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Boost Inverter For Grid Connected Wind Energy Systems

P Sriram[#1],K VKrishna rao[*2], V S Prasadarao k [#3]
 # 1 Assistant Professor, Department of electrical and electronics engineering, JNTU Kakinada, Mandava institute of science and technology,jaggaiahpet, Krishna (dt), AP, India. srirampendem@gmail.com
**2 Assist Professor, Department of Electrical and Computer engineering, JIG JIGA University, Ethopia. lakshmikrishna.99@gmail.com*
#3 Assistant Professor, Department of electrical and electronics engineering, KLUniversity, Green fields, vaddeswaram, Guntur (dt), AP, India kvsprasad86@kluniversity.in

Abstract

In recent years, the research interest in renewable energy source has increasing interests due to the worldwide increasing energy consumption, global warming, and pollution. Of all renewable energy sources, wind power is the most mature in terms of commercial development. For grid interconnection of wind energy system we need an inverter which produces an output voltage greater than dc input voltage. But most of the classical inverters (vsc) produce an AC output instantaneous voltage always lower than the DC input voltage. For eliminating this disadvantage, this paper proposes a high performance, single-stage inverter topology referred to as boost inverter for grid connected wind energy systems. The most important characteristic of a boost inverter is that it can generate an ac output voltage from a lower dc input voltage in a single power stage. Based on the idea of indirectly controlling the output voltage through the inductor current, a dynamical sliding-mode controller (SMC) for the boost inverter is proposed in this paper. Matlab/ simulink software is used to validate the proposed concept. The results shows that the boost inverter has the same voltage, frequency and phase angle that of grid.

Keywords: Wind generation system, boost inverter, sliding mode control, grid-connected.

Introduction

Fossil fuel for electricity generation has several drawbacks: it is costly due to transportation to the remote areas and it causes global warming pollution and green house gases. The need to provide an economical, viable and environmental safe alternative renewable green energy source is very important. As green renewable energy resources such as Photovoltaic (PV) and Fuel Cells have gained great acceptance as a substitute for conventional costly and scare fossil fuel energy resources. Also, they have the additional advantage of being complimentary, the integration between them being favorable. Wind is one of the sources of renewable energy. Wind power is converted to electricity by wind turbine. Grid interconnection of wind energy system requires an inverter which produces an output voltage greater than dc input voltage. But most of the classical inverters (VSI) produce an AC output instantaneous voltage always lower than the DC input voltage. The boost inverter exhibits several advantages, the most important of which is that it can generate an ac output voltage from a lower dc input voltage in a single power stage [1]. The sliding mode control is proposed to control the boost inverter in [2]-[5]. However, the controller requires an inductor current reference which is not formally specified, and the controller is sensitive to the controller parameters. A sliding mode control using a new sliding surface just depending on the output voltage is proposed for the boost inverter in. The controller focuses on generating a sinusoidal voltage on the load despite the capacitors voltage form. The resulting controller is very easy to implement, does not need current sensors and only the desired output voltage is used as reference.

Wind Energy Conversion System

The WECS considered for analysis consist of a PMSG driven by a wind turbine, three phase rectifier, an intermediate dc circuit, and a boost inverter. Fig.1 shows a schematic of the power circuit topology of a variable speed wind turbine system that will be discussed in this paper.

