Example **15.8. A 3-phase, 50 Hz, 20** pole salient **pole** alternator **with star-connected** stator **winding** has **180** slots on the stator. **Each slot consists of 8** conductors. **The flux per pole is 25 mWb and is** sinusoidally **distributed. The** coils **are full-pitched. Calculate (i) the speed of** the alternator **(ii) winding factor (iii) generated emf per phase and (iv)** line voltage.

Solution:

Flux per **pole, p = 25 mWb = 0.025 Wb**

Frequency, f = 50 Hz

Number of armature conductors, Z = 180 x 8 = 1,440

Number of armature conductors **per** phase $= \frac{1,440}{3} = 480$

Number of turns per **phase**, T $= \frac{480}{2} = 240$

Number **of** poles, **P** = 20

(i) **Speed,** N $= \frac{120 f}{P}$ $\frac{120 \times 50}{}$ **300 rpm Ans.**

20

180

= **9**

20

(ii) Number of slots per **pole**, n =

Number of **slots** per pole per phase**,**

m =

n

Number **of phases**

Angular displacement **between** the slots,

11

9

3

180°

180°

B

=

= 20° (elec.)

n

9

mB

Sin

3 × 20° Sin

Distribution factor, **K**

2

2

Sin 30°

= *d*

= 0.96

B

20°

3 sin 10°

msin

3 sin

2

2

• **Coils** are full-pitched

Pitch factor,

Kp

(ii) Winding factor**, Kw**

=

=

K1 K1 = 0.96 × 1 = 0.96 **Ans**.

K&K P

(iii) Generated emf per phase

= **4.44** K, **K,**

d

P

fT volts

= **4.44** × 0.96 **×** 1 × **0.025 × 50 × 240**

= 1.280 V **Ans**.

(iv) Line voltage, VL

√3 × 1,280 = **2,215 V**

Ans.

Example 15.19. A 3-phase star-connected alternator is rated at 1,600 kVA, 13.5 kV. The per phase armature effective resistance and synchronous reactance are 1.5 and 30 respectively. Calculate voltage regulation for a load of 1.280 MW at power factors of (i) 0.8 leading *(ii)* unity and *(iii)* 0.8 lagging.

[U.P. ***Technical Univ****. Electromechanical Energy Conversion-II, 2005-06]*

Solution: Load, P = 1.28 MW

Phase voltage, Vp

$$\frac{13.5 \times 1{,}000}{\sqrt{\sqrt{3}}}$$

= 7,794 V

Effective resistance per phase, **Re**

Synchronous reactance per phase, Xs **(i) At power factor 0.8 leading.**

Load current, I=

$$\frac{\text{Load in MW} \times 10^6 \sqrt{3}}{V_1 \cos \&}$$

Power factor, cos \$ = 0.8

= **1.5** Ω

= 30 Q

$$\frac{1.28 \times 10^6 \sqrt{3} \times 13.5 \times}{10^3 \times 0.8}$$

x

= 68.4 A

Sin = $\sqrt{1 - 0.8^2} = - 0.6$

minus sign **for** leading pf

Open-circuit voltage per **phase,**

EOP

=

$$\sqrt{(V_p \cos \& + IR_a)^2 + (V_p \sin \& + IX_s)^2}$$

$$\sqrt{(7{,}794 \times 0.8 + \mathbf{68.4} \times 1.5)^2 + [7{,}794 \times (-0.6) + 68.4 \times 30]^2}$$

= **6,860** V

Percentage regulation

EOP-VP

Vp

6,860 - 7,794

× 100 =

x 100 = - - 11.98 % **Ans**.

7,794

(ii) At unity **power factor**

1.28 × 106

Load current, **I** =

√3x

Cos

√3 x 13.5 × 103 × 1.0

x

= 1.0 **and sin = 0**

Open-circuit voltage **per** phase,

=

= 54.74 **A**

'OP (7,794 × 1.0 + 54.74 × 1.5)2 + (7,794 ×0 +54.74 × 30)2

=

(7,794 +82.11)2 + (0+1,642.2)2 = 8,045.5 V

Percentage **regulation**

=

8,045.5 - 7,794

× **100** = 3.227 % **Ans**.

7,794

***(iii)* At power factor 0.8 lagging**

Load current, I = **68.4 A**, **same as in** case (i)

Cos = 0.8 and sin = 0.6

Open-circuit **voltage** per phase,

EOP

=

(7,794 × 0.8 + 68.4 × 1.5)2 + (7,794 × 0.6 + 68.4 × 30)2

= 9,243 V

Percentage **regulation =**

9,243-7,794

7,794

× 100 = 18.6 % **Ans**.

Example 15.28. A 2000 kVA, 11 kV, 3-phase star-connected **alternator** has a **resistance of 0.3 ohm and reactance of 5 ohms per phase**. **It delivers full-load**

current at a **pf of 0.8 lagging** and normal **rated voltage. Compute the terminal voltage for** the same excitation **and load current** at a **0.8 pf leading**.

[*U.P.S.C. I.E.S. Electrical* Engineering, *2000*; U.P. Technical Univ. *Electromechanical* Energy *Conversion*, 2006-07]

Solution: Rated voltage per phase, V =

$$\frac{11 \times 1{,}000}{\sqrt{3}} = 6{,}350.85 \text{ V}$$

Full-load current,

$$I = \frac{\textbf{Rated } \text{kVA} \times 1{,}000}{\sqrt{3} \times V_L}$$

$$= \frac{2{,}000 \times 1{,}000}{\sqrt{3} \times 11{,}000} = 104.97 \text{ A}$$

E2 =

√(x

Power factor, cos **= 0.8** (lagging) and **sin &** = 0.6

Open-circuit voltage per phase,

(V cos **&** + IR)2 + (V sin

$ **+** IX§)2

لعا

al

(6,350.85 **×** 0.8 + 104.97 ×

0.3)2

sy

= 6,703 V

+(**6,350.85** × 0.6 +104.97 x

5)2

0..

x

When supplying same load current **at 0.8** pf (leading)

for the same

excitation

Eo

=

or **6,703**

=

$$(V \cos o + IR_,)^2 + (V \sin \$ + IX \S)^2$$

$$\sqrt{(Vx0.8+104.97\times0.3)^2 + [V\times(-0.6)+104.97\times5]^2}$$

or V = 6,978 V

Terminal **voltage** (line-to-line)

=

$$\sqrt{3}\times6,978 = 12,086 \text{ V}$$

or

12.086 kV Ans.

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