Simulation and Study of a Chopper Fed DC Motor with and without an Inductive Smoothing Coil

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***Abstract*—**Modeling and simulation of a DC motor driven by a series chopper is given in this study.

DC motor is driven by a step down chopper. DC source is used to supply the chopper.

The effect of utilizing a smoothing coil on the control system and the motor performance is analyzed in both cases.

The study covers the main modes of motor operation such as the transient state and steady state, at two cases. Finally simulation results are analyzed and compared for both modes.

***Keywords*—**Choppers, Inductive coil, DC. Motors, DC. Motors drives.

I. Introduction

IN practical applications and industrial very often need arise to convert a DC voltage to Variable Voltage DC source by using DC choppers:

A *dc chopper* is a dc-to-dc voltage converter. It is a static switching electrical device that in one conversion, changes an input fixed dc voltage to an adjustable dc output voltage with inductive intermediate energy storage. The name chopper is connected with the fact that the output voltage is a 'chopped up' quasi-rectangular version of the input dc voltage.

Choppers are used extensively in traction engines that are used in electric vehicles and other applications such as DC Voltage Regulators and Trolley cars.

Choppers provide the possibility of a rapidly smooth control of the machines, and a smooth dynamic response. This feature appears in the transportation systems where there is frequent-time stop page.

Fig 1 below illustrates control stages for chopper drive the DC motor.[1].

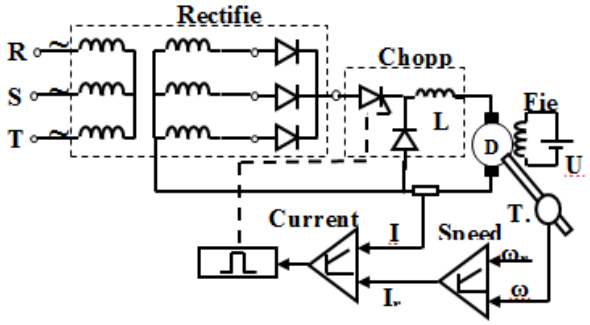

Fig. 1 General structure of the chopper fed Dc motor

The proposed chopper system consists of:

1- Step-down chopper using thyristors type GTO/Diode.[3]

2- Generated pulses driving thyristor control circuit which generates pulses that drive the thyristor with a frequency and frequency depending on the speed signal and motor current.

3- The chopper with the motor and motor drive circuit are simulated using simulink tool and the supply of the chopper is simulated as a battery source.

4- In practice normally we use a 3phase source and 3phase Rectifier Bridge in order to get 340v DC, where:

ψ= Triggering angle

To make a comparison between the results of modeling in all cases study and demonstrate the impact of inductive on the performance of choppers is following stages:

- Make simulation for drive system when supply the chopper from battery 280v
- The simulation for drive system when two cases the first one the presence of inductive 0.01H and second one without.
- With indicating the effect on the chopping frequency, and thus the current and voltage given to motor load from the source.

As shown in Figure (2) block diagram, which has a full simulation for both cases:

Chopping frequency control and therefore the current drawn by the motor through the stages of operation {starting stage, rotation nominal speed stage, Loading stage and then return to the nominal rotation speed} Is by speed controller Which compares the real speed (ωm) with the reference motor speed (ωref), so that the output is current reference signal (Iref) and depends on the model of (PI) controller.

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The Current Controller compared to the real current drawn by motor with the current reference (Iref), which was generated by speed control show in fig 2.

Current controller input has real current signal and reference current signal , the output of them is signal to control the time on-off chopper. We control the frequency of chopper by change hysteresis band.

Differential Equations

$$V_a = e_a + i_a R_a + L_{aq}\frac{di_a}{dt} + V_{bru} \quad , e_a = K_a \phi \omega_m \quad (V)$$

$$V_f = i_f + L_{af}\frac{di_f}{dt} \quad ; \quad R_f = R_{ff} + R_{sh}$$

$$P_e = \omega_m \cdot T_{em} = e_a \cdot i_a$$

$$T_{em} = \frac{P_e}{\omega_m} \quad , \quad T_{em} = K_b \cdot i_a$$

$$J\frac{d\omega_m}{dt} + B_m \cdot \omega_m = T_{em} - T_{mech} = T_a$$

Conversion of the mathematical model of the motor from the form of differential equations to form state space equations. [2]

$$\frac{di_a}{dt} = \frac{1}{L_a}(V_a - e_a - R_a \cdot i_a)$$

$$e_a = K_b \cdot \omega_m \ , T_{em} = K_b \cdot i_a \quad , \quad V_{bru} = 0$$

$$\frac{di_a}{dt} = -\frac{R_a}{L_a} i_a - \frac{K_b}{L_a}\omega_m + \frac{1}{L_a} V_a$$

$$\frac{d\omega_m}{dt} = \frac{K_b}{J} i_a - \frac{B_m}{J}\omega_m - \frac{1}{J} T_L$$

