FUZZY BASED CONTROLLER FOR AC/DC BOOST CONVERTER

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Abstract

In this paper , a fuzzy based controller for boost type AC/DC converter has been presented . Its operation and performance have been investigated through its simulation in the environment of Mat Lab.

The system has been tested under various loading conditions . The obtained results showed that this fuzzy based controller can effectively control the power factor and the harmonic contents of the current drawn from the power factor system distribution network .

مسيطر مضبب لمحول تيار متناوب \ مستمر من النوع الرافع

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الخلاصة:

في هذا البحث تم تقديم مسيطر ضبابي لمحول AC/DC من النوع الرافع - عمل واداء المسيطر تم اختباره باعتماد برنامج Mat LAB.
تم اختبار المنظومة عند احمال مختلفة ، النتائج التي تم الحصول عليها تثبت كفاءة المسيطر للسيطرة على معامل القدرة والمكونات التوافقية للتيار المسحوب من شبكة التوزيع .

1-Introduction

It is well known that conventional AC/DC converters use rectifier diodes and bulky capacitor to convert the distribution network ac voltage into dc one to power the electronics and power electronics driven appliances. These types of converters draw non sinusoidal currents. Actually they draw narrow ac current pulses because the bulky filter capacitor remain charged to near the peak value of the ac voltage for a large portion of the voltage half cycle and so prevents the rectifier diodes from being forward biased except for small period of time when the supply voltage exceeds that of the capacitor.

Fourier transform analysis of these current pulses shows that these pulses are constructed of a number of harmonics which stand for the distortion of the current drawn and the low power factor accompanying the devices powered by such conventional converters.

The accumulated effect of these harmonics give raise to the following drawbacks:

1-Low power factor .
2-Large wiring, & circuit breakers capacity.
3-Over heating of power cables, ac motors, transformers, and var compensating capacitors.
4-Causing metering error of signals whose sensing depends upon the zero crossing points.
5-Distortion of transmission line voltages because of their passage in the series impedences of these lines.
6-Interference with communication equipments.
7-Causing electrical resonances in power systems which intern lead to excessive currents and voltages that cause damage to the connected devices.

To overcome these drawbacks and get maximum throughput from the electrical distribution network, the literature has witnessed development of the power factor correction preregulators. These preregulators operate at higher frequencies than the line frequency to allow large reduction in the size and cost of the passive filter elements. Shape the line current (to be as close as possible to sinusoidal one with zero phase shift with respect to utility line voltage), and to regulate the dc output voltage of the converter unit.

The goals assigned to these power factors preregulators have been achieved through different control techniques.Some of which depend upon the traditionl well defined linear PID control [1,2,3,4,5], some make use of the vast development in digital signal processing techniques and replaced the analog type PID converter controllers with DSP technology implemented ones [6,7,8], some developed neural based controllers[9], and others make use of the fuzzy set theory introduced by Lotfi Zadaeh and developed fuzzy logic based power factor converter controllers[10].

In this research work , a fuzzy logic based approach has been adopted to get AC/DC converters with high power factor, low harmonic distortion , and regulated dc output voltage .

2-Fuzzy Controller Implementation of Boost AC/DC Converter

2.1 Power Circuit Operating States

The boost converter circuit under examination is shown in Fig.(1). It comprises a diode bridge, an inductor, transistor switch, diode switch, filtering capacitor, and load resistance.

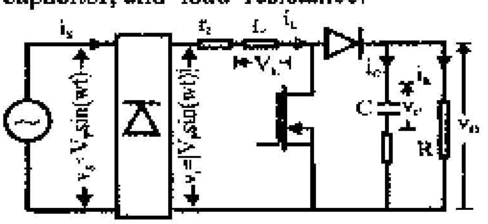

Fig.1: Boost converter power circuit.

Generally this circuit may loops through two states (for continous current conduction mode) or three states (for discontinous current conduction mode).

