LECTURE 5

Determination of the parameters of the equivalent circuit from test data

- The equivalent circuit of a synchronous generator that has been derived contains three quantities that must be determined in order to completely describe the behaviour of a real synchronous generator:
  - The saturation characteristic: relationship between I_f and ϕ (and therefore between I_f and E_f)
  - The synchronous reactance, X_s
  - The armature resistance, R_a

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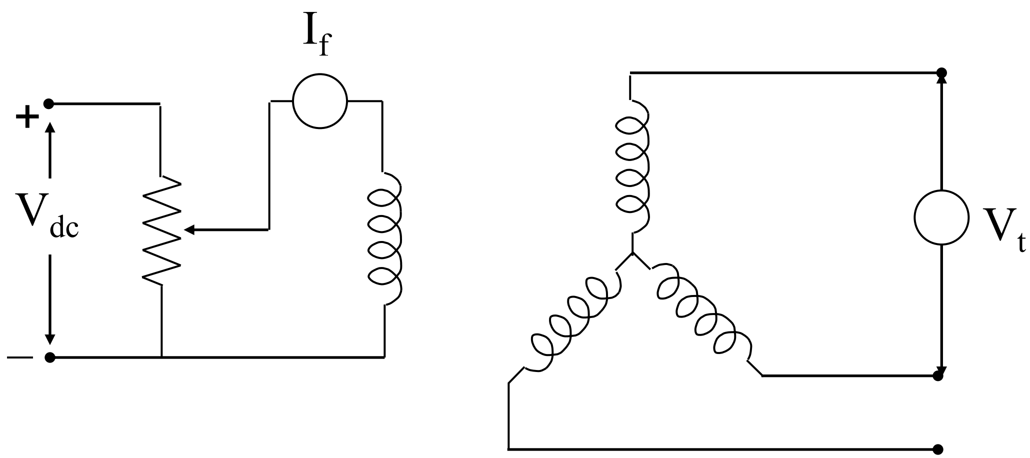
- The above three quantities could be determined by performing the following three tests:
  - Open-circuit test
  - Short-circuit test
  - DC test

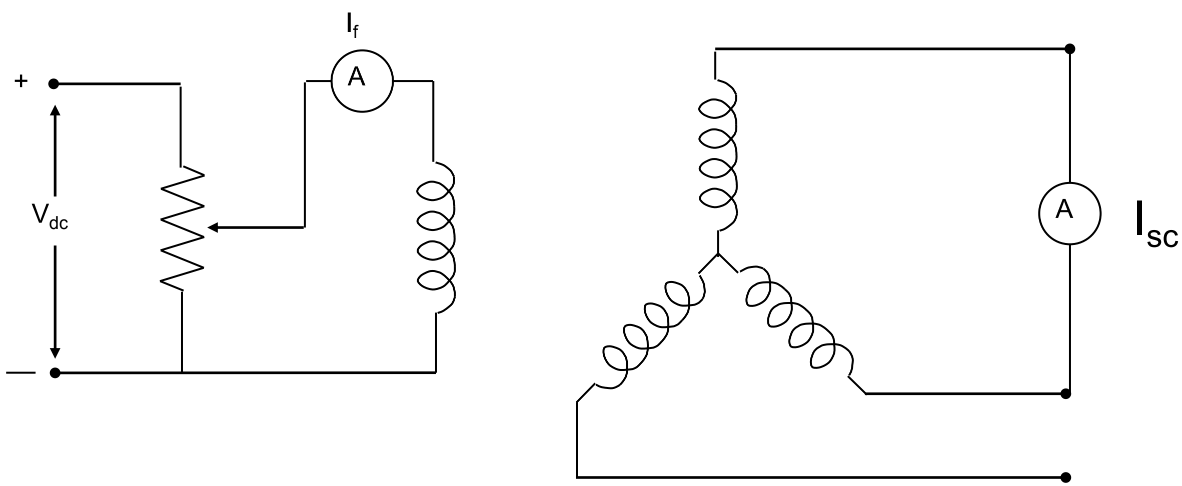
Open-circuit test

- The generator is turned at the rated speed
- The terminals are disconnected from all loads, and the field current is set to zero.
- Then the field current is gradually increased in steps, and the terminal voltage is measured at each step along the way.
- It is thus possible to obtain an open-circuit characteristic of a generator (E_f or V_t versus I_f) from this information



Short-circuit test

- Adjust the field current to zero and short-circuit the terminals of the generator through a set of ammeters.
- Record the armature current I_{sc} as the field current is increased.
- Such a plot is called short-circuit characteristic.



