INSTALLATION OF CAPACITOR BANK IN 132/11 KV SUBSTATION FOR PARING DOWN OF LOAD CURRENT

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ABSTRACT

This paper presents an approach for optimal placement of hybrid system consist of capacitor banks and STATCOM in a real power network for the purpose of economic enhancement of voltage and load relief. The optimization problem is solved by the use of MATLAB simulation. As a result, the size and proper location of capacitors and STATCOM are determined. By applying the proposed method, the economic costs and power losses are reduced to a considerable extended while enhancing the voltage profile and decreasing load current. Simulation results are investigated on the substation in Vidarbha region, Maharashtra State, India.

Keyword:– *Load relief, Loss Reduction, Optimization, Capacitor Placement, Economic Cost, and Power Factor.*

1. INTRODUCTION

In Indian power system have 20-40% losses and overloaded 30% where as some country has comparatively less losses. The major reason for this losses is the inductive load, to reduce this losses we need to analyze the proper size and location of capacitors/ FACTS device as per the optimization is concern. The increase in power demand and high load density in the rural areas makes the operation of power system complicated. To meet the load demand, the system is required to expand by increasing the substation capacity and the number of feeders. Capacitors are generally used for reactive power compensation in distributed system. The purpose of capacitor is to minimize the energy losses and to maintain better voltage regulation for load buses and to improve system stability and life. The amount of compensation provide with the capacitor/STATCOM that are place in distributed system depends on the location, size and type of the device placed in the system.

There are many research papers are publish on this topic All the topic are differ and their method are differ to get the results. In some the method they have applied the voltage control method. In some where they have applied only fixed capacitors and load changes which are very vital in capacitor, proper location was not consider.

However, this may not be easily achieved for many utilities due to various constraints. Even though by putting all the efforts many utilities could not achieve the proper result due to some constraint. Therefore, to meet the increase in load demand the substation capacity has to enhance. Due to more losses the life of the equipment is reduces and the effect of this there are more chanced of failure of equipements and ultimately more number of supply failure occurrences in power system.

It is observed that about 13% of power losses in the distribution. [1] To minimize these losses, shunt capacitor banks are installed on distribution network. To get the more benefits by installation of shunt Capacitors banks we will get

1) Improvement in the power factor.
2) Improvement in the voltage profile
3) Reduction in Power loss reduction
4) Increase in available capacity of feeders.

Therefore it is necessary to improve distribution network by proper placing of adequate capacity **of capacitors** in the distribution network. In this paper we have studied instead of putting only large sizes of capacitor banks in addition to this STATCOM is also provide. We get better results than the previous results. (Small size of capacitor banks and STATOCM)

J.V. Shill [2] developed a basic theory y of optimal capacitor placement. He presented his well-known 2/3 rule for the placement of one capacitor assuming a uniform load and a uniform distribution feeder. H. Duran *et al* [3] considered the capacitor sizes as discrete variables and employed dynamic programming to solve the problem. Grainger and Lee [4] developed a nonlinear programming based method in which capacitor location and capacity were expressed as continuous variables. Grainger *et al* [5] formulated the capacitor placement and voltage regulators problem and proposed decoupled solution methodology for general distribution system.

2. CAPACITOR BANK

In order to provide more reactive power installation of capacitor banks close to the load center and middle of the transmission line. In transmission network the most common method in practice today for improving power factor (correct to near unity) is the installation of capacitor banks. Capacitor banks are very economical and generally trouble free. Installing capacitors will decrease the magnitude of reactive power supplied to the inductive loads by the utility distribution system thereby improving the power factor of the electrical system. Capacitors are rated in “VARs”, which indicates how much reactive power is supplied by the capacitor. While dealing with a large distribution network of many feeders, it is very difficult to decide the size and locations of shunt capacitors becomes an optimization problem. The placement of the capacitor bank should be such that, it minimizes the reactive power drawn from the load system. Neale and Samson (1956) developed a capacitor placement approach for uniformly distributed lines and showed that the optimal capacitor location is the point on the circuit where the reactive power flow equals half of the capacitor VAR rating. From this, they developed the 2/3 rule for selecting capacitor size and placement to optimally reduce losses. For a uniformly distributed load, the bank Kaur size should be two-thirds of the KVAR as measured at the substation, and the bank should be located two-thirds the length of the feeder from the substation. For this optimal placement of a uniformly distributed load, the substation source provides reactive energy for the first 1/3 of the circuit, and the capacitor provides reactive energy for the last 2/3 of the circuit. [8]

