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# Integrated Inverter Or Converter Circuit For Motor Drives With Dualmode Control For Hybrid Electric Vehicle Applications

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**ABSTRACT:In recent years, renewable energy sources such as photovoltaic (PV), wind, fuel cell, etc gain importance due to the limitations of conventional energy sources. Renewable energy sources play an important role in rural areas where the power transmission from conventional energy sources is difficult. Other advantages of renewable energy sources are clean, light and does not pollute atmosphere. In order to meet the required load demand, it is better to integrate the renewable energy sources with the load. Hybrid electric vehicles (HEVs) powered by electric machines and an internal combustion engine (ICE) are a promising mean of reducing emissions and fuel consumption without compromising vehicle functionality and driving performances. The proposed integrated circuit allows the permanent magnet synchronous motor to operate in motor mode or acts as boost inductors of the boost converter, and thereby boosting the output torque coupled to the same transmission system or dc-link voltage of the inverter connected to the output of the integrated circuit. Electric Motors, those are used for EV propulsion must have high efficiency for maximum utilization of the energy from batteries and/or fuel cells. Motor control algorithm for a dual power split system is proposed for hybrid electric vehicles (HEV). A new control technique for the proposed integrated circuit under boost converter mode is proposed to increase the efficiency. Since the light load performance is in recent focus of interest, appropriate algorithms to improve light load efficiency were implemented. The proposed control technique is to use interleaved control to significantlyreduce the current ripple and thereby reducing the losses and thermal stress under heavy-load condition. In order to evaluate performance of the control algorithm, HEV simulator is developed using MATLAB/ Simulink. Finally PV fed converter model is connected to induction motor and check the speed torque characteristics of IM. Matlab/Simulink model is developed and simulation results are presented.**

## I.INTRODUCTION

PV technologies are expected to become an attractive power source for automotive applications because of their cleanness, high efficiency, and high reliability. Although there are various PV technologies available for use in automotive systems, many commercial hybrid electric vehicle (HEV) systems use a traditional bidirectional dc-dc converter to interface the battery and the inverter dc bus. There is growing interest in electric vehicle (EV) and hybrid electric vehicle (HEV) technologies because of their reduced fuel usage and greenhouse emissions [1–3]. PHEVs have the advantage of a long driving range since fuel provides a secondary resource. Connection to the electric power grid allows opportunities such as ancillary services, reactive power support, tracking the output of renewable energy sources, and load balance. For purposes of this paper, plug-in vehicles will be lumped together with EVs. Most EV charging can take place at home overnight in a garage where the EV can be plugged in to a convenience outlet for Level 1 (slow) charging. Level 2 charging is typically described as the primary method for both private and public facilities and requires a 240 V outlet.

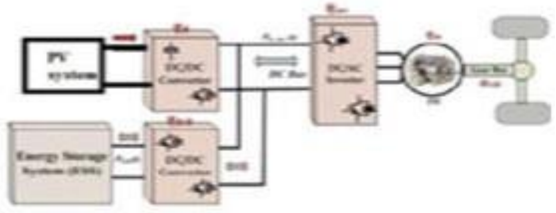

**Fig.1 Block diagram of the PV based HEV**

An electric vehicle is an emission free, environmental friendly vehicle. However, the electric vehicles remain unpopular among the consumers due to their lack of performance and their inability to travel long distances without being recharged. So, vehicle that embraces both the performance characteristics of the conventional automobile and the zero-emission characteristics of the electric vehicles are greatly being anticipated by the general consumers and the environmentalists alike. Technically, the quest for higher fuel economy is shaped by two major factors: how efficiently a power train converts fuel energy into useful power, and how sleek a vehicle is in terms of mass, streamlining, tire resistance, and auxiliary loads. On the other hand, vehicle functionality and comfort are shaped by various other factors, many of which run counter to higher fuel economy. Examples abound, from the way torque converter sacrifices efficiency to provide better shift smoothness and responsiveness to the wide variety of features that add mass to a vehicle.