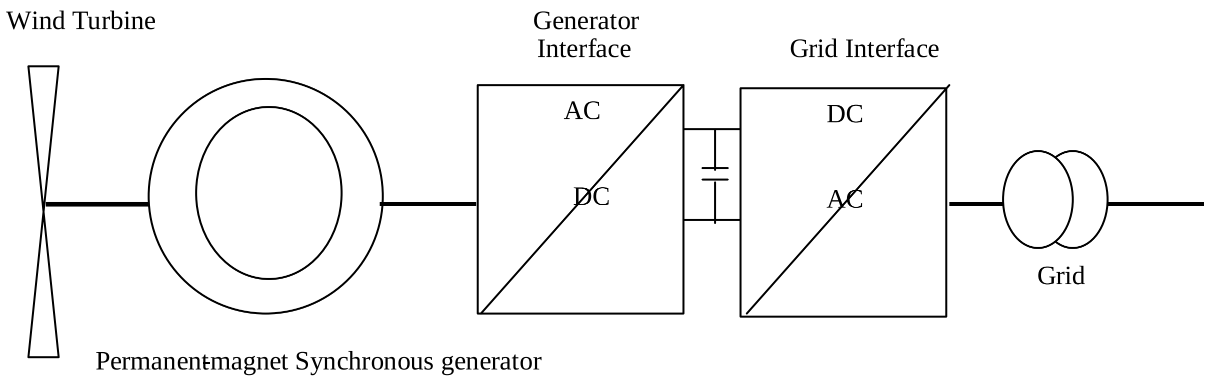

Figure 1: Wind Energy Conversion System

Since the wind is the intermitted source of energy, the output voltage and frequency from generator will vary for different wind velocities. The variable output ac power from the generator is first converted into dc using the rectifier. The available dc power is fed to the grid at the required constant voltage and frequency by regulating the modulation index of the inverter.

Boost Inverter

The scheme of boost inverter is shown as Fig.2, and it is composed of two boost converters with the load connected.

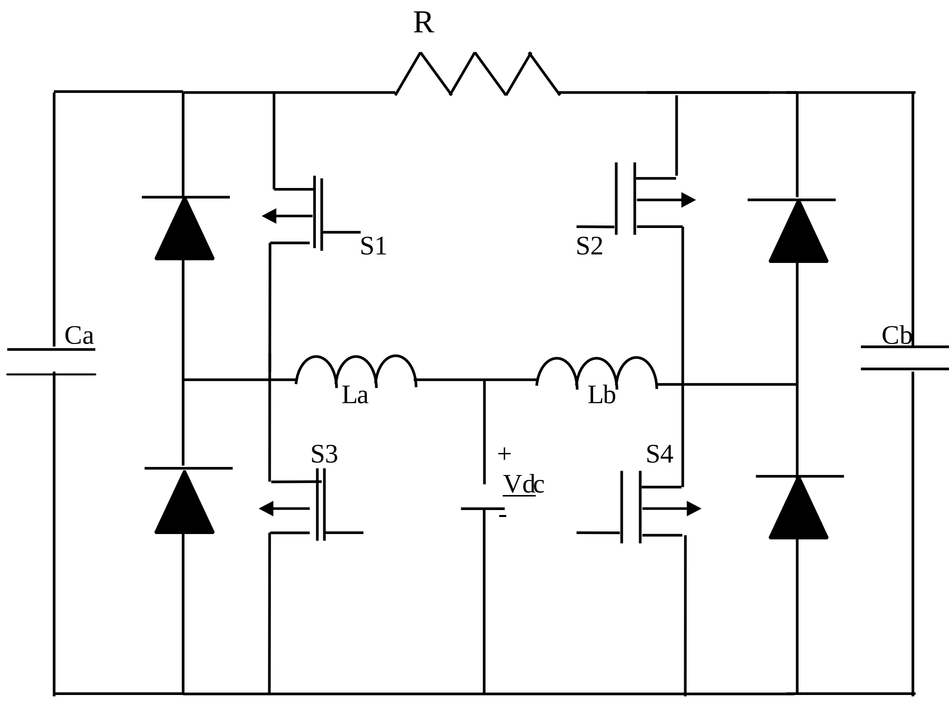

Figure 2: The Boost Inverter

Basic Principle:

Let us consider two dc-dc converters feeding a resistive load R as shown in figure 3a.The two converters produces dc-biased sine wave output such that each source only produces a unipolar voltage as shown in figure 3b. The modulation of each converter is 180 degrees out of phase with the other so that the voltage excursion across the load is maximized [1]. Thus, the output voltage of the converters are described by

$$V_a = V_{dc} + V_m sin\omega t$$
$$V_b = V_{dc} - V_m sin\omega t$$

.... (i) ……… (ii)

Thus, the output voltage is sinusoidal as given by

$$V_0 = V_a - V_b = 2V_m sin\omega t$$

……. (iii)

Thus, a dc bias voltage appears at each end of the load with respect to ground, but the differential dc voltage across the load is zero.

