



A Layman's Guide to Converters & Inverters and Frequently Asked Questions

Manufactured by



A Layman's Guide to Converters & Inverters for Single-Phase Supplies

Phase Conversion, Frequency Conversion & Motor Control



Phase conversion (with or without motor control) is a subject of growing interest to the user of machinery in the home workshop, particularly as the cost of inverter technology has dropped dramatically in the last 5 years.

Trying to get realistic advice as to what is available, what machine modifications are necessary and what performance can be expected is a little more difficult. This guide is designed to help you negotiate the various issues raised.

There is great confusion surrounding the differences between the two distinctly different technologies available for operating three-phase motors from a single phase supply: **Phase Converters and Inverters**.

The traditional "analogue" **Phase Converter** (static or rotary) is based on the "Steinmetz" capacitor principles first applied by the American, Charles Steinmetz, in the late 19th century. The old adage "you can't get something for nothing" holds true for phase conversion like anything else. There is, always has been, and always will be an element of artificiality about the supply a phase converter produces. Despite the idiosyncrasies associated with the nature of the supply, phase converters continue to offer a proven and reliable compromise for people wishing to operate three-phase machinery in single phase environments.

- A **Phase Converter** varies the voltage in the conversion (240v single-phase to 415v 3-phase) but fixes the frequency (50Hz) so there is no motor control available. The supply remains a.c. throughout the conversion.
- A **Phase Converter** is a so-called "Linear Load". There are no electro-magnetic compatibility issues (EMC). No power quality issues. No Harmonic distortion. No filters required.
- As the output from a **Phase Converter** is 415v, the converter retrofits directly to a machine that is wired for 415v three phase operation so no machine modification is necessary.
- The output from a **Phase Converter** is flexible and (within reason) can be applied to a variety of different machines whether operated one at a time or simultaneously.
- **Phase converters** are available to support any motor requirement, provided there is enough single phase supply available to support the three phase demand. TRANSWAVE Converters are available to 22kW/30hp. Larger ratings are accommodated by paralleling two units together.



STC Static Converter (1.1kW - 4kW)



STC Static Converter (5.5kW - 7.5kW)



MT Style Rotary Converter (1.1kW - 2.2kW)



MT Style Rotary Converter (3kW - 11kW)



MT Style Rotary Converter (11kW - 22kW)

So is a "Digital" Inverter also a Phase Converter?

Yes. "Digital" Inverters offer a 21st century approach to the dilemma of operating three phase motors from a single phase supply. These days, most people who are aware that a device exists to operate three phase equipment from single phase tend to know about inverters and assume that the concept has superseded the traditional "analogue" static or rotary phase converter. However, the two products will always co-exist as the technologies service different market requirements.



In contrast to the "Analogue" Static or Rotary Phase Converter:

- A "digital" **Inverter** fixes the voltage in the conversion (240v single phase to 0-240v 3-phase) and also varies the frequency (e.g. 0-400Hz) thereby offering motor control. The three phase supply at 240v is created by rectifying the ac supply to dc and inverting it back to ac (Hence the name **Inverter**).
- The involvement of DC means that **Inverter** supplies are defined as "Non-Linear". The input and output supply is subject to EMC regulation as the conversion process affects the a.c. single phase supply network. Current harmonics are present as a direct consequence. RF (Radio Frequency) mains filters may be required to ensure your contractual obligations to the electricity supply company are not compromised.
- As the output from an **Inverter** is 240-v 3-phase, an inverter cannot be accommodated without machine modification.
- The output from an **Inverter** can only be applied to one motor, or one load that starts and stops at the same time.
- **Inverter** manufacturers **do not offer product for single-phase supplies in excess of 3kW** to ensure compliance with European Power Quality Standards such as BSEN 61000-3-2:2006 and BS EN 61000-3-12:2005. For similar reasons **Inverter** manufacturers do not offer product with an output voltage that is different to the supply voltage (e.g.: 240v input, 415v output).

Can I retrofit an inverter to my existing single phase machine?

No, motor control is a three phase motor technology available for operation from both single phase and three phase electricity supplies. A single phase input inverter offers the facility to electronically vary the speed of a three phase motor from a single phase supply by varying the frequency of the supply to the motor.

