1. Determine suitable no. of slots conductor for stator winding of 3φ, 3300V, 50Hz, 3000rpm alternator, diameter in 2.3m, axial length of core is 0.35m, the maximum flux density in air gap 0.9 wb/m². Assume sinusoidal flux distribution use single layer winding and star connected for stator

Given data:-

$V = 3300$ $\quad$ $B_{av} = 0.9\,wb/m^2$

$f = 50Hz$ $\quad$ $N = 300rpm$

$L = 0.35m$

Solution:-

$$n_s = \frac{N}{60} = \frac{300}{60}$$

$$n_s = \frac{2f}{P} \qquad P = 20$$

$$B_{av} = \left(\frac{2}{\pi}\right) \times B_{av}$$

$$B_{av} = \frac{P\phi}{\pi DL}$$

$$\phi = \frac{B_{av} \times \pi DL}{P}$$

$$= \frac{0.574 \times \pi \times 2.3 \times 0.35}{20}$$

$$\phi = 0.07245 Wb.$$

For star connection,

$$E_{ph} = \frac{E_L}{\sqrt{3}} = \frac{3300}{\sqrt{3}} = 1905V$$

$$T_{ph} = \frac{E_{ph}}{4.44 f \phi K_{ws} n_s \times 10^{-3}}$$

$$T_{ph} = 124$$

For 3.3KV machine slot pitch = 40mm

$$q = \frac{\pi D}{3 P y_s}$$

$$= \frac{\pi \times 2.3}{3 \times 20 \times 40 \times 10^{-3}}$$

$$q = 3$$

For single layer winding,

$$S = 3pq = 3 \times 20 \times 30 = 1800$$

$$\text{Star conductor} = 6 T_{ph}$$

$$= 6 \times 124$$

$$= 744 \qquad \frac{744}{1800} = 0.413.$$

$$T_{ph} = \frac{744 \times 0.413}{26} = 123$$

2. Find the main dimension of 2500KVA, 187.5rpm 50HZ, 3φ, 3KV salient Pole synchronous generator is to be vertical water wheel type. The specific magnetic loading is 0.6 wb/m². the Specific electric Loading is 34000 amp/cond/m. Use circular Poles with the ratio of core length to pole pitch is 0.65 Specify the type of pole construction used if the runaway speed is about 2 times the normal speed.

Given data:-

$Q = 2500KVA$ $ac = 34,000$ $\frac{L}{\tau} = 0.65$

$F = 50HZ$ $N = 187.5rpm$

$Q = 3KV$ $B_{av} = 0.6 wb/m^2$

Solution:-

$$n_s = \frac{N}{60} = \frac{187.5}{60} = 3.125 rps$$

$$P = \frac{2f}{n_s} = \frac{2 \times 50}{3.125} = 32$$

$$Q = 11 B_{av} ac K_{ws} \times 10^{-3} D^2 L n_s$$

$$2500 = 11 \times 0.6 \times 0.955 \times 10^{-3} D^2 L \times 3.125$$

$$D^2 L = 3.733$$

$$\frac{L}{\tau} = 0.65$$

$$L = 0.65$$

$$L = 0.65\left(\frac{\pi D}{p}\right)$$

$$L = 0.0638\,D$$

$$D^2(0.0638D) = 3.733$$

$$D = 3.88\,m$$

$$L = 0.2477\,m$$

$$V_a = \pi D n_s$$

$$= \pi \times 3.88 \times 3.125$$

$$V_a = 38.07\,m/s$$

peripheral speed at run away condition $\}$ $= 2 \times 38.07$

$= 76.1$

This type of construction is dove tail construction.

3. Determine the main dimensions of 75,000 KVA, 13.8KV, 50HZ, 62.5rpm, 3Φ star connected alternator also find the no. of. slots conductor per slot, peripheral speed is 40m/s, $B_{av} = 0.65\,wb/m^2$ $ac = 40,000$, $\delta = 4A/mm^2$.

Given Data :-

$Q = 75,000$ $\qquad$ $\delta = 4\,A/mm^2$

$V = 13.8\,KV$ $\qquad$ $N = 62.5$

$F = 50\,HZ$

$B_{av} = 0.65$

As the terminal voltage is 13.8KV, a slot pitch of about 55mm should be used.

Slots per pole per phase

$$q = \frac{\pi D}{y_s \times 3p} = \frac{\pi \times 12.2 \times 100}{55 \times 3 \times 96}$$

$$= 2.42.$$

4. Explain the design of field winding of synchronous machine (or) Alternator.

1. In order to design the Field winding, the exciter voltage must be known. The exciter voltage varies between 50V to 400V. This is usually specified by the customer. However, a voltage of 125V is used for large size machines while an exciter voltage of 250V is used for large size machines.

