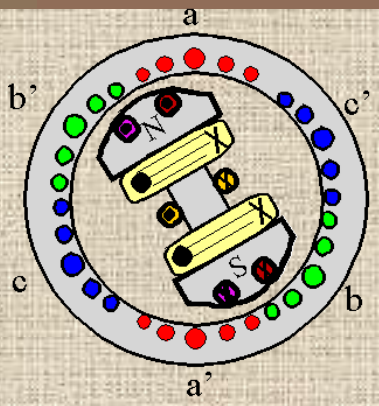
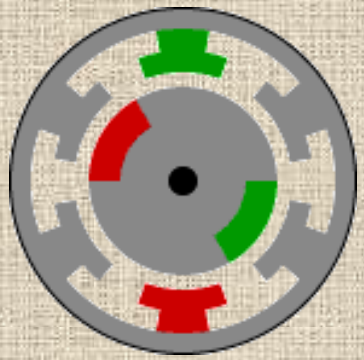
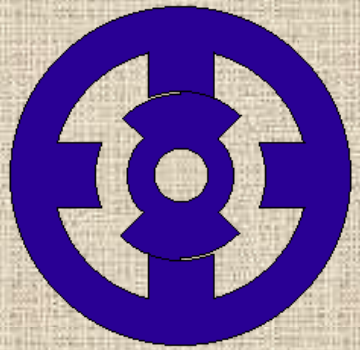
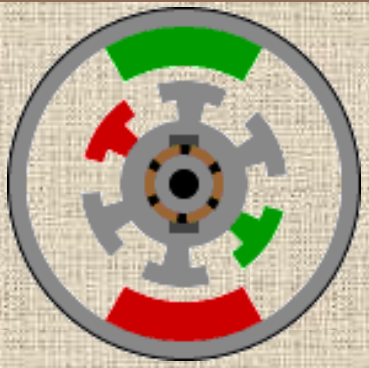
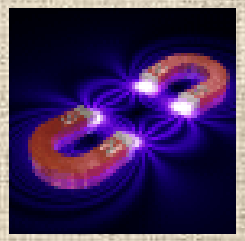




