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Voltage Slump Compensation using Facts Controllers on Power System

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***Abstract*: This article dispense the different FACTS controllers integrated circuits using a simulation program that emphasis with PSPICE. The FACTS controller controls series impedance, shunt impedance, voltage, current and phase angle. In this paper, a simplified circuit model of Series Compensator and Unified Power Quality conditioner has been analyzed and the simulation results coincides with the theoretical results..**

***Index Terms*: FACTS controllers, FACTS, power electronic equipment, Compensator, UPQC.**

I. INTRODUCTION

At the present time, the active methods for power quality control have become more appealing correlate with passive ones due to their compact size, fast response, and higher performance. The state estimation algorithm has been proposed related to the performance with the IEEE standard system, that has been modified by the inclusion of UPQC. As a result, observing and checking these FACTS devices and their respective parameters is also being to be pivotal for power system control. Various devices on FACTS are thyristor controlled series compensation (TCSC) and unified power quality controller (UPQC) [1]. A UPQC be composed of shunt and series voltage converters in contact to a transmission line that permits the individualistic control of the real and the reactive power flows through the line [2, 3].

In order to determine the condition for the power system FACTS devices, a better forming method to separate the power network, TCSC and UPQC, thereby permitting a forming solution, being proposed [4]. Nevertheless, the limitations of these devices are not contemplated. The UPFC's limitations are, the condition approximation problem gets the nonlinear weighted least squares (WLS) optimization with a set of equality and inequality limitations [5]. Then this optimized solution obtained by employing a solution method based on the interior point method [6].

The weighted least absolute value condition approximation has been far apart used for power system condition approximation [7]. In spite of, providing a quick retaliation, it is not vigorous in the existence of the bad computation. A special standard called the WLAV can be employed to enhance the efficiency [8]. The Weighted least absolute value (WLAV) is able to refuse the bad computation as long as these are no dominance points [9, 10]. Lately, the appeal of the interior point method for WLAV condition approximation of the standard power system has been dispensed [11, 12].

In this paper, we suggested a technique for resolving the condition approximation problem accommodating UPQC by contrive the difficulty as a nonlinear WLAV makes the best, with a set of equality and inequality nonlinear constraints.

II. SERIES COMPENSATOR

A. Review Stage

A series compensator circuit is shown in Fig.1 that incorporates two capacitors 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.

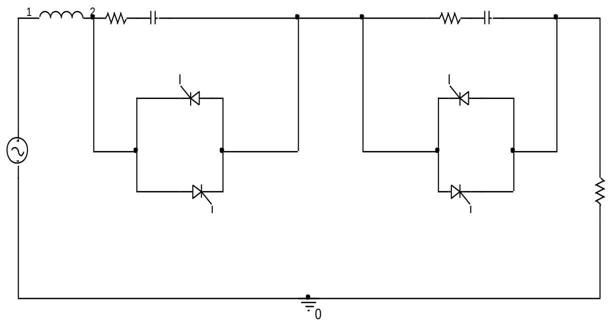

Fig. 1. Series Compensator

The simulated waveform in Fig. 2 represents at Inductor alone and with switch to be in closed state.

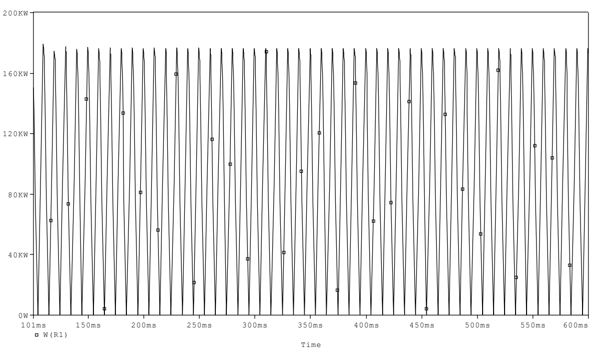

Fig .2. Power waveform (195 kw)

The simulated waveform in Fig. 3 represents at Inductor and capacitor and with switch to be in open state.

