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Performance of Series Compensator with UPQC in Power System

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Abstract

This paper deals with the simulation of various FACTS controllers using a simulation program with Integrated circuits Emphasis (PSPICE).FACTS controllers control series impedance, shunt impedance, current, voltage and phase angle. In this paper, simple circuit model of Series Compensator and Unified Power Quality conditioner are analyzed. The simulation results coincide with the theoretical results.

Keywords: FACTS controllers, FACTS, power electronic equipment, Compensator, UPQC.

INTRODUCTION

Now a day the active methods for power quality control have become more attractive compared with passive ones due to their fast response, smaller size, and higher performance. The proposed WLAV state estimation algorithm is represented. The performance of the proposed state estimation method is demonstrated by using the IEEE standard system, which has been modified by the inclusion of UPQC. Consequently, monitoring these devices and their parameters is also becoming crucial for power system control. There are several types of FACTS devices such as thyristor controlled series compensation (TCSC) and unified power quality controller (UPQC) [1]. A UPQC consists of the series and the shunt voltage converters connected to a transmission line which allows the independent control of the real and the reactive power flows along the line [2, 3].

In order to estimate the state of the power system containing FACTS devices, an improved sequential method which uses matrix reduction to decouple the power network, the TCSC, the TCSC and the UPQC, thereby allowing a sequential solution, has been proposed [4]. However, the constraints of these devices are not considered. In [5] the UPFC's constraints are included; the state estimation problem becomes the nonlinear weighted least squares (WLS) optimization with a set of equality and inequality constraints. This optimization problem is then solved by using a solution method based on the interior point method.

The WLS state estimation has been widely used in the past for power system state estimation. Although, it provides a fast solution, it is not robust in the presence of the bad measurements. One criterion called the weighted least absolute value (WLAV) can be used to improve the robustness. The WLAV estimator is able to reject the bad measurements as long as these are not leverage points. Recently the application of the interior point method for WLAV state estimation of the conventional power system has been presented.

In this paper, we propose a method for solving the state estimation problem of power system containing UPQC by formulating the problem as a nonlinear WLAV optimization with a set of equality and inequality nonlinear constraints.

SERIES COMPENSATOR

The series compensator circuit is shown in Fig.1. Two capacitors are connected in series with the line. The resistance in series with the capacitor is the current limiting resistance. The AC switches are connected in parallel with the respective capacitors.

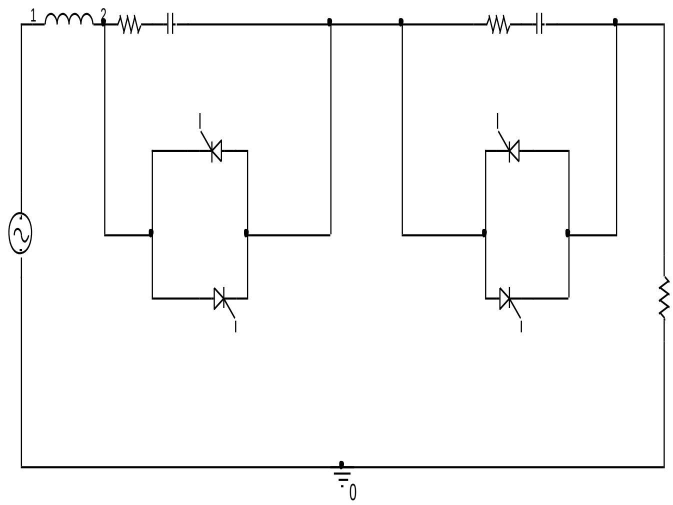

Figure 1. Series Compensator

In interconnected power systems, the actual transfer of power from one region to another might take unintended routes depending on impedances of transmission lines connecting the areas. Controlled series compensation is a useful means for optimizing power flow between region for varying loading and network configuration. The simulated waveform with Inductor alone and with switch closed is shown in Fig.2.

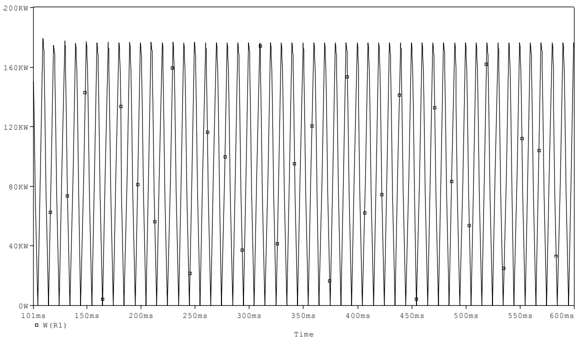

Figure .2. Power waveform (195 kw)

The simulated waveform with Inductor and Capacitor and with switch open is shown in Fig .3.

