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Power Electronics for Drives and Generators

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Abstract

The field of electrical engineering is generally segmented into three major areas such that:- electronics, power and control. Power electronics is a combination of these three areas. The advent of power semiconductor devices, thyristors in 1957, has been an exciting breakthrough in the art of electric power conversion and its control.
In a modern power electronic equipment, there are essentially two types of semiconductor elements: the power semiconductors that can be considered as the muscle of the equipment, and the microelectronic control chips that provide the power to the brain.
The DC motor are used extensively in adjustable-speed drives and position control applications. Their speeds below base speed can be controlled by armature-voltage control. Speeds above base speed are obtained by field-flux control. As speed control methods for DC motors are simpler and less expensive than those for ac motors, dc motors are preferred wide-speed control range is required.
The dc motors used in conjunction with power-electronic converters are dc separately excited motors or dc series motors. Depending upon the type of ac source or the method of voltage control, dc drives are classified as under:
1. Single-phase dc drives
2. Three-phase dc drives
3. Chopper drives.

Keywords: Power electronics, Semi-conductor, thyristor, drives, converters, microelectronics.

1. Introduction
The advent of power electronics in the industries today has changed the scene completely. Direct current dc motors have been used in variable speed drives for a long

time. The versatile control characteristics of dc motors have contributed to their extensive use in the industry, dc motor can provide high starting torque which are required for traction drives. Control over a large speed range, both below and above the rated speed can be easily achieved. The methods of speed-control are simpler and less expensive than those of alternating current motors.

Fig. 1: Block diagram of Typical power electronics system, Thyristor dc drives frequently require sophisticated control systems. Both analogue and digital feedback controls are used. Phase-locked loop control techniques are employed in some dc drives to provide precise speed control and essentially zero speed regulation microcomputer control of complex drive systems can provide great operating flexibility when required. No wonder that today this technology is well understood and proven which resulted in its popularity the world over.

Fig. 2: Classification of Regulated Power Supplies Power supply is the heart of any electronic system. Since electronic components are sensitive to voltage, the power supply must provide regulated voltage to the system for satisfactory performance.

An ideal regulated power supply is an electronic circuit that provides a predetermined dc voltage as output, which is independent of:

I) The current drawn by the load
II) Any change in the input ac line voltage (RMS)
III) Any change in temperature of components and ambient.

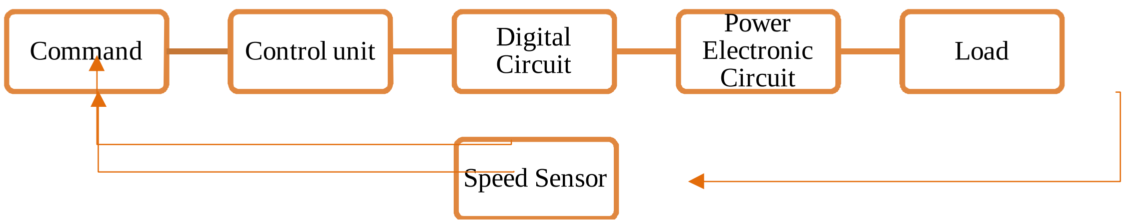

Fig. 1: Block diagram of a typical power electronic system

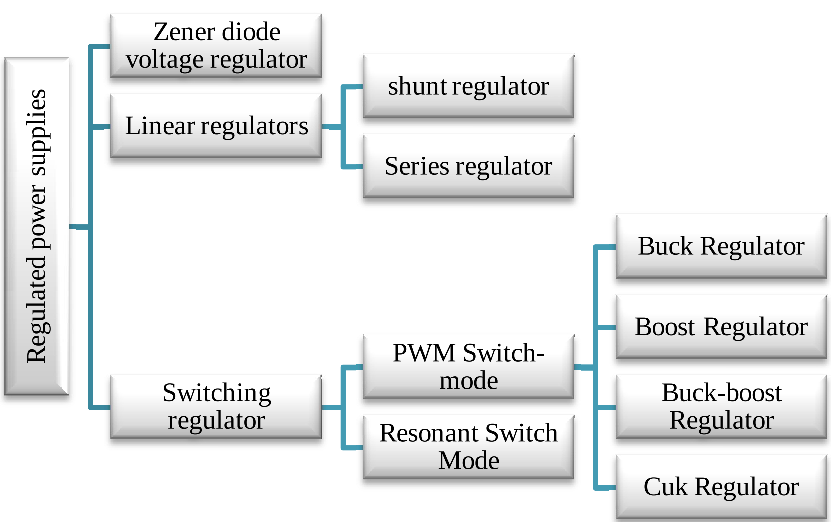

Fig. 2: Classification of Regulated Power Supplies.

