THREE PHASE POWER SOLUTIONS

1. Newton Tesla Variable Speed Inverter drive fitted to Myford Super seven

David Sharman examines the options for operating three phase machinery.

Many readers will be familiar with the issue: they have either acquired or are considering acquiring a piece of three-phase machinery yet they do not have three-phase electrical power in their premises. The purpose of this article is to outline the options available to them and the factors they ought to take into account. It is not intended as a technical electrical engineering article but some basic electrical terms are introduced so that the article makes sense. The author is an engineer with the phase converter manufacturer Boost Energy Systems, but the article attempts to present all the options objectively.

Why is three-phase machinery attractive

Three-phase machinery is typically cheaper than single-phase machinery of the same power rating as it can be more easily located on the used machinery market. The reason for this is that historically single phase machinery has only been of low power, a situation which is unlikely to change as most industrial machinery continues to be manufactured using three-phase motors. Single-phase motors of less than 1hp or so are readily available whereas motors of greater than 3hp are seldom single phase. Moreover, the poor starting torque characteristics of single-phase motors and their increased cost are such that if a machine has a primary three-phase motor in it – and therefore can be assured of having three phase power available - then it is quite likely that the designers of the machine will have installed three-phase motors in even the smallest drives.

What is three-phase power

Electricity comes in either alternating current (AC) or direct current (DC). With direct current two wires are maintained with a steady potential difference between them, measured in volts (V), and when a load is connected between the two wires current flows from one to the other doing work. The symbol for DC is straight line above a straight dashed line, which represents the fact that the voltage remains fairly constant in a DC system. The system of wires and loads is colloquially known as a network.

2. Static Converter from Transwave

However for the vast majority of systems consuming significant amounts of power, electrical networks make use of alternating current for generation, transmission, and distribution, because with AC we can make use of transformers to obtain different voltages. In a single-phase AC network the potential difference between two wires oscillates in a sinusoidal manner at a constant frequency. It so happens that one wire (known as the neutral, N) normally remains at the same potential difference as ground (literally the earth, variously designated E or PE) whilst the other wire (known as the live, L) alternates from being positive with respect to neutral through to being negative. With AC the voltage is constantly changing and so as to get a single number to use for discussion and calculation purposes, engineers use normally the root of the mean of the square (RMS) voltage, or occasionally either the peak, or the peak to peak voltage. With a pure sinusoidal waveform the voltage that is generally discussed is the RMS voltage because this is equivalent to the DC voltage that produces the same heating effect for a given current. So 240V RMS is equivalent to 339 V peak, or 679 V peak to peak and can be written as 240 V_{rms}. (the formula is $V_{rms} = V_{max}/\sqrt{2}$). This is illustrated in **Figure 1**, which shows a sinusoid varying about a neutral, and which can also be drawn as a vector with a single arrow pointing away from neutral. When a load is connected in an AC network the electrons oscillate backwards and forwards rather than flowing through it as they do in a DC network. Broadly speaking current is related to voltage and resistance by the formula V=IR and so in a given system as voltage rises and falls so will current, although there can be a time lag between the two as a result of capacitance and inductance in the circuit.

In a three-phase network there are three live wires called L1, L2, and L3 and a potential difference exists between each of these and neutral. If a potential difference of 240 V_{rms} exists between each phase and neutral, and if the phases oscillate at the same frequency, and if the frequency of each phase is offset by a constant and equal amount from each of the other two phases then the waveform looks like **Figure 2**. This diagram can also be drawn as a vector except that now each of the three phases occurs at 0, 120 and 240 degrees around the neutral.

The magic thing is that there is also a potential difference between L1 and L2, and L1 and L3, and L2 and L3, and simple maths reveals that the voltage between phases is 415V_{rms} and that this voltage also varies as a sinusoid (the formula is $240V = 415V/\sqrt{3}$). This is the system we have in the UK and it happens to operate at 50Hz whereas most North American systems operate at 60Hz. This is how electrical distribution systems are set up so that three-phase 415V phase to phase is provided to industrial customers whereas domestic customers are provided with single-phase (N-L) 240 V from the same network.

Continental Europe formerly operated at 380V phase to phase, 220 V phase to neutral but all of Europe including the UK is now harmonising around a common voltage of 400V phase to phase, 230V phase to neutral. This has been done by changing the tolerances, and so there is now more latitude over the next decade or so, for the UK voltage to drop and the continental voltage to rise (fortunately we were already all on the same 50 Hz frequency). The subject of voltage harmonisation is considerably more complicated than this brief mention, and has aroused some controversy over various technical details, but rest assured that it is being done with the best of intentions. It is because of this harmonisation that much machinery is dual labelled as either 220/240V or 380/415V and in practice even machinery that is not labelled in this manner is extremely unlikely to be adversely affected by the change.

