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T Source Inverter Based Shunt Active Filter with LCL Passive Filter for the 415V 50 Hz Distribution Systems

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ABSTRACT

The inverter topology is being used as an active filter to reduce the harmonics in the power system. The traditional voltage source or current source inverters are having the disadvantages of limited output voltage range hence it may not be able to supply enough compensating currents during heavy switching surges, Vulnerable to EMI noise and the devices gets damaged in either open or short circuit conditions and the main switching device of VSI and CSI are not interchangeable. The active filters are the type of DC-AC system with wide range of voltage regulation and integration of energy storages is often required. This cannot be achieved with conventional inverters and hence the impedance source inverters have been suggested. The T source inverters are basically impedance source inverters which can be used as an active filter in the power system. The MATLAB simulation is done and the results are discussed in this paper for both the types. The proposed dampening system is fully characterized by LCL based passive filters and T source inverter based shunt active filter. The disturbances in the supply voltage and load current due to the non linear loads are observed in the simulation. The same is studied after connecting the designed hybrid shunt active filter in the distribution system. The simulation results obtained from the proposed method proves that it gives comparatively better THD value.

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1. INTRODUCTION

The Harmonic in the distribution system are leads to poor power quality problems. With the proliferation of non-linear loads in industrial applications and frequent switching of loads in the distribution systems, the compensation of harmonic and reactive power is becoming increasingly concerned. The passive filters have been widely used because of their low cost. However, the performances of such filters are not sensitive to the variation of reactive power for the realization of better power factor. Hence the usage of active filters yields the effective and dynamic compensation with the variation of the current which cannot be carried out with passive filters. The compensation of harmonic and reactive power can be achieved dynamically in the case of SAF. The research in this field has been done for many years and researchers proposed several methods of improving THD value up to 5% by eliminating harmonics selectively or reducing it by using different filtering techniques in the active filters. The continuous power flow method is implemented in STATCOM and TCSC as their control strategy to improve the power system phenomenon and voltage stability [1-4]. A non-linear function based closed loop control strategy (without load current extraction) for three-phase SAF with LC passive filter to enhance the quality of power by reducing the harmonics [5]. The References papers have reported field test results of active filters intended for installation on distribution systems. The active filter is characterized to behave like a resistor for harmonic frequencies. The proposed distribution system consists of three distribution lines, installing the active filter on the end bus of each line is effective in harmonic damping. The power factor, reactive power flow, the voltage and current variations due to an non linear loads are observed using power quality meter and the same is verified in the simulation. The proposed shunt active filter consists of a three phase pwm inverter works based on instantaneous power theory and yields better results for source current THD, reactive power and power factor.

2. INSTANTANEOUS P-Q THEORY [CONTROL STRATEGY]

The instantaneous p-q theory has been used in active filters to determine the instantaneous reactive power that has to be compensated in active filters [2]-[3]. In this method, the Instantaneous real and imaginary powers have first been defined in the time domain. Let the three phase voltages are sensed at point of common coupling and denoted as ea, eb and ec. The load side currents are iaL, ibL and icL. The three phase voltages and load currents can be transformed into their orthogonal co ordinate equivalents as given below.

$$e_\alpha = \sqrt{\frac{2}{3}}\left(e_a - \frac{1}{2}e_b - \frac{1}{2}e_c\right)$$

$$e_\beta = \sqrt{\frac{2}{3}}\left(\frac{\sqrt{3}}{2}e_b - \frac{\sqrt{3}}{2}e_c\right)$$

$$e_0 = \sqrt{\frac{2}{3}}\left(\frac{1}{\sqrt{2}}e_a + \frac{1}{\sqrt{2}}e_b + \frac{1}{\sqrt{2}}e_c\right)$$

$$i_{\alpha\_load} = \sqrt{\frac{2}{3}}\left(i_{aL} - \frac{1}{2}i_{bL} - \frac{1}{2}i_{cL}\right)$$

$$i_{\beta\_load} = \sqrt{\frac{2}{3}}\left(\frac{\sqrt{3}}{2}i_{bL} - \frac{\sqrt{3}}{2}i_{cL}\right)$$

$$i_{0\_load} = \sqrt{\frac{2}{3}}\left(\frac{1}{\sqrt{2}}i_{aL} + \frac{1}{\sqrt{2}}i_{bL} + \frac{1}{\sqrt{2}}i_{cL}\right)$$

