International Journal on Emerging Technologies **2**(2): 40-45(2011)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Power Quality Analysis of Domestic Wind Mill Inverter-Harmonic Analysis and its Mitigation

Anubhuti Khare*, Manish Saxena** and Bhagawati Patil**

**Department of Electronics and Communication, University Institute of Technology, Rajeev Gandhi Technical University, Bhopal, (MP)*
***Department of Electronics and Communication, Bansal Institute of Science and Technology, Bhopal, (MP)*

(Received 12 August, 2011, Accepted 14 October, 2011)

ABSTRACT : An Domestic Wind Mill Inverter is a DC to AC converter, used to convert a DC input voltage into a symmetrical AC output voltage of desired magnitude and frequency. Nonlinear loads are becoming a larger percentage of the total load in residential/commercial areas. Fluorescent lighting as always resulted in some harmonic generation. Now, single phase power electronic loads are a major portion of the load in many residential/ commercial facilities. The electronic devices are non-linear loads consuming harmonic distorted currents. These harmonic currents distort the voltages due to the presence of system impedances. The switching of power semiconductor devices in system results in generation of harmonics i.e. wave shape of voltage/current gets distorted from sinusoidal. These harmonics are injected into supply system and load. The harmonics adversely affect the performance of load. The basic idea is to provide the accurate study of domestic Wind Mill inverter and study of harmonic generation due to use of non-linear loads in the domestic inverter and the solution for minimizing the same. In this case, three types of loads are used such as resistive load (100 W bulbs), inductive load (40W) and capacitive load (2.5 µ f). Due to this load the harmonics generation is different and its harmonics frequency is identified by using narrow band pass filter. In this case narrow band pass filter is used with 150 Hz frequency tuned. This harmonics information is obtained on PC using microcontroller89c51 and then using passive filter the harmonics is minimized exactly for such a tuned frequency. The output voltage of a domestic Wind Mill inverter can be controlled by controlling the operation of inverter itself. The control is within the inverter itself. The most efficient method of controlling the output voltage is use pulse-width- modulation technique (PWM) within the inverter. In this technique, the on and off periods are adjusted to control the output voltage. This developed domestic PWM Inverter is identifies the order of VTHD and ITHD Harmonics free output is obtained and system performance is improved with accuracy.

Keywords: Wind Mill Inverter, PWM, Harmonics, Non-linear loads, Active and Passive Filter, Harmonics Mitigation, Power Quality.

I. INTRODUCTION

An inverter is a DC to AC converter, used to convert a DC input voltage into a symmetrical AC output voltage of desired magnitude and frequency. The output voltage could be fixed or variable at a fixed or variable frequency. A variable output voltage can be obtained by varying the input DC voltage and maintaining the gain of the inverter constant. On the other hand, if the DC input voltage is fixed and it is not controllable, a variable output voltage can be obtained by varying the gain of the inverter, which is normally accomplished by pulse-width-modulation (PWM) control within the inverter. The inverter gain may be defined as the ratio of the AC output voltage to DC input voltage. The output voltage waveforms of ideal inverters should be sinusoidal. However, the waveforms of practical inverters are non sinusoidal and contain certain harmonics. For low and medium power applications, square wave or quasi-square wave or distorted sinusoidal wave may be acceptable and for high-power applications, low distorted sinusoidal waveforms are required. With the availability of high speed power semiconductor devices, the harmonics contents of output voltage can be minimized significantly by switching techniques. Inverters are widely used in:

- Standby power supplies
- Uninterruptible power supplies (UPS)
- Battery-vehicle drives
- Regulated-voltage and frequency power supplies
- Ultrasonic wave generators
- Static VAR generators
- Active power line filters

The DC voltage input to the inverter is provided by battery, fuel cell, solar cell or any other DC Voltage source. The switching devices used in inverters include MOSFETs, BJTs, IGBTs, MCTs, SITs, GTOs and SCRs. The selection of particular device depends upon power handing capacity, switching frequency and cost. Nonlinear loads are becoming a larger percentage of the total load in residential/ commercial areas. Fluorescent lighting as always resulted in some harmonic generation. Now, single phase power electronic residential/commercial areas. They have become a problem for neutral conductors, transformer heating, and interference with other loads on the facility. Harmonic problems can be solved by detecting the harmonics frequency through narrow band pass filter and filtered out by passive filter. Evaluation of harmonic distortion is important for a number of reasons. An increasing load consists of electronics equipments; new high efficiency fluorescent lighting uses electronic ballasts and can have higher harmonic content than conventional fluorescent lighting using magnetic ballasts. These Harmonics sources can result in neutral conductor overheating, transformer overheating, and interference with communication systems. The harmonic current limits specified in IEEE 519-1992 for the overall performance purpose. The voltage distortion levels depend on the circuit impedances as well as the harmonic generation characteristics. The circuit impedance is usually dominated by step down transformers and conductor impedances because power factor correction is not commonly applied within commercial facilities.

