Power Electronics Laboratory (EE3P004)

EXPERIMENT-10

Speed Control of DC Motor using 1-ϕ Half Controlled Rectifier

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Aim of the Experiment:

To control the speed of DC Shunt Motor using 1 phase Half Controlled Rectifier.

Apparatus Required:

- 1 Phase Converter firing circuit
- DC Shunt Motor 3 HP, 220V
- 1 Phase Half Controlled Rectifier
- Rheostat 50 Ohms/5A
- Isolation Transformer 230/230V @15 A with tapings.
- Digital Tachometer
- Power Scope CRO 10:1 probe

Theory:

Single Phase Half Controlled Rectifier Control is shown in Fig. 5.29(a). In a cycle of source voltage defined by Eq. (5.71), T1 receives gate pulse from α to π and T2 from (π+ α) to 2π. Motor terminal voltage and current waveforms for the dominant discontinuous and continuous conduction mode are shown in Figs. 5.29(b) and (c) respectively.

In discontinuous conduction mode, when T1 is fired at α, the motor gets connectedto the source through T1 and D1 and va = vs. The armature current flows and D2 gets forward biased at π. Consequently, armature current freewheels through the path formed by D1 and D2, and the motor terminal voltage is zero. Conduction of D2 reverse biases T1 and turns it off. Armature current drops to 0 at β and stays zero until T2 is fired at (π+ α). Similarly, the continuous conduction mode can be explained.

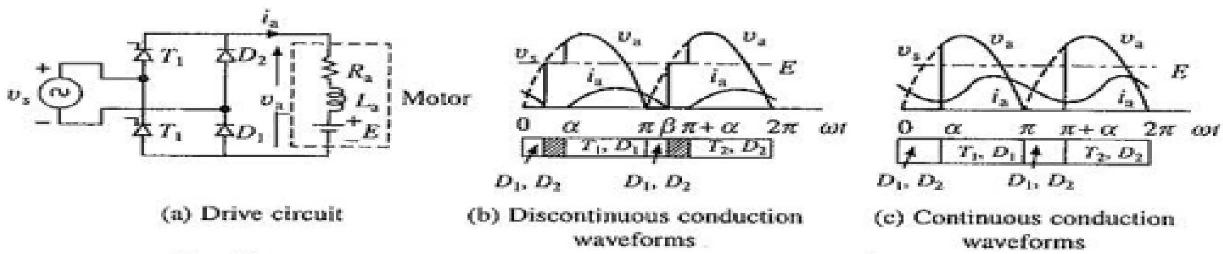


Fig. 5.29 Single-phase half-controlled-rectifier fed separately excited motor

Discontinuous Conduction:

A cycle of motor terminal voltage consists of three intervals (Fig. 5.29(b)):

- Duty interval ($\alpha \le \omega t \le \pi$): Armature current is given by Eq. (5.77). Substitution of $\omega t = \pi$ in this equation gives ia(π).
- Freewheeling interval ($\pi \le \omega t \le \beta$): Operation is governed by the following equation:

$$i_a R_a + L_a \frac{di_a}{dt} + E = 0 \qquad (5.87)$$

Solution of (5.87) subject to ia(π) as the initial current yields

$$i_a(\omega t) = \frac{V_m}{Z}[\sin\phi \cdot e^{-(\omega t-\pi)\cot\phi} - \sin(\alpha-\phi)\cdot e^{-(\omega t-\alpha)\cot\phi}]$$
$$-\frac{E}{R_a}[1-e^{-(\omega t-\alpha)\cot\phi}], \quad \text{for } \pi \le \omega t \le \beta \tag{5.88}$$

- Zero current interval ($\beta \le \omega t \le \pi + \alpha$): Equation (5.73) is applicable. Since $i_a(\beta) = 0$, one gets from (5.88)

$$e^{\beta\cot\phi} = \frac{R_a V_m}{ZE}[\sin\phi\, e^{\pi\cot\phi} - \sin(\alpha-\phi)e^{\alpha\cot\phi}] + e^{\alpha\cot\phi} \tag{5.89}$$

β can be calculated by the solution of Eq. (5.89). Now

$$V_a = \frac{1}{\pi}\left[\int_\alpha^\pi V_m \sin\omega t\, d(\omega t) + \int_\beta^{\pi+\alpha} E d(\omega t)\right]$$
$$= \frac{V_m(1+\cos\alpha) + (\pi+\alpha-\beta)E}{\pi} \tag{5.90}$$

