

# Transient Free TBSC Compensator Mechanism for Dynamic Reactive Load and Voltage Sag Mitigation

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**ABSTRACT:** It is very much archived in writing and through open exchanges at different levels that a significant force misfortune is occurring in our low voltage dissemination frameworks because of poor influence component, because of deficient receptive influence remuneration offices and their uncalled for control. Exchanged LT capacitors can straightforwardly supply the responsive force of burdens and enhance the working condition. Administration of India has been demanding shunt capacitor establishments in enormous way and empowering the state power sheets through Rural Electrification Corporation and different other financing bodies. The development of rustic force dispersion frameworks with new associations and taking into account agrarian division in across the board remote territories, offering ascend to more inductive burdens bringing about low power elements [1]. The voltages at the remote closures are low and the rancher's utilization high HP engines working at low load levels with low efficiencies. This is offering ascend to expansive misfortunes in the circulation system. Consequently there exists an awesome need to nearly coordinate receptive force with the heap in order to enhance power element, support the voltage and diminish the misfortunes. The routine strategies for responsive force supply are through exchanged LT capacitors, for the most part in equivalent strides in different programmed power element controllers created by number of organizations. In this paper, a more solid, in fact sound, quick acting and minimal effort plan is displayed by organizing the thyristor exchanged capacitor units in five twofold consecutive strides. This empowers the responsive force variety with the slightest conceivable determination.

**KEYWORDS:** TBSC, transient free switching, binary current generation, switching strategies and thyristors.

## I. INTRODUCTION

As there is decrease in misfortune with shunt pay in the feeders, the proficiency increments and preservation of vitality happens. Other than the upgrade transformer stacking ability the shunt capacitor likewise enhances the feeder execution, decreases voltage drop in the feeder and transformer, better voltage at burden end, enhances power component, enhances framework security with improved use of transformer limit, gives scope for extra stacking, increments over all productivity, spares vitality because of lessened framework misfortunes, keeps away from low influence variable punishment, and diminishes greatest interest charges. Force is the life stream of advancement for any country. Power frameworks have developed a long ways in every one of the nations especially amid the most recent four decades. Because of the settled specialized points of interest and monetary contemplations, power frameworks are interconnected which makes then to some degree convoluted in real operation and control. The central goals of any supply endeavors are: to keep up progression of supply with consistent recurrence and relentless voltages of unadulterated sinusoidal waveforms at different hubs, to decrease the general expense of era and ration accessible assets, and to make the framework exceedingly secure and solid. The essential issue is to deliver both genuine and responsive powers most financially at proper areas for every one of the interims of time and consistently coordinate with the framework necessities. All the while, number of managing measures must be taken, to keep the alluring

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voltage profile in the framework, to lessen the responsive force streams in the lines and to minimize the system misfortunes. Voltage control and receptive force pay have remained the most captivating issues in force framework designing. Force is dispersed through outspread feeders, reaching out over broad ranges. The LT shoppers are of both 3- $\emptyset$  and 1- $\emptyset$ . The purchaser end voltages are poor, the P.F. are especially slacking and system misfortunes are high. By virtue of these reasons, parcel of consideration is paid to reduce these issues in the appropriation part. Thus it has gotten to be important to give more accentuation on the appropriation frameworks for keeping up great voltage at remote finishes, minimize misfortunes, enhance the influence elements and monitor the vitality. Henceforth to begin with the issues connected with run of the mill spiral feeders are presented in the following segment. The essential dissemination framework chart for regular feeders at a substation. It comprises of three conveyance transformers offering associations with different customers through a typical transport bar course of action with transport couplers, in order to build the unwavering quality of administration and adaptability in operations. Most generally, the buyers are across the board and the utility gives association both for single stage and three stage loads. The electrical equal chart of a regular 3 $\emptyset$  feeder on single stage proportional. For short line beneath 50 km, line charging capacitance is disregarded. For effortlessness, it is customary practice to speak to stack as steady power.

