.4 Unbalanced Load flow Analysis of IEEE 4 Bus system without capacitor placement

ID	Losses		%Vdrop in Vmag
	Kw	Kvar	
Line 1	A 17.1	26.2	1.19
	B 11.3	26.5	0.98
	C 10.9	26.5	1.04
T1	A 28.9	173.4	4.69
	B 31.4	188.1	5.18
	C 27.5	165.0	4.92
Line 2	A 191.9	296.3	12.63
	B 127.1	299.7	10.27
	C 121.9	299.4	10.88
Total Losses	568.0	1501.2	-

4.2.2 LOSS REDUCTION FOR IEEE 4 BUS SYSTEM WITH CAPACITOR PLACEMENT

The table 4.5 shows power losses in IEEE 4 bus at unbalanced load flow analysis of radial distribution system with capacitor placement.

Table 4.5 Unbalanced Load flow Analysis of IEEE 4 Bus system with capacitor placement

ID	Losses		%Vdrop in Vmag
	Kw	Kvar	
Line 1	A 16.9	26.4	1.17
	B 8.7	23.7	0.83
	C 9.9	21.7	0.93
T1	A 27.7	166.4	4.19
	B 28.2	168.9	4.48
	C 23.6	141.5	4.36
Line 2	A 190.4	297.6	12.21
	B 97.7	268.2	8.44
	C 111.2	245.0	9.82
Total Losses	514.4	1359.3	-

4.2.3 LOSS REDUCTION FOR IEEE 4 BUS SYSTEM WITH SOLAR PANEL PLACEMENT

The table 4.6 shows power losses in IEEE 4 bus at unbalanced load flow analysis of radial distribution system with solar panel placement.

Table 4.6 Unbalanced Load flow Analysis of IEEE 4 Bus system with solar panel placement

ID	Losses		%Vdrop in Vmag
	Kw	Kvar	
Line 1	A 14.3	22.3	1.08
	B 7.2	19.9	0.76
	C 8.4	18.0	0.86
T1	A 23.3	140.1	3.93
	B 23.6	141.7	4.18
	C 19.7	118.1	4.07
Line 2	A 160.5	251.5	11.42
	B 80.8	224.7	7.85
	C 93.7	204.1	9.18
Total Losses	431.6	1140.2	-

5. CONCLUSION

In these paper three different steps has been presented for the analysis of the feeder. First, the proposed of an IEEE 4 Node test system for testing and evaluating of three phase delta grounded wye transformer connection. Second, implement the Real and Reactive power loss reduction using capacitor and solar panel. Thus, the proposed system for total loss reduction is tested on IEEE 4 Node test system and the results obtained by ETAP Software.

6. FUTURE SCOPE

This paper can be further extended to various ways to improve the performance of distribution system,

- To implement the loss reduction in higher order system.
- To allocated the other FACTS devices and observe the improvement of the system response.
- To include the various objective functions such as security, transient stability, and operational cost minimization to be achieved.

REFERENCES

[1] Leandro Ramos de Araujo, Debora Rosana Ribeiro Penido, Sandoval Carneiro (2018), “optimal unbalanced capacitor placement in distribution systems for voltage control and energy loss minimization”, International Journal of Electrical Power and Energy Systems 154:110-121.

[2] Dnyaneshvar Y. Watpade, P.M. Sonwane(2016), “Optimal Capacitor Placement for IEEE 14 bus system using Genetic Algorithm", International Journal of Innovative Research in Advanced Engineering, issue 09,Vol.3,239-2763.

[3] Prashanta Sarkar, Soumesh Chatterjee, Saheli Ray (2013),“Optimal Placement of Capacitor for Voltage Support and Minimizing Overall Cost in Radial Distribution System", International Journal of Computer Applications, Vol.65, no.2, 0975-8887.

[4] Pravin Chopade and Dr.Marwan Bikdash (2011), “Minimizing Cost and Power loss by Optimal Placement of Capacitor using ETAP”, IEEE Power and Energy Society General Meeting 978:4244-9593.

[5] Manoj Kumawata, Nitin Guptaa, Naveen Jainb, R.C. Bansal (2017), “Optimally Allocation of Distributed Generators in Three-Phase Unbalanced Distribution Network”, International Conference on Applied Energy 142: 749–754.

[6] Ihsan Jabbar Hasan, Chin Kim Gan, Meysam Shamshiri, Mohd Ruddin AbGhani, and Ismadi Bin Bugis(2015), “Optimal Capacitor Allocation in Distribution System using Particle Swarm Optimization”, Journal of Applied Mechanics and Materials, Vol. 699 ,pp 770-775.

[7] Chamana M, Chowdhury BH, Jahanbakhsh F (2017), “Distributed control of voltage regulating devices in the presence of high PV penetration to mitigate ramp rate issues”, IEEE Transaction Smart Grid 99:1-1.

[8] Murphy KM, Nair NKC.(2016), “ Voltage control in distribution networks with penetration of solar PV: estimated voltages as a control input”,IEEE Power and Energy Society General Meeting (PESGM), 1-5.

[9] Araujo LR, Penido DRR, Carneiro S, Pereira JLR (2015) “A three-phase optimal power flow algorithm to mitigate voltage unbalance”, IEEE Transaction Power Delivery 28:2394–402.

[10] J.Cabral Leite, I. Perez Abril, M.S.Santhos Azevedo (2017), “Capacitor and passive filter placement in distribution systems by non dominated sorting genetic algorithm-II”, International Journal of Electrical Power System Research 143:482-489.

[11] N.Mohandas,R.Balamurugan,L.Lakshmi narasimman (2015),“Optimal location and sizing of real power DG units to improve the voltage stability in the distribution system using ABC algorithm united with chaos”, International Journal of Electrical Power and Energy Systems, vol.60: 4.

[12] Kumara swamy, B. Venkata Prasanth, S.Tarakalyani (2014), “Role of Distributed Generation in Voltage Stability Enhancement”, International Journal of Current Engineering and Technology 66:41–52.

[13] S.Nojavan, M.Jalali, K.Zare (2014), “optimal allocation of capacitors in radial/mesh distribution systems using mixed integer nonlinear programming approach”, International Journal of Electrical Power Systems Research 107:119-124.

[14] A.R.Abdul Wafa (2013), “optimal capacitor allocation in radial distribution systems for loss reduction: a two stage method”, International Journal of Electrical Power Systems Research 95:168-174.

[15] Kalyuzhny, G. Levitin, D. Elmakis, H. Ben-Haim(2000), “System approach to shunt capacitor allocation in radial distribution systems”,International Journal of Electric Power System Research 56:51-60.