SIEMENS

MICROMASTER

Applications Handbook **Issue A1**

User Documentation

IMPORTANT NOTICE

Not all inverters currently have UL approval.

UL listing can be determined by examining the inverter's Rating Label.

For UL listed products the following UL mark is used:

Further information is available on the Internet under:

http://www.siemens.de/micromaster

Approved Siemens Quality for Software and Training is to DIN ISO 9001, Reg. No. 2160-01

Other functions not described in this document may be available. However, this fact shall not constitute an obligation to supply such functions with a new control, or when servicing.

We have checked that the contents of this document correspond to the hardware and software described. There may be discrepancies nevertheless, and no guarantee can be given that they are completely identical. The information contained in this document is reviewed regularly and any necessary changes will be included in the next edition. We welcome suggestions for improvement.

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SIEMENS

MICROMASTER

Applications Handbook
User Documentation

Valid for A1 Release

Inverter Type Control Version

MICROMASTER MM4

Issue: A1

Table of Contents

List of Figures

List of Tables

1 Introduction

This manual is intended to help users of variable speed drives successfully install and utilize Siemens Standard Drives.

It includes an introduction to drives, which may be informative to first time users.

Detailed technical information and complete parameter descriptions are available in the Reference Manual and the Parameter List.

INTERNET Address:

http://www.siemens.de/micromaster

These sites will allow access to handbooks, application and training information, as well as Frequently Asked Questions. (FAQs).

1.1 What is a Variable Speed Drive?

A Variable Speed Drive (VSD) consists of a Motor and some form of controller. Early electric VSDs consisted of AC and DC motors combinations which were used as rotating controllers. The first electronic controllers used Thyristor (SCR) Rectifiers which controlled the voltage, and therefore the speed of DC motors. These DC VSDs are still widely used and offer very sophisticated control capability.

However, the DC motor is large, expensive and requires periodic brush maintenance. The AC induction motor is simple, low cost, reliable and widely used throughout the world.

In order to control the speed of an AC induction motor a more complex controller, usually called an inverter is required.

In order to understand how an inverter works, it is necessary to understand how an induction motor works.

An induction motor works like a transformer. When the stator (the fixed, outer winding) is connected to a three-phase power source, a magnetic field is set up which rotates at the frequency of the supply.

Figure 1-1 shows a simplified cross-section of an induction motor.

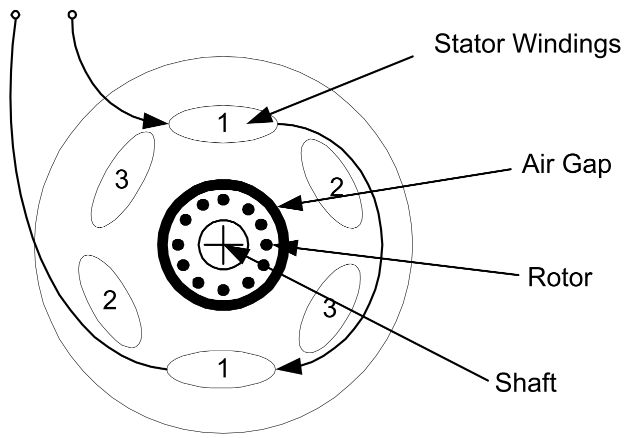


Figure 1-1 Induction Motor. Simplified Cross Section

This field crosses the air gap between the stator and rotor and causes currents to flow in the rotor windings. This produces a force on the rotor as the current interacts with the changing magnetic field, and the rotor turns.

If the windings are arranged in several pairs (or poles), the frequency of the rotating field will be less than the applied frequency (e.g. two pole = 50/60 Hz = 3000/3600 rpm, but four pole = 50/60 Hz = 1500/1800 rpm). However, if the rotor runs at the same speed as the rotating field, there will be no changing magnetic field, and therefore no torque. Therefore the rotor always runs a little slower than the rotating field in order to generate torque. This difference in speed is known as slip.

You can see that the speed of the motor depends on the applied frequency, as well as the winding arrangement, and a little on the load. Therefore in order to control the motor speed it is necessary to control the frequency of the supply.

If the frequency is reduced, the voltage must be reduced or the magnetic flux will be too high and the motor will saturate so the voltage must be controlled as well. If the frequency is increased above normal, more voltage would normally be needed to maintain maximum flux. Since this is not usually possible, less torque is available at high speed.