## II. LITERATURE SURVEY

Power utilities and their clients are regularly fretted about three noteworthy issues that incorporate expanded force cost, decreased framework limit and weakened force quality. The dispersion framework is ceaselessly subjected to changes in burden will bring about comparing deviations in voltage at the heap transport or the PCC. The heaps, for example, tedious welding operations, pulling forces, lifts, lifts and so on will likewise come about dunks in rms voltage. Additionally there are different loads, for example, curve heaters which draw a noteworthy segment of responsive force. For such loads the overwhelming receptive current required results in noteworthy voltage drop in the line impedance. Our center of exploration in the theory work is on a specific FACTS gadget – the versatile static VAR compensator. The SVC is irreplaceable and in light of demonstrated innovation for force variable remedy and responsive force pay. Customarily SVC has been utilized as a shunt gadget that offers voltage soundness and responsive force pay to the heap or at PCC. Since EPRI's (Electric Power Research Institute) arrival of FACTS procedures in 1987 SVC's have developed in ubiquity and are entrenched in force industry [11]. The SVC is viewed as the first in the arrangement of FACTS gadgets. The Basin Electric Power Corporation introduced the principal SVC in Nebraska in 1977 [12, 13]. The least complex arrangement for a propelled shunt compensator basically comprises of the thyristor exchanged capacitor manage an account with every capacitor step associated with the framework through a thyristor switch. The capacitor bank step qualities are picked in double arrangement weights to make the determination little. On the off chance that such n capacitor steps are utilized then 2n distinctive pay levels can be given because of those numerous potential outcomes. Ensure that static compensator steps are exchanged at fitting times with the goal that homeless people are minimized not permitted happening. For both capacitors and inductor, the proper exchanging moments happen at the zero intersection of both current and voltage waves. In the standard setup of TSC, a damping reactor is incorporated to restrict the di/dt on changing and to soggy the exchanging homeless people that take after. The main condition can be met precisely by timing the control hardware and the second condition is just met instantly subsequent to exchanging off thyristor. The arrangement for five capacitor bank ventures in parallel grouping weight with thyristors switch and inrush current constraining reactors. Capacitors have a most extreme hypothetical exchanging in postponement of one cycle, expecting that the capacitor is pre-charged to the wrong extremity. The capacitor can be changed out down the middle cycle. Capacitors are exchanged totally in or out of the circuit as and when required. There are two control techniques for SVC's which are talked about in [12]. The principal procedure is food forward control, which over and again comprehends the model conditions to decide the quantity of capacitor ventures in the bank required. The second system, criticism control is valuable for shut circle control when minimization of mistake sign in the contrast between characterized kVAr and genuine kVAr. Any adjustment in the blunder sign will bring about an adjustment in susceptance of compensator. Due to shut circle operation, mistake flag dependably tracks to zero quality. It is a constant adaption of blunder sign towards zero [15]. A spearheading work in the Error Adaptive Power Factor Controller [EAPFC] was finished by M. El. Sharkawi [16, 17]. These EAPFC's don't make utilization of an inductor branch as in SVC's however commitments to compelling capacitor exchanging strategies are striking. The versatile VAR remuneration innovation was created at the University of Washington with

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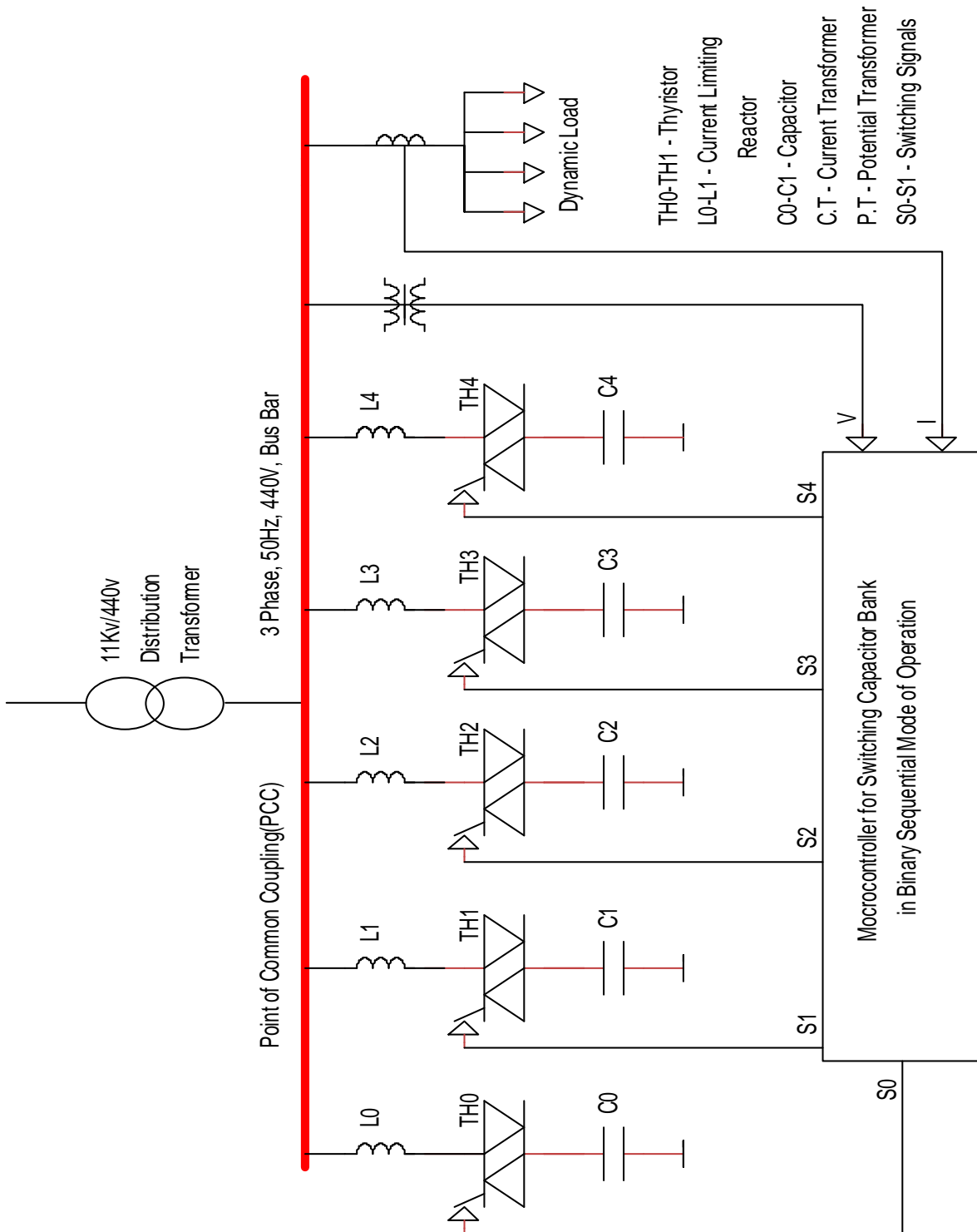
sponsorship of Bonneville Power Administration (BPA) and Southern California Edison (SCE). The undertaking was begun in 1980 and finished in 1993. In this manner identified with this work number of papers were distributed [18]. The significant work was conveyed in the outline, advancement and usage of 15 kV class of versatile VAR compensator. The Adaptive Var Compensator (AVC), was strong state exchanged, paired ventured capacitor bank, used to remunerate any quickly changing receptive interest inside one half cycle without presenting homeless people or music [19]. The control technique gave in this anticipate depends on receptive force detecting and giving the pay required consequently. It is conceivable to keep up the voltages inside a wanted estimation of minimum resistance band. The control methodology depends on real responsive force required by burden to keep up the sought force variable. Hence voltage sign is not utilized. In the light of the considerable number of improvements that have been accounted for in the later past, the alluring components for the controller to be produced are recorded beneath which frames the fundamental topic of Thesis work under taken. Any of the modes can be actualized at once and can be controlled by determined time planning [19]. The potential uses of AVC are at burden end or at framework level remuneration. The heap end application incorporates those requiring quick remuneration, for example, lumber factories, rock pounding plants, steel factories, lifts, circular segment heaters, pumps, electric railroads. The conveyance framework application incorporates receptive VAR remuneration, upgrade of voltage direction, avoidance of voltage breakdown, discharged framework limit, decrease in line misfortunes and expansion in productivity. The inventive and helpful outline of the AVC has brought about commercialization of the gadget and reported in three US licenses. All the above alluded controllers don't have any reactor part accordingly. To keep up the force variable at solidarity, twofold stages required are high to lessen the determination.

