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DC Motor Speed Control Using PI and PID Controller

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Abstract*— In recent years, rapid industrial growth has contributed to widespread usage of DC drives and their utilization. Conventional industrial drives rely substantially on DC drives due to the fact that they offer superior performance, reliability, flexible speed control, etc. In numerous industrial contexts, DC motor speed modulation is essential because speed regulation systems exert a significant impact on DC drive effectiveness. Essentially, the controller plays a critical role in driving control for both dynamic and transient circumstances. This study presents a chopper that provides the armature with an uneven voltage and uses PI and PID control to achieve the necessary speed. With eliminating delay and offering quicker control, these controllers improved drive efficiency. This paper enlightens the comparative analysis for PI PID controllers, Effective speed control for the drive is studied and modeled in MATLAB.

Keywords: PI, PID.

I. INTRODUCTION

A motor known as DC motor that converts electrical energy into mechanical energy. They are extensively employed in instances where a wide speed control range is essential [1].

The précised speed control of DC motors for accelerating and braking is commonly regarded. In fact, power supplies are connected directly to motor fields and result in voltage control, which is required for applications that demand for speed and torque control [2].

Nowadays as high-performance motor drive systems are having unique qualities including dynamic speed command tracking and load regulation response, they are becoming a crucial component of industrial applications [3].

Despite having higher maintenance costs than AC motors, DC motors are widely employed in industry due to their excellent speed control properties. As opposed to AC motors, DC motors may be controlled for speed in more straightforward and affordable ways [4].

DC drives often cost less than AC drives for applications requiring changeable speed. AC drives would be more costly and complicated. Therefore, DC motors have long been known as machines with variable speeds. The correct adjustment of the terminal voltage is required to operate a DC motor across a broad range of speed. [5].

Acquiring a signal that specifies the desired speed and driving the motor at a certain speed are the objectives of controllers intended for speed regulation of a motor [6].

Closed loop and open loop controllers are the two types of controllers that are used to measure the speed of a DC motor. A motor's true speed can be measured by a closed-loop controller, but not by an open-loop controller. Although closed loop controllers are superior to open loop ones, they are also more costly and complex because of the feedback components. The most common use of a closed loop control system is for precise motor speed control [7].

A close loop controller known as PI controller is frequently used to regulate the speed of DC motors. P-I controllers are capable of producing zero steady state error whenever the reference speed changes steplessly [8].

Both PID and PI control are forms of feedback control systems that compute the control output using the proportional, integral, and derivative elements of the error signal. PID control incorporates the derivative term, but PI control does not; this is the primary distinction between the two types of control. But occasionally, especially in systems with quick dynamics, PI control can become unstable.

In this literature brief study for PI and PID control is investigated to control the speed for separately excited DC motor. Their structure is explored and outcomes revealed their aptness for enhancing smoother speed control than conventional, yielding improvement in speed regulation.

II. DC MOTOR DRIVE SCHEME

Fig.1 below shows blocks schematic for general drive scheme. It comprises source chopper Load i.e. Dc motor along with control circuitry.

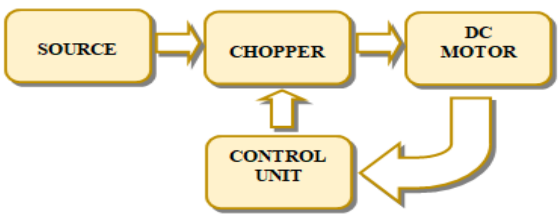

Fig. 1. Block Schematic for DriveScheme

In the scheme source is supplied chopper circuit along with load. By employing essential control, PWM pulses are generated to trigger chopper switch.

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III. PROPOSED SCHEME

Fig. 2 depicts anticipated scheme for DC motor drive with PI control. The chopper receives DC power, and its primary job is to change fixed DC voltage into variable DC voltage. In general, a chopper controls the motor's armature voltage. The output of the motor is speed N, which is compared to the reference speed N*, and the error speed is provided to PI controller, which regulates the output and it is equated with higher frequency triangular wave so as to generate PWM pulses for triggering the MOSFET. While in open loop control only pulse generator is employed in order to switch the device of chopper by varying duty cycle of pulse generator