$$\begin{bmatrix} pi_a \\ p\omega_m \end{bmatrix} = \begin{bmatrix} \frac{-R_a}{L_a} & \frac{-K_b}{L_a} \\ \frac{K_b}{J} & \frac{-B_m}{J} \end{bmatrix} \begin{bmatrix} i_a \\ \omega_m \end{bmatrix} + \begin{bmatrix} \frac{1}{La} & 0 \\ 0 & \frac{-1}{J} \end{bmatrix} \begin{bmatrix} V_a \\ T_L \end{bmatrix}$$

$$\dot{X} = AX + BU \quad , \quad X = [i_a \quad \omega_m]^t \quad , \quad U = [V_a \quad T_L]^t$$

$$Y = CX + DU \ ; \ C = [0 \quad 1] \ ; \ D = 0$$

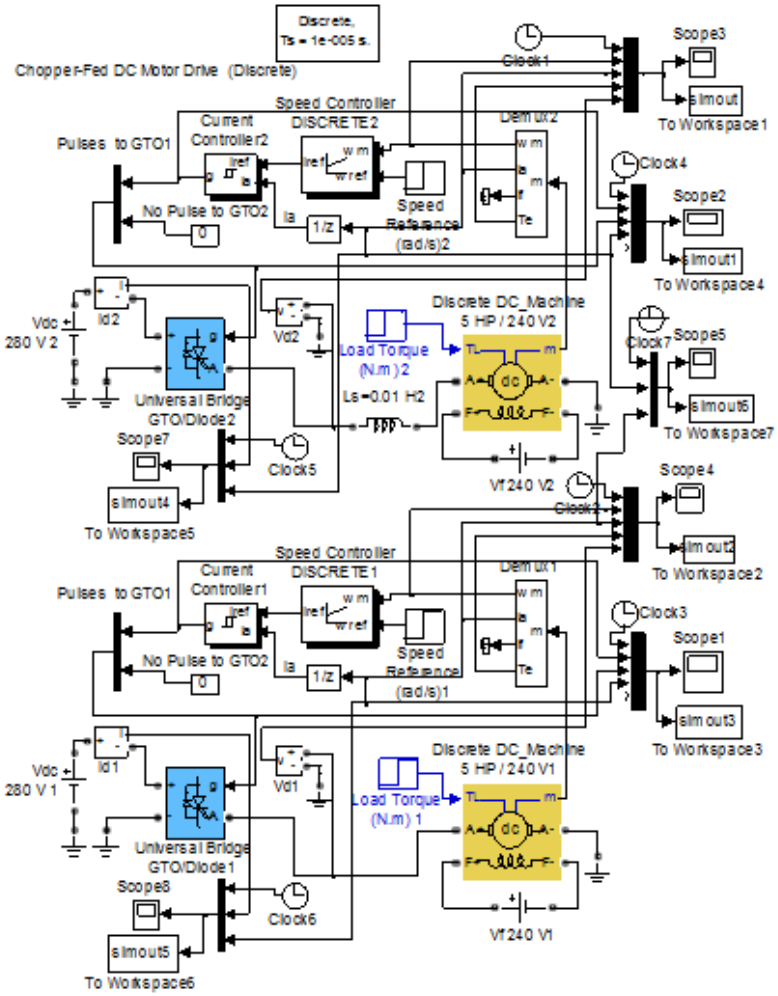

Fig. 2 block diagram to simulate the driving system when chopper supply by battery

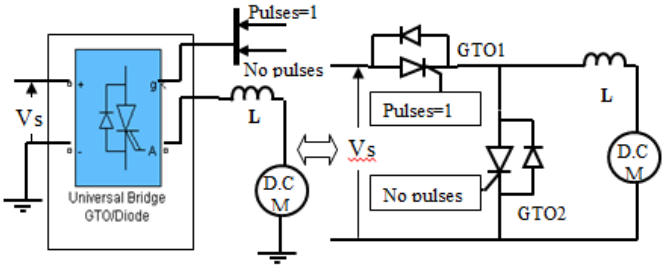

Fig. 3 chopper elements

The curves shown in fig 4 when L=0.01H the Current Ripple Frequency less than when L=0H, if we added smoothing inductive coil to DC chopper convertor, will have current ripple frequency less so the pure DC we have got.[3].

