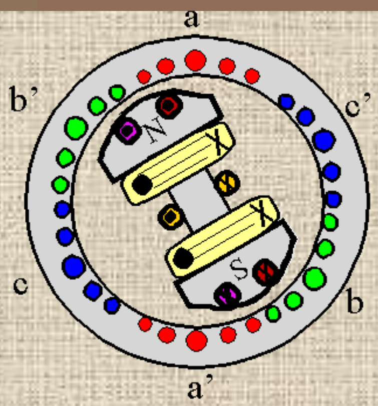
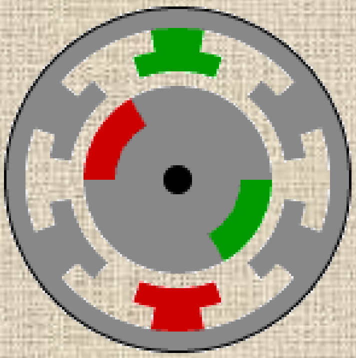
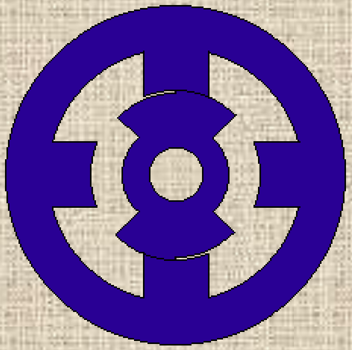
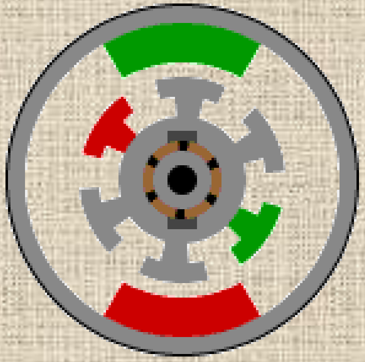
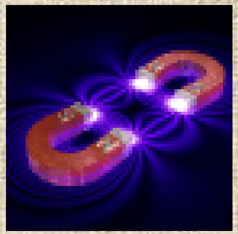


