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Research Article

REVIEW ON CONTROLLERS FOR SPEED CONTROL OF DC MOTOR DRIVE

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Abstract

DC motor drives are being used extensively in modern industrial applications where improved transient performance is needed. 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. Typically, the controller plays a critical role in driving control for both dynamic and transient circumstances. The comparative review of P, PI, PID controllers for DC motor drive presented in this work. It is examined and compared how well P, PI, and PID controllers operate

Keywords: P, PI, PID, Ev, PWM, TRC.

INTRODUCTION

DC motors have existed around for a century or more. Actually, these were the first motors ever created and used using direct current electricity. When AC motors were developed, they quickly became the industrial horsepower of choice because of their high speed operation, small size, low cost, low maintenance, and low weight. DC motors are still in use today, though, because of their many benefits. Their wide speed range, powerful starting and accelerating torques, and superb speed regulation are the reasons for this. They are less expensive to drive and have simpler controls. DC motors are still used today in a variety of applications, including the textile industry, the manufacturing and processing of paper pulp, propulsion, and EVs [1]. The design and advancement of higher performance motor drives is crucial for industrialized usage. Effective load regulating reaction and dynamic speed command tracking are essential for a high performance motor drive system [2]. Excellent speed control is offered by DC motors for both acceleration and deceleration. For applications requiring precise control of voltage along with speed as well as torque control, a DC motor's power supply is directly connected to the motor's field [3]. DC drives has became foundation for industrial applications due to their affordability, simplicity, ease of application, and dependability. Compared to AC drives, DC drives have a simpler system. Low horse power ratings sometimes result in cheaper DC drives. Since DC motors may be utilized to modify speed, many different solutions have been developed for this application. Cooling air is supplied over a broad speed range at constant torque using cooling blowers and intake air flanges. For applications needing constant regeneration for overhauling loads, DC regenerative drives are offered [4]. Electric propulsion has traditionally been mostly provided by DC motors. They are also utilized in mining and quarry operations. DC motors are easily transportable and suitable for specialized uses, such as industrial machinery and equipment that are difficult to operate from distant power sources [5]. The torque and speed characteristics of a DC motor make it a SISO system that can be used for most mechanical loads. This enables DC motor to be controlled across a broad speed range by appropriate terminal voltage modification. Modern electric traction systems often employ synchronous motors, brushless DC motors, and induction motors. Even yet, efforts are ongoing to use creative design and control strategies to get them to operate like DC motors. Because other motor types may also benefit from the idea of DC motor speed control, DC motors are always an excellent choice for sophisticated control algorithms. In independently excited DC motors, the armature voltage may be varied to produce a speed below rated value, and the field flux can be varied to reach a speed above the rated speed [6–8]. Conventionally, armature voltage is controlled for low power DC motors using the rheostatic technique; for constant power motors conventional PID controllers and neural controllers for higher speed system, a single phase uniform PWM AC-DC buck-boost power converter by means of a switching device is used for voltage control of armature; and for invariable torque NARMA-L2 controllers are employed [9]. In this literature presents the study for various controllers along with their behavior. Their structures are explored.

Drive Scheme

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

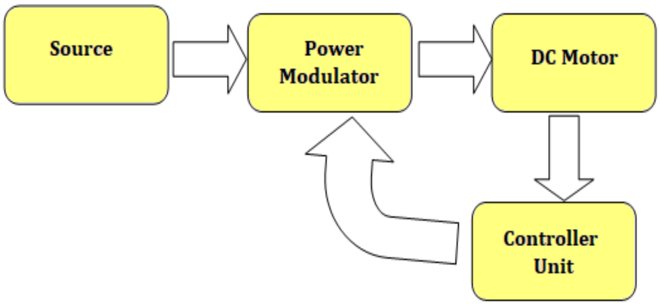

Fig. 1. Drive Scheme

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The various parts of the scheme are described below in brief.