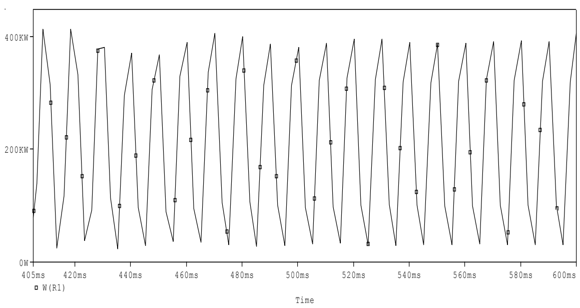

Figure .3. Power waveform

By introducing capacitor into the system the power transmitted can be increased. As shown in Fig. 2, when inductor alone is present in the system the power transmitted is 195 KW. As shown in Fig. 4, when the capacitor is introduced into the system the power transmitted increases to 400 KW.

SERIES COMPENSATOR WITH CAPACITORS

The simulation circuit with two capacitors and one uncontrolled reactor is shown in Fig. 4.

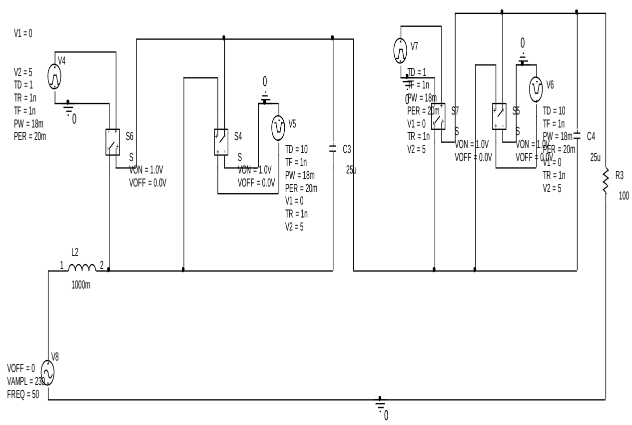

Figure 4. Simulation Circuit with two capacitors and one uncontrolled reactor

By introducing the capacitor into the system, the power transmitted can be increased. As shown in the Fig. 5, that inductor alone is present in the system; the power transmitted is 47 Watts. As shown in the Fig. 6, when one capacitor is introduced into the system, the power transmitted increases to 110Watts. As shown in the Fig. 7, when two capacitors are introduced into the system, the power transmitted increases to 345Watts.

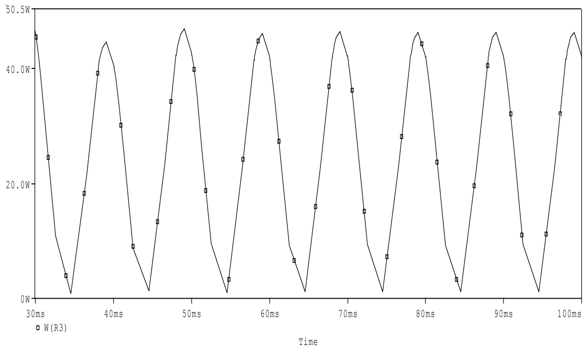

Figure 5. Power waveform with inductor alone.

