Pump ED 101

AC Motors Part 3 – Single Phase Operation

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It has been said that Washington DC is the home of the largest invertebrate population in the US. This, of course, refers to the population of politicians and their lack of the backbone or guts that are required to make difficult decisions. The same analogy could be applied to the single phase motor as it has only one third of the "guts" of its three phase cousin. Unlike many politicians, however, it can still perform well as long as our expectations are reasonable.

Single Phase Magnetic Field

Figure 1 illustrates one cycle (Hz) of a single phase AC sine wave. Unlike the three phase curve we saw last month, this one peaks only twice per cycle and the peaks occur 180 degrees apart. It was those peaks that occurred just 60 degrees apart that provided a true rotating magnetic field in the three phase stator. Can the single phase wave form produce a rotating field in a single phase stator and if so, what does it look like?

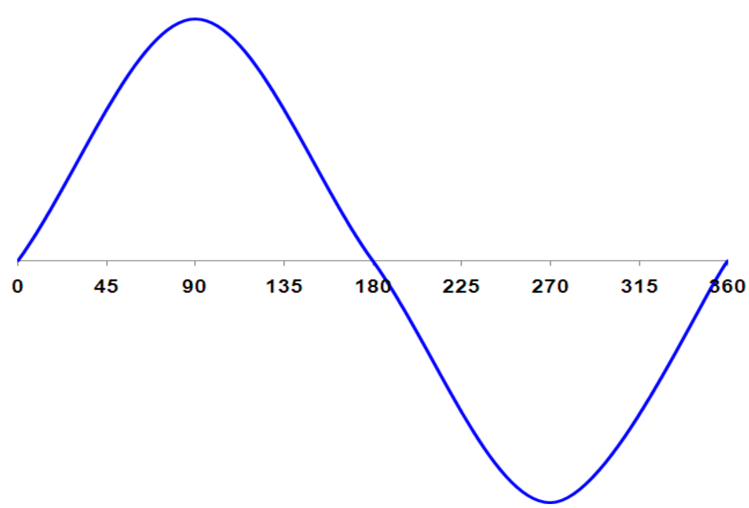
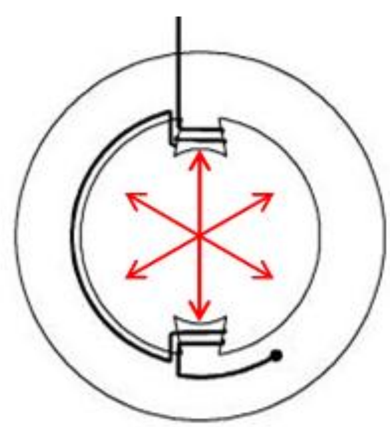


Figure 2 shows a single phase, two pole stator with the poles oriented in a north / south position. It looks very similar to the three phase version except that it is missing four poles. It is not as easy to visualize the field that is created between the two poles without an animation but let's give it a try. At 90 degrees the wave reaches it positive peak and the field strength in the upper pole is at its maximum. At 270 degrees the wave



reaches its negative peak and the magnetic field is transferred to the bottom pole. During this downward migration, the magnetic field travels toward the lower pole on both sides of the stator. When the wave begins to rise again the magnetic field begins to reverse direction and travels toward the upper pole and again, it occurs on both sides of the stator. The result is a pulsating field that occurs twice each cycle. It is not a rotational field and if single phase power were applied to this stator, the rotor would not turn. If, however, you give it a twist with your hand (either direction) it will begin to rotate and will remain in rotation as long as power is applied. Twisting the shaft causes induction to occur and the interaction between the induced fields and the stator fields plus the inertia of the rotor maintains the rotational motion. Unlike the three phase motor, all single phase motors require an auxiliary starting component in order to begin rotation.

Single Phase Starting

Although there are a number of single phase starting techniques, most use a second set of poles to create an "synthetic" second phase (split phase) that works in conjunction with the primary phase to produce a rotating magnetic field among the four poles. A good comparison is the two phase motor. Figure 3 shows the pole positions of a two phase, two pole motor. A two phase generator produces phases that are separated by 90 degrees and the positive and negative peaks will create a rotating field in a two phase stator. Single phase motors mimic the two phase motor by using the phase two poles as a start winding that can create a rotating field similar to that of a two phase motor.

