Few Words About Three-Phase Alternator

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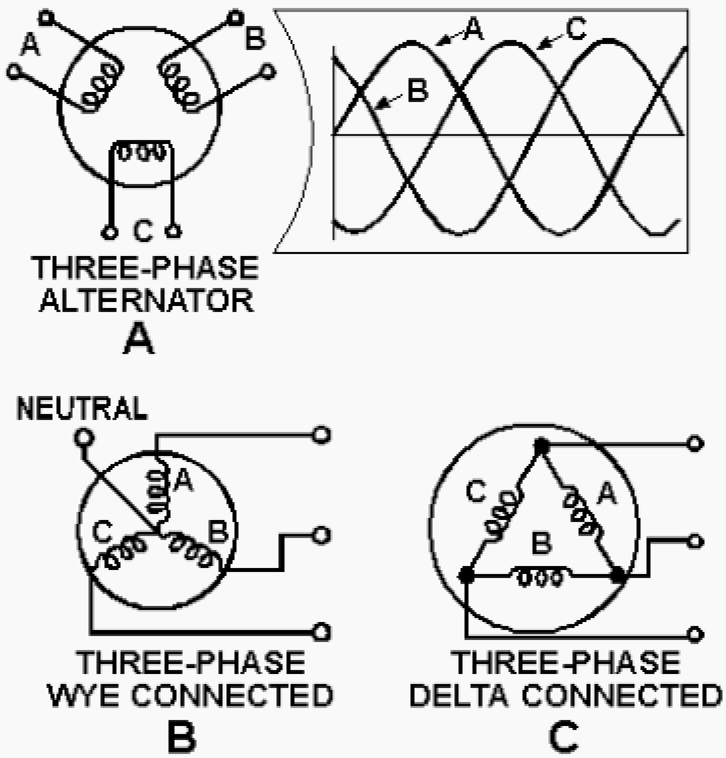
Introduction

The three-phase alternator, as the name implies, has three single-phase windings spaced such that the voltage induced in any one phase is displaced by 120º from the other two. A schematic diagram of a **three-phase stator** showing all the coils becomes complex, and it is difficult to see what is actually happening.

The simplified schematic of ***figure 1***, view A, shows all the windings of each phase lumped together as one winding.
The rotor is omitted for simplicity. The voltage waveforms generated across each phase are drawn on a graph, phase-displaced 120º from each other. The three-phase alternator as shown in this schematic is made up of three single-phase alternators whose generated voltages are out of phase by 120º.

The three phases are independent of each other.



Rather than having six leads coming out of the three-phase alternator, the same leads from each phase may be connected together to form a ***wye (Y) connection***, as shown in ***Figure 1***,***view B***.

It is called a ***wye connection*** because, without the neutral, the windings appear as the letter Y, in this case sideways or upside down.

The neutral connection is brought out to a terminal when a single-phase load must be supplied. Single-phase voltage is available from neutral to A, neutral to B, and neutral to C. In a three-phase, Y-connected alternator, the total voltage, or line voltage, across any two of the three line leads is the vector sum of the individual phase voltages. Each line voltage is ***1.73 times*** one of the phase voltages.

Because the windings form only one path for current flow between phases, the line and phase currents are the same (equal). A three-phase stator can also be connected so that the phases are connected end-to-end; it is now delta connected (***fig. 1, view C***). (*Delta because it looks like the Greek letter delta,* Δ.)

In the delta connection, line voltages are equal to phase voltages, but each line current is equal to 1.73 times the phase current. Both the wye and the delta connections are used in alternators.

The majority of all alternators in use today are three-phase machines. They are much more efficient than either two-phase or single-phase alternators.

Three-Phase Connections

The stator coils of three-phase alternators may be joined together in either wye or delta connections, as shown in ***Figure 2***. With these connections only three wires come out of the alternator. This allows convenient connection to **three-phase motors** or power distribution transformers.
It is necessary to use three-phase transformers or their electrical equivalent with this type of system.

