B. THE GENERATOR

ENABLING OBJECTIVES:

3.13	Describe how an AC generator produces electrical energy.
3.14	Explain how heat is generated in and removed from a large AC generator.

AC GENERATOR ENERGY CONVERSION

A generator converts mechanical energy into electrical energy. The basic prerequisites to produce electricity from an AC generator are:

- there must be a conductor,
- there must be a magnetic field,
- there must be a relative motion between the conductor and the magnetic field.

Whenever these three conditions are met, a voltage is induced in the conductor. In a practical generator, a large number of conductor coils multiply the effect.

Figure 3.14 shows a simplified arrangement of a generator coupled to a steam turbine drive. The stationary conductors (coils) and the associated iron cores are referred to as a stator. Conductors (coils) and the associated iron core mounted on the shaft are referred to as a rotor.

Insulated slip rings on the shaft transfer DC current to create a magnetic field in the rotor. The stator windings act as the conductors for the main generator current while the turbine provides the mechanical torque on the shaft of the generator. The rotating motion provided by the shaft produces the relative motion between the rotor magnetic field and the stator conductors. As a result, a voltage is induced in the stator conductors and transferred to the transmission lines through a stepup transformer.

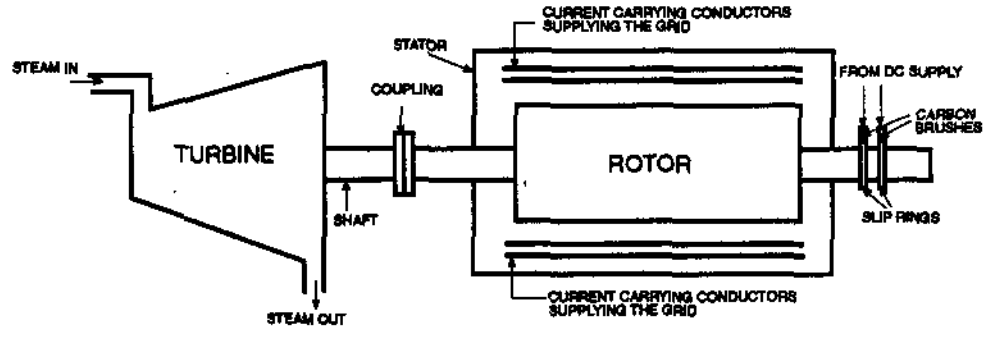

Figure 3.14
Simplified Arrangement of a Generator Coupled to a Turbine Drive

In a generator, the rotor velocity determines the frequency. When the generator is connected to the grid the frequency is fixed at 60 Hz.[9] Since the frequency for the Ontario Grid is fixed at 60 Hz, the velocity of the rotor is kept constant.

As electrical consumers use electricity they create a load current on the Ontario grid thereby increasing counter torque to the turbine shaft. The tendency of the turbine is to slow down as counter torque is increased which would decrease the frequency. To compensate for the increased counter torque more steam is admitted to the turbine to produce more shaft mechanical power and to maintain the generator speed.

GENERATOR COOLING

The modern electric generator for a steam power station is an extremely efficient machine. Approximately 98% of the mechanical power delivered on the shaft from the turbine is converted to electrical power. The remaining 2% appears as heat in various places in the generator. Two percent does not appear to be very much until you consider that 2% of a 750 MW machine is equal to 15 MW. Since all of this 15 MW is converted to heat, it is like putting a heater of this size inside the generator.

The heat that is produced in a generator comes from several sources including windage (gas friction) between the rotor and the circulating cooling gas, the electrical heating due to the current resistance in the windings of both the rotor and stator, and the electrical heating due to current induced in the structural material of the rotor and stator.

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[9] For a CANDU generator a frequency of 60Hz represents 1800 rpm.

Even small increases in the operating temperature of a generator will lead to rapid deterioration of the insulation on the windings. For this reason, two systems are provided to cool the generator. One system uses hydrogen circulated through the generator. Hydrogen has the advantages of:

- better thermal conductivity than air;
- less damaging to insulation than air;
- less dense than air so less heat is produced from windage.

The disadvantage is that it is explosive when mixed with air. To avoid this hazard, the generator requires very good seals to prevent air in-leakage or leakage of hydrogen out of the generator.

By itself, the hydrogen cooling system is inadequate. To complement it, a stator cooling water system is also provided. The conductors in the stator are hollow and water is circulated through them. This water has to be exceptionally pure to prevent leakage of current from the stator conductors to ground through the coolant.

The combination of hydrogen and stator water cooling is sufficient to cool generators as large as 1500 MW which is far larger than any generator in service in Ontario Hydro.

ASSIGNMENT

1. What are the three basic prerequisites to producing electricity in an AC generator?

2. How is heat produced in an AC generator and what are the two methods we use for removing it?