New Control Methods For Compensation Reactive Power in Electrical Systems With FC-TSR-TCR

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Abstract

The dynamic behavior of industrial loads needs to use compensator that adapts themselves with load changes. In this paper, reactive power control using fixed capacitor with controlled reactor with thyristor and switched reactor with thyristor (FC-TSR-TCR) was performed. Control draw current from FC-TSR-TCR conducted by control changing the thyristor firing angle, command circuits and power of electronic keys power and simulated static keys and current step changes obtained by thyristor reactor switching. Performed simulation results are shown using the MATLAB/Simulink software in different situations. Finally, simulation results are compared with theoretical results.

1. Introduction

In power electronic systems, systems and processes are used to compensate for the deleterious effects of dynamic non-linear loads. Dynamic industrial loads behavior need to use compensator that adapt themselves with load changes [1]. Some compensators are carried out to reduce line destitution losses, reduce harmonic components and improve power factor.

Compensation process should be done without major changes in the quality of the source signal. Unfortunately, the techniques that are often use for compensation base on circuit controller's change the signal waveform. Such as static compensators responsible for eliminates harmonics, reactive power compensate, power factor correction and save Energy.

However, normal static under conditions of voltage sinusoidal, with the creation of the corresponding waveform used to control the high- order harmonic component. In this paper, reactive power control using FC-TSR-TCR was performed. The simple structure of FC-TCR circuit is shown in Fig. 1 [2]. As this figure implies, compensation with TCR includes current control of reactor L from maximum (close thyristor conduction valve) to zero (opening thyristor conduction) using control method of thyristors firing delayed angle. Fixed capacitor (FC) and TCR for reactive power basic compensate are combined in FC-TCR arrangements. Command circuits and power of keys power electronic and static keys are simulated. A step change in current is obtained using the thyristor reactor switching. The simulation results are compared with theoretical results and the simulation results was conducted under different conditions is shown using MATLAB/Simulink software.

2. FC-TSR-TCR System

FC-TSR-TCR system by using TCR has been corrected. TSR system creates current changes as a step and TCR smooth current changes. Therefore, reactive power control range can be increased by TSR. TSR system is comprised of three reactors and three IGBT. Three ranges of current is achieved using three different switching [3]. FC-TSR-TCR system is the best system for dynamic loads.

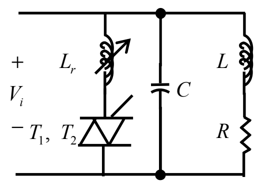


Fig. 1. A simple circuit FC-TCR

3. The Firing Angle of the Thyristors Calculating

Firing angle is calculated in the time domain or frequency domain by using various techniques. Assuming a sinusoidal voltage source, calculate the firing angle is obtained with less complexity. To calculate the firing angle of the TCR thyristor, we consider electrical circuits of Fig. 1 with circuit analysis as Fig. 2 [4].

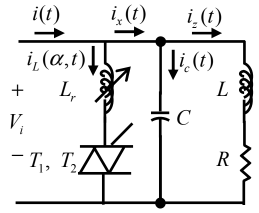


Fig. 2. FC-TCR electrical circuit for finding firing angle of the thyristors

According to the figure, load does not have to be linear, non-linear load can also be analyzed. All elements and currents branches clearly presented in Fig. 2 and do not need explanation. We should be careful if in Fig.2 consider the L reactor as variables; the FC-TSR-TCR structure is obtained. Therefore, the circuit analysis for both FC-TCR and FC-TSR-TCR is similar.

We calculate the firing angle α so that the drawn current from the voltage source to reach their minimum and power factor is also modified [5]. Assuming a density-voltage relationship the source current as follows:

$$v(t) = V \cos \omega t \tag{1}$$

$$J_1 = \int_0^T i^2(t)dt \qquad T = 2\pi / \omega \tag{2}$$

As shown in Fig. 2, by writing Kirchhoff's current law at TCR node we have:

$$i(t) = i_x(t) + i_L(\alpha, t) \tag{3}$$

$$i_L(\alpha,t) = \begin{cases} \frac{V}{L\omega}(\sin\omega t - \sin\alpha) & \alpha \le \omega t \le \pi - \alpha \\ \frac{V}{L\omega}(\sin\omega t + \sin\alpha) & \pi + \alpha \le \omega t \le 2\pi - \alpha \end{cases} \tag{4}$$

Minimizing J_1 is obtained using the following equation [6-7]:

$$\int_0^T \frac{\partial i^2(t)}{\partial \alpha} dt = 2\int_0^T (i_L + i_x)\frac{\partial i_L}{\partial \alpha} dt = 0 \tag{5}$$

