Numericals On Emf Equation

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Question 1

A belt driven 60KW shunt generator running at 500rpm, is supplying full load to a bus-bar at 200V. At what speed will it run if the belt breaks and the machine runs as a motor taking 5 KW from the bus-bar ? The armature and the field resistance are 0.1 Ω and 100 Ω respectively. $V_{brush} = 2volts$. Neglect armature reaction. (421.403 rpm)

Answer 1

Understanding the problem

A dc machine can be used in any mode. The same machine can be used as generator or motor in different situations. In this problem, a generator is used to feed a bus-bar [1].

When the belt breaks, primemover to the generator is disconnected (mechanically) from the generator. So there is no mechanical power input to the dc machine and it cannot output any electrical power. On the other hand, the electrical connections of the machine with the bus bar are intact. So the machine **takes power from** the bus bar and runs like a motor. We are asked to find at what speed the machine will run in motor mode.

Data

$$
\begin{aligned}
P_g &= delivered\ full\ load\ power = 60KW \\
rpm &= 500\ (generator) \\
V_B &= bus\ bar\ voltage = 200V
\end{aligned}
$$

[1] **bus-bar:** Bus-bar is considered to be an infinite (very large) pair of wires connected to infinite number of generators and also motor or other loads. Thus at any time, the bus-bar voltage never changes.

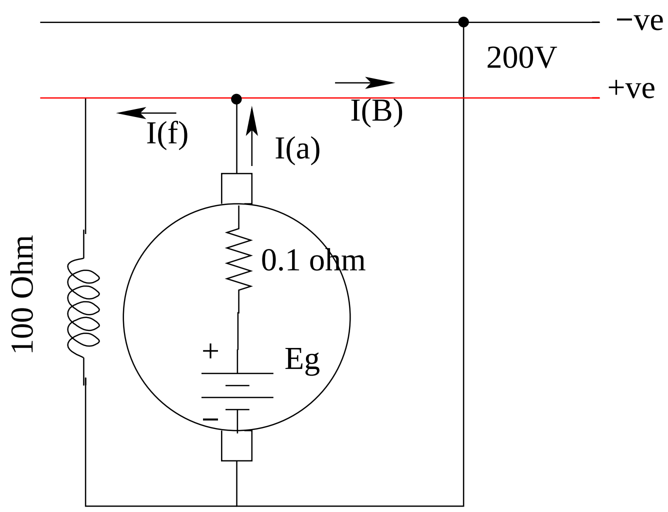

Figure 1: Machine in generator mode

$$R_F = 100\Omega$$
$$R_a = 0.1\Omega$$
$$P_m = 5000W$$
$$V_{brush} = 2V$$

Generator Mode

In figure 1, dc machine is shown as a generator. Observe the current directions.

1. I_a is total armature current - generated from inside.
2. I_B the bus bar current supplied by the generator.
3. I_f is the field current through the filed winding.

Now,

$$\begin{aligned} I_a &= I_B + I_f \\ &= \frac{60 * 10^3}{200} + \frac{200}{100} \\ &= 300 + 2 = 302\ Amp \end{aligned} \tag{1}$$

$$Also,$$
$$E_g = V_t + I_a * R_a + V_{brush}$$

$$
\begin{aligned}
&= 200 + (302 * 0.1) + 2 = 232.2\ V \qquad (2) \\
However, & \\
E_g &= \frac{\Phi * Z * rpm * P}{60 * a} ....emf\ equation \\
\Phi,\ Z,\ P\ are\ not\ known.\ So, & \\
E_g &= \frac{\Phi * Z * P}{a} * \frac{rpm}{60} \\
But,\ rpm = 500,\ so... & \\
\frac{\Phi * Z * P}{a} &= 27.864 \qquad (3)
\end{aligned}
$$

