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POWER QUALITY IMPROVEMENT OF SINGLE-STAGE SOLAR INVERTER WITH HYBRID ACTIVE FILTER

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Abstract- solar systems with grid connected to power electronic interfaces are becoming popular since they do not produce environmental pollution. Even though one of the problem with grid feeding inverter is the requirement of high dc-link voltage. Due to this , single stage solar inverters using conventional inverters may not be preferable, since it require input dc voltage more than the peak of line-line voltage. Therefore, two-stage topologies typically consist of one dc-dc power stage to boost the dc voltage, in addition to a Current Source Inverter (CSI) for dc-ac conversion are reported for applications where the input voltage is lower than the peak of the output voltage. However, which increases the circuitry complexity. In addition, Current source inverter requires bulky inductance in DC side, which increases losses. Hence, In this paper a single stage solar inverter using shunt active hybrid filter is presented. The inverter features a single power stage, with dc link voltage less than the peak line-line voltage, which will reduce the power losses and circuit complexity. In addition, the proposed solar inverter can also provide harmonic filtering to improve the power quality of the system. The operation and control of the single stage solar inverter for active power control and harmonic control is described. A detailed analysis, simulation results for the proposed single stage solar inverter is presented. The proposed inverter has an efficiency of 94%, compared to an conventional active filter based solar inverter's efficiency of 90%. Moreover, it has been shown that the switching ripple injected by the proposed solar inverter is just half of the conventional active filter based solar inverter.

keywords-Hybrid Active Filter, Active Filter, solar photovoltaic, D-Q Control, Harmonic Compensation

I. Introduction

Electrical energy is the most efficient and popular form of energy and the modern society is heavily dependent on the electric supply. The life cannot be imagined without the supply of electricity. And also the quality of the electric power supplied is also very important for the efficient functioning of the end user loads. The term power quality became most important in the power sector and both the electric power supply company and the end users are concerned about it. The quality of power delivered to the consumers depends on the quality of the voltage and frequency of the power. If there is any deviation in the voltage and frequency of the electric power delivered from that of the standard values then the quality of power delivered is affected.

Now-a-days with the advancement in technology there is a drastic improvement in the semi-conductor devices. With this development and advantages, the semi-conductor devices got a permanent place in the power sector helping to ease the control of overall system. Moreover, most of the loads are also semi-conductor based equipment. But the semi-conductor devices are non-linear in nature and draws non-linear current from the source. And also the semi-conductor devices are involved in power conversion, which is either AC to DC or from DC to AC. Due to the power conversion contains lot of switching operations which may introduce discontinuity in the current. Due to this discontinuity and non-linearity, harmonics are present which affect the quality of power delivered to the end user. To maintain the quality of power delivered, the harmonics should be filtered out. Thus, a device named *Filter* is used which serves this purpose.

There are many filter topologies in the literature like- active, passive and hybrid. In this project the use of hybrid power filters for the improvement of electric power quality is studied and analyzed.

Initially passive filters are used but they are dependent heavily on the system parameters. They also have the problems of resonance with system impedance and are suitable for filtering out a particular frequency harmonics. Therefore, to overcome the problems of passive filters, active filters are used. It is found that the active filters are facing some drawbacks when employed for power quality improvement. They are

- High converter ratings are required
- Costlier when compared to passive filters
- Huge size
- Increased losses

To overcome the drawbacks of Active & Passive filters, a hybrid power filter which is a combination of active and passive filters is proposed in this proposal gives how a

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combination of both active and passive filters is an optimal solution for power quality improvement. The most effective solution to improve the power quality is the use of filters to reduce harmonics. The basic idea of using a filter is explained in Fig. where the filter injects a compensating current that compensates the harmonics in load current.

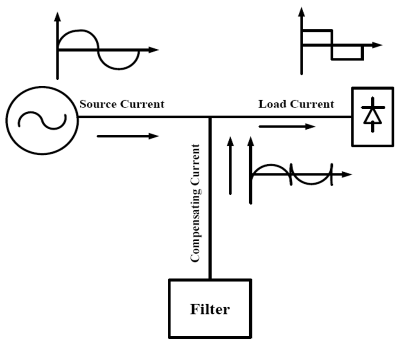

Fig 1:Basic operation of Filter

II. Literature Review

In conventional systems Two-stage topology that boosts the PV voltage by a dc-dc converter in the first stage and then inverts it into ac voltages in the second stage But, this increases the number of stages and component count and thus reduces the overall system efficiency. Hence, single-stage inverter topologies are gaining interest.