## II. HEV CONFIGURATIONS

In Parallel hybrid electric vehicle (HEV) [1]–[3] and electric vehicle (EV) [4], [5] system as shown in Fig. 3.1, the converter is used for boosting the battery voltage to rated dc bus for an inverter to drive motor. In the multimotor drive system [6], [7], the system will use two or more motors to boost torque, especially under low speed and high-torque region as shown in Fig. 3.2. For such applications, two or more inverters/converters are required. Fig. 3.3 shows the application of the proposed integrated circuit for motor drives with dual-mode control for EV/HEV applications. As shown in Fig., the proposed integrated circuit allows the permanent magnet synchronous motor

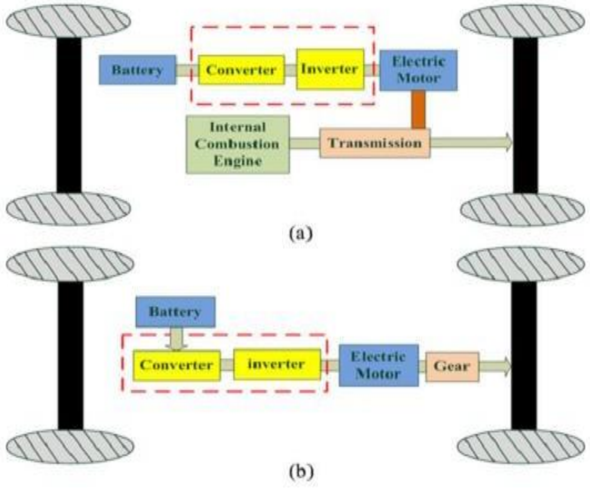

**Fig. 2. HEV and EV system. (a) Parallel HEV drive train. (b) EV drive train**

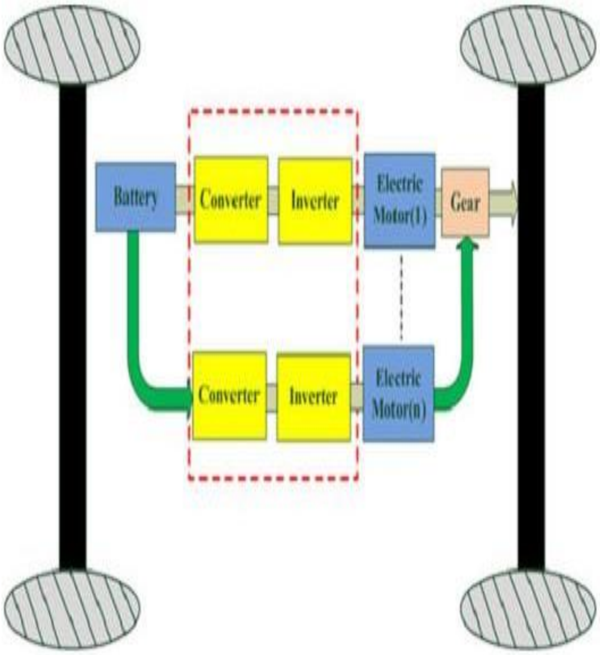

**Fig. 3. Conventional multimotor drive system of EV/HEV.**

(PMSM) to operate in motor mode or acts as boost inductors of the boost converter, and thereby, boosting the output torque coupled to the same transmission system or dc-link voltage of an inverter connected to the output of the integrated circuit. In motor mode, the proposed integrated circuit acts as an inverter and it becomes a boost-type boost converter, while using the motor windings as the boost inductors to boost the converter output voltage. Therefore, the proposed integrated circuit can significantly reduce the volume and weight of the system.