What are the options

When considering purchasing a piece of three-phase machinery where only single-phase power is available there are five options:

1. Have three-phase power installed.
2. Move to somewhere with three-phase power.
3. Change the motors etc. to single-phase motors.
4. Install a variable speed drive (VSD/VFD).
5. Install a single to three-phase converter.

I will skip over options 1 and 2, and proceed to deal with each of the remainder in turn.

Change the motors

In fairly simple machinery it is possible to change a three-phase 415 V motor for a single-phase 240 V motor. The single-phase motor will be bulkier and this can cause problems if the motor is embedded in a confined space. Also a single-phase motor might have insufficient starting torque – this might not be a problem for most machine tools but is a real issue for loads such as car hoists and lifts in which the motor must develop maximum torque from rest. It may also be necessary to change relay coils or heating elements to suit 240V supplies.

Install a VSD

Variable speed motor drives (also known as inverter drives or variable frequency drives – VSD or VFD) work by taking the constant frequency sinusoidal AC input, rectifying it to DC, and then chopping it into a variable frequency AC output with a fairly blocky waveform. By altering the frequency of the waveform they are able to control the speed of the motor, and by altering the nominal amplitude (i.e. the voltage) they are able to control the power available. A positive aspect of motor drives is that they provide a lot of control over the operation of a motor – one can vary the frequency (which determines motor speed) over a wide and continuous range, reverse rotation, accelerate motors gradually from or to rest, and jog motors backwards and forwards.

However all is not perfection and motor drives do have limitations. Firstly they should only be used to control motors. This is because the waveform is not perfectly sinusoidal and in fact contains quite a lot of high frequency components that can upset sensitive control circuits. Because of these high frequency components, bare motor drives can also cause radio frequency interference and so all motor drives installed in the European Union must have filters fitted. Secondly they should only control one motor at a time as otherwise all the motors will change speed in lockstep with the main motor. Thirdly, although a motor drive might be able to turn a motor at low speed, it is possible for this to cause overheating, as the cooling fan in the motor is shaft mounted and moves less air at low speeds. This is why motor manufacturers now sell separately powered bolt on fans which mount behind or instead of the normal fan. At the power levels typical of the amateur shop, it may not be necessary, or may be solved by fitting a low cost computer fan.

Because of these drawbacks it is typically necessary to rewire the machine tool to take a motor drive. Firstly the drive itself needs to be packaged with a filter and a circuit breaker or other protective device, and often this needs stuffing into a small cabinet with sufficient passive cooling allowance. Then the drive needs to be wired directly through to the main motor (by-passing the existing motor stop / start control and any existing speed controls) as the motor drive can be damaged if the driven circuit (i.e. the motor) is abruptly disconnected, and so the drive itself must be used to stop or start the motor (or the start/stop be connected upstream of the drive). Depending on the exact motor drive used it might also be necessary to rewire the motor itself or even change it (many three-phase 415V 'Y' connected motors should be changed to 'Δ' connected 240 V motors for use with a 240 V motor drive). Lastly an alternative power supply needs to be arranged for any other items in