The α-β-0 is a three dimensional stationary frame of reference where as the voltage and current space vectors are rotating vectors. The two instantaneous real power p0 and pαβ, and an instantaneous imaginary power qαβ in three phase four wire system are defined with respect to load side and given below,

$$p_{0\_load} = (e_0 i_{0L})$$
$$p_{\alpha\beta\_load} = (e_\alpha i_{\alpha L} + e_\beta i_{\beta L})$$
$$q_{\alpha\beta\_load} = (-e_\beta i_{\alpha L} + e_\alpha i_{\beta L})$$

The system load currents in α-β-0 co ordinate system can also be determined using above equations by forming matrix and taking inverse transform. The reference powers are assigned to the Load Instantaneous Powers as follows,

$$p_0^* = -p_{0\_load}$$
$$p_{\alpha\beta}^* = p_{0\_load}$$
$$q_{\alpha\beta}^* = -q_{\alpha\beta\_load}$$

The compensating currents in α-β-0 reference frame can be calculated by using the reference powers mentioned in the above equations and are given below,

$$i_{c\_0} = \frac{p_0^*}{e_0} = -i_{0L}$$
$$i_{c\_\alpha} = \left(\frac{e_\alpha}{e_{\alpha\beta}^2}\right).p_{\alpha\beta}^* + \left(\frac{-e_\beta}{e_{\alpha\beta}^2}\right).q_{\alpha\beta}^*$$
$$i_{c\_\beta} = \left(\frac{e_\beta}{e_{\alpha\beta}^2}\right).p_{\alpha\beta}^* + \left(\frac{e_\alpha}{e_{\alpha\beta}^2}\right).q_{\alpha\beta}^*$$

Where, $e_{\alpha\beta} = e_\alpha^2 + e_\beta^2$
The same can be calculated in $a - b - c$ reference frame using following expressions,

$$i_{ca} = 0.57 \cdot i_{c\_0} + 0.82 \cdot i_{c\_\alpha}$$
$$i_{cb} = 0.57 \cdot i_{c\_0} - 0.41 \cdot i_{c\_\alpha} + 0.707 \cdot i_{c\_\beta}$$
$$i_{cc} = 0.577 \cdot i_{c_0} - 0.41 \cdot i_{c_\alpha} - 0.707 \cdot i_{c\_\beta}$$

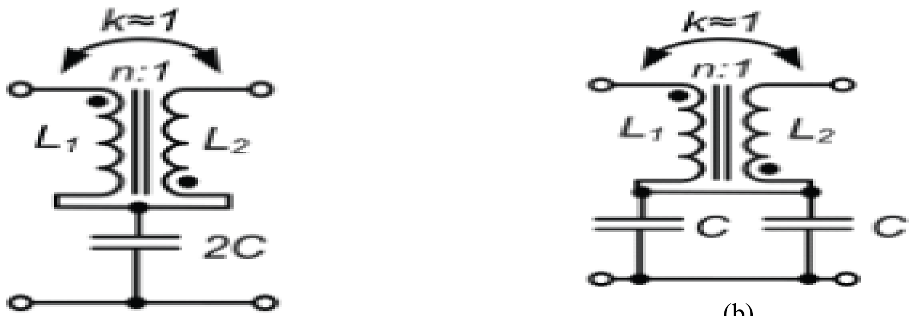
Finally the resultant source currents are obtained by adding the compensating currents with the load currents as follows,

$$i_{sa\_clean} = i_{aL} + i_{ca}$$
$$i_{sb\_clean} = i_{bL} + i_{cb}$$
$$i_{sc\_clean} = i_{cL} + i_{cc}$$

This theory is implemented to produce gate pulses for the T source inverter based shunt active filters. The LCL passive filter also connected in the distribution system at PCC. A non linear load of rectifiers supplying power for different loads is connected to the system. The same is simulated in the MATLAB and the diagram is given below.

3. T SOURCE INVERTER

The aim of this work is to show the possibility of realization of SAF using T Source inverter similar to Z-source inverter but with use of high frequency transformer with low leakage inductance. Theoretical analysis as well simulation and experimental results are shown in this paper. The idea here is to use this T source inverter instead of voltage source inverter as an active filter in the distribution system. The two possible configurations are shown in Figure 1 a and b. The number of passive elements used in T source inverter less compared to Z-source inverter. The shoot through state of source current is well handled in T source inverter compared to Z type. The performance of T-Source inverter based SAF is observed from the MATLAB simulation, the results are given below.



