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The issue is not as simple as you might have thought. Here's what the experts have to say about dealing with voltage ratios and wye/delta connections.

In the world of three-phase electric motors, the use of motors with more than one voltage rating seems to cause great confusion. Especially today, with so much international commerce, misunderstanding of the simple term "dual voltage" often leads to premature motor failures.

Maintenance professionals in the U.S. are accustomed to "dual-voltage," 230/460-volt ratings. This 1:2 ratio lends itself to 9-lead windings that are connected externally as either 1 & 2-Y or 1 & 2-delta. The high-voltage (460v) connections are the same for both; the 230v connections are not. Internally, the winding connection can vary, but always with that 1:2 ratio between circuits. The common factor is that the circuits and possible operating voltages have the same 1:2 ratio.

Using two circuits at 230 volts produces the same magnetic flux density—*and therefore the same torque*—as using one circuit at 460 volts:

230v x 2 circuits = 460v x 1 circuit

That makes off-the-shelf electric motors more versatile. (We use 60 Hz power in North America, Brazil and parts of Japan—*albeit not all use the same voltage systems.)*

The rest of the world uses 50 Hz power, and is accustomed to the Y/delta dual-voltage system, which is wye-delta for a ratio of 1:1.732. Common voltage ratings for these machines are 220/380 and 230/400. The same ratio applies to the medium-voltage (2300v delta/4000v wye) machines in North America. The ratio is derived from the square root of three (√3) and results in the Y-connected motor producing the same torque at 400v as it would when connected delta for 230v.

Table I. For a wye-delta dual voltage, the ratio of low- to high-voltage is 1:√3.

Low voltage (Delta)	High voltage (low V x √3)
220	380
230	400
550	950
2300	4000
1740	3000

Table II. U.S. dual-voltage typically means a 1:2 ratio of low to high voltages (230 x 2 = 460).

Low voltage	High voltage
230	460

It is understandable that a person accustomed to one system might not realize the differences in the other. Based on reported winding failures, that is indeed the case. Let's look at the reason for the confusion, and why many motors successfully operate on the other system-—*the one they were not designed for.*

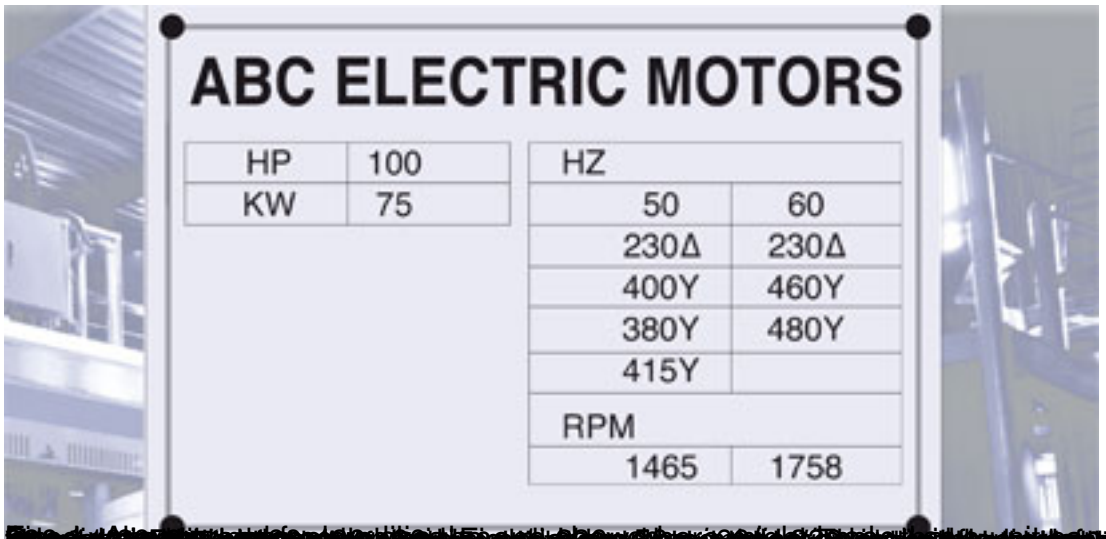
North America generates and uses 60 Hz (Hertz or cycle) power, while most of the rest of the world uses 50 Hz power. The history behind this is fascinating, but that's for another article. Let's just say there used to be a lot of competing frequencies, and like Apple versus PC, both have advantages, disadvantages and loyal followers.

The relationship between voltage and frequency is straightforward: The volts/Hertz ratio must be constant to produce the same torque. The speed of the motor (rpm) is proportional to the frequency, so a motor operating at 60 Hz turns 1.2 times as fast at it would on 50 Hz power (50 x 1.2 = 60):

60/50 x 50 Hz voltage =
the 60 Hz voltage that will produce the same torque

For example, 400v x 60/50 = 480v—*meaning that a 400v 50 Hz winding is equivalent to a 480v 60 Hz winding*. In other words, a 400v 50 Hz motor, applied to a 480v 60 Hz power supply will operate at the same magnetic flux density and, thus, produce the same torque. Since it is rotating 20% faster (60/50), however, the output power (measured as Hp or kW) also increases by 20%.

Understandably, someone might look at the 400v 50 Hz/480v 60 Hz issue and feel safe in using a 230/400v 50 Hz motor on a 60 Hz system. After all, when the motor is connected wye, and operated at 460v 60 Hz, it produces the correct torque. So what's the problem?



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