Power Quality Improvement using Combined SHPF and TCR for Micro grids

B.Venkateswara Rao, Ch Chinna Veeraiah

Abstract- Nonlinear loads cause significant harmonic currents with poor input power factor (PF), which create serious problems at the power supply system. Traditionally, passive filters have been used to eliminate current harmonics of the supply network. However, these devices suffer from resonance. This paper proposes a combined system of a thyristor-controlled reactor (TCR) and a shunt hybrid power filter (SHPF) for harmonic and reactive power compensation. The SHPF is the combination of a small-rating active power filter (APF) and a fifth-harmonic-tuned LC passive filter. The tuned passive filter and the TCR form a shunt passive filter (SPF) to compensate reactive power. The small-rating APF is used to improve the filtering characteristics of SPF and to suppress the possibility of resonance between the SPF and line inductances. A proportional–integral controller was used, and a triggering alpha was extracted using a lookup table to control the TCR. A nonlinear control of APF was developed for current tracking and voltage regulation. The shunt filter is controlled by the pulse width modulation technique. Integral compensators were added in both current and voltage loops in order to eliminate the steady-state errors due to system parameter uncertainty. The MATLAB simulation results are found to be quite satisfactory to mitigate harmonic distortions and reactive power compensation.

Index Terms- Power Quality, Shunt hybrid Power Filter, Thyristor controlled reactor, Shunt Passive filter..

I. INTRODUCTION

Global competition is ballooning, forcing companies to seek value and automate processes where ever possible. Computer technology is increasingly used to accomplish these goals, which means more compute power is required [1]. The growing use of non-linear and time varying loads has led to distortion of voltage and current wave forms and increased in reactive power demand in AC mains. Harmonic distortion is known to be source of several problems such as increased power losses, excessive heating of rotating machines, audible noise and incorrect operation of sensitive loads etc [2].

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To design a more cost-effective power distribution system for modern computer systems, this paper defines mitigation technique using SHPF-TCR, discusses options that might be recommended to control Shunt Active Filter [1],[9]. Traditionally passive filters have been used to eliminate current harmonics of the supply network. However these devices are suffers from resonance. Recently the active filters were developed to mitigate the problems of passive filters and used to compensate the reactive power flow in the transmission line and The supply current is distorted by the non-linear loads such as UPS,DC drives, AC drives and arc furnaces etc.

The THD obtained without using the shunt active filter is much more than described in the IEEE standard-519. According to this standard the THD value should be less than 5%. The THD equation for voltage harmonics is given by

$$\%THD\ (V) = \frac{\sqrt{V_2^2 + V_3^2 + \cdots + V_n^2}}{V_1} \times 100$$

and the THD equation for current harmonics is given by

$$\%THD\ (I) = \frac{\sqrt{I_2^2 + I_3^2 + \cdots + I_n^2}}{I_1} \times 100$$

In this paper, a new combination of a shunt hybrid power filter (SHPF) and a TCR (SHPF-TCR compensator) are proposed to suppress current harmonics generated from the load and compensate the reactive power. The APF sustains very low fundamental voltages and currents of the power grid, and thus, its rated capacity is greatly reduced. Because of these merits, the presented combined topology is very appropriate in compensating reactive power and eliminating harmonic currents in power system. The tuned passive filter in parallel with TCR forms a shunt passive filter (SPF) [3]. This latter is mainly for fifth harmonic compensation and PF correction. The small-rating APF is used to filter harmonics generated by the load and the TCR by enhancing the compensation characteristics of the SPF aside from eliminating the risk of resonance between the grid and the SPF. The TCR goal is to obtain a regulation of reactive power. The set of the load is a combination of a three phase diode rectifier and a three phase star-connected resistive inductive linear load [9].

A control technique is proposed to improve the dynamic response and decrease the steady state error of TCR. The shunt active filter needs to be controlled to obtain the best performance and thus PI controllers are used. The

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performance of shunt active filter here is studied under balanced and unbalanced source voltage condition for nonlinear load. The simulation result shows that, this technology will throw light on the emerging solutions available for the power quality problem faced by small industries, [8] especially with harmonics current and reactive power demand drawn by the non-linear loads. Fig.1 shows the topology of the proposed combined SHPF and TCR. The SHPF consists of a small-rating APF connected in series with a tuned LC passive filter. In this paper, controlling of the shunt active filter using the PI controller with SPWM technique is analyzed and studied.

