ENHANCEMENT OF POWER SYSTEM STABILITY BY SIMULTANEOUS AC-DC POWER TRANSMISSION USING SVC COMPARED WITH TCSC BY REDUCING THE OSCILLATIONS

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Abstract

Aim: The aim of this work is to evaluate the performance of power system stability enhancement of simultaneous AC-DC power systems using Static VAR Compensator (SVC) compared with Thyristor Controlled Series Capacitors (TCSC) by reducing the transmission line oscillations.
Materials and Methods: A total number of 14 samples are collected from MATLAB simulation, The first method is Static VAR Compensator (SVC) and the second method is Thyristor controlled series capacitors (TCSC) consists of 7 samples of each. By implementing the static VAR compensation method, the power system stability enhancement is achieved. The G power taken as 0.8.
Results: Based on the results obtained it is observed that the SVC based compensation method enhances the optimum level of power system stability around 94.3% when compared to TCSC based compensation method of 81.72%. The significant value obtained is 0.0417 ($p<0.05$) which is statically significant.
Conclusion: It is observed that the SVC technique performed significantly better than the TCSC compensation technique for enhancement of total power system stability and oscillations.

Keywords: Simultaneous AC-DC Power Transmission, Power System Stability, Novel Static VAR Compensator, Thyristor Controlled Series Capacitors, Line Reactance, Reactive Power, Oscillations, Power Systems.

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1. Introduction

This work reveals a novel concept of Static VAR Compensator in simultaneous AC-DC power flow with the transmission line already in use for achieving enhancement of power system stability and reduction of oscillations. This includes three types of stability concerns steady state, transient and dynamic stability. Power factor correction used to be the domain of massive rotating machinery like synchronous condensers or switched capacitor banks before the discovery of the SVC (Zhang et al. 2019). The SVC is an automatic impedance matching device that aims to bring the power factor of the system closer to unity. The FACTS devices are the outcomes of power electronics technology. By compensating SVC in simultaneous AC-DC power transmission lines, it improves the line reactance and overall stability of the power system to achieve bulk power transmission (Sree et al. 2017). This work offers a simple technique for achieving overall power system stability by using simultaneous AC-DC power flow with an object to reduce the oscillations (Arora, Tayal, and Singh 2017). Parallel HVDC transmission lines with EHV AC transmission lines are advised to increase power system stability and dampen power system oscillations. (Zhang et al. 2019). To provide a sufficient margin against power system instability, The thermal limitations of lengthy EHV AC wires cannot be exceeded (Ashok Kumar and Mohana Sundaram 2020). The novel approach had been exploited and the power system stability is accomplished without changing the original extra high voltage AC transmission line (Rahman and Khan 2008). The main applications of the novel method are mainly utilized to regulate the transmission voltage (Khalili, Namdari, and Rokrok 2020), and for improving power quality by connecting it nearer to the large industrial loads (Industrial SVC).

In recent years more than 300 research articles were published in PubMed, Elsevier, Springer and IEEE Xplore. The most cited article is (Amin 2019) and this author has suggested SVC can control oscillations very quickly, as well as regulate the voltage profile. The authors (Rout and Pati 2018) have suggested SVC with PI controllers were more effective for enhancing the reactive power and overall power system stability. The authors (Pradip, Kotwal, and Pujara 2019) have concluded that for IEEE 14 bus systems, SVC can reduce line losses by adjusting inductive reactance and thereby improving active power. The authors (Jena, Swain, and Dash 2021) have suggested that SVC can be operated in a coordinated manner to achieve voltage regulation and improved power system stability. The authors (Sobbouhi and Vahedi 2021) have concluded that SVC offers the ability to damp out oscillations. The author (Ma 2018) has abated that SVC can efficiently dampen electromechanical oscillations in a power transmission system. The authors (Lei et al. 2020) have suggested SVC can be adjusted in a coordinated manner to increase power system performance by attaining line reactance and overall stability.

