International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 5 Issue 2, January-February 2021 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Performance Analysis and Comparison of Transmission Line (Varying the Capacitor Value) with (PI and PID) Controllers using TCSC

Sameer Khan, Dr. Aziz Ahmad

Electrical & Electronics Engineering, Al-Falah School of Engineering and Technology,
Al-Falah University, Dhauj, Faridabad, Haryana, India

ABSTRACT

In this paper, performance analysis of transmission line (11 KV) with thyristor controlled series capacitor providing stability and power enhancement under the application of PI and PID controllers is compared after varying the capacitance of transmission line capacitor. Simulation results of uncompensated and also for compensated transmission line of 11 KV are compared with PI and PID controllers working with the transmission line system for improving the real power as well as reactive power in the supportive MATLAB environment; self tuning is applied through MATLAB-PID TUNER for both (PID and PI) controllers.

KEYWORDS: *FACTS; PI; PID; Power System; Power Quality; Transmission lines*

How to cite this paper: Sameer Khan | Dr. Aziz Ahmad "Performance Analysis and Comparison of Transmission Line (Varying the Capacitor Value) with (PI and PID) Controllers using TCSC" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-5 | Issue-2, February 2021, pp.267-272, URL: www.ijtsrd.com/papers/ijtsrd38401.pdf

IJTSRD38401

INTRODUCTION

Incorporation of power electronics in power system provides flexibility to the AC transmission system with enhancement in power, controllability with good demonstration of transfer in power [10]. Reduction in TCSC system's cost, complexity and power loss is due to the usage of thyristor providing natural commutation and switching at low frequency [4]. The effectiveness of TCSC device is checked by simulation before its real implementation into any power system for ensuring the economical operation desired for the smooth functioning of the designed power system [1]. TCSC acts accordingly to the contemporary loading condition of transmission line with the introduction of desired reactance observing the present state of load in series with the transmission line; sometimes line are heavily loaded then capacitive reactance is provided by TCSC while under light load condition inductive reactance is made to enter the transmission system by TCSC device for the enhancement in power transfer of the operational power system; back-to-back thyristor along with reactor TCR highly responsible for the complete control of the total reactance [7]. TCSC providing the range of solutions to the problems like: scheduling of the fast power flow; limiting the short circuit currents; regulating the continuous reactance; mitigate the sub-synchronous resonance(SSR); damping the power oscillation; enhancing the transient stability; and TCSC along with PID controller is helpful in industrial operational work [6]. In this paper, performance analysis of transmission line (11 KV) model with TCSC compensated model with the addition of PID controller and PI controller addition to the said transmission system model separately compared; firstly uncompensated system performance is studied then TCSC compensation technique is applied to make the system compensated then finally the performance of the 11 KV transmission model is separately compared and studied with the introduction of PID controller and PI controller independently with varying capacitance values and the controllers performances are compared with TCSC device using MATLAB software.

LITERATURE REVIEW

A. TCSC addition into the transmission system

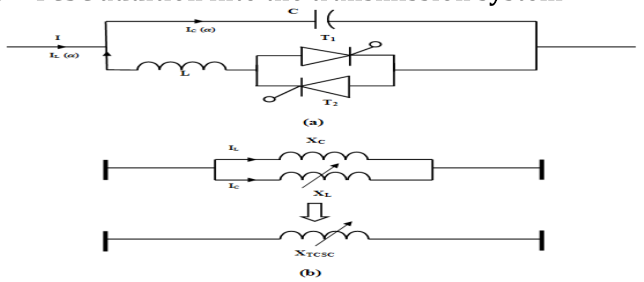

Fig.1.TCSC added in the transmission system (a) Schematic diagram of TCSC (b) TCSC reactance

