# Loss Minimization by Optimal Capacitor Placement in Distribution System Using ETAP Software

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***Abstract:*** **Electrical power system provides a essential service to the people. For well operation of electrical power generation, transmission and distribution, it is essential that system should be balanced. Power flow analysis stands out as the organization of power system initial investigate as well as design. They are really essential for planning, operation, economic development and interchange of power among utilities. In this paper power flow study of 132/33kV substation using ETAP is carried out to overcome the low power factor and under voltage problem. There can be the improvement in power factor when applying the capacitor bank of 12 Mvar. The existing substation can be applied with a capacitor bank to improve the power factor about 6-9% and there can also be voltage improvement with the reduction in current.**

***Key Words:*** **Reactive power compensation, Load flow Analysis, Voltage Sensitive Load, Power Constant ETAP, Voltage Intensification, Power factor improvement, Reactive Power compensation**

## I- INTRODUCTION

### 1.1 Electrical Power System

In the study of power systems power flow study has the vital importance. Power flow study deals with the study of different quantities of the power systems such as real power, reactive power, and magnitude of voltage and angle of voltage. Load flow study is done on a power system to make sure that generation supplies load and losses. From load flow study, we can make sure that bus voltage should be near to the rated values and the generation operates within real and reactive power limits. We can insure that transmission lines and transformers are not overloaded.

A secondary substation may further have its primary and secondary distribution systems as the area under any secondary substation may be large. The primary distribution system has main feeders and laterals. The main feeders run from low voltage buses and are main source of supply for sub-feeders or laterals and direct connected distribution transformers. The lateral extends through the load area with connection to distribution transformers.

The distribution transformers may be located in specifically constructed enclosures or might be pole mounted. Here the voltage is further stepped down to 400V and after that the power is received by the secondary distribution systems. A secondary distribution system consists of distributors that are laid along road sides. The connections to regulars are tapped off from these distributors. The main feeders, distributors and laterals consist of either overhead lines or cables or sometimes both. For distribution generally 3 phase, 4 wire circuits are used, where the neutral wire is mandatory so that power can be supplied single phase loads. Usually major part of consumers (residential or commercial) is fed with single phase power supply.

The main difference between a transmission system and distribution system is in the network structure. Transmission system has a loop structure whereas the latter generally, a radial structure [1].

### 1.2 Stations and Substations

Transmission and distribution stations exist at various scales throughout a power system. In general, they represent an interface between different levels or sections of the power system, with the capability to switch or reconfigure the connections among various transmission and distribution lines. On the largest scale, a transmission substation would be the meeting place for different high-voltage transmission circuits.

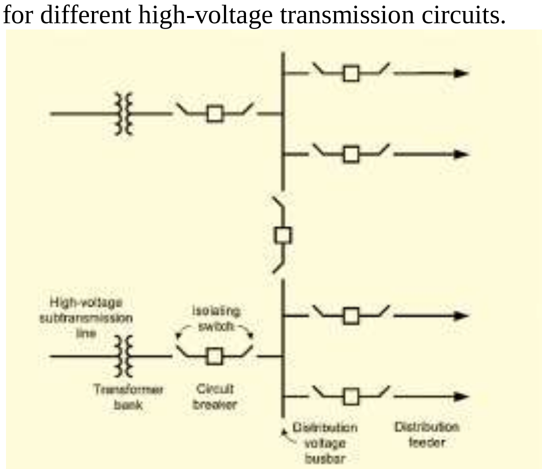


**Figure 1.1 Distribution Substation Layout**

 

**Figure 1.2 Distribution Substation**

### 1.3 Load Flow Analysis

The steady state power and reactive power supplied by a bus in a power network are expressed in terms of nonlinear algebraic equations.

### 1.4 Motivation and problem statement

The power triangle and its components can be best illustrated as shown in Figure 1.3.

