SNS COLLEGE OF ENGINEERING

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

19EE711 SOLAR AND WIND ENERGY

UNIT II-WIND GENERATOR TOPOLOGIES

Permanent Magnet Synchronous Generator:

Introduction:

Wind turbines run at inconveniently low speeds, typically 25-50rpm. A speed- increasing gear box is required to run induction machines and conventional Synchronous machines at 1500 rpm for operation with the utility network. Additional cost, weight, power loss, regular maintenance, and noise generation are some of the problems associated with the gear box required to increase the speed.

There are two methods by which the gear box can be avoided. If a standard Generator with number of poles say 4 is used , then a power electronic converter (Converter /inverter) has to be used which first converts the low frequency AC (which would be 1Hz with P = 4 and Ns = 30 RPM) from the generator to DC and then converts the DC to 50 Hz AC. Otherwise a Synchronous generator should have higher number of poles say around 240 such that with input synchronous speed of 25 RPM it produces 50 Hz electrical output which can be directly connected to the Utility Grid. But such large number of poles necessitate large diameter Generator since Synchronous machines cannot be built with pole pitches less than 150 mm. Consequently it's size and weight will become abnormally large and heavy and hence it is not practically possible to accommodate in the Nacelle. Therefore, low-speed, direct-coupled generators with low pitch requirement are required particularly for turbines with large diameters.

Permanent magnet (PM) excitation considerably brings down the pole pitch requirement, which can be less than 40 mm. This allows the rotor to be within an acceptable diameter, which makes the housing of the generator inside the Nacelle possible. Even then a Power converter or at least a smaller gear box (withsmaller ratio and hence smaller size and weight) are required.

Constructional features:

Several rotor configurations of Permanent Magnet Synchronous Machines have been developed. Some typical ones are illustrated here.

In the surface-type permanent magnet machine, high-energy, rare-earth magnets such as neodymium-iron-boron (Nd-Fe-B) are mounted on the rotor surface, as shown in Fig. 3.11.

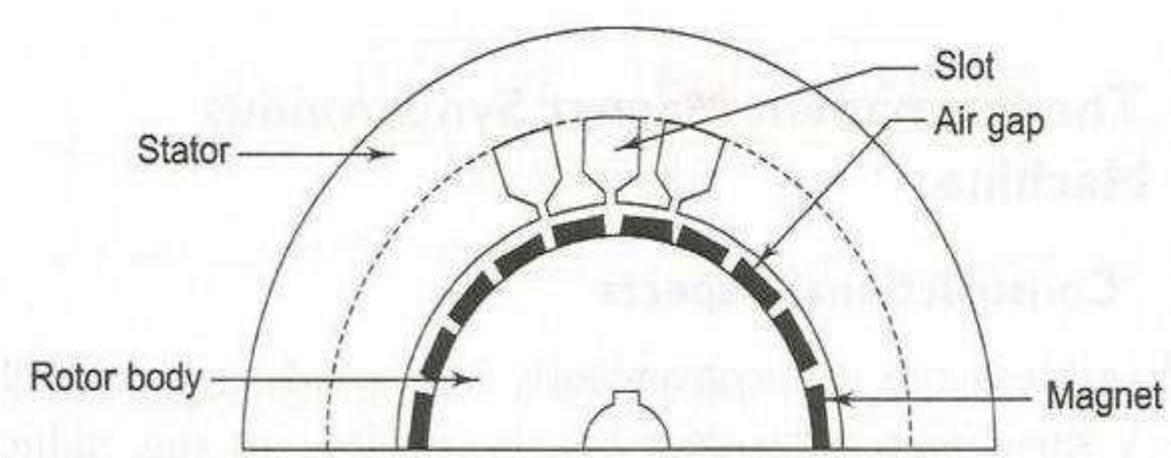

Figure - 7: Cross sectional view of a Surface mounted PM Machine

In an interior-type machine, as shown in Fig. 3.12, cheaper ferrite magnets are circumferentially oriented between flux-concentrating pole pieces.

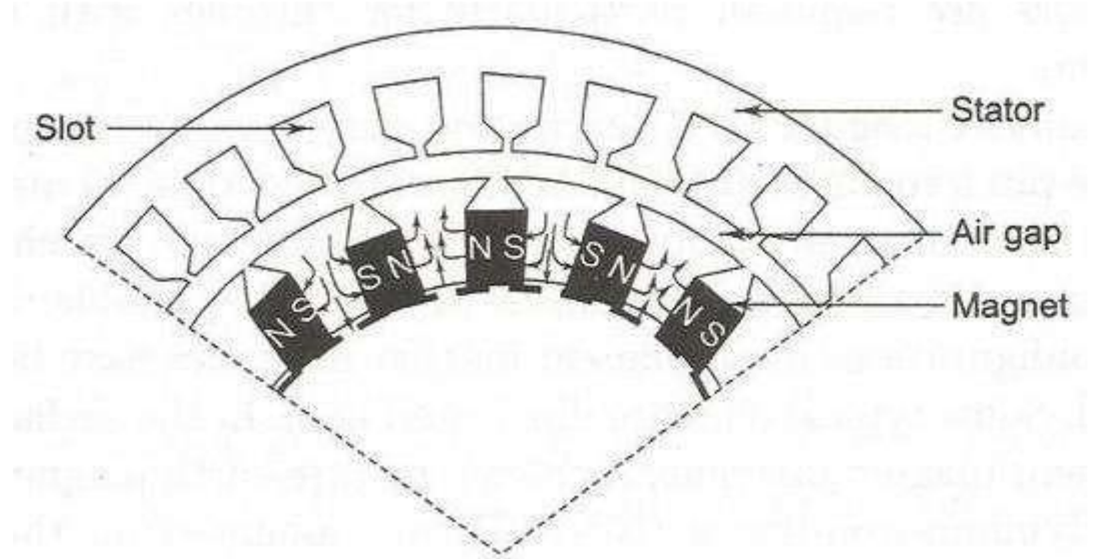

Figure - 8: Cross sectional View of an Interior type (Buried) PM Machine (Circumferential Magnet motor)