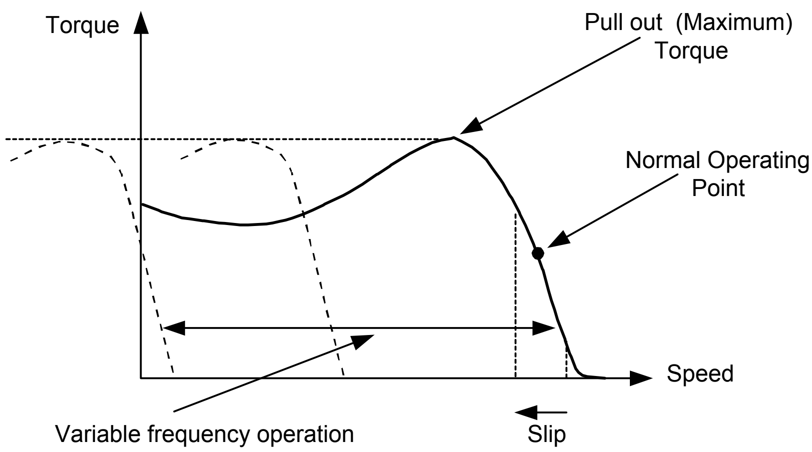


Figure 1-2 Torque Speed Characteristics of an Induction Motor

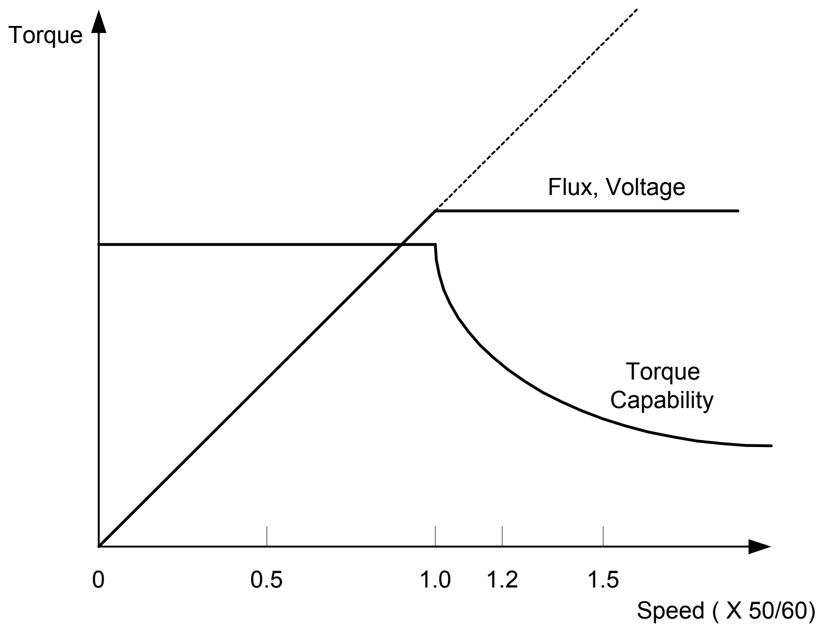


Figure 1-3 Torque Reduction above Base Speed

Therefore in order to control the speed of a standard AC motor, the applied frequency and voltage must be controlled.

Although it is difficult to control voltage and frequencies at these high powers, the use of a standard induction motor allows a cost-effective speed control system to be built.

1.2 The Variable Frequency Inverter

An electronic converter that converts Direct Current (DC) to Alternating Current (AC) is known as an inverter. Electronic speed controllers for AC motors usually convert the AC supply to DC using a rectifier, and then convert it back to a variable frequency, variable voltage AC supply using an inverter bridge. The connection between the rectifier and inverter is called the DC link. The block diagram of a speed controller (often called an inverter) is shown in Figure 1-4.

