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PWM Based Voltage Commutated Chopper with Active & Passive Loads Simulation Based Study

N. R. Samal, Professor, Department of Electrical Engineering, Orissa Engineering College, Bhubaneswar, India. Email: nayan15_samal@yahoo.co.in

Abstract: This paper describes a simulation study on PWM based voltage commutated chopper with active and passive load. In this study, pulse width modulation control scheme is implemented for obtaining better response .The simulation studies are carried out at a chopping frequency of 263 Hz. The output obtained from these studies are verified and compared with theoretical as well as hardware based experimental results. The response obtained from this study is better and quite impressive for passive and active load. The simulation is performed using SIMULINK environment of MATLAB 7.5 software.

Keywords: Switch mode power supply (SMPS), Voltage commutated chopper, Power Quality, Pulse width modulation (PWM).

I. Introduction

On account of rapid transit systems, choppers are widely used all over the world. Converting the unregulated DC input to a controlled DC output with a desired voltage level is an important issue in power electronic engineering. .A chopper is a static power device which is used to obtain a variable dc voltage from a constant dc voltage source. This device is dc equivalent of ac transformer [1]. As the choppers perform dc to dc conversion in one stage they are efficient and compact. The conversion of a fixed dc voltage to an adjustable output by using a controlled switch is known as chopping. A chopper is also known as dc-to-dc converter. A chopper system offers greater efficiency, faster response, lower maintenance, smaller size and smooth control.

Conventionally, a variable dc voltage was obtained from a fixed dc voltage by potentiometer method or by motor generator set method. In the former method, a variable resistance was used in between the fixed voltage dc source and the load. The input dc voltage is connected at the two fixed terminal of potentiometer and the load is connected at the fixed end from one side and to movable terminal of the potentiometer [2]-[4]. This method is some drawback of high energy losses in the resistance and consumes supply power. In motor generator set method a variable dc output voltage is obtained by controlling the field current of the dc generator but this method is buckly,costly,slow response and less efficient. Now a day's power controlled switches are like thyristor, MOSFET,IGBT are used for converter circuits. As the conversion in chopper is performed by switching action, the power is lost during the switching action only. Choppers are widely used in trolley cars battery operated vehicles, traction motor control, control of large number of dc motors, etc traction motor control, control of large number of dc motors, etc[5]-[7]. Applications of dc to dc converter are associated with Switched-mode power supply (SMPS), DC motor control, battery Charger

II. Control Strategies

The output dc voltage can be varied through duty ratio by opening and closing the devices periodically. In order to change the duty ratio, time ratio control and current limit control are being implemented. Time Ratio Control is realized in two different categories, one is constant frequency system and other is variable frequency system

Pulse Width Modulation (PWM)

This method is also known as constant frequency system. In this method T_{on} is varied keeping chopping frequency f & hence, chopping period T is constant. This system is generally used for power control in chopper circuit.

Frequency Modulation (FM)

This method is also known as variable frequency system. In this method, chopping frequency f & hence, chopping period T is varied but either T_{on} or T_{off} is kept constant. .

To obtain full output voltage range, frequency has to be varied over a wide range. This method produces harmonics in the output and for large *tOFF* load current may be come discontinuous

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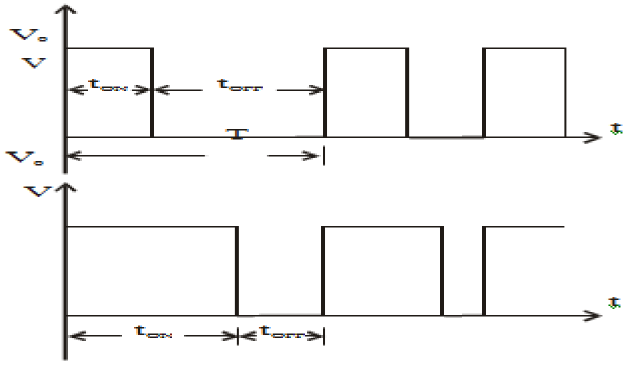