It is not possible to vary the speed of a single-phase AC motor so if your machine is currently single-phase you will have to change the motor.

So are all 3-phase motors compatible with the output of an inverter?

Generally, yes. Most small single speed three-phase motors are wound for operation from **either** a 380/415v **or** a 220/240v 3-phase supply. A typical "dual-voltage" motor plate will indicate a voltage rating such as "**V 220-240 Δ / V 380-415 Y**" together with two current ratings. The lower current will refer to the higher voltage, the higher current to the lower voltage.

STAR CONFIGURATION – In the "Y" or "Star" configuration, the motor will run on a three phase supply from 380v to 415v phase to phase. The "Y" sometimes appears as a three-pointed star.

DELTA CONFIGURATION – In the "Δ" or "Delta" configuration, the motor will run on a three phase supply from 220v to 240v phase to phase. The "Δ" sometimes appears as a "D"

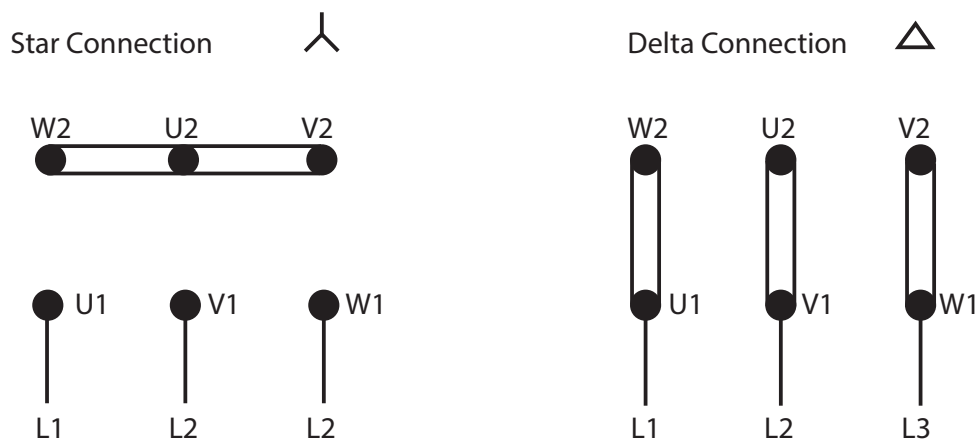


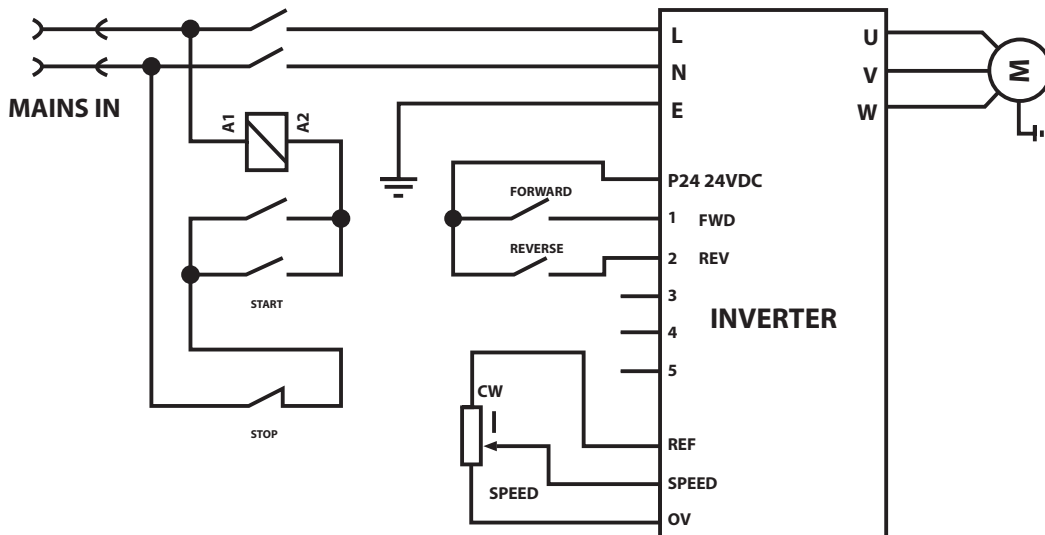
Fig. 1 above shows a typical motor terminal arrangement for the star configuration. Three terminals are linked together with a set of three brass/copper links. The other three terminals (commonly marked U1, V1 and W1) are then connected to the three phase 415v supply (L1, L2 and L3).