Motor Mode

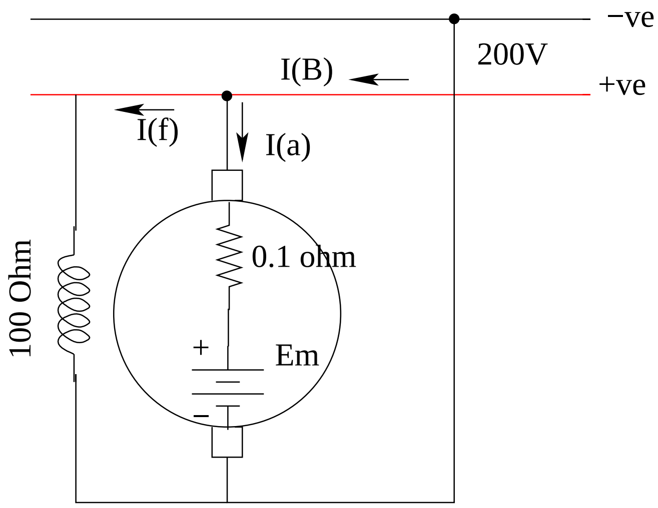

Figure 2: Machine in motor mode

See the figure 2. The machine is running in motor mode. Observe the current directions.

1. Direction of I_B is reversed, because the motor is taking current **from the bus bar.**

2. Direction of I_a is reversed, because the motor is taking current **from the bus bar.**

3. Direction of I_f is unchanged, because polarity across the field coil is unchanged.

$$
\begin{aligned}
I_B &= I_a + I_f \\
\frac{5000}{200} &= I_a + 2 \\
I_a &= 23\ Amp \\
So, & \\
E_m &= V_t - (I_a * R_a) - V_{brush} \\
&= 200 - 2.3 - 2 = 195.7V \qquad (4) \\
so, & \\
E_m &= 195.7 = \frac{\Phi * Z * P}{a} * \frac{rpm_m}{60} \\
so, rpm &= \mathbf{421.4039\ \ rpm}.....\ Answer \qquad (5)
\end{aligned}
$$

Question 2

A 4 pole lap wound DC generator has no-load generated e.m.f. of 500 V at 1200 rpm. Calculate the flux per pole if the armature has 120 slots with 6 conductors per slot. If each conductor has 0.01 Ω resistance, find the resistance of the armature winding. (34.72 mWb, 0.45 Ω)

Answer 2

Data

$$
\begin{aligned}
P &= 4 \\
a &= 4 \\
Z &= 120 * 6 = 720 \\
E_g &= 500 \\
0.01\Omega &= \ resistance\ of\ single\ conductor
\end{aligned}
$$

Solution

Using e.m.f. equation, $E.M.F. = \frac{\Phi * Z * rpm * P}{60 * a}$
Subsitituting the values from given data and rearranging,
$\Phi = 0.03472Wb =$ **34.72 mWb**
Now refer to the figure 3 on page 5.
The 720 armature conductors are arranged in 4 parallel paths.
One conductor has 0.01Ω resistance.

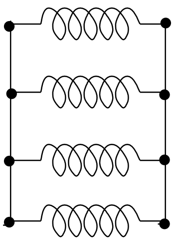

Figure 3: Parallel Paths

Each path coil has restistance $180 * 0.01 = 1.8\Omega$.
And these coils are in parallel to each other.
So the total resistance is $1.8/4 = 0.45\Omega$.
Thus armature winding resistance is 0.45 Ω

Question 3

Find the resistance of the load taking 6KW from a DC generator whose external characteristic is given by $V_t = 300 - 0.5I_L$. I_L is the load current. (13.982 Ω)

Answer 3

External characteristic equation is useful to corelate all dc machine electrical parameters **outside the machine**, i.e. it *excludes* armature resistance, brush drop, emf induced and field ckt parameters. Terminal voltage V_t, and load current I_L are the external parameters.

Multiplying both sides of the external characteristic equation, we get:

$$V_t * I_L = 300 * I_L - 0.5I_L^2 \quad (6)$$

$$\textit{Solving the quadratic in } I_L,$$

$$\textit{we have } I_L = 579.285 \textit{ or } I_L = 20.715 \quad (7)$$

$$\textit{Power} = I_L^2 * R_L = 6000 \quad (8)$$

So,R_L**=13.982** Ω.

Question 4

A 220V,1.5kW,859 rpm, separately excited motor has armature resistance 2.5Ω. It draws a current of 8 Amp at rated load. If the field current and the armature voltage are fixed, at the value of the rated speed, what will be the no-load speed of the motor? Assume losses remain constant between no-load to full-load condition. Also assume I_a at no-load is zero.

