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Speed Control of DC Motor Using Soft Starter: A Review

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Abstract: *DC motor has variety of industrial applications which have variable speed and load characteristics due to its ease of control. The speed control can be achieved in many different ways such as, Field Control, Armature voltage control, Armature resistance control. The traditional method of speed control has many drawbacks such as, mechanical losses, switching losses. To minimize such losses new and advanced technique is being used. This paper will be focusing on a simplified techniques of speed control by use of Soft Starter. The technique to achieve soft starting is by use of Pulse Width Modulation, Firing Angle method, PID controller, Chopper control, Fuzzy logic. These methods are widely used because of their high efficiency and they can be implemented with any type of dc motor.*

Keywords *–Chopper control, Firing Angle, Fuzzy Logic, PID controller, Pulse Width modulation*

I. Introduction

Motion plays an important role in industries. The production process of industries varies differently and require different speed profiles. Also the speed control of DC motor is simpler & less costly compare to other drive. DC machine is highly versatile & flexible machine. They also employ in many cutting applications such as actuators & speed sensors that is DC motors are very versatile for the purpose of speed control. Motors use different types of control in industry. Due to this there is increased machine wear as increasingly fast acceleration causes high torque transients and high peak currents. Soft starters solve this problem through controlling the application of current during acceleration production and deceleration.

Armature voltage variable speed control was first used in the early 1930s using a system involving a constant speed ac motor driving a DC generator. DC output of generator was varied using a rheostat to vary the field excitation and resulting dc voltage was used to power the armature circuit of the ac motor. This system was properly known as Ward-Leonard system. This system was used until late 1960s when the Electric Regulator Company introduced a general purpose, static, solid state controller which converted the line ac directly to dc using SCR(Thyristor) devices.

The paper will focus on the speed control of DC motor using soft starter. Pulse width Modulation, Firing angle method, PID control, Fuzzy Logic, Chopper control method of speed control will be discussed.

II. Methodology

1. Pulse Width Modulation

1.1 Concept of PWM

Pulse width modulation is a simple method of speed control of DC motor by controlling the driving voltage**,** when the voltage is high speed is high. There are many applications where voltage control would cause a lot of power loss in the system, so PWM method is mostly used in DC motor. In PWM method high frequency is avoided as we know that large motor is highly inductive. We know that on and off time is referred as duty cycle. If we consider an example, Figure 1 shows waveforms for different duty cycles,75%, 50% and 25%. For 50% waveform 50% duty cycle signal in on and 50% off while a for 25% waveform 25% duty cycle signal is on and 75% off. The end result of the PWM is that power is send to the motor and it can adjust from 0% to 100% duty cycle with stable control and high efficiency. [1]

When a specific voltage is supplied to the motor, it rotates the motor shaft at some speed**.** The motor's power can be controlled by varying applied PWM pulses by changing there width and thereby varying the average DC voltage applied to the motors terminals.By changing or adjusting the timing of the pulses speed of the motor can be controlled. The longer time the pulse is "ON", the faster the motor will rotate and whereas, the shorter time the pulse is "ON" the slower the motor will rotate.

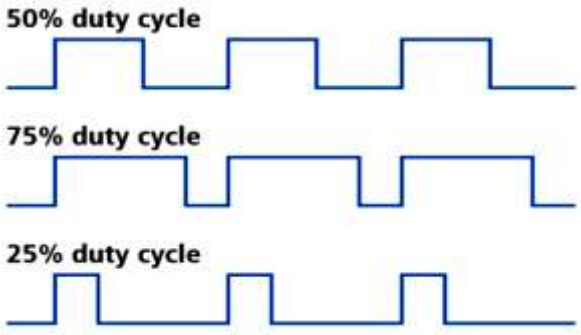

Fig.1 Duty cycle waveforms

The speed of the motor is determined by duty cycle of the motor. The desired speed can be obtained by changing the duty cycle. PWM pulse is used to control duty cycle of DC motor drive. Power is supplied to the motor in square wave of constant voltage but varying pulse-width or duty cycle. The duty cycle of PWM is determined by the pulse width. The PWM ON period at 60 % of duty cycle is higher than at 40 % duty cycle. This contributes to higher motor speed at 60 % duty cycle compared to 40 % duty cycle. Microcontrollers have been used to control the speed of the motor due low cost and has many features. This technology provides fast response in controlling multiple parameters and these parameters are programmable by the user. [2]