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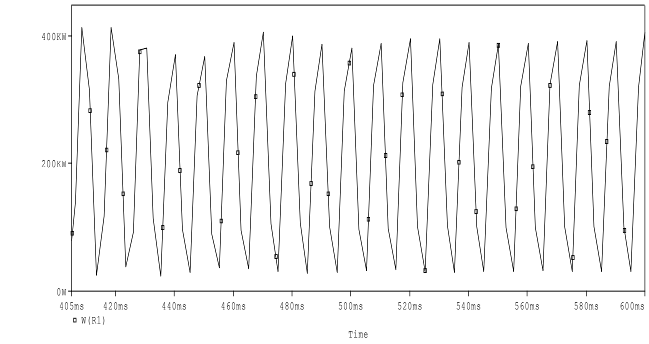

Fig .3 Power waveform (400kw)

It has been analyzed from Fig. 2, when inductor alone is added, the power transmitted is 195 KW. As the same, shown in Fig. 3, on adding a capacitor to the system, the power transmission can be increased to 400 kW.

III. SERIES COMPENSATOR WITH CAPACITORS

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

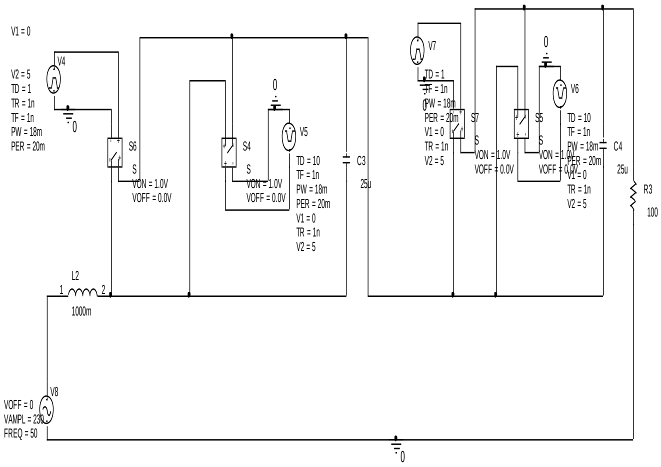

Fig.4 Simulation Circuit with two capacitors and one uncontrolled reactor

By introducing the capacitor in 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.

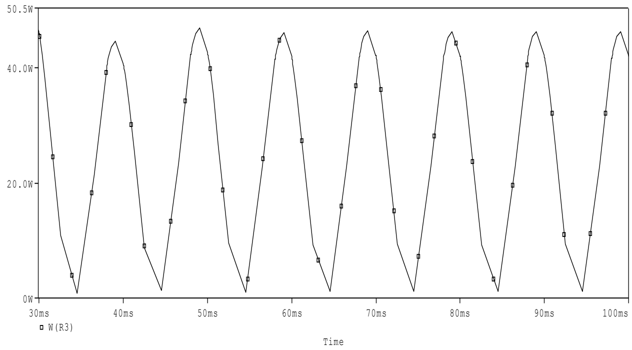

Fig. 5. Power waveform with inductor alone.