By replacing $\Delta\alpha / \Delta i_L$ into equation (5) we have:

$$-\frac{V \cos\alpha}{L\omega}\left[\int_{\alpha/\omega}^{(\pi-\alpha)/\omega} (i_L + i_x)dt - \int_{(\pi+\alpha)/\omega}^{(2\pi-\alpha)/\omega} (i_L + i_x)dt\right] = 0 \tag{6}$$

For $\alpha \neq \pi/2$, phrase in square brackets must be zero. With insertion of equation (4) in the above equation, we have:

$$\frac{4V}{L\omega^2}\left[(\frac{\pi}{2} - \alpha)\sin\alpha - \cos\alpha\right] = A(i_x, \alpha) \tag{7}$$

In the above equation $A(i_x,\ \alpha)$ are defined as follows:

$$A(i_x, \alpha) = \int_{\alpha/\omega}^{(\pi-\alpha)/\omega} i_x dt - \int_{(\pi+\alpha)/\omega}^{(2\pi-\alpha)/\omega} i_x dt \tag{8}$$

Fig. 3 shows the function $A(i_x, \alpha)$ and α amount that satisfies the equation (7) [8].

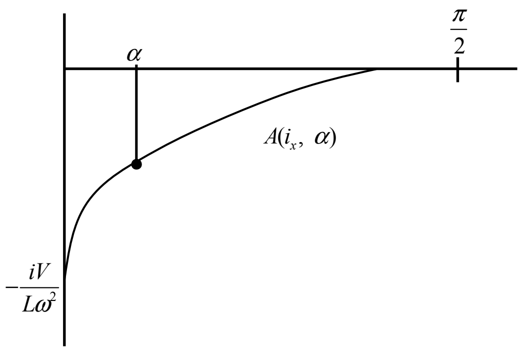


Fig. 3. The optimal value

We should note that $\alpha = \pi / 2$ is always a solution to equation [7]. If i_Z current measured instead of i_x current, optimal value of α is obtained by solving the following equation [9-10]:

$$\frac{4V}{L\omega^2}\left[(\frac{\pi}{2} - \alpha)\sin\alpha - (1 - LC\omega^2)\cos\alpha\right] = A(i_z, \alpha) \tag{9}$$

4. Simulation Results

The FC-TSR-TCR system simulation circuit is shown in Fig. 4. The simulation results that are shown in Figs. 5 to 13 are obtained by considering $50Hz$ frequency, $\omega = 100\pi\ (rad / \sec)$, $k_L = 300$, $k_Z = 20$, and $\alpha = 60^\circ$. Fig. 5 is illustrated source current in switching T_1 and T_2 thyristors which their switching pulses are shown in Fig. 6. Also, the voltages of TAP reactors are shown in Fig. 7(a) to 7(d). The current passing through the TCR, its output voltage and current are shown in Figs. 9 and 10, respectively.

According to switched system and operating of it, the active and reactive powers of load are obtained as Fig. 12. Considering obtained waveforms and comparison of active and reactive powers of FC-TSR-TCR, FC-TCR and FC-TCR-TSC with variable inductance, we should be careful that the shunt reactor performance in FC-TSR-TCR circuits and FC-TCR-TSC by signals that are given to shunt keys entering the circuit. In this reactor simulation, the reactor at 1.4 seconds is removed from the circuit.

