International Journal of Research (IJR)
e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 10, October 2015
Available at http://internationaljournalofresearch.org

Implementation of Intelligent Control Strategy for Boost Converter/Inverter for Hybrid Vehicle

Ch V N Saikumar
M.Tech Student Scholar Department of Electrical & Electronics Engineering, Vasireddy Venkatadri Institute of Technology, Namburu (V), Pedakakani (M), Guntur (Dt); A.P, India.
U.Ramanaiah
Assistant Professor Department of Electrical & Electronics Engineering, Vasireddy Venkatadri Institute of Technology, Namburu (V), Pedakakani (M), Guntur (Dt); A.P, India.

Abstract:

This paper introduces a new control strategy "PWAM" method for HEV/EV motor drive system. This modulation method is quite different from other PWM methods that have been well researched or commonly used for the inverter in HEV/EV system. By using this method, only one phase leg of the inverter is doing switching action for every PWM-carrier period. The system configuration including green power generator, energy storage element, dc appliance and equipment, and energy management system with fuzzy logic will be introduced. The proposed integrated circuit allows the machine 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. 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. Enhancement of a renewable power management system with intelligence control techniques (Fuzzy) for a micro grid system. Modeling, analysis, and control of distributed power sources and energy storage devices with MATLAB/ Simulink.

Keywords: Fuzzy logic controller; Boost converter; Hybrid electric vehicle/Electric vehicle; Pulse width amplitude modulation (PWAM)

I.INTRODUCTION

In today's HEVs and EVs, high speed motors are used. It uses a boost converter and inverter system. The DC to DC conversion technology has been developing very rapidly. They are considered to be the most advantageous supply tools for feeding electronic systems in comparison with linear power supplies which are simple and have low cost [1] - [2]. Consequently, DC to DC converters have been widely used in industrial applications such as dc motor drives, computer systems and communication equipments. DC to DC converters are non-linear in nature. The design of high performance control for them is a challenge for both the control engineering engineers and power electronics engineers. In general, a good control for dc–dc converters always ensures stability in arbitrary operating condition.

Moreover, good response in terms of rejection of load variations, input voltage changes and even parameter uncertainties is also required for a typical control scheme. The boost type DC to DC converters are used in applications where the required output voltage is higher than the source voltage.

To turn on and off the inverter switches PWM technique is used. Pulse-width modulation (PWM) is the basis for control in power electronics. The theoretically zero rise and fall time of an ideal PWM waveform represents a preferred way of driving modern semiconductor power devices. With the exception of some resonant converters, the vast majority of power electronic circuits are controlled by PWM signals of various forms. The rapid rising and falling edges ensure that the semiconductor power devices are turned on or turned off as fast as practically possible to minimize the switching transition time and the associated switching losses.

For DC–DC converters, the PWM reference is a constant when the converter operates in a steady state but varies whenever the converter goes through a transient. Whereas inverter used this system uses only one phase leg and it is doing PWM switching while the other two phases are clamped to the dc rails. Therefore, the inverter total switching time is reduced to 1/3rd that of the conventional SPWM method and the total switching loss can be reduced to 1/3rd to 1/9rd. Besides, the inverter dc-link requires much smaller capacitance when PWAM method is applied, which makes the system more compact and lighter.

The conventional control method used, such as simple voltage feedback control cannot satisfy the requirement any longer, thus a fast closed-loop control method is necessary. To reduce the drawback with the previous concept multi loop feedback linearized control strategy is introduced to realize the fast control of the boost converter. The outer loop ensures steady-state reference tracking performance and the inner loop provides fast dynamic compensation for system disturbances (including sudden reference or load changes) and improves stability.

This thesis focus on a very simple but very wildly used topology for control method analysis. Figure .1.shows the boost converter – inverter system, which consists of a DC/DC boost converter and a simple three-phase PWM voltage source inverter. Generally, a large capacitor is installed on the dc-link between boost converter and inverter. This is because an ideal dc source is expected at the input side of inverter. If there is not a battery on the dc-link, the big capacitor is required to store enough energy and absorb the current ripple.