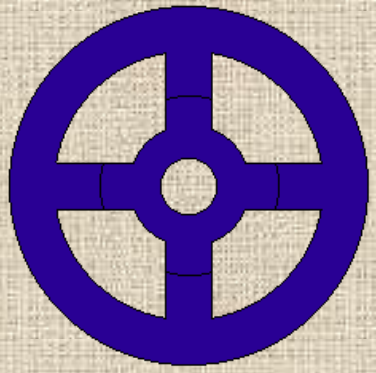


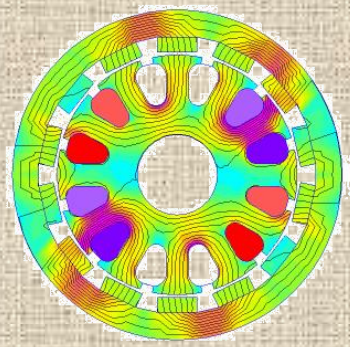


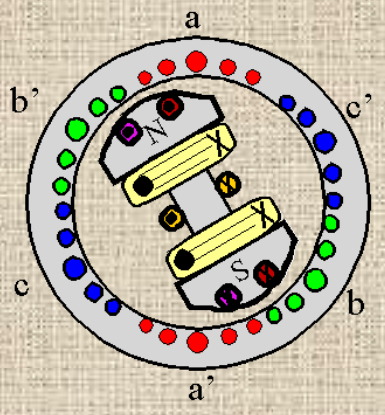
EE552 ELECTRICAL MACHINES III



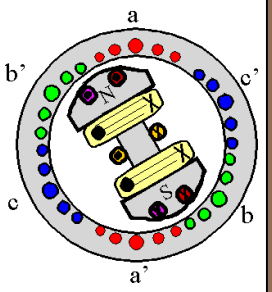
LECTURE 5



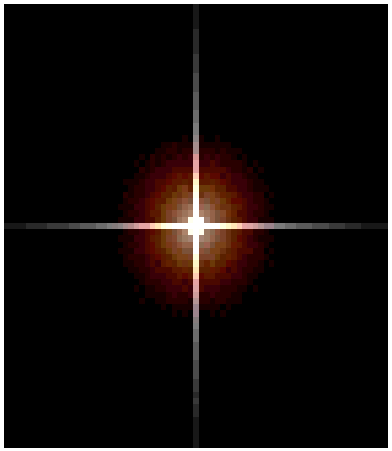




LECTURE NOTES



ELECTRICAL MACHINES III



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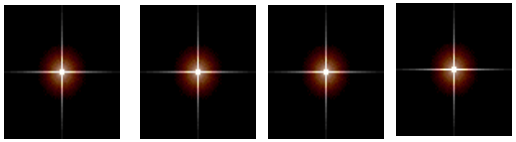
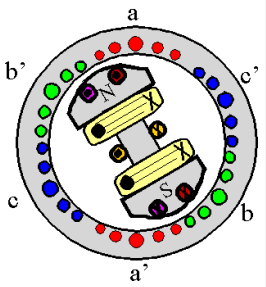


SPRING 2018

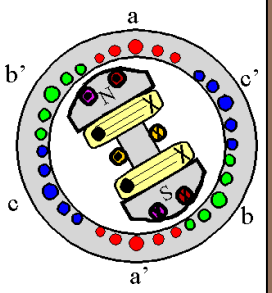
Dr : MUSTAFA AL-REFAI



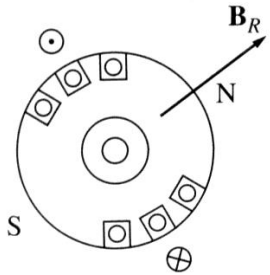
LECTURE 5

SYNCHRONOUS MACHINES

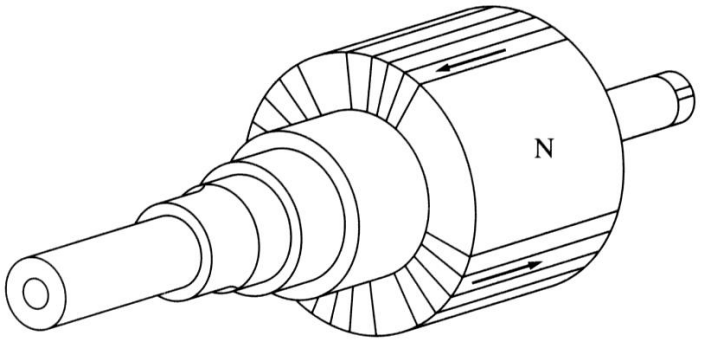
Construction of synchronous machines



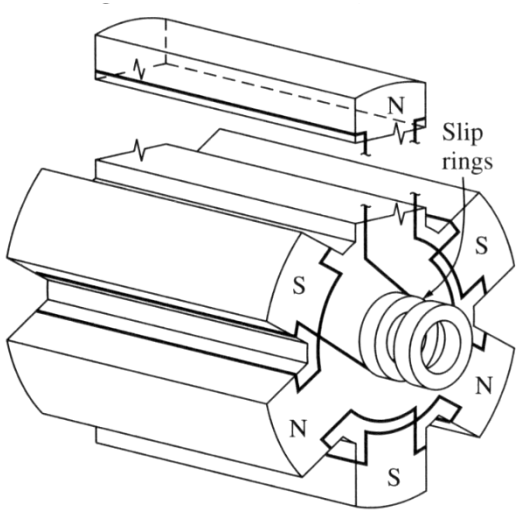
The rotor of a synchronous machine is a large electromagnet. The magnetic poles can be either salient (sticking out of rotor surface) or non-salient construction.