Our institution is keen on working on latest research trends and has extensive knowledge and research experience which resulted in quality publications (Rinesh et al. 2022; Sundararaman et al. 2022; Mohanavel et al. 2022; Ram et al. 2022; Dinesh Kumar et al. 2022; Vijayalakshmi et al. 2022; Sudhan et al. 2022; Kumar et al. 2022; Sathish et al. 2022; Mahesh et al. 2022; Yaashikaa et al. 2022). In the previous research, the researchers have not considered overall stability of the power system in simultaneous AC-DC power transmission and also failed to optimize the oscillations in the transmission system. Hence an enhanced power system stability improvement technique has been proposed to optimize the power system oscillations as well as stability. The aim of this work is to introduce SVC in a simultaneous AC-DC power transmission system for optimizing the power system oscillations and for the enhancement of the overall power system stability.

2. Materials and Methods

The research was performed in the Power Systems lab in the Department of Electrical and Electronics and Engineering at Saveetha School of Engineering, Saveetha Institute of Medical And Technical Sciences. This work involves two compensation techniques with 7 samples of a total 14 tests using the G Power software (Ganthia, Rana, et al. 2018). The statistical test-difference between two independent means, ɑ-0.05, G power-0.80, effect size-0.5, mean TCSC-0.8133, mean SVC- 0.9437, Standard Deviation (SD)-0.00743. This research was carried out using the MATLAB (R2021a) software (Shah et al. 2018).

Novel Static VAR compensation

The sample preparation of group 1 had been developed by collecting the output load values (pu) after installing the novel Static VAR Compensator in the simultaneous AC-DC power transmission those output values are obtained by varying the parameters (capacitance and inductance). At the receiving end, a static VAR absorber is connected in parallel with the transmission line circuit, in which the output is modified in order to replace the inductive or capacitive current is shown in Fig. 2. Transmission networks with high-voltage electricity require a SVC which is a collection of electrical devices that produce reactive power quickly and improve line reactance. SVC is one of the FACTS, which improves voltage, power factor, harmonics, and system stability. There are no substantial moving parts in a static VAR compensator (except for internal switchgear). It's a shunt-type controller that regulates power flow in the transmission system and increases the system's transient stability. The quantity of reactive power injected or absorbed from the power supply is controlled by this controller, which also improves the voltage at its terminals. SVC creates reactive power when the system power is reduced, and vice versa. The SVC circuit is depicted in Fig. 2 and the simulation for this compensation approach is presented in Fig. 1.

Thyristor controlled series capacitor

Group 2 sample preparation has been developed by collecting the output load values (pu) after compensating the thyristor controlled series capacitor in the simultaneous AC-DC power transmission line system and the output values are obtained by varying the parameters (capacitance and inductance). To maintain the dynamic power flow and improve the power quality and reactive power, thyristor controlled series capacitors are connected in parallel to the transmission lines. Figure 3 depicts a TCSC's connecting circuit. From Fig. 3 it is observed that extra long pilot wires are required for this TCSC compensation. The three basic components of thyristor-controlled series capacitors are capacitor bank, bypass inductor, and bidirectional thyristors such as silicon control rectifier 1 and silicon control rectifier 2. The thyristors' firing angles are adjusted in line with a system control algorithm to alter the TCSC reactance. By adjusting the firing angle of the thyristor controlled reactor, the controller's capacitive reactance may be changed (Widyan and Harb 2010). The system's load capacity is boosted by lowering the system's effective line reactance (Ghorbani and Mehrjerdi 2020). A Google colab open source stage with a center i5, tenth era processor and 8GB RAM is utilized for proposed work.

Statistical Analysis

The statistical analysis is done by using SPSS tools for obtaining the performance of the SVC. The statistical features such as mean, standard mean error and standard deviation are acquired for both the techniques using the statistical tools. capacitance and inductance are independent variables and power system stability is a dependent variable. Independent sample T-test analysis was carried out by comparing the SVC with TCSC technique (Nuchhi 2017).

3. Results

The simulated model is executed for the input line to line RMS voltage of 617.53kV and the parameters such as inductance, capacitance, line reactance observed and the source inductance is taken as 98.03mH. The novel Static VAR Compensator gives an efficiency of 94% and it is illustrated in Fig. 4 and the TCSC compensation technique gives an efficiency of 81 % and it is illustrated in Fig. 5 for the overall power system stability.

Table 1 depicts per unit values of simultaneous AC-DC power systems for the input RMS voltage of 617.53kV and it shows that 7 samples were considered for the calculation of mean values and its accuracy. Table 2 illustrates the standard deviation and significance difference of SVC technique and TCSC compensation technique. These were utilized to determine the substantial results in SPSS. Table 3 illustrates the statistical analysis of independent sample tests for both sample groups. The significant value obtained is 0.0417 ($p<0.05$) which is statically significant.

