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Phase Conversion, Inverters and Motor Control for the Single-Phase Workshop.

Nearly all large machine tools are equipped with industrial-style 3-phase motors. If you wish to operate these motors in a single-phase environment there are a number of options available:

1. Install a mains three-phase supply into the workshop
2. Use a diesel/petrol-driven 3-phase generator
3. Change the 3-phase motor to a single-phase motor
4. Use a "digital" phase inverter
5. Use an "analogue" phase converter

Option 1 is the ideal solution but can be cost-prohibitive, particularly when the proposed investment is being made on behalf of a landlord.

Option 2 is also likely to be cost-prohibitive given the ongoing maintenance issues, fuel costs, not to mention the noise.

Option 3 can also present issues. A single phase motor is less torque efficient than its 3-phase equivalent so invariably a larger hp rating is required for performance reasons. 1-phase motors are often housed in a larger frame size making them difficult to accommodate. Indirect costs are incurred modifying the 415v circuitry to 240v

Options 4 and 5 are covered below.

The terms "converter" and "inverter" are often confused and misapplied.

A "converter" ***varies the voltage*** of the circuit but ***fixes the frequency*** of the supply at which the motor operates.

An "inverter" ***fixes the voltage*** of the circuit but ***varies the frequency*** of the supply at which the motor operates

Option 4

- ***Inverters*** fix the voltage in the conversion (240v single phase input to 240v 3-phase output) but vary the supply frequency (e.g. from 50Hz to 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** (**R**adio **F**requency) mains filters are generally required to ensure your contractual obligations to the electricity supply company are not compromised.
- As the output from an ***Inverter*** is 240v 3-phase, an inverter cannot be accommodated without machine modification.
- The output from an ***Inverter*** can only be applied to one motor, or one fixed demand.
- 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).
- ***Inverters*** are manufactured worldwide by hundreds of companies (e.g. IMO, Mitsubishi, ABB, Siemens, Teco, Lenze, Schneider, SSD, Control Techniques, Omron, Invertech etc.) Tens of thousands of inverters are manufactured every week of the year. Most of these companies will not deal with the end-user direct. You will be talking to an appointed reseller.
- ***Terms such as "Inverter", "Drive", "Phase Inverter", "Variable Frequency Drive", "Variable Speed Drive", "VFD" and "VSD"*** correctly define this type of product.
- ***IF YOU WISH TO CONNECT A 400/440V THREE-PHASE MOTOR TO THE OUTPUT OF AN INVERTER, THE INVERTER WILL BE DESIGNED FOR CONNECTION TO A MAINS THREE-PHASE 400/440V SUPPLY.***

Transwave PHASE CONVERTERS

Option 5

- ***Converters*** vary the voltage in the conversion (240v single-phase to 415v 3-phase) but fix the supply frequency (50Hz) so there is no motor control available. The supply remains a.c. throughout the conversion.
- ***A 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 ***Converter*** is 415v, the converter retrofits directly to a machine that is wired for 415v three-phase operation so no machine modification is usually necessary.
- The output from a ***Converter*** is flexible and (within reason) can be applied to a variety of different machines whether operated one at a time or simultaneously.
- ***Converters*** are available to support any motor requirement, provided there is enough single phase supply available to support the three phase demand. Converters are available to 22kW/30hp. Larger ratings are accommodated by paralleling two units together.
- ***Converters*** are manufactured by a small number of UK companies. The largest UK manufacturer produces about 1000 units per year.
- ***Terms such as "Converter", "Phase Converter", "Static Converter" and "Rotary Converter"*** correctly define this type of product.

PHASE CONVERTERS

Motor Compatibility

When considering the use of a converter or inverter, the starting point is always the motor plate on the driven machine. As a general rule, 3-phase motors up to 2.2kW/3hp are "dual-voltage" marked 220/240v-380/415v. Both of these voltages are 3-phase voltages, reflecting different network voltage configurations in different parts of the world.

A dual-voltage 3-phase motor of this nature can be operated from either a **Converter** or an **Inverter.** The Converter uses the "star" 380/415v configuration; the Inverter uses the "delta" 220/240v configuration.

A "single-voltage" motor (i.e. 400/440v only) can only be operated in conjunction with a **Converter.** Similarly, a "pole-change" 2-speed motor (e.g. 1400rpm/2800rpm) can only be configured for operation at 400/440v so again, can only be operated in conjunction with a Converter.

If you wish to incorporate motor control into an application with either a "pole-change" or "single-voltage" motor, the factory-fitted 3-phase motor has to be replaced with an inverter-compatible 3-phase dual-voltage motor.

Similarly, if you wish to incorporate motor control into an application driven by a single-phase motor, the 1-phase motor has to be replaced with an inverter-compatible 3-phase dual-voltage motor.