From Eqs. (5.7), (5.8), (5.79) and (5.90)

$$\omega_m = \frac{V_m(1+\cos\alpha)}{K(\beta-\alpha)} - \frac{\pi R_a}{K^2(\beta-\alpha)}T \tag{5.91}$$

The boundary between continuous and discontinuous conduction is reached when $\beta = \pi + \alpha$. Substituting $\beta = \pi + \alpha$ in (5.89) gives the critical speed ω_{mc}, which separates continuous conduction from discontinuous conduction for a given a.

$$\omega_{mc} = \frac{R_a}{K}\frac{V_m}{Z}\left[\frac{\sin\phi \cdot e^{-\alpha\cot\phi} - \sin(\alpha-\phi)e^{-\pi\cot\phi}}{1-e^{-\pi\cot\phi}}\right] \tag{5.92}$$

Continuous Conduction:

From Fig. 5.29(c)

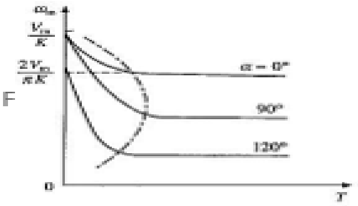


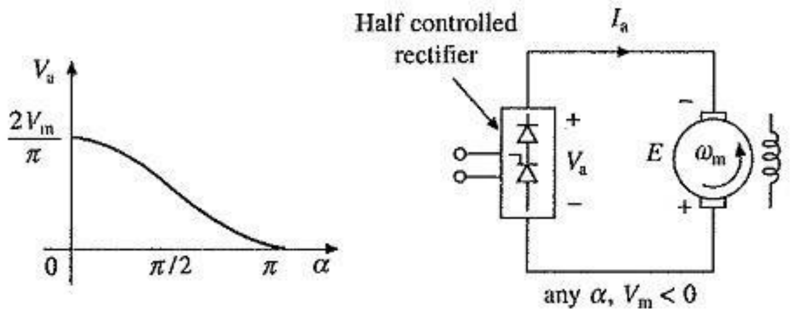
Fig. 5.30 Speed torque curves of single-phase half-controlled rectifier fed separately excited motor

$$) = \frac{V_m}{\pi}(1+\cos\alpha) \tag{5.93}$$

F ... and (5.93)

$$\frac{a}{2}\,T \tag{5.94}$$

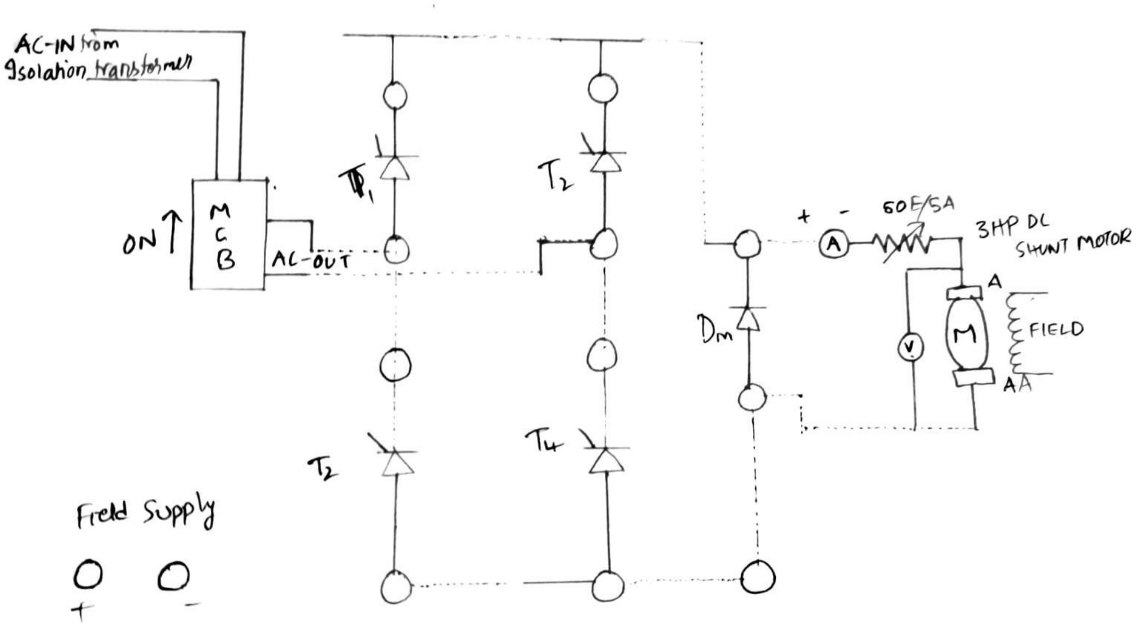
Speed-torque curves are shown in Fig. 5.30. No-load speeds are given by Eqs. (5.85) and (5.86). Operation of drive, which operates in quadrant I only, is represented by the equivalent circuit of Fig. 5.28(b). It is useful to note why the drive should not be operated in quadrant IV. Figure 5.31(a) shows a plot of Va with α (Eq. (5.93)) for Single Phase Half Controlled Rectifier Control for continuous conduction operation. The output voltage cannot be reversed. When coupled to an active load, the motor speed can reverse, reversing E as shown in Fig. 5.31(b). As the current direction does not change, the machine now works as a generator producing braking torque. Since rectifier voltage cannot reverse, generated energy cannot be transferred to an ac source, and therefore, it is absorbed in the armature circuit resistance. Braking so obtained is nothing but reverse voltage braking (plugging). Such braking is not only inefficient but also causes a large current [Ia = (Va + E)/Ra] to flow through the rectifier and motor. Since it cannot be regulated by adjustment of firing angle, it will damage the rectifier and motor. Therefore, when the load is active, care should be taken to avoid such an operation. If such an operation cannot be avoided, a fully-controlled rectifier should be used.



