Mitigation of Current Harmonics in A Solar Hybrid System By Using Hybrid Filter

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Abstract - *There is a growing need for renewable energy systems especially solar PV systems to act as auxiliary sources of power and support the grid in meeting the demand. Though such a scheme may seem advantageous it also brings in various power quality issues due to the converters involved in the process of regulating the power obtained from PV panel. Harmonics is one of the major issues. Hybrid power filters are more attractive in harmonic filtering than the pure filters from both viability and economical points of view. This project discusses the idea of hybrid harmonic filtering applied to improve power quality by reducing current harmonics in a PV hybrid system.*

***Key Words*: Harmonics, Passive Filter, Active Power Filter, Total Current Harmonic Distortion, Hybrid Power Filter**

1.INTRODUCTION

With the increasing use of non-linear loads such as diode bridge rectifiers, adjustable speed-drives and cyclo converters, the generation of harmonic currents has steadily increased and has heightened the interests in power quality. Power quality can be defined from two different perspectives, depending on whether you supply (utility) or consume (end user) electricity. Power quality on generator(utility) refers to generator's ability to generate power at 50Hz, with little variations. While power quality transmission and distribution (end user) levels refer to the voltage staying within 5% tolerance. The growth in application of electronic equipment and distributed generation has concentrated the interest in power quality in recent years. There are economic impacts on utilities, their suppliers, and customers of load equipment. Harmonics is one of the major power quality issues. It is caused by nonlinear loads like choppers, converters, inverters etc. These nonlinear loads produce harmonic currents and inject them into the supply system. This reduces the overall efficiency of the system. There are various techniques to eliminate these harmonic currents. One of the major techniques is usage of filters.

Filters are of active and passive types. Passive filters are made up of Resistor, Inductor and Capacitor elements. Active Power Filters (APF) are made up of power electronic devices. Since passive filters are simpler and cheaper when compared to active filters, passive filters were considered for harmonic mitigation. Single tuned filter is the most commonly used passive filter. It is very cheap and easy to design. It creates a low impedance path for the corresponding designed order of harmonics and mitigates it. Since passive filters are called "Fixed Frequency Filter", it doesn't respond well to the nonlinear loads. Hence the "Variable Frequency Filter" named active power filter comes into picture. Hybrid power filters are more attractive in harmonic filtering than the pure filters from both viability and economical.

2. THE PROPOSED SYSTEM

The system taken for consideration and analysis consists of a solar PV panel and single phase AC system whose output is regulated by using separate converters and choppers. The output from both the choppers is combined to form a regulated DC output which is fed to DC load. The single phase AC system is considered as the grid. Due to the converter operation harmonics are injected in source side current waveform. In this HPF configuration, the passive filter acts as the main compensator and the APF is used to compensate the remaining current harmonic contents, which have been filtered by the Passive filter, are installed on source side of AC system and the simulation is carried out and harmonic analysis is done to observe the variation in Total harmonic distortion or THD of the system. This paper discusses the design and installation of the passive filters and subsequent improvement in results obtained by simulation.

3. HYBRID POWER FILTERS

The HPF topology –shunt APF and shunt Passive filter circuit configuration is shown in Fig. 1 The shunt APF can be connected to the distribution power system through coupling inductor (L) without CT.

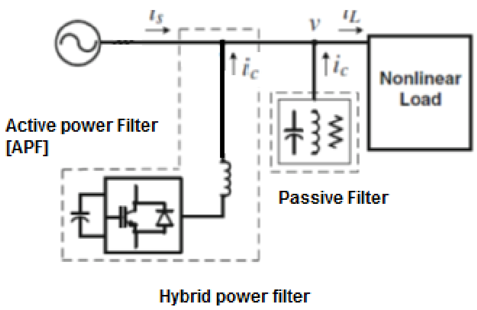

Fig-1:Hybrid power filters topology

In this HPF configuration, the passive filter acts as the main compensator and the APF is used to compensate the remaining current harmonic contents, which have been filtered by the PF, so as to improve the system filtering performances. In addition, the advantages of this topology are the shunt APF Applicable if the shunt Passive Filter already exists and reactive power controllable. Moreover, it can prevent the parallel resonance phenomenon.

