METU EE462 Utilization of Electric Energy

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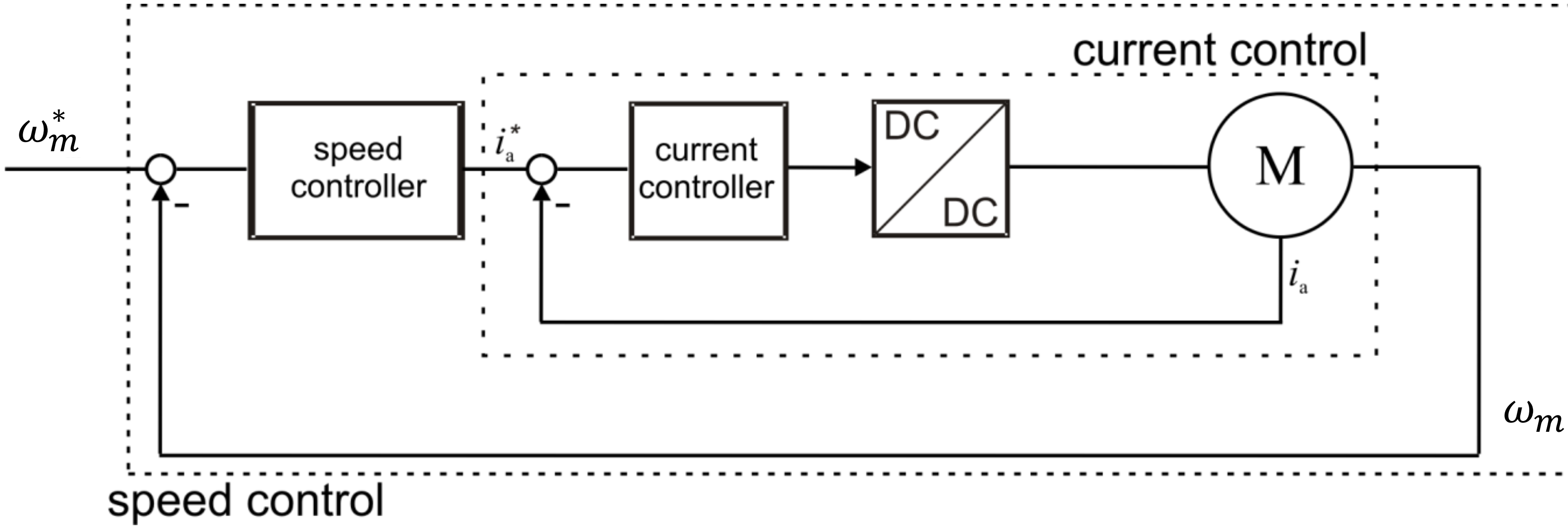
Office: C-107

Content

Control (Cascade Structure)



