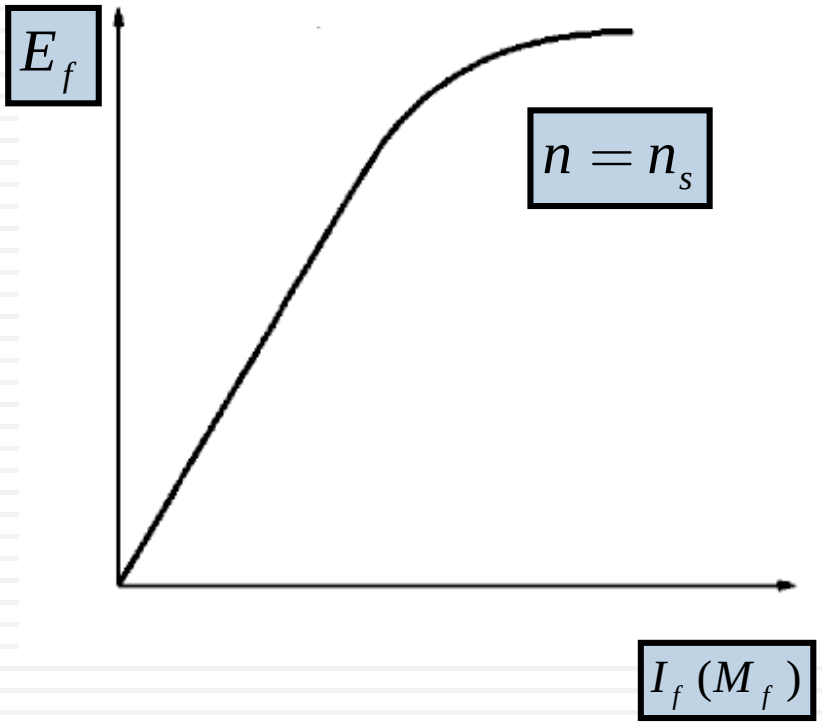
Synchronous Machines

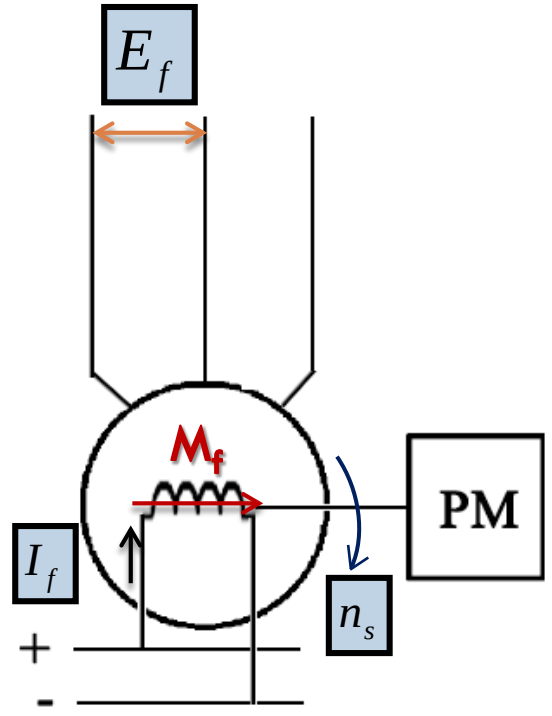
1. Synchronous Generators

- Principle of Operation
- Phasor Diagram and Equivalent Circuit
- Power and Torque
- Synchronous Generator Characteristics & Tests
- Generator Modes of Operation
- Generator Stability
- Generator Rating
- Practical Generator