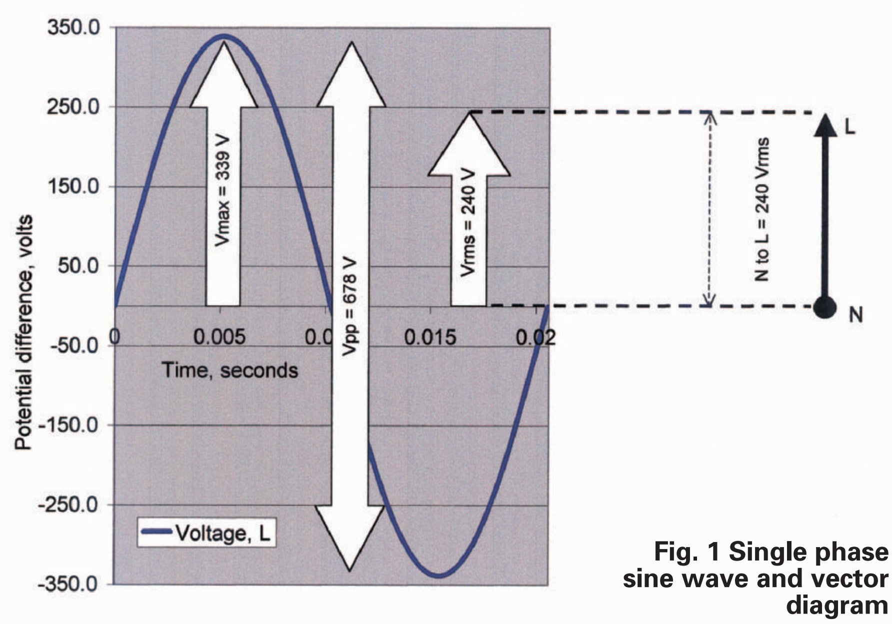


Fig. 1 Single phase sine wave and vector diagram

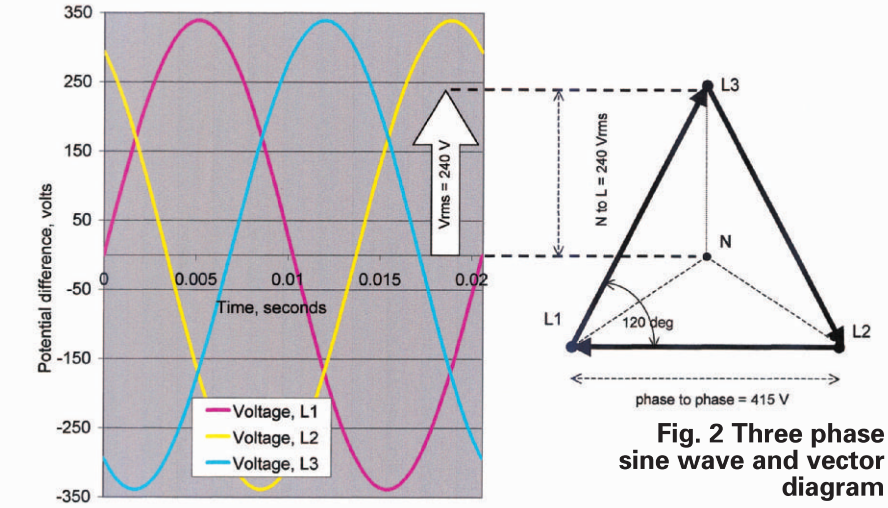


Fig. 2 Three phase sine wave and vector diagram

3. Motorun Static Converter

4. Range of "Classic" Static converters from Boost covering from 0.4 to 5kW.

the machine tool and these in turn may need modifying.

If one enjoys rewiring machine tools this can be quite good fun but one does need to keep an eye on the cost of it all. An alternative is to buy in a commercial VFD modification kit to suit your machine tool such as is shown in **photo 1**, fitted to a Myford Super Seven. Newton Tesla is a regular advertiser in ME/MEW and has standard packages built around off-the-shelf motor drives to suit the most common machine tools. Newton Tesla's packages are highly regarded by some of our customers, and the CL 750 package was reviewed in MEW issue 95.

Phase converters

The final option is to use a single to three-phase converter. The easiest of these to visualise is a single-phase electric motor driving a three-phase electric generator and such motor generators do indeed exist. However this approach is uneconomic for almost all applications and tends to be restricted to exotic frequency changing problems. Having discarded the conceptually simplest we are now left with three other types of phase converter: static phase converters, rotary phase converters, and sine wave inverters.

Sine wave inverters are similar to motor drive inverters in that they first rectify to give DC, and then invert it back to AC but on three different phases. The difference is that they add extra circuitry and give out a clean sinusoidal waveform of constant frequency. They are not manufactured in the UK and have proven uneconomic to import from the USA.

Static converters and rotary converters are variants on the same basic design, which has been utilised for several decades including by three regular advertisers in ME/MEW, namely ourselves at Boost, as well as Motorun, and Transwave. In a static converter the 240 Vrms input (phase to neutral, L-N in the diagram below) is first passed through a transformer to raise it to 415 V (in these diagrams the transformer outputs are L1 and L3, but other manufacturers may label their connections differently). Then one 415 V connection is exposed to a capacitor bank which yields an L2 where L1-L2 is also of 415 V but which is at almost exactly the same phase angle as the first, i.e. L2-L3 is almost zero when at rest, as in **Figure 3**. When this is connected to a three-phase motor the inductance of the motor is added in to the circuit and once the motor is up to speed the 'back emf' generates the voltage L2-L3 shown in **Figure 4**. It is worth explaining all of the problems that can occur with static converters and then discussing rotary converters and how far they overcome the problems.