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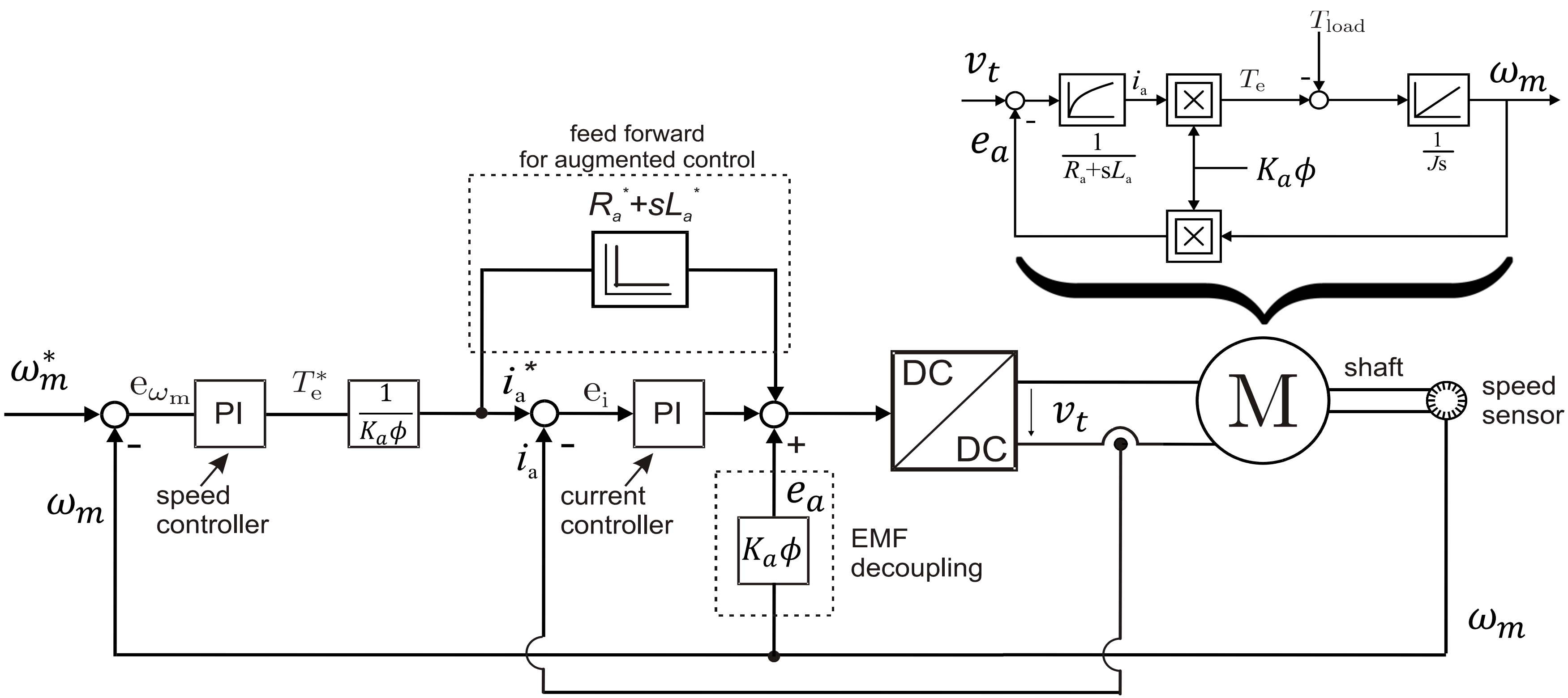


v_t

Exercise DC1

A separately-excited DC machine drive system is operated with a 4-quadrant converter and coupled to a flywheel. The converter is controlled so that the armature current is always equal to the desired I_a.

Frictions and all losses except in the DC machine can be neglected. The quantities of the drive system are given as fallows:

Nominal torque $T_N = 36.75$ Nm

Nominal speed $n_N = 3900$ rpm

Nominal armature voltage $V_{t,N} = 500$ V

Nominal armature current $I_{a,N} = 35$ A

Armature inductance $L_a = 25$ mH

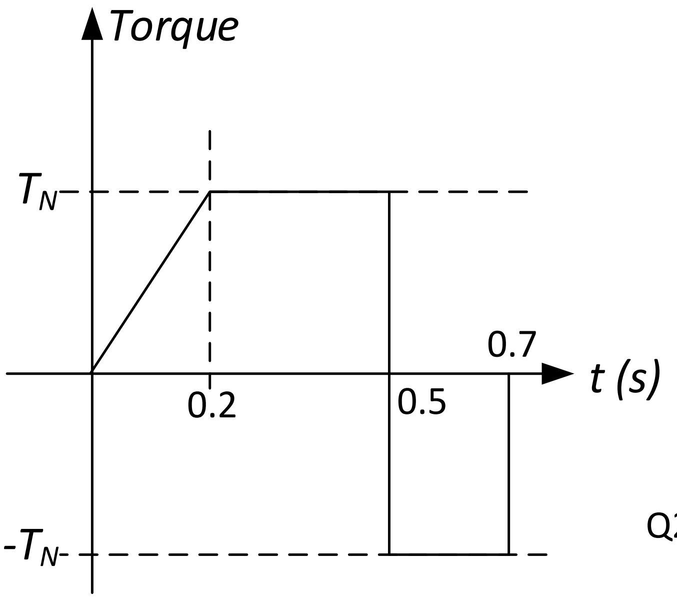
Nominal field current $I_{f,N} = 1.9$ A

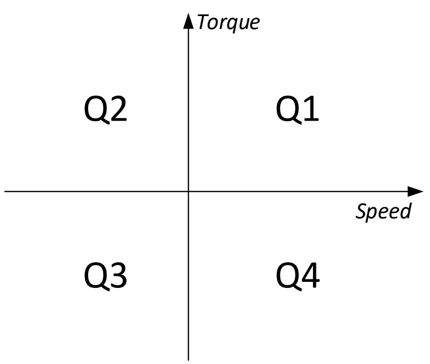
Minimum field current $I_{f,min} = 0.5$ A

Nominal field voltage $V_{f,N} = 330$ V

Field inductance $L_f = 900$ mH

Total inertia $= 0.25$ kg m^2





DC machine delivers the driving torque as shown in the driving torque characteristics given above. At t=0s, the DC machine stands still (n = 0 rpm).

