International Journal of Electronics and Electrical Engineering

Volume 4 | Issue 1 Article 4

February 2022

Power Flow and Power Quality Enhancement by TCSC using five different Novel Methods

Niharika Agrawal
SJB Institute of Technology, niharika.svits@gmail.com

Mamatha Gowda
SJB Institute of Technology, mahesh.mamatha@gmail.com

Recommended Citation

Agrawal, Niharika and Gowda, Mamatha (2022) "Power Flow and Power Quality Enhancement by TCSC using five different Novel Methods," *International Journal of Electronics and Electrical Engineering*: Vol. 4: Iss. 1, Article 4.
DOI: 10.47893/IJEEE.2022.1183
Available at: https://www.interscience.in/ijeee/vol4/iss1/4

Power Flow and Power Quality Enhancement by TCSC using five different Novel Methods

Niharika Agrawal and Mamatha Gowda
SJB Institute of Technology, Bengaluru, India
niharika.svits@gmail.com and mahesh.mamatha@gmail.com

Abstract

The demand of electricity is continuously increasing due to increase in population and urbanisation**.** Due to shortage of transmission and generationfacilities there is greater use of present resources. The present transmission lines are overloaded which make the system prone to stability problems.So, there is a need to use the existing system in a better way to save huge expenses in the erection of new lines and system. In the proposed work the power flow is increased byimplementing power electronics-basedseries FACTS device- TCSC using five different methods. They are firing by TCR pulse generator, using control subsystem based on RS Flip Flop, using Synchronised six (PG) pulse generator, using Thyristor -6 pulse generator with PLL, andPulse generator (PG) block of MATLAB.Next problem discussed here is the power quality. The power quality of the system is polluted due to use of common harmonic loads like computers, motor drives, arc and induction furnaces, battery charges, rectifiers, induction heating equipment. Here also, TCSC is used to enhance the power flow and power quality of the system. In the present work is shown here that the active power at the receiving end is enhanced using the above different methods.The THD analysis of the system is done in the present work using all the different methods.

Keywords: transmission line, stability. oscillations, power flow, power quality.

I. Introduction:

The power system is interconnected and complexsystem. Due to increase in load demand some of the transmission lines are heavily loaded. Thisdeteriorates the power quality and voltage profile of the system. The system stability and security are also affected. The TCSC is a series FACTS device used in the present work to enhance the flow of active power in the system.The TCSC device consists of a series capacitor which is connected in parallel with a thyristor-controlled reactor (TCR).The TCSC is used to provide variable compensation as against fixed compensation by TCSC.This is done by changing the impedance of the transmission line with appropriate firing angle. The TCSC can be made to work in two modes which are the thyristor blocking and the bypass modes.It is changed by changing the firing angle of thyristors. In the blocking mode the performance of TCSC is just as a fixed capacitor.In the bypass mode the TCSC performance is as a parallel connection of inductor with the series capacitor.There is one resonance region between the inductive and capacitive regions where the TCSC should not be operated. Thevalue of resonant factor must be less than 3 to avoid multi resonant points as it will reduce the operating span of TCSC. [1,2,3,4,5]

II. Literature Review

The simulation of various FACTS devices for power flow control was done and results were analysed. The work was done with different values of capacitor. The Pulse Generator block was used to generate the firing pulses with the proper selection of pulse delay and pulse width. The active and reactive power were plotted against the load angle. The TCSC was used for real and reactive power control. Initially the system was analysed using series capacitor and then it was evaluated by TCSC. [6,7,8,9,10]. The modelling and power flow control by TCSC at different P and Q loads was done. The parameters of TCSC inductor and capacitor should be properly chosen. [11,12] The TCSC should not be operated in the resonance region. It was concluded that using TCSC the power flow decreases in inductive region and increases in capacitive region. [13,14,15,16]. The hardware model of transmission line was prepared and the hardware implementation, practical aspects of TCSC were explained. [18,19,20].

III. System Data.

To investigate the performance of TCSC for power flow control the technical data of 400 KV Kanpur -Ballabhgarh Transmission line is taken in the proposed work.

The inductance of the line/Km= 1.044 mHLength of the line=400 Km.
Total line inductance=0.4176 HTotal Line Reactance =131.1929 ohms.
The line is designed for 75% compensation for which the values of L and C are 0.07829 H and 32.3503 microfarad. The resonant factor is chosen as 2 in this work. By using this value of resonant factor, the resonance angle was found to be 45º. So, the TCSC is prohibited in the range 35º to 55º. The inductive range is from 0º to 35º and capacitive range is from 55º to 90º. In the proposed work the TCSC is used in the capacitve mode and firing angle for different methods is kept as 78º.

