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Mathematical Modelling and Representation of DC to DC Converter (Buck Converter)

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I. INRODUCTION

The switched mode dc to dc converters are one of the easiest power electronic circuits which convert voltage to one level into another level by its own switching action. These converters have covered wide areas of Power-electronics, due to their various applications like power supplies for personal computers, office equipment's, industrial applications, DC drives, automotive, aircraft, etc. Control and stabilization of converters by their switching phenomenon are the main factors.

Simple as well low cost and easily maintainable structure is always in demand for industrial and high performance applications. Every control method has some advantages and drawbacks though considered as a suitable control method under some specific conditions like control philosophy, Output value variation to some extent, compared to other control methods. So, the method that gives the best performances under any conditions is always in demand.

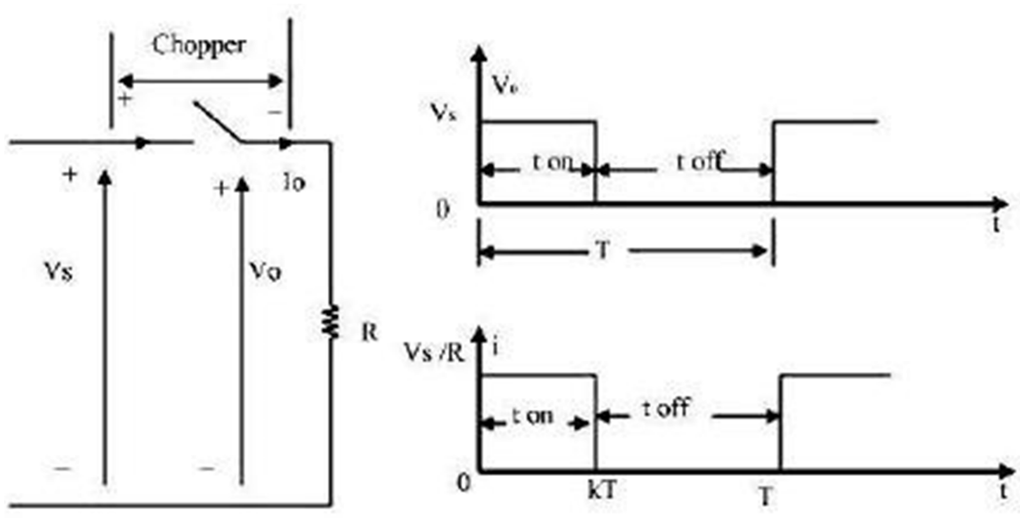
Dc-dc converters can be operated either in continuous conduction mode (CCM) or in discontinuous conduction mode (DCM). These converters operated in DCM, provide faster transient response (As its low inductance) at the expense of higher device stresses. It also presented a fixed frequency PWM based sliding mode controls operating in DCM. Buck converter when operated in CCM, gives a continuous output current, with very smaller current ripple and low switching noise. Continuous Conduction operation is usually preferred for large current applications, because it can deliver more current than the converter operating in DCM. However, a DCM converter has also much faster transient response and a loop gain that is easier to compensate than a CCM converter.

Hence, for fulfill of both the requirements, a new converter that combines the advantage of both CCM and DCM converters is developed. Converters operate in a new operation mode-the pseudo CCM.

II. PRINCIPLE OF CHOPPER OPERATION

CHOPPER is a high speed on or off semiconductor switch. A constant dc supply of magnitude (Vs) is given as input voltage and let its output voltage across load be (Vo)[fig 2(i)].

During the period (Ton), chopper is on and load voltage is equal to source voltage (Vs).During the period (Toff), chopper is off, load voltage is zero. By this manner a waveform [fig2 (ii)] is maintained sequentially.



(a) Circuit (b) Waveforms

Fig 2(i) Fig 2(ii)

Average voltage (Vo) = (Ton/ (Ton+Toff))*(Vs)
= (Ton/T)*(Vs)
= f*Ton*Vs
[Ton=on time, Toff=off time, T = Ton + Toff = chopping period, f = chopping frequency, Ton/T = duty cycle]
By varying duty cycle we can use different control strategies like 'timeratio control' and 'current limit control'.
Here we have done this only on buck converter or step down converter. Thename is step down because of the output voltage (Vo < Vs), whatever the output voltage is that is less than the input voltage.

