Tech Talk:
So you are thinking about three-phase

By Troy Knutson, EIT

Are you thinking about adding or upgrading to three-phase power? Sounds easy enough, right? Just get an electrician to add a few wires and presto, you're ready to go. We only wish it could be that easy. But there are some real issues to understand so you can make an informed decision before you jump into three-phase power.

Why do we use Alternating Current?

First a little background information is necessary so you can understand why we use alternating current systems. There was a war of sorts going on in the late 1800's between two brilliant inventors named Nikola Tesla and Thomas Edison. One of Edison's famed inventions of the time was his direct current (DC) distribution system that was serving parts of downtown Manhattan Island. One of the main disadvantages with Edison's DC system was that over long distances the voltage would drop to an unusable low level where it needed to be boosted often. Around the same time Nikola Tesla had an idea that changed the world we live in today. He found that he could create a rotating magnetic field, and use this to generate (generator) or consume (motor) alternating current (AC). The major advantage of this AC system is that it could transform these voltages into much higher or lower voltages with ease. This made it possible for power to be produced at one point, transformed up to high voltages and sent long distances, then transformed back down for end use. Besides motors, another major reason for using three-phase is that loads can be spread out over 3 wires instead of all on one, making it possible to use smaller wires for the same sized load. This is why utilities use three-phase lines as their main feeder circuits.

So what is three-phase?

Without getting too technical, a good analogy for how three-phase power works on a motor is like rolling an oversized tire. Anyone who has rolled an oversized tire knows that it is difficult to get it started alone. Now try to imagine starting to roll the tire with the help of two other people. The tire is still the same size but it takes much less effort by each individual person because the work is spread out over three people. Three-phase acts on a motor in a similar way. It keeps a constant torque on the rotor. Lose one of the phases of a three-phase motor and it's like rolling the tire with two people instead of three, it will still roll, but not as smoothly. Now this is not to say that single-phase motors have any lesser qualities than three-phase motors. If there were two identically sized motors one single-phase and one three-phase, the main difference would be that the single-phase motor would take more electrical current whereas the three-phase motor would get that current spread over three wires. More simply, three-phase motors can handle more power and start heavier loads. That is why three-phase is the most common set up for industrial and commercial services.

How is three-phase power generated?

An induction motor is shown in figure 1. The terms “motor” and “generator” are similar. They basically decide which way the power flows through the rotor. The electric generator has two main parts a stator and a rotor. The rotor, with some kind of initial moving force, spins. By using the magnetic force of induction, a rotor in motion creates electric current which is induced upon the stator or “stationary” part of the generator. Three lead wires, (shown in Figure 1.), are then taken out of this stator to a transformer where the voltage is raised and sent off. Using a network of transformers and wires, electric power is delivered to the end user where the voltage is transformed to a lower and safer level.

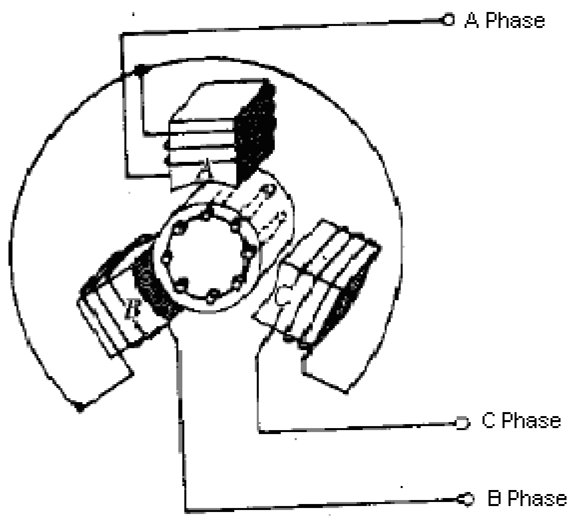

Figure 1.
A standard three- phase electric motor.

A standard type of generator is a 3-pole design. The three poles allow for peak power to be attained at three separate instances in one full rotation. This creates a waveform like the one shown in Figure 2. The phases are commonly referred to as A, B, and C phase. For now just think of “phase” as a waveform, much like when kids play with a skipping rope; each phase has a magnitude and a direction. The magnitude of the waveform could be any standard voltage, but in most US households it is 120 Volts.