A. System without TCSC:

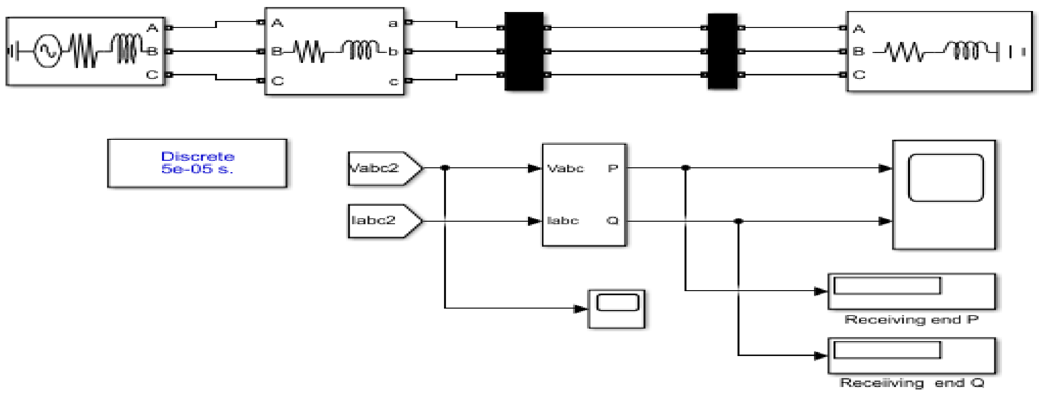

Fig 1. System Without TCSC

The system without TCSC consists of a transmission line, measurement block, scope, display, power measurement block, three phase AC source and three phase loads. The active power without TCSC is 234.70 MW.

B. System with TCSC

Method 1: Using TCR Pulse Generator

The voltage and current of the TCSC is measured and feed as input to the system. It is used for calculating the TCSC impedance. There are thyristors inside the TCSC block. The firing unit consists of firing unit A phase, firing unit B phase and firing unit C phase. The TCSC work in constant impedance mode.Three single phase PLL in the firing circuit. For synchronisation the line current is used. TCR pulse generator generate firing pulse for one TCR and other TCR pulse generator generate the firing pulses for the other TCR.There Is a block which generate square-wave synchronised with the line current. For positive (Sync +) and negative (Sync -) transition [11,12,13,14]

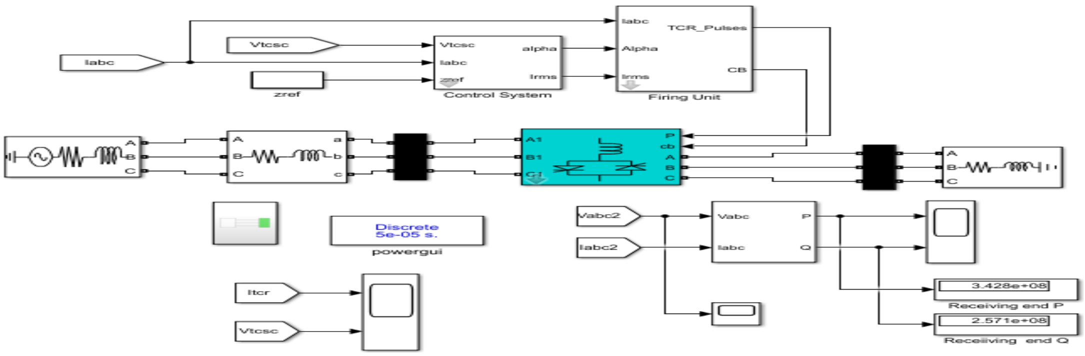

Fig 2. System With TCSC with TCR Pulse Generator

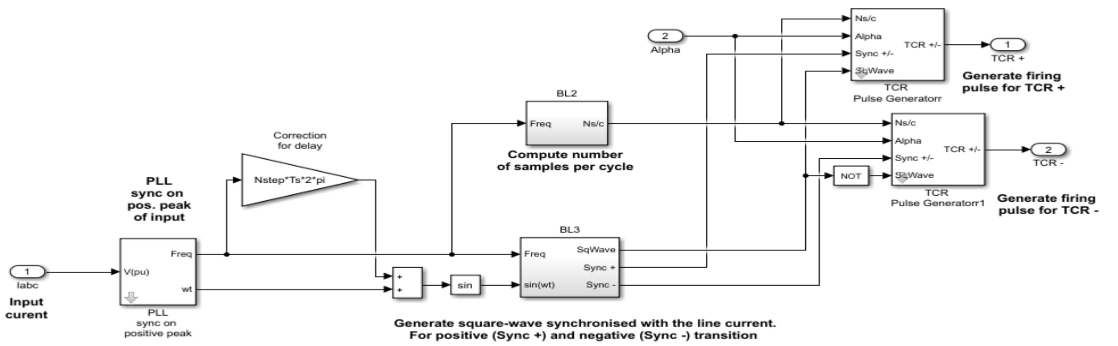

Fig 3. Internal Subsystem with TCSC with TCR Pulse Generator.

