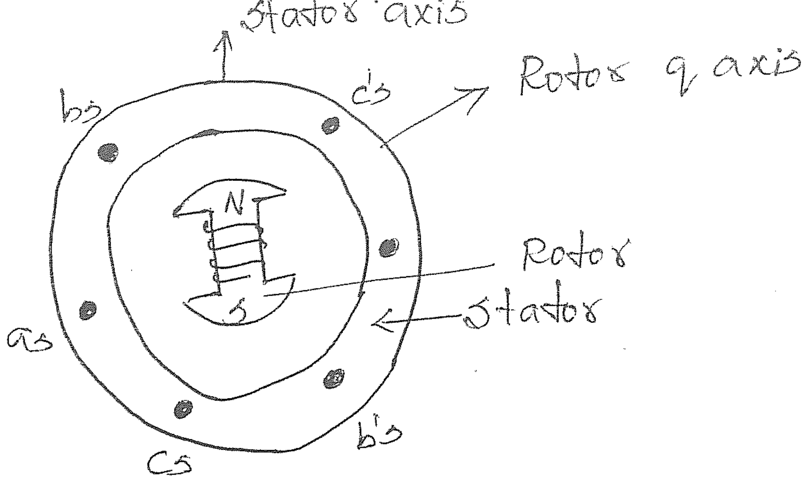
UNIT - IV Other Special Machine

Synchronous Reluctance Motor

Constructional features of synchronous variable reluctance motor



The stator has three phase winding which creates sinusoidal rotating magnetic field in the air gap & the reluctance torque is developed because the induced magnetic field in the rotor.

The synchronous reluctance motor consists of two main parts, namely stator & rotor.

Stator:-

Stator has smooth & distributed poles, It has laminated iron core with open or semi closed uniformly distributed slots.

open slot configuration may be used to house multi phase concentrated coils/phase. In order to improve the performance, Semiclose slots are used.

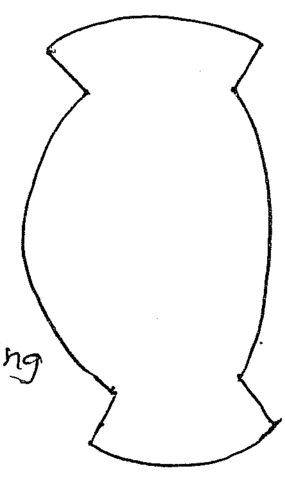
Each slot consists of stator windin which creates the stator magnetic field when the alternating current is supplied.

Rotor :-

Generally the rotor are three types nameu segmental, flux barrier, axially laminated structure. The ideal synchronous reluctance machine is having a rotor whose structure is such that the inductance of the stator winding in the 'dq' reference frame varies sinusoidally from a minimum value Ld a maximum value 'Lq' as a function of angular displacem of the rotor.

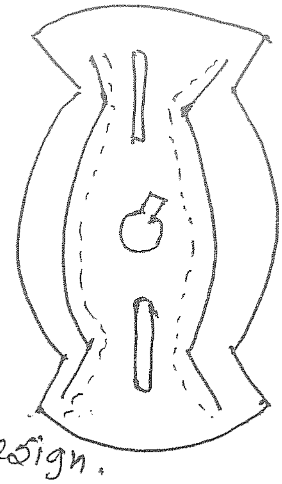
i) salient Pole rotor :-

Quadrature air gap is much large than the direct air gap. L_d/L_q ratio is small in the range of 2:3. This results with circulating flux in the pole faces of the rotor.



ii) Radially laminated Rotor :-

The flux barriers & the central hole of the lamination required for the shaft weaken the rotor structurally & thus makes a poor choice for high speed design.



iii) Axially laminated rotor :-

They are designed to have high saliency ratio, It offers very good performance in terms of torque capacity, pf and efficiency. By increasing Ld/Lq ratio, motor p.f & efficiency can be increased. Higher Ld/Lq ratio are obtained only in axial lamination rotor.