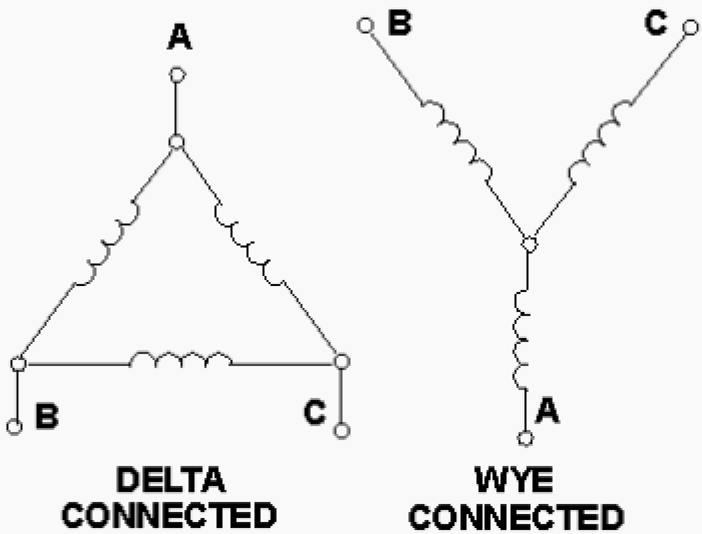


Figure 2 - Three-phase alternator or transformer connections

A three-phase transformer may be made up of three, single-phase transformers connected in***delta***, ***wye***, or a ***combination of both***. If both the primary and secondary are connected in wye, the transformer is called a ***wye-wye***.
If both windings are connected in delta, the transformer is called a delta-delta. ***Figure 3*** shows single-phase transformers connected delta-delta for operation in a three-phase system. You will note that the transformer windings are not angled to illustrate the typical ***delta (Δ)*** as has been done with alternator windings.
Physically, each transformer in the diagram stands alone. There is no angular relationship between the windings of the individual transformers.

However, if you follow the connections, you will see that they form an electrical delta. The primary windings, for example, are connected to each other to form a closed loop. Each of these junctions is fed with a phase voltage from a three-phase alternator.

The alternator may be connected either delta or wye depending on load and voltage requirements, and the design of the system.

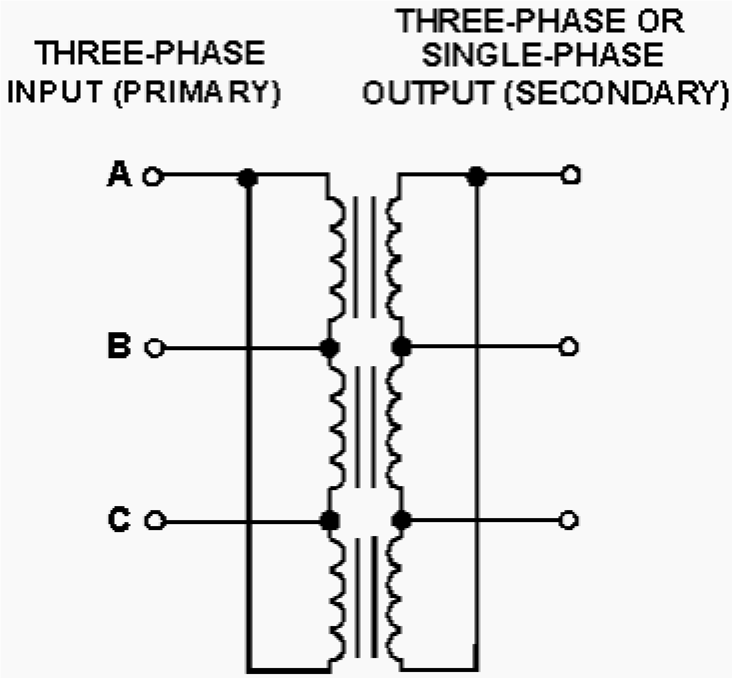


Figure 3 - Three single-phase transformers connected delta-delta

Figure 4 shows three single-phase transformers connected wye-wye. Again, note that the transformer windings are not angled. Electrically, a Y is formed by the connections. The lower connections of each winding are shorted together. These form the common point of the wye. The opposite end of each winding is isolated. These ends form the arms of the wye.

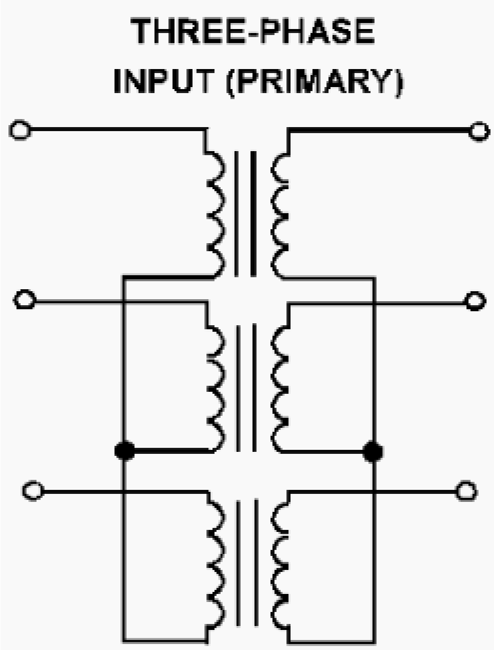


Figure 4 - Three single-phase transformers connected wye-wye

The ac power on most ships is distributed by a three-phase, three-wire, 450-volt system. The single-phase transformers step the voltage down to 117 volts. These transformers are connected delta-delta as in ***figure 3***.
With a delta-delta configuration, the load may be a three-phase device connected to all phases; or, it may be a single-phase device connected to only one phase.

