ECE 320: Lecture 25

Notes

DC motor:

- We will concentrate on DC motors in this class.
- DC generators will have behavior similar to what we've seen so far, and we will discuss a cases for comparison.

Armature Windings

So far we have assumed that that the armature winding has only one turn.

- There are generally N turns. These turns may also be connected into "m" parallel circuits.
- The commutator is also spread ot with many segments for the parallel circuits so the outpu voltage no longer has gaps with 0 V on the output.
- There are also "P" field poles. In the earlier example we assumed there were 2, but there ca be more, but they must increase in powers of 2 (i.e. 4 poles, 6 poles, etc).
- View each turn as producing a voltage.

Each turn produces:

$$e_{a1} = 2 \cdot r \cdot l \cdot B \cdot \omega_m$$

Where ω_m is the mechanical speed of the rotor, in rad/sec

Not all of the turns will be under a pole face, there will be

$$N_m = \frac{P}{2} \cdot \frac{N}{m \cdot \pi}$$ turns under a pole face

So now:

$$e_a = N_m \cdot e_{a1} = \frac{P}{2} \cdot \frac{N}{m \cdot \pi} \cdot 2 \cdot r \cdot l \cdot B \cdot \omega_m$$

$$e_a = k_a \cdot \phi \cdot \omega_m$$

Where: k_a is the armature constant. Can calculate based on a machine geometry. Can also determine from tests.

A similar analysis can be performed for the Torque equation. Now the current is divided betweer "m" parallel branches

$$\tau = 2 \cdot r \cdot l \cdot B \cdot \frac{P}{2} \cdot \frac{N}{\pi} \cdot \frac{i_a}{m}$$

So the net Torque is:

$$\tau = k_a \cdot \phi \cdot i_a$$

Steady-state analysis

- For this class we will concentrate on steady-state behavior. We won't look at the time respons
- We will now explore the equivalent circuit for a dc motor (and make a few comparisons to th generator equivalent circuit
- Since this is a dc circuit in steady-state, the inductances will be replaced by short circuits....

$$i_a = I_a$$

$$e_a = E_a$$

$$i_f = I_f$$

- The armature constant will stay the same.

Field Excitation Options

- The field connection needs to be included in the circuit
- The flux: ϕ will be related to the field curent and the number of field turns and a constant.

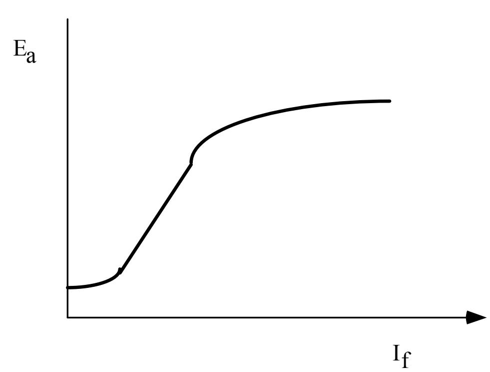
Separately Excited Machine

Field current:

$$I_f = \frac{V_f}{R_f}$$

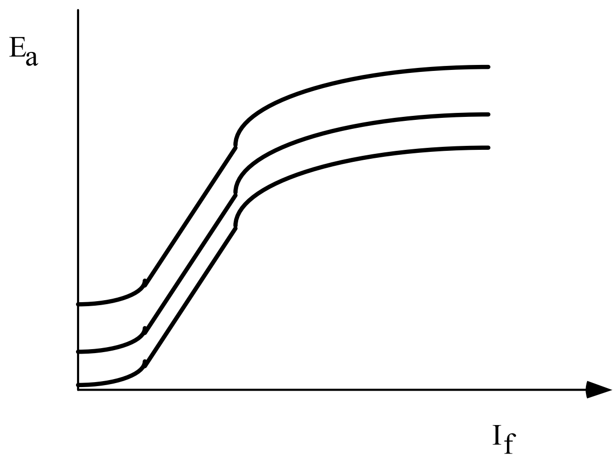
- R_f is the resistance of the field circuit. In some cases this is a variable
- In other cases V_f, the voltage applied to the field is varied.