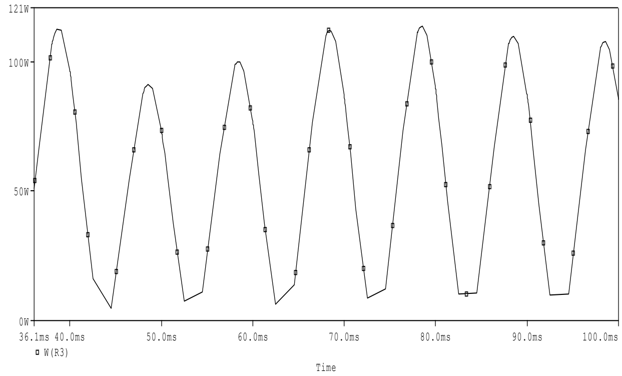

Fig.6. Power waveform with inductor and one capacitor

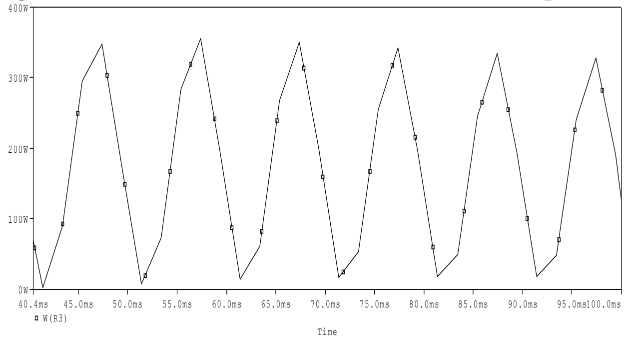

Fig .7. Power with inductor and two capacitors with both switch open

IV. SERIES COMPENSATOR WITH TWO CAPACITORS AND SINGLE UNCONTROLLED REACTOR

By varying the reactor connection 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.

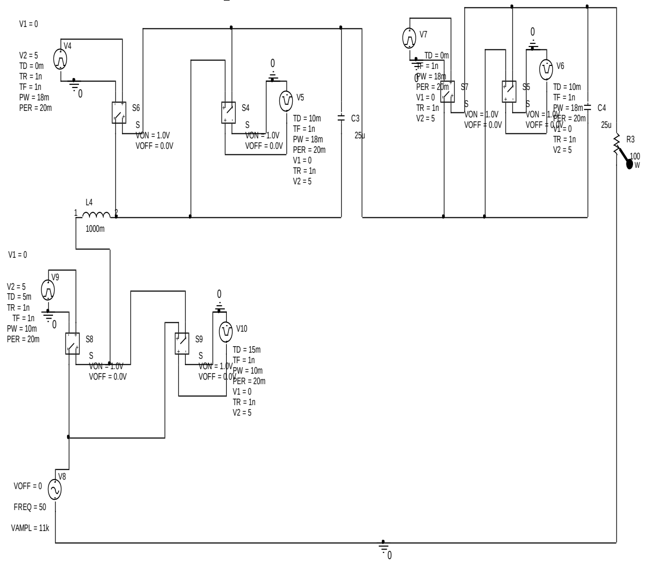

Fig .8. Simulation Circuit

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The waveform of series compensator with inductor alone is shown in Fig .9.

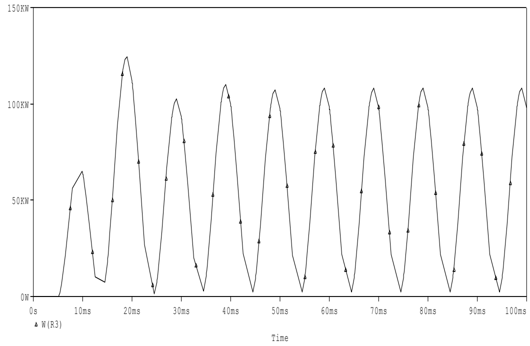

Fig.9. Power waveform of series compensators single controlled reactor

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

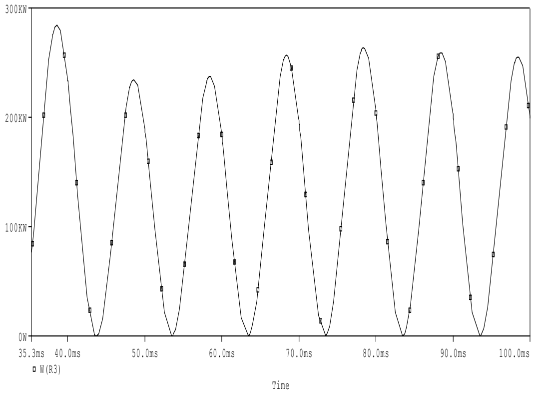

Fig.10. Power waveform of series compensator with one inductor and one capacitor

V. PERFORMANCE OF UPFC AND UPQC

On Consider a simple two-machine transmission model as shown above, the source of variable phase angle is inserted at the midpoint of a model. Mid point is the best location because, the voltage drops along the not compensated transmission line is the extensive at the midpoint. The compensation at mid point, shatters the transmission line into two equal divisions for each of which transmittable power is the same. By changing the phase angle of midpoint source, the real power transmitted can be varied. When the phase angle of midpoint source is set at 60˚ and 270˚, the corresponding variation in real power is shown in the results below. Thus on managing the phase angle of midpoint source, the flow of real power can be managed. The simulation circuit of UPFC is as shown in the Fig.11.

