International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Thyristor Binary Switched Reactor for Voltage Regulation and Reactive Power Compensation

Ashish A.Patil[1], Ashwini shivdas[2], Ashish P. Kinge[3]

[1]M.E. Student, TSSM'S, BSCOER, Narhe, Pune, India
[2]Assistant Professor,Department of Electrical Engineering, TSSM'S, BSCOER, Narhe, Pune, India
[3]Assistant Professor , Department of Electrical Engineering, TSSM'S, BSCOER, Narhe, Pune, India

ABSTRACT

Voltage regulation is most important factor in power system as well as reactive power compassion too. In recent trends so many inventions are done which have so many advantages and disadvantages too that is there are so many loads ate connected to power supply and which causes or creates disturbances in healthy supply system. . This paper proposes a Thyristor binary switched Reactor that has a wide controlling range with minimum loss in the operating components. As a result of these cons of TBSR presented first and its result is investigated by switching the thyristor in binary mode as per the requirement of reactive power. The most highlight of this project is it reduces Ferranti effect in power system. For transient free switching we use TBSR's is carried out. Conventional SVC,TSR inject harmonic in the system.

Keywords: Thyristor binary switched reactor (TBSR), wide compensation range, reduce Ferranti effect , Binary switching is possible , provided protection for auto turn off of thyrisror.

1 INTRODUCTION

In this project Topology for reactive power compensation and Voltage regulation of dynamic load in closed loop is presented. The scheme consists of a Thyristor Binary Switched Reactor (TBSR).TBSR is based on a chain of Thyristor Switched Reactor (TSR) banks arranged in binary sequential manner. A transient free switching of TBSRs is carried out.The conventional SVC, TCR plays important role but TCR inject the harmonics in the system, which is not acceptable in many situations. To eliminate the harmonics thyristor switched reactor (TSR) in binary switching pattern are used. The variable shunt reactor (VSR) can be requires for various situations such as to reduce voltage spikes in the network, adjustable to seasonal loads and varying daily loads, provides flexibility to meet future developments and changes in the grid hence binary switched reactor bank will be proposed. The proposed topology allow almost step-less reactive power compensation and does not inject harmonic components of voltages and harmonic components of currents into the line. Hence, a harmonic filter is not required. The control circuitry has been proposed in such a way that transient free switching of TBSRs will takes place. The above topology allows step less reactive power compensation of dynamic load in closed loop.

1.1. OBJECTIVES

The purpose of this seminar is to present a new topology forThyristor binary Switched Reactors are shunt compensators that canabsorb reactive power. This topology has the following distinctive characteristics;

- ✓ It does not generate harmonics;
- ✓ It's operating principle simple, delay of one half.
- ✓ It can compensate reactive power cycle by cycle;
- ✓ It does not require forced commutation switches; and

Inrush current problems during connection and out flow current disconnection are avoided

1.2 DESIRABLE FEATURES:

The desirable features of the proposed scheme are as follows:

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

1.3 ADVANTAGES:

- ✓ It does not generate harmonics.
- ✓ It is much simpler &cheaper.
- ✓ It can Compensate Reactive Power Cycle By Cycle.
- ✓ It does not Require Forced Commutation.
- ✓ Inrush & Outflow Current Problems are avoided.

1.4 FUTURE SCOPE:

The static VAR compensator developed and installed on one of the transformer in the college campus is a good demonstrating model for both students and faculty members. It offers in depth knowledge of the SVC scheme, its control for various aspects of reactive power compensation, voltage maintenance, power factor improvement, reduction in maximum demand and effective utilization of transformer and feeder. It is possible to operate SVC with individual phase control to mitigate the unbalanced related problems.

- ✓ The working feasibility of the scheme for flicker control similar to dynamic voltage restorer needs to be investigated.
- ✓ The application of the developed scheme at a substation making use of the tested circuitry can be undertaken.
- ✓ It is also possible to hook up the system developed with SCADA without any difficulty for continuous control in real time mode.

2 LITERATURE SURVEY

2.1 GENERAL:

The basic pioneer work of binary switching theory of reactor and capacitor has been carried out by, S. B. Dewan, R. S. Segworth and M. S. Mckinney in 1969 [1]. From 1969 to 1994 this theory was hidden and no practical solution was developed. Then from 1994 on word Prof. El. Sharkavi (Washington University), come up with practical implementation of binary switching capacitor compensator for 125KVA transformer and also was patented under US government [2-3]. Then subsequently Juan Dixon comes up with transient free switching of binary sequence capacitor [4-6]. Also recently practicability of TBSC compensator has been reported in literature [8-9]. Unfortunately though the theory of binary switching of reactor which is reported in 1969, but till now there is no hardware implementation so far.

