AC GENERATOR OPERATION

Because of the nature of AC voltage and current, the operation of an AC generator requires that rules and procedures be followed. In addition, there are various types of AC generators available, each type having advantages and disadvantages.

EO 1.5 DESCRIBE the bases behind the kW and current ratings of an AC generator.

EO 1.6 DESCRIBE the conditions that must be met prior to paralleling two AC generators including consequences of not meeting these conditions.

EO 1.7 DESCRIBE the difference between a stationary field, rotating armature AC generator and a rotating field, stationary armature AC generator.

EO 1.8 EXPLAIN the differences between a wye-connected and delta-connected AC generator including advantages and disadvantages of each type.

Ratings

Typical name plate data for an AC generator (Figure 4) includes: (1) manufacturer; (2) serial number and type number; (3) speed (rpm), number of poles, frequency of output, number of phases, and maximum supply voltage; (4) capacity rating in KVA and kW at a specified power factor and maximum output voltage; (5) armature and field current per phase; and (6) maximum temperature rise.

Westinghouse
AC generator air cooled NO. 6750616 Type ATB 3600 RPM
2 poles 60 hertz 3-phase wye-connected for 13800 volts
Rating 15625 KVA 12500 kW 0.80 PF exciter 250 volts
Armature 654 amp field 183 amp
Guaranteed temp. rise not to exceed 60° C on armature by detector 80° C on field by resistance

Figure 4 AC Generator Nameplate Ratings

Power (kW) ratings of an AC generator are based on the ability of the prime mover to overcome generator losses and the ability of the machine to dissipate the internally generated heat. The current rating of an AC generator is based on the insulation rating of the machine.

Paralleling AC Generators

Most electrical power grids and distribution systems have more than one AC generator operating at one time. Normally, two or more generators are operated in parallel in order to increase the available power. Three conditions must be met prior to paralleling (or synchronizing) AC generators.

- Their terminal voltages must be equal. If the voltages of the two AC generators are not equal, one of the AC generators could be picked up as a reactive load to the other AC generator. This causes high currents to be exchanged between the two machines, possibly causing generator or distribution system damage.
- Their frequencies must be equal. A mismatch in frequencies of the two AC generators will cause the generator with the lower frequency to be picked up as a load on the other generator (a condition referred to as "motoring"). This can cause an overload in the generators and the distribution system.
- Their output voltages must be in phase. A mismatch in the phases will cause large opposing voltages to be developed. The worst case mismatch would be 180° out of phase, resulting in an opposing voltage between the two generators of twice the output voltage. This high voltage can cause damage to the generators and distribution system due to high currents.

During paralleling operations, voltages of the two generators that are to be paralleled are indicated through the use of voltmeters. Frequency matching is accomplished through the use of output frequency meters. Phase matching is accomplished through the use of a synchroscope, a device that senses the two frequencies and gives an indication of phase differences and a relative comparison of frequency differences.

Types of AC Generators

As previously discussed, there are two types of AC generators: the stationary field, rotating armature; and the rotating field, stationary armature.

Small AC generators usually have a stationary field and a rotating armature (Figure 5). One important disadvantage to this arrangement is that the slip-ring and brush assembly is in series with the load circuits and, because of worn or dirty components, may interrupt the flow of current.

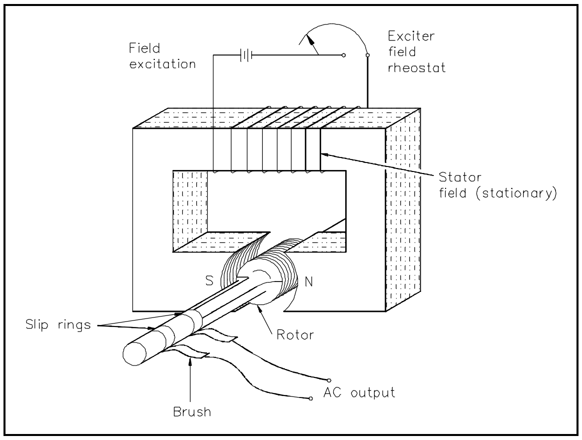

Figure 5 Stationary Field, Rotating Armature AC Generator

If DC field excitation is connected to the rotor, the stationary coils will have AC induced into them (Figure 6). This arrangement is called a rotating field, stationary armature AC generator.

