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Performance Analysis of Grid Connected Single Phase Pv Inverter Using Pi Controller

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Abstract

This paper proposes the performance analysis of grid-connected single phase photovoltaic (PV) inverter topology is considered to interfacing with the grid. Basically the harmonics are generated on load side only. However, the non-ideal factors in the system such as core saturation-induced distorted magnetizing current of the transformer and the dead time of the inverter also introduce the small amount of lower order harmonics in the grid current. A Proportional-integral (PI) controller and Low Pass Filter (LPF) are implemented to reduce the lower order harmonics that are present in the PV system. The complete design has been validated with MATLAB/SIMULINK software version (8.1.0.604) and the overall system operation is observed.

Key word: Lower Order Harmonics, Photovoltaic (PV), PI Controller, Low Pass Filter (LPF) and Distribution Generation (DG).

Introduction

Renewable sources of energy such as solar, wind, and geothermal have gained popularity due to the depletion of conventional energy sources. Hence, many distributed generation (DG) systems making use of the renewable energy sources are being designed and connected to a grid.The capacity of small - and large-scale renewable energy systems based on wind energy, solar energy, etc., installed at distribution as well as transmission levels is increasing significantly. In this paper, one such DG system with solar energy as the source is considered. Single-phase grid tied inverter is one among types of inverters widely used in photovoltaic (PV) generation system due to the advantages they offer. Application of photovoltaic (PV) as a source of electrical energy showed a tendency to increase in terms of generation capacity and in terms of its spread in large areas around the world.

These newly emerging DG systems are imposing new challenges to electrical power industry to accommodate them without violating standard requirements (such as, IEEE 1547, IEEE 519) [1]–[3]. Moreover, most of the DG systems utilize power electronic converters as interfacing device to deliver the generated power to the grid. The switching operation of these systems is contributing as increased harmonic levels both in the grid voltages and currents [4]-[6]. Harmonics are produced due to the non linear loads present in the power system. Non linear loads are those which draw current in non sinusoidal manner when applied with sinusoidal voltage. Some examples for non linear load which draw non sinusoidal current are Personal Computers, Uninterruptible Power Supplies (UPS), Variable Speed Drives, Television Receivers, Fluorescent lighting and also the system itself the lower order odd harmonics are generated by distorted magnetizing current drawn by the transformer[7], the inverter dead time[8]-[11] and the semiconductor device voltage drops. Other factors are the distortion in the grid voltage itself and the voltage ripple in the dc bus. The dead-time effect introduces lower order harmonics which are proportional to the dead time, switching frequency, and the dc link voltage. The various harmonics reduction methods are analyzed [12]-[18].

Proposed System

The Proposed system consists of an Photovoltaic (PV) panel, a boost converter section, a low-voltage single-phase inverter with an inductive filter, and an isolation transformer interfacing with the grid. The main objective of the proposed system is to reduce the Lower order harmonics present in the system by using PI Controller and Low pass filter (LPF).

Advantage

- The switches are all rated for low voltage which reduces the cost Lesser component count in the system improves the overall reliability.
- It will be a good choice for low-rated PV inverters of rating less than a kilowatt.
- The cost of the system is very low.

PV Panel

The simulation block diagram of 150 W PV panel is shown in Fig.1 andthe output voltage waveform are shown in Fig.2 and the corresponding design parameter list are shown in table.1.

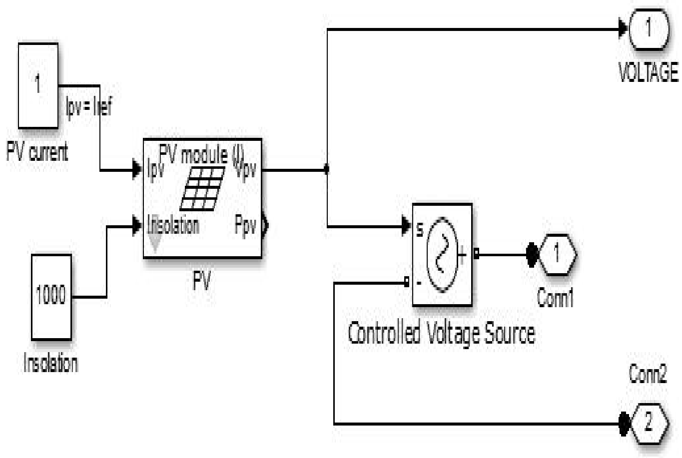


Figure 1: PV Simulation Block Diagram

Table 1. PV Panel Parameter List

S.No	Parameters	Values
1)	PV Insolation	1000
2)	Reference Current (Iref)	1 A
3)	Short Circuit Current (Isc)	5.45 A
4)	Open Circuit Voltage (Voc)	20 V
5)	Maximum Current At Pmax	5 A
6)	Maximum Voltage At Pmax	30 V