Many big industries, commercial and industrial electrical loads include power transformers, welding machines, arc furnaces, induction motor driven equipment such as elevators, pumps, and printing machines etc., which are mostly inductive in nature. These loads create serious power quality problems. Low Power Factor is the predominant problem now a day. Poor P.F. has various consequences such as increased load current, large KVA rating of the equipment, greater conductor size, larger copper loss, poor efficiency, poor voltage regulation, Reduction in equipment life etc. [2]. Therefore it is necessary to solve the problem of poor P.F. There are different reactive power compensation techniques to improve the P.F. such as: synchronous condenser, capacitor banks, Static VAR Compensators [12], Self commutated VAR Compensators etc. However, most of them have disadvantages: synchronous machines are bulky, require strong foundation, have a poor dynamic behaviour, require significant amount of starting and protective equipment, capacitor banks generate high transients during connection & disconnection, SVCs are harmonic polluters and controlled semiconductors [Insulated Gate Bipolar Transistors (IGBTs) and Integrated Gate Controlled Thyristor (IGCTs)] used in self-commutated VAR compensators have a limited capacity. Actual semiconductors can handle a few thousands of amperes and have reverse voltage blocking capabilities of 6 to 10 kV, which is not enough for high voltage applications [4]. Also these compensators are expensive. Loads constitute a major part of the power system and their characteristics greatly influence the stable operation of the system. Modern power systems are enormous and interconnected to serve large, remote load regions. In recent years, voltage stability and voltage regulation have received wide attention. Voltage control, voltage regulation, reactive power control, steady state stability etc. are important problems of power systems. The basic structures of a Static Var Compensator (SVC) are fixed shunt capacitor (FC) and Thyristor Controlled Reactor (TCR). Furthermore, the SVC is investigated in TSC (Thyristor Switched Capacitor) - TCR, MSC (Mechanically Switched Capacitor)-TCR and TSC- TSR configurations. In order to abstain harmonic generation it is decide to use a TSR instead of a TCR. Also, with choice of TSR both voltage stability and stepwise control of bus load bus voltage have been provided [13].

The thyristor switched reactor (TSR) is a shunt-connected reactor in series with a thyristor valve that is used to switch the reactor ON or OFF. Basically, the TSR fulfills the same purpose as the shunt-connected mechanically switched reactor which has been employed in the AC transmission system since its early days. The only difference between these two components is that the former uses a thyristor to switch the reactor in and out of operation, while the latter uses a mechanical switch. Compared to the mechanical switch, the thyristor allows the switching process to be a lot faster. Another advantage is that it will not face the same limitations on wear and tear as a mechanical switch, which is only capable of a finite number of switches. The higher investment cost could possibly be earned by the reduction in service and maintenance costs of the mechanical switches. Installation of TSR-Based SVC in the system is caused to improve power factor and voltage profile for both static loads and dynamic loads. TSR-Based SVC provides to rapid control of the voltage at week points at every load level in the test system. Test system with TSR-Based SVC is not needed a harmonic filter and this is a great advantage of TSR-Based SVC [13].

2.2 PROPOSED TOPOLOGY DESCRIPTION:

Thyristor Switched Reactor (TSR) banks in binary sequential steps known as Thyristor Binary Switched Reactor (TBSR).
The Proposed work demonstrates the power quality problem due to reactive power in the system. In this proposed scheme TBSR Compensator is presented.

