LECTURE 4

Induced Emf in a synchronous machine

- E(average)=PZNø/60A
- E(rms)/E(average)=1.11
- E(rms)=2.22PøNT/60 (Z=2T)
- N=120f/P
- 2f=PN/60
- E=2.22øT*2f
- E=4.44øfT

Generated Voltage(OCC)

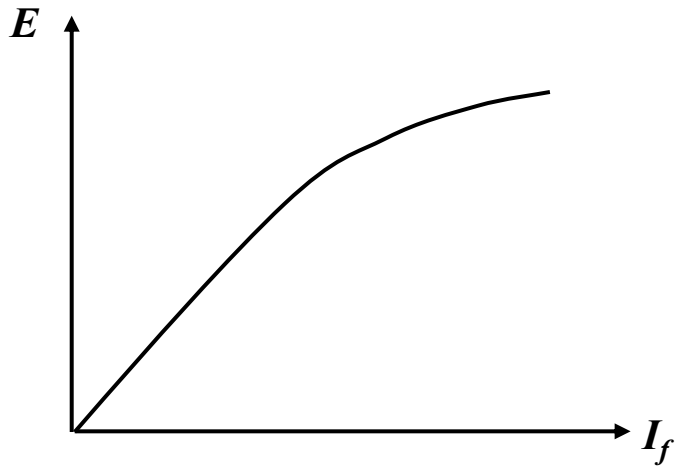
The generated voltage of a synchronous generator is given by

$$E = K_c \phi f_e$$

where ϕ **= flux in the machine (function of** I_f**)**

f_e **= electrical frequency**

K_c **= synchronous machine constant**



Saturation characteristic of a synchronous generator.