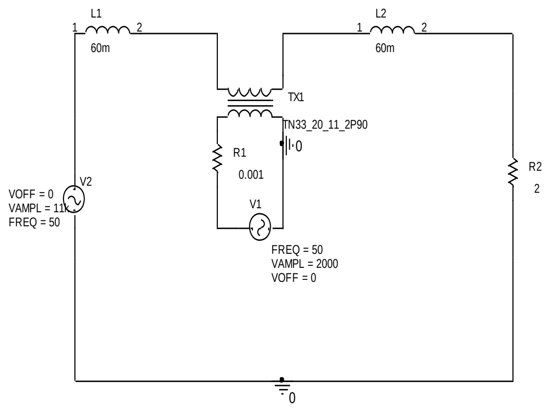

Fig .11. Simulation Circuit of UPFC

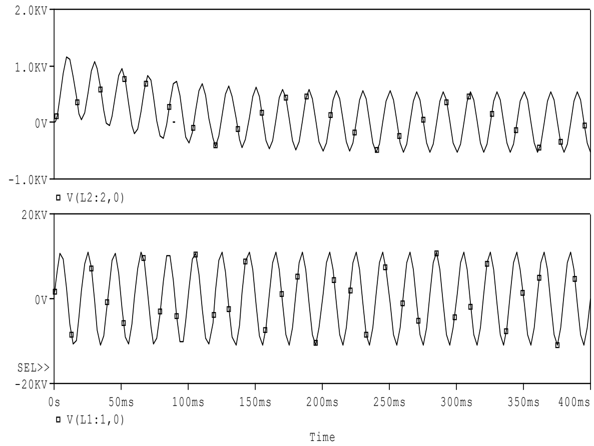

Fig. 11(a) For an angle of injection at 60o Sending and receiving End voltages

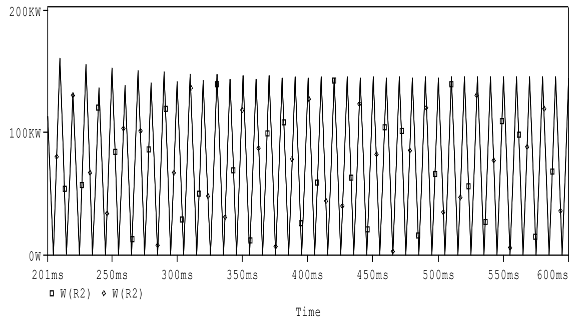

Fig 11(b) Real power at angle of injection 60 degrees

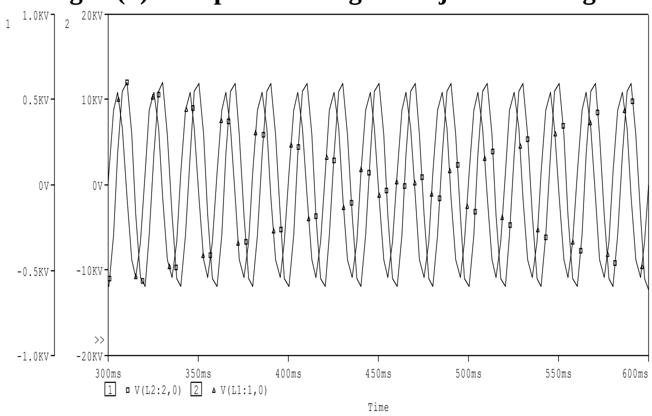

Fig. 12(a) For an angle of injection at 270o Sending and receiving End voltages

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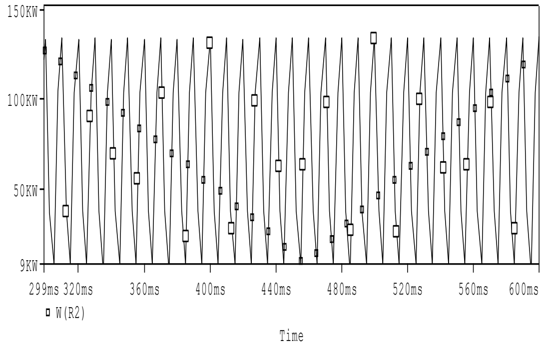

Fig. 12(b) Real power at angle of injection 270 degrees

The above results clearly shows that the real power flows for 60° is 160kw and real power flow can be controlled on increasing the injecting angle. The angle of injection for 270°.

The real power flow will be decreased by 135kw. In this analysis it has been observed that, the transmitted power can be varied by changing the angle of injection. In the Fig. 13 depicts the amended IEEE 14-bus system. One UPQC is located in branch 6-12 at bus number 6. Table I shows the variables and limitations of the UPQC. The computed data's are given in Table II. The computed set inheres of 32 flow measurement, 12 power