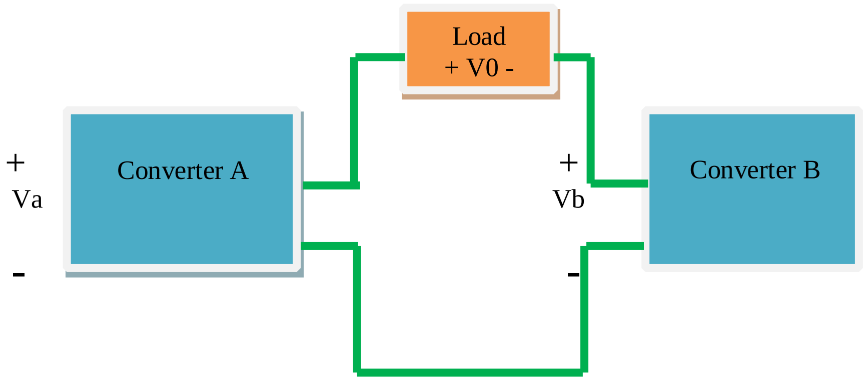

Figure 3a:

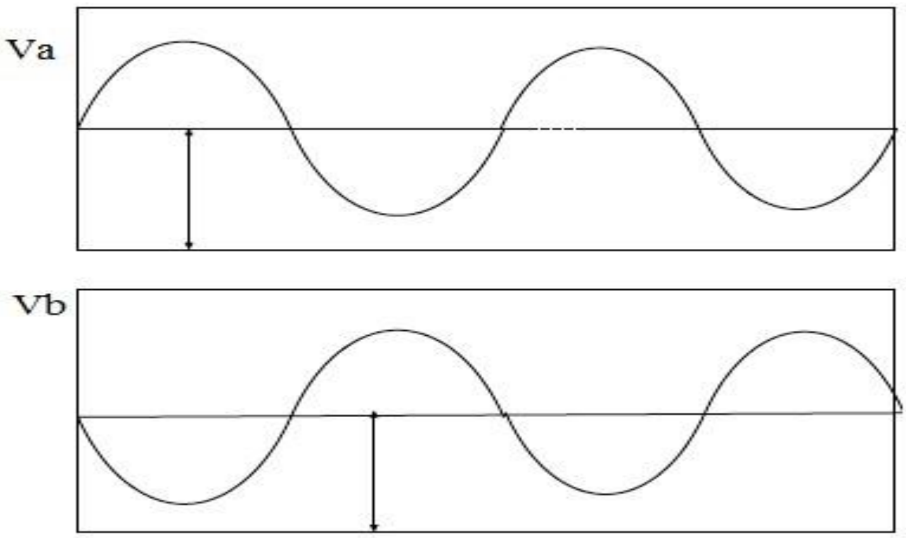

Figure 3b:

The gain of the boost inverter is by

$$Gdc = \frac{2D-1}{D(1-D)} \qquad \text{............ (iv)}$$

Sliding Mode Control For Boost Inverter

Assuming the switches of the two boost converters are complementary, that is *ub* □1*ua*, the model of the boost inverter can be shown as

$$\dot{X_{1a}} = \frac{V_{in} - (1-u_a)}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(V)}$$

$$\dot{X_{2a}} = -\ \frac{X2a - X_{2b}}{RC} + \frac{X_{1a}(1-u_a)}{C} \quad \ldots\ldots\ldots \text{(VI)}$$

$$\dot{X_{1b}} = \frac{V_{in} - u_a Z_{2b}}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(VII)}$$

$$\dot{X_{2b}} = -\ \frac{X2a - X_{2b}}{RC} + \frac{X_{1b}u_a}{C} \quad \ldots\ldots\ldots\ldots\ldots \text{(VIII)}$$

