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LCL filter as Shunt Active Power filter & its analysis using MATLAB

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Abstract

The exorbitant use of power converters and non-linear load on power system have led to polluted power supply. In the past era the cable used for 3-phase supply used to be 3.5 cable i.e one each for R phase, Y phase and B phase and half this cross section for neutral. Now a days the cross-sectional area required for neutral is almost twice the cross-sectional area of the one used for each phase. The pollution of the supply means the distortion of current and voltage waveforms which should have been purely sinusoidal otherwise. A large amount of harmonics are fed into the supply through power converters which include 1-phase & 3-phase rectifiers, thyristor converters and other power electronics components. The design and operation of all the power system & its components is simpler if it is a sinusoidal voltage at constant frequency. The injection of harmonics also results in reduced efficiency and less power factor. This can be minimized using shunt filter which can be either tuned L-C Filter or High pass filter. Another option in this regard is active filter. Active filter when connected in series with the load are called as series filters and when in parallel, called as shunt filters. This paper mainly deals with how a shunt filter enhances the power quality by cancelling the harmonics. Voltage source Inverters (VSI) are normally employed in active filters for storing energy. Pulse Width Modulation (PWM) techniques along with the VSI is the latest trend in the new era control topologies.

Index Terms — 3.5 Cable, Active filter, High pass filter, L-C Filter, VSI, PWM.

I.INTRODUCTION

Harmonics in the current from supply can be eliminated by Shunt Active Power Filter (SAPF). The detection of these harmonics as well as their compensation depends a lot on the position of these filters.These filters can be either placed near the source of near the point of common coupling

(PCC). Using PWM technique along with causes the injection of higher order harmonics pollute the supply and thus causing serious issues for sensitive equipment. Amongst the different control method available presently, the most commonly used methods are instantaneous active & reactive current component method [1] and instantaneous & reactive power component method [2].

For proper reduction or nullification of harmonics caused SAPF, a better filter is needed. For better results, L filter is to be replaced by LCL Filter. This will result in compact size and also the current harmonics will be reduced significantly. In LCL filter, the design becomes more complicated owing to increase in the number of parameters. There is also a risk of resonating on power grid frequency as the impedance is almost zero at the resonating frequency of LCL filter. There can be different strategies to avoid these resonant frequency issues. The performance of filter is highly influenced by the filter parameters chosen. The calculation of these filter parameters cannot fulfil all the criteria and the calculation needs trial and error technique. But despite all this, all the criteria can not be considered and few are to be skipped.

The basic structure of LCL Filter is as shown in fig.1 below. For the optimum design, it is necessary that the process should be simple and justifiable with the help of computer programs and the trial & error iterations. An innovative design procedure is proposed here in this paper

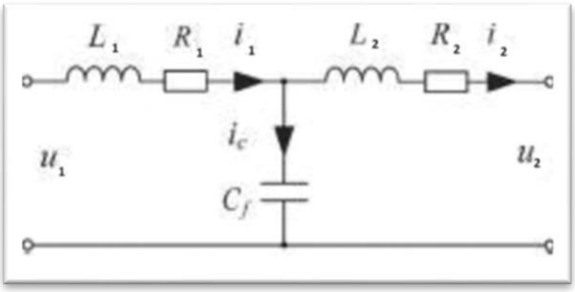

Fig. 1 basic structure of LCL Filter

II. Background

The PWM in SAPF, in the existing topologies, have higher order harmonics polluting the supply. Hence a suitable filter is to be designed to take care of all the challenges faced. For the lesser attenuation to be achieved, lesser values of inductor are needed. Two more constraints in the design of filter are compact size and reduced cost.

Some of the flaws found in earlier designs are as follows: For validating the criteria, testing with the parameters calculations is done. Thus, all the conditions cannot be fulfilled. The interdependence of these parameters is not considered. The voltage source inverters (VSI) are normally employed over current source inverters (CSI) due to the facts such as improved efficiency and the reduced cost [3], [4], [5]. The most commonly used PWM techniques in the inverter are Sinusoidal PWM & space vector PWM. The rise of power electronics in 1960, remarkably increased the non-linear loads and hence the distortion of current & voltage waveforms leading to high harmonics content in the supply. The instantaneous power or p-q theory also emerged in the next decade [6]. The performance analysis of open loop cascaded control with PI controller for double active bridge converter is done using MATLAB Simulink[7].

III. Proposed System:

In the proposed system, the lone L is replaced by LCL to achieve the reduced attenuation coefficient. The filter parameters and the SAPF performance indices should be so chosen that it results in the expected attenuation.Fig.2 shows a block diagram of the proposed LCL filter[8],[9].

