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Research Article

A Study of Harmonic Mitigation using Active Power filters in a PV system Integrated with GRID through a multilevel inverter

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Abstract

The new age has paved way for the new and renewable energy based power generation and thus solar PV arrays have found widespread implementation since then not only as a clean source but also an alternative that is available in abundance. But the nature of power that is obtained from a photovoltaic setup is non – alternating in nature. Hence if it needs to be integrated with the grid then it ought to be converted to Alternating form. Hence the usage of inverters is inevitable. But inverters as seen from the supply side affect the power quality due to their switching nature. In order to address this problem, multilevel inverters are used. But still the problem can't be eradicated without the usage of filters. In this work active harmonic filter is implemented for a PV Multilevel inverter interfaced Grid system and the performance aspects are studied and compared with those obtained for their passive counterparts.

Keywords: Active power filters; Grid; Multilevel cascaded inverter; Harmonics; Total harmonic distortion.

Introduction

Meinhardt and Cramer [1] gave an overview on what are the opportunities and challenges in grid integration of photovoltaic systems and how they are seen as the energy reservoir of the future. Carrasco et al [2] in their survey on power electronic inverters discussed the various possible options available for successful integration of renewable energy sources to grid. Kjaer et al [3] concentrated their work exclusively on single phase inverters which can be custom designed especially for photo voltaic modules. Harmonic filtering should be preceded in design phase by successful technique for harmonic extraction. Various such time domain techniques were discussed by Areerak et al [4]. Harmonics mitigation using the technique of active power filter was discussed by Salam et. al [5] and Masood et. al [6]. Various such topologies of active filters available were elaborated by Lakshman Naik, K Palanisamy et. al [7].

The IEEE Standards on Harmonic filtering directs that the current harmonics to be within 5% (THD) [8]. Active Filtering is of two types namely shunt and series active filters. The time domain techniques involved in harmonic extraction process of shunt active filters was exclusively discussed by Karsh [9]. Renewable energy sources especially solar PV arrays and the successful integration of power generated from them into the grid involves lots of challenges especially with regards to maintaining the power quality at the point of common coupling. Apart from maximum power point tracking algorithms PV modules have been specially designed to meet specific rated loads [10-11]. But In order to have an intrinsic technique for the mitigation of harmonics, multilevel inverters are used, which were investigated in detail [12-14]. Such multilevel inverters can also boost the level of power given to the grid by connecting them in a cascaded manner [15,16]. This was also reduced the stress on the PV module [17]. But multilevel inverters alone can't be a standalone solution and harmonic filters are definitely indispensable for a large scale PV system connected to grid. Vinodhini and Sudhakar developed passive harmonic filters for the PV system connected to grid to reduce harmonics at the PCC [18].

The system

The system is a typical solar based power generation system which is connected to the grid via a converter inverter setup. This setup is quite commonly seen in areas where the PV module or

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Wind based power generation systems are upgraded into grid connected systems rather than continuing as standalone systems. The setup consists of signal conditioning filters as well as harmonic filters. The THD levels are studied and are checked for allowable levels of THD or harmonics in the system. The PV module consists of its own Maximum Power Tracking algorithm. The converter is to convert variable DC to Fixed constant source of DC and is conventionally a chopper or a DC–DC converter.

Nowadays modern topologies like luo converters also find widespread applications in this regard. The inverter used here is typically a three phase multilevel inverter. Such inverters slowly but steadily have started to replace conventional inverters since they are inherently capable of controlling the harmonics by their operational mechanism. The AC output obtained thus is connected to the main grid. This process is grid integration of renewable energy source. This grid integration has become the need of the hour as with standalone sources of power the consumer cannot avail the facility to sell the surplus power. But even though multilevel inverters can address the problem of harmonics to some extent, in order to ensure that the harmonic levels are well within limits, which is a prerequisite for stable and secure operation of power system, one must go in for the implementation of harmonic filters in the system. Thus here active harmonic filters are used and are compared in performance with the results obtained with the implementation of passive harmonic filters as discussed [18].