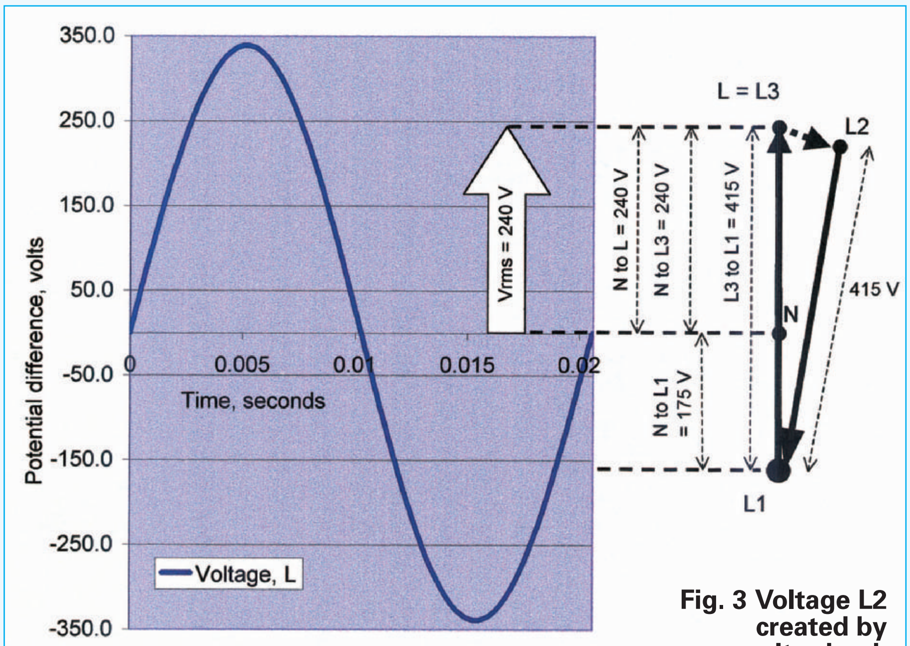


Fig. 3 Voltage L2 created by capacitor bank

Firstly there has to be a motor in the circuit. A static converter such as that shown in **photos 2, 3 and 4,** simply cannot produce three phases on its own and so it will only power two of the three phases used in equipment such as ovens (unless they have a huge three-phase fan in them). However this point probably will not trouble most readers unless they are contemplating using welders, wire erosion machines, or plasma cutters.

Secondly the capacitance in the circuit needs to be matched to the inductance in the circuit. Unfortunately the amount of capacitance required will change as the load varies on a given machine, or as different machines are operated. This characteristic is most pronounced when the primary motor starts as it will draw up to six times the normal current for a very brief period and the capacitance must vary accordingly. Because of this the 'boost' circuit was introduced which switches in a much larger capacitance at motor start (our company was named after this circuit). This boost can either be manual or automatic. The automatic circuits sense either voltage or current changes and, in the case of those manufacturers who advertise here, use electromechanical contactors to switch in the additional capacitance for a short period. However in addition to the boost circuit there needs to be more ability to tune the amount of capacitance so as to match the needs of the motor. Therefore manufacturers provide a capacitor bank with multiple levels controlled by another switch so that the operator may manually select the appropriate amount of capacitance. Manufacturers also provide an ammeter so that an operator has a guide (aim for lowest reading) in choosing the correct amount of capacitance – in practice the human ear is a better guide as it can fairly reliably tell when a motor is running most sweetly). As a response to the need for manual adjustment, Motorun have in their range the "Autophase" **(photo 5)** which might be described as a fully automatic static, which automatically adjusts the capacitance to maintain the "artificial" third phase within close limits, whilst avoiding the weight/ noise disadvantages of a rotary.

There are a number of other problems with statics which arise from all this. Because of the way the main motor is effectively generating the third phase it will not generate its full rated torque, particularly at start up. The largest motor must always be started first. This is probably OK in simple lathes and mills where operators can choose to switch the suds pump on after the main drive, but certainly cannot be guaranteed in CNC machinery or indeed in many common machines with semi-automatic features (e.g. industrial washing machines). Finally, if the motor stalls then it will start to 'two-phase' and burn out its windings more readily than if it had been on a regular three-phase supply. This stalling issue is particularly relevant to woodworking equipment.

Figure 4 shows the situation once a

5. "Autophase" static converter from Motorun

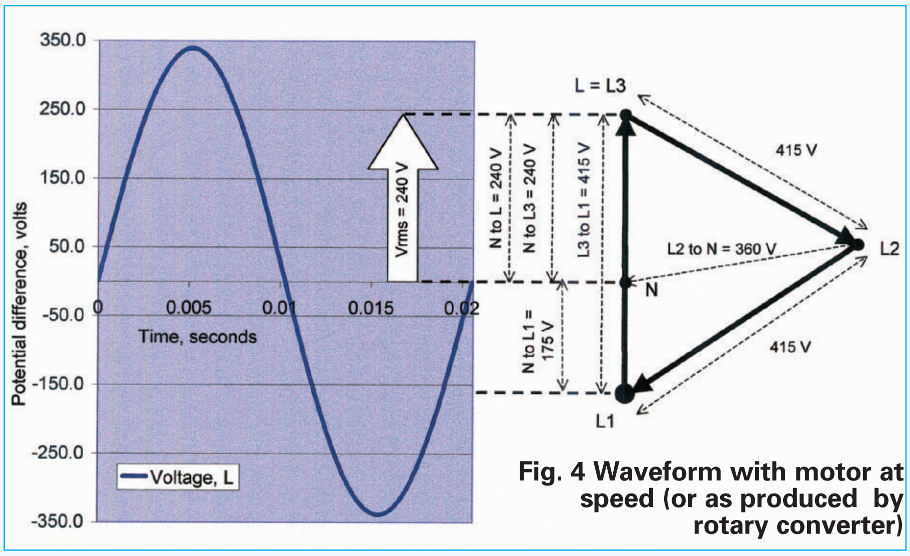


Fig. 4 Waveform with motor at speed (or as produced by rotary converter)

