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MADE EASY PUBLICATIONS

ELECTRONICS ENGINEERING

CONVENTIONAL Practice Sets

CONTENTS

BASIC ELECTRICAL ENGINEERING

1 CHAPTER

DC Machines

Q.1 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,

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

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

If the armature is wave connected, then

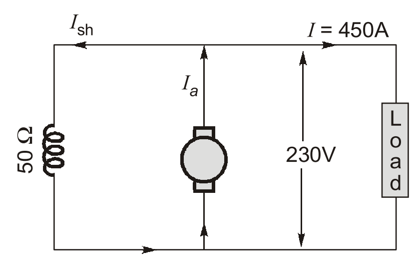
$\because$ in wave-connected armature $A = 2$

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

Q.2 A shunt generator delivers 450 A at 230 V and the resistance of the shunt field and armature are 50 Ω and 0.03 Ω respectively. Calculate the generated e.m.f.

Solution:

Generator circuit shown in figure,



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

Load current, $I = 450$ A

$\therefore$ Armature current $I_a = I + I_{sh}$

$= 450 + 4.6 = 454.6$ A

Armature voltage drop, $I_a R_a = 454.6 \times 0.03 = 13.6$ V

Now E_g = terminal voltage + armature drop

$= V + I_a R_a$

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

$E_g = 230 + 13.6 = 243.6$ V

Q.3 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 6×10^{-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:

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

Number of armature conductors, Z = Number of slots × number of conductors per slot = 90 × 6 = 540

Number of parallel paths, $A = P = 4$

∵ The machine is lap-connected

$$\text{Speed, } N = 1{,}500 \text{ rpm}$$

$$\text{Induced emf, } E_g = \Phi\, Z\frac{N}{60}\times\frac{P}{A} = 6\times10^{-2}\times540\times\frac{1500}{60}\times\frac{4}{4} = 810 \text{ V}$$

$$\text{Current per conductor, } I_c = 100 \text{ A}$$

$$\text{Armature current, } I_a = I_c\times A = 100\times4 = 400 \text{ A}$$

$$\text{Electrical power developed} = E_g\times I_a = 810\times400 = 324{,}000 \text{ W or } 324 \text{ kW}$$

Q.4 **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 Ω. 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.

$$E - V = I_aR_a \Rightarrow 20 = I_a\times0.2 \Rightarrow I_a = 100 \text{ A}$$

Now,
$$E_b = \frac{\phi ZN}{60}\times\left(\frac{P}{A}\right) \text{ or } 240 = 10\times10^{-3}\times Z\times\frac{900}{60}\times\frac{4}{2}$$

$$\Rightarrow \quad Z = 800$$

Since there are 8 turns in a coil, it means there are 16 active conductors/coil. Hence, the number of coils $= \frac{800}{16} = 50.$

Q.5 **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.

Q.6 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 $\tau = \dfrac{PZ}{2\pi A}\phi I_a$

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

Let us assume lap winding

$\Rightarrow$ $A = P$

$\therefore$ $\tau = \dfrac{ZI_a\phi}{2\pi}$

Given, $ZI_a = 4500$

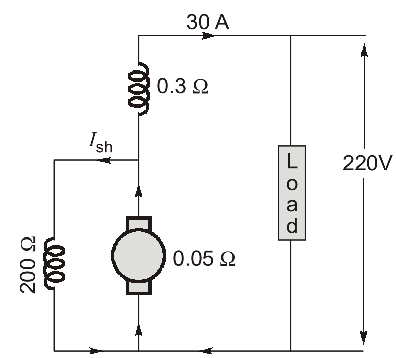
$\phi = 0.14$ Wb

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

Q.7 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 Ω, 0.30 Ω and 200 Ω 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.



Voltage drop in series winding = 30 × 0.3 = 9 V

Voltage across shunt winding = 220 + 9 = 229 V

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

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

$$I_aR_a = 31.145 \times 0.05 = 1.56 \text{ V}$$

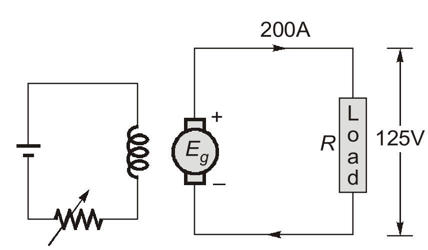
Brush drop = 2 × 1 = 2 V

$E_g = V$ + Brush drop + I_aR_a + Series drop = 220 + 9 + 2 + 1.56 = 232.56 V

Q.8 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 Ω.

