International Journal of Power System Operation and Energy Management

Volume 3 | Issue 3 Article 2

January 2022

Comparison of Power flow Enhancement for varying loads using different Controllers

Niharika Agrawal Ms
Ghousia College of Engineering, niharika.svits@gmail.com

Faheem Ahmed Khan Dr
Ghousia College of Engineering, faheemahmedkhan11@gmail.com

Mamatha Gowda Dr.
, BGS College of Engineering and Technology,, mahesh.mamatha@gmail.com

Recommended Citation
Agrawal, Niharika Ms; Khan, Faheem Ahmed Dr; and Gowda, Mamatha Dr. (2022) "Comparison of Power flow Enhancement for varying loads using different Controllers," *International Journal of Power System Operation and Energy Management*: Vol. 3: Iss. 3, Article 2.
DOI: 10.47893/IJPSOEM.2022.1133
Available at: https://www.interscience.in/ijpsoem/vol3/iss3/2

Comparison of Power flow Enhancement for varying loads using different Controllers

Cover Page Footnote

The authors would like to express sincere thanks to Electrical and Electronics Engineering Department, Principal of Ghousia College of Engineering for providing extended support to carry out this work.

COMPARISON OF POWER FLOW ENHANCEMENT FOR VARYING LOADS WITH DIFFERENT CONTROLLERS

Niharika Agrawal[1] , Dr. Faheem Ahmed Khan[2]
Dr. Mamatha Mahesh Gowda[3]

[1]*Research Scholar , Department of Electrical and Electronics Engineering*
Ghousia College of Engineering Ramanagaram, Karnataka, 562159, *India*
niharika.svits@gmail.com

[2]*Professor and Director R & D, Dept. of EEE*
Ghousia College of Engineering Ramanagaram, Karnataka, 562159, *India*
faheemahmedkhan11@gmail.com

[3]*Professor, Electrical and Electronics Engineering Department, BGS College of Engineering and Technology, Bengaluru*, 560086, *India*
mahesh.mamatha@gmail.com

Abstract

The power demand is continuously increasing due to population growth and changes in lifestyle. Due to shortage of generation and transmission facilities it is desired to increase the existing transmission line power transfer capacity in order to meet the rising demand. Fixed capacitors(FC) and TCSC FACTS device are used to increase the power flow of the line .The advantage in TCSC is that it provides variable compensation instead of fixed compensation by FC. In the present work the comparison of power flow enhancement by fixed capacitors , single TCSC and two modules of TCSC is done for three cases . The three cases are load is suddenly increased and decreased, load is suddenly decreased and increased, load is increased and then further increased. Various Power quality issues like voltage sag ,voltage swell are discussed. The THD voltage and receiving end voltage with different controllers/devices are shown. The power flow is more with TCSC in the system than with FC. The power flow is further enhanced using two modules of TCSC in the system.

Keywords: *Demand, voltage, transmission line, capacitors, limits, power oscillations.*

1. INTRODUCTION

The demand of electricity is continuously increasing due to rapid industrial domestic and all other developments. There is need to transfer more power through existing transmission lines due to limitation on generation and transmission facilities. Also due to contingencies other lines are heavily loaded. There is thermal limit and voltage stability limits which has to be taken care of while transmitting the increased power through the existing lines. Fixed capacitors are used to increase the power flow through the existing line by decreasing the net impedance of the line, but it is slow and provide fixed compensation. There is problem of sub synchronous resonance with fixed capacitors. So, for providing variable series compensation TCSC a series FACTS device is used to increase the power transfer capacity of the existing transmission line. It is power electronics-based, high rating, fast, accurate device and provide dynamic compensation. It is used to control the power flow, increasing stability margins, damping SSR, power oscillations, reliability, line load ability, flexibility and providing secure interconnections. To have more power flow there can be a cascaded combination of several TCSC modules connected with a fixed series capacitor (FC). In the present work two TCSC modules of the same rating are used to increase the power flow through the existing system. The various parameters like active power (AP),current and voltage with different controllers like the system without any device, system with FC only , system with FC and TCSC, system with FC and two modules of TCSC are compared. The receiving end voltage is checked and is found to be increasing with using FC and TCSC and then FC and two modules of TCSC. The various results of power , voltage and THD are tabulated .[1,2,3,4].

2. LITERATURE REVIEW

Thyristor Controlled Series Capacitor (TCSC) : A series FACTS device which has a series capacitor shunted by a thyristor-controlled reactor. It provides variable compensation by TCR. N.G. Hingorani suggested a damping control scheme based on thyristor in 1981 which later developed into TCSC concept by Vithayathil in 1986.The TCSC device has different operating modes like bypassed-thyristor mode, blocked thyristor mode and vernier mode also called partially conducting mode. The TCSC reactance characteristic diagram show the variation of firing angle and reactance given by TCSC in inductive and capacitive working regions. In between the inductive and capacitive regions there is resonance region where TCSC is prohibited. TCSC has been successfully applied in Kanpur Ballabhgarh power transmission line in India. It was put in installation by the Power Grid corporation of India Limited (PGCIL) on 400 kV, Kanpur Ballabhgarh transmission line and it was called Kanpur-Ballabhgarh (KB)TCSC project. The length of the line was 400 km. By installing TCSC in the line there was an increase of power flow from previous 400 MW to 600 MW power approximately using TCSC. The mathematical modelling and single-phase representation of TCSC was done . The various waveforms were plotted for capacitor voltage, thyristor current, line voltage. The value of capacitor was changed and the variation in power flow was observed. Various FACTS devices like TCSC, STATCOM,UPFC ,SSSC were used in the system and the performance were analysed. The impedance characteristic curve was plotted by varying the firing angle .The TCSC work in inductive and capacitive modes. In between these two regions there is resonance region where the operation of TCSC is prohibited . In the inductive mode the power flow decreases and in the capacitive mode of TCSC the power flow increases . This is done by varying the firing angle in the system. [5,6,7,8,9]

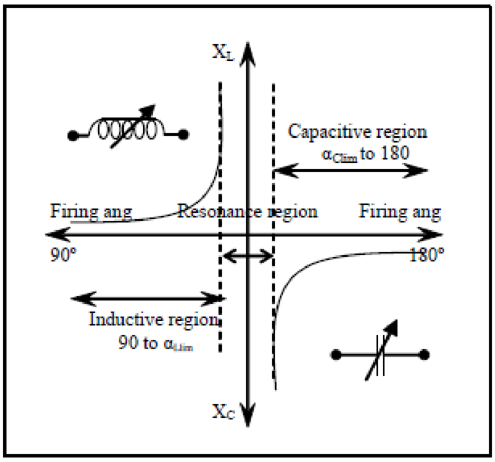

Fig 1. TCSC Reactance Characteristic Curve.

