# A Implementation of Two Stage Ac-Dc Converter For Speed Control of A Dc Motor

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***Abstract-*** *A AC-DC converter has been proposed for the application of speed control of a DC motor. The converter comprises two stages. The first stage is the diode bridge rectifier and the second stage is AC-DC buck converter. The two stages are coupled by a dc-link capacitor which also eliminate the ripple present in the output of the rectifier. For AC-DC buck converter, a feedback control system, based on PWM technique, has been designed which regulates its output to control the speed of dc motor. The prototype model has been designed and results obtained with it have a closed resemblance with the simulation results which has been done in MATLAB software. The results of the simulation and prototype demonstrate that the output voltage of AC-DC converter and hence the speed of the dc motor can be controlled by controlling the duty cycle of AC-DC converter. The results also demonstrate the faster dynamic response of the converters.*

***Keywords***- AC-DC converter, PWM technique, speed control of dc motor,full wave rectifier.

## I. INTRODUCTION

The designed two stage ac to dc converter is unidirectional and is used to control the speed of a dc motor. To control the speed of motor, the output of the buck converter must be regulated, which can be achieved by an efficient feedback control loop [1]. However, the design of an efficient feedback loop is not easy as its performance is significantly affected by the disturbances [2]. These disturbances are basically created by load variations, changes in input voltage, and electromagnetic interference, which is caused by the switching operations of semiconductor devices such as thyristors.

To achieve desired level of performance the motor requires suitable speed controllers. In case of permanent magnet motors, usually speed control is achieved by using proportional- integral (PI) controller.[3]

- When commerce with DC motor, the problem come across with it are efficiency and losses.
- In order for DC motor to function efficiently on a job, it must have some special controller with it.
- Thus, the Two Stage AC-DC Converter will be used.

## II. MODELLING OF DC MOTOR DRIVE

To understand the DC motor in details lets consider the diagram (shown in Fig.3.1)

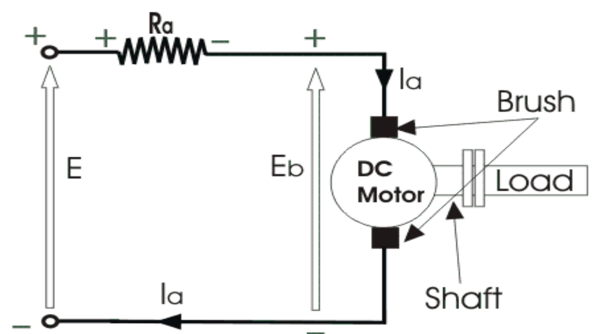


***Fig.2.1 Motor circuit diagram***

The direct current motor is represented by the circle in the center, on which is mounted the brushes, where we connect the external terminals, from where supply voltage is given. On the mechanical terminal we have a shaft coming out of the Motor, and connected to the armature, and the armature-shaft is coupled to the mechanical load. On the supply terminals we represent the armature resistance Ra in series. Now, let the input voltage E, is applied across the brushes. Electric current which flows through the rotor armature via brushes, in presence of the magnetic field, produces a torque Tg . Due to this torque Tg the dc motor armature rotates. As the armature conductors are carrying currents and the armature rotates inside the stator magnetic field, it also produces an emf Eb in the manner very similar to that of a generator. The generated Emf Eb is directed opposite to the supplied voltage and is known as the back Emf, as it counters the forward voltage. The back emf like in case of a generator is represented by

$$E_b = \frac{P.\emptyset.Z.N}{60.A} \qquad (2.2)$$

Where,

- P = no of poles
- φ = flux per pole
- Z= No. of conductors
- A = No. of parallel paths
- and N is the speed of the DC Motor.

So from the above equation we can see Eb is proportional to speed 'N'. That is whenever a direct current motor rotates, it results in the generation of back Emf. Now lets represent the rotor speed by ω in rad/sec. So Eb is proportional to ω.the same speed under variable load. Now armature current Ia is represented by

$$I_a = \frac{E - E_b}{R_a} \quad (2.3)$$

Now at starting, speed ω = 0 so at starting Eb = 0.

$$I_a = \frac{E}{R_a} \quad (2.4)$$

Now since the armature winding electrical resistance Ra is small, this motor has a very high starting current in the absence of back Emf. As a result we need to use a starter for starting a DC Motor.

Now as the motor continues to rotate, the back Emf starts being generated and gradually the current decreases as the motor picks up speed.

## III.TWO STAGE AC-DC CONVERTER

The single phase ac to dc conversion system basically consists of two stages. The first stage is full bridge rectifier which converts the ac input from the main supply into dc and is widely used in many previous designs front end rectifier is operating at power frequency, i.e 50Hz, switching loss is not an issue for it. The ripples present in the output of the full bridge rectifier is minimized by placing a capacitor at the output of rectifier

The second stage is a dc to dc buck converter which consists of an inductor L1, a filter capacitor C2, a switch, and a diode D5. The output of the converter is given to the dc motor.