These operating states whose configurations are shown in Fig.(2) are defined by the switching states of the transistor switch "S_1" and the diode "D_1".

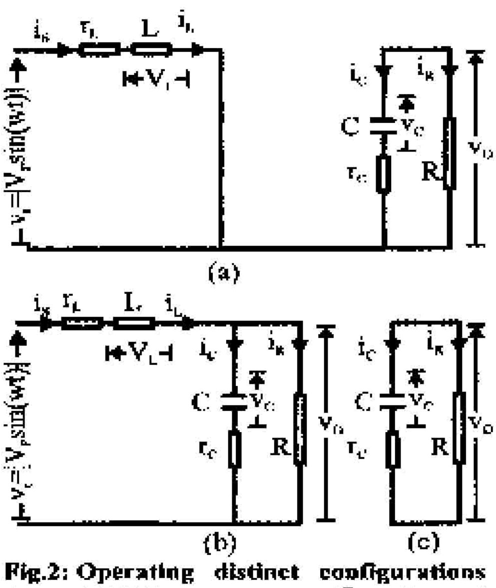

Fig.2: Operating distinct configurations of boost AC/DC converter: a) 1st configuration; b) 2nd configuration; 3rd configuration.

First state: (S_1 is ON & D_1 is OFF)

$v_r = r_L i_L + L\, di_L/dt$

$di_L/dt = -r_L i_L/L + v_r/L$ ....(1)

$i_C = -i_R$

$C\, dv_C/dt = -(C r_C\, dv_C/dt + v_C)/R$

$dv_C/dt = -v_C/C(R + r_C)$ ....(2)

Second state: (S_1 is OFF & D_1 is ON)

$dv_C/dt = [R/C(R + r_C)]i_L - [1/C(R + r_C)]v_C$ ...(3)

$i_L = C\, dv_C/dt + (C r_C\, dv_C/dt + v_C)/R$

$v_r = r_L i_L + L\, di_L/dt + (C r_C\, dv_C/dt + v_C)$...(4)

substitute (3) and (4)

$di_L/dt = v_r/L - [(r_C R/(R + r_C) + r_L)/L]i_L$

$- [R/L(R + r_C)]v_C$ ....(5)

Third states : (S_1 is OFF & D_1 is OFF)

$i_C = -i_R$

$C\, dv_C/dt = -(C r_C\, dv_C/dt + v_C)/R$

$dv_C/dt = -v_C/C(R + r_C)$ ....(6)

2.2 Control unit

The controller is intended to achieve an acceptable and quite simple regulation of the output voltage and also the current drawn from the distribution network

Close look at the integrated system shown in Fig.3, one can see that the fuzzy controller takes the mission of controlling the output voltage and the input current features in an interleaved strategy . This strategy has been done through the addition of its output (which is mainly designed to control the output voltage regulation) to weighted replica of rectified input voltage to produce a current reference from which the inductor current is subtracted to generate the inductor current correction action (which stands for controlling the shape and phase of input current). These mixed correction commands are translated into switching action by the pulse width modulation circuit (PWM) and fed to the power transistor whose role is to control energy flow in the inductor & the capacitor of the power circuit .

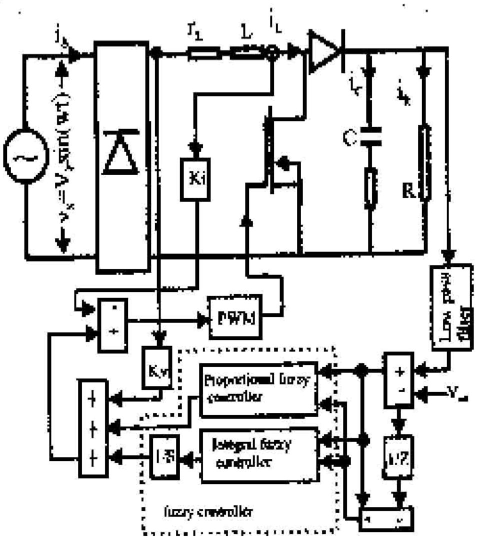

Fig.3: The whole circuit (power & control parts).