Method 2. Using Control subsystem based on RS flip flop

In this method the RS flip flop is used for generation of pulses to the thyristor. RS flip flop belong to the family of digital electronics. The other different blocks used for generating the pulses are Hit crossing, integrator, constant, switch block and different gains blocks. These are included in the control circuitry for pulse generation to the thyristor. The ramp signal and firing angle are compared inside the subsystem. Using ADD, RS Flip and other blocks of MATLAB in the subsystem the appropriate firing pulses are generated and it is passed to the TCSC block.

Table 1: Truth table of RS flip flop

R	S	Q	Q'
0	0	0	1
0	1	1	0
1	0	0	1
1	1	0	1

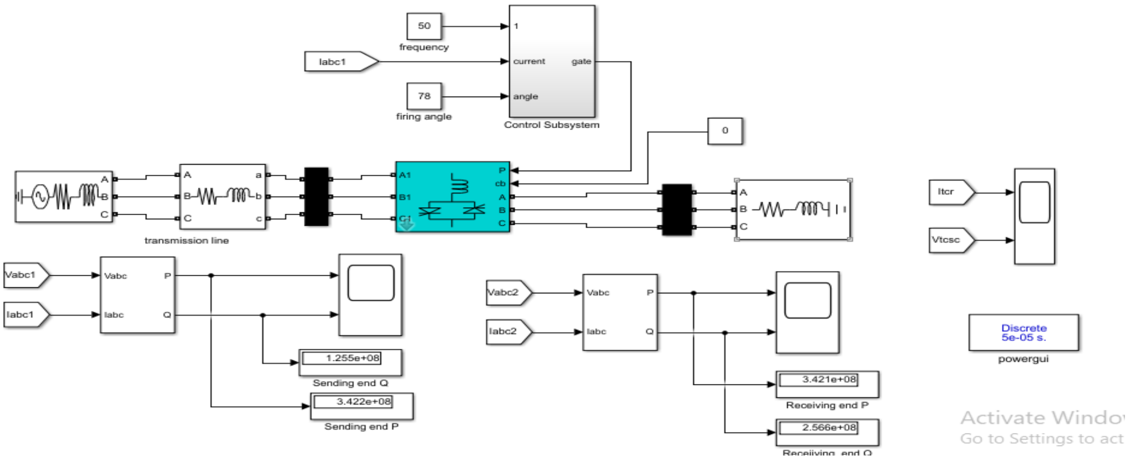

Fig 4. System with TCSC based on RS flip flop control subsystem

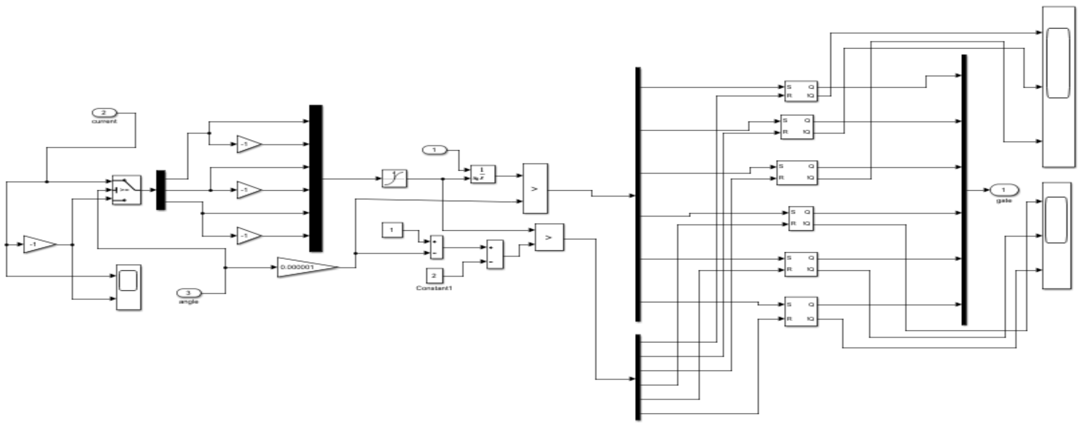

Fig 5. Internal Control subsystem based on RS Flip Flop

Method 3: Using Synchronised six Pulse Generator

In this method the synchronised Pulse Generator block is used for the generation of firing pulses to the TCSC block. The zero crossings of the three line-to-line synchronization voltages are used here for the generation of pulses. The firing angle is passed to this generator using constant block. Inputs AB, BC, CA are the synchronisation voltages. The pulses output block of the PG contains the six pulse signals.This block is also used to fire the six thyristors of a six-pulse converter. The output of the block is a vector of six pulses individually synchronized on the six thyristor voltages. The pulses are generated alpha degrees after the increasing zero crossings of the thyristor commutation voltages. The frequency of synchronisation voltages is 50Hz and the pulse width in degrees is kept15 for this work. Here, the double pulsing is kept off. It can be configured to double pulsing mode. [15,16]