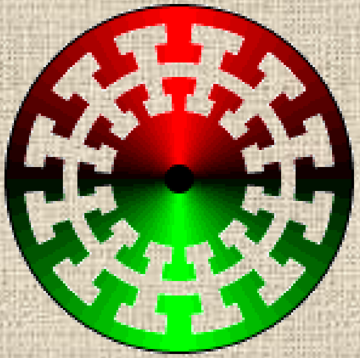




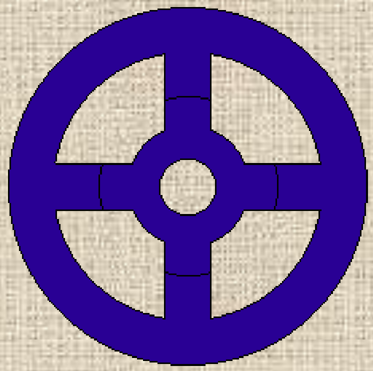


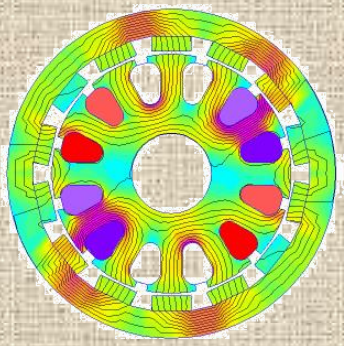
EE552 ELECTRICAL MACHINES III

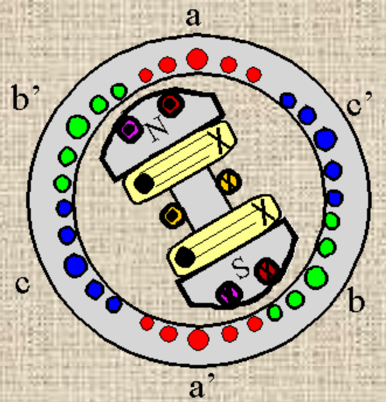




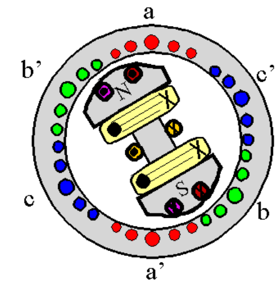
LECTURE 13







LECTURE NOTES

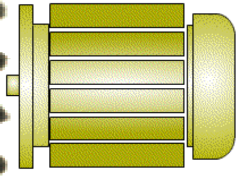


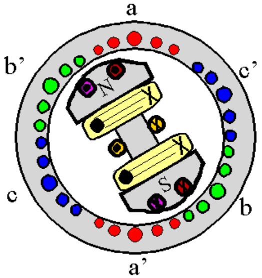
ELECTRICAL MACHINES III

EE552

SPRING 2018

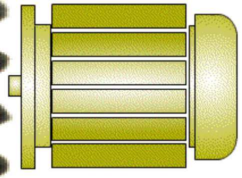
Dr : MUSTAFA AL-REFAI



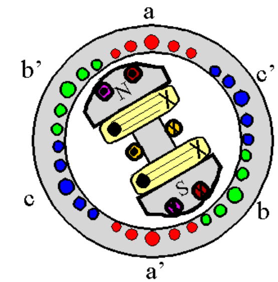


LECTURE 13

SYNCHRONOUS GENERATOR



Measuring parameters of synchronous generator model

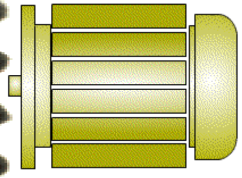


The three quantities must be determined in order to describe the generator model:

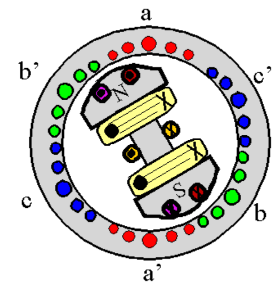
1. The relationship between field current and flux (and therefore between the field current I_F and the internal generated voltage E_A);
2. The synchronous reactance;
3. The armature resistance.

OPEN CIRCUIT TEST (OCC)

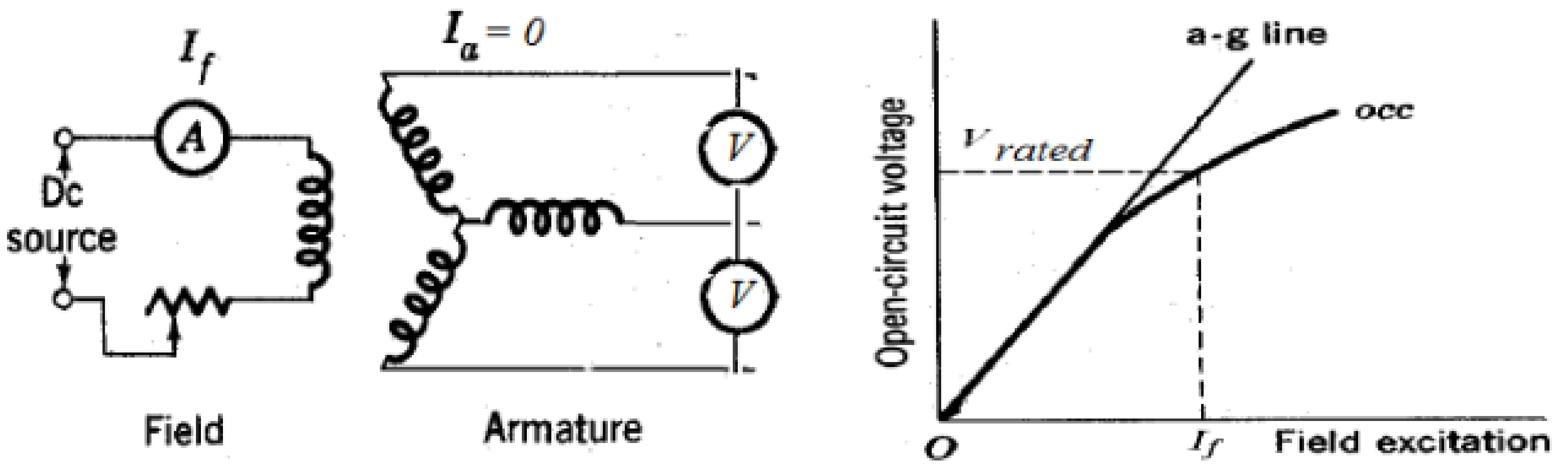
We conduct first the open-circuit test on the synchronous generator: the generator is rotated at the rated speed, all the terminals are disconnected from loads, the field current is set to zero first. Next, the field current is increased in steps and the phase voltage (whish is equal to the internal generated voltage E_A since the armature current is **zero**) is measured.