The expression for the maximum power calculation is

Pmax = Vmax * Imax- (1)

Where,

Pmax = Maximum Power of PV

Vmax = Maximum voltage of PV

Imax = Maximum current of PV

As per the parameter list shown in table.1 substitute the values forVmax = 30 V and Imax = 5 A in equation (1). Thus the maximum power of PV panel is

Pmax = 30 * 5

Pmax = 150 W

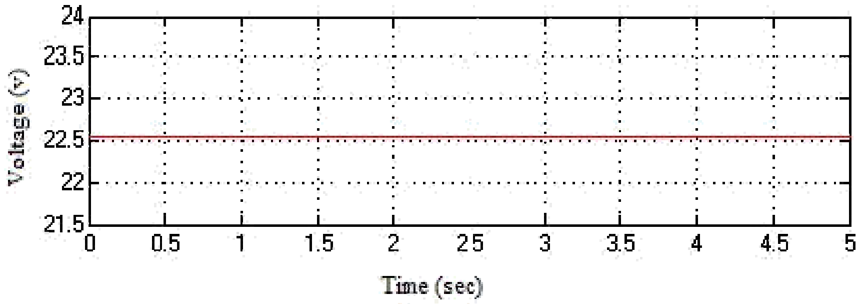


Figure 2: PV Output Voltage Waveform

The masked block diagram of the PV panel is shown in Fig.3. In this the panel insolation and reference current are taken as input to block and the voltage and power are taken as output.

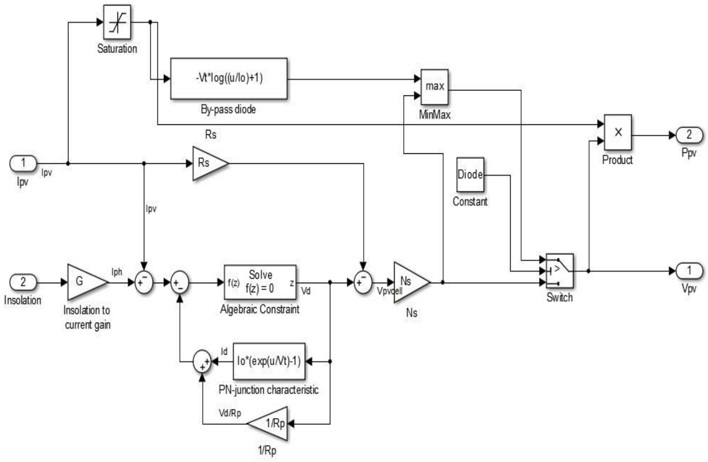


Figure 3: PV Block Diagram

Boost Converter

A simple boost converter are used for DC-DC conversion, In this a 22.5 V DC from the PV panel can be step up to 250 V DC. The boost converter stage consists of an inductor, a diodeand one switch (the switch may be MOSFET, IGBT, GTO) for this an IGBT are used as shown in Fig.4 and the parameter list are shown in Table 2. The inductor (L) connected in series with the positive supply will act as an energy storage device when switch is in off mode the inductor will supply energy to load. The diode is connected as forward biased mode. The output voltage waveform is shown in Fig.5.