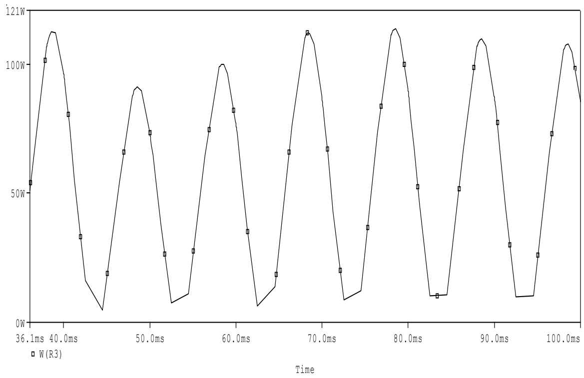

Figure 6. Power waveform with inductor and one capacitor

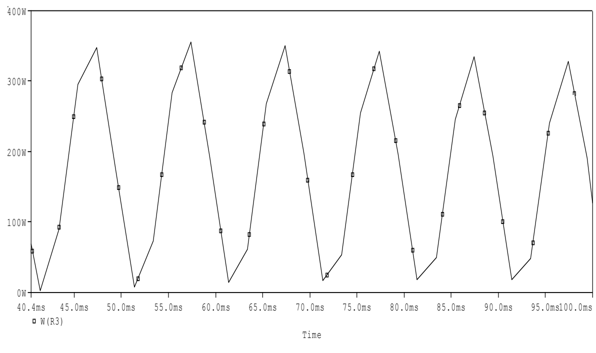

Figure 7. Power with inductor and two capacitors with both switch open

SERIES COMPENSATOR WITH TWO CAPACITORS OPERATED BY SINGLE UNCONTROLLED REACTOR

By varying the reactor connected in the system, the power transmitted can be varied. The simulation circuit is shown in the

Fig. 8. As shown in the Fig.9, when a reactor is introduced into the system at a firing angle delay of 90°, the power transmitted is 110 KW. As shown in the Fig.11, when a reactor is introduced into the system at a firing angle delay of 63°, the power transmitted is 260 KW. Thus by varying the value of reactor, the power transmitted can be varied.

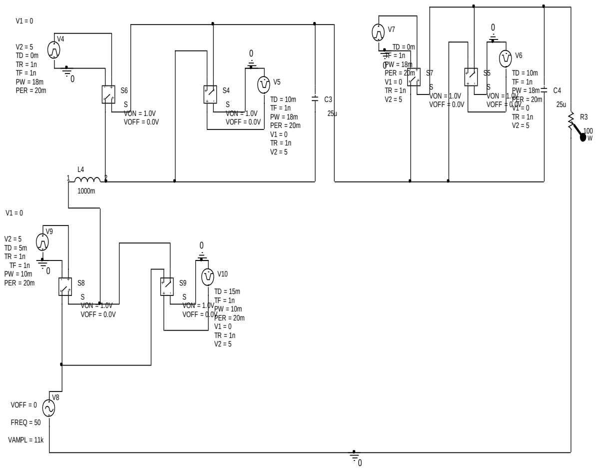

Figure 8. Simulation Circuit

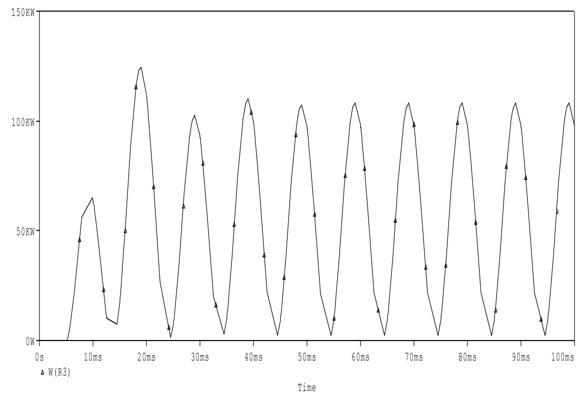

Figure 9. Power waveform of series compensators single controlled reactor

The waveform with inductor and one capacitor is shown in Fig.10.

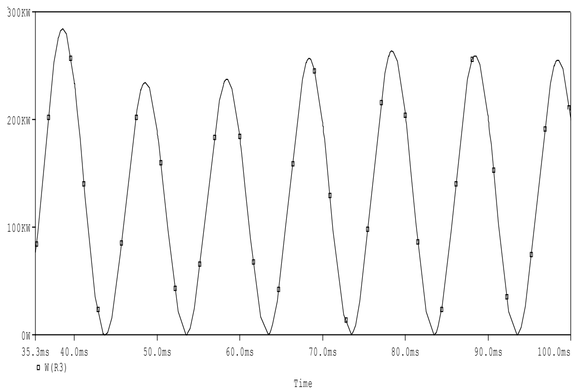

Figure 10. Power waveform of series compensator with one inductor and one capacitor

The simulation diagram of the proposed method of UPQC is shown in the figure 11. The three phase operating voltage source is shown in the figure 12.