(a) (b)

Figure 1 The two possible configurations; a and b equivalent circuits of T Source

4. LCL FILTER

The LCL filter as Figure 2 has commonly been used to give a better smoothing of output currents from a voltage source based converters compared to other L and LC filters. A lot of research has been done in the applications of LCL filters with grid-connected inverters and PWM based rectifiers mainly due to its ability to minimize the harmonics injected into the grid [6]-[7]. The investigations on LCL filter now have focused on fundamental current tracking and resonance damping for mostly simple grid connected inverters and rectifiers. The resonance frequency of LCL filter is usually tuned to be at least ten times of the fundamental line frequency for the above mentioned applications. It is therefore not difficult to simultaneously achieve the desired control objectives at fundamental frequency using existing control techniques. The Model, Design criteria and performance of LCL filter is discussed in the ferences [6] and [7].

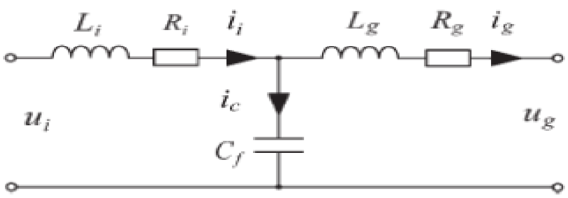


Figure 2. LCL Equivalent circuit of LCL filter

5. SIMULINK MODEL OF PROPOSED SYSTEM

The hybrid shunt active filter consists of LCL passive filter and impedance [T connected] source inverter based active filter. The switching pulses for the active filter are produced using instantaneous p-q theory based controller. The power quality parameters such as source current THD, power factor and reactive power requirements are observed by MATLAB simulation and tabulated. The values of them prove the effectiness of HSAF, as Figure 3.

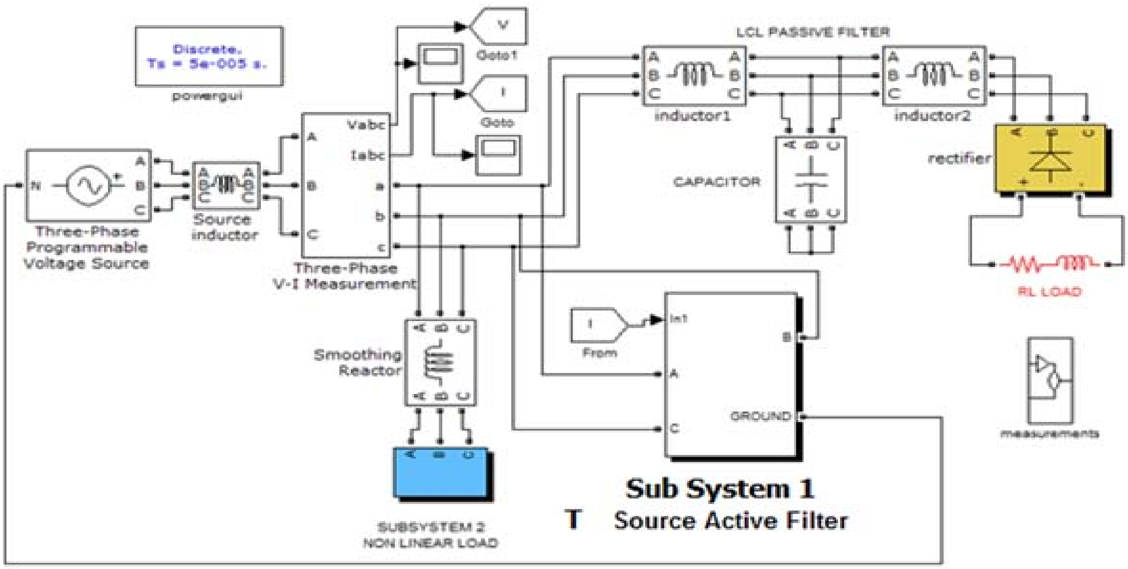


Figure 3. Simulink Model of DS with SAF

6. SIMULINK MODEL OF T SOURCE BASED SHUNT ACTIVE FILTER [SUB SYSTEM 1]

Figure 4 shows T Source based shunt active filter.