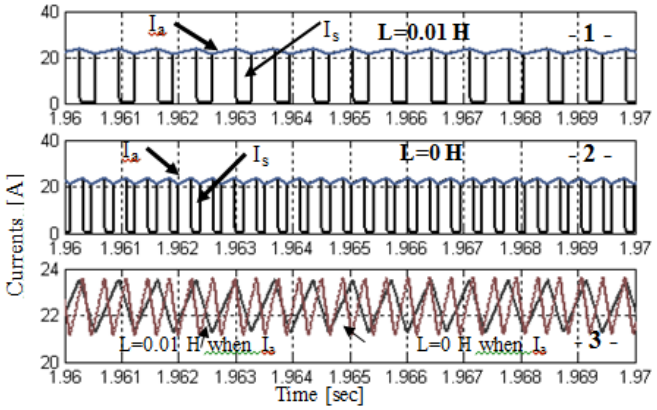

Fig 4 shows Ia and Is with and without smoothing coil

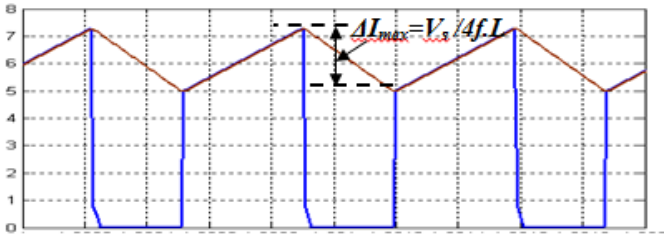

Fig 5 illustrate current signal form during unloaded motor operation

To appear the effect of L in series with motor as form of output voltage chopper,

We have taken the Steady-state motor operation that period of time to reach the motor speed to the nominal after loaded.

The fig 8 shows chopper voltage Vd , motor torque and Ia drawn by motor when the inductive smoothing coil is L=0.01H and fig 9 shows when L=0H.

We notice that frequency chopping for chopper without L is increase more than 50% and current ripple factor is decrease.

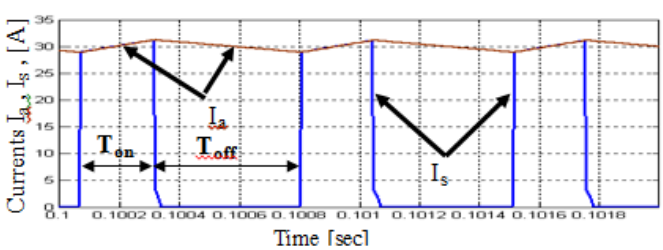

Fig 6 illustrates signal form at starting time, during chopper connected stage so Ia increase and Ia decrease during chopper cutoff.

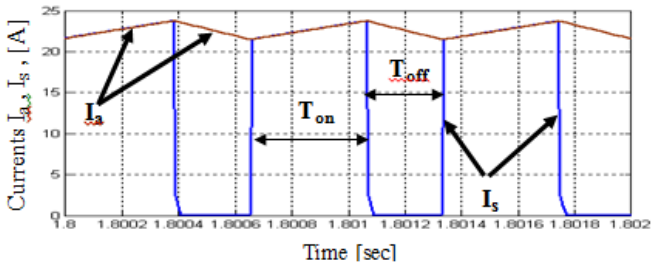

Fig 7 illustrate current signal form during loaded motor operation (Choppers Period connecting is increased)

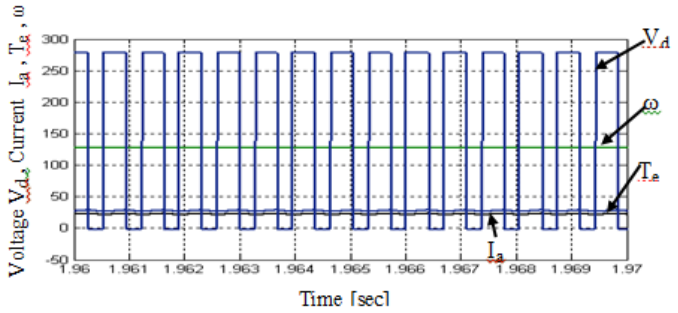

Fig 8 shown signal shape for Te, Ia, ω, Vd at L=0.01H

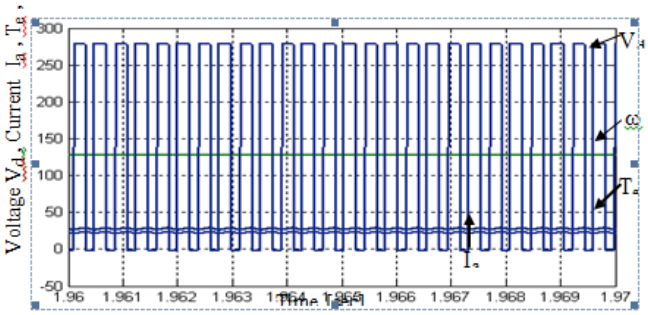

Fig 9 shown signal shape for Te, Ia, ω, Vd when L=0H

II. Results

1- With L= 0.01H current ripple frequency decrease.

2- At motor starting Ia increase and decrease at time off.

3- We have seen when unloaded motor operation ΔImax=Vs/4f.L ripple represents in the load current is inversely proportional with each of inductance. And chopping frequency to supply voltage.

4- We have seen when loaded motor operation the chopper connected period is increase.

5- With L=0H chopping frequency increase more than 50% compare with L=0.01H.

6- If L not exist there is the motor inductance do a similar role.

7- From the results it is considering for signal torque and current at every case of operating, we find that whenever voltage supply for chopper closer to the form of continuous there was a regularity and smoothness in torque and current signal than in the case of small frequencies.

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