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Notes for Class 1:

Topics of Discussion:

- Torque vs Speed Characteristics of Separately excited DC motor (Constant Flux and Flux weakening region)
- Various Quadrants of operation for DC motor
- Open Loop Model for separately excited DC motor.

Dynamic Equations for DC motor:

1. Vt = E –Ia Ra – La d Ia/dt
2. E = Kb w
3. T g= Kt Ia
4. T l – Tg =J dw/dt + Bw
5. Vf= Lf dIf/dt + If Rf

Steady State Equations for DC motor:

At steady state dw/dt =0 ,dIa/dt=0.

1. Vt = E-Ia Ra
2. E= Kb w
3. Tg =Kt Ia
4. Tl – Tg = Bw
5. Vf= If Rf

Points to note:

- E proportional to Speed (at constant flux)
- Tg proportional to Current(at constant flux)
- Since IaRa drop is usually negligible as compared to E , speed can be considered proportional to Vt.
- At no load motor generates torque so as to overcome viscous frictional losses.
- The construction of DC motor and the current carrying capability of the armature and brushes is what puts limit on the Maximum Torque and Maximum speed of the DC motor.
- Constants Kb and Kt are dependent on Flux (Phi f), which in turn depends of If. If can too be adjusted so long as it doesn’t cause saturation of the core.

Torque Speed Curve:

The curve represents Tg vs w both of which are normalized with respect to their rated values.

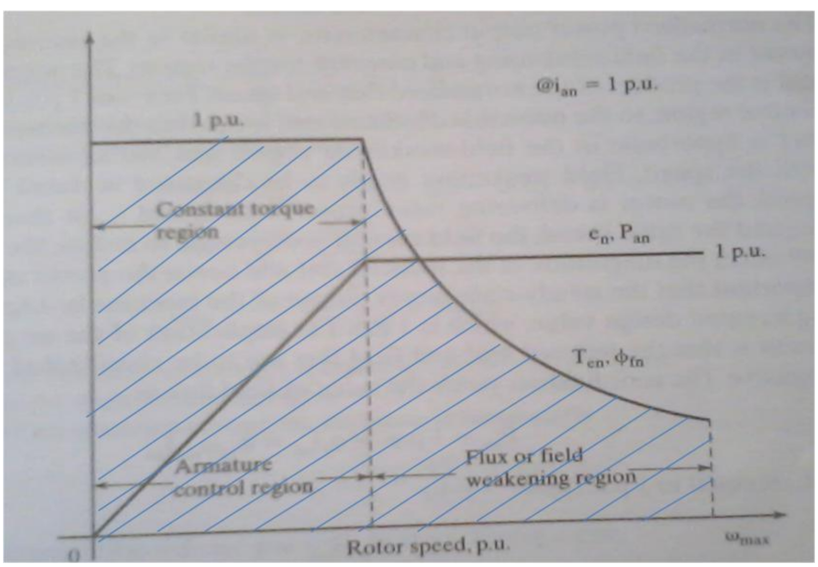
I.e. Tg,w,Ea,Ia all represented below are normalized values.

The Shaded Portion in the curve represents the area of Operation for the DC motor.

The curve is divided in two regions:

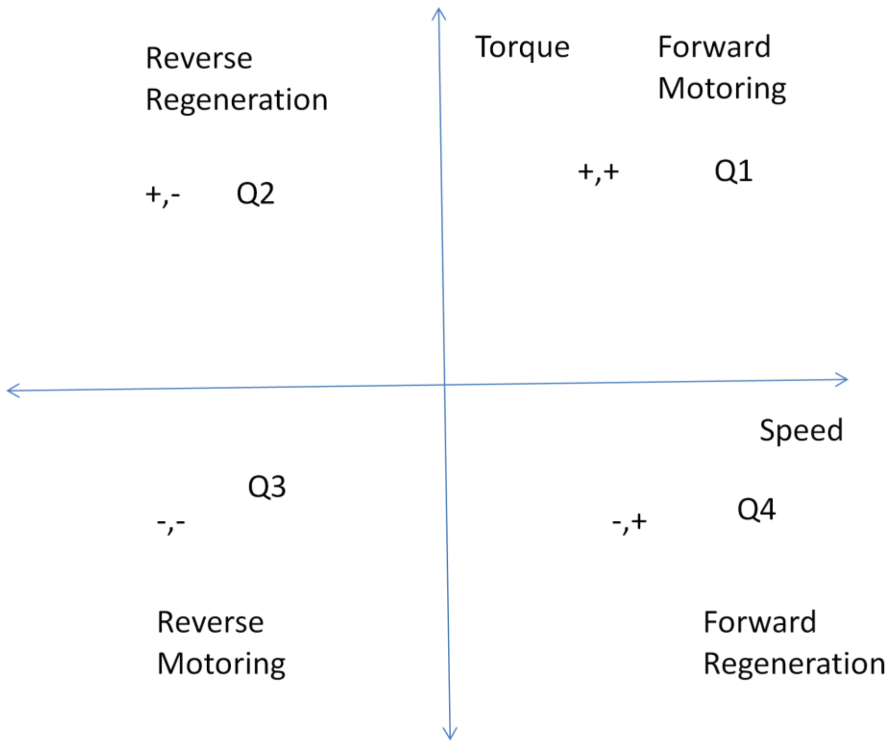
1. Constant Flux region (Speed Proportional to E – Armature Control)
2. Flux Weakening or Constant E region (Speed inversely proportional to Phi f—Flux control)