Exercise DC1

1.1 Determine and draw the characteristics of the machine speed corresponding to the torque characteristics given in the example.

1.2 Corresponding to this torque , in which quadrants of T/n diagram is the DC machine operating?

The operation given above will not be considered further in the following questions.

1.3 Draw the complete equivalent circuit of this separately excited DC machine.

1.4 Determine P_N, $K_a\phi$, R_a and R_f.

1.5 Which quantity can be adjusted in order to operate the DC machine with nominal power t speeds higher than nominal speed? What is the maximum speed that can be reached by this kind of operation? How much torque is obtained at this maximum speed.

1.6 Sketch the operating range of this DC machine only in 1st quadrant with information of all operating limits.

1.7 Which equation is applied in the controller to calculate the control value V_t^* on the basis of available quantities I_a^* and n^*? Draw the block diagram of the controller. It is assumed that machine is operating at nominal field current.

Exercise DC1

The drive system is decelerated from the nominal speed $\boldsymbol{n_N}$ to standstill. The inductance $\boldsymbol{L_a}$ and $\boldsymbol{L_f}$ can be neglected in the following questions. The excitation is kept contrast at nominal value.

1.8 In order to brake the drive, a negative torque is applied. What value should the braking torque T_b have, so that the drive is decelerated to standstill in t_b=4 s.

1.9 What value of the kinetic energy is stored in the drive at nominal speed?

1.10 How much energy is fed back into the power grid during the braking process from 1.8?

1.11 To which value much the braking torque T_b be reduced in order to halve the loss power in the armature? How much time is needed for this braking process? How much energy is fed back into the grid now? Comment on the results.

Elementary AC Machine Example

Source: Electric Machinery by Fitzgerald, Kingsley and Umans.

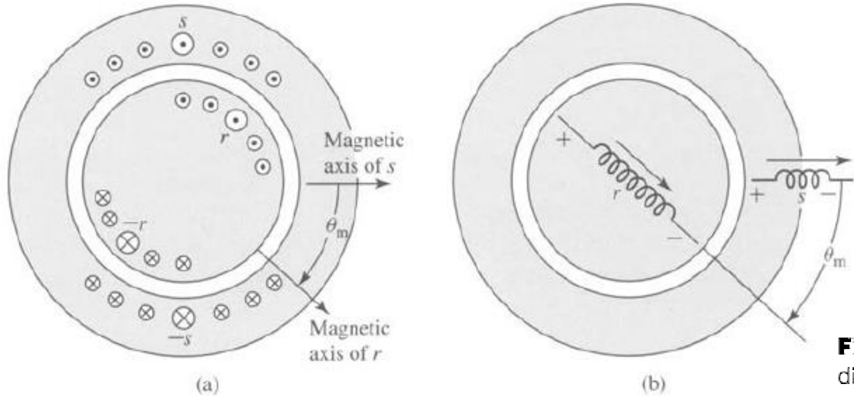


Figure 4.34 Elementary two-pole machine with smooth air gap: (a) winding distribution and (b) schematic representation.