The switching frequency is

$$F = 1/T$$

and duty cycle is D. The converter is operating in continuous conduction mode by selection of suitable value of inductor

- *Feedback Control*

To efficiently control the output of buck converter, a high performance feedback controller for dc-dc switched converter system is needed which have high disturbance rejection ability, smaller steady-state error, faster dynamic response, and lower overshoot. In this paper, PWM technique is used to control the switching of semiconductor device. A type III compensator is used in the feedback loop which generates the error signal by comparing the feedback voltage to the reference voltage. The comparator compared this error signal with the signal obtained from ramp generator. If the magnitude of error signal is more than ramp signal, then the output of comparator will be high and vice versa. Therefore, the output voltage of the control circuit produces pulses, with a duty cycle 'D' varying from 0 to 1, which control the switching action of the switch of converter. The frequency of the ramp signal determines the frequency of the comparator output which is the frequency of the converter

The various components of feedback control system is described below:

*1) Compensator:* The compensator circuit is shown in Fig. 2. A type III compensator (lead compensator) is used in our design. The design demonstrated in this paper uses a simple error amplifier to provide rudimentary feedback, achieving closed-loop control of the buck converter. To improve output stability and response to changing load, a compensator should be implemented as an enhancement to the original design.

The topology of the buck converter gives it a characteristic frequency response:

Two complex conjugate poles from the LC circuit formed by the output filter, and a single zero from the R-C circuit formed by the output capacitor and its parasitic equivalent series resistance (ESR). The desired closed-loop frequency response should have high gain at DC and decreasing gain with increasing frequency rejecting high-frequency noise and ripple due to the switching characteristic of the DC-DC converter. Additionally, the closed-loop phase response should have high phase margin for closed-loop stability.

A type III compensator is suitable for providing two poles and three zeroes to shape the magnitude and phase response to meet these requirements. The Placement of poles and zeroes of the compensation network aims to nullify the effect of the poles and zeroes of the uncompensated buck converter, producing the desired linear roll-off response. Design of a type III compensator is heavily reliant on the inductance, capacitance, and resistance of the filter components of the buck converter design.

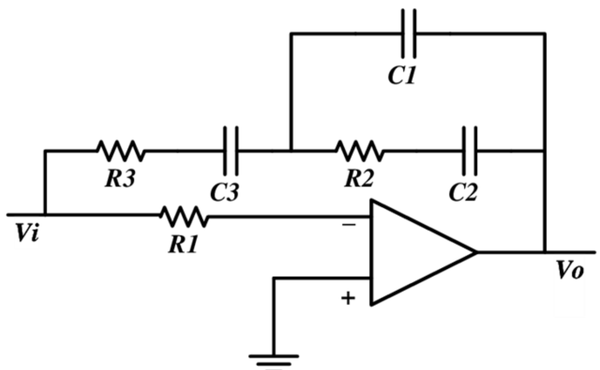


***Fig.3.1 A type III compensator (lead compensator)***

## IV. PULSE WIDTH MODULATION

In power electronics a Pulse-width modulator is an integral part of feedback control. The reference signal, r(t), used in the spectral analysis is usually the output of a feedback controller (compensator). The modulation process itself is highly nonlinear. Since most practical designs use linear control, a linear, time invariant model that captures the small-signal behaviour of a modulator is needed for converter-level analysis and control design. For the Such small-signal models are developed for both constant-frequency and variable-frequency PWM.

The operation of multiple pulse-width modulators with phase-shifted carrier signals. We will briefly discuss the application of interleaving in parallel- and series-connected converters, and use the spectral models developed in the previous section to characterise the harmonica cancellation effects resulting from different interleaving arrangements.

