1. A 220 V 50 Hz 6 pole star connected alternator has a resistance of 0.06 ohm per phase. The OC SC and ZPF data are :

I_f	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.8	2.2	2.6	3.0	3.4
E_f	29	58	87	116	146	172	194	232	261.5	284	300	310
I_{sc}	6.6	13.2	20.0	26.5	32.4	40.0	46.3	59.0	--	--	--	--
V_t at zpf	--	--	--	--	--	0	29.0	88.0	140.0	177.0	208.0	230.0

Find the regulation for full load of 40 A at pf. at 0.8 lagging by (a) emf method (b) mmf method (c) z.p.f. method; (d) ASA method; (e) saturated synchronous reactance method.

Sol: Rates terminal voltage = $V_t = \frac{220}{\sqrt{3}} = 127\ V$

Per phase voltage of OCC and ZPFC are ;

I_f	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.8	2.2	2.6	3.0	3.4
E_f/ph	16.73	33.5	50.2	67.0	84.3	99.3	112.	134	151	164	173.2	179.0
I_{sc}	6.6	13.2	20.0	26.5	32.4	40.0	46.3	59.0	--	--	--	--
V_t/ph at zpf	--	--	--	--	--	0	16.73	50.2	80.8	102	120	132.7

(a) EmF Method:

I_f	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.8	2.2	2.6	3.0	3.4
E_f/ph	16.73	33.5	50.2	67.0	84.3	99.3	112.	134	151	164	173.2	179.0
I_{sc}	6.6	13.2	20.0	26.5	32.4	40.0	46.3	59.0	--	--	--	--
Z_s	2.535	2.535	2.51	2.53	2.51	2.48	2.42	2.27	--	--	--	--
X_s	2.53	2.53	2.52	2.53	2.51	2.48	2.42	2.27	--	--	--	--

So, X_s = 2.27 ohm

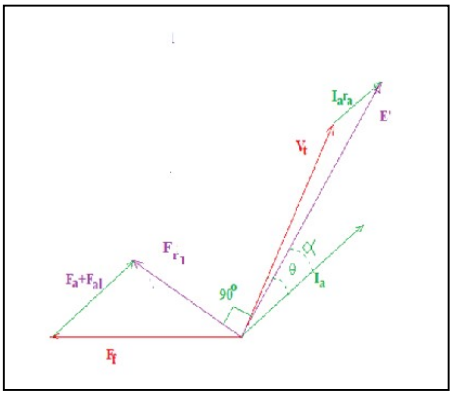
$$\bar{V}_t = 127 + j0.0$$
$$\bar{I}_a = 40(0.8 - j0.6) = 32 - j24$$
$$\overline{E_f} = \bar{V}_t + \bar{I}_a(r_a + jX_s) = 127 + (32 - j24)(0.06 + j2.27) = 182.92 + j70.16$$
$$|E_f| = \sqrt{182.92^2 + 70.16^2} = 195.5\ V$$

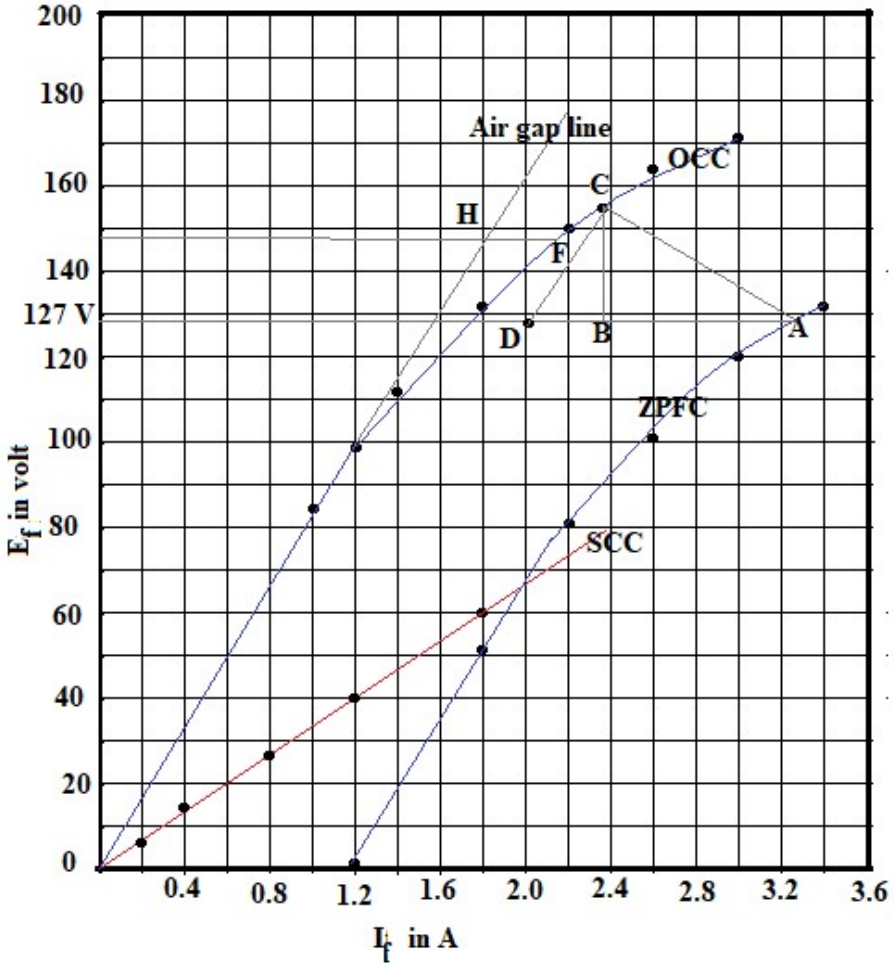
Percentage regulation = $\frac{195.5-127}{127} \times 100\% = 53.9\%$