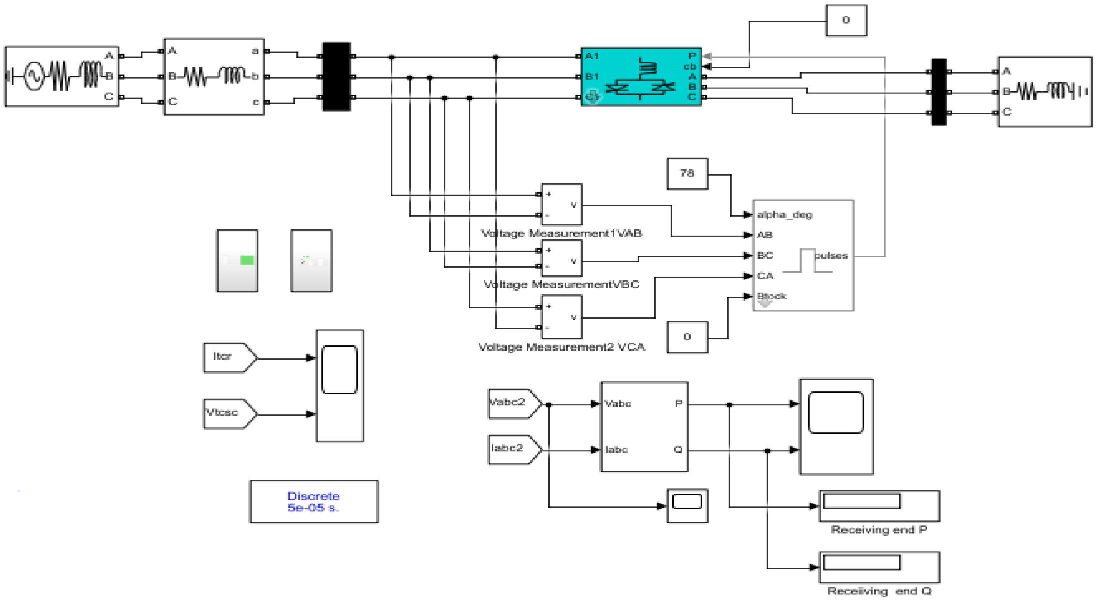

Fig 6. System with TCSC with Synchronised six pulse Generator

Method 4. Using PLL and Thyristor Six Pulse Generator

This pulse generator can be used in two types 6 pulse and 12 pulse. In the present work the 6pulse is used for passing pulses to the TCSC block of the simulation. The Double pulsing is used. The pulse width is kept 10 degrees. The three phase PLL block is used here has regulator gains kp, ki,kd are 500, 6000, 0. The minimum frequency used is 50 Hz in this block. The time constant for derivative action is 1e-4. The firing angle 78 is passed to the system using alpha input of the block.

