

# POSTAL Book Package

# 2023

## ESE

### Electronics Engineering Conventional Practice Sets

#### Basic Electrical Engineering

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# 1

## CHAPTER

## Basic Electrical Engineering

# DC Machines

**Q1** An 8-pole dc generator has 500 armature conductors and a useful flux of 0.05 Wb. What will be the emf generated, if it is lap-connected and runs at 1,200 rpm? What must be the speed at which it is to be driven to produce the same emf, if it is wave-wound?

**Solution:**

EMF generated when the generator is lap-connected,

$$E_g = \frac{\phi Z N}{60} \times \frac{P}{A} = \frac{0.05 \times 500 \times 1,200}{60} \times \frac{8}{8} = 500 \text{ V}$$

$\therefore$  in lap-connected armature, number of parallel paths,  $A = P = 8$

If the armature is wave connected, then

$\therefore$  in wave-connected armature  $A = 2$

$$N' = \frac{E_g \times 60}{\phi \times Z} \times \frac{A}{P} = \frac{500 \times 60}{0.05 \times 500} \times \frac{2}{8} = 300 \text{ rpm}$$

**Q2** A shunt generator delivers 450 A at 230 V and the resistance of the shunt field and armature are  $50 \Omega$  and  $0.03 \Omega$  respectively. Calculate the generated e.m.f.

**Solution:**

Generator circuit shown in figure,

$$I_{sh} = \frac{230}{50} = 4.6 \text{ A}$$

Load current,

$$I = 450 \text{ A}$$

$\therefore$

Armature current

$$I_a = I + I_{sh} = 450 + 4.6 = 454.6 \text{ A}$$

Armature voltage drop,

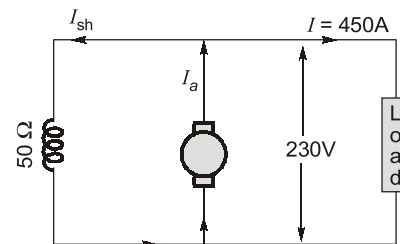
$$I_a R_a = 454.6 \times 0.03 = 13.6 \text{ V}$$

Now

$$E_g = \text{terminal voltage} + \text{armature drop} = V + I_a R_a$$

$\therefore$  e.m.f. generated in the armature

$$E_g = 230 + 13.6 = 243.6 \text{ V}$$



**Q3** A 4-pole machine running at 1,500 rpm has an armature with 90 slots having 6 conductors per slot. The flux per pole is  $6 \times 10^{-2}$  Wb. Determine the induced emf as a dc generator if the coils are lap connected. If the current per conductor is 100 amperes, determine the electrical power output of the machine.

**Solution:**

$$\text{Flux per pole, } \Phi = 6 \times 10^{-2} \text{ Wb}$$

$$\text{Number of armature conductors, } Z = \text{Number of slots} \times \text{number of conductors per slot} = 90 \times 6 = 540$$

$$\text{Number of parallel paths, } A = P = 4$$

∴ The machine is lap-connected

Speed,  $N = 1,500$  rpm

$$\text{Induced emf, } E_g = \Phi Z \frac{N}{60} \times \frac{P}{A} = 6 \times 10^{-2} \times 540 \times \frac{1500}{60} \times \frac{4}{4} = 810 \text{ V}$$

Current per conductor,  $I_c = 100$  A

Armature current,  $I_a = I_c \times A = 100 \times 4 = 400$  A

Electrical power developed =  $E_g \times I_a = 810 \times 400 = 324,000$  W or 324 kW

**Q4** A 4-pole, 900 r.p.m. d.c. machine has a terminal voltage of 220 V and an induced voltage of 240 V at rated speed. The armature circuit resistance is  $0.2 \Omega$ . Is the machine operating as a generator or a motor? Compute the armature current and the number of armature coils if the air-gap flux/pole is 10 m Wb and the armature turns per coil are 8. The armature is wave-wound.

**Solution:**

Since the induced voltage  $E$  is more than the terminal voltage  $v$ , the machine is working as a generator.

$$E - V = I_a R_a \Rightarrow 20 = I_a \times 0.2 \Rightarrow I_a = 100 \text{ A}$$

$$\text{Now, } E_b = \frac{\phi Z N}{60} \times \left( \frac{P}{A} \right) \text{ or } 240 = 10 \times 10^{-3} \times Z \times \frac{900}{60} \times \frac{4}{2}$$
$$\Rightarrow Z = 800$$

Since there are 8 turns in a coil, it means there are 16 active conductors/coil. Hence, the number of coils

$$= \frac{800}{16} = 50.$$

**Q5** Describe the meaning of “armature reaction”. How does it affect the performance of a D.C. generator? How can the performance be improved with regard to the above?

