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Power Quality Enhancement Through Reduced Switches and Transformer Less Hybrid Power Filter

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Abstract— This paper deals with the implementation of transformer less hybrid power filter based on six switches two leg inverter. This system provides superior compensation capability without increasing the number of switches in the active filter, mitigate voltage SAG condition, eliminate of the series transformer so as to make the configuration is simple and reduce the harmonic presents in the circuit.

Key words: Power Quality Enhancement, Hybrid Power Filter

I. INTRODUCTION

Power quality have become an important issue in recent days .This is due to the huge number of electrical devices of different standards are being connected to the grid. Equipment becomes more advanced, complicated and in fact more sensitive to quality of power supply. On the other hand, a lot of power electronic devices like power switches, UPS systems etc. connects the load to comman network and generates distortion (higher harmonics).Earlier problem related to harmonic was marginal but now it has become very serious problem due to the connection of non-linear power electronic devices into the system. Harmonic distortion reduces the life time of the equipment and can interfere with communication lines and sensitive equipment. Conventional harmonic compensation method is installation of passive filters based on LC elements tuned to particular frequency. This method is relatively easy to implement, however, there are few disadvantages as problems with resonance, size and price of passive elements, dependency on temperature and frequency, etc [1]. The drawback of passive filter is overcome by the shunt active filter which consist of voltage source inverter with a large capacitor on its DC link, is considered a well-established solution to reduce the current harmonics to the recommended standard limits [2]. The major drawback of shunt active power filters is the high-power rating components required to compensate high peak harmonic currents and their associated costs [3].

An alternative to active power filter (APF) is hybrid power filter (HPF), combination of active filters and passive filters. Such a combination with the passive filter makes it possible to significantly reduce the rating of the active filter [4]. The task of the active filter is not to compensate for harmonic currents produced by the thyristor rectifier, but to achieve, harmonic isolation between the supply and the load As a result, no harmonic resonance occur [5].

A hybrid filter topology have a common drawback that a large number of passive components and transformer that directly influence the size and weight of these filter. Therefore greater effect has been made to reduce the components in HPFs [6]

II. PROPOSED SYSTEM

The aim of this HPF is not only to increase the harmonic compensation but also to reduce the cost. The system consists of two three phase inverter connected to the point of common coupling (PCC) through two series passive LC filters tuned to different frequencies [7],[8].

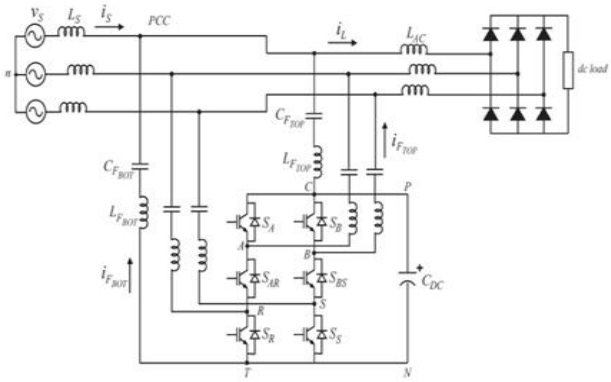

Fig. 1: Proposed reduced switches transformer less Hybrid power filter

The top unit consisting of outputs ABC is connected in series with the LC filters tuned around 7th harmonic component to PCC. This is responsible for compensating 7th order harmonic and 5th order harmonic, its harmonic pair. Top unit is also responsible to maintain desire DC link voltage. Similarly, the bottom unit represented by RST outputs is connected in series with the LC filters tuned around 13th harmonic component to PCC, responsible to compensating 13th order harmonic and 5th order harmonic, its harmonic pair.

