DOI: 10.2478/ijasitels-2023-0003

Different Chopper Types for Supply Separately Excited DC Motor

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Abstract

Nowadays saving the planet's resources plays a very important role in improving our life conditions. The purpose of the paper is to supply the separately excited dc motor by using different chopper circuits. A very sustainable solution is to replace the resistors from classic theory with dc choppers for better efficiency. The armature voltage can be controlled by using IGBT chopper and the PWM signal received from controller is done with a dedicated block created by MATLAB environment. The advantages of developing this technique are that the speed changes proportionally with armature voltage and inversely with field voltage by keeping field and armature voltage constant respectively. The chopper designed with IGBT and Diode modules offers good control at any frequency value and the speed, the armature current and electromagnetic torque of DC motor can be control. In this paper, different choppers had been simulating were working in four quadrants for supply an excited dc motor by using Matlab program.

Keywords: DC-DC converters, Matlab, open-loop control.

1 Introduction

Power electronic plays an important role in electric drives and control in the last decades. The semiconductor properties create high performance and high flexibility in electrical drives with many variable speed applications. DC drives are used in applications such as, good speed regulation adjustable speed control, braking and reversing frequent starting. The modern techniques of controlling the speed supply of a DC motor used different types of choppers instead of variables resistances placed in series with armature circuit.

The DC chopper system converts directly from DC to DC by turning the switch ON/OFF the voltage supply. The choppers are classified in different types, from A to E, according to the polarity of the output voltage and current. Thus, they can be of one quadrant (type A and B), two quadrants (type C, D), depending on the quadrant in which the output voltage and current lie.

In this paper, the control speed is done with different types of choppers which supply the armature circuit. The chopper is done with IGBT and Diode modules because offers a fast response, smooth control capability with good efficiency. The simulation of the model is done and analysed in MATLAB (Simulink) using different chopper types. The chopper control needs a required control signal for the IGBT which is done using the PWM Generator (DC-DC) block from SIMULINK library.

The speed of the DC machine could be observed by an outer speed loop using a PI controller.

2 Supply speed control of separately excited DC motor

The chopper converts the fixed DC voltage to variable DC voltage. Self-commutated devices (directly on or off devices via gate) like MOSFET, IGBT, power transistors, GTO are used for making choppers because they can be commutated by low power control signal and do not need commutation circuit. [1]
The open loop control voltage of separately excited DC motor is done in figure 1.

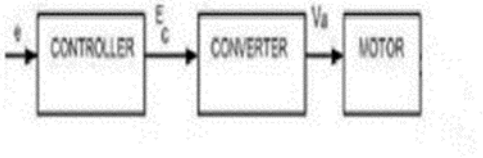

Figure 1 The block diagram for separately excited dc motor

To obtain a variable DC source an IGBT chopper controlled with a PWM signal is done and with this is possible to manage operating the excited dc motor in all four quadrants. Further, the paper presents converters for one quadrant equipped with choppers (A, B types) which supply the dc motor. The waveforms of current and voltage done by each type of chopper and the influence of them on dc motor speed and armature current values are presented. In this paper a dedicated block to generate PWM signals is used. The parameters of dc motor are given from Matlab blocks preset model with following values: 5HP 240V 1750 RPM Field: 300V [2].

2.1 Chopper Type – A

This chopper is representative of working in the first quadrant where the output voltage and current can be zero or positive as well as the power delivered to the motor. Thus, the power can flow only from the source to the load. The model created in Matlab/Simulink for supplying a dc motor is presented in figure 2. The waveforms obtained from type-A chopper are done in figure 3.