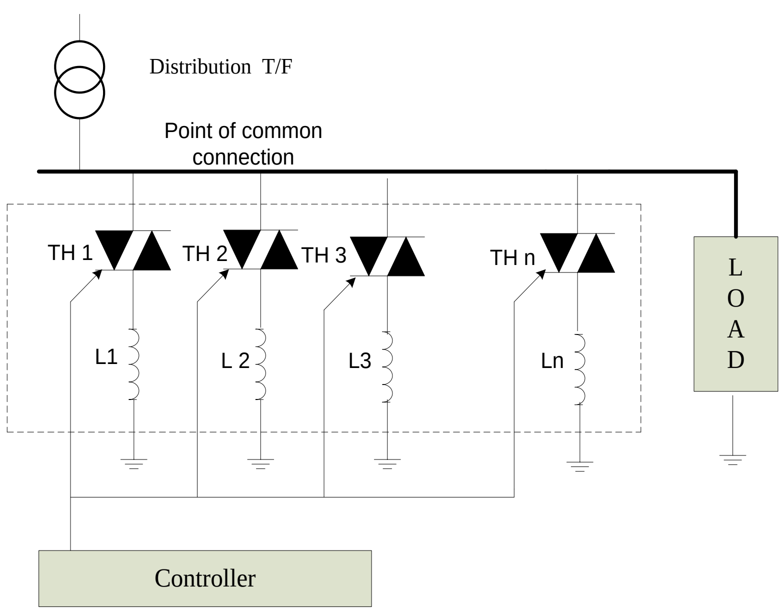
- ✓ Normally we are using SVC (TSC-TCR) for reactive power compensation. But SVC has some drawbacks due to TCR;
- ✓ TCR generates Harmonics
- ✓ More losses in TCR
- ✓ SVC required additional filter for Harmonic reduction which is generated by TCR.
- ✓ Cost of SVC is more due to TCR and Filter.

To avoid these drawbacks we design a new compensator that is TBSR Compensator. Also we are added one additional concept that is Transient Free Switching of TBSR Bank. With the help of TBSR Compensator we can achieve almost stepless control of reactive power and voltage regulation.

2.2.1 **The proposed topology has following distinctive features:**

- ✓ It does not inject harmonic into transmission system.
- ✓ In can maintain voltage profile of system.
- ✓ Fast recovery time.
- ✓ No transients generated due to switching of reactor at the current zero instant.
- ✓ It compensates for rapid variation in reactive power.
- ✓ It eliminates possible over compensation and resulting leading power factor.
- ✓ It compensates load bus voltage in the transmission system.
- ✓ Harmonics generation less as compare with other SVC.
- ✓ It can also mitigate voltage swell, voltage sag usually originate from faults.
- ✓ Simple in principle, elegant in usage and of low cost. Transient free operation is achieved
- ✓ It is used for compensation, regulation and damping of oscillations in power systems.
- ✓ Reactors are sized in binary sequential ratio for minimum size of switching steps.

2.2.2 TBSR (Thyristor Binary Switched Reactor):



Thyristor Binary Switched Reactor (TBSR):

TBSR Compensates leading reactive power due to TBSC, by switching reactor in binary sequence. Also it reduce the over voltage on long transmission line due to Ferranti effect. This Q can be arranged in binary sequential 'n' steps, satisfying the following equation [1]:

$$Q_L = 2^n L + 2^{n-1} L + ... + 2^2 L + 2^1 L + 2^0 L$$

In the proposed scheme, reactor bank step values are chosen in binary sequence weights to make the resolution small. If such 'n' reactor steps are used then 2^n different compensation levels can be provided. [3] This scheme TBSR banks different values of reactor are arrange in binary sequential manner.

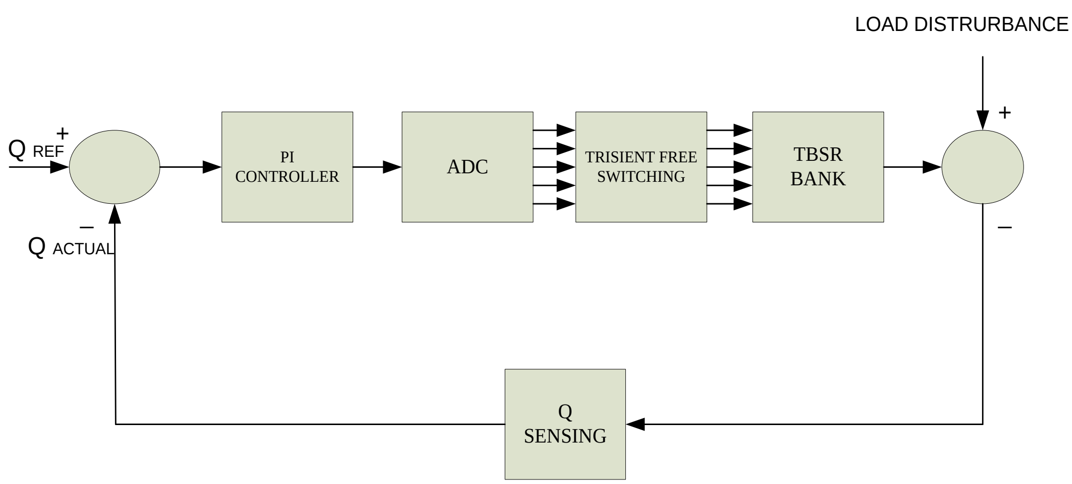
2.2.3 CONTROLLER:

Controller is the heart of compensator. Voltage V and current I at PCC are sensed by Potential Transformer (P.T.) & Current Transformer (C.T.) respectively and given to controller.