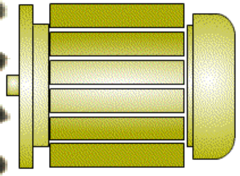
Open-Circuit Characteristic (OCC)



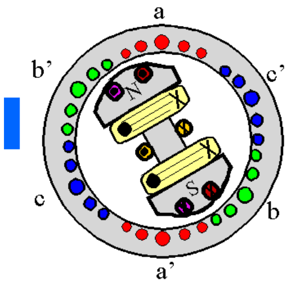
Therefore, it is possible to plot the dependence of the internal generated voltage on the field current – the open-circuit characteristic (OCC) of the generator.



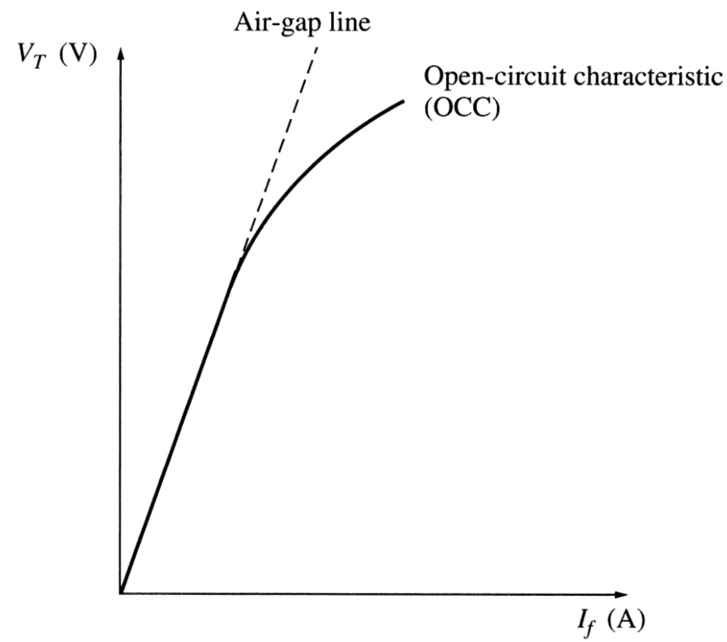
Open-Circuit Characteristic (O.C.C.)



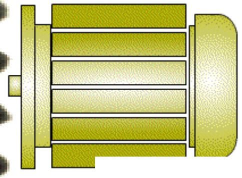
Measuring parameters of synchronous generator model



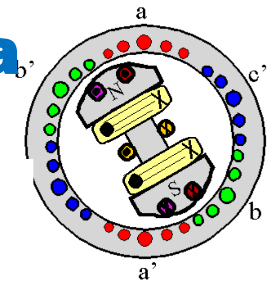
Since the unsaturated core of the machine has a reluctance thousands times lower than the reluctance of the air-gap, the resulting flux increases linearly first. When the saturation is reached, the core reluctance greatly increases causing the flux to increase much slower with the increase of the mmf.