EXAMPLE 4.6

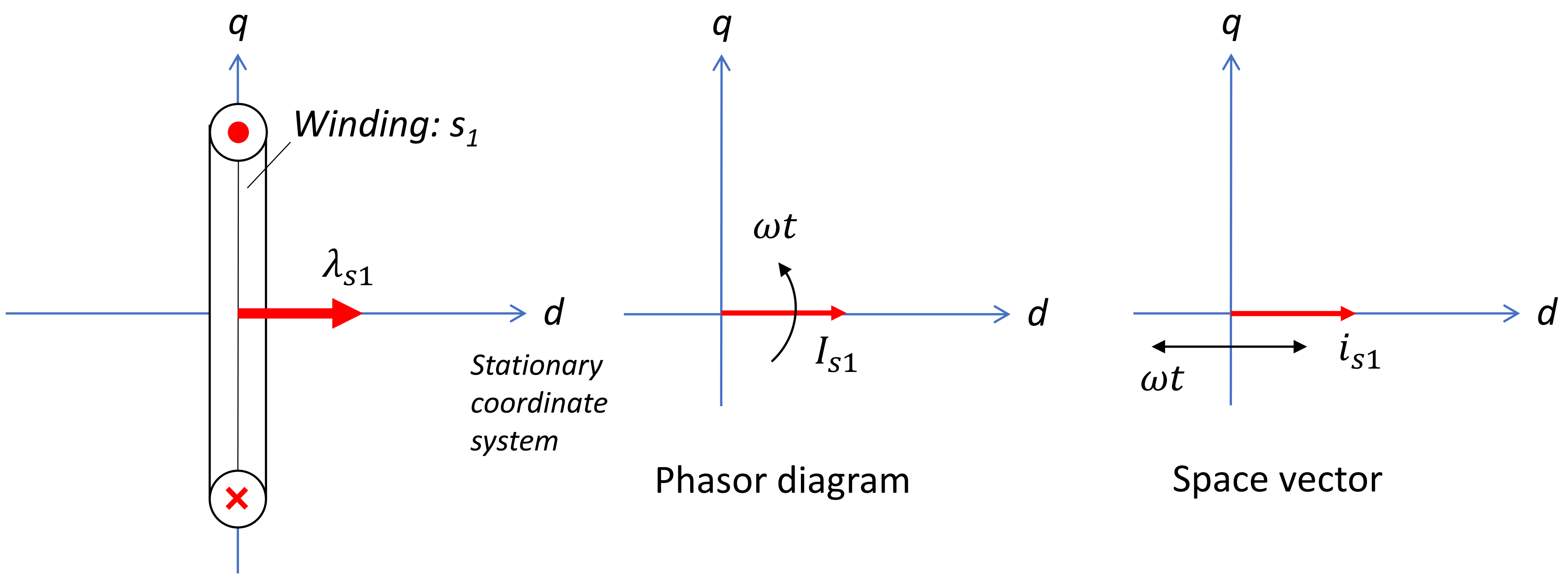
Consider the elementary two-pole, two-winding machine of Fig. 4.34. Its shaft is coupled to a mechanical device which can be made to absorb or deliver mechanical torque over a wide range of speeds. This machine can be connected and operated in several ways. For this example, let us consider the situation in which the rotor winding is excited with direct current I_r and the stator winding is connected to an ac source which can either absorb or deliver electric power. Let the stator current be

$$i_s = I_s \cos \omega_e t$$

where $t = 0$ is arbitrarily chosen as the moment when the stator current has its peak value.

a. Derive an expression for the magnetic torque developed by the machine as the speed is varied by control of the mechanical device connected to its shaft.
b. Find the speed at which average torque will be produced if the stator frequency is 60 Hz.
c. With the assumed current-source excitations, what voltages are induced in the stator and rotor windings at synchronous speed ($\omega_m = \omega_e$)?

