Known in the industry as the PAM motor, the Pole Amplitude Modulation motor is an innovative AC induction motor.

The pole amplitude modulation (PAM) motor

Although it is basically a single-winding, two-speed squirrel cage motor, the PAM motor features one outstanding characteristic that makes it versatile in application and efficient in operation, especially where less than peak load operation is desired: the PAM motor does not have to be engineered with a 2:1 ratio for its two speeds. It can be built with any number of speed ratios, such as 600/500, 750/600, 750/500, 500/428, 750/428, 230/150, 375/300, 1000/750 or 1500/1000 rpm, to name a few of the many possible combinations.

This availability of a great variety of two-speed combinations (relatively close together) gives the PAM motor a much wider range of application than that of conventional single-winding, two-speed motors where the ratio of one speed to the other must always be 2:1.

Benefits

- Reduced wear and erosion on the driven equipment (and less noise) during operation at low speed. Speeds are changed electronically, not mechanically, which means additional apparatus between the motor and the driven equipment is not required; there is no slip energy loss from speed adjusting couplings.

Energy savings

Many electric utility and industry customers have turned to the PAM motor to drive fans, pumps, compressors, Banbury mixers or any other equipment where changing speed provides significant benefits. Although the applications and the speed combinations are different, the underlying reason for choosing the PAM motor is always the same: for applications where a change of speed can offer operating economies, the PAM motor is less costly to install and more efficient to operate than two-winding motors, two-motor arrangements or motors with any kind of hydraulic coupling or VFD.

For example, the PAM motor is an efficient power drive for fan applications where either short or extended periods of operation at less than maximum capacity are required.

Value

An accurate projection of application economics was made using our PAM Motor Evaluation Program. The result, based on computer analysis, is a cost comparison covering a 35-year operating period. In five-year increments, this projection provides such cost-related data as operating schedules, fixed costs, energy costs and operating savings—including comparisons between the monetary investment and the resultant savings for a particular PAM motor.

The results show that a PAM motor, although initially more expensive than a single-speed motor of comparable rating, typically earns back its investment within one to three years.

Speed change advantages

The PAM motor saves energy costs with its ability to switch speeds as operating conditions dictate changes in flow rates.

In fan and pump applications, for example, it is this speed change,
accomplished without use of outlet dampers or valves, that is the key to this motor’s usefulness.

To illustrate the greater efficiency of the PAM motor over other means of accommodating variable flow rates, let us look at the three most popular methods: outlet damper control, inlet vane control and speed control.

The simplest way to change the flow rate is to throttle the system by using inlet vanes or outlet dampers on fans and suction or discharge valves on pumps. When such devices are used, the output of the fan or pump is reduced by the additional pressure drop of the throttling device involved.

For example, a fan with outlet damper control will require 50 percent of rated power input at 30% flow, as shown in the top curve of Fig. 1. When using inlet vane control, 30% of rated kilowatt will produce 30% of rated flow, as shown in the middle curve of Fig. 1.

The most efficient method of varying the capacity of fans or pumps is to vary their speed, as can be seen in the lower curve on Fig. 1, because both the pressure and the flow are reduced. Using this method, the input power to the fan can be reduced to approximately 3% of rated output flow. The PAM motor design enables users to take advantage of this principle.

Although a 70% variation in flow may seem extreme, it does illustrate the fundamental point that controlling flow by varying the speed of the motor is more efficient than throttling at all flow rates.

Speed control is actually more efficient if there is a wide range in the fluctuation of the flow or if a motor must operate at reduced load for considerable periods of time. A related advantage of the PAM motor is that its capability to change speeds allows it to easily accommodate any future contingencies when the load may have to be changed.

**Increased efficiency**

A graphic comparison (Fig. 2) of four methods used to drive a forced draft fan shows that the PAM motor is most efficient at the maximum continuous rating (MCR) point of the fan: First, compare a one-speed, 750 rpm motor where the fan has vane control (Curve 1) with a similar motor that uses a hydraulic coupling (Curve 2). We see that the first combination is more efficient than the hydraulic coupling control at all points above 75% Although the hydraulic coupling is more efficient below 75%, base load generating stations are not likely to operate in this range.

However, at the probable operating point of 75% flow, the PAM motor design (a two-speed, 750/600 rpm motor where the fan has vane control) results in an efficiency of about 80% (Curve 3) compared to only 60% for either of the other two arrangements. A fan operating at this higher efficiency for a number of years will give you considerable savings in energy costs. Also, the elimination of the hydraulic coupling with its high initial investment costs, decreased maintenance costs and use of less floor space will result in additional savings.

Curve 4 shows how a conventional two-speed motor with a 2:1 speed ratio would perform under similar flow conditions. The dotted line indicates a speed change.

This kind of comparison becomes especially meaningful when one considers that fan-type loads are usually operated at 80 percent of output, and in a single-winding configuration, only the PAM motor can operate at 600 rpm (the most efficient speed for loads in that range) and then switch to the 750 rpm speed whenever required. The capability is available when it is needed.

**How the PAM motor works**

The PAM motor works on a very simple principle: Superimposing one alternating frequency on another alternating frequency produces both the sum and the difference of those frequencies.

For example: A 750 rpm induction motor will have an eight-pole fluctuating magnetic wave in the air gap between the rotor and the stator. So, by doubling up connections on specific coils, sequenced according to the desired second speed, a second magnetic field will be produced—in this case, a two-pole field. This superimposition of a two-pole on an eight-pole field could result in both the sum and the difference of those two fields, namely a mixture of a ten-pole and a six-pole field. In the PAM motor, however, we suppress the resultant six-pole field and keep the
original eight-pole field together with the ten-pole field.
The end product of this “Pole Amplitude Modulation” is an AC induction motor with two predetermined and distinct speeds (750 and 600 rpm in our example). The PAM motor, in fact, differs from conventional AC induction motors only in its winding design. Actual motor construction details are identical.

**One winding = two**
The PAM motor is not a variable speed drive. It is designed to operate at only two distinct, fixed speeds. While on the one hand, a conventional single-winding motor can operate at two fixed speeds, the ratio of the speeds must always be 2:1, which has proven to be practically useless in driving “fan-type” loads. On the other hand, any two distinct speeds, regardless of ratio, can always be obtained, but two windings are necessary to accomplish this, unless the PAM concept is applied.

The advantages related to the PAM motor’s single winding versus two winding machines are:
- Only one winding is needed; it is energized the entire time the motor is in operation.
- The single-winding design results in an inherently more efficient motor.
- The PAM motor is up to 25% lighter and smaller.

**The speed changing switch**
The most widely accepted speed changing device for the PAM motor is the oil-filled, five-pole, motor-operated speed changing switch. It is typically installed close to the motor to minimize cable requirements. There are six leads (three for each speed) on a PAM motor installation. A schematic diagram of this type of switch is shown in Fig. 3.

The PAM motor should be started on its low-speed winding to limit the inrush current. This prolongs motor life by keeping rotor and core temperatures to a minimum. Starting on the low speed is also more desirable for driven equipment considerations.

When starting the motor with the speed changing switch at the low-speed setting, the main breaker is closed. To change speed once the motor is operating, the main breaker must be opened, the switch transferred to the other three leads, and the main breaker closed again. It is important, however, to allow the magnetic flux in the air gap to decay before finally closing the main breaker. This pause will usually take about one to two seconds, depending on motor size.

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