

3.3 Choice of specific loadings

Specific magnetic loading:

Following are the factors which influences the performance of the machine.

(i) Iron loss:

A high value of flux density in the air gap leads to higher value of flux in the iron parts of the machine which results in increased iron losses and reduced efficiency.

(ii) Voltage:

When the machine is designed for higher voltage space occupied by the insulation becomes more thus making the teeth smaller and hence higher flux density in teeth and core.

(iii) Transient short circuit current:

A high value of gap density results in decrease in leakage reactance and hence increased value of armature current under short circuit conditions.

(iv) Stability:

The maximum power output of a machine under steady state condition is indirectly proportional to synchronous reactance. If higher value of flux density is used it leads to smaller number of turns per phase in armature winding. This results in reduced value of leakage reactance and hence increased value of power and hence increased steady state stability.

(v) Parallel operation:

The satisfactory parallel operation of synchronous generators depends on the synchronizing power. Higher the synchronizing power higher will be the ability of the machine to operate in synchronism. The synchronizing power is inversely proportional to the synchronous reactance and hence the machines designed with higher value air gap flux density will have better ability to operate in parallel with other machines.

Specific Electric Loading:

Following are the some of the factors which influence the choice of specific electric loadings.

(i) Copper loss:

Higher the value of q larger will be the number of armature of conductors which results in higher copper loss. This will result in higher temperature rise and reduction in efficiency.

(ii) Voltage:

A higher value of q can be used for low voltage machines since the space required for the insulation will be smaller.

(iii) Synchronous reactance:

High value of q leads to higher value of leakage reactance and armature reaction and hence higher value of synchronous reactance. Such machines will have poor voltage regulation, lower value of current under short circuit condition and low value of steady state stability limit and small value of synchronizing power.

(iv) Stray load losses:

With increase of q stray load losses will increase. Values of specific magnetic and specific electric loading can be selected from Design Data Hand Book for salient and non-salient pole machines.

Separation of D and L:

Inner diameter and gross length of the stator can be calculated from D^2L product obtained from the output equation. To separate suitable relations are assumed between D and L depending upon the type of the generator. Salient pole machines: In case of salient pole machines either round or rectangular pole construction is employed. In these types of machines, the diameter of the machine will be quite larger than the axial length.

3.4 Selection of number of poles

As the armature current increases, cross sectional area of the conductor and hence the eddy current loss in the conductor increases. In order to reduce the eddy current loss in the conductor, cross-sectional area of the conductor must be made less or the current / path must be restricted.

For a normal design, current / parallel path should not be more than about 200A. However, often, under enhanced cooling conditions, a current / path of more than 200A is also being used. By selecting a suitable number of paths for the machine, current / path can be restricted and the number of poles for the machine can be decided. While selecting the number of poles, the following conditions must also be considered as far as possible.

In order to decide what number of poles (more or less) is to be used, let the different factors affecting the choice of number of poles be discussed based on the use of more number of poles.

- Frequency
- Weight of the iron used for the yoke
- Weight of iron used for the armature core (from the core loss point of view)
- Weight of overhang copper
- Armature reaction
- Overall diameter
- Length of the commutator
- Flash over
- Labour charges

Frequency

As the number of poles increases, frequency of the induced EMF $f = PN/120$ increases core loss in the armature increases and therefore efficiency of the machine decreases.

Weight of the iron used for the yoke

Since the flux carried by the yoke is approximately $\phi/2$ and the total flux $\phi_T = p\phi$ is a constant for a given machine, flux density in the yoke

$$B_y = \frac{\phi/2}{\text{cross sectional area of the yoke } A_y} = \frac{\phi_T}{2P A_y} \propto \frac{1}{P A_y}.$$

It is clear that A_y is $\propto 1/p$ as B_y is also almost constant for a given iron. Thus, as the number of poles increases, A_y and hence the weight of iron used for the yoke reduces.

Weight of overhang copper:

For a given active length of the coil, overhang \propto pole pitch goes on reducing as the number of poles increases. As the overhang length reduces, the weight of the inactive copper used at the overhang also reduces.

