COURSE CODE:	*ELE 306*
COURSE TITLE:	*Electrical Machines II – Asynchrounous (Induction) Machines*
NUMBER OF UNITS:	*3 Units*
COURSE DURATION:	*Three hours per week*

COURSE DETAILS:

Course Coordinator: **OPEODU F.A**
Email: opeodufa@unaab.edu.ng
Office Location: **Civil Engineering Building**
Other Lecturers: **None**

COURSE CONTENT:

Magnetic flux, distribution of induced emf, equivalent circuit, power balance, equivalent circuit referred to stator. Torue-slip characteristics for generating and motoring actions. The circle diagram. Methods of starting and speed control. Double cage induction motor. Single phase motors.

COURSE REQUIREMENTS:

This is a compulsory course for all 200 level students in the College of Engineering. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be able to write the final examination.

READING LIST:

LECTURE NOTES

Part II : D.C Generators; D.C Motors; A.C. Generators; and AC Motors.

ELECTRICAL MACHINERY GENERALIZATIONS

Rotating Electrical Machines. Rotating electrical machines are widely used for the purpose of converting energy from one form to another. The two most frequent used types of such machines are *generators* and *motors.*

In the first of these, the generator, mechanical energy is converted into electrical energy. In the motor, electrical energy is converted into mechanical energy.

When an electric motor is in operation, it is supplied with electrical energy and develops torque, that is, a tendency to produce rotation. And if the rotating element of the motor is free to turn, it will do so and thereby cause mechanical rotation of itself and its application.

All rotating electric generators consist essentially of two important parts; (1) an even set of electromagnets or permanent magnets and (2) the laminated steel core containing current-carrying copper wires, the latter being called the *armature winding.* In the d-c generator, the armature winding is mechanically rotated through the stationary magnetic fields created by the electromagnets or the permanent magnets; in the a-c generator, the electromagnets or the permanent magnets and their accompanying magnetic fields are rotated with respect to the stationary armature winding. In the d-c motor, current is sent into the armature winding, the latter being placed inside a set of radically supported magnet poles.

In the a-c motor, current is sent into the armature winding, which is usually placed in a stationary laminated iron core; the rotating element may or may not be a set of magnet poles. Since there are many kinds of a-c motor construction, no general statement can be made concerning them as can be done in the case of d-c motors.

Armature Windings. The armature winding of all types of motors and generators, whether of direct or alternating current, are always wound on *laminated* steel cores of good magnetic permeability. Alternating Voltages generated in the windings of a-c and d-c generator, the generated alternating electromotive force (emf) is transmitted directly to the load; in the d-c generator, the generated alternating emf is first rectified by a commutator and its brushes, that is, changed to direct current, before it is transmitted to its load.

The a-c motor receives its energy directly from an a-c source and, without any change to direct current, before it is transmitted to its load. The a-c motor receives its energy directly from an a-c source and, without any change whatever in form, uses it as alternating current in its winding to develop torque. In the d-c motor, however, direct current is delivered the brushes but flows as alternating current in the armature winding after passing through the brushes and commutator.

Field Poles. The electromagnets (called field poles) used in all d-c generators and motors, in a-c generators, and in one type of a-c motors are very simple in construction. There are always an even number of them in a given machine, and each one consists of a laminated steel core, of rectangular cross-section, surrounded by one or more copper coils. Project radially outward toward the stationary armature core; this construction is called a salient pole field. When the alternator is driven by a high-speed turbine, the field winding is placed in a slotted core; this construction is called a non-salient pole field.

Types of Direct-current Generator. Practically speaking, there are only two general types of d-c generator. They are distinguished by the way in which the flux is produced by the electromagnets.

- **Shunt Generators.** If the excitation is produced by a single winding connected to its own positive and negative brushes, the machine is called a self-excited shunt generator.
- **Compound Generators.** The second type of generator has two complete sets of field windings for excitation purposes; (1) the shunt field and (2) the series field.

In some special installations in which it is used for purposes of control, a generator contains a series field only; it is then called a series generator.

Voltage Characteristics of Direct-current Generators. The most important characteristic of a generator is its voltage behavior with respect to loading.

If a shunt generator is operating at full load at a given voltage (rated voltage, for example) and the load is suddenly removed so that the machine is performing at no load, the voltage will always rise above the full-load value.

When full load is removed from a compound generator, the voltage may drop, remain constant, or rise.

Speed of Direct-current Generators. It is customary for a d-c generator, whether shunt or compound, to operate at a speed that remains substantially constant at all times.