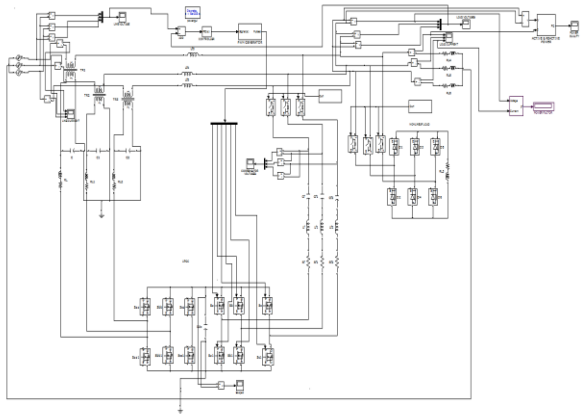

Figure 11. Simulation Diagram for Proposed Method of UPQC

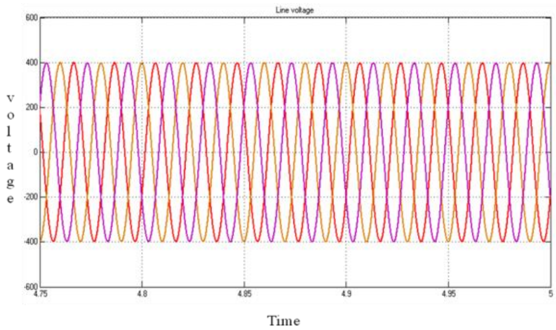

Figure 12. Waveform of Line Voltage

Here in this system, there is no compensator; the load voltage gets reduced due to the addition of non-linear loads. In the Fig. 13 (a) shows the decrease in voltage due to the addition of non-linear load. It can be observed that there is a decrease in voltage during the interval of 2 to 3 cycles. By performing the output of Figure 13 (b) shows the output voltage of the compensator. It provides the voltage only in the interval of 2 to 3 cycles. Figure 13 (c) shows the compensated load voltage. In this we can see the rated voltage is obtained at the receiving end of the power system.

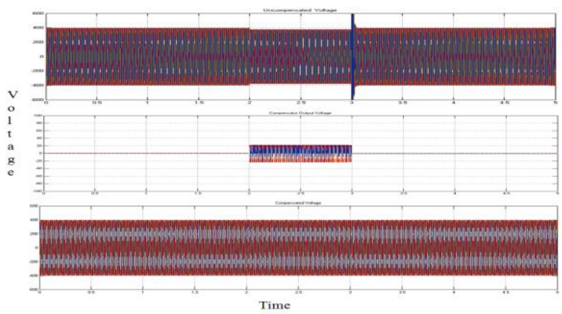

Figure 13. Waveform of (a) Uncompensated Load Voltage (b) Compensator (UPQC) Output Voltage (c) Compensated Load Voltage

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The voltage across the DC link capacitor is shown in the Fig 14. From this we can depict that the magnitude of voltage is between 0 to 22V. When compared to conventional method the value of DC link voltage obtained is less. So the level of the harmonic imbalance in the injected voltage will be reduced.

Hence by this method the harmonics present in the load voltage will be considerably reduced and the power quality of the same will be improved. The Fig.15 gives the percentage of the Total Harmonic Distortion (THD) obtained by this proposed method.