The simple introduction of TCSC into the transmission system is shown in figure.1 (a). The capacitor series connection with parallel reactor TCR makes a TCSC compensated system in which firing angle of thyristor is adjusted to control TCR [3]. TCR is found in non-conducting state at 180° while at 90°, it comes to full conduction [3]. In this TCSC device, GTO (Gate turn-off) thyristor is not required [3]. The impedance of the TCSC system due to LC circuit is given by equation (1)

$$X_{TCSC} = \frac{X_L X_C(\alpha)}{X_L(\alpha) - X_C} \qquad (1)$$

Where, X_L and X_C are the variable inductive reactance and fixed capacitive reactance respectively and the delay angle is calculated **[10]**.

$$X_L(\alpha) = X_L \frac{\pi}{\pi - 2\alpha - \sin\alpha}, X_L \leq X_L(\alpha) \leq \infty \qquad (2)$$

$$X_C = \frac{1}{\omega_C} = \frac{1}{2\pi fc} \qquad (3)$$

$$X_L = \omega_L = 2\pi fL \qquad (4)$$

From [10], transmission line compensation (percentage) is given by equation (5)

$$\frac{X_C}{X_L} \times 100 \qquad (5)$$

B. Operational parameters of TCSC

TCSC injects a variable reactance X_{TCSC} in the transmission line as given by equation (6)

$$X_{TCSC}(\alpha) = X_C \left[1 - \frac{K^2}{K^2-1}\left(\frac{\sigma + \sin(\sigma)}{\pi}\right) + \frac{4K^2}{K^2-1} \cos^2\left(\frac{\sigma}{2}\right) \frac{K\tan\left(\frac{K\sigma}{2}\right) - \tan\left(\frac{\sigma}{2}\right)}{\pi}\right] \qquad (6)$$

Where, the values of σ, K and λ are given by equations (7), (8) and (9) respectively.

$$\sigma \text{ is equal to } 2(\pi - \alpha) \qquad (7)$$

$$K \text{ is equal to } \frac{\lambda}{\omega} \qquad (8)$$

$$\lambda \text{ is equal to } \frac{1}{\sqrt{LC}} \qquad (9)$$

σ Represents the cyclic portion of thyristor which is in operation state and α being the function of X_{TCSC}, divide the TCSC reactance into Inductive region, capacitive region and in the region of resonance [2].

C. TCSC power controller model with PID controller

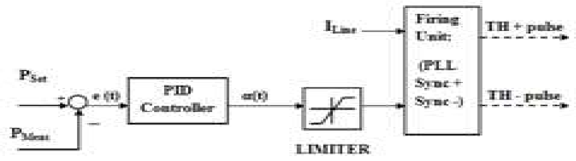

Fig.2.PID control diagram to transmission system

Figure.2 shows the PID control; In PID controller error power signal is found by equation (10) to find firing angle $\alpha(t)$ as PID output written by equation (11)

$$e = P_{REF} - P_{meas} \qquad (10)$$

$$\alpha(T) = K_p\, e(t) + K_i \int_0^t e(t)dt + K_d \frac{de(t)}{dt} \qquad (11)$$

Where, proportional, integral, and derivative gains are written as K_p, K_i and K_d respectively [6].

D. TCSC power controller model with PI controller

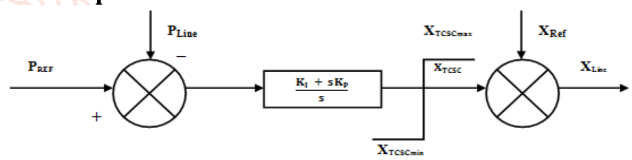

Fig.3.PI control diagram to transmission system

Figure.3 shows the PI control of TCSC-PI transmission system, it changes or controls the TCSC reactance within as written by equation (12) with reference power as P_{REF} and line power as P_{line} [9].

$$X_{TCSC} = (K_P + K_I/S)\ (P_{REF}\ P_{line}) \qquad (12)$$

MODELLING

A. TCSC DEVICE

Figure.1 shows the addition of TCSC device in transmission system; the impedance provided by TCSC is given by equation (13) equation (14) represents the impedance of the reactor, equation (15) tells about the impedance of capacity, equation (16) and (17) state the relationship between the impedances of capacity and reactor and finally equation (18) describes reactance of TCSC with firing angle α from [5].