injections, and 2 voltages. Note that the computation set will create the network and UPQC fully perceptible. The reckon states of the UPQC are recaptitulate in Table III. It is observed that the UPQC conditional approximation and its apparent powers are inside its boundary. The real power shift between both voltage sources is close to zero, $P_{sh} + P_{se} = 0$.

The simulation diagram of the proposed method of UPQC is shown in the figure 13. The three phase source volt age is shown in the figure 14.

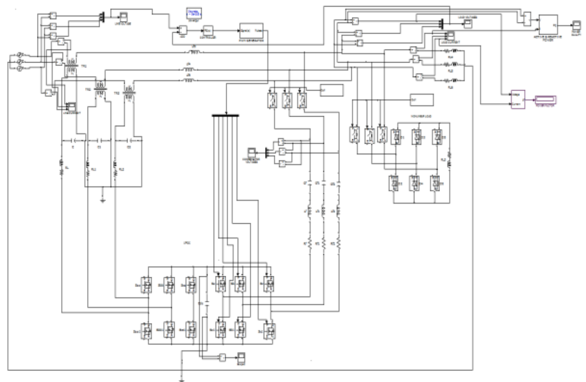

Fig.13 Simulation Diagram for Proposed Method of UPQC

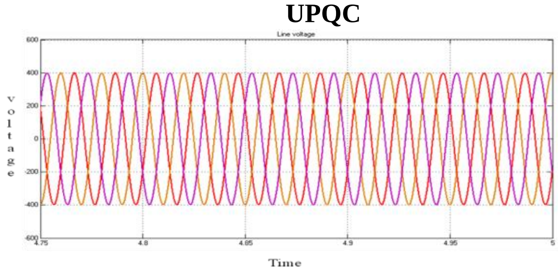

Fig.14. Waveform of Line Voltage

Here in this system, there is no compensator; the load voltage gets reduced due to the addition of non-linear loads. In the Fig. 15 (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 at the interval of 2 to 3 cycles. By performing the output of Figure 15 (b) shows the output voltage of the compensator. It provides the voltage only in the interval of 2 to 3 cycles. Figure 15 (c) shows the compensated load voltage. In this we can see the rated voltage is obtained at the receiving end of the power system.