All the techniques for the placement of capacitor banks are not much effective in practical case. And hence for proper management of the reactive power, is more significant. In a power system, distributor and the consumers, both work together for providing the reactive power compensation. The power utilities have to provide reactive compensation for the transmission system’s which reduces the line losses and improves voltage regulation. Whereas the consumers have to compensate for the additional reactive power requirement by the loads at their installations. The power providers have taken a number of steps for installation of reactive power compensation equipment. These include –

- 33 kV series compensation equipment.
- 220 kV series compensation equipment
- Synchronous condensers.
- 33 kV shunt capacitors.
- 11 kV and LT shunt capacitors.
- Static VAR compensation equipment.

Based on the reactive power requirement at their installations, the consumers have to provide for the necessary reactive compensation at their end to achieve the minimum power factor level prescribed by the utility.

The most economical and reliable method of reactive compensation is the installation of power capacitors. Lagging power factor can be corrected by connecting capacitors in shunt with the system. The current in a capacitor produces a leading power factor. Current flows in the opposite direction to that of the inductive device. When the two circuits are combined, the effect of capacitance tends to cancel that of the inductance. Most customer loads (particularly motors, but many lighting circuits also) are inductive. A low power factor can generally be corrected by connecting appropriate capacitors. This is not the case if low power factor is caused by harmonics, in which, in case the installation of capacitors will not help, and may cause a serious problem. In high harmonic situations, expert help should be obtained before attempting to correct power factor problems.

3. STATCOM

The D-STATCOM employs an inverter to convert the DC link voltage V_{dc} on the capacitor to a voltage source of adjustable magnitude and phase. D-STATCOM can be treated as a voltage controlled and current controlled source. The capacitor of D-STATCOM is needed to store the DC energy and is used to inject reactive power to the D-STACOM.

The D-STATCOM is connected in shunt with 11KV system and as shown in Fig. 1.5 the Capacitor is replaced by D-STATCOM and Fig 1.6 shows the simulation result.

The classical active and reactive power is given by an expression

$$P = \frac{|vi||Vs|}{Xe} Sin\sigma is - - - - - - - - - (1)$$

$$Q = \frac{|Vi|^2}{Xe} - \frac{|Vi||Vs|}{Xe} \cos \sigma is - - - - - - - (2)$$

Where Xe is equivalent reactance of coupling transformer.

The reactive power exchange between the STATCOM and AC power system is controlled by adjusting the voltage magnitude difference across the coupling transformer. STATCOM neither inject nor absorbed active and reactive power from system when |Vi|-|Vs|=0 and σ_{is} =0=0. STATCOM inject reactive power when |Vi|>|Vs| and STATCOM absorbs reactive power when |Vi|<|Vs|

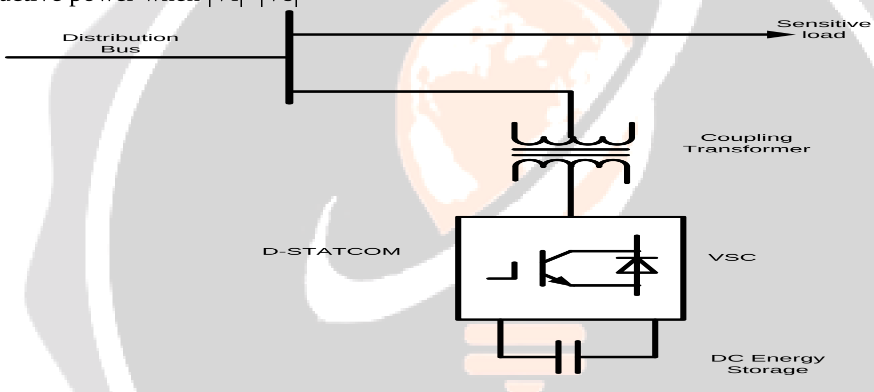

Fig 1.1 Case study with STATCOM

For the simulation purpose the actual data for Kampti rural substation is taken. The 33 KV is incoming feeder from Pardi substation. The number of power transformer are connected in substation are 2 no's. In which one is keep as standby incomer feeder. The simulation is done using the MATLAB 2009R shown in fig. 1.2