It is well known that a nonlinear load draws a highly distorted current from the source, which consists of harmonics, fundamental active and reactive current components.

• Harmonic can be defined as a sinusoidal component of periodic wave or quantity having frequency that is an integral multiple of the fundamental frequency.

- If the source or the load is unbalanced, the source also contains negative sequence currents.
- The harmonic currents in combination with line impedance of the distribution network in turn causes distortion in supply voltage.
- Further, the AC source because of its non ideal characteristics also contributes to this distortion and thus aggravates the problem.
- The amount of voltage distortion depends on (*a*) system impedance (*b*) load current.
- The value and wave shape of the current drawn is decided by the characteristics of end user equipment and the value of system impedance by the utility

II. SYSTEM DEVELOPMENT

This developed system is to study the domestic inverter and also enhance the analytical study of harmonics generated due to use of non-linear loads and minimization of harmonics using passive filter accurately. The main advantages of this developed domestic inverter using passive filter are high performances and reduced size, light weight and low cost than existing system, which is applicable in emergency lighting system, frequency converters, standby power supplies, uninterruptible power supplies (UPS), battery vehicle drives, regulated voltage and frequency power supplies, ultrasonic wave generators, Static VAR generators, active power line filters, etc.

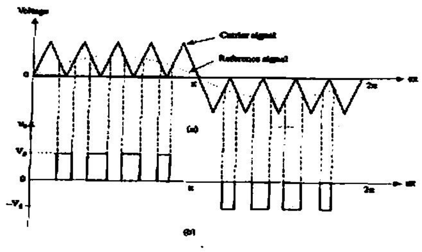
A. Base Unit

The base unit basically consists of following parts

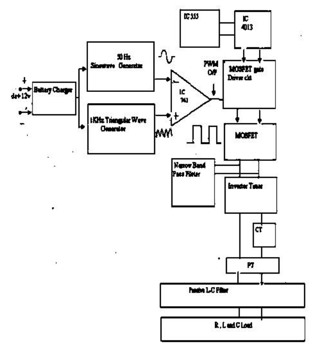
- Battery Charger
- XR 2206 Sine wave generator
- XR 2206 Triangular wave generator
- IC 741 OP-AMP
- IC 555 Timer (astable operation)
- 4013 S-R Flip-Flop
- MOSFET Driver
- MOSFET
- Transformer and CT, PT
- Passive Filter
- Load (Resistive, Inductive and Capacitive)
- Battery
- Relay
- Narrow band pass filter (Active filter)
- ADC 0809 (analog to digital converter)
- IC 89C51 Microcontroller
- Max 232 serial port.

Sinusoidal-Pulse Width Modulation

In this technique several pulses are produced in each half- cycle but the width of the pulses is not the same as in the case of multiple-pulse width modulation, however the width of each pulse is varied in accordance with the amplitude of the sine wave reference voltage. The width of the pulse at the centre of the half-cycle is maximum and decreases on either side. Figure shows the generation of the output signal by comparing a sinusoidal reference signal f with a triangular carrier wave of frequency f.The carrier and reference waves are mixed in a comparator and when the sinusoidal wave has a higher magnitude than the triangular wave the comparator output is high, otherwise it is low. This output of the comparator is used to turn on the MOSFETs which generate the output voltage [14]. The reference signal frequency f of the inverter, and its peak amplitude controls the modulation index M, and thereby the rms output voltage v the output voltage is controlled by varying the amplitude of the sine wave within the range of zero to v is the peak of the triangular wave. The number of pulses in each half cycle depends on the carrier frequency f If the ratio of these two signals (reference and carrier) is equal to m, then the number of pluses in each half-cycle is (m-1) [6]. From figure, it is clear that the widths of the pulses do not change significantly with the modulation index variation at the middle of the Half-cycle. This is because of the characteristics of the reference sine wave. If the carrier wave is applied during the first and last $\pi/3$ interval in each half-cycle, *i.e.*, at 0 to 2/3 to then the widths of the pulses can be changed significantly.



(*a*) Gate Signal Voltage



(*b*) Output Voltage

Fig. 1. Sinusoidal Pulse Width Modulations.

