Reactive Power Control in Eight Bus System Using FC-TCR
T. Vijayakumar and A. Nirmalkumar

Abstract—This paper deals with the simulation of eight bus system having fixed capacitor and thyristor controlled reactor. The system is modeled and simulated using MATLAB. The simulation results are presented. The power and control circuits are simulated. The current drawn by the TCR varies with the variation in the firing angle. The simulation results are compared with the theoretical results.

Index Terms—Facts, TCR, MATLAB, FC, FFT, THD, PWM, harmonics, Simulink, reactive power.

I. INTRODUCTION
In the control of Electric Power Systems, systems and procedures are used to compensate dynamically the detrimental effects of non-linear loads. The compensation process should be carried out without important alteration of source signal quality. Some benefits are expected using compensation reduction of losses in distribution lines, harmonic content minimization, and power factor improvement. The dynamic behavior of industrial loads requires the use of compensator that can be adapted to load changes. Unfortunately, the techniques frequently used for compensation are based on circuit controllers that alter the waveform of the signal subjected to control. Such is the case of the static compensator [1], [2], which must perform harmonic cancellation, reactive power compensation, power factor correction, and energy saving. Although the static compensator is commonly used and studied under sinusoidal voltage conditions, waveforms corresponding to the controlled current present high harmonic content. This paper focuses on the thyristor-controlled reactor [3] as shown in Fig. 1.

Compensation with TCR consists of controlling the current in the reactor L from a maximum (thyristor valve closed) to zero (thyristor valve open) by the method of firing delay angle control. The fixed capacitor (FC) and TCR constitute a basic VAR-generator arrangement (FC-TCR). The constant capacitive VAR generation of C is opposed by the variable VAR absorption of the TCR. The circuit model of FC TCR system is shown in Fig. 2.

Calculation of the firing angle can be made in the time domain or in the frequency domain, using different approaches. Assuming the supply voltage to be sinusoidal, calculation of the firing angle is obtained with minimum complexity. However, the increase in $\alpha = \pi / 2$ to $\alpha = \pi$, produces increasing distortion of the current in the TCR branch, and consequently that of line current. It increases the rms value of the line current and the THD, and deteriorates the power factor.

The literature [1] to [13] does not deal with the simulation of 8 bus system with FC-TCR system. An attempt is made in the present work to simulate 8 bus system with FC-TCR system using MATLAB® Simulink.

II. STEP BY STEP ALGORITHM
Step 1: Obtain the schematic structure of practical bus system (Sources, Transmission Lines, FACTS Devices and Load) using Simulink blockset.
Step 2: Obtain the switching sequence of the FACTS Devices through Pulse Width Modulation scheme when operating between the active regions of the firing angles from $90^\circ$ to $180^\circ$.
Step 3: Run the simulation and study the impact of FC-TCR with normal conditions.
Step 4: Obtain the voltage and reactive power quantities by connecting the above FACTS devices at different load nodes.
Step 5: Demonstrate the impact of FC-TCR device when subjected to vulnerable condition such as non linear load fault conditions.

III. SIMULATION RESULTS
The components of FC-TCR are modeled in the simulink block set as shown in Fig. 2. FC-TCR is connected with a voltage source along with a transmission line. The triggering of FC-TCR is done by PWM technique between $90^\circ$ and $180^\circ$. The firing angle of FC-TCR is set at $110^\circ$ and the corresponding pulse waveform is illustrated in Fig. 3(a). The voltage and reactive power profile for the corresponding firing angle are illustrated in Fig. 3(b). The bidirectional switch is implemented using 4 diodes and 1 thyristor. It is inferred that FC-TCR is regulating the reactive power and maintains the voltage profile within the tolerable limits. Since it is a power electronics device, the harmonic analysis is also demonstrated in the Fig. 3(c). The performance of real power due to FCR is also demonstrated in Fig. 3(d). The voltage, real and reactive power profiles for the FC-TCR firing angle 144 is also demonstrated from Figs. 3(e), 3(f).
Fig. 2. Circuit model of FC-TCR.

Fig. 3. (a) Switching pulses of FC-TCR, (b) Voltage and reactive power with Alpha=110, (c) FFT Analysis for the voltage, (d) Real power with alpha=110, (e) Voltage and reactive power with alpha=144, (f) Real power with Alpha=144.
From the illustrated demonstrations, it is inferred that the FC-TCR is capable of delivering the reactive power and regulates the voltage in the system. The above firing angles are selected because control range of $\alpha$ lies between 90 and 180.

IV. EIGHT BUS SYSTEM WITH VARIOUS LOADS

The circuit model of 8 bus system is shown in Fig. 4. An additional load is connected in parallel with the load at bus 8. When the additional load is connected, the amplitude of the voltage decreases as shown in Fig. 5(a). The voltage across the second load is shown in Fig. 5(b). It can be seen that the additional load is connected at $t = 0.2$ second.

Eight bus system with FC-TCR is shown in Fig. 6. The FC-TCR circuit alone is shown in Fig. 7. Voltage across load-1 is shown in Fig. 8. A non-linear load is connected instead of linear load at the eighth bus. In the non-linear load a diode rectifier is connected with parallel resistance/capacitive $dc$ load as shown in Fig. 9. The voltage analysis for the above case study has been carried out with the FC-TCR and the corresponding waveform is given in Fig. 10. It shows that the magnitude of the voltage remains settle with the FC-TCR. The harmonic voltage
The circuit model for FC-TCR is a combination of thyristor controlled reactor and fixed capacitor system. The variation in the firing angle is studied. The range of FC-TCR is analyzed. The variation of reactive power with the curve shown in Fig. 12. It can be seen that the reactive power in the load buses increases by using FC TCR system. Reactive power drawn by the load increases with FC-TCR since the bus voltage increases. The simulation results are in line with the predictions.

**TABLE I**

<table>
<thead>
<tr>
<th>Bus No</th>
<th>Reactive Power (MVA) Without Compensation</th>
<th>Reactive Power (MVA) With Compensation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUS-1</td>
<td>0.55</td>
<td>0.551</td>
</tr>
<tr>
<td>BUS-6</td>
<td>0.449</td>
<td>0.449</td>
</tr>
<tr>
<td>BUS-2</td>
<td>0.680</td>
<td>0.699</td>
</tr>
<tr>
<td>BUS-8</td>
<td>0.639</td>
<td>0.649</td>
</tr>
</tbody>
</table>

**TABLE II**

<table>
<thead>
<tr>
<th>THETA (DEGREE)</th>
<th>REACTIVE POWER (MVA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>36</td>
<td>0.779</td>
</tr>
<tr>
<td>72</td>
<td>0.644</td>
</tr>
<tr>
<td>108</td>
<td>0.647</td>
</tr>
</tbody>
</table>

The reactive power at various buses with and without compensation is given in Table I. It can be seen that the reactive power in the load buses increases by 2% with the addition of a single FC-TCR system. The variation of reactive power with the variation in the firing angle is given in Table II. The variation is also given in the curve shown in Fig. 12. It can be seen that the reactive power decreases with the increase in firing angle.

**V. CONCLUSIONS**

The control of reactive power in 8 bus system using FC-TCR is analyzed. The variation of reactive power with the variation in the firing angle is studied. The range of reactive power control can be increased by using the combination of thyristor controlled reactor and fixed capacitor system. The circuit model for FC-TCR is obtained and the same is used for simulation using MATLAB® Simulink. From the simulation studies it is observed that the reactive power variation is smoother by using FC TCR system. Reactive power drawn by the load increases with FC-TCR since the bus voltage increases. The simulation results are in line with the predictions.

**REFERENCES**


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