(a) $V_a - \alpha$ curve (b) Braking operation

Fig. 5.31 Reverse voltage braking operation of the drive of Fig. 5.29(a)

Circuit Diagram:



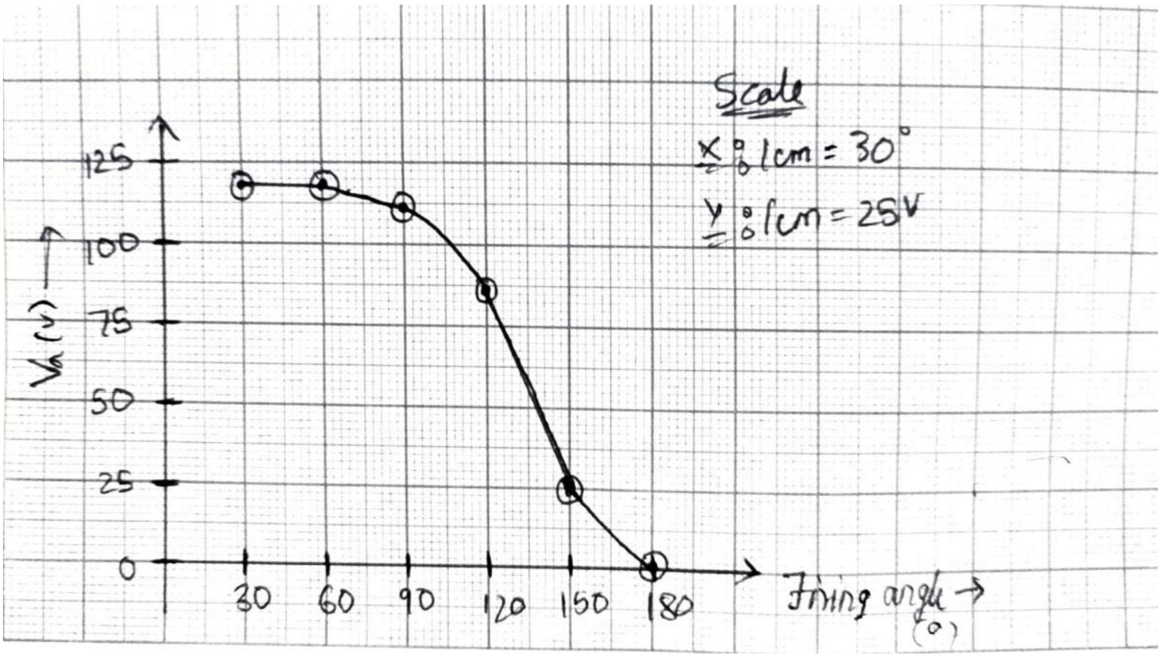
Observation Table:

S.no	Field Voltage	Vin (Volt)	Firing angle	Va	Ia	Speed (Rpm)
1	202.5	100	180	0	0	0
2	202.5	100	150	25	0.41	162.9
3	202.5	100	120	86	0.50	572
4	202.5	100	90	112	0.53	760
5	202.5	100	60	118	0.53	802
6	202.5	100	30	118	0.53	802

Speed control of DC shunt motor using a full-bridge rectifier.

Relevant Plots:

Va Vs FIRING ANGLE



CONCLUSION

Hence, the experiment videos were seen and the theory was understood and thecalculations were made from the data provided.