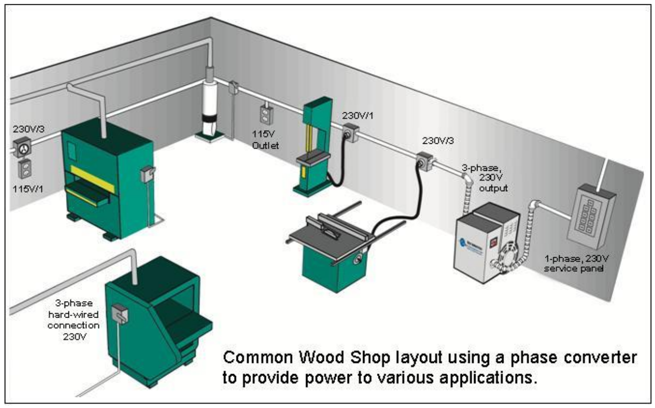
INTRODUCTION TO PHASE CONVERTERS FOR WOODWORKING SHOPS

A very common problem encountered by small and medium size woodshops is the lack of 3-phase utility power to supply their various production machines.



Common Wood Shop layout using a phase converter to provide power to various applications.

Utility companies must provide electric service to anyone who requests and can pay for it. However, that obligation only does not require them to provide 3-phase power. That decision is usually based on how much service the customer needs, how far new lines must be run and the total expected energy usage.

When confronted with this dilemma, a shop owner can choose to 1) purchase only single-phase machinery 2) Convert 3-phase machines to operate on 1-phase, or 3) Use a phase converter to operate the 3-phase machines from a 1-phase supply.

The choices of 1-phase machines above 5HP are very limited and converting a 3-phase machine to run on 1-phase is complicated and expensive. Consequently, the most cost effective solution to this dilemma is to use a phase converter to run the 3-phase machines from a new or existing 1-phase service.

Phase converters have existed in one form or another for nearly 100 years. Their construction is well understood and well documented. Unfortunately, that's about as far as any typical shop owner knows about converters.

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.

There is a tremendous amount of information about converters online. Unfortunately, much of it is contradictory and/or outright confusing. But there are some simple steps to take that will enable a shop owner to make a technically good decision. A successful converter application depends on proper converter selection.

Phase converters for woodworking equipment

Woodworking shops come in all sizes. Larger facilities generally are located in areas already served by three-phase power, but not always. For the small and medium size shops, a phase converter is often the most cost effective alternative.

A rotary converter can supply power to multiple machines. A typical shop might include a 5HP sliding table saw, 5HP planer, 5HP dust collector and edgebander with several small motors and glue heater. This arrangement of equipment could easily be fed from a single converter with a rating no larger than 10HP.

Characteristics of woodworking machines

As a rule, woodworking equipment loads are not particularly severe. In fact, most woodworking equipment is rather easy to start. This includes saws, drills, wide-belt sanders, boring machines, routers, among others. It is important to treat each machine according to its operating characteristics. The most severe loads are those that run at high speed including shapers, jointers and planers. Edgebanders can also be problematic considering their mix of frequency drives and glue heaters. A technically knowledgeable converter representative should be able to sort through the specifics and recommend an appropriate selection.

What you must know in order to apply a converter in your shop

Any load can be operated from a phase converter. The key to a successful installation is careful sizing. "I need a converter for 20 HP" is a typical request. Unfortunately, that description provides no information to zero-in on an optimal selection. *It is absolutely essential to be familiar with the HP or KW ratings of each machine that you will be running and which machines will normally operate together. That is the only way to be certain you getting a converter of appropriate capacity.*

Service size

Sometimes great plans get sidetracked when the available service is inadequate to supply the equipment to be operated. A very common question that gets overlooked regularly is how much single-phase service is necessary to run a line-up of machines. It does not matter how much 3-phase equipment you plan to run or what size converter you purchase if you do not have enough single-phase service. That means you must have enough service over and above what is needed to supply your other single-phase loads such as lighting, HVAC, single-phase machinery, etc.

<u>A rule you can count on every time is: You must provide the converter with a minimum of 5A (and preferably 6A) of single-phase 240V for every horsepower of 3-phase motor load that runs simultaneously.</u>

Key point to remember: One amp of single-phase does not translate to one amp of three-phase. One amp of single-phase is actually equal to .58 amps of three-phase. This has nothing to do with the phase converter. It is entirely the laws of physics and electricity at work. For the sake of simplicity, just plan on using a conversion ratio of 50%. Thus a 100A single-phase service can be turned into 50A of three-phase.

Sizing and selecting a phase converter
Selecting a converter is a process. It starts with determining three essential pieces of information. With them, you can make a preliminary selection. The second step involves asking several specific questions to determine if the preliminary sizing is adequate.