Many applications that have been mentioned previously use this topology, including HEV/EV system. In HEV/EV system, a battery is needed to provide and to restore the power.

The DC/AC inverter is used to convert dc power on the dc-link into AC power so that it can drive the electric motor/traction motor. During regenerative mode, the motor could also run as a generator and inverter should be able to transfer the power back from the AC to DC side. For most of the time, a DC/DC converter is also installed in the system between battery and inverter to boost battery voltage to match the dc-link voltage.

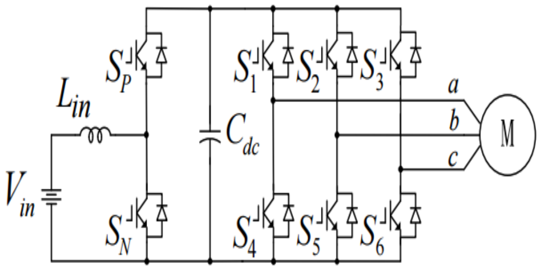

Figure .1.the boost converter – inverter system topology for PWAM method.

II.BOOST-CONVERTER-INVERTER SYSTEM USING PWAM METHOD

A. System configuration

The circuit configuration is shown in Fig.2. 1-kW experiment prototype is built for boost-converter-inverter system using PWAM method. The input is a battery with a voltage range between 100 V and 150 V. The output is a three-phase motor, operating at maximum line-to-line voltage of 230 V rms. For simplicity, simulation and experimental setup uses resistive load instead, and the output frequency varied from 60 Hz to 500 Hz to simulate the working condition of HEV/EV motor drives.

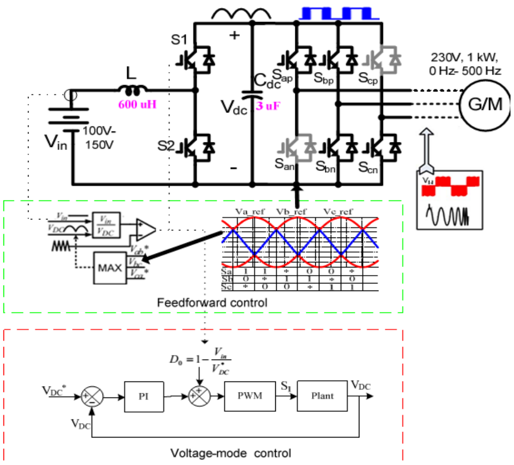

Fig.2. PWAM based boost-converter-inverter system.

B.Operating principle

The principle of PWAM method is to generate a bus voltage with 6ω sinusoidal envelop where ω is the fundamental frequency driving the motor. The peaks of the ripple are corresponding to the peaks of output three-phase line-to-line voltage.

In order to generate this ripple, the boost converter needs to be controlled. Only one phase leg is switching at any time for the inverter. The expression for the dc-link voltage is

$$V_{DC} = \begin{cases} V_{peak}\sin(\omega_f t + \pi/3) & (0 \le \omega_f t \le \pi/3) \\ V_{peak}\sin(\omega_f t) & (\pi/3 \le \omega_f t \le 2\pi/3) \\ V_{peak}\sin(\omega_f t - \pi/3) & (2\pi/3 \le \omega_f t \le \pi) \\ V_{peak}\sin(\omega_f t - 2\pi/3) & (\pi \le \omega_f t \le 4\pi/3) \\ V_{peak}\sin(\omega_f t - \pi) & (4\pi/3 \le \omega_f t \le 5\pi/3) \\ V_{peak}\sin(\omega_f t - 4\pi/3) & (5\pi/3 \le \omega_f t \le 2\pi) \end{cases} \quad (1)$$