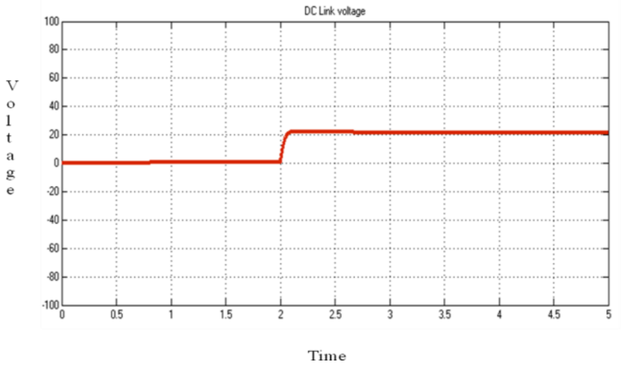

Figure 14. Waveform of DC Link Capacitor Voltage for proposed method

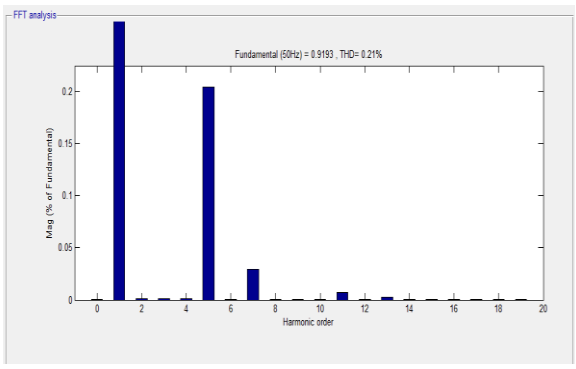

Figure 15. Measurement of Total Harmonic Distortion

From the Fig.15 we can depict that the percentage of Total Harmonic Distortion (THD) is 0.21%. Thus the harmonic content in the load voltage is reduced. When compared to the conventional method, total harmonic distortion (THD) is reduced in our proposed model. Also the power factor is improved. The IEEE 14-bus system with UPQC is as shown in the Fig.16.

Table I. Parameters and Constraints of UPQC in IEEE 14-Bus System

Shunt Source		Series Source	
R_{sh}	0.00	R_{se}	0.00
X_{sh}	0.07	X_{se}	0.07
$V_{sh,max}$	1.11	$V_{se,max}$	0.60
$S_{sh,max}$	0.11	$S_{se,max}$	0.10

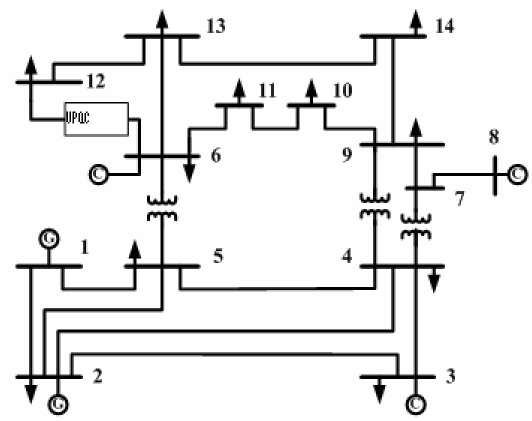

Figure 16. IEEE 14-bus system with UPQC.

Table II. Measurement Data of IEEE 14-Bus System

Bus voltage measurements					
Bus	Voltage		Bus	Voltage	
1	1.0599		4	1.0187	
Injection measurements					
Bus	P	Q	Bus	P	Q
3	-0.8419	0.0430	8	-0.0001	0.1699
9	-0.2949	-0.1659	10	-0.0899	-0.0581
13	-0.1351	-0.0580	14	-0.1490	-0.0500
Flow measurements					
Branch	P	Q	Branch	P	Q
1-5	0.8591	0.0352	2-3	0.7321	0.0357
2-5	0.4180	0.0072	4-7	0.2760	-0.0966
4-9	0.1580	-0.0052	6-5	-0.4557	-0.0823
6-11	0.0628	0.0367	6-12	0.2733	0.0104
7-9	0.2761	0.0531	8-7	-0.0002	0.1703
9-7	-0.2761	-0.0454	9-14	0.0760	0.0335
10-11	-0.0273	-0.0178	12-6	-0.2223	-0.0303
13-12	-0.1567	-0.0100	13-14	0.0746	0.0204

Table III. Estimated Values of UPQC Control Variables in IEEE 14-Bus System

States of UPQC	WLS		WLAV	
	Shunt Source	Series Source	Shunt Source	Series Source
V	1.0801	0.1111	1.0707	0.1183
θ°	-14.3398	43.9997	-14.4993	45.0114
P	-0.0109	0.0109	-0.0124	0.0124
Q	0.0141	0.0224	0.0132	0.0262
S	0.0178	0.0249	0.0181	0.0290

To investigate the effectiveness of the proposed algorithm under the presence of bad data, the gross errors in measurements are introduced by changing the sign of the measured values i.e. the real power flow in branch 9-14 and the power flow (P & Q) in branch 9-7. Figs. 17 & 18 show the absolute of percentage of the estimation errors for magnitude and phase angles with gross errors introduced. Note that the proposed WLAV method yields the smaller error both in the magnitude and phase angles. In addition, the percentage of the estimation errors of the UPQC control variables is shown in Table IV. A comparison of the algorithm performance for these test cases is given in Table V. Note that the condition number of ***A*** is evaluated in this work. Mean squared error of the estimated states is also determined. It can be seen that the proposed method provides smaller MSE in the both case studies.