CONTROLLER DESCRIPTION:

TBSR Closed Loop Operation:-

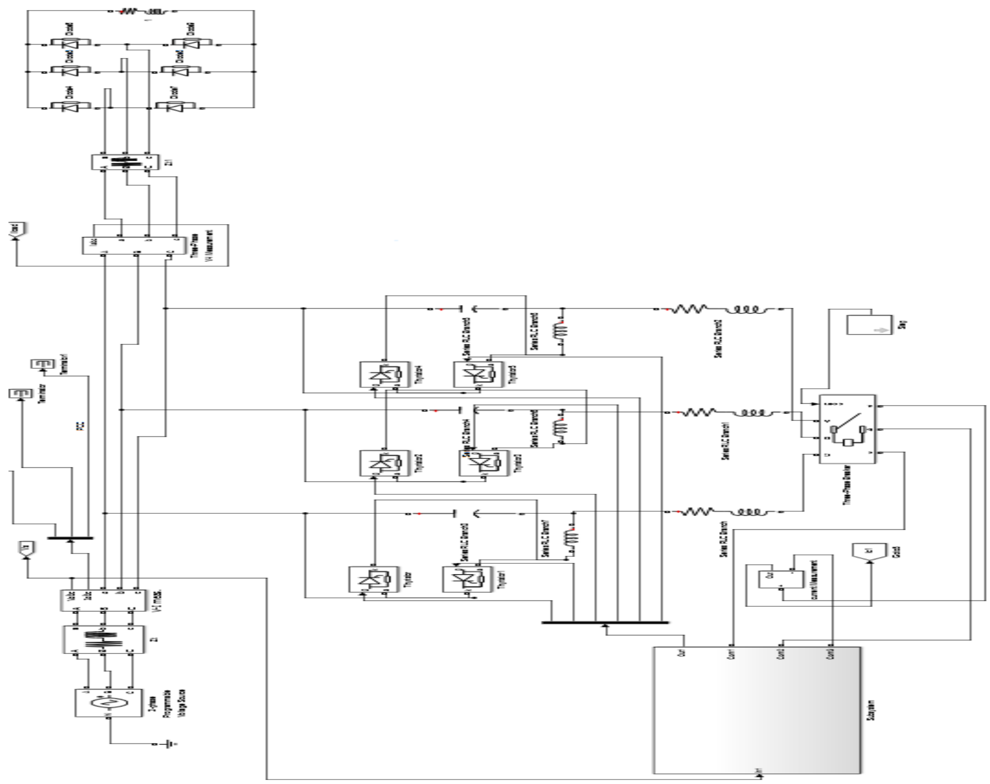
A block diagram of reactive power compensator using TBSR banks is shown in Fig.2. Reference reactive power, Q_{Ref} is calculated from the desired leading reactive power. Actual reactive power at PCC, Q_{Actual} is calculated by sensing voltage and current at PCC by P.T. and C.T. respectively. Error between Q_{Ref} and Q_{Actual} is given to PI Controller. A Discrete PI Controller is used. Output of PI Controller is given to ADC and its output is given to TBSR banks in such a way that no transients occur. In this way closed loop operation of TBSR banks for reactive power compensation is achieved.



Figer 2: TBSR closed loop operation

3.Simulation

3.1. Simulation Detail



3.1.1 Three phase voltage source:

This block implements a three-phase zero-impedance voltage source. The common node (neutral) of the three sources is accessible via input 1 (N) of the block. Time variation for the amplitude, phase and frequency of the fundamental can be pre-programmed. In addition, two harmonics can be superimposed on the fundamental.

3.1.2. Line impedance:

The characteristic impedance or surge impedance (written as Z_0) of a uniform transmissionline is the ratio of the amplitudes of voltage and current of a single wave propagating along the line; that is, a wave travelling in one direction in the absence of reflections in the other direction.