Synchronous speed is achieved as the salient poles lock in step with magnet poles of the rotating stator field & make it to run at the same speed as the rotating field.

Stator winding is similar to squirrel cage induction motor, as the synchronous reluctance motor is not self starting without the squirrel cage. During run up, it behaves as an induction motor but as it approaches synchronous speed.

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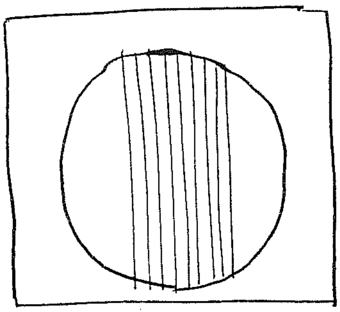
Types :-

Classification of synchronous reluctance motor according to the magnetization or lamination of the rotor.

i) Radial Type.

ii) Axial Type.

Axial Type motor :-



This motor is to laminate the rotor in the axial direction. By increasing the ratio L_d/L_q motor power factor and efficiency can be increased. Higher L_d/L_q ratios are obtained with axial-lamination rotors.

For two pole rotors, with axial lamination, the shaft should be made either two parts attac. axially to the rotor core or it may go through.

In this case, the rotor consists of alternating layers of ferromagnetic & non-magnetic steel.

If the thickness of the steel is chosen such that the pitch of the ferro magnetic rotor segment matched the slot pitch of the stator, then regardless of the angle of rotation of the rotor.

In reluctance motor, a reluctance torque is to be created on the rotor by the way of making the magnetic field induced in the rotor.

Radially Type motor

In this motor rotor is radially laminated or flux barrier type synchronous reluctance motor comprises a rotational shaft.

The rotor core is formed as a plurality of steel plates are laminated to one another, the steel plate having a shaft hole for inserting the rotational shaft,

A coupling hole is penetratingly formed between the adjacent two flux barrier groups & a coupling member inserted into the coupling hole & fixing the steel plate.

The fabrication process is facilitated with a shortened fabrication time, also a large coupling intensity is obtained.

It is having salient rotor shape & it is such that the quadrature air gap is much larger than the direct air gap.

This yields reactively small L_d/L_q ratios. The low L_d/L_d ratio are largely the result of circulating flux in the rotor pole faces.

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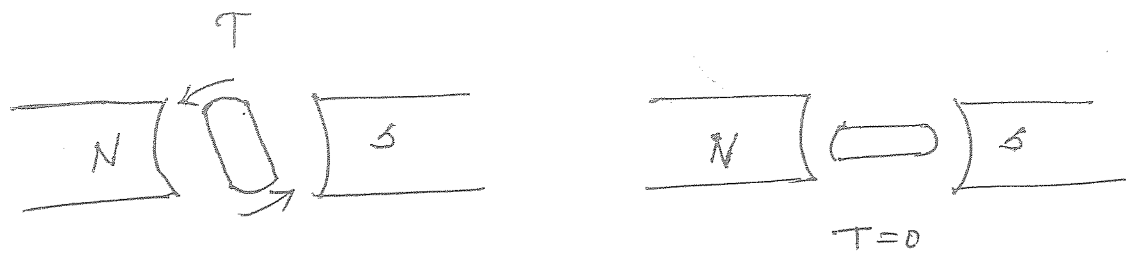
Operating principle of synchronous reluctance Motor (Variable reluctance motor)

It works on minimum reluctance principle when a piece of ferro magnetic material is located in a magnetic field, a force acts on the material, tending to bring it into the most dense portion of the field. The force tends to align the specimen of the material in such a way that reluctance of the magnetic path is minimum.

When a 3ϕ supply is given to the stator winding, the revolving magnetic field will exert reluctance torque on the unsymmetrical rotor tending to align the salient pole axis of the rotor.



