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Harmonic Elimination using Hybrid Filter

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Abstract : This paper presents a Harmonic elimination using series active shunt passive filter based hybrid filter. Filter operation is based on PLL logic which comprised with PI controller and mathematical operation on voltage signals. The proposed approach is comprised of PLL based series active filter with shunt passive filter. Here passive filter design is done based particular frequency calculations. The series active filter switching gives better steady state operating conditions. The hybrid filter system is used for many simulation of different loads which reveals that it effectively compensate reactive power as well voltage and current harmonics.

Keyword : Hybrid Filter, Active filter , PLL

I. INTRODUCTION

Electrical energy is vastly used due to it being easily transmitted to long distances and conversion from any energy form to electrical energy is easy because it is vastly studied and more studies are going on. In current times standard are made for transmission of electrical energy based on current ,Voltage and its frequency .In modern time most equipment uses electronic component like Diode, IGBT, MOSFET, SCR, GTO for transmission which have non liner characteristics [1] . Due to this equipment effect current and voltage of sinusoidal wave destroyed And produce current and voltage waveform fundamental plus non-fundamental frequency components of a distorted power frequency waveform. This non fundamental component are called harmonics. The harmonics in the power lines causes in high losses of power in distribution which can induce noise problems in communication systems and can lessen life of electrical equipments. Sometimes cause operation may fail of electronic equipment which have higher sensitivity due to the presence of microelectronic control systems and these systems are low power switches and thus a little noise can be much-more effective [2]. Due this reasons power quality is one of the most concerned factors in recent times as far the end user is concerned.

International standards for electrical energy consumption strictly prohibits that electrical equipments should produce harmonic contents lesser than specified values. Mean while it should be that harmonic problems created by those switches which have already been installed needs removal[2]. A usual solutions to solve harmonic current and voltage problems is to use passive filter but they have some disadvantages, as following: 1)they filter only the frequencies they were tuned for thus tuning is required at first; 2)their effective operation is limited to a certain load; 3)resonances may occur due to the interaction of the passive filter and loads and causes unpredictable results.

Active filter is another solution for harmonic reduction by VSC or CSC topology. Under most conditions it has been proven that the active filters are more effective and is able to compensate harmonics, asymmetric currents caused by nonlinear and unbalanced loads [1]. The recent advancements in the field of power electronics switches with forced commutation, active filters have been studied extensively and a large amount of works have been published. These Voltage Source Converter topologies subdivided into two types widely known as series active and shunt active filters same as that with passive filters. The disadvantages for active filters as well such as : 1)costly components , 2)usage of extra source (if necessary) ,3)difficult control schemes .

II. HYBRID FILTER

Passive and active filters are the two filter types and combining both will intern give us more effective filter as hybrid filter. Passive filters are tuned for certain frequency thus are not much flexible and for low THD high number of passive filter may be needed meanwhile for active filters are flexible operation for low THD is much complex. Thus combining both type of filters and using them in such a way that the operations are divided among both will intern reduce stress on both and can give us a low THD system. There are different control strategies for hybrid filter but most control strategies are based on PQ theory and SRF method [3]. Due to recent advancement in devices and a lot of studies based on PQ theory have been done and a few theory modified form of PQ theory has been established modified PQ theory based control strategy is implemented in this paper.

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A schematic diagram of the system is shown in figure 1. As seen from figure it evident the combination of series active and shunt passive filter is done to make hybrid filter. The active filter is an inverter. The inverter operation is based on control technique of PLL logic. The passive filters are so chosen that it eliminates 5^{th} and 7^{th} harmonics. Thus in case of active. operation is based on other harmonics elimination and in terms of unbalanced load condition it can eliminate supply side harmonics and reduces strain on supply side.