The hardware implementation of the system was done using inductor , zero crossing detector,optoisolator. The frequency response curves were plotted for different combinations of capacitor and inductor values of TCSC. The values of TCSC inductor and capacitor should be properly chosen to have both the inductive and capacitve modes of operation of TCSC. The value of resonant factor should be properly chosen otherwise it would lead to multi resonant operating points which will reduce the operating range of TCSC. The system was designed in closed loop mode, and it was found that the closed loop mode gave better results that the open loop system .The transient stability of the system was also improved in closed loop operation of the system. The TCSC was implemented in Kalpakam Khamman line, and the results were analysed for sudden increase or decrease in load. The TCSC was installed in multi bus system, and it was found to effective in congestion management. The TCSC was used for improving the voltage profile of the system . The simulation modelling was done in medium transmission line, Various power quality problems like voltage sag and voltage sag were investigated . The TCSC was found to be effective in mitigating these power quality issues .The harmonic analysis was done for voltage sag and swell with and without installing TCSC device in the system. The open loop impedance control is most commonly used for power flow variation. In the closed loop control, there are constant current and constant angle control, enhanced control, constant power control methods for providing variable series compensation. TCSC is used for improving the system stability, limiting short circuit currents, damping oscillations, mitigating SSR. In the present work the TCSC is implemented in the system to analyse the power quality issues like voltage sag, voltage swell . The THD analysis of the system is done with various controllers and the results are tabulated. The THD is performed using FFT analysis in MATLAB with Power GUI tool.[10,11,12,13,14].

3. METHODOLOGY

The system is checked for

1. Without any controller /device (only transmission line)
2. With (Fixed Capacitor) FC alone.
3. With FC and TCSC
4. With FC and two modules of TCSC.

FC and TCSC are used to improve the power quality problem like voltage sag and voltage swell in the present work. The comparison is done for three cases with varying loads at different time intervals. The receiving end voltage and harmonic analysis are made with the inclusion of various devices and various results are plotted. [15,16,17,19,20]

3.1 Test system

A 3 phase, 400 kV Transmission line which is 400 km long is considered as a case study for comparing the power flow in the line without any controller and with various controllers/devices like FC and TCSC. Technical Data of TCSC system used for comparing the controllers. [13,14,15,18].

Length of line = 400 km

Inductance /km(L)= 1.044 mH .

Total line Inductance for 400 km=417.6 mH.

Total line reactance =131.19 ohms.

Fixed Capacitance = 90.7 µF

KB TCSC Capacitor=306 µF

KB TCSC Inductor=4.4 mH.

For 0.0 to 0.2 sec the connected load was 350 MW for all the three cases. Then the load is varied as follows:

Case 1.

Load first increase at 0.2 sec by 300 MW and then decrease at 0.6 sec by 300 MW.

Case 2.

Load first decrease at 0.2 sec by 300 MW and then increase at 0.6 sec by 300 MW.

Case 3.

Load first increase at 0.2 sec by 300 MW and further increase at 0.6 sec by 300 MW.

3.2 Simulation diagrams

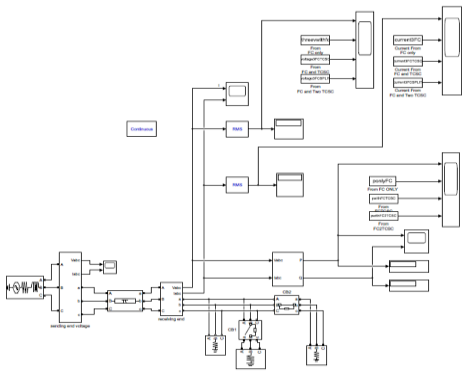

Fig.2 Simulation Diagram for Uncompensated System (Line only)

The simulation diagram for the uncompensated case of fig 2 consists of three phase AC source, pai section line, measurement block,display,scope,circuit breaker, power measurement block. In figure 3 the simulation diagram includes Fixed capacitor in the system. In Figure 4 the simulation diagram includes one Fixed Capacitor and TCSC. The firing angles to the TCSC are provided using Synchronised 6 pulse generator. The two TCSCs are connected in cascade in figure no 5 with FC. The firing angles in all the cases are kept 180º.The POWERGUI is kept in continuous mode in all the cases. There are two circuit breakers in the system for varying loads.

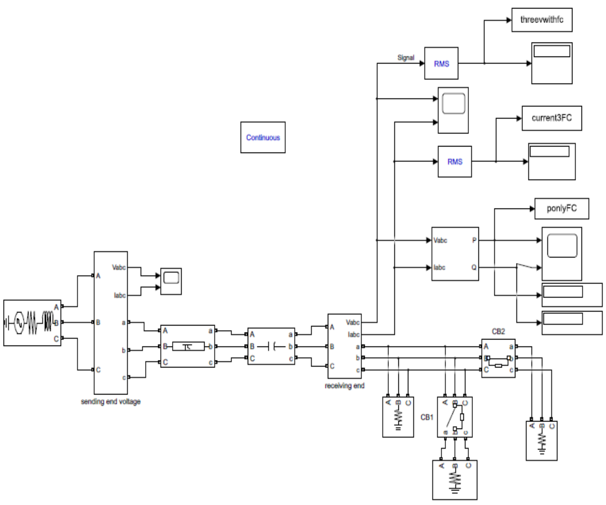

Fig.3. Simulation Diagram of the system including Fixed Capacitor (FC)

