

INDUSTRIAL ELECTRONICS AND CONTROL OF DRIVES

Unit IV : Thyristor Control of Electric Drives

Topic: DC Drives: Speed Control, Half-Wave, Full-Wave and Chopper Drives

Important Questions with Answers (5th Semester, Electrical Engg.)

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Short Answer Questions

Q.1 Explain the methods of speed control of a DC motor. Which method is used to obtain speed above the normal speed?

Ans. For a DC motor, the back emf is $E_b = V_a - I_a R_a$, and E_b is proportional to ϕN . So the speed is:

$$N \propto (V_a - I_a R_a) / \phi$$

Here V_a is the armature voltage, I_a the armature current, R_a the armature resistance and ϕ the flux per pole (standard textbook relation). The speed can be changed by changing V_a , ϕ or R_a .

Method	What is changed	Speed obtained	Remark
Armature voltage control	V_a (by a converter or chopper)	Below the normal (base) speed	Constant torque; smooth and efficient; used in thyristor drives
Field (flux) control	ϕ (by changing the field current)	Above the normal (base) speed	Constant power; limited speed range
Armature resistance control	R_a (resistor in series)	Below the normal speed	Wasteful; not used in thyristor drives

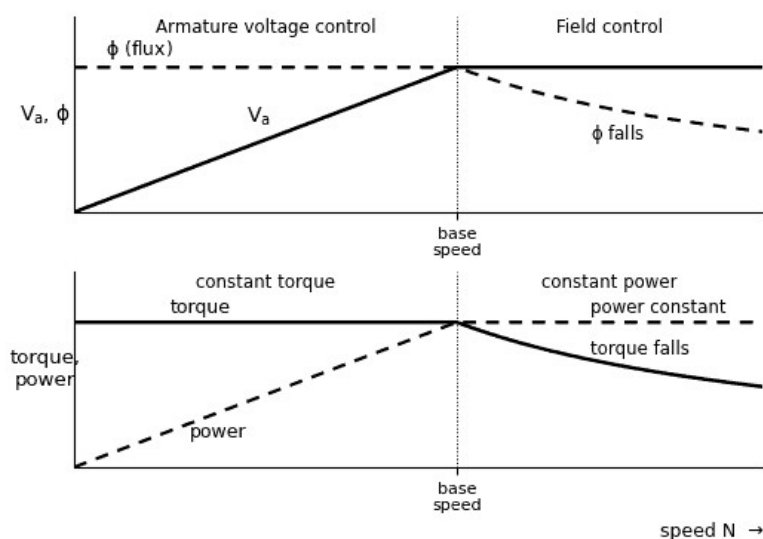


Fig. 1 Speed control regions of a DC motor (sketch)

The two methods are often used together. Below the base speed, the field is kept at its full value and V_a is raised from zero to its rated value (constant torque). Above the base speed, V_a is kept at its rated value and the field is weakened (constant power).

Remember: Speed above the normal speed is obtained by field (flux) control.

Q.2 Explain the half-wave DC drive.

Ans. In the half-wave DC drive, one SCR is connected in series with the armature of the DC motor and the AC supply. A freewheeling diode is connected across the armature. The field winding gets a separate, constant DC supply.

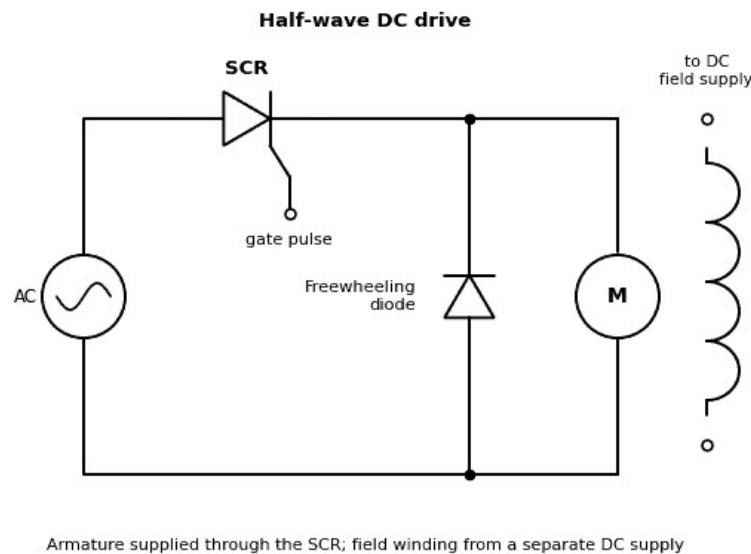


Fig. 2 Half-wave DC drive (circuit sketch)

