PHASE CONVERSION TECHNOLOGIES & HOW THEY WORK

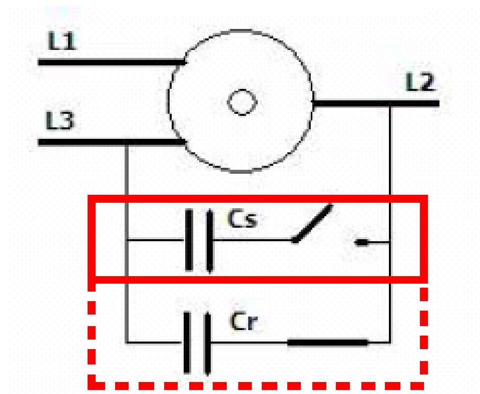
Investing in a three phase utility supply can be very expensive. With utility estimates averaging $40,000 per mile to install, many three phase equipment users are forced to turn elsewhere to find a three phase supply. **Phase Converters** are the economical option, however power **quality is often compromised** with poor voltage balancing and for most equipment loads, an oversized converter must be specified to enable motor start-up. These inefficiencies lead to increased energy consumption and eventually may cause damage to the three phase equipment, especially digital or electronic machinery.

We have outlined the various phase conversion technologies and points to be aware of when choosing a phase converter. At the end you will find a brief description of how **Boosters overcome these problems.** If you have any further questions please contact our friendly staff at 1-866-910-0699 for service and advice.

How Does a Static Converter Work?

The Static Converter is made up of two small components: A voltage sensitive relay and a standard capacitor (Cs) connected to your motor application (Red Box). The capacitor delays waveforms (or shifts the phase) during the start-up of your motor application. The relay disconnects this start capacitor after the motor has started. From this point, the motor will continue turning on the single phase supply. The performance of such a motor is fairly poor and can be compared to a car motor running on only a few cylinders Motors operated on a static converter will produce about 50-60% of their name plate power. When you add another low cost run capacitor (Red Dotted Box) to the simple design, rated power goes up to around 70% of the motors name plate power.

Your Machine Motor



L1 & L3 are the single phase legs going to your motor application and L2 is produced when motor starts turning. Cs is the start capacitor which is switched out after the motor starts. Red dotted box shows the improved static converter.

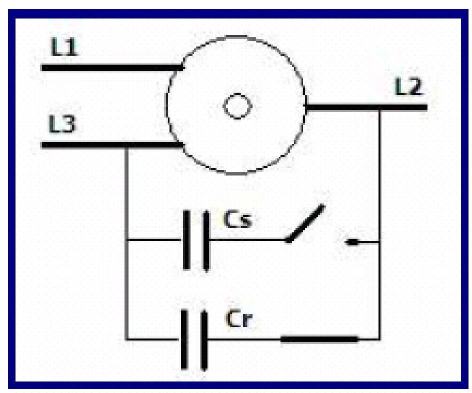
To help with understanding, the Start Capacitor (Cs) is used only to start the motor and then it is switched out completely. The Run Capacitor (Cr) is always in the circuit and is carefully sized to balance the voltages at one load rating (generally around 50% full load). Since Cr is fixed the voltage balancing at either end (0% and 100%) is quite poor.

How Does A Rotary Converter Work?

If you add an idle running motor to a static converter, you have a rotary converter (Blue Box).

The added motor will compensate for some of the static converter weaknesses and help extend the range of motor sizes and loads. The internal motor is inactive at average load, but works hard when loads don't match the value of the chosen run capacitor (Cr).

Rotary converters are clearly somewhat better than static converters. They can run several motors of different sizes. Large motors will produce up to 90% of their nameplate power, small motors (motor being much smaller than the converters idling motor or pilot motor) a bit more. If the manufacturers oversize these motors, the output symmetry, start capability and capacity will all be increased. This is why manufacturers ask you so many questions about your applications. When in doubt, they will offer a converter with a larger pilot motor or suggest a larger converter altogether.



L1, L2, L3 are the three phases of the internal motor. Cs is the start capacitor which is switched out after the internal motor starts. Cr is the fixed run capacitor.

Should Static Converters With Their Weak Performance Be Used At All?

Sure, why not? Many motors don’t have to produce 100% of their name plate power. Static converters are ok to run one motor running at low or average loads. A small saw in a private workshop for example, or a pump which isn’t working hard. But the motor may stall and/or overheat when more shaft power is needed than the (60%-70%) provided with a Static Converter.