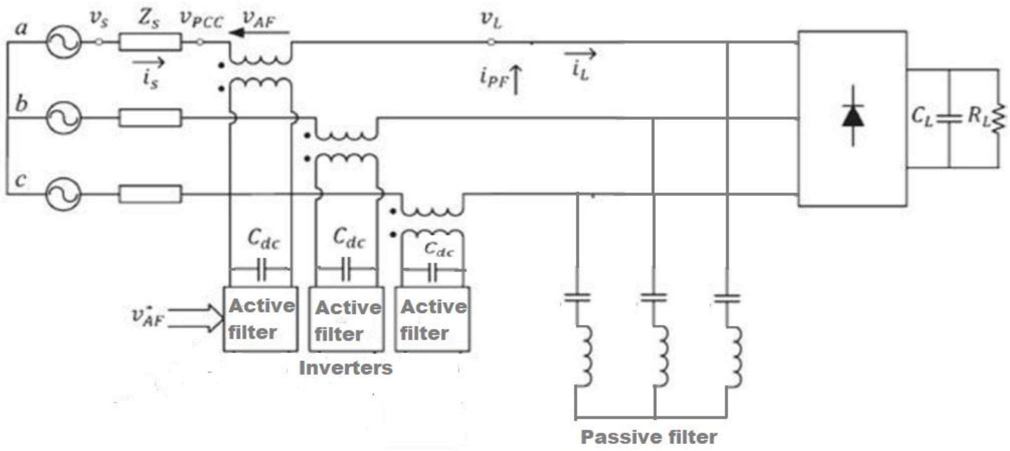

Figure 1. Schematic diagram of hybrid filter

For passive filter a LC Series combination is used as seen from figure 1. A Diode bridge is used with different combinations of RLC loads as a non-linear load. A 230V(RMS) 50Hz AC supply is used . for active filters a supply of 12V DC is used. The transformers are rated 15:200 from primary to secondary. The inverter is made from MOSFET switches.

2.1 PLL(Phase Locked Loop) Logic

PLL is commonly used in various signal applications e.g. radio- and telecommunications, computers and electrical motor control. The techniques can be adapted to work in a wide frequency spectrum from a few hertz to orders of gigahertz. A phase locked loop (PLL) is a system which synchronizes its output signal with a given input signal or reference signal both in frequency and in phase. It is a non-linear closed loop control which automatically changes the frequency of a controlled oscillator depending on the frequency and phase of the input signal such that the output is matched both in frequency and phase with the reference or the input signal. The main components of a PLL are :

1. A phase detector which compares the input/reference signal and the output signal and generates an error signal.
2. A loop filter which removes unwanted harmonics erms from the error signal.
3. A voltage controlled oscillator (VCO) which generates the output signal whose frequency varies around a central frequency depending on the output of the loop filter [4] and [5].

There are three types of PLL systems for phase tracking: 1)zero crossing; 2)stationary reference frame and 3)synchronous rotating reference frame based PLL. The SRF PLL from above mentioned has best performance under distorted and non-ideal grid conditions. [4]. Figure 2 shows us block diagram of PLL:

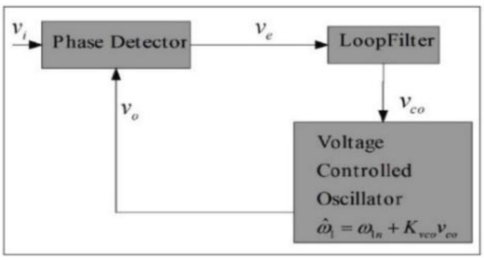

Figure 2. Block diagram of PLL Logic

2.1.1 Three-Phase SRF PLL (dq PLL): The idea of this PLL is of feedback system with a PI-controller for tracking the phase angle wherein Input is the 3-phases of the grid voltage and output from the PLL is the phase angle of one of

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the 3-phases. In supply substation there will be one inverter leg for each of the 3-phases.for aforementioned logic there are two alternatives as: 1)For balanced voltage tracking single phase and then shift with 120 degrees for other two phases ; or 2)to have three PLL systems i.e. one for each phase. Basic stricture schematic of SRF PLL given below Figure-3.