End view



Side view

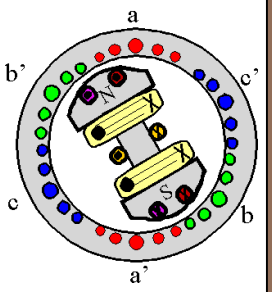


Non-salient-pole rotor: usually two- and four-pole rotors.

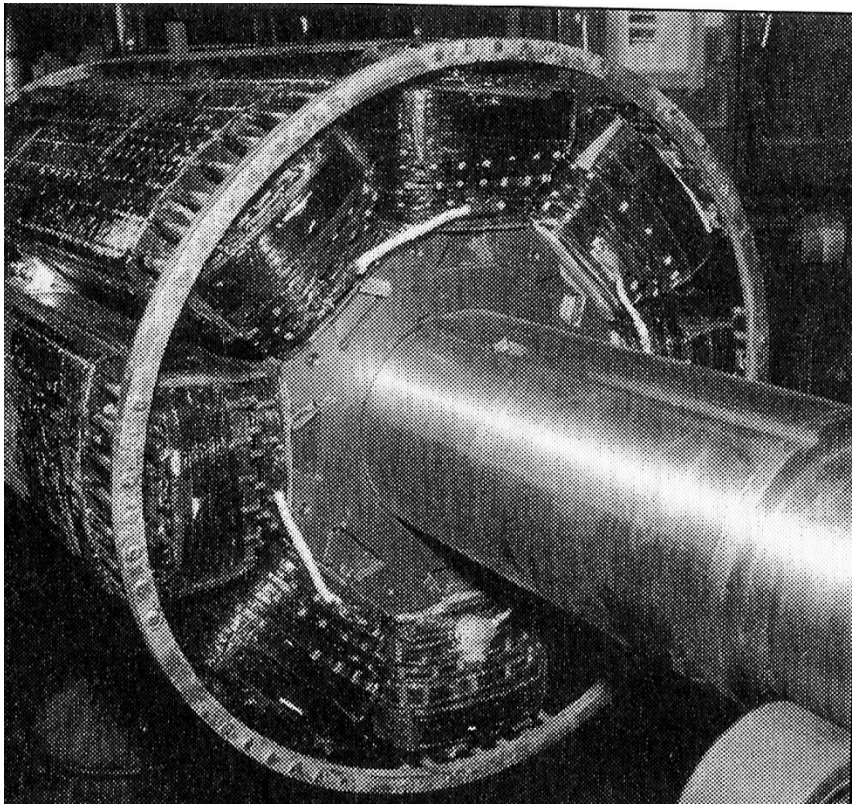
Salient-pole rotor: four and more poles.

Rotors are made laminated to reduce eddy current losses.

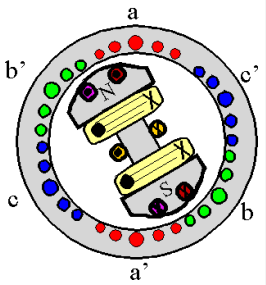
SYNCHRONOUS GENERATOR CONSTRUCTION



- Photograph of a salient 8-pole synchronous machine rotor



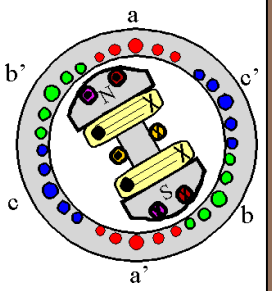
SYNCHRONOUS GENERATOR CONSTRUCTION



- **Rotor** experience varying magnetic fields, therefore is constructed of thin laminations to reduce eddy current losses
- To supply the rotor winding while it is rotating, special arrangement employed to connect its terminal to dc supply

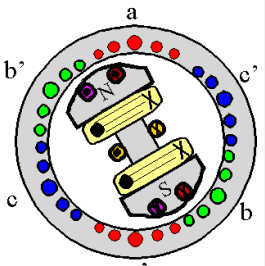
1. supply dc power from an external dc source to rotor by means of slip rings
2. supply dc power from a special dc power source mounted on shaft of rotor