Where X1ais the inductor current flowing through *La*, X1bis the inductor current flowing through *La*, Z2ais the voltage across *Ca*, Z2b is the voltage across Cb. The control objective of the boost inverter is V_0□X2a- X2b [2].

The following sliding mode control for the boost inverter is Proposed in [6].

$$U_a(t) = \begin{cases} 0 & \sigma(X,t) < 0 \\ 1 & \sigma(X,t) > 0 \end{cases} \ldots\ldots\ldots\ldots\text{(IX)}$$

$$\sigma = \frac{1}{L}\int_0^t \left(u_a X_{2b} - (1-u_a) X_{2a}\right) dt + K_p\left(V_0 - V_{ref}\right) + K_i \int_0^t \left(V_0 - V_{ref}\right) dt \ldots\ldots\ldots\text{(X)}$$

To reduce the chattering of sling mode control, the hysteresis-loop is used in the controller implement.

Grid-Connected Wind Energy System Based on The Boost Inverter

The configuration of a grid-connected wind energy system is shown as Fig.4

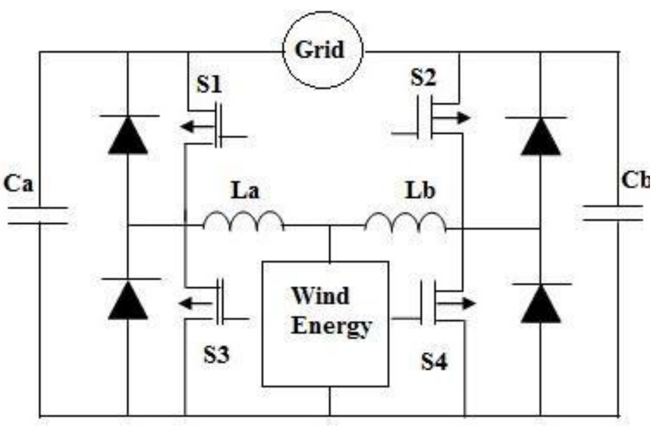

Figure 4: Schematic diagram of a grid-connected wind energy system

It consists of wind system, direct current (DC) bus capacitor C_{DC}, boost inverter, filter inductor, where the boost inverter consists of two boost converters. Considering the symmetry properties, the devices on the symmetrical position are selected the same parameters, including the inductors Assuming the grid voltage Es(t) Vm sinωt, and the output reference voltage of the boost inverter Vref Es(t)L1Iref ωcosωt, the grid-connected current is Iref sinωt if the output voltage of the boost inverter has tracked the reference voltage with no amplitude and phase error. However, simulation results show there are tracking errors on the amplitude and phase. The system control diagram is proposed as Fig.5 in order to achieve gridconnected current in phase with the grid voltage, where Irefis the amplitude of the grid-connected reference current, and the MPPT can be realized by regulating Irefin single-stage grid-connected wind energy system, iLis the actual grid- connected current, Es(t) is the grid voltage. The negative zero crossing of iL and Es(t) are detected and the corresponding time is recorded.

