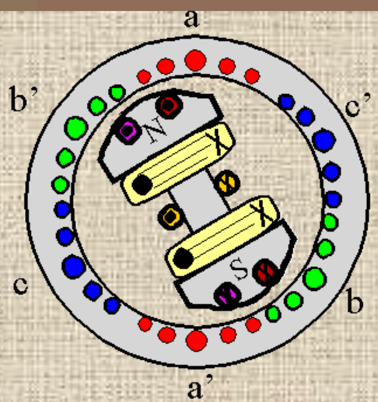
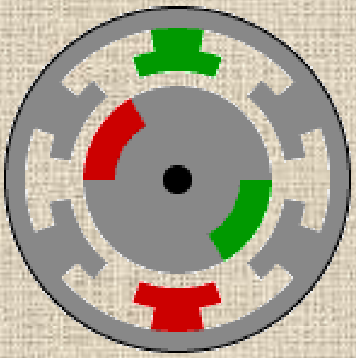
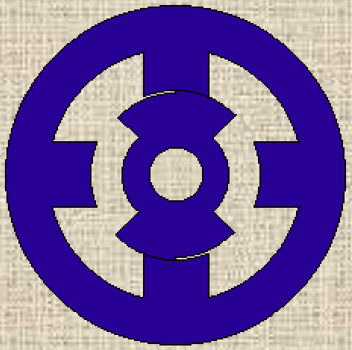
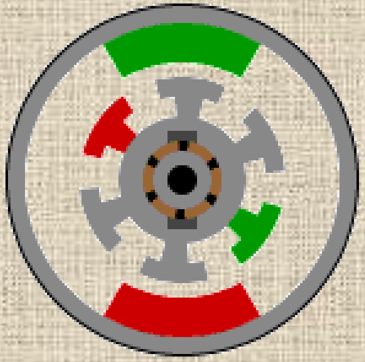
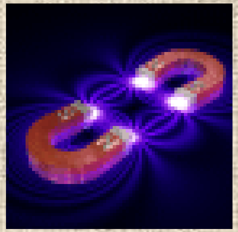
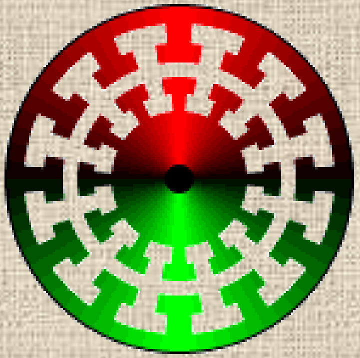


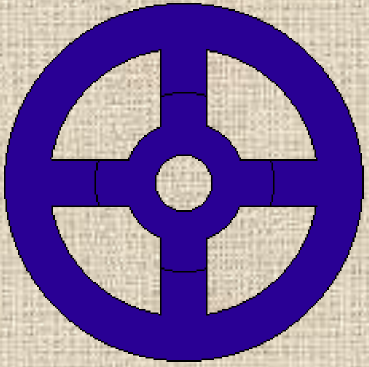
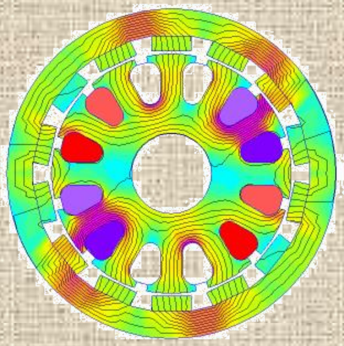
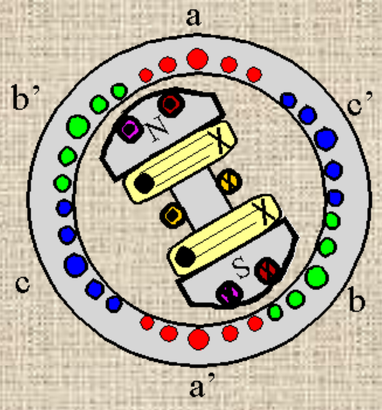