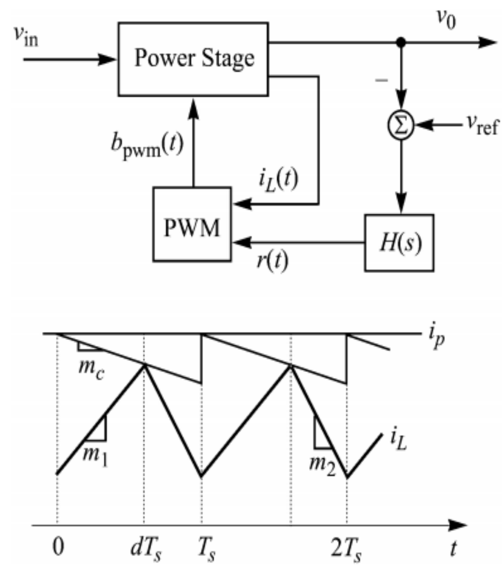


*Fig3.2 Principle of peak current control of PWM*

## V. IMPLEMENTATION OF METHODOLOGY BY USING SIMULATION

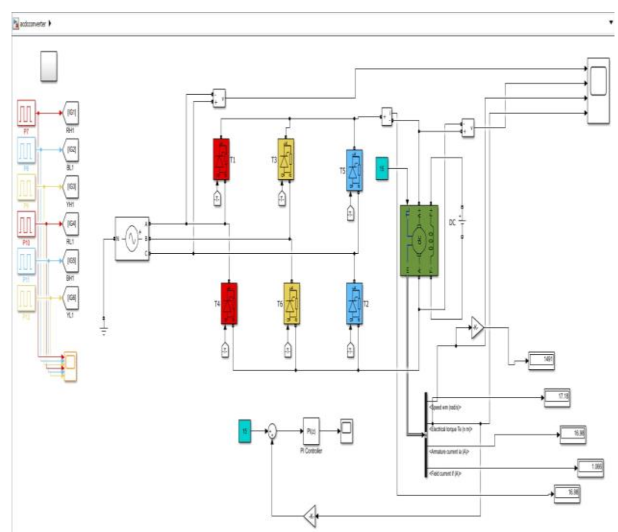

*Fig. 5.1 simulation model for speed control of dc motor by using a two stage AC-DC Converter*

The search of DC motor is placed on the acceptance for simplification and windings are identical and the self and Mutual inductances are stable. A controller of speed, the braking chopper, and the intelligent controller models are limited to the Electric Drives library. It is desirable to practise a simplified version of the drive involving an average-value model of the inverter for rapid simulation. A DC motor (DC) is a DC motor twisted inside out; therefore the field is on the rotor and the armature is on the stator (as shown fig. 5.1)

The energetic equations of DC motor using assuming point scan be derived as

Va = RIa + (L-M)dia dt +ea (5.1)
Vb =RIb + (L-M)dib dt +eb (5.2)
Vc =RIc + (L-M)dic dt +eb (5.3)

Where,

- Va , Vb, Vc = Stator phase voltages
- Ia , Ib, Ic = Stator phase currents
- ea , eb, ec = Back emf of phases
- M= Mutual inductance

The DC motor is actually a permanent magnet AC motor in which a torque-current tendency mimes the DC motor Rather of commutating the armature current by using the brushes, commutation of electronic is used. This rejects the problems joined with the brush and the commutator adjustment for pattern, flickering and wearing out of the commutator-brush adjustment, thereby, making a DC motor more rugged as compared to a DC motor. DC motors have so many similarities to the AC induction motors and the brushed DC motors in terms of the construction and working principles respectively. Same as other motors, DC motors also consists of a rotor and a stator (shown in Fig.5.2)

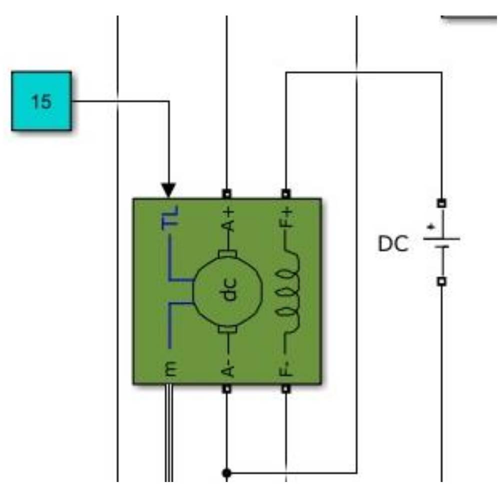


*Fig. 4.5 Detail model for speed control of dc motor drive*

DC motors are very popular in areas which need high performance because of their smaller volume, high force, and simple system structure. In practice, the design of the DCM drive involves a complex process such as modeling, control scheme selection, simulation and parameters tuning etc. An expert knowledge of the system is required for tuning the controller parameters of servo system to get the optimal performance. Recently, various modern control solutions are proposed for the optimal control design of DC motor.

## VI. SIMULATION RESULTS AND DISCUSSION

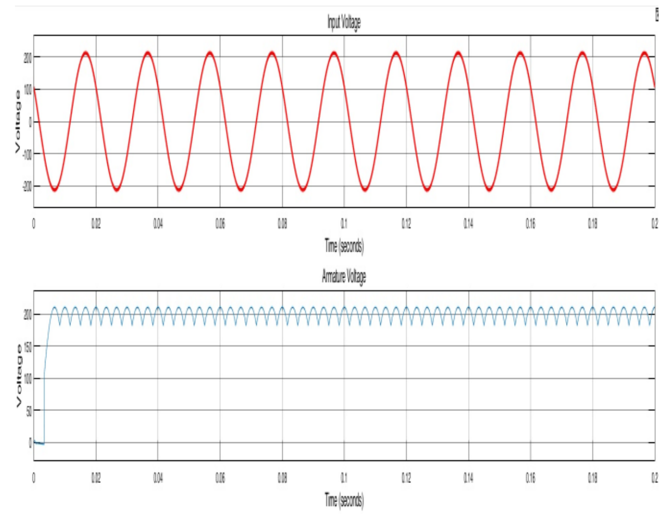


*Fig. 6.1 Input voltage VS time curve of speed control of dc motor without using a Two stage AC-DC Converter*