Where *peak* is the line-to-line peak voltage.
The equation of voltage gain for boost converter is

$$V_{DC} = \frac{1}{1 - D_0} V_{in} \quad (2)$$

Where *D0* is the duty ratio function of boost converter. So in the boost-converter-inverter system,

$$D_0 = 1 - \frac{V_{in}}{V_{DC}} \quad (3)$$

is the duty ratio function and can be calculated from (1) and (2).This is used as feed forward control for inverter and boost converter. Fig. 1 shows the control block diagram of PWAM based boost-converter-inverter system [4]. Unlike the traditional SPWM control which requires maintaining a constant dc-link voltage, the dc capacitor voltage *vC* is fluctuating like a three-phase bridge rectifier waveform in case of the PWAM method. It combines the technique of both pulse width modulation as well as amplitude modulation together. The detailed explanation for the principle and operation can be found in [3]. Although the benefit it brings with reduced switching loss and smaller dc-link capacitor, it also brings a new challenge for the control of boost converter, whether the single loop voltage-mode control can provide fast tracking of 6ω sinusoidal envelop How to improve the transient response of the system.

III.TRADITIONAL CLOSED-LOOP CONTROL FOR BOOST CONVERTER

A. Voltage-mode control for boost converter

The voltage-mode closed-loop control for boost converter is using voltage feedback loop to compensate for the error of the feed forward control, which can be seen from the voltage-mode control from Fig.2. This causes the sluggish behavior of the boost converter in transient response. For designing controller of the boost converter, the small-signal analysis is usually adopted [6]. Given the small-signal analysis, the value of each variable can be written as the summation of the dc term with its perturbation. The details of deriving the small-signal transfer function of the boost converter is omitted here and readers can refer to [6] for details. The conclusion is directly given. A small-signal control-to-output transfer function for the boost converter is

B. Current-mode control for boost converter

The narrow-gain-bandwidth limitation of voltage-mode control as applied to the non-buck derived converters can be somehow overcome with current-mode control, where an inner current feedback loop is used in addition to the outer voltage feedback loop.

Since *Ti* (*s*) ≥ 1 − *K r* * *Fm* * *G vd* (*s*) , and neglect the influence of equivalent series resistance, the current-mode control-to-output transfer function for the boost converter can be simplified as Voltage is fluctuating. Therefore, to totally tackle the problem, a feedback linearized control with proportional plus resonant (PR) compensator is then added into the outer voltage regulation loop to achieve zero steady-state error. The analysis and simulation result is shown in next section.

C. Feedback linearization control for boost converter.

Since the single loop voltage-mode control cannot satisfy the system response requirement and the steady-state error still exists in current-mode control, a modified multi loop control is considered for this case. The benefit of using multi loop control has been addressed in [9-12]. To obtain a quicker response of the whole system, it is expected to decouple the voltage loop with inner current loop, which is addressed in this paper as the feedback linearized control method. Then the problem becomes to design compensator for a first order system. First, the transient response equation for boost converter is

$$\begin{cases} V_L = V_{in} * D_0 + (V_{in} - V_{DC}) * (1 - D_0) \\ I_C = I_L * (1 - D_0) - I_o \end{cases} \quad (4)$$

and reorganized as

$$\begin{cases} L\dfrac{dI_L}{dt} = V_{DC} * D_0 - (V_{DC} - V_{in}) \\ C\dfrac{dV_{DC}}{dt} = I_L * (1 - D_0) - I_o \end{cases} \quad (5)$$

Based on transient-state equations for boost converter, a nonlinear decoupling method is used to build the closed loop compensator as shown in Fig. 3.

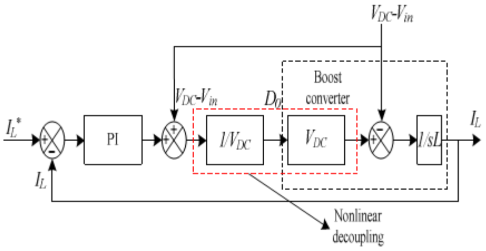

Fig.3.Feedback linearization control for boost converter.

IV. FUZZY LOGIC CONTROL

L. A. Zadeh presented the first paper on fuzzy set theory in 1965. Since then, a new language was developed to describe the fuzzy properties of reality, which are very difficult and sometime even impossible to be described using conventional methods. Fuzzy set theory has been widely used in the control area with some application to power system [5]. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior. Matlab/Simulink simulation model is built to study the dynamic behavior of converter. Furthermore, design of fuzzy logic controller can provide desirable both small signal and large signal dynamic performance at same time, which is not possible with linear control technique. Thus, fuzzy logic controller has been potential ability to improve the robustness of compensator.