Fig. 2 above shows a typical motor terminal arrangement for the delta configuration. The three metal links are simply removed and rearranged. The other three terminals (U1, V1 and W1 as before) are then connected to a three phase 240v supply **or the output of an inverter/frequency converter**.

If the motor plate does not display a 240v three phase connection facility, it may still be possible to reconfigure the voltage rating from 415v to 240v three phase. Seek advice from a local motor repair or rewind company. A pole change three phase motor (displaying more than one synchronous speed e.g. 1400rpm/2800rpm) can only be connected for 380/415v so is usually incompatible with the output of a single phase inverter. This type of motor would have to be changed to a single speed, dual-voltage motor to facilitate the use of an inverter.

How do I connect a machine to the output of an inverter?

Once an existing three phase motor has been reconfigured from 415v operation (STAR) to 240v operation (DELTA), the equipment wiring loom (start/stop/forward/reverse/feed/coolant/limit switches etc) has to be disabled and is made redundant. The reconfigured motor is connected directly to the output of the inverter and the single phase supply is connected to the input of the inverter.



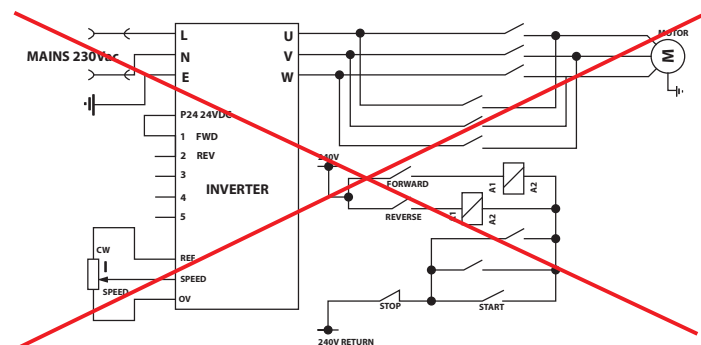
The SD1 inverter offers "local" control in the form of small buttons for start & stop and a potentiometer for speed adjustment.

For some people these buttons are an acceptable means of controlling the motor; however the majority find the buttons too small and impractical.

We highly recommend a remote control station/pendant (see image) for a minimum additional outlay, which offers the basic control functions in an acceptable form. The pendant connects directly to the inverter control terminals and comes with a 2 metre length of cable so it can be mounted in an appropriate area of the machine. The inverter itself can then be put out of harm's way.



The motor must be connected directly to the inverter output so controls should not "make and break" the supply to the motor under any circumstances. Be wary of ancillary motors such as coolants and table feeds. These are likely to have to be disconnected completely and fed from an alternative source, as are lighting circuits and control transformers.



It is possible to rewire a machine wiring loom to the inverter control terminal rail so that existing switchgear/levers/limit switches etc can be used. Seek advice from a competent electrician as there is often a lot of work involved.

What performance can I expect from the motor once it has been connected to the SD1 inverter?

The speed of an induction motor is directly related to its supply frequency. The frequency from your single phase supply is fixed at 50Hz, so if the output from the inverter is set at 50Hz the motor will operate at its synchronous speed (e.g. 750-1000-1500-3000rpm). Any mechanical ratios will operate at plated mechanical speeds. Your inverter is simply acting as a phase converter under these circumstances.

The relationship between frequency and speed is linear, so if the frequency of the supply to the motor is reduced by 50% (to 25Hz) the motor speed is reduced Pro-rata. So, theoretically, as the SD1 inverter offers a range of 0-200Hz, your machine can now operate between zero speed and four times motor speed.

Understandably this leads to an assumption that belt/pulley changing is a thing of the past.