In the existing inverters, serial connection of several PV modules is necessary, so that the PV voltage is maintained higher than the peak of input voltage. These long strings of panels (and hence cells) bring with them many complications like large size and poor efficiency, when individual panels are running under different conditions.

A current source inverter (CSI) based single stage solar inverter has been presented. This requires bulky inductor in DC side, which increases losses. Further, in CSI filtering switching ripple at grid side becomes difficult. To overcome this problem we can go for VSI

III. Types of Hybrid Power Filters

There are different hybrid filters based on the circuit combination and arrangement. They are

- Shunt Active Power Filter and Series Active Power Filter.
- Shunt Active Power Filter and Shunt Passive Filter.
- Active Power Filter in series with Shunt Passive Filter.
- Series Active Power Filter with Shunt Passive Filter.

In our research proposal we are using APF in Series with Shunt Passive Filter

In this filter configuration, the Active Power Filter is connected in series with a Shunt connected Passive Filter. The circuit diagram of this filter configuration is shown in Fig. The advantage of this configuration is that the passive filter reduces the stress on the power electronic switches present in the APF. This filter has its application in medium to high voltage ranges.

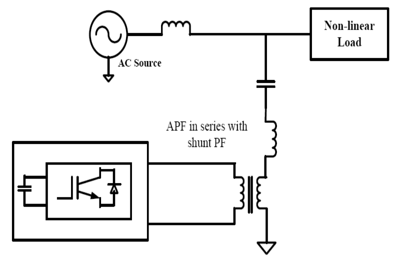

Fig:2

A. Proposed system

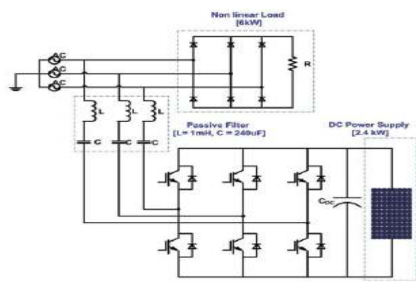

Fig 3:Power Circuit Diagram Proposed Signal Stage Solar Inverter

The proposed, single stage solar inverter consists of a passive filter in series with an active filter(VSI) connected to a DC bus capacitor and PV array, feeding a non-linear load of 6kW.

In order to reduce the size of the passive filter (LC), it is tuned for 7th harmonic frequency (L = 1mH, and C= 240uF).

The capacitor has been selected to supply 7kVAR of reactive power (at 300V (L-L)), which can compensate for lagging load.

IV Voltage Controller Of DC-Bus

The main function of DBVC (Voltage Controller of DC Bus) is to control power supply to the insulated gate bipolar transistor converter. To avoid using external power such as DC power supply, Batteries, and many more, the charging and discharging phenomenon of capacitor element is manipulated. The charging and discharging phenomenon of capacitor is controlled by the DBVC for maintaining the DC voltage level at constant and the transient response reached the stability. There are several approaches that can be implemented for the DBVC such as using the PI controller but in this paper, the approach used is based on [22]. Fig. 2 shows the voltage controller of DC bus. Voltage controller of DCbus regulates the voltage of the capacitor on DC side of the converter and compensates losses of the converter. The voltage of the capacitor is measured and then it is compared to constant value. The resultant difference is then fed into gain. In this way, HAPF regulates and builds up the DC voltage of capacitor without using any external source.

A. Hysteresis Control Technique

With help of hysteresis control technique gating signals for voltage source converter is generated. For controlling the output currents of the HAPF various control techniques have been used. Among these techniques hysteresis current control techniques is the most popular technique for the application of the HAPF. In this technique, as shown in Fig. 3, the actual compensation current reference is compared with predescribed band of hysteresis around reference current. The resultant current will feed into the hysteresis band comparator which generates the switching signals for VSC. The switching pulses are generated when actual compensation current reference crosses the upper and lower tolerance bands. If actual compensation current reference is within a tolerance band then no switching pulses are generated.