At this point, it is important to remember that such a distribution system includes everything between the alternator and the load. Because of the many choices that three-phase systems provide, care must be taken to ensure that any change of connections does not provide the load with the wrong voltage or the wrong phase.

Output Frequency

The output frequency of alternator voltage depends upon the speed of rotation of the rotor and the number of poles. The faster the speed, the higher the frequency. The lower the speed, the lower the frequency.

The more poles there are on the rotor, the higher the frequency is for a given speed. When a rotor has rotated through an angle such that two adjacent rotor poles (a north and a south pole) have passed one winding, the voltage induced in that winding will have varied through one complete cycle. For a given frequency, the more pairs of poles there are, the lower the speed of rotation.

This principle is illustrated in ***figure 5***; a two-pole **generator** must rotate at four times the speed of an eight-pole generator to produce the same frequency of generated voltage.

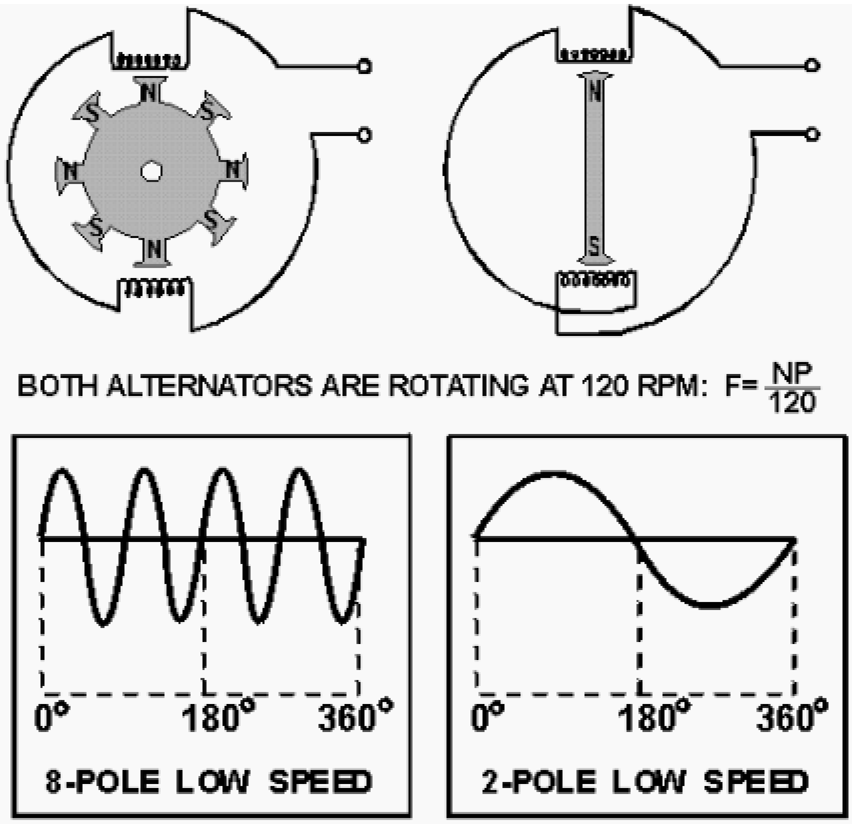


Figure 5 - Frequency regulation

The frequency of any ac generator in hertz (Hz), which is the number of cycles per second, is related to the number of poles and the speed of rotation, as expressed by the equation:

F = NP / 120

where P is the number of poles, N is the speed of rotation in revolutions per minute (rpm), and 120 is a constant to allow for the conversion of minutes to seconds and from poles to pairs of poles.

Examples

For example, a 2-pole, 3600-rpm alternator has a frequency of 60 Hz; determined as follows:

(2 x 3600) / 120 = 60 HZ

A 4-pole, 1800-rpm generator also has a frequency of 60 Hz. A 6-pole, 500-rpm generator has a frequency of:

(6 x 500) / 120 = 25 Hz

A 12-pole, 4000-rpm generator has a frequency of:

(12 x 4000) / 120 = 400 Hz

Resource: *Introduction to motor and generator - Navy Electricity and Electronics Training Series*

Source:

http://electrical-engineering-portal.com/few-words-about-three-phase-alternator