Synchronous Generator: Characteristics & Tests

1. Open Circuit Characteristics

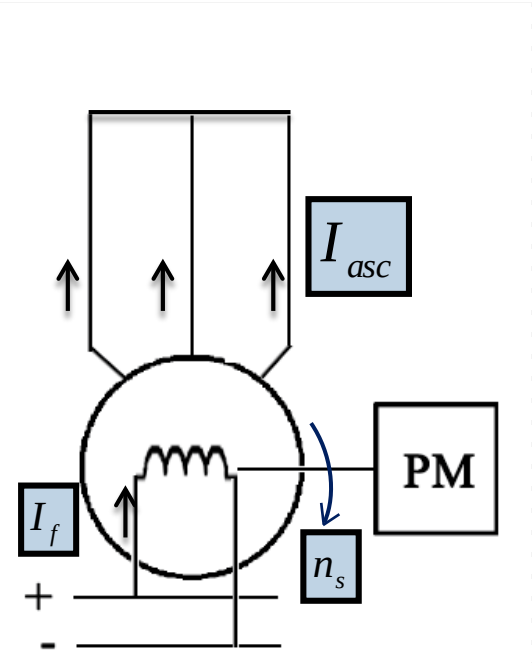




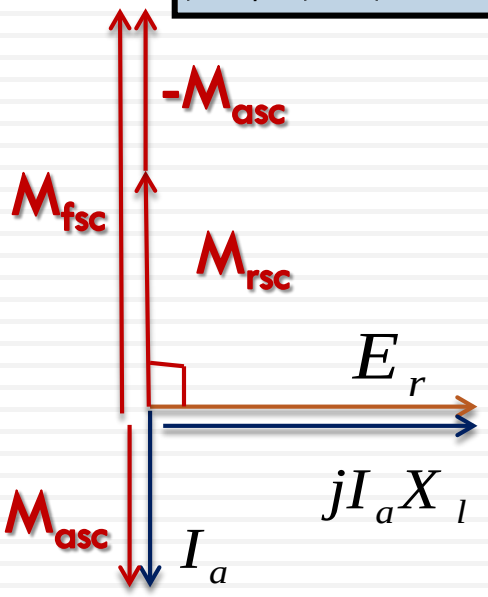
$M_f \rightarrow E_f$

Synchronous Generator: Characteristics & Tests

2. Short Circuit Characteristics



$$|M_{fsc}| = |M_{rsc}| + |M_{asc}|$$



$$V/_{t\phi} = E_r - I_a(jX_l)$$

Neglecting R_a

$$M_{rsc} = M_{fsc} + M_{asc}$$

Synchronous Generator: Characteristics & Tests

2. Short Circuit Characteristics

$$|M_{fsc}| = |M_{rsc}| + |M_{asc}|$$

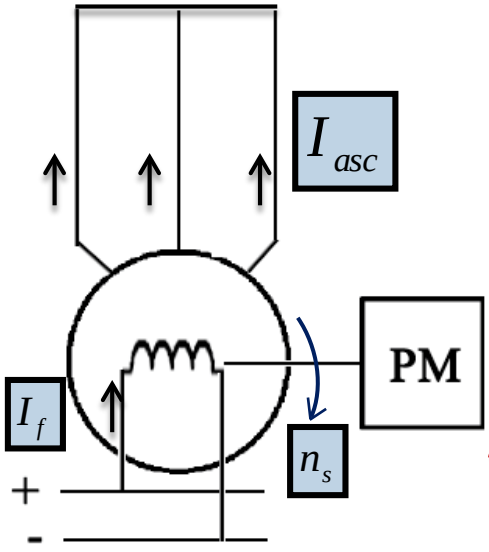
$$M_{asc} \propto I_{asc}$$

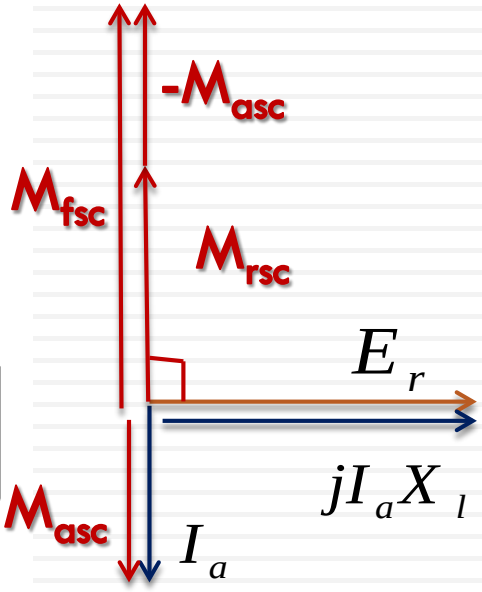
$$M_{rsc} \propto E_{rsc} \propto I_{asc}$$

