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HOW PHASE CONVERTERS HELP APPLY MOTORS: PART 2

This concludes the article on phase converters,* discussing relative merits of basic types and showing how to size and select one.

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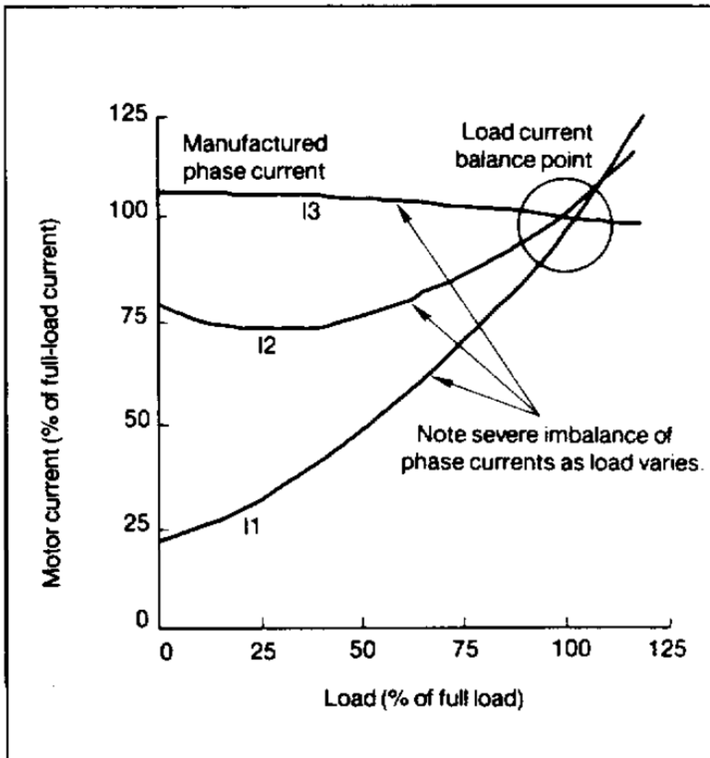
The major performance difference between a static and a rotary converter is their behavior with varying load conditions. Figure 1 shows output currents of a capacitor or autotransformer static converter. Note that they balance at only one load point – the chief disadvantage of any static design. It can produce balanced inputs only to a *constant* load. If the load were to swing through a wide range, the motor would be subjected to potentially damaging unbalanced currents. Now compare the output current of a rotary converter as a function of load, Figure 2. It remains much more closely balanced over a wide load variation, making the rotary better suited to variable loads.

In Figure 3, note how manufactured phase voltages drop off as load increases. At starting conditions (equivalent to about 600% of full-load current), the manufactured phase drops substantially. The effect of this characteristic is that, in general, a rotary converter cannot develop as much starting torque as a static. This can pose a problem for loads which a static cannot handle but which require high starting duty.

Figure 1 - Static phase converter output current vs. load



One solution: Increase the frame size of the rotary converter enough to maintain a higher manufactured phase voltage on start-up. Users and specifiers should be aware of the effect of frame size when sizing converters and evaluating manufacturers.

The need to switch start capacitors in and out of the motor circuit means that a static converter can be used only on *single-motor* loads. A related problem is that repeated starts or load variations may subject relays and starting capacitors to excessive heating. By contrast, there is no limit to the number of motors

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which a rotary can operate. Some applications such as refrigeration have several motors with a wide range of horsepower. A rotary is the required selection because its output can support a broader load range. Another reason, of course, is that a static can perform its capacitor switching on one motor only.

Unlike a static, which is always *on* and ready to go, a rotary must be switched on and be operating at full speed before any load can be applied. And, as with all rotating machines, it makes some noise. Most rotaries can operate continuously unloaded or at full load without effect. However, losses are much higher at no load.

Moreover, a static is impractical on any non-inductive load. This restricts its use to motors. A static *cannot* be used on any resistance or rectifier load. The rotary converter has a successful record with radio transmitters, lasers, X-ray devices, welders, and electric-heat loads.

On balance, the rotary converter is far more versatile. But despite the static converter's limitations, it offers a low-cost solution to small motor applications. Also, it offers high starting torque, compactness, low losses, and quiet operation. The key to its successful application is user awareness of its shortcomings. Even the lowest-cost versions can provide acceptable performance as long as the user has realistic expectations of their capabilities. Table 1 summarizes some major differences between converter types.