A. The Dc-dc Buck Converter

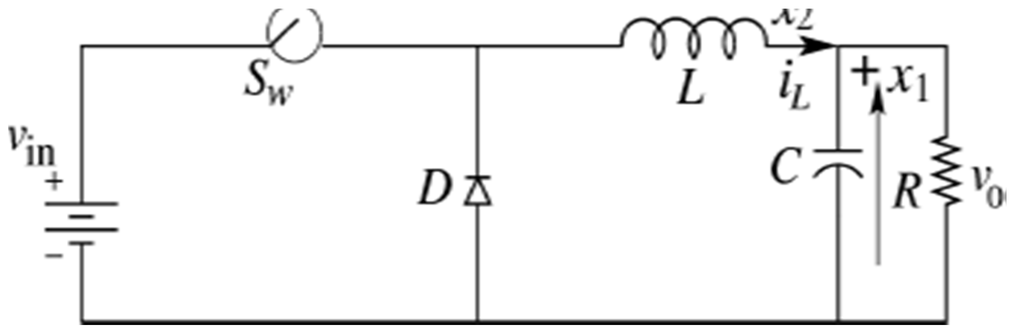


FIG-2.1(i)

B. Working Of Buck Converter

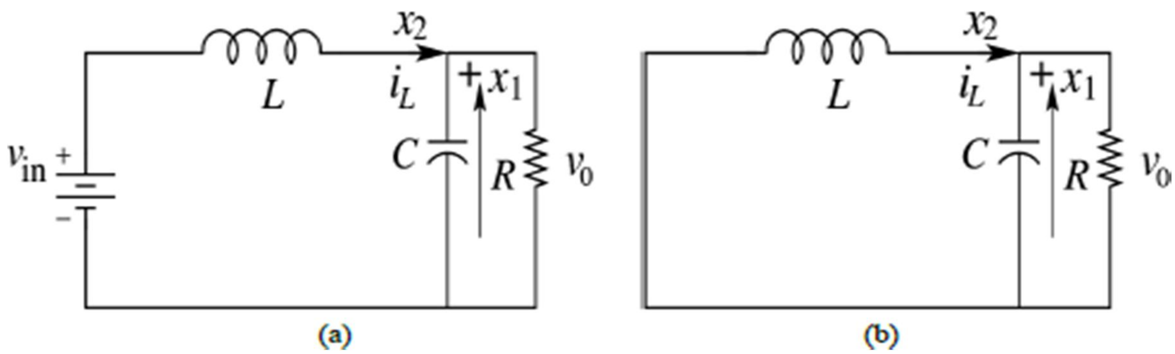


FIG-2.1(ii) chopper switch on FIG-2.1(iii) chopper switch off

In the fig 2.1(ii) the chopper switch is on (closed), that's why it becomes short, and the diode does not work in this case.
In fig2.1 (iii) only the diode works due to the energy storing element (inductor) present in the circuit.

III. MODES OF CHOPPER OPERATION

A. Continuous Conduction Mode

When the inductor current flow is continuous of charge and discharge during a switching period, it is called Continuous Conduction Mode (CCM) of operation. The converter operating in CCM delivers larger current than in DCM.
In CCM, each switching cycle consists of two parts. During, inductor current increases linearly and then in it ramps down i.e. decreases linearly.

B. Discontinuous Conduction Mode

When the inductor current has an interval of time staying at zero with no charge and discharge then it is said to be working in Discontinuous Conduction Mode (DCM) operation and the waveform of inductor current is illustrated.
At low load currents, converter operates in DCM. The regulated output voltage in DCM does not have a linear relationship with the input voltage as in CCM. In DCM, each switching cycle is divided into of three parts.