Wiring a machine to the output of an inverter

Any Inverter designed and manufactured for connection to a single phase supply will offer a 3-phase output voltage equal to the input voltage, i.e. 220/240V. You must ensure that the 3-phase motor is configured correctly to accept 220/240v otherwise the torque performance at the tool will be unacceptable. Motor configuration options are usually stamped on the motor itself.

The inverter output is connected directly to the motor, bypassing any existing machine switchgear (including any ancillary circuits). The functionality associated with start, stop, forward, reverse and speed passes from the machine to either a keypad/panel on the inverter or a remote pod supplied as an optional extra. Any safety circuits/features such as limit or guard switches, emergency stop etc. will need to be reworked into the inverter wiring loom.

An inverter is a bespoke solution for one motor (or one demand where multiple motors are starting and stopping simultaneously). The primary role of an inverter is to control the speed of a motor so if motor control forms part of your requirement, the inverter is the only solution that achieves this. An inverter is often used as a “cost-effective” phase converter for single motor requirements where the motor is compatible and motor control may not be a requirement.

What performance can I expect from the motor once it has been connected to the 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, if your 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. Inverters come in all shapes, styles and ratings – voltage/frequency, torque-vector etc. Like most things, you get what you pay for. The more money you spend, the more performance you are likely to achieve. For small machine tool applications, inverters should be 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 “entry-level” inverters, typically available for about £100 plus VAT, are recommended to pre-set the frequency window between 25Hz and 60Hz to ensure that the level of torque available is acceptable. So-called vector inverters enhance the torque performance at low frequencies compared to traditional voltage-to-frequency inverters.

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. The frequency window outlined above typically eliminates this requirement. 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.

A word of caution: setting the maximum frequency level in excess of the motor’s plated frequency allows spindles to be run at speeds far in excess of the maker's original intentions. In addition chucks mounted on the headstock spindle are always limited in how fast they can be spun, especially large ones; often made of cast iron they will eventually burst - and the clamping force of the jaws also weakens as the speed rises.

Where to buy your inverter

EBay is, of course, awash with sellers of low-cost units - but take care. Are these people just box-shifters who offer no advice or back-up service? Will they answer your questions when your unit does not perform as expected? Are they familiar with the common makes and model of lathe and milling machine and know what advice to give regarding the ideal unit to run them.

Best I suppose to run past them a few sample questions to see how they perform.

Most motor-repair shops in your local area now sell inverters and usually have experience of industrial applications - and may well be able to offer a delivery and installation service. Obviously, having overheads, their prices may well not be as competitive as an online-only seller but at least you know where they are should things not work out. My advice is to buy a high quality inverter from a reputable and experienced manufacturer such as IMO or Mitsubishi.

Modified inverters – a word of warning

No inverter manufacturer on planet earth produces an inverter that varies voltage. If you wish to vary the frequency of a 380/415v 3-phase motor you can purchase an inverter that connects to a 380/415v 3-phase supply and gives a 380/415v 3-phase variable frequency output. If you purchase an inverter designed to connect to a single-phase 220/240v supply, the output from the inverter will be 3-phase 220/240v ***NOT*** 3-phase 380/415v.

Any so-called "Advanced" inverters offering a 380/415v 3-phase output from a 220/240v single-phase supply are in reality, ***modified*** versions of the standard 3-phase 380/415v input products.

Companies offering this type of product, take a standard inverter designed to operate on a 3-phase 380/415v supply and modify it for use on a 220/240v supply. The modification creates two issues, namely:

1. Any warranty offered by the inverter manufacturer is now null and void because the inverter has been modified away from its original specification.
2. The inverter no longer complies with European Power Quality Standards such as the EMC directive, BSEN 61000-3-2:2006 and BS EN 61000-3-12:2005 so cannot be CE marked without further approval.

Original labels often appear on the modified products suggesting compliance so tread very carefully before considering these products. There are no cosmetic changes to the inverter, so the only way you know the inverter has been modified is because has a label (usually stuck over the manufacturer's label) confirming the modified input and output voltages.

Conclusion

If you intend to operate several 3-phase machines in your workshop a rotary converter is likely to be the most appropriate option. A static converter offers similar flexibility of output on the understanding that only one motor can be operated at any one time.

If motor control is on your radar, then an Inverter is what you require. This can only be applied to one motor and will require machine modification. Inverters also offer a cost-effective “converter” solution for “one-off” applications where the motor is compatible.

As is the case with most specialist equipment, it is important that you discuss your requirements with a knowledgeable provider prior to purchase. Every option has advantages and disadvantages. A specialist provider should take time to cover all the options and steer you to the most suitable solution for your requirement.

If you have any doubts about your ability to undertake work connected with electrical installations, you should employ an electrician, qualified to work on machine tools, to do the job for you; you will find it money well spent.

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