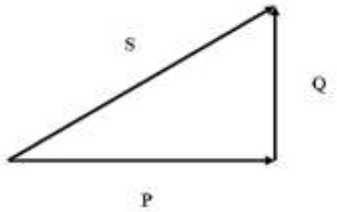


**Figure 1.3 Power Triangles**

The Active power (P), also known as working power, is the energy converted into useful work. Apparent power (S ), on the other hand, is the total energy consumed by a load or delivered by the utility. The power that is not converted into useful work is called reactive power (Q). However, this power is needed in order to generate the magnetic field in inductors, motors, and transformers. Nevertheless**,** it's undesirable because it causes a low power factor. A low power factor means a higher apparent power, which translates into excessively high current flows and inefficient use of electrical power. These currents cause elevated losses in transmission lines, excess voltage drop, and poor voltage regulation.

Power factor is given by the proportion of active power (P) to apparent power (S), as shown in Figure 1.3. The power factor is the proportion of power converted into useful work to the total power consumed by the loads or delivered by the power source. Improving power factor can reduce system and conductor losses, boost voltage levels, and free up capacity.

The most common method for improving power factor is to add capacitors banks to the system. Capacitors are attractive because they're economical and easy to maintain. Not only that, they have no moving parts, unlike some other devices used for the same purpose. A power triangle as shown in Figure 1.2 is used to represent the proportion and calculate the reactive power, using the Pythagorean Theorem as stated in the equation (1.1)

$$S^2 = \sqrt{(P^2 + Q^2)} \qquad \text{……….. (1.1)}$$

### II-RESEARCH OBJECTIVES

There are several objectives that need to be completed at the end of this project.

1. Actual record of three parameters, namely, Bus Voltage, Load on Transformer and Power factor of load with one transformer in service under maximum load condition; With and Without Shunt Capacitor in circuit.
2. To calculate the percentage of power losses reduction of the selected system.
3. Repetition of exercise mentioned in with two transformers in service
4. To configure all the calculation in minimizing the power losses by applying the tools that are provided by ETAP software.
5. To decide if there is need of additional compensation or not, based on results obtained after ETAP simulation and MATLAB Coding of problem.

**Fig 1.3 The substation under study**

### III- LITERATURE REVIEW

Basically, Reactive Power compensation is management of reactive power to improve the performance of ac power systems. Reactive Power compensation revolves round two key issues, namely, system and customer problems, related with power quality issues. Most power quality problems can be resolved with an adequate control of reactive power.

Some of the work has been carried out by different researchers with different but related aims

- ***Analysis of the Load Flow Problem in Power System Planning Studies***, Olukayode A. Afolabi, Warsame H. Ali, Penrose Cofie, John Fuller, Pamela Obiomon, Emmanuel S. Kolawole, Energy and Power Engineering DOI: 10.4236/epe.2015.710048 Oct 09, 2015

 

Load flow is an important tool used by power engineers for planning, to determine the best operation for a power system and exchange of power between utility companies. In order to have an efficient operating power system, it is necessary to determine which method is suitable and efficient for the system's load flow analysis. A power flow analysis method may take a long time and therefore prevent achieving an accurate result to a power flow solution because of continuous changes in power demand and generations.

This paper presents analysis of the load flow problem in power system planning studies. The numerical methods: Gauss-Seidel, Newton-Raphson and Fast Decoupled methods were compared for a power flow analysis solution. Simulation is carried out using MATLAB for test cases of IEEE 9-Bus, IEEE 30-Bus and IEEE 57-Bus system.

The simulation results were compared for number of iteration, computational time, tolerance value and convergence. The compared results show that Newton-Raphson is the most reliable method because it has the least number of iteration and converges faster.

- ***Design Analysis of 220/132 KV Substation Using ETAP*** Kiran Natkar, Naveen Kumar For healthy operation of electrical power generation, transmission and distribution, it is important that system should be balanced. This research paper deals with the simulation of 220/132 kV substation. The analysis is done by using advance software Electrical Transient Analyzer Program (ETAP) with detailed load flow analysis. All the data used for analysis is real time and collected from 220/132 KV substation under M.S.E.T.C.L.

**CASE STUDY**

The system under study is one of the 133kV substations under Madhya Pradesh power Distribution Company Limited. It consists of two power transformers, Circuit breakers, Current transformers, potential transformers, Lightning arresters ,Isolators, Many feeders etc. This substation is a step down as well as distribution substation. There are seven feeders. There are two 40MVA 110/66kV transformers .these transformers are normally operated in parallel. There is a 12MVAr shunt capacitor bank and are used to improve the power factor. All 110kV circuit breakers are SF6 and motor operated. All 66kV circuit breakers are SF6 type out of these three are and pneumatically operated mechanism.