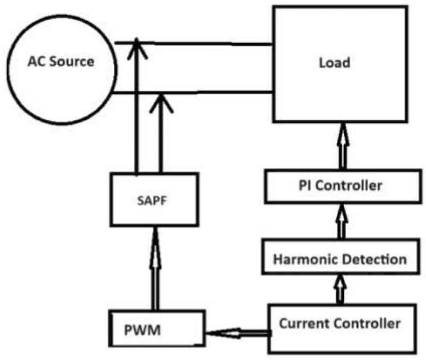

Fig. 2 block diagram of the proposed LCL filter.

PWM Technique:

In the inverters where different voltage levels are there and the switching of devices is to be handled in each of the voltage level, the most popular method is PWM technique [10],[11]. The PWM technique used in inverters facilitates the control on output voltage. A constant DC Voltage is supplied to the inverter and a controlled voltage is received as its output. This is done by varying the ON/ OFF duration of the inverter. The main features of PWM Technique [12] are that the control on the output voltage is obtained without any additional component and the corresponding filter design is simpler. On the basis of parameters such as Totalharmonic distortion (THD) in output voltage and output current, switching losses, Maximum ripple content in load current, Maximum output voltage of inverter, there are two main types of PWM techniques i.e. space vector PWM and sinusoidal PWM. In the proposed system, Sinusoidal PWM is used because the frequency, amplitude and harmonic content in the output voltage can be controlled in very simple manner[13].

PI Controller: In PI [14], [15] P stands for proportional which indicates the product of difference between the measured value of the output and reference value of output and constant (Also known as proportional gain). The Integral factor in PI adds accuracy to the controller.

VSI: The full bridge [16], [17] consists of symmetrical legs comprising of 4 diodes (D1, D2, D3 & D4) & 4 switching devices (S1, S2, S3 & S4). The output voltage is VO/P as shown in fig. 3 and the output characteristics in fig. 4 below.

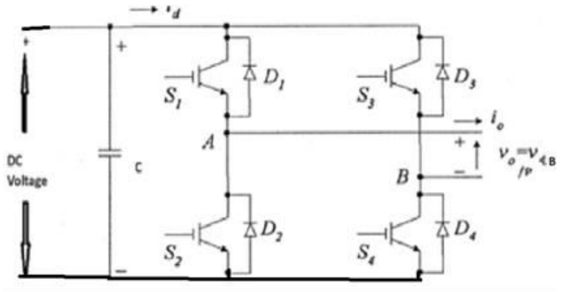

Fig. 3 Full bridge VSI

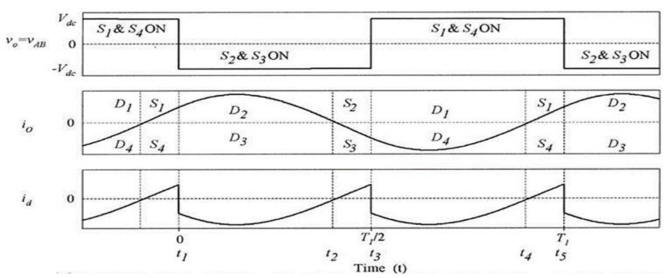

Fig. 4 Output waveforms

The converter can operate [18], [19] in four different operating quadrants as shown in fig. 4 &5. The change in power flow is also evident from the diagram.

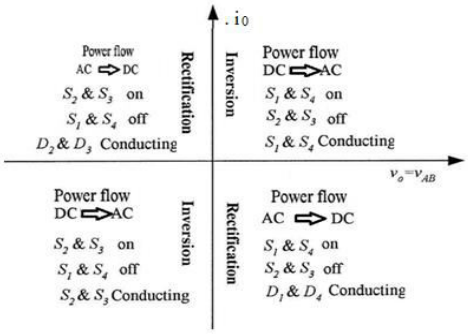

Fig. 5 Operation of 1-phase converter in 4 quadrants

IV. Results and discussion

The attenuation achieved by LCL filter is far better at the inverter switching frequency than the other filters available. The capacitor in LCL filter reduces the current ripples. Moreover, the LCL filter needs very low values of L & C for the efficient working.However, the challenges faced in the design of the filters are Current harmonics attenuation at switching frequency, Current ripples through inductors, Capacitor absorbing the reactive power, total impedance of filter and resonance [20], [21]. All these concerns are reasonably taken care of by LCL filters. The overall inductance of LCL filter is much lesser than the L filter. This results in lesser size, reduced cost and increased attenuation.