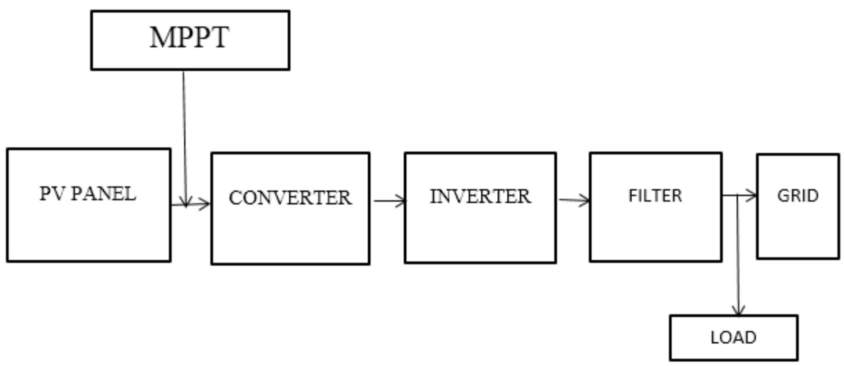

Figure 1. Implementation block diagram of the system

Multilevel inverters

The CMI or cascaded multilevel inverters synthesizes its output in a nearly sinusoidal voltage waveform by combining many isolated voltage levels. An n level cascaded H - bridge multilevel inverter needs 2(n-1) switching devices where n is the number of the number of the output voltage levels. In this work a three phase cascaded multilevel inverter is used. The output voltage of this inverter has 5 levels. The inverter consists of two H - bridge inverters that are cascaded. For this multilevel inverter, 8 switching devices are needed. The truth table for operation of the inverter is given in Table 1.

Table 1. Truth table of cascaded multilevel inverter

Switches (ON)	Voltage Output (DC)
S1,S2,S5,S8	V_{dc}
S1,S2,S5,S6	$2V_{dc}$
S2,S3,S7,S8	$-V_{dc}$
S3,S4,S7,S8	$-2V_{dc}$

The output waveform of three phase multilevel inverter is given as follows. The waveforms for three phases are given separately. The matlab Simulink diagram for the implementation of CMI is given in figure 3.

Harmonic analysis and passive filtering

FFT analysis is an effective tool to mathematically analyze the magnitude of harmonics present in a waveform. Harmonic analysis is carried out using MATLAB Simulink FFT analysis toolbox. The setup is first simulated without filter and the THD values are noted. Then the setup is implemented with active harmonic filters and the results are compared with passive filters. The Simulink diagram of the system without filters is given in figure 4. Initially the non-linear load is connected to the system and the value of THD of the system is calculated and the value is found to be 1.8. These values are obtained without connecting the filters to the system. The power factor has to be improved and the THD must be decreased for synchronization. The following diagram shows the level of THD before filtering.