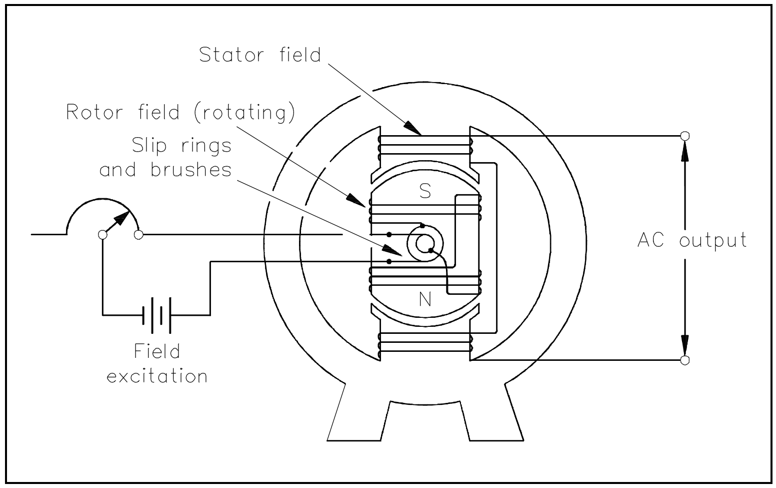

Figure 6 Simple AC Generator - Rotating Field, Stationary Armature

The rotating field, stationary armature type AC generator is used when large power generation is involved. In this type of generator, a DC source is supplied to the rotating field coils, which produces a magnetic field around the rotating element. As the rotor is turned by the prime mover, the field will cut the conductors of the stationary armature, and an EMF will be induced into the armature windings.

This type of AC generator has several advantages over the stationary field, rotating armature AC generator: (1) a load can be connected to the armature without moving contacts in the circuit; (2) it is much easier to insulate stator fields than rotating fields; and (3) much higher voltages and currents can be generated.

Three-Phase AC Generators

The principles of a three-phase generator are basically the same as that of a single-phase generator, except that there are three equally-spaced windings and three output voltages that are all 120° out of phase with one another. Physically adjacent loops (Figure 7) are separated by 60° of rotation; however, the loops are connected to the slip rings in such a manner that there are 120 electrical degrees between phases.

The individual coils of each winding are combined and represented as a single coil. The significance of Figure 7 is that it shows that the three-phase generator has three separate armature windings that are 120 electrical degrees out of phase.

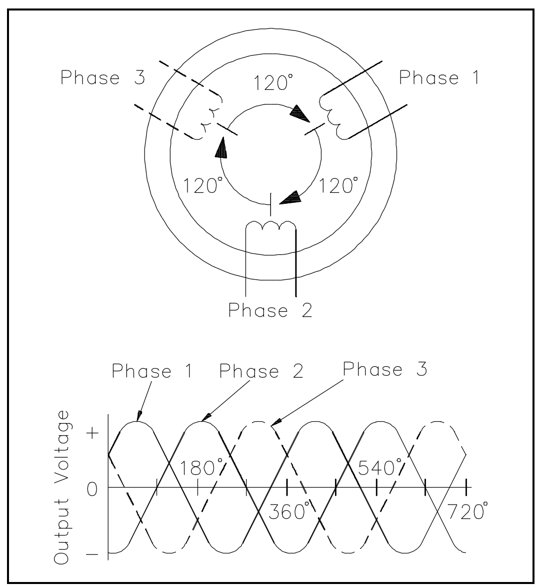

Figure 7 Stationary Armature 3ϕ Generator

AC Generator Connections

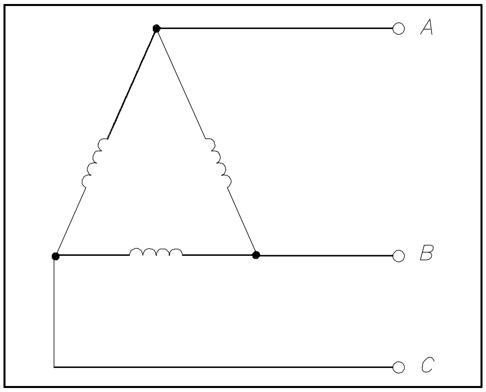

Figure 8 Delta Connection

As shown in Figure 7, there are six leads from the armature of a three-phase generator, and the output is connected to an external load. In actual practice, the windings are connected together, and only three leads are brought out and connected to the external load.