### III. SCOPE AND OBJECTIVES

The purpose of this work is to present a new topology for a var compensator, which eliminates the problems already mentioned. This topology has the following distinctive characteristics [7, 8]

1. It maintains the power factor at the PCC to any specified value.
2. It compensates for rapid variation in reactive power or voltages.
3. Maximum compensation time is 20 msec.
4. No transients or harmonics are allowed to be present due to fast selective instants of switching in well co-ordinate manner.
5. It is adaptive in the sense that the amount of the compensation is determined and provided on a cycle by cycle basis.
6. It can compensate each phase independently which makes ideal for unbalanced systems.
7. Capacitors are sized in binary sequential ratio for minimum size of switching steps.
8. The control strategy is error activated to match with the load reactive power for the chosen time interval.
9. It eliminates possible over compensation and resulting leading power factor.
10. It is flexible to choose required number of steps as per the resolution.
11. Resolution can be made small with more number of steps.
12. Simple in principle, elegant in usage and of low cost.
13. Possible to incorporate the idea presented in the controllers for large size transformers at substations.

**IV. PROPOSED SYSTEM DESIGN**



**Fig 1 Block Diagram of Proposed Work**

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Capacitor is the most indispensable static device in a power system. It can be connected either in series form or shunt form for power frequency applications. Below 650 volts the capacitors are categorized as LT and above 650 volt as HT. It is possible to design and manufacture capacitor units of standard sizes and banks can be formed with series parallel combinations of units for the required capacities. Capacitors are relatively cheap; no foundations are required for installations, most efficient due to very low losses (0.3 to 1.5% of the rating), least maintenance and incur low annual charges. Their limitations are: incapable of providing step less variation in Q, the reactive power is proportional to the square of mains supply voltage, associated with switching transients and resonance problems.

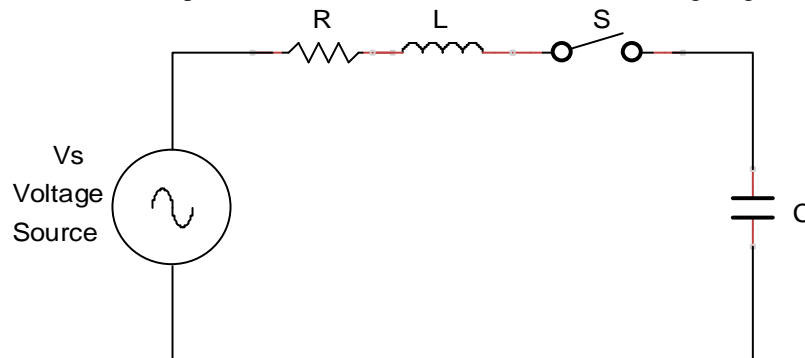
Since 1940's the voltage stress has increased from 18 volts per micron to 70 volts per micron, loss got reduced from 0.5 % to 0.01%, the size of individual unit from a few KVAR up to 600 KVAR, voltage few volts to 11 KV and the volume got reduced from 600 cm<sup>3</sup> per KVAR to about 100 cm<sup>3</sup> per KVAR. These figures are indicative of technological advancement in the manufacture of capacitor units for both LT and HT applications. The LT capacitors are manufactured with metalized poly-propylene (MPP) in either three phase single units or single phase units. The capacitors are designed and built for delta connection in LT applications. On the other hand they are connected in star for HT applications. HT capacitors are manufactured making use of bi-axially oriented poly-propylene (BOPP) of small sizes. They are connected in series-parallel combinations forming banks to suit the voltage and KVAR requirements.