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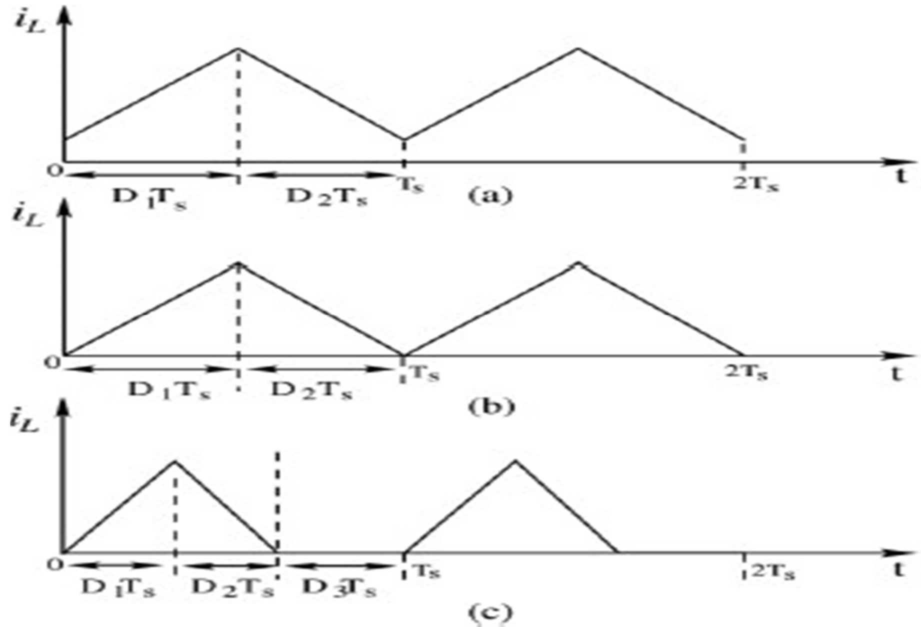

FIG-3.1(i) switching cycle

In this fig the continuous and discontinuous operation is there.in (a) section it is continuous, after the increasing of current it directly ramps down.

In (c) section this is discontinuous because there is time staying at zero.

C. Control Strategy For Duty Cycle

There are various control strategies for varying duty cycle. They are time ratio Control and current-limit control.

In time ratio control α is varied by two ways constant frequency method and variable frequency method. In constant frequency method 'f' remains constant and Ton is varied. This scheme is also called pulse-width-modulation scheme. In variable frequency method 'f' varies and either T-on or T-off is kept constant. This method is also called frequency modulation scheme.

In current-limit control scheme, the switching of chopper circuit is decided by the previous set values of load current. The two set values should be maximum load current and minimum load current. When the load current reaches the value more than maximum value of load current then chopper is switched off and it falls below minimum value, the chopper is switched on. Here Switching frequency of chopper is controlled by setting maximum and minimum level of current. Current limit control also involves feedback loop and therefore the trigger circuit for the chopper becomes more complex .PWM technique is the most common control strategy for the power control in chopper circuit.

We will implement here pwm technique by software mathematical block. Here the total frequency remains in constant and the Ton period is varied. So as a result of that duty cycle also varies. So we can use this method.

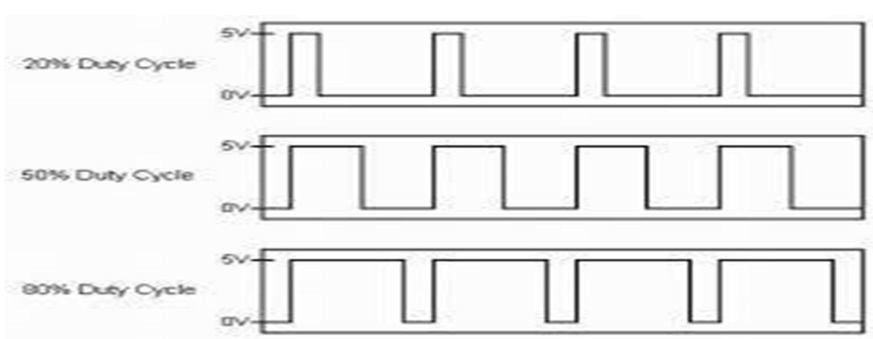

Fig 3.2(i) duty cycle variation

Duty cycle variation in pwm [fig 3.2(i)]. The total time-period remains in constant in every case. Only duty cycle varies.

We will implement now some matlab block about chopper and will see its related output.