The basic scheme of a fuzzy logic controller is shown in Fig.4 and consists of four principal components such as: a fuzzyfication interface, which converts input data into suitable linguistic values; a knowledge base, which consists of a data base with the necessary linguistic definitions and the control rule set; a decision-making logic which, simulating a human decision process, infer the fuzzy control action from the knowledge of the control rules and linguistic variable definitions; a de-fuzzification interface which yields non fuzzy control action from an inferred fuzzy control action [10].

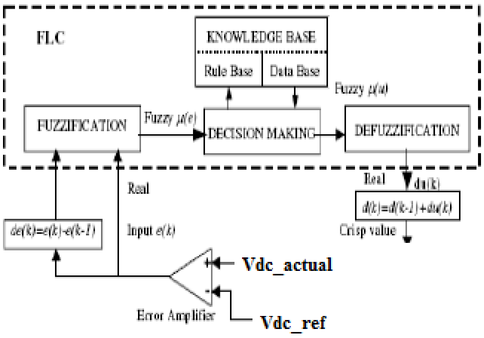

Fig.4. Block diagram of the Fuzzy Logic Controller (FLC) for proposed converter.

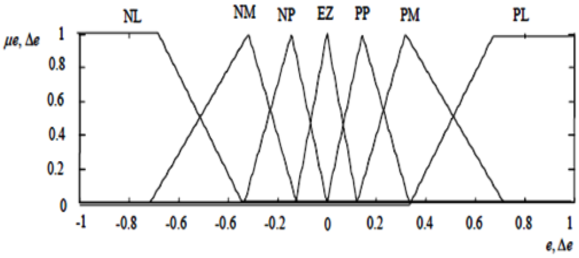

Fig.5. Membership functions for Input, Change in input, Output.

Rule Base: the elements of this rule base table are determined based on the theory that in the transient state, large errors need coarse control, which requires coarse in-put/output variables; in the steady state, small errors need fine control, which requires fine input/output variables. Based on this the elements of the rule table are obtained as shown in Table, with ‘Vdc’ and ‘Vdc-ref’ as inputs.

Δe \ e	NL	NM	NS	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	EZ
NM	NL	NL	NL	NM	NS	EZ	PS
NS	NL	NL	NM	NS	EZ	PS	PM
EZ	NL	NM	NS	EZ	PS	PM	PL
PS	NM	NS	EZ	PS	PM	PL	PL
PM	NS	EZ	PS	PM	PL	PL	PL
PL	NL	NM	NS	EZ	PS	PM	PL

V.MATLAB/SIMULINK RESULTS

Simulation results with the proposed control method are shown in Fig. 7 to Fig.9. In Fig. 7, the boost converter is operating at f_{line}=240 Hz and f_{sw}=20 kHz. As can be seen from the simulation results, the dc-link voltage tracks well with the 6ω reference with the closed-loop control. The steady-state error is almost zero owing to the PR compensator. Another test is carried out for the case with output fundamental frequency changes. Since the resonant frequency is known by the operator, the PR compensator still works well and the simulation result is shown in Fig.8. And Fig. 9.

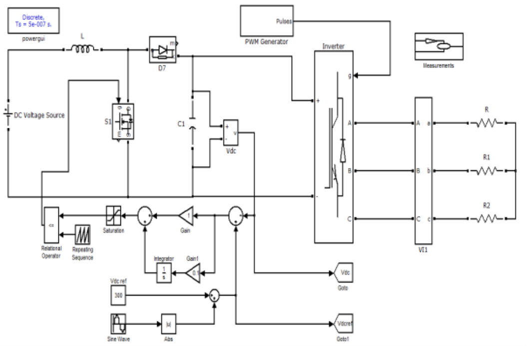

Fig.6. Matlab/Simulink model for PWAM boost-converter-inverter system with voltage-mode control with f_{sw}=20 kHz and f_{line}=60 Hz

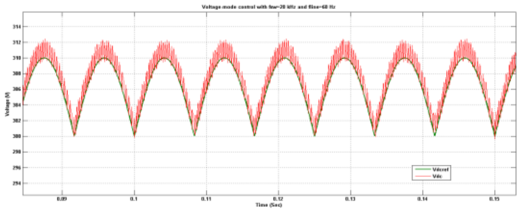

Fig.7. Circuit based simulation for PWAM boost-converter-inverter system with voltage-mode control with f_{sw}=20 kHz and f_{line}=60 Hz.