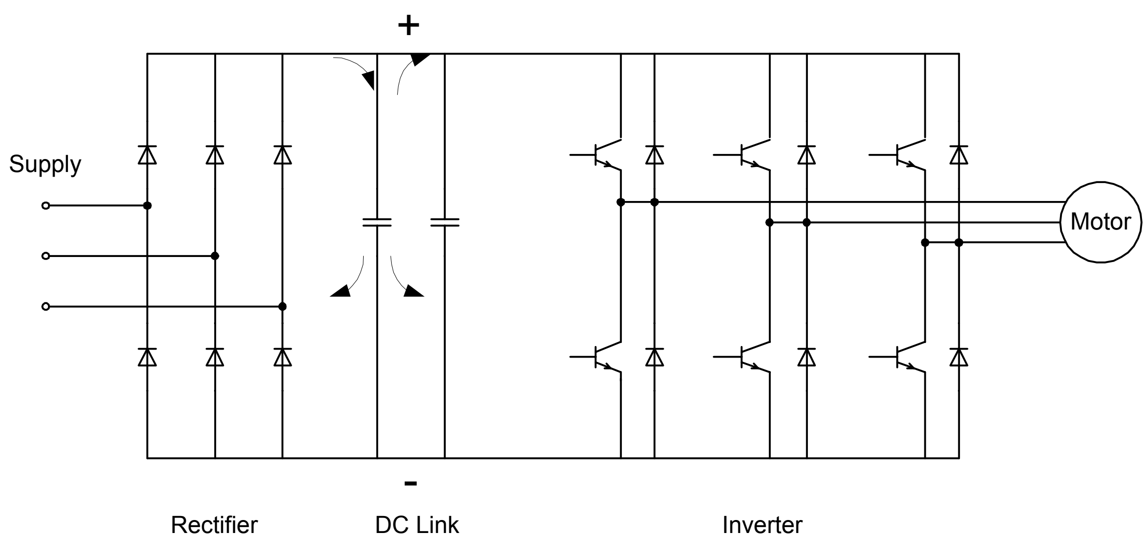


Figure 1-4 Inverter Block Diagram

The supply, which can be single phase (usually at low power) or three-phase is fed to a full wave rectifier which supplies the DC link capacitors. The capacitors reduce the voltage ripple (especially on single-phase supplies) and supply energy for short breaks in the input supply. The voltage on the capacitors is uncontrolled and depends on the peak AC supply voltage.

The DC voltage is converted back to AC using Pulse Width Modulation (PWM). The desired waveform is built up by switching the output transistors (Insulated Gate Bipolar Transistors (IGBTs) on and off at a fixed frequency (the switching frequency). By varying the on and off time of the IGBTs the desired current can be generated, but the output voltage is still a series of square wave pulses. Pulse Width Modulation is shown in Figure 1-5.

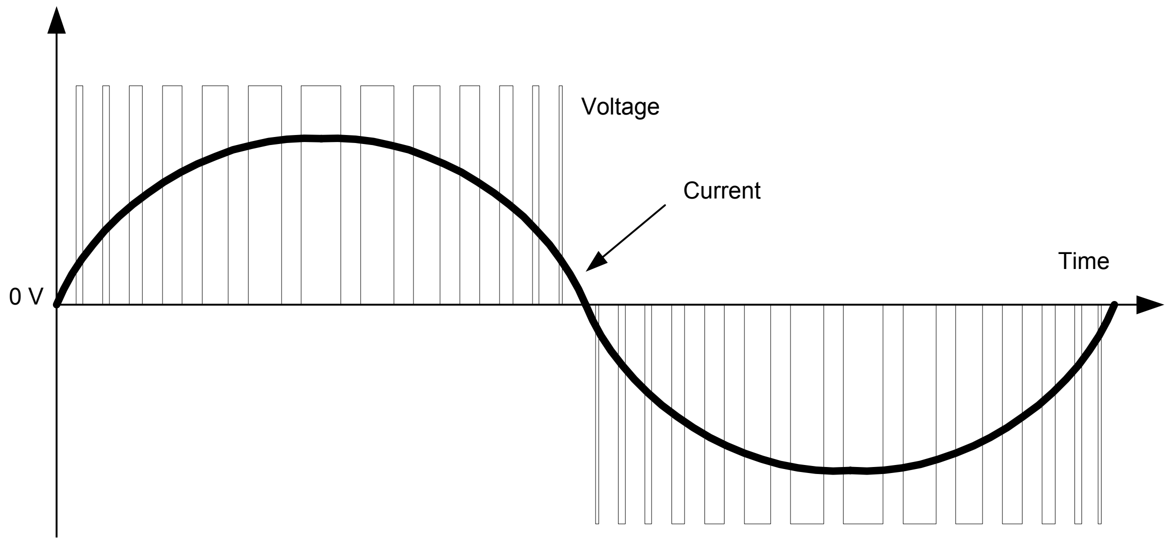


Figure 1-5 Pulse Width Modulation

There are many complex aspects of inverters which need to be considered during the design:

- The control system to calculate the PWM requirements is very complex and specially designed integrated circuits (ASICs) are needed.
- The control electronics are often connected to the DC link, which is connected to the supply, so the customer connections, display etc. must be safely isolated from this.
- The output current must be carefully monitored to protect the inverter and the motor during overload and short circuit.
- At first switch on the DC link capacitors are discharged, and the inrush current must be limited, usually using a resistor which is bypassed by a relay after a few seconds.
- All connections to the inverter, especially the supply and control connections, may carry a lot of interference and must be fitted with suitable protection components.
- An internal power supply with several different output voltages is needed to supply the control electronics.
- The inverter, especially the IGBTs and rectifier diodes, produce heat which must be dissipated using a fan and heatsink.

- The PWM output voltage contains many high frequency harmonics (because of the fast switching) and can be a major source of EMI.

- The input rectifier draws current only at the peak of the supply waveform, so the input currents have a poor form factor (i.e. the RMS value can be quite high - this does not mean the inverter is inefficient!).

A practical inverter needs to be designed for ease of use and installation. Large inverters are often specially designed or engineered for each application; smaller inverters are designed for general purpose use and are of standard design. Siemens Standard Drives division manufacture standard inverters for this purpose.