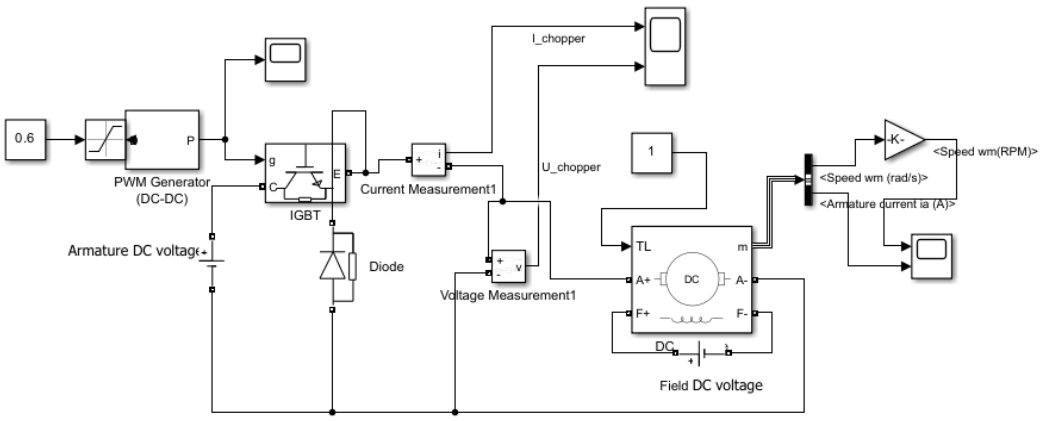

Figure 2 Simulink model of open loop model of chopper with dc machine (first quadrant).

The chopper contains an IGBT power electronics device for a very smooth transition between on/off period. [3]
The values of output electrical measures are according to the type-A chopper working principle. This chopper is attached to a dc motor. The results of speed motor and armature current obtained for dc motor fed by a type-A chopper are presented in figure 4.

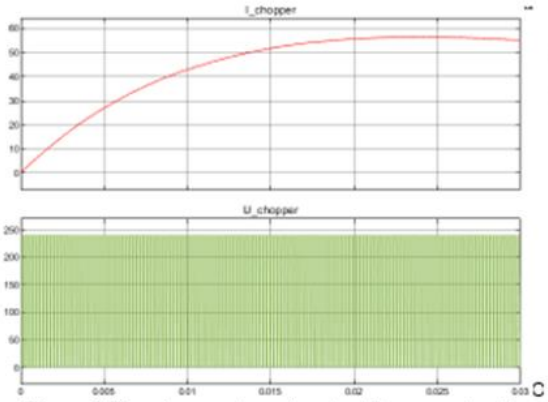

Figure 3 The chopper type-A output for current and voltage waveforms.

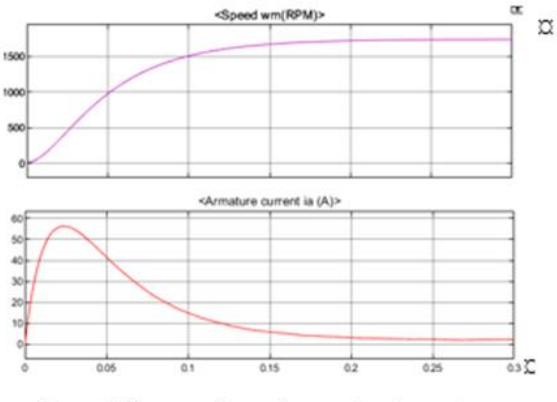

Figure 4 The waveforms for speed and armature current of dc machine.

In the open loop model of speed control of separately excited D.C. Motor for the machine the output speed is around 1750 RPM, and the armature current is observed to be above the rated value.

2.2 Chopper Type-B

Operation in the second quadrant corresponds to forward braking, so the sign of energy is changed because the output voltage is positive or zero and the output current is zero or negative. The simulation model is presented in figure 5. The dc motor in this case acts for a short duration as a generator and the kinetic energy stored in the system is returned to the input dc source.