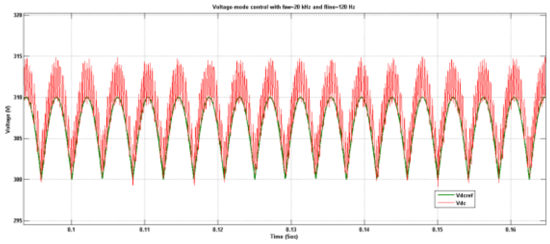

Fig.8.simulation for PWAM boost-converter-inverter system with voltage-mode control with f_{sw}=20 kHz and f_{line}=120 Hz.

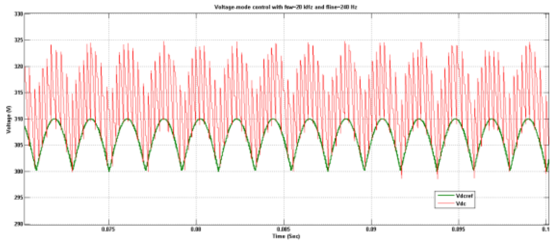

Fig.9. Circuit based simulation for PWAM boost-converter-inverter system with voltage-mode control with f_{sw}=20 kHz (a). and f_{line}=240 Hz.

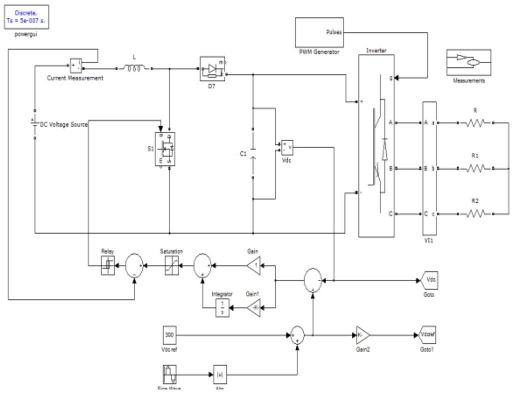

Fig.10. Simulink model for current-mode control of PWAM boost converter inverter system for f_{line}=240 Hz and f_{sw}=20 kHz.

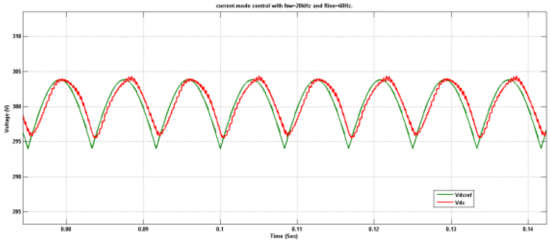

Fig.11. Circuit based simulation for current-mode control of PWAM boost converter inverter system for f_{line}=240 Hz and f_{sw}=20 kHz.

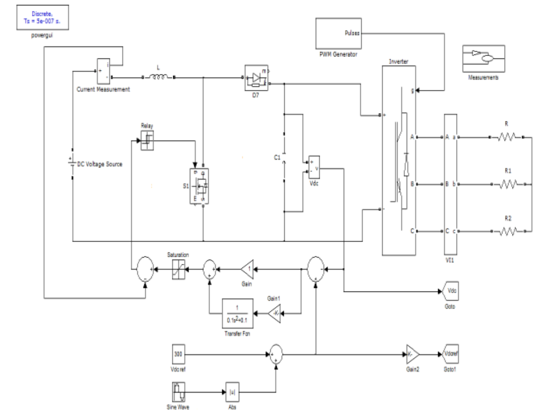

Fig.12. Simulation model of PWAM based boost-converter-inverter system with feedback linearization control for f_{line}=240 Hz and f_{sw}=20 kHz.