2 Siemens Drives Product Range

The current product range consists of several different product types:

The MICROMASTER Vector (MM440). A VSD high performance inverter for general purpose applications available in various voltage ranges.

The MICROMASTER (MM420). A similar range with fewer features for simple applications.

The MICROMASTER Eco. A VSD especially designed for Heating, Ventilating and Air Conditioning applications.

The COMBIMASTER. An induction motor with an inverter mounted in place of the terminal box.

Larger and more sophisticated drives for engineered applications can be supplied by other Siemens drives divisions.

The following information refers to the operation of the MICROMASTER products in particular, but is applicable to all VSDs.

3 Selecting a Drive

Often drive selection is straight forward, as a motor is already installed and the speed range requirement is not excessive. However, when a drive system is selected from first principles, careful consideration may avoid problems in installation and operation, and may also save significant cost.

3.1 Overall Considerations

Check the Current rating of the inverter and the motor. Power rating is only a rough guide.

Check that you have selected the correct operating voltage. 230 V three-phase input MICROMASTERs will operate with single or three-phase inputs. 400 V MICROMASTERs are for three-phase application only. Single-phase input units can be more cost effective in some cases, but note that 230 V units will be damaged if operated at 400 V. See section 3.2.1.

Check the speed range you require. Operation above normal supply frequency (50 or 60 Hz) is usually only possible at reduced power. Operation at low frequency and high torque can cause the motor to overheat due to lack of cooling.

Synchronous motors require de-rating, typically by 2-3 times. This is because the power factor, and hence the current, can be very high at low frequency.

Check overload performance. The inverter will limit current to 150 or 200% of full current very quickly. A standard, fixed speed motor will tolerate these overloads.

Do you need to stop quickly? If so, consider using a braking resistor to absorb the energy. A separate braking unit may be required for some VSDs. See section 0,

Do you need to operate with cables longer than 50m, or screened or armored cables longer than 25m? If so, it may be necessary to de-rate, or fit a choke to compensate for the cable capacitance.

3.2 Supply Side Requirements

In order to achieve reliable operation, the main power supply to the inverter system must be suited to the inverter and the anticipated power supplied. The following points should be considered:

3.2.1 Supply Tolerance

Inverters are usually designed to operate on a wide range of supply voltages. For example:

Low Voltage units	200 - 240 V ±10%	i.e. 180 - 264 V
High Voltage units	380 - 480 V ±10%	i.e. 342 - 528 V
Very High Voltage units	500 - 600 V ±10%	i.e. 450 - 660 V

Inverters will operate over a wide supply frequency range, typically 47 - 63 Hz

However, many supplies vary outside these voltage levels. For example:

Supplies at the end of long power lines in remote areas can rise excessively in the evening and weekends when large loads are no longer present.

Industries with locally controlled and generated supplies can have poor regulation and control.

Power systems in certain parts of the world may not meet expected tolerances.

In all installations, check that the supply will remain within the tolerances stated above. Operation outside of the stated supply levels will probably cause damage.

3.2.2 Supply Disturbance

Many supplies are well controlled and remain in tolerance, but are affected by local disturbances. These can cause faulty operation and damage to inverters. In particular, check for:

- Power Factor Correction equipment. Unsuppressed switching of capacitor banks can produce very large voltage transients and is a common cause of inverter damage.
- High power welding equipment, especially resistance and RF welders.
- Other drives (in particular large, old DC drives), semiconductor heater controllers etc.

Note.
Inverters are designed to absorb high levels of supply disturbance. Voltage spikes up to 4 kV for instance. However, the above equipment can cause power supply disturbances in excess of this. It will be necessary to suppress this interference - preferably at source - or at least by the installation of an input choke in the inverter supply. EMC filters do not suppress disturbances with this level of energy; over voltage protection products such as metal oxide varistors should be considered.

Damage can also be caused by local supply faults and the effects of electrical storms. In areas where these are expected, similar precautions are recommended.