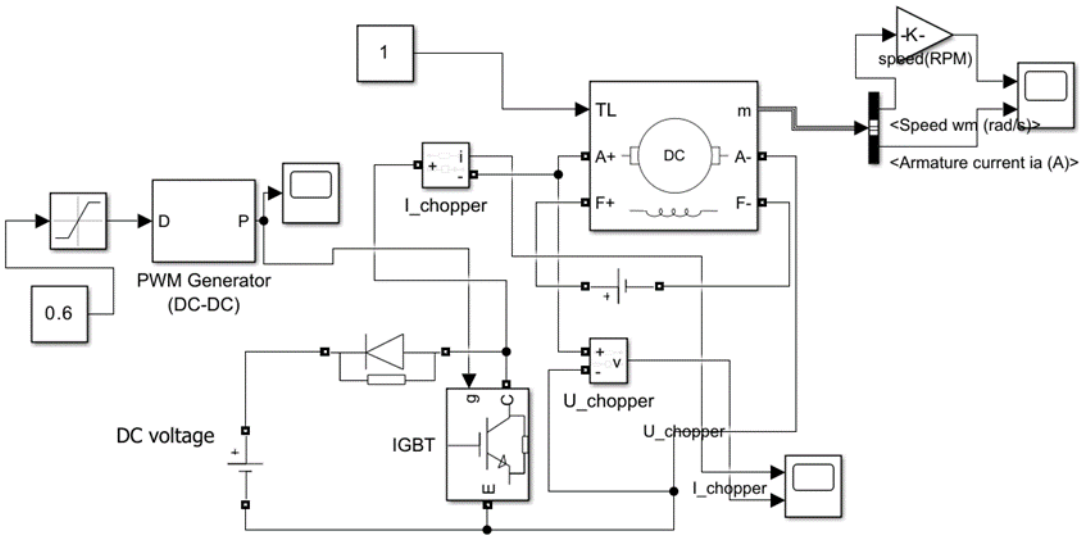

Figure 5 Simulink model of open loop model of chopper with dc machine (second quadrant).

The type-B chopper model has the waveforms obtained for current and voltage presented in figure 7. If the load is a dc motor and the voltage value described by (1) should be always greater than the dc source.

$$V_{(out)} = E + R_a i + L_a \frac{di}{dt} \qquad (1)$$

Where: - E is back emf, Ra – armature circuit resistance, La – armature circuit inductance. The results obtained by simulation are presented in figure 6. The power delivered to the load is negative, and the diode will allow the current to flow only from the load to source. The average output voltage of the chopper depends on the duty cycle of the switch. Due to the electrical loading the speed of the dc machine (now acting as generator) decreases Figure 7, and the armature current remains negative for a short period of time like in figure 8.

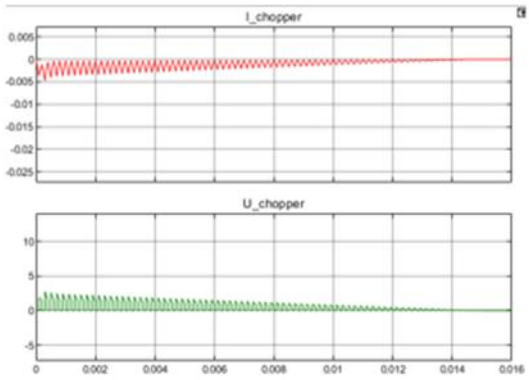

Figure 7 The chopper type-B output for current and voltage waveforms.

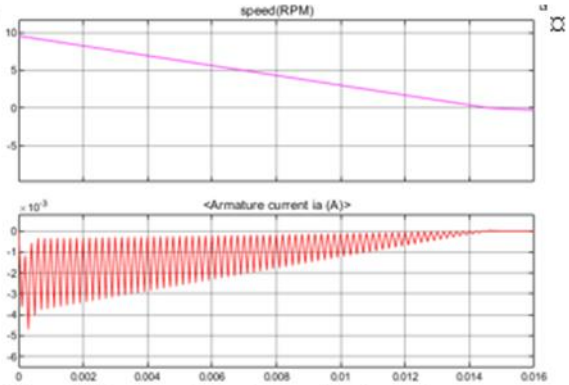

Figure 8 The waveforms for speed and armature current of dc machine.

An external inductance is added in most applications to increase the of dc motor armature inductance value.[4]

The other situations for converters build up with choppers for two and four quadrants a closed loop control is more adequately. A type-C chopper is also called a Two-Quadrant Class-A Chopper where the power can either flow from source to load or load to source and it can be used as a step-down or step-up chopper. Type-D chopper for example, is a circuit configuration of chopper in which power can flow in either direction, from source to load and load to source. The operation of this chopper is confined to the first and fourth quadrant. This type of chopper is also known as Two quadrant Type-B Chopper.

3 Conclusions

The paper presents a possibility to feed a separately excited DC motor by a chopper of one quadrant. The speed and the armature current of a dc motor has been successfully modelled by using chopper as a converter with IGBT electronic device and diode based on the opened loop model of DC motor. The simulation is done in MATLAB under the Simulink program which has a ready-to-use PWM generation block as well. The results are also studied and analysed under above mentioned conditions. The model shows good results under all conditions employed during simulation. Since, the simulation of speed supply in open loop of DC motor has been done.

The speed of the DC machine could be compared by an outer speed loop using a PI controller, that means a closed loop control which should be a future development of this paper.
Thus, the future aim is to develop the other types of choppers (C, D, E) to have total control on speed values in both situations: open loop and closed loop diagram.
The simulation results indicate that the proposed control schemes have good performance and robustness with appropriate safety for the DC drive system under steady and variable operating conditions, and in the presence of motor supply parameter variations.

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