Let ve be the exciter voltage.

Voltage across Each Field coil,

$$E_f = \frac{(0.8 \text{ to } 0.85) v_e}{p}$$

2. We know hpl the height of the pole. From this we subtract the height of shoe h_1 and also the thickness of pool, flanges etc.

$$h_f = h_{pl} - h_1 - \text{Space taken by spool, flanges, etc.}$$

Solution :-

$$n_s = \frac{N}{60} = 1.0416$$

$$n_s = \frac{2f}{P} \Rightarrow P = 96$$

$$Q = 11\, B_{av}\, ac\, K_{ws} \times 10^{-3}\, D^2 L n_s$$

$$D^2 L n_s = \frac{75000}{11 \times 0.65 \times 40000 \times 0.995 \times 10^{-3}}$$

$$D^2 L = 263.61$$

$$V_a = \pi D n_s$$

$$40 = \pi \times D \times 1.0416$$

$$D = 12.23\,m$$

$$L = 1.76133\,m$$

Pole pitch,

$$\tau = \pi \times \frac{12.2}{96} = 0.4\,m$$

∴ Flux per pole $\phi = B_{av} \tau L = 0.65 \times 0.4 \times 1.77$

$$= 0.46\,wb$$

Voltage per phase $E_{ph} = \frac{13800}{\sqrt{3}} = 7960V$

with one circuit per phase,

Turns per phase $T_{ph} = \frac{E_{ph}}{4.44 f \phi K_w} = \frac{7960}{4.44 \times 50 \times 0.46 \times 0.955}$

$$= 81.8 \simeq 82$$

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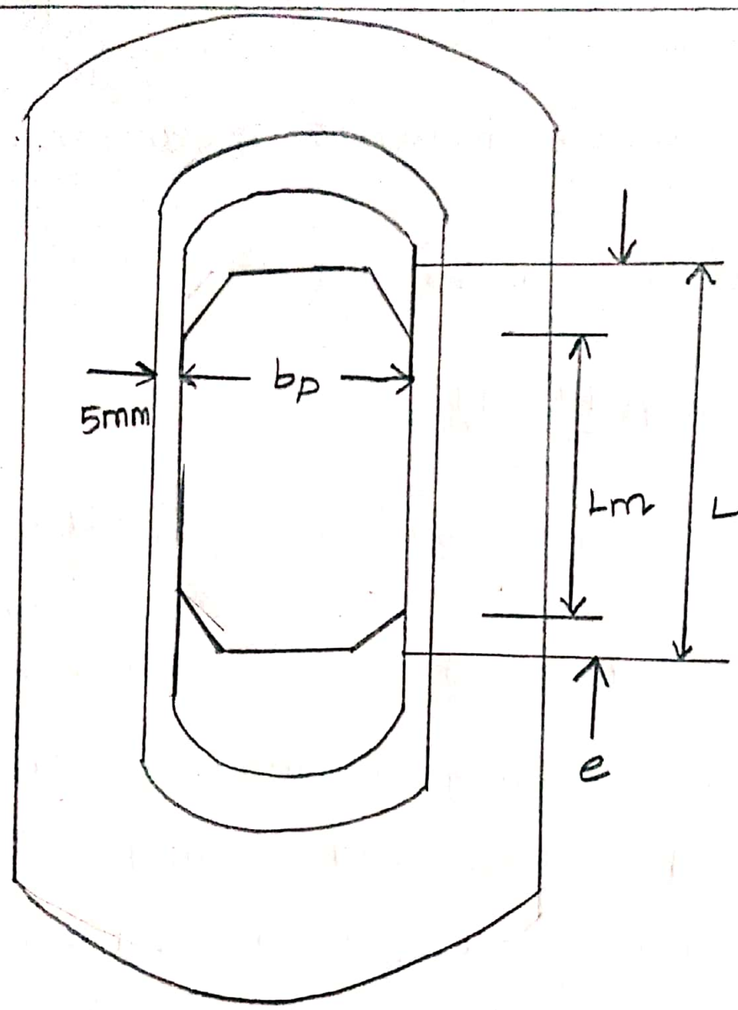

3. Now a suitable depth of winding d_f is assumed and the mean length of turn is evaluated.

Pole pitch mm	winding depth mm
0.1	25
0.2	35
0.4	45

4. Voltage across each Field coil,

E_f = Field current × resistance of each Field coil at 75°c

$$= I_f R_f = \frac{T_f P L_{mtf}}{a_f}$$

where

T_f = number of turns in each field coil

$I_f T_f$ = Field mmf per pole at full load = AT_{fl}

$$E_f = AT_{fl} \frac{PL_{mtf}}{a_f}$$

Area of field conductors $a_f = \frac{A_{fl} PL_{mtf}}{E_f}$

5. Now the value of the field current can be calulated by assuming a suitable value of current density in the field conductors.

current density in the field conductors δ_f is 3 to 4 A/mm^2

Field current I_f = current density × Area of conductors

$$I_f = \delta_f a_f$$

6. No. of. field turns $T_f = AT_{fl} / I_f$

7. we know the winding space and thus we can easily find out whether it is possible to accommodate the field turns (or) not.

