SYNCHRONOUS MACHINES

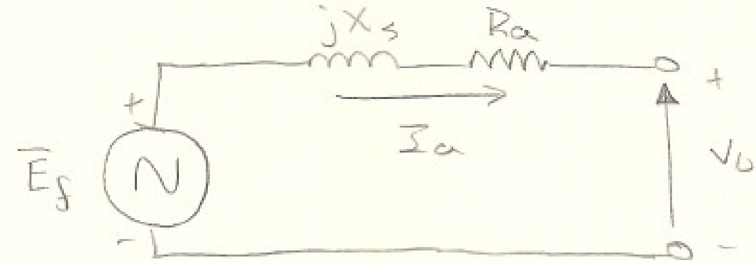
They are capable of operating as motors and generators. There is no difference, except the direction of power flow. The operation of these machines is based on Faradays Law.

Sync speed (N_s) is given by:

$$\boxed{N_s = \frac{60f}{P/2} \text{ rmp.}}$$

f: freq of supply.
N_s: synchronous speed (rpm)
P: # of poles

Equivalent cct of a synchronous generator (cylinderical rotor)



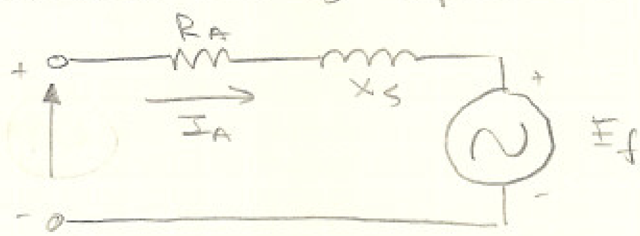
note: R_a is usually neglectable.

V_t, I_a, E_f, X_s, R_a are all on a per phase basis.

V_t: terminal voltage
E_f: no load generator voltage.

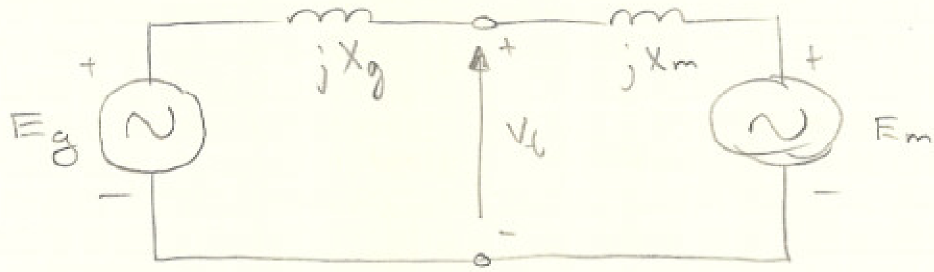
$$\boxed{\bar{V}_t = \bar{E}_f - (R_a + jX_s)\bar{I}_a}$$

Equivelent cct of synchronous motor



on per phase basis.

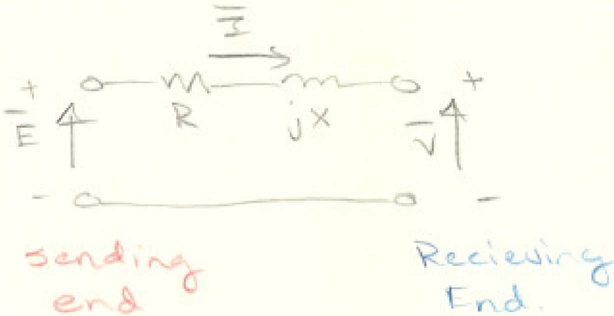
GENERATOR MOTOR CONFIGURATION



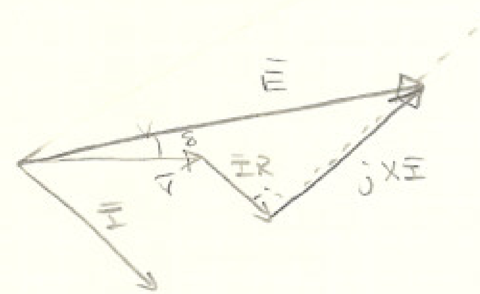
$$V_t = E_g - jI_a X_g$$
$$V_t = E_m + jI_a X_m$$

SYNCH MACHINE EXCITATION.