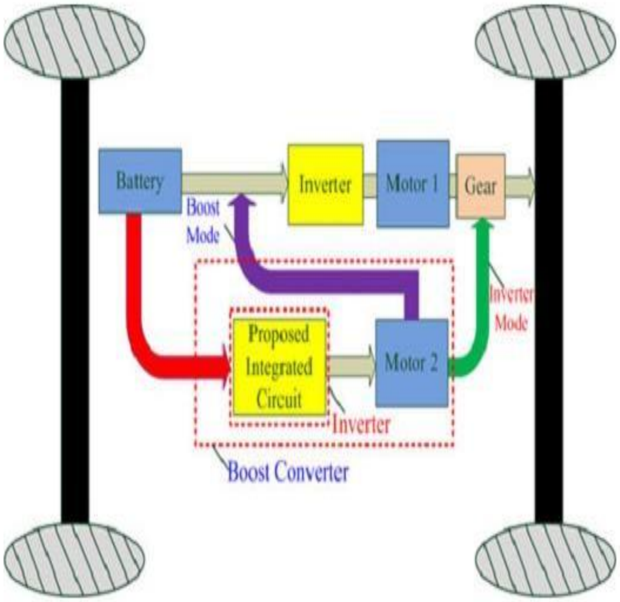

**Fig. 4. Proposed integrated inverter/converter for the multimotor drive system of EV/HEV.**

## III. PROPOSED INTEGRATED CIRCUIT AND CONTROL TECHNIQUE

Fig. shows the integrated circuit for dual-mode control. In Fig.Cin and Cout can stabilize the voltage when input and output voltages are disturbed by source and load, respectively. Diode(D)is used for preventing output voltage impact on the input side. When the integrated circuit is operatedininverter

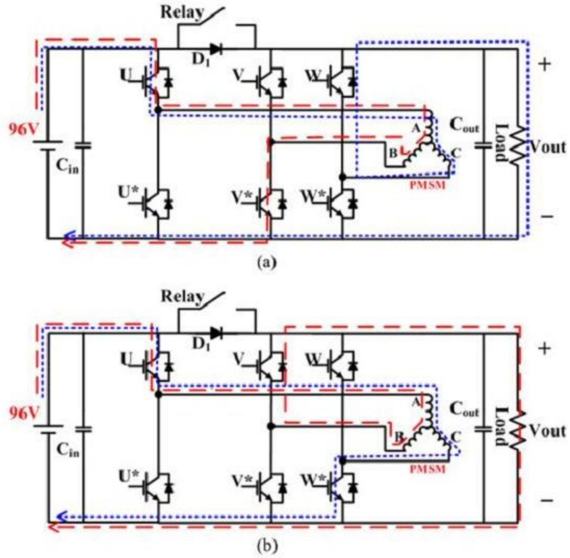

**Fig. 5. Proposed interleaved boost mode. (a) PhaseB: Charge; Phase C:**

**Discharge. (b) PhaseB: Discharge; PhaseC:Charge.**

(motor) mode, relay will be turned ON and six power devices(IGBTs in Fig. 3.5) are controlled by pulse width modulation(PWM) control signals. Details of the component specifications are shown in Table I. When the proposed integrated circuit is operated in the converter mode, relay is turned OFF. And a single-phase or interleaved control method will be applied to control of the powerdevices depending upon the load conditions. In Fig, the single-phase boost converter uses power switch$V^*$, stator winding“A” and winding “B”to boost the output voltage. In Fig., two-phase interleaved boostconverter uses power switches $V^*$and$W^*$, stator winding “A”winding“B” and winding “C” to boost the output voltage and reduce the current ripple.

## *MODELLING AND CONTROLLER DESIGN UNDER BOOST MODE*

This section will introduce the model of boost converter and derive the transfer function of the voltage controller. Fig.shows the non ideal equivalent circuit of the boost converter, it considers non ideal condition of components: inductor winding resistance $R_L$, collector-emitter saturation voltage $V_{CE}$, diode forward voltage drop $V_D$, and equivalent series resistance of capacitor. Analysis of the boost converter by using the state-space averaging method [14], small-signal ac equivalent circuit can be derived, the transfer function of the voltage controller can be derived as shown in (3.1), at the bottom of the next page.