$$M_{fsc} \propto I_{asc}$$

$$M_{fsc} \propto I_{fsc}$$

$$I_{asc} \propto I_{fsc}$$



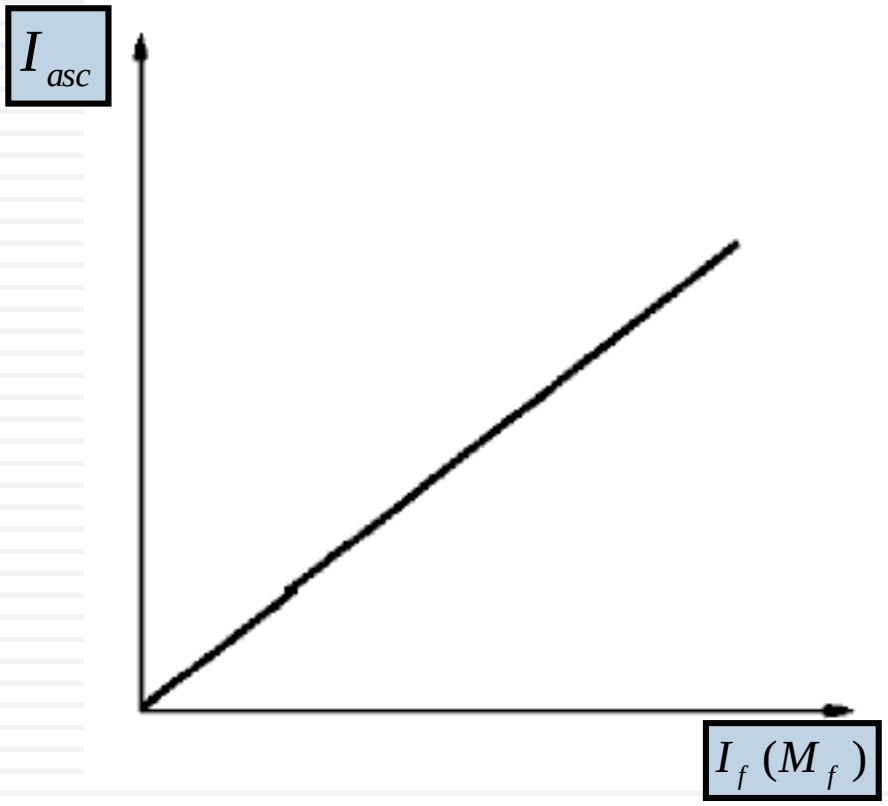


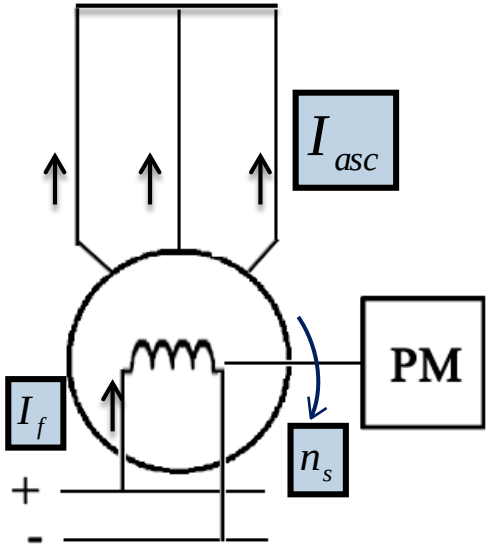
$$E_{rsc} = jI_{asc}X_l$$

Synchronous Generator: Characteristics & Tests

2. Short Circuit Characteristics

$$I_{asc} \propto I_{fsc}$$