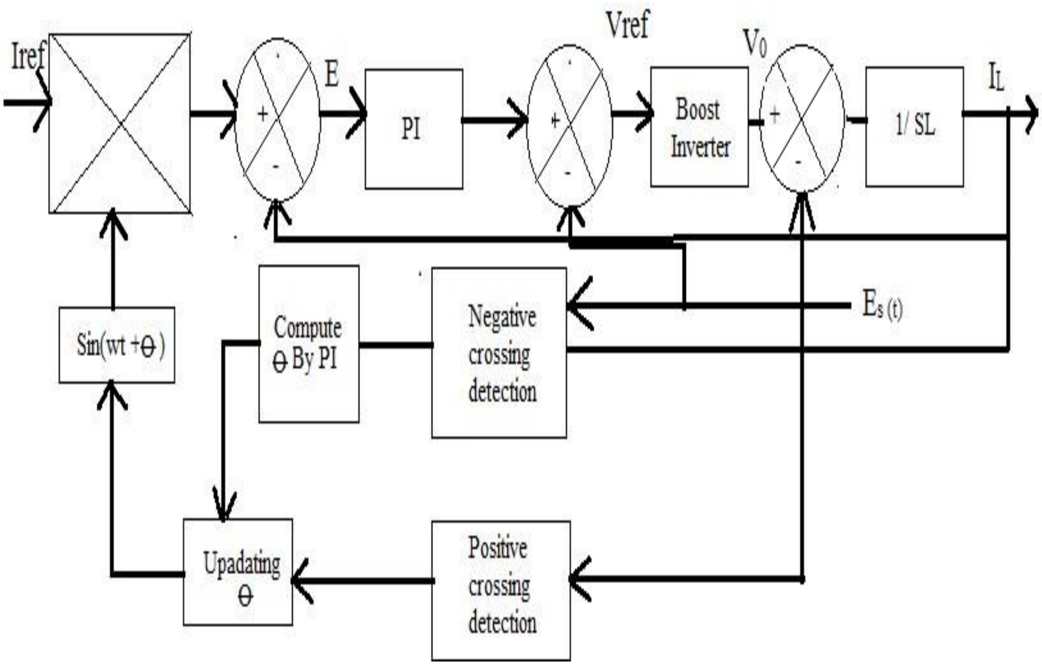

Figure 5: The System Control Diagram

The phase error between iL and Es(t) is computed when the negative zero crossing ofEs(t) is detected, which is the input of the PI controller, andthe phase shift value α is computed by the PI controller. Toguarantee the sine degree of the gridconnected current, theamplitude and phase of grid-connected reference current areupdated at the time of the positive zero crossing of Es(t).Thecurrent error signal is acquired by subtracting iL from the grid connectedreference current Iref sin(ωt+ α) which is as theinput of the following PI controller, and the reference voltageof the boost inverter Vref is acquired by adding the output ofthe PI controller to the Es(t). The aforementioned sliding mode controller is used for the boost inverter.

Simulations

To verify the validity of the proposed control scheme, the system as shown in Fig.4 is simulated in matlab/simulink, where L1= L2=1mH, L3= L4=10mH, C1= C2=500uF, Es (t) =311 sinωt. The simulation result of sliding mode control for the boost inverter is shown as Fig.7 if the □Es(t)□L1Iref ωcosωt.