SYNCHRONOUS GENERATOR CONSTRUCTION



- **SLIP RINGS:** are metal rings encircling shaft and are insulated from it
  - one end of rotor winding is connected to each of the 2 slip rings
  - and a stationary brush mounted on the machine casing ride on each slip ring
- **Brush:** a block of graphite like carbon compound that conducts and has low friction
- same dc voltage is applied to field winding during rotation

Construction of synchronous machines



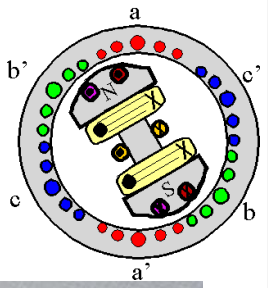
Two common approaches are used to supply a DC current to the field circuits on the rotating rotor:

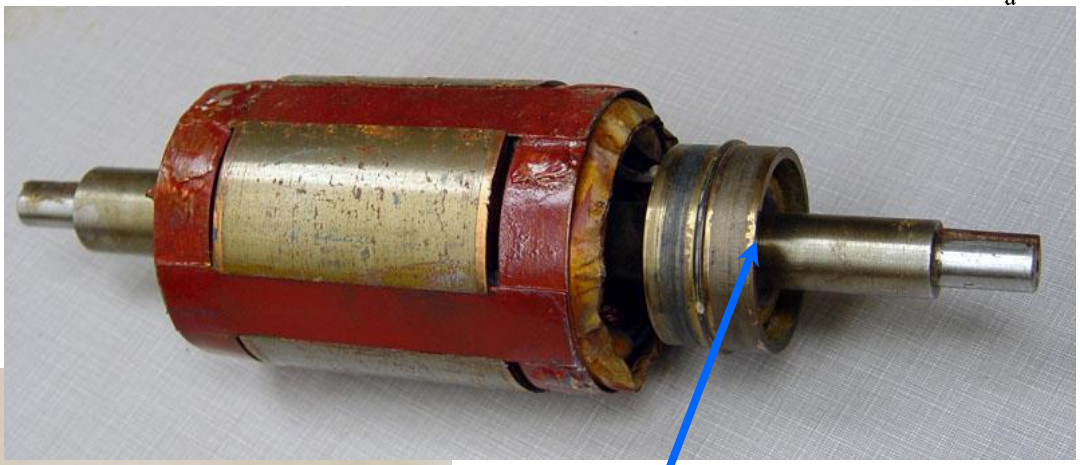
1. **Supply the DC power from an external DC source to the rotor by means of slip rings and brushes;**

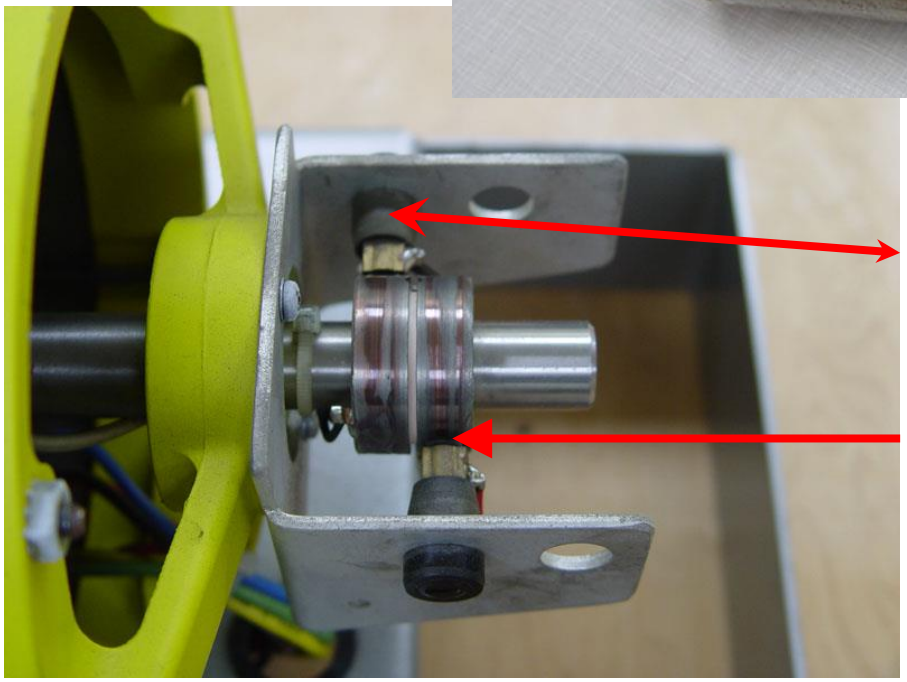
2. **Supply the DC power from a special DC power source mounted directly on the shaft of the machine.**