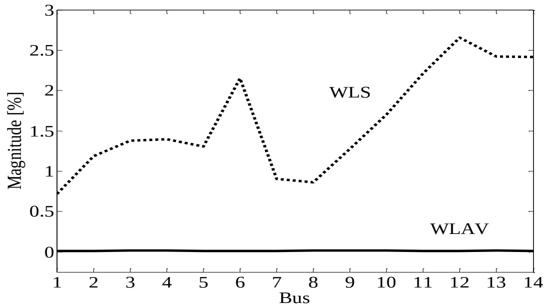

Figure 17. Absolute of percentage error of voltage magnitudes in IEEE 14-bus system

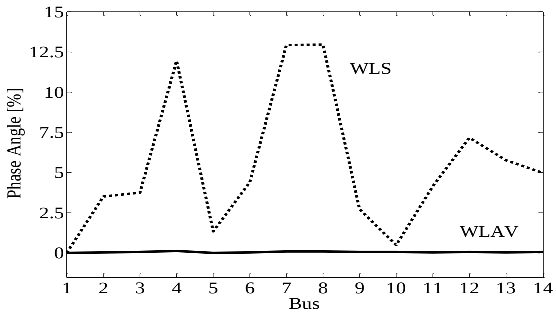

Figure 18. Absolute of percentage error of phase angles in IEEE 14-bus system

Table IV. Percentage Error of UPQC control variables in IEEE 14-Bus System (Case 2)

STATES OF UPQC	WLS		WLAV	
	SHUNT SOURCE	SERIES SOURCE	SHUNT SOURCE	SERIES SOURCE
V	-3.1384	-0.2536	0.0289	0.0000
θ°	5.4139	2.5864	-0.0290	0.1446
Q	7.0150	11.6870	0.0000	0.0000
P	7.4516	7.4516	0.0000	0.0000

Table V. Comparison results

METHOD	CASE	CONDITION NUMBER*	MSE	ITER.	CPU TIME (SEC.)
WLS	1	8.6×10^{8}	4.17×10^{-2}	13	2.75
	2	2.7×10^{10}	3.70×10^{-1}	14	2.93
WLAV	1	2.4×10^{9}	1.21×10^{-4}	13	2.85
	2	1.2×10^{10}	1.48×10^{-4}	13	2.85

CONCLUSION

In this paper series compensator and unified power quality conditioner circuits are simulated. In this analysis, we observe the series compensators are simulated for different values of capacitance and inductance. Based on the simulation studies and THD level, it can be recommended that this method is suitable for all the power quality issues Unified power quality controller is simulated for different phase angles of midpoint source. . The results on the modified IEEE 14-bus system illustrate that the proposed algorithm can be applied satisfactory for estimating the state variables of the power system with UPQC.

REFERENCES

[1] M. Noroozian, L. Angquist, M. Ghandhari, G. Andersson, “Improving power system dynamics by series-connected FACTS devices,” *IEEE Trans. on Power Delivery*, vol. 12, no. 4, pp. 1635-1641, Oct. 2014.

[2] N.G. Hingorani and L. Gyugyi, *Understanding FACTS: concepts and technology of flexible ac transmission systems*, IEEE Press, 2015.

[3] L. Gyugyi, C.D. Schauder, S.L. Williams, T.R. Rietman, D.R. Torgerson, and A. Edris, “The unified power flow controller : a new approach to power transmission control,” *IEEE Trans. on Power Delivery*, vol. 10, no. 2, pp. 1085-1097, April 2015.

[4] D. Qifeng, Z. Boming, and T.S. Chung, “State estimation for power systems embedded with FACTS devices and MTDC systems by a sequential solution approach,” *Electric Power Systems Research*, vol. 55, no. 3, pp. 147-156, Sept. 2014.

[5] X. Bei, and A. Abur, “State estimation of systems with UPFCs using the interior point method,” *IEEE Trans. on Power Syst.*, vol. 19, no. 3, pp. 1635–1641, Aug. 2013.

[6] M. Noroozian, L. Angquist, M. Ghandhari, G. Andersson, “Improving power system dynamics by series-connected FACTS devices,” *IEEE Trans. on Power Delivery*, vol. 12, no. 4, pp. 1635-1641, Oct. 2010.

[7] N.G. Hingorani and L. Gyugyi, *Understanding FACTS: concepts and technology of flexible ac transmission systems*, IEEE Press, 2012.