A capacitor subjected to switching operations is invariably associated with the transient phenomenon. The voltage across a capacitor cannot be changed abruptly and when switched on at  $t = 0^+$  it acts like a short circuit. In their application as a shunt compensator, they are provided with current limiting reactors. However, in LT applications the problem is not that severe. A shunt capacitor connected across a load injects reactive power and directly compensates the load reactive power. Shunt capacitors are widely employed in both LT and HT systems, on account of their attractive features. Numbers of advances have taken place in the design and manufacture of both LT and HT capacitors. Once they are installed in a system, they are long lasting, give trouble free service and highly reliable if they are provided with requisite protection. A capacitor bank can be formed with capacitors in steps, more number of steps gives reduced resolution but the cost of switch gear will increase in order to get a continuously variable reactive power. The LT capacitors employed for experimental set up are of the following rating:

**Table 1 Capacitor bank value:**

Capacitor Bank	VAr Value	Microfarad Value
C0	100	10 $\mu$ f
C1	200	20 $\mu$ f
C2	400	40 $\mu$ f

A capacitor bank when energized or d-energized by switching on or off, it is subjected to both voltage and current transients. In order to understand this phenomenon consider the electrical circuit energizing an isolated capacitor bank.



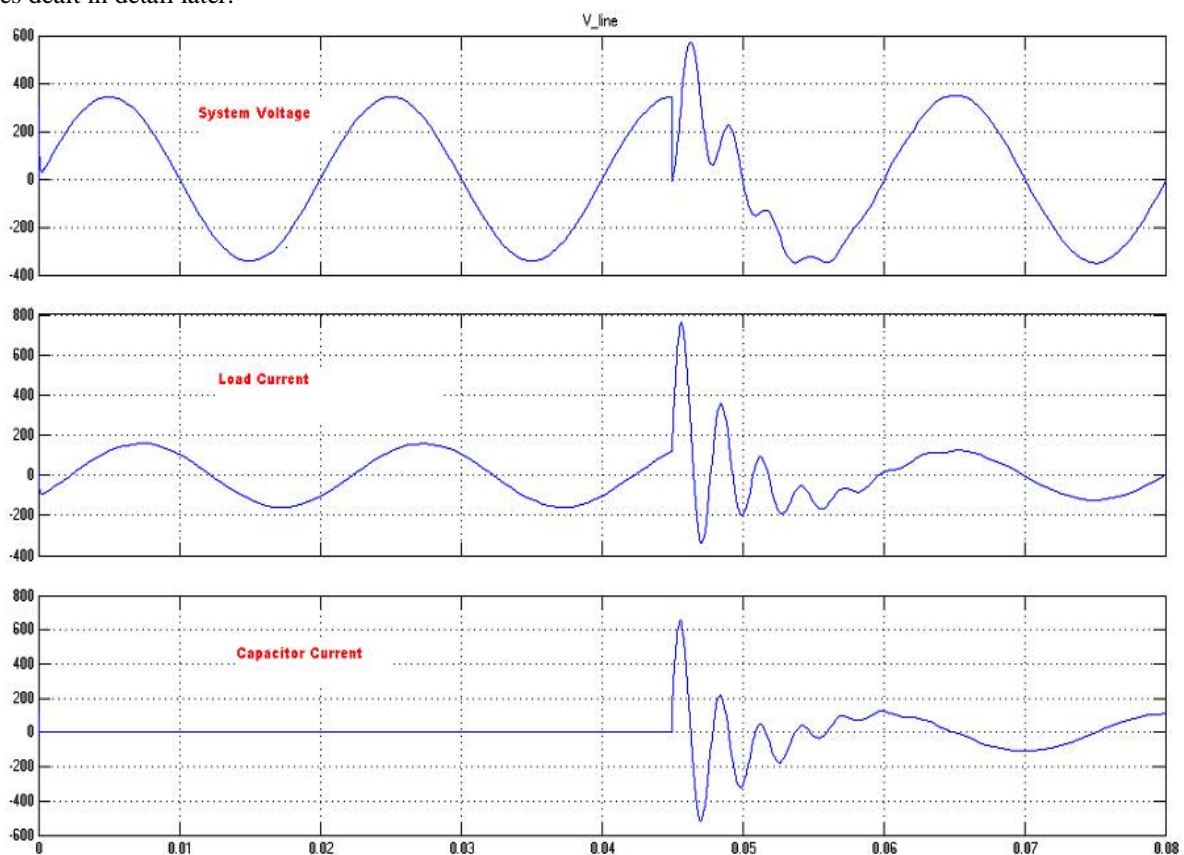
**Fig. 2 Energizing of capacitor through switch**

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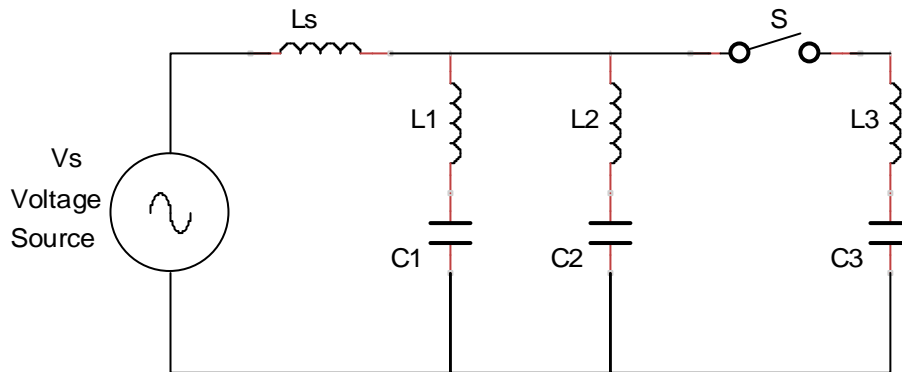
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Electrical equivalent circuit for energizing an isolated capacitor bank from a predominantly inductive source. Immediately following the closure of switch, a high frequency and large magnitude current flows into the capacitor, so as to equalize capacitor voltage with the system voltage. The voltage surge and the inrush current depend on the instant at which the switch is closed on the supply wave form. The voltage surge for an isolated grounded star bank can reach a maximum of 1.8/2.0 per unit. It gives the voltage surge waveform for a typical isolated capacitor switching when the voltage is passing through peak value. The magnitude of the surge, its frequency and duration depend on C, L and R values dealt in detail later.