Table 2 shows that the Group 1 based model gives the highest performance compared to Group 2. The results produced by both the methods are in the acceptable range. The results of the independent samples T-test for group statistics have a significance which is less than the usual significance range 0.05, as shown in Tables 2 and 3. As an outcome, it can be proved that the innovative methods of SVC and TCSC are significantly different from each other. Then the bar graph is plotted representing the relation between the group and accuracy, specificity and sensitivity with the error bar indications of 95% CI and +/-1 SD which are shown in Fig. 6. It gives clarity about which compensation produces better outcomes. The graph shows that the SVC gives least discrepancy in Accuracy values with high performance compared to other compensation in transient stability improvement.

Figure 1 represents the simulation of a double circuit simultaneous AC-DC power transmission line with novel static VAR compensator at the receiving end of the transmission line and it is connected to the 3 phase load. Figure 2 represents the simulation of thyristor connections of SVC technique. Figure 3 represents the simulation of the double circuit simultaneous AC-DC power transmission line system with thyristor controlled series capacitor compensation which is connected to the load. Figure 4 represents the overall power system stability of the simultaneous AC-DC power transmission line system when static VAR compensator technique is used. Figure 5 represents the overall power system stability of the simultaneous AC-DC power transmission line system when TCSC technique is used.

Figure 6 represents the comparison of novel static VAR compensator technique and thyristor controlled series capacitors technique in terms of mean overall power system stability in per unit. The mean accuracy and the standard deviation of static VAR compensator (SVC) technique is better than Shunt capacitor technique. It also represents the bar chart for accuracy of static VAR compensation technique and TCSC compensation technique using the SPSS tool. A statistically significant difference was found when an independent t-test was performed to evaluate the accuracy of two techniques. The static VAR compensation technique gives the optimum accuracy of 94.3% when compared to TCSC compensation technique with 81.7%.

4. Discussions

The results of the work reveals that the novel Static VAR Compensator based compensation provides more promising results in enhancement of overall power system stability than the TCSC based compensation. Automatic measurement of accuracy in the detection of overall power system stability is the most important consideration because of the failure to achieve conclusions based on the TCSC compensation method. In this work, the Accuracy of 94.37 ± 0.743 is calculated using the SPSS tool and compared with TCSC based model accuracy of 81.33 ± 0.399. The results showed a statistical significance difference of <0.5 between the two groups.

By varying the voltages, the steady state and dynamic stability changes are examined. Initially the comparative analysis of SVC and TCSC techniques have been carried out and it is found that SVC has maximum power extraction than the TCSC based system and the overall power system stability was increased when SVC is used. This compensator is inspired from a medium voltage transmission line (Ganthia, Rana, et al. 2018). SVC gives better performance and it balances the distribution system for the full operating time and it also includes good harmonic performance with fast response (Amin 2019). SVC can control the grid voltage under normal and contingency conditions (Pradip, Kotwal, and Pujara 2019). The SVC has the ability to prevent/reduce risk of voltage collapses in the grid and it can also prevent the over-voltages during sudden loss of load (Jena, Swain, and Dash 2021). During under-voltage disturbances and faults it can boost voltage and the damping active power oscillations are reduced (Kumari 2018).

The SVCs are made up of capacitors and thyristor-controlled inductors, and they have the drawbacks of being large and having a sluggish dynamic response (Sun et al. 2020). This makes it inadequate for operations like reducing voltage flicker caused by arc furnace loads. where it cannot minimize the impact of the (EAF) electric arc furnace (Lei et al. 2020). From the above discussion, a significant scientific contribution supports the SVC compensator for increasing the power transmission system's stability.

Although the results of the study showed better performance with limited attributes using the SVC compensation along with certain limitations. Since SVC device have no revolutionary parts, for the implementation of surge impedance compensation, additional equipment is needed. The size of the device is heavy with deliberate dynamic response. This device is not suitable to employ for the regulation of voltage up and downs if furnace loads are connected. By Implementing the PID controller along with SVC the steady state and dynamic stability performance will be better and more accurate. More novel ideas should be explored in future with modern evaluation using SVC with a PID controller. Also Extra high voltage transmission lines can be consolidated in a more efficient way with SVC to achieve the maximum power system stability with reduced oscillations (Ganthia, Rana, et al. 2018; Ganthia, Abhisikta, et al. 2018).