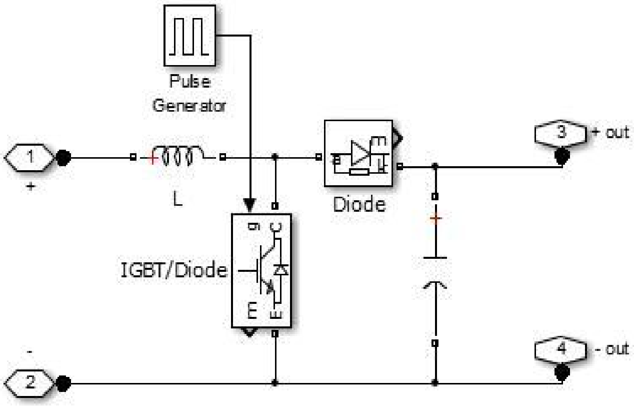


Figure 4: Boost Converter

Table2. Boost Converter Parameter List

S.No	Parameters	Values
1)	Series Inductor (L)	470 uH
2)	IGBT Switch	
	i) Internal Resistance (Ron)	$1e^{-3}\Omega$
	ii)Snubber Resistance (R s)	$1e^{5}\ \Omega$
	iii) Snubber Capacitance (Cs)	Infinity
3)	Pulse Generator Type	Time Based
	i) Amplitude	1
	ii) Peroid (sec)	0.022 sec
	iii) Pulse Width (% of period)	90%
	iv) Phase Delay (sec)	0
4)	Diode	
	i) Resistance (Ron)	0.001Ω
	ii) Inductance (Lon)	0
	iii) Forward Voltage (v)	0.8 V
	iv) Snubber Resistance (Rs)	500Ω
	v) SnubberCapactiance (Cs)	$200e^{-9}$F
5)	Parallel Capacitance	5500uF

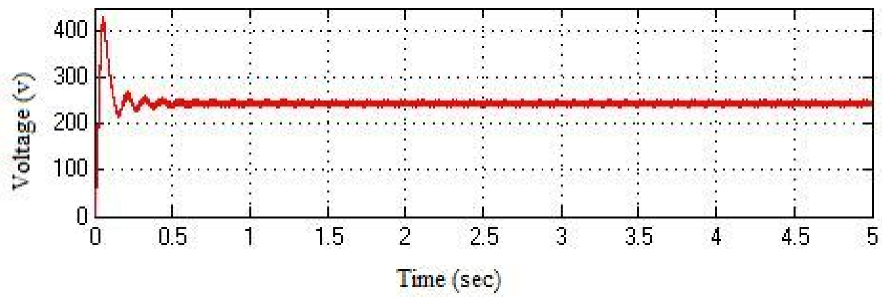


Figure 5: Boost Converter Output Voltage

PI Controller

PI controller is the simplest method of control and widely used in industries. Proportional plus Integral Controller increases the speed of response. It produces very low steady state error [19].In this paper the current value of the system is given as input to pi controller and the output is taken for PWM generation. General equation of the pi controller is

$$Y(s) = Kp\ U(s) + (KiTs / Z^{-1})\ U(s) \qquad - (2)$$

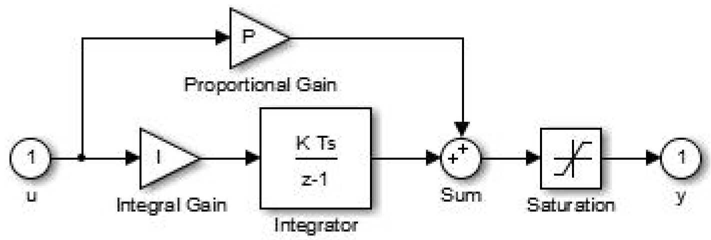


Figure 6: PI Controller

Where Kp is proportional gain, Ki is the integral gain, U(s) is the controller input and Y(s) is the controller output. Fig.6 shows the block diagram of PI controller. Ziegler Nichols' method of tuning is adopted to find the optimum value of Kp& Ki values.

Simulation Result

The simulation is carried out on MATLAB (Matrix laboratory) r2013a (version 8.1.0.604). The main motive of this project is to reduce the THD of the PV inverter. All the simulation results are carried out based on the single phase grid connected PV inverter system depicted in Fig.7.The PI (Proportional & Integrator) controller is used to perform the closed loop system of the PV inverter. The system parameters are given in Table3. The PV system without an battery storage are consider. For simple analysis a universal H-bridge inverter are used to convert the 250 V dc into 230 V AC voltages.