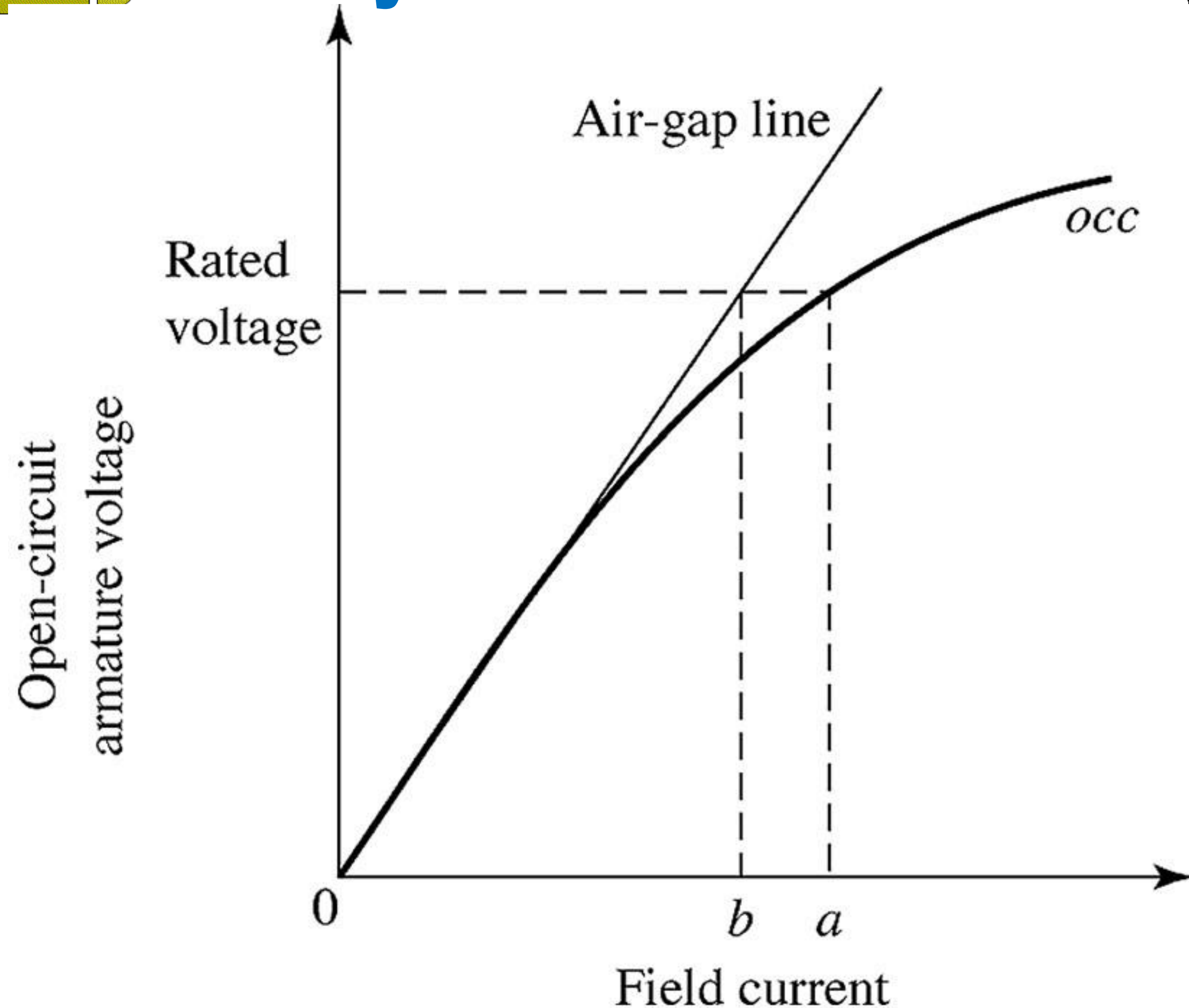


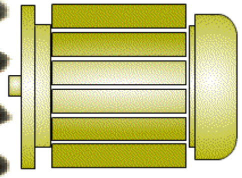
Open-Circuit Characteristic (O.C.C.)



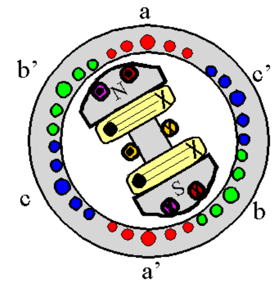
Open-circuit characteristic of a synchronous machine.