Two means are available to connect the three armature windings. In one type of connection, the windings are connected in series, or delta-connected (Δ) (Figure 8).

In a delta-connected generator, the voltage between any two of the phases, called line voltage, is the same as the voltage generated in any one phase. As shown in Figure 9, the three phase voltages are equal, as are the three line voltages. The current in any line is $\sqrt{3}$ times the phase current. You can see that a delta-connected generator provides an increase in current, but no increase in voltage.

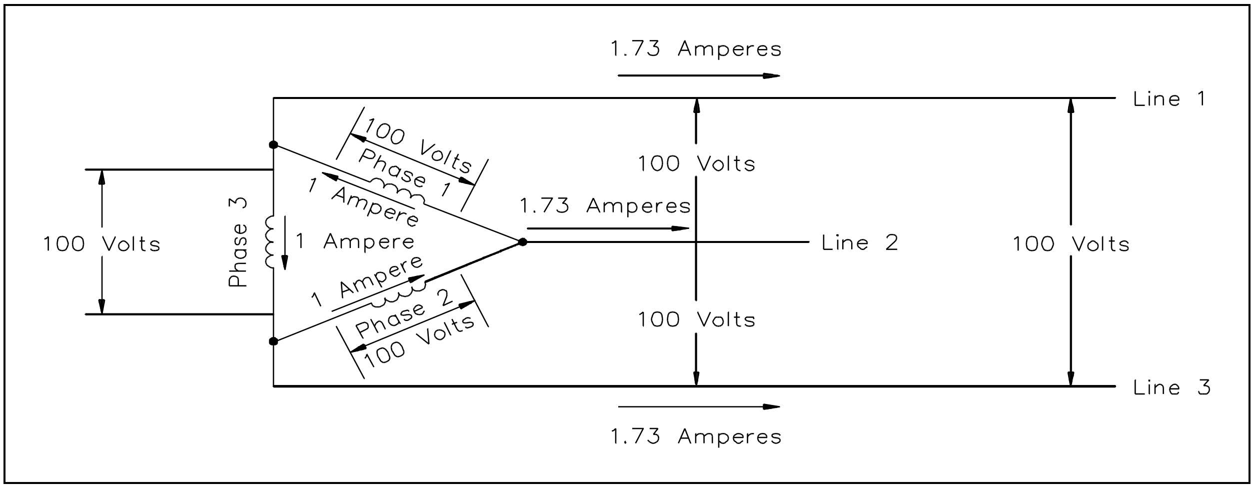

Figure 9 Characteristics of a Delta-Connected Generator

An advantage of the delta-connected AC generator is that if one phase becomes damaged or open, the remaining two phases can still deliver three-phase power. The capacity of the generator is reduced to 57.7% of what it was with all three phases in operation.

In the other type of connection, one of the leads of each winding is connected, and the remaining three leads are connected to an external load. This is called a wye connection (Y) (Figure 10).