Actually the motor starts as an induction motor & after it has reached its max. speed. as an induction motor, the reluctance torque pulls its rotor into step with the revolving.

The reluctance torque developed by this motor is given as,

$$T_e = 3\left(\frac{P}{2}\right)\left[\psi_s^2\left(\frac{L_{ds}-L_{qs}}{2L_{ds}L_{qs}}\right)\sin 2\delta\right]$$

where

$P \rightarrow$ No. of poles.

$\psi_s \rightarrow$ Stator flux linkages

$L_{ds} \rightarrow$ Direct axis inductance w.r. to synchronous rotating frame.

$L_{qs} \rightarrow$ quadrature axis inductance w.r. to synchronously rotating frame.

$\delta \rightarrow$ Torque angle.

Even though the rotor revolves synchronous it poles lag behind the stator poles by a certain angle known as torque angle. Reluctance torque increases with increase in torque angle.

reluctance motors are subjected to cogging, since the locked rotor torque varies with the rotor position, but the effect may be minimised by skewing the rotor bars.

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Voltage and Torque Equation

The basic voltage equation neglecting the effect of resistance is,

$$V = E - jI_{sd}X_{sd} - jI_{sq}X_{sq}$$

w.k.t

$$V\cos\delta = E + I_{sd}X_{sd}.$$

$$I_{sd} = \frac{V\cos\delta - E}{X_{sd}}$$

$$I_{sq}X_{sq} = V\sin\delta$$

$$I_{sq} = \frac{V\sin\delta}{X_{sq}}$$

$$I_s\cos\phi = I_{sq}\cos\delta - I_{sd}\sin\delta$$

$$I_s\cos\phi = \frac{E\sin\delta}{X_{sd}} + V\frac{(X_{sd} - X_{sq})}{2X_{sd}X_{sq}}.$$

$$P = 3VI_s\cos\phi$$

$$P_m = 3\left[\frac{VE}{X_{sd}}\sin\delta + V^2\frac{(X_{sd}-X_{sq})}{2X_{sd}X_{sq}}\sin 2\delta\right]$$

$$T = \frac{P_m}{\omega_s}$$

$$= \frac{3}{\omega_s}\left[\frac{VE}{X_{sd}}\sin\delta + \frac{V^2(X_{sd}-X_{sq})}{2X_{sd}X_{sq}}\sin 2\delta\right]$$

sub. $E=0$

$$T = \frac{3}{\omega_s}V^2\left[\frac{X_{sd}-X_{sq}}{2X_{sd}X_{sq}}\right]\sin 2\delta$$