8. The resistance of the winding is calculated at 75°C

$$R_f = \frac{T_f PL_{mtf}}{a_f}$$

copper loss in each Field coil at 75°C

$$Q_f = I_f^2 R_f = I_f^2 T_f \frac{(PLmtf)}{a_f}$$

Dissipating surface of the coil is

$$S = 2Lmt(h_f + d_f)$$

cooling coefficient to rotating Field coils $C_f = \frac{0.08 \text{ to } 0.12}{1+0.1 V_a}$

temperature rise $\theta = Q_f \, C_f / S$

9. The Final check applied to note the clearance between adjacent Field coils From the pole drawing. The minimum clearance between them should be 15mm.

A 1250KVA, 3φ, 6600V, salient Pole alternator has the Following data :- Air-gap diameter = 1.6m, length of core = 0.45m, no.of.poles = 20, Armature Ampere conductors per meme = 28000, ratio of pole arc to pole pitch = 0.68, Stator slot pitch = 28mm, current density in damper bars 3 A/mm². Design a suitable damper winding for the machine.

Given data :-

$Q = 1250KVA$

$P = 20$

3ϕ

$E_L = 6600V$

$b/\tau = 0.68$

$ac = 28000 \, ac/m$

$y_{ss} = 28mm$

$D = 1.6m$

salient Pole alternator

$L = 0.45m$

$\delta_d = 3A/mm^2$

To Find :- Ad, Nd, ad, dd, Ld

Solution :- Total area of damper bars per pole

$$A_d = \frac{0.2 ac \tau}{\delta_d} \Rightarrow \tau = \frac{\pi D}{P} = \frac{\pi \times 1.6}{20} = 0.251\,m$$

$$A_d = \frac{0.2 \times 28000 \times 0.251}{3} = 468.5\,mm^2$$

Number of bars per pole

$$N_d = \frac{\text{Pole arc } (b)}{0.8 \times \text{stator slot pitch}}$$

$$N_d = \frac{0.170\,m}{0.8 \times 28 \times 10^{-3}} = 7.58 \simeq 8$$

$b/\tau = 0.68$

Pole arc, $b = 0.68 \times \tau$

$b = 0.68 \times 0.251$

$b = 0.170\,m$

Area of Each bar :-

$$a_d = \frac{\text{total area}}{\text{Number of bars}}$$

$$a_d = \frac{A_d}{N_d} = \frac{468.5}{8}$$

$$a_d = 58.56 \simeq 59\,mm^2$$

Diameter of each bar

$$d_d = \sqrt{\frac{4 a_d}{\pi}} \Rightarrow d_d = \sqrt{\frac{4 \times 59}{\pi}} \quad \left[\because a_d = \frac{\pi}{4} d_d^2\right]$$

$$= 8.667 \simeq 8.7\,mm$$

Length of each bar :-

$$L_d = 1.1 \times L$$

$$= 1.1 \times 0.45$$

$$L_d = 0.5\,m.$$

1. For a 250 KVA, 1100V, 12 Poles, 500 rpm, 3ϕ alternator. Determine airgap diameter, core length, no. of. Stator conductor, no. of. Stator slots and cross Section of Stator conductors Assume Average gap density as 0.6 wb/m², Specific electric loading of 30,000 Amp condr/m and L/τ = 0.85

Given data :-

3ϕ alternator $Q = 250KVA$

$P = 12$, $N = 500 rpm$

$ac = 30000$ amp condr/m $L/\tau = 0.85$

$E = 1100V$.

$B_{av} = 0.6 wb/m^2$

To Find :-

D, L, Z_s, S_s, a_s

Solution :-

$$Q = C_o D^2 L n_s \Rightarrow D^2 L = \frac{Q}{C_o n_s}$$

$$C_o = 11\ B_{av}\, ac \times 10^{-3} \times K_{ws}$$

$$= 11 \times 0.6 \times 30000 \times 10^{-3} \times 0.955$$

$$C_o = 189\ KVA/m^3 - rps$$

$$D^2 L = \frac{250}{189 \times n_s}$$

$$n_s = \frac{N}{60} = \frac{500}{60} = 8.333\ rps$$

$$D^2L = \frac{250}{189 \times n_s}$$

$$D^2L = \frac{250}{189 \times n_s}$$

$$D^2L = \frac{250}{189 \times 8.333}$$

$$D^2L = 0.1587 m^3$$

Given that

$$\frac{L}{\tau} = 0.85$$

$$L = 0.85\tau$$

$$L = 0.85\left(\frac{\pi D}{P}\right)$$

$$L = 0.85\left(\frac{\pi D}{12}\right)$$

$$L = 0.222D$$

Sub (2) in (1)