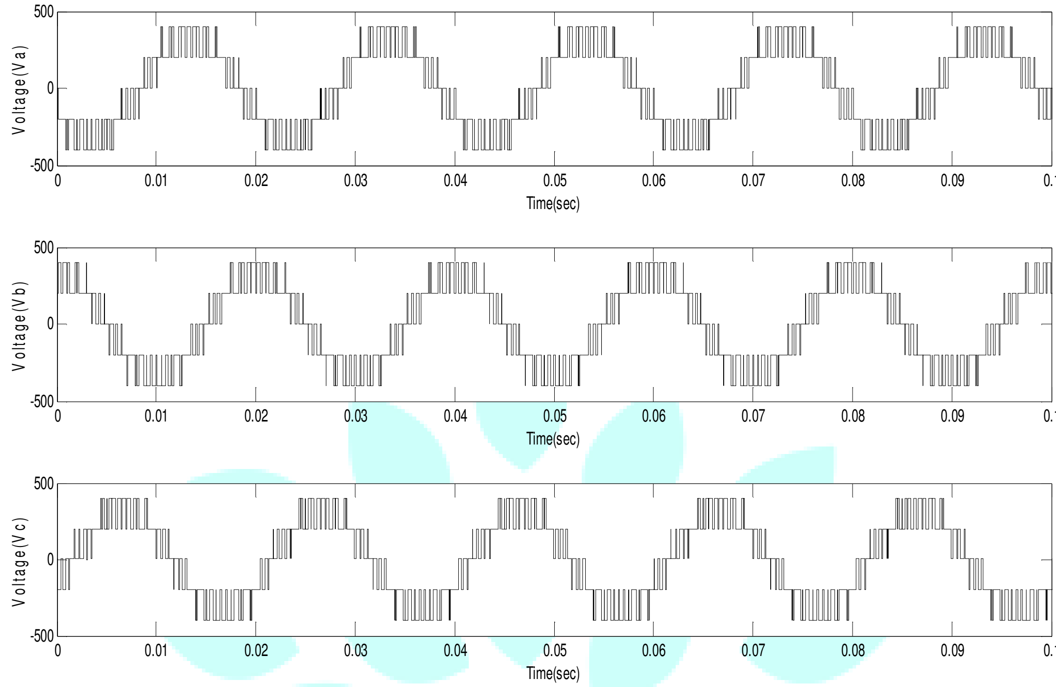

Figure 2. Output waveforms of multilevel inverter

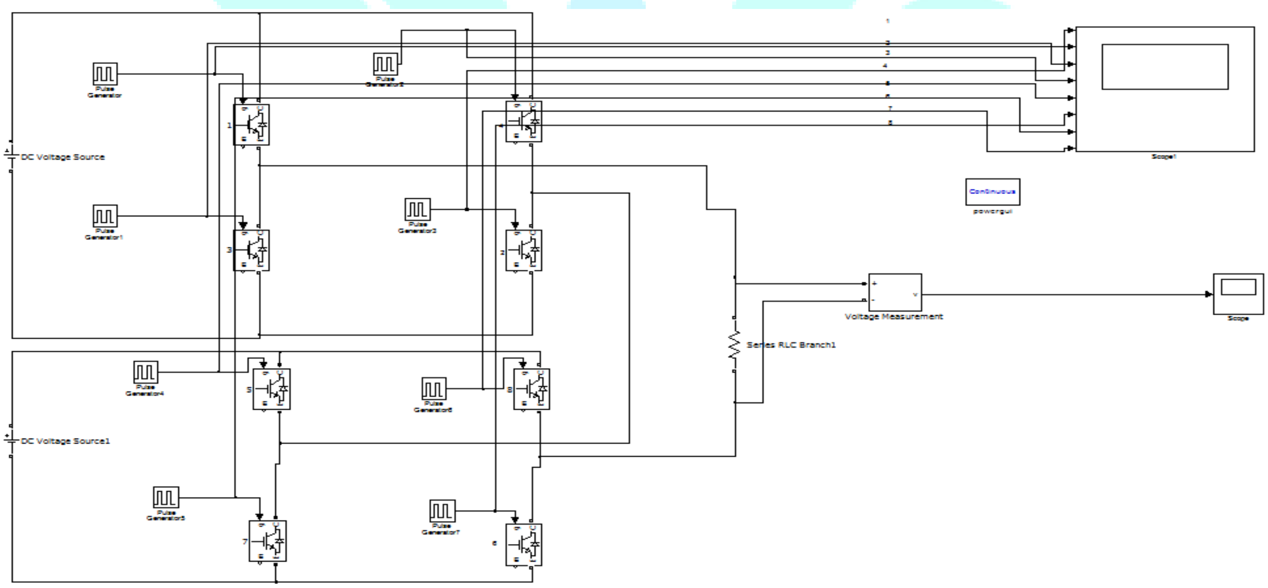

Figure 3. SIMULINK diagram of cascaded Multilevel Inverter

Then passive filtering approach is adopted. Passive harmonic filters are adopted as discussed in [18] and the THD values are again analyzed. The results are given in table 2.

Harmonic filtering using active power filter

The process of active harmonic filtering involves the following steps. Harmonic component extraction, inverter operation to generate compensating current and to moderate the compensating current by control of gating pulses to the inverter based on reference current mechanism. Active power filters are advantageous since they dynamically address the totality of all order harmonics in a system. Active power filter with suitable harmonic extraction method [4] is designed and implemented. The MATLAB Simulink implementation diagram is given in figure 6.