Synchronous Generator: Characteristics & Tests

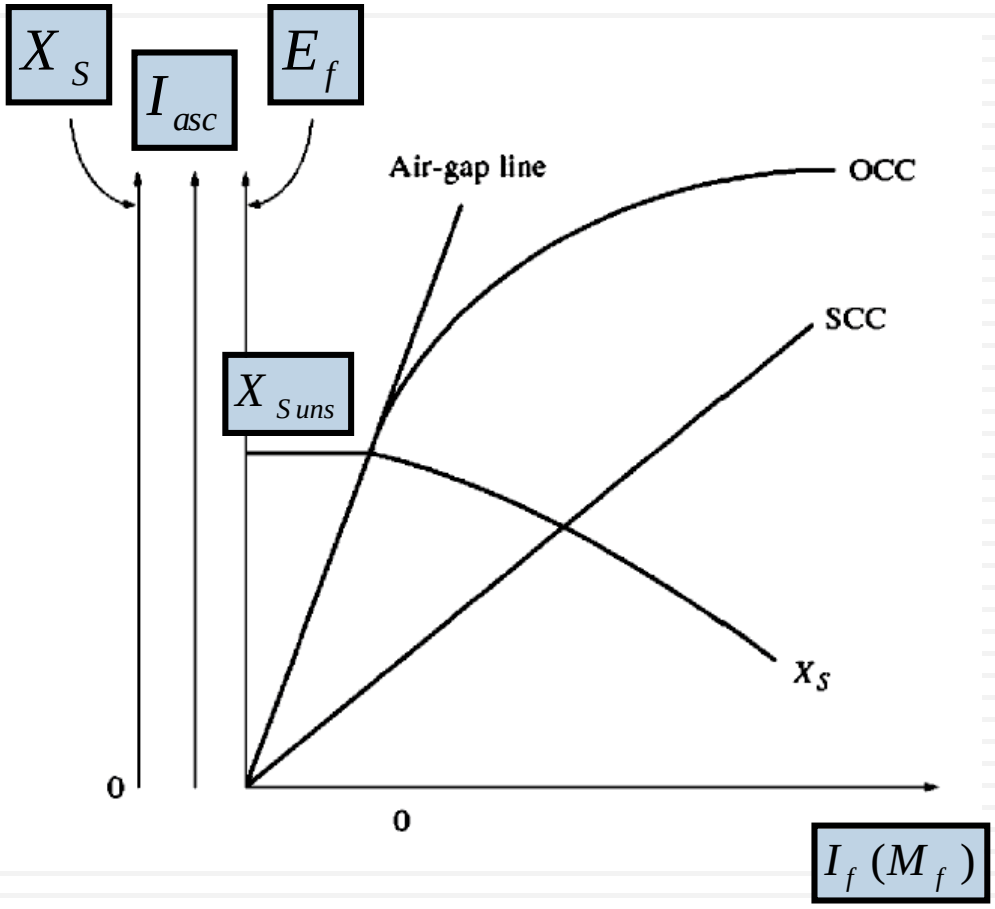
Calculation of X_S

At Short Circuit

$$\not{V}_{t\phi} = E_f - I_a(jX_S)$$

$$X_S = \left.\frac{E_f}{I_{asc}}\right|_{I_f = const.}$$

$$\not{X}_S = X_l + \not{X}_{ar}$$



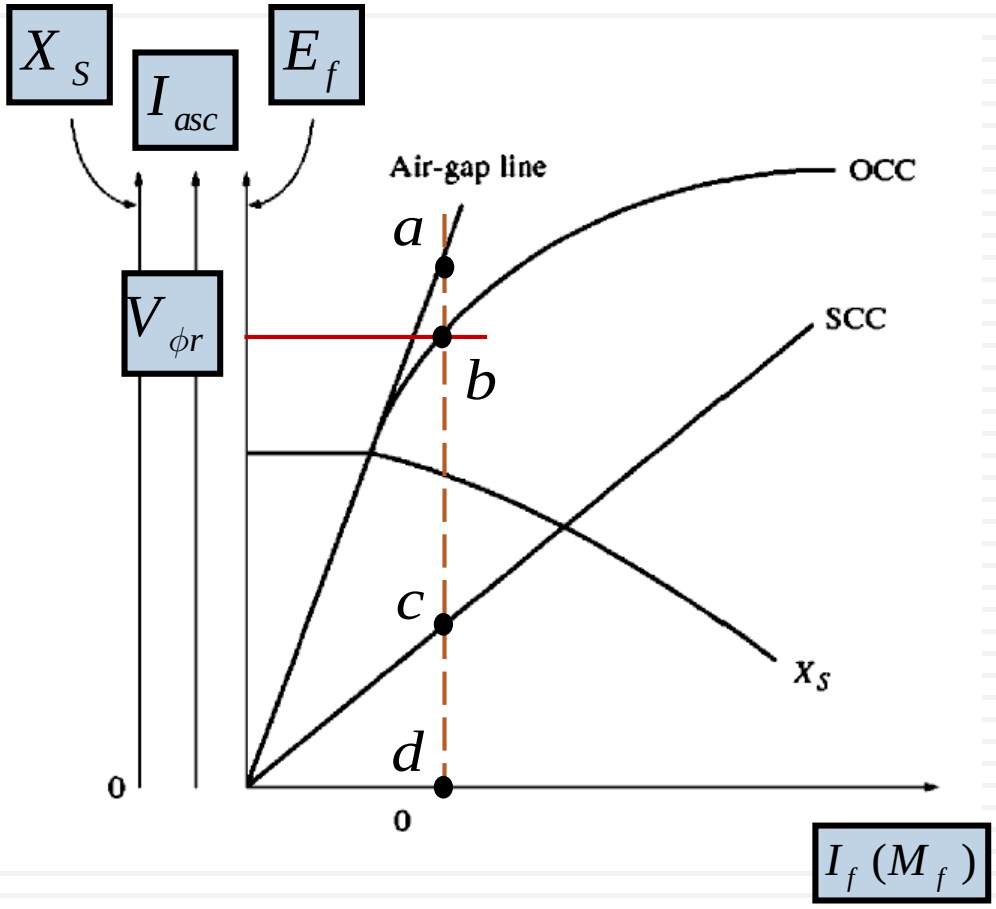
Synchronous Generator: Characteristics & Tests