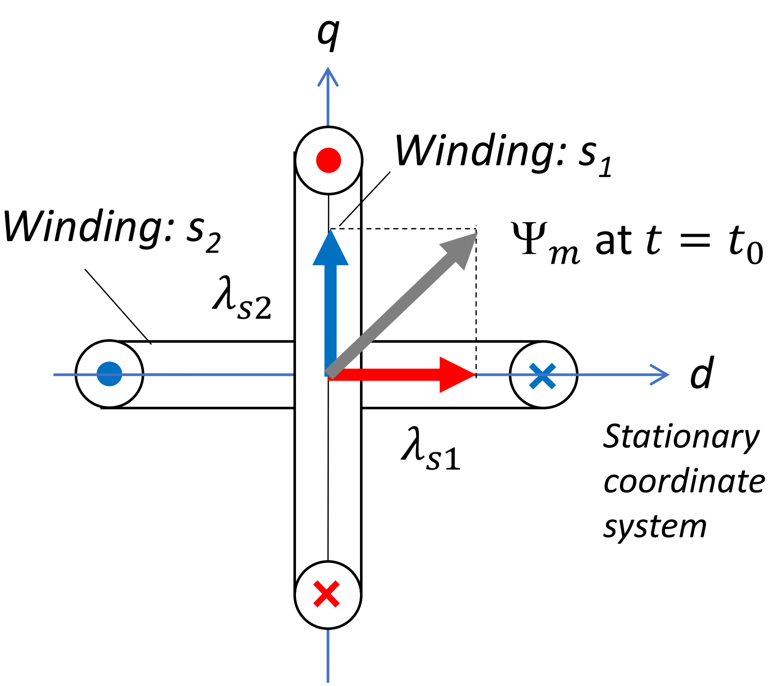
Creating a Rotating Field – 1-Phase

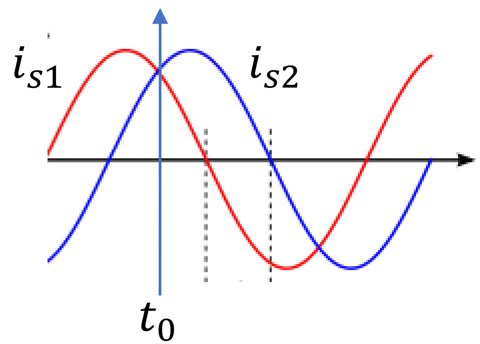


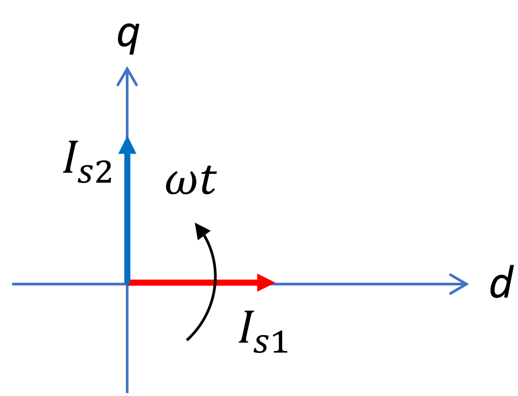
$$\lambda_{s1}(t) = \lambda_m(\mathrm{t}) = \lambda_d(\mathrm{t})$$