B. Technical Specification of PWM Inverter

- Compact size.
- Modular design.
- Front access.
- User-selectable output voltages.
- Selected models.
- Economical Operation.
- Models with a static transfer switch provide considerable savings in operating costs due to high operating efficiency.
- High Reliability.
- Versatile Operation.
- User-selectable output voltages allow for greater system flexibility.
- Inverter operates at frequencies of 50 Hz for domestic and international.
- Applications.
- Space Savings.

III. EXPERIMENTAL ANALYSIS

Initial design of new hardware and its working according to requirement is really challenging job. Experimental evaluation testing demo states that the hardware functions appear to be working according to specifications, that behavioral and performances requirements appear to have been met. Accuracy offers degree of closeness or conformity to true value of quantity under measurement. To test developed PWM inerter performance and its accuracy by applying resistive load (100W Bulb), inductive load (choke of 40 W) and capacitive load (capacitor of 3.1 μ f) wi t h an d wi t h out filter [4]. Harmonic can be defined as a sinusoidal component of periodic wave or quantity having frequency that is an integral multiple of the fundamental frequency. One of the ways of expressing the goodness of an inverter or other device is to use a number, based on measurements at a given power output level, expressing its Total Harmonic Distortion. If an inverter or other device is given a pure sine wave (i.e. just one frequency) at its input, the signal at the output will never be an exact copy of the input. There will always be some deviation in the shape of the waveform, which can be expressed as a series of harmonics of the fundamental frequency. This number indicates the RMS voltage equivalent of total harmonic distortion power, as a percentage of the total output RMS voltage.

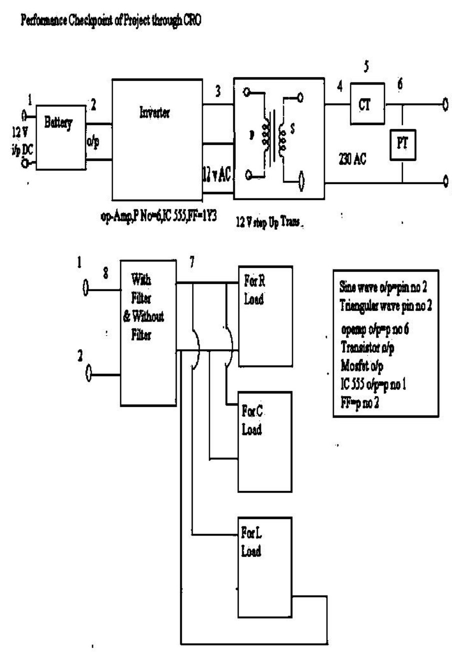
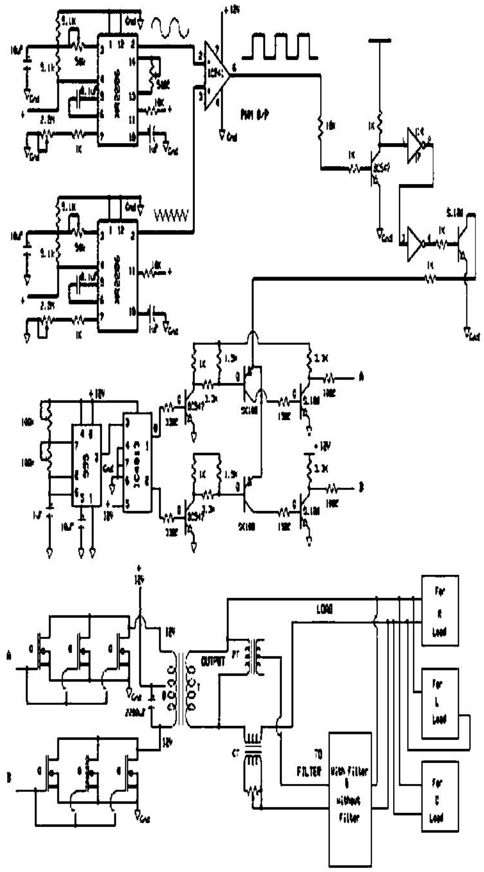


Fig. 2. Performance Check Points.

The equation of Harmonics is given below in term of THD, THD (%) = $100 * SQRT [(V^2 2+ V^2 3 + V^2 4 + ... + V^2 n)] / Vt$.

where THD (%) is total harmonic distortion, V represents the RMS voltage of each Harmonic, and V is the total RMS output voltage.

A. Circuit Diagram



Harmonics Data Extracted From Computational Analysis (Test).