Fig.1(a) Pulse width modulation Waveform

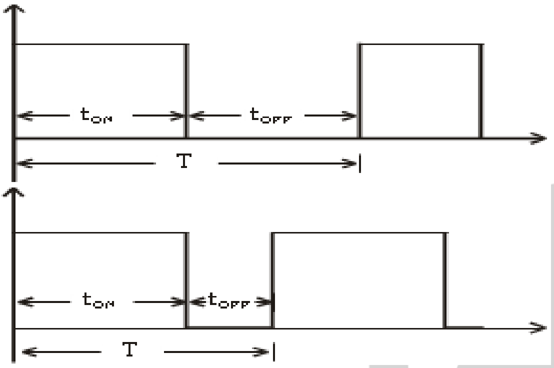

Fig.1(b) Variable frequency waveform

III. Overview Of Voltage Commutated Chopper

This Chopper is generally used in high power circuits where load fluctuation is not very large. This Chopper is also known as parallel- capacitor turn-off chopper, impulse-commutated chopper, classical chopper, henman's chopper or oscillation chopper. The chopper circuit in which output voltage is less than input voltage is called step-down chopper or buck converter.

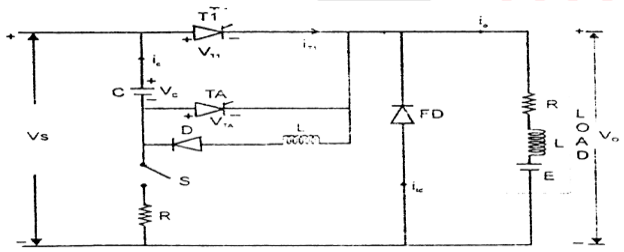

Fig.2 Circuit diagram of voltage commutated chopper with RLE Load

The output voltage can be varied by changing the duty ratio α, which can be accomplished by changing the pulse width of gate pulse block. The average output voltage for buck chopper is

$$V_{out} = \frac{T_{on}}{T} \times V_s = \alpha V_s \qquad (1)$$

Similarly, the average output voltage for step up or boost chopper is

$$V_{out} = \frac{V_s}{1-\alpha} \qquad (2)$$

The figure shows the power circuit diagram for this type of chopper. In this diagram, thyristor TI is the main power switch. Commutation circuitry for this chopper is made up of an auxiliary thyristor TA, capacitor C, and inductor L. FD is the freewheeling diode connected across the RLE type load. Working of this chopper can start only if the Capacitor C is charged with polarities as marked in figure This can be achieved in one of the two ways as under: Close switch S so that capacitor gets charged to voltage V_s through source V_s, C, S and charging resistor R. Switch S is then opened. Auxiliary thyristor TA is triggered so that C gets charged through source V_s,C, TA and the load the charging current through capacitor C decays and as it reduces zero, $V_c = V_s$ and TA is turned off. Assumptions for this chopper are (i) load current is constant. (ii) thyristors and diodes are ideal switches. For convenience, the chopper operation is divided into certain modes and is explained as under: Mode I operation (0 <t < t1), At the end of the model I at t = t_1; $i_c = 0$, $V_c= V_s$, $V_{TA}= V_s$, $V_0 = V_s$ Model II operation $t_1 \leq t \leq t_2$, In mode II operation only main SCR T_1 is conducting i.e. i_c=0, $i_{T1}= i_0$, $V_c = V_s$, $V_{TA} =V_s$, $V_0 = V_s$, i_D=0. Model III operation $t_1 \leq t \leq t_3$, In this mode, V_c and V_{TI} change linearly from ($-V_s$) at t_2 to V_s at t_3, since load current I_0 is assumed constant. Similarly, V_0 changes linearity from $2V_s$ at t_2 to zero at t_3.Mode IV operation, during this mode, i_c =0, i_{TI}=0, $I_{fd}=i_{on}$ $V_{TI} = V_s$; $V_c = V_s + \Delta V$, V_o=0, i_{T2}=0. At t = T, the main SCT T1 is triggered again and the cycle as described form t = 0 to t = T repeats. Voltage commutated chopper is very simple chopper circuit, it is therefore widely used. However, if suffers form the following disadvantages.