The analysis has been carried out for, before and after adding the required capacitors with its required reactive powers in the specific locations to obtain the best compensation which give the best power factor in spite of the enhancement of the voltage profile with minimum losses in active and reactive power due to the reduction in loads currents. The case study consists of the following steps:

- Obtaining the required measurements.
- Simulate the system with the help of ETAP and analysing it with the help of MATLAB software.
- Obtaining the required Calculation of Energy Saving and power factor enhancements

**Table 5.1 Detail of Components**

| Component | Type | Rating |
|---|---|---|
| Power Transformer | Transformer 1 | 63MVA |
| | Transformer 2 | 63 MVA |
| Feeders | Load 1 | |
| | Load 2 | |
| | Load 3 | |
| | Load 4 | |
| | Load 5 | |
| | Load 6 | |
| | Load 7 | |
| BUS | 132 KV aux. Bus | Single Zebra |
| | 132 KV Main Bus | Twin Zebra |
| | 33 KV Main Bus | Twin Zebra |
| | 33 KV aux. Bus | Single Zebra |
| Capacitor Bank | | 12 MVAR |

***Case 1: Analysis for the September 2015***

The following data has been considered for the study

**Table 5.2 Data for the month of September 2015 (capacitor Bank off condition)**

| Name of Feeder | Real Power (MW) | Reactive Power (MVAR) |
|---|---|---|
| 33 KV incoming 1 | 23 | 8.7 |
| 33 KV incoming 2 | 25.6 | 12.6 |
| 33 KV Load 1 | 14 | 7.2 |
| 33 KV Load 2 | 15.5 | 9.2 |
| 33 KV Load 3 | 13.5 | 7.9 |
| 33 KV Load 4 | 10 | 4.5 |
| 33 KV Load 5 | 14.9 | 5.1 |

 

**Table 5.3 Data for the month of September 2015 (capacitor Bank on condition)**

| Name of Feeder | Real Power (MW) | Reactive Power (MVAR) |
|---|---|---|
| 33 KV incoming 1 | 20.4 | 5.6 |
| 33 KV incoming 2 | 23.4 | 06 |
| 33 KV Load 1 | 12.1 | 5.8 |
| 33 KV Load 2 | 14.0 | 7.9 |
| 33 KV Load 3 | 12.4 | 5.4 |
| 33 KV Load 4 | 8.8 | 4.4 |
| 33 KV Load 5 | 12.2 | 3.9 |