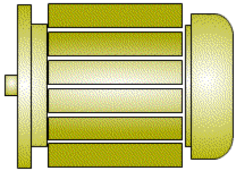
EE552 ELECTRICAL MACHINES III



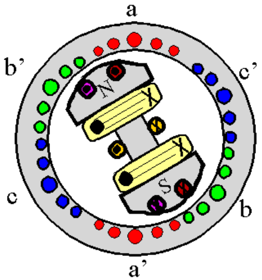
LECTURE 14



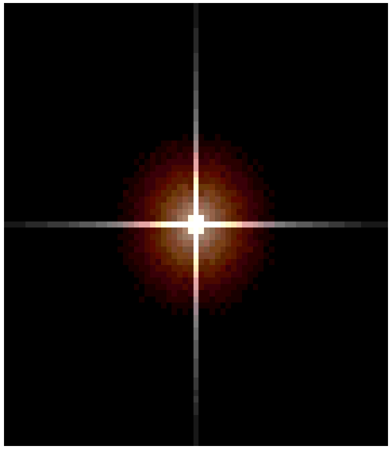







LECTURE NOTES



ELECTRICAL MACHINES III



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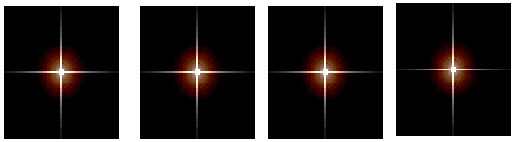

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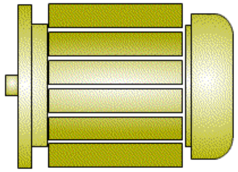
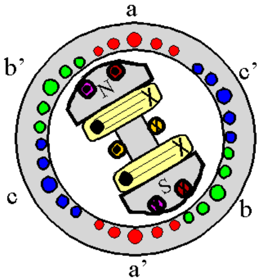
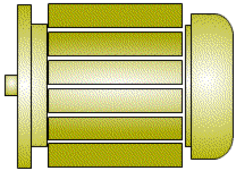


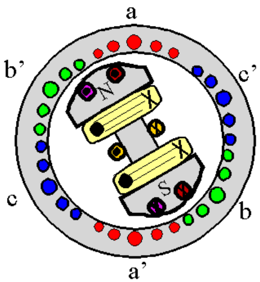


LECTURE 14

SYNCHRONOUS GENERATOR



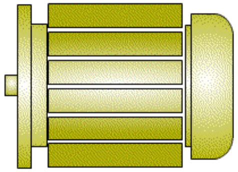
The Synchronous generator operating alone



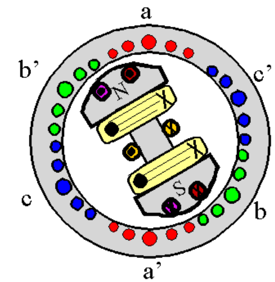
The behavior of a synchronous generator varies greatly under load depending on the power factor of the load and on whether the generator is working alone or in parallel with other synchronous generators.

Although most of the synchronous generators in the world operate as parts of large power systems, we start our discussion assuming that the synchronous generator works alone.

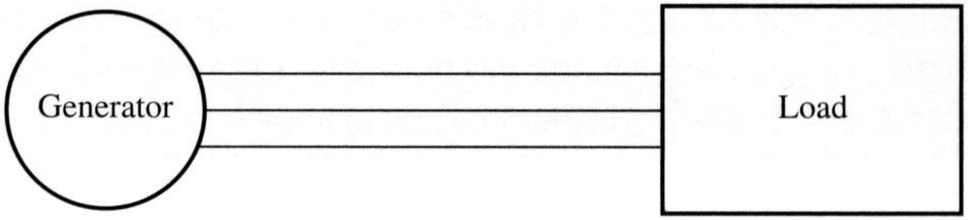
Unless otherwise stated, the speed of the generator is assumed constant.



The Synchronous generator operating alone



Effects of load changes



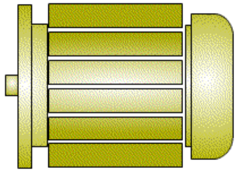
A increase in the load is an increase in the real and/or reactive power drawn from the generator.