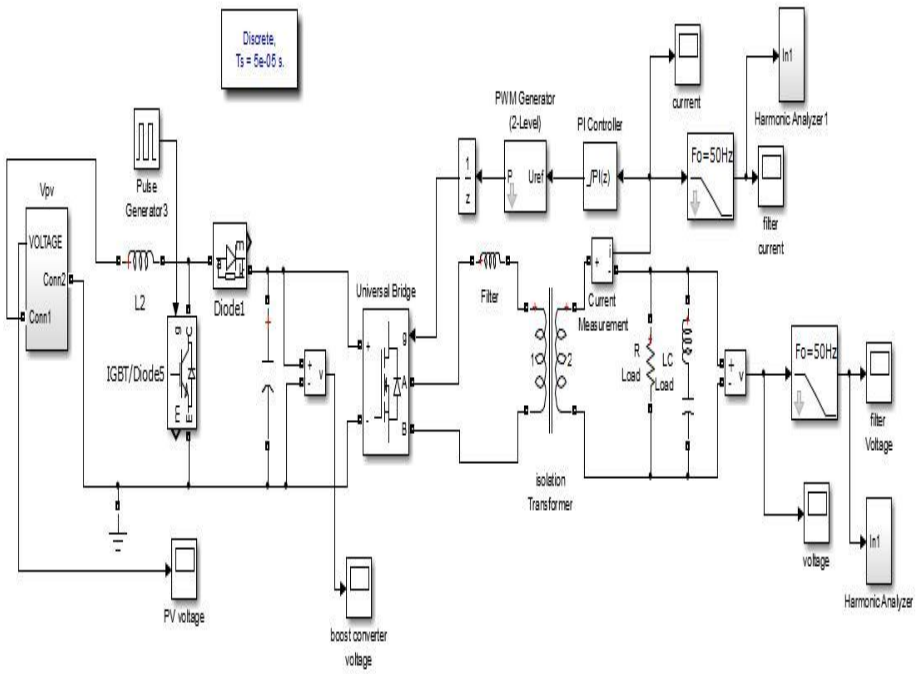


Figure7: Simuation Diagram

Table 3: Simulation Parameter List

Parameters	**Values**
Nominal line voltage	230 V
Dc link voltage VDC	250 V
Fundamental frequency	50 HZ
Resistive load	10
Nonlinear load(series inductance and capacitance)	10mH, Ω 10 uF
Output filter inductance	20uH
Damping factor for 2nd low pass filter	0.52

The closed loop system consist of PI controller , the output current of the inverter can be given to PI controller. According to the THD value of the inverter the PI controller are tuned in order to reduce the harmonics that are present in inverter, while tuning set the limits in order to reduce the time. The two values kp&ki can be varied to adjust the modulation index value, either keeps kp or ki as constant and adjust the other values. The values for k p&ki are shown in Table4. The integrator method used is forward Euler. Both the linear and non-linear loads are used in the simulation. Normal low cost H- Bridge inverter topologies are used and the MOSFET are used as Switches.The 2-level PWM generator are used to generate pulses to switches, the reference value are get from PI controller. The voltage waveforms withoutfilter are shown in Fig.8 and current waveforms withoutfilter are shown in Fig.9.