Stationary Reference Frame αβ0 : To track the phase angles V_a, V_b and V_c signals are transferred from 3-phases to a stationary system of 2-phases v_α-v_β. Where θ is phase angle π2+2πft. The transformation matrix is given in equation below in v_α-v_β.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \begin{bmatrix} v_m * \cos\theta \\ v_m * \sin\theta \end{bmatrix}$$

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \begin{bmatrix} v_{m+} * \cos\theta_+ + v_{m-} * \cos\theta_- \\ v_{m+} * \sin\theta_+ + v_{m-} * \sin\theta_- \end{bmatrix}$$

Synchronous Rotating Reference Frame : The phase angle θ∗ is tracked through synchronization of voltage space vector along DQ axis in the SRF. In above discusses the value of V_d and V_q from equation is same as voltage so .

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = \begin{bmatrix} -v_m * \cos(\theta - \theta^*) \\ v_m * \sin(\theta - \theta^*) \end{bmatrix}$$

$$\begin{bmatrix} v_d \\ v_q \end{bmatrix} = \begin{bmatrix} v_{m+} + v_{m-} * \cos(2\omega t) \\ v_{m+} - v_{m-} * \sin(2\omega t) \end{bmatrix}$$

Here equation represents unbalanced load condition voltage equation. The phase angle θ is estimated with θ∗ which is the integral of the estimated frequency ω'. The estimated frequency ω' is the total of the PI-output as well feed forward frequency (ωff). Gains of the PI-regulator is then designed so that Vq follows the reference value Vq* = 0 . If Vq = 0 then the space voltage vector is synchronized along the q-axis and the estimated frequency ω' is locked on the system frequency ω. This results in an estimated phase angle θ∗ * that equals the phase angle θ. if θ∗ ≈ θ then the small angle approximation for sinus function yields Vq = -Vm (θ -θ∗) and the structure in Figure 3 can be simplified, see Figure 4.

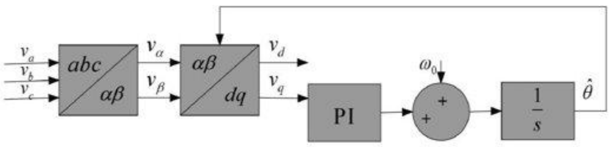

Figure 3 Basic Structure of SRF PLL

The purpose of the feed forward frequency, ω ff, is to have the PI-regulator control for an output signal that goes to zero. In our case the feed forward frequency will be 2πf = 100π. In the ideal case when the grid frequency is exactly 50Hz once the regulator has tracked the phase the output of the regulator is zero. [5]

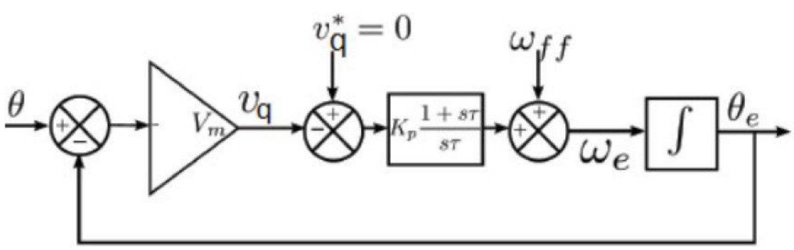

Figure 4. Simplified System for SRF PLL

III. SIMULATION ANALYSIS AND RESULTS

A typical 230V/2kVA medium voltage system is considered in simulation, which is shown in Figure 1 with all the parameters. The non-linear load is simplified as a diode rectifier with RLC combination loads. A H-bridge inverter-based active power filter is connected in series with the 230V System through a transformer to distribution line. MOSFETs are used as switching device for inverter operation. Gate pulses for each phase are provided by PLL logic as

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represented in block diagram figure 5 in which the signals provided are leveled down. Simulation results for the proposed strategy are as shown in Below Figure 6 and Figure 7.
As Seen From simulation results the current THD is Greatly reduced to a level of less than 5% From a THD of around 30%. While the increment in voltage is there but is not evident as that of current THD reduction. The results are as shown in below table:

Description	Compensation on	%THD
Current	Without Filter	27.40
	Load Side	28.73
	Source Side	1.20
Voltage	Without filter	6.19
	Load Side	1.87
	Source Side	1.84

IV. CONCLUSION

A hybrid power filter simulation based on Series active Shunt Passive filter has been developed with the control strategy to obtain almost sinusoidal voltages and currents in line at source side. The effect of nonlinear loads on the power line is analyzed and rectified at source side. The control used in this paper for compensation of harmonics is based on PLL logic which is based on PQ theory(modified). The hybrid filter compensates for harmonic voltage source generated by loads. The operation of the system is done by comparing the harmonic profile with and without filter.