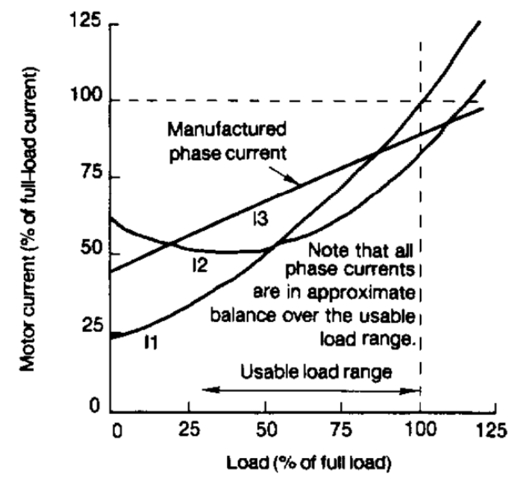

Figure 2 - Rotary phase converter output current vs. load

Efficiency

A common engineering concern is with phase converter efficiency. With no moving parts, a static converter has low loss, so the questions has little meaning. For a rotary, the proper response lies in understanding the difference between converter efficiency taken alone and overall system efficiency. The phase converter sees only one third of the system energy; two of its three load connections come directly from the utility supply without passing through the converter. Therefore, its stand-alone efficiency is not significant. Converters, like most rotating machines, are nominally 85 to 90% efficient at the upper end of their load range. Thus, maximum full-load system losses are approximately equal to 15% X 33% = 5% of rated load. System efficiency is lowest when the converter operates at no load or far below rated capacity.

Standards

Unfortunately, there are no published industry standards governing ratings, sizes, or performance of phase converters. The three best-known approval agencies in North America, CSA, UL, and ETL have approval and listing procedures for converters. However, these procedures are little more than material and safety audits. They do not verify manufacturers' specifications or performance claims. Without strict industry standards, a crude but nonetheless reliable yardstick of relative performance is a comparison of converter frame size and weight. This technique is more applicable to rotary converters because they are built on NEMA T frame sizes.

Installation, maintenance

The installation of any static or rotary phase converter is simple for a qualified electrician. A typical installation of a rotary or a large static can be made in a few hours. Pay attention to the manufacturer's instructions – most startup problems are traceable to

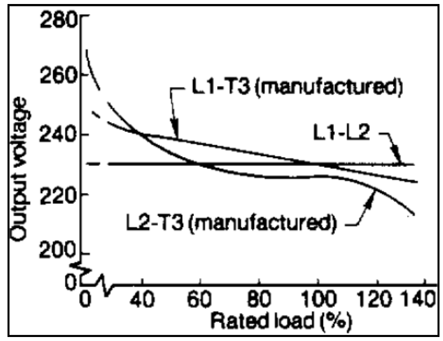

Figure 3 - Output voltage vs. load for a rotary converter with 230-V supply. At much higher loads, voltage falls off drastically

installer deviations from recommended practice. A few basics to insure successful installation include:

- Ample utility service. Always allow at least 5A of single-phase service per HP of load.
- Adequate wire size. Make sure the gage is large enough to minimize voltage drop.
- Tight connections. Bolt all connections. Never use wire nuts.
- Correct fusing. Use high inrush tolerant circuit breakers or time-delay fuses.

Most static units are wall-mounted. Smaller statics can also attach directly to the load device. Rotaries are floor-mounted. They may be installed near the main power service entrance or adjacent to the load. Most rotary converters, with a few exceptions, need not be bolted down; they do not have to be braced against starting loads.

Autotransformer converters require several initial adjustments.

The taps must be adjusted for best balance. This must be done carefully and rechecked as line voltage varies. Once set, relays should be checked regularly for contact condition particularly on heavy starting duty applications. A capacitor-type static has few adjustments or maintenance needs.

A rotary converter requires little ongoing maintenance. Once in service, the unit should be inspected periodically. Ventilation slots must stay open and bearings must be lightly lubricated at regular intervals. Typically, no other formal maintenance is required or recommended.

Reliability

Phase converters *are not* service prone. Except for the bearings in a rotary, all components are static devices. The most common field failure mode of a rotary converter relates to wiring and connectors. Bad bearings, shorted windings, and capacitor failures also occur, but are not frequent problems. Connector and wiring problems usually stem from abrasion of taped joints or connections which are inadequately tightened during installation.

Bearings are the most commonly expressed concern of rotary converter owners. In service, however, bearing failures are uncommon. The main reason is that the bearings carry only the load of the spinning rotor. There is no external shaft extension on a phase converter and, consequently, no outside mechanical load on the bearings. Field experience shows that bearing life of 10 to 15 years is not uncommon; 5-year life is a minimum expectation for installations running without shutdown.