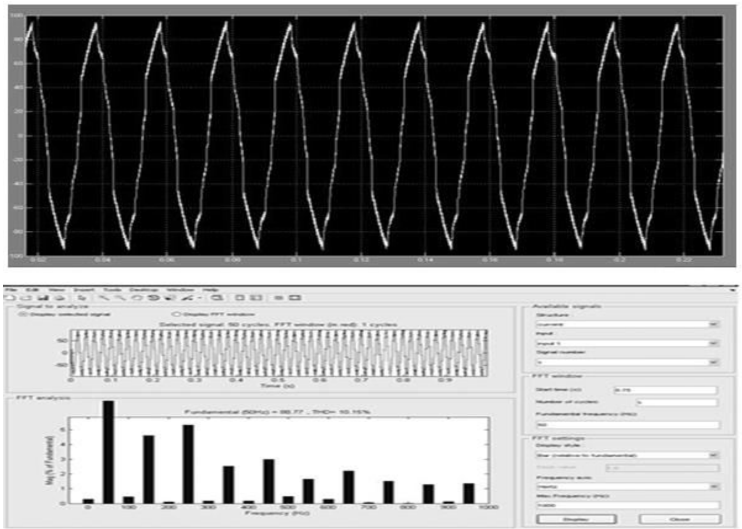

Fig. 6 Grid current and THD in L filter

The output waveforms confirm that the attenuation achieved in case of LCL filter is more along with the lesser values of L & C. Thus reducing, volume, size, weight and ultimately cost of the filter.

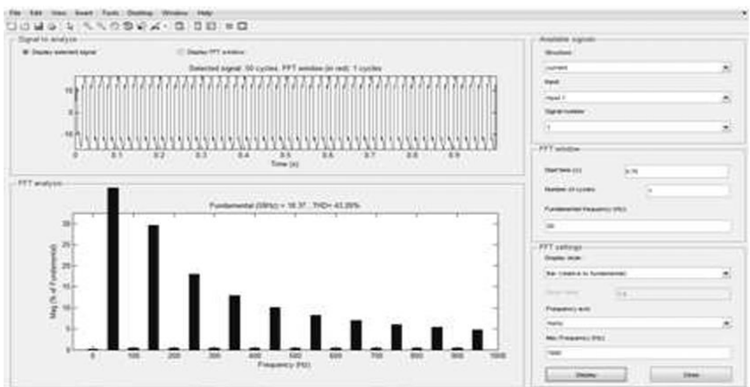

Fig. 7 Grid current and THD without LCL filter

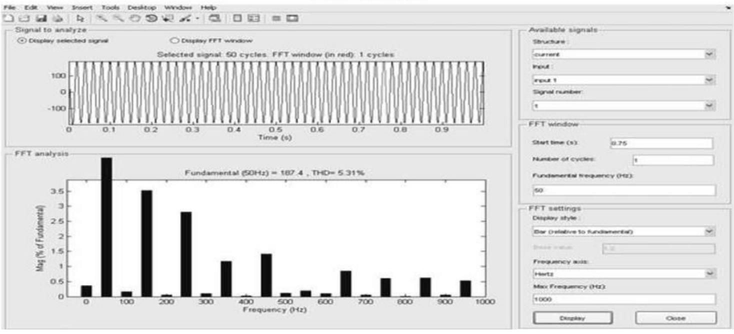

Fig. 8 Grid current and THD in LCL filter

Comparison of the results of L filter (as shown in fig. 6) and LCL filter (as shown in fig. 7)shows that the percentage Total Harmonic Distortion is reduced in LCL filter [22], [23].