The input fuzzy variables of this controller along with their membership functions are shown in Fig.(4).

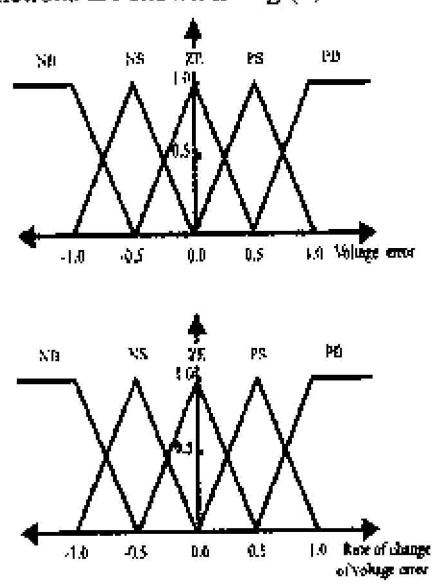

Fig.4:Membership functions for the controller inputs.

The crisp outputs of this fuzzy controller is tabulated in Tables 1& 2 and it is based on the following facts:

1-When the voltage error (Vout-Vref) is too large , the corresponding correction action should be too large also. For positive large voltage error, the duty ratio correction amount should be 1. For negative voltage error, the duty ratio correction should be (-1).

2-When the voltage error is equal or close to the required one, the control action should takes into account the status of the second input of the controller represented by the output voltage change (change of error).

3-No integral action under large voltage error. This is to avoid the occurrence of overshoot.

Table 1: Rules set for the proportional controller.

		Rate of change of voltage error				
		NB	NS	ZE	PS	PB
Voltage error	PB	-0.3	-0.35	-0.45	-0.65	-1.0
	PS	0.0	-0.1	-0.2	-0.35	-0.5
	ZE	0.2	0.1	0.0	-0.1	-0.2
	NS	0.5	0.35	0.2	0.1	0.0
	NB	1.0	0.65	0.45	0.35	0.3

Table 2: Rules set for the integral controller.

		Rate of change of voltage error				
		NB	NS	ZE	PS	PB
Voltage error	PB	0.0	0.0	0.0	0.0	0.0
	PS	0.0	-0.1	-0.2	-0.35	-0.5
	ZE	0.2	0.1	0.0	-0.1	-0.2
	NS	0.5	0.35	0.2	0.1	0.0
	NB	0.0	0.0	0.0	0.0	0.0

4-Simulation Results

To examine the validity and explore the performance of the presented controller, it has been applied to single phase boost AC / DC converter with simulation parameters tabulated in Table 3.

The integrated converter circuit has been tested under three loading conditions (Fig.5, Fig.6 and Fig.7).

Also it has been tested for step down changes in supply voltage (Fig.8 and Fig.9).

Fig.5 shows the inductor current , output voltage variation, combination of the supply voltage & current in addition to the duty ratio. As it is evident from Fig.5, very close to zero phase shift has been achieved between the supply voltage and current resulting in very close to one power factor. The output voltage variation is within ±1.5%. The current's shape is highly sinusoidal.

Fig.6 depicts that with five ohm increase in the load resistance, it also registers an output voltage variation with in ±1.5% but there is slight distortion around the zero crossing.

Fig.7 pictures what happen when the load resistance is reduced by 5Ω. It recites that the voltage variation is acceptable. It is less than ±2%. It is within the range ±1.7%. The figure also higlights the presence of the distortion in the vicinity of the zero crossing.

Fig.8 and Fig.9 display a dynamic behavior of the proposed controller. Fig.8 assures that, the proposed fuzzy dependent controller can easily bring the converter output voltage into the permissible range after the occurrence of step down in the supply voltage (the peak value of the supply voltage has been stepped down from 30√ to 25√ 2 volts).