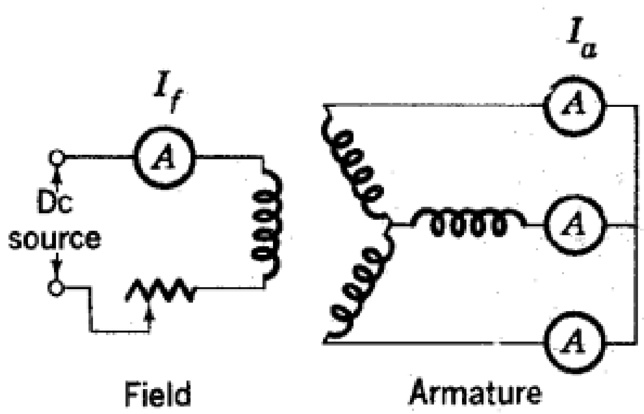


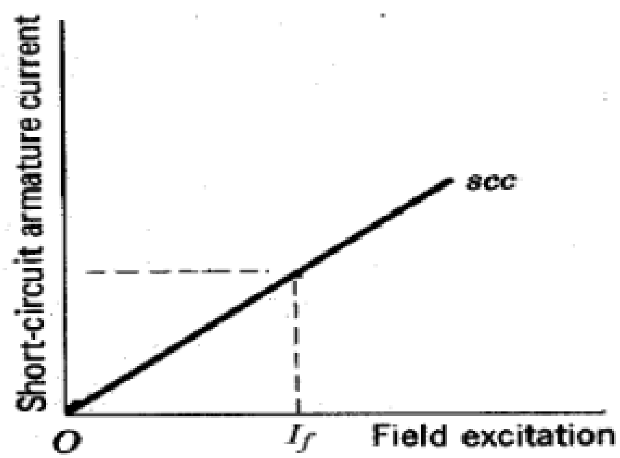


SHORT CIRCUIT TEST (SCC)

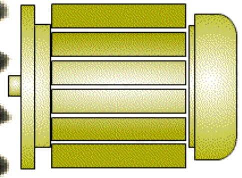


We conduct next the **short-circuit test** on the synchronous generator: the generator is rotated at the rated speed, all the terminals are short-circuited through ammeters, the field current I_F is set to zero first. Next, the field current is increased in steps and the armature current I_A is measured 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 gene