IV. SOFTWARE & HARDWARE WORK

A. *Chopper Output Using Pulse Generator*

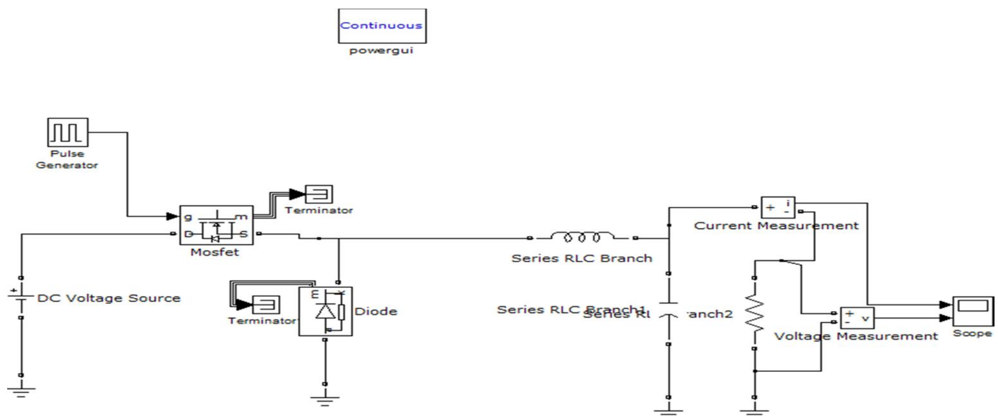

Fig4.1 (i) matlab simulation of chopper output using p.g.