$$i_{s1}(t) = \sqrt{2}\, I_{s1} \cos(\omega t)$$

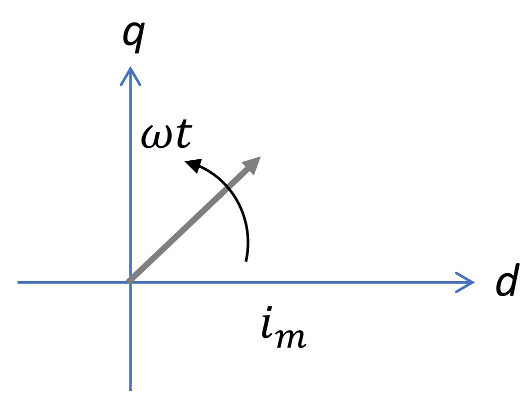
Creating a Rotating Field – 2-Phase







Phasor diagram



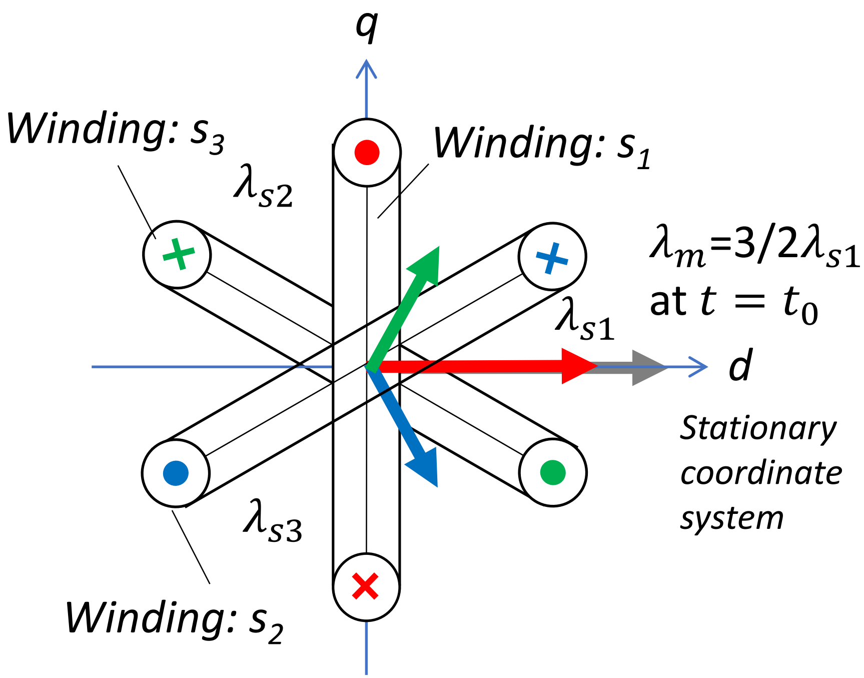
Space vector

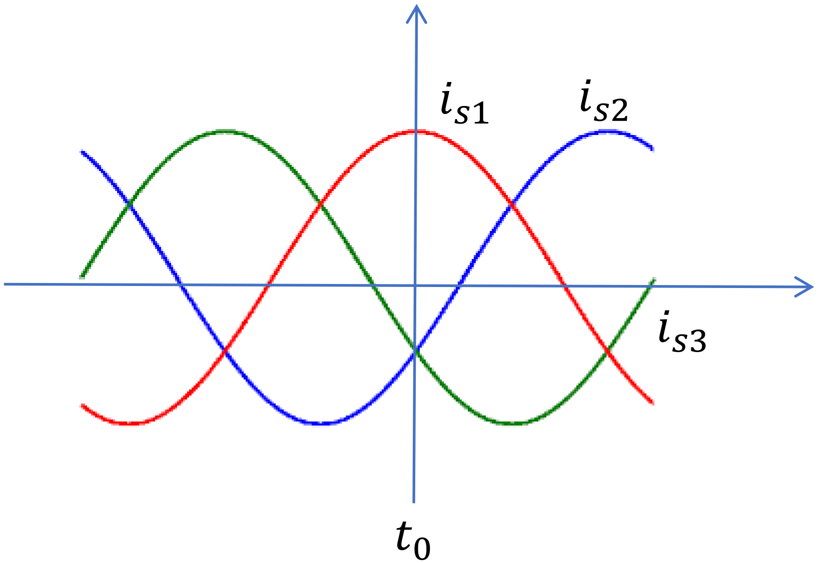
$$i_{s1}(t) = \sqrt{2}\, I_{s1} \cos(\omega t)$$

$$i_{s2}(t) = \sqrt{2}\, I_{s2} \cos\left(\omega t - \frac{\pi}{2}\right)$$

$$\lambda_m(\mathrm{t}) = \overrightarrow{\lambda_{s1}}(t) + \overrightarrow{\lambda_{s2}}(t) = \lambda_m\ cos(\omega \mathrm{t}) + \mathrm{j}\lambda_m sin(\omega t) = \lambda_m\ e^{j\omega t}$$

Creating a Rotating Field – 3-Phase





$$i_{s1}(t) = \sqrt{2}\, I_{s1} \cos(\omega t)$$

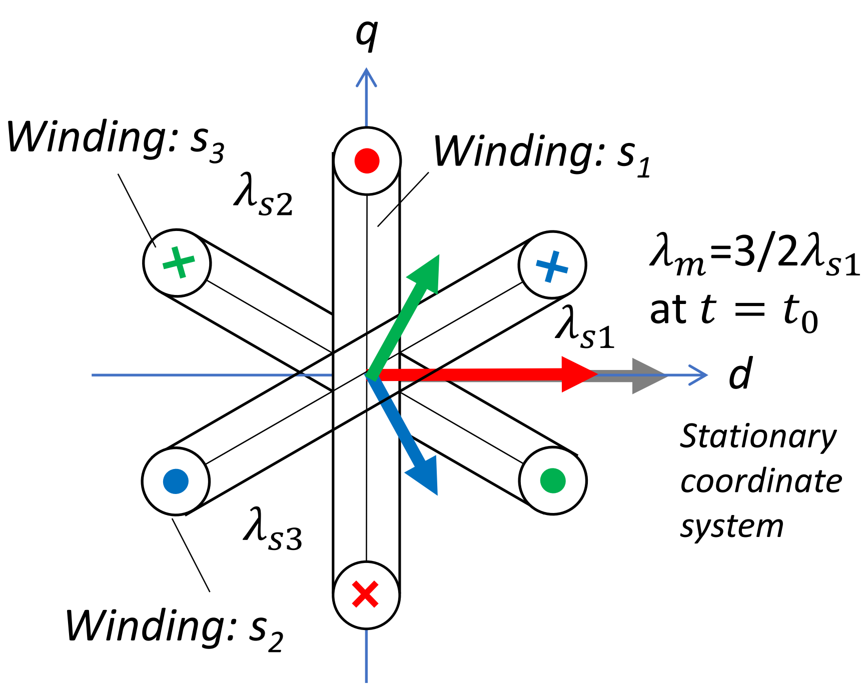
$$i_{s2}(t) = \sqrt{2}\, I_{s1} \cos\left(\omega t - \frac{2\pi}{3}\right)$$