**Fig. 3 voltage surge for capacitor bank**

In the distribution system the capacitor banks are arranged in steps and switching operations are carried out to obtain the reactive power required to match with the prevailing load requirement so as to maintain the power factor at desired level. This necessitates parallel operations and capacitor bank arrangement in steps. A typical back to back switching arrangement is shown in fig.3, where in C1 and C2 are already in the circuit and C3 being switched on [22].



**Fig. 4 Back to Back switching of capacitor bank**

Consider  $C_1$  and  $C_2$  are in energized condition and  $C_3$  with NIL / least charge is switched on. At,  $t=0^+$  a high frequency inrush current flows due to energisation of capacitor  $C_3$ . This switching operation is associated with two types of transient oscillations, (i) very high natural frequency by which the  $C_3$  has to be brought to the same potential level of that of  $C_1$  and  $C_2$  and, (ii) with a considerable lower natural frequency by which all the three capacitors should be brought to the same potential level of the source. The first phenomenon given rise to large magnitude of inrush current at very high frequency and the second one is associated with relatively smaller transient current at low frequencies in KHz lasting for a longer duration.

The objective of this dissertation is to present “An Innovative Transient Free TBSC Compensator for Dynamic Reactive Load and Voltage Sag Mitigation” scheme for reactive power compensation and power quality improvement in power system.

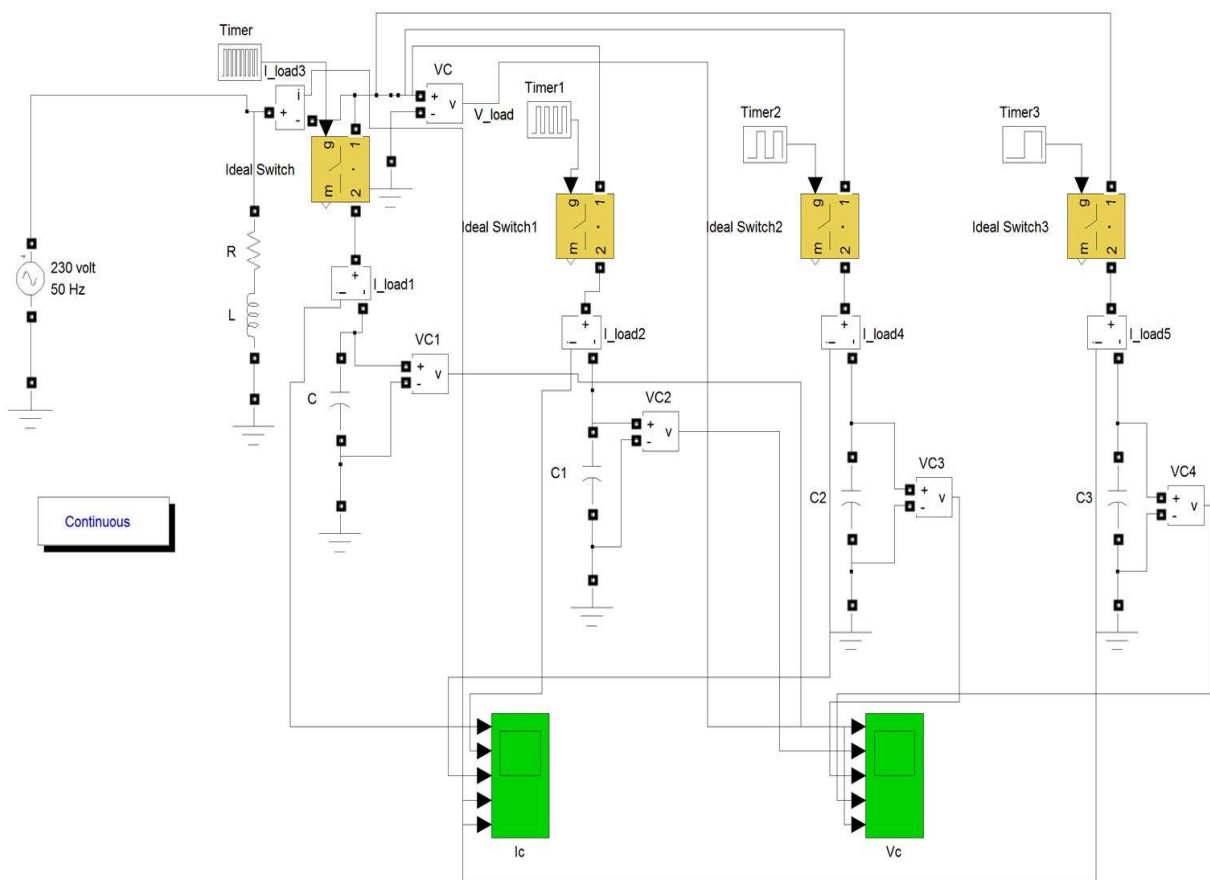
This synopsis presents a topology. The proposed scheme consists of Thyristor Switched Capacitor (TSC) banks in binary sequential steps known as Thyristor Binary Switched Capacitor (TBSC) [25, 26]. This TBSC facilitates step-less control of reactive power closely matching with load requirements so as to maintain desired power factor. The proposed topology has following distinctive features [7]:

1. TSC (Thyristor Switched Capacitor) banks are arranged in Binary sequential steps to provide almost continuous reactive power compensation.
2. Transient free switching is obtained by switching the capacitors to the negative/positive peak of supply voltage and firing the thyristors at the negative/positive peak of supply voltage.
3. It compensates for rapid variation in reactive power.
4. Reactive power compensation is achieved in cycle by cycle basis. That is step-less compensation.
5. **Inrush** current problems during connection and **Outrush** current disconnection are avoided.
6. At the distribution transformer requiring total reactive power  $Q$  for improving the power factor from some initial value  $P.f1$  to the desired value  $P.f2$  at the load. This  $Q$  can be arranged in binary sequential ‘n’ steps, satisfying the following equation [1]:

$$a. \quad Q = 2^n C + 2^{n-1} C + \dots + 2^2 C + 2^1 C + 2^0 C$$

**VI. SIMULATION RESULTS**

**1. MATLAB Simulation model of single phase TBSC compensator:**



**Fig 5 Open loop Simulation model for single phase system**

Above fig shows the TBSC compensator with four capacitor bank, load, switch, pulse generator and with single phase 230volt AC supply. This model specially designed for to generate binary compensating current. In this model value of capacitor is chosen in binary sequence and the values are  $1\mu\text{f}$ ,  $2\mu\text{f}$ ,  $4\mu\text{f}$  and  $8\mu\text{f}$ , therefore due to this value and switching pulse step less control and transient wave form is obtained. To obtain transient free switching I m chosen one instant that is negative peak of supply, at this instant capacitor current is zero. If we switch capacitor and off at this instant then the there will be no transient occurs across switch. It shows the binary operation of the TBSC compensator proposed. the total compensating current from phase "R" (total  $I_c$ ), is being increased step by step. The capacitor



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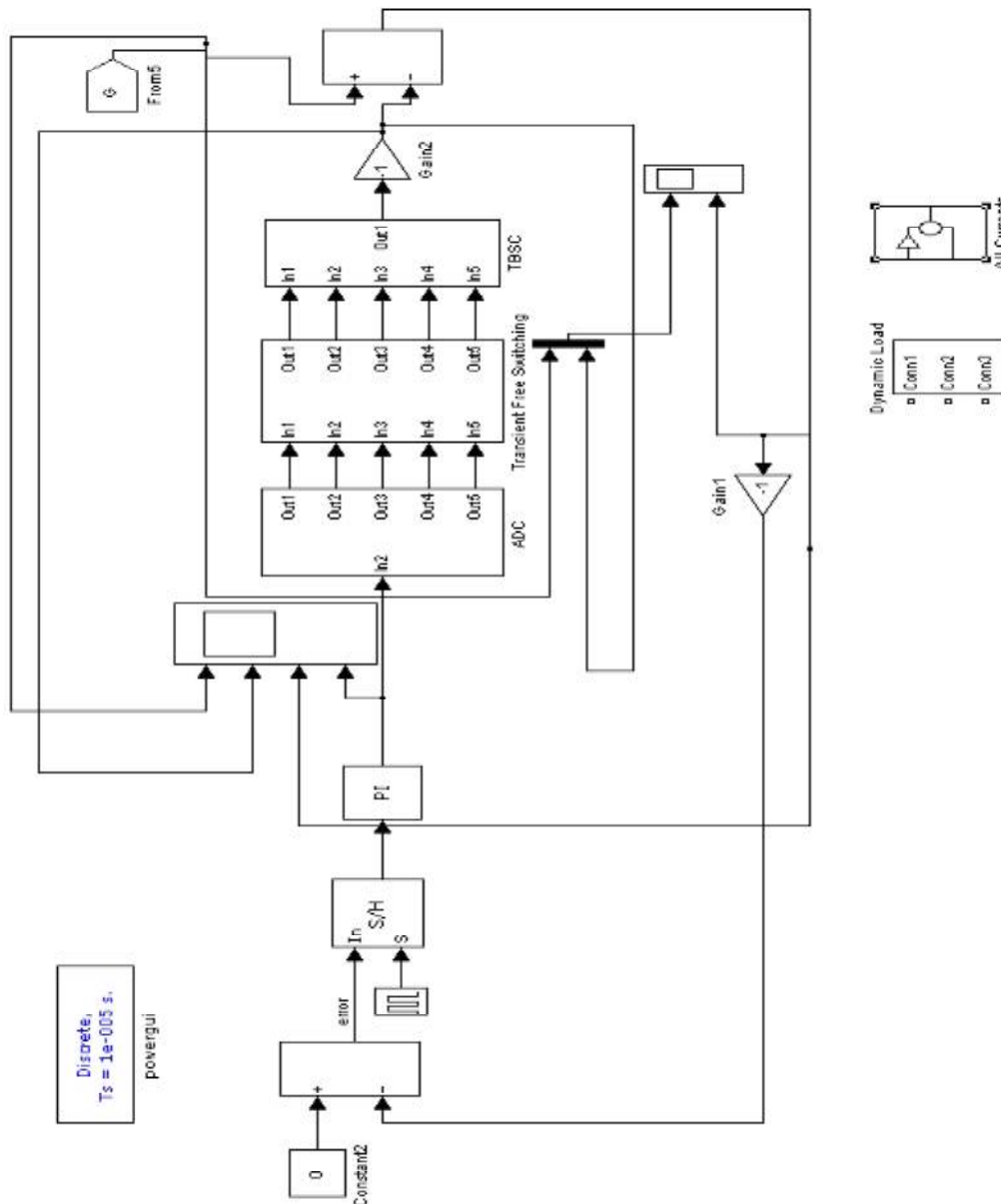
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currents from the branches B1 (ic1), B2 (ic2), B4 (ic4), and B8 (ic8) are shown in fig.3 respectively. In the total compensating current for the phase "R" (total ic) is displayed (total ic=ic1+ic2+ic4+ic8).