**Solution:**

**Armature Reaction:** When the armature of a d.c. machine carries current, the distributed armature winding produces its own mmf (distributed) known as armature reaction. The machine air-gap is now acted upon by the resultant mmf distribution caused by simultaneous action of the field ampere-turns ( $A T_f$ ) and armature ampere-turns ( $A T_a$ ). As a result the air-gap flux density gets distorted as compared to the flat-topped (trapezoidal) wave with quarterwave symmetry when the armature did not carry any current.

The effect of armature mmf

1. net reduction in the main field flux per pole.
2. distortion of the main field flux wave along the air-gap periphery.

This reduction in flux causes a decrease in the generator terminal voltage.

The cross-magnetizing effect of armature mmf can be minimised at the design and construction stage of a d.c. machine. Various methods of mitigating the effects of armature reaction:

- (a) High-reluctance Pole Tips:** If the reluctance of the pole tips is increased, then the magnitude of armature cross flux is reduced and the distortion of the resultant flux density wave is minimised.
- (b) Reduction in Armature Flux:** Another constructional technique of reducing the armature cross flux is to create more reluctance in the path of armature flux without reducing the main field flux. This is achieved by using field-pole laminations having several rectangular holes punched in them.
- (c) Strong Main-field Flux:** During the design of a d.c. machine, it should be ensured that the main field mmf is sufficiently strong in comparison with full-load armature mmf.
- (d) Interpoles:** The effect of armature reaction in the interpolar zone can be overcome by inter poles, placed in between the main poles.
- (e) Compensating Winding:** The effect of armature reaction under the pole shoes can be limited by using compensating winding. This winding is embedded in slots cut in the pole faces of the d.c. machine.

- Q6** A DC machine has total armature ampere conductors of 4500 and total flux in the machine is 0.14 Wb. Calculate the torque developed in the machine.

**Solution:**

The torque equation of a DC machine is  $\tau = \frac{PZ}{2\pi A} \phi I_a$

where,  $P$  = Number of poles,  $Z$  = Total armature conductors,  $\phi$  = Flux,  $I_a$  = Armature current and  $A$  = Number of parallel paths.

Let us assume lap winding

$\Rightarrow$

$$A = P$$

$\therefore$

$$\tau = \frac{Z I_a \phi}{2\pi}$$

Given,

$$Z I_a = 4500$$

$$\phi = 0.14 \text{ Wb}$$

$$\tau = \frac{4500}{2\pi} \times 0.14 = 100.2676 \text{ Nm}$$

- Q7** A short-shunt compound generator delivers a load current of 30 A at 220 V, and has armature, series-field and shunt-field resistances of 0.05  $\Omega$ , 0.30  $\Omega$  and 200  $\Omega$  respectively. Calculate the induced e.m.f. and the armature current. Allow 1.0 V per brush for contact drop.

**Solution:**

Short-shunt compound Generator circuit diagram is shown in figure.

$$\text{Voltage drop in series winding} = 30 \times 0.3 = 9 \text{ V}$$

$$\text{Voltage across shunt winding} = 220 + 9 = 229 \text{ V}$$

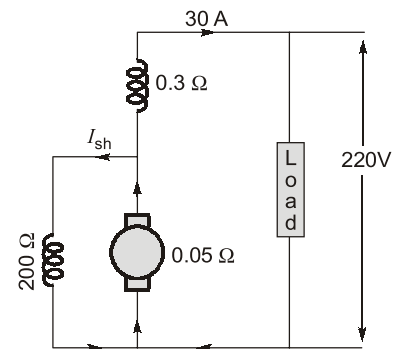
$$I_{sh} = \frac{229}{200} = 1.145 \text{ A}$$

$$I_a = 30 + 1.145 = 31.145 \text{ A}$$

$$I_a R_a = 31.145 \times 0.05 = 1.56 \text{ V}$$

$$\text{Brush drop} = 2 \times 1 = 2 \text{ V}$$

$$E_g = V + \text{Brush drop} + I_a R_a + \text{Series drop} = 220 + 9 + 2 + 1.56 = 232.56 \text{ V}$$



- Q8** A separately excited generator, when running at 1000 r.p.m. supplied 200 A at 125 V. What will be the load current when the speed drops to 800 r.p.m. if  $I_f$  is unchanged? Given brush drop = 2 V and armature resistance = 0.04  $\Omega$ .