Synchronous Machine Equivalent Circuit

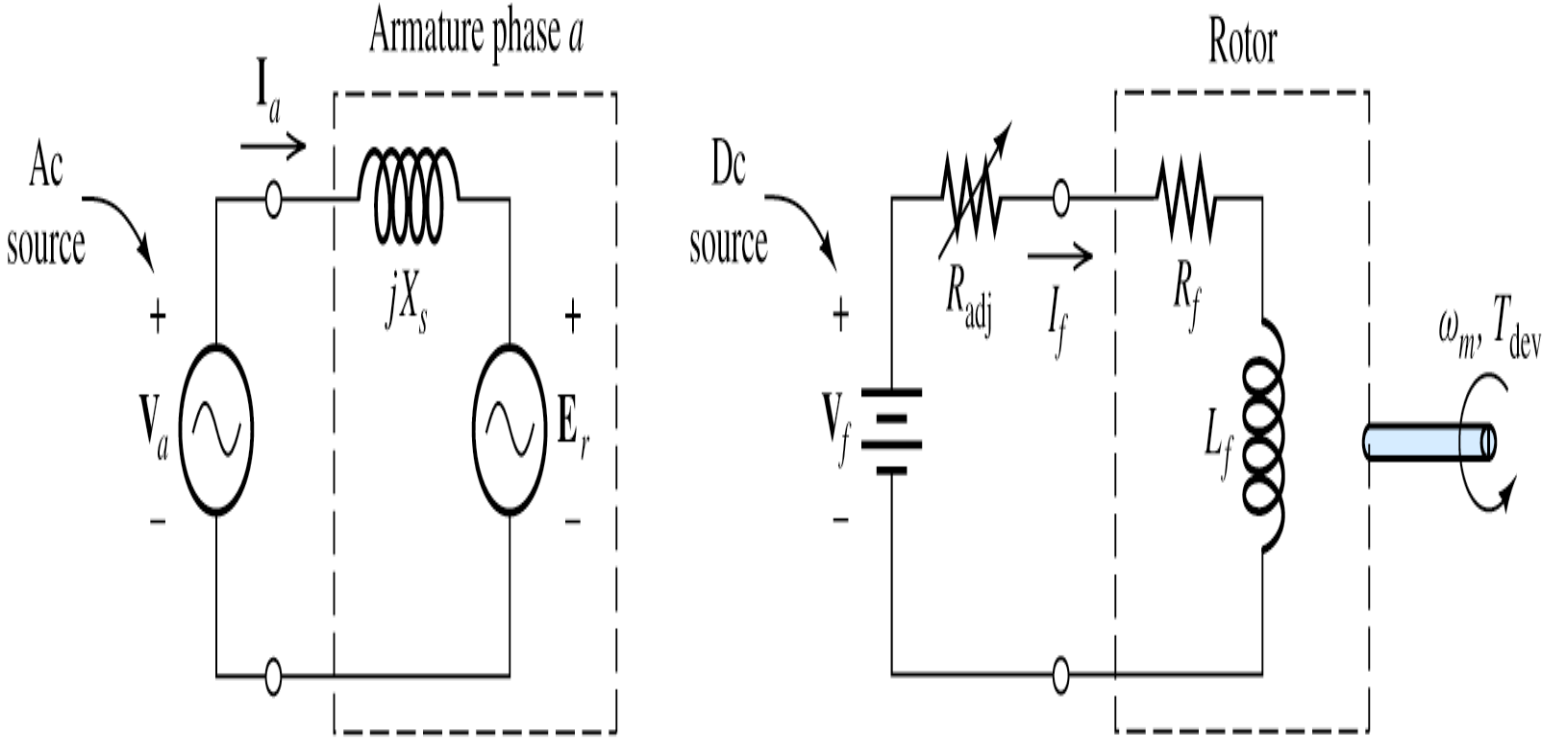


Figure 17.18 Equivalent circuit for the synchronous motor. The armature circuit is based on Equation 17.42.

Synchronous Reactance

- Equivalent circuit of a synchronous generator:

Each phase has resistance R and inductance L

Synchronous reactance:

$X_s = 2\pi fL$

R is typically << Xs, therefore neglected unless interested in efficiency or heating effects

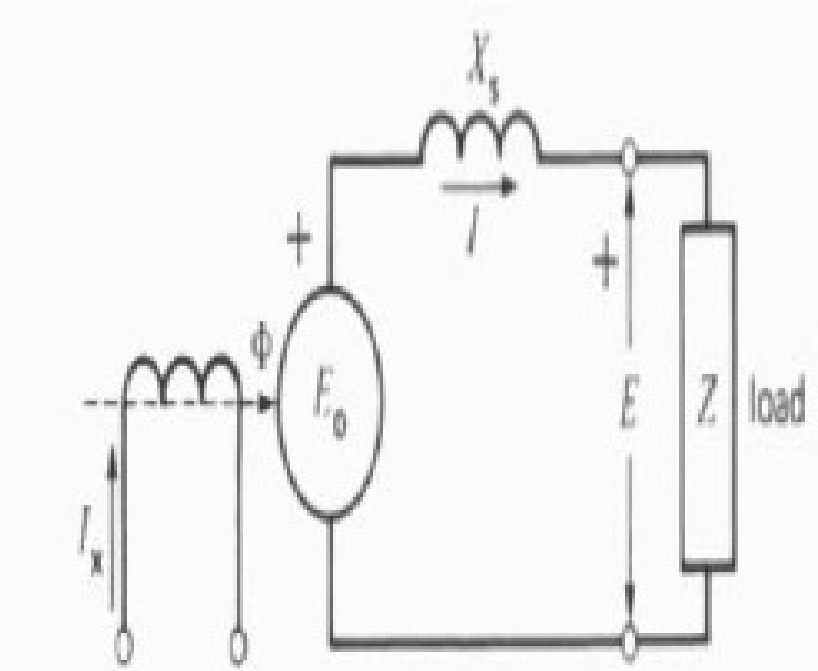


Figure 16.17
Equivalent circuit of a 3-phase generator, showing only one phase.