II. SYSTEM CONFIGURATION OF SHPF-TCR COMPENSATOR

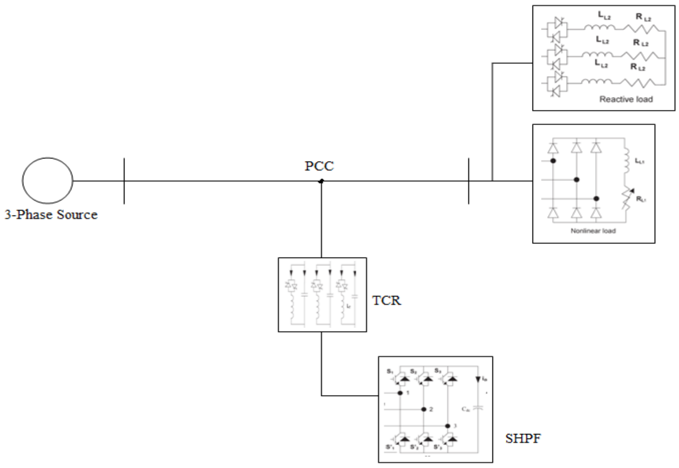

Fig. 1. Basic circuit of the proposed SHPF-TCR compensator.

A. Thyristor-Controlled Reactor

A linear air - cored reactor is connected in series with the anti-parallel connected thyristor is known as TCR. Fig .2 shows the schematic representation of the TCR [3]. The TCR goal is to obtain the regulation of reactive power. The anti-parallel connected thyristor pair acts like a bidirectional switch, with the thyristor valveT1 conducting in positive half cycles and the thyristor valve T2 conducting during the negative half cycle. The firing angle of the thyristors is measured from the zero crossing of the voltage appearing across its terminals.

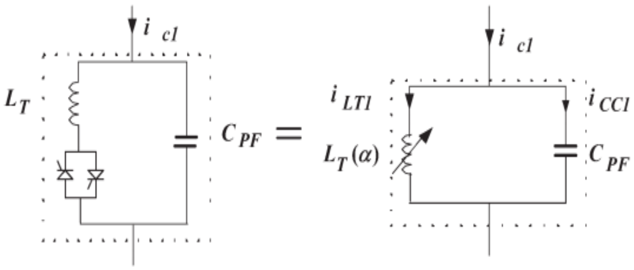

Fig. 2 Equivalent circuit of TCR

Fig. 2 shows equivalent circuit of thyristor controlled reactor used to filter out harmonics in proposed concept. The TCR is connected in series with combination of shunt hybrid active power filter. The equivalent inductance of the thyristor controlled reactor is given by

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

And susceptance is given by

$$B(\alpha) = B\frac{2\pi - 2\alpha + \sin(2\alpha)}{\pi}$$

Where $B = \frac{1}{L_{PF}\omega_0}$

B. Shunt Active Power Filter(SAPF)

Shunt active power filter (SAPF) is commonly used as an effective method in compensating harmonic components in non-linear loads. Fig. 3 shows the basic principle of SAPF in which APF is connected in parallel to the power system at a point of common coupling (PCC) between power supply station and power users. The objective of SAPF is to minimize the distortion in power supply using four main components – harmonic detection, compensating current control, DC bus voltage control, and active power filter.