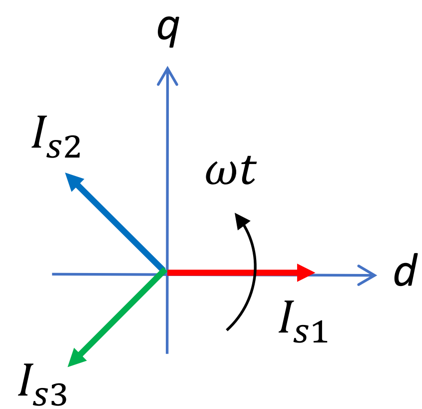
$$i_{s3}(t) = \sqrt{2}\, I_{s1} \cos\left(\omega t - \frac{4\pi}{3}\right) = \sqrt{2}\, I_{s1} \cos\left(\omega t + \frac{2\pi}{3}\right)$$

$$\lambda_m(\mathrm{t}) = \overrightarrow{\lambda_{s1}}(t) + \overrightarrow{\lambda_{s2}}(t) + \overrightarrow{\lambda_{s3}}(t)$$

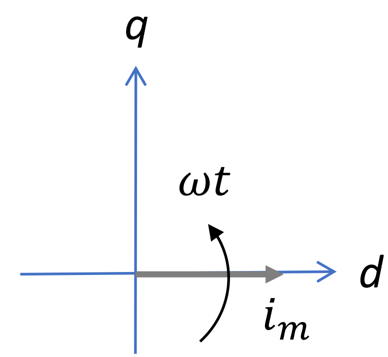
$$= \lambda_{s1}\, e^{j0} + \lambda_{s2} e^{j\frac{2\pi}{3}} + \lambda_{s3} e^{j\frac{4\pi}{3}} = \lambda_m e^{j\omega t}$$

Creating a Rotating Field – 3-Phase





Phasor diagram



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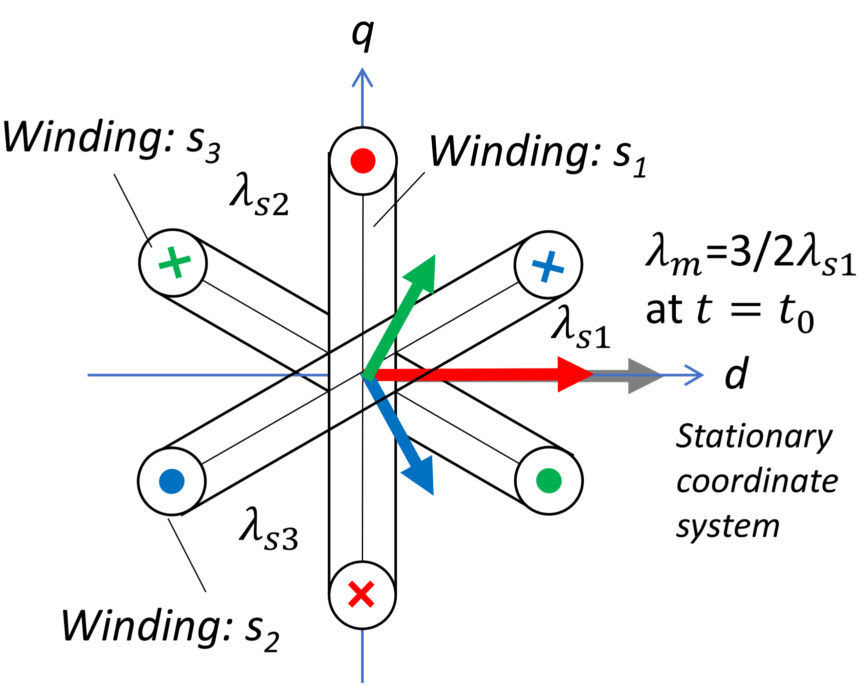