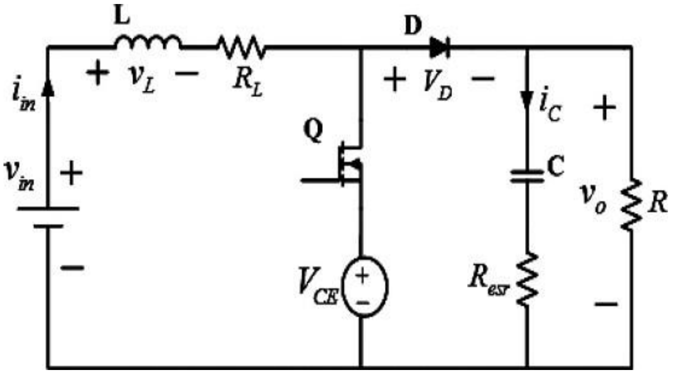

**Fig. 6. Equivalent circuit of the boost converter.**

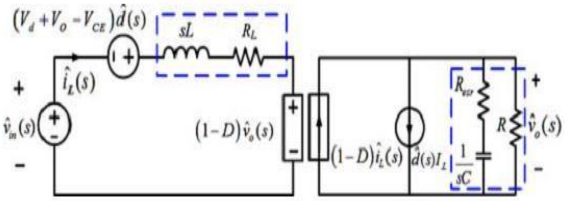

**Fig. 3.9. Small-signal equivalent circuit.**

$$G_{vd}(s)=\frac{\hat{V}_o(s)}{\hat{d}(s)}=\frac{s^2\cdot L\cdot C(R+R_{esr})+s[L+C\cdot R_L(R+R_{esr})+(1-D)^2C\cdot R\cdot R_{esr}]+[(1-D)^2\cdot R+R_L]}{-s^2\cdot C\cdot R\cdot R_{esr}\cdot L\cdot I_L+s\{C\cdot R\cdot R_{esr}[(V_d+V_o-V_{CE})(1-D)-R_LI_L]-R\cdot L\cdot I_L\}+R\cdot[(V_d+V_o-V_{CE})(1-D)-R_LI_L]}$$

Substituting the parameters shown in Table II into (3.1) gives

$$G_{vd}(s)=\frac{-6.737\times10^{-5}s^2+0.06827s+2498}{2.004\times10^{-5}s^2+0.00409s+3.242}$$

Fig. shows the block diagram of voltage loop, using a proportional-integral (PI) controller for the compensator. In this project, the switching frequency is 20 kHz and voltage loop bandwidth will be less than 2 kHz. And the phase margin should be more than 45°to enhance the noise immunity. For the designed controller shown in (3.3), the Bode plot of the closed loop gain as shown in Fig, the bandwidth is 7.73 Hz and the phase margin is 91.8◦