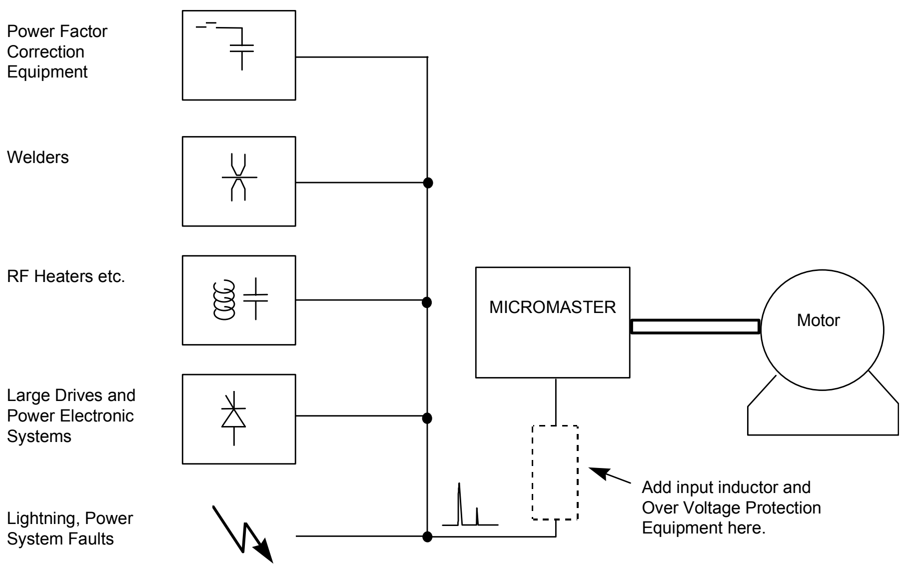


Figure 3-1 Sources of Supply Disturbance

3.2.3 Ungrounded Supplies

Certain industrial installations operate with supplies that are isolated from the protective earth (IT supply). This permits equipment to continue to run following an earth fault. However, MICROMASTERs are designed to operate on grounded supplies and are fitted with interference suppression capacitors between the supply and ground. Hence operation on ungrounded supplies may be restricted. Some inverters are designed to allow the removal of these capacitors and enable limited operation with ungrounded supplies. Please consult Siemens for clarification.

3.2.4 Low Frequency Harmonics

The inverter converts the AC supply to DC using an uncontrolled diode rectifier bridge. The DC link voltage is close to the peak AC supply voltage, so the diodes only conduct for a short time at the peak of the AC waveform.

The current waveform therefore has a relatively high RMS value as high current flows from the supply for a short time.

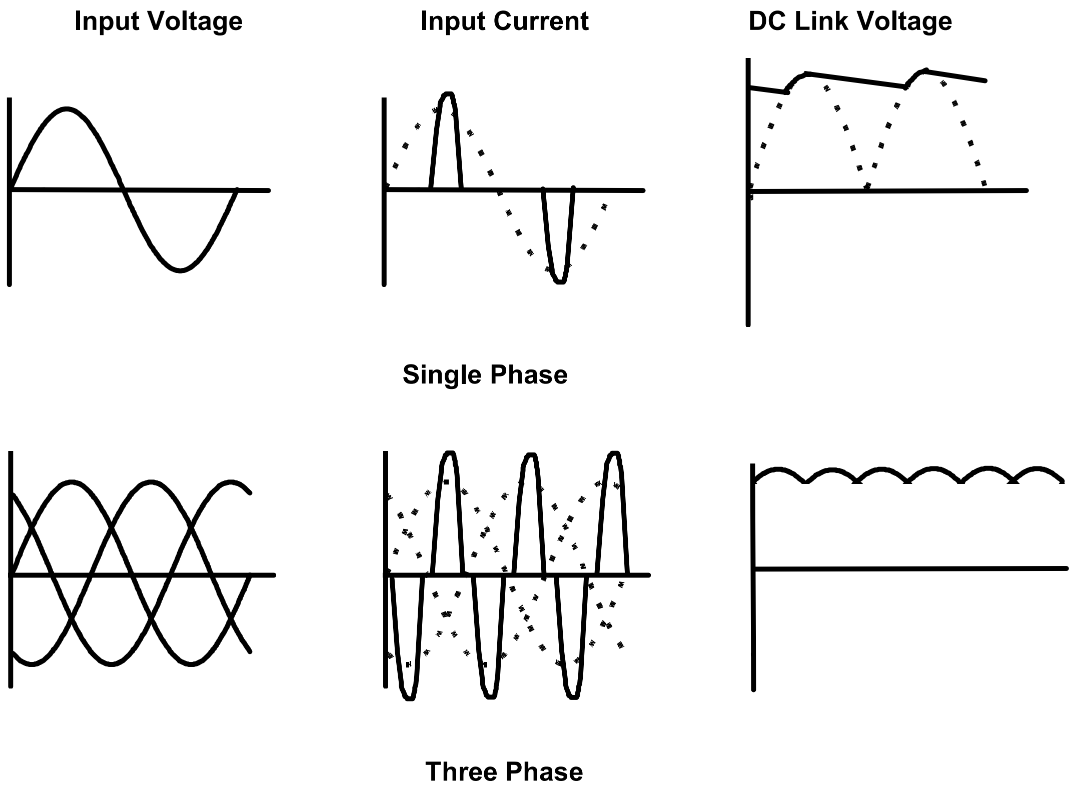


Figure 3-2 Rectifier Input Voltages and Currents

This means that the current waveform is consists of a series of low frequency harmonics, and this may in turn cause voltage harmonic distortion, depending on the supply impedance.