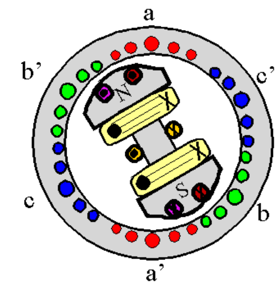


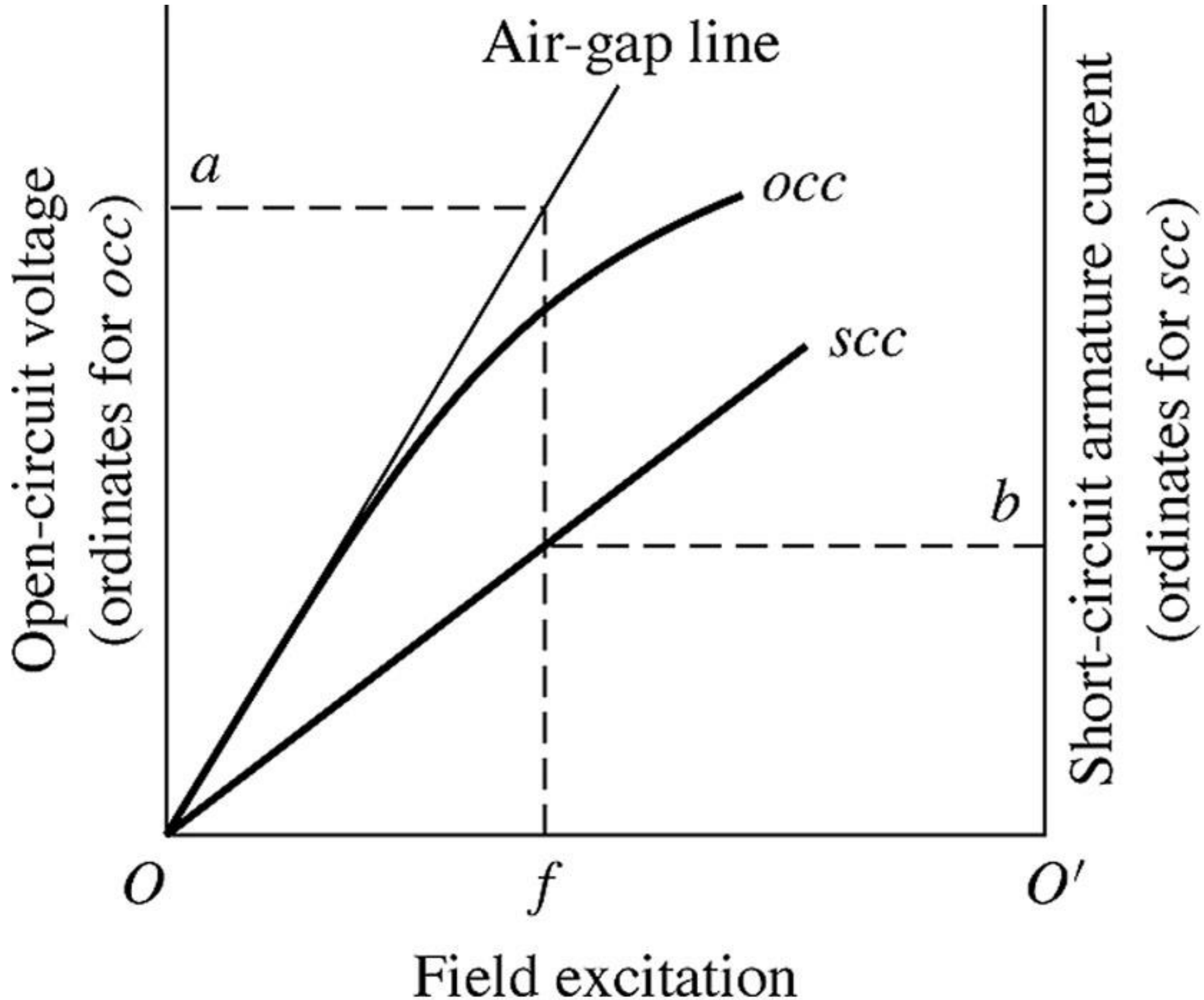


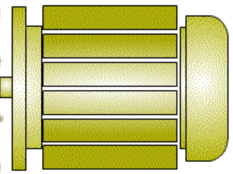
Short-circuit characteristics S.C.C.



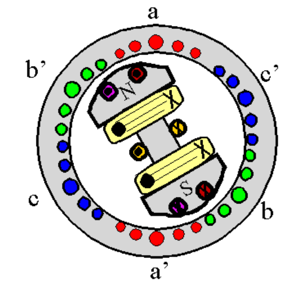
Open- and short-circuit characteristics of a synchronous machine.





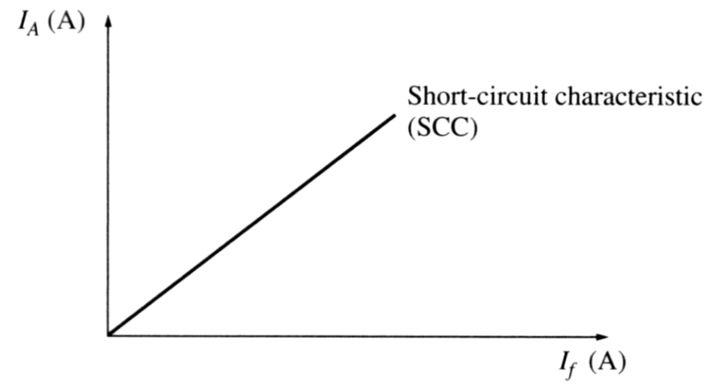


Measuring parameters of synchronous generator model

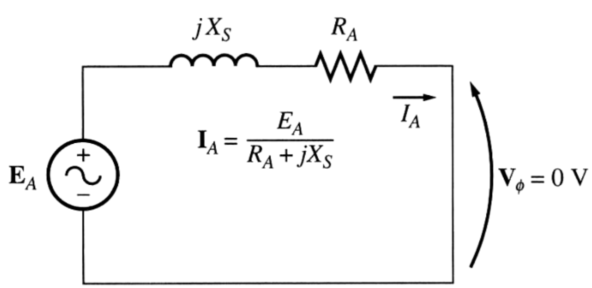


The SCC is a straight line since, for the short-circuited terminals, the magnitude of the armature current is