Slip rings are metal rings completely encircling the shaft of a machine but insulated from it. One end of a DC rotor winding is connected to each of the two slip rings on the machine's shaft. Graphite-like carbon brushes connected to DC terminals ride on each slip ring supplying DC voltage to field windings regardless the position or speed of the rotor.

Construction of synchronous machines



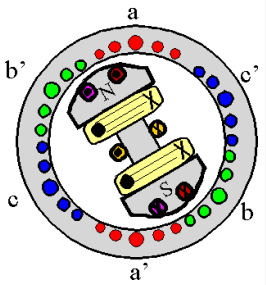




Slip rings

Brush

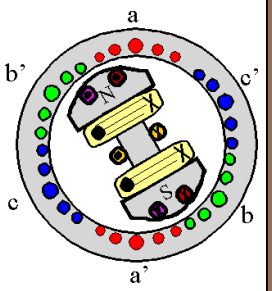
Synchronous Machines - Rotor



Solid steel rotor with single winding (field winding) supplied by DC current DC current fed into rotor through slip – rings or brushless excitation system mounted on same shaft as motor

- **Field exciters use 2.5% 0.5 % rated power of generator to produce rotor field.**
- **Excitation of larger machines are more efficient**
- **Rotor driven at appropriate synchronous speed**

SYNCHRONOUS GENERATOR CONSTRUCTION



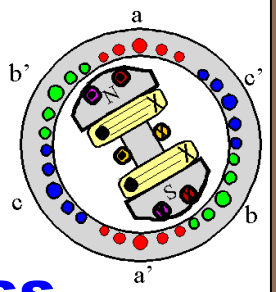
- **Problems associated with slip rings and brushes:**

  1- increase the required maintenance (brushes should be examined for wear regularly)

  2- brush voltage drop results in significant power losses if field current is high

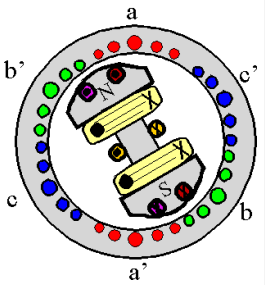
- **Despite of above problems, SLIP RINGS & BRUSHES used for smaller synchronous machines since is cost-effective**