Unfortunately, there is a relationship between the frequency at which a motor operates and the power/torque it can deliver.

We recommend that SD1 Inverters are used in conjunction with, rather than as a direct replacement for, an existing mechanical variation of speed. It is better to achieve a 50rpm shaft speed from a 100rpm geared speed at 25Hz than a 250rpm geared speed at 10Hz.

Users of SD1 inverters, are recommended to pre-set the frequency window to ensure that the level of torque available is acceptable.

At particularly low frequencies, it may be necessary to consider the implications of secondary motor cooling since the fan built into the motor could lose its ability to cool the motor effectively. At higher frequencies than 50Hz, it is in the user's interest to check that the integrity of the driven motor/ machine will not be compromised at the higher speeds involved.

Added benefits of using an inverter are a soft-start in the form of a controlled acceleration over a time determined by the machine-user. Similarly, there is a controlled deceleration option, dc braking and "reverse-on-the-fly", a particularly useful feature when tapping or screw-cutting. Once you have programmed the software parameters to meet your requirements, the parameters do not need to be changed again.



Degrees of Protection - First Digit

The first digit of the IP code indicates the degree that persons are protected against contact with moving parts (other than smooth rotating shafts, etc.) and the degree that equipment is protected against solid foreign bodies intruding into an enclosure.

0	No special protection
1	Protection from a large part of the body such as a hand (but no protection from deliberate access); from solid objects greater than 50mm in diameter.
2	Protection against fingers or other object not greater than 80mm in length and 12mm in diameter.
3	Protection from entry by tools, wires, etc., with a diameter of thickness greater than 1.0mm.
4	Protection from entry by solid objects with a diameter or thickness greater than 1.0mm
5	Protection from the amount of dust that would interfere with the operation of the equipment.
6	Dust tight.

Degrees of Protection - Second Digit

The second digit indicates the degree of protection of the equipment inside the enclosure against the harmful entry of various forms of moisture (e.g. dripping, spraying, submersion, etc.)

0	No special protection
1	Protection from dripping water.
2	Protection from vertically dripping water.
3	Protection from sprayed water.
4	Protection from splashed water.
5	Protection from water projected from a nozzle.
6	Protection against heavy seas, or powerful jets of water.
7	Protection against immersion.
8	Protection against complete, continuous submersion in water.

Inverters are mass produced by a finite number of major multi-national electrical and electronics companies. The vast majority are supplied to OEM's for incorporation into electrical control panels. For this reason most inverters are supplied in an IP20 enclosure and should be located away from swarf and dust. If an inverter is enclosed to avoid contact with dust or swarf, the enclosure has to be sized correctly to ensure acceptable levels of heat dissipation.

The manufacturer's manual usually outlines minimum enclosure requirements. Clearly this will add to the cost of the overall project. Some manufacturers offer entry-level specification inverters in an IP65 enclosure for an additional cost.

If part or all of your workshop supply incorporates an earth-leakage circuit breaker (ELCB), residual current device (RCD) or residual current circuit breaker (RCCB), check before wiring the inverter to the supply as you may experience nuisance-tripping resulting from additional earth leakage introduced by the RF filter used. Typically, inverters fitted with the RF filters internally ('integrated filter design') have moderate to high earth leakage in the order of 6 – 15mA and some much higher! If the circuit already has some existing level of earth leakage current, adding this extra component when employing a filtered inverter may take the total to >30mA hence the trip operates. Also, a typical 13A socket supply should typically have less than 3.5mA leakage as the earth connection is deemed non-permanent. In this case, a low earth leakage mains filter (<1.5mA) is used in conjunction with the inverter and so this is compatible, this also then means the risk of nuisance tripping is greatly reduced. Otherwise, connection of the inverter could be via a fused switch outlet (with the earth permanently connected).



Frequently Asked Questions

An A to Z of explanatory notes



21-day Money Back Guarantee

Power Capacitors Limited (PCL) offers a 21 day no obligation money back guarantee (carriage excluded) on condition that the converter is returned to PCL in a state fit for resale. No handling charge will be raised.

2-Year Warranty

The TRANSWAVE converter is covered by a **2-year parts warranty** against failure due to faulty manufacture, further details of which are available on request. Extended warranties are also available on request.