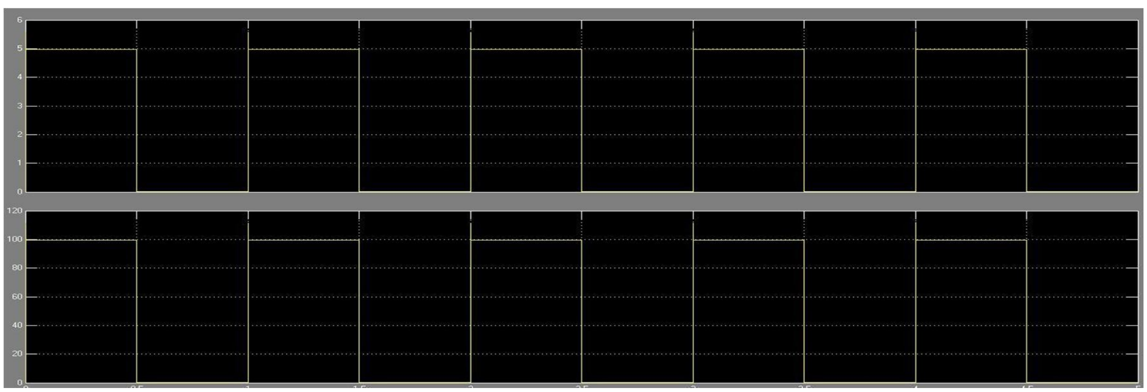

Fig 4.1(ii) Related output of voltage & current respectively

B. *Chopper Operation Using PWM*

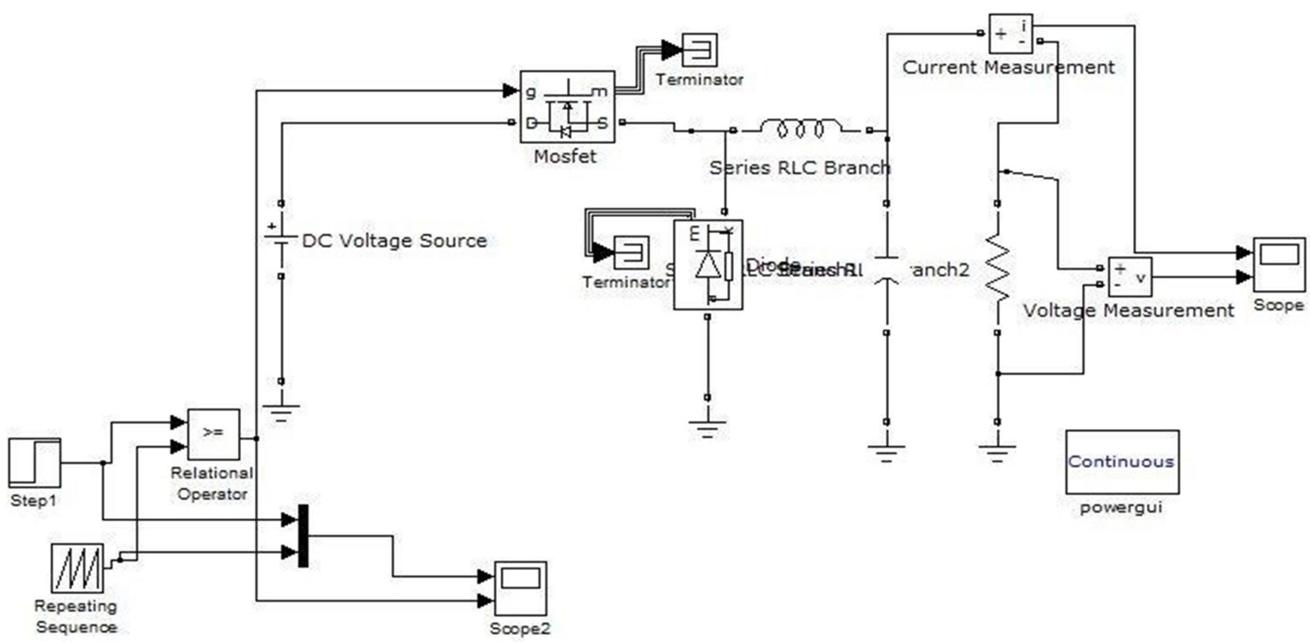

Fig 4.1(iii) matlab simulation of chopper using pwm

C. Related Outputs

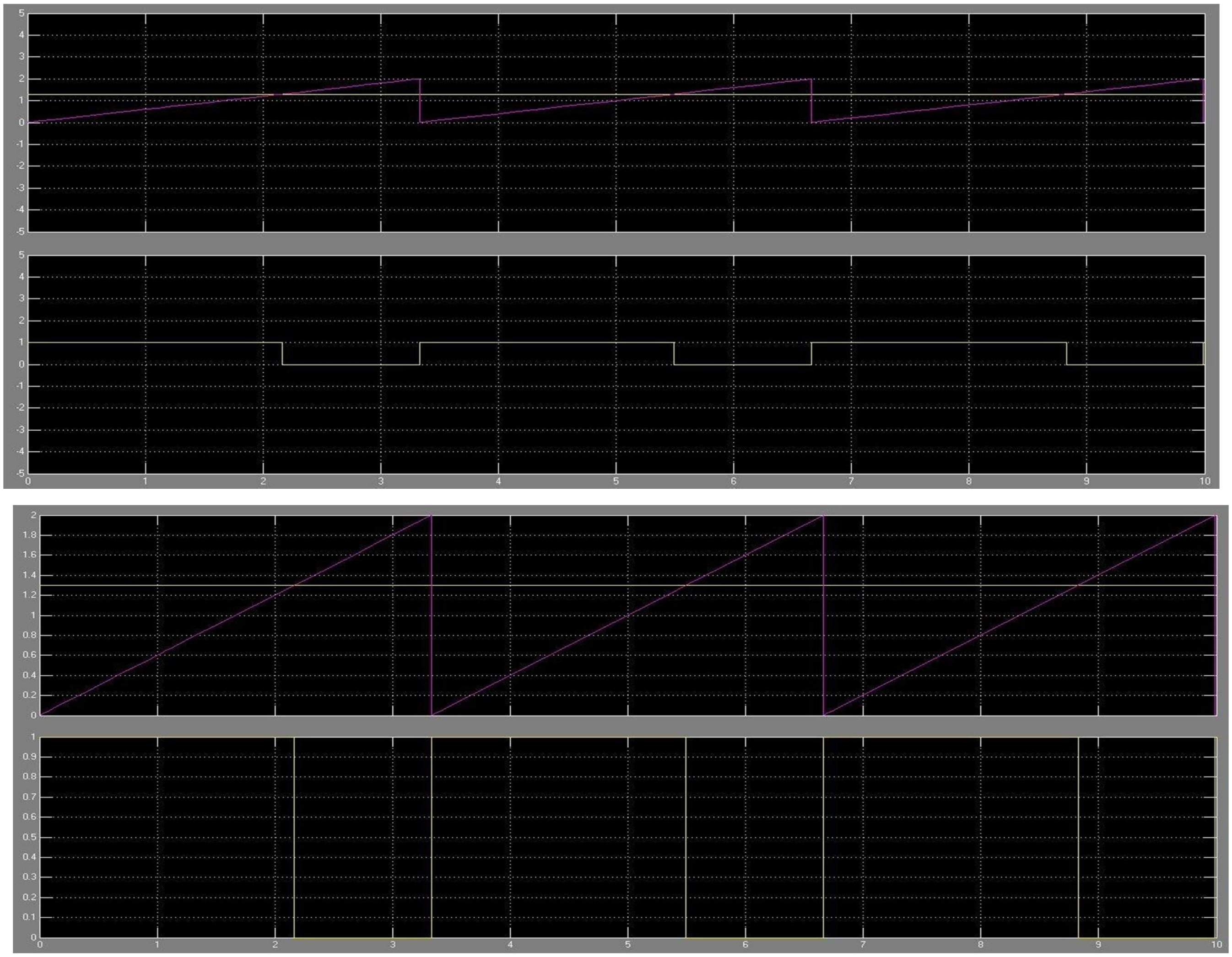

Fig 4.1(iv) making pwm wave

Till now the work as on open loop configuration. If we want to analyze the closed loop operation