Design of New Harmonic Filter for Renewable Energy Source with High Attenuation and Less Damping

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Abstract— Optimal design of passive filter (combination of L, C & R) for grid connected inverter system is studied. For that, initially normal design is considered. Higher order passive filters are essential in meeting the interconnection standard requirement for grid-connected voltage source converters. The IEEE 1547-2008 specifications for high-frequency current ripple are used as a major constraint early in the design to ensure that all subsequent optimizations are still compliant with the standards. The choice of switching frequency for pulse width modulation single-phase inverters, such as those used in grid-connected photovoltaic application, is usually a trade-off between reducing the total harmonic distortion (THD) and reducing the switching loss. The total inductance per unit of the passive filter is varied, and filter parameter (L, C & R) values which give the highest efficiency while simultaneously meeting the stringent standard requirements are identified. Then the conduction and switching losses that are caused by the filter are calculated and are optimized considering the level of reduction of harmonics. Hence the main aim of the study is to attenuate higher order harmonics along with the reduction in switching losses to ensure sinusoidal current injection into the grid. Further, the different switching schemes for single phase full bridge inverter are studied and compared to get the switching scheme which gives lesser switching losses. Proposed filter will be design for optimal inductance and capacitance values are obtained. Stability Analysis of Grid-Connected Inverters with proposed Filter Considering Grid Impedance expected more stable than available work. Simulation will be done on MATLAB SIMULINK environment for feasibility of the study in near future.

Keywords: THD, MATLAB SIMULINK, Distributed Generation (DG)

I. OVERVIEW

Growing demand of power and limited availability of conventional sources are the two key issues worrying researchers to think other alternatives of generating power. That's why other non-conventional sources have become popular now-a-days. Simultaneously, rising cost and complexity in existing electricity distribution systems and the inability of current systems to serve remote areas reliably has led to search for alternate distribution methods. One viable solution is use of renewable energy sources directly at point of load, which is termed as Distributed Generation (DG). Most renewable sources of energy, like wind, solar, fuel cell etc. are interfaced to the existing power supply by a power converter. This eliminates the transmission and distribution losses and improves reliability of the power supply. But use of power converters will also introduce undesirable harmonics that can affect nearby loads at the point of common coupling to the grid. Hence all such converters have a filter to eliminate these harmonics.

The proposed work is on design of such filters for high power (10's to 100's of kW), Pulse width modulated voltage source converters for grid-connected converter applications. The conventional method to interface these converters to grid is through a simple first order low-pass filter, which is bulky, inefficient and cannot meet regulatory requirements such as IEEE 512-1992 and IEEE 1547-2008. The design of efficient, compact higher order filters to attenuate the switching harmonics at the point of interconnection to the grid to meet the requirement of DG standards of interconnection is studied. Also different switching schemes for single phase unipolar full bridge inverter are studied and compared to get the switching scheme which gives lesser switching losses. The proposed passive filter will be designed accordingly and optimal inductance and capacitance values are obtained. All the related models are simulated using the MATLAB software and graphs are studied.

II. RESEARCH MOTIVATION

In recent years availability of power in India has both increased and improved but demand has consistently outstripped supply and substantial energy and peak shortages prevailed in 2009-10. That's why non-conventional sources have become the center of attraction. Among these fast growing is the wind energy system. Now India has become fifth in installed capacity of wind power plant. As in 2012 the installed capacity of wind power in India was 18,421 MW. But, as the wind is season and region based, it was not so reliable as long as Power Electronics had not been advanced much. Now-a-days the interface of Power Electronics has made wind energy system one of the reliable sources. Most renewable sources of energy, like wind, solar, fuel cell etc. are interfaced to the existing power supply by a power converter this eliminates the transmission and distribution losses and improves reliability of the power supply. But use of power converters will also introduce undesirable harmonics that can affect nearby loads at the point of common coupling to the grid. Hence all such converters have a filter to eliminate these harmonics. An attempt is initiated to reduce harmonic content of Grid side converter in this project.