**Solution:**

**Given data:** The load resistance,  $R = \frac{125}{200} = 0.625 \Omega$ , in figure.

$$E_{g1} = 125 + 200 \times 0.04 + 2 = 135 \text{ V}$$

$$N_1 = 1000 \text{ r.p.m.}$$

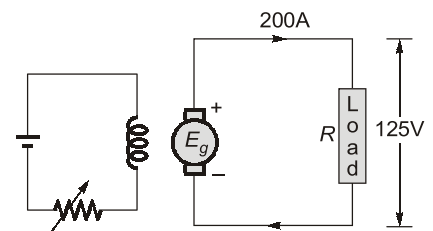
Since,  $E_g \propto N$ . Therefore,  $E_{g2} = E_{g1} \cdot \frac{N_2}{N_1}$

$$\text{At 800 r.p.m. } E_{g2} = 135 \times \frac{800}{1000} = 108 \text{ V}$$

if  $I$  is the new load current, then terminal voltage  $V$  is given by

$$V = 108 - 0.04 I - 2 = 106 - 0.04 I$$

$$I = \frac{V}{R} = \frac{(106 - 0.04 I)}{0.625} = 159.4 \text{ A}$$



- Q.9** A 4-pole, long-shunt lap-wound generator supplies 25 kW at a terminal voltage of 500 V. The armature resistance is 0.03 ohm, series field resistance is 0.04 ohm and shunt field resistance is 200 ohm. The voltage drop per brush may be taken as 1.0 V. Determine the e.m.f. generated. Calculate also the No. of conductors if the speed is 1200 r.p.m. and flux per pole is 0.02 weber. Neglect armature reaction.

**Solution:**

$$I = \frac{25000}{500} = 50 \text{ A}$$

$$I_{sh} = \frac{500}{200} = 2.5 \text{ A}$$

$$I_a = I + I_{sh} = 50 + 2.5 = 52.5 \text{ A}$$

$$\text{Series field drop} = 52.5 \times 0.04 = 2.1 \text{ V}$$

$$\text{Armature drop} = 52.5 \times 0.03 = 1.575 \text{ V}$$

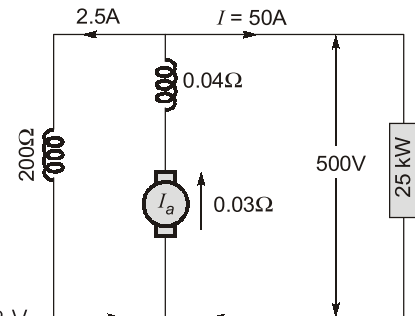
$$\text{Brush drop} = 2 \times 1 = 2 \text{ V}$$

$$\text{Generated e.m.f., } E_g = 500 + 2.1 + 1.575 + 2 = 505.68 \text{ V}$$

$$\text{Generated emf, } E_g = \frac{\phi Z N}{60} \times \left( \frac{P}{A} \right) \quad A = P (\because \text{Lap-wound})$$

$$\therefore Z = \frac{60 E_g}{N \phi} = \frac{60 \times 505.68}{1200 \times 0.02}$$

Number of conductors,  $Z \simeq 1264$



- Q.10** The following information is given for a 300 kW, 600-V, long-shunt compound generator: Shunt field resistance = 75 Ω, armature resistance including brush resistance = 0.03 Ω, commutating field winding resistance = 0.011 Ω, series field resistance = 0.012 Ω, diverter resistance = 0.036 Ω. When the machine is delivering full load, calculate the voltage and power generated by the armature.

**Solution:**

**Given data:** Power output = 300,000 W; Output current =  $\frac{300000}{600} = 500 \text{ A}$

$$I_{sh} = \frac{600}{75} = 8 \text{ A}; \quad I_a = 500 + 8 = 508 \text{ A}$$

A diverter is a resistance shunting the series field resistance of compound generator to adjust the degree of compounding to produce a desired voltage regulation.