### 2. MATLAB Simulation of TBSC Compensator for fast varying dynamic load:

Data used in Simulation:-

- a. Source:-  
Voltage  $V = 400$  V,  $R_s = 0.0287\Omega$ ,  $L_s = 0.20471$ mH.
- b. TBSC banks:-  
Five TBSC banks are used in the simulation whose values are shown.

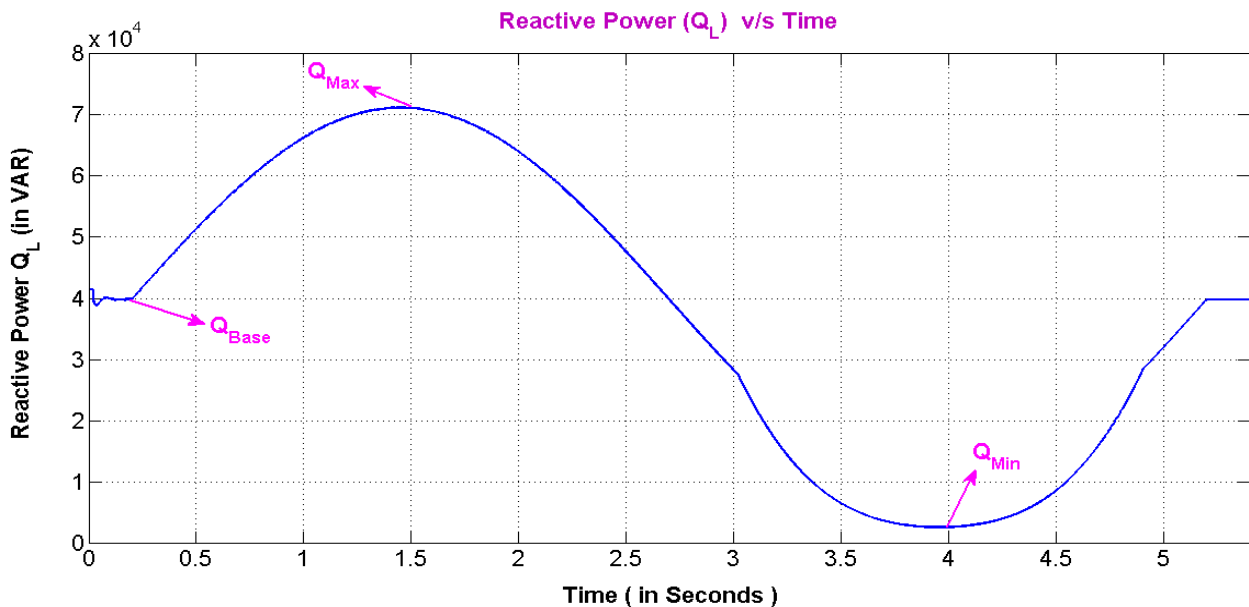


**Fig 6 Closed loop Simulation model for three phase system**

**Table 2 Values of five TBSC banks**

Sr. No.	Q (in KVAR)	C (in $\mu$ F)	L (in mH)
1.	2.5	45	0.32
2.	5	90	0.16
3.	10	180	0.08
4.	20	360	0.04
5.	40	720	0.02

Continuously changing reactive power,  $Q_L$  is obtained by simulating three phase dynamic load. The nature of load variation is as shown.



