Performance Analysis of boost chopper - Current controlled inverter on PMSG Based Wind Energy conversion Systems

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***Abstract*–**Now days in many high performance applications of Voltage source PWM inverters,current control is an important part of the overall control system. In this paper, a new current-control method is proposed for the grid side inverters employed with the PMSG based WEC systems. The main purpose of this proposed method is to provide a pure sinusoidal current to the grid, even in the existence of nonlinear and unbalanced loads. The inverter receives the DC input from the Boost converter .The purpose of connecting boost converter in WEC System and its the mathematical model are clearly presented .To show the improvement in working performance this novel method is compared with the Current hysteresis control ,voltage oriented method . The proposed method is simulated using Matlab Simulink.
The Simulation result shows the improved performance of this new inverter current control scheme.

Keywords—*Boost converter, Inverter, Permanent Magnet Synchronous Generator (PMSG) , wind power.*

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I. INTRODUCTION

Wind energy is one of the easily available form of renewable energy and it is economically competitive with the other electrical power sources. Wind flows from the high atmosphere pressure region to the low atmosphere pressure region In Recent decades more electrical power is produced from the wind energy due to the fast development of wind energy conversion systems[1].Customers electrical power demand is compensated by using this surplus wind power.

In WEC systems Wind generators plays an important role. Before selecting the suitable type of generators, special importance is given to the fault ride through characteristics of the wind generators. some of the available wind generatorsutilized in the WEC systems are Permanent Magnet synchronous generators(PMSG),doubly fed induction generators (DFIG),wound field synchronous generators (WFSG),switched reluctance Generators(SRG) .Among the all types of wind generators PMSG is commonly used in all wind power plants to extract more power from the wind [2].PMSG has no field winding; the magnetic field is created by Permanent Magnets.It has large air gap length which leads to the low flux linkages irrespective of the Number of Magnetic poles. In comparing with the other components gear box is the more critical component in WTGS .Its down time failure is high .One of the main advantages in PMSG based WEC systems is the absence of gear box resulting in lower cost.

Figure 1 shows A Commonly used direct driven PMSG Based WEC System. The generator side

Converter circuit consists of diode bridge rectifier and Boost converter. In some cases a capacitor is connected in parallel at the output of diode bridge rectifier .the function of capacitor is to reduce the ripples of DC output voltage. In some cases the capacitor connection is omitted due to the high cost and more complexity of circuit. In comparing with the three phase diode bridge full wave converter, the boost converter has lower cost, simpler control circuits and high reliability[3].Boost converter can produce the maximum power within the particular operating range. In recent Many research is going on the performance of boost converter in WEC Systems. In(5) the inductor of the Boost converter is omitted, and three LC filters are connected in parallel at the output of the generator stator side to remove the high frequency harmonics of the current. The main function of the boost converter in PMSG based WEC are reducing Stator current harmonics, internal temperature rise and increasing the working life of generator. The boost converter is included in (6)to increase the Wind generator speed regulation range to capture the more power from wind at low speed. In (7) the grid is considered as the variable resistive load and simulated. From this simulation result the characteristics of the generator side converters are studied [4]-[18]. The transient stability of the direct driven PMSG based WEC system is increased by the co ordinate control of the grid side converter circuitand generator side converter circuit.

In this paper the working performance of the PMSG Based Wind Energy Conversion system with Boost converter and Single phase Inverter is analysed .The purpose of connecting Boost converter and single phase inverter in the WEC is explained clearly. Thenovel current control technique is implemented in the single phase inverter which produce the improved sinusoidal current

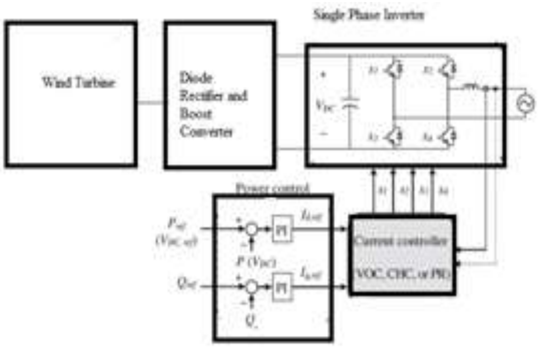


Fig.1.PMSG Based WEC Connected with Single Phase PWM Inverter

II. MATHEMATICAL MODEL OF THE SYSTEM

A .Wind Turbine

The output power produced by the Wind Turbine is given by the following /equation [5]

$$P_{WT}=0.5\rho\pi R^2C_p(\lambda,\beta)v^3 \quad (1)$$

Where ρ is the air density in Kg/m^3,R is the blade radius in meter ,$C_p$is the performance co efficient of the wind turbine which is the function of the pitch angle of rotor blades β in degrees and tip speed ratio λ. and v is the wind speed in m/s