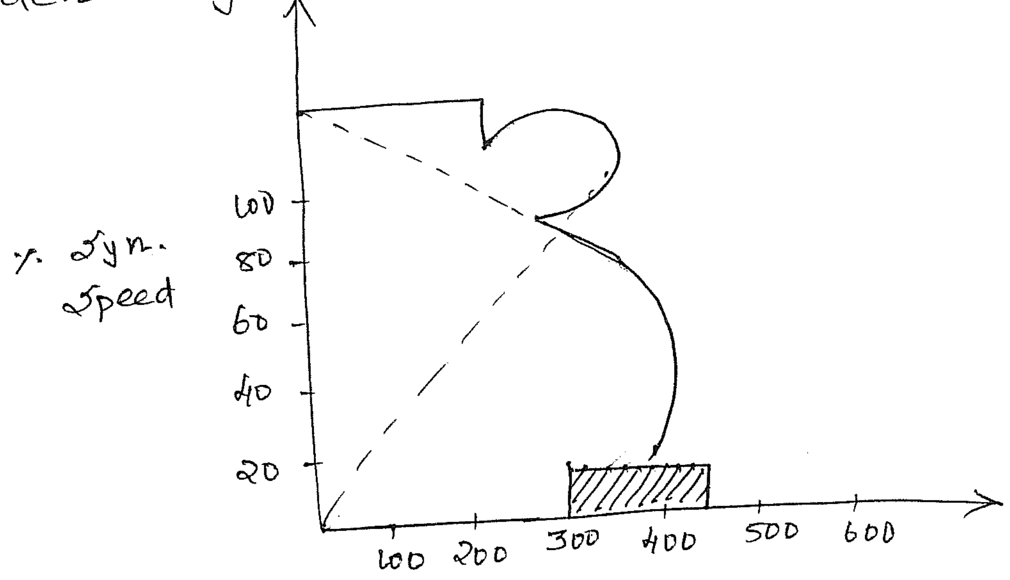
Torque-speed characteristics :-

In synchronous reluctance motor, the reluctance torque is developed by the tendency of a ferromagnetic material to align itself with a magnetic field.

On a fixed frequency ac supply, the synchronous reluctance motor is not self-starting, unless the rotor is fitted with a squirrel cage winding which permit starting by Induction motor action.

When the rotor speed approaches the synchronous speed, the reluctance torque is superimposed on the induction motor torque & as a result the rotor speed above & below its average value.

If the load torque & inertia are not excessive, the instantaneous rotor speed increases so as to reach synchronous speed.



The motor starts as an induction motor at any where from 300 to 400 % of its full load torque as a two phase motor.

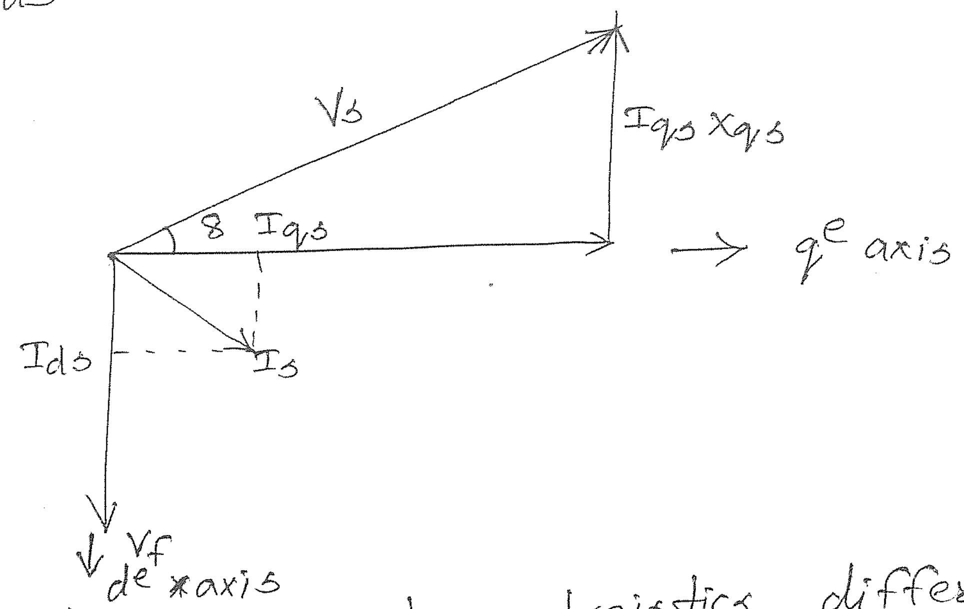
As it approaches the synchronous speed, the reluctance torque is sufficient to pull the rotor into synchronism with pulsating single phase field.

The motor operates at constant speed up a little over 200 % of its full load torque.

If it is loaded beyond the value of pull out torque, it will continue to operate as 1φ IM upto 500 % of its rated output.

Phasor Diagram:-

Figure shows the phasor diagram of synchronous reluctance motor.