Since the series field resistance and diverter resistance are in parallel their combined resistance is

$$= \frac{0.012 \times 0.036}{0.048} = 0.009 \Omega$$

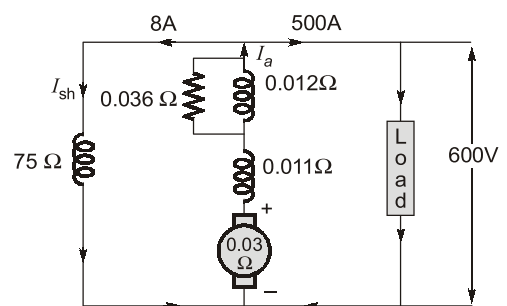
$$\text{Total armature circuit resistance} = 0.03 + 0.011 + 0.009 = 0.05 \Omega$$

$$\text{Voltage drop} = 508 \times 0.05 = 25.4 \text{ V}$$

$$\text{Voltage generated by armature} = 600 + 25.4 = 625.4 \text{ V}$$

$$\text{Power generated} = 625.4 \times 508 = 317,700$$

$$\text{Power generated in kW} = 317.7 \text{ kW}$$



- Q.11** A shunt generator has a full load current of 196 A at 220 V. The stray losses are 720 W and the shunt field coil resistance is 55 Ω. If it has a full load efficiency of 88%, find the armature resistance. Also, find the load current corresponding to maximum efficiency.

**Solution:**

$$\text{Output} = 220 \times 196 = 43,120 \text{ W}; \eta = 88\% \text{ (overall efficiency)}$$

$$\text{Electrical input} = \frac{43120}{0.88} = 49,000 \text{ W}$$

$$\text{Total losses} = 49,000 - 43,120 = 5,880 \text{ W}$$

$$\text{Shunt field current} = \frac{220}{55} = 4 \text{ A}$$

$$\therefore I_a = 196 + 4 = 200 \text{ A}$$

$$\therefore \text{Shunt Cu loss} = 220 \times 4 = 880 \text{ W}; \text{Stray losses} = 720 \text{ W}$$

$$\text{Constant losses} = 880 + 720 = 1,600 \text{ W}$$

$$\therefore \text{Armature Cu loss} = 5,880 - 1,600 = 4,280 \text{ W}$$

$$\therefore I_a^2 R_a = 4,280 \text{ W}$$

$$200^2 R_a = 4,280 \text{ or } R_a = 4,280/200 \times 200 = 0.107 \Omega$$

$$\text{For maximum efficiency } I^2 R_a = \text{constant losses} = 1,600 \text{ W}; I = \sqrt{\frac{1600}{0.107}} = 122.28 \text{ A}$$

**Q.12** A long-shunt compound-wound generator gives 240 volts at full load output of 100 A. The resistances of various windings of the machine are: armature (including brush contact)  $0.1 \Omega$ , series field  $0.02 \Omega$ , interpole field  $0.025 \Omega$ , field (including regulating resistance)  $100 \Omega$ . The iron loss at full load is  $1000 \text{ W}$ ; windage and friction losses total  $500 \text{ W}$ . Calculate full load efficiency of the machine.

**Solution:**

$$\text{Output} = 240 \times 100 = 24,000 \text{ W}$$

$$\text{Total armature circuit resistance} = 0.1 + 0.02 + 0.025 = 0.145 \Omega$$

$$I_{sh} = \frac{240}{100} = 2.4 \text{ A}$$

$$\therefore I_a = 100 + 2.4 = 102.4 \text{ A}$$

$$\therefore \text{Armature circuit copper loss} = (102.4)^2 \times 0.145 = 1,521 \text{ W}$$

$$\text{Shunt field copper loss} = 2.4 \times 240 = 576 \text{ W}$$

$$\text{Iron loss} = 1000 \text{ W}; \text{Friction loss} = 500 \text{ W}$$

$$\text{Total loss} = 1,521 + 1,500 + 576 = 3,597 \text{ W}; \eta = \frac{24,000}{24,000 + 3,597} \times 100 = 87\%$$

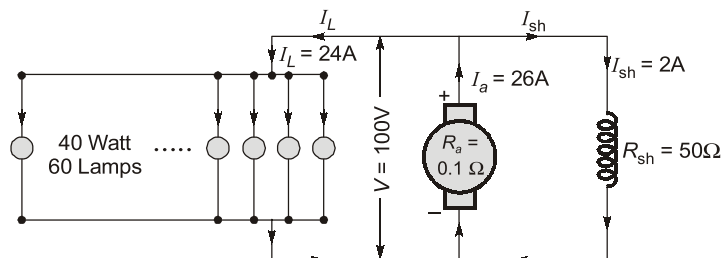
**Q.13** A 4-pole generator with lap-connected armature having field and armature resistances of  $50 \Omega$  and  $0.1 \Omega$  respectively supplies 60, 40 W lamps at 100 V. Calculate the total armature current, current per path and the generated emf. Assume a constant drop of 1 V per brush.