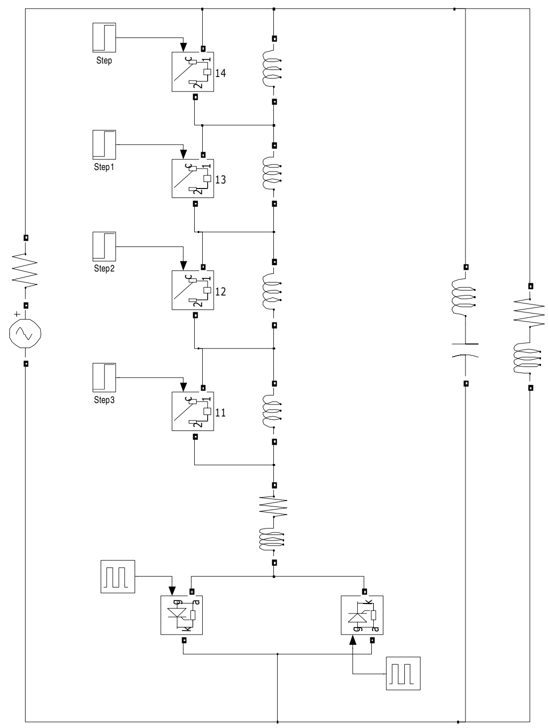


Fig. 4. The FC-TSR-TCR system

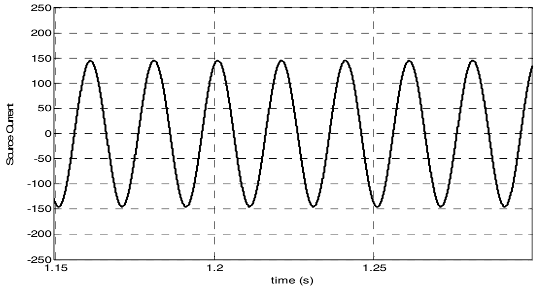
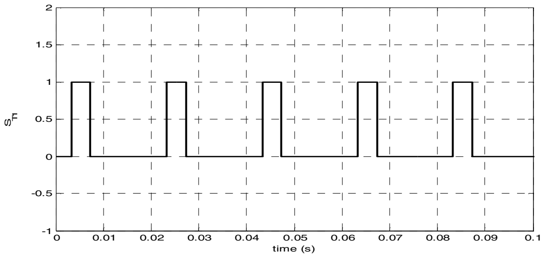
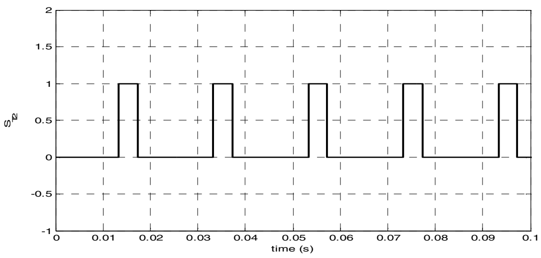


Fig. 5. The current of source

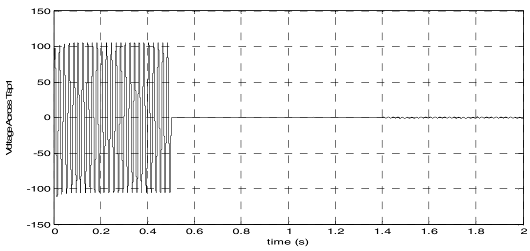


(a)

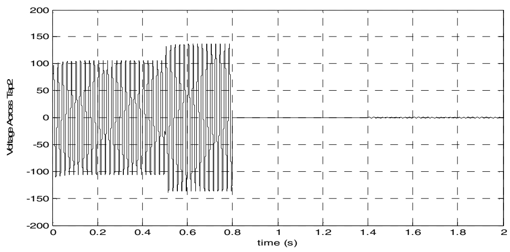


(b)

Fig. 6. Switching pulse of thyristors; (a) for T_1, (b) for T_2



(a)



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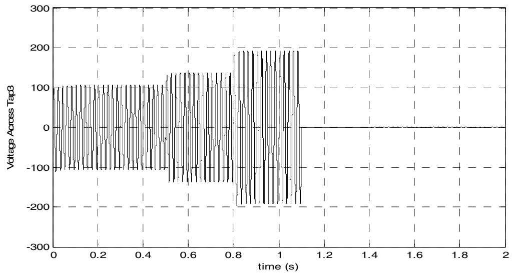
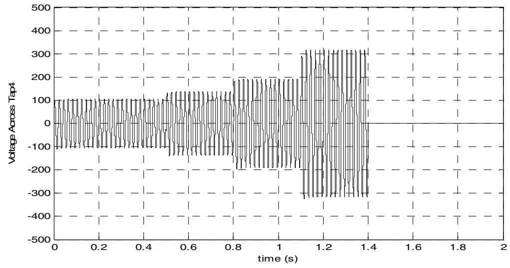
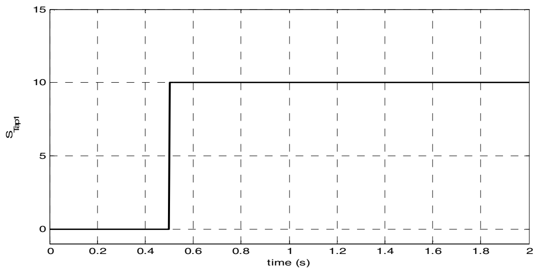


(c)

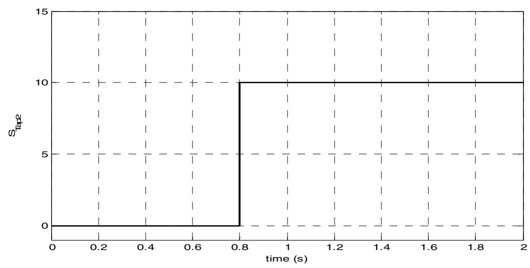


(d)

Fig. 7. The voltages waveforms of TAP reactors



(a)



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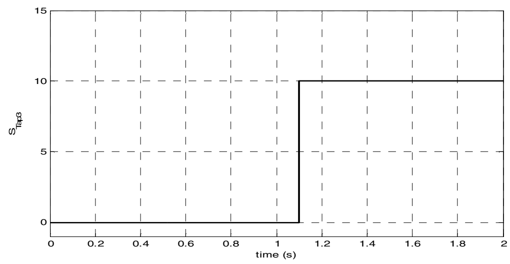