Voltage Regulation

A convenient way to compare the voltage behaviour of two generators is by their *voltage regulation* (*VR*). The *VR* of a synchronous generator at a given load, power factor, and at rated speed is defined as

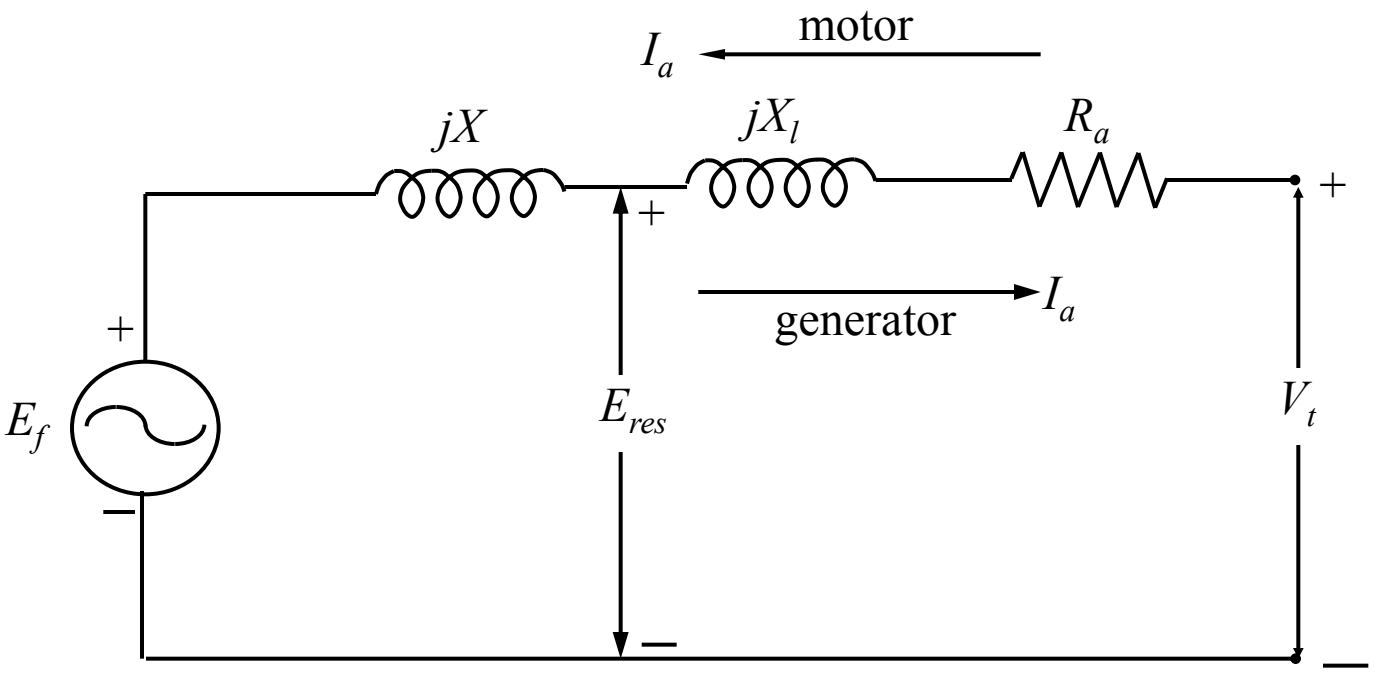
$$VR = \frac{E_{nl} - V_{fl}}{V_{fl}} \times 100\%$$

Where V_{fl} is the full-load terminal voltage, and E_{nl} (equal to E_f) is the no-load terminal voltage (internal voltage) at rated speed when the load is removed without changing the field current. For lagging power factor (*PF*), *VR* is fairly positive, for unity *PF*, *VR* is small positive and for leading *PF*, *VR* is negative.