$$C(s)=\frac{0.0248387s+13.073}{s}$$

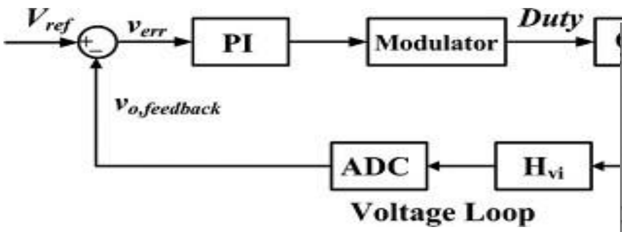

**Fig. 7 Block diagram of voltage loop.**

### *IV. SIMULATION RESULTS*

### *A) ESISTING RESULTS*

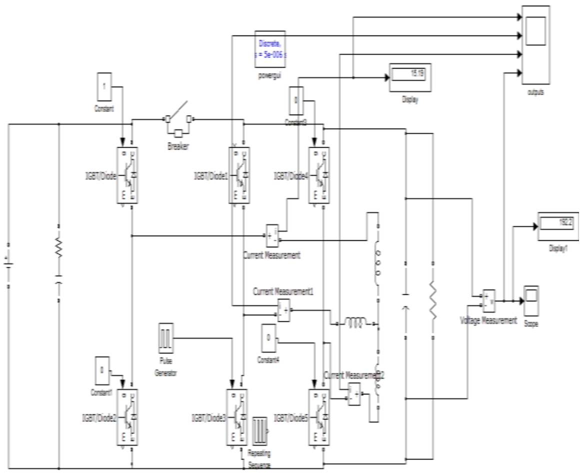

**Fig.8.Matlab/simulink model of the integrated circuit and controller.**

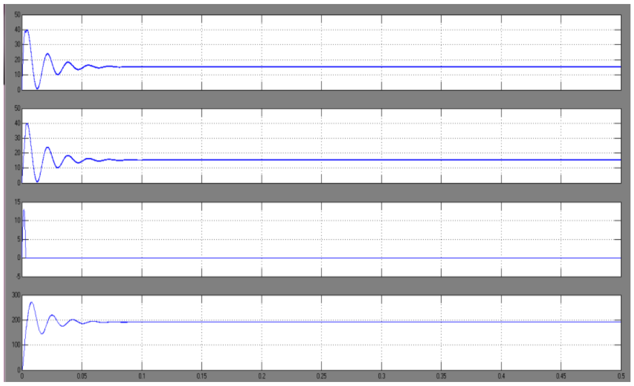

**Fig.9. measured current with and without interleaved control, Single-phase interleaved boost converter.**

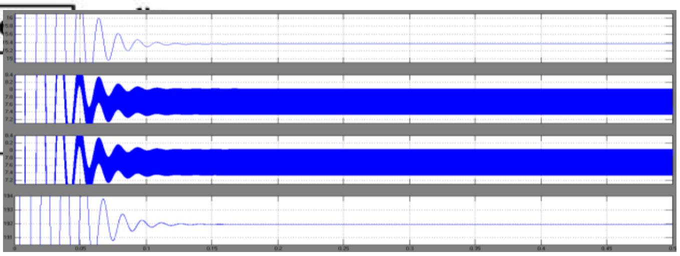

**Fig.10.Measured current with and without interleaved control, Two-phase interleaved boost converter.**

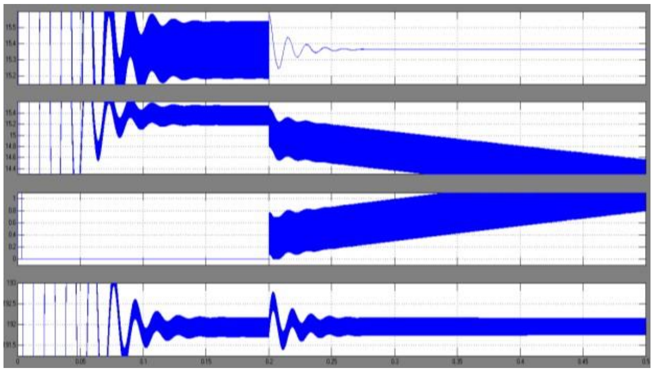

**Fig. 11. Simulated waveforms for the transition between single-phase control and two-phase interleaved control from two-phase interleaved to single-phase modes.**