Are All Rotary Converters The Same?

Not quite. There are two groups of rotary converters: Low impedance & high impedance. LOW IMPEDANCE: Modern standard motors used in the industry are so called “low impedance” motors. These motors produce very high torque when starting and when overloaded. But they also consume very high currents under start and overload conditions. These motors require a start and a run capacitor and a contactor to switch between the two capacitors. Contactors don’t live forever, especially when loaded frequently with high start-up currents. Such a converter is not maintenance free. HIGH IMPEDANCE: The magnetic structure of a motor can be modified to achieve lower start-up currents. This motor is called “high impedance” motor. Such a motor can be used in phase converters without the need for a start capacitor i.e. the start and run capacitors are the same. The good news: No contactors are required; therefore the converters lifetime is extended. If bearings are greased for lifetime, these converters are maintenance free. The bad news: Such a motor is much weaker as a generator when external motors start, therefore converters have to be oversized in order to be acceptable. It will also tend to produce over- and under voltage when operated outside the ideal load which can be partially corrected once again by oversizing the converter.

There is also another converter concept: Convert AC to DC and chop this into slices, feed it through filters and convert back to AC – the same as a variable speed drive. They are lightweight because no motor is needed and offer good voltage symmetry and stability. When applying higher loads by starting external motors under load or when dealing with short overloads they react very fast and sensitively and switch off to protect their fragile IGBTs. The cost for larger AC drives is relatively high and the availability for different voltages and higher throughputs is still limited.

How Good Is Three Phase Power Generated By A Rotary Converter?

Because the run capacitor used in a typical rotary converter has a fixed value, the power quality is only acceptable at one specific load condition.

At smaller or larger loads the output symmetry of that motor-capacitor structure will become less perfect. Manufacturers compensate for this mismatch by using internal motors with a larger frame size.

Imagine: If the internal motor used is 10 times bigger than the largest external motor, the output symmetry would not be affected much whether a load is connected or not.

A compromise has to be found:
Manufacturers of rotary converters use motor frames typically about 150% to 200% of the largest motor load. This adjusts the output symmetry to values found in development countries (around +-10%) but also brings some disadvantages with the higher weight, less efficiency and higher converter start currents.

Because converters with “high impedance” motors need even more compensation, they are larger and heavier.

Both concepts, high and low impedance, have difficulties supplying power to resistive loads like heaters or mixed loads where heating as well as motor power is needed. For use with kilns or industrial washing machines manufacturers for example suggest to use larger converters than actually needed.

How Do I Know If A Converter Is Of The “High Impedance” Type?

You know it when a manufacturer claims to offer a maintenance free converter. Most units with “low impedance” motors use internal contactors to switch out the start capacitor once the internal motor has come up to speed. No manufacturer can claim such a unit is maintenance free.

Will My Application Produce 100% Motor Nameplate Power When Using A Rotary Converter?

Well, sort of. If your motor is much smaller than the motor used as an internal motor-generator: Yes. Larger motors will not produce 100% of their rated power when running under full load or they may overheat due to unbalanced loads on their windings.

What Does Motor Frame Size Mean?

Sizes of induction motors are standardized world-wide. Only the coils are different because European type of three phase voltages are around 3x 400V between phases and North American voltages are either 3x 230V or 3x 460V between phases. Motor frames (frame sizes) are available as 3Hp, 5hp, 7.5hp, 10hp, and so on which are standardized in North America by NEMA. By asking the motor (NEMA) frame size you will know exactly how big the internal motor actually is and thus how much the converter is oversized.

Why Do I Read So Often About The Largest Motor I Can Start?

Ideally you would like to have your converter producing three phase power in the same quality as utility supplied power. Most converters don’t because they have compromised in one way or another. Three phase induction motors can require about 600% of their maximum rated power when they start. A three phase utility grid is able to provide this. Fuses and overload circuit breakers are available as “motor rated” to cope with 600% loads for a short time. But a standard rotary converter can only produce about 200-300% power when an external motor starts or is overloaded.
Motors and machines start slower compared to utility supplied motors or cannot start at all. This is why most manufacturers of converters ask you lots of questions about your application. Converter suppliers suggest to buy a standard unit only when motors start without load on the shafts (easy), or may suggest one size up when motors start under light loads (medium) or go even higher when large motors are to be started under full shaft load (heavy duty).