However, the APF cannot change either the voltage across the Passive Filter or the current through the Passive Filter. Therefore, large circulating current will be generated by the Passive Filter if the Passive Filter impedance is low at the voltage distortion frequency. In order to prevent the harmonic current flows to the supply, the required APF current rating will still be high. If the APF is directly connected to the distribution power system without CT. By choosing the Passive Filter as a high pass filter, this HPF topology can avoid obtaining low PPF impedance at the voltage harmonic frequencies. However, high pass filters increase the filter loss and reduce the filtering effectiveness at the tuned frequency.

4.PASSIVE FILTER

Passive filters are applied either to shunt the harmonic currents off the line or to block their flow between parts of the system by tuning the elements to create a resonance at a selected harmonic frequency The passive filter used here is the single tuned passive filter which is shown in fig. 1. It is the simplest and easy to construct among all shunt passive filters. In this filter the inductor and capacitor are designed to mitigate a particular order of frequency by providing a low impedance path.

Passive filters are employed in various electrical systems involving power electronic circuits to mitigate the problem of harmonics. Passive filters work on the concept of tuned RLC circuits undergoing electrical resonance at their tuned frequencies. Based on the number on tuning frequencies a filter is associated with, there are various types of passive harmonic filters in practice namely single tuned harmonic filters, double tuned harmonic filters and high pass harmonic filters or damped filters. These filters reduce harmonic components corresponding to single, two or more than two orders respectively. The choice or trade-off between implementing filters in a system depends on the system requirements and the nature of harmonics associated with a system.

Passive harmonic filters are simple rlc circuits and the value of l and c depend on their resonant frequency. The formulae for calculation of L and C are given as following equations 1 and 2.

$$F_r = 1/(2\pi\sqrt{LC}) \quad (1)$$

$$F_c = 1/(2\pi RC) \quad (2)$$

Where R, L and C are the respective resistor inductor and capacitor values for the filters. Equation 1 describes the mathematical relation between resonant frequency and R and C values as in case of single or double tuned filters and equation 2 describes the cut off frequency of high pass or damped harmonic filters.

5. SHUNT ACTIVE POWER FILTER

The shunt inverter controlled in current control mode such that it delivers a current which is equal to the set value of the reference current as governed by the control algorithm. Additionally, the shunt inverter plays an important role in achieving required performance from system by maintaining the dc bus voltage at a set reference value. In order to cancel the harmonics generated by a nonlinear load, the shunt inverter should inject a current. Hence shunt active power filter is a device which is able to compensate for both current harmonics and reactive power. The performance of an active power filter depends mainly on the technique selected to generate reference compensating current. The template to generate the reference current must include amplitude and phase information to produce the desired compensating current. In the proposed model, the technique chosen for extracting reference currents and with the synchronous reference frame (SRF) method

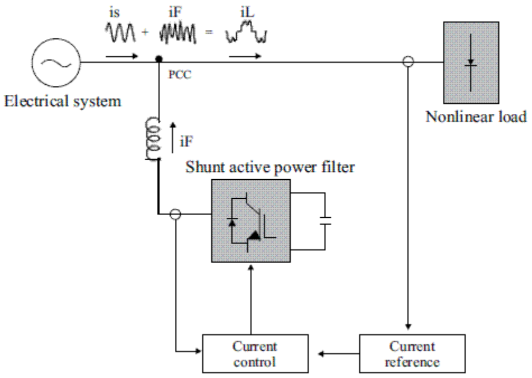

Fig-2: SAPF topology

5.1 SRF-BASED CONTROLLER FOR CURRENT COMPENSATION

The SRF-based controller was used to generate the sinusoidal compensating current references. In this work, for this purpose, an algorithm based on SRF is also used. The sensed load current is shifted by 90^0, to obtain two orthogonal load components of current i_α and i_β. These components are again transformed into3. direct and quadrature axis components of load current using following transformation and are treated as active and reactive component of load current. In this method the measured load currents are transformed into the rotating reference frame (d-q frame) that is synchronously rotating at the line voltage frequency using (3).Park's transformation is used to converter α-β is converted in d-q frame by using equation

$$\begin{bmatrix} I_d \\ I_q \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t \\ -\sin\omega t & \cos\omega t \end{bmatrix} \begin{bmatrix} I_\alpha \\ I_\beta \end{bmatrix} \qquad (3)$$

A low pass filter in the d-q frame, with a cut-off at the line frequency can be used to extract the dc components. Currents to transform them back to original frame, the inverse transformation from d-q to α-β frame.