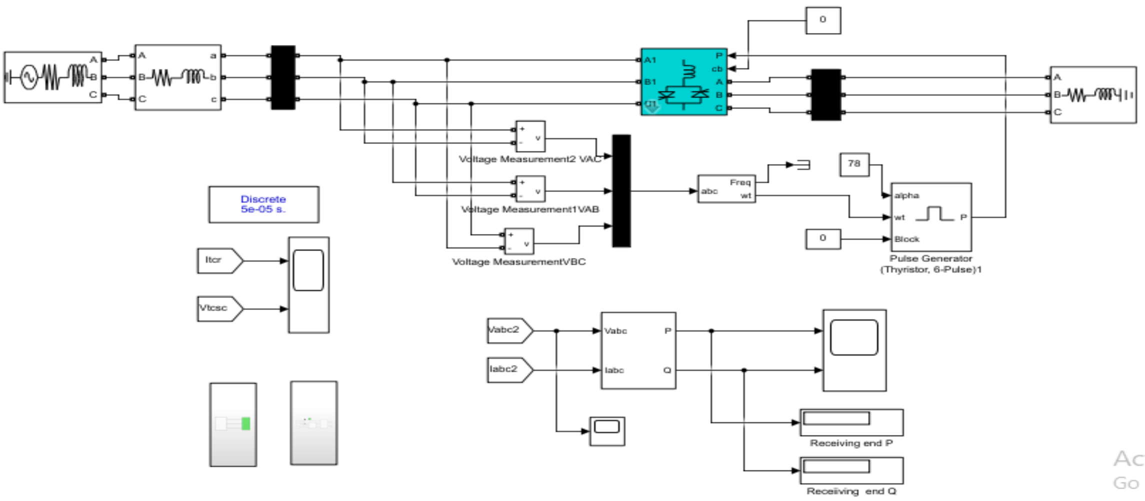

Fig 7. System with TCSC and thyristor six Pulse Generator based on PLL

Method 5: UsingPulseGenerator (PG)MATLAB Block

The firing pulses are given to the system in this method using (PG)Pulse Generator. The aim is to generate pulses of square wave at regular intervals. Thevalues for amplitude, Pulse Width, Period, Phase Delayof this block are set suitably to generate the appropriate firing angle. There are two Pulse generator used for each phase. A subsystem is created for the Pulse generator. The pulses to be applied are according to the vernier inductive and vernier capacitive mode of TCSC. In the present work the pulses are set for the capacitive mode of TCSC. Here again the synchronisation with the line voltage is used because it reduces the harmonic content.

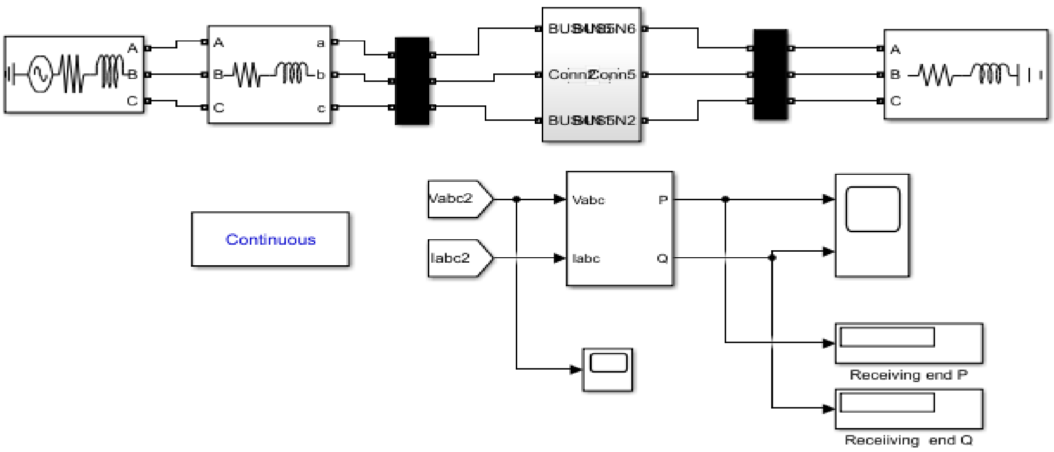

Fig 8. System with TCSC with Pulse Generator

Table 2. Power flow Enhancement and THD analysis by different methods

S. No	Method	Active Power at receiving end (P) MW	THD Voltage (%)
1	Without TCSC	234.70	0.00
2	With TCSC with TCR Pulse generator	342.80	3.10
3	With TCSC with control subsystem based on RS flip flop	342.10	3.70
4	With TCSC with Synchronised 6 Pulse Generator	287.30	6.53
5	With TCSC with thyristor 6 pulse generator based on PLL	237.20	7.18
6	With TCSC with Pulse Generator	241.60	7.57

IV. THD analysis

There is enormous use of electronic equipment now a days due to modernisation like computers, variable frequency drives, PLCs, LED, staticrectifiers, converters which causes pollution of the power quality.The non-linear loads cause distortion in supply voltage and current waveforms. Due to harmonics produced by non-linear loads the power factor is reduced, there is electromagnetic interference, the line losses are increased and there is malfunction of electronic equipment. So here FACTS device TCSC is used for mitigating the problems of voltage profile and power quality deterioration and improving the reliability of the system. The TCSC belong to family of power electronics-based devices which are very fast, efficient and have advanced control actions. The voltage sag mitigation, fault current limiting by adjusting the impedance of the line is possible using TCSC.The voltage sag problem has a very bad effect on production process which lead to bad economic consequences. The THD analysis is done using FFT analysis of MATLAB.