static phase converter has the driven motor running at speed, or that of a rotary phase converter. You will see that whilst the 415 V equilateral triangle is the same size and shape as that for the electrical supply from a utility company, it has been rotated a bit. This is because most manufacturers use what are called autotransformers in order to reduce the cost. Therefore, as the diagram shows, only L3-N will be 240 V whilst L1-N will be 175V and L2-N will be 360 V. This is important because some three-phase machinery uses 'phase to neutral' as a 240 V supply to drive lighting and/or control circuits. If so, all these have to be supplied from L3 rather than randomly choosing a phase. Fortunately in most such machinery the manufacturers place all the single-phase loads on one phase as typically there is a step down transformer in the design and this means the manufacturer only needed to buy one transformer. Similarly – and especially with static phase converters – it is best to make sure that all the control circuits that use 415 V are fed from L1-L3 which is the maintained phase and does not vary at all.

After all this you are probably wondering why a phase converter manufacturer can remain in business for any length of time. Well a rotary converter such as those shown in **photos 6,7 and 8**, improves things dramatically and so most reputable manufacturers encourage clients to purchase rotaries rather than statics wherever reasonably possible. A rotary converter simply adds a correctly sized motor to a static converter. The motor functions simply as an electrical component to create the third phase irrespective of what is happening to the driven loads, largely eliminating the need to finely tune the capacitance and so phase converter manufacturers can then guarantee a certain amount of phase balancing across a given operating range. Indeed there might be no level switches at all in a rotary phase converter. **Figure 5** shows the degree of phase balancing from a 4-kW rotary converter with no level switches.

A rotary eliminates the problem of having to start the largest load motor first (or the need to have a load motor at all), and precludes the possibility of load motors ever two-phasing. Provided a sufficiently good quality rotary phase converter is purchased it will give an output that is equal in quality to the utility company's three-phase supply. There is naturally extra purchase cost associated with a rotary converter, due to the motor, starter etc.

6. Transwave Rotary Converter

A commonly asked question is what is the efficiency of a phase converter. Efficiency is a function of the useful power output so when expressed as a % it can be highly misleading if the useful load is very small. Instead it is more straightforward to discuss the parasitic power consumption of a phase converter. A typical 4-kW rotary has a fairly constant 500-W of parasitic losses (windage, bearing losses, iron losses, and copper losses). So at full power – supplying a 4-kW load, it is 89% efficient. Clearly as load falls off this efficiency figure worsens, e.g. to 80% for a 2-kW load, and 67% for a 1-kW load. This is one reason why it is better not to buy too large a phase converter as ideally one would like to keep parasitic losses to a minimum.

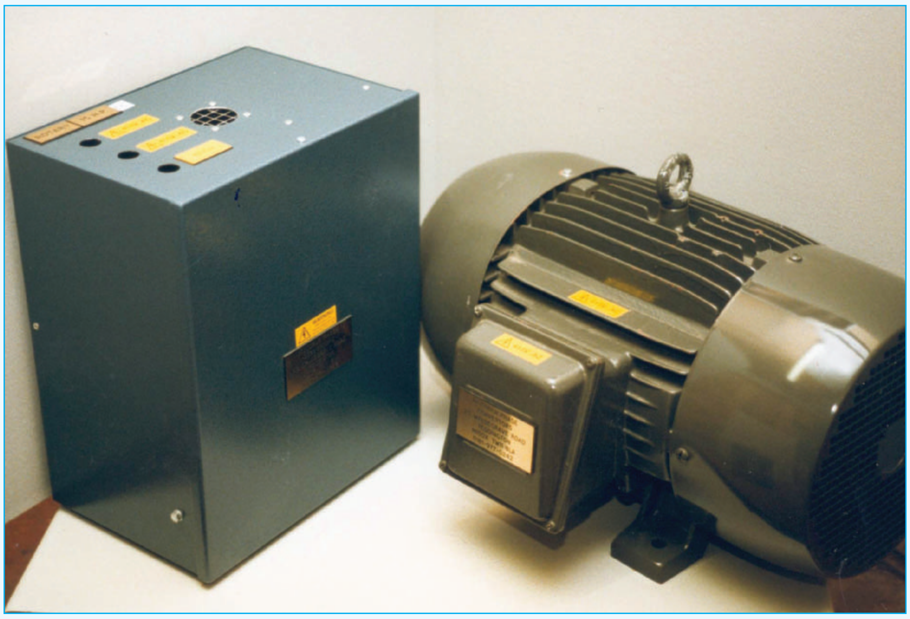
The electricity companies charge for Watts consumed rather than current. This is important because the same 4-kW rotary phase converter that consumes 500-W when idling will actually draw about 8-Amps of current rather than the 2-Amps that the parasitic losses would lead one to expect (500W/240V=2A). The other 6-Amps is simply current flowing in and then out of the phase converter as the capacitors charge and discharge. It won't make your meter spin wildly, and you do not have to pay the electricity company for it.