2. Methods for D.C. Motor Speed Control

The speed of a d.c. motor has to be controlled from an a.c. or d.c. source. The two basic method of dc motor speed control *is shown in Fig. 3* is more common, where a controlled rectifier is used to supply the motor armature. The most common form of variable-speed d.c. drive is based on the control of armature voltage. Hence, the motor speed is dependent on the firing delay angle of the rectifier. The speed of the motor is determined its mean armature voltage, any oscillating torque produced by the harmonic voltage components being heavily damped by the motor inertia. If required, the field can be supplied via a controlled rectifier. Where the machine is required to generate, if rapid braking is required, then the converter must be capable of operation in the inverting mode.

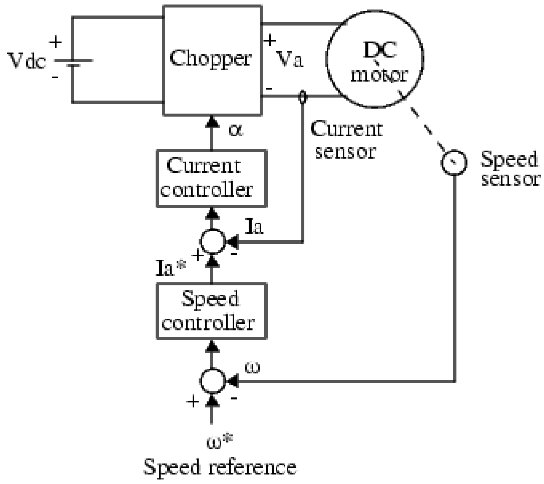

Fig. 3: Speed control of DC motor.

3. Single-Phase separately excited drives

In phase-controlled dc drives, an ac to dc phase-controlled converter is used to control the dc drive motor. Controlled rectifier for dc drives are widely used in applications requiring a wide range of speed control and frequent starting, braking and reversing. Some prominent applications are in rolling mills, paper mills, printing presses, mine winders, machine tools, etc.

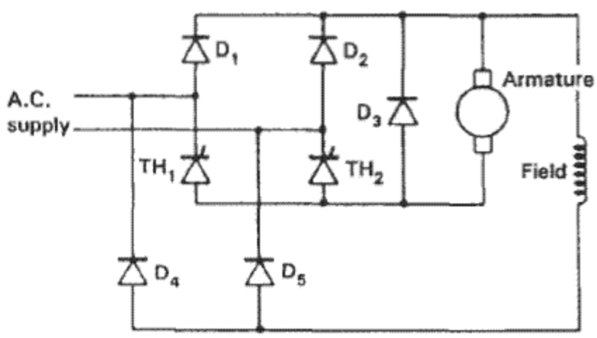

Fig. 4: Single-Phase separately excited drives.

The converter used for a particular application depends on such factors as supply available, rating of the drive, amount of voltage ripple to be tolerated, reversible or non-reversible drive, need for regeneration etc. The basic circuit arrangement for a single-phase separately excited dc motor drive *is shown in Fig. 4*. The armature voltage is controlled by a semi converter or full converter and the field circuit is fed from the ac supply through a diode bridge. The motor current cannot reverse due to the Thyristors in the converters.

4. Single phase Half-wave Converter Drives

Fig. 5 and Fig. 6, Half-wave converter for controlling a separately excited dc motor. It requires a single Thyristor and a freewheeling diode. In this circuit the motor current is always discontinuous, resulting in poor motor performance. This type of converter is employed only for motors below 400W.