$$Z_{TCSC} = jX_{TCSC} \qquad (13)$$

$$Z_{TCR} = jX_{TCR} = j\frac{X_L \pi}{2(\pi - \alpha) + \sin 2\alpha} \qquad (14)$$

$$Z_C = -jX_C \qquad (15)$$

$$Z_{TCSC} = Z_C / Z_{TCR} = \frac{-jX_C jX_{TCR}}{-jX_C + jX_{TCR}} \qquad (16)$$

$$= j\frac{X_C X_L}{\frac{X_C}{\pi}(2(\pi - \alpha + \sin 2\alpha) - X_L} \qquad (17)$$

$$X_{TCSC}(\alpha) = \frac{X_C X_L}{\frac{X_C}{\pi}(2(\pi - \alpha) + \sin 2\alpha) - X_L} \qquad (18)$$

B. Power analysis (for P and Q) of transmission line system

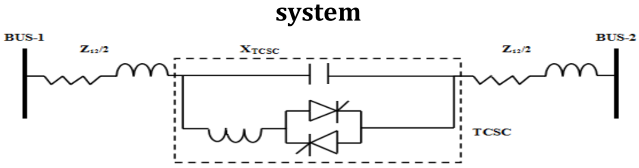

Fig.4. Mounting of TCSC device in transmission line system

Figure.4 representing the implementation of TCSC in transmission line, equation (19), (20), (21) and (22) represent the value of real power (P_{12}), reactive power (Q_{12}), line reactance (X_{LINE}), and TCSC reactance (X_{TCSC}) respectively.

$$P_{12} = \frac{V_1 \times V_2}{Z_{12} - X_{TCSC}} \quad (19)$$

$$Q_{12} = \frac{V_2^2 - (V_1 \times V_2)\cos\delta}{Z_{12} - X_{TCSC}} \quad (20)$$

$$X_{Line} = X_{12} + X_{TCSC} \quad (21)$$

$$X_{TCSC} = K_{TCSC} X_{Line} \quad (22)$$

TCSC changes power flow of the system with changing its capacitive reactance setting [8].

PERFORMANCE ANALYSIS OF THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC) DEVICE

A. Uncompensated (without TCSC) system model

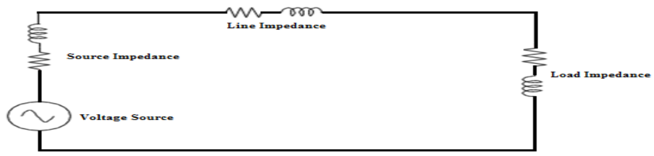

Fig.5.Uncompensated system model

Figure.5 shows the uncompensated system with the source [Phase (deg) = 0, Source Impedance of (0.01+0.001)Ω] and Line Impedance of (5+0.023)Ω provided while load parameters are 25MW and 50 MVAR for the system. Voltage and current (sending as well as receiving) and power flows from simulation (using MATLAB-SIMULINK) are presented in figure 6, figure 7, and figure 8 respectively:

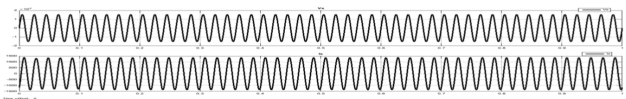

Fig.6.Sending (voltage and current) from supply of uncompensated system

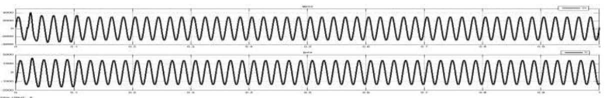

Fig.7.Receiving (voltage and current) at load of uncompensated system

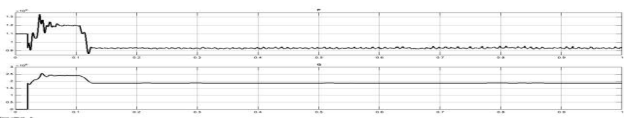

Fig.8.Power curves of uncompensated system model

A. Compensated TCSC transmission line system model

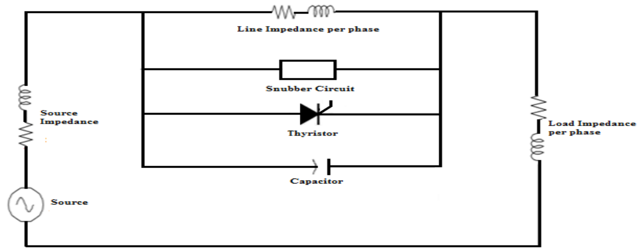

Fig.9.Compensated TCSC system model

The TCSC transmission (11 KV) system model used for providing compensation is displayed in figure.9, system stability is maintained by the fixed value of TCR (100 mH) while the real and reactive power flows are carried out with capacitance = $350\mu F$ in compensated TCSC system models as well as TCSC (including PID and PI controller) transmission line models also and simulation results for compensated system model are shown as below:

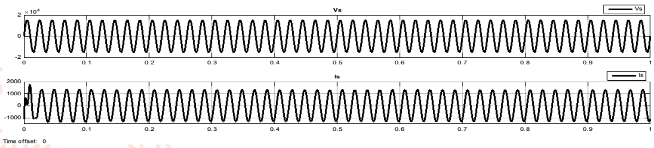

Fig.10.Sending (voltage and current) from supply of compensated TCSC system

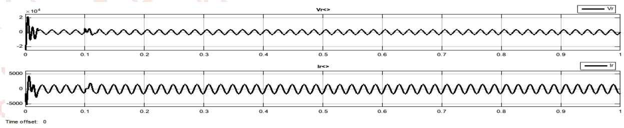

Fig.11.Receiving (voltage and current) at load of Compensated TCSC system

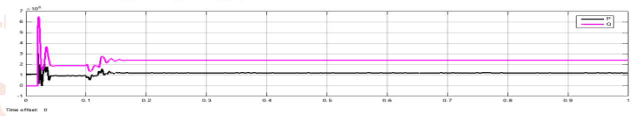

Fig.12. Power curves of compensated system mode

Table I Power flow presentation for TCSC compensated transmission (11 KV) system

S.NO	Capacitor Value (in micro farad)	P (in mega watt)	Q (in mega volt ampere reactive)
1.	50	0.88	1.77
2	200	1.02	2.05
3.	350	1.19	2.39
4.	500	1.41	2.82
5.	600	1.57	3.15
6.	800	1.97	3.99
7.	1000	2.49	5.01
8.	1200	3.10	6.24
9.	1400	3.72	7.52
10.	1500	3.94	7.93

The power flows have been improved from (0.88 to 3.94) MW (P) and (1.77 to 7.93) MVAR (Q) respectively by varying the capacitance in the range (50 to 1500) μF for the stable operation of the transmission system model as shown in table.I. The same range of capacitance is used for both (PID and PI) controller system of transmission line. The firing angle of 90° is used for triggering the thyristor

T_1 and it is also applicable for both the system models comprising of PID and PI controller.

PERFORMANCE ANALYSIS OF COMPENSATED TCSC TRANSMISSION LINE (11 KV) SYSTEM MODEL (with PID CONTROLLER)

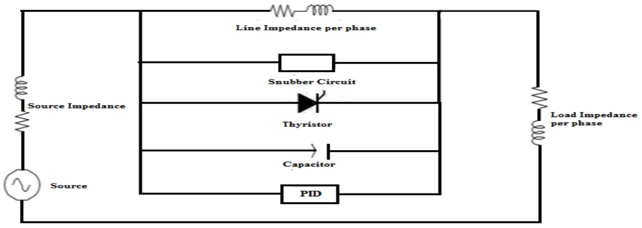

Fig.13. Compensated TCSC system model with PID controller

The compensated TCSC transmission line system model with PID controller is shown in figure.13. The Function Block Parameter: Gain = -1 at (P= 0, I= -1, D = 0) selected for obtaining the results. PID controller based TCSC system model simulation results are as below:

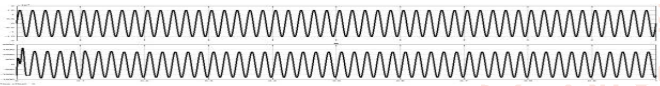

Fig.14.Sending (voltage and current) from source of TCSC-PID

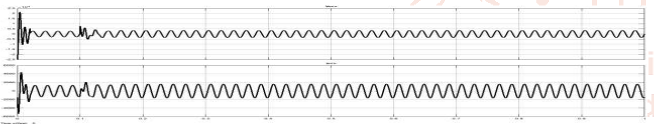

Fig.15.Receiving (voltage and current) at load of TCSC-PID

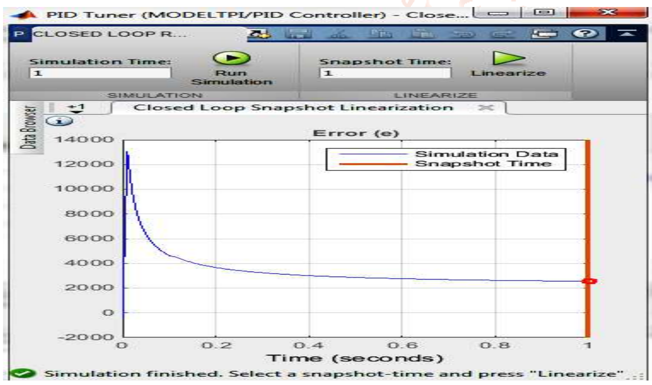

Fig.16.Close Loop Snapshot Linearization for compensated TCSC-PID system model

The closed loop snapshot linearization for TCSC-PID transmission line (11 KV) system model is given in figure.16 is selected for the system model to study the performance of the given transmission system model.

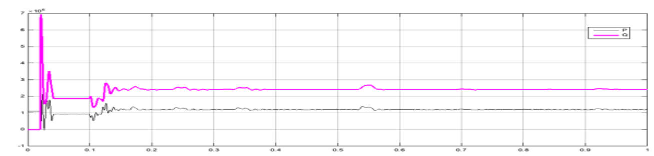

Fig.17.Power curves for compensated TCSC-PID system model

TABLE II Power flow presentation by TCSC-PID compensated transmission (11 KV) system

S.NO	Capacitor Value (in micro farad)	P (in mega watt)	Q (in mega volt ampere reactive)
1.	50	1.028	1.905
2	200	1.042	2.066
3.	350	1.21	2.399
4.	500	1.438	2.829
5.	600	1.587	3.161
6.	800	2.008	3.975
7.	1000	2.56	5.018
8.	1200	3.12	6.228
9.	1400	3.709	7.47
10.	1500	3.905	7.961

The real (P) and reactive power (Q) flows have shown improvement from (1.028 to 3.905) MW and (1.905 to 7.961) MVAR, respectively in the range of capacitance from (50 to 1500) µF as shown in table.II.

PERFORMANCE ANALYSIS OF COMPENSATED TCSC SYSTEM MODEL (WITH PI CONTROLLER)

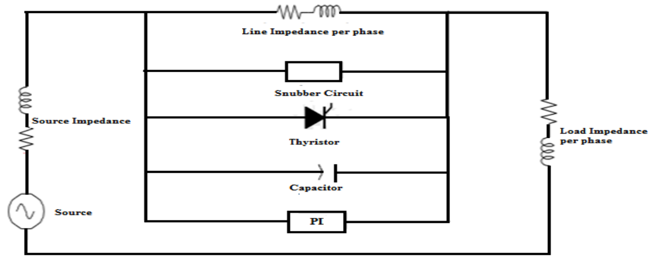

Fig.18.Compensated TCSC system model with PI controller

Compensated TCSC model with PI controller is shown in figure.19. The Function Block Parameter: Gain = -1 at (P= 0, I= 1, D = 0) selected for obtaining the results.