Power Modulator

The core of an electronics system is a power modulator [10], which uses controller-supplied command input to modulate the power available from the source as needed by the load. The following tasks are carried out by the power modulator:

a) It adjusts the power flow from the source to the motor so that the motor receives the speed-torque characteristics the load requires.
b) It limits the source and motor current to allowable levels when performing transitory functions like braking, starting, and speed reversal.
c) It transforms the source's electrical energy into a form that the motor can use.
d) It chooses the motor's operating mode, such as driving and braking.

Generally the DC chopper circuitry is employed as power modulator for power processing for dc loads

Controllers

The control unit contains the controls for a power modulator. The power modulator that is being utilized determines the type of control unit for that specific drive. Transistors and microprocessors are utilized when complex control is needed, and firing circuits using linear and digital integrated circuits make up the control unit when semiconductor converters are employed. Power electronics modulators are controlled by built-in control units, which typically run at far lower voltage and power levels. It can provide directives for the protection of power electronic modulators and motors in addition to running the power electronics modulator. Input command signal that modifies the drive's operating point by examining the controller's feedback signal.

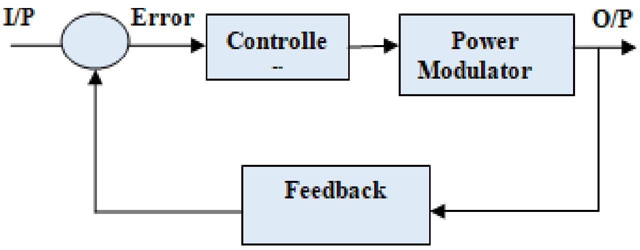

Fig. 2. Controller Scheme

Both analog and integrated circuits are used to implement the controller. The current tendency is to incorporate a set of functionalities in the controller using microprocessors, single chip modulators, VLSI, Digital Signal Processors (DSP), and unique custom chips known as Application Specific ICs (ASIC) [11].

Separately Excited DC motor

The equivalent circuitry for independently energized DC motor is depicted in Fig. 3. The armature and field winding of the individually excited DC motor are powered by separate supplies. The DC motor's field windings employed to stimulate field flux. The rotor receives current from armature circuit through the commutator section and brush to perform mechanical work. The combination of armature current and field flux generates the rotor torque.

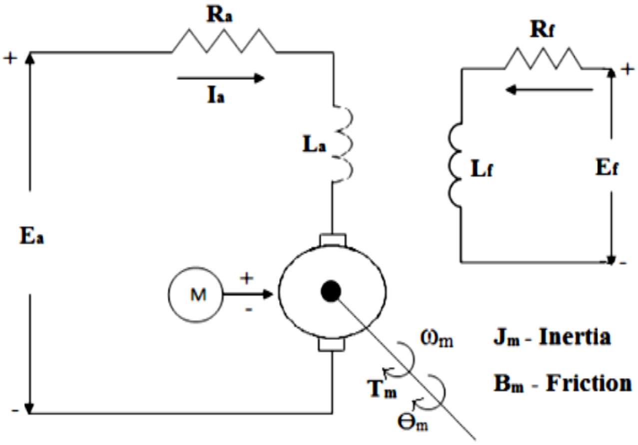

Fig. 3. Equivalent Circuit

A independently excited DC motor creates back EMF as well as torque to maintain load torque at specific speed when it is stimulated by an armature current and a field current that flow through the circuit. Armature current doesn't affect the field current. Every winding is supplied individually. [12]

Control strategy

The periodically opening and closing the semiconductor switch will regulate the average output voltage. . In DC choppers, there are two different control schemes that could be applied to operate the switches. Current limit control and TRC are these control methods

Time-Ratio Control

The value of Ton/T of is changed in this control approach. There are two manners whereby this is impacted: by constant frequency control and by variable frequency control. The chopping frequency is maintained varying in variable frequency control, and as a result, the on or off time is maintained constant. For instance, this method is known as a frequency modulation scheme. This method performs effectively with switches that need to be driven to commutate in order to turn off. [13] The chopping duration is constant in a constant frequency control method, but the pulse width is adjusted to regulate the output. Consequently, this is referred to as PWM control.