Fig.9 summarizes the phase relationship between the supply voltage and its line current before and after the change occurrence. The result presents considerable improvement in the power factor and line current harmonic reduction.

Table 3: (Simulation parameters)

Inductance (L)	1mH
Inductor series resistance (r_L)	0.1Ω
Capacitance	4700uF
capacitor series resistance (r_C)	0.0Ω
Load resistance	25Ω
Supply voltage	30V/50HZ
Output voltage	60V
Switching frequency	100KHz

5-Comparasion with related works

Asaad Selim Alsheraida [4] prpoposed a single phase boost rectifier converter controlled by PI controller. This approach gives reasonable values of power factor and THD for the operating point for which it has been designed, but if the output power is varied, new setting of the inductor current gain should be used.

P. Mattavelli , et al.[10] proposed a PI fuzzy logic based controller in which the sinusoidal current reference is internally generated by multiplication of the rectified input voltage with scale factor calculated by the fuzzy controller. This approach gives a sinusoidal input current (with some distortion) but it requires multiplier in addition to an extra calculations to determine the current reference scale factor.

The current work is characterized by its simplicity and its ability of achieving the goals of high power factor and low THD values for a range of output powers.

6-Conclusions

The use of the fuzzy logic based controller for the control of the shape and phase of the current drawn by the single phase AC/DC boost converter has been studied . The study had been done under three different loading conditions in addition to one at which the supply voltage had been stepped down to check its dynamic behavior. The results were satisfactory and pinpointed the capability of the mathematically less dependent fuzzy controller in keeping the converter output voltage, input current phase, and input current shape within the standards.

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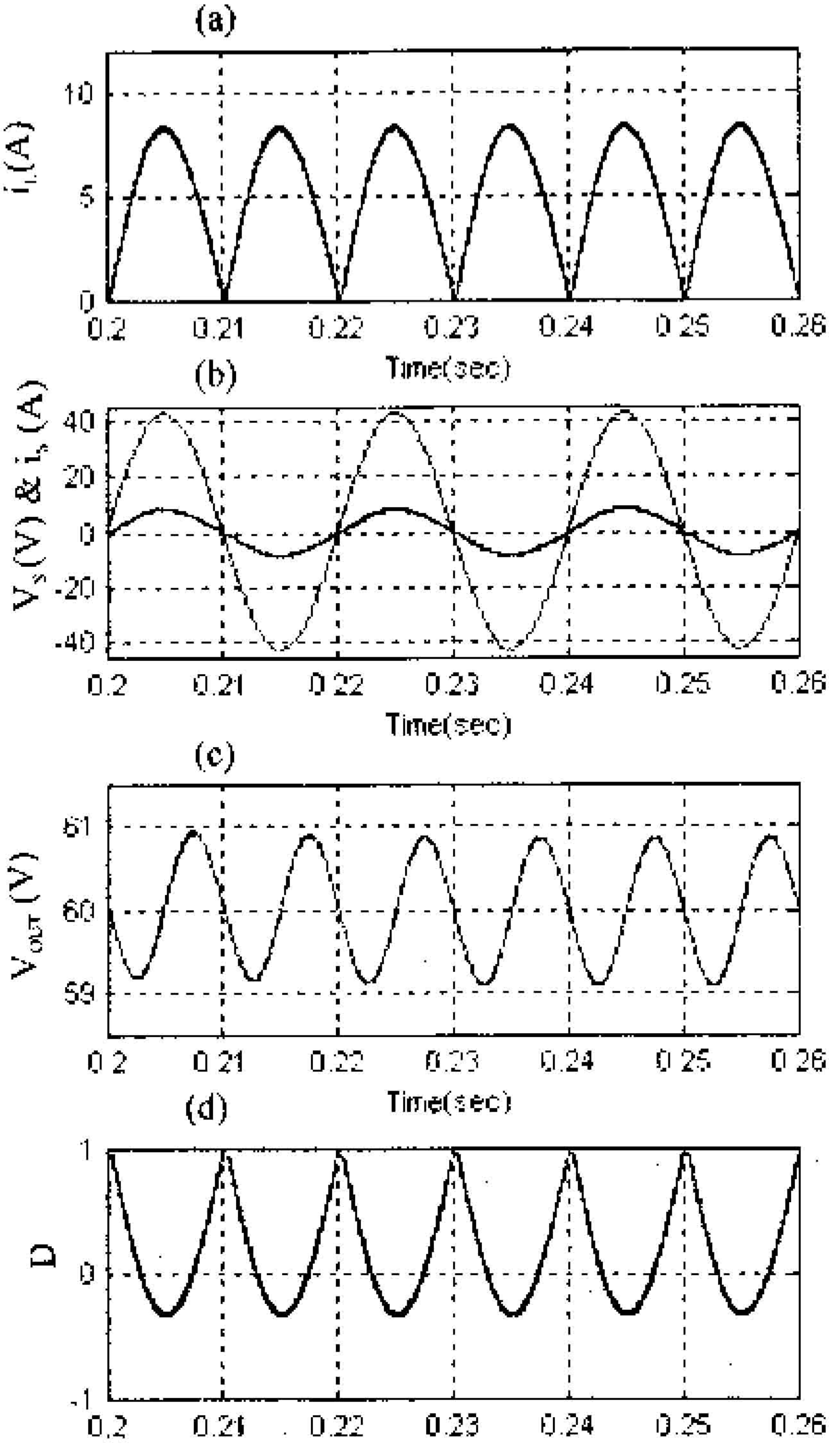