Calculation of X_S: Including Saturation

At: $E_f = V_{\phi rated}$

$$X_{S\ uns} = \frac{ad\,(V\,)(\text{phase})}{cd\,(A\,)}$$

$$X_{S\ sat} = \frac{bd\,(V\,)(\text{phase})}{cd\,(A\,)}$$



Synchronous Generator: Characteristics & Tests

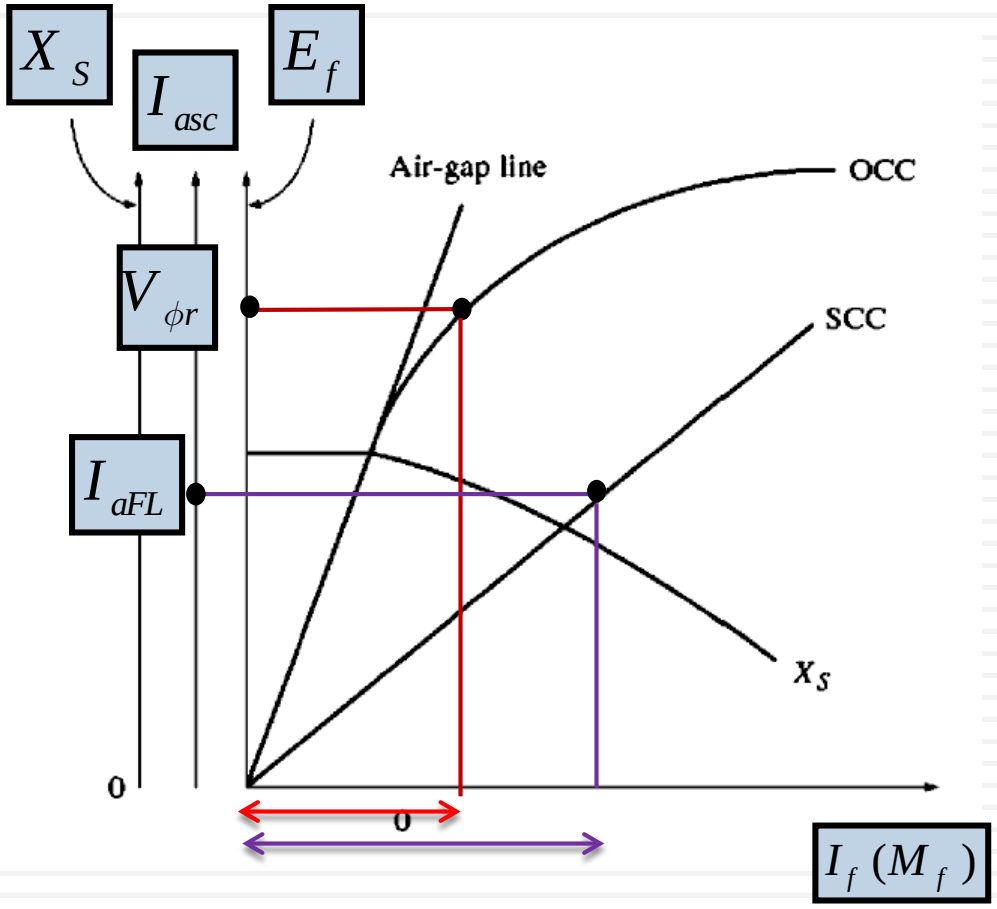
Calculation of X_S: Short Circuit Ratio

$$SCR = \frac{I_f \text{ at } E_f = V_{\phi rated}}{I_f \text{ at } I_{asc} = I_{aFL}}$$

$$X_{s\ sat} = \left(\frac{1}{SCR}\right) \times \frac{V_{\phi r}}{I_{aFL}}$$

$$X_{s\ sat} = \left(\frac{1}{SCR}\right) \times Z_{base}$$

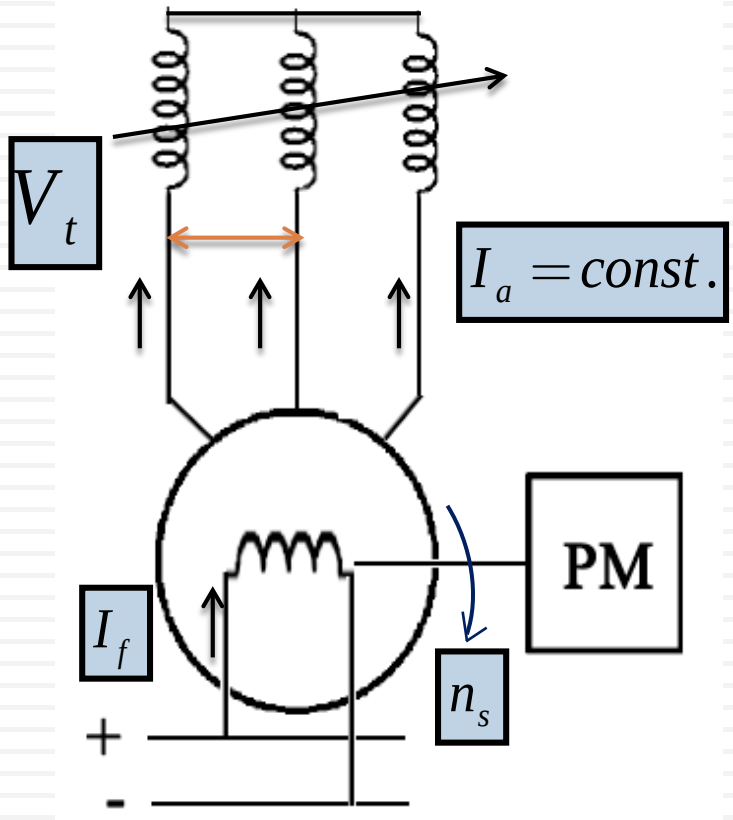
$$SCR = \frac{AFNL}{AFSC}$$



Synchronous Generator: Characteristics & Tests

3. Zero Power Factor Characteristics

It's the relation between the **terminal voltage** and the **field current** when the generator is connected to a variable **pure inductive load** at a **constant armature current.**