The characteristic impedance of a transmission line is the ratio of the voltage and current of a wave travelling along the line. When the wave reaches the end of the line, in general, there will be a reflected wave which travels back along the line in the opposite direction. When this wave reaches the source, it adds to the transmitted wave and the ratio of the voltage and current at the input to the line will no longer be the characteristic impedance. This new ratio is called the input impedance. The input impedance of an infinite line is equal to the characteristic impedance since the transmitted wave is never reflected back from the end. It can be shown that an equivalent definition is: the characteristic impedance of a line is that impedance which when terminating an arbitrary length of line at its output will produce an input impedance equal to the characteristic impedance. This is so because there is no reflection on a line terminated in its own characteristic impedance.

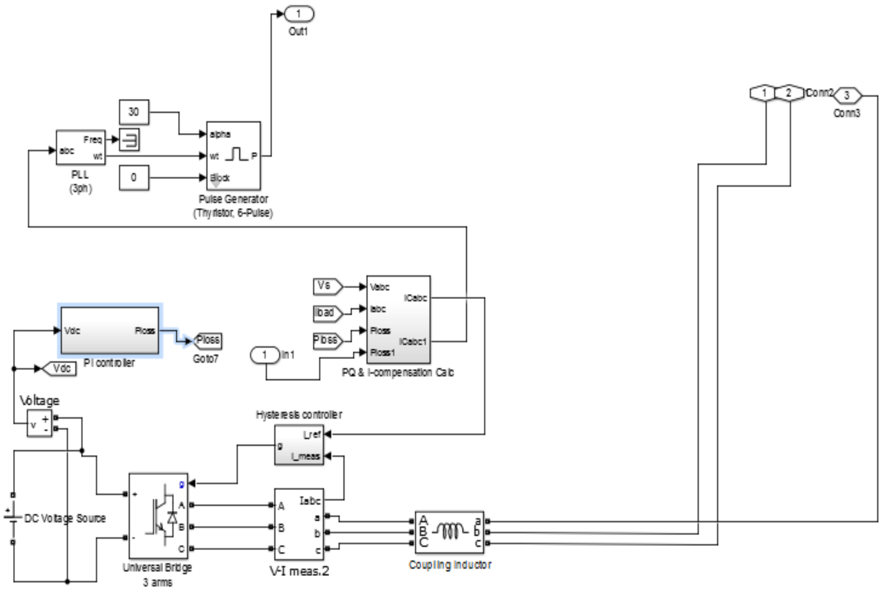
3.1.3. V-I Measurement:

From input and output side for comparison purpose which measure,this block can output the voltages and currents in per unit values or in volts and amperes

3.1.4 Diode full bridge:-

Implements a diode in parallel with a series RC snubber circuit. Snubber circuit is the energy –absorbing circuit used to suppress the voltage spikes caused bycircuit inductance when a switch electrical or mechanical opens.The most common snubber circuit is used capacitor and resistor connected series across switch.

3.2. Sub-system 1:



Figer 4**:**Sub-System 1

Sub-system consists following components:-

3.2.1. Universal Bridge:-

When you select Switching-function based VSC, a switching-function voltage source converter type equivalent model is used, where switches are replaced by two voltage sources on the AC side and a current source on the DC side. This model uses the same firing pulses as for other power electronic devices and it correctly represents harmonics normally generated by the bridge." It is required dc source which having amplitude of 50 Volts.

3.2.2. PLL:-

This Phase Locked Loop (PLL) system can be used to synchronize on a set of variable frequency, three-phase sinusoidal signals. If the Automatic Gain Control is enabled, the input (phase error) of the PLL regulator is scaled according to the input signals magnitude.

For optimal performance, set regulator gains [Kp Ki Kd] = [180 3200 1] and check the Enable Automatic Gain Control parameter.