DC Test

- The purpose of the DC test is to determine R_a. A variable DC voltage source is connected between two stator terminals.
- The DC source is adjusted to provide approximately rated stator current, and the resistance between the two stator leads is determined from the voltmeter and ammeter readings
- then $$R_{DC} = \frac{V_{DC}}{I_{DC}}$$
- If the stator is Y-connected, the per phase stator resistance is

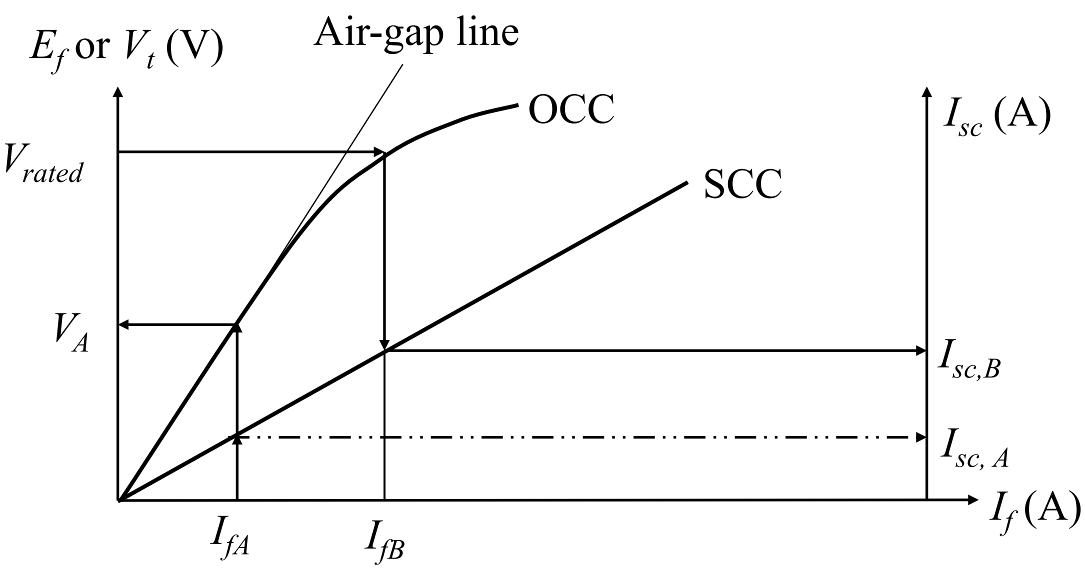
$$\boldsymbol{R_a = \frac{R_{DC}}{2}}$$

- If the stator is delta-connected, the per phase stator resistance is

$$\boldsymbol{R_a = \frac{3}{2} R_{DC}}$$

Determination of X_s

- For a particular field current I_{fA}, the internal voltage E_f ($=V_A$) could be found from the occ and the short-circuit current flow $I_{sc,A}$ could be found from the scc.
- Then the synchronous reactance X_s could be obtained using



$$Z_{s,unsat} = \sqrt{R_a^2 + X_{s,unsat}^2} = \frac{V_A(=E_f)}{|I_{scA}|}$$

$$X_{s,unsat} = \sqrt{Z_{s,unsat}^2 - R_a^2}$$

: R_a is known from the DC test.