Table 4: PI Controller Parameter List

Parameter	Values
Proportional constant (kp)	0.41
Integrator constant(ki)	150

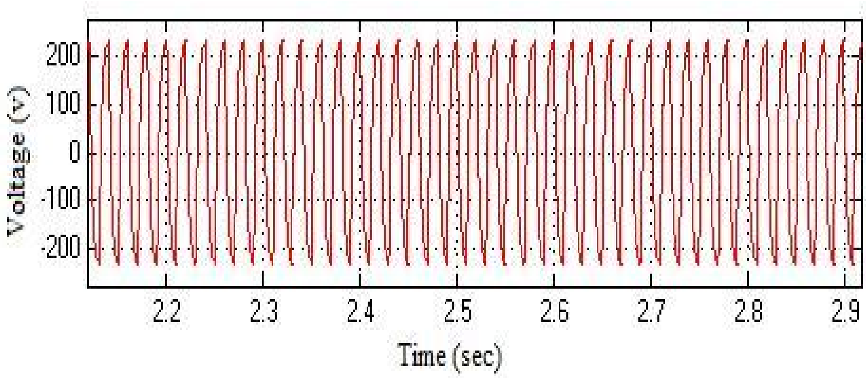


Figure 8: Voltage Waveform without Filter

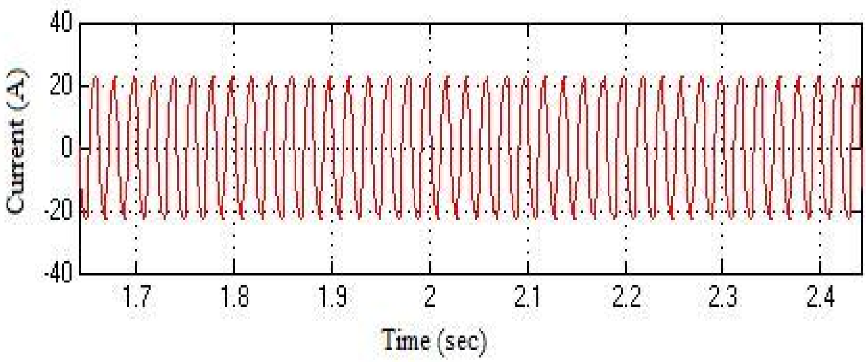
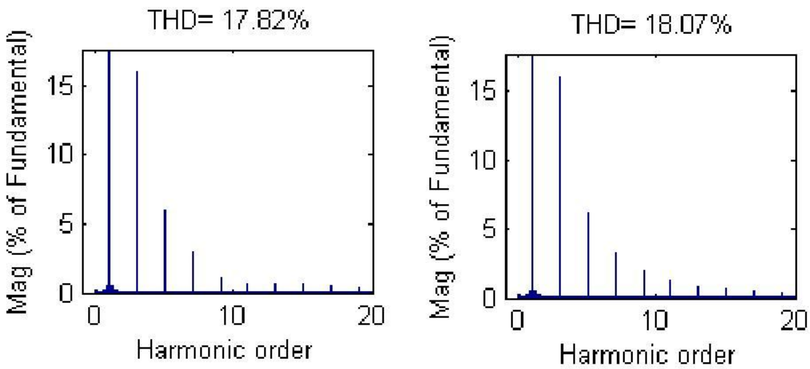


Figure 9: Current Waveform without Filter

The lower Order harmonics that are present in the system changes the shape of the pure sinusoidal Waveform as shown in Fig.8 & 9.The total harmonic distortions of the system without filter are shown in Fig.10.The voltage THD of system without filter is 17.82% as shown in Fig.10 (a) and the current THD of the system is 18.07% are shown in Fig.10 (b). In order to reduce the THD below 5% further the LPF filters are used to bring it to the required IEEE standards.



a) Voltage THD **b) Current THD**

Figure10: THD Value without Filter

Similarly the inverter output waveforms with second order low pass filter are shown below. The voltage waveforms with LPF are shown in Fig.11and the current waveforms with LPF are shown in Fig.12.The Low Pass Filter is mainly used to reduce the Low order harmonics that are present in the system. By adjusting the damping factor of the LPF the total harmonic distortion of the proposed can be reduced. The value of damping factor is mentioned in Table3 and the cut off frequency of low pass filter is 50 Hz.