SRF controller is based on transformation techniques to derive the direct and quadrature axis load current The transformation angle "θ" is derived using a modified PLL under distorted conditions of supply voltage.

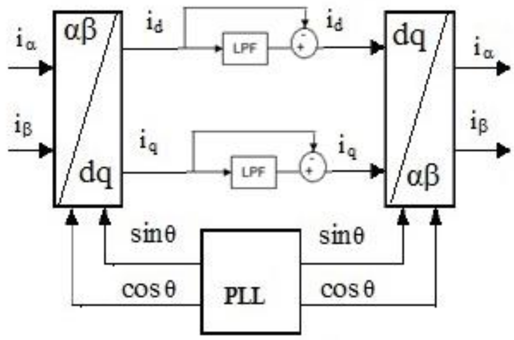

Fig **- 3**:Reference Compensating Currents Generated Using SRF theory

These active and reactive component of load current consist of average and oscillating component and are filtered out using a fourth order alternative HPF(obtained from a LPF). These compensating d-q components of current are again transformed in order to obtain the reference compensating current. The reference and actual compensating current is compared in a hysteresis controller to generate switching signals for the shunt inverter.

5.2 HYSTERESIS CURRENT CONTROL

Hysteresis current control method of generating the switching signal for the inverter switches in order to control the inverter output current. It is adopted in shunt active filter due to best among other current control methods, easy implementation and quick current controllability.

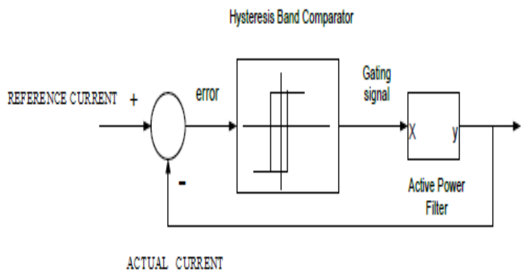

Fig -4 ; Block Diagram of Hysteresis Current Controller

It is basically a fed back current control method, where the actual current continuously tracks the reference current in the hysteresis band .the actual current with in this hysteresis band. The reference and actual current is compared with respect to hysteresis band which decides switching pulse of voltage source inverter.

As the current crosses a set hysteresis band, the upper switch in the half-bridge is turned off and the lower switch is turned on.as the current exceeds the lower band limit, the upper switch is turned on and the lower switch is turned off.

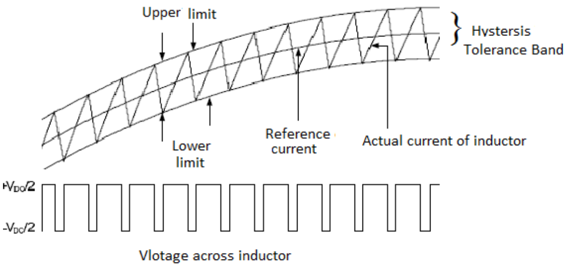

Fig- 5: hysteresis tolerance band

The switching frequency depends on how fast the current changes from upper limit to lower limit and vie versa. This ,in turn depend on voltage v_d and load inductance.