5. Conclusion

The novel Static VAR Compensator approach was compared to the TCSC method in this study to improve overall power system stability. The results clearly shows that the SVC method was found to be more effective and enhances power system stability with an accuracy of 94.3 % when compared to TCSC of 81.2%. The difference between the two groups is within a reasonable range. By observing the results it can be clearly evident that the SVC technique would offer an advanced and accurate power system stability. The Independent T-test analysis reveals that the significance value is 0.0417 ($p<0.05$) which is statistically significant.

Declaration

Conflict of Interest

No conflict of interest in this manuscript.

Author Contribution

Author TMKR was involved in data collection, data analysis and manuscript writing, and author RB involved in conceptualization, data validation, and critical review of the manuscript.

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Tables and Figures

Table 1. Simulated result output power per unit (pu) values of simultaneous AC-DC power transmission by using SVC and TCSC technique.

Sl.No	Output power (pu)	
	SVC	TCSC
1	0.942	0.814
2	0.945	0.807
3	0.931	0.815
4	0.944	0.819
5	0.943	0.810
6	0.955	0.816
7	0.949	0.812

Table 2. Comparison of standard error mean for the SVC technique with TCSC technique. For 14 different data sets, mean accuracy, standard deviation, and standard error values were calculated.

	Groups	Number of samples	Mean	Standard Deviation	Standard Error Mean
Output power (pu)	SVC	7	.9437	.00743	.00281
	TCSC	7	.8133	.00399	.00151

Table 3. Independent sample T-test is performed for the two groups for significance and standard error determination. The significant value obtained is 0.0417 (p<0.05) which is statically significant.

Independent Samples Test									
Levene's Test for Equality variances						T-test for Equality of means		95% Confidence Interval of the Differnce	
	F	Sig	t	diff	Sig	Mean	Std Error	Lower	Upper

						(2-tailed)	Difference	Difference		
Output power (pu)	Equal variances assumed	.707	0.0417	40.913	12	.0001	.13043	.00319	.12348	.13737
	Equal variances not assumed			40.913	9.191	.0001	.13043	.00319	.12324	.13762

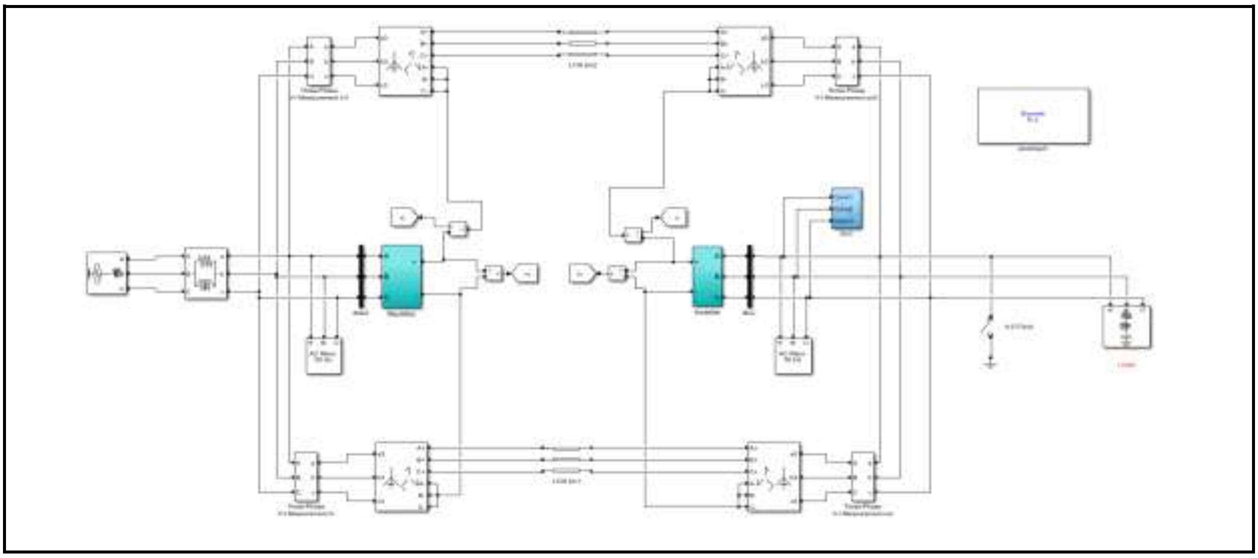

Fig. 1. Simulation diagram of double circuit simultaneous AC-DC power transmission with SVC