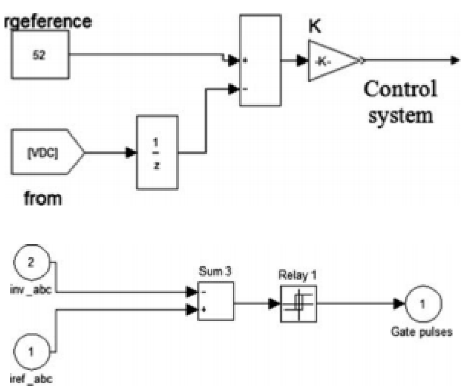

Fig.4:Voltage Controller of DC Bus

V Results & Discussions

The simulations based on PSIM software are executed tovalidate the performance of the proposed single stage solar inverter and the above analysis of proposed solar inverter. The simulation parameters considered are given as follows: AC Voltage = 300V (L − L), 50Hz, Filter Active Power = 1.5kW, (IFdRef : 4A), Filter fund. Reactive Power = 7kV AR, Filter Harmonic kVAR = 1.5kV AR, Load Power= 5.2kW, DC Voltage = 300V, L = 1mH, C = 240uF, R= 0.1Ω PWM frequency used is 12.8kHz. Fig shows the steady state simulation results for 1.5kW power injection and 1.5 kVAR harmonic compensation The current reference(IFd Ref) given is 4 A. From Fig., it can be observed that the proposed control regulates the filter active current and effectively controls the harmonic current, so that the source current is free from harmonics. The active current(IFd) injected to grid is 4 A, which corresponds the active power of 1.5kW. The inverter reactive current (IFq) is 19 A, which corresponds to reactive power of 7 kVAR. Here, we can observe that the source current is free from harmonics and it's THD is 4%, while the load current THDis 27%. Fig.10, shows the simulated transient response ofthe system, when IFd Ref changes from 4A to 6A, with the controllers designed as given in Section-III. From Fig., itcan be observed that the transient response of the simulated system is around 50 ms. Comparing Fig.6 and Fig., it can be observed that the transient response of mathematical model and simulation model are in close agreement. Experiments are performed for IFd Ref = 4A, 1.5kVAR harmonic compensation and 7kVAR reactive power compensation, with 300V(L-L) AC Voltage. The experimental setup parameters are similar to the simulation circuit parameters, except for the inductive loading (Load Reactive Power) beingabsent.

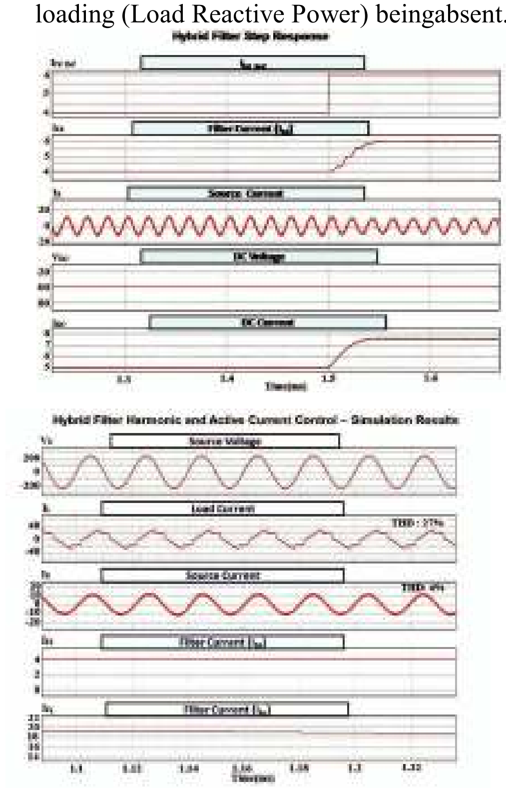

Fig.5:Step Response Simulation Of Proposed Solar Inverter

VI.Conclusion

In this paper, a novel single-stage solar inverter is proposed for a three-phase grid-connected inverter which employs a single power stage for power conversion from a low dc voltage source to the ac grid system, along with power quality improvement. A control method for combined active current control and harmonic current control is presented. Analysis of active current control and harmonic current control loop is also presented. The modeling and control system analysis are explained and some design guidelines are presented. Simulation and experiments are carried out with 1.5kW active power, 7 kVAR reactive power and 1.5 kVAR harmonic kVAR. Step response of the system is presented and is shown that the experimental and simulation results are in close agreement with the results predicted by the model. Further, the efficiency of the proposed solar inverter with the conventional active filter based solar inverter is compared. It is shown that, the efficiency of the proposed solar inverter is 94%, while the conventional active filter based solar inverter efficiency is 90.8%. In addition it is shown that the ripple current injected by the proposed solar inverter is half of the conventional active filter based solar inverter.

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