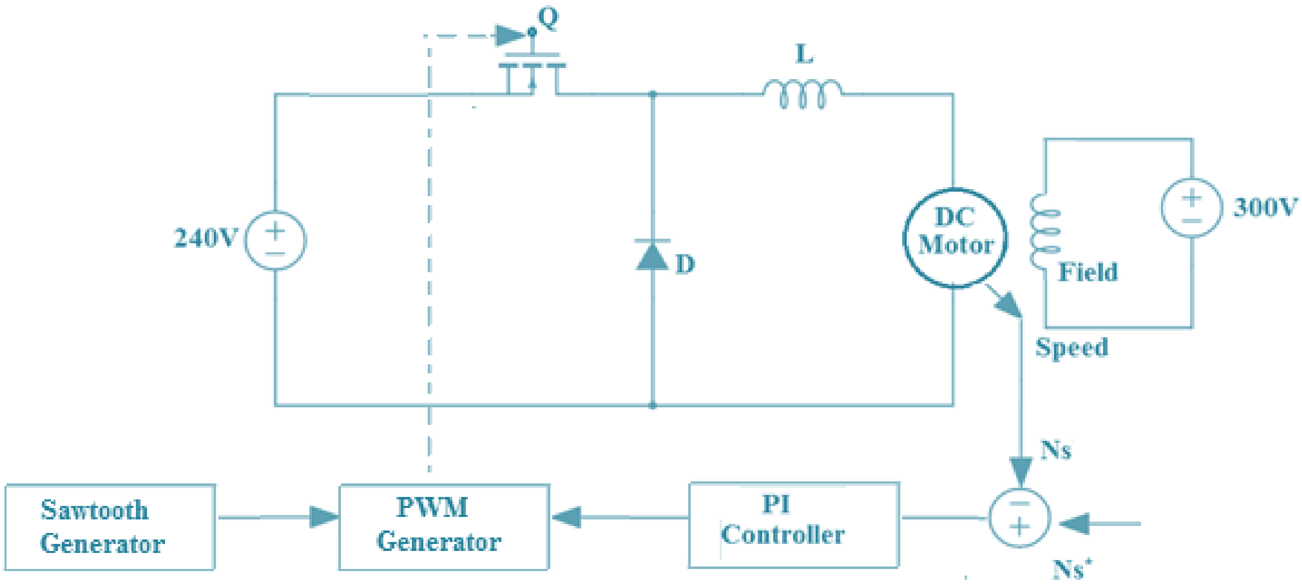


Fig.2. Proposed Scheme

A. Separately Excited DC Motor

The armature and field windings are electrically isolated from one another, and the field winding is stimulated by a separate DC source. Additionally, the voltage and power equations are the same for this kind of machine. [2]

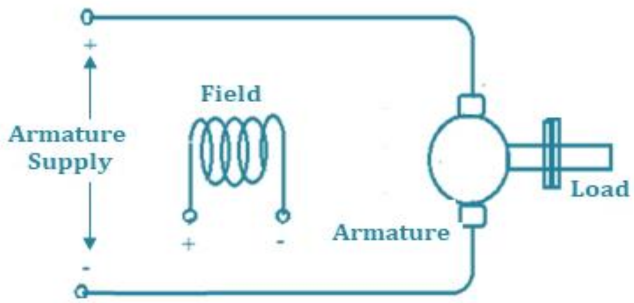


Fig. 3. Separately Excited DC Motor

Input power is,

$$P = V_f I_f + V_t I_a$$

The armature equation [9] is expressed as,

$$V_a = E_g + I_a R_a + \frac{L_a dI_a}{dt}$$

The torque equation is given by

$$T_d = \frac{jdw}{dt} + B_w + T_l$$

Equation for back emf of motor will be,

$$E_g = K\emptyset W$$

Current armature When a DC motor is activated by field current If, Ia flows in the circuit, creating a back EMF and a torque to balance the load torque at a specific speed. By adjusting Va and Vf, the motor speed may be adjusted, and it is often more beneficial to utilize variable DC voltage to manage the speed and torque of DC motors since the field current If exhibits no changes in response to changes in armature current Ia. [3]

B. PI Controller

The corresponding circuit of the PI controller is seen in Fig. 4. The PI controller has been in use in the industrial era for the past few decades. As time goes on, progress brought about a significant shift in controller production, which is nothing more than an analogue to digital conversion. The control algorithm, however, has not altered. For the majority of industrial applications, the PI controller has proven effective [3].

The final control element receives the output signal that was produced (T) at every sample. Two parameters that are adjusted are the current I and the torque TL. The primary purpose of a PI controller is to prevent a rise in reaction time, thus keeps the DC motor's speed constant.