- The field flux is produced applying this current through N_f turns on the field winding, producing an MMF.
- The magnetic material will saturate.
- But you can characterize this characteristic (or in some cases it will be provided to you) by measuring the open circuit armature voltage as the field current is varied
- This must be done at a constant speed, since the armature voltage depends on speed as well as field flux.



This won't necessarily start at zero Volts due to residual magnetism in the magnetic core material

Recall that the voltage depends on the speed. This is a linear relationship, so the curve moves up and down with speed, with higher voltages with higher rotor speeds.



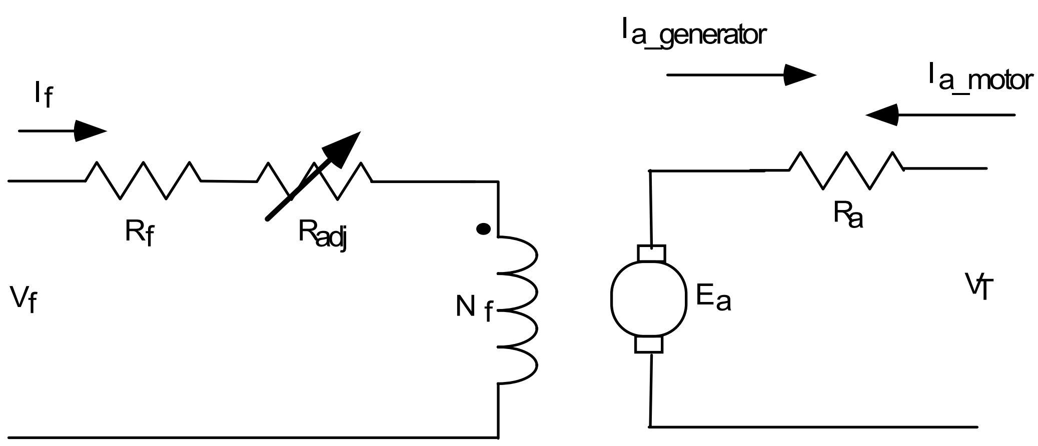
So we can always relate voltage and speed (assuming constant flux density) with:

$$\frac{Ea1}{\omega 1} = \frac{Ea2}{\omega 2}$$ where ω1 and ω2 are two different speeds in rad/sec

or with:

$$\frac{Ea1}{n1} = \frac{Ea2}{n2}$$ where n1 and n2 are the rotor speeds in revolutions per minute

Equivalent circuit:



Now:

$$I_f = \frac{V_f}{R_f + Radj}$$

- Radj is a variable resistor (called a rheostat)

Generator Case

- Define armature current as leaving the machine.
- For a generator, armature current is greater than terminal voltage
- R_a is the armature resistance

$$I_a = \frac{E_a - V_t}{R_a}$$

- The electrical load connected to the terminals can be treated as a resistance, or a voltage source behind a resistance (usually another machine).
- In some of the labs, a generator will connected to the same shaft as a motor.
- The generator will have an electrical load, that will in turn cause it to require mechanical power (or torque) from the motor.

Electromagnetic Torque is applied to the rotor to make it turn faster than no-load speed

$$\tau = \frac{E_a \cdot I_a}{\omega_m}$$ ω_m must be in rad/sec for this calculation

Motor Case:

- Now define the current as entering the machine from the terminals
- The motor now appears as a load to the electrical circuit and will supply mechanical work to rotor shaft.
- For the seperately excited case, the field circit will be exactly the same, except there will be l field current, since the armature voltage will now be smaller than the terminal voltage.

$$Ia = \frac{V_t - E_a}{R_a}$$

Now treat the torque, or the mechanical power (now power will be given in HP in North America instead of Watts) as the output