III. LITERATURE REVIEW

Energy crisis and the threatening increase of greenhouse gases have naturally caused more attention to the use of renewable energy resources in modem distribution networks. The dispersed nature of these resources, sometimes called Distributed Resources (DR), along with other technical and economical issues has consequently brought the subject of Distributed Generation (DG) into consideration [3].Many types of distributed resources produce electrical energy in the form of dc voltage source. Well known examples are photovoltaic (PV) and fuel cells.

Furthermore, in some other type of DR, although the generated electrical energy is in the form ac, it is preferred to perform energy exchange through an ac/dc/ac conversion stage for the incompatibility of the generated voltage and/or frequency with that of grid. Examples of this type are micro-turbines, in which the electrical energy is generated via high speed permanent magnet generators with the frequency around a few kilohertz, or in some types of wind turbines in which technical characteristics of the system do not allow direct connection of the generator to the utility grid [2].As a result, with currently available technologies, many DRs need a dc/ac conversion stage for energy transfer to the grid. Apparently, static dc/ac converters are the best alternative for this task and thus widely used in such applications.

Voltage Source Converters (VSC) is almost exclusively used for conversion of energy between a dc source and utility grid for the power range normally available in DR. The non-sinusoidal nature of PWM voltages at the output of these converters calls for adequate filtering in order to limit the current harmonics injected to the grid. Traditionally, a simple first order L filter is used to connect converter to the grid and reduce injected harmonic currents. However, implementation of third-order LCL filters has been recently proposed by some researchers [3-5]. Despite many potential advantages, some important parameters must be carefully taken into consideration in design of an LCL filter. This subject, specifically when the converter is used to connect a DR to the utility grid for active power transfer, has not been rigorously studied and available literature on it is very limited. We are concerned with the investigation of LCL filters and their effects on the overall performance of a grid-connected VSC when the flow of power is from dc side to the ac utility grid. Analytical expressions and plots are provided for better understanding of the filter behaviour.

IV. Passive Filter

Optimal design of passive filter for grid interfaced distributed power generation system is studied. For that, initially normal design is considered. Higher request LCL channels are crucial in gathering the interconnection standard necessity. The IEEE 1547-2008 determinations for high-frequency current ripple are utilized as a real imperative ahead of schedule in the outline to guarantee that all resulting improvements are still agreeable with the models.

The output filter helps in reducing the harmonics in generated current caused by semiconductor device switching. There are various types of filters. The simplest one is the filter inductor connected to the inverter's output. But various combinations of inductor and capacitors like LC or LCL can be used. The schematic diagram of a single phase grid connected inverter along with LCL filter is shown in Figure 1.

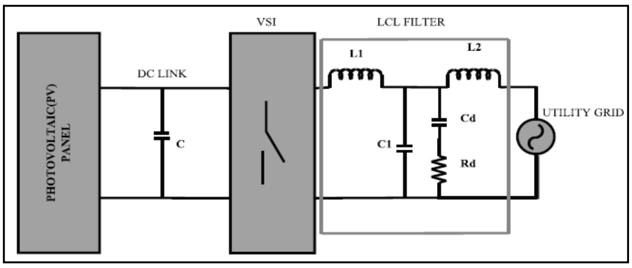

Fig. 1: single phase grid connected to Conventional LCL filter[2]

A. L-Filter:

The L-Filter is the first order filter with attenuation 20dB/decade over the entire frequency range. Hence this type of filter is suitable for converters with high switching frequency, where the attenuation is sufficient. On the other side, inductance greatly decreases dynamics of the whole system converter filter [2].

B. LC-Filter:

The LC-Filter is the second order filter having better damping as compared to L-Filter. It is easy to design and works mostly without problems. This filter provides 12dB per octave of attenuation after the cut-off frequency fo, it has no gain before fo, but it presents a peaking at the resonant frequency fo. Transfer function of the LC-filter is

$$F(s) = \frac{1}{1 + sL_F + S^2 L_F C_F}$$

In order to suppress the negative behaviour near cut-off frequency the damping circuit is added to the filter. The damping can be either series or parallel. The damping circuit selection influences the transfer function of the filter.