1. Type of load – motor, resistance, or rectifier. Any resistance (heaters) or rectifier load requires a rotary converter.
2. Number of motors to be operated and including both the largest motor and the total connected load.
3. Total load and largest horsepower. Converters must be sized for the largest motor.

If there is only a single motor, the converter size can usually be determined at this point. If there are multiple motors, it becomes helpful to know some addition application specifics:

- 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.

A qualified converter technical sales person will address these points at a minimum. If they do not, they are not truly qualified.

Converters types
There are several varieties of converter so let's cover some background. There are generally three types: static, rotary and electronic. A variable frequency drive (VFD) is another method of operating a 3-phase motor from single-phase but it can only run a single motor and it cannot supply control power for a machine. Therefore, we will not go into any further discussion on VFD's as phase converters.

The ***capacitor type static converter*** is the least expensive and appropriately, offers the least performance. They are designed to start *single* motor loads only and once started they switch out of the circuit, allowing the motor to essential run on single phase. This is normally not a problem as long as the load never exceeds about two thirds of its nameplate rating.

The ***rotary converter*** is far and away the most cost effective and fully functional type and is the workhorse of the woodworking industry. It is more expensive than the static converter but it is capable of running any number of motors, heaters or rectifier loads simultaneously.

Electronic converters are solid state devices that use inverter technology to create a third manufactured leg that replicates utility 3-phase. Such converters tend to be significantly more expensive for the same load capacity as compared to rotary or static types but they do have the advantage of somewhat better output voltage regulation and since they are not rotating machines, they do not have to be started up prior to applying a load

Because of their dominant presence in woodworking facilities, this discussion deals primarily with the rotary construction.

Rotary converters - Construction, operation.
A rotary phase converter is an induction machine that operates on a single-phase supply and produces a true 3-phase output. It can supply the full rated input requirement of any 3-phase motor (including service factor), resistance, or rectifier load. The manufactured phase of the rotary converter is a true measurable sinusoid, unlike that of the static type.

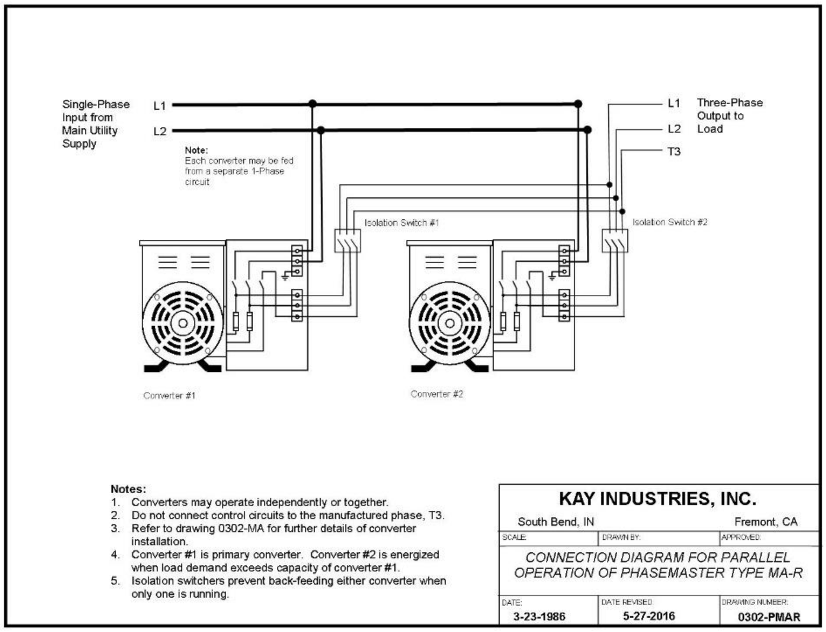
A common misconception is that a rotary converter is similar to a mechanically coupled motor-generator set. In fact, the converter is a single-armature device similar to a 3-phase induction motor. It has a stator frame with a symmetrical 3-phase winding and a specially modified squirrel-cage rotor. A large capacitor bank is placed across a coil group between one input line and the manufactured phase.