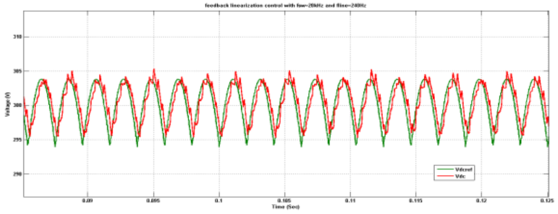

Fig.13. Simulation result of PWAM based boost-converter-inverter system with feedback linearization control for f_{line}=240 Hz and f_{sw}=20 kHz.

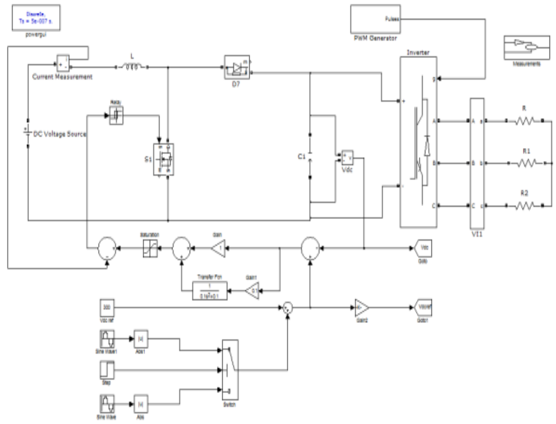

Fig.14. Simulation model of PWAM based boost-converter-inverter system with feedback linearization control for f_{line} changes from 240 Hz to 300 Hz and f_{sw}=20 kHz.

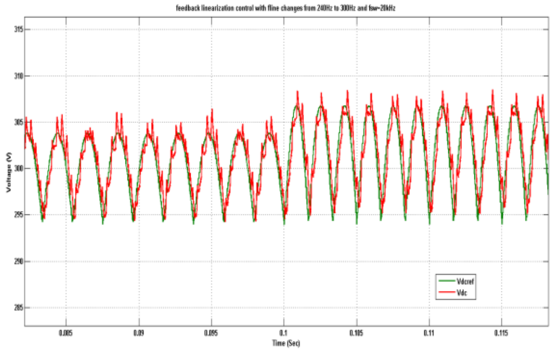

Fig.15. Simulation result of PWAM based boost-converter-inverter system with feedback linearization control for f_{line} changes from 240 Hz to 300 Hz and f_{sw}=20 kHz.

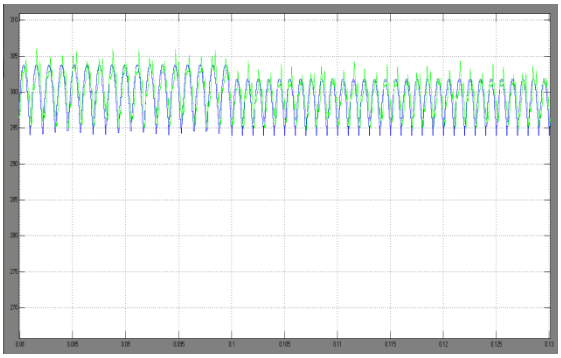

Fig.16. Simulation result of PWAM based boost-converter-inverter system with feedback linearization control for f_{line} changes from 420 Hz to 500 Hz and f_{sw}=20 kHz.

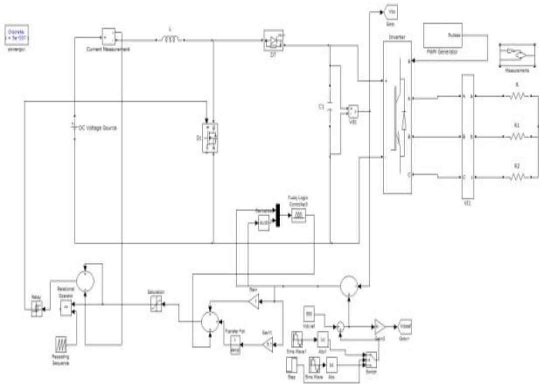

Fig.17. Simulation model of fuzzy based boost-converter-inverter system with feedback linearization control for f_{line}=240 Hz and f_{sw}=300 kHz.