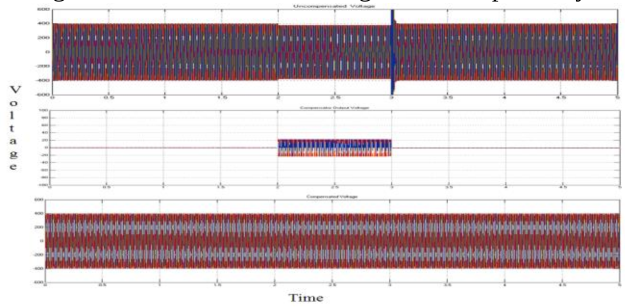

Fig.15. Waveform of (a) Uncompensated Load Voltage (b) Compensator (UPQC) Output Voltage (c) Compensated Load Voltage

The voltage across DC link capacitor is shown in the Fig 16. 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.17 gives the percentage of the Total Harmonic Distortion (THD) obtained by this proposed method.

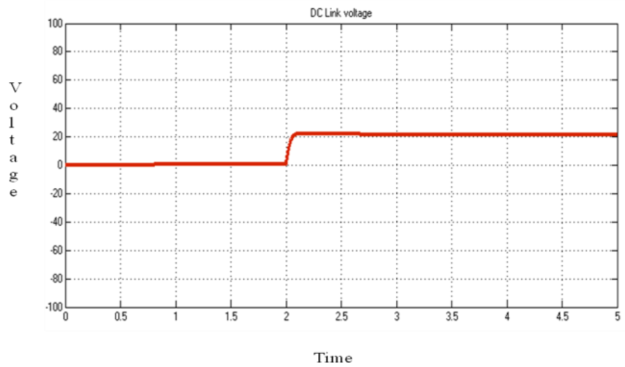

Fig.16 Waveform of DC Link Capacitor Voltage for proposed method

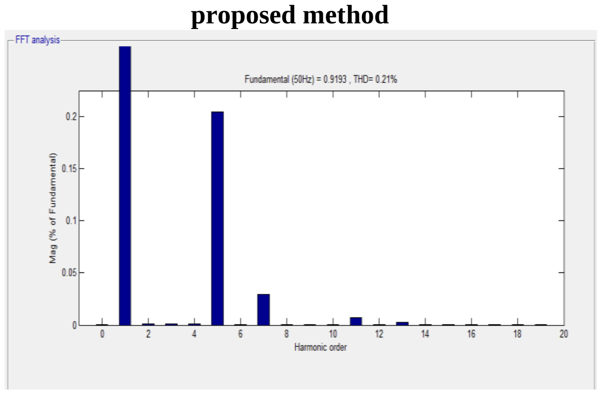

Fig.17. Measurement of Total Harmonic Distortion

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From the Fig.17 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 limited in our suggested model. Also the power factor is improved. The IEEE 14-bus system with UPQC is as shown in the Fig.18.

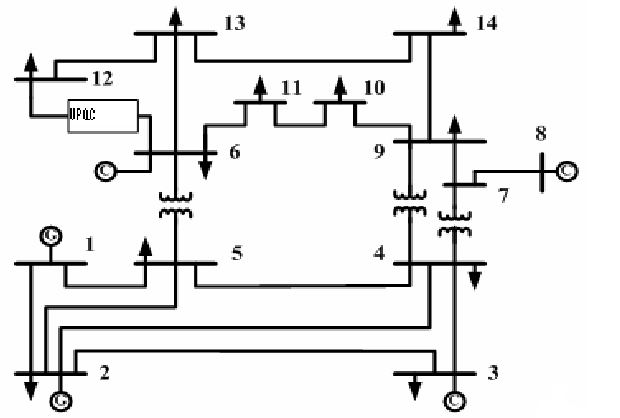

Fig. 18. IEEE 14-bus system with UPQC.