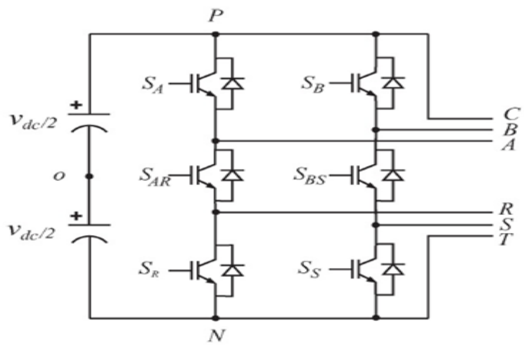

Fig. 2: Reduced switch inverter

This six switches inverter has same number of switches as the conventional three- phase inverter. Two peculiarities are noted from the above stated non conventional reduced switch inverter topology derived from nine switch inverter leg. first, DC link voltage imbalance occur due to removing one nine switch inverter leg and the removed phase is connected to the o terminal of Fig.2.This problem can be overcome by connecting the remaining phase to the negative or positive pole of the DC link. If the capacitor of LC filters (CFtop and CFbot) were not placed between DC link poles and the PCC this approach would lead to injection of DC voltage in the grid. DC current could be generated in the system due to the connection of both inverter units to PCC through phases ABC and RST. Again the capacitors of LC filters block DC current circulation and DC link short circuit is avoided. Second, it is necessary a minimum DC -link voltage capable of generating the sum of both output voltages, as this unit share the same DC link voltage. The dc-link voltage level is not an issue in the proposed system because of the series connection of the inverter with the passive filters in HPFs guarantees a much lower voltage requirement at the inverter's output when compared with conventional active filters.

III. HARMONIC INDICES

The power quality industry has developed certain indices values to relate the quality of service with distortion caused by harmonics. The most commonly used indices for measuring harmonic distortion are

A. Total Harmonic Distortion(THD)

Total harmonic distortions is the term used to describe net deviation of waveform from fundamental sin wave. THD is the ratio of RMS value of harmonic to RMS value of fundamental.

$$THD\%=100\sqrt{\frac{\sum_{h=2}^{\infty} U_h^2}{U_1^2}}$$

Where U1 represent fundamental component,Uh represent harmonic component and h represent harmonic order.

B. Total Demand Distortion(TDD)

The TDD index is most often describes current harmonic distortion. Total Demand Distortion is defined as the ratio of square root of the sum of the squares of the RMS value of the currents from 2nd to hth maximum harmonic to peak load demand current.

$$TDD\% \text{ of peak demand}=100\sqrt{\frac{\sum_{h=2}^{max} I_h^2}{I_{d\,max}}}$$

Where IRMS distorted is the RMS value of the distorted waveform with the fundamental left out of the summation, and Id max is the peak load demand current at the fundamental frequency.

The utility is responsible for maintaining the quality of the overall system Fig.3. Summarises the voltage distortion guidelines for different system voltage levels.

Bus Voltage at PCC (V_n)	Individual Harmonic Voltage Distortion (%)	Total Voltage Distortion - THD_{Vn} (%)
$V_n \leq 69$ kV	3.0	5.0
69 kV < $V_n \leq 161$ kV	1.5	2.5
$V_n > 161$ kV	1.0	1.5

Fig. 3: IEEE 519-1992 harmonic distortion limit

IV. SIMULATION AND RESULT

To demonstrate the practical operation of the reduced switches transformer less hybrid power filter simulation results are presented. MATLAB/simulink is used as the simulation software in this paper. The system parameters are given in the Table I.

Parameter	Symbol	Values
Grid voltage amplitude(line-to-line)	V_s	220v
Grid frequency	f_S	60Hz
Switching and sampling frequency	f_{sw},f_{samp}	20kHz
Dc-link voltage reference	v_{dc}	120V
Dc-link capacitor of the inverter	C_{dc}	4700µF
Top filter capacitor(7th harmonic)	C_{Ftop}	30.7µF
Top filter inductor(7th harmonic)	L_{Ftop}	5mH
Bottom filter capacitor(13th harmonic)	C_{Fbot}	61.2µF
Bottom filter inductor(13th harmonic)	L_{Fbot}	0.8mH
Top filter resonant frequency	f_{Ftop}	406.2Hz
Bottom filter resonant frequency	f_{Fbot}	719.3Hz
Nonlinear load input inductor	L_{AC}	1.3mH
Nonlinear load dc-link resistor	R_L	33Ω

Table 1. System Setup Parameters

The simulation diagram of reduced switches and transformerless HPF is shown in Fig.4.