The simulation is done on the 33/11 KV substation by actual inserting the capacitor banks in the feeder at different location by changing the value of capacitor and changing the location of capacitor on transmission line. The KVA rating and the load on the feeder are as follows

a) Load on Feeder 1and 2:- Apparent power 5.385 MW

b) Length of Feeders: 50 KM

The scope result without capacitor bank is shown in fig. 1.3. Voltage P.U is 0.915 and current is at 520 amp.

substaion

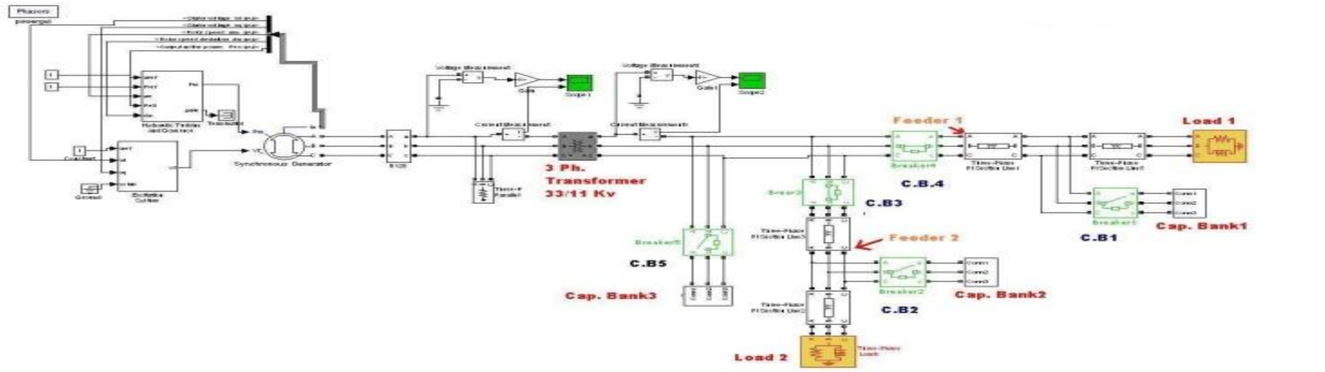

Fig.1.2 Simulation of kampti rural substation

The current and voltage in P.U. is measured by keeping the C.B (Circuit Breaker) open which is shown in Fig. 1.2. As per table No 1.1 [8]

Feeder 1	Feeder 2
50 km	50 km

Load 1		Load 2	
Active Power	Reactive Power	Active Power	Reactive Power
5.0 e6	2.0 e6	5.0 e6	2.5 e6

Cap. Bank 1	Cap. Bank 2	ap. Bank
(0.05e6)*3	(0.05e6)*3	(0.05e6)*3

Table 1.1

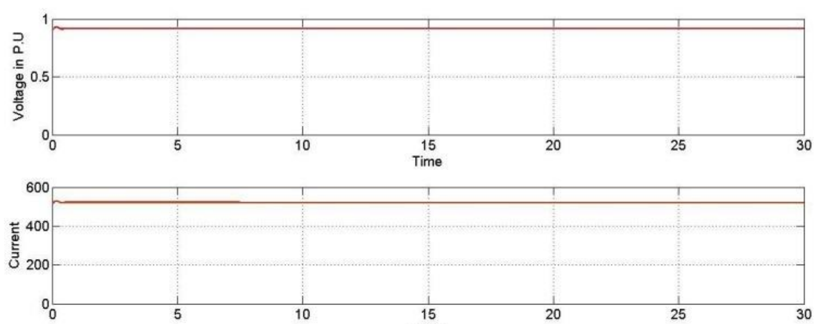

Fig 1.3 Scope 2 result with capacitor bank

After insertion of capacitor banks in either first or second feeder at location 1 km from power transformer. There is a load relief of 120 amps. Fig. 1.4 shows the scope2 result at location of capacitor banks.