Why Not Use Different Capacitors for Each Application to Overcome the Load Mismatch

We have learned previously that there is a large capacitor which helped to start the internal motor. Why not using this again to start external motors as well? This would start large motors under load. We also understand that each running load ideally needs a different size of run capacitor. Why not using a few and switch them in and out as needed? This would provide a stable three phase output as found with utility supplied power. No need for a larger motor frame size because you would not have to compensate capacitor mismatches. The problem is that charged capacitors all behave like little hand grenades, each one stores a fraction of a converter’s output energy. Connecting them using contactors, while a converter is running is dangerous: Some of the capacitors are empty, others might be fully charged with high energy and others follow the up and down of the alternating three phase voltages. Electric contacts are too slow. Using them to connect capacitors with different charges would produce arcs, sparks and flames and would limit the life time of contactors considerably. This is why ordinary rotary converters don’t use this obvious technique.

ARE THERE NEW TECHNOLOGIES AVAILABLE TO MAKE A SUPERIOR PHASE CONVERTER

A BOOSTER™ converter is a modified rotary converter. But several banks of capacitors are used for the perfection of the three phase output when starting and running loads. Fast solid state switches (SCRs- Silicon Controlled Rectifiers, also known as Thyristors) are used to connect and disconnect charged capacitors as needed. These SCRs are very insensitive, very forgiving, take excessive loads easily and are well known as electronic workhorses for rough conditions. Electric trains, trams and subways use them for motor and speed control. In a BOOSTER™, groups of capacitors are constantly adjusted to maintain high output power quality. Switching is performed at high speed only when no charges can flow from one to another.

This means that no stress is put on any component within the converter or the power lines. It eliminates any radiation of electric or magnetic disturbances and transients through wires or through the air as found with contacts, variable speed drives or AC drives.

Do You Need An Internal Motor With A Larger Frame Size?

No. Capacitors are always adjusted to the load. This eliminates the need for larger internal motor frame sizes. The internal motor used is only as large as the largest motor load. The BOOSTER™ will produce 100% shaft power on any connected motor.

Does It Have Any Motor Start Limitations?

No. Fast capacitor switching provides full torque to all driven motors under all load conditions up to 600%. Small and large motors start in the shortest possible time. Driven motors accelerate fast even when their shafts have to accelerate large loads or masses, during start-ups and continue running when excessive loads occur as often found with lathes, horizontal and vertical mills, with ARC and MIG welders, grinders and cut-off saws, submersible pumps, compressors and refrigeration systems. Bending, cutting and milling in the Metalworking Industry and cutting and pressing in the printing industry is known to produce high overload conditions for brief moments similar to crushers and compactors in the Waste Industry. Digital processing within the BOOSTER™ observes the three phases in real time and corrects any load changes instantly. This is why a BOOSTER™ can be used not only with motor loads but also with resistive and mixed loads where heaters and motors are used: Kilns, industrial washing machines, extrusion systems.

What Happens In Case Of A Stalled Motor Or A Short Circuit?

SCRs resist short circuits and the high over currents of stalled motors. For short moments they can take up to about 6000% of the Booster's total throughput. Momentary short circuit conditions are therefore harmless to a BOOSTER™.

Is It Sensitive To "Dirty" Line Conditions?

No. Power lines can carry all kind of harmonics produced by any electronic or other equipment. High voltage transients generated by lightning strikes to the power lines or by electric switch gear are harmless to a BOOSTER™.

How Perfect Does The Three Phase Voltage Balance Have To Be?

Utility supplied power is not perfect because loads are not always well distributed to all three phases. In most industrialized countries, the symmetry between phases is very good (typically +-5%). In development countries it often is not as good (about +-10%). Induction motors are built to cope well with voltage unbalance but at high levels will dramatically increase the motor losses due to heat. This leads to both a decrease in efficiency of the motor and shortens its life, therefore voltage unbalance of greater than +/-5% is not recommended; this is what a BOOSTER™ provides.

Is There An Upper Throughput Limit?

No. The limit could only be the amount of single phase current being available to a property. Boosters are currently available in standard sizes of up to 85hp. Larger versions such as those required for oil exploration will be available soon.

Is There a Limited Lifetime?

No. The lifetime of semiconductors is comparable to mechanical switches or parts; indefinite. Motor bearings are greased for lifetime. Capacitors are polypropylene; self healing should anything ever happen.

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