The tip speed ratio λ is calculated using the following expression [5]

$$\lambda=\frac{\omega_m R}{v} \quad (2)$$

Where R is the blade length in meter and ω_m *is* the wind turbine rotor speed in radian /second

The mechanical torque produced by the wind turbine is described as [6]

$$T_m=0.5\rho AC_p(\lambda,\beta)v^3\frac{1}{\omega_m} \quad (3)$$

B. Permanent Magnet Synchronous Generator

In the PMSG based WEC systems,the main function ofpermanent magnet synchronous generator is converting the mechanical energy of the Wind turbine intoelectrical energy. Based on the rotor reference frame d-q axis analysis of the PMSG,we can express the stator voltages of the generators as follows,[7]

$$V_d=R_si_d-\omega_e L_qi_q+\frac{d}{dt}(L_di_d) \quad (4)$$

$$V_q=R_si_q+\omega_e(L_di_d+\psi_{PM})+\frac{d}{dt}(L_qi_q) \quad (5)$$

The electromagnetic torque produced by the PMSG is given by the following expression [8]

$$Te=\frac{3P}{2}(\psi_d i_q - \psi_q i_d) \quad (6)$$

Where,$\psi_d=L_di_d+\psi_{PM}$, $\psi_q=L_qi_q$and p is the number of pole pairs. The active power and reactive power equation can be expressed as ,

$$P=\frac{3}{2}(v_di_d+v_qi_q) \quad (7)$$

$$-Q=\frac{3}{2}(v_qi_d-v_di_q) \quad (8)$$

C.Diode Bridge Rectifier

With the help of diode bridge rectifiers we can converts the three phase AC voltage of the PMSG into DC voltages. The average output voltage of the rectifier is given by

$$V_{DCR}\,(avg)=\frac{3\sqrt{3}V_{Ph}}{\pi} \quad (9)$$

Where, V_{Ph} is Peak value of the PMSG phase voltage .

D.Boost Converter

The Boost converter is connected at the output side of the diode bridge rectifier. It steps up the magnitude of rectifier output voltage. The schematic diagram of the boost converter is shown in fig 2.When the Power transistor is switched on ,the input voltage of the boost converter appear across the inductor. the current flows through the inductor increases gradually. andthe diode becomes reverse biased [9] .When the Power transistor is switched off ,the inductor releases its stored energy to the capacitor through the diode. the Equivalent circuit of the boost converter is shown in fig 3 .From the diagram, the voltage and current equations are given by