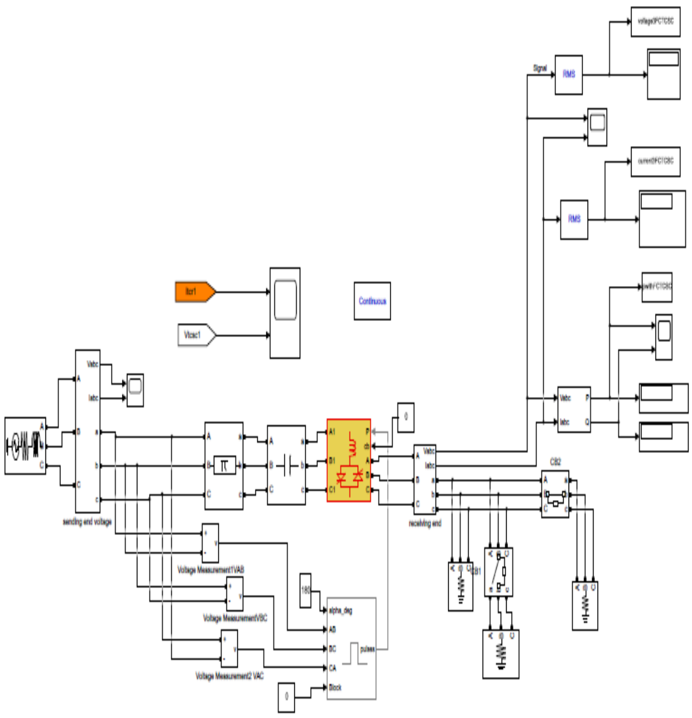

Fig.4. Simulation Diagram of the system including Fixed Capacitor (FC) and TCSC

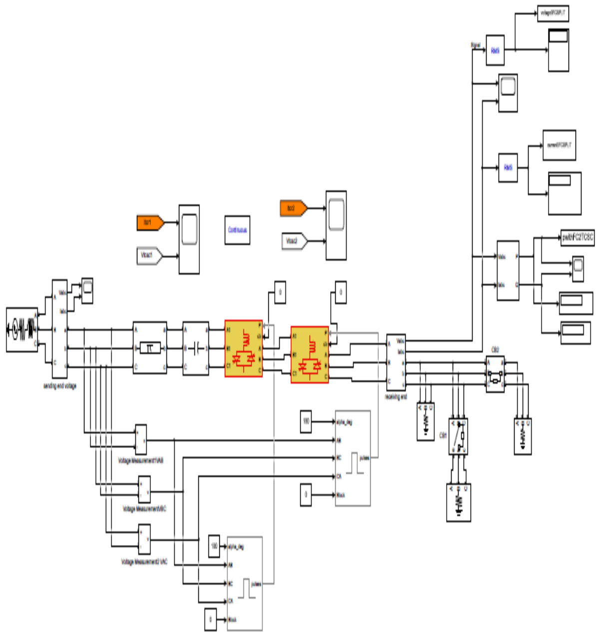

Fig.5. Simulation Diagram of the system including Fixed Capacitor (FC) and Two TCSC

3.3 Performance Analysis and Results

The above controllers/devices are tested for power flow control using varying loads. The three cases are:

3.3.1 Case 1. (Voltage Sag)

From 0.0 to 0.2 sec the connected load is 350MW.From 0.2 to 0.6 sec the connected load is 650 MW (load increase by 300 MW at 0.2 sec). From 0.6 to 1.0 sec the connected load is again 350 MW ((load decrease by 300 MW at 0.6 sec)

Table 1. for Case 1.

S. No	Controller	Active Power (MW)	Receiving End Voltage (kV)	Voltage Sag in %	THD% (voltage)
1	Line only	590.40	219.90	14.30	0.41
2	Line with FC only	653.00	231.30	10.44	0.73
3	Line with FC and TCSC	672.00	234.60	9.79	0.35
4	Line with FC and Two TCSC	690.00	237.80	9.21	0.19

3.3.2 Various graphs and figures

A. The power flow, voltage and current profile at the receiving end are analysed.

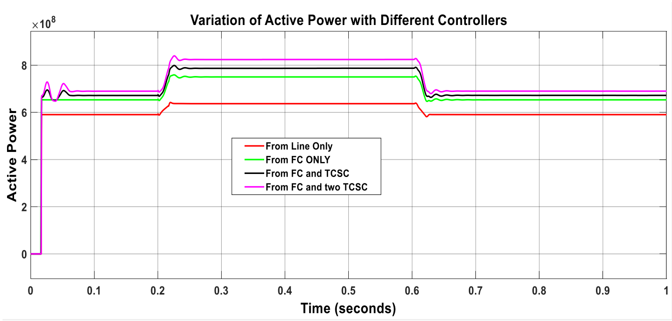

Fig.6 Variation of Active power with Different Controllers

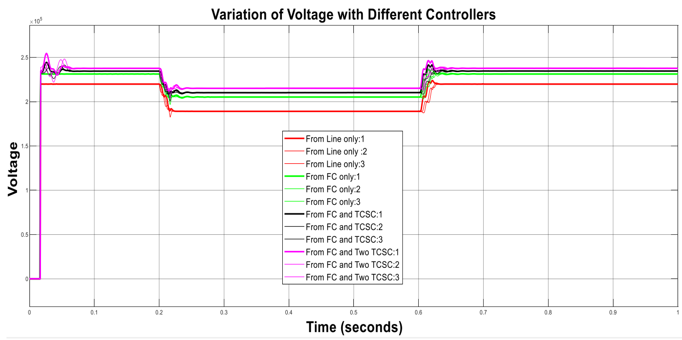

Fig.7 Variation of Voltage with Different Controllers

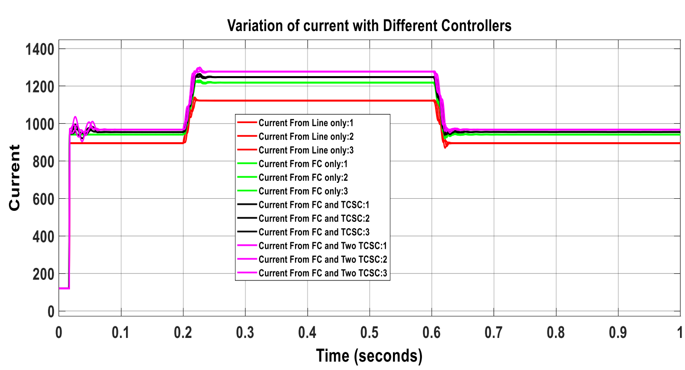

Fig.8 Variation of current with Different Controllers/devices

Description: From the results of figure 6,7,8 it is seen that active power transfer is increasing from without any controller to FC with two TCSC controller till 0.2 sec. There is proper alignment. At 0.2 sec the load is increased by 300 MW so the active power transfer to the load is increased and at 0.6 sec the load is decreased by 300MW, so the active power transfer is decreased at 0.6 sec in the figure 6. But the power transfer is max when FC with two TCSCs is used. Similar results are seen for voltage and current in figure 7 and figure 8.