Sometimes these harmonics need to be assessed in order to ensure that certain levels are not exceeded. Excessive harmonic levels can cause high losses in transformers, and may interfere with other equipment. In any case, the rating and selection of cabling and protection equipment must take these high RMS levels into account. Some measured harmonic levels are shown In Figure 3-3.

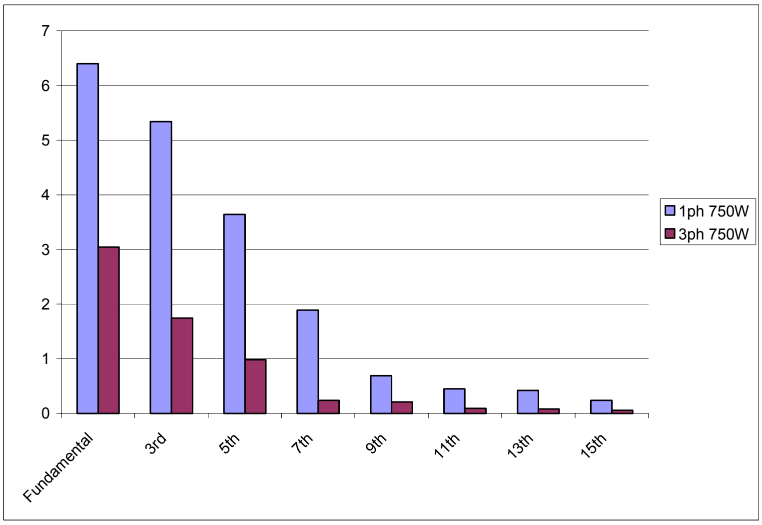


Figure 3-3 Typical Harmonic currents in 230 V single and three-phase supplies, (750 W Inverter).

In order to calculate the harmonics in a particular supply system it is essential that the supply impedance is known. This is usually stated in terms of fault current levels, transformer size and installed impedance such as line inductors etc.

Computer programs are available to calculate the current and voltage harmonic levels, dependent on the load, type and number of inverters in the system. In general, industrial supplies do not require this level of assessment.

Where supplies have very low impedance (such as below 1%) an input inductor is recommended in any case to limit peak currents in the drive.

3.3 Motor limitations

For more information concerning calculation of Power requirements, Torque, and Moment of Inertia, see Appendix B.

The motor speed is determined mainly by the applied frequency. The motor slows down a little as the load increases and the slip increases. If the load is too great the motor will exceed the maximum torque and stall or 'pull out'. Most motors and inverters will operate at 150% load for a short time, (60 seconds for instance).

The motor is usually cooled by a built in fan that runs at motor speed. This is designed to cool the motor at full load and base speed. If a motor runs at a lower frequency and full torque - that is high current - cooling may be inadequate. Motor manufacturers will give the necessary de-rating information, but a typical derating curve would limit output torque to 75% at zero frequency rising to full capability at 50% of base speed. See Figure 3-4. Ensure that these limitations are not exceeded for long term operation.

Consider using the I^2t function to help protect the motor (see section 5.7.1) or consider using a motor with built in protection such as a PTC.

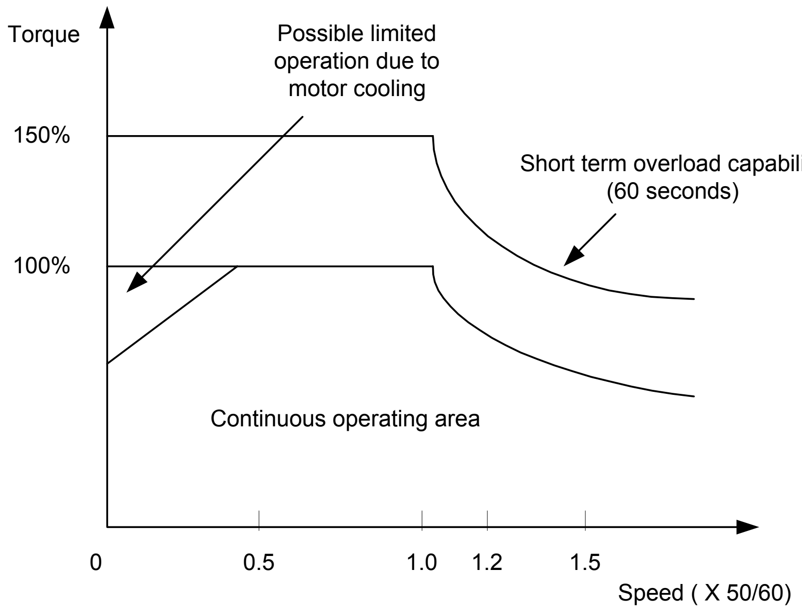


Figure 3-4 Operating Capabilities of Motor/Inverter Combinations

High speed operation of standard motors is usually limited to twice the normal operating speed (i.e. up to 6000 or 7200 rpm) of a two-pole motor because of bearing limitations. However, because the flux level will reduce above base speed (because the output voltage is limited to approximately the input voltage) the maximum torque will also fall in inverse proportion to the speed above base speed.