then feedback loop is required it may be voltage or current feedback.

The voltage mode controlled buck converter is made in matlab block:-

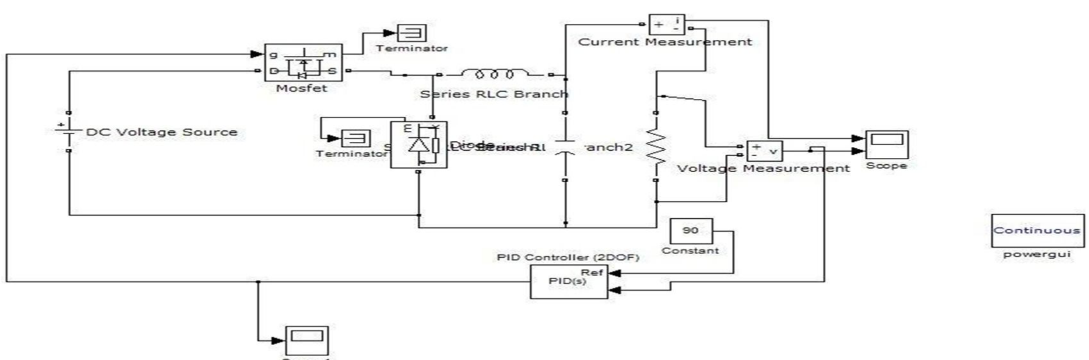

Fig4.1 (v) matlab simulation of closed loop buck converter

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There is one feedback is connected. It is closed loop operation of chopper.
PID block is used also in feedback circuit.