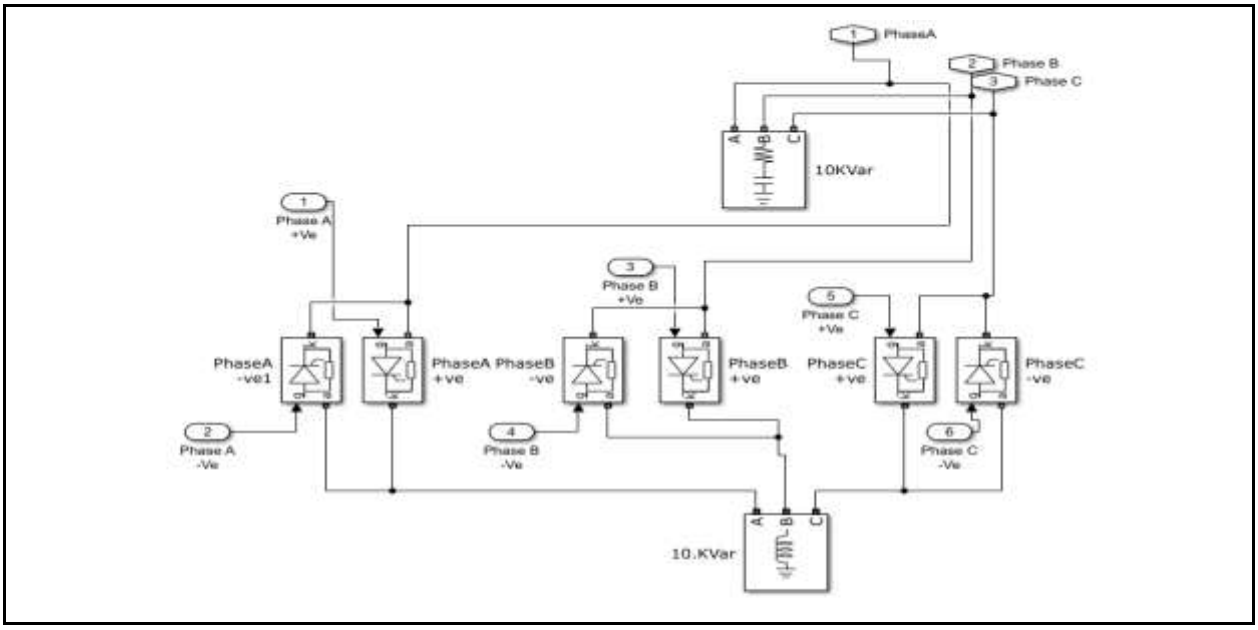

Fig. 2. Simulation diagram of SVC with Thyristor connections

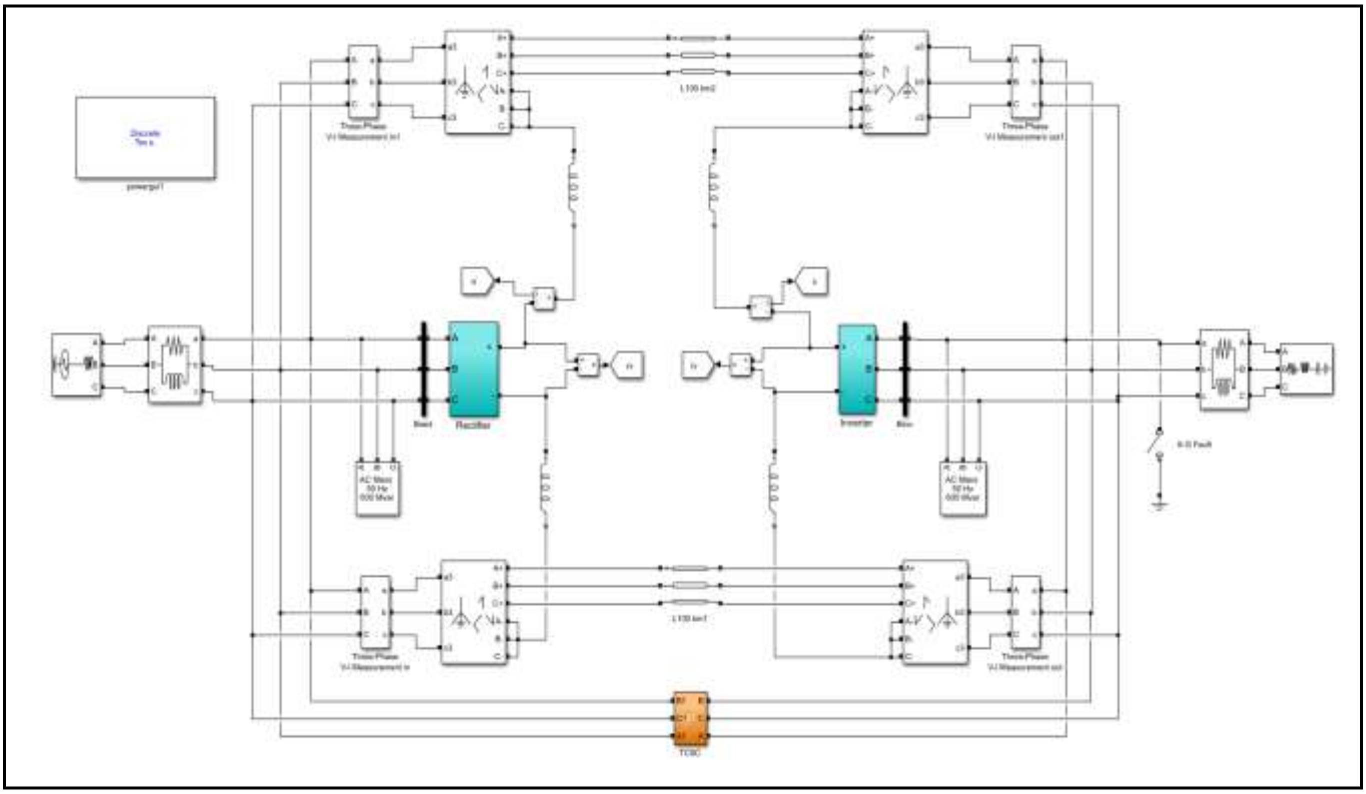

Fig. 3. Simulation diagram of double circuit simultaneous AC-DC power transmission line system with TCSC