1.2 Block Diagram

The block diagram consists of, power supply which is regulated by regulator. The regulated power supply is fed to the microcontroller; we know that microcontroller works at low voltages. The microcontroller is programmed to provide pulse width modulation for the desired time. The motor cannot be controlled directly to the microcontroller as motor operates relatively at higher current. Motor driver IC is used to interface the microcontroller with the motor. [1]

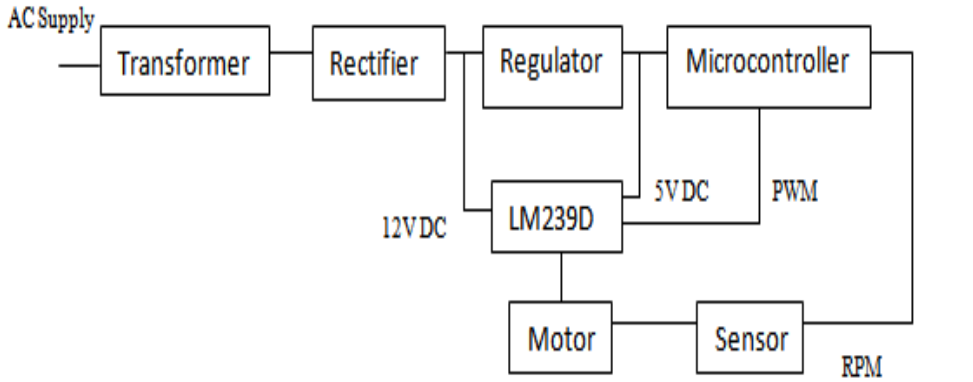

Fig. 2 Block diagram for speed control of dc motor using PWM.

2. Firing Angle Scheme

2.1 Concept of firing angle scheme

Thyristor is a switch like an diode. It only turns on when the anode voltage becomes greater than the cathode voltage. If we consider the wave form of ac source voltage, the point at which the SCR is triggered is called as as firing angle. The SCR conducts only when it is triggered ON. The earlier the thyristor is triggered, more is the output voltage. Also angle at which the thyristor is triggered is called as Firing angle.

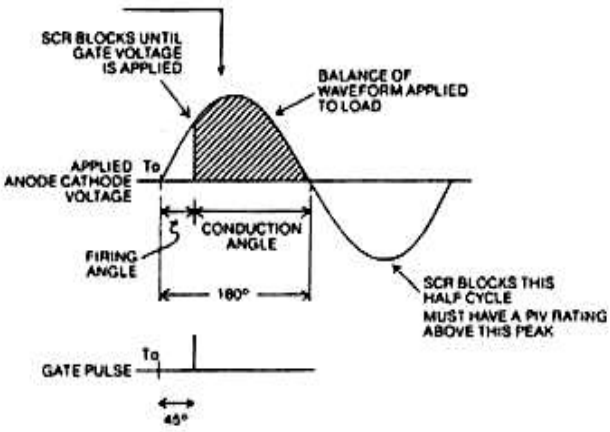

Fig.3 Schematic Diagram of Firing Angle.

Firing angle control has applications such as, speed control of dc motor by controlling the application of power to the SCR. The firing angle control is achieved by varying the time of application of Gate pulses to the SCR. The Gate terminal voltage to the SCR can be applied at a given time decided by the remote user. Basically managing the triggering point on the AC signal waveform when the SCR is going to be triggered is called as Firing Angle control method.

2.2 Firing Angle Scheme in dual converter

The motor speed control is based on thyristraised dual converter. Generally, microprocessor based control circuit is used. The performance exhibited is good and the firing angle can be controlled smoothly with fast response. In Fig.4 a converter system is used for supplying the DC motor. A pulse generator is used for firing angle control of converter. The thyristor of converter receives the firing pulse in continuous conduction mode or discontinuous mode. Two of these full converters are connected back to back as shown in Fig. 4 for simplifying the circuit. The converter will provide four quadrant operation and hence is called dual converter. Dual one positive group converter and a negative group converter connected back to back. One converter acts a rectifier and another act as inverter. α_A and α_B are delay angle of converter 1 & 2 respectively & corresponding average output voltages are V_1 & V_2.