I. A started circuit is required, and the starting circuit (logic circuit) should be such that it triggers auxiliary SCT TA first.

II. At the commutation occurs, the load voltage rises to twice the supply voltage ($2V_s$)

III. The circuit imposed turn-off time is load dependent. At very low load currents, the capacitor takes longer time to discharge thus limiting the frequency of the chopper.

IV. This circuit does not work at no load conditions, because, at no load, capacitor would not get charged from – V_s to V_s when auxiliary SCR, T_A is triggered for commutating the main SCR TI.

V. The main SCR T1 has to carry the load current as well as the commutation current.

The designed value of commutating components C is based on the turn-off time (t_c), of the main SCR T_1 and is given by

$$C = I_0 \frac{(t_{off} + \Delta t)}{V_S} \qquad (3)$$

Similarly, commutation Inductor L is based on the peak value of the capacitor current i_c, which flows through T1 when it is triggered, and the time (t_1-t_0) during the which the capacitor current i_c pulse lasts.

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$$L \le \frac{0.01T^2}{\pi^2 C} \qquad (4)$$

TABLE 1 PASSIVE LOAD PARAMETERS FOR SIMULATION

SL.No	Specifications	Rating
1	Resistance	R=145 ohm
2	Inductance	L= 170 mH

TABLE II - ACTIVE LOAD PARAMETERS FOR SIMULATION

SL.No	Specifications	Rating
1	Terminal Voltage	V_t = 180 volts
2	Armature Speed	ω_m = 175.4 rad/sec
3	Armature Resistance	R_a = 3 ohm
4	Armature Inductance	L_a = 56 mH
5	Field Resistance	R_f = 785 ohm
6	Induced emf constant	K_b = 1.0148 v/rad/sec
7	Total friction constant	B_t = 0.004Nm /rad/sec
8	Moment of Inertia	J =0.001 Kg. m^2
9	Supply to Motor field	V_f =220 V
10	Armature current	I_a =5.1 Amp
11	torque at full load	T_a =5.23N.m

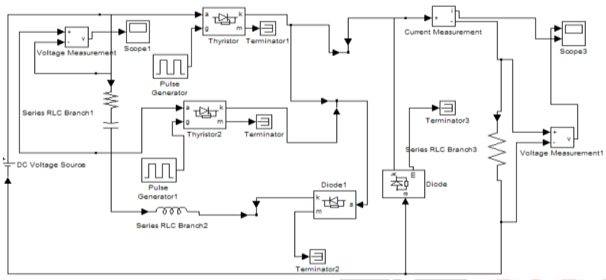

Fig. 3 Simulink diagram of voltage commutated chopper with passive load

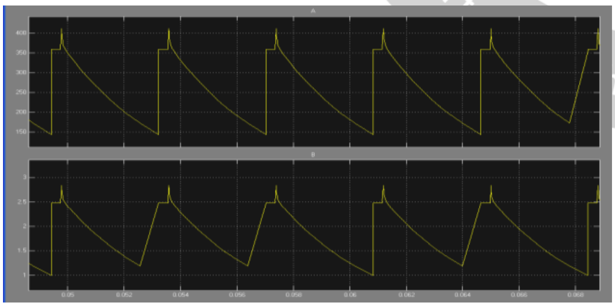

Fig.4. Waveform of Output voltage V_o and output current $I_o$of VCC with R-load at f_{sw}=250Hz