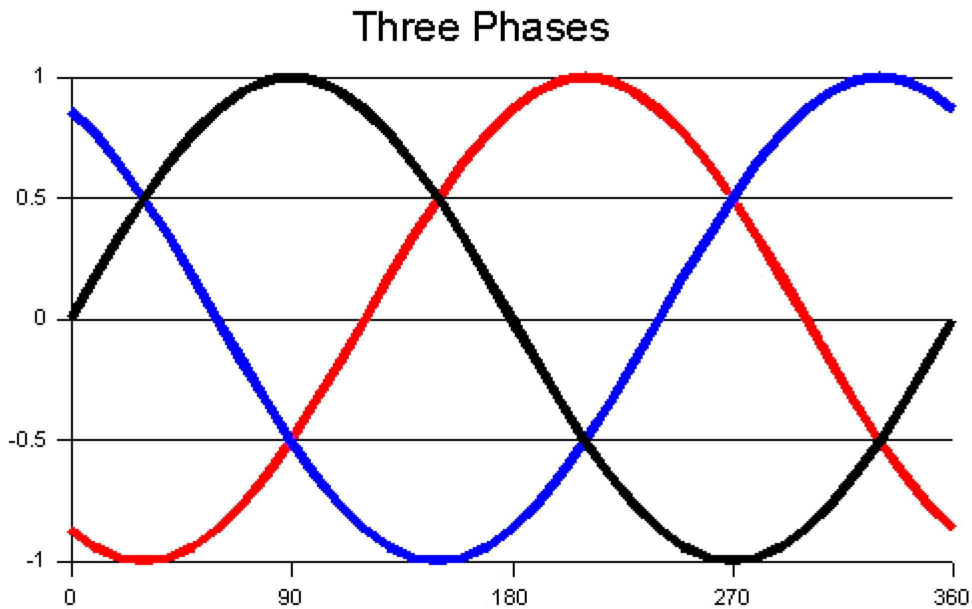

Figure 2.
A standard three- phase waveform. 360 degrees is one cycle.

What is the difference between single-phase and three-phase services?

Single-phase services are typically used to serve residential housing load such as appliances and lighting. Three-phase services are typically used on services that need to run motors and commercial grade appliances. Typical US households have single-phase services with a service voltage of 120/240. The addition of two more phases gives you a standard three-phase voltage of 120/208. This difference is important. 120/240 single-phase and 120/208 three-phase voltages are not equal. A common misconception about three-phase is that since 240 and 208 are only 32 volts apart they can be interchanged. In some instances they can, but in the case of motors they cannot. Another common three-phase voltage for large commercial services is 277/480 volts.

What are CCEC's policies on three-phase?

Whether you are planning on adding a new three-phase service or revamping your current service, CCEC has policies in place to help you decide. It's important for you to contact CCEC to learn which policies pertain to your situation and what they involve. An important aspect, when considering changing to three-phase, is the cost to change your own service wiring, as single-phase service wiring may not be suitable for three-phase services. This will likely include new service panels and wiring for most installations.

Other Considerations

There are several other considerations when deciding on three-phase power such as the best three-phase voltage for your service needs, how to serve single-phase loads you wish to retain, and protection of your three-phase equipment in the event one phase of your three-phase service is lost (called loss-of-phase protection). Severe damage can result to three phase equipment if one phase is lost and the equipment does not have proper loss-of-phase protection.

CCEC also has policies in place on motor starting. When an electric motor starts, it requires a large in-rush of electrical current, which in turn causes voltage flicker on the line. Before you purchase any electric motor, you should check on CCEC's detailed motor-starting policy. Depending on your location within the CCEC system, you may have to use special equipment to start your motor so as to not cause power quality problems for your own service or your neighbors.

Motor horsepower and NEMA ratings can be found on the nameplate of your motor. As you can see from the nameplates shown in Figure 3 (3a, a 10 hp single-phase motor and 3b., a 10 hp three-phase motor) have very different operating characteristics. The single phase motor requires higher amperage to run and is slightly less efficient than the three phase motor, yet both produce the same horsepower.

Hp: 10	**Phase:** 1	**Volts:** 230	**HZ:** 60
RPM: 3500	**Amps:** 40.0		
Insul Class: F	**SF:** 1.15	**SFA:** 45.0	
Max Ambient: 40	**NEMA Frame:** 215JM	**Encl:** TE	**Code:** G
Shaft End Bearing: 6309-2Z-J/C3		**Opp End Bearing:** 6205-2Z-J/C3	
NEMA Nom Eff: 86.9	**Thermally Protected:** N/A		**Type:** UTM4

Figure 3a. A single-phase 10 HP motor from US Motors

Hp: 10	**Phase:** 3	**Volts:** 230/460	**HZ:** 60
RPM: 3510	**Amps:** 23.8/11.9		
Insul Class: F	**SF:** 1.15	**SFA:** 27.6/13.8	
Max Ambient: 40	**NEMA Frame:** 215T	**Encl:** TE	**Code:** G
Shaft End Bearing: 6208-J/C3		**Opp End Bearing:** 6206-J/C3	
NEMA Nom Eff: 89.5	**Thermally Protected:** N/A		**Type:** FLC

Figure 3b. A 10 HP three-phase motor from US Motors.

As you can see, upgrading to or adding a three-phase service is a large commitment and can be a substantial expense that can vary greatly between underground and overhead lines. CCEC recommends that you contact its engineering department to arrange for a site visit and a cost estimate before undertaking a large project such as this. It requires a lot of planning and consideration of many issues before making such a decision and investment. CCEC policies may also affect your plans. CCEC is here to help you in making good decisions based upon your needs and Cooperative policy.

References:
[1] Charles I. Hubert. "Electric Machines". 2002, Pearson Education, Inc.

[2] http://www.3phasepower.org/