2-6 Energy Diagram:

$$\sum P_{losses} = P_1 - P_2$$

$$= P_{fe} + P_{cua} + P_{cue} + P_{fw} + P_{add}$$

P_{fe}: **Iron Losses**

P_{cua}: **Cupper Losses in Armature**

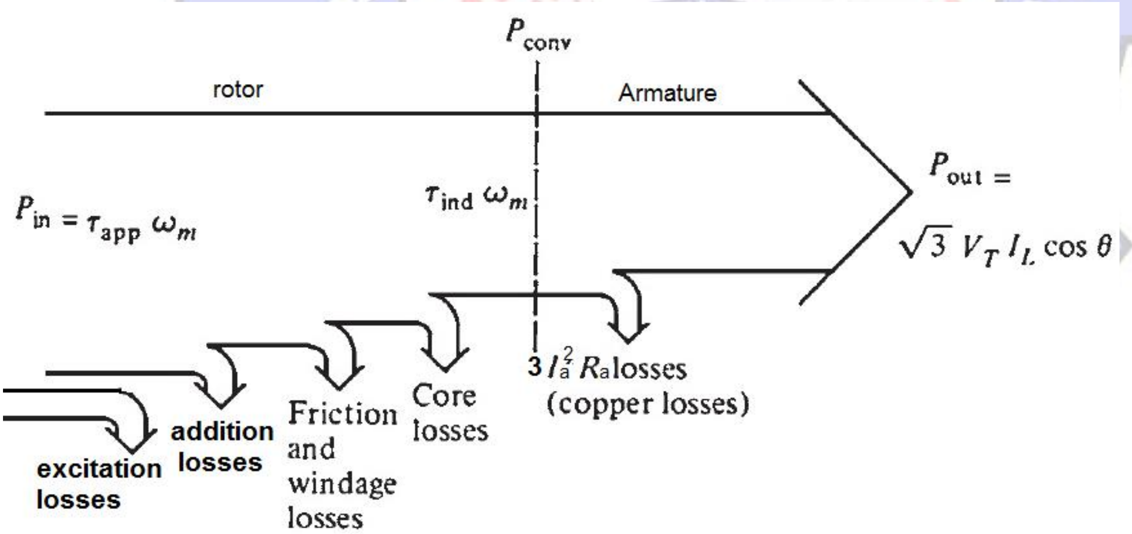
P_{cue}=**Cupper Losses in Excitation Winding**

P_{fw}: **Friction and Winding Losses**

P_{add}: **Addition Losses**

$$P_{cua} = 3I_a^2 R_a$$

$$P_{cue} = I_e^2 R_e$$



The power flow diagram of a synchronous generator.

$$P_{add} = 0.5\%\, P_1 \quad , P_{fw} = 50\%\, P_{losses}$$

$$P_{em} = P_2 + P_{cua} \quad or \quad P_2 = P_{em} - P_{cua}$$

:For separate excitation then

$P_i = P_1 + P_{ex}$

For self-excitation, then:

$P_o = P_2 - P_{ex}$

$\eta\% = \frac{P_o}{P_i} \times 100\% = \frac{P_o}{P_o + P_{fw} + P_{fe} + P_{cua} + P_{ad}} \times 100\%$

2-7 Measuring parameters of synchronous generator model

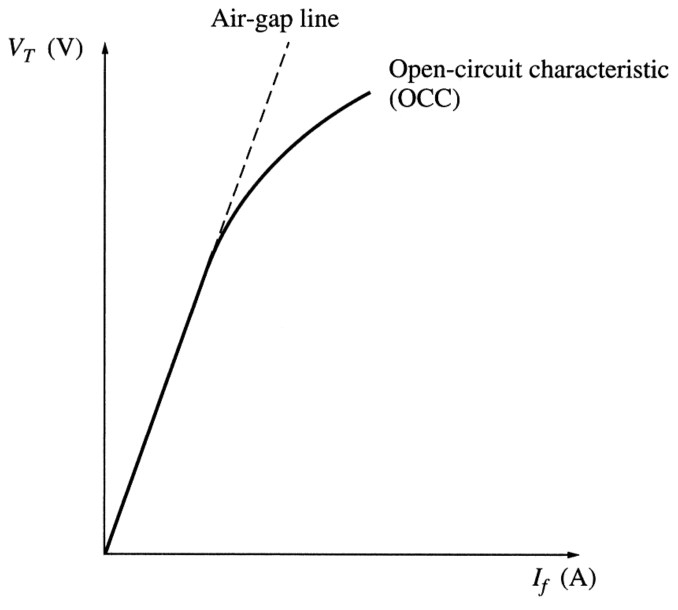
The three quantities must be determined in order to describe the generator model:
1.The relationship between field current and flux (and therefore between the field current *IF* and the internal generated voltage *EA*);
2.The synchronous reactance;
3.The armature resistance.