B. The Receiving End Voltage with all the different controllers/devices

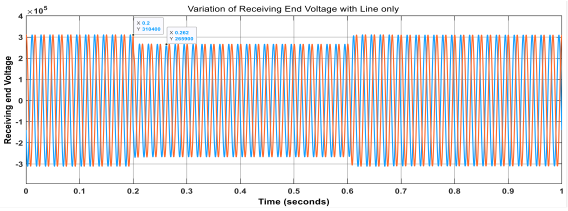

Fig.9. Receiving End voltage without any controller

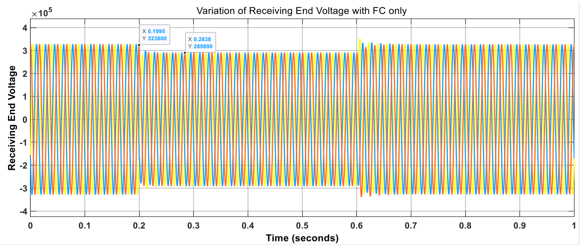

Fig.10. Receiving End voltage with FC only

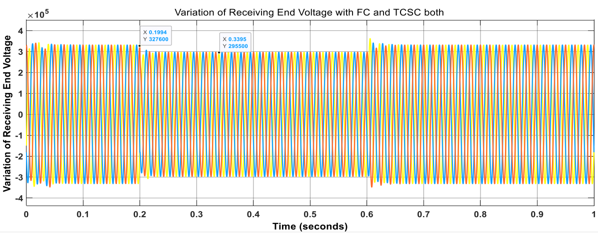

Fig.11. Receiving End voltage with FC and TCSC

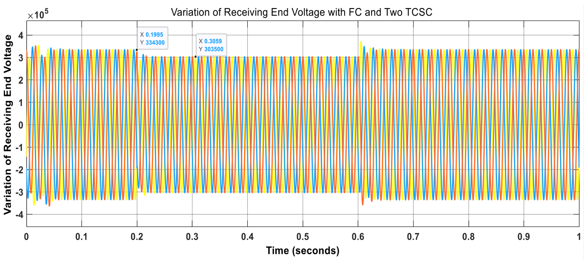

Fig.12. Receiving End voltage with FC and Two TCSC

Description: Figure 9,10,11,12 show the variation of receiving end voltage without any controller and with different controllers. Due to load increase at 0.2 sec the voltage decreased and load decrease at 0.6 sec the voltage is again increased. With different controllers the magnitude of voltage increase is different and shown in the table 1.

C. THD analysis with all the different controllers/**devices.**

To calculate the THD in voltage the FFT analysis tool of POWER GUI in MATLAB is used here. This THD gives information about how much distortion is there in voltage due to the presence of harmonics in the signal. It is an important measurement in power system and should be low. In a pure sinusoidal signal, there is no harmonic distortion .If the signal does not look like a sine wave there are harmonic distortions in the signal. The harmonic distortion is caused by nonlinear loads in the system If the THD is low it means that the power factor is high, and the efficiency of the system is also high. The peak currents are lower in the system. The ways to control harmonics are reduction of the harmonic currents which are produced by load, filters should be added, the frequency response of the system is to be modified using capacitors ,inductors and filters. The THD is also significant for power factor calculation with nonlinear loads.

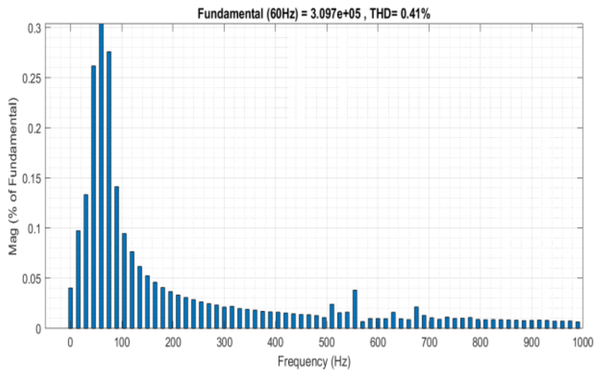

Fig.13. THD voltage without any Compensation

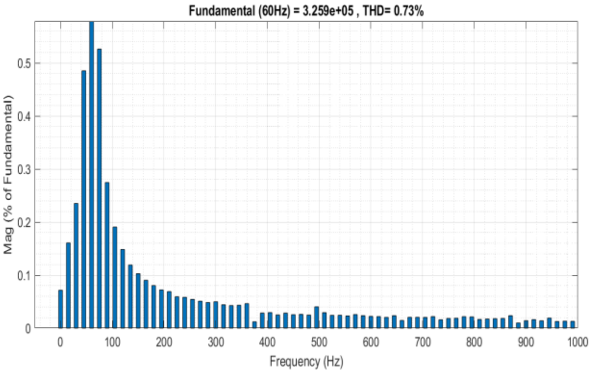

Fig.14. THD voltage with FC alone

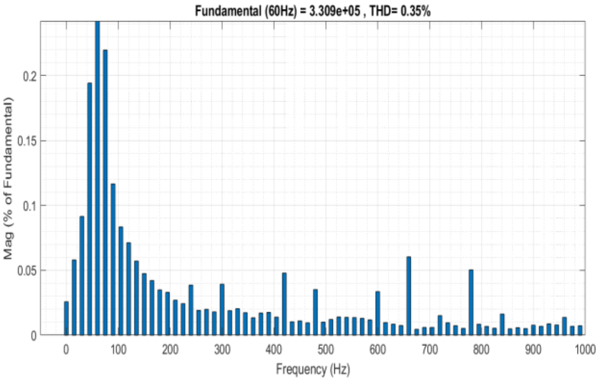

Fig.15. THD voltage with FC and TCSC

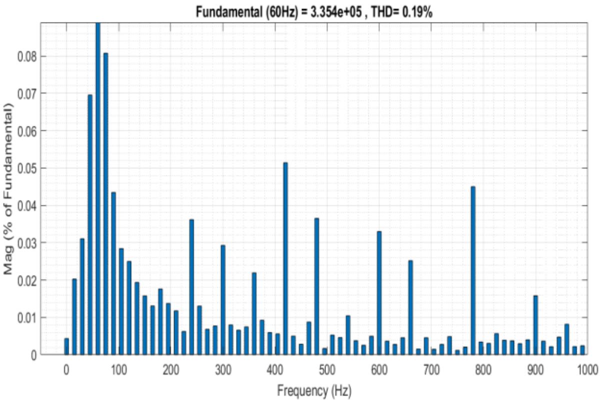

Fig.16. THD voltage with FC and Two TCSC

Description: Figure13,14,15,16 show the Voltage THD without any controller and with different controllers. The THD voltage is decreasing with different controllers as shown in table 1. The control system is well designed to mitigate the voltage sag consequences during load variation and emergencies. The TCSC can be used to mitigate power quality problems.