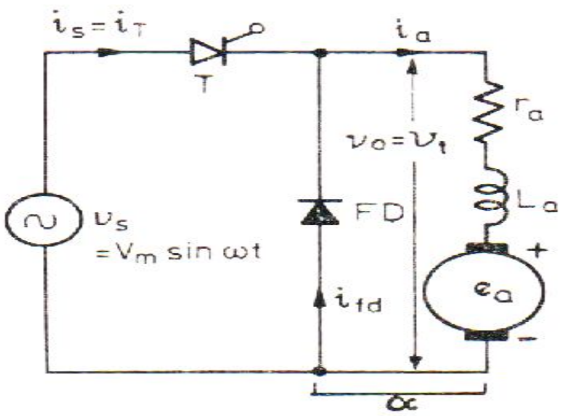

Fig. 5: Half-wave Converter Drive

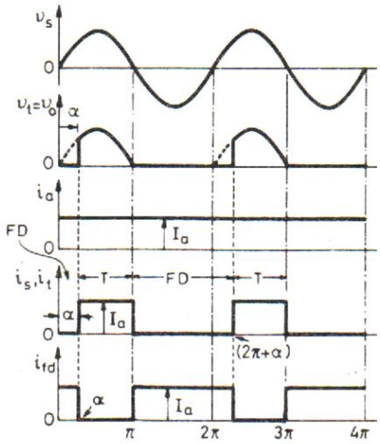

Fig. 6: Wave form Half-wave converter drive

5. Single-phase full Converter Drive

A full converter feeding a separately excited dc motor. In the full converter system Thyristor T_{11} and T_{13} are simultaneously triggered at α, and Thyristor T_{12} and T_{14} are triggered at (π + α). The voltage and current waveform under continuous current conduction *are shown in Fig. 7(a) and figure7(b).* The motor is always connected to the input supply through the Thyristor. Thyristors T_{21} and T_{23} conduct during the interval α <wt < (π + α) and connect the motor to the supply. A full converter is a two quadrant converter in which the voltage polarity of the output can reverse, but the current remains unidirectional because of the unidirectional Thyristor. If the motor back emf is reversed, it will behave as a dc generator and will feed power back to the ac supply this is known as the inversion operation of the converter, the inversion mode of operation is used in the regenerative breaking of the motor.

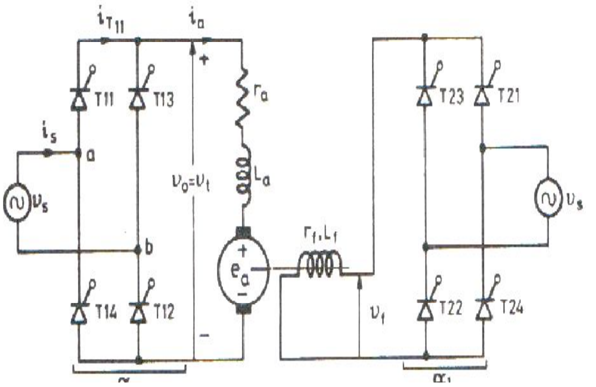

Fig. 7(a): Single Phase full converter

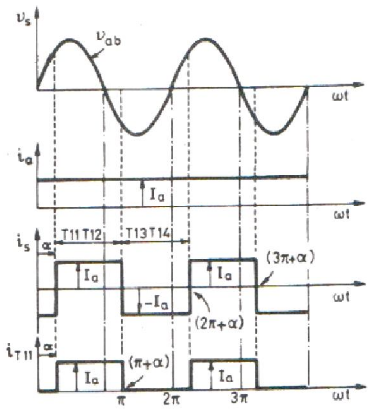

Fig. 7(b): Waveform

6. DC chopper Drives

A **chopper** circuit is used to refer to numerous types of electronic switching devices and circuits. Control of a dc motor speed by a chopper is required where the supply is dc or an ac voltage that has already been rectified to a dc voltage. A chopper may be thought of as an ac transformer since they behave in an identical manner. Chopper controlled dc drives have also applications in servos in battery operates vehicles such as forklift trucks, trolleys, and so on. A chopper is a static device that converts fixed dc input to a variable dc output voltage directly. Choppers are used for the control of dc motors because of a number of advantages, such as high efficiency, flexibility in control , light weight , small size, quick response, and regeneration down to very low speeds. The choppers offer a number of advantages over a controlled rectifiers for a dc motor control in open-loop configurations. A reduction or elimination of discontinuous conduction region improves speed regulation and transient response of a drive. The most important applications of choppers are in the speed control of dc motors used in industrial or traction drives. Because higher frequency of the output voltage-ripple, the ripple in the motor armature current is less and the region of discontinuous conduction in the speed-torque plane is smaller. A reduction in the armature current ripple reduces the machine losses and its derating. The DC chopper drives *is shown in Fig. 8.*

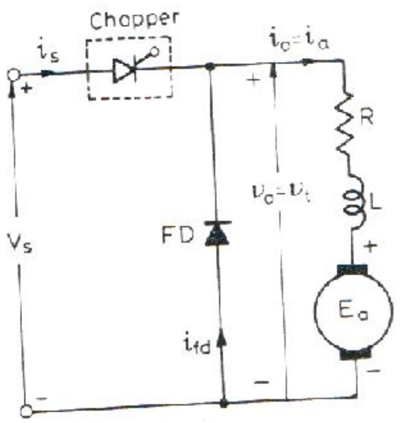

Fig. 8(a): DC chopper Drive

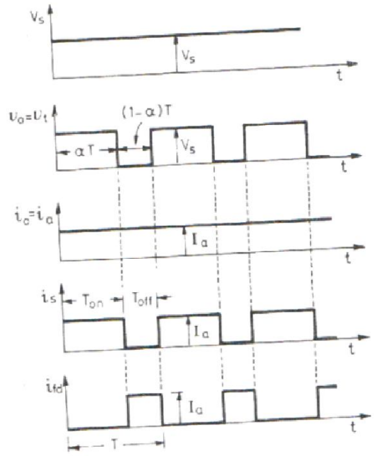

Fig. 8(b): Waveform

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