Output voltage of converter 1 at firing angle α_A:

$V_1=2V_M/\pi \quad COS\alpha_A \quad (0 < \alpha_A < 90)$ (1)

Similarly output voltage of converter 2 operates at firing angle α_B:

$V_2=2V_M/\pi \quad COS\alpha_B \quad (0 < \alpha_B < 90)$ (2)

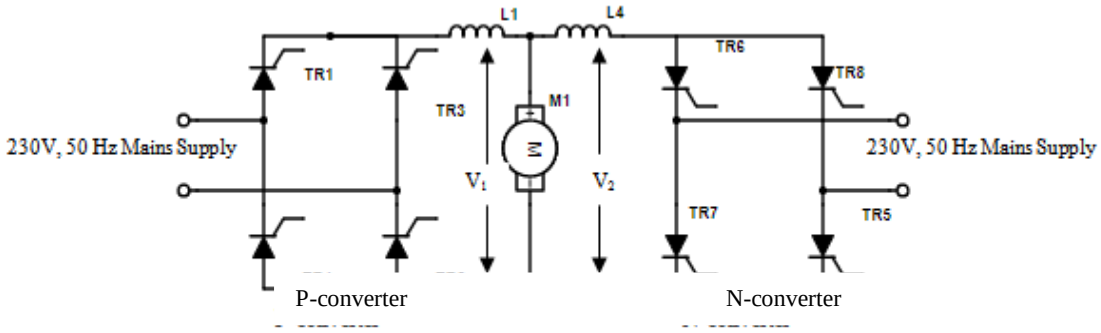

Fig.4 firing angle scheme for dual converter.

Different firing angle are taken to observe the effect of armature voltage on speed torque curve. AC supply is applied to input of single phase dual converter. Different output voltage & current are obtained on armature of motor. When firing angle are 30^0& 150^0, 60^0& 120^0, 120^0& 60^0, 150^0& 30^0. The average value of output voltage can be controlled by controlling or changing the firing angle α. [6]

2.3 Firing angle scheme for dual converter using DSPIC 30F 6012A

The speed control of DC motor is crucial in applications were high precision is required. To control the motor for different loads and processes we need to procure a control algorithm with precision, for this we would need a controller that is precise and accurate. The controller used in this firing angle scheme is DSPIC 30F 6012A.

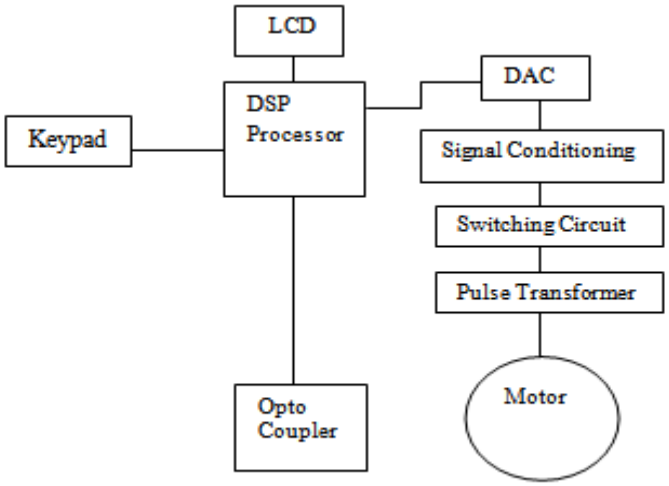

Fig.5 Block Diagram for speed control using DSPIC.

When we enter the speed for example, 20rpm using key pad, Initially DSP will give pulses to run motor at speed of 20rpm, when motor reaches the entered speed again DSP will generate firing pulses to increase motor speed to 40 rpm i.e. speed of motor will be increased in the steps of 20 rpm and so on, hence motor will start running at its set speed. In this method output is increased by proportional amount to try and restore the speed. However, as the motor speed recovers, the error reduces and motor speed is maintained. In this closed loop system speed of motor is controlled using a PID controller implemented using DSP processor in this work. [11]

3. Chopper Control method

Devices used to convert fixed dc input voltage to a variable dc output voltage are termed as chopper. It can be step up or step down. Chopper circuit offer smooth control, high efficiency and faster response features. Thyristor, BJT, MOSFET, IGBT and GTO are the power semiconductor devices used for a chopper circuit. IGBT and GTO are widely used switches in the chopper circuit. These are generally represented by a switch. When switch is OFF, there is no current flow in the circuit and when switch is ON current flows through the load.During an operation the chopper circuit connects the load to the source and when in off condition it disconnects the load from the source at high speed.

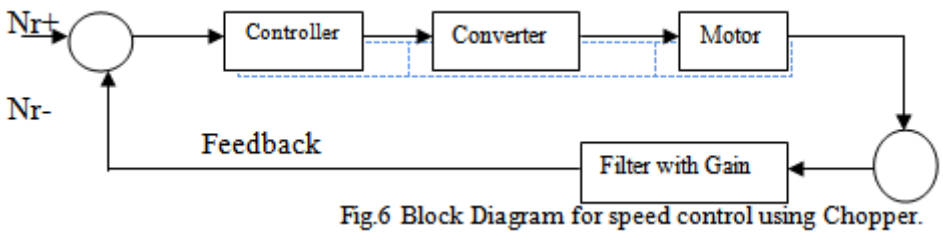

Fig.6 Block Diagram for speed control using Chopper.