(b) MMF method:

$$\overline{E'} = \bar{V}_t + \bar{I}_a r_a = 127 + (32 - j24) \times 0.06 = 104 + j76.2$$

$$|E'| = \sqrt{104^2 + 76.2^2} = 129.0\ V$$
$$F_{r_1} = 1.69\ a\ from\ OCC; \quad and \quad F_a + F_{al} = 1.2\ A$$
$$\propto = \tan^{-1}\frac{76.2}{104} = 36.2°$$
$$\overline{F_{r_1}} = 1.69\ (\cos(90°+\propto) + j\sin(90°+\propto))$$





$$\overline{F_{r_1}} = 1.69[-\sin\propto + j\cos\propto] = 1.69[-0.591 + j0.807] = -1 + j\,1.365$$

$$\overline{F_f} = \overline{F_{r_1}} - (\overline{F_a} + \overline{F_{al}}) = -1 + j1.365 - 1.2 = -2.2 + j1.365$$

$$\left|F_f\right| = 2.59\ A$$

E_f from OCC is 163.5 V

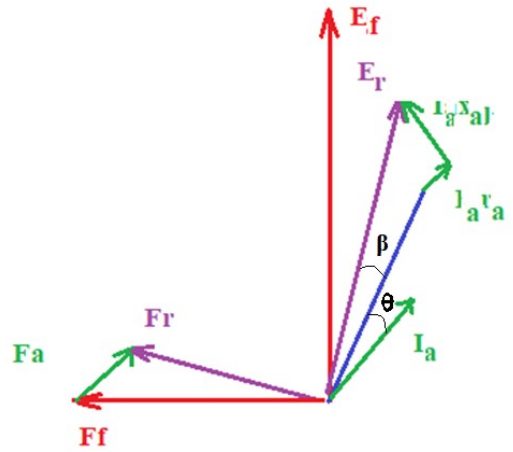
Percentage regulation = $\frac{163.5-127}{127} \times 100\% = 28.75\%$

(c) ZPF method

The potier triangle is drawn . From potier triangle $x_{al} = \frac{BC}{I_a} = \frac{30}{40}$ = 0.75 ohm and F_a = 0.84 A

$$\overline{E_r} = \overline{V_t} + \overline{I_a}(r_a + jx_{al}) = 127 + (32 - j24)(0.06 + j0.75) = 146.92 + j21.6$$

E_r = 148.5 V, from OCC field current is 2.134 A $\therefore F_r = 2.134\ A$ and $\beta = 8.36^o$



Angle between F_a and F_r is $(90° + \beta + \theta) = 90° + 8.36° + 36.86° = 135.22°$

$$\overline{F_f} = \overline{F_r} - \overline{F_a}$$

$$F_f = \sqrt{{F_r}^2 + {F_a}^2 - 2F_rF_a\cos(90 + \theta + \beta)}$$

$$= \sqrt{2.134^2 + 0.84^2 - 22.134.0.84\cos(90° + 36.86° + 8.36°)} = 2.794\ A$$

E_f from OCC = 169 V

Percentage regulation = $\frac{169-}{127} \times 100\% = 33.07\%$

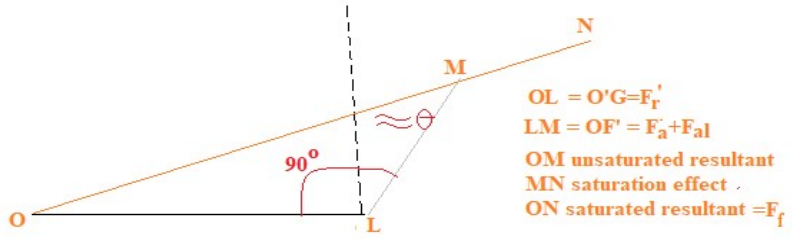
(d) ASA method:

Er = 148.5 V , corresponding to this difference between air gap line and OCC is =0.366 A = saturation effect.(MN)

Corresponding to Vt field current from air gap line = 1.507 A (OL)

$$\boldsymbol{\theta} = \cos^{-1} 0.8 = 36.9°$$

LM = $F_a + F_{al}$ = 1.2A



F_f (Unsaturated) OM = $\sqrt{OL^2 + LM^2 - 2OL.LM\ \cos(90 + \theta)}$

$$= \sqrt{1.507^2 + 1.2^2 - 2 \times 1.507 \times 1.2\cos(90 + 36.9)} = 2.425\ A$$

F_f (Saturated) = 2.425 A+ 0.366 A= 2.791 A

From OCC E_f = 169 V

Percentage regulation = $\frac{169-127}{127} \times 100\% = 33.07\%$

(e) Saturated Synchronous Reactance Method

Er = 148.6 V. from air gap line Erag = 179.5 V

Saturation factor =k = $\frac{KL}{KF} = \frac{179.5}{148.6} = 1.207$

Xal = 0.75 ohm

Unsaturated synchronous reactance = $\frac{100.5}{40} = 2.5\ ohm$

Saturated synchronous reactance = $0.75 + \frac{2.5-0.75}{1.207} = 2.2\ ohm$

$$\overline{E_f} = \overline{V_t} + \overline{I_a}(r_a + jX_s) = 127 + (32 - j24)(0.06 + j2.2) = 179.8 + j68.48$$

$$E_f = 192.1\ V$$

$$percentage\ regulation = \frac{192.7 - 127}{127} \times 100 = 51.2\%$$