Since the field resistor is unaffected, the field current is constant and, therefore, the flux ϕ is constant too. Since the speed is assumed as constant, the magnitude of the internal generated voltage is constant also.

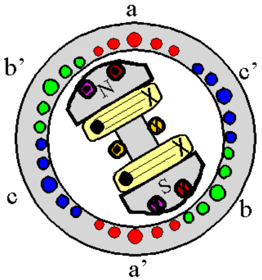
Assuming the same power factor of the load, change in load will change the magnitude of the armature current I_A. However, the angle will be the same (for a constant PF). Thus, the armature reaction voltage jX_SI_A will be larger for the increased load. Since the magnitude of the internal generated voltage is constant

$$E_A = V_\phi + jX_S I_A$$

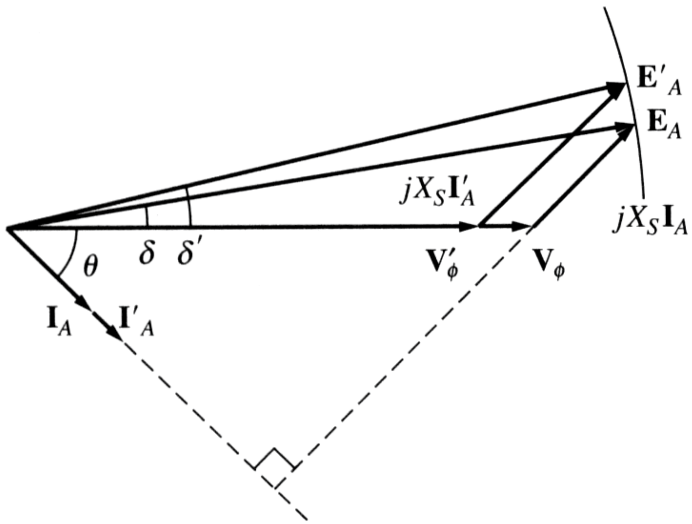
Armature reaction voltage vector will "move parallel" to its initial position.



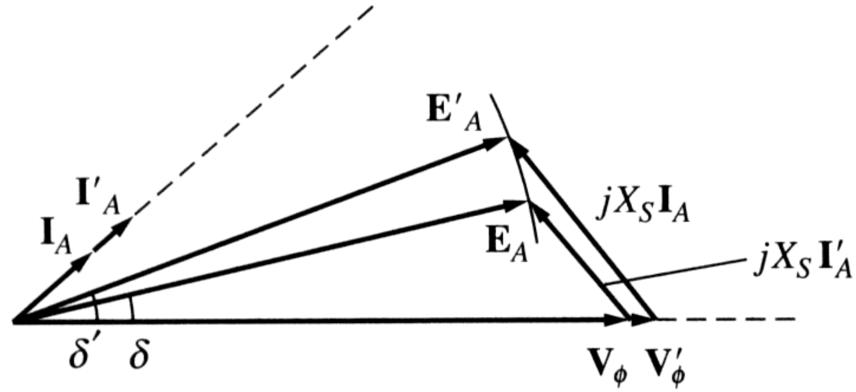
The Synchronous generator operating alone