Fig.5 : Steady state response under load resistance of 25 Ω and input voltage of 30V/50Hz
a: Inductor current b:Line voltage & current
c:Output voltage d:Duty ratio

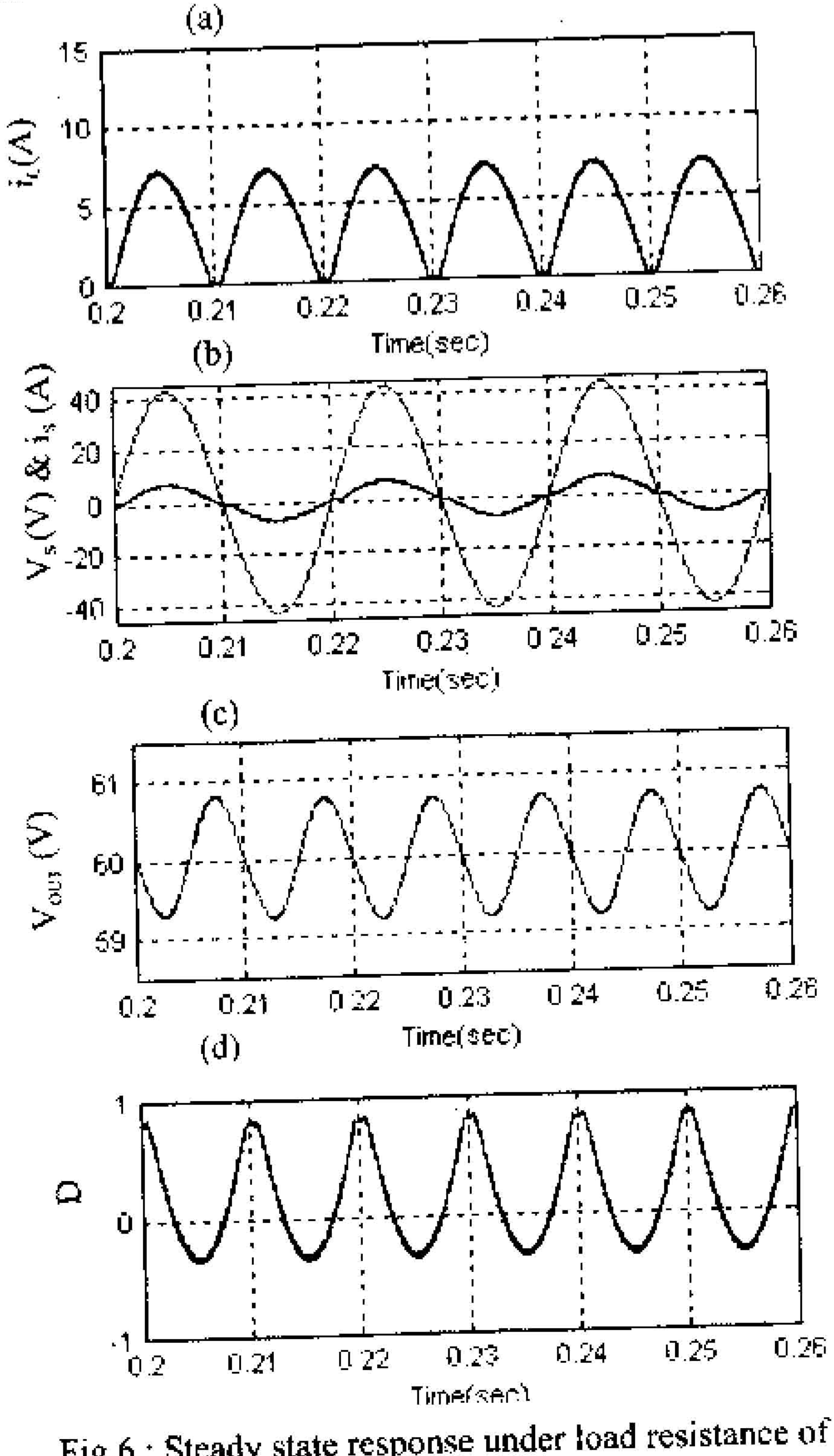

Fig.6 : Steady state response under load resistance of 30 Ω and input voltage of 30V/50Hz.
a:Inductor current b:Line voltage & current
c:Output voltage d:Duty ratio