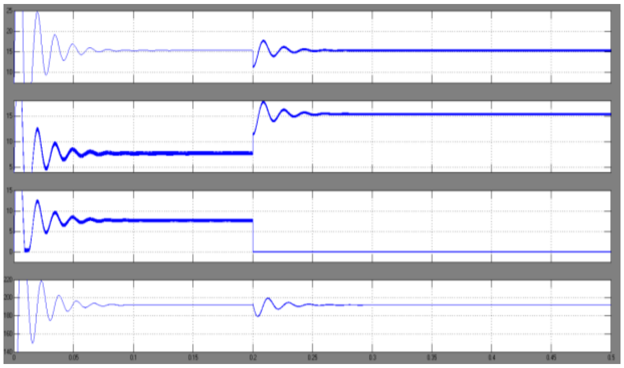

**Fig. 12. Simulated waveforms for the transition between single-phase control and two-phase interleaved control single-phase to two-phase interleaved modes.**

## B) EXTENSION RESULTS

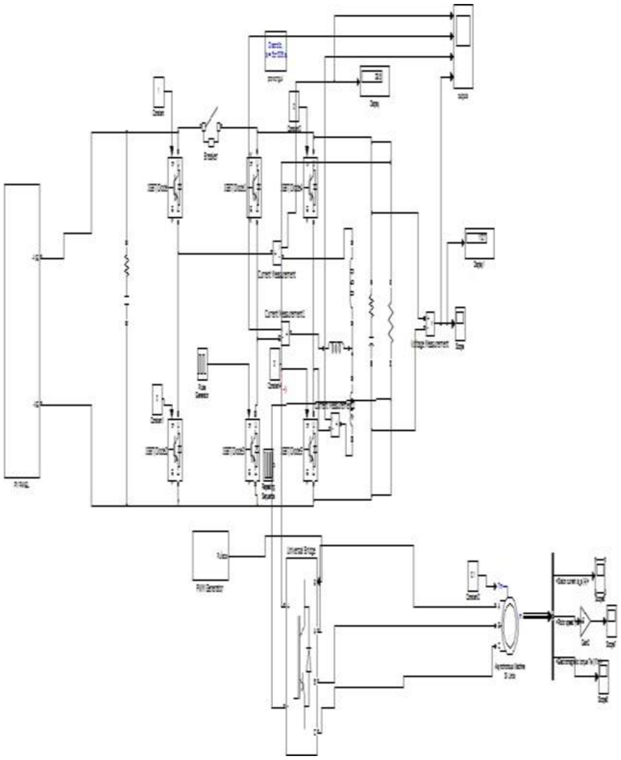

**Fig.13. Matlab/simulink model of the integrated circuit and controller with PV as input source.**

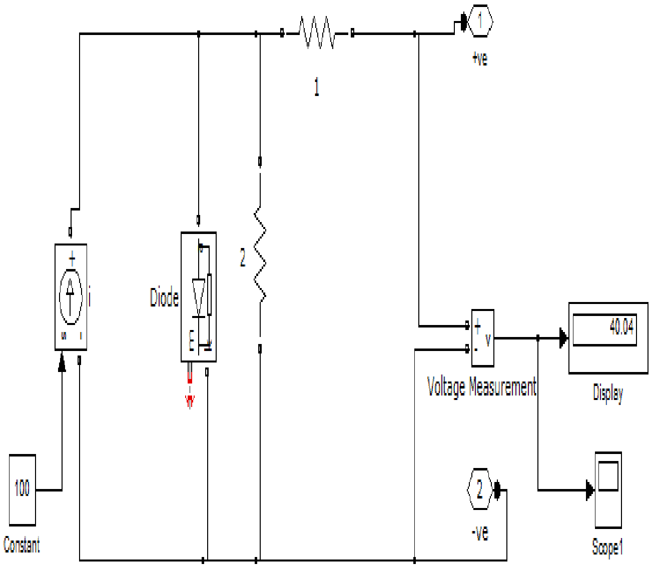

**Fig.14. Simulation model of PV system.**

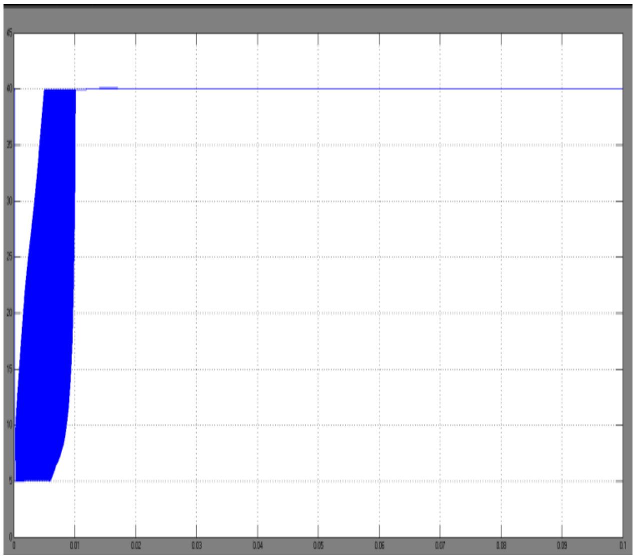

**Fig.15. shows simulated PV output voltage.**

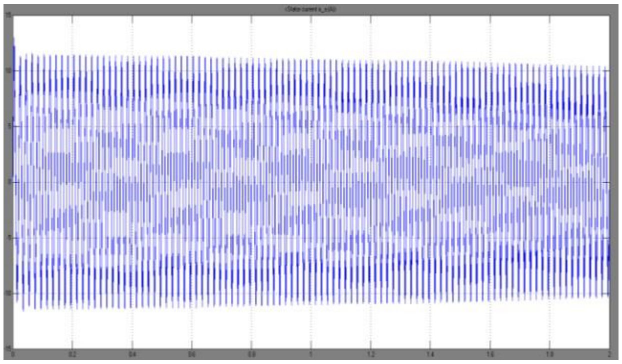

**Fig.16. Armature current of induction motor.**

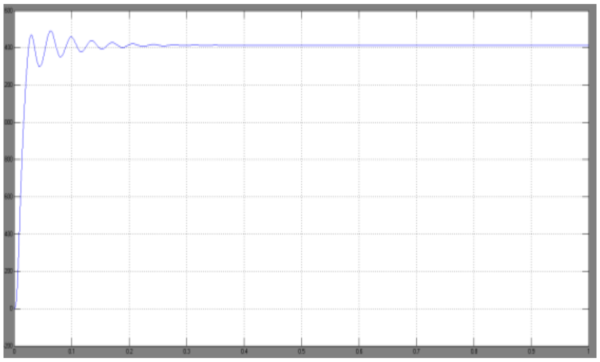