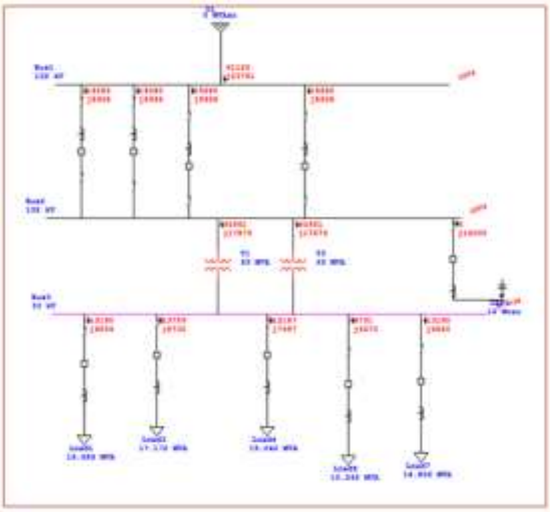

**Figure 5.2 ETAP Simulation for September 2015 (Capacitor Bank off Condition)**

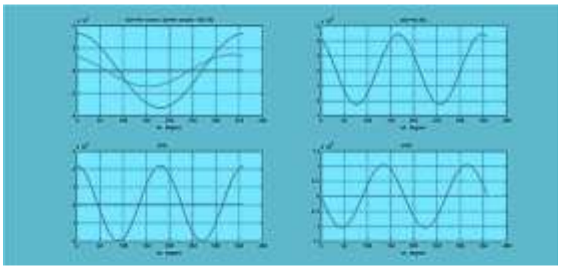

**Figure 5.3 Time traces for various parameters (Capacitor Bank off Condition)**

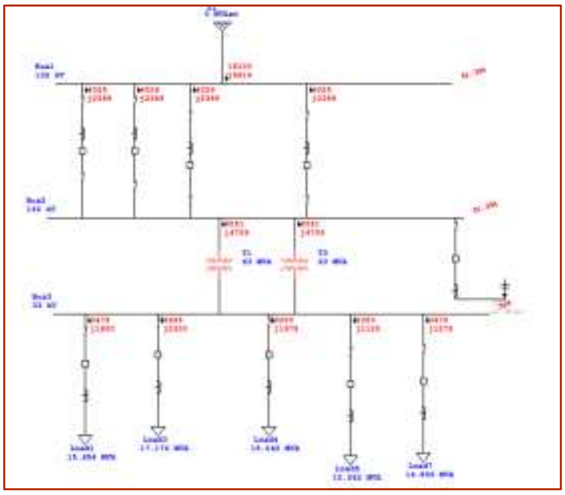

**Figure 5.4ETAP Simulation for September 2015 (Capacitor Bank on Condition)**

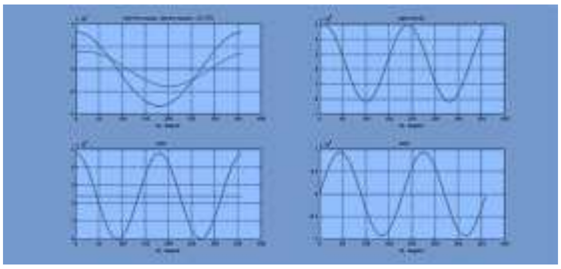

**Figure 5.5Time traces for various parameters (Capacitor Bank on Condition)**

In figure 5.2 the red indicates the abnormal condition in ETAP .Here it is under voltage problem. Table 5.2 and 5.3 shows the power flowing through the system; both real and reactive power in both the condition (i.e. Capacitor Bank is on/off condition).

***Case 2: Analysis for the December 2015***

The following data has been considered for the study

Table 5.4 Data for the month of December 2015 (capacitor Bank off condition)

| Name of Feeder | Real Power (MW) | Reactive Power (MVAR) |
| --- | --- | --- |
| 33 KV incoming 1 | 20.1 | 8.2 |
| 33 KV incoming 2 | 21.3 | 9.59 |
| 33 KV Load1 | 17.2 | 10.9 |
| 33 KV Load2 | 11 | 8.8 |
| 33 KV Load3 | 13.2 | 10.2 |
| 33 KV Load4 | 11.2 | 8.5 |
| 33 KV Load5 | 5.2 | 1.2 |

**Table 6.7 Data for the month of January 2014 (capacitor Bank on condition)**

| Name of Feeder | Real Power (MW) | Reactive Power (MVAR) |
| --- | --- | --- |
| 33 KV incoming 1 | 20.1 | 8.2 |
| 33 KV incoming 2 | 21.3 | 9.59 |
| 33 KV Load1 | 14.8 | 6.5 |
| 33 KV Load2 | 9.6 | 6.4 |
| 33 KV Load3 | 12.6 | 06 |
| 33 KV Load4 | 11.0 | 3.2 |
| 33 KV Load5 | 4.4 | 2.4 |

