Power Quality Enhancement Using Thyristor controlled reactor and Thyristor switch capacitor

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Abstract
This paper proposed the combination of thyristor controlled reactor and thyristor switched capacitor for enhancing the power quality by reducing the harmonic distortion and reactive power of the system. In this paper we discuss about the thyristor controlled reactor and thyristor switch capacitor and their combination with passive filter for controlling reactive power and current harmonics of the power system. By the raise of nonlinear loads in any the power system, additional more filters are required. Hence this scheme is helpful for nonlinear loads types power system. In this The simulation and investigational results are found to be fairly acceptable to reducing harmonic distortions and reactive power damages.

Keywords: power quality, harmonic distortion, thyristor controlled reactor, thyristor switch capacitor, passive filter.

1. Introduction
In today’s circumstances the use of modern semiconductor switching devices is becoming more important in a many ranges of applications in supply networks, mainly in domestic and manufacturing loads. Examples of such applications commonly used are adjustable-speed motor drives, diode and rectifiers, uninterrupted power supplies, present nonlinear operational characteristics, these devices bring in contamination to voltage and current waveforms at the PCC of nonlinear industrial loads. The thyristor controlled reactors of a variety of network configurations that are commonly used in industries and all other power systems for harmonic reduction and dynamic power factor improvement. These thyristor operated reactors are operate as a variable reactance in together the inductive and capacitive domains. For the bidirectional power supply applications system, for this the current supply converter is modeling and simulated with nonlinear types RL load. The required modeling and simulations are carry out in MATLAB software using SIMULINK and power system block. The performance of different configurations of filters on power quality is studied carryout. In this paper we have resolve the problem of reactive power by the use of filters and thyristor controlled reactor and capacitor with combination in the power system.

Power quality
Power quality is defined by the factor that expresses reactive power, harmonic pollution and load unbalance. The best ideal electric supply will be sinusoidal voltage waveform through constant magnitude and frequency but into the reality due to the greater than zero impedance of the power supply system the large range of loads can be encountered and other phenomena that is transients and outages, the actuality is often different. If the power quality of network will be good then any load connected to the network will be run satisfactorily and efficiently. In AC supply, the current is usually phase-shifted in the source voltage. It leads to dissimilar power definition. The active power P[KW], it is responsible for the useful work, which is related with the fraction of the current which is in phase to the voltage. The relation between the dynamic power and the apparent power is referred to as the power factor (cosφ) and is a measure of efficient utilization of the electrical energy. Unity power factor (cosφ equals to one) refers to the more proficient transfer of positive energy. A cos φ , which is equals to zero refer to the more inefficient way of transferring the energy.

Harmonic Distortion
The harmonic contamination is generally associated by the total Harmonic Distortion or else THD which is by
the explanation equal to the ratio of the RMS harmonic substance to the fundamental:

$$\text{THDV} = \frac{\sqrt{V_{\text{rms}}^2 - V_1^2}}{V_1} = \sqrt{\sum_{k=2}^{\infty} \frac{V_k^2}{V_1}}$$

Where $V_k$ is the kth harmonic component of the signal $V$. These measures, expressed in percentage, are very practical when the elementary value component is perfectly given or known. Consequently, the THD is mainly significant information in favor of the voltage (as the rated voltage are known). In order to be able to gauge THD of the current, it is imperative that a fundamental frequency current reference be defined. Harmonics has several undesirable effects on electric PQ. mysterious computer network failures, premature motor burnouts, humming in telecommunication lines, and transformer overheating are only a few of the damage that quality problems may bring into home and industrial installations. What may appear like minor quality problems may bring entire factories to a standstill.

2. Thyristor controlled reactor (TCR)

A TCR is a very effective parts of thyristor-based SVCs. even though it can be also use alone, it is more frequently employed in grouping with set of thyristor switched capacitors to propose rapid and continuous control of reactive power above the complete preferred lagging-to-leading range. A primary single phase TCR comprises as an anti-parallel attached pair of thyristor valves, Th1 and Th2, in sequence with a linear air-core reactor, as shown in fig. The anti parallel thyristor pair acts like a bidirectional toggle, with thyristor Th1 conducting in +ve half-cycles and thyristor Th2 conducting in the -ve half-cycles of the provide voltage. The firing angle of the thyristors is deliberate from the zero crossing of the voltage appear across its terminal.

The current lags 90° behind the voltage in harmony with normal AC circuit assumption. As $\alpha$ raise above 90°, up to a greatest of 180°, the current decreases and becomes irregular and non-sinusoidal. The TCR current, as a function of time, is then given by

$$\omega t < \pi - \alpha : I(\omega t) = I_{\text{tor-max}}\sqrt{2}[\cos(\alpha) - \cos(\omega t)]$$
$$\omega t > \pi + \alpha : I(\omega t) = I_{\text{tor-max}}\sqrt{2}[\cos(\alpha) - \cos(\omega t)]$$
$$\alpha < \omega t < 2\pi - \alpha : I(\omega t) = I_{\text{tor-max}}\sqrt{2}[\cos(\alpha) - \cos(\omega t)]$$

a. The capacitor voltage is not corresponding to the provide voltage while the thyristors is fired. immediately after closing the switch, an current of unlimited magnitude is flow and charge the capacitor to the provide voltage in an substantially small time. The switch realized by the thyristor cannot survive this stress and will be fail.

b. The power of capacitor is equal to the supply voltage (vs.) then The current will leap without delay to the charge of the steady-state current.
even though the quantity of the current does not go above the steady-state values, the thyristor has a higher boundary of that they can survive during the firing procedure. Here is unlimited, and the thyristor switch will once more fail.