However, if a motor is connected as a low voltage motor (delta) and operated on a higher voltage inverter, full torque may be obtained up to 1.7 times base frequency if the inverter is correctly set up. The correct voltage/frequency curve may be defined by setting the appropriate motor voltage (e.g. 400 V) and frequency (87 Hz).

3.4 Load Considerations

The inverter and motor requirements are determined by the speed range and torque requirements of the load. The relationship between Speed and Torque is different for different loads. Many loads can be considered to be Constant Torque loads. That is, the torque remains the same over the operating speed range. Typical constant torque loads are conveyors, compressors and positive displacement pumps. See Figure 3-5

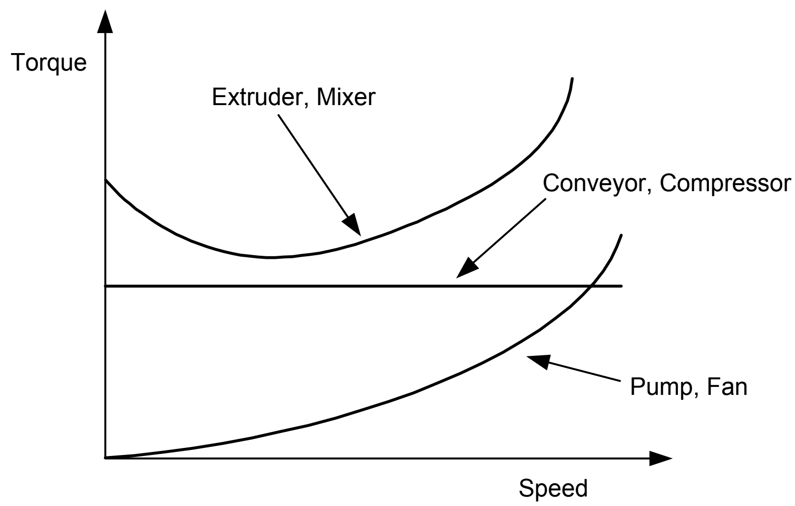


Figure 3-5 Torque/Speed Characteristics

3.4.1 Variable Torque Applications

Some loads have a Variable Torque characteristic. That is, the torque increases with the speed. Typical variable torque loads are centrifugal pumps and fans. In these applications the load is proportional to the square of the speed, and therefore the power is proportional to the cube of the speed. This means that at reduced speeds there is a great reduction in power and therefore energy saving - a major advantage of variable speed drives applied to pumps and fans. For example, a 10% reduction in speed will give a theoretical 35% reduction on power!

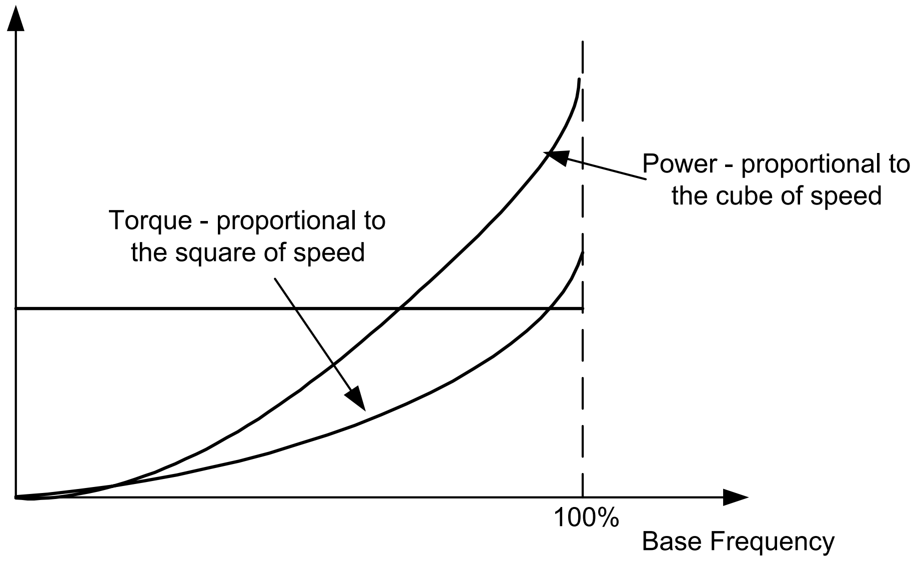


Figure 3-6 Variable Torque/Load Characteristics

Because the power is greatly reduced, the voltage applied to the motor can also be reduced and additional energy saving achieved. A separate ‘quadratic’ or ‘pump and fan’ voltage to frequency relationship can usually be programmed into the inverter.

