Three-phase motors are used in many industrial applications to control loads such as pumps, compressors, valves, conveyors and other motor-driven devices. They are efficient, relatively simple in design, and capable of a high starting torque compared to single-phase motors. Smaller and typically less expensive than single-phase motors with comparable ratings, three-phase motors also may tend to last longer than single-phase motors with the same power rating.

Many loads driven by a three-phase motor simply require the motor to turn on and off in order for them to perform their required function (figure 1). One such load would be an industrial fan, which only needs the motor to rotate in one direction in order for air to circulate. A compressor is another example of a three-phase load where the motor simply needs a connection to a three-phase AC network in order to perform its desired function. These applications typically use a simple three-phase solid-state relay, contactor or motor starter to switch power to and from the motor.

Some applications are not as straightforward, however, and require a bit more than simply turning the motor on and off. Sun tracking solar panel systems, for example, use motors to move the panels throughout the day so that they can follow the path of the sun across the sky. At the end of the day, they must return to their original position in order to greet the sun on the following morning. This requires a controller that can energize the motor and also reverse its direction when needed.

The power of three

Three-phase motor-reversing solid-state relays offer many benefits.

By Doug Sherman, Crydom

Reversing a Three-Phase Motor

Figure 1 shows a simple wiring diagram for controlling a three-phase motor with a contactor. When the contactor is energized, it switches the three phases of the AC mains to the motor, and it begins to rotate accordingly. It will continue to rotate at a constant speed and direction for as long as the contacts remain closed. However, if you change the connection of any two phases of the AC mains to the contactor — connect L1 to terminal No. 2 and L2 to terminal No. 1 for example — the direction of the motor will reverse when it is re-energized.

Of course, physically changing the connection on the contactor every time you want to change the direction of the motor is a bit impractical. Therefore, a device is needed that can do this automatically when a “direction” command is provided by a controller. Traditionally, this was accomplished by using discrete components, multiple mechanical relays or, more conveniently, a three-phase motor-reversing contactor. Unfortunately, the mechanical solutions have the same drawbacks associated with any electromechanical device. The most significant of these drawbacks is life expectancy, especially in applications where the motor is “bumped” or “inched” in order to achieve a specific position.

One possible motor-reversing solution that addresses the problems associated with mechanical devices is the utilization of multiple single-phase solid-state relays. As seen in figure 2, L1 of the AC mains is connected directly to the motor. Solid-state relay (SSR) No. 1 and SSR No. 3 connect either L2 or L3 to the second leg of the motor. Likewise, SSR No. 2 and SSR No. 4 connect either L2 and L3 to the third leg of the motor. When the No. 1 and No. 2 relays are energized, the motor will rotate in one direction. To reverse the direction, the No. 1 and No. 2 relays are de-energized, and the No. 3 and No. 4 relays are energized, effectively swapping the connection of L2 and L3 to the motor.

It is important to keep the following notes in mind regarding the use of multiple solid-state relays in a motor-reversing application:

• The system controlling the solid-state relays must have an interlock circuit that prevents the “forward” and “reverse” relays from turning on simultaneously! Failure to comply with this requirement may result in a phase-to-phase short through the relays, which is a very dramatic and unwanted effect.

• Relays with internal overvoltage protection must not be used in motor-reversing applications. An internal transient voltage suppressor (TVS) may switch on the output of the solid-state relay when subjected
to an electrical transient, effectively creating a phase-to-phase short. A metal oxide varistor (MOV) may be placed across the output of each solid-state relay to provide protection from transients.

- A fifth solid-state relay can be used to switch the third phase of the motor — if required by the application. It is not necessary for this relay to be part of the interlock circuit, but it must be energized at the same time as the “forward” or “reverse” relays to prevent the motor from being damaged.

**Table 1**

<table>
<thead>
<tr>
<th>Solid-State Relay Input-Output Status</th>
<th>Control Signal Applied To:</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1-T1</td>
<td>A1 (Forward)</td>
</tr>
<tr>
<td>L2-T2</td>
<td>Closed</td>
</tr>
<tr>
<td>L1-T2</td>
<td>Open</td>
</tr>
<tr>
<td>L2-T1</td>
<td>Open</td>
</tr>
</tbody>
</table>

Table 1. The table shows the load-current path through the SSR outputs for a given input.

**Motor-Reversing Solid-State Relays**

Yet another and often more preferred solution for many applications is a motor-reversing solid-state relay. Some motor-reversing solid-state relays offers two significant advantages over the methods just discussed:

- All four solid-state relays are contained in one industry-standard three-phase relay package.
- The interlock circuit is already built into the relay.

As can be seen from figure 3, with a motor-reversing solid-state relay, two of the three phases are wired through the solid-state relay, and the third phase is connected directly to the motor. When a logic signal is applied to the “forward” terminal, the solid-state relay switches L1 and L2 directly to the motor. When the signal is removed, the “reverse” terminal, the solid-state relay switches L1 and L2, effectively reversing the direction of the motor’s rotation. If a logic signal is simultaneously placed on the “forward” and “reverse” terminals, the relay will shut off (table 1).

External metal oxide varistors can be added externally to the solid-state relay’s output circuit(s) to provide additional protection from overvoltage conditions. As with figure 2, the solid-state relay has four separate output circuits to provide the motor-reversing function (two for forward and two for reverse), so four metal oxide varistors would be required. Also, as with any electrical circuit, proper fusing and a suitable disconnect from the AC mains is required.

All solid-state relays dissipate thermal energy in their conduction of load current, and therefore often require the use of external heat sinks to maintain allowed operating temperatures. Information about heat sink selection is readily available from most relay manufacturers. "PH"

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