**Solution:**

Total lamp load,  
Terminal voltage,

$$P_L = \text{Number of lamps} \times \text{wattage of each lamp} = 60 \times 40 = 2,400 \text{ W}$$

$$V = 100 \text{ V}$$



Load current,

$$I_L = \frac{P_L}{V} = \frac{2,400}{100} = 24 \text{ A}$$

$$\begin{aligned}\text{Shunt field current, } I_{sh} &= \frac{V}{R_{sh}} = \frac{100}{50} = 2 \text{ A} \\ \text{Total armature current, } I_a &= I_L + I_{sh} = 24 + 2 = 26 \text{ A} \\ \therefore \text{ For lap-connected } A &= P = 4 \\ \text{Current per path, } I_c &= \frac{I_a}{A} = \frac{26}{4} = 6.5 \text{ A} \\ \text{Generated emf, } E_g &= V + I_a R_a + \text{brush drop} = 100 + 26 \times 0.1 + 2 \times 1 = 104.6 \text{ V}\end{aligned}$$

**Q.14** A 25 kW, 250 V dc shunt generator has armature and field resistances of  $0.06 \Omega$  and  $100 \Omega$  respectively. Determine the total armature power developed when working (i) as generator delivering 25 kW output and (ii) as a motor taking 25 kW input.

**Solution:**

$$\begin{aligned}\text{Line voltage, } V &= 250 \text{ volts} \\ \text{Shunt field resistance, } R_{sh} &= 100 \Omega \\ \text{Shunt field current, } I_{sh} &= \frac{V}{R_{sh}} = \frac{250}{100} = 2.5 \text{ A} \\ \text{Armature resistance, } R_a &= 0.06 \Omega \\ \text{(i) As generator} \\ \text{Load current, } I_L &= \frac{\text{Output in kW} \times 1,000}{V} = \frac{25 \times 1,000}{250} = 100 \text{ A} \\ \text{Armature current, } I_a &= I_L + I_{sh} = 100 + 2.5 = 102.5 \text{ A} \\ \text{Generated emf, } E_g &= V + I_a R_a = 250 + 102.5 \times 0.06 = 256.15 \text{ V} \\ \text{Power developed by armature, } P_g &= \frac{E_g I_a}{1,000} = \frac{256.15 \times 102.5}{1,000} = 26.26 \text{ kW} \\ \text{(ii) As motor} \\ \text{Line current, } I_L &= \frac{\text{Input in kW} \times 1,000}{V} = \frac{25 \times 1,000}{250} = 100 \text{ A} \\ \text{Armature current, } I_a &= I_L - I_{sh} = 100 - 2.5 = 97.5 \text{ A} \\ \text{Back emf, } E_b &= V - I_a R_a = 250 - 97.5 \times 0.06 = 244.15 \text{ V} \\ \text{Power developed by armature, } P_m &= \frac{E_b I_a}{1,000} = \frac{244.15 \times 97.5}{1,000} = 23.80 \text{ kW}\end{aligned}$$

**Q.15** A 250 V dc shunt motor having an armature resistance of  $0.25 \Omega$  carries an armature current of 50 A and runs at 750 rpm. If the flux is reduced by 10%, find the speed. Assume that the torque remains the same.

**Solution:**

$$\begin{aligned}\text{Supplied Voltage, } V &= 250 \text{ V} \\ \text{Armature current, } I_{a1} &= 50 \text{ A} \\ \text{Back emf, } E_{b1} &= V - I_{a1} R_a = 250 - 50 \times 0.25 = 237.5 \text{ V} \\ \text{Flux, } \phi_2 &= 0.9 \phi_1 \\ \therefore \text{ Flux has been reduced by } 10\% \\ \text{Since torque developed remains unchanged,} \\ I_{a2} \phi_2 &= I_{a1} \phi_1 \text{ as } T \propto \phi I_a \\ \text{or Armature current, } I_{a2} &= I_{a1} \times \frac{\phi_1}{\phi_2} = 50 \times \frac{1}{0.9} = 55.55 \text{ A} \\ \text{Back emf, } E_2 &= V - I_{a2} R_a = 250 - 55.55 \times 0.25 = 236.11 \text{ V}\end{aligned}$$