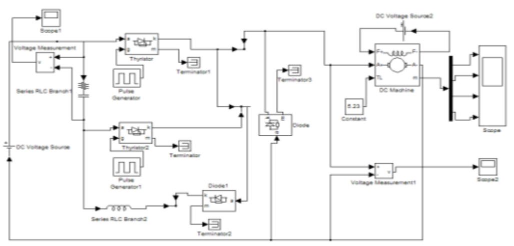

Fig.5 Simulink diagram of voltage commutated chopper

with motor load

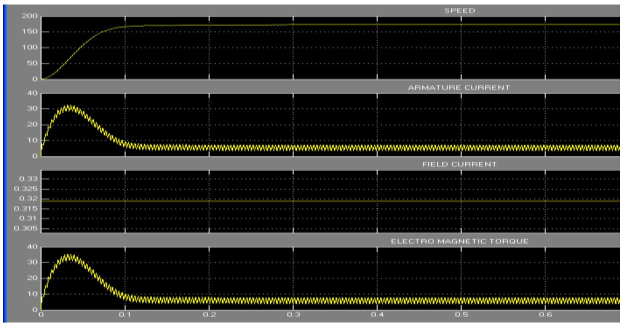

Fig.6. Waveform of motor speed, armature current, field current and torque of motor load at f_{sw}=250Hz

IV. Simulation Results And Discussion

In this simulation study, the PWM control scheme has been applied to voltage commutated chopper by considering active and passive load to investigate the better simulation results. The results obtained from the simulation approaches have been compared with theoretically developed results and hardware based experimental results. The software has been written in MATLAB-7.5 language and executed on a 2.3-GHz Pentium IV personal computer with 512-MB RAM. The optimal parameters setting of resistive and separately excited dc motor have been applied to obtain better simulation response. The following parameters are judiciously chosen for obtaining better results. The value of resistance and inductance are chosen as 145 ohm and 170mH respectively for passive load while the different parameters for active load are presented in Table II.

Description of the Test Systems

Initially, the PWM control technique is applied on voltage commutated chopper by considering the resistive load. The chopping frequency is considered as 163 Hz for obtaining better output response. Table I indicates parameters of passive load while the Table II indicates details specification of active load. The output results of voltage commutated chopper for passive load are shown in Table III. It is seen from Table III that the output voltage and output current are better response in simulation as compared with hardware based results. The simulation time is taken as 90 seconds. Similarly, the output results of voltage commutated chopper for motor load are shown in Table IV. It is seen from Table IV, that the output voltage and output current are better response in comparison to hardware based results. The simulation time is considered as 120 seconds. Fig.1 (a) shows the Pulse width modulation waveform while fig.1(b) depicts variable frequency waveform. Circuit diagram of voltage commutated chopper with RLE Load is represented in fig.2.

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TABLE III OUTPUT RESPONSE OF VOLTAGE COMMUTATED CHOPPER FOR PASSIVE LOAD

S.N	Resistance (ohm)	Chopping frequency (Hz)	From Theoretical result		From Hardware based Experiment		From Simulation response	
			V_0 (volt)	I_0 (amp)	V_0 (volt)	I_0 (amp)	V_0 (volt)	I_0 (amp)
01	145	263	250	1.74	250	1.62	250	1.73

TABLE IV OUTPUT RESPONSE OF VOLTAGE COMMUTATED CHOPPER FOR ACTIVE LOAD

S.N	D.C. Motor load	Chopping frequency (Hz)	From Theoretical result		From Hardware based Experiment		From Simulation Response	
			V_0 (volt)	I_0 (amp)	V_0 (volt)	I_0 (amp)	V_0 (volt)	I_0 (amp)
01	25% of full load	263	180	1.21	180	1.26	180	1.29

Simulation diagram of Voltage commutated chopper with passive load is seen in fig. 3. Waveform of output voltage V_o and output current I_o of VCC with R-load at fsw=250Hz are shown in Fig.4.Similarly fig.5 indicates simulation diagram of voltage commutated chopper with motor load while fig.6. addresses the waveform of motor speed, current, and torque of motor load at f_{sw}=250Hz

V. CONCLUSION

A simulation study is performed for voltage commutated chopper by considering resistive and separately excited dc motor or active load by using PWM scheme .The basic objective of the PWM scheme is to obtain fast response to changes in torque in motor load. It is shown that the PWM scheme gives faster transient response to torque changes. The ripple content in the resulting torque can be minimized by further refining the tuning parameters of motor load. The discharging and charging time of commutation capacitor are dependent on the load current and this limits high frequency operation, especially at low load current.

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