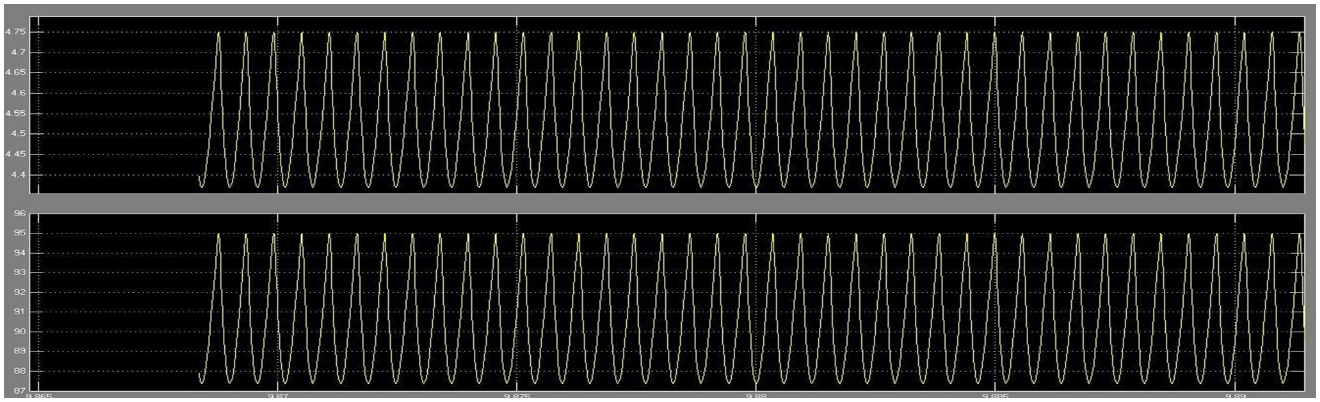

Fig 4.1(vi) Output of voltage & current in closed loop.

Some hardware operation is also done to enlarge its future scope, applications thoroughly.
To made it in hardware different components have been used as per requirements. To make pwm first of all we have to make square wave then triangular and at last we can get pwm wave.
Simple bread-board circuit is done. Op-amp, timer is used in stepwise to make pwm wave & at last practical chopper circuit is made and here as switching device mosfet is used. As a gate pulse of mosfet we use the pwm wave and see the chopper output. Voltage source is given by battery supply. DSO is used for checking the output waveform.
Some hardware output is given to understand the concept.

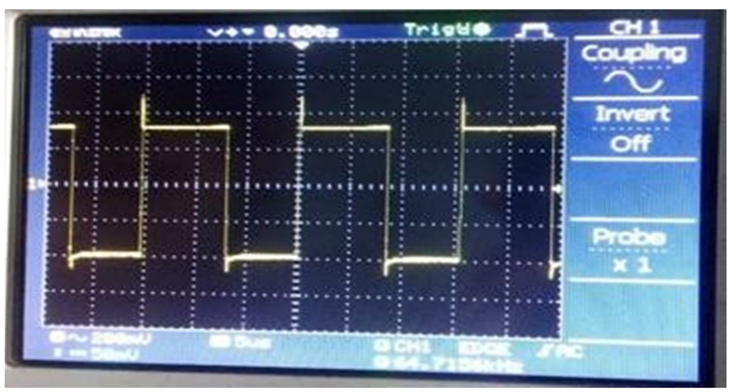

Fig 4.1(vii) Square wave in hardware

Fig 4.1(viii) Pwm wave in hardware

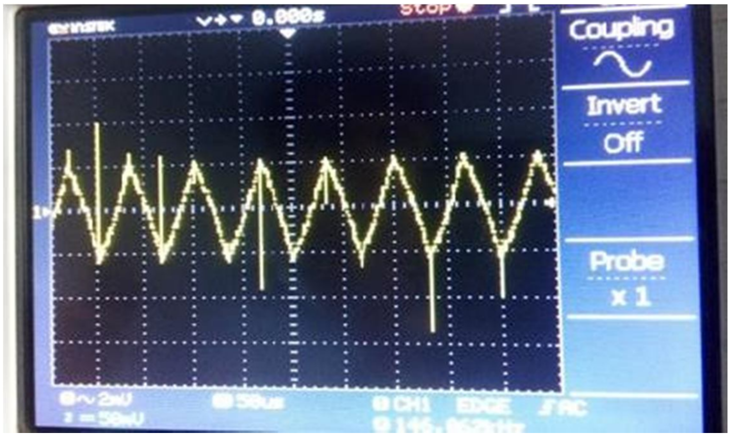

Fig 4.1(ix) Chopper output

The software and hardware waveform is quite same. we have done this work in only buck converter and using pwm technique. In case of closed loop operation voltage controlled operation is done.

V. FUTURE SCOPE

A. This analysis can help to make closed loop operation of chopper as per application.
B. It can help to control the speed of dc motor.
C. PWM technique is reliable so it can have wide applications.
D. In many more practical application where speed control or low voltage output or control action is required this analysis can help.

VI. CONCLUSION

A. We have done practical chopper circuit using MOSFET as a switch.
B. We have described some control strategies of chopper such as time ratio control and current limit control.
C. We controlled the gate of MOSFET by giving PWM as well as square wave, have done mathematical modeling as well as hardware.
D. To implement the software we used Matlab 7.5.
E. To do hardware works we used different components, bread-board, dso. This analysis will help in many applications.

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