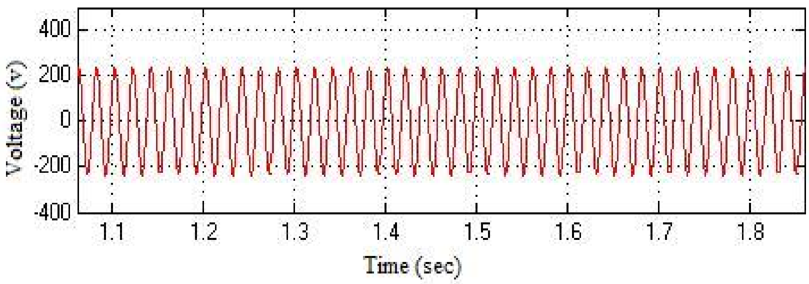


Figure 11: Voltage Waveform With LPF

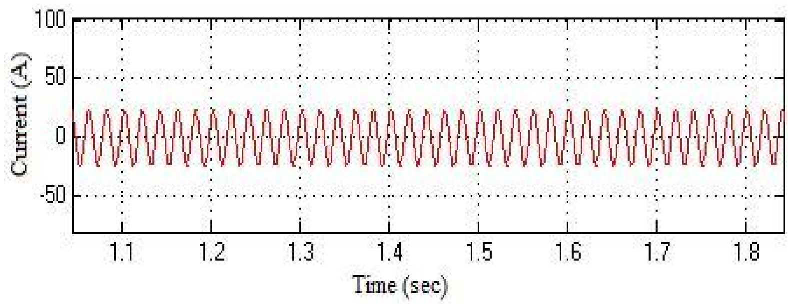
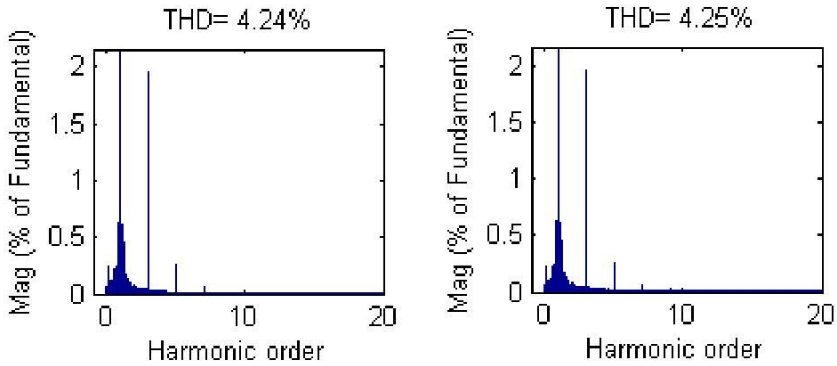


Figure 12: Current Waveform with LPF

The total harmonic distortions of the system with filter are shown in Fig.13. The voltage THD of the system was reduced by 4.24 % as shown in Fig.13 (a) and the current THD are reduced by 4.25% as shown Fig.13 (b).



a) Voltage THD **b) Current THD**

Figure 13: THD Value with Filter

By using the PI controller and the LPF the THD of the system can be reduced as per IEEE-519 standards. The Table5 gives the THD value of the system with and without filter added on the system.

Table5. THD Value of the Proposed System

SINGLE PHASE PV INVERTER	**Voltage THD**	**Current THD**
Without filter	17.82%	18.07%
WithLow pass filter	4.24%	4.25%

Conclusion

The performance analysis of grid connected single phase PV inverter using PI controller are implemented to reduce the lower order harmonics. As a consequence, single phase, low power H-bridge inverters are commonly used for the interconnection between PV modules and the utility grid to ensure that the power quality meets grid standard of IEEE-1547. By implementing the PI controller using simulation it was observed that the overall THD value of the PV system is reduced less than 5% as per the standards of IEEE- 519.

References

[1] R. Walling, R. Saint, R. Dugan, J. Burke, and L. Kojovic, “Summary of distributed resources impact on power delivery systems,” *IEEE Trans. Power Del.*, vol. 23, no. 3, pp. 1636–1644, Jul. 2008.

[2] R. Zavadi, N. Miller, A. Ellis, E. Muljadi, E. Camm, and B. Kirby, “Queuing up,” *IEEE Power Energy Mag.*, vol. 5, no. 6, pp. 47–58, Nov./Dec. 2007.

[3] C. Masters, “Voltage rise: The big issue when connecting embedded generation to long 11 kv overhead lines,”*Power Eng. J.*, vol. 16, no. 1, pp. 5–12, Feb. 2002.

[4] J. Dolezal, P. Santarius, J. Tlusty, V. Valouch, and F. Vybiralik, “The effect of dispersed generation on power quality in distribution system,” *in Proc. IEEE PES/CIGRE Int. Symp. Quality Security Electr. Power Del. Syst.*, Oct. 8–10, 2003, pp. 204–207.

[5] A. Oliva and J. Balda, “A PV dispersed generator: A power quality analysis within the IEEE 519,” *IEEE Trans. Power Del.*, vol. 18, no. 2, pp. 525–530, Apr. 2003.

[6] J. Enslin and P. Heskes, “Harmonic interaction between a large number of distributed power inverters and the distribution network,” *IEEE Trans. Power Electron.*, vol. 19, no. 6, pp. 1586–1593, Nov. 2004.