4. TCR-TSC combination

The Thyristor controlled reactor and thyristor switched capacitor comprises usually n-series of TSC and only TCR that are attached in parallel. The capacitor could switch in discrete steps, while continuous controlled inside the reactive power period of each step is provided by TCR. As the dimension of TCR is little the harmonic production is significantly reduced. The TSC twigs are tune with series reactor at dissimilar governing harmonic frequencies.

Fig.4: circuit diagram of TCR-TSC combination

The most important aim of developing TCR-TSC arrangement are for enhancing the operational suppleness of the compensator for the duration of big instability and to reducing the steady-state losses. What mainly aggravate the difficulty in which harsh voltage swings are knowledgeable and it is followed by the load rejection. But TCR-TSC could rapidly activate to cut off or disconnect every capacitor from the compensator, providing ringing oscillations.

Extraction of firing angle ‘α’

The reflected reactance could be modeled and its value is defined by a role of firing angle there is two types of correlation that are star and delta model of connection. The corresponding inductance of the star connection is given by

\[ L_{PF}(\alpha) = L_{PF} \frac{\pi}{2\pi - 2\alpha + \sin(2\alpha)} \]

Where firing angle is bounded as \( \alpha \leq \pi \)

The corresponding delta inductance is given by

\[ L_{PF}(\alpha) = L_{PF} \frac{\pi}{2\pi - 2\left(\alpha + \frac{\pi}{6}\right) + \sin\left(2\left(\alpha + \frac{\pi}{6}\right)\right)} \]

Where firing angle is bounded as \( \frac{\pi}{3} \leq \alpha \leq \frac{5\pi}{6} \)

The delta connection susceptance is

\[ B(\alpha) = B \frac{\pi}{2\pi - 2\left(\alpha + \frac{\pi}{6}\right) + \sin\left(2\left(\alpha + \frac{\pi}{6}\right)\right)} \]

Where \( B = \frac{1}{L_{PF}} \)

The total reactive power of filter is

\[ Q_{PF}(\alpha) = 3V^2 \left(B_L - B_C(\alpha)\right) \]

Where \( B_L(\alpha) = \frac{1}{x_L(\alpha)} \) and \( B_C = \frac{1}{x_C} \)

5. Passive filter with TCR-TSC

Passive filter with the arrangement of thyristor control reactor and thyristor switch capacitor with the synchronous reference frame method for reimbursement of reactive power along throughout voltage and current harmonics. The most imperative idea for designing of TCR-TSC were for enhancing the operational speed of the compensator for the duration of bulky disturbances and for the dropping of the steady-state losses. What predominantly exaggerate the problem in which harsh voltage swings are comes in practiced and follow by the load elimination. But TCR-TSC could rapidly activate to cut off all the capacitor from the compensator producing ringing oscillations. The arrangement of the passive filters in the company of TCR and TSC are also be designed and analyzed to advance the power quality at the ac mains. This system has resulted in the enhanced power quality in the company of overall condensed rating of passive components used in front last part ac-dc converters with RL load.
6. Simulation result
The results of the simulation are taken all through the Power System tools in MATLAB and the taken system speciation as given below.

**TABLE 6. Specification for Test System**

<table>
<thead>
<tr>
<th>Component</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC source</td>
<td>$V_e = 415\text{ V, } f=50\text{Hz}$</td>
</tr>
<tr>
<td>Nonlinear load</td>
<td>Three-phase Thyristor Rectifier RL=40(Ω) LL=50(mH)</td>
</tr>
<tr>
<td>Passive filter</td>
<td>LPF=16(mH),RPF=0.83(Ω),CPF=25(μF)</td>
</tr>
</tbody>
</table>

Waveform of Total harmonic distortion of the power system with and without tcr-tsc combination.

**TABLE 6. Comparisons THD with Different Schemes**

<table>
<thead>
<tr>
<th>Matlab/simulink modal</th>
<th>Voltage harmonics</th>
<th>Current harmonics</th>
<th>Total reactive power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without filter</td>
<td>29.83</td>
<td>7.49</td>
<td>5</td>
</tr>
<tr>
<td>With filter</td>
<td>21.55</td>
<td>1.42</td>
<td>0.5</td>
</tr>
<tr>
<td>With TCR-TSC combination</td>
<td>7.19</td>
<td>0.746</td>
<td>0</td>
</tr>
</tbody>
</table>

7. Conclusion
As in the above table It has been shown that the choice of TCR-TSC arrangement helps to sinking the passive filter capacitor rating near approximately 80%. The overall enhancement of power quality of the system has been confirmed by simulation results. The most important goals were to pay compensation the load reactive power and the current & voltage harmonics generated by the current source types of non linear load.
The THD less than the current source type of non linear load has been decrease for delta connection from 25% to 1.3%. The foremost principle of this study has been to buildup different power quality improvement techniques for enhancing different power quality indexes at ac mains same as for dc supply in ac-dc converter power system with RL load. It have also proposed to resolve the amount of improvement in special power quality indices in a variety of techniques for application.

Reference

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