Reliability of static converters is somewhat less than that of rotaries. The principal reason is excessive starting duty which burns capacitor switching relays and shortens the life of the electrolytic starting capacitors. Still, these converters are highly reliable.

The future

The economic forces that made phase converters attractive are still active. The market shows no sign of diminishing over the next several years. Future developments in converters will most likely center on two areas: the fully electronic phase converter, and advancements in output control of rotary converters. At present, electronic converters are on the market but they have proved limited in capability and they are very expensive. Nonetheless, just as advances have been made in solid-state controls and power

How to size and select a phase converter

Any load can be operated from a phase converter. The key to a successful installation is careful sizing. “I need a converter for 5 hp” is a typical request. Unfortunately, that inquiry provides no information to zero-in on an optimal selection.

Actually, selecting a converter is a lot easier than picking out a car. It’s a 2-step process. Step 1 starts with determining three essential pieces of information. With them, you can make a preliminary selection. Step 2 involves asking several specific questions to determine if the preliminary sizing is adequate.

Step 1. Determine:

- Type of load – motor, resistance, or rectifier. This tells whether you need a rotary or static converter. Any resistance or rectifier load requires a rotary converter; there is no alternative. A motor load could go either way. You need more data. One thing is certain: Any load that can operate on a static will also operate on a rotary. The converse is not true.
- Number of motors. If the load contains just one motor, it may be a candidate for a static converter. Determine if the load requires full motor nameplate horsepower. If not, use a static. If the load has more than one motor, no question – it needs a rotary.
- Total load and largest horsepower. For a single-motor application, you can select a capacitor-type static converter equal in rating to motor horsepower. Remember, you will not get full nameplate horsepower out of the motor on this type converter. Note: It does no good to oversize a static converter. Bigger capacitors still won’t let a motor achieve full nameplate horsepower. Only an autotransformer static or a rotary will do that. If it is a multi-motor load, select a rotary converter to match the largest motor’s rating. For example, a load with motors rated 5, 7.5, and 15 hp would require a 15-hp rotary converter. Why not 27.5 hp? Because the 15-hp motor is the heaviest starting duty, and a rotary converter can operate a total of two to four times the horsepower that the largest motor can start. If the load is resistive, you can use maximum total kilowattage to select a converter. Some manufacturers publish kW ratings. Alternately, you can make a close approximation of size by converting the horsepower rating to kilowatts.

Step 2. Application specifics:

Be sure to find out what kind of machine is to be run – one of the most valuable pieces of information you can get. Knowing this may tell you a good deal about the type or size of converter. For example, small machine tools generally do well on small statics, but CNC machines use computer controls with rectifiers – that calls for a rotary. A further example: A lathe has a 2-speed motor. That application requires a rotary, because the static could not serve two windings.

Also ask:

- Will the motors be starting together? If so, increase converter size.
- Do the small motors run while the big ones are off? Refer to the manufacturer.
- Is the application unattended? If so, add automatic controls.
- Does the load require high starting torque? If so, increase converter size.
- Will you run two motors of the same rating? If so, increase converter size.

Table 1—Comparison of static and rotary converters			
	Capacitor static	Autotrans. static	Rotary
Single-motor loads	**Yes**	**Yes**	**Yes**
Multiple motor loads	No	No	Yes
Rectifier & heat loads	**No**	**No**	**Yes**
Variable load range allowed	No	No	Yes
Frequent starting duty	**No**	**No**	**Yes**
Starting torque	High	High	Med.
Breakdown torque	**Low**	**Low**	**Med.**
No-load losses	Low	Low	High
Overall eff. at full load	**98%**	**98%**	**85 to 95%**
Dual voltage, 230/460 V	No	No	Yes
% Motor nameplate rating	**65 to 85%**	**100%**	**100%**

supplies, there is reason to believe that converters will go that route eventually.

More likely in the short term will be major improvements to rotary converters to broaden capabilities on complex applications. Such situations involve multiple motors, large and small, with widely varying loads. The changes will will include much more elaborate control that will be able to adjust converter output to many load conditions.

From a manufacturer's perspective, in today's competitive business climate, it is a commercial imperative that manufacturers and dealers of 3-phase equipment address the lack of 3-phase service when it affects their products. It is understandable why machines are designed to operate only on 3-phase service, but the needs of those users who don't have it should not be ignored.

From a user's perspective, the converter offers the flexibility to operate any piece of equipment from any existing single-phase source without incurring the cost or delay of utility construction, and without sacrificing machine performance or reliability.

For more about phase converters contact Kay Industries, Inc.