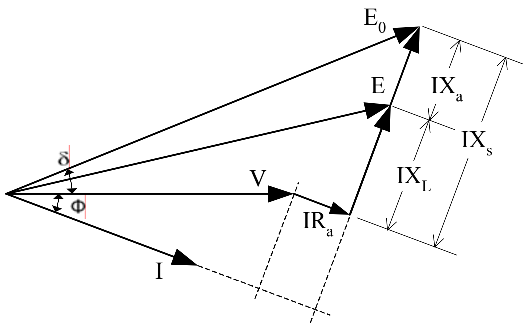
Regulation of Alternators

Phasor diagram of an alternator at lagging power factor is as follows.



Regulation is found by the following expression

$$\%\ \text{regn} = \frac{E_0 - V}{V} \times 100$$

where V is the terminal voltage and E_0 is the induced voltage. E_0 is estimated by one of the following methods.

EMF method

(Synchronous impedance method)

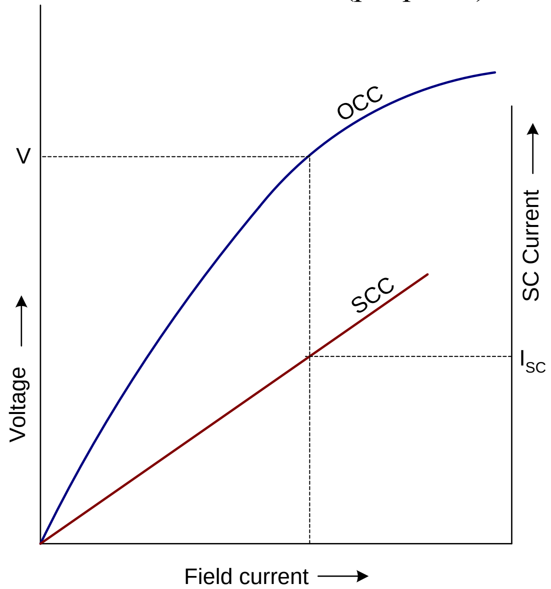
Tests:

Conduct tests to find

OCC (upto 125% of rated voltage)

SCC (for rated current)

Armature resistance (per phase)



V = rated phase voltage

I_{sc} = short circuit current corresponding to the field current producing the rated voltage

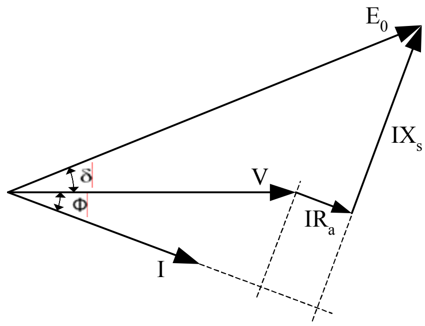
Synchronous impedance per phase,

$$Z_s = V / I_{sc}$$

$$X_s = \sqrt{Z_s^2 - R_a^2}$$

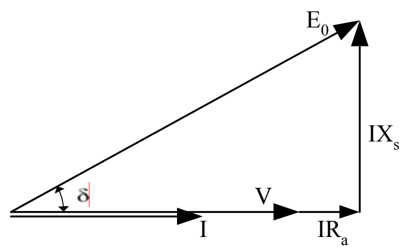
For any load current I and phase angle Φ, find E_0 as the vector sum of V, IR_a and IX_s

For lagging power factor



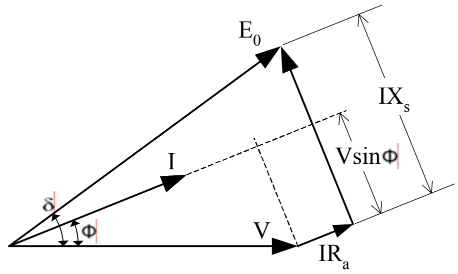
$$E_0 = \sqrt{(V\cos\Phi + IR_a)^2 + (V\sin\Phi + IX_s)^2}$$

For unity power factor



$$E_0 = \sqrt{(V + IR_a)^2 + (IX_s)^2}$$

For leading power factor



$$E_0 = \sqrt{(V\cos\Phi + IR_a)^2 + (V\sin\Phi - IX_s)^2}$$

MMF method

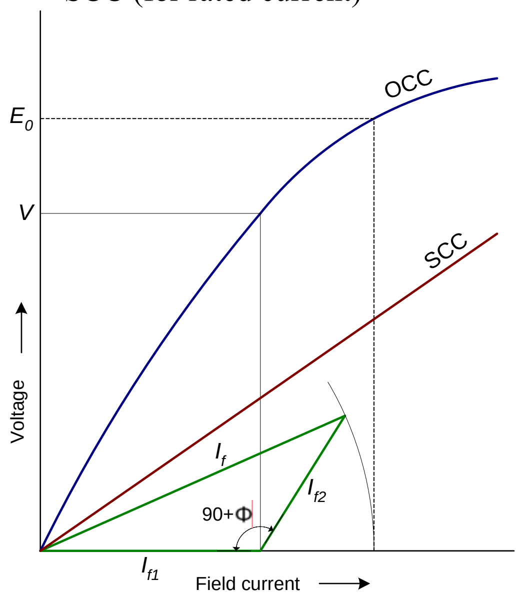
(Ampere turns method)

Tests:

Conduct tests to find

OCC (upto 125% of rated voltage)

SCC (for rated current)



Steps:

1. By suitable tests plot OCC and SCC
2. From the OCC find the field current I_{f1} to produce rated voltage, V.
3. From SCC find the magnitude of field current I_{f2} to produce the required armature current.
4. Draw I_{f2} at angle (90+Φ) from I_{f1}, where Φ is the phase angle of current from voltage. If current is leading, take the angle of I_{f2} as (90-Φ).
5. Find the resultant field current, I_f and mark its magnitude on the field current axis.
6. From OCC. find the voltage corresponding to I_f, which will be E_0.