3.3.3 Case 2. (Voltage Swell)

From 0.0 to 0.2 sec the connected load is 350 MW. From 0.2 to 0.6 sec the connected load is 50 MW (load decrease by 300 MW at 0.2 sec). From 0.6 to 1.0 sec the connected load is again 350 MW. (Load increase by 300 MW at 0.6 sec)

Table.2 for Case 2.

S. No	Controller	Active Power (MW)	Voltage (kV)	Voltage Swell in %	THD voltage %
1	Line only	590.50	220.00	13.28	1.55
2	Line with FC only	653.00	231.30	9.88	1.53
3	Line with FC and TCSC	672.60	234.70	9.95	0.43
4	Line with FC and Two TCSC	690.30	237.70	8.35	0.25

3.3.4. Various Figures and Graphs

A. The power flow, voltage and current profile at the receiving end are analysed.

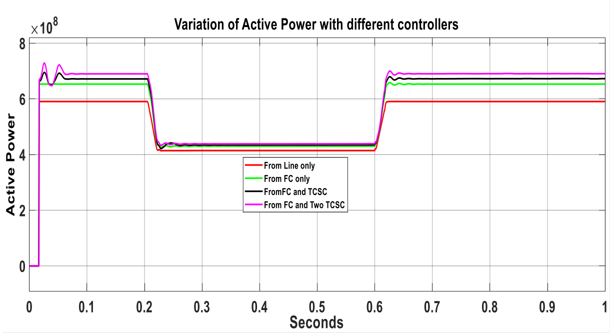

Fig 17. Variation of Active power with different controllers/devices

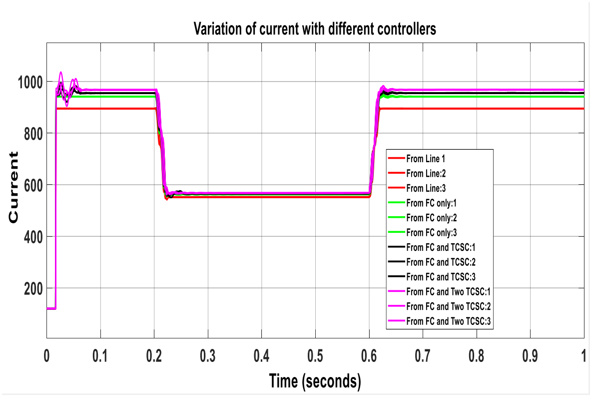

Fig 18. Variation of current with different controllers/devices

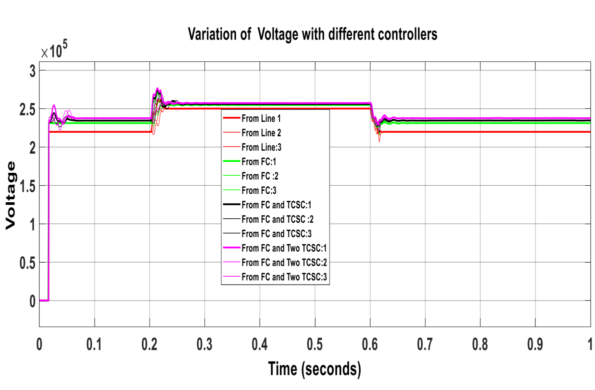

Fig 19. Variation of voltage with different controllers/devices

Description: From the results of figure 17,18,19 it is seen that active power transfer is increasing from without any controller to the system with FC and two TCSC till 0.2 sec. There is proper alignment. At 0.2 sec the load is decreased by 300 MW so the active power transfer to the load is decreased and at 0.6 sec the load is increased by 300MW, so the active power transfer is increased at 0.6 sec. Similar results are seen for voltage and current in figure 18, 19. But the active power transfer is maximum in all the time variation with using a combination of FC and two TCSCs.

B. Receiving End Voltage with all the different Controllers/devices

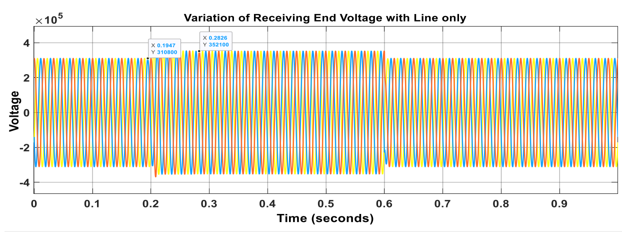

Fig.20 Variation of Receiving End voltage without any Controller

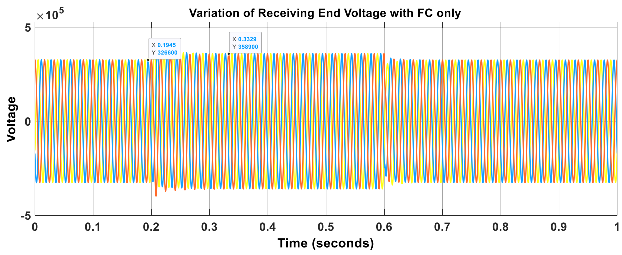

Fig.21 Variation of Receiving End voltage with FC alone

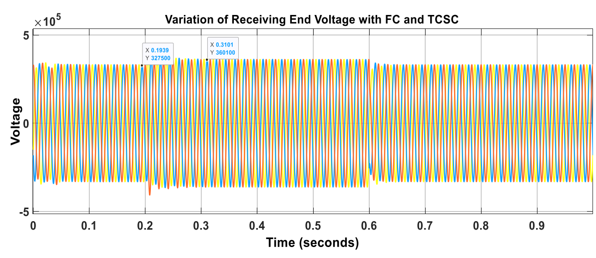

Fig.22 Variation of Receiving End voltage with FC and TCSC

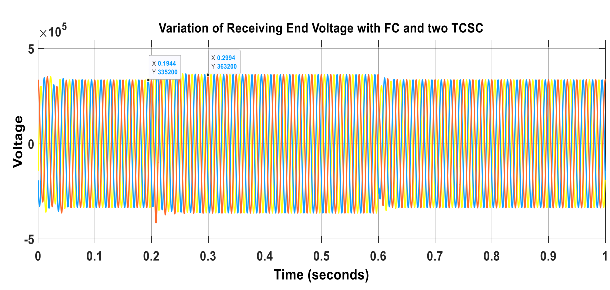

Fig.23 Variation of Receiving End voltage with FC and Two TCSC

Description: Figures 20,21,22,23 show the variation of receiving end voltage without any controller and with different controllers. Due to load decrease at 0.2 sec the voltage is increased and load increase at

0.6 sec the voltage is again decreased. With different controllers the magnitude of voltage increase is different and is shown in the table 2.