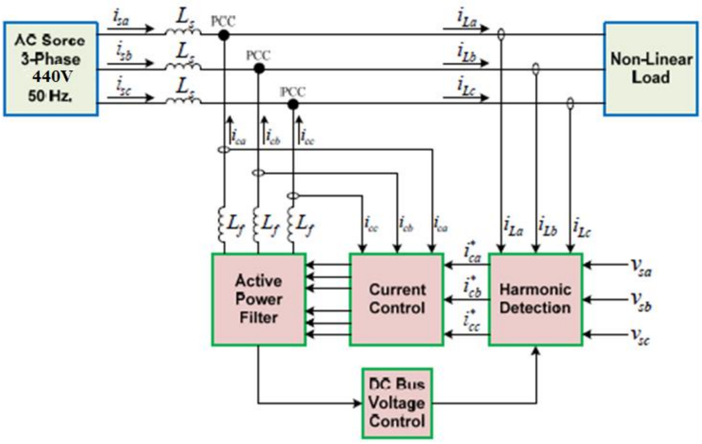

Fig 3. **Three – phase shunt active power filter**

In the harmonic detection component, the distorted signal can be detected by several harmonic detection techniques, i.e., the instantaneous reactive power theory (PQ), the synchronous reference frame (SRF), the d-q axis with Fourier (DQF), and the synchronous detection (SD) etc. Then, APF injects the compensating currents into the power system. The current control techniques are hysteresis current control, Pulse Width Modulation (PWM), and Space Vector Modulation (SVM) etc. For dc bus voltage control, proportional integral (PI) is employed.

The three voltages of shunt hybrid active filter are

$$v_{s1} = L_{PF}\frac{di_{c1}}{dt} + R_{PF}i_{c1} + v_{CPF1} + v_{1M} + v_{MN}$$

$$v_{s2} = L_{PF}\frac{di_{c2}}{dt} + R_{PF}i_{c2} + v_{CPF2} + v_{2M} + v_{MN}$$

$$v_{s3} = L_{PF}\frac{di_{c3}}{dt} + R_{PF}i_{c3} + v_{CPF3} + v_{3M} + v_{MN}$$

C. Control Strategy for SHAPF

The shunt hybrid active power filter current is controlled by using sinusoidal pulse width modulation technique. The sinusoidal pulse-width modulation (SPWM) technique produces a sinusoidal waveform by filtering an output pulse waveform with varying width. A high switching frequency leads to a better filtered sinusoidal output waveform. The desired output voltage is achieved by varying the frequency and amplitude of a reference or modulating voltage. The

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variations in the amplitude and frequency of the reference voltage change the pulse-width patterns of the output voltage but keep the sinusoidal modulation. A low-frequency sinusoidal modulating signal is compared with a high frequency triangular signal, which is called the carrier signal. The switching state is changed when the sine waveform
intersects the triangular waveform. The crossing positions determine the variable switching times between states. In three-phase SPWM, a triangular voltage waveform (VT) is compared with three sinusoidal control voltages (Va, Vb, and Vc), which are 120̊ out of phase with each other and the relative levels of the waveforms are used to control the switching of the devices in each phase leg of the converter.

D. DC Bus Voltage Regulation

The dc component will force the SHPF-TCR compensator to generate or to draw a current at the fundamental frequency. To regulate the dc voltage v_{dc}, the error $\tilde{v}_{dc} = v_{dc}^* - v_{dc}$ is passed through a PI-type controller given by

$$u_{dc} = k_1 \tilde{v}_{dc} + k_2 \int \tilde{v}_{dc}\, dt$$

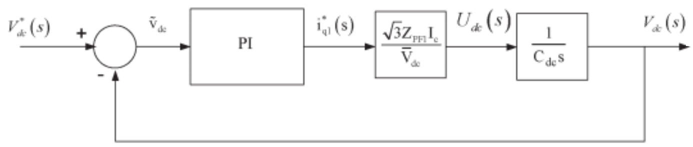

Fig. 4. Compensated voltage regulated model.

III. SIMULATION RESULTS

The proposed combination of shunt hybrid active power filter and thyristor controlled reactor is studied using MATLAB/ SIMULINK. The overall system configuration and controller are shown in fig 5(a), (b) & (c) for proposed system and shunt hybrid active filter. The system parameters are given in Table I. The simulation results of load bus & point of common coupling voltages and currents, THD are presented. The THD of uncompensated system is about 27% and it is reduced to 9.2% with the combination of shunt hybrid active power filter and TCR.