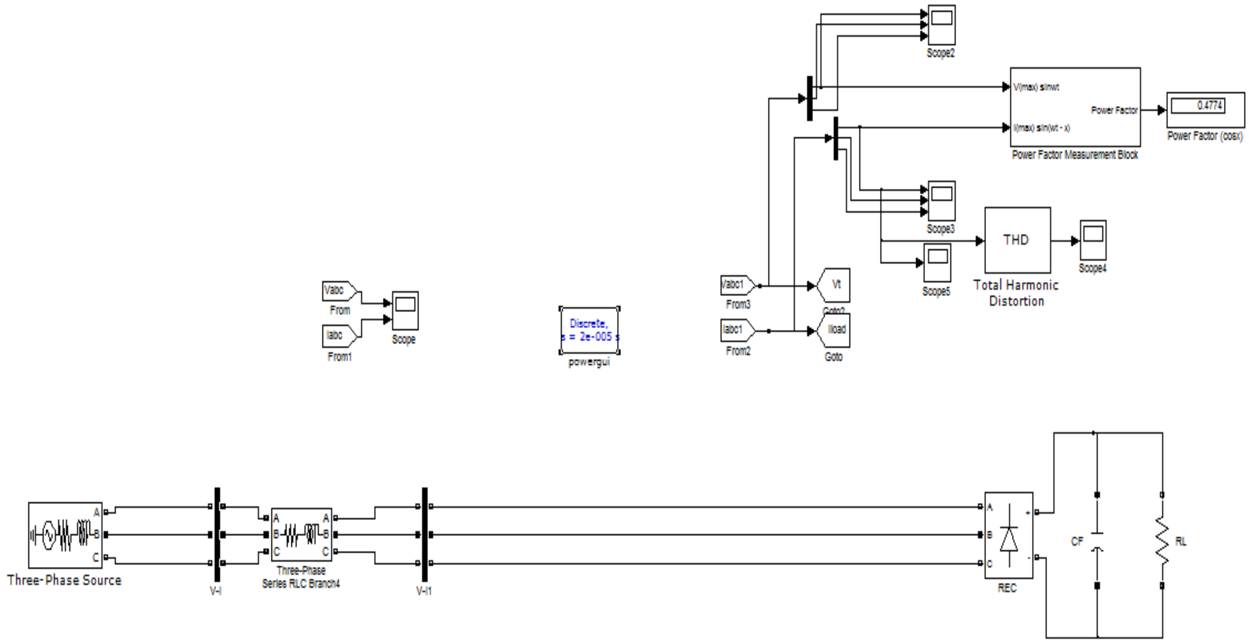

Figure 4. System without harmonic filtering

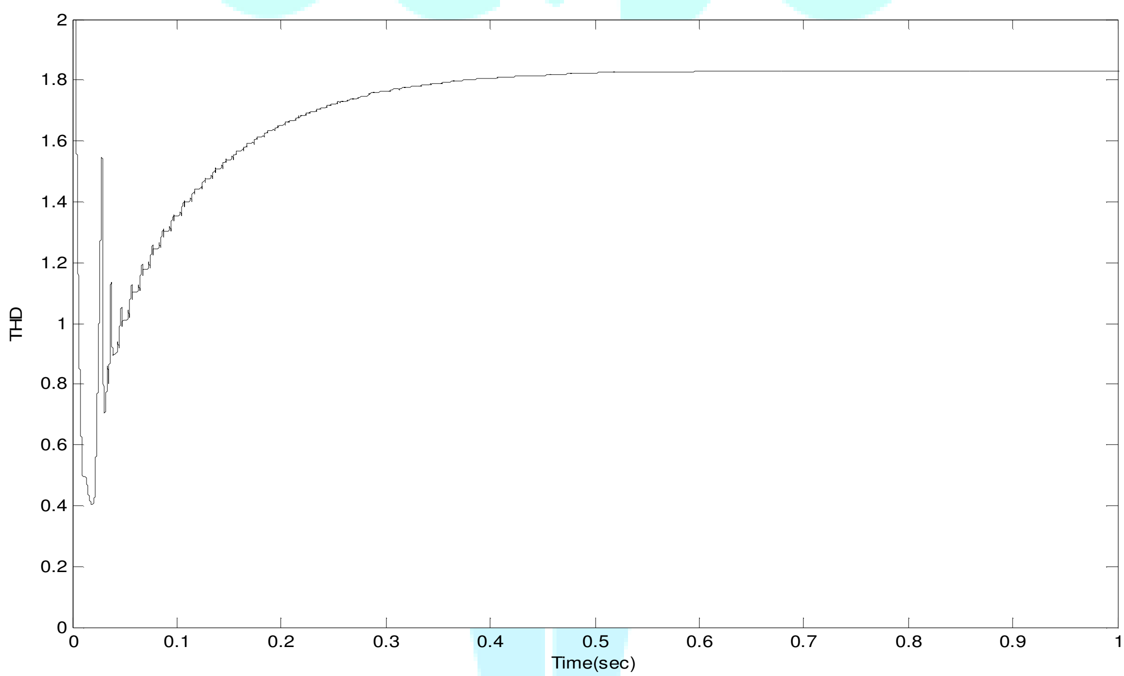

Figure 5. Measure of THD in the system voltage before filtering

Table 2. THD comparison with and without filter

Category	Voltage THD value (%)	Current THD Value (%)
Without filter	20.39	17.29
Passive filter	4.83	4.74

The results obtained with active filter are compared with those obtained for passive filters. The results are given in the table 3.