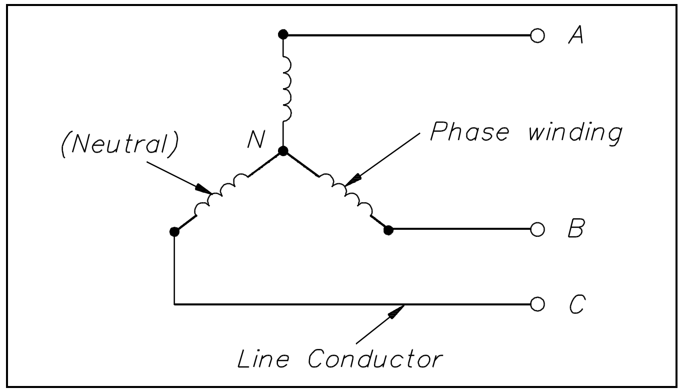

Figure 10 Wye Connection

The voltage and current characteristics of the wye-connected AC generator are opposite to that of the delta connection. Voltage between any two lines in a wye-connected AC generator is 1.73 (or $\sqrt{3}$) times any one phase voltage, while line currents are equal to phase currents. The wye-connected AC generator provides an increase in voltage, but no increase in current (Figure 11).

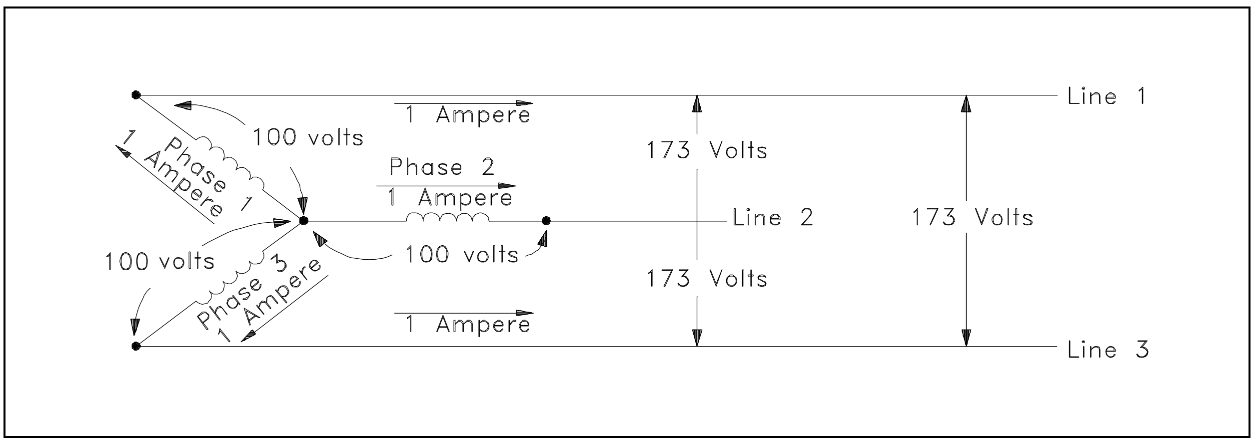

Figure 11 Characteristics of a Wye-Connected AC Generator

An advantage of a wye-connected AC generator is that each phase only has to carry 57.7% of line voltage and, therefore, can be used for high voltage generation.

Summary

The important information covered in this chapter is summarized below.

AC Generator Operation Summary

- Power (kW) ratings of an AC generator are based on the ability of the prime mover to overcome generation losses and the ability of the machine to dissipate the heat generated internally. The current rating of an AC generator is based on the insulation rating of the machine.

- There are three requirements that must be met to parallel AC generators:

  1) Their terminal voltages must be equal. A mismatch may cause high currents and generator or distribution system damage.

  2) Their frequencies must be equal. A mismatch in frequencies can cause one generator to "motor," causing an overload in the generators and the distribution system.

  3) Their output voltages must be in phase. A mismatch in the phases will cause large opposing voltages to be developed, resulting in damage to the generators and distribution system due to high currents.

- The disadvantage of a stationary field, rotating armature is that the slip-ring and brush assembly is in series with the load circuits and, because of worn or dirty components, may interrupt the flow of current.

- A stationary armature, rotating field generator has several advantages: (1) a load can be connected to the armature without moving contacts in the circuit; (2) it is much easier to insulate stator fields than rotating fields; and (3) much higher voltages and currents can be generated.

- The advantage of the delta-connected AC generator is that if one phase becomes damaged or open, the remaining two phases can still deliver three-phase power at a reduced capacity of 57.7%.

- The advantage of a wye-connected AC generator is that each phase only has to carry 57.7% of line voltage and, therefore, can be used for high voltage generation.