Consider the following circuit.



Phase diagram



$\bar{V}$ = refrence voltage = $|\bar{V}| \angle 0^\circ$

$\bar{E} = |\bar{E}| \angle \delta^\circ$

$\bar{Z} = R + jX = |\bar{Z}| \angle \psi$

$$\bar{I} = \frac{\bar{E} - \bar{V}}{\bar{Z}}$$

$$\bar{I} = \frac{|\bar{E}|}{|\bar{Z}|} \angle \delta - \psi - \frac{|\bar{V}|}{|\bar{Z}|} \angle -\psi$$

Complex power $\bar{S}$ in general is given by,

$\bar{S} = \bar{V}\bar{I}^*$

$\bar{S}_1 = \bar{E}\bar{I}^*$ sending end

$\bar{S}_2 = \bar{V}\bar{I}^*$ recieving end

$\bar{S}_1^* = \bar{E}^*\bar{I}$

$$\bar{S}_1^* = \frac{|\bar{E}|^2}{|\bar{Z}|} \angle -\psi - \frac{|\bar{E}||\bar{V}|}{|\bar{Z}|} \angle -\psi - \delta$$

$$\bar{S}_2^* = \frac{|\bar{E}||\bar{V}|}{|\bar{Z}|} \angle \delta - \psi - \frac{|\bar{V}|}{|\bar{Z}|} \angle -\psi$$

$$\boxed{\bar{S}^* = P - jQ}$$

$$P_1 = \frac{|E|^2}{|Z|}\cos(-\psi) - \frac{|E||\bar{V}|}{|Z|}\cos(\psi+\delta)$$

$$Q_1 = \frac{|E_1|^2}{|Z|}\sin(\psi) - \frac{|E||\bar{V}|}{|Z|}\sin(\psi+\delta)$$

$$P_2 = \frac{|E||V|}{|Z|}\cos(\delta-\psi) - \frac{|V|^2}{|Z|}\cos(\psi)$$

$$Q_2 = \frac{|E||V|}{|Z|}\sin(\psi-\delta) - \frac{|V|^2}{|Z|}\sin(\psi)$$

An important case is when R is neglected, then

$$\psi = 90^\circ \quad \text{and} \quad |Z| = X$$

then

$$P_1 = P_2 = \frac{|E||\bar{V}|}{X}\sin\delta$$

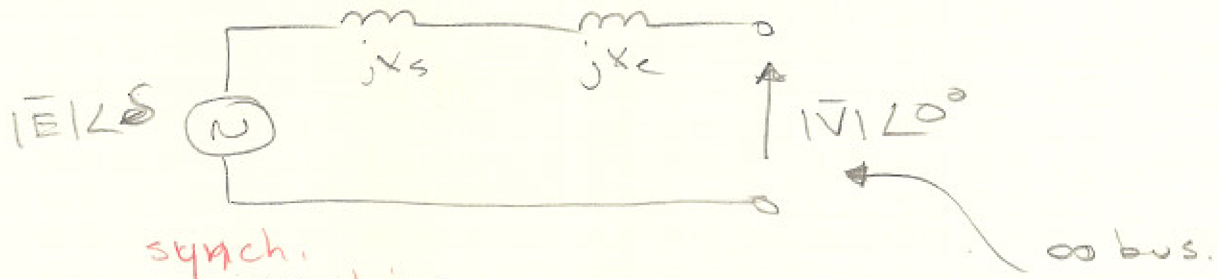
$$Q_1 = \frac{|E|^2 - |E||V|\cos\delta}{X}$$

$$Q_2 = \frac{|E||V|\cos\delta - |V|^2}{X}$$

note: max power transfer (P) when $\delta = 90^\circ$, but we can't do this do to instability.

In large scale power systems, a 3ϕ synch machine is parallelled through an equivalent system reactance X_e to the network, which has a high generating capacity, to any single unit. We often refer to the network or system as an infinite bus, where when a change in input of mechanical power or excitation to the unit does not cause an appreciable change in system freq or term. voltage.

An infinite bus (∞ bus) is an ideal 3ϕ power supply with constant terminal voltage and freq. So such a situation is shown below:



synch. machine connected to an infinite bus.

$$\boxed{X_T = X_S + X_E}$$