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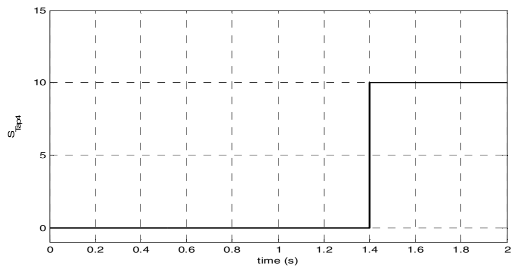


(d)

Fig. 8. Switching pulses for parallel switches

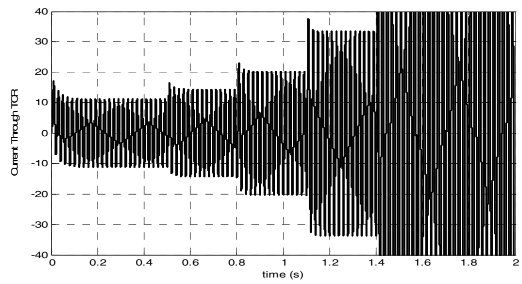


Fig. 9. Passing current through TCR

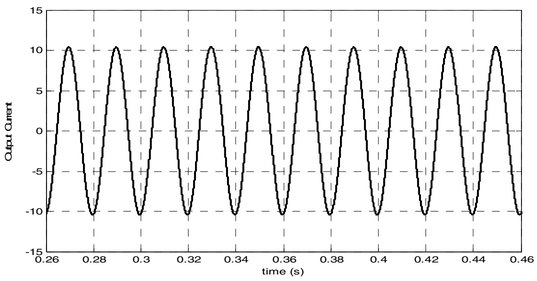


Fig. 10. Output current waveforms

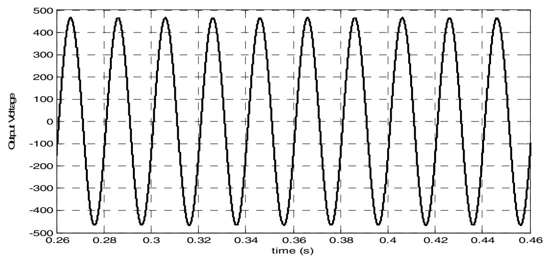
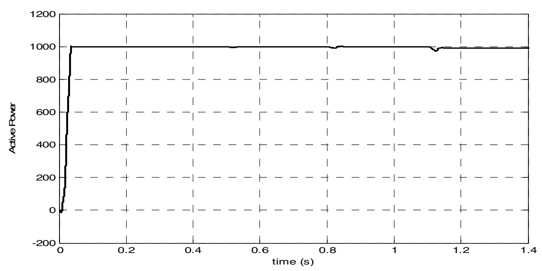
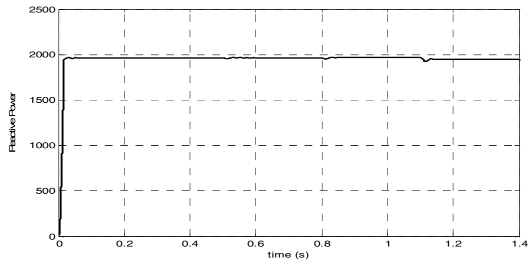


Fig. 11. Output voltage waveforms

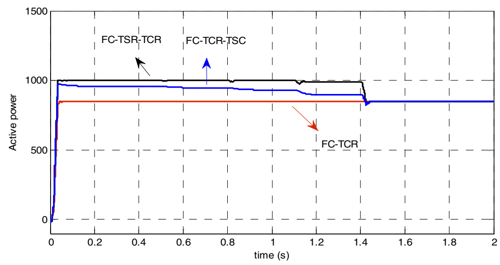


(a)

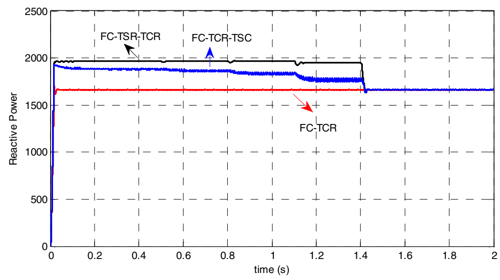


(b)

Fig. 12. The output powers of load; (a) active power, (b) reactive power



(a)



(b)

Fig. 13. Comparison of active and reactive power by mentioned compensators; (a) active power, (b) reactive power

5. Conclusion

Reactive power variation with changing fire angles can be measured. The reactive powers can increases using thyristor controlled reactor system and fixed capacitor. FC-TSR-TCR circuit model is simulated using MATLAB software. From the simulation results it can be concluded that the change of reactive power by FC-TSR-TCR system is smoother. Simulated results are quite close to the theoretical results.

6. References

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