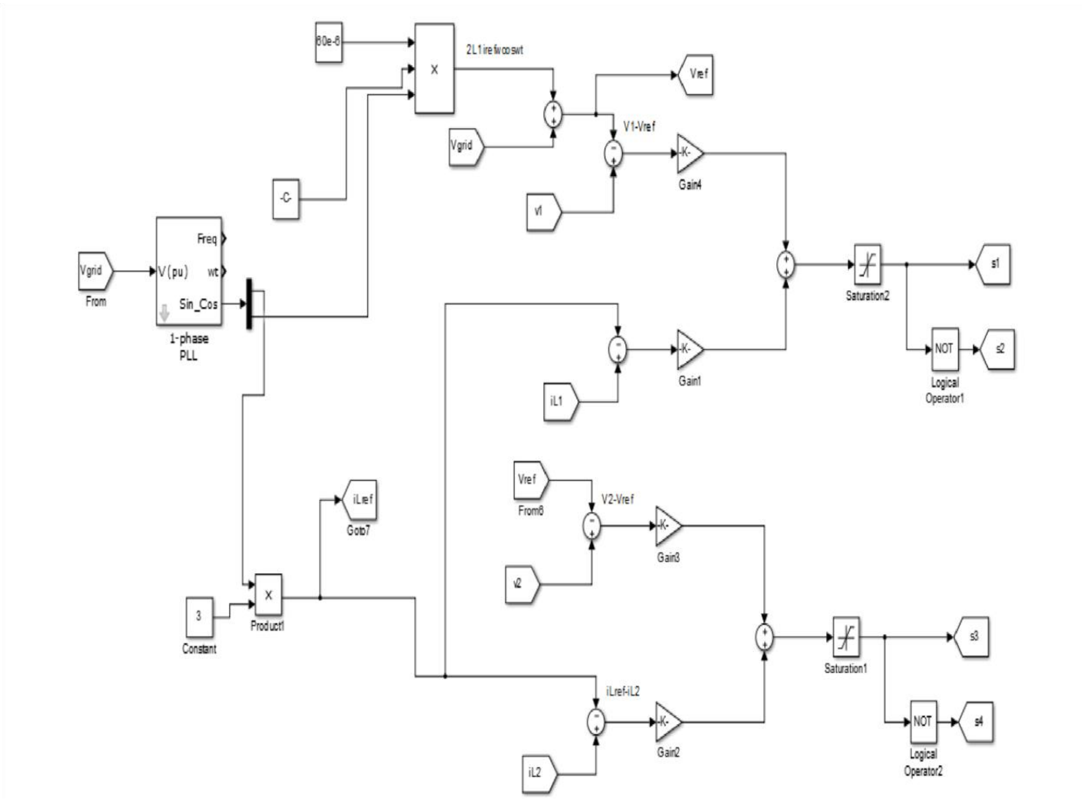

Figure 5: Simulink Diagram of Sliding Mode Controller

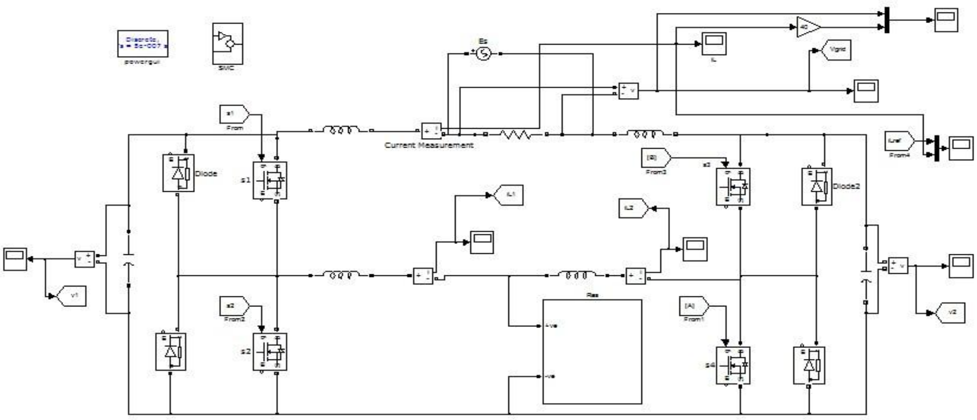

Figure 6: Simulink Diagram of A Grid-Connected Wind Energy System.