$$V_b=V_{dc}/(1-D) \quad (10)$$

$$I_b=I_{Lconv}(1-D) \quad (11)$$

Where D is the PWM modulation factor

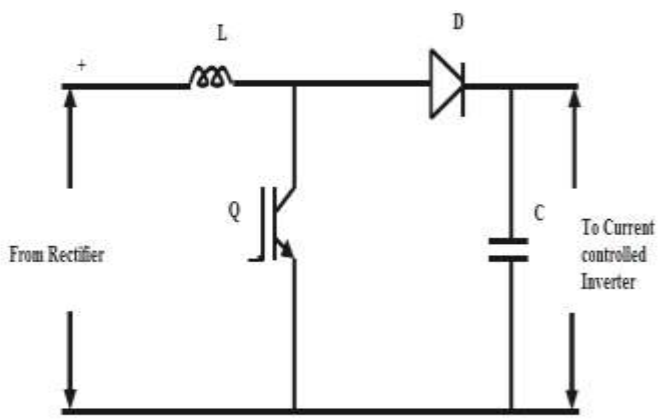


Fig.2.Schematic Diagram of Boost Converter

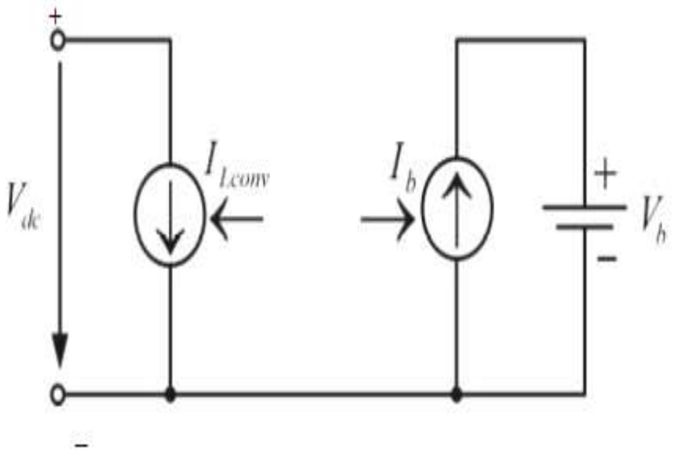


Fig.3.Equivalent Circuit of Boost converter

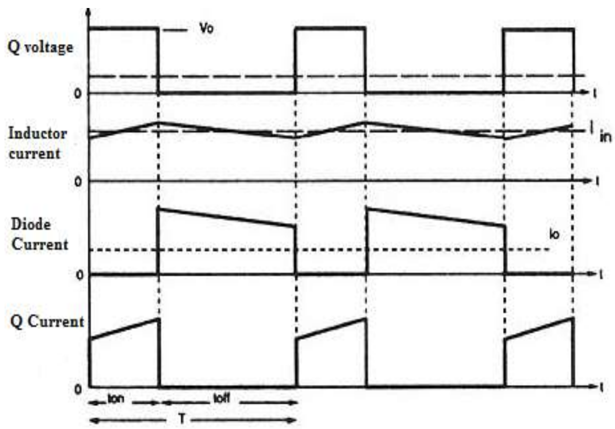


Fig.4.waveforms for a boost converter used in WEC systems

III. CONTROL STRATEGIES FOR SINGLE PHASE GRID –TIE CONVERTERS

The Power control methods applied for the single phase inverters resembles the concept of decoupled active and reactive power control of three phase inverters which realized in the synchronous reference frame. In this way AC current is divided into active power component I_d and reactive Power component I_q,by regulating these component we can eliminate the error between the measured value and reference value of the active and reactive powers. In many cases the active power current component I_d is controlled by controlling DC link voltage to maintain the balanced active power flow in the systems. Fig8 shows the reference voltage calculation

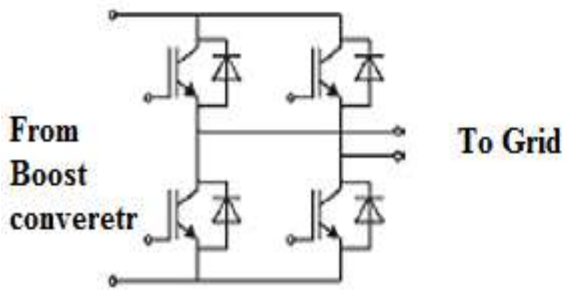
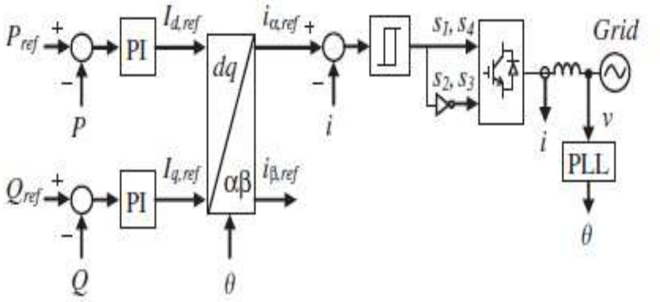


Fig.5.Single phase IGBT-PWM Based Inverter

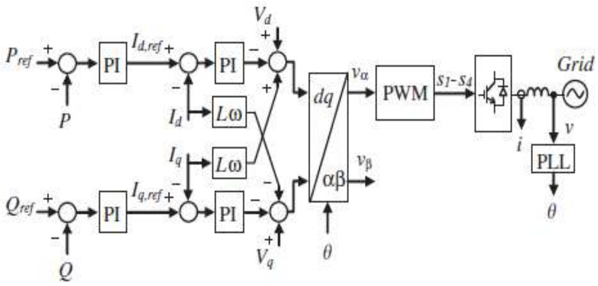
The function of current controller is generating the switching sequences for the inverter. This is achieved by comparing the measured and reference currents. Inthis way the current error is eliminated and we can obtain the desired DC current wave form by using L type filter .improved harmonic suppression performance is achieved at lower switching frequencies with small filter size .Now a days the multi loop current control method is employed to increase the system stability and resonant damping .We can use this method for single phase grid application also.