Input: Vector containing the normalized three-phase signals [VaVbVc]

Output 1: Measured frequency (Hz) = w/(2pi)

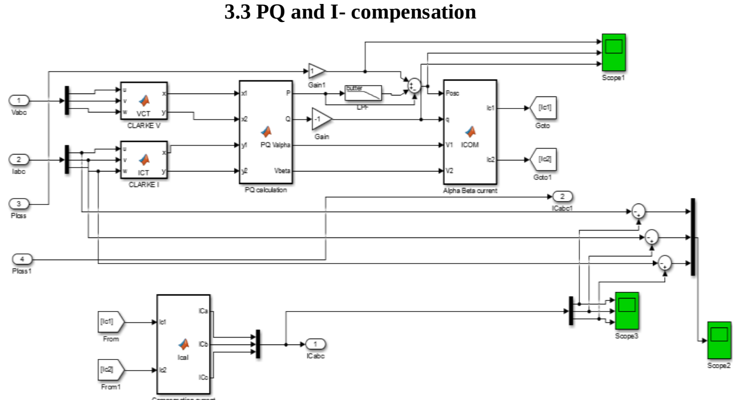
Output 2: Ramp w.t varying between 0 and 2*pi, synchronized on zero crossings of the fundamental (positive-sequence) of phase A.

3.2.3. Pulse generator:-

Generate pulses for a 12- or 6-pulse thyristor converter. The block outputs 'P' (for the 6-pulse generator) or 'PY' and 'PD' (for the 12-pulse generator) containing vectors of 6 pulses (0-1) to be sent to the thyristor bridges. Input 'alpha': Alpha firing angle (deg).Input 'wt': Angle (in rad) of the phase A of the primary transformer voltage, obtained from a PLL synchronization system. Input 'Block': Allows blocking of the pulses when the applied signal is TRUE (1).

When the 'Double pulsing' parameter is checked, two pulses are sent to each thyristor: a 1st pulse when the alpha angle is reached, then a 2nd pulse 60 degrees later, when the next thyristor is fired.

3.3 PQ and I- compensation



:

Figer4 : PQ and I- compensation

3.3.1. Clarke Transformation:

This transformation converts balanced three-phase quantities into balanced two-phase quadrature quantities.

The three-phase quantities are translated from the three-phase reference frame to the two-axis orthogonal stationary reference frame using Clarke transformation as shown in Figure 3.The Clarke transformation is expressed by the following equations:

$I\alpha$= 2/3(Ia) −1/3 (Ib−Ic) ----------------------------------EQ1

$I\beta$= 2/(√3)(Ib−Ic) ---EQ2

Where,

Ia, Ib, and Ic are three-phase quantities

Iα and Iβ are stationary orthogonal reference frame quantities

When Iα is superposed with Ia and Ia + Ib + Ic is zero, Ia, Ib, and Ic can be transformed to Iα and Iβ as:

$I\alpha$= Ia ---EQ3

$I\beta$=1/(√3) (Ia+2Ib) --EQ4

WhereIa + Ib + Ic = 0

3.3.2. Inverse Clarke Transformation:

The transformation from a two-axis orthogonal stationary reference frame to a three-phase stationary reference frame is accomplished using Inverse Clarke transformation, The Inverse Clarke transformation is expressed by the following equations:

Va=$V\alpha$- --EQ5

Vb=(- V α +√3*V β)/2----------------------------------EQ6

Vc=−(- Vα-√3*Vβ)/2--------------------------------------EQ7

3.3.3. Park Transformation:

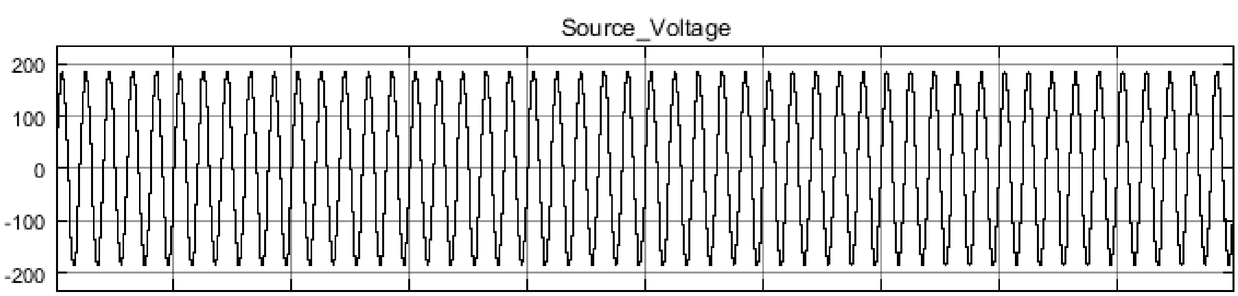
This transformation converts vectors in balanced two-phase orthogonal stationary system into orthogonal rotating reference frame. Basically, the three reference frames considered in this implementation are:

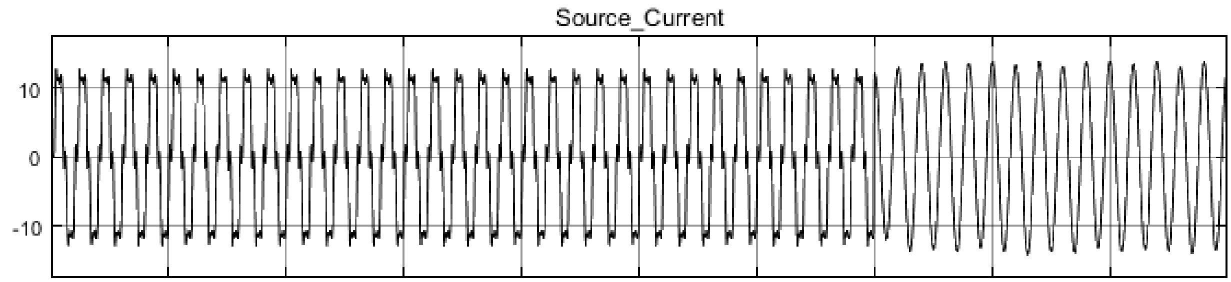
1. three-phase reference frame, in which Ia, Ib, and Ic are co-planar three-phase quantities at an angle of 120 degrees to each other.

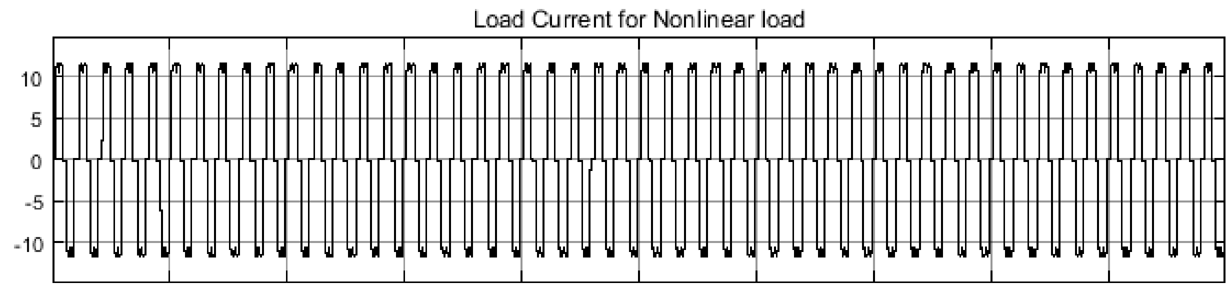
2. Orthogonal stationary reference frame, in which Iα (along α axis) and Iβ (along β axis) are perpendicular to each other, but in the same plane as the three-phase reference frame.

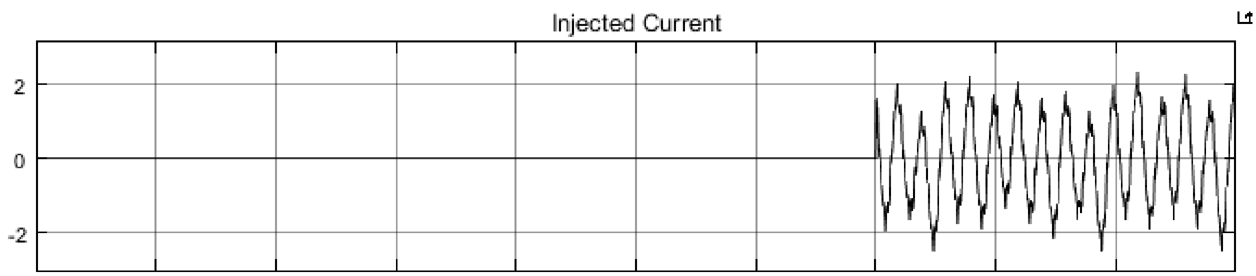
3. Orthogonal rotating reference frame, in which Id is at an angle θ (rotation angle) to the α axis and Iq is perpendicular to Id along the q axis.

4.Simulation Results:









3. Advantages

The scheme developed is most suitable for highly nonlinear, fluctuating and harmonic generating loads. It gives following benefits:

- ✓ Minimum feeder current and loss reduction.
- ✓ Improvement in distribution feeder efficiency.
- ✓ Improvement in the voltage at load end.
- ✓ Relief in maximum demand and effective utilization of transformer capacity.
- ✓ Conservation of energy takes place.
- ✓ It is possible to get step less control of Q closely matching with load requirements
- ✓ The combination offers greater flexibility in control.