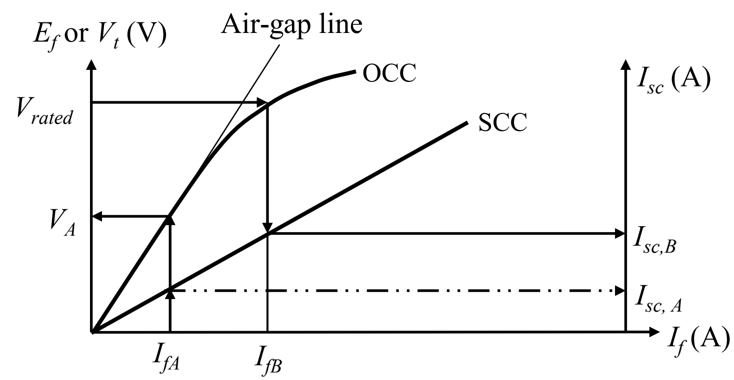
Since $X_{s,unsat} >> R_a$,

$$X_{s,unsat} \approx \frac{E_f}{I_{scA}} = \frac{V_{t,oc}}{I_{scA}}$$

X_s under saturated condition

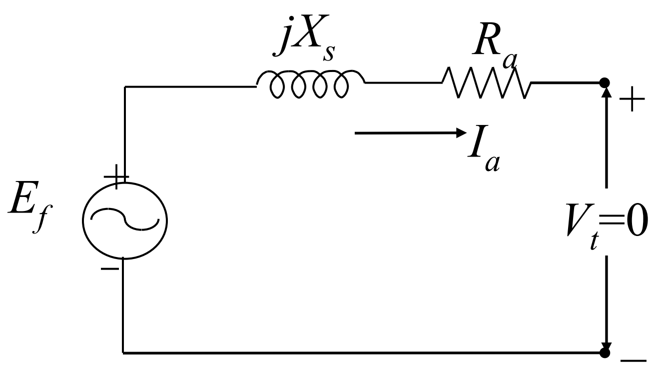
At $V = V_{rated}$,

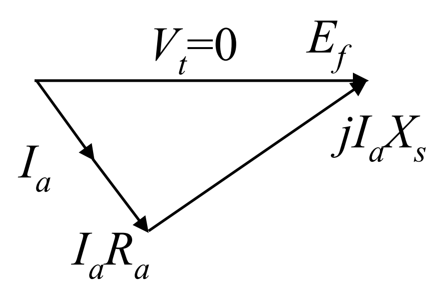
$$Z_{s,sat} = \sqrt{R_a^2 + X_{s,sat}^2} = \frac{V_{rated}\left(= E_f\right)}{\left|I_{scB}\right|}$$



$$X_{s,sat} = \sqrt{Z_{s,sat}^2 - R_a^2}$$ R_a is known from the DC test.

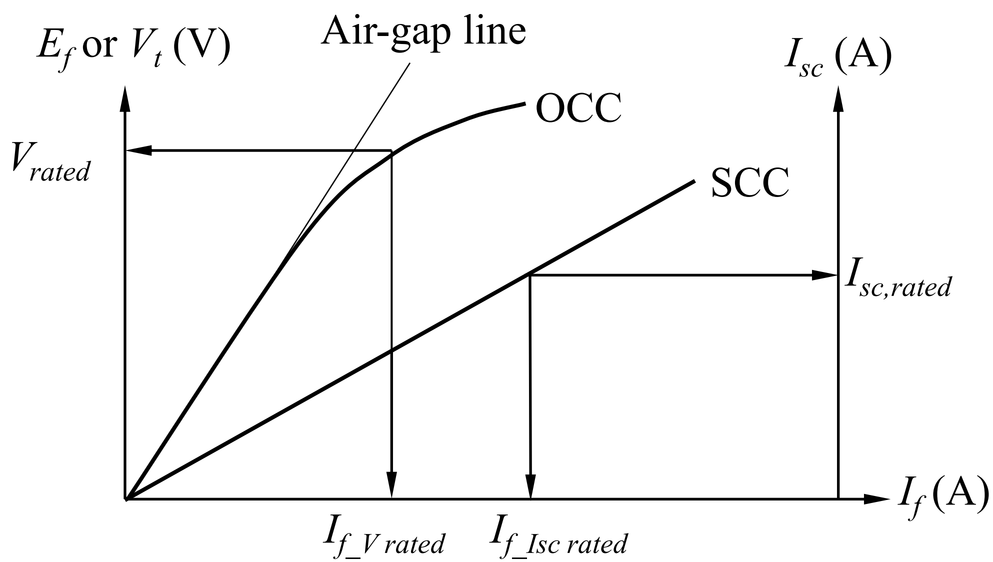
Equivalent circuit and phasor diagram under condition





Short-circuit Ratio

Another parameter used to describe synchronous generators is the short-circuit ratio (*SCR*). The SCR of a generator defined as the ratio of the *field current required for the rated voltage at open circuit* to the *field current required for the rated armature current at short circuit*. *SCR* is just the reciprocal of the per unit value of the saturated synchronous reactance calculated by



$$SCR = \frac{I_{f\_Vrated}}{I_{f\_Iscrated}} = \frac{1}{X_{s\_sat}\,[in\ p.u.]}$$