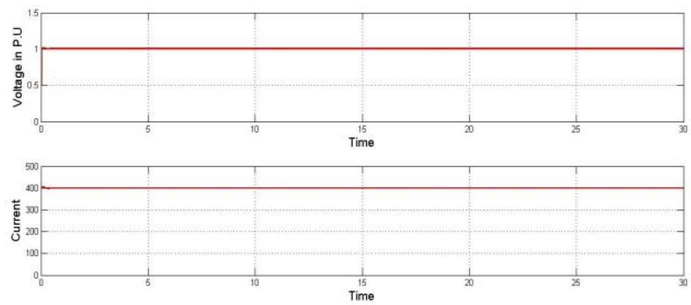

Fig 1.4 Scope 2 result with capacitor banks

4 .How capacitor bank improves the power factor

Induction motors, transformers and many other electric loads require magnetizing current (kVAR) as well as actual power (kW). By representing these components of apparent power (KVA) as the side of a right triangle shown in fig.1.5, we can determine the apparent power from the right triangle rule: $\mathbf{kVA^2 = kW^2 + kVAR^2}$. To reduce the KVA required for any given load, we must shorten the line that represents the kVAR. By supplying the kVAR right at the load, the capacitor relieves the utility of the burden of carrying the extra kVAR. This makes the distribution system more efficient, reducing cost for the utility. The ratio of actual power to apparent power is expressed in percentage and is called power factor.

$$P.F = \frac{KW}{KVA} \quad \text{----------- (3)}$$

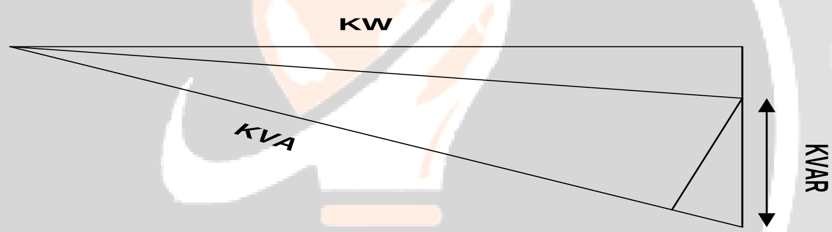

Fig. 1.5

For analysis purpose capacitor banks which are connected at substation is now replace with D-STATCOM. The simulation diagram is shown in fig.1.5

Case study with STATCOM

STATCOM has wide range of features. Distribution STATCOM exhibits high speed control of reactive power to provide voltage stabilization, flicker suppression and other type of system control. Fig 1.6 shows the simulation diagram with STATCOM.