Table I: Variables and limitations of UPQC in IEEE 14-Bus System

Shunt Source		Series Source	
Rsh	0.00	Rse	0.00
Xsh	0.05	Xse	0.05
$V_{sh,max}$	1.11	$V_{se,max}$	0.59
$S_{sh,max}$	0.11	$S_{se,max}$	0.09

Table II: Computed Data's of IEEE 14-Bus System

Bus voltage measurements			
Bus	**Voltage**	**Bus**	**Voltage**
1	1.06	4	1.012

Injection measurements					
Bus	**P**	**Q**	**Bus**	**P**	**Q**
3	-0.8419	0.0432	8	-0.0011	0.17
9	-0.295	-0.166	10	-0.09	-0.06
13	-0.132	-0.06	14	-0.15	-0.1

Flow measurements					
Branch	**P**	**Q**	**Branch**	**P**	**Q**
1-5	0.8591	0.04	2-3	0.8	0.034
2-5	0.42	0.001	4-7	0.3	-0.1
4-9	0.16	-0.01	6-5	-0.5	-0.13
6-11	0.063	0.04	6-12	0.3	0.013
7-9	0.28	0.11	8-7	-0.0019	0.23
9-7	-0.281	-0.05	9-14	0.1	0.034
10-11	-0.03	-0.02	12-6	-0.223	-0.032
13-12	-0.2	-0.09	13-14	0.12	0.022

Table III: Computed Values of UPQC Control Variables in IEEE 14-Bus System

States of UPQC	WLS		WLAV	
	Shunt Source	Series Source	Shunt Source	Series Source
V	1.10	0.121	1.071	0.12
θ°	-13.34	44.01	-14.5	44.02
P	-0.011	0.011	-0.02	0.013
Q	0.0138	0.03	0.021	0.032
S	0.02	0.025	0.02	0.03

To scrutinize the efficiency of the proposed algorithm under the conventional data, the aggregated errors measurements are initiated by altering the sign of the computed values i.e. the real power flow in 9-14 and the power flow (P & Q) in 9-7. Figs. 19 & 20 show the entire percentage of the approximated errors for magnitude and phase angles with aggregated errors established. Note that the suggested WLAV method produces the smaller error both in the magnitude and phase angles. Besides, the percentage of the aggregated errors of the UPQC control parameters are shown in Table IV. An algorithm performance comparison for these test cases is given in Table V. Note that the state number of A is assessed in this work. Mean squared error of the condition approximation is also resolved. It can also be noticed that the suggested method dispense smaller MSE in the both case studies.

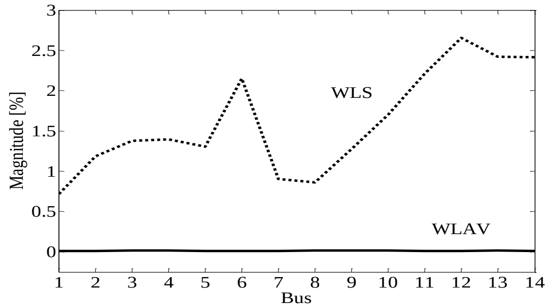

Fig. 19. complete value of percentage error of voltage magnitudes in IEEE 14-bus system

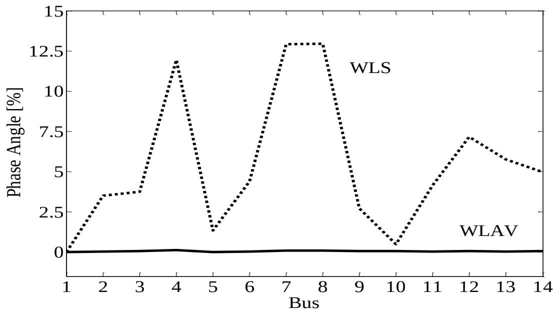

Fig. 20. Complete value of percentage error of phase angles in IEEE 14-bus system

Table IV: Percentage Error of UPQC control parameters 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

ethod	Case	Condition number*	MSE	Iter.	CPU Time (sec.)
WLS	1	8.5×10^{8}	4.16×10^{-2}	14	2.68
	2	2.6×10^{10}	3.68×10^{-1}	15	2.89
WLAV	1	2.3×10^{9}	1.17×10^{-4}	14	2.79
	2	1.3×10^{10}	1.45×10^{-4}	14	2.81

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VI. 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 solution for the altered IEEE 14-bus system elucidate the suggested algorithm that can be appealed competent for approximating the condition parameters of the power system with UPQC.

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