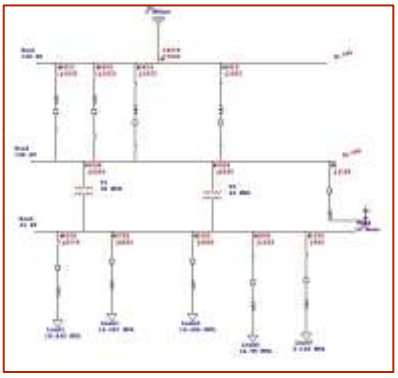

**Figure 5.6ETAP Simulation for December 2015 (Capacitor Bank off Condition)**

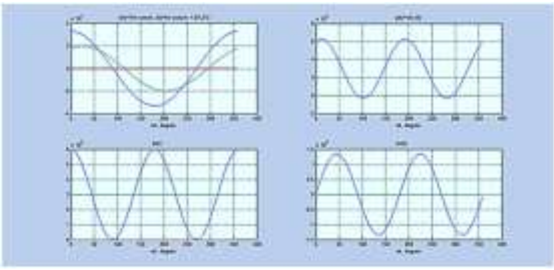

**Figure 5.7 Time traces for various parameters (Capacitor Bank is off)**

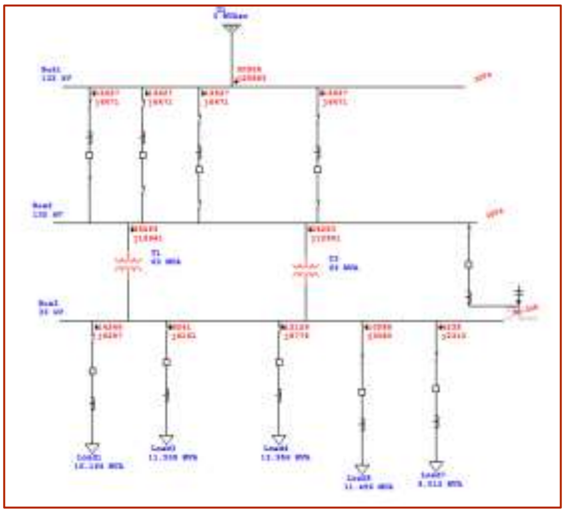

**Figure 5.7ETAP Simulation for December 2015 (Capacitor Bank on Condition)**

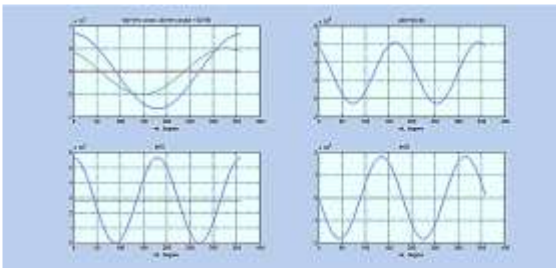

**Figure 5.8 Time traces for various parameters (Capacitor Bank is on)**

In the case of month September 2015 the following analysis has been carried out

- Power factor is improved with the application of capacitor bank from the value of 0.83 to 0.89, which is quite well.
- There is considerable improvement in voltage is also there
- There is also reduction in current.
- The current is leading the voltage at an angle of 24.98° after applying the Capacitor Bank while it was lagging about 31.6°.

While in the case of month December 2015 the following analysis has been carried out

- Power factor is improved with the application of capacitor bank from the value of 0.82 to 0.9, which is quite well.
- There is considerable improvement in voltage is also there (i.e. from 33 KV to 33.3 KV)
- There is also reduction in current.
- The current is leading the voltage at an angle of 25.21° after applying the Capacitor Bank while it was lagging about 33°.

 

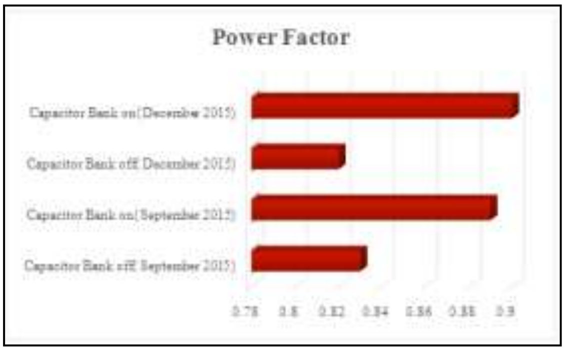


**Figure 5.9 Power factor improvements**

## Conclusion

Software is an outstanding tool for system development. Several operating procedures can be analysed such as the loss of generator, a transmission line, a transformer or a load. Load flow studies can be accustomed govern the optimum size and location of capacitors to overcome the problem of an under voltage and Power factor correction. In this dissertation work power flow study of 132/33kV substation using ETAP is carried out to overcome the low power factor and under voltage problem. There can be the improvement in power factor when applying the capacitor bank of 12 Mvar. The existing substation can be applied with a capacitor bank to improve the power factor about 6-9% and there can also be voltage improvement with the reduction in current.

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