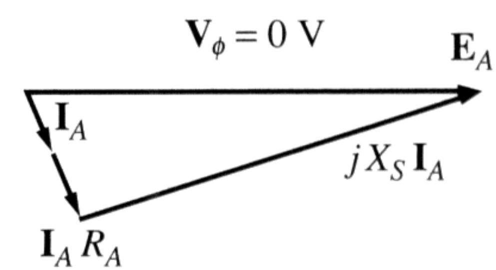
$$I_A = \frac{E_A}{\sqrt{R_A^2 + X_S^2}} \quad (20)$$



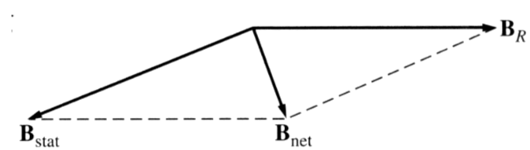
The equivalent generator's circuit during SC



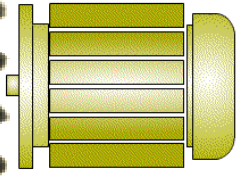
The resulting phasor diagram



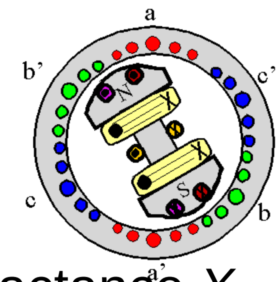
The magnetic fields during short-circuit test



Since B_S almost cancels B_R, the net field B_{net} is very small.



Measuring parameters of synchronous generator model



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

1. Get the internal generated voltage E_A from the OCC at that field current.
2. Get the short-circuit current $I_{A,SC}$ at that field current from the SCC.
3. Find X_S from

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

Since the internal machine impedance is

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

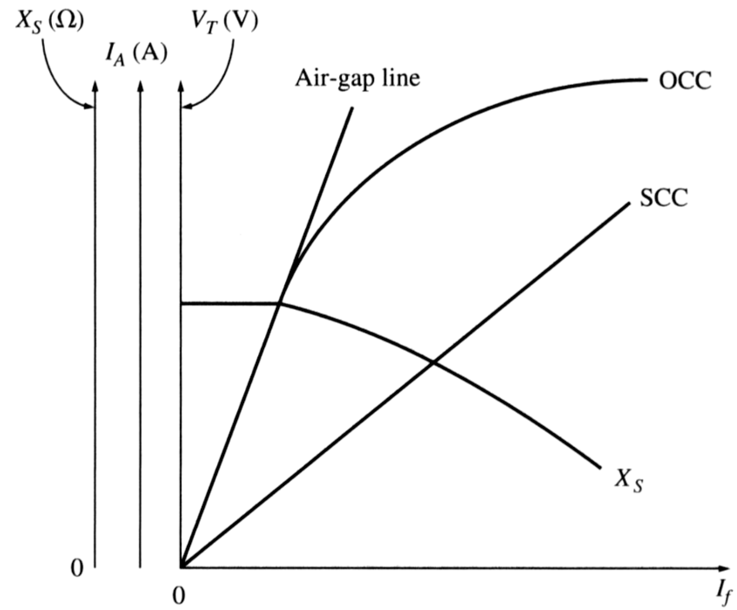
Measuring parameters of synchronous generator model

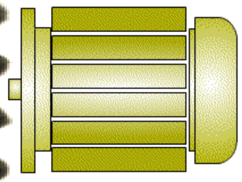
A drawback of this method is that the internal generated voltage E_A is measured during the OCC, where the machine can be saturated for large field currents, while the armature current is measured in SCC, where the core is unsaturated. Therefore, this approach is accurate for unsaturated cores only.

The approximate value of synchronous reactance varies with the degree of saturation of the OCC.

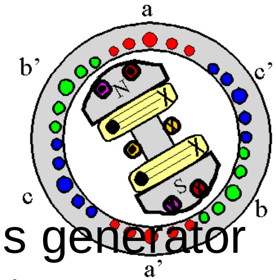
Therefore, the value of the synchronous reactance for a given problem should be estimated at the approximate load of the machine.

The winding's resistance can be approximated by applying a DC voltage to a stationary machine's winding and measuring the current. However, AC resistance is slightly larger than DC resistance (skin effect).