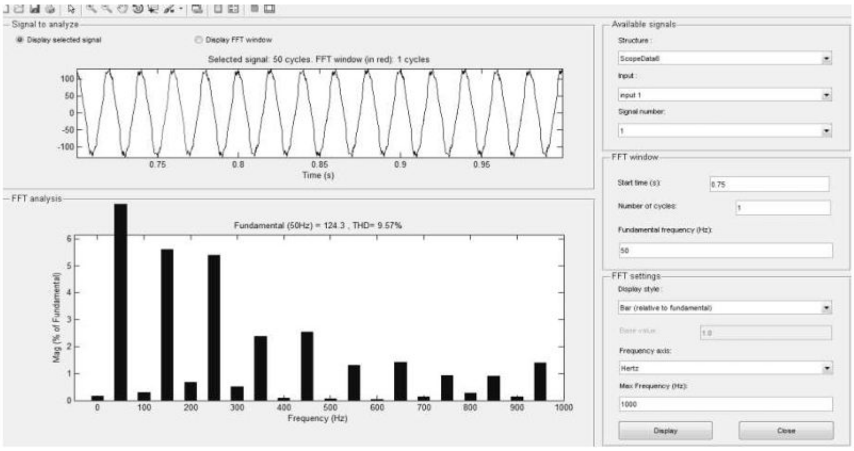

Fig. 9 Load current THD in LCL filter

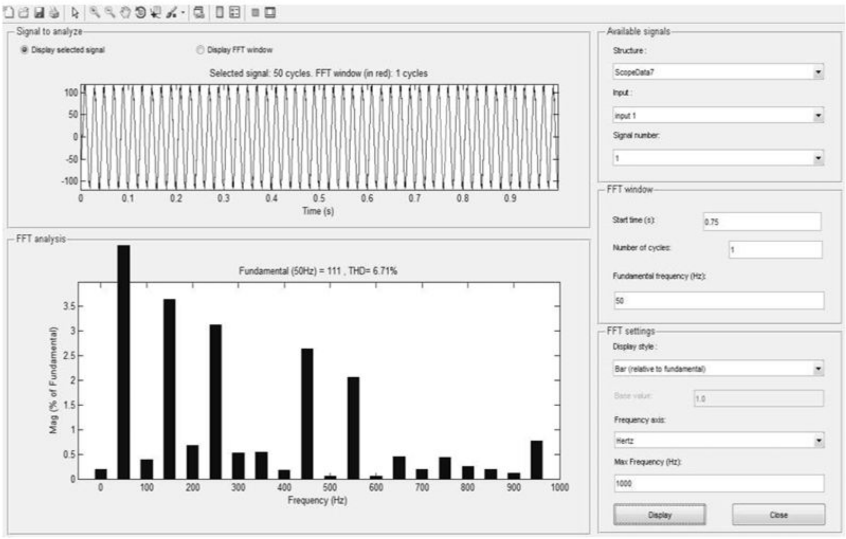

Fig. 10 Inverter current THD in LCL filter

The output waveforms as shown in Fig. 9, 10, 11,12&Table 1 depict that the performance of LCL filter is the best in the class [24], [25].

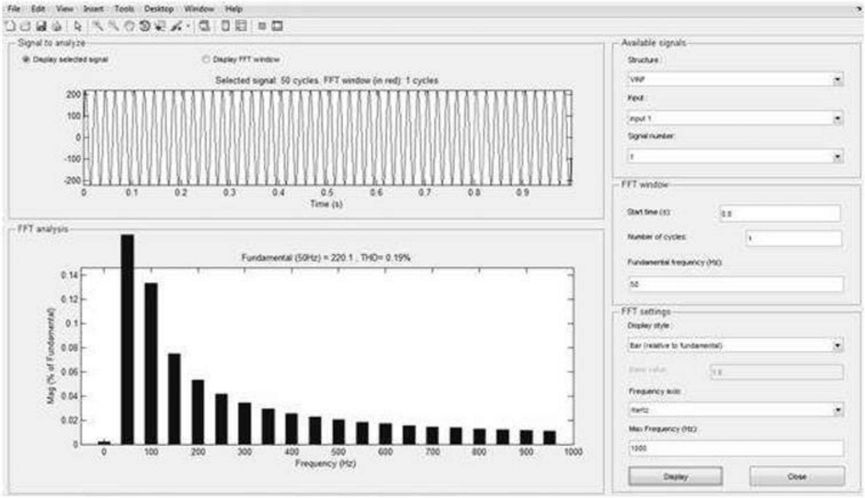

Fig. 11 Inverter voltage THD in LCL filter

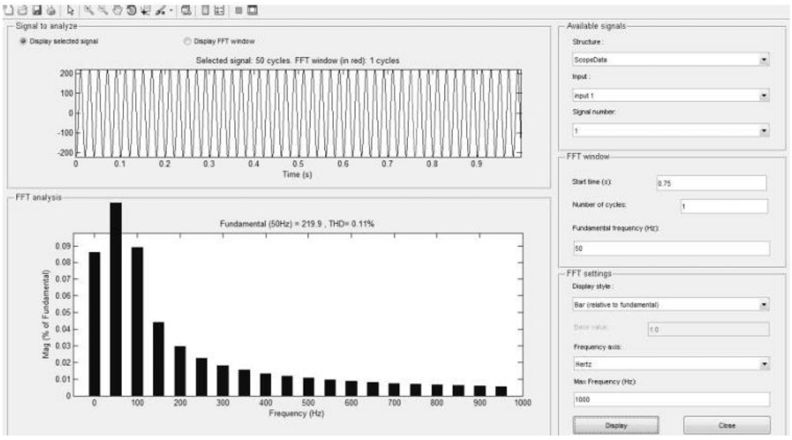

Fig. 12 Grid voltage THD in LCL filter

Table1: Result table with & without LCL filter

Sr.No.	Parameter	Without LCL Filter	With LCL Filter
1	Grid Current THD	43.06	9.75
2	Load CurrentTHD	48.19	9.57
3	Inverter voltageTHD	43.62	0.19
4	Grid VoltageTHD	0.11	0.11

V. **Conclusion**:

The graphical simulation results reconfirm that the LCL filter gives best results with lesser values of L & C and reducing the size, weight and ultimately the cost of filter. The simulation results for various parameters are studied with the help of MATLAB simulation. LCL filters can be applicable to single phase as well as three phase inverters. With the application of LCL filter the total harmonic distortion in the grid current has been reduced drastically from 43% to 10% and distortion in the load current is also reduced by 38%.

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