C. THD analysis with all the different controllers/devices

The THD analysis is performed for all the controllers and the results are shown in the following figures.

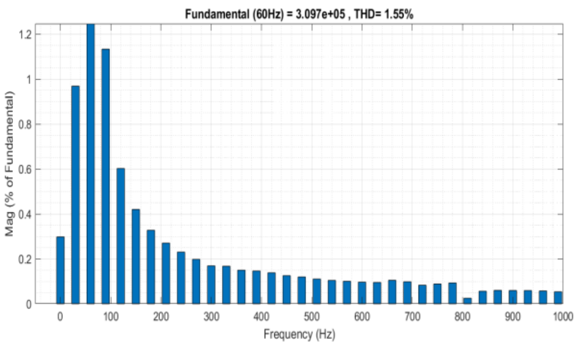

Fig 24. THD voltage without any Controller

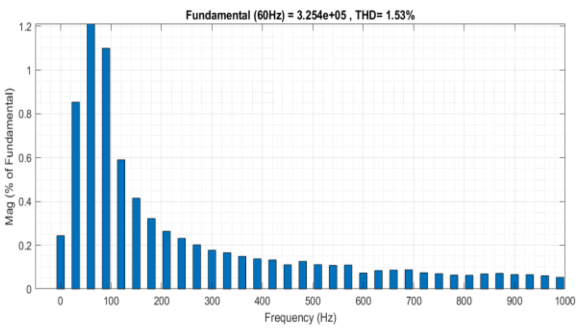

Fig 25. THD voltage with FC alone

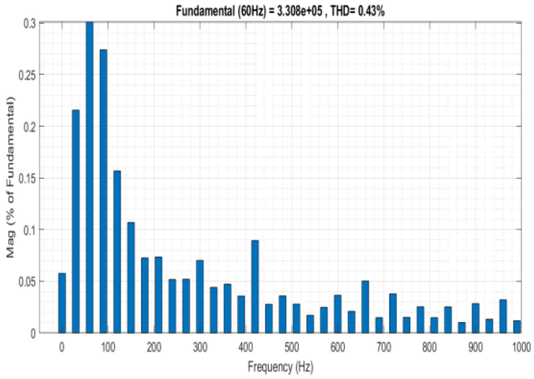

Fig 26. THD voltage with FC and TCSC

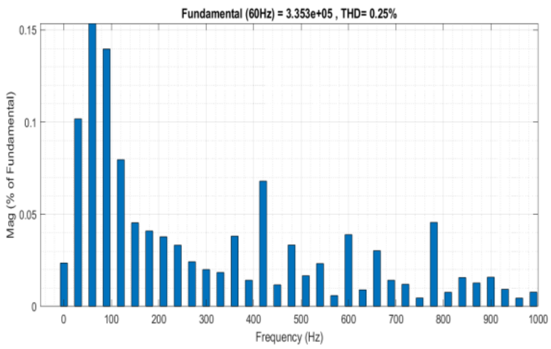

Fig 27. THD voltage with FC and Two TCSC

Description: Figures 24,25,26,27show the Voltage THD without any controller and with different controllers. The THD voltage is decreasing with different controllers as shown in table 2. The TCSC control system is well designed to mitigate the voltage swell consequences during load variation and emergencies. The TCSC can be used to mitigate power quality problems.

3.3.5 Case 3. Load increase and then further increase

From 0.0 to 0.2 sec the connected load is 350MW.From 0.2 to 0.6 sec the connected load is 650 MW. (Load increase by 300 MW at 0.2 sec) From 0.6 to 1.0 sec the connected load is again 950 MW. (Load increase by 300 MW again at 0.6 sec)

Table .3 for Case 3.

S. No	**Controller**	**Active Power (MW)**	**Voltage (kV)**	**THD Voltage %**
1	Line only	636.90	189.20	1.03
2	Line with FC only	750.20	205.30	0.80
3	Line with FC and TCSC	787.20	210.40	0.28

4	Line with FC and Two TCSC	824.40	215.20	0.06

3.3.6 Various Figures and Graphs

A. The power flow, voltage and current profile at the receiving end are analysed.

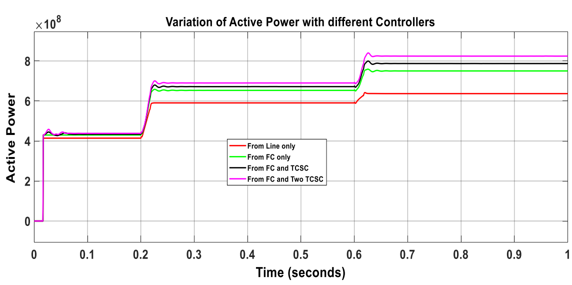

Fig.28. Variation of Active Power with different Controllers/devices

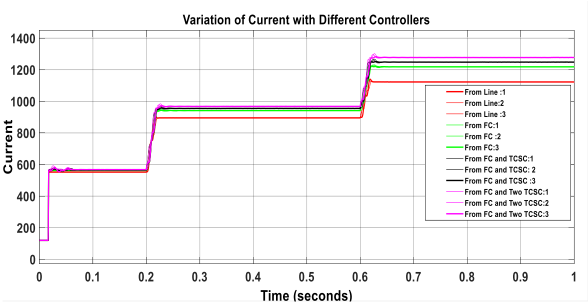

Fig.29. Variation of current with different Controllers/devices

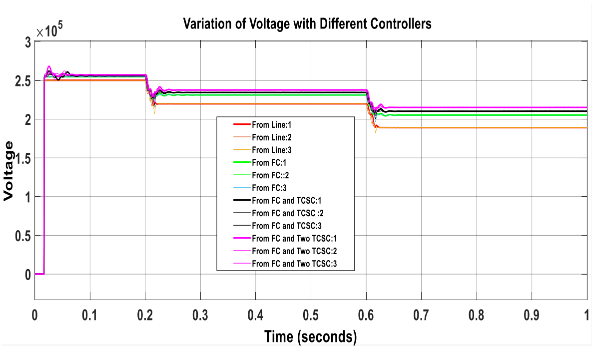

Fig.30. Variation of Voltage with different Controllers/devices

Description: From the results of figures 28,29,30 it is seen that active power transfer is increasing from without any controller to controller with FC and two TCSC. There is proper alignment. At 0.2 sec the load is increased by 300 MW so the active power transfer to the load is increased and at 0.6 sec the load is again increased by 300MW, so the active power transfer is increased again at 0.6 sec in the figure 28. Similar results are seen for current and voltage in figure 29,30.