Table 3. THD comparison with and without filter

Category	Voltage THD value (%)	POWER FACTOR
Without filter	20.39	0.45
Passive filter	4.83	0.94
Active filter	1.4	0.98

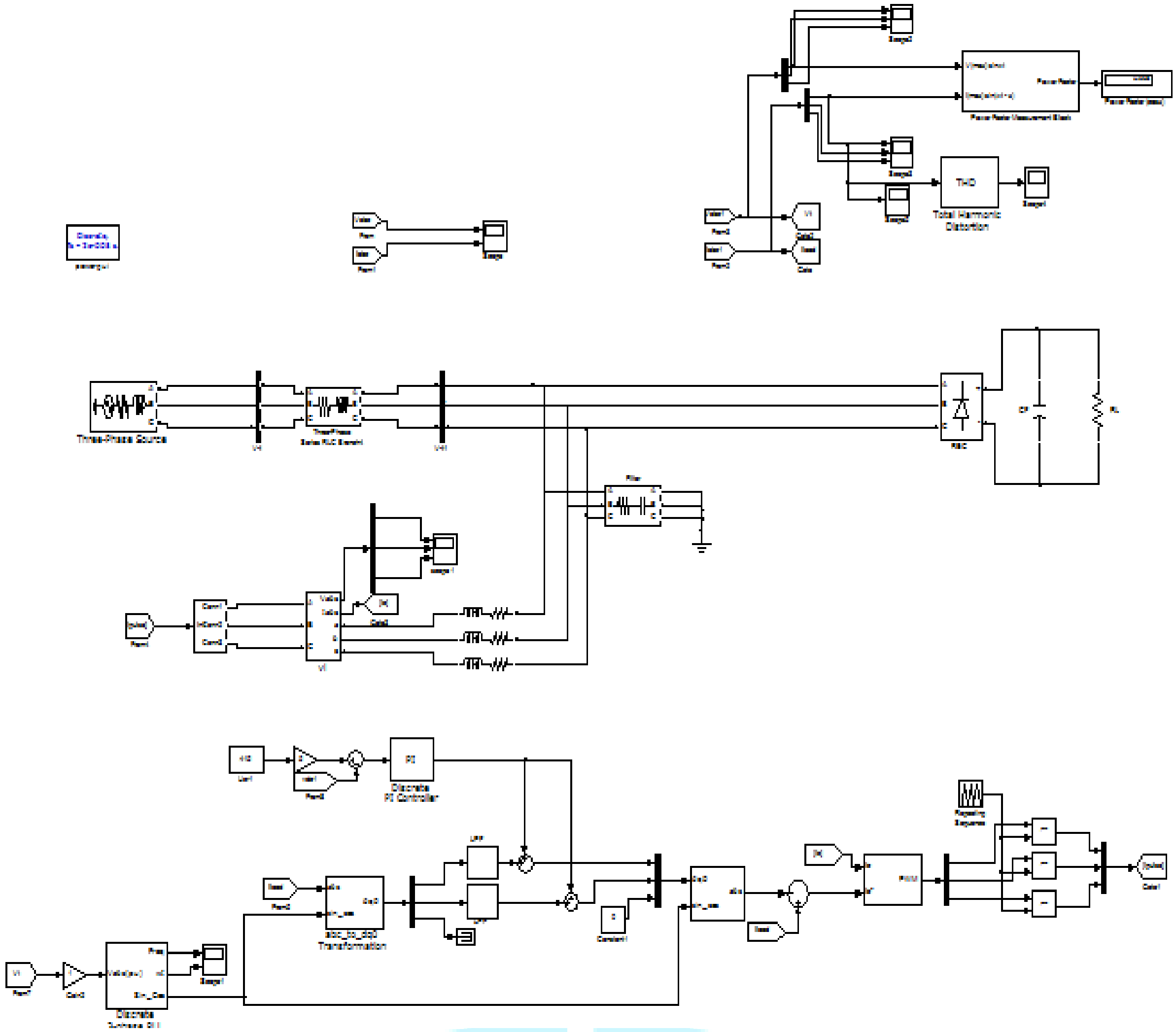

Figure 6. Matlab Simulink diagram of the system with APF

Conclusion

Thus the THD level of the three phase five level inverter is found to be reduced using the active filter. The Multilevel Inverters are beneficial as the number of switches in inverter increases but this increases the harmonic distortion. The distortion in the output is reduced by the proper design of the filter for the inverter. Distortion in AC output voltage and current decreases the performance of the system and in grid connected systems it is important to maintain the voltage. A filter is required between a inverter and grid, imposing a current-like performance for feedback control and reducing harmonics of the output current. Both active and passive filters play an important role in reducing harmonics of the system and it also improves the power factor of the system. A LC filter is having good performance to mitigate the harmonics present in the output if the inverter. An active filter decreases the harmonics to a larger extent compared to the passive filter.

Conflict of Interest

Authors declare there are no conflicts of interest.

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