ECE 320: Lecture 27

Notes

Machine Ratings:

Usually given: Vt
Ifmax (for the shunt field)
Vf (rated voltage for shunt field, often same as Vt)
Rated speed
Rated power
HP for motors (at the shaft, after rotational losses out)
kW for generators (at the terminal)

Power Flow:

For a generator: Pin is the power applied to the shaft:

$P_{em} = P_{in} - P_{fw}$

- Power crossing air gap
- Pfw are mechanical friction and windage losses (air drag)

$P_{em} = E_a \cdot I_a = \tau \cdot \omega$

$Pout = Pem - \left(I_a\right)^2 \cdot R_a = V_t \cdot I_a$

There will also be a small loss term with brushes (Pbrush)

$P_{out} = P_{in} - Pfw - \left(I_a\right)^2 \cdot R_a$

For a motor: Pin is the power at the electrical terminal:

$P_{in} = V_t \cdot I_a$

$P_{em} = P_{in} - \left(I_a\right)^2 \cdot R_a$

There will also be a small loss term with brushes (Pbrush)

$P_{em} = E_a \cdot I_a = \tau \cdot \omega$

$P_{out} = P_{em} - P_{fw}$

- Power crossing air gap
- Pfw are mechanical friction and windage losses (air drag)

$P_{out} = P_{in} - Pfw - \left(I_a\right)^2 \cdot R_a$

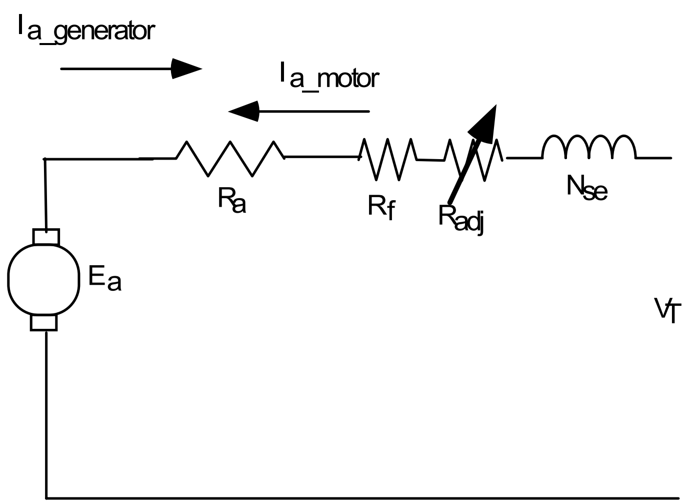
Field Excitation Options Continued

- 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.

Series Excited:

- Now we have $I_f = I_a$
- Small number of turns on the field circuit, to minimize added resistance to the circuit
- Also the "field" current will now be large.
- The shunt field has a lot of turns and small current, the series field has few turns and a lot of current

- Series excited machines tend to produce very high starting Torques, since the armature current large when machine isn't turning (no armature voltage)
- They do not perform well as generators. They will have poor voltage regulation.

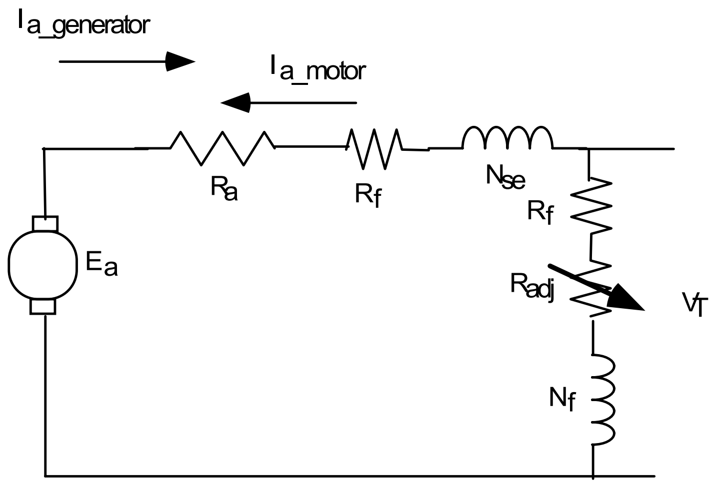


- The field rheostat for a series field machine will have a small resistance.
- Series winding is connected on the stationary part of the machine (before the connection tc commutator.
- Series machines used for loads where very high torque is needed when starting the machin for example in a freight locomotive.
- The maximum exciting current for occurs when the machine isn't turning (Ea = 0). This provides the largest Ia and the largest B for producing starting Torque.

$$\tau = K_a \cdot \phi \cdot I_a$$

Combined Series/Shunt excitation:

- Referred to as compounding
- Can be cumulative compounded where the two field components add, this is more common
- This improves voltage regulation
- Can also be differentially compounded, here the field components cancel. It is more difficult get a stable operating point for a generator.



- Shunt field can be connected between series field and armature winding (short shunt) or between the series field and terminal voltage (long shunt).

Permanent Magnet:

- More common in small machines
- Field (the magnet) is usually on the rotor, and the armature winding is on the stator (stationar part)
- Sometimes called a "brushless DC machine" since there is no commutator and no brushes
- Now it is not possible to vary the field flux, it is fixed, so Ea and τ are only dependent on spe and armature current.

$$E_a = K_{pm} \cdot \omega$$

$$\tau = K_{pm} \cdot I_a$$

Starting DC Motors:

- When the motor is not rotating, the armature voltage will be zero
- The motor can draw a large current from the dc power source
- This current determines the starting torque. In most cases this is the largest torque the machine produce.

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

- The other variable in this equation is the flux produced by the field
- As discussed above, this depends on the field circuit connection
- For a series field motor, it will basically bootstrap itself up to speed.
- For a seperately excited, shunt, or permanent magnet machine, the armature current may be too large.
- This could result in damage to the machine, or
- In some cases this could even damage the load by producing excessive starting torque.

Motor Starting Options:

- Reduced voltage starter:

1. Reduce terminal voltage by reducing output of dc source (power converter or dc generator)
2. Resistive voltage divider (similar to starter box used in the labs). The voltage divider is bypass or switched out of the circuit once the back emf (armature voltage) is sufficiently high to limit current.