Armature reaction

Since the flux produced by the armature and armature ampere turns AT_a/pole is proportional to $1/P$, Φ_a reduces as the number of poles increases. This in turn reduces the effect of armature reaction.

Overall diameter

When the number of poles is less, AT_a / pole and hence the flux, produced by the armature is more. This reduces the useful flux in the air gap. In order to maintain a constant value of air gap flux, flux produced by the field or the field ampere-turns must be increased. This calls for more field coil turns and size of the coil defined by the depth of the coil d_f and height of the coil h_f increases. In order that the temperature rise of the coil is not more, depth of the field coil is generally restricted. Therefore, height of the field coil increases as the size of the field coil or the number of turns of the coil increases. As the pole height, is proportional to the field coil height, height of the pole and hence the overall diameter of the machine increases with the increase in height of the field coil. Obviously as the number of poles increases, height of the pole and hence the overall diameter of the machine decreases.

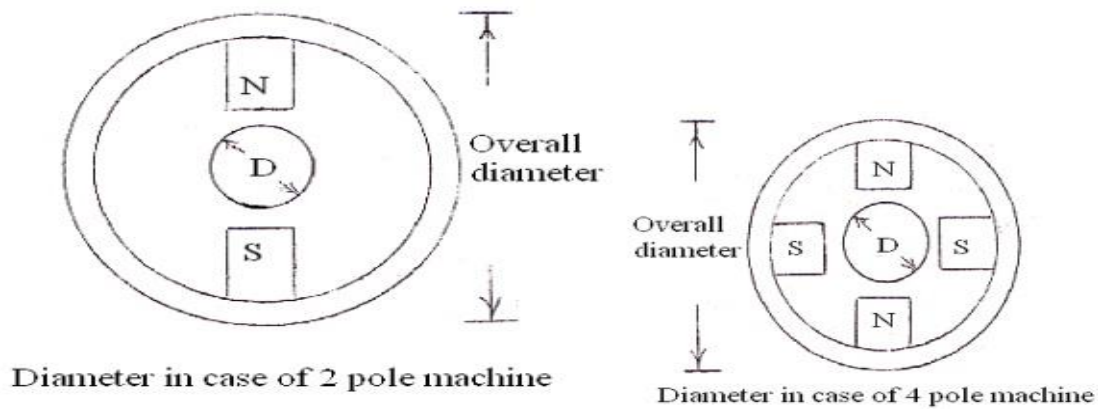


Figure 3.4.1 Decrease in machine dimensions increase the number of poles

[Source: "A Course in Electrical Machine Design" by A.K.Sawhney, page-9.19]

Length of the commutator

Since each brush arm collects the current from every two parallel paths, current / brush arm

$$= 2 I_a / A \text{ and the cross sectional area of the brush / arm}$$

$$A_b = 2I_a / A\delta_b = 2I_a / P\delta_b$$

$$\propto 1 / P$$

reduces as the number of poles increases. As $A_b = t_b w_b n_b$ and t_b is generally held constant from the commutation point of view, $w_b n_b$

reduces as A_b reduces. Hence the length of the commutator

$$L_c = (w_b n_b + \text{clearances}) \text{ reduces as } A_b \text{ reduces or the number of poles increases.}$$

w_b – width of the brush,

t_b – thickness of the brush,

n_b – number of brushes per spindle

Flash over

As the number of poles increases, voltage between the segments increases. Because of the increased value of E_b and carbon dust collected in the space where the mica is undercut, chances of arcing between commutator segments increases. The arc between the segments in turn may bridge the positive and negative brushes leading to a dead short circuit of the armature or flash over.

$$E_b = \frac{\text{voltage between positive and negative brushes}}{\text{number of segments / pole}}$$

Labour charges

As the number of poles increases cost of labor increases as more number of poles are to be assembled, more field coils are to be wound, placed on to the pole, insulate, interconnect etc. It is clear that, when the number of poles is more, weight of iron used for yoke and armature core, weight of inactive copper, overall diameter, length of commutator and effect of armature reaction reduces. On the other hand, efficiency reduces chances of flash over increases and cost of machine increases. Since the advantages outnumber the disadvantages, more number of poles is preferable.

Electrical Machine Design