Solution:

Given data: The load resistance, $R = \dfrac{125}{200} = 0.625$ Ω, in figure.



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

$N_1 = 1000$ r.p.m.

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

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

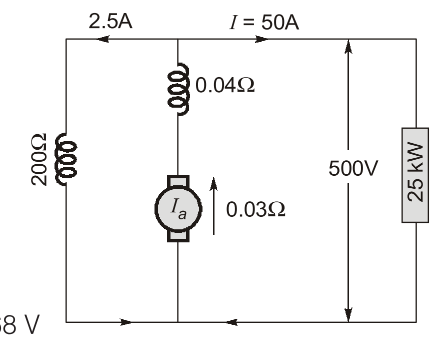
if I is the new load current, then terminal voltage V is given by

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

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

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:



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

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

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

Series field drop $= 52.5 \times 0.04 = 2.1$ V

Armature drop $= 52.5 \times 0.03 = 1.575$ V

Brush drop $= 2 \times 1 = 2$ V

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

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

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

Number of conductors, $Z \simeq 1264$

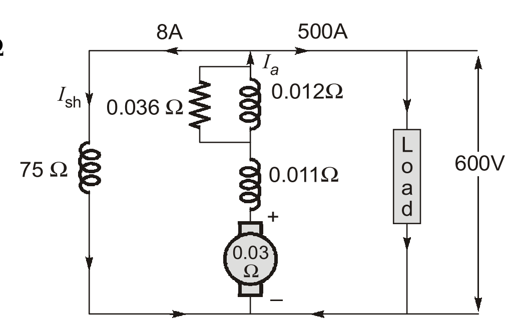
Q.10 The following information is given for a 300 kW, 600-V, long-shunt compound generator: Shunt field resistance = 75 Ω, armature resistance including brush resistance = 0.03 Ω, commutating field winding resistance = 0.011 Ω, series field resistance = 0.012 Ω, diverter resistance = 0.036 Ω. When the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

Solution:

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

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

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



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

Total armature circuit resistance $= 0.03 + 0.011 + 0.009$

$= 0.05$ Ω

Voltage drop $= 508 \times 0.05$

$= 25.4$ V

Voltage generated by armature $= 600 + 25.4 = 625.4$ V

Power generated $= 625.4 \times 508$

$= 317{,}700$

Power generated in kW $= 317.7$ 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:

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

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

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

$$\text{Shunt field current} = \frac{220}{55} = 4 \text{ A} \qquad \therefore I_a = 196 + 4 = 200 \text{ A}$$

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

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

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

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

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

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 Ω, series field 0.02 Ω, interpole field 0.025 Ω, field (including regulating resistance) 100 Ω. The iron loss at full load is 1000 W; windage and friction losses total 500 W. Calculate full load efficiency of the machine.

Solution:

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

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

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

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

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

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

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

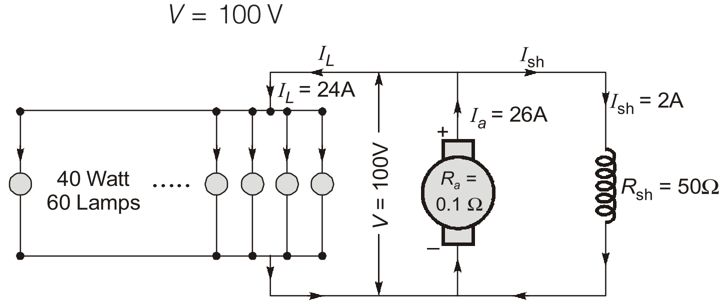
$$\text{Total loss} = 1{,}521 + 1{,}500 + 576 = 3{,}597 \text{ W}; \eta = \frac{24{,}000}{24{,}000 + 3{,}597} \times 100 = 87\%$$

Q.13 A 4-pole generator with lap-connected armature having field and armature resistances of 50 Ω and 0.1 Ω 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, P_L = Number of lamps × wattage of each lamp = 60 × 40 = 2,400 W