At time period Ton, chopper is on and load voltage equals source voltage and during the time period Toff, load voltage is zero and chopper is off. A DC drive consist of a combination of controller, converter and DC motor. In this method we are using chopper as a converter. output speed of DC motor can be attenuated by

varying the armature voltage and keeping field voltage constant. The output speed is compared with the reference speed and error signal is then fed to speed controller. Difference in the reference speed and the feedback speed makes the controller output vary. Motor speed is brought back to the desired speed by the controller output voltage V. Now the output speed of motor is measured by Tacho-generator. We require a filter with a gain to bring Tacho output back to controller level as output from Tacho-generator contains ripples. [12]

4. Speed control using PID controller

The speed control of motor is necessary to overcome the problem in industry to avoid machine damages and to avoid slow rise time and high overshoot. As we know that starting voltage is high, it is not suitable for machine. So, a controller like PID, fuzzy is developed to overcome this problem. A PID controller is a feedback mechanism controller mainly used for controlling industrial systems. In PID controller, output of the proportional path is large when error is large. In Integral path it will continuously add the error and multiply with a constant. The output signal of derivative path is contributed by the rate of change of error. The output is small when the rate of change of error is low and it is large when the rate of change of error is high. The speed of the motor is controlled by controlling the armature voltage by fully controlled thyristor bridge. This is controlled by thyristor bridge and the input voltage is controlled by varying the firing angle. It is the easiest and efficient method compared to other complicated methods. PID controller provides a constant speed. Proportional Integral and derivative control is extensively used due to its simplicity, stability and robustness. The constant Kp, Ki, Kd values are set by using resistor and capacitor. These are now replaced by the microcontroller PIC18f family. [14]

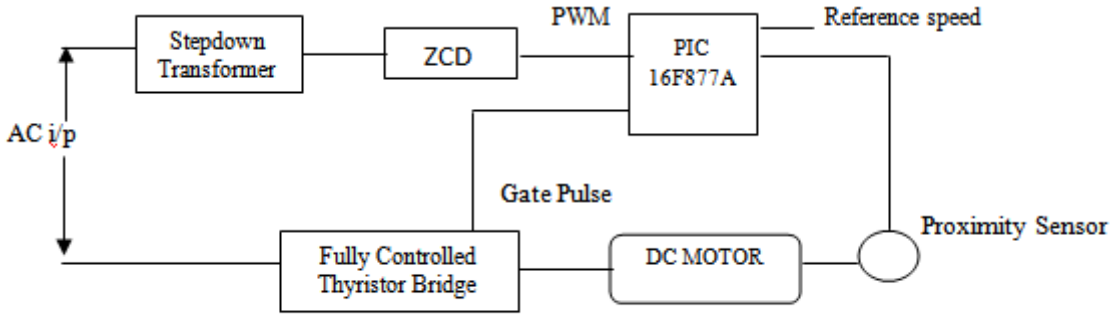

Fig.7 Block Diagram of speed control using PID controller.

III. Result

Pulse Width modulation	Frequency (0-2000 Hz)	Speed (4200-4500rpm)	Voltage (9.6v)
Firing Angle method	Firing Angle(In Degrees)	Speed(in rpm)	Voltage(volts)
	90	100	2.25
	60	300	5.11
	40	500	9.1
Chopper control	Time in seconds	Current(mA)	Speed(rpm/Sec)
	240	63	3
	500	145	10
	650	180	18
PID controller	Technique/algorithm	i/p for DC motor	Result
	Genetic algorithm	TF=0.01	Steady state error reduced to 0.04%
	Adaptive PID	Load torque of 0.3nm	Chattering problem is reduced

IV. Conclusion

Different methods of speed control, pulse width modulation, Firing angle method, speed control using chopper and speed control using PID control are discussed in this paper. In PWM technique the relationship between duty cycle and output voltage shows that when the pulse width is wider more average voltage is applied to the motor. Due to this there is stronger magnetic force in the armature windings. The motor rotates at maximum speed. The application of microcontroller provides flexible and smooth control of duty cycle of the PWM pulse. Also, in Firing Angle Scheme there was linear relationship between the speed and the firing angle of the converter. Thus, PWM and Firing Angle Scheme are efficient methods for speed control of DC motor.

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