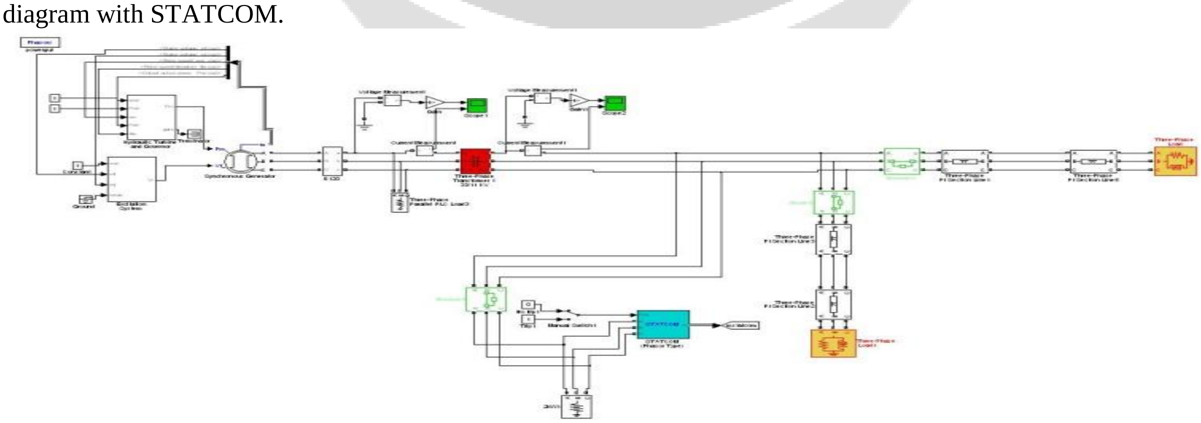

Fig 1.6 Simulation with STATCOM

The total capacity of STATCOM is of 10MVAR and due to which the load current is reduce to 136 AMP (about 2.7 MW load relief) and there is significantly improvement in power factor and voltage. In Summer days the load burden on the transformer increases, due to which voltage profile goes to below unity margin i.e. 0.98 or below. The table shows the total load on feeders. The simulation is done on the increased load and capacitors required for providing the reactive compensation.

The scope result shows the improved voltage and current profile using STATCOM

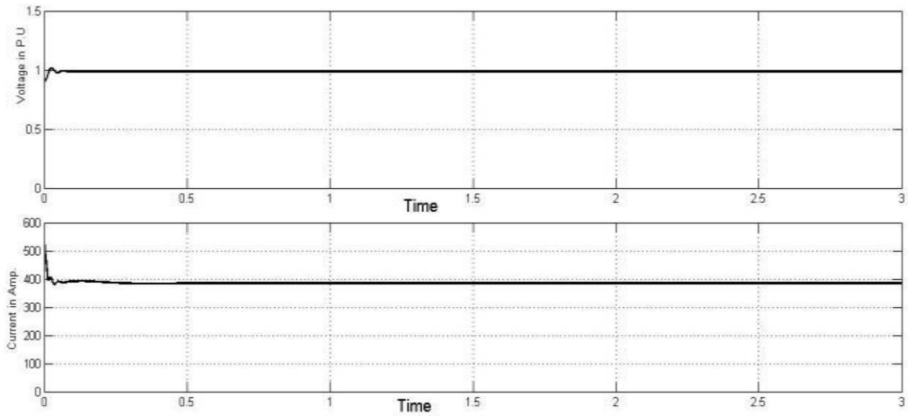

Fig. 1.7 Scope result with D-STATCOM

It has been observed that with replacing Capacitor bank with D-STATOCM the total load relief increased from 118 amp to 136 amp of current. The voltage profile meet to 0.97 P.U. (1P.U. =11kv). D-STATCOM is connected to load side to inject controlled reactive power. The result of scope by STATCOM. The application of STATCOM or Capacitor banks reduces the installation cost of higher KVA rating transformers and by reducing the loading it reduces the line losses (I^2R). Due to which the life of cables get increases. Loading of the line can also increases to considerable level on the same rating of transformers and switchgears. Replacing the capacitor by STATCOM is shown in fig.1.7.

The load on the feeder is not always constant through the year and it varies to season to season. In summer season load is increased very high.

The simulation is done by loading the system by 50% more. Load on distribution transformer is increased by addition of feeder and load on each feeder is increased. The table 1.2 shows various loading condition on distribution transformer.

Feeder 1	Feeder 2	Feeder 3
50 km	50 km	50 km

Load 1		Load 2	
Active Power	Reactive Power	Active Power	Reactive Power
5.0 e6	2.0 e6	5.0 e6	2.0 e6