Brushless DC Motor Drive during Speed Regulation with a Two stage AC-DC Converter

Brushless DC motor, at this moment is extensively used being many industrial functions due to the different features like high efficiency and dynamic response and high speed range (Fig 6.1)

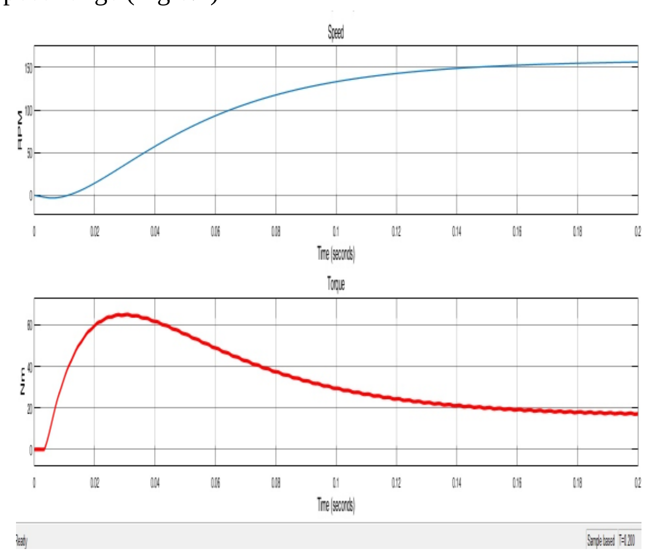


*Fig.6.2 speed VS time curve of speed control of DC motor by using a Two stage AC-DC Converter*

The speed of separately excited DC motor can be controlled from below and up to rated speed using chopper as a converter. The chopper firing circuit receives signal from controller and then chopper gives variable voltage to the armature of the motor for achieving desired speed. There are two control loops, one for controlling current and another for speed. The controller used is Proportional-Integral type which removes the delay and provides fast control. The complete layout of DC drive mechanism is obtained. (Fig.6.2)

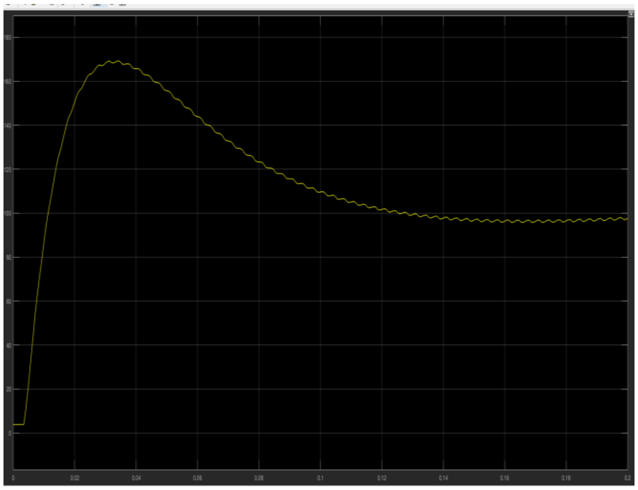

*Fig. 6.3 Torque VS Time curve of speed control of DC motor by using a Two AC-DC Converter*

Now placing this block to the controller of speed controller by replacing PI by a Two AC-DC Converter. As in practical MATLAB, the variation in the speed of PI and a Two AC-DC Converter is seen. The speed variation is given for 1491 rpm. Therefore it is found that a Two AC-DC Converter works more efficiently than PI for the large number of data. In PI controller if any change occurs, then big variations occur in the result of speed. And once a Two AC-DC Converter gets trained, it gives efficient results(shown in Fig.4.8)

## VII. CONCLUSION

The speed of separately excited DC motor can be controlled from below and up to rated speed using chopper as a converter. The chopper firing circuit receives signal from controller and then chopper gives variable voltage to the armature of the motor for achieving desired speed. There are two control loops, one for controlling current and another for speed. The controller used is Proportional-Integral type which removes the delay and provides fast control. The complete layout of DC drive mechanism is obtained. The designing of current and speed controller is carried out. The optimization of speed controller is done using soft starter approach, in order to get stable and fast control of DC motor. After obtaining the complete model of DC drive system, the model is simulated using MATLAB(SIMULINK).The simulation of DC motor drive is done and analyzed under varying speed and varying load torque conditions like rated speed and load torque.

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