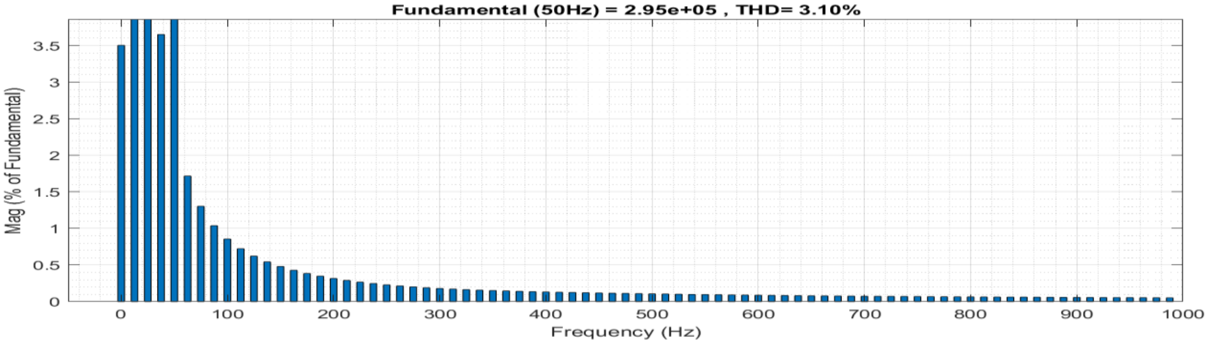

Fig 9. THD analysis with TCSC with TCR Pulse generator

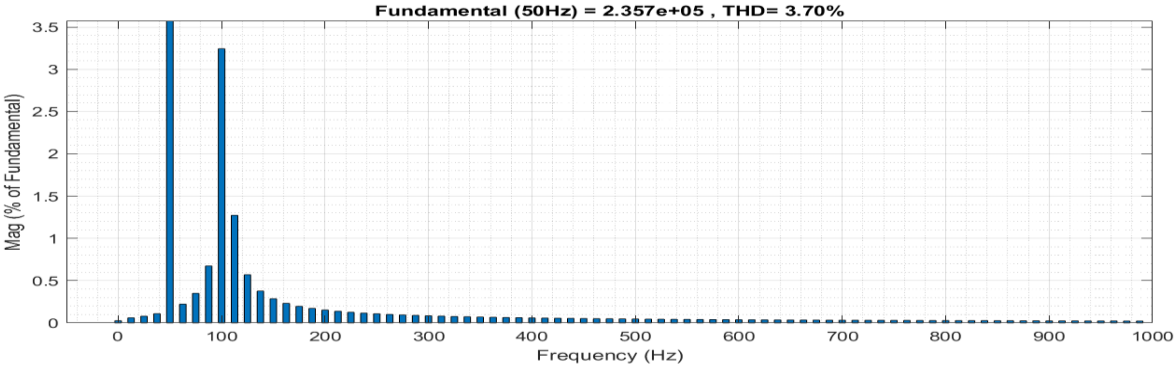

Fig 10 THD analysis with TCSC with RS flip Flop

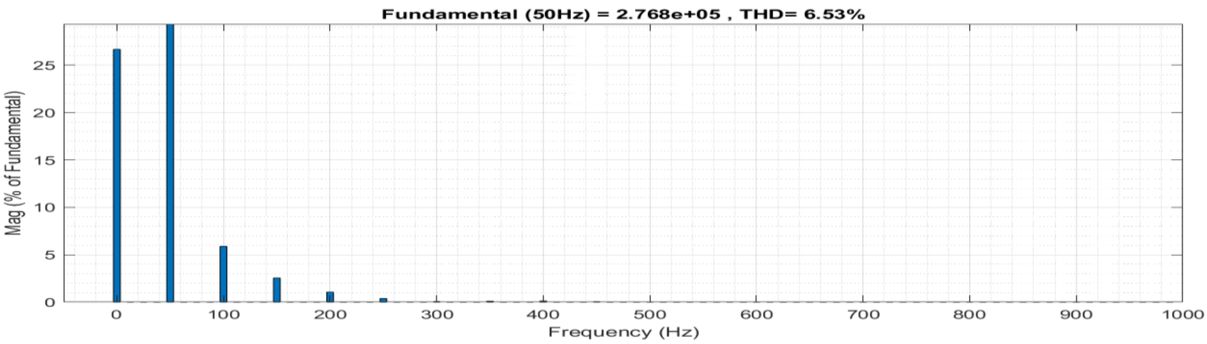

Fig 11. THD analysis with TCSC with Synchronised 6 Pulse Generator

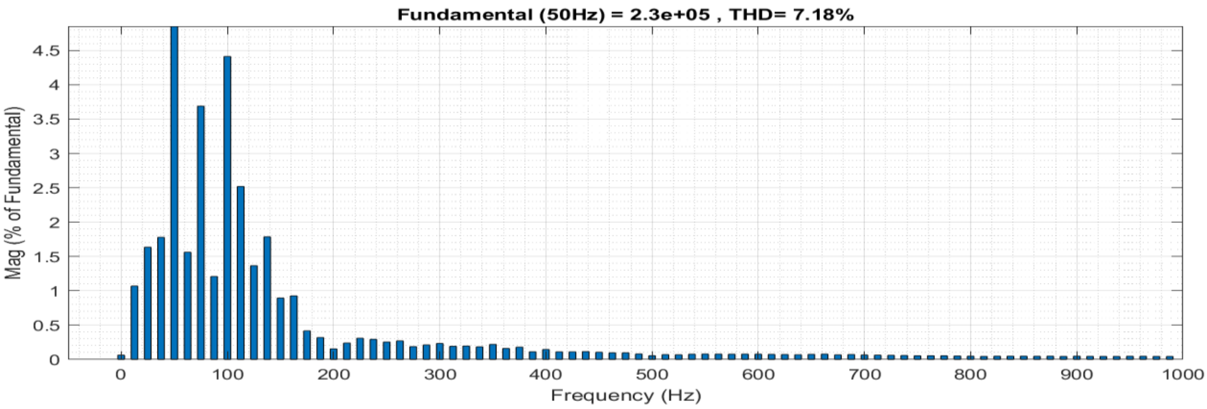

Fig 12.THD analysis with TCSC with thyristor 6 pulse generator based on PLL

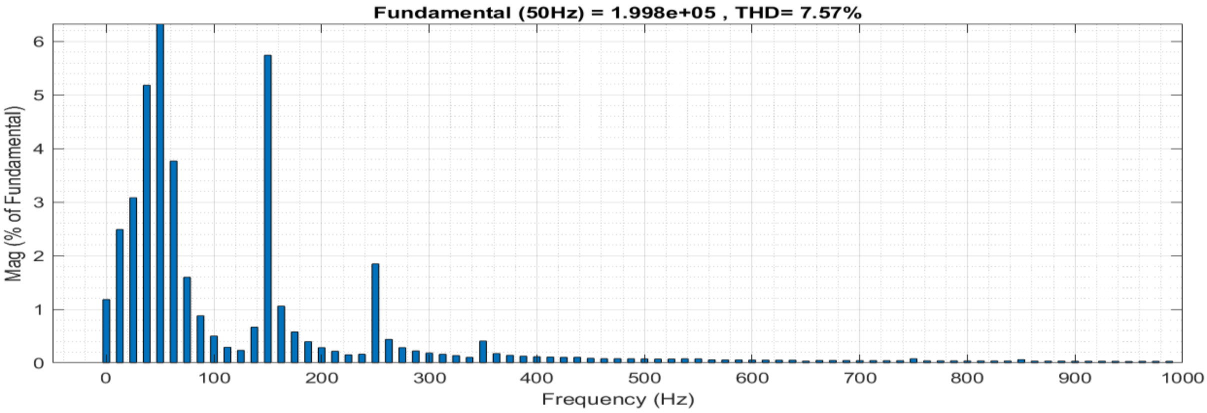

Fig 13.THD analysis with Pulse Generator

The table numbered 2 showed the THD performed on the system using different methods. The THD is found to be least in case of method based on TCR generator. Hence it can be concluded as the best method for power quality improvement of the present power system. The active power (true power) flow is also maximum for this method. Hence this method is the best method for enhancing the power transfer capacity of the system as well as to improve the power quality.

V. Conclusion

In the present work it is seen that the active power transfer to the system is increased at the receiving end using the above different methods. Using TCSC the power system efficiency is increased, there is improvement in powerquality, damping of power system oscillations, enhancement in transient stability and minimization of power losses.The TCSC is used to improve the voltage profile and power quality of the system. The analysis has been carried out by MATLAB Simulink firing methods.The installation of TCSC device in the system prevents the investment in installation of new transmission and generation facilities and thus it provides a cost-effective solution to meeting the increasing power demand problem. The results of the different novel methods are tabulated in table 2 for active power and power quality improvement. The method based on TCR generator is concluded to be the best method for enhancing the power transfer capacity as well as power quality improvement of the system.

VI. Future Scope

The present work can be extended to power flow control in multi bus system like IEEE 5 bus, IEEE 14 bus system etc. The TCSC can be used for congestion management and handling the problems of deregulated power system. For locating the TCSC in multi bus system the optimal location of TCSC device has to be found out using optimization method or other methods like loss sensitivity index method. By the proper location of TCSC in multi bus system the TCSC has the ability to reduce the overall operating cost, increased load ability of the system, reducedloss and improvement in stability. The Load flow analysis can be incorporated to determine the line flows and bus voltages. The simulation of system can be compared with the real time simulator tools.