CE marking/EMC Compliance

Power Capacitors Limited manufactures and sells CE marked products compliant with EMC regulations, The Low Voltage Directive and BS EN ISO 61000-3-2:2006. The company can provide, on request, a Declaration of Conformity (DOC) for every product.

ISO9001/2015 - Quality Assurance

We believe that the TRANSWAVE Converter is the only converter manufactured in an ISO9001/2015 quality assured manufacturing

facility. PCL was first accredited with a British Standard in 1996. Over 23500 units have been sold to OEM's, machinery dealers and end-users since 1984. The Company employs 23 people in the UK and achieved an annual turnover in excess of £2.7 million in the financial year 2020.

After-Sales Support

Sales engineers are available on our Direct Dial Helpline (0800-035-2027) from Monday to Friday 8am to 5pm to answer any sales or technical support issues. Answering machine service available otherwise.

Air Compressors

Most compressor motors can be operated successfully using static converters. Direct-on-line starting is essential. A rotary converter is recommended for Hydrovane-style systems. In all instances please ensure that you advise the motor size and current rating before ordering. Aluminium Bodied Motors Aluminium motors may not operate successfully in conjunction with static converters. We would recommend the use of a rotary converter to address this issue where necessary.

Brake Testing Equipment

The use of a rotary converter is recommended for both Class 4 and Class 7 brake testers.

Car Ramps

These applications are regularly used in conjunction with static converters. Ensure that you advise the motor size, current rating and style of car ramp (electro-mechanical or hydraulic) at the point of enquiry. Hydraulic ramps generally work a motor to full load whereas screw-type electro-mechanical ramps often work a motor to short term overload. Plated motor currents often suggest a higher shortterm kW demand - e.g. a 3kW/8A motor would suggest the motor is likely to develop 4kW so we would recommend a 5.5kW converter rather than the 4kW unit. (Note that a 3kW motor on a machine tool would only be plated at 6.5A). The power regulator switch fitted to the converter may have to be adjusted in line with a variation in load. Even though the ramp may have a 3 ton capacity mechanically, the artificial nature of the supply created by a converter may result in one power setting to lift a Ford Mondeo and another to lift a Land Rover. The operation of the equipment in conjunction with a converter may involve some operator discipline. The rotary converter may offer a more operator-friendly solution.

CNC Equipment

A Rotary Converter should be considered for this type of equipment.

The CNC Primary Circuit should have sufficient voltage tolerance to accommodate the inherent voltage imbalance created by the converter.

Should you require any clarification, please seek advice from our support team.

Continuous Duty Applications

We do not recommend the use of TRANSWAVE Converters for applications which operate on a 24hr/day continuous duty. Where a converter is used 24/7 **the warranty will be reduced to 12 months**. For remote, non-operator controlled, cyclic-duty applications such as refrigeration compressors and pumps, the need for an "on-demand" supply is often accommodated by static converter. See "*refrigeration compressors and pumps*" below.

D.C. braking circuits (rectifier circuits) and lighting circuits (control transformers)

There is more room for error connecting these circuits to a converter output than would be experienced on a mains three-phase supply. Two specific phases must be connected to 415v 2-wire circuits, both on rotary and static converters. Similarly a specific phase has to be selected for 240v phase-neutral requirements. In some instances, particularly woodworking applications, a wiring diagram of the braking circuit would be helpful as it may be necessary to modify the control wiring of the machine to ensure that the braking circuit is connected to the same two phases as the starter control circuit. This ensures the successful operation of the brake/light. Failure to identify the need to modify the circuit or connecting to the wrong phases could lead to malfunction of the braking mechanism or light.

Digital Phase Converters/Modified Inverters

A standard converter varies voltage from 240/415 but fixes the supply frequency at 50Hz. A standard inverter fixes voltage at 240/240 but varies the supply frequency. Any digital inverter device that varies voltage from 240/415 has been modified away from its original

design specification. Please seek advice before considering this type of device as it is unlikely to comply with regulatory requirements governing the use of inverters.