Working:

1. In the positive half cycle, the SCR is triggered at the firing angle α . The armature gets the supply voltage and the motor speeds up.
2. At the end of the half cycle, the SCR turns OFF. The armature current continues through the freewheeling diode, so the armature voltage does not become negative.
3. In the negative half cycle, the SCR is OFF. The motor keeps running because of its inertia.
4. The average armature voltage (for continuous current) is $V_a = (V_m / 2\pi)(1 + \cos \alpha)$.

Speed control:

If α is decreased, V_a increases and the speed increases. If α is increased, V_a decreases and the speed decreases.

Limitations: Only one half cycle is used, so the armature current has a large ripple and the torque pulsates. The supply current has a poor power factor. It is used only for small motors.

Q.3 Explain the full-wave (half-controlled and fully controlled) DC drives.

Ans. Full-wave drives use both half cycles of the supply. There are two types.

(a) Half-controlled (semi-converter) drive:

The bridge has two SCRs and two diodes. The armature voltage is $V_a = (V_m / \pi)(1 + \cos \alpha)$.

The diodes give a natural freewheeling path, so the armature voltage never becomes negative. The drive works in one quadrant only: it gives motoring in one direction, but no regenerative braking.

(b) Fully controlled drive:

The bridge has four SCRs. For a highly inductive armature circuit, the armature voltage is $V_a = (2V_m / \pi) \cos \alpha$.

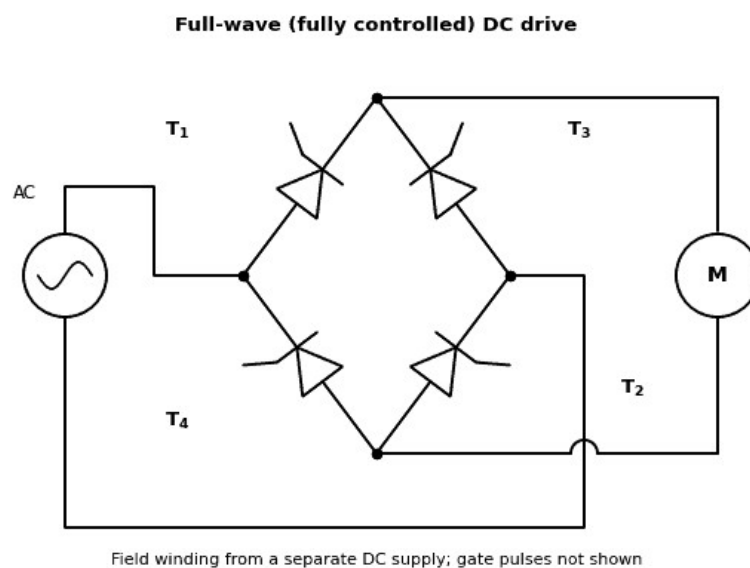


Fig. 3 Full-wave (fully controlled) DC drive (circuit sketch)

1. For α less than 90° , V_a is positive and the motor works as a motor (rectifier mode).
2. For α more than 90° , V_a is negative and the converter works as an inverter. If the motor is rotating fast, it can return energy to the supply (regenerative braking).
3. So the drive works in two quadrants. To reverse the motor, the field or the armature connections are reversed by a contactor. For four-quadrant operation, a dual converter is used.

Note: These are textbook relations for ideal devices. Changing α changes V_a , and so the speed.

Q.4 Explain the chopper drive for a DC motor.