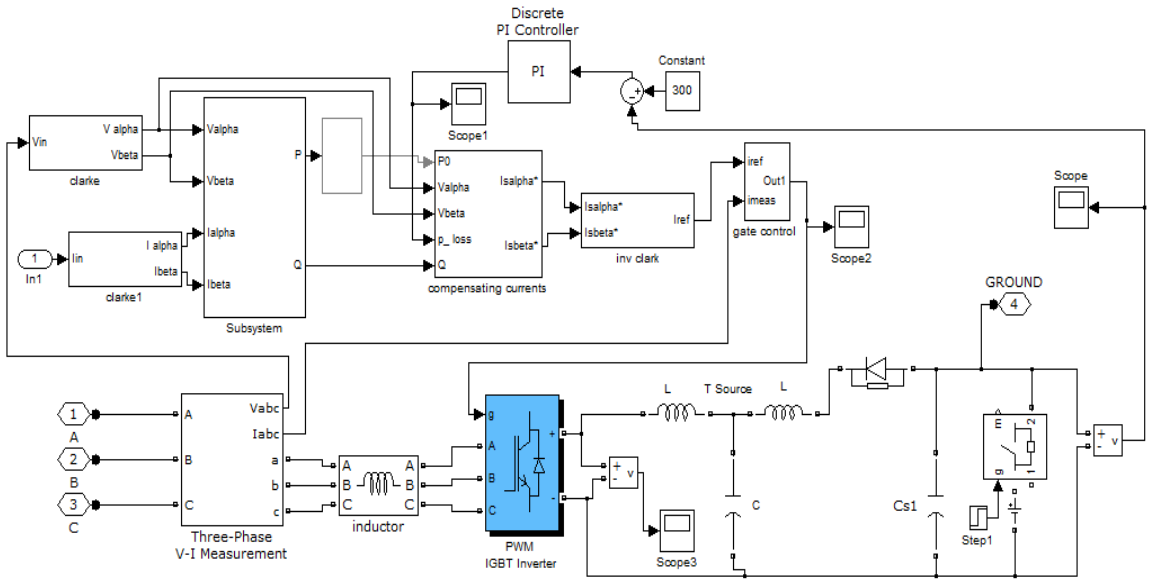


Figure 4. T Source Based Shunt Active Filter

7. RESULTS AND ANALYSIS

The FFT analysis is done and the source current THD of didtribution system without and with HSAF is given as Figure 5 and Figure 6. The other power quality parameters such as reactive power and power factor are also improved.

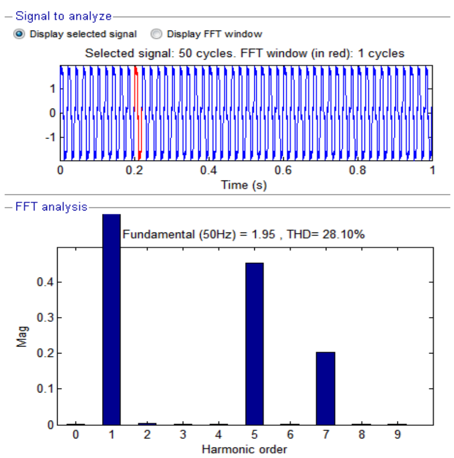


Figure 5. Source Current THD without HSAF

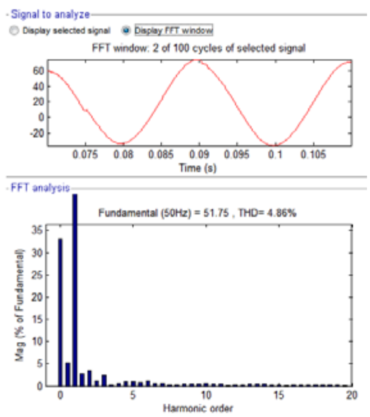


Figure 6. Source Current THD with HSAF

8. CONCLUSION

The power quality parameters such as power factor, reactive power and source current THD of three phase 440V 50Hz distribution system with non linear loads have been observed by MATLAB simulation. They are very much above their standard values. The same have been observed with T source inverter based HSAF and power quality values found to be within their standards. The source current THD has been reduced from 28.1% to 4.86%, the reactive power requirement has been reduced from 3580VAR to 2470 VAR and the power factor improved from 0.26 to 0.72. The above results show that the T source inverter based hybrid shunt active filter connected to the distribution system improves the quality of power.

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