B. Receiving End Voltage with all the different Controllers

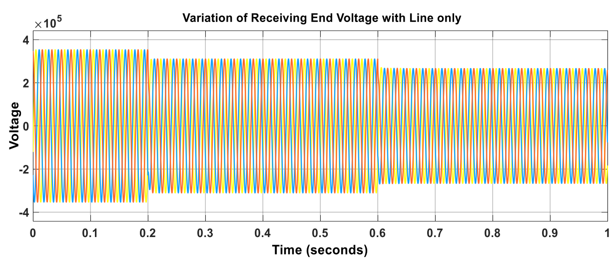

Fig.31.Variation of Receiving end voltage without any controller

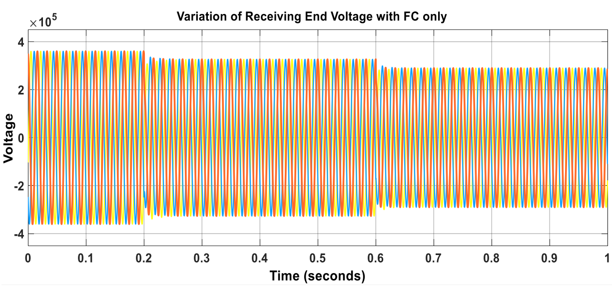

Fig.32.Variation of Receiving end voltage with FC alone

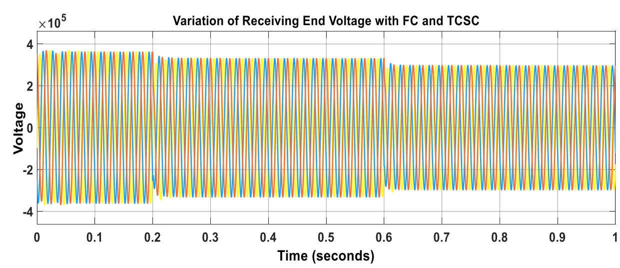

Fig.33.Variation of Receiving end voltage with FC and TCSC

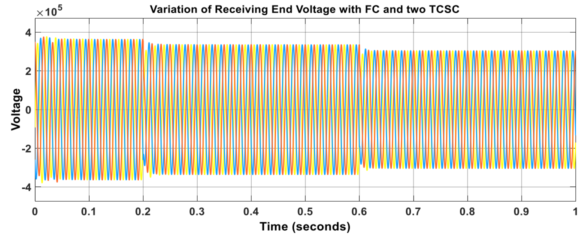

Fig.34.Variation of Receiving end voltage with FC and Two TCSC

Description: Figures 31,32,33,34 show the variation of receiving end voltage without any controller and with different controllers. Due to load increase at 0.2 sec the voltage is decreased, and load again increase at 0.6 sec the voltage is again decreased. With different controllers the magnitude of voltage increase is different and is shown in the table 3.

C. THD analysis with all the different controllers/devices

The THD analysis is performed for all the controllers and the results are shown in the figures.

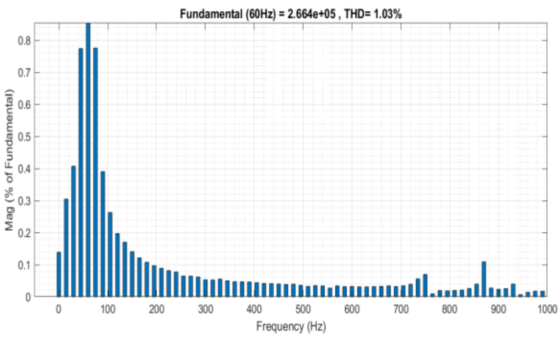

Fig.35 THD Voltage without any Controller.

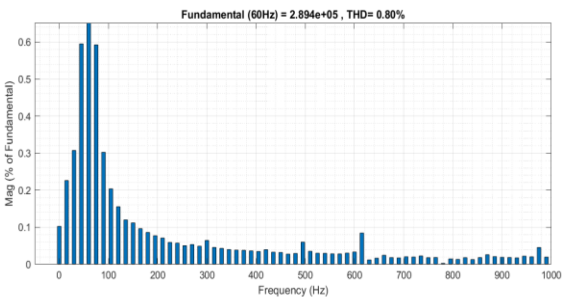

Fig.36 THD Voltage with FC alone.

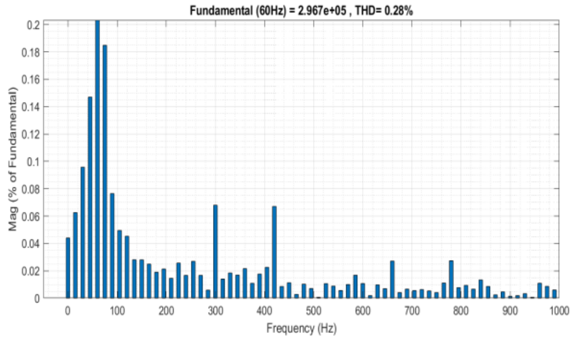

Fig.37 THD Voltage with FC and TCSC

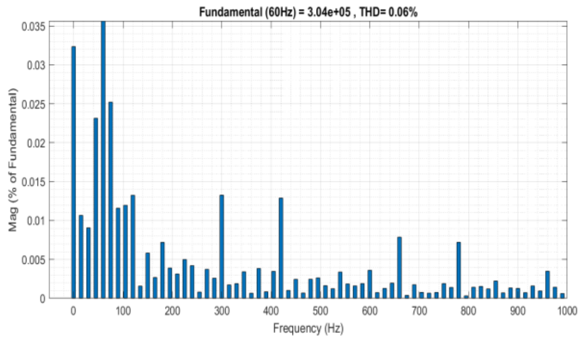

Fig.38 THD Voltage with FC and Two TCSC

Description: Figures 35,36,37,38 show the voltage THD without any controller and with different controllers. The firing angles of TCSC are adjusted to have less distortion. The THD voltage is decreasing with different controllers as shown in table 3. The dynamics of TCSC influence the voltage of the power system and thus it can be used to mitigate the power quality problems.