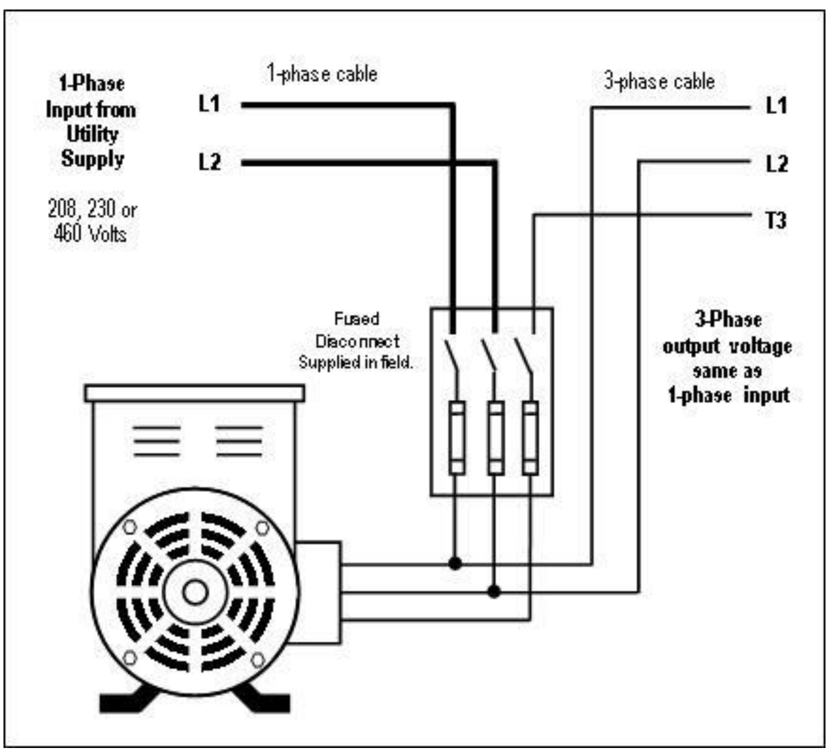
As the rotor spins, it picks up a replica of the utility supply through induction. The rotor current, in turn, creates its own field and, as the rotor passes each stator coil group (each separated by 120 mechanical degrees), the single-phase rotor field is replicated in the other two coil groups. The result is **true 3-phase sinusoidal output with each phase shifted by 120 deg**.

A phase converter can change phases but not voltage. Converters can operate at 240 or 480V and will produce the same voltage at the 3-phase output terminals. The output of a rotary converter is 3-wire closed delta. It cannot be changed to a 4-wire wye output. If such output is required, a delta-wye transformer must be used. In practice, it is often possible to work around this problem without a transformer. Loads rated 208/120 V usually require the 120-V leg for control purposes only. In such cases, the 3-wire converter output can connect directly to the 3-phase load with the control circuits wired separately.

Output characteristics. Two of the three lines in a rotary system come directly from the utility supply. Therefore, the most important output characteristic is behavior of the manufactured phase voltage relative to the utility lines. Phase converter output voltage is load-dependent. At no load, the manufactured phase voltages are substantially higher than the incoming line voltage. As load increases, the voltage drops so that, at full load, the three voltages are closely balanced. When connected load exceeds converter capacity, the manufactured phase voltage drops off sharply. At that point, the third phase can no longer sustain the voltage needed to maintain rated running torque.

An interesting phenomenon occurs when a rotary converter starts a motor. After the motor reaches full speed, it has a supporting effect on the system. As a result, a rotary converter can *operate* much more total horsepower that it can *start* at one time. In fact, a rotary converter can power two to four times its nameplate rating as long as only one load motor equals the converter's maximum rating. Thus, a 25-hp rotary converter could easily handle a total of 40-60 HP if it served a 25-hp motor, the other 15-30 hp was made up of motors smaller than 25 HP, and they are not all started at once.





Ratings, dimensions, prices. Rotary converters come in ratings from 1 to 100 hp. The practical limit on the single largest motor that can operate from one rotary converter is about 125 hp. But there is no theoretical limit to total load size converters can serve. Rotary converters may be paralleled indefinitely for any load. This capability is convenient for users who must add system load often, or for applications where utility supply lines could not withstand the inrush currents of a single large rotary converter. The only true converter capacity restriction is the maximum connected single-phase load the utility allows.

A rotary converter is dense and compact. A typical 10-hp unit will fit in an 18 inch cube, weighs around 200-250 lb and sells in the range of $1500-2000. At 25-hp, size increases to 24 inches on a side and the price moves up to $3500-$4000. Rotary converters are rated for the largest motor it can start, but it can also operate an additional load ranging from two to three times the starting capacity in motors of smaller rating. Consequently, the cost per total horsepower capacity is lower for a rotary converter than a static.

Controls.

Since it is a rotating machine, a rotary converter (actually any converter) requires some sort of disconnect means for on-off control. The most common and least expensive control scheme for a rotary converter is a fusible disconnect. The converter is manually switched *on* and runs continuously until it is manually switched *off*. However, some conditions call for more control or for remote operation. In these cases, a converter may have automatic controls. A magnetic contactor can start and stop the converter from a remote actuator. A timing relay locks out the load until the converter reaches full speed and is producing 3-phase power (about 3 seconds). Automatic controls serve unattended or intermittently used installations such as lift station pumps, elevators, and air conditioners.

Unlike a static or electronic converter, 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.

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.

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 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 gauge 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.

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.

A final word when evaluating converters.

Do not assume that all converters are the same. It is well known that some manufacturers rate their converters much higher than others. In other words, all converters of the same horsepower rating are not truly the same. Comparing the weights will give you a better idea of equivalent capacity. A rotary converter consists principally of iron and copper. You cannot get more capacity with less weight.

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