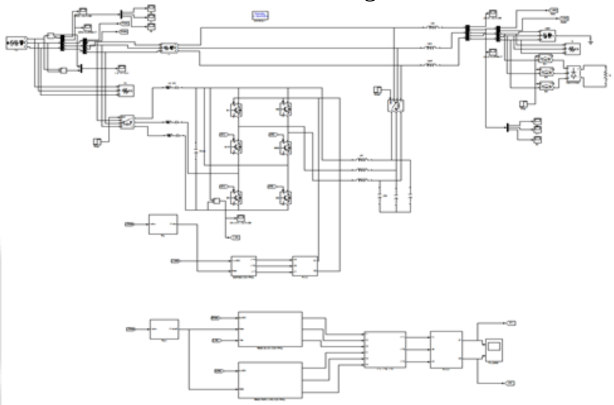

Fig. 4: simulation diagram

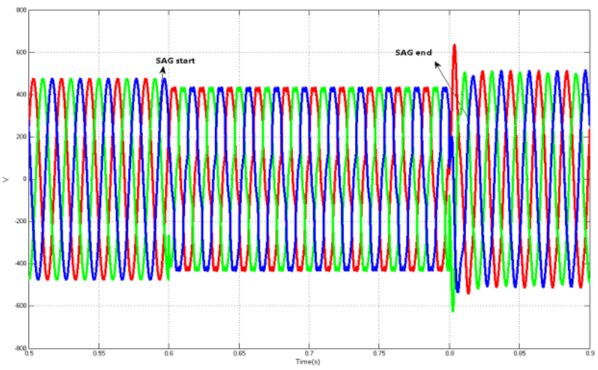

Fig. 5: grid current

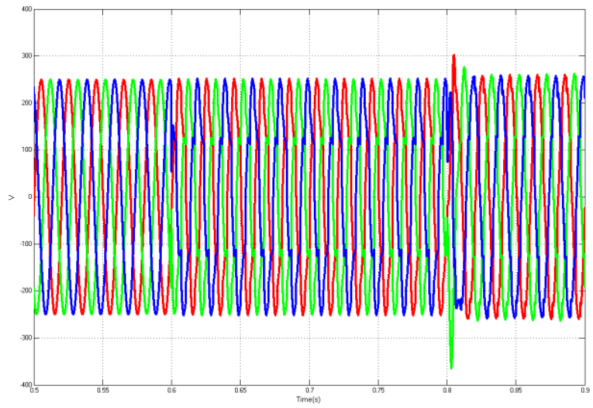

Fig. 6: load current

The voltage at the grid side and load side when the proposed system is OFF shown in the Fig.5 and Fig.6. This explains the presence of harmonic distortion in the transmission lines. The THD of load current in the R phase is 9.26%, Y phase is 9.29% and B phase 9.41% is shown in the Fig.7-9.It is inferred from the Fig.3. That the allowable THD for the voltage less than 5%, so it is found that the system suffer from a serious harmonic distortion problem.