Load 3	
Active Power	Reactive Power
5.0 e6	2.0 e6

Table 1.2

The simulation on matlab is done on overload condition

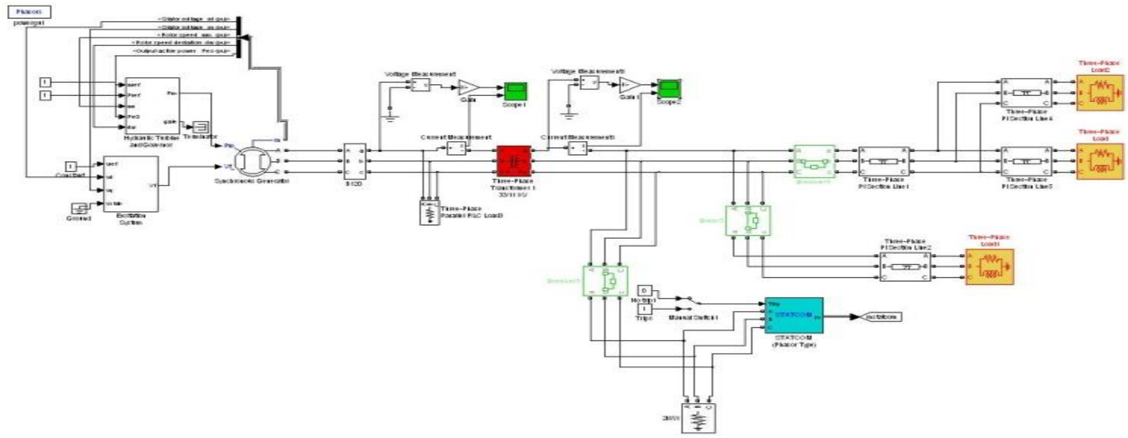

Fig 1.7 with overload condition using STATCOM

The total apparent power load in MW on each feeder is 5.385 (as shown in fig no. 1.7 three feeder are taken)

1) Load on feeder1 5.385MW
2) Load on Feeder2 is 5.385MW
3) Load on feeder3 is 5.358MW.

A) The total load of three feeders is 16.155 MW.

B) Capacity of Distribution transformer is 10 MVA.

C) System is overloaded about 50% more than its capacity. D) The 5 Mvar STATCOM capacity is introduced in network system for the overload condition then voltage profile goes significantly low to 0.95 P.U. (as shown in Fig 1.8)

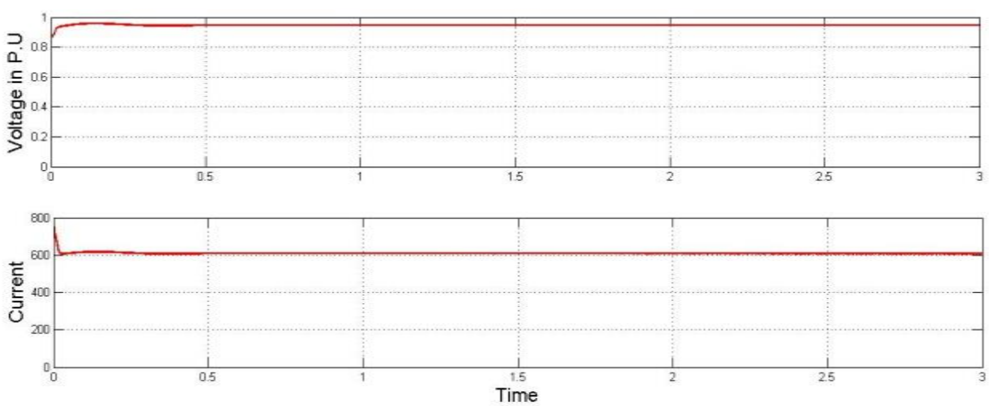

Fig. 1.8 result with 5 Mvar STATCOM

In order to increase the voltage level up to1 P.U. 20 Mvar capacity of STATCOM is required. (Fig. 1.9 shows the result of scope with 20 Mvar STATCOM)