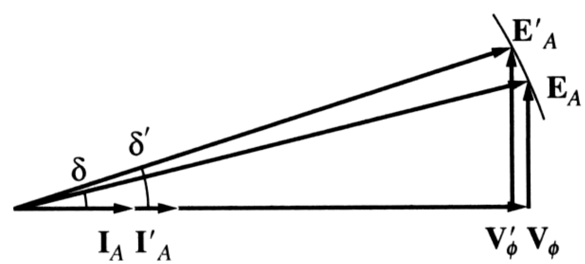
Increase load effect on generators with



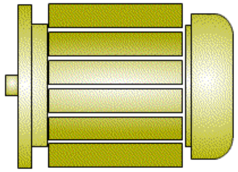
Lagging PF



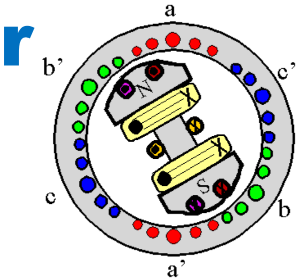
Leading PF



Unity PF

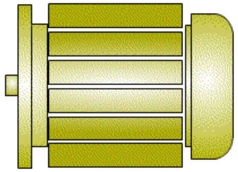


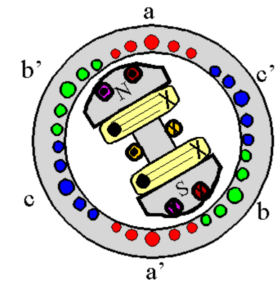
The Synchronous generator operating alone



Generally, when a load on a synchronous generator is added, the following changes can be observed:

1. **For lagging (inductive) loads, the phase (and terminal) voltage decreases significantly.**
2. **For unity power factor (purely resistive) loads, the phase (and terminal) voltage decreases slightly.**
3. **For leading (capacitive) loads, the phase (and terminal) voltage rises.**



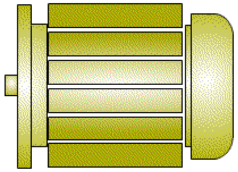


Effects of adding loads can be described by the voltage regulation:

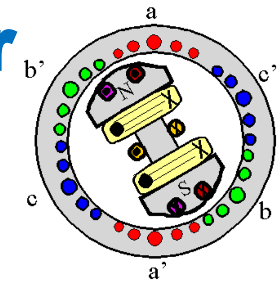
$$VR = \frac{V_{nl} - V_{fl}}{V_{fl}} 100\%$$

Where V_{nl} is the no-load voltage of the generator and V_{fl} is its full-load voltage.

A synchronous generator operating at a lagging power factor has a fairly large positive voltage regulation. A synchronous generator operating at a unity power factor has a small positive voltage regulation. A synchronous generator operating at a leading power factor often has a negative voltage regulation.



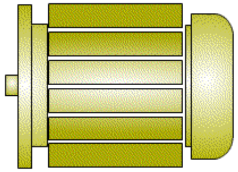
The Synchronous generator operating alone



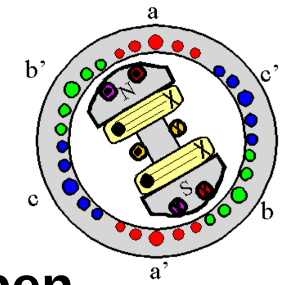
Normally, a constant terminal voltage supplied by a generator is desired. Since the armature reactance cannot be controlled, an obvious approach to adjust the terminal voltage is by controlling the internal generated voltage $E_A = K\phi\omega$. This may be done by changing flux in the machine while varying the value of the field resistance R_F, which is summarized:

1. Decreasing the field resistance increases the field current in the generator.
2. An increase in the field current increases the flux in the machine.
3. An increased flux leads to the increase in the internal generated voltage.
4. An increase in the internal generated voltage increases the terminal voltage of the generator.

Therefore, the terminal voltage of the generator can be changed by adjusting the field resistance.



Example



A 3-phase synchronous generator produces an open-circuit line voltage of 6928 V when the dc exciting current is 50 A. The ac terminals are then short-circuited under the same excitation, the three line currents are 800 A

1) Calculate the per-phase synchronous reactance
2) Calculate the resulting terminal voltage if 12-ohm resistors are connected in wye across the terminals

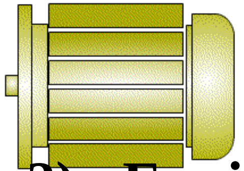
Solution:

1) Line to neutral induced voltage is

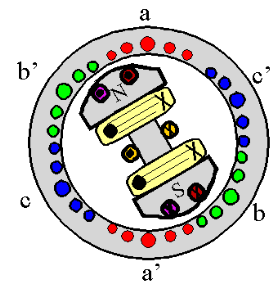
$$E_O = E_L/\sqrt{3} = 6928/\sqrt{3} = 4000V$$