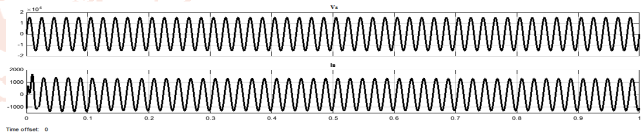

Fig.19. Sending (voltage and current) from source of TCSC-PI system

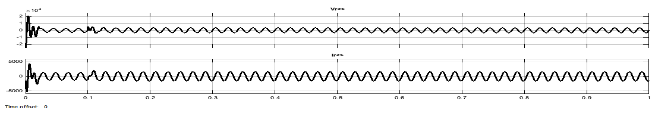

Fig.20.Receiving (voltage and current) at load of TCSC-PI system

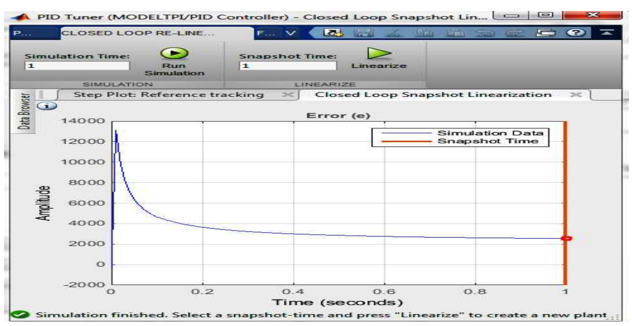

Fig.21.Close Loop Snapshot Linearization for compensated TCSC-PI system model

The close loop snapshot linearization for TCSC-PI transmission line (11 KV) system model in figure.21.

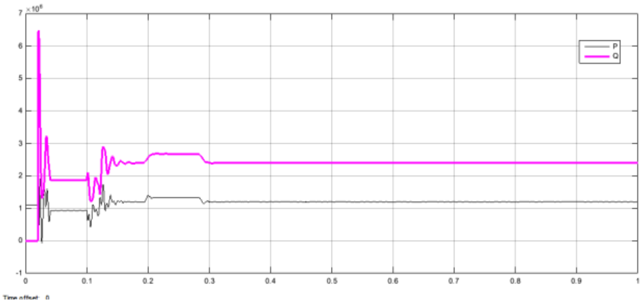

Fig.22. Power curves for compensated TCSC-PI system

Table III Power flow presentation for TCSC-PI compensated transmission (11KV) system

S.NO	Capacitor Value (in micro farad)	P (in mega watt)	Q (in mega volt ampere reactive)
1.	50	0.886	1.77
2	200	1.033	2.069
3.	350	1.2	2.4
4.	500	1.416	2.825
5.	600	1.586	3.163
6.	800	1.975	3.988
7.	1000	2.499	5.018
8.	1200	3.092	6.227
9.	1400	3.723	7.429
10.	1500	3.94	7.895

The TCSC compensated transmission line system with PI controller provides improvement in real and reactive power flows from (0.886 to 3.94) MW and (1.77 to 7.895) MVAR respectively as shown in table.III.

RESULTS

A. Compensation of transmission line (11 KV) system using TCSC

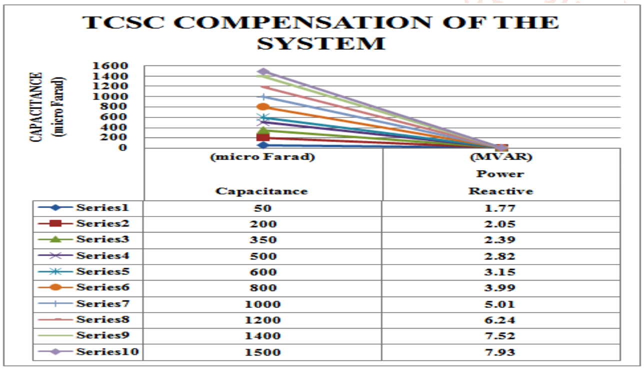

Fig.23. Variation of power flow of TCSC compensated system within the range of capacitance (50 to 1500) *μF*

The compensation of the transmission line after varying capacitor values of TCSC connected system results in the improvement of reactive power with increasing capacitance value is shown in figure.23.