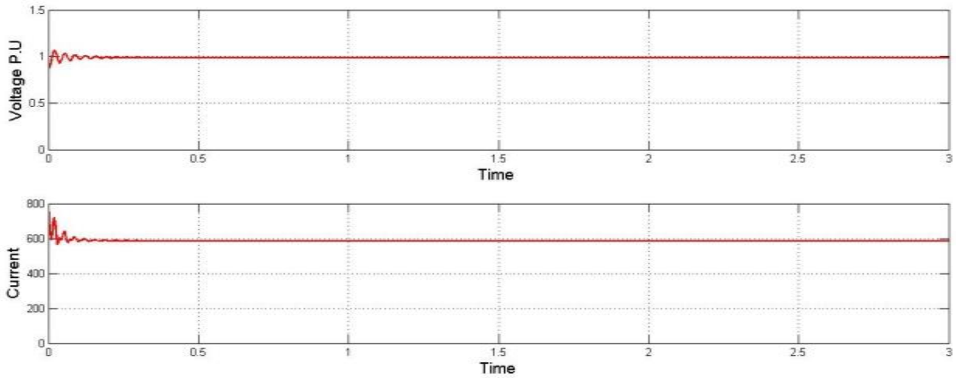

Fig. 1.9 Result with 20 Mvar STATCOM

Due to high range of STATCOM (20 Mvar) it is observed that at the initial stage there is transient in voltage and in current profile. Also the cost of 20 Mvar STATCOM will much more which will not be economical from point of payback period. These are the main disadvantages.

In order to reduce the cost and capacity of STATCOM, a small value of shunt capacitor can be connected. Such system will call as hybrid system.

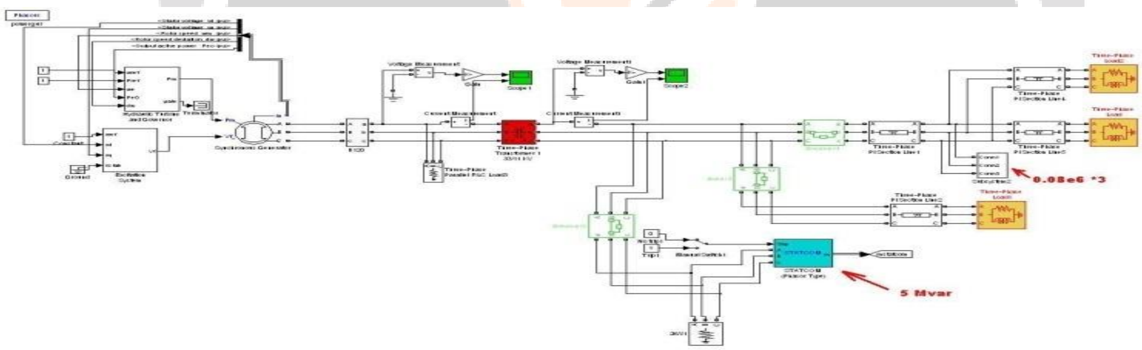

Fig. 2.0 Hybrid model of STATCOM and capacitor bank

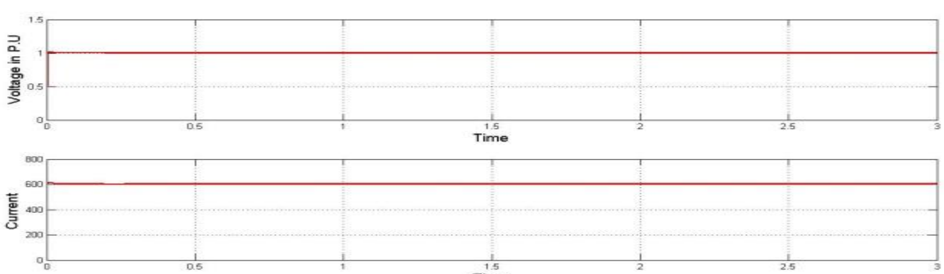

Fig. 2.1 Result of Hybrid System

5. Conclusion:

From these studies it is observed that by using only large size of shunt capacitors and STATCOM, the results are
a) Voltage level is not improved up to the satisfactory level i.e. 1P.U
b) Similarly the loading on the system is not reduced up to the makeable limit on the distribution system due to which additional substation capacity has to increase.
c) The reliability of the system is not so improved, due to which the energy losses is not reduce up to the satisfactory level. It is not so economical system.

But by introducing the small size of capacitors and STATCOM (Hybrid system), we get the better results of voltage level and improved in capacity of system.

Hence it is more cost beneficial than previous method.

6. REFERENCES

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