Sr. No.	Types of Load	Harmonics Data Without Filter		Harmonics Data With Filter	
		V_{THD}	I_{THD}	V_{THD}	I_{THD}
01	Resistive Load (100 W of Bulb)	10.22%	15.00%	9.00%	13.00 %
02	Inductive Load (Choke of 40 W)	11.08%	18.58%	4.06%	12.00%
03	Capacitive Load (Capacitor of 2.5 µf)	11.48%	19.08%	9.00%	16.00%

B. Computational Analysis

MATLAB is very sophisticated software developed to minimize the manual efforts. It is very user friendly and applicable almost all the practical situations i.e. can be given input the practical situations effectively. MATLAB is used for all engineering discipline when large amount of data is to be sort, analyzed and presented in systematic way and to get the meaningful results In this, one can simulate the situation and can guess the results almost accurately depending how accurately one can define the situation with a all possible variables. The most important thing is its user friendly environment the standard library available with all possible ranges. It is a software package for high performance numerical computation and visualization. The combination of analysis capabilities, flexibility, reliability, and powerful graphics makes MATLAB the premier software package for electrical engineers. MATLAB provides an interactive environment with hundreds of reliable and accurate. Built-in mathematical functions. These functions provide solutions to a broad range of mathematical problems including matrix algebra, complex arithmetic, linear systems, differential equations, signal processing, optimization, nonlinear systems, and many other types of scientific computations. The most important feature of MATLAB is its programming capability, which is very easy to learn and to use, and which allows user-developed functions. It also allows access to FORTRAN algorithms and C codes by means of external interfaces. There are several optional toolboxes written for special applications such as signal processing, control systems design, system identification, statistics, neural networks, fuzzy logic, symbolic computations, and others. As per the execution of programme through MATLAB the following results is obtained in terms of voltage and current harmonics, with and without filter.

Sr.No.	Types of load	Harmonics data without filter		Harmonics data with filter	
		V_{THD}	I_{THD}	V_{THD}	I_{THD}
01	Resistive load (100 W of Bulb)	9 %	14%	8%	11 %
02	Inductive load (Choke of 40 W)	12%	19%	5%	13%
03	Capacitive load Capacitor of 2.5 µf)	11%	17%	8%	15%

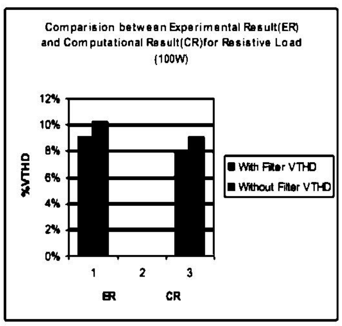
C. Comparison between Experimental and Computational Results

The comparative analysis of experimental evaluation test and computational analysis test is shown in following table.

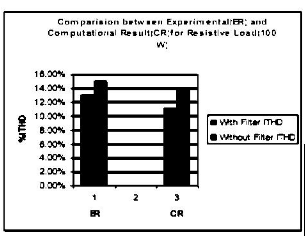
Sr. No.	Types Of Load	Harmonics Data Extracted From Experimented Test		Harmonics Data Extracted From Computational Test	
		Without Filter	With Filter	Without Filter	With Filter
01	Resistive Load (100 W of Bulb)	V_{THD} =10.22% I_{THD} =15.00%	V_{THD} =9.0% I_{THD} =13.00%	V_{THD} =9.00% I_{THD} =14.00 %	V_{THD} =8.00% I_{THD} =11.00%
02	Inductive Load (Choke of 40 W)	V_{THD} =11.08% I_{THD} =18.58%	V_{THD} =4.06% I_{THD} =12%	V_{THD}= 12.00% I_{THD} =19.00 %	V_{THD} =5% I_{THD} =13%
03	Capacitive Load (Capacitor of 2.5 µf)	V_{THD} =11.48% I_{THD} =19.08%	V_{THD} =9.00% I_{THD} =16.00%	V_{THD} =11% I_{THD} =17%	V_{THD} = 8.00% I_{THD} =15.00%