Synchronous Generator: Characteristics & Tests

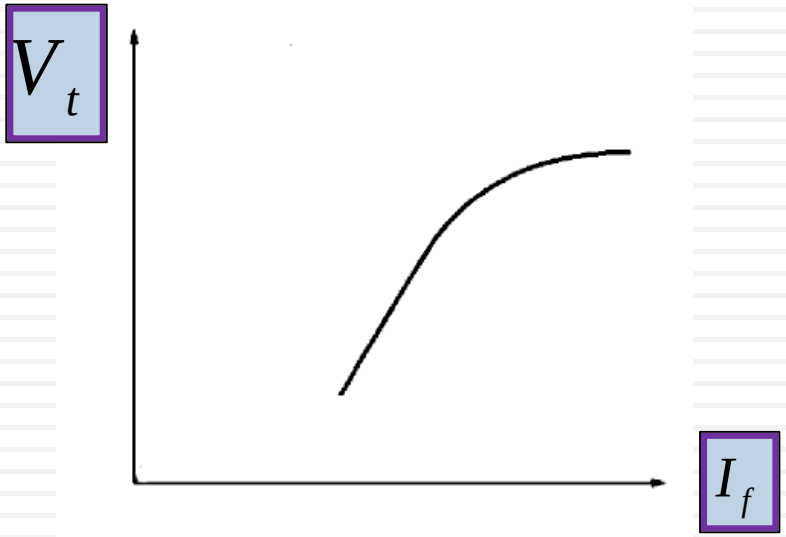
3. Zero Power Factor Characteristics

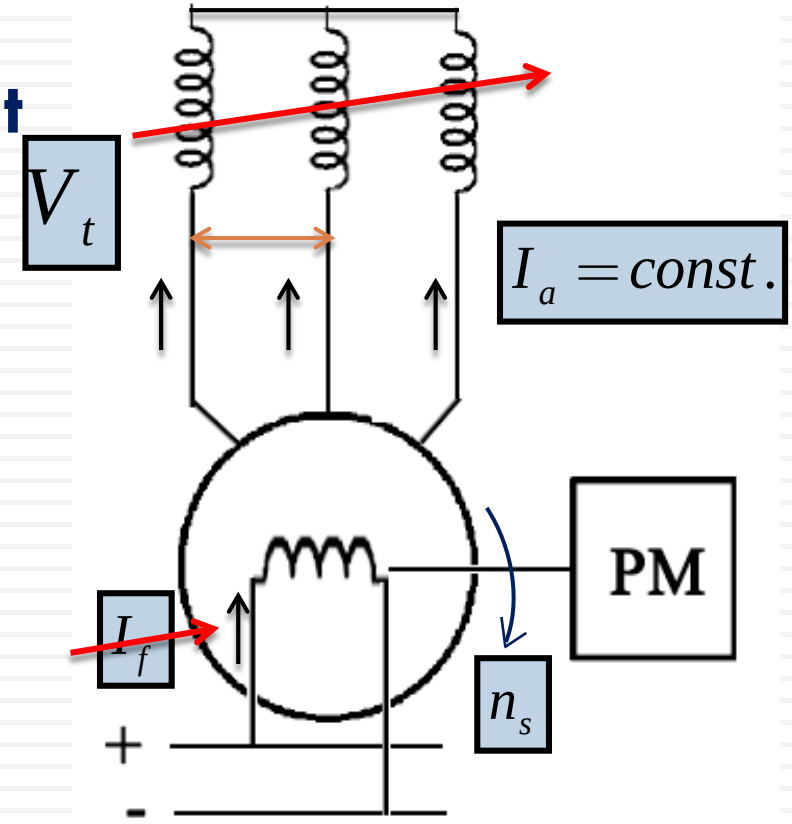
At different load settings,

adjust I_f to keep **I_a constant**

then take the reading

of **V_t** and **I_f** at each load





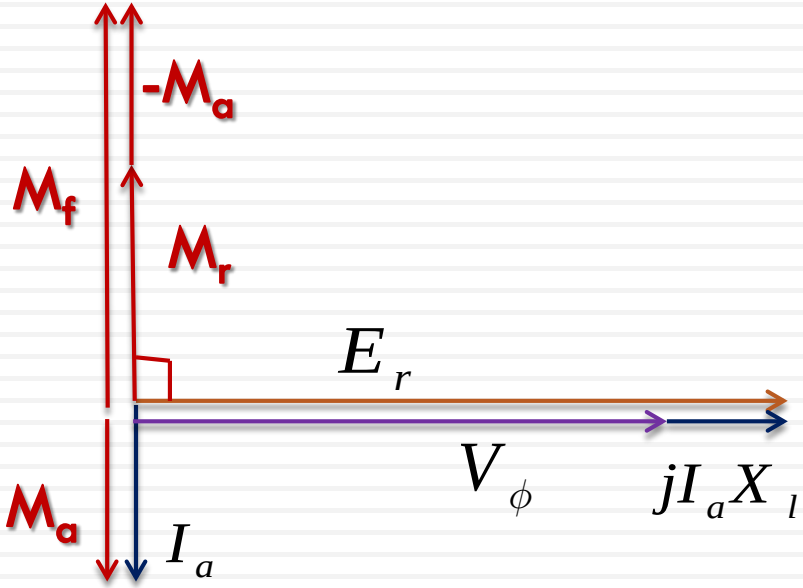
Synchronous Generator: Characteristics & Tests