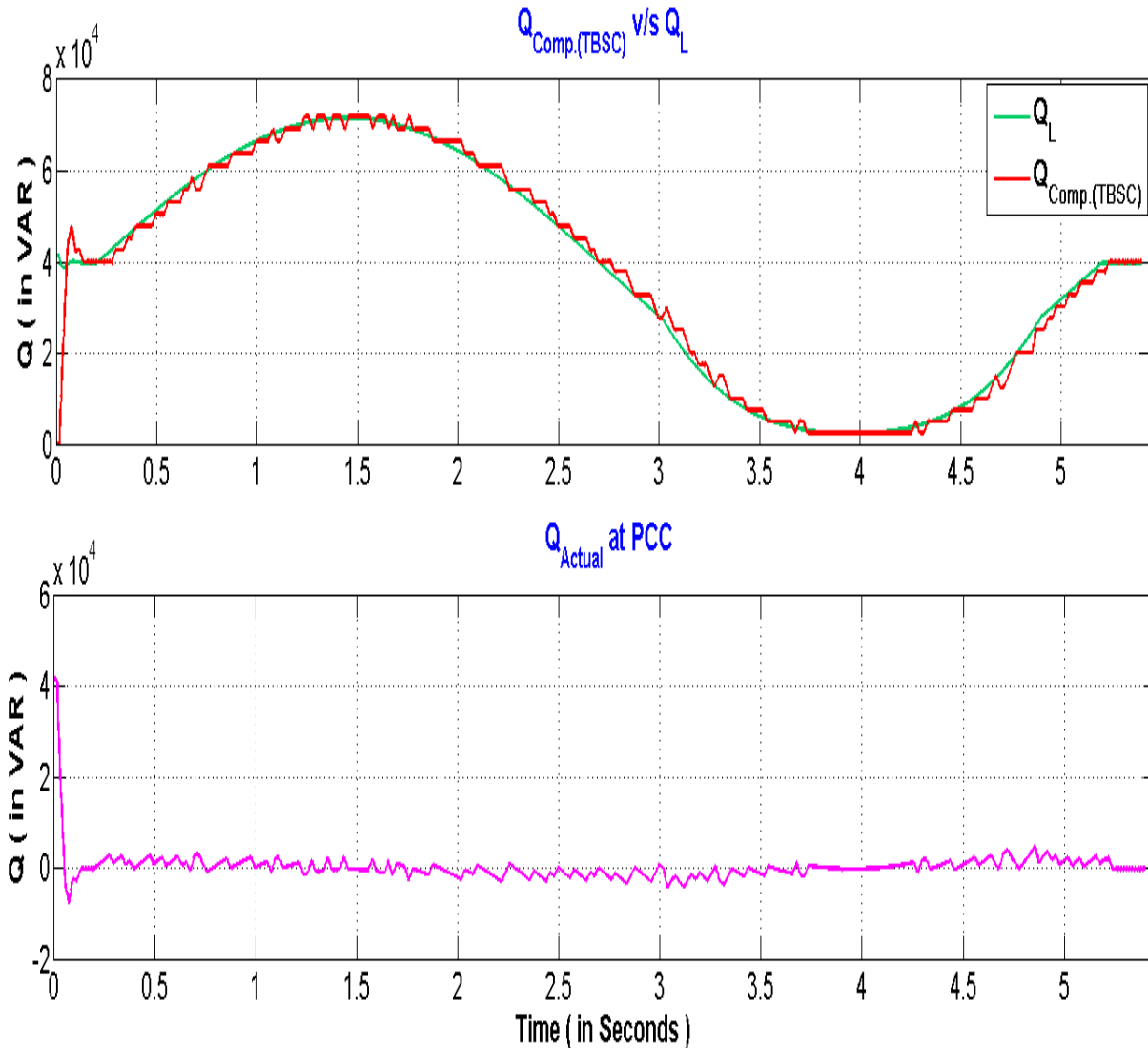
**Fig.7 Simulation of three phase dynamic load**

Minimum reactive power  $Q_{min}$ , maximum reactive power  $Q_{max}$ , and base reactive power  $Q_{base}$  can be varied by changing the parameters of three phase dynamic load. In all simulations  $Q_{Ref}$  is set to zero since it is assumed that desired P.F. is unity at all times. Discrete PI controller with  $K_p = 0.565$  and  $K_i = 25$  is used. 5 bit ADC is used in simulation. Parameters of Three-phase dynamic load block are adjusted in such a way that  $Q_L$  varies continuously from  $Q_{Min} = 2.5$  KVAR to  $Q_{Max} = 77$  KVAR with base load  $Q_{Base} = 40$  KVAR. This variation takes place in five seconds. Waveforms of load reactive power  $Q_L$ , reactive power given by TBSC,  $Q_{comp.(TBSC)}$  and actual reactive power  $Q_{Actual}$  at PCC.

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**Fig.8 Simulation Result of TBSC operation**

From simulation results it is seen that  $Q_{comp.(TBSC)}$  closely follows  $Q_L$ , and actual reactive power  $Q_{Actual}$  at PCC is approximately +500 to -500 VARs at all discrete switching instances. The small error is due to the binary switching arrangement of TBSCs. These errors can be minimized by adding more number of capacitor banks in TBSC.

## VII.CONCLUSION

A topology utilizing a TBSC has been exhibited. The TSC bank step qualities are picked in double grouping weights to make the determination little. Current coursing through TBSC and in addition source is without transient. Consonant substance in source current is unimportantly little. By planning the control of TBSC, it is conceivable to get completely stepless control of receptive force. Likewise one can work the framework at any fancied force component. Proposed topology can make up for fast variety in responsive force on cycle to cycle premise. An endeavor is made through this work to build up a plan with thyristors to decrease the expense by staying away from

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IGBT's and IGCT's, in fact sound with dependable execution amid both relentless state and transient conditions, appropriate for quickly changing/fluctuating burdens, for example, curve heaters, pulling forces loads, welding gear's and so on., and automatic operations are essentially both transient and music free. The plan created is most reasonable for very nonlinear, fluctuating and symphonious producing loads. It gives taking after advantages. Quick fluctuating element receptive force remuneration. Voltage droop alleviation at the season of Induction Motor beginning. Likewise it can be utilized for, at the season of long transmission and high evaluating of transformer charging. Additionally it can be utilized for, to maintain a strategic distance from reverberation condition

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