B. Compensation of transmission line (11 KV) system using TCSC (with PID) controller

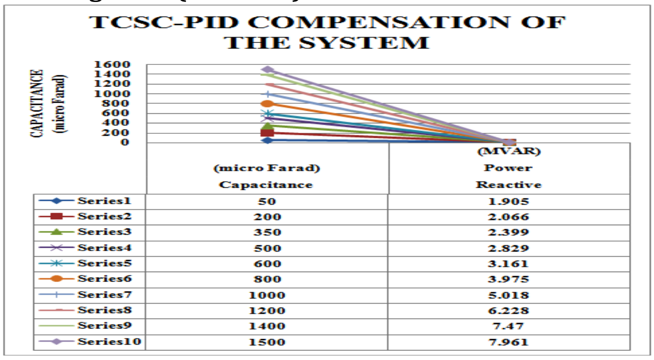

Fig.24. Variation of power flow of TCSC-PID compensated system within the range of capacitance (50 to 1500) μF

Figure.24 shows the improvement in reactive power with increasing capacitance. It is found that the transmission system containing TCSC with PID controller gives better performance than the transmission system using TCSC.

C. Compensation of transmission line (11 KV) system using TCSC (with PI) controller

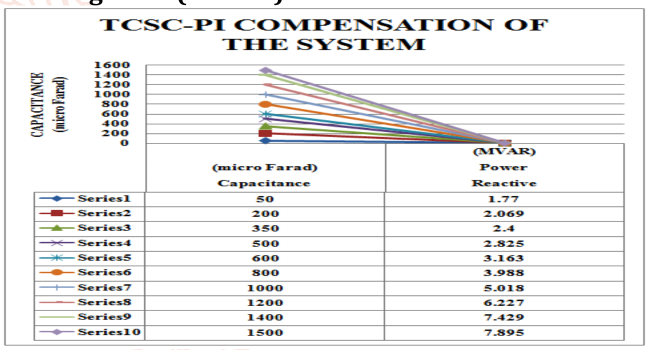

Fig.25. Variation of power flow of TCSC-PI system within the range of capacitance (50 to 1500) *μF*

Figure.25 shows the improvement of reactive power with increasing the capacitance of transmission line system. The TCSC-PI transmission line system is performing best at 1500 μF of the capacitor.

TABLE IV Comparison of power flows between transmission line (11 KV) systems using TCSC with (PID and PI) controllers

Transmission System	Capacitance (350 μF)		Capacitance (1500 μF)	
Device	Real Power (Mw)	Reactive Power (Mvar)	Real Power (Mw)	Reactive Power (Mvar)
TCSC	1.19	2.39	3.94	7.93
TCSC-PID	1.21	2.399	3.905	7.961
TCSC-PI	1.2	2.4	3.94	7.895

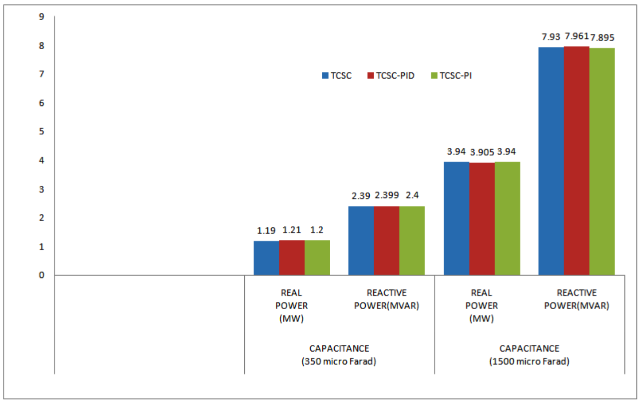

Fig.26.Representation of power flows variation of different transmission (11KV) compensated systems within the range of capacitance (50 to 1500) µF

Variation of power flow of different transmission line systems is shown in Figure.27 shows the variation of power of different systems. At 1500µF, TCSC-PI compensation is providing best power flow while at 350µF TCSC-PID and TCSC compensation performing well in the transmission system.