**Fig.17. Speed of a induction motor.**

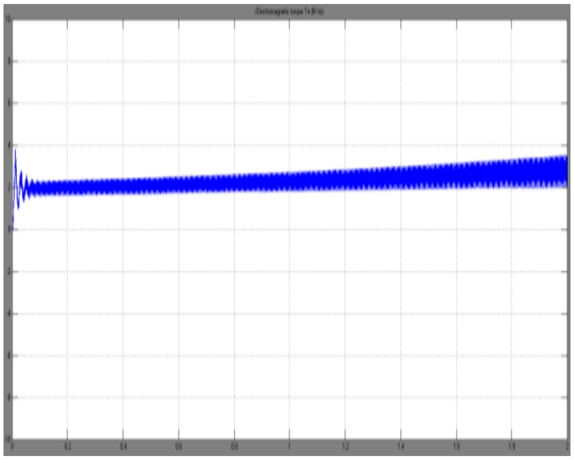

**Fig.18. Electromagnetic torque of a induction motor.**

## CONCLUSION

The contributions of this project include:

1) proposal of a new integrated inverter/converter circuit ofmotor drives with dual-mode control for EV/HEV applications to significantly reduce the volume and weight;
2) proposal of a new control method for the integrated inverter/converter circuit operating in boost converter modeto increase the efficiency;
3) verification of the proposed integrated inverter/convertercircuit;

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