C. LCL- Filter:

The LCL-filter is a third order filter having attenuation of 60db/decade for frequencies above full resonant frequency, hence lower switching frequency for the converter switches could be utilized . Decoupling between the filter and the grid connected inverter having grid side impedance is better for this situation and lower current ripple over the grid inductor might be attained. The LCL filter will be vulnerable to oscillations too and it will magnify frequencies around its cut-off frequency. Therefore the filter is added with damping to reduce the effect of resonance. Therefore LCL-filter fits to our application. In the interim, the aggregate inductance of the received LCL filter is much more diminutive as contrasted with the L filter. Commonly, the expense is lessened. Besides, enhanced dynamic execution, harmonic attenuation and decreased volume might be accomplished with the utilization of LCL filter. The conduction and switching losses that are caused by the filter are calculated and are optimized considering the level of reduction of harmonics.

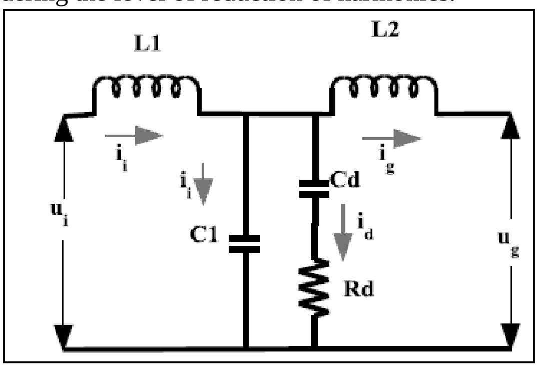

Fig. 2: standard LCL filter[2]

D. LCL-LC filter:

LCL-LC filter is modeled and analyzed. And then two resonant frequency characteristics are obtained. A parameter design method for presented filter is proposed based on the obtained characteristics. The proposed parameter design method decomposes the whole filter parameter design into a traditional *LCL* filter part and an *LC* series resonant circuit part. In the proposed parameter design method, an *LCL* filter is designed first and then the whole *LCL-LC* filter parameters are obtained by designing the *LC* series resonant circuit parameters on the base of the designed *LCL* filter parameters. The advantage of proposed method is that the method can easily make full use of the existing research results about the traditional *LCL* filter parameter design.

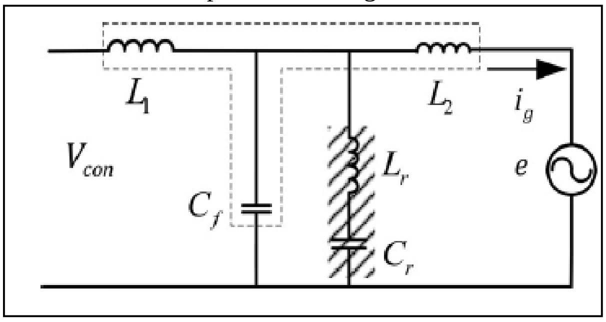

Fig. 3: LCL-LC filter proposed by base work [1]

E. Power Losses:

Power losses are calculated at fundamental frequency and switching frequency. Inductor: Essentially, losses in inductor are separated into core and copper loss. In spite of the fact that, there are some extra losses which are unimportant. So with the assistance of Magnetic design software both core and copper losses at switching and fundamental frequencies are ascertained. [3].

V. CONCLUSION

Optimal LCL filter design along with switching loss reduction is planned to design. So, the optimal filter is design very good ripple factor. And for that value of inductor different switching losses are studied. The analysis showed that for meeting the same THD requirement with a available filter, the optimal switching scheme saves only up to 19.5% under "best-case" conditions compared to the fixed switching frequency scheme. Thus, new scheme requires reducing the size of the heat sink or, for an existing heat sink design, reducing the temperature of the switches and possibly extending the inverter life.

These loss curves were used to find the most efficient arrangement of filter design. A frequency-domain analysis to design the control systems, system stability and the control scheme of the grid current based on the averaged small-signal model is studied. The resistive component in the grid impedance is able to improve the stability margin of the grid-connected system, on behalf of information above an optimized filter can be developed.

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