$$D^2(0.222D) = 0.1587$$

$$D = 0.894m.$$

Subs (3) in (2)

$$L = 0.222 \times 0.894$$

$$L = 0.198m.$$

Stator conductor,

$$Z_s = 6T_{ph}$$

$$T_{ph} = \frac{E_{ph}}{4.44 f \phi K_{ws}}$$

$$T_{ph} = \frac{1100/\sqrt{3}}{4.44 \times 50 \times \phi \times 0.955}$$

$$\phi = \frac{B_{av} \pi D L}{P} = \frac{0.6 \times \pi \times 0.894 \times 0.198}{12.}$$

$$\phi = 0.028 \text{ wb}$$

$$T_{ph} = \frac{1100/\sqrt{3}}{4.44 \times 50 \times \phi \times 0.955}$$

$$= \frac{1100/\sqrt{3}}{4.44 \times 50 \times 0.028 \times 0.955}$$

$$T_{ph} = 106$$

Total armature conductors, $= 6T_{ph}$

$= 6 \times 106$

$= 636$

Stator slots

S_s = No. of. phases × No. of. poles × q

$q = 2$, $S_s = 3 \times 12 \times 2 = 72$

$q = 3$, $S_s = 3 \times 12 \times 3 = 108$

$q = 4$, $S_s = 3 \times 12 \times 4 = 144$

$q = 5, \; S_s = 3 \times 12 \times 5 = 180$

Taking $S_s = 108$

$$Y_{ss} = \frac{\pi D}{S_s} = \frac{\pi \times 0.894}{108} = 26mm$$

$Y_{ss} < 60mm \quad \therefore \; S_s = 108$

$$I_{ph} = \frac{KVA}{3E_{ph} \times 10^{-3}} = \frac{250}{3\left(\frac{1100}{\sqrt{3}}\right) \times 10^{-3}}$$

$$I_{ph} = 131.21A$$

Area of armature conductor,

$$a_s = \frac{I_{ph}}{\delta} = \frac{131.21}{3.5}$$

Choosing $\delta = 3.5 \; A/mm^2$

$\therefore \; a_s = 37.49 \, mm^2$

1. ## Choice of Specific Magnetic Loading :-

The choice of specific Magnetic loading depends on the Following Factors:-

1. Iron Loss
2. Voltage
3. Transient short circuit current
4. Stability
5. Parallel operation.

Iron Loss :-

When specific magnetic Loading is Higher, the amount of flux becomes more which results increase in Ironloss. As Ironloss Increases, which will results in rise in temperature.

Voltage :-

If Voltage rating is high then space used for Insulation becomes greater and teeth space is small.

Transient short circuit current :-

A High value of Bav results in decrease in the leakage reactance Xse of the machine which leads to Increase in the Initial value of armature current Under short circuit condition. therefore, Bav should be a Low value.

Stability :-

At Steady State, the maximum power, $P_{max} = \frac{EV}{X_s}$

If the value of synchronous reactance is low then Power delivered by the machine Increases, which Improves the stability. To make X_s Low, Higher value of Bav is selected.

Parallel operation :-

Parallel operation is depends on the synchronizing Power. Higher the synchronizing Power, the Higher is the capability of the system to keep the machines in synchronism, Synchronizing Power in Inversely Proportional to Xs.

For Salient Pole, Bav = 0.52 to 0.65 wb/m²

For turbo- Alternator, Bav = 0.54 to 0.65 wb/m²

Choice of specific Electric Loading (ac) :-

The choice of specific electric Loadings depends on the Following Factors.

1. voltage
2. copper loss and temperature rise.
3. Stability
4. stray load loss.

Voltage rating :-

For low voltage machine the space required For Insulation is small. So Higher values of ac is Preferred.

Copper-loss and temperature rise :-

with Higher value of ac, the current per conductor Increases, so copper-loss become more, As loss is more temperature Increases. so ac value should be low.

Stability :-

Higher value of ac leads to Higher value of X_s which causes decreases in synchronous power, therefore stability decreases. Therefore, low value of ac is preferred.

Stray Load Loss :-

The stray Load Loss Increase, with Increase in ac.

For salient pole, ac = 20,000 to 40,000 A/m

For turbo-Alternator, ac = 50,000 to 75,000 A/m.