Neglecting resistance, synchronous reactance per phase is

$$X_S = E_n/I_{SC} = 4000/800 = 5\Omega$$



Example



2) Equivalent circuit per phase is shown

The impedance can be calculated as:

$$Z = \sqrt{R^2 + X_s^2} = \sqrt{12^2 + 5^2} = 13\Omega$$

The current is :

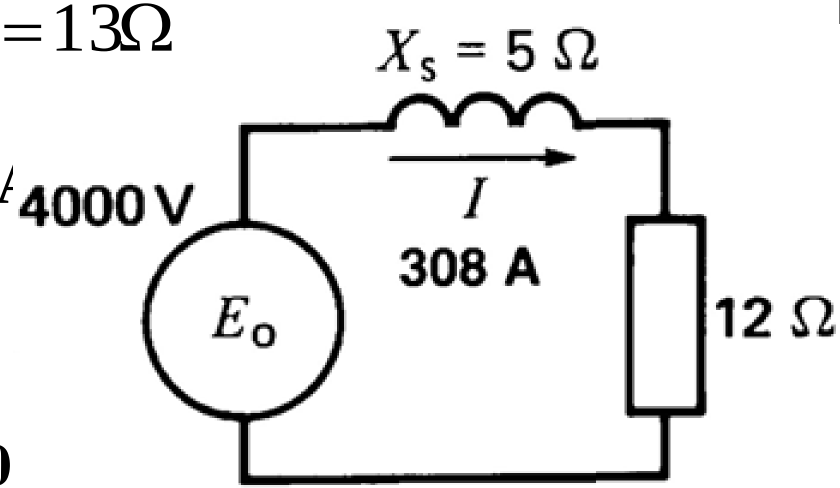
$I = E_O / Z = 4000 / 13 = 308$ A

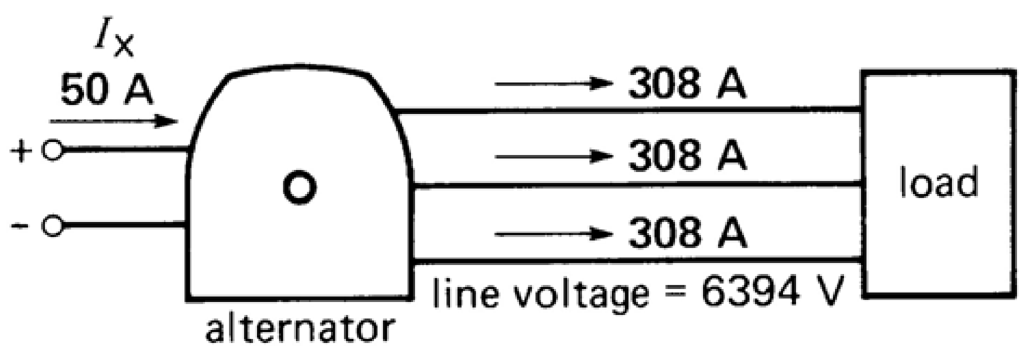
Voltage across the resistor is:

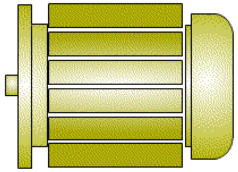
$E = I\,R = 308 \times 12 = 3696$ V

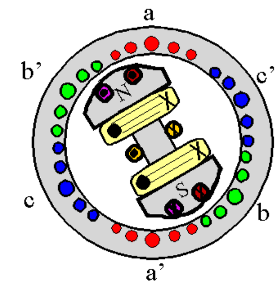
The line voltage under load is:

$E_L = \sqrt{3}\,E = \sqrt{3} \times 3696 = 640$








a
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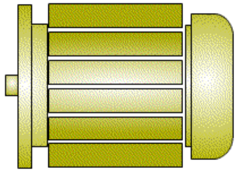

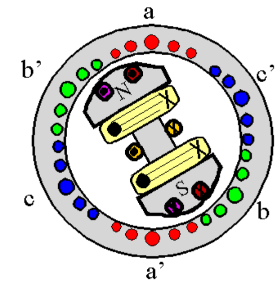
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