The operating performance of the grid side connected system is mainly depending upon the types of control and quality of the control strategies employed in the WEC conversion systems. In recent CHC, VOC, and PR types are the mainly used control method .Fig shows the schematic representation of these control strategies.

*A. Current Hysteresis control Method*This is the easiest method among all types. The AC current is controlled between the upper and lower limit We can achieve this using hysteresis current controller It is simple and gives high dynamics. Currenthysteresis controller has no pulse width modulation block. The converter switching sequences are the output of the hysteresis controller. The advantages are simplicity, robustness, betterstability, automatic current controlling and more dynamic response. The disadvantages are widely varying switching frequency and more current ripples. The value of the switching frequency is depending upon the load and system parameters, sampling frequency and hysteresis band width. The AC current has the significant low order harmonics. Based on this we can design the filter and power stages. high gain of the hysteresis controller leads to thecontrol difficulties and power quality problems



(a)



(b)

Fig 6. Block diagram of (a) Current Hysteresis Control (b) Voltage oriented control

B.Voltageoriented Control (VOC)

It is an indirect active and reactive current control method. This method is based on the current vector orientation with respect to the line voltage vector. This method is analysed using direct-quadrature (dq) synchronous reference frame. Fig 6 (a) and (b)Shows the block diagram of current Hysteresis control and voltage oriented control [2].The reference values and the error measured between the quadrature (I_q) and direct (I_d) components of the ac current are the inputs of PI Controllers. Based on this value the PI controllers produce the reference voltage for the converter .This reference voltage is applied to the converter utilizing PWM modulator..In comparing with the current hysteresis controller, the switching frequency of the converter is constant. In this method, the switching losses, THD and harmonic currents are reduced.

IV. PROPOSED METHOD AND SIMULINK RESULT

Hysteresis current controlled inverters are mainly used in the low and medium voltage applications. Line current harmonics generated by this inverter are depending upon the particular switching sequences applied to the switching devices.

Figure shows the schematic representation of the single phase neutral point inverter. The dc voltage is separated in to two constant and balanced DC sources as in diagram each value of V_c. The RL component on the ac side denotes the combined line and transformer inductances and losses.

The ac source v_{sa} denotes the system voltage seen at the inverter terminals. The inverter line current i_a tracks a sinusoidal reference i_a*.Its equation is given below

$$I_a^*=\sqrt{2}I_a^* \sin(\omega t+\phi) \qquad (12)$$

Using the action of the relay band and the error current ea(t)=I_a^*-I_a .From the diagram the reference voltage is given by

$$v_a^*=\sqrt{2}V_a^* \sin(\omega t+\phi) \qquad (13)$$

Figure compares the reference voltage to the instantaneous inverter voltage using the action of the hysteresis loop.

$$R.e_a+L\frac{d}{dt}(e_a)=V_a^*-V_a(14)$$

In referring fig when the switch is triggered on ,the inverter voltage is given by $v_a=V_c>v_a^*$.This produce the line current i_a,' to move upward till the lower limit of relay band becomes at ea(t)= - ε . At thatinstant the relay triggered on Q' and inverter voltage is $V_a=-V_c<v_a$* which cause the line current to reverse downward until the upper limit of the relay band becomes at $e_a(t)=\varepsilon$.The bang bang action produced bythe hysteresis current controlled inverter, therefore drives the instantaneous line current to find the reference within the relay band (-ε,ε.).

V. CONCLUSION

This Paper Presents a the working of PMSG Based wind energy conversion system ,connected with the Boost converter and single phase Inverter. The Proposed inverter topology provides an cost-effectively attractive and technically viable choice to the other types. The control method and the system configuration are very simple. The combination of the Boost converter and the inverter has been designed using MATLAB-SIMULINK for Small Scale Wind Turbine .The Performance was analysed by conducting many Experiments and the effectiveness of the system was confirmedTo control the single phase inverter, the Principle of Hysteresis control is used in this method. The Produced line currents have the acceptable harmonic distortion with simple control circuit