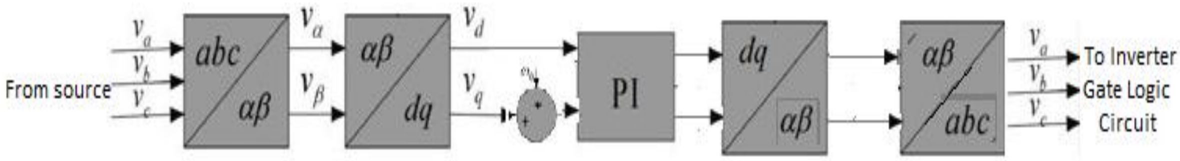
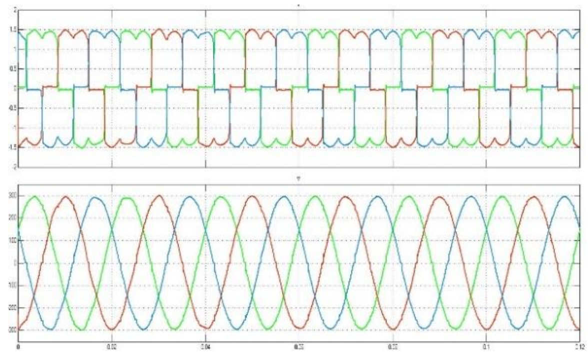
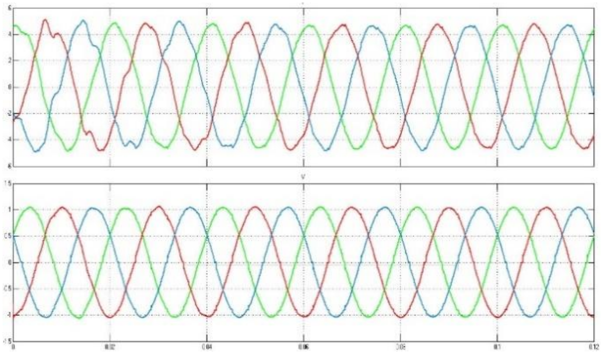


Figure 5. PLL logic Circuit Block Diagram for simulation.



(a)For load side line current and voltage



(b)For source side line current and voltage
Figure 6.Simulation Response

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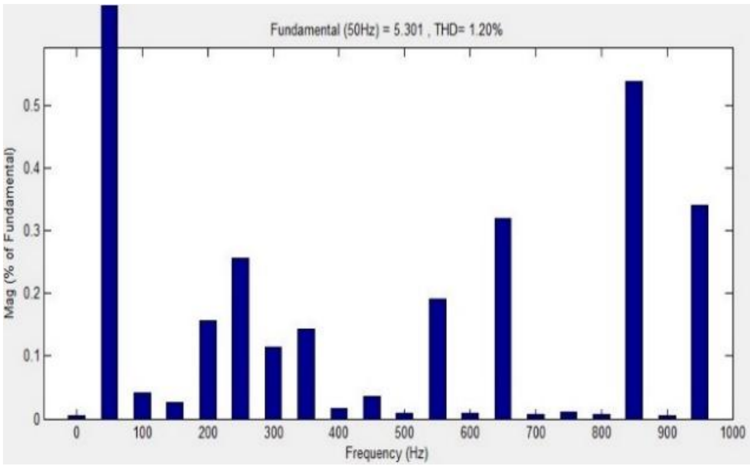
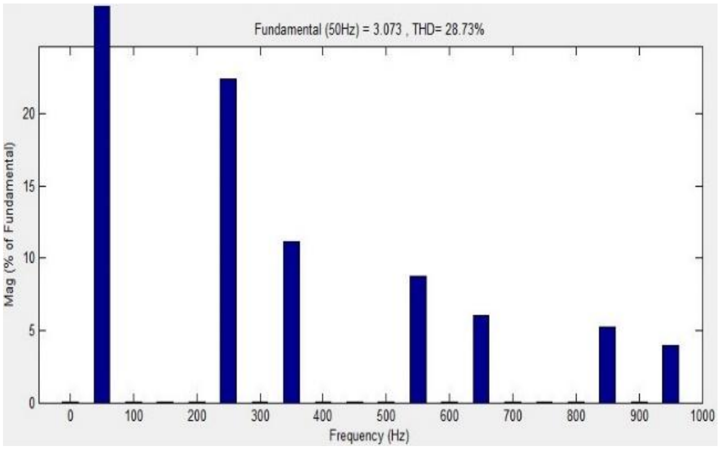