3. Zero Power Factor Characteristics

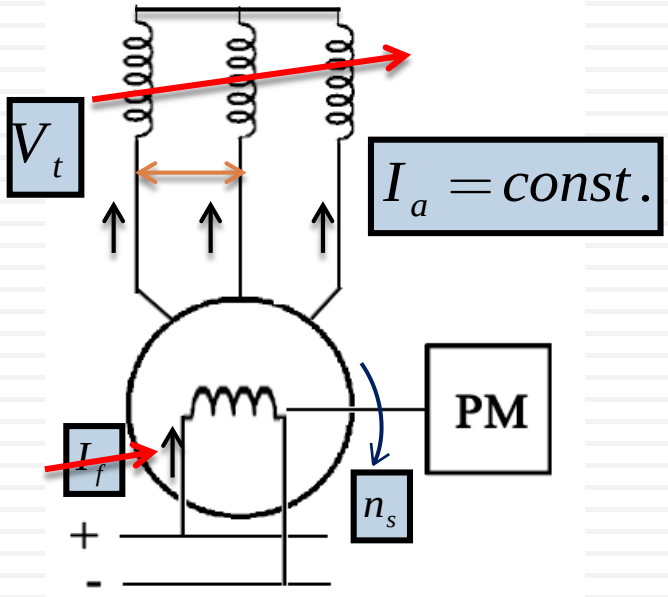
$$V_{t\phi} = E_r - I_a(jX_l)$$

$$V_{t\phi} = I_a(jX_L)$$

$$I_a = \frac{E_r}{jX_l + jX_L}$$

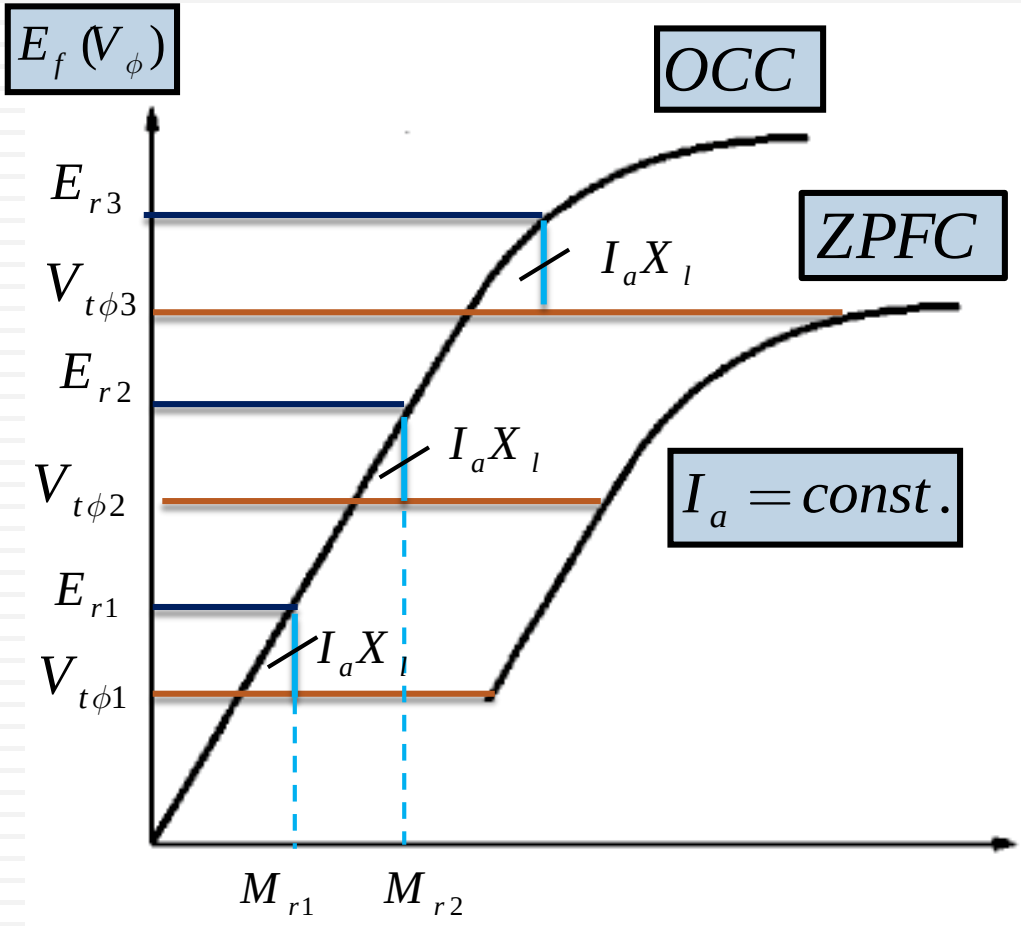


$$|M_f| = |M_r| + |M_a|$$



Synchronous Generator: Characteristics & Tests

3. Zero Power Factor Characteristics