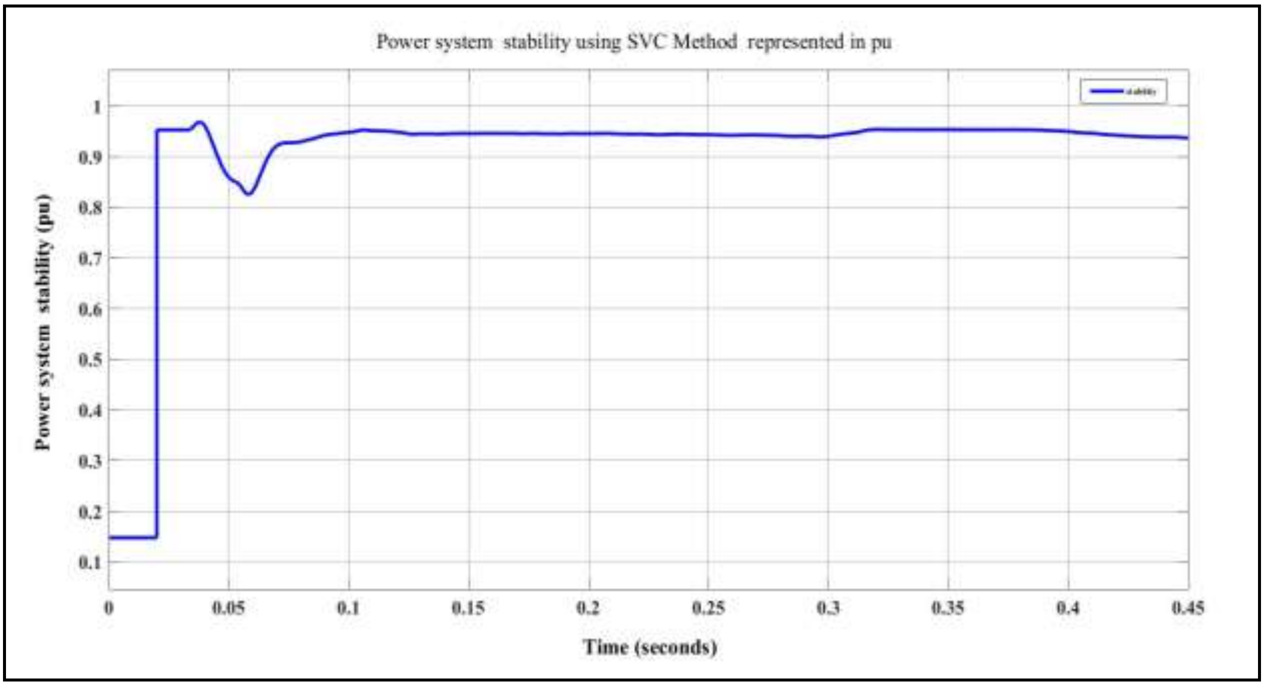

Fig. 4. Overall power system stability of the simultaneous AC-DC power transmission line system with SVC

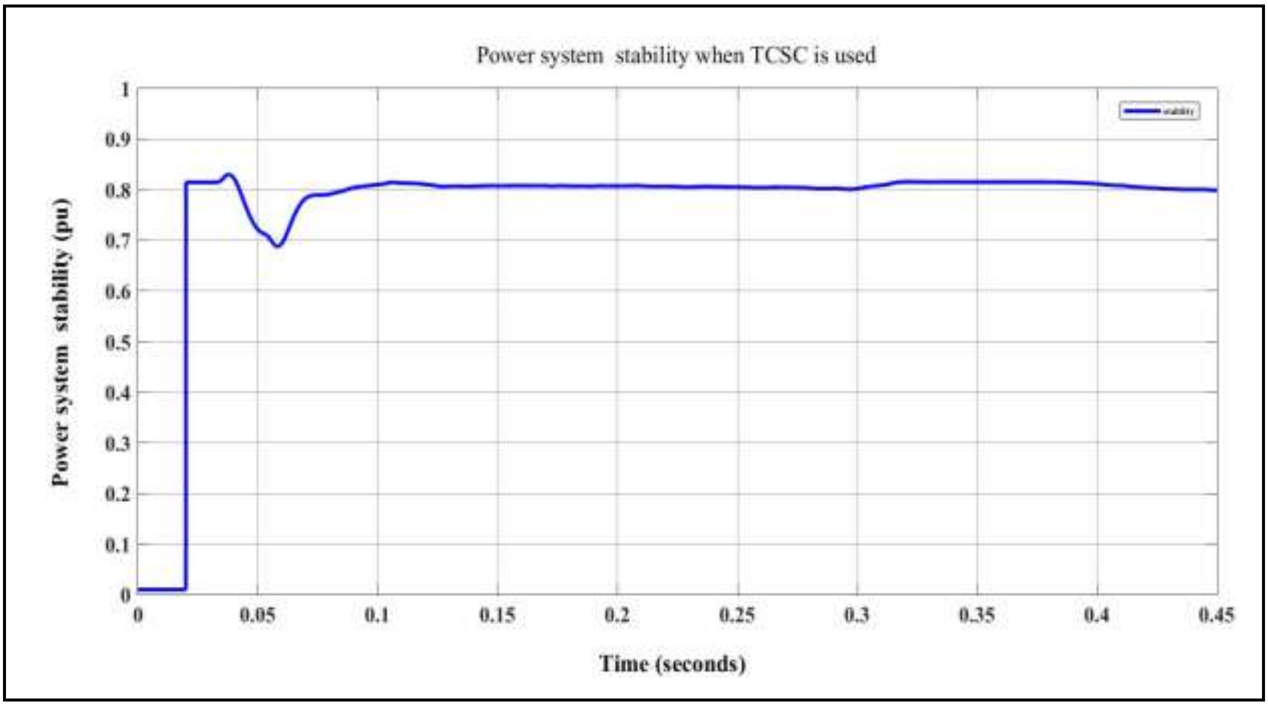

Fig. 5. Overall power system stability of the simultaneous AC-DC power transmission line system with TCSC