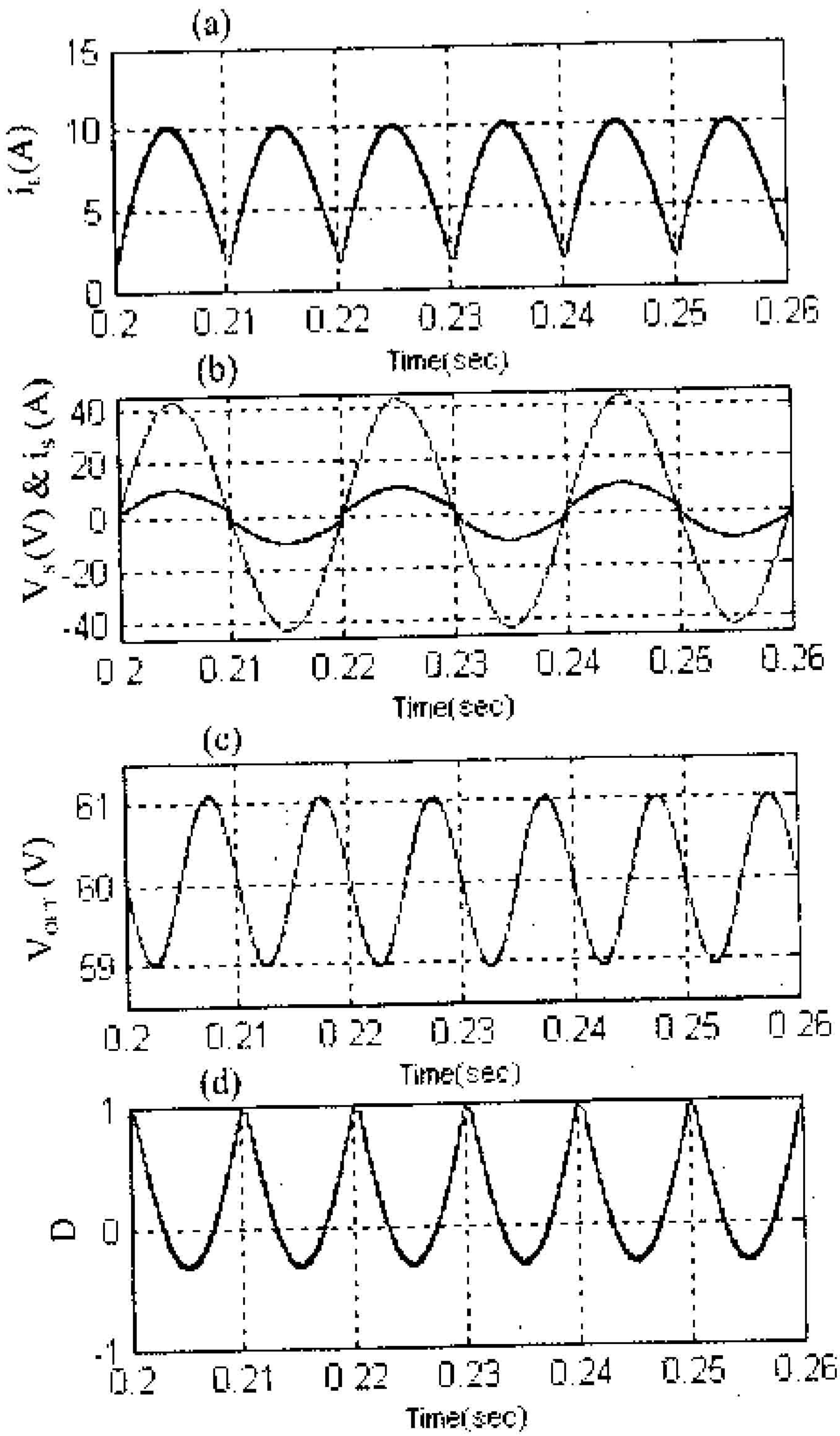

Fig.7 : Steady state response under load resistance of 20 Ω and input voltage of 30V/50Hz
a:Inductor current b:Line voltage & current
c:Output voltage d:Duty ratio