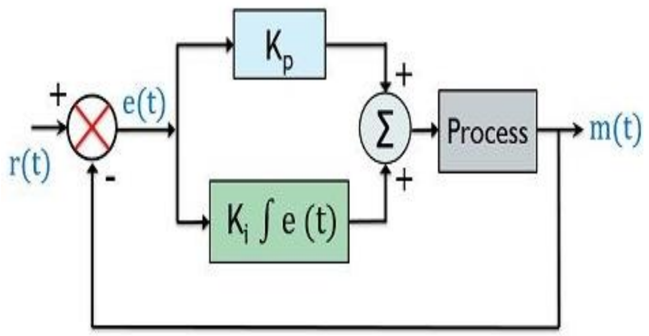


Fig. 4. Block Illustration for PI

The steady state error caused by P controller is primarily removed by the PI controller. However, it has a detrimental impact on the system's overall stability and efficiency of responsiveness. Since the PI controller is unable to anticipate the systems upcoming faults, it is unable to lessen the rise time and get rid of oscillations. Consequently, PI controllers are widely utilized in industry, particularly where speed of response is not a concern.

Here, the regulating task is carried out via a PI controller. PI controllers are more efficient than proportional controllers. The usage of a proportional controller is restricted, because it never forces the motor to operate at the precise speed that is specified. It is highly challenging to acquire a derivative term in the output of a PID controller that has a considerable impact on the motor speed.

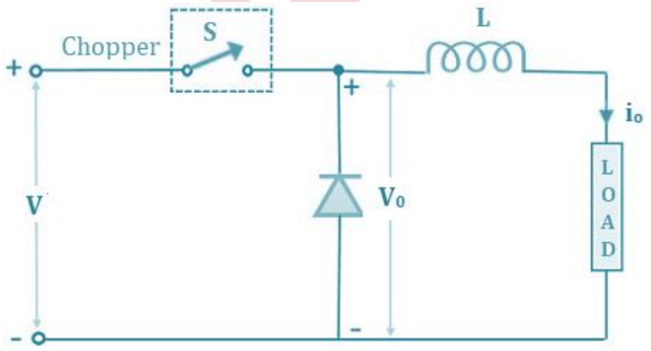
It produces noise in core signal hence PI controllers are best apposite for speed control.

In the PI controller, the proportional term enables quick correction, while the integral term acts in a finite amount of time and eliminates steady state inaccuracy.

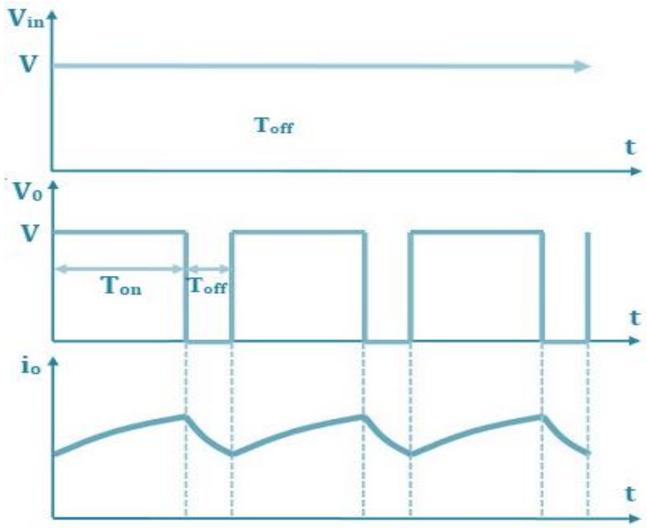
C. DC Chopper

The device that changes a stable dc I/p voltage into a variable dc output voltage is referred as a "chopper." In context of the switching process, it is commonly referenced as "on" or "off "semiconductor switch that is so fast.

Fig 5(a) and (b) depicts the chopper structure.As the chopper contains single step conversion, hence these are much more effective choppers that are usually employed in marine-hoists, along with forklift-truck [5].



(a)



(b)

Fig. 5. (a) Circuit (b) Waveforms

Chopper completes its operation instantly. It quickly links the source to load and unplug the load from source. Forced commutated thyristor like GTO, MOSFET, and IGBT are a few instances of power semiconductor components that are employed in chopper circuitry. Typically, those devices are expressed by a switch. Whenever the switch is "off," no current flows, and when it's "on," current passes through the load.

D. PID Controller

The fundamental function of feedback control is to ensure that the system's reaction is in line with the intended setpoint by leveraging the output data to affect the input. The system's self-regulating quality, which makes it resistant to outside disruptions and changes in system dynamics, is a result of this attribute.

The measured variable is continuously supplied back into a PID loop and contrasted with the intended setpoint. Error is defined as the difference between the measured value and the setpoint. By changing the control variable, the PID controller tries to reduce this mistake as much as possible.