A final issue with phase converters is their power rating. Manufacturers used to place an fairly arbitrary label on their converters in horsepower and then advise clients to buy a converter "two to three times the size of the largest motor or larger". Well such a vague piece of advice is not a great deal of use, and most (not all) phase converter manufacturers have now moved to a system where they label their converters clearly as to maximum and minimum useful power ratings (in both horsepower and kilowatts, taking into account internal parasitic power losses) for typical single motor and multi-motor cyclical duty. Provided this has been done correctly by the manufacturer there is generally not much point in buying a much larger phase converter than they advise, unless you are considering purchasing larger machine tools in the future. Equally it is unwise to buy a smaller converter on the basis that you are just a 'hobby' user as the phase converter is typically most stressed at start-up, which is an unavoidable element of the duty cycle and because an overstressed phase converter will in turn stress your machine tool and can cause its motor(s) to burn out.

Other issues

Power availability and protective devices

Irrespective of how you get your power there needs to be enough of it. In this section it is assumed that you are using a phase converter from a domestic supply to power a small workshop, e.g., at the back



7. Rotary Converter by Motorun

of a detached garage, but the same points would apply equally if you had selected a motor drive or fitted single-phase motors etc. Any piece of machinery has a normal operating full load current (FLC) at a given voltage and/or a full load power. So if say it is a 3-hp (2.2-kW) lathe it will draw 9.2 Amps at 240 Volts single phase when fully loaded and in steady state operation:

2200 W / 240 Vrms = I
= 9.17 A single phase

2200 W / 415 Vrms = I
= 5.3 A total at unity power factor and 100% efficiency at a unity power factor

5.3 A/v3
= 3.06 Arms per phase which is what you should find on the motor tally plate

However it will draw 50 Amps or so from the single phase when it starts up. Exactly how much current it will draw and for how long depends on the inertia of the load – clearly a lathe with a clutch is an easier start than a clutchless lathe with a heavy large diameter workpiece. So the house's supply will need to be at least 9.2 Amps. However even if the utility company has provided a 60 Amp supply this might not be enough if, at the same time as you start your heavily loaded lathe, the cooker, the washing machine, the tumble drier, and several electric heaters are all switched on.

In most small workshops only one piece of equipment is in use at a time, and we have observed that with one exception all the items of equipment tend to be similar in power consumption, which eases this sort of calculation. The exception is welders and similar items (wire erosion machines, plasma cutters, etc.) which tend to have about four or five times the power consumption of anything else in a given workshop. With welders etc. it is very important to obtain the actual power (kW) consumption of the item as simply knowing the weld current can be highly misleading unless one is absolutely certain of weld voltage and duty factor.

The power supply to your workshop will have fuses or circuit breakers (often called miniature circuit breakers, MCB's), which are rated in Amperes for a given voltage. A circuit breaker is a resettable electro-mechanical switch that automatically trips if the current through it exceeds a preset threshold. Because its core component is a bimetallic strip it can accept an overcurrent situation for a predetermined length of time. Most modern domestic premises will have type 'A' or 'B' rated circuit breakers installed, which will trip quite rapidly in an overcurrent situation. However machine tools are industrial items that will draw an overcurrent at start up for somewhat longer than the average hair dryer and for this reason a motor rated circuit breaker should be installed throughout the circuit that feeds the workshop: ideally a 'D' rated breaker but a 'C' rated breaker might be acceptable. A similar situation exists with fuses. Your phase converter supplier will advise you as to which rating breaker to install as they know the time for which a given breaker will hold in, e.g. 63 Amp 'D' – they should not be much more expensive than a domestic breaker.

Returning to the average hair drier for a moment; it has three components which each have an electrical role to play. The switch is used to start or stop it in normal operation or if it is failing in service; the plug is used to disconnect it from electrical power so that one can safely take it apart; and the fuse in the plug is there to prevent an excessive current flowing and thereby protect both the user and the hairdryer. A phase converter is just the same. It needs a switch that can be operated to start and stop it in normal operation and should be immediately adjacent to it – in converters of up to 6-kW or so it is reasonable for this to be a MCB, and from 8-kW and above this should be a motor starter. In the smaller converters of 6-kW or less the MCB also acts as the overcurrent device and in the larger converters the overload relay in the motor starter fulfils this function.

Converters of 8-kW or above should also have an isolator fitted to positively isolate the internals when any covers are open, but this isolator is not a suitable device for using as a starter – it is essentially a switch that should only be operated with no current flowing as it is simply there to securely de-energise a section of a circuit. All these components should either be integrated into the converter by the manufacturer or added into the total cost of purchase when comparing the prices of the different manufacturers. If the manufacturer integrates them into the unit then the purchaser has less wiring to do and the final installation will be neater and less failure prone. The equivalent of the plug is the MCB at the supply end of the cable, which has already been discussed in the paragraph above.