Open circuit Test:

The generator is rotated at the rated speed,
•all the terminals are disconnected from loads,

•the field current is set to zero first.

•Next, the field current is increased in steps and the phase voltage (whish is equal to the internal generated voltage *EA* since the armature current is zero) is measured.
Since the unsaturated core of the machine has a reluctance thousands times lower than the reluctance of the air-gap, the resulting flux increases linearly first. When the saturation is reached, the core reluctance greatly increases causing the flux to increase much slower with the increase of the mmf.



Short Circuit Test

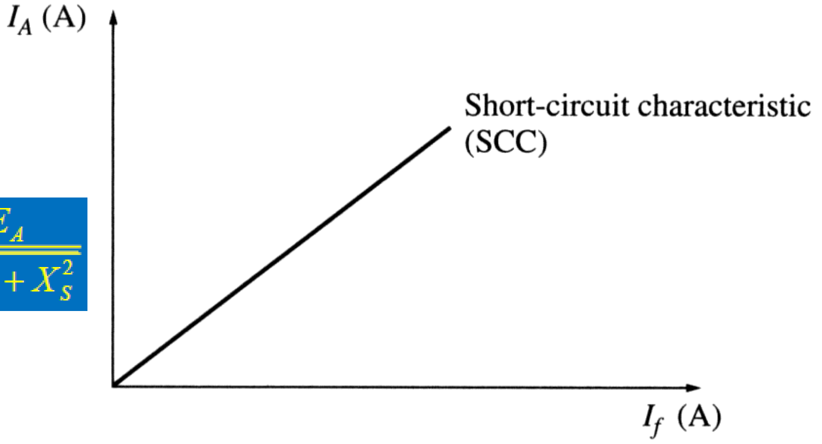
In here,

• The generator is rotated at the rated speed, with the field current is set to zero first, and all the terminals are short-circuited through ammeters.

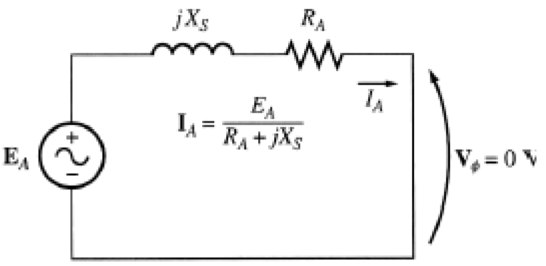
• Next, the field current is increased in steps and the armature current *IA* is measured as the field current is increased. The plot of armature current (or line current) vs. the field current is the short-circuit characteristic (SCC) of the generator.

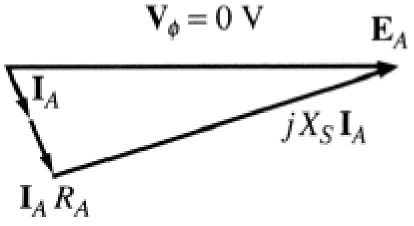
The SCC is a straight line since, for the short-circuited terminals, the magnitude of the armature current is

$$I_A = \frac{E_A}{\sqrt{R_A^2 + X_S^2}}$$



The equivalent generator's circuit during SC





An approximate method to determine the synchronous reactance *XS* at a given field current:

1. Get the internal generated voltage *EA* from the OCC at that field current.
2. Get the short-circuit current *IA,SC* at that field current from the SCC.
3. Find *XS* from

$$X_S \approx \frac{E_A}{I_{A,SC}}$$

Since the internal machine impedance is

$$Z_S = \sqrt{R_A^2 + X_S^2} = \frac{E_A}{I_{A,SC}} \approx X_S \qquad \{\text{since } X_S \approx R_A\}$$