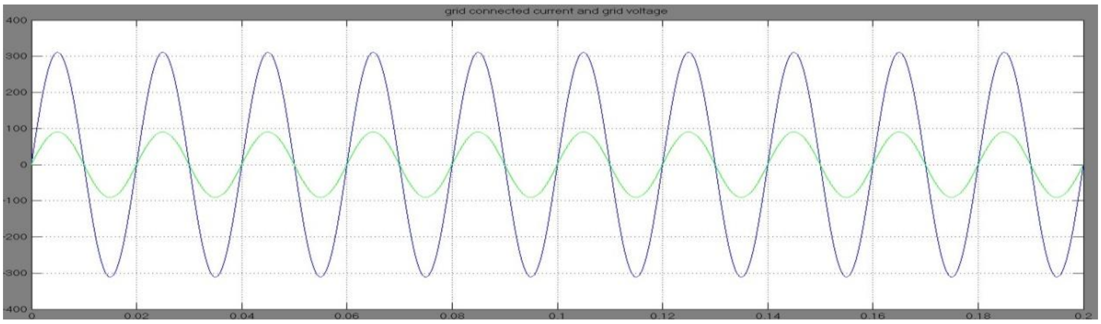

Figure 7: The Grid-Connected Current and Grid Voltage When Sliding Mode Control Is Used

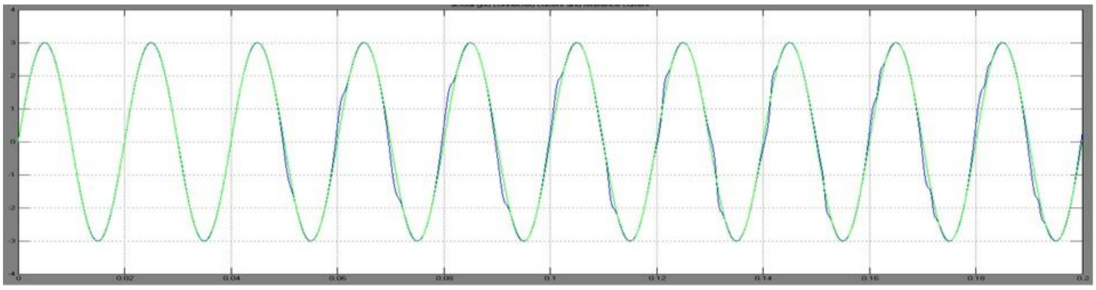

Figure 8: Actual Grid Connected Current and Reference Current When SMC Is Used

The FFT analysis for the fourth cycle of iLis shown as Fig.9, and the THD of iL is 1.41% in an acceptable level (IEEE-519 rule), in addition to fundamental, followed by three times and fifth times harmonic, in line with the actual conditions .

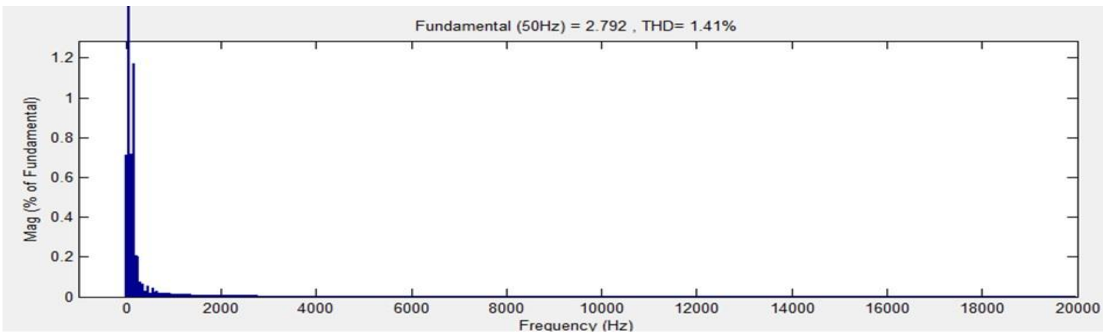

Figure 9: THD of the load current

Conclusion

This paper presents a new type of DC – AC converter, referred to as boost inverter. The boost inverter is proposed to realize single-stage grid connected wind energy system, and a double control diagram is proposed, which include the outer current loop and inner voltage loop. Two PI controllers are used in the outer current loop to regulate the phase of the grid-connected reference current and compute the reference voltage of inner loop. The new inverter is applicable in UPS design, whenever a AC voltage larger than the DC link voltage is needed, with no need of a second power conversion stage.

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