Line drop, other voltage variations, and electrical noise Ohm's law (V= I.R) tells us that to drive a current I along a wire of resistance R will require voltage V. The current in the wire causes heating in proportion to the square of the current times the voltage (known as I^2R heating). So the voltage available at the start of the wire is not quite the same as the voltage available at the end of the wire. In rural location where a single-phase line supplies a couple of farms the voltage can drop as low as 200 V at times, at the end of the line. Such a large line drop is excessive but instances of this do exist where the utility companies are being parsimonious to the extreme. Also the utility company is permitted to vary the line voltage over a given range – the range was recently widened as part of the European harmonisation process and will reduce over the course of the decade as the nominal supply voltage is reduced from 240 V to 230 V. So basically what you get at your house's fuse board might not be the steady 240 V you expected - at the Boost premises, we tend to get about 242-243 V but with a slightly clipped waveform. The easiest thing is simply to measure what you have, a few times a day over the course of a week and make a note of the likely supply voltage. Good quality phase converters are provided with a range of tappings on their transformers and you can then shift the tapping in use as appropriate when you install your converter. The reason that the phase converter manufacturer cannot do this in advance is that there is a legal obligation to despatch newly constructed electrical equipment with the 230 V tapping selected.

The same line drop phenomenon can occur on a smaller scale at your house. Typically the consumer unit is towards the front of the house whereas most workshops tend to be tucked away at the back of the garage or down the garden. So there can easily be a hundred feet or so of cable that might not be of sufficient size (i.e. cross sectional area) to transport the required current. However you must not shift the transformer tapping to compensate for any steady state line drop within your premises, instead you should install a larger cable! Remember that an overloaded cable is a long electrical heater and at some point it is doing the heating in your house and can act as an ignition source.

In any case it is in your machinery's best interests to install an adequately sized cable. This is because whereas the line drops discussed above are steady state affairs, a similar thing occurs over a much shorter timescale when starting a motor. If there is a constraint in the electrical system, when current increases voltage will fall – and your motor will not accelerate to full speed as rapidly as it ought to. We have observed the voltage fall to 180 V or so when conducting tests at a client's premises where the cable to the workshop was simply inadequate.

Sizing wires to ensure that you don't have too much voltage drop is most important in the longer cable runs. A good on-line calculator for this has been written by Jeff Lucius and is at: www.stealth316.com/2-wire-resistance.htm together with explanations. To a certain extent a rotary phase converter is better than a static in locations where the electrical supply is weak. This is because the motor or rotary transformer acts as an energy storage device (both because of the mechanical flywheel effect and the equivalent magnetic field storage), which is available for release during start up of the driven load. Automatic line drop compensation is possible but to date has not been economic to provide.

Low frequency voltage / current variations can be transmitted via the phase converter. These occur because the machine tool is a pulsating load and, if the electrical supply is constrained, then either the voltage or current will vary in sympathy. The worst case of this that I observed was a 15-hp hydraulic blacksmiths hammer with a reciprocating motion at about two cycles per second. Even though the highly geared motor turned at about 1200 rpm the torque variations were sufficient to cause a noticeable flicker in the lights at a rather annoying 2 Hz or so, which affected the nearby houses. This was at the end of a very long electrical supply line in a rural location. It is possible to insert filters to overcome these effects but they tend to be expensive and it might be cheaper to buy your neighbours a bottle of wine – and you can be pretty sure that everyone's lights flicker when a washing machine starts. Converting your machine tool to single phase motors would actually exacerbate such a situation as it is the machine tool that is the source of the flicker rather than the phase converter, and a single phase motor has a less constant torque delivery characteristic than a three phase motor.