The speed of a generator is determined end controlled by the machine that drives it, that is, its prime mover. Therefore, if the prime mover is a constant-speed machine, speed will be constant.

If, for some reason, a d-c generator is operated at a speed much higher or lower than intended by the manufacturer, it will usually not perform with complete satisfaction unless corrective measures are taken to forestall faulty operation. The fields of d-c generators operating at speeds other than those recommended by the manufacturer would have to be modified to accommodate such changes; for example, if the speed of a generator were to be increased without a change in voltage, it would be necessary to weaken the field.

Starting Direct-current Motors.

Since the armature current (not the shunt-field current) is usually much higher than normal during this starting period, arcing at the commutator is likely to be very severe.

During the starting period, an external resistance must be added to limit the current in the armature circuit, where the current must pass between brush and commutator and where the serious effects of poor commutation are likely to result.

A starter, of which there are many types of construction, functions primarily to limit the current in the armature circuit during the starting period only.

Commutating Poles for Direct- current Machine. When current passes between brushes and commutator in a d-c machine, generator or motor, the ends of those coils joined to commutator segments that are bridged by the brushed are short-circuited for an instant. The ingenious scheme finally developed to perform causing the generated voltage in the short-circuited coil to be zero for all values of load – involves the use of special, narrow poles located between the large main poles.

Practically all d-c machines, except very small ones or those supplying unvarying loads, the brushes of which may be carefully set for the best commutation conditions, have commutating poles. They provide virtually sparkles commutation under the most severe condition of variable loading.

Alternating-current Generators. A-c generators, generally called alternators, are nearly always constructed so that the armature core and its winding are stationary while the field rotates. Moreover, the speed of rotation of the frequency of the generated voltage in circles per second, which is directly proportional to the speed, must be maintained at a constant value at all times. This requirement, therefore, imposes a very important obligation on the prime mover, the speed of which must not change, even slightly, if the frequency is to be maintained at a constant value. To maintain a constant voltage at the load, it is usually customary to equip an a-c generator with a regulator, a device that tends to maintain the terminal voltage constant regardless of the load.

A-c generators are usually constructed to generate much higher voltages than are generators built for d-c service.

One of the important reasons for the use of a-c generators in comparatively large power systems is that alternating current can be transformed efficiently from one voltage to another by the use of transformers.

Types and Characteristics of Direct-current Motors

There are three general types of d-c motor, and these, like d-c generators, are classified on the basis of the kind of excitation used.

- Shunt Motor
- Series Motor
- Compound Motor

It is the kind of excitation provided by the field and nothing more, that differentiates one type of motor from another, the construction of the armature has nothing whatever to do with the type of motor.

Each type of motor has very definite operating characteristics in so far as starting torque, overload capacity, and speed variation with changes in load are concerned.

The speed of all three types of motor can be controlled quite readily and in essentially the same way. There are three methods that may be employed to alter the speed of a d-c motor:

i. By changing the flux through resistance control

ii. By changing the voltage across the armature through resistance control, and

iii. By changing the voltage across the armature when the latter is supplied with power from a separate voltage-controlled generator.

Types and Characteristics of Alternating-current Motors

Classification of single-phase Motors. Single- phase motors generally have low horsepower ratings and are used to operate mechanical devices and machines requiring a comparatively small amount of power. Motors larger are sometimes used on farms and in small shops and factories where polyphase power is not available. Polyphase motors generally have better operating characteristics that single-phase machines and cost lesser horsepower.

In the single-phase classification may be listed the following types of motor: shaded-pole, reluctance, split-phase (without without capacitor starting), repulsion, repulsion-start, repulsion-induction, series (a-c only or universal), and synchronous.

Shaded-pole and reluctance motors are built in very small sizes.

Split-phase when their capacitor is used only during the starting period, they are called capacitor-start split-phase motors; when two values of capacitor are provided, one for starting and another for running, they are called two-value capacitor motors.

Series motors are called universal motors.

Synchronous motors, as the name implies, operate at synchronous speed, that is a definite, constant speed determined only by the frequency of the supply and the number of poles on the machine. The one important characteristic possessed by none of the motors previously discussed, that is, absolute constancy of speed, a requirement that is very important for timing devices.

Classification of Polyphase Motors. Polyphase motors, that is machines served with two- or three-phase power, may be classified as follows: induction (squirrel-cage or wound-rotor types), commutator or synchronous.

Squirrel-cage induction motors are widely used because they have desirable all-purpose characteristics.