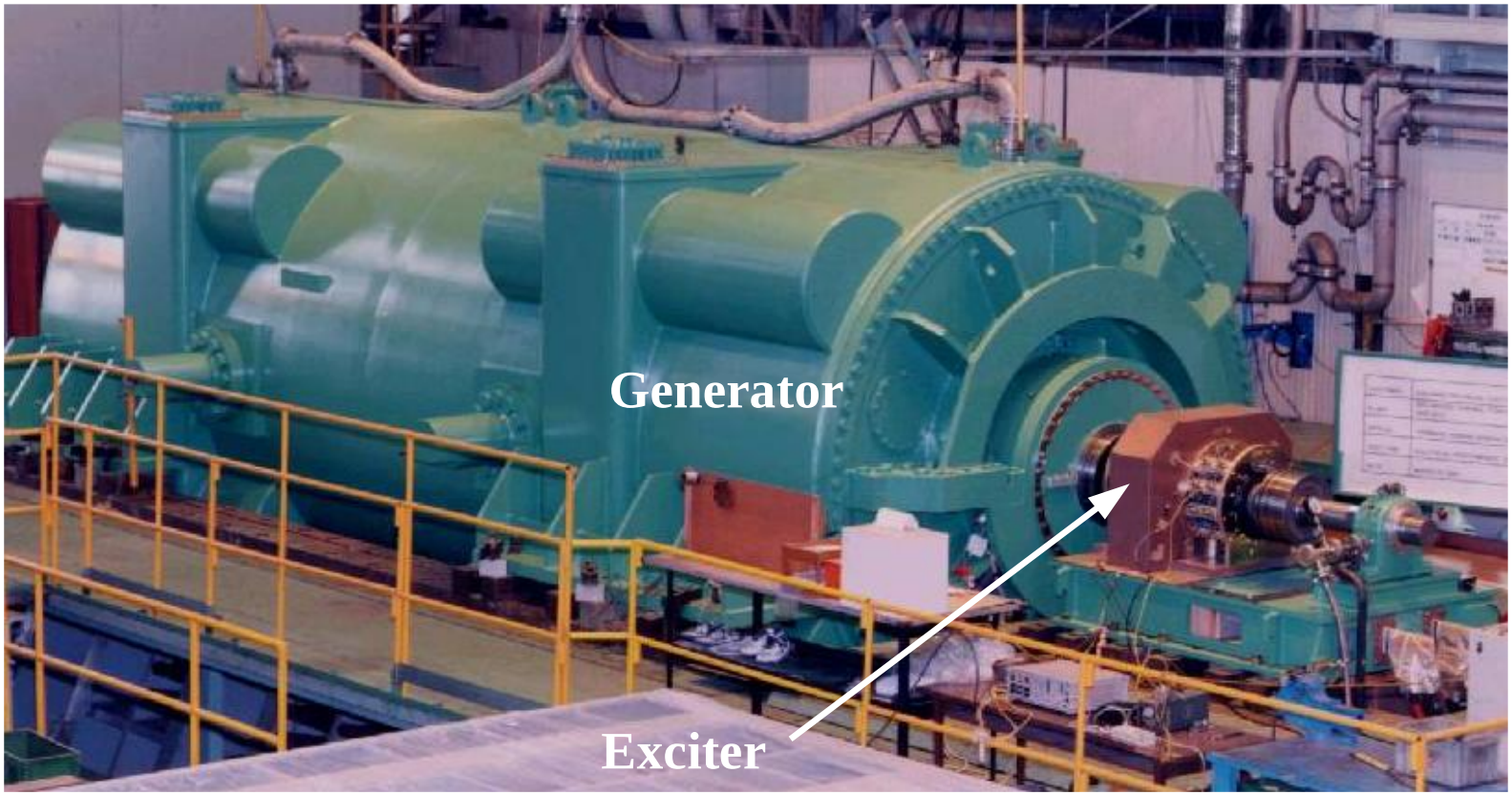
SYNCHRONOUS GENERATOR CONSTRUCTION



- on larger generator & motors, brushless exciters are used
- **Brushless Exciter:** is a smaller ac generator with its field circuit mounted on stator & its armature circuit mounted on rotor shaft
  - 3 phase output of exciter generator rectified by a 3 phase rectifier mounted also on shaft
- By controlling small dc field current of exciter generator, it is possible to fed (and also adjust) field current of main machine without slip rings and brushes

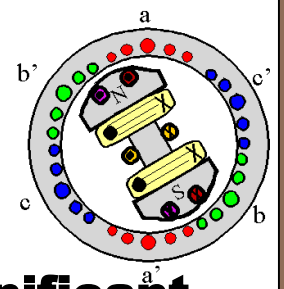
Synchronous Generators





View of a two-pole round rotor generator and exciter. (Westinghouse)

Construction of synchronous machines



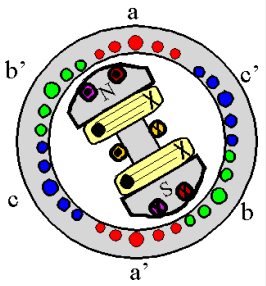
Slip rings and brushes have certain disadvantages: increased friction and wear (therefore, needed maintenance), brush voltage drop can introduce significant power losses. Still this approach is used in most *small* synchronous machines.