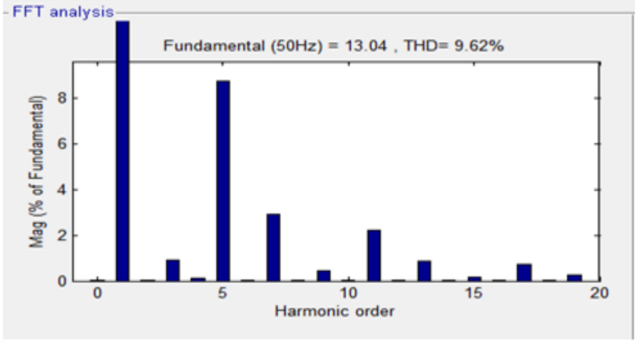

Fig. 7: THD for R phase current at load side

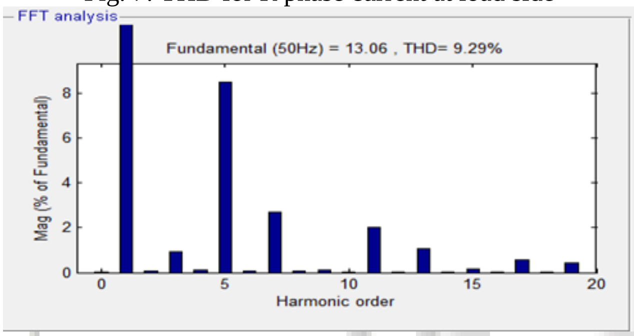

Fig. 8: THD for Y phase current at load side

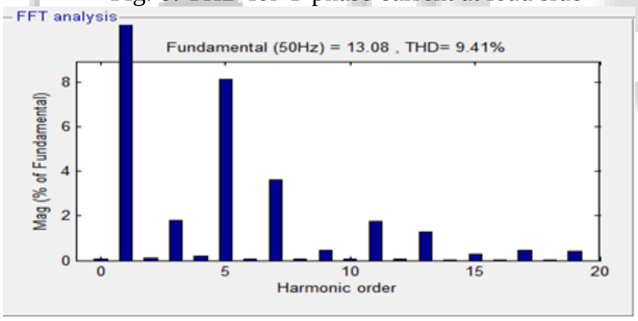

Fig. 9: THD for B phase current at load side

When proposed system is switched ON the distorted voltage at the load side under goes a superior harmonic compensation and fed into the grid side. The THD of grid current in the R phase is 3.44%, Y phase is 3.97% and B phase 4.43% is shown in the Figs.10-12. Thus it has been proved that the THD value is reduced below 5%, as per the IEEE 519-1992 harmonic distortion limit.

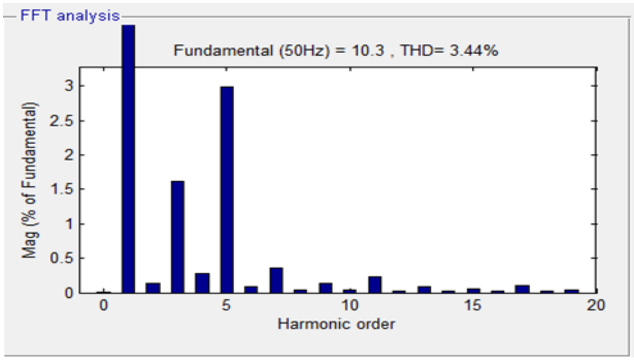

Fig. 10: THD for R phase current at grid side

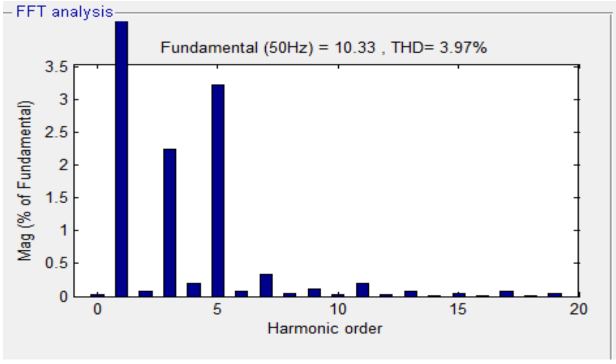

Fig. 11: THD for Y phase current at grid side.

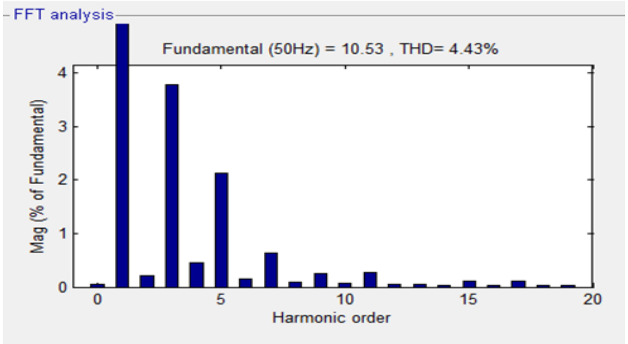

Fig. 12: THD for B phase current at grid side

V. ADVANTAGE

HPF connected to the grid without matching transformer so that the losses due to transformer are eliminated. Switching losses is reduced due to less number of switches. Improved harmonic compensation, when compared to other topologies. Simple configuration and cost is less.

VI. CONCLUSION

This paper explains about transformer less HPF topology base on six switch inverter. The proposed system consists of two three phase inverter connected in series with the two passive LC filters tuned to desired frequency and the number of switches are reduced when compared to other dual topology, aiming an improvement in the harmonic compensation performance. The results obtained from simulation of system using MATLAB program show that the proposed controller effectively cancels the harmonic components of the source current.

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