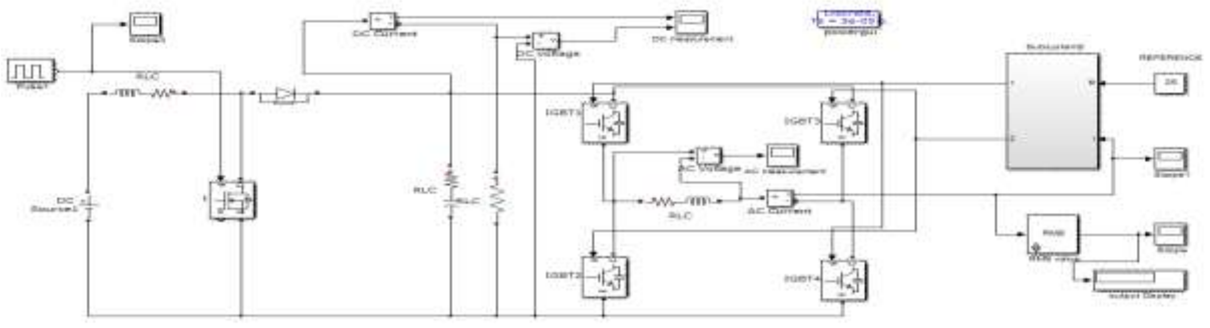


Fig.7.Simulink Circuit of the proposed method

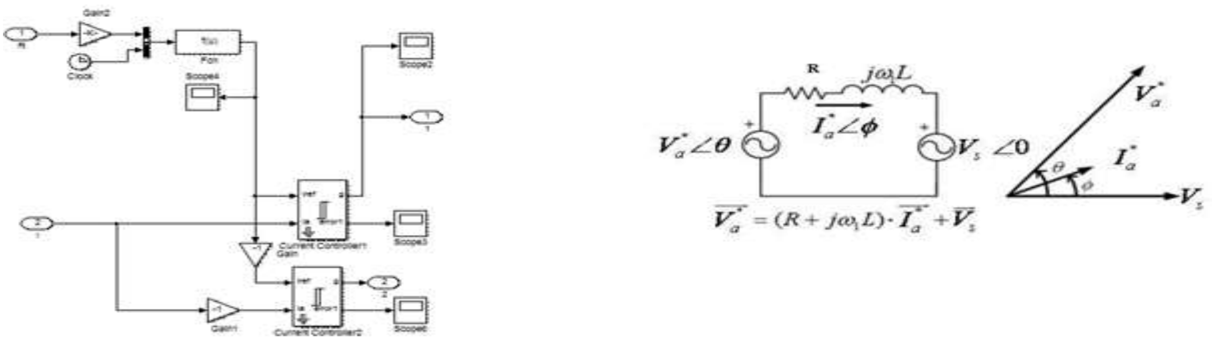


Fig.8. Reference voltage calculation

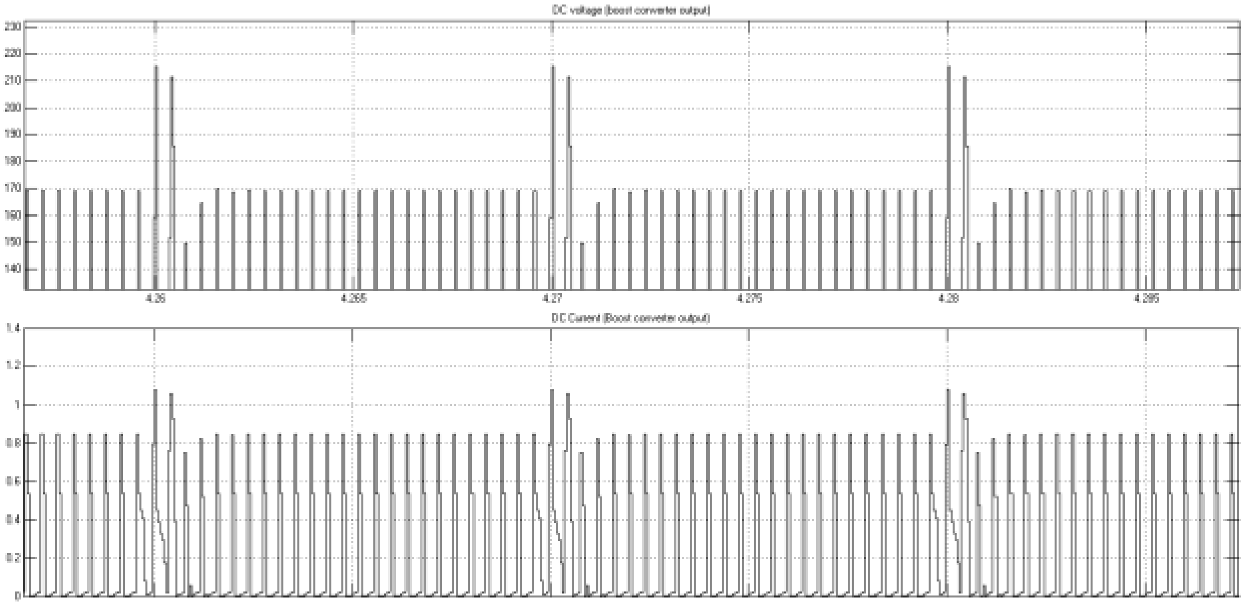


Fig.9.Boost converter output voltage and output current