On large generators and motors, brushless exciters are used.

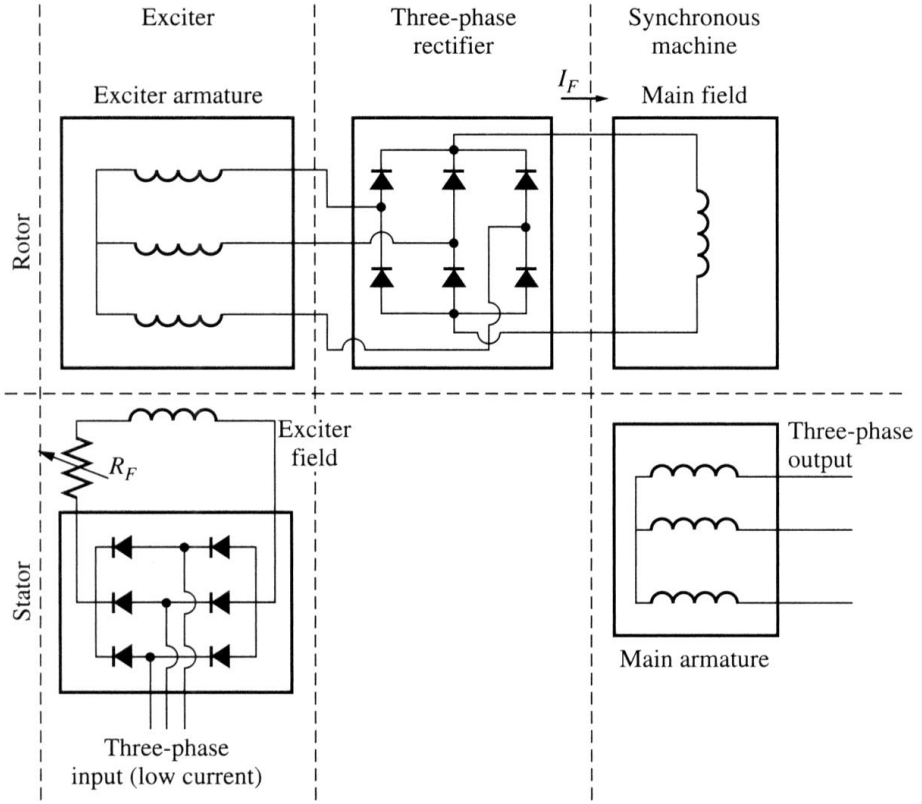
A brushless exciter is a small AC generator whose field circuits are mounted on the stator and armature circuits are mounted on the rotor shaft. The exciter generator's 3-phase output is rectified to DC by a 3-phase rectifier (mounted on the shaft) and fed into the main DC field circuit. It is possible to adjust the field current on the main machine by controlling the small DC field current of the exciter generator (located on the stator).

Since no mechanical contact occurs between the rotor and the stator, exciters of this type require much less maintenance.

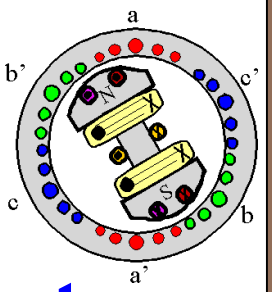
Construction of synchronous machines



A brushless exciter: a low 3-phase current is rectified and used to supply the field circuit of the exciter (located on the stator). The output of the exciter's armature circuit (on the rotor) is rectified and used as the field current of the main machine.