Table: 1 Simulation Parameter

Line to line Voltages and frequency	Vs = 440V, f = 50Hz
Line Impedance	0.1Ω, 0.5mH
Non Linear Load	30Ω, 20mH
Linear Load	30Ω
Passive filter parameters	1.2mH, 240µF
Active filter parameters	3000µ, 1kΩ
DC bus voltage of APF of SHAPF	50V
Cut off frequency of low pass filter	70Hz
Switching frequency	1200Hz

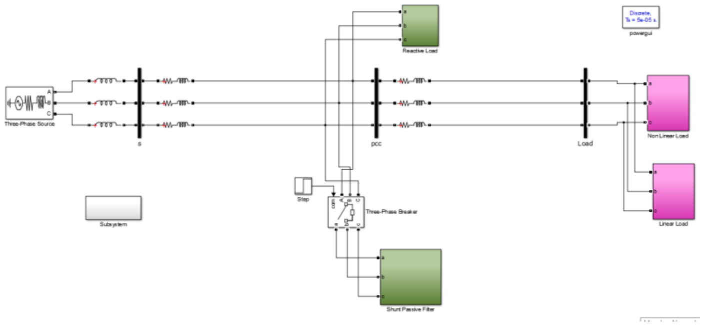

Fig 5(a) Simulation circuit of Proposed System with SHAPF - TCR

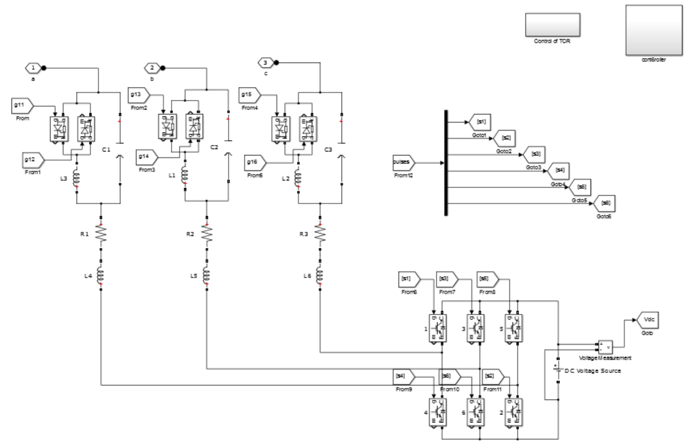

Fig 5(b) Simulation Circuit of Combined SHAPF - TCR

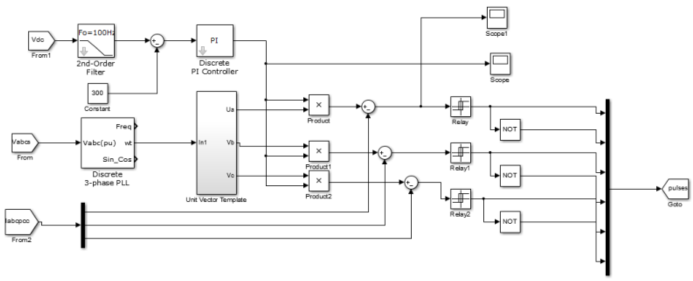

Fig 5(c) Control Circuit

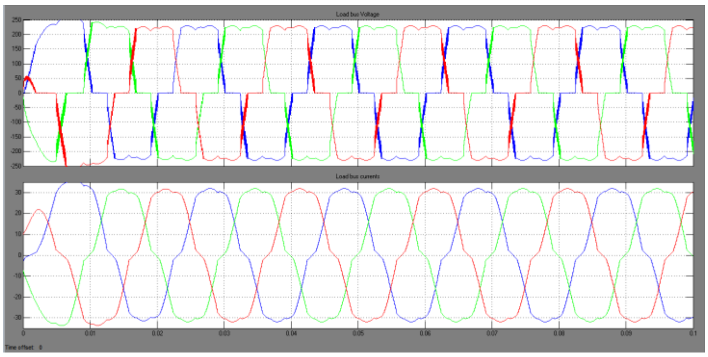

Fig 6 Load bus voltages and currents

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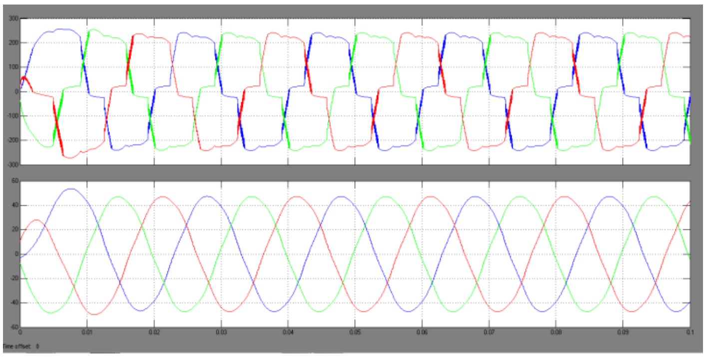

Fig 7 Voltages and currents at point of common coupling

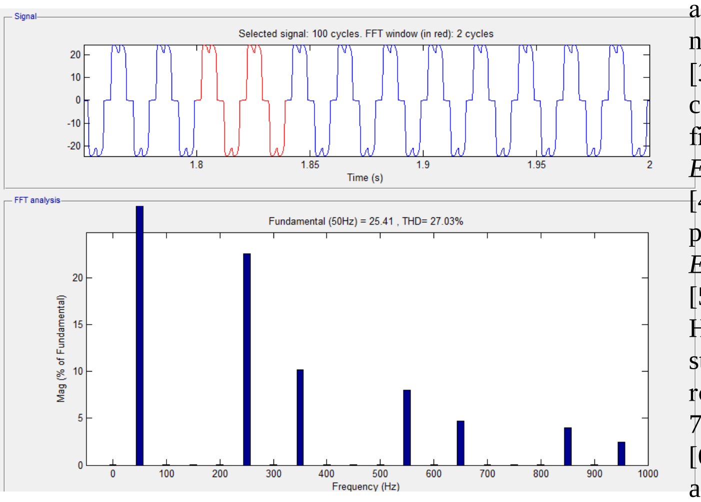

Fig 8 THD of Uncompensated System

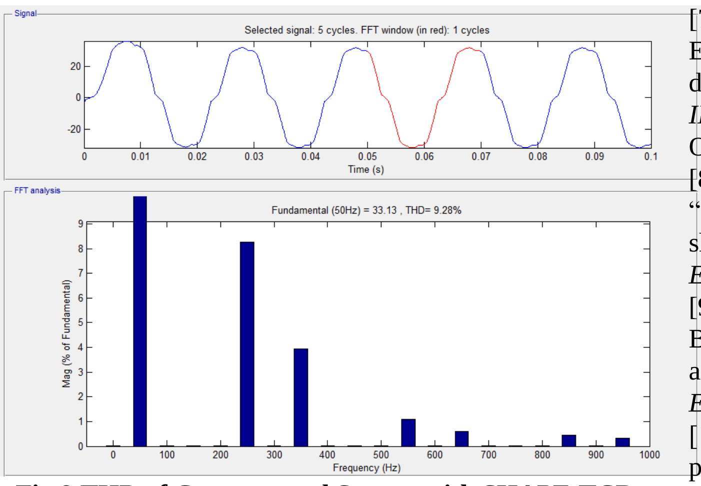

Fig 9 THD of Compensated System with SHAPF-TCR

IV. CONCLUSION

The combination of shunt hybrid active power filter and thyristor controlled reactor is proposed to eliminate the harmonics and to compensate the reactive power. The proposed system is implemented in two bus power system to analyze the effect with and without the combination of SHAPF and TCR and simulated in MATLAB/SIMULINK. The shunt active filter and SPF have a complementary function to improve the performance of filtering and to reduce the power rating requirements of an active filter. It has been found that the SHPF-TCR compensator can effectively eliminate current harmonic and reactive power compensation during steady and transient operating conditions for a variety of loads. It has been found that the total harmonic distortion of load currents without compensation is 27.03% and it is reduced to 9.2% in load and 2.09% in supply.

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