CONCLUSION

The comparative study of transmission line (11 KV) system model and simulation with TCSC, PID and PI controller is done through MATLAB-SIMULINK environment. This paper presents performance analysis of the transmission line (11 KV) system model using TCSC with (PID and PI) controllers and an elaborate comparison between their performances. Results show that TCSC, TCSC-PID and TCSC-PI compensated transmission line system model, reactive power flow is improved by increasing capacitance than uncompensated transmission system and it displays max value at capacitance (1500µF). The function block parameter gain is fixed at -1, helped to make comparison between PID and PI controller installed on transmission system and reciprocal value of I parameter from both PID as well as PI controller to each other found useful to make the thyristors operational to utilize the full complete range of capacitances used in the system and it will be helpful to operate the transmission system within all capacitance values with both controller taken into consideration for economical operation in any power system for future work . The addition of TCSC with PI and PID controller into the transmission line not only improved the power flows but also enhanced the power quality of the transmission system also as compared to the uncompensated transmission system. Hence it can be concluded that transmission line (11 KV) system using TCSC and TCSC-PID controller provides the most desirable performance at 350 µF while TCSC-PI is performing best at 1500 µF capacitance of compensated transmission system.

REFERENCES

[1] Martin German Sobek, Lubomir Bena, Roman Cimbala, "*Using of the Thyristor Controlled Series Capacitor in Electric Power System*", ELEKTROENERGETIKA Vol. 4; (2011).

[2] M. Zellagui1, A. Chaghi2; "*Impact of TCSC on Measured Impedance by MHO Distance Relay on 400 KV Algerian Transmission Line in Presence of Phase to Earth Fault*", J. Electrical Systems 8-3 (2012): 273-291.

[3] Samima Akter1, Anulekha Saha2, Prof. Priyanath Das3, "*Modelling, Simulation and Comparison of Various FACTS Devices in Power System*", IJERT, Vol. 1 Issue 8, October – 2012.

[4] M. Nayeripour1, M. Mahdi Mansouri2, "*Analyze of Real Switching Angle Limits in TCSC on Capacitor and Inductor Values and their Selection Factors*", IJAST Vol. 57; August (2013).

[5] H. Guentria1, F. Lakdjaa2, M.Laouera3, "*The opportunity of power electronics on improving the quality of voltage and power flow in the west Algeria network*", Energy Procedia, 50 (2014) 870 – 881.

[6] Mohsen Hosseinzadeh1, Soreshjani2, Navid Reza Abjadi3, Abbas Kargar4, Gholamreza Arab Markadeh5, "*A comparison of fuzzy logic and PID controllers to control transmitted power using a TCSC*", Turk J Electrical Engineering & Comp Science (2014) 22: 1463 – 1475.

[7] D. Chatterjee1, A. Mitra2, S. Sarkar3, "*A Conceptual Study for Control Strategy of TCSC in Inductive and Capacitive Region*", ICCPCT, (2014).

[8] Lazhar Bougouffa1, Abdelaziz Chaghi2, "Investigation of TCSC controller effect on IDMT directional over current Relay", Procedia – Social and Behavioral Sciences 195 (2015) 2421 – 2429.

[9] M. Dilip Kumar1, P.Sujatha2, "Design and Development of Self Tuning Controller for TCSC to Damp Inter Harmonic Oscillation", Energy Procedia, 117 (2017) 802- 809.

[10] Niraj H. Patel1, Raju B. Chaudhary2, Rozina R. Surani3, Hemant N. Raval4, "TCSC – Modeling and Operation", IJAERD Volume 4, Issue 5, May (2017)