4. CONCLUSION AND FUTURE WORK

The power demand is increasing at a rapid rate, but the generation and transmission facilities are not developing at the same rate. There are limited resources and restrictions due to environment also. So, some transmission lines are overloaded and cause problems of stability in the system. FACTS devices are used in the system for controlling power flow and improvement of voltage profile in the system. In the present work the TCSC is used to improve the power flow in the system with variable loads. Three cases of varying load are considered, and various results are shown. The power flow is increased using TCSC in capacitive mode and decreased in inductive mode. The active power is increasing from using FC alone, FC and TCSC, FC and two modules of TCSC. Besides increasing the power flow capacity in the transmission line, TCSC is used in the present work to improve power quality issues like voltage sag and voltage swell. The receiving end voltage, THD voltage, voltage sag and voltage swell results are shown using various controllers. The active power, voltage and current are compared using different controllers and the results are plotted. The active power transfer to the load is increasing from without any controller to using a combination of FC and two TCSC. The inclusion of TCSC device improves the stability of the system also due to increase in power transfer to the system. Thus, the system performance ,efficiency and reliability are improved using FC and TCSC. The TCSC is a successful device for meeting various power problems and challenges like shortage of power, stability and oscillations problem ,power quality problems, losses in the transmission and distribution lines .This work can be extended to multimachine bus system. The different optimization algorithm can be applied for the PI controller. The load flow analysis of the system can be performed. TCSC can be used for congestion management in multi machine system. The TCSC can be implemented with Fuzzy logic controller or Artificial neural network-based controller.

5. ACKNOWLEDGEMENT

The authors would like to express sincere thanks to Electrical and Electronics Engineering Department, Principal Ghousia College of Engineering for providing extended support to carry out this work.

6. REFERENCES

[1] Kusum Arora, SK Agarwal Narendra Kumar Dharamveer, “Simulation Aspect of Thyristor Controlled Series Compensator in Power System,” IOSR Journal of Engineering, vol.3, Issue -4, pp. 17-26, April 2013.

[2] Bhakti S Nitve, “Modelling, Simulation and Analysis of Thyristor Controlled Series Capacitor (TCSC),” Journal of Smart Grid Technology, vol.2, Issue-2, pp. 1-14.

[3] Sunita Tiwari, S.P. Shukla, “Compensation by TCSC in open loop control system,” International Journal of Advanced Engineering Technology, vol.3, Issue-1, pp.175-179, Jan-March 2012.

[4] Sangeetha AP. S. Padma, “Study of Thyristor Controlled Series Compensator for the Enhancement of Power Flow and Stability,” International Journal of Scientific and Engineering Research, vol. 5, Issue-4, pp.112-117, April 2014

[5] Sangeetha A. P., S. Padma B. Thiyaneswaran, “HDL based Control Circuit for Power Flow Regulation of TCSC,” Proceedings of the International Conference on Advancement in Electrical and Electronics Engineering, pp.c20-c24, January 2015.

[6] K. Manjusha,S. Balamurugan, N.Krithika, “Real Power Flow Control in Transmission System using TCSC,” Biennial International Conference on Power and Energy Systems: Towards Sustainable Energy (PESTSE),2016.

[7] Pavan Kumar Shirur, Aravind Patil, D Venkatesh, “Modelling and Simulation of Thyristor Controlled Series Compensator connected with Single Source Transmission Line, “School of Electrical Engineering.

[8] Deepa Choudhary “Enhancement of Power System Voltage Stability Using SVC and SSSC,” International Journal

of Scientific and Engineering Research, vol.4, Issue-1, pp.1-6, Jan- 2013.

[9] Anil Kumar, Jyoti Shrivastava," Modelling of Power System for improving stability using Thyristor Controlled Series Capacitor," International Journal of Science, Engineering and Technology Research, vol.5, Issue-5, pp.1434-1438, May 2016.

[10] Satvinder Singh, Pawan Kumar, Atma Ram, "Modelling and Analysis of Thyristor controlled Series Capacitor using MATLAB/Simulink," International Journal of New Innovations in Engineering and Technology (IJNIET), vol.1, Issue-3, pp.61-66, February 2013.

[11] Pravin G. Dhawale, Sandip S. Godhade, "Design and Implementation of TCSC for Power Flow Enhancement".

[12] Anita Kanwar, Rachit Saxena, "Behaviour of TCSC in transmission line using MATLAB/Simulation," International Journal of Innovative Research in Electrical, Electronics, Instrumentation and Control Engineering, vol.2, Issue -5, pp.195-197, May 2015.

[13] G.V.T. Prudhviraj, Raghu, S. Meikandasivam and D. Vijayakumar, "Implementing TCSC Device in Kalpakam-Khammam Line for Power Flow Enhancement," "International Conference on Circuits, Power and Computing Technologies, pp.138-141, 2013.

[14] Dhanush Patel, Kashyap Detroja, Mohit Patel, Krunal Rana, Praful Chudasama, "Voltage Stability Improvement using Thyristor Controlled Series Capacitor," International Journal of Electrical and Electronics Engineering, vol.3, Issue-5, pp.1-3, May 2016.

[15] Yadu Ram,Dr.Dharmendra Kumar Singh, Amit Agrawal, "Voltage Profile improvement with Thyristor controlled series capacitor, "International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, vol.4, Issue-6, pp.4999-5005, June 2015.

[16] Uma Rathore, Dharmendra Kumar Singh "A Study to Improve the Power Quality of Transmission Line Using TCSC," International Journal of Engineering Science and Computing, vol.6, Issue-3, pp.2396-2399, March 2016.

[17] Lukesh Kumar Sahu, Ankit Dubey, Shruti Soni, "Power Quality Improvement by Using TCSC," International Journal of Research Studies in Science, Engineering and Technology, vol. 1, Issue-2, pp.56-59, May 2014.

[18] A Sivasankar, T.S.Sirish, "Real Power Flow Control in Transmission Line Using TCSC with Fuzzy Controller," International Journal of Engineering Research and Application,vol.7, Issue-9, pp.55-60, Sept 2017.

[19] D.Chatterjee, A.Mitra,"Simulink based three phase closed loop power flow control using TCSC," International Journal of scientific research and management,vol.3,Issue-4,pp.2644-2651,2015.

[20] Kailash Bharatbhai Khimsuriya,Mehul Dansinh Solanki," Power Transfer capability Improvement of transmission line using TCSC," International Journal for Scientific Research and Development,vol.4,Issue-02,pp.1428-1431,2016.