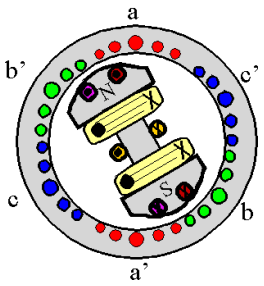


SYNCHRONOUS GENERATOR CONSTRUCTION

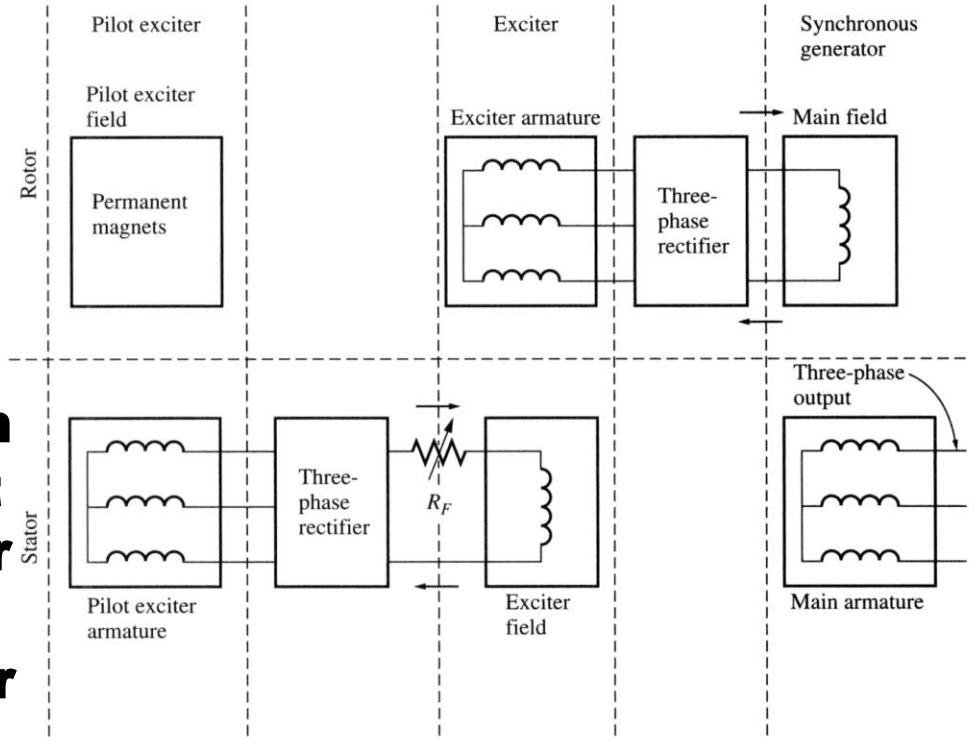


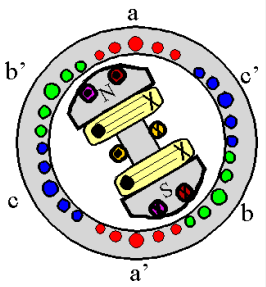
- a small pilot exciter often included in system to have the excitation of generator independent of any external power sources
- A pilot exciter is a small ac generator with permanent magnets mounted on rotor shaft & a 3 phase winding on stator
- It produces power for field circuit of exciter, which in turn controls the field circuit of main machine
- With pilot exciter on shaft of generator, no external electric power is required to run generator
- Many Syn. Gen.s with brushless exciters also have slip rings and brushes, as an auxiliary source of dc field in emergencies

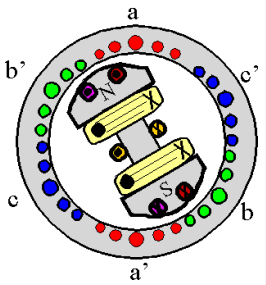
Construction of synchronous machines



To make the excitation of a generator completely independent of any external power source, a small pilot exciter is often added to the circuit. The pilot exciter is an AC generator with a permanent magnet mounted on the rotor shaft and a 3-phase winding on the stator producing the power for the field circuit of the exciter.






a
b'
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c
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END OF LECTURE 5