Heating Elements

See "Resistive Loads"

Hi-Torque Starting Requirements

Standard specification static and rotary converters operate the vast majority of applications successfully. However there are instances where additional starting performance is required for applications such as screw-type car ramps where the plated motor current suggests a higher short-term kW demand than stated on the motor plate. Similarly some machine tools offer mechanical ratios in excess of the synchronous speed of the motor. A standard specification static or rotary converter will invariably only start a 1:1 ratio of motor to geared speed, particularly where there is a direct drive rather than a clutch-assisted start. For example: the Harrison M300 lathe is driven by a 3hp 1400rpm motor but has a top mechanical speed of 2500rpm. The standard

specification converter is likely to achieve only 10 of its 12 mechanical speeds; however the hi-torque version should achieve all 12. Please do not hesitate to seek further advice from the company's sales engineers if you are unsure as to which size of converter is suitable for your application.

Inverter-Driven 3-Phase applications

A Rotary Converter should be considered for this type of equipment.

The Inverter primary circuitry should have sufficient voltage tolerance to accommodate the inherent voltage imbalances created by the converter,

Should you require any clarification, please seek advice from our support team.

Motors & Motor Control Packages

PCL is a stockist of TEC motors in both Metric and B56 Imperial Frame Sizes. Motor Control Packages are available for both single and three phase supplies. Please ask for details.

Variable Demand Environments - Multi-Motor and multi-operator applications

The rotary converter is the most appropriate solution for these examples as it automatically adjusts in line with any variation in demand or sequence of motor starting. If considering the use of a static converter, sequential starting (large followed by small) is necessary and the power regulator switch will have to be adjusted in line with any variation of demand. This is likely to prove impractical.

Multi-speed or Pole-change motors. Applications requiring frequent stopping and starting. It may be prudent to consider the use of a rotary converter for these applications. Otherwise a pilot motor may be required with a static converter if the magnetic characteristics of the motor do not lend themselves to the creation of a satisfactory artificial phase. Motors with 720rpm and 960rpm windings may prove problematic. Please do not hesitate to seek further advice from the company's sales engineers.

Output variations

All standard static and rotary converters are fitted with a 5-pin 3-phase neutral and earth socket offering the facility for both 415-volt and 240-volt control requirements. A 16A or 32A plug is supplied free of charge with the converter as a loose item. The facility for input and output terminals for "hard wiring" is available on all converter styles on request.

Printing Machinery

Machines without an inching facility can be operated directly from a suitably rated static converter. Applications requiring an inching facility must be operated in conjunction with a rotary converter to avoid electrical damage to the motor windings. Japanese printing machines (e.g. Ryobi) often incorporate 200 volt three phase motors, connected to a mains supply via a three-phase 200/415-volt transformer. To ensure

successful operation of the machine, the use of a rotary converter is recommended, together with a means of isolation between the converter output and the three-phase transformer.

Produce Conveyors, Grading and Potting Equipment

Care should be taken to ensure that the TRANSWAVE converter rating is high enough to enable the motor to start under a load condition. Be wary of multi-motor applications where it may be necessary to consider a rotary converter or to ensure that one motor is running constantly to allow fractional horsepower ancillary motors to switch on and off at will. Other solutions to minimise this impracticality are available using individual capacitor circuits. Motors sized below the minimum loading of the converter will be damaged if operated independently from any converter other than the rotary. Please seek further advice from the company's sales engineers if unsure as to which converter to order.

Pump applications (slurry/dirty water - irrigation/clean water), aerators and mixers.

Most installations of this nature are controlled remotely, rather than via an operator. The majority of converters manufactured for this type of application are of the "Hi-Torque" static style, often custom-built. The recommended converter rating is determined by the duty cycle of the motor - i.e. cyclic or continuous - the application, motor current, power rating and speed. On-site commissioning by a PCL engineer or qualified electrician is recommended; technical assistance is available if required.

Refrigeration Compressors

Compressor motors can be operated successfully using the "Hi-Torque" static converter. For motor sizes in excess of 2.2kW/3hp the fitting of an off-load valve is advisable. Direct-on-line starting is essential. The use of a rotary converter is recommended for Hydrovanestyle air compressors. In all instances please ensure that you advise the motor size and current rating before ordering.