6. SIMULATION RESULTS

Case1 : Hybrid Power System Without Filter

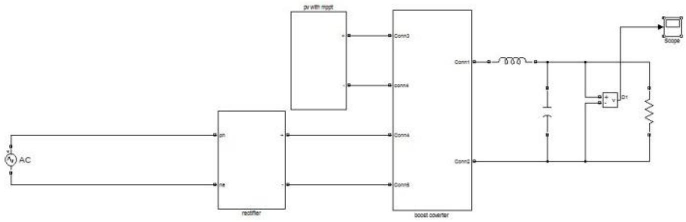

Fig -6: Hybrid power system without filter at ac source

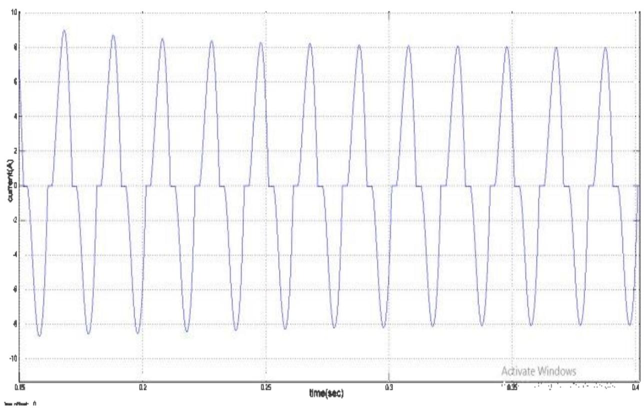

Fig. 7 :current wave form at source without filter

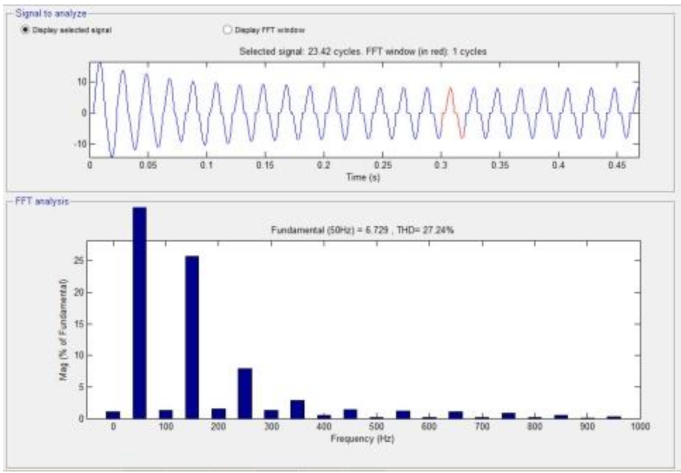

Fig- 8 :FFT analysis current wave form at source without filter

Case 2 : Hybrid Power System With Passive Filter At Ac Source

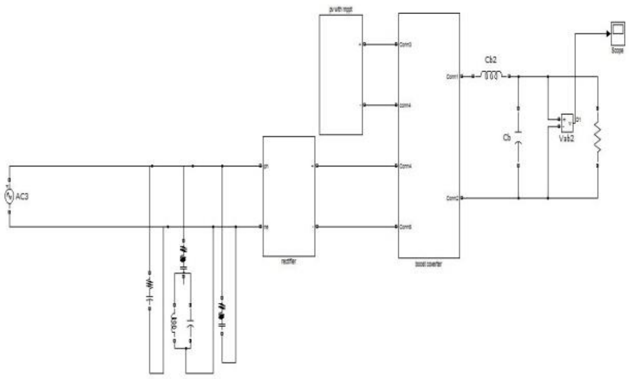

Fig - 9 :hybrid power system with passive filter at ac source side

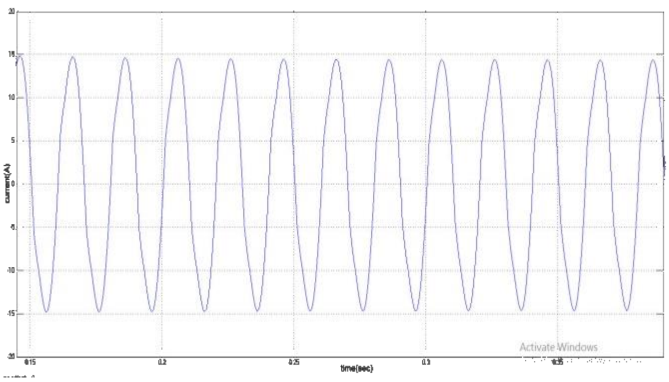

Fig - 10 :current wave form at source with passive filter in system

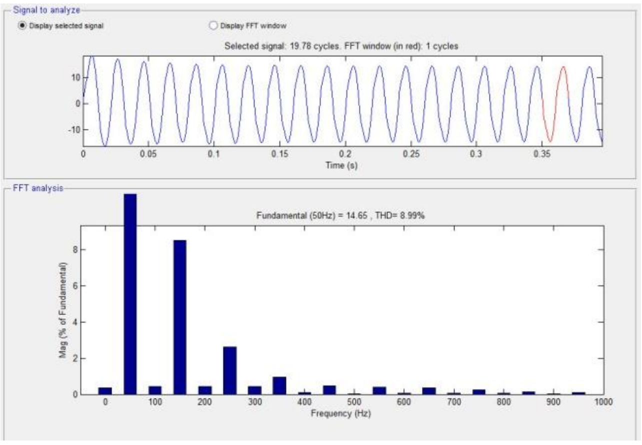

Fig - 11: FFT analysis current wave form at source with passive filter

Case 3 : Hybrid Power System With Hybrid Filter At Ac Source Side

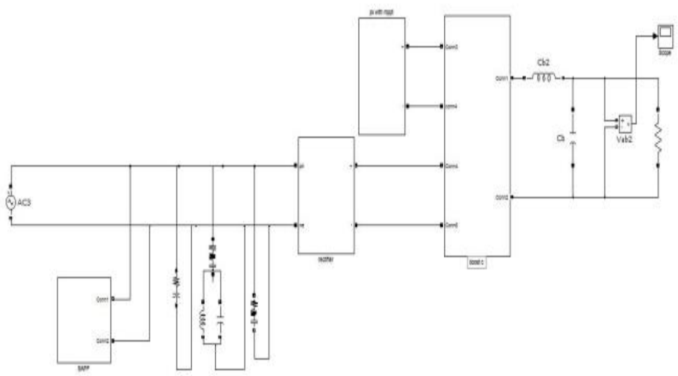

Fig - 12 : Hybrid Power System With Hybrid Filter At Ac Source Side