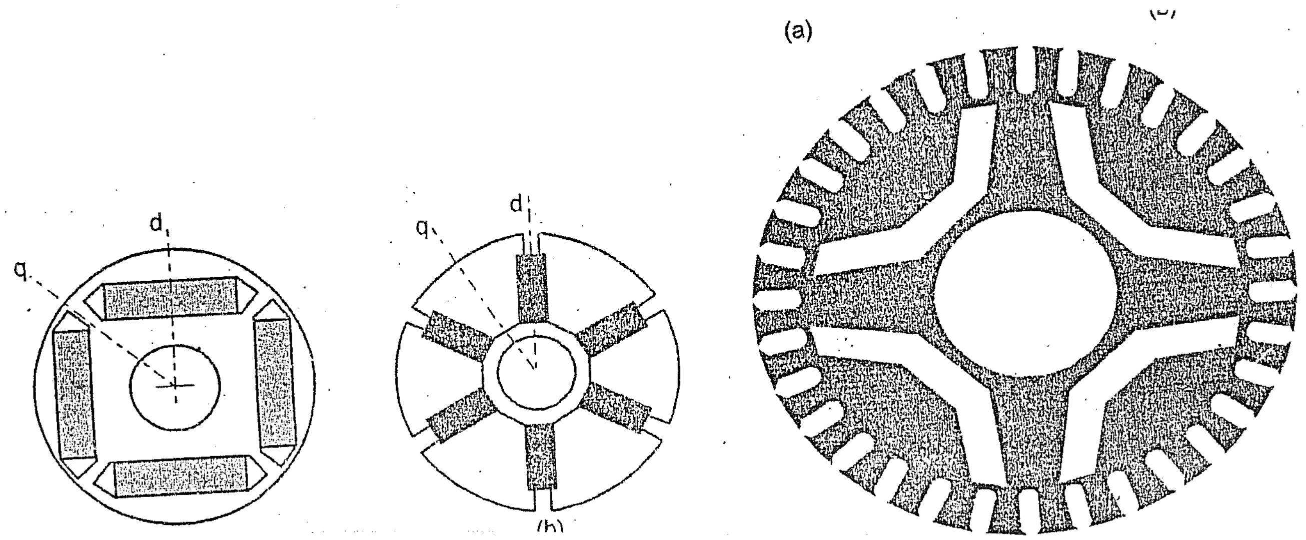
Salient pole machine characteristics differs from those of non- salient pole machine because of non uniform airgap reluctance in the d^e & q^e axis

In general for a two phase machine, we need to represent $d^s - q^s$ (stator) & $d^r - q^r$ rotor circuit & their variable in a synchronously rotating $d^e - q^e$ frame.

A special advantage of $d^e - q^e$ dynamic model of the machine is that all the sinusoidal variables in stationary frame appear as dc quantities in synchronous machine.

Hybrid Motor

A permanent magnet synchronous motor was derived from the conventional wound field synchronous motor. If a cage winding is included in the rotor, then the motor can start synchroniz. & run from A.C supply.



Properties of synchronous reluctance hybrid motor

i) It has combined reluctance & magnet alignment torque.

ii) It has field weakening capability.

iii) It has high inductance.

iv) It has high speed capability.

v) It has high temp. capability.

construction:-

This motor consists of stator & rotor. The ~~stat~~ stator construction is similar to the permanent magnet synchronous motor.

Figure shows the two configurations of interior magnet motors, although several others are used. Here, the airgap flux density on open-circuit is less than the flux density in the magnet. This design in therefore essentially underexcited and relies on the addition of a magnetizing component of armature current to produce the total airgap flux

This machine has considerable reluctance torque and field weakening capability, providing a constant power characteristics at high speed. It is a true Ac motor & cannot be operated as a square wave brushless motor.

Both of these torque components can be kept constant only with a fixed load angle, and this requires a rotating field of the type that is possible only with sine-distributed windings and sinusoidal phase currents on the stator.

The magnets are circumferentially magnetized and alternately poled so that two magnets communicate flux to each pole piece. The sum of the two magnet pole areas exceeds the pole area at the rotor surface, producing an open-circuit air gap flux-density greater than that in the magnet.