By exploring through various processes, the PID controller employs a closed feedback control system to adjust the needed parameters to their set point or intended value. One of the most precise and appropriate control systems is the PID controller. PID controllers carry out various input procedures that maintain the value of a certain variable at the intended or goal point in order to regulate the output variable. Process variable and setpoint output values are continually monitored by PID controllers, which perform their functions utilizing proportional, integral, and deviation methods.

In order to decrease error and get the value of a process variable ready to the intended point, this correction mechanism keeps working automatically.

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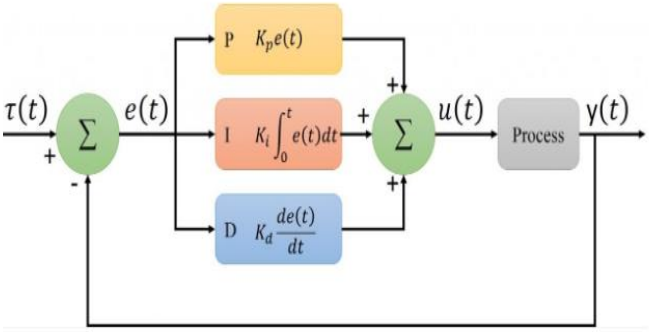

Fig. 6. Block Illustration for PID

The most popular kind of feedback control is the PID controller. P, I, and D are the three components that the PID controller employs. Fig.6 depicts illustration of attributes for PID control

When responding on the error signal produced by the controller output, P controller only takes proportionate action to rectify deviations from the target parameter value.The integral action is also used by PI controllers to sustain closed-loop performance under steady-state circumstances for lengthy periods of time. It is therefore extremely stable, but because its corrective effect is delayed, it may lead to system overrun.

The derivative action is used by the PD controller to rectify deviations from the target parameter value as determined by the process variable's rate of change, or the error signal produced by the controller's output.

IV. SIMULATTIONS AND RESULT

The drive scheme is studied in MATLAB so as to analyze performance of DC motor drive with and without PI control.

A. Without PI Controller

The Simulink scheme without PI Control for respected DC drive is revealed in Fig.7

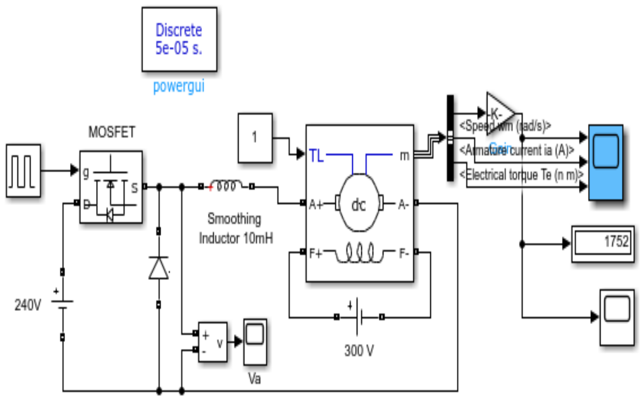

Fig. 7. MATLAB Model of DC Motorwithout PI

Fig.8 depicts the speed waveform of DC motor drive without PI control. Two waveforms are shown in outcome. A yellow waveform indicates the reference speed whereas blue colored waveform represents actual speed. The motor achieves its constant speed at around 3 seconds. Motor takes few seconds to run at constant speed.

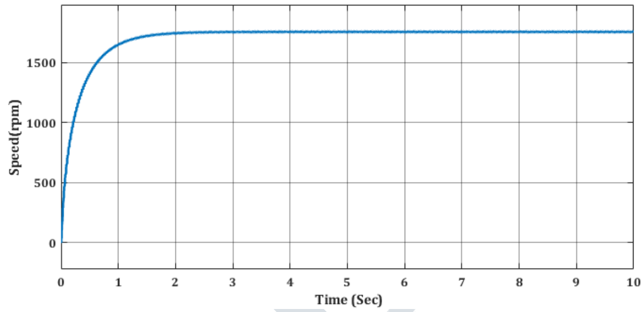

Fig. 8. Speed (Without Controller)