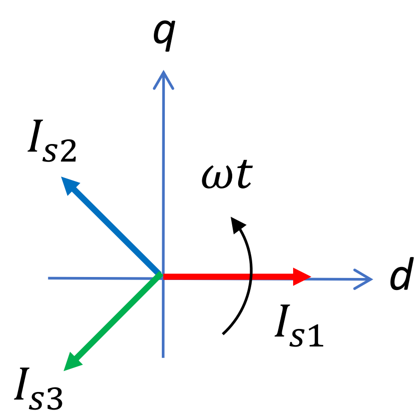

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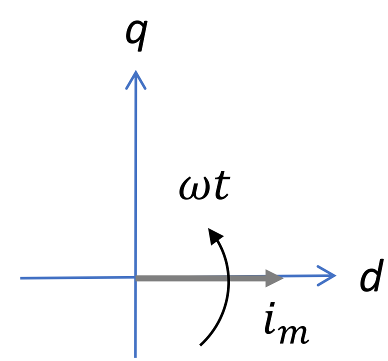

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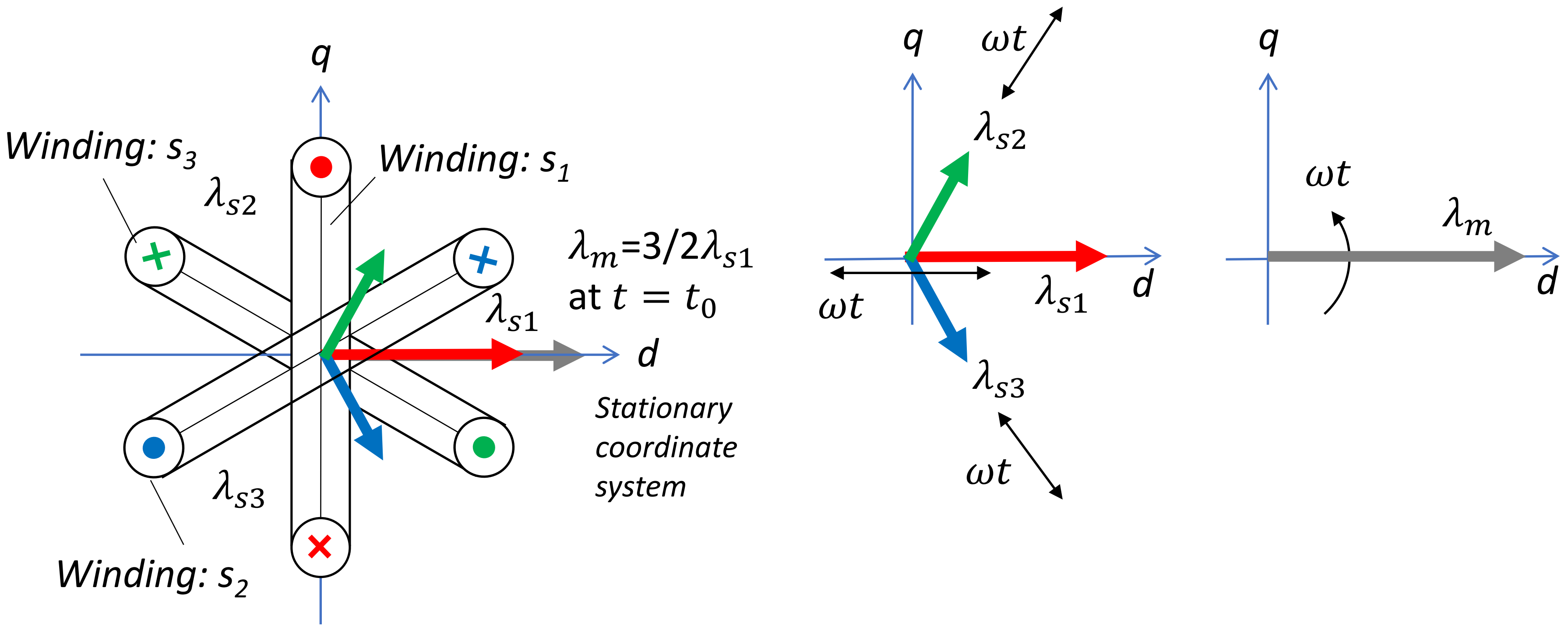

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Animations: http://people.ece.umn.edu/users/riaz/animations/listanimations.html