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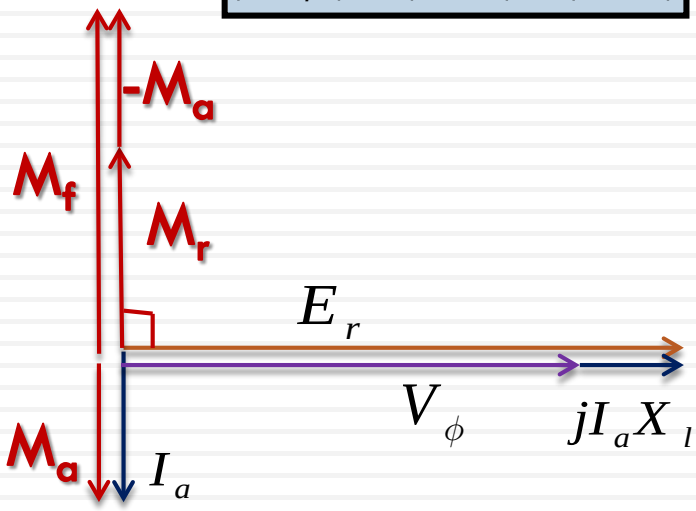
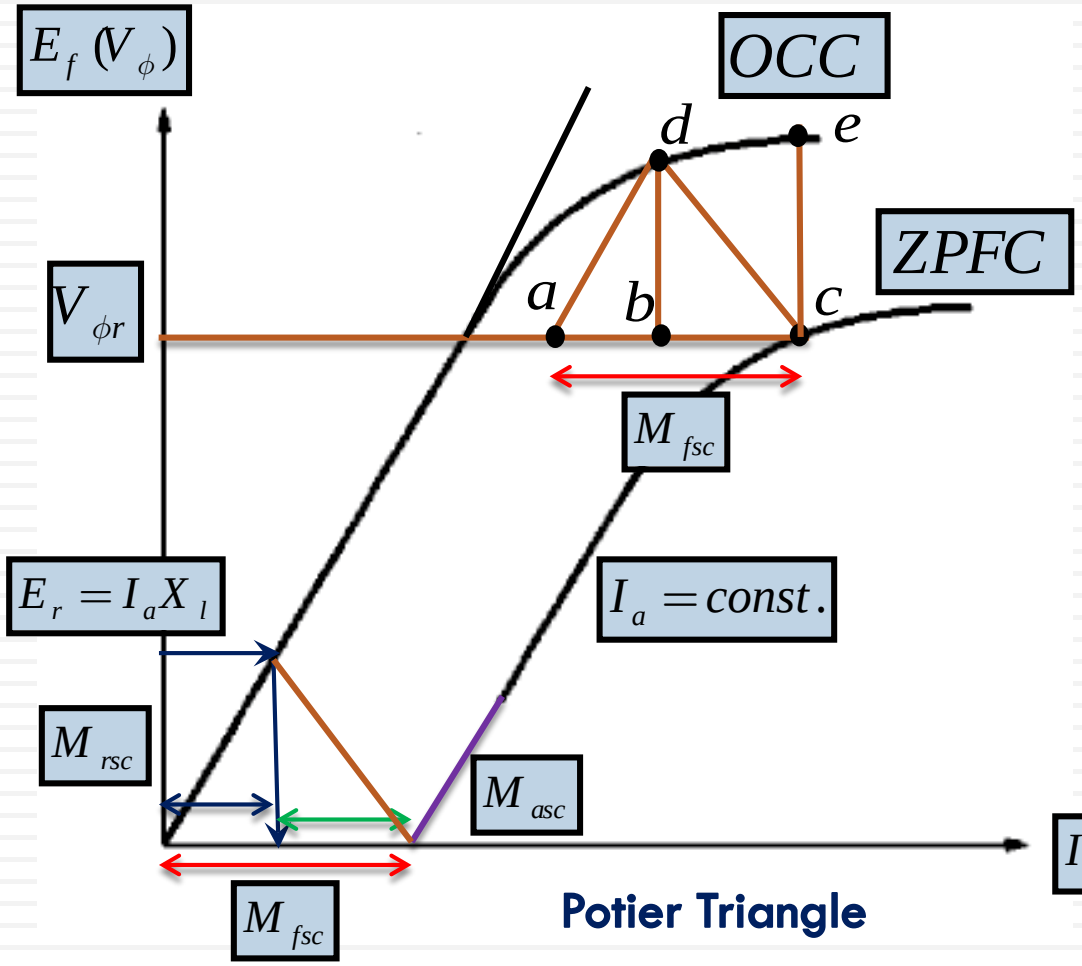
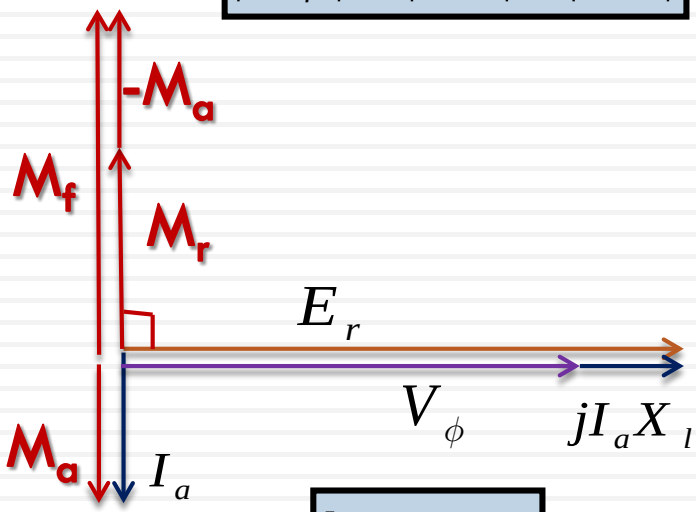


Synchronous Generator: Characteristics & Tests

3. Zero Power Factor Characteristics



$$|M_f| = |M_r| + |M_a|$$



$$bc = M_a$$

$$\frac{bd}{I_a} = X_l$$

$$\frac{ce}{I_a} = X_s$$