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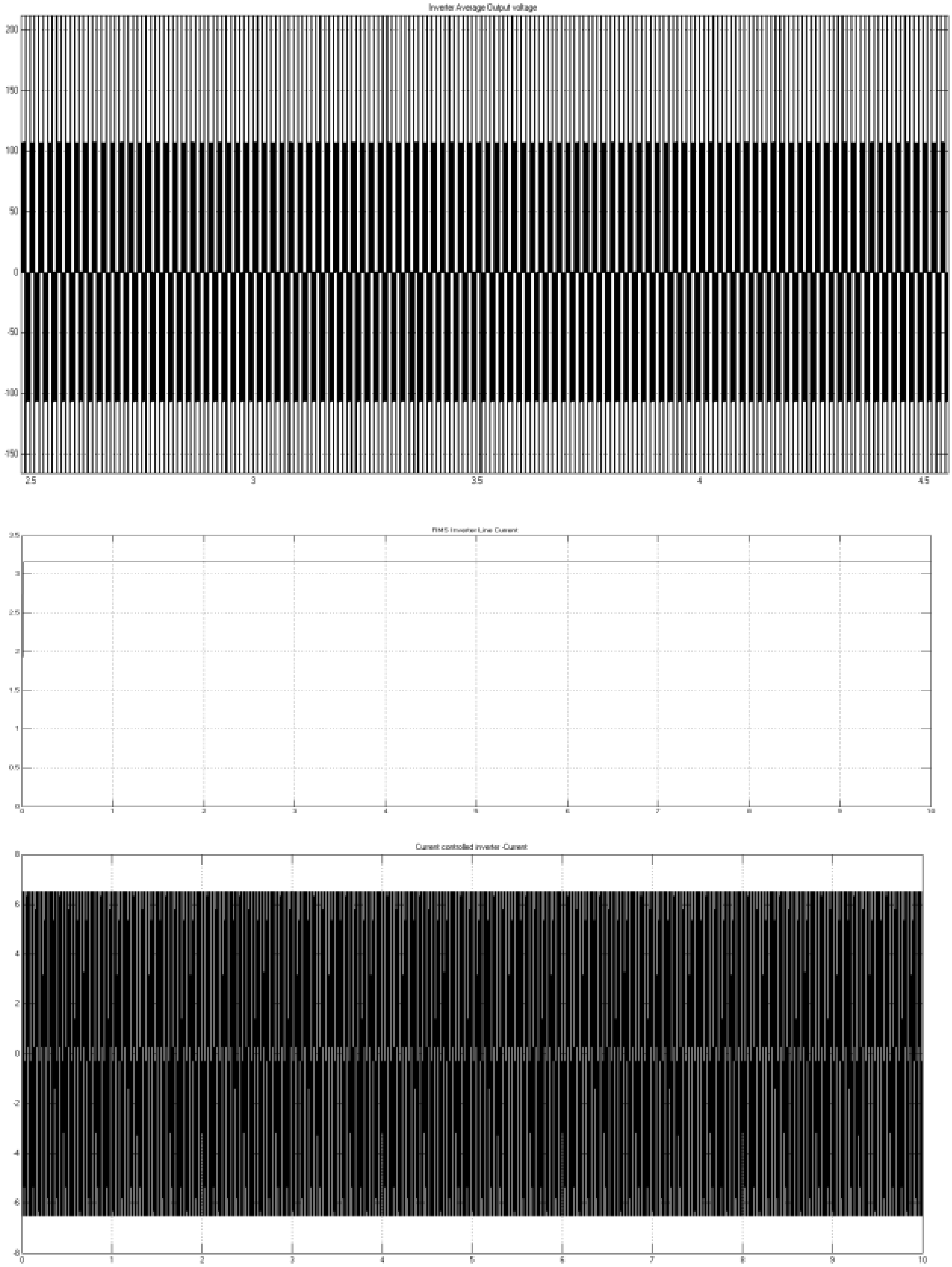

Fig .10.Current controlled inverter output Voltage and output current

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