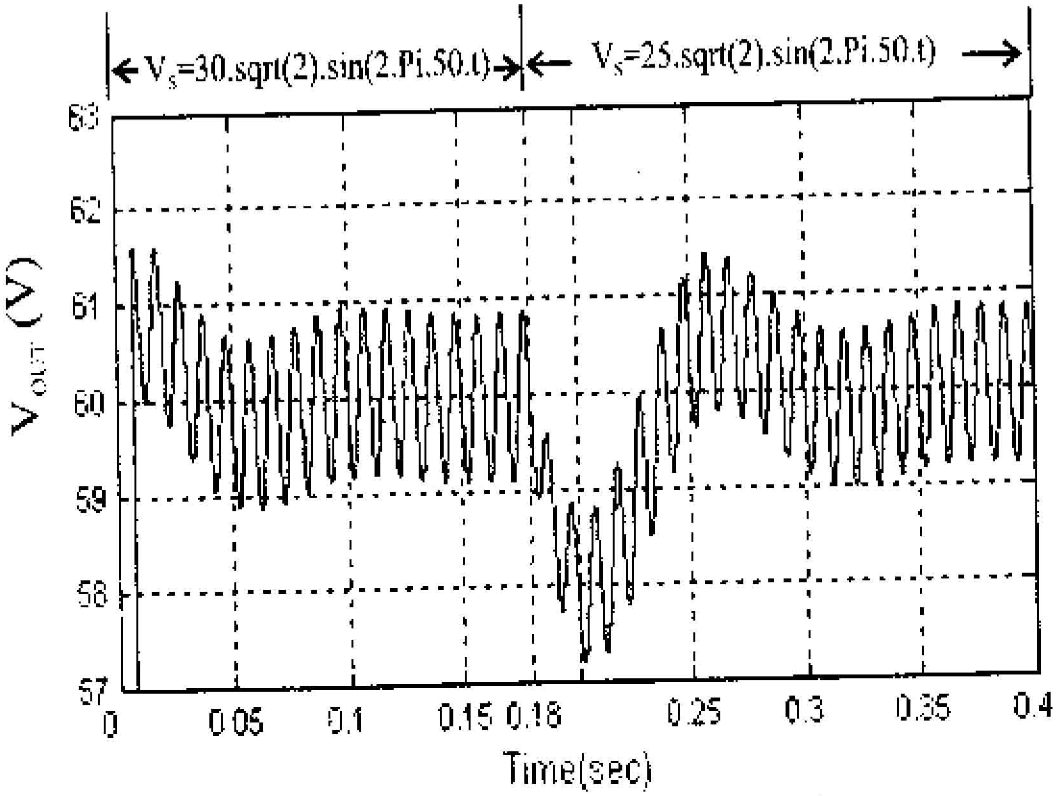

Fig8: Output voltage response under supply voltage step responses

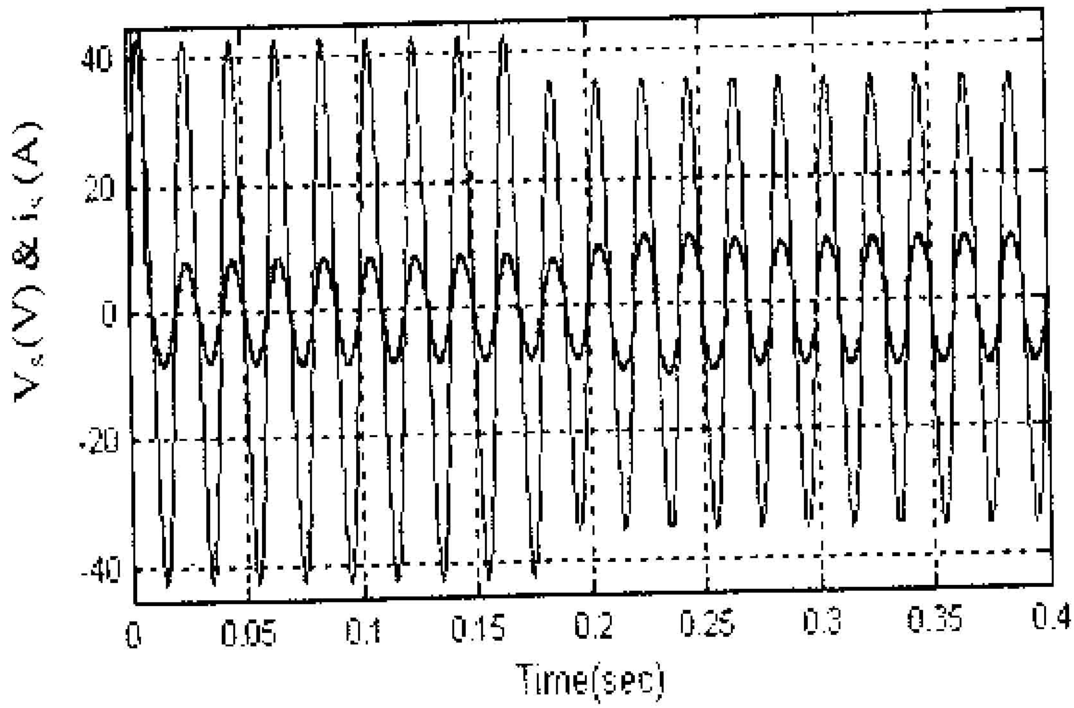

Fig9: Input voltage and current responses