[7] IEEE Standard for Interconnecting Distributed Resources with the Electric Power System, *IEEE Standard 1547-2003*, 2003.

[8] A.R Munoz and T. A. Lipo, “On-line dead-time compensation technique for open-loop PWM-VSI drives,” *IEEE Trans. Power Electron.*, vol. 14, no. 4, pp. 683–689, Jul. 1999.

[9] Bin Zhang, Member, IEEE, Danwei Wang, Senior Member, IEEE, Keliang Zhou, Member, IEEE, and Yigang Wang, Student Member, IEEE “Linear phase lead compensation repetitive control of a CVCF PWM inverter,” *IEEE Trans. Ind. Electron.*, vol. 55, no. 4, pp. 1595-1602 , April 2008.

[10] L. Chen and F.Z. Peng,“Dead-time elimination for voltage source inverters,” *IEEE Trans. Power Electron.*, vol. 23, no. 2, pp. 574–580, Mar. 2008.

[11] A.C. Oliveira, C. B. Jacobina, and A. M. N. Lima, “Improved dead-time compensation for sinusoidal PWM inverters operating at high switching frequencies,” *IEEE Trans. Ind. Electron.*, vol. 54, no. 4, pp. 2295–2304, Aug. 2007.

[12] G. Escobar, P. G. Hernandez-Briones, P. R. Martinez, M. Hernandez-Gomez, and R. E. Torres-Olguin, “A repetitive-based controller for the compensation of 6l±1 harmonic components,” *IEEE Trans. Ind. Electron.*, vol. 55, no. 8, pp. 3150–3158, Aug. 2008.

[13] frame repetitive controller for three-phase UPS inverters,”IEEE Trans. Power Electron., vol. 27, no. 6, pp. 2994– 3005, Jun. 2012.

[14] R. Grino, R. Cardoner, R. Costa- Castelloand E. Fossas, “Digital repetitive

control of a three-phase four-wire shunt active filter," *IEEE Trans. Ind. Electron.*, vol. 54, no. 3, pp. 1495–1503, Jun. 2007.

[15] T. Hornik and Q. C. Zhong, "A current-control strategy for voltage-source inverters in micro-grids based on H∞ and repetitive control," *IEEE Trans. Power Electron.*, vol. 26, no. 3, pp. 943–952, Mar. 2011.

[16] S. Jiang, D. Cao, Y. Li, J. Liu, and F. Z. Peng, "Low-THD, fast-transient, and cost-effective synchronous-Sincy George, Member, IEEE, and VivekAgarwal, Senior Member, IEEE "Optimum Control of Selective and Total Harmonic Distortion in Current and Voltage Under Non sinusoidal Conditions," *IEEE transactions on power delivery.*, vol. 23, no. 2, pp. 937-944, April 2008.

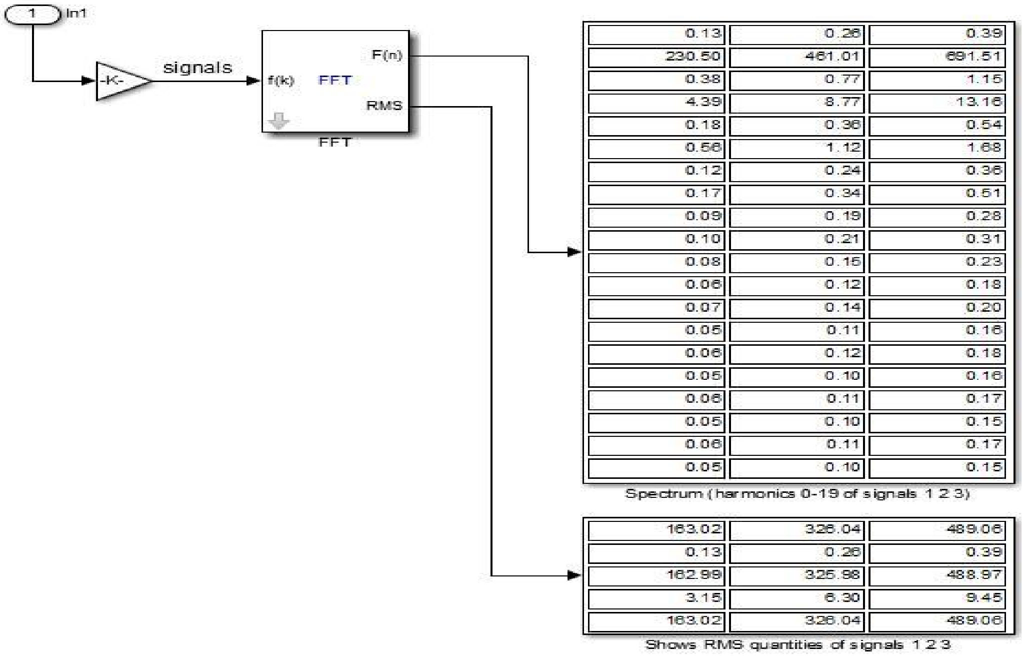
[17] H.X. Wu, S. K. Panda, and J. X. Xu, "Design of a plug-in repetitive control scheme for eliminating supply-side current harmonics of three-phase PWM boost rectifier under generalized supply voltage conditions," *IEEE Trans. Power Electron.*, vol. 25, no. 7, pp. 1800–1810, Jul. 2010.