6. CONCLUSION

A topology using a TBSR has been presented. The TSR bank step values are chosen in binary sequence weights to make the resolution small. Current flowing through TBSR as well as source is transient free. Harmonic content in source current is negligibly small. By coordinating the control of TBSR, it is possible to obtain fully step less control of reactive power. Proposed topology can compensate for rapid variation in reactive power on cycle to cycle basis. An attempt is made through this work to develop a scheme with thyristors to reduce the cost by avoiding IGBT‘s and IGCT‘s, technically sound with reliable performance during both steady state and transient conditions, suitable for rapidly changing / fluctuating loads such as arc furnaces, tractions loads, welding equipment’s etc., and self-regulating operations are practically both transient and harmonics free.

References

1) S. B. Dewan, R.S. Segsworth Senior Member IEEE, and M. S. Mckinney, “A DC Controlled Reactor Using Thyristors”, IEEE Transaction on Magnetics, Sept. 1969, pp. 342-346.
2) M. A. EI. Sharkawi, T. Williams, N. Buller, “An Adaptive Power Factor Controller for Three Phase Induction Generator”, IEEE tranction on Power App and Systems, Vol. PAS 104, No. 7, July 1985, pp1825-1831.

3) M. A. EI Sharkawi, S. S. Vankuta, G. Andexler, Mingliangchen and Tony Huang, "Reactive Power Compensation", us patent No. 5, 134, 356 July 28, 1992.

4) Maffrand, J. W. Dixon, and L. Morán, "*Binary controlled, static VAR compensator, based on electronically switched capacitors*," in Proc. IEEE PESC'98, pp.1392–1396, 1998.

5) 5. Juan Dixon, Yamilledel Valle, et al.: A Full Compensating System for General Loads,Based on a Combination of Thyristor Binary Compensator, and a PWM-IGBT ActivePower Filter, IEEE Trans. Industrial Electronics, vol. 50, no. 5,pp. 982- 989.(2003)

6) Juan Dixon, Luis Morán, José Rodríguez, Ricardo Domke, "Reactive PowerCompensation Technologies, State of- the-Art Review", proceedings of the IEEE, vol. 93,no.12, pp. 2144- 2164, 2005

7) D. R. Patil and U. Gudaru, *"The Experimental Studies of Transient Free Digital SVC Controller with Thyristor Binary Compensator at 125 KVA Distribution Transformers",* Proceedings of the World Congress on Engineering 2012 Vol II WCE 2012, July 4 - 6, 2012, London, U.K.

8) AyetulGelen, and TankutYalcinoz "The behavior of TSR-based SVC and TCR-based SVC Installed in an infinite bus system", IEEE 2008, !-4244-2482-5/08/$20.00 ©2008 IEEE.

9) Swapnil. D. Patil, IrfanMujawar, IsakMujawar, D. R. Patil, *Member, IAENG*, U. Gudaru, *Senior Member IEEE*, "TBSC-TCR Compensator Simulation: A New Approach in Closed Loop Reactive Power Compensation of Dynamic Loads",Proceedings IMECS 2014, Vol II, March 12 - 14, 2014, Hong Kong.

10) AyetulGelen, TankutYalcinoz "Experimental studies of a scaled-down TSR-basedSVC and TCR-based SVC prototype for voltage regulation and compensation" Turk JElec Eng.& Comp. Sic, Vol.18, No.2, 2010, T¨UB˙ITAK doi: 10.3906/elk-0907-138.

11) Salem Rahmani, AbdelhamidHamadi, *Student Member, IEEE*, Kamal Al-Haddad, *Fellow, IEEE*, and Louis A. Dessaint, *Fellow, IEEE "*A Combination of Shunt Hybrid Power Filter and Thyristor-Controlled Reactor for Power Quality", IEEE transactions on industrial electronics, vol. 61, no. 5, may 2014.

12) M. A. EI Sharkawi, T. J. Williams and S. S. Venkata, "Reactive power compensation systems, US patent No. 4, 677, 364, 1987.

13) D. R. Patil and U. Gudaru, *"An Innovative Transient Free Adaptive SVC in Stepless Mode of Control"*, International Science Index Vol:5, No:5, 2011 waset.org/Publication/6880.