Equivalent Circuit_1

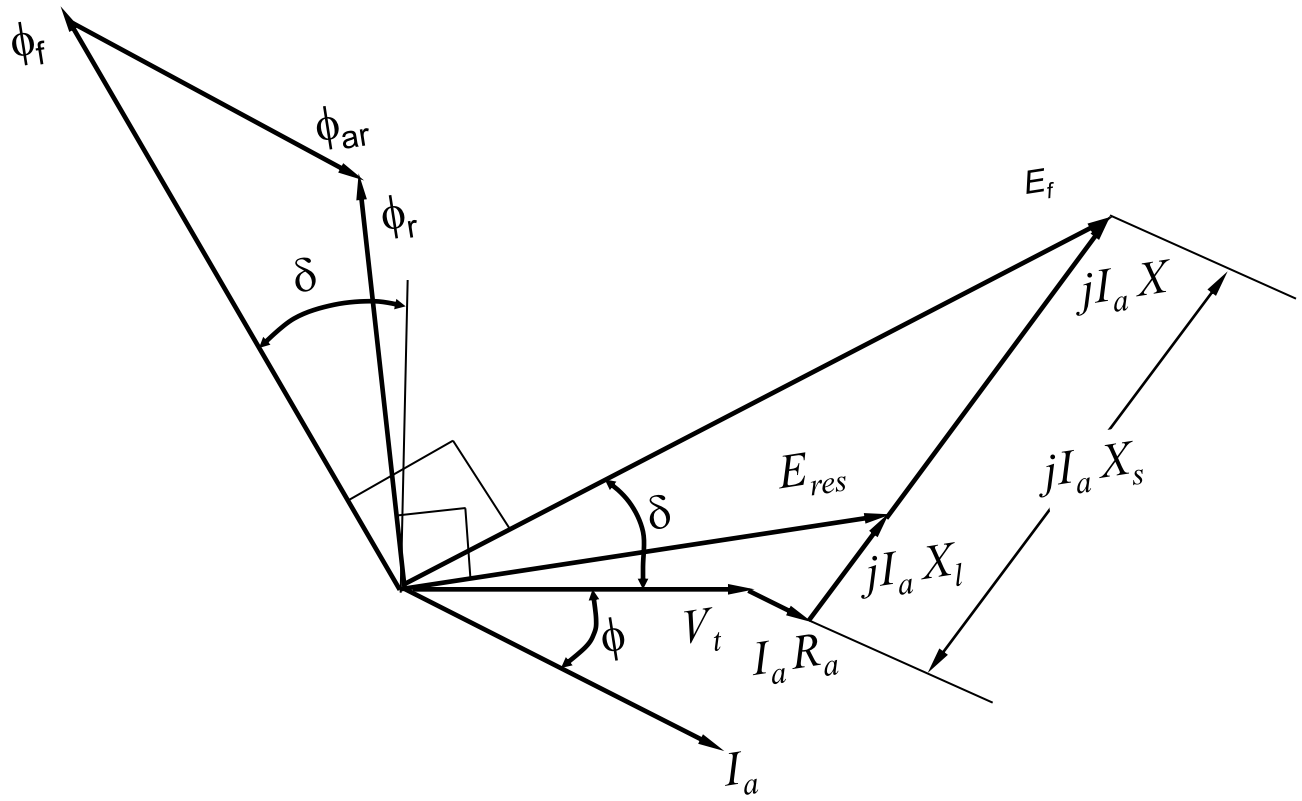
- The internal voltage E_f produced in a machine is not usually the voltage that appears at the terminals of the generator.
- The only time E_f is same as the output voltage of a phase is when there is no armature current flowing in the machine.
- There are a number of factors that cause the difference between E_f and V_t:
  - The distortion of the air-gap magnetic field by the current flowing in the stator, called the armature reaction
  - The self-inductance of the armature coils.
  - The resistance of the armature coils.
  - The effect of salient-pole rotor shapes.

Equivalent Circuit_2



Equivalent circuit of a cylindrical-rotor synchronous machine

Phasor Diagram



Phasor diagram of a cylindrical-rotor synchronous generator, for the case of lagging power factor

Lagging PF: $|V_t|<|E_f|$ for overexcited condition
Leading PF: $|V_t|>|E_f|$ for underexcited condition

Three-phase equivalent circuit of a cylindrical-rotor synchronous machine

The voltages and currents of the three phases are 120^o apart in angle, but otherwise the three phases are identical.