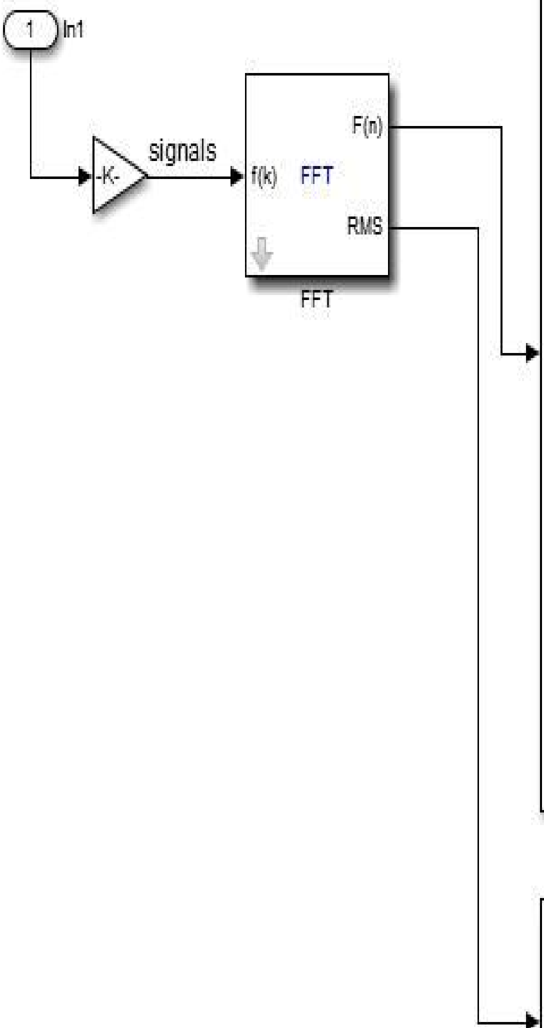
[18] L. Li, L. Xie, W. Yan, and Y. C. Soh, "Design of low-order linear-phase IIR Filters via orthogonal projection," *IEEE Trans. Signal Process.*, vol. 47, no. 2, pp. 448–457, Feb. 1999.

[19] G.B. Mohankumar and S. Manoharan," Performance Analysis of Multi Converter Unified Power Quality Conditioner using PI Controller,"*Aust. J. Basic & Appl. Sci.*, 7(9): 331-340, 2013.

Appendix

Voltage harmonic analyzer
Current Harmonics Analyzer





0.01	0.02	0.04
23.06	46.13	69.19
0.04	0.07	0.11
0.44	0.88	1.32
0.02	0.04	0.05
0.05	0.11	0.16
0.01	0.02	0.04
0.01	0.03	0.04
0.01	0.02	0.03
0.01	0.01	0.02
0.01	0.02	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.01	0.01	0.02
0.00	0.01	0.01

Spectrum (harmonics 0-19 of signals 1 2 3)

16.31	32.62	48.93
0.01	0.02	0.04
16.31	32.62	48.93
0.31	0.63	0.94
16.31	32.62	48.93

Shows RMS quantities of signals 1 2 3