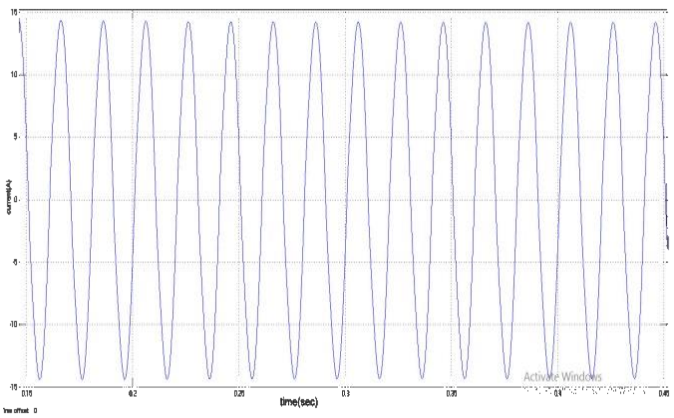

Fig - 13 :current wave form at source with hybrid filter in system

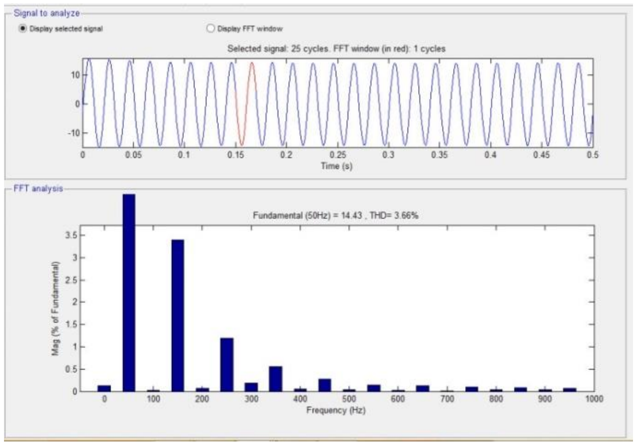

Fig - 14: FFT analysis current wave form at source with hybrid filter

Table 6.1 comparison passive filter and hybrid filter

Power quality issues	Without filter	Passive filter	Hybrid filter
THD- current	27.24	8.96	3.66
PF	0.71	0.84	0.95

7 CONCLUSIONS

In this work, a comparative analysis of the performance of passive filter with the hybrid filter for a hybrid power system is proposed. In this simulation work passive filter and a hybrid power filter employed to reduce current harmonics. The simulated results of total current harmonic distortion (THD) for the hybrid filter may have better harmonic reduction as well as improved power factor compared to passive filter.

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