- Rated Toque is the maximum torque produced by the motor at rated current and rated flux.
- Rated speed is the speed at which the motor runs when rated voltage and rated field is applied to the armature.
- Thus when we say the motor is running at rated conditions ,it implies that we are running at Rated Torque and Rated speed, thus delivering rated Power.
- The outer envelope determines the maximum limits at which the motor can be operated at any given speed.
- In the constant flux region, it is the rated flux and rated current that determine the boundary.
- In the flux weakening region, it is the rated emf and rated current that determine the boundary.
- The maximum speed is determined by the construction of the motor and it the limiting factor in the flux weakening region.



4 Quadrants of Operation:

The four quadrants of operation can be summarized as in the figure below: (Torque,Speed)



Understanding Regenerative Operation:

Consider the motor to be operating in forward motoring mode. Now consider what happens if the source voltage is made less than the back emf instantaneously. Now because of the inertia of the motor it will continue to rotate in the same direction and thus the back emf's polarity won't change. But since the applied voltage is less than the back emf, the current will change its direction and start flowing from the motor back to the source. That is the motor starts acting like a generator supplying its inertial energy back to the source.This process is known as regeneration.

Regeneration can be used for braking operations where in the inertial energy can be used back to charge batteries (if it is the source of DC supply) .

Ways to bring DC motor to halt:

Basically to halt the motor we have two options :

1. Reduce the Tg to zero, so that the load and friction itself will decelerate the motor and bring it to halt. For this we need to reduce Ia to zero, i.e. if we cut-off the power supply to the motor.
2. Apply a reverse torque –Tg, so that both the generated and load torque act in the same direction, thus decelerating the motor faster and bringing it to halt faster.

There are two techniques to achieve the 2^{nd} option:

1. Regenerative braking
2. Dynamic Braking

Basically in terms of energy , the energy stored in the motor system has to be removed in order to halt it. Now the frictional energy as is cannot be recovered. But we can try to recover the inertial energy stored in the system if we use regenerative braking as explained above.

In Dynamic braking , we can halt the system really fast by disconnecting the supply and putting in a dissipative load across the motor. A large reverse current will flow in the motor, producing a large retarding torque and bring the motor to halt immediately. But when compared to previous case, the energy here is not recovered and rather dissipated.

Open Loop Model for separately excited DC motor:

Taking the Laplace transform of the dynamic model equations as stated above,we can conclude with the following system model for separately excited DC motor:

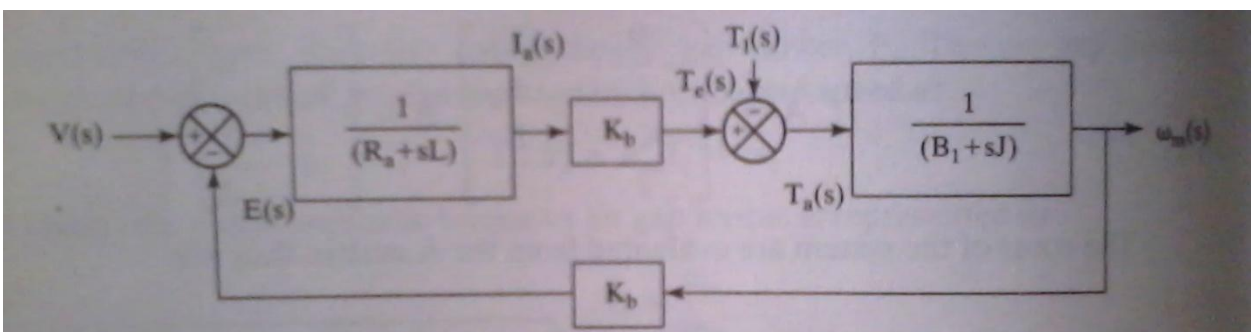


Figure 2.3 Block diagram of the dc motor