A nonmagnetic shaft or spacer is needed to prevent the magnets from being short circuited at their inner edges, and with this the permeance to q axis flux is very low. Therefore this machine has small reluctance torque.

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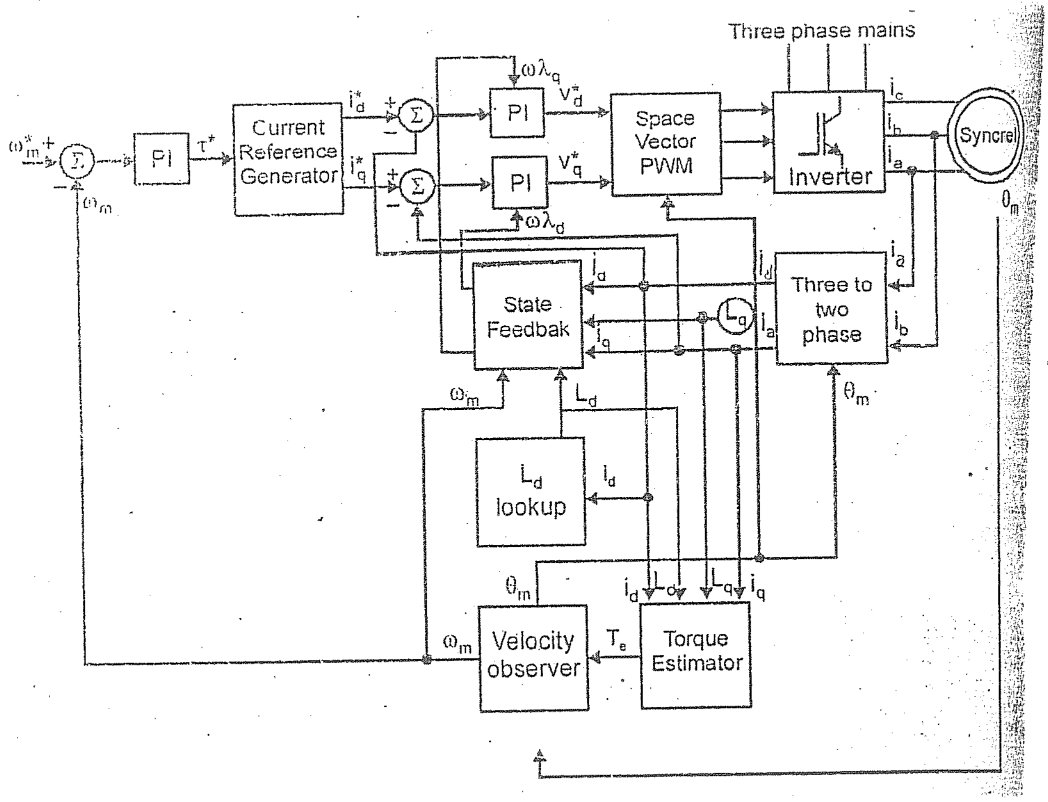
SYNREL Motors:

The basic structure of a variable speed drive system based on using the synrel. Many components of the drive are very similar to those found in an induction machine drive system.

One notable exception is the L_q lookup table block and the current reference generator

The L_d lookup stores the current Vs d-axis inductance table for the machines. there by allowing the inductance to be determined for various current level.



This table is also used to generate the incremental d-axis inductance. The inductence values generated from this table are used in the state feedback block & torque estimator.

The state feedback block effectively generates an offset voltage to the PWM generator so that the voltage it produces is at least enough to counter back emf.

The current reference generator takes the desired torque as an input & generates the required d & q axis currents at the output

The three to two phase block converters the currents from the 3ϕ stationary frame to a 2ϕ rotating frame.

The Synrel control algorithm is essential a simplified vector controller, and consequently the computational requirements are not High. This means that a Synrel controller can be implemented on a modest microprossor.

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