Properties: The surface-type machine has lower structural integrity and mechanical robustness. The surface type gives equal 'd' and 'q'-axis reactances while the latter (Interior type) has a somewhat greater q-axis reactance than the d-axis reactance. In per-unit terms, both the reactance values are small because of the large number of poles. This provides the PM machines high peak torque capability to resist higher-than-rated torque for short periods during wind gusts and repeated torque pulsations of up to 20% of the rated torque.

Steady-state Equations:

The generated EMF $\mathbf{E_g}$ of a permanent magnet generator can be expressed as:

$$E_g = K_E\,\omega$$

Where **ω** is the angular frequency of the generator (Rad/sec) and is related to the mechanical speed as $\boldsymbol{\omega = P\,\omega_r/2}$ (where $\boldsymbol{\omega_r}$ **=** Generator mechanical speed in Radians per second)
Assuming unity power factor and referring to the figure shown below in Fig. 3.10,

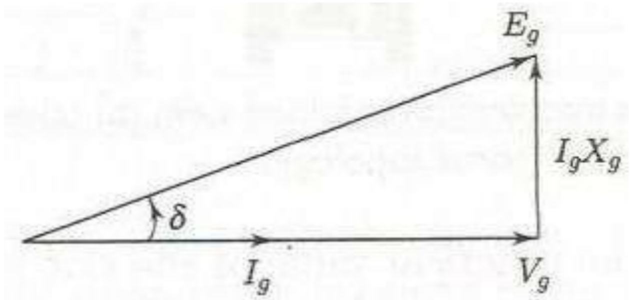

Figure - 9: The Phasor diagram of a PM Synchronous Generator

The relationship between the stator terminal voltage $\mathbf{V_g}$ and the current $\mathbf{I_g}$ is

$$E_g = V_g + j\, I_g\, X_S$$

The generated power can be expressed as

$$P_g = 3V_gI_g = 3(E_g\, V_g / X_S)\, \text{Sin}\, \delta \qquad (3.3)$$

From the phasor diagram shown above (Fig 3.13)

$$V_g = E_g\, \text{Cos}\, \delta \qquad (3.4)$$

Using Eqn (3.4) in equation (3.3), the power equation can be expressed as

$$P_g = (3\, E_g^2 / 2X_s)\, \text{Sin}2\delta$$

Using Eqn (3.106) in Eqn (3.110), the equation representing torque can beexpressed as

$$T_g = T_{max}\, \text{Sin}2\delta$$

Where $\mathbf{T_{max} = (3K_E^2 p/4L_s)}$

Operation of a Permanent Magnet Synchronous Generator in a variable-speed wind energy conversion scheme:

The basic wind energy conversion requirements of a variable-speed permanent magnet generator are almost the same as those of a wound-field synchronous generator. The power circuit topology is basically the same as that shown in Fig. 3.7.(Scheme pertaining to Synchronous Generator)The permanent magnet

generator dispenses with the need for external excitation. Therefore, the output voltage, under variable-speed operation, varies both in frequency and in magnitude. As a result, the dc-link voltage changes in an uncontrolled manner. The control, therefore, is realized via a dc/ac converter, i.e., an inverter, on the grid side as shown in the figure below.

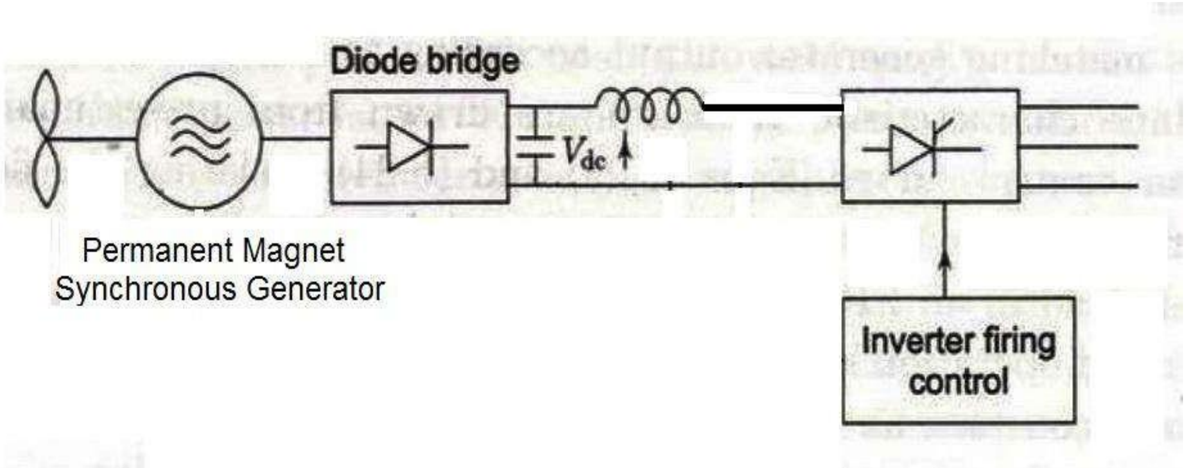

Figure - 10: Operation of a Permanent Magnet Synchronous Generator with aGrid side Inverter.