ZPF method

(Potier method)

Tests:

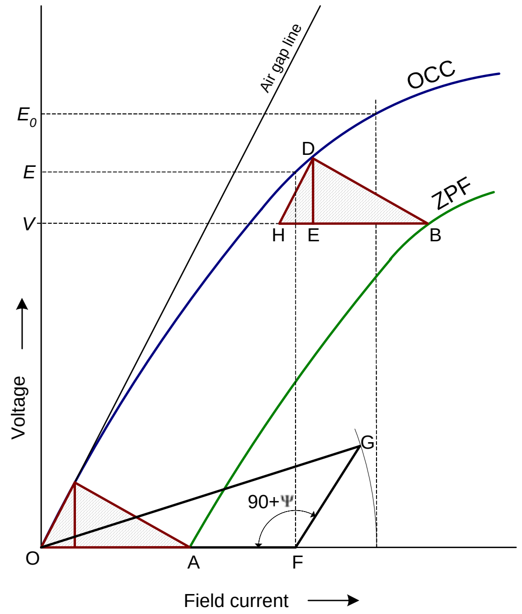
Conduct tests to find

OCC (upto 125% of rated voltage)

SCC (for rated current)

ZPF (for rated current and rated voltage)

Armature Resistance (if required)



Steps:

1. By suitable tests plot OCC and SCC
2. Draw tangent to OCC (air gap line)
3. Conduct ZPF test at full load for rated voltage and fix the point B.
4. Draw the line BH with length equal to field current required to produce full load current at short circuit.
5. Draw HD parallel to the air gap line so as to touch the OCC.
6. Draw DE parallel to voltage axis. Now, DE represents voltage drop IX_L and BE represents the field current required to overcome the effect of armature reaction.

   Triangle BDE is called Potier triangle and X_L is the Potier reactance

7. Find E from V, IX_L and Φ. Consider R_a also if required. The expression to use is

$$E = \sqrt{(V\cos\Phi + IR_a)^2 + (V\sin\Phi + IX_L)^2}$$

8. Find field current corresponding to E.
9. Draw FG with magnitude equal to BE at angle (90+Ψ) from field current axis, where Ψ is the phase angle of current from voltage vector E (internal phase angle).
10. The resultant field current is given by OG. Mark this length on field current axis.
11. From OCC find the corresponding E_0.

ASA method

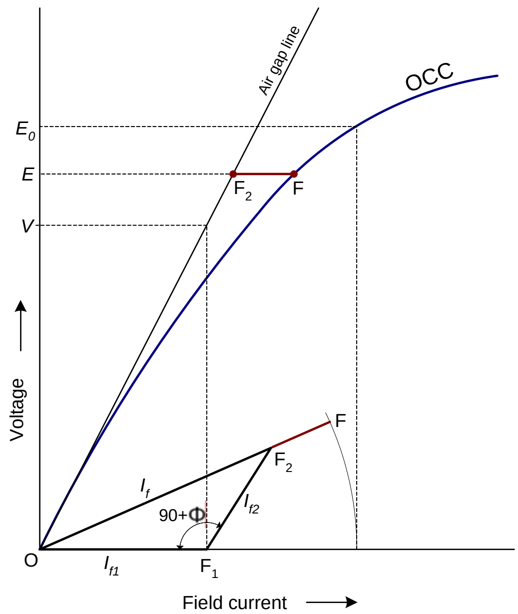
Tests:

Conduct tests to find

- OCC (upto 125% of rated voltage)
- SCC (for rated current)
- ZPF (for rated current and rated voltage)
- Armature Resistance (if required)

Steps:

1. Follow steps 1 to 7 as in ZPF method.
2. Find I_{f1} corresponding to terminal voltage V using air gap line (OF_1 in figure).
3. xDraw I_{f2} with length equal to field current required to circulate rated current during short circuit condition at an angle (90+Φ) from I_{f1}. The resultant of I_{f1} and I_{f2} gives I_f (OF_2 in figure).
4. Extend OF_2 upto F so that F_2F accounts for the additional field current accounting for the effect of saturation. F_2F is found for voltage E as shown.
5. Project total field current OF to the field current axis and find corresponding voltage E_0 using OCC.



Slip Test

(for salient pole machines only)

Tests:

Conduct tests to find

- X_d and X_q
- Armature Resistance (if required)

1. Energise the alternator with field unexcited and driven close to synchronous speed by a prime mover.
2. Measure the line voltage and line current of the alternator.
3. Find X_d and X_q by the following expressions

$$X_d = \frac{V_{max}}{\sqrt{3}I_{min}} \qquad X_q = \frac{V_{min}}{\sqrt{3}I_{max}}$$

4. Find I_d as follows

$$\Psi = \tan^{-1}\frac{V\sin\Phi + I X_q}{V\cos\Phi + I R_a} \;;\quad I_d = I\sin\Psi$$

5. Then expression for E_0 is

$$E_0 = \left[(V\cos\Phi + IR_a)^2 + (V\sin\Phi + IX_q)^2\right]^{1/2} + I_d(X_d - X_q)$$