Terminal voltage, V = 100 V



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

Shunt field current, $I_{sh} = \frac{V}{R_{sh}} = \frac{100}{50} = 2\text{ A}$

Total armature current, $I_a = I_L + I_{sh} = 24 + 2 = 26\text{ A}$

$\because$ For lap-connected $A = P = 4$

Current per path, $I_c = \frac{I_a}{A} = \frac{26}{4} = 6.5\text{ A}$

Generated emf, $E_g = V + I_a R_a + \text{brush drop} = 100 + 26 \times 0.1 + 2 \times 1 = 104.6\text{ V}$

Q.14 **A 25 kW, 250 V dc shunt generator has armature and field resistances of 0.06 Ω and 100 Ω 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:

Line voltage, $V = 250$ volts

Shunt field resistance, $R_{sh} = 100\ \Omega$

Shunt field current, $I_{sh} = \frac{V}{R_{sh}} = \frac{250}{100} = 2.5\text{ A}$

Armature resistance, $R_a = 0.06\ \Omega$

(i) As generator

Load current, $I_L = \frac{\text{Output in kW} \times 1{,}000}{V} = \frac{25 \times 1{,}000}{250} = 100\text{ A}$

Armature current, $I_a = I_L + I_{sh} = 100 + 2.5 = 102.5\text{ A}$

Generated emf, $E_g = V + I_a R_a = 250 + 102.5 \times 0.06 = 256.15\text{ V}$

Power developed by armature, $P_g = \frac{E_g I_a}{1{,}000} = \frac{256.15 \times 102.5}{1{,}000} = 26.26\text{ kW}$

(ii) As motor

Line current, $I_L = \frac{\text{Input in kW} \times 1{,}000}{V} = \frac{25 \times 1{,}000}{250} = 100\ A$

Armature current, $I_a = I_L - I_{sh} = 100 - 2.5 = 97.5\text{ A}$

Back emf, $E_b = V - I_a R_a = 250 - 97.5 \times 0.06 = 244.15\text{ V}$

Power developed by armature, $P_m = \frac{E_b I_a}{1{,}000} = \frac{244.15 \times 97.5}{1{,}000} = 23.80\text{ kW}$

Q.15 **A 250 V dc shunt motor having an armature resistance of 0.25 Ω 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:

Supplied Voltage, $V = 250\text{ V}$

Armature current, $I_{a1} = 50\text{ A}$

Back emf, $E_{b1} = V - I_{a1} R_a = 250 - 50 \times 0.25 = 237.5\text{ V}$

Flux, $\phi_2 = 0.9\,\phi_1$

$\because$ Flux has been reduced by 10%

Since torque developed remains unchanged,

$$I_{a2}\phi_2 = I_{a1}\,\phi_1 \text{ as } T \propto \phi I_a$$

or Armature current, $I_{a2} = I_{a1} \times \frac{\phi_1}{\phi_2} = 50 \times \frac{1}{0.9} = 55.55\text{ A}$

Back emf, $E_2 = V - I_{a2} R_a = 250 - 55.55 \times 0.25 = 236.11\text{ V}$

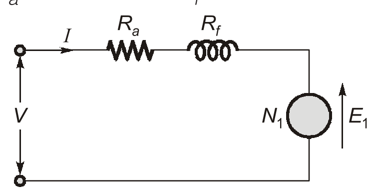
$\because$ $\qquad E_b \propto \phi N$

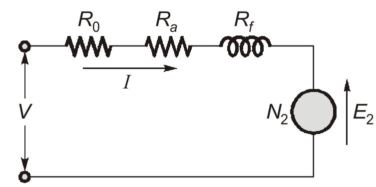
Speed, $\qquad N_2 = \dfrac{E_{b2}}{E_{b1}} \times \dfrac{\phi_1}{\phi_2} \times N_1 = \dfrac{236.11}{237.5} \times \dfrac{1}{0.9} \times 750 = 828.5 \text{ rpm}$

Q.16 A series motor has an armature resistance of 0.7 ohm and field resistance of 0.3 ohm. It takes a current of 15 A from a 200 V supply and runs at 800 r.p.m. Find the speed at which it will run, when connected in series with a 5 ohm resistance and taking the same current at the same supply voltage.

Solution:

Given data: $R_a = 0.7\ \Omega$; $R_f = 0.3\ \Omega$; $R_0 = 5\ \Omega$; $I = 15$ A; $V = 200$ V; $N_1 = 800$ rpm





We have to calculate N_2.