Ans. When the supply is DC (a battery or a DC line), a chopper is used to control the armature voltage of the DC motor.

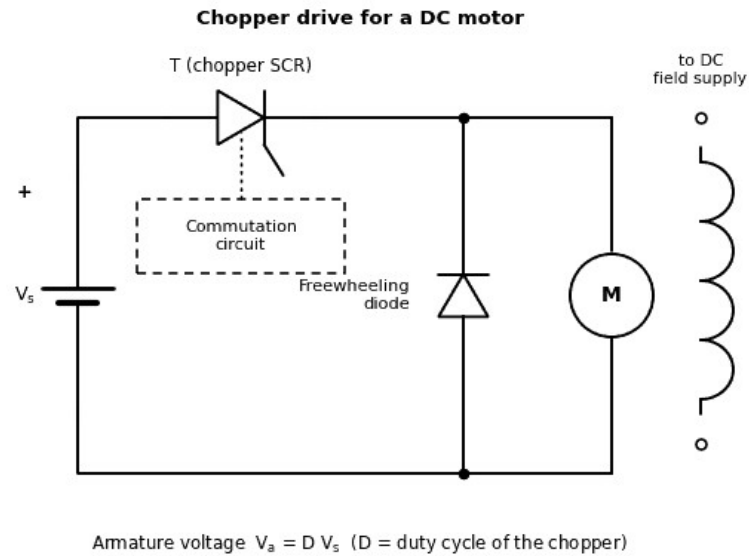


Fig. 4 Chopper drive for a DC motor (circuit sketch)

Working:

1. When the chopper switch is ON for T_{on} , the full supply voltage V_s is applied to the armature.
2. When it is OFF, the armature current continues through the freewheeling diode and the armature voltage is zero.
3. The average armature voltage is $V_a = D V_s$, where $D = T_{on} / T$ is the duty cycle. Increasing D increases the speed.

Features and applications:

A class A chopper gives motoring in one direction. Class C or class E choppers give regenerative braking and reversal. The efficiency is high and the speed control is smooth. It is used in battery vehicles, forklifts, trolley buses, metro trains and electric locomotives.

Long Answer Question

Q.5 Explain the control of a DC motor using thyristor converters: half-wave, full-wave and chopper drives.

Ans. The speed of a DC motor is controlled by the armature voltage below the base speed and by the field flux above it. In a DC drive, a thyristor converter gives the variable armature voltage.

Note: In the exam, draw Fig. 2, Fig. 3 and Fig. 4 given in Q.2, Q.3 and Q.4.

Drive	Supply	Devices	Quadrants	V_a
Half-wave	Single-phase AC	1 SCR and 1 diode	One	$(V_m/2\pi)(1 + \cos \alpha)$
Half-controlled full-wave	Single-phase AC	2 SCRs and 2 diodes	One	$(V_m/\pi)(1 + \cos \alpha)$

Fully controlled full-wave	AC	4 SCRs (or 6)	Two	$(2V_m/\pi) \cos \alpha$
Chopper	DC	SCR or switch, diode	One to four	$D V_s$

Working in short:

1. **Half-wave drive:** An SCR in series with the armature; a freewheeling diode keeps the armature voltage positive. Speed is increased by decreasing α .
2. **Half-controlled full-wave drive:** Two SCRs and two diodes; one quadrant; no regenerative braking.
3. **Fully controlled drive:** Four SCRs; for $\alpha < 90^\circ$ it gives motoring and for $\alpha > 90^\circ$ it gives regenerative braking (two quadrants).
4. **Chopper drive:** A chopper between the DC supply and the armature; $V_a = D V_s$; used for battery and traction drives.

Points to Remember (for MCQ and True/False)

1. Field control of a DC motor gives speed above the normal speed.
2. Flux control is used to get speed above normal speed in a DC shunt motor.
3. Armature voltage control gives speed below the normal speed.
4. A fully controlled converter uses thyristors only.
5. In a chopper drive, $V_a = D V_s$.
6. In a fully controlled drive, $\alpha > 90^\circ$ gives regenerative braking.