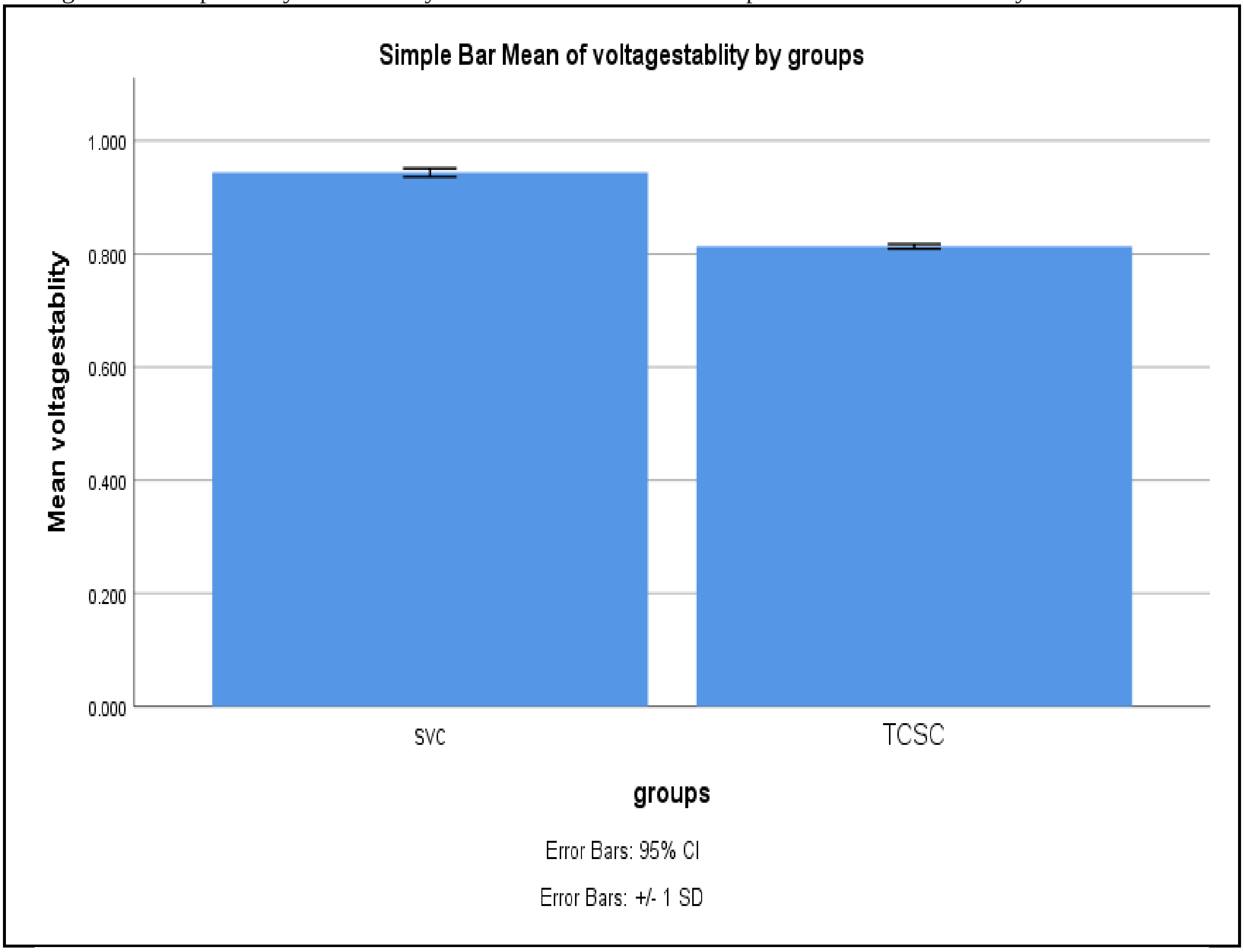

Fig. 6. In terms of mean power system stability, the SVC approach and the TCSC technique are compared. The SVC technique's mean accuracy and standard deviation are indeed higher than those of the TCSC. X Axis : SVC technique vs TCSC, Y Axis : Mean transient stability ± 1 SD