(a)Harmonic Spectra for load side line Current



(b)Harmonic Spectra for Source side line Current
Figure 7. FFT analysis for line Current

REFERENCES

[1]. K.Arthi, C.Ramakrishnan ,"Reduction of Harmonics by Hybrid Series Active Filter using Cascaded Seven Level Inverter " , IEEJ - Vol. 5 (2014) No.4, pp. 1376-1380 .
[2]. Fang Zheng Peng, Member, IEEE, and Jih-Sheng Lai, Senior Member, IEEE ,"Generalized instantaneous Reactive Power theory for three-Phase Power System" IEEE transaction on INSTRUMENTATION AND MEASURMENT.
[3]. Waware Madhukar Student Member IEEE Member, and Pramod Agarwal Member, IEEE , "Comparison of Control Strategies for Multilevel Inverter based Active Power Filter used in High Voltage Systems"
[4]. L. R. Limongi, B. C. Pica, F. Profumo, A. Tenconi, "Analysis and Comparison of PhaseLocked Loop Techniques for Grid Utility Applications," in Proceedings of the PowerConversion Conference – Nagoya 2007, PCC'07, Nagoya, Japan, 2-5. April 2007
[5]. S.–K. Chung, "Phase-locked loop for grid-connected three-phase power conversionsystems," IEE Proceedings on Electric Power Applications, Vol. 147, No. 3, May 2000
[6]. João L. Afonso , H. J. Ribeiro da Silva and Júlio. S. Martins,"Active Filters for Power Quality Improvement ", IEEE Porto PowerTech, 10-13 Set. 2001,
[7]. Akagi H,Watanabe E,H Aredes "Instantaneous Power Theory and Applications to Power Conditioning"
[8]. M Aredes and e. h. Watanabe, "New Control Algorithms for Series and shunt three-Phase Four-Wire Active Power Filters," IEEE Transactions on Power Delivery. Vol, 10 ,no 3 July 1995
[9]. F. Z. Peng , H Akagi , and A Nabae, "New Approach to Harmonic Compensation in Power systems – A combined System of Shunt Passive and Series Active Filters" in Conference Record IEEE-IAS Ann. Meeting 1988(IEEE transaction on Industry Application)
[10]. Bhim Singh, Kamal Al-Haddad and A. Chandra,"A Review of activefilters for power quality improvement", IEEE Trans. on IndustrialElectronics Vol.46, no .5, Oct 1999,pp.960-971.
[11]. Akagi H, Nabae A: 'Instantaneous reactive power Compensatorscomprising switching devices without energy storage components',IEEE Trans. on Industry Application, vol.IA 20.No 3 May/June1984 pp-625-630
[12]. Bhim Singh, Kamal Al-Haddad and A. Chandra, "A new controlapproach to three phase Harmonics and reactive power compensation",IEEE Trans. On power systems Vol. 13,No 1 Feb 1998 pp. 133-138