Current Limit Control

The chopper is turned on and off in accordance with this strategy between upper as well as lower limits for load current. Whenever load current goes above the maximum limit, the chopper shuts off. At this point, the load current freewheels until it hits the lower permissible value. While the load current reaches the lower margin, the chopper turns on. A storage component is required in the load since this approach involves the freewheeling action. This kind of system is only suitable at constant frequency when the load current fluctuates between the two specified limits. In this instance, the switching frequency is determined by the difference between the higher and lower values of the load current, which is continuous. The switching frequency increases as the current differential decreases. Consequently, there are less output ripples.[14] The output's ripple content can be decreased by increasing the switching frequency in proportion to the further lowering of the current's upper and lower limits.

Controllers

A controller is a device that keeps track of and modifies a dynamic system's operational parameters. The two primary categories of control algorithms are typically Open-loop and Closed-loop. An open-loop scheme is a kind of control system where the input determines the outcome of system, yet the controller or input is independent of system's output. These systems are referred to as non-feedback systems since they are not part of any response loop. Whereas, in closed-loop control scheme regulating action is contingent upon the system's produced output. To put it simply, the input provided to the system is controlled by output in these systems. More accurate system output is produced when the input varies based on the output. Thus, by using a feedback link, the closed-loop system's output is formed, achieving controllability.[15]

P Controller

Another distinct type of linear feedback type control scheme is a proportional controller [16] system. The P controller system is not as complex as PID control found in devices like car cruise controls, but more sophisticated than on-off control scheme like a bimetallic household thermostat. P controllers are often thought to be unable to stabilize higher order processes. The disparity between the process variable and set point, or the error signal, determines the controller output in the P controller algorithm [17].

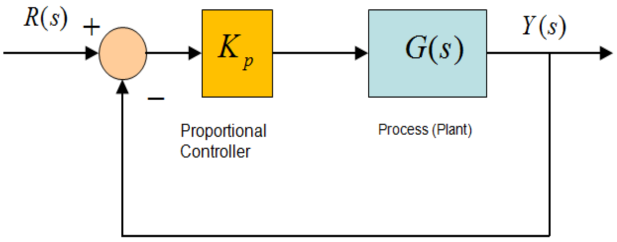

Fig. 4. P Control

The error in signal is given by

$$e(t) = K[r(t) - h(t)] \qquad (1)$$

The error signal determines the proportionality of actuating signal for control action while using P controller. The disparity between the reference and feedback signal produces error signal. With the benefit of speedy reaction, it is recommended that the control system be under damped. The output time response of an under damped control system indicates exponential decay within the transient phase.

PI Controller

The PI control [18] is now being mostly used in industries because of its affordable, simple design, and straightforward construction. Even with these benefits, a highly nonlinear and unpredictable controlled object causes PI controller to fail. Enforced oscillations along with error in steady state will be eliminated by the PI controller, enabling the P and on-off controllers to operate, respectively. Integral mode introduction, however, has a detrimental impact on system's overall stability and reaction time. As a result, the PI controller won't quicken reaction time. It makes sense since the PI controller lacks the ability to forecast the error's future direction. This issue can be resolved by using the derivative mode, which can reduce the controller's reaction time by predicting what would happen to upcoming errors. In industry, PI controllers are widely utilized, particularly where reaction time is not a concern. A control without D mode is employed when [19] [20].

The system does not need to respond quickly.

There are loud noises and significant disruptions while the procedure is running.

The controller outcome is

$$u(t) = K_p e(t) + K_i \int e(t)dt \qquad (2)$$

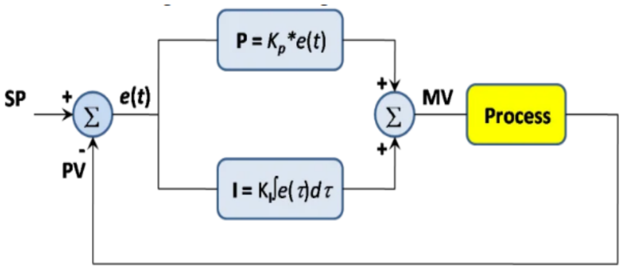

Fig. 5. PI Control

The PI controller's integral error reparation scheme is depicted in the picture. The actuating signal's integral influences the output response in some way. Using controller which generates output signal by two terms one proportional to actuating and other to its integral. Such controller is expressed as PI controller [21].