We know that, $\qquad E \propto \phi N \qquad$ [ϕ = Field flux]

But, as I has not changed, so ϕ will remain same in this case,

$\Rightarrow \qquad E \propto N$

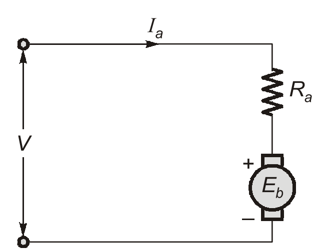
$\Rightarrow \qquad \dfrac{E_1}{E_2} = \dfrac{N_1}{N_2} \qquad$ ...(1)

Now,
$$E_1 = V - I(R_a + R_f)$$
$$= 200 - 15(1) = 185 \text{ V}$$
$$E_2 = V - I(R_a + R_f + R_0)$$
$$= 200 - 15(6) = 110 \text{ V}$$

From equation (1), $\qquad N_2 = \dfrac{N_1 E_2}{E_1} = \dfrac{800 \times 110}{185} = 475.6756 \text{ rpm}$

Q.17 A DC motor with permanent magnet field is running with 200 V DC supply and consuming 2 A current. A voltmeter is connected across its armature and DC supply is disconnected. The voltmeter reads 190 V just after disconnection of DC supply. Calculate the armature resistance of the machine.

Solution:



Equivalent circuit of the motor

Given data: $V = 200$ V; $I_a = 2$ A; $E_b = 190$ V this is present because of field magnets

We can write, $\qquad V = I_a R_a + E_b \qquad$ [Neglecting voltage drop across brushes]

$\Rightarrow \qquad 200 = 2R_a + 190$

$\Rightarrow \qquad R_a = 5\ \Omega$

Q.18 A 250 V, 50 hp, 1000 rpm d.c. shunt motor drives a load that requires a constant torque regardless of the speed of operation. The armature circuit resistance is 0.04 Ω. When this motor delivers rated power, the armature current is 160 A.

If the flux is reduced to 70% of its original value, find the new value of the armature current.

Solution:

It is given that load torque will remain constant. Therefore, to match the load conditions, motor torque should be constant. The torque of a DC machine is given by

$$\tau = \frac{PZ}{2\pi A}\phi I_A$$

$$\tau = k\phi I_a \qquad \left[k = \frac{PZ}{2\pi A} = \text{constant}\right]$$

Now, for τ to stay constant, I_a has to increase by the same factor by which ϕ was reduced.

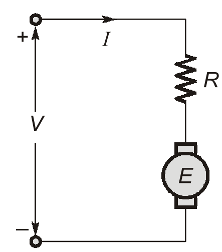
$\therefore$ New armature current $= \dfrac{160}{0.7} = 228.57$ A

Q.19 Explain speed current and torque current characteristics of d.c. series motor.

Solution:

$$V = IR + E_b \qquad (R = R_a + R_{se})$$

$$\Rightarrow \quad E_b = V - IR$$



Equivalent circuit of DC series motor

Now, $E_b \propto \phi N$ [ϕ = flux]

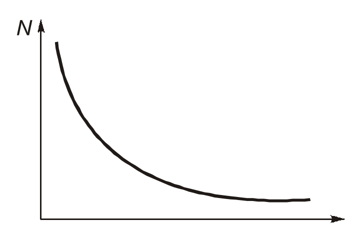
$\therefore$ $\phi N \propto V - IR$

$\Rightarrow$ $N \propto \dfrac{V - IR}{\phi}$

Now, $\phi \propto I$ [series motor]

$\therefore$ $N \propto \dfrac{V - IR}{I}$

$N \propto \dfrac{V}{I}$ [V is constant]

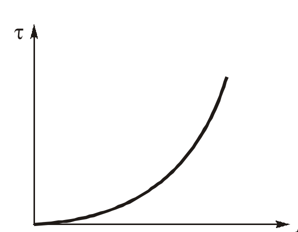


Speed current characteristic

The speed is proportional to back emf E_b and inversely proportional to flux per pole ϕ. With the increase in armature current, voltage drop in armature circuit and series field (IR) increases and therefore back emf E_b decreases. However, under normal conditions IR drop is quite small and may be neglected. Thus, if the applied voltage remains constant, speed N is inversely proportional to flux ϕ.

Now, Torque $= \tau \propto \phi I$

$\Rightarrow$ $\tau \propto I^2$ [$\phi \propto I$ for DC series motor]



Torque-current characteristic