1. Resistive Load

(*i*) For V THD

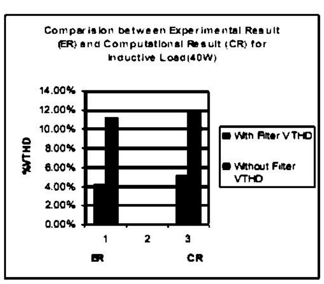


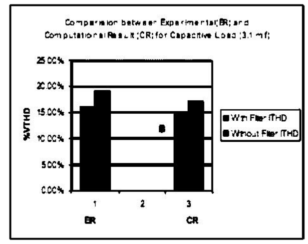
(*ii*) For ITHD



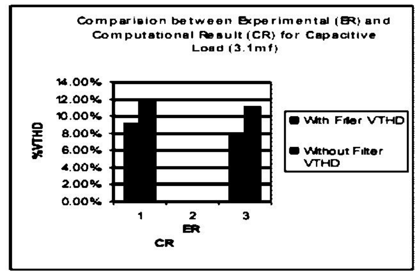
2. Inductive Load

(*i*) For VTHD



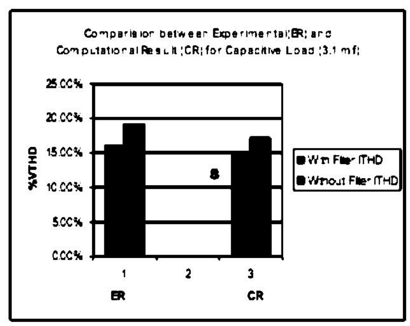


(*ii*) For ITHD

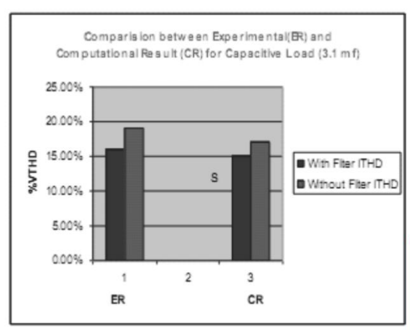


3. Capacitive Load

(*i*) For V THD



(*ii*) For ITHD



IV. CONCLUSIONS

The feasibility study for harmonics in low voltage inverter has been carried out in this case. The result of investigation shows that, in general charging of inverter and with the use of resistive, inductive and capacitive load that causes significant current harmonics distortion in the supply system. This in turn highly distorts the supply voltage waveforms at the load side. It is necessary to minimize this harmonics because it affects the performance of the inverter and also affects other equipments connected across the same source and load. Due to use of three different types of load such as resistive (Bulb-100 W), inductive (choke of tube -40 W) and capacitive load (capacitor-2. 5 µ f), th e di ffer en t n a tur e of harmonics waveforms are observed and accurate harmonics mitigation is done with the help of active and passive filter.

V. ACKNOWLEDGEMENT

Mrs. Anubhuti Khare one of the authors is indebted to Director UIT RGPV Bhopal for giving permission for sending the paper to the journal. Manish Saxena is also thankful to the Chairmen, Bansal Instituteof Science & Technology Bhopal for giving permission to send the paper for publication. Last but not least, I would also like to thanks our HOD and colleagues for supporting us.

REFERENCES

[1] S. Kundu, Gashok, M. Dengare, R. Agarwala and Dr. R. Gupta, Members of IEEE, "Harmonics Analysis of Commonly used Inverters and UPS", American Power Conversion white paper, (2003), PP. 130-137.

[2] Cavallini,G. Ganbelli, G.C.Mantanari Members of IEEE, "Analysis and Modeling of Harmonics Pollution Due to Consumer Electronics" VII International Conference on Harmonics and Quality of Power, USA, (1996), pp. 675-680.

[3] Mark Mc-Granaghan, Electrotek concepts, Inc, Knoxville, T.N., Members of IEEE , " Controlling Harmonics from Non-Linear Loads in Commercial Facilities" VI International Conference On Harmonics In Power System, Bolonga, Itally, September (1994), pp.172-178.

[4] P. Br ogan, R. Ya cam ini , " Measurement and Simulation of an Active Filter" IEEE , American Power Conversion White Paper, 2002, pp. 323 to 330.

[5] W.G. Cigre, EPRI Power Electronics "AC Harmonics Filters", (1999), pp. 123 to 128.

[6] A.B. Plun kett, "A current controlled PWM Transistor Inverter Drive", IEEE Paper / IAS Ann. Meet . Conference, (1997), pp. 785 to 792.

[7] Michael A. Boost and Phoivos D. Ziogas, Members, IE EE, "State-of-the-Art Carrier PWM Techniques", *IEEE Transans. Applicat.*, Vol. **24**, No. 2, 1988, pp. 271 to 280.

[8] Hirofumi Akagi, Akira Nabae and Satoshi Atoh, Mem ber s of IE E E, "Control Strategy of Active Power Filter Using PWM Converters", *IEEE Transans. Applicat.*, Vol. **IA-22**, No. 3, 1986, pp. 460 to 465.