Measuring parameters of synchronous generator model: Ex



Example : A 200 kVA, 480 V, 50 Hz, Y-connected synchronous generator with a rated field current of 5 A was tested and the following data were obtained:

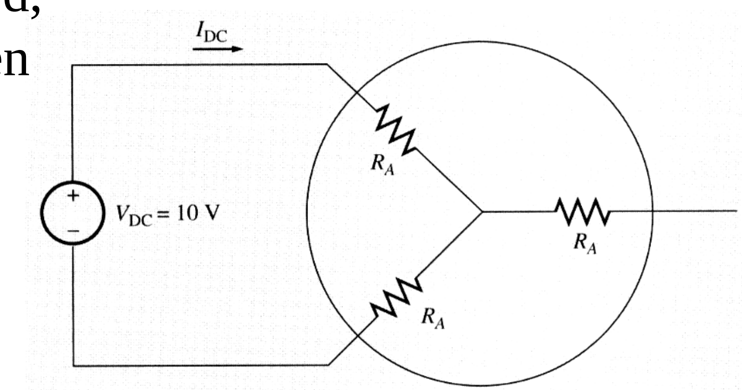
1. $V_{T,OC}$ = 540 V at the rated I_F.
2. $I_{L,SC}$ = 300 A at the rated I_F.
3. When a DC voltage of 10 V was applied to two of the terminals, a current of 25 A was measured.

Find the generator's model at the rated conditions (i.e., the armature resistance and the approximate synchronous reactance).

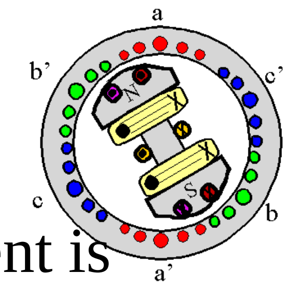
Since the generator is Y-connected, a DC voltage was applied between its ***two*** phases. Therefore:

$$2R_A = \frac{V_{DC}}{I_{DC}}$$

$$R_A = \frac{V_{DC}}{2I_{DC}} = \frac{10}{2\cdot 25} = 0.2\,\Omega$$



Measuring parameters of synchronous generator model: Ex



The internal generated voltage at the rated field current is

$$E_A = V_{\phi,OC} = \frac{V_T}{\sqrt{3}} = \frac{540}{\sqrt{3}} = 311.8\,V$$

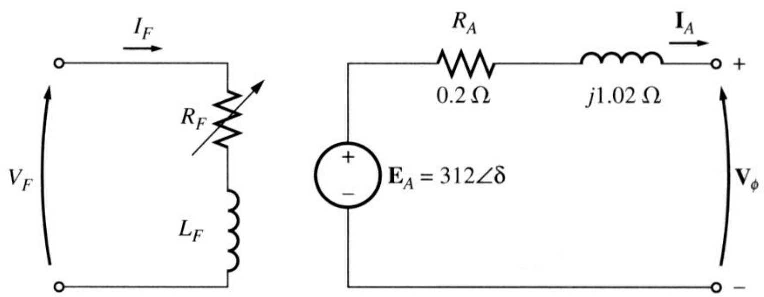
The synchronous reactance at the rated field current is precisely

$$X_S = \sqrt{Z_S^2 - R_A^2} = \sqrt{\frac{E_A^2}{I_{A,SC}^2} - R_A^2} = \sqrt{\frac{311.8^2}{300^2} - 0.2^2} = 1.02\,\Omega$$

We observe that if X_S was estimated via the approximate formula, the result would be:

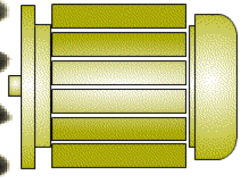
$$X_S \approx \frac{E_A}{I_{A,SC}} = \frac{311.8}{300} = 1.04\,\Omega$$

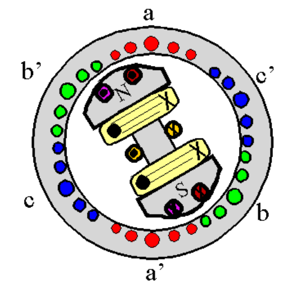
Which is close to the previous result. The error ignoring R_A is much smaller than the error due to core saturation.



The equivalent circuit


PresenterMedia




a
b'
c'
c
b
a'
N
S

END OF LECTURE 13