Resistive Load (Heating Elements)

Phase Converters are not designed to support resistive load such as Heating Elements, Ovens, Chip Fryers, Pizza Ovens, and Sunbeds. We are not aware of any product capable of supporting this type of three-phase load on a single phase supply. Such demands often take the form of three separate single phase elements with a common neutral.

Shock-Load applications (e.g. Sheet Metal Equipment such as Guillotines & Presses)

The use of a rotary converter is recommended for these applications. The converter should be rated at a level that is at least twice the rating of the motor on the equipment i.e. a 5hp guillotine requires a 10hp rated rotary converter.

Static converters - Maximum single motor load?

The starting characteristics of a three-phase motor supplied by a static TRANSWAVE converter are generally similar in nature to that of a star/delta starter. The motor starting current is suppressed by the converter to approximately 3 times the full load current of the motor, significantly reducing the amount of available starting torque. This leads to starting difficulties, particularly if the maximum loading of the converter is sized close to the load of the motor. The maximum

single motor rating reflects the largest single motor the converter is capable of starting. The maximum loading of the converter reflects the maximum multi-motor running capability. Where possible, the use of direct-on-line starters is recommended for machinery operated in conjunction with a TRANSWAVE converter - note that the combination of a converter and a star/delta starter could compound these starting difficulties further.

Static converters - Minimum load?

Motors driving a table rise/fall, scribing saw, feed rollers, coolant pump or table feed are invariably of a fractional horsepower nature. If operated independently from a TRANSWAVE static converter, these motors would be subjected to an electrical condition, which would damage the motor windings. The minimum load reflects the minimum size of motor capable of interfacing independently with the converter, thereby establishing an acceptable artificial three-phase supply. Ancillary motors sized below the minimum loading of the TRANSWAVE should be operated in conjunction with and not independently of a larger drive motor that falls within the rating of the converter. Note that the Rotary converter does not have a minimum load.

Starting Currents/Star-Delta Starters

The full load running current (f.l.c) of an induction motor operating on a single-phase supply is approximately 4 amps per hp. When operated in conjunction with a TRANSWAVE Converter, the starting current of a three-phase motor is limited to approximately 3 times its f.l.c. This is significantly lower than the motor starting current of an equivalent sized single-phase motor, which would typically draw between 6-8 times its f.l.c.

As the starting characteristics of a three-phase motor supplied by a converter are similar in nature to Star/Delta starting on a three-phase supply, significant reductions in starting torque are experienced when compared with direct on line starting on a three-phase supply. Generally, when machinery is operated in conjunction with a TRANSWAVE Converter direct on line starting is recommended. For machinery fitted with a Star/Delta starter, the period in the star connection should be set as short as possible to ensure a successful start. We may invite you to alter the Star/Delta timer setting to facilitate the above. This is not the case when machinery is operated on a mains three-phase supply.

Variable Speed Drives (often referred to as Inverters or Frequency Converters)



PCL is a Tier One Reseller of IMO SD1 Inverter Products. The inverters are offered with a 2-year manufacturer's warranty.

Voltage Imbalance

The output from a TRANSWAVE Converter is inherently imbalanced from the perspective of both voltage and current. If the equipment being connected to the converter output incorporates any phase imbalance, current imbalance or phase failure protection, the equipment is unlikely to operate successfully in conjunction with a converter.

Welding Equipment

Both "3-wire" 415v three-phase and "2-wire" single-phase 415-volt welding sets can be operated with a suitably rated rotary converter. As welding load is resistive, not inductive, it is necessary to use a rotary converter to develop the voltage in the "artificial" third phase, independently of the welder. The converter should be of sufficient capacity to maintain the voltage on the artificial phase when the welder is operated at its maximum current rating.

All Rotary converter sizes need to be modified for welding purposes. This modification incorporates a hand/auto switch, which bypasses the automatic boost circuit.

Two-phase welding sets can also be operated from dedicated transformers. Note that any rotary converter used for welding purposes can still be used for standard motor applications. Please seek advice from our sales staff





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