B. With PI Controller

The Simulink scheme with PI Control for proposed drive is depicted in Fig.9

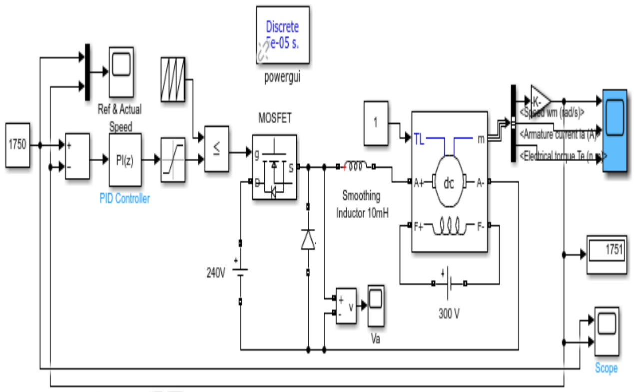

Fig.9. MATLAB Model of DC Motor with PI

A single sensor i.e. Speed is used for closed loop control for DC motor. Speed is regulated by employing PI controller to motor drive with appropriate controller attributes

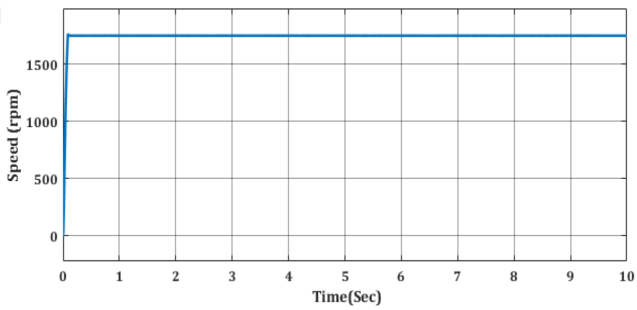

Fig. 10. Speed (With PI)

Fig.10 reveals speed of DC motor drive along with PI control. The motor attains its constant controlled speed at around 0.14 seconds. Motor requires very small time to get in steady speed as compared to conventional one.

C. With PID Controller

The Simulink scheme with PID Controller intended for DC drive is depicted in Fig.11

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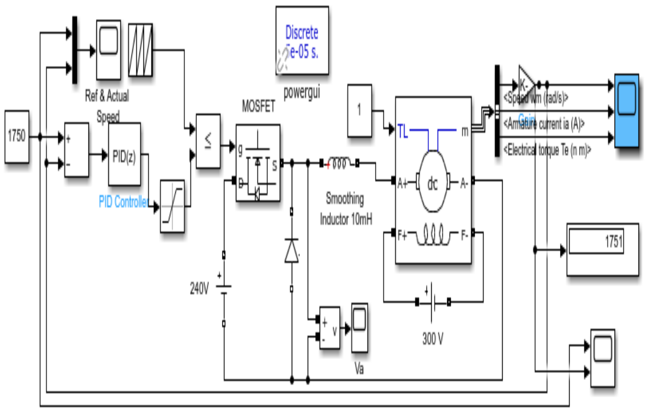

Fig. 11. Speed (Without Controller)

Speed is regulated by employing PI controller to drive scheme with suitable controller parameters. In PID the oscillating spike in the waveform is eliminated.

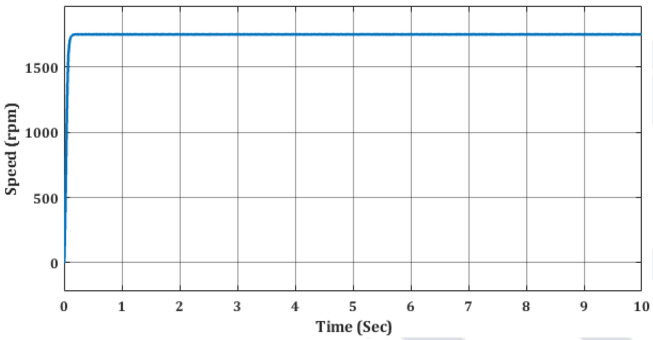

Fig. 12. Speed with PID

Fig.12 depicts speed for DC motor drive along with PID controller. The motor achieves its constant controlled speed at around 0.16 seconds

V. CONCLUSION

The speed of DC motor is effectively controlled by using chopper as converter. The intended PI and PID controller gives better performance at varying speed condition and act as a controller for close loop control system. PI and PID control provided the enhanced smoother control for motor rather than conventional one i.e. without control or open loop scheme, using buck converters switching losses is reduced.

Results indicated that the controllers' performances are similar for most of the processes and constraints specified.

PI controllers can be utilized to prevent significant disruptions and noise during operation. On the other hand, a PID controller's lengthy tuning time might be a disadvantage when working with higher order sensitive systems.

The SIMULINK model provided better results under rated speed during simulation. The simulation outcome yielded the steady armature voltage with field and torque too.

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