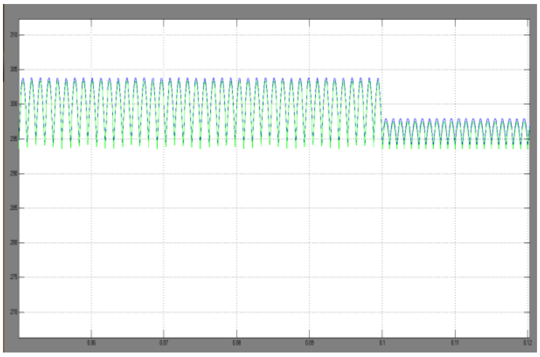

Fig.18.Simulation wave form of Fuzzy logic control based PWAM based boost-converter-inverter system with feedback linearization control for $fline$=240 Hz and f_{sw}=300 HZ.

VI.CONCLUSION

In this paper, a fuzzy based control strategy for boost converter/inverter for hybrid vehicles is implemented. The system with its control strategy is especially suitable for HEV/EV motor drives. The PWAM method requires only one phase leg to do PWM switching action. Thus, switching loss can be greatly reduced by more than 2/3. Furthermore, unlike the conventional inverter system, which requires relatively larger dc-link capacitor to absorb ripple and keep voltage stable, the PWAM based system with fast control needs much smaller capacitance since dc-link voltage is fluctuating. This is a special feature of PWAM method. Fast control of the boost converter will make sure the dc-link voltage tracks well with 6ω sinusoidal envelops required by the PWAM method. The multi loop feedback linearized control strategy provides fast dynamics and accurate control of the boost converter and PR controller for outer voltage loop guarantees zero steady-state error. Fuzzy logic control based system makes the system more efficient and reliable and also it will increase the overall system performance.

REFERENCES

[1] Mohammad Rashid, "Power Electronics Handbook" Academic Press, A Harcourt Science and Technology Company

[2] P. S. Bimbhra, "Power electronics", Khanna publications

[3] H. Fujita, "A three-phase voltage-source solar power conditioner was using a single-phase PWM control method," in Energy Conversion Congress and Exposition, 2009. ECCE 2009. IEEE, 2009, pp. 3748-3754.

[4] Q. Lei and F. Z. Peng, "PWAM boost-converter-inverter system for EV engine starter/alternator," in 2012 IEEE Energy Conversion Congress and Exposition (ECCE), 2012, pp. 2969-2976.

[5] R. B. Ridley, "A new, continuous-time model for current-mode control [power convertors]," IEEE Transactions on Power Electronics, vol. 6, pp. 271-280, 1991.

[6] R. W. Erickson and D. Maksimovic, Fundamentals of power electronics: Kluwer Academic Pub, 2001.

[7] Pavol Fedor and Daniela Perduková, "A Simple Fuzzy Controller Structure," Acta Electrotechnica et Informatica No. 4, Vol. 5, pp. 1-4, 2005.

[8] Ramón C. Oros, Guillermo O. Forte, Luis Canali, "Scalar Speed Control of a d-q Induction Motor Model Using Fuzzy Logic Controller",

Departamento de Electrónica, Facultad Regional Córdoba, Universidad Tecnológica Nacional, Conf. paper.

[9] R.Ouiguini, K. Djeffal, A.Oussedik and R. Megartsi, “Speed Control of an Induction Motor using the Fuzzy logic approach.”, ISIE’97 - Guimariies, Portugal, IEEE Catalog Number: 97TH8280, vol.3, pg. 1168 – 1172.

[10] J.-S. R. Jang, C.-T. Sun, E. Mizutani, “Neuro-Fuzzy and Soft Computing,” Pearson Education Pte. Ltd., ISBN 81-297-0324-6, 1997, chap. 2, chap. 3, chap. 4.