VII. Acknowledgement

The authors of the present work are thankful to the Department of Electrical and Electronics Engineering and Principal SJBIT for providing extended and warm support for carrying out this work.

VIII. References

1. N.G. Hingorani, L. Gyugyi, “Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems,” IEEE Press, New York, 1999.
2. P. Kundur “Power System Stability and Control,” McGraw-Hill, New York,1994.
3. K. R. Padiyar, “FACTS Controllers in Power Transmission and Distribution,” New Age Int. Publisher, 2007.
4. R.MohanMathur,RajivK.Varma, “Thyristor-based Flexible AC Transmission System Controllers for Electrical Transmission Systems,”IEEE Press, Wiley India Pvt.Ltd.,New Delhi.
5. R. Ramanujam., “Power System Dynamics Analysis and Simulation, PHI Learning Pvt.Limited, New Delhi,”2009.
6. S. Sankar, S.Balaji and S.Arul, “Simulation and comparison of Various FACTS Devices in Power System,” International Journal of Engineering Science and Technology,vol.2,Issue-4, pp.538-547, 2010.
7. Sahil Mehta, Surya Prakash, “Performance Evaluation of FACTS Controllers for Short Transmission Line,” International Journal of Applied Engineering Research, vol. 13, no. 7, pp-5140-5153, 2018.
8. Samima Akter, Anulekha Saha, Prof.Priyanath Das, “Modelling, Simulation and Comparison of Various Facts Devices in Power System,” International Journal of Engineering Research and Technology (IJERT), vol.1, Issue-8, pp.1-12, October 2012.
9. Rachna Chauhan, Rakesh Singh Lodhi, “Selection of FACTS Devices for better Reactive Power Compensation through Capacitor,” International Journal of Engineering and Techniques, vol.2, Issue 5, pp. 28-35, Sep-October 2016.
10. G.Archana, Shaik Basha, “ Performance Analysis and Comparison of Various FACTS Devices in Power System,” International Journal of Engineering And Science, vol.3, Issue 12, pp.104-119,Dec 2013.

11. Himani Joshi,Shuvam Sahay, " Analysis of Different Types of FACTS Controllers in a Transmission Line, "International Journal on Emerging Technologies ,pp. 243-249, 2017.
12. Anulekha Saha, Priyanath Das And Ajoy Kumar Chakraborty, "Performance Analysis and Comparison of Various FACTS Devices in Power System", International Journal of Computer Applications, vol.46 Issue-15, pp.9-14, May2012.
13. Muqueem M Khan, M.M Ansari, Dynamic Stability Enhancement in Multimachine Power Systems by Different FACTS Device," International Journal of Electrical Engineering & Technology vol. 7, Issue -3, pp.169–179, May–June, 2016
14. Chauhan ChandkuwarbaaHitendrasinh, Dr.Vijay Makwana, "Thyristor Controlled Series Capacitor: Simulation and Analysis," International Journal of Advance Engineering and Research Development,vol.2,Issue-5,pp.796-805,May -2015.
15. Vatsal J.Patel,C.B.Bhatt, "Simulation and Analysis for Real and Reactive Power Control with Series Type FACTS Controller,"International Journal of Emerging Technology and Advanced Engineering,vol.2,Issue-3,pp.7-12,March 2012.
16. D.Chatterjee,A.Mitra,S.Sarkar, "A Conceptual Study for Control Strategy of TCSC in Inductive and Capacitive Region, "International Conference on Circuit,power and Computing Technologies,"IEEE,pp.1-6,2014.
17. Kapadia Mohmedhusein, HardikMistry,VivekNai,Doodhwal aMubashsir,Adil Kazi, "Simulation of TCSC Controller for power factor improvement using MATLAB Simulink, " International Journal of Research in Engineering Technology,vol.3,Issue 1,pp.17-20,Nov-Dec 2017.
18. Kusum Arora, SK Agarwal, Narendra Kumar, Dharam Vir, "Analysis of Power Flow Control in Power System Model using TCSC," International Journal of Engineering Research and Applications, vol.3, Issue-3, pp. 821 – 826, May-June 2013.
19. Neeraj H Patel, Raju B.Chaudhari, Rozina R.Surani, Hemant N. Raval, "TCSC Modelling and Operation," International Journal of Advanced Engineering and Research Development, vol.4,Issue-5,pp.380-386,May 2017.
20. D.Murali, Dr.M. Rajaram,N. Reka,"Comparison of FACTS Devices for Power System Stability Enhancement," International Journal of Computer Applications,vol.8,Issue-4, pp.30-35,October 2010.