PID Controller

The proportional, integral plus differential PID regulator configuration is commonly used by industrial controllers, and it may be customized to improve a specific control system. The most popular method for controller design and most frequently used in industry is PID controller [22]. PID controllers or their enhanced variants are the controllers utilized in industry. Parallel, serial, and mixed controllers are the three fundamental forms of PID controllers. The design velocity algorithm, commonly known as the incremental algorithm, is the PID controller algorithm that is used. PID controllers are widely used control approach in practical applications within the industry.

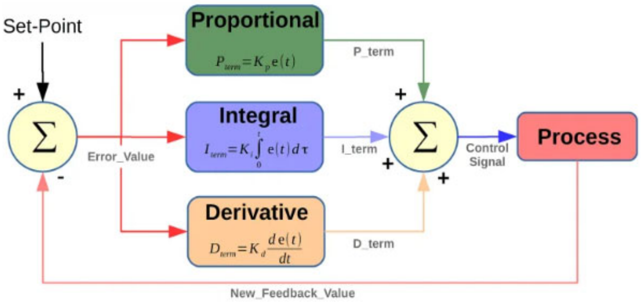

Fig. 6. PID Control

The controller outcome is

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de(t)}{dt} \tag{3}$$

The error signal along with the proportional gain Kp are relative to control signal. P controller will lessen but never completely eradicate, the rising time. Control signal is comparative to integral of error and the integral gain Ki , if an integrator is introduced. The error will theoretically be decreased to zero value using integral control. The addition of the in principle is necessary as every system has limitations when it comes to accuracy. By employing corrective measures based on the error signal's rate of change, Derivative control helps predict how the error signal will behave in the future. Kd is the gain of the derivative, and the control signal is proportional to the error's derivative.

The system will become more stable, overshoot will be less, and the transient response will be better using derivative control. Since the derivative control action is only effective for brief periods of time, it can never be employed alone. The PID controller is by far the most widely used control approach because it allows a control loop to respond more quickly and with less overshoot. Every benefit of the three separate control acts is present in the combined action. The derivative approach boosts system stability, furthermore permits a gain K increase and a drop in the integral time constant, which quickens the controller's reaction. The most popular controllers in the process sector are PID controllers. PID controllers being mostly used controller worldwide [23] and more than 95% of controllers [24] in process control applications are PID type controllers. The benefits of integral, derivative, and proportional control actions are combined in a PID controller.

Selection for Controller

Whenever the control system is being investigated, an appropriate controller should be chosen and designed [25]. Some of the crucial characteristics of the popular P, PI, and PID controllers are:

a) Operational lag
b) Manner of Action.
c) The mistake correction's speed.
d) The steady-state error's acceptability.

Table 1. Depicts the effects of controllers on parameters

Parameter	Speed of Response	Stability	Accuracy
Increasing K_i	Decrease	Deteriorates	Improves
Increasing K_d	Increase	Improves	No
Increasing K_p	Increase	Deteriorates	Improves

Conclusion

DC motors are extensively employed for inconsistent speed applications. Due to its easy controllability and highly demanding speed-torque characteristics. Review of chopper fed DC motor with controllers is presented in this study. Based on the literature survey, controllers and systems can be linked as follows:

- P controllers are employed for simple scheme where steady-state faults are acceptable.
- PD controllers are employed in systems with significant latency where the offset is acceptable.
- I controllers are employed where there is less need to manage dynamics and the system doesn't show significant delays.
- PI controllers are utilized to provide active control response exclusive of displaying the error at steady state.
- PID controllers are utilized when it's necessary to respond as quickly as feasible, despite a larger latency.

A comparison of P, PI, and PID controllers is conducted; the study show that PID controllers respond better than any other controllers. P, PI, and PID controller will be used to assess the DC motor drive's output response in the future. Depending on the many industrial uses for DC motors, the right controller can be selected.

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