Answer 4

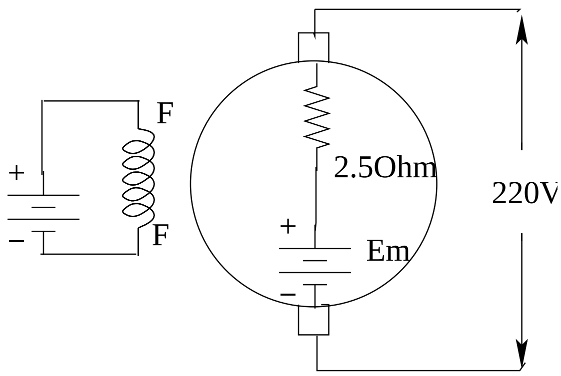

Figure 4: Separately excited motor

Refer to the figure 4. Using the formulae, and the data in the question above,

$$
\begin{aligned}
rps &= \frac{rpm}{60} \\
E_m &= \frac{\Phi * Z * P * rps}{a} && (9) \\
E_m &= V_t - I_a * R_a && (10) \\
So,\ E_{mfl} &= 220 - (8 * 2.5) = 200V && (11) \\
and,\ E_{mnl} &= 220 - (0 * 2.5) = 220V && (12) \\
rps_{fl} &= \frac{859}{60} = 14.317 && (13) \\
Re-arrange\ equation\ 9\ to\ get, & \\
E_m &= \frac{\Phi * Z * P}{a} * rps \\
&= K * rps \\
For\ full\ load\ condition, &
\end{aligned}
$$

$$\begin{aligned} 200 &= K * rps = K * 14.317 \\ so\ K &= 13.9697 \\ Using\ this\ value\ of\ K, & \\ E_{mnl} &= 220 = 13.969 * rps_{nl} \\ rps_{nl} &= \frac{220}{13.9697} = 15.748 rps \end{aligned}$$

So no-load rpm is $rps_{nl} * 60$= **944.9 rpm**

Question 5

A 4 pole DC series motor has wave connected winding with 600 conductors. Total resistance of the motor is 0.8 Ω. At 250V dc, the motor supplies a load of 10KW and takes 50A with flux per pole of 0.3mWb. For these conditions, calculate developed torque τ_e and shaft torque τ_s.

Answer 5

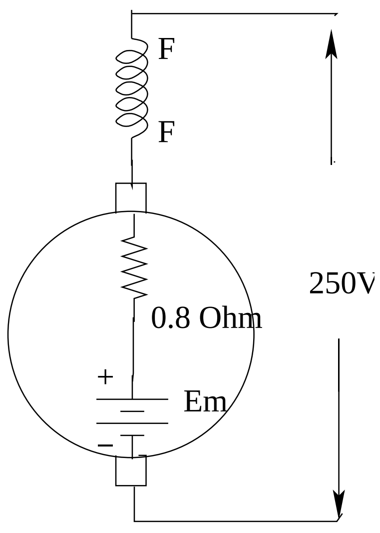

Figure 5: DC series motor

Refer to figure 5. To use the data from the question, following formulae are useful. **Note that the rated output (mechanical) power is 10KW.** Also, $Torque_{electromagnetic} = Torque_{friction} + Torque_{shaft}$

$$E_{mfl} = \frac{\Phi * Z * P}{a} * rps$$

$$
\begin{aligned}
a &= 2....wave\ winding \\
&= \frac{3*10^{-3}*600*4}{2}*rps_{fl} && (14)\\
rps_{fl} &= 58.333 && (15)\\
\omega_{fl} &= 2*\pi*rps_{fl} = 366.519\ rad/sec && (16)\\
However,\ E_{mfl} &= V_t - I_a * R_{total} = 250-(50*0.8) = 210V && (17)\\
Now,\ \tau_e*\omega_{fl} &= E_{mfl}*I_a...power\ balance\ eqn. \\
so, \tau_e &= \frac{210*(50)}{366.519} = 28.6478\ Nm. && (18)\\
Also\ P_{mechanical} &= \tau_s*\omega_{fl} = 10kW && (19)\\
& && (20)
\end{aligned}
$$

So $\tau_s = \frac{10000}{366.519} = 27.28Nm.$

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