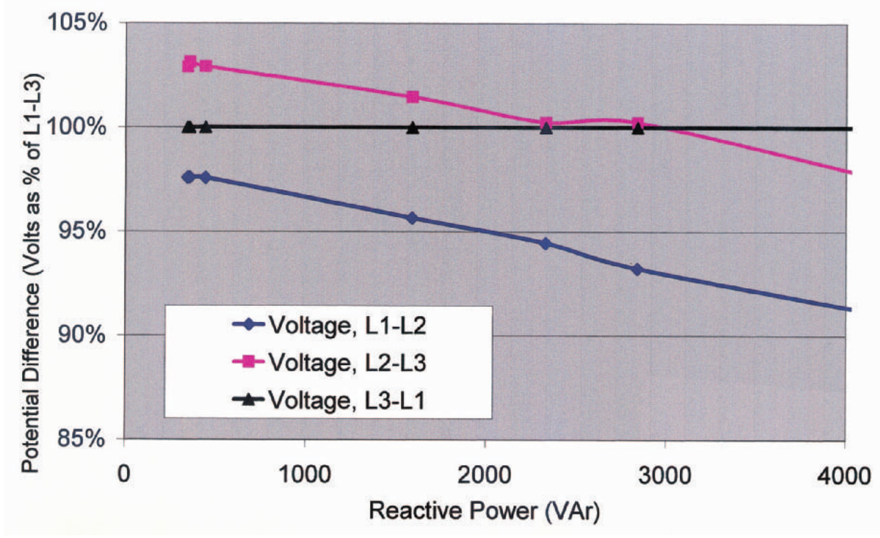


Fig. 5 Phase balance on 4Kw rotary converter

The only high frequency voltage components a static or rotary phase converter is associated with, originate from switching the capacitor banks (for boosting or to adjust power levels). This is an infrequent exercise unless a fully automatic control system is installed and the load is varying a lot, or unless a boost circuit is chattering. If this is the case then the phase converter will probably cause radio frequency interference. In fact in normal operation a phase converter cannot cause radio frequency interference (unless something is failing) and in this respect they may be considered superior to inverter drives.

8. Range of Rotary converters from Boost (1.1 to 16kW.)

Acoustic noise and other packaging points

A safety issue is that any slave motors should either have their shafts parted or have shaft guards fitted. Other safety issues are that any ventilation holes should be small enough to prevent childrens' fingers from reaching through to electrical harnesses. It is also possible for the capacitors in a phase converter to hold their charge for a considerable time (days even) and give a very nasty electrical shock. For this reason converter manufacturers fit warning labels and/or discharge resistors (colloquially referred to as bleed resistors as they short circuit the capacitors).

Most phase converters should be installed in dry locations where there is no possibility of water spraying or dripping into them. Ideally they should not be located where metal shavings or metal dust collect for obvious reasons. Because of static, dust and wood shavings do tend to accumulate internally, especially in bakeries and carpentry shops, but we have yet to observe a unit that has actually failed due to this.

Static phase converters make very little noise (just a transformer hum) whereas rotary phase converters will make the same noise as an unloaded motor, i.e. the rush of air through the motor fan and a limited amount of mechanical vibration.

The three ways to overcome this noise are to enclose the motor in a cabinet, to mount the motor on anti-vibration mountings, and to install the entire converter in a separate enclosure with sufficient ventilation – under stairs, in the roof space, or in a lean-to are the most common. I have not seen any scientific noise measurements given by any manufacturer.

There is a medley of other physical packaging considerations including switch location, socket location, cable entry/exit location, weight, manual handling, split or integrated units, handles, and delivery. Switches and other controls should be towards the front of the unit, and should still be accessible if the unit is mounted sideways on due to workshop space limitations. Any sockets should also be towards the front of the unit, but cable entry / exit location can be more tricky – in general the rear or rear/side is preferred but some clients ask for the front. Although phase converters are quite compact they are fairly dense and so weigh a lot (in fact checking the weight of a unit is a fairly good way to check the quality of the key components) and this can create manual handling difficulties. This is one reason why some customers prefer the slave motor to be supplied separately although I am coming round to the view that this is best fitted internally in units of up to 4-kW / 5-hp and externally on a common frame for 8-kW / 10-hp and above. In any case the units of up to 6-kW really ought to be supplied with robust handles for general positioning purposes.

Customer support

Crudely there are three stages of customer supports – pre sale, at sale, and post sale. None of the phase converter manufacturers mentioned are set up to accept on-line ordering and so you will need to talk to them by telephone or write/email/fax them in order to make a purchase. In Boost's case we deliberately operate this policy because we want to ensure that clients purchase a product that will suit their needs as we have seen too many instances of clients innocently pre-selecting inappropriate products over the years. Once you have talked through your situation with a manufacturer they will be able to advise you on your options and then you will purchase. Lastly you might need support in-service if a failure occurs, or if you are considering purchasing new machine tools or even selling your workshop and want pricing advice. It follows from all of this that the quality of service matters a lot and so you should be evaluating who is easy to contact, the duration and terms of any guarantees, and in general the extent to which they genuinely support their products.

Installation

The very small converters (say of 1.8-kW / 2.5-hp) are simple devices that just plug in to a 13 Amp socket and, unless clients are completely allergic to electricity, they will be able to install themselves. The medium sized converters up to say 6-kW / 8-hp will need to be connected to fuse boards (via an MCB) and have cabling run to the machinery. Many clients choose to run the cabling and position the equipment themselves, but then use the services of a professional electrician or knowledgeable friend to make the final connections. Above 8-kW / 10-hp it is increasingly common for professional electricians to be more involved.

Acknowledgements & Contact Details

Product photos courtesy of:

Company	Tel.	Fax.	Internet
Boost Energy	0118 903 4881	0118 903 4882	www.boost-energy.com
Motorun	020 8977 0242	020 8943 3326	www.motorun.com
Newton Tesla	01925 444 773	01925 241 477	www.newton-tesla.com
Transwave	0121 708 4522	0121 765 4054	www.powercapacitors.co.uk

On-line voltage drop calculator by
Jeff Lucius: www.stealth316.com/2-wire-resistance.htm