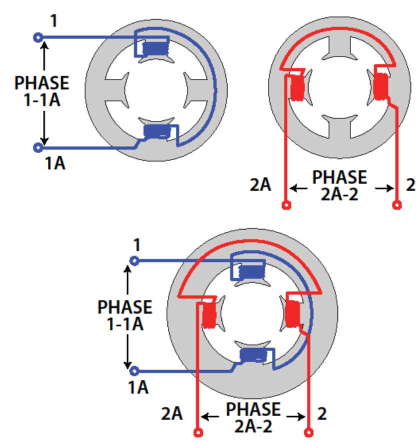
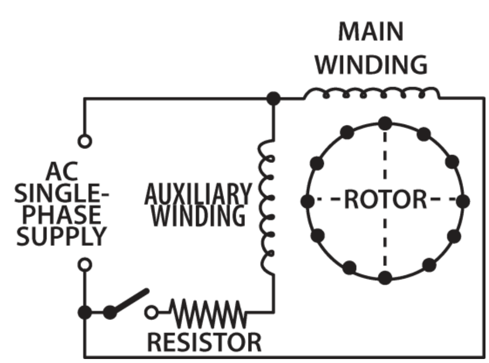
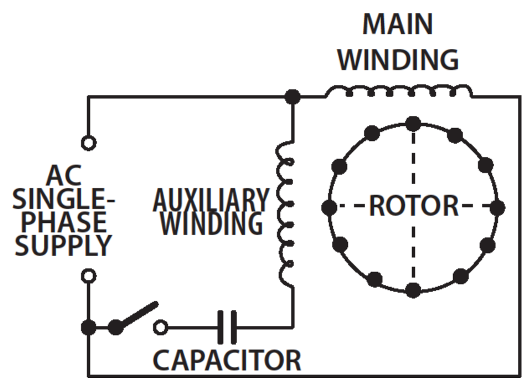


Figure 4 is a schematic of a split phase, resistance start - induction run motor. In this arrangement the auxiliary or start winding is wound with a smaller wire size than that of the main winding. This increases the resistance (and lowers inductance) in the winding and results in a smaller delay in current flow than does the main winding. An external resistance can also be used in conjunction with a larger wire size to obtain the same result. The resulting phase shift between the



two windings is about 30 degrees and is sufficient to produce a low torque rotating field. It is not as good as the 90 degree shift produced by the two phase motor but it works. A centrifugal or thermal switch removes the start winding from the circuit once the motor reaches a certain speed. Resistance start motors are available up to ½ Hp and are popular due to their low cost. Their disadvantages include low starting torque and high inrush current which produces additional heat during starting.



The split phase design shown in Figure 5 is called a capacitor start – induction run motor. In this design the start winding is wound with a normal wire size and connected in series with a capacitor. As we learned last fall (AC Power) current leads voltage in a capacitive circuit but, in an inductive circuit (main winding) current trails voltage. This results in a phase shift of nearly 90 degrees and gives rise to a rotating field that is almost identical to the one produced by a two phase motor. As with the previous example, a centrifugal or current activated switch removes the start winding from the circuit as the motor approaches a certain speed. Due to the greater phase shift, capacitor start motors have a relatively high starting torque (two to four times full load torque) and a moderate inrush current. This very popular single phase motor typically ranges in size from fractional to 3 Hp. A potential problem with larger single phase, induction run motors is vibration. When operated on 60 Hz power single phase motors vibrate at 120 Hz and this particular frequency can create excessive noise if they are connected to a resonant prone load.

A variation of the capacitor start – induction run design is the capacitor start – capacitor run motor. This design is very similar to Figure 5 except that it utilizes two capacitors. In addition to the start capacitor and its switch a smaller, run capacitor is permanently wired in series with the start winding. After starting, the start capacitor is removed from the circuit but the run capacitor remains in series with the start winding and improves motor performance by providing a weaker but smoothing second phase during operation. This second run phase will substantially reduce vibration and noise. Capacitor start – capacitor run motors are typically available from 2 – 15 Hp.

Yet another capacitor design is the PSC or permanent split capacitor motor. This design is also very similar to the configuration shown in Figure 5. The major difference is that there is no switch and a single capacitor is permanently in series with the start winding. The capacitor is sized as a run capacitor but also provides a rotating field that initiates rotation. Because of the smaller capacitor, starting torque is limited to about 100 percent of full load torque. PSC motors are available up to 1 Hp and are used in variable torque applications.

The simplest member of the single phase family is the shaded pole motor shown in Figure 6. It does not employ the split phase technique but instead uses a "notched" pole design. A copper shorting ring is installed around the smaller portions of the notched poles and delays the buildup of the magnetic fields in those pole areas. From a rotor perspective, the field appears to rotate from the main portion of the pole to the shaded area and thus it begins to rotate. Once rotating the motor accelerates to full speed. Shaded pole motors are usually found in small heating and ventilating fans and range from 1/100 to 1/6 Hp.

Lower power, single phase motors are essential components in both commercial and residential applications and will be around for decades. There is, however, a trend to use VFD's to replace higher horsepower models with three phase motors. As a rule of thumb, drive horsepower is doubled when converting single phase power to three phase. The cost of a drive today is much lower than just a few years ago. Its cost can often become a wash when you consider the savings on wiring, starting components and reduced electrical consumption due to higher efficiency.

For further study refer to the two sites referenced in last month's article on three phase operation. Next month we will review motor frame size, the types of motor enclosures and motor nameplate data.

Joe Evans is responsible for customer and employee education at PumpTech Inc, a pumps & packaged systems manufacturer & distributor with branches throughout the Pacific Northwest. He can be reached via his website www.pumped101.com. If there are topics that you would like to see discussed in future columns, drop him an email.