It is not generally useful to run pumps or fans above base speed as the power will rise excessively and the fan or pump may become inefficient. Therefore when the ‘quadratic’ voltage to frequency curve is selected, the overload capability of the inverter is often reduced. This allows a higher continuous rating output current to be achieved.

Many inverters, particularly at higher powers, are **dual rated**, and the higher rating available for pump and fan operation can give an additional capital cost saving in these applications.

Note.
Some pumps (such as peristaltic, positive displacement or some screw types) require a constant torque, and therefore are not suitable for use with quadratic voltage to frequency curves. Conventional linear relationships should be used.

3.4.2 Other Loads.

Many other loads have non-linear or varying torque relationships. The torque requirement of the load should be understood before the inverter and motor is selected.

By comparing the load/speed requirement with the motor capability, the correct motor can be selected. Remember a different pole pair arrangement may give a better match to the load needs.

Starting torque may need special consideration. If a high starting torque is required this must be considered during rating.

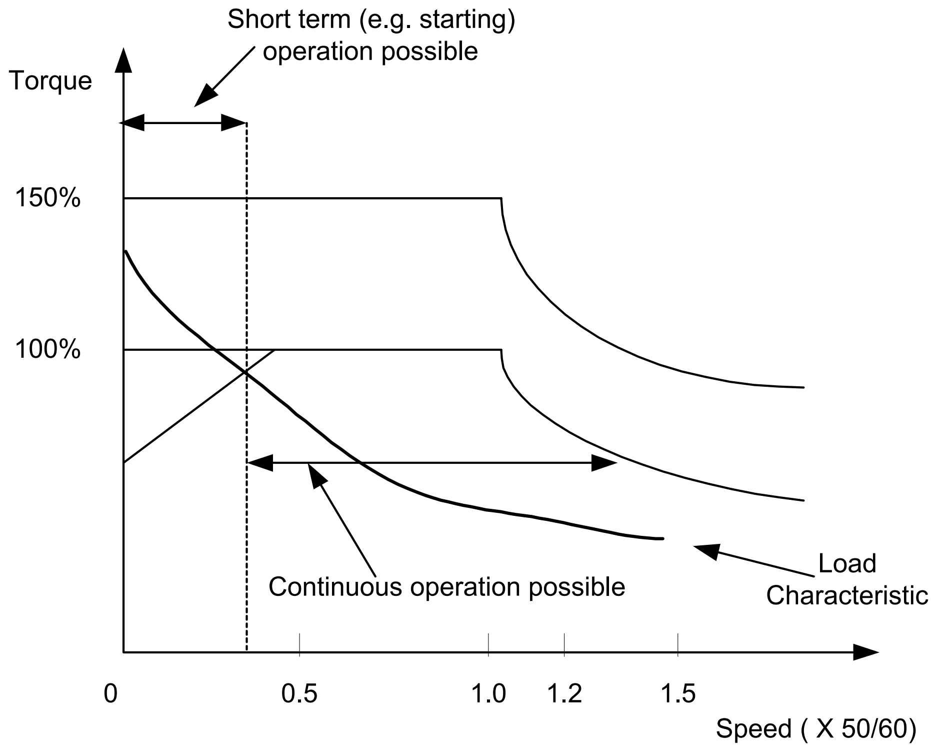


Figure 3-7 Matching the load to the Motor/Inverter Capabilities

3.5 Acceleration and Braking requirements

If the load has high inertia and there is a requirement for fast acceleration or braking, the load due to the inertia must be considered.

During acceleration, additional torque will be needed. The total torque needed will be the sum of the steady state torque and this additional torque. Details of these calculations are described in Appendix B.

During braking, the inertial energy of the load must be dissipated. If a mechanical brake is used this is no problem, providing the inverter is disabled during brake operation. If the motor is decelerated by reducing the inverter output frequency, the energy from the load will be returned to the inverter. Other options such as DC braking and Compound braking will minimize regeneration to the inverter, but in this case the energy will be dissipated in the motor windings. Braking methods and options are described in detail in section 8.2.

3.6 Environmental Considerations

The inverter is designed for operation in an industrial environment. However there are certain limitations which must be considered; the following check list should help:

- Check that the airflow through the inverter will not be blocked by wiring etc.
- Make sure the temperature of the air does not exceed 50°C. Remember to allow for any temperature rise inside the box or cubicle.
- Most inverters are available with protection levels of IP20 , IP21 or IP56. IP20 and IP21 units need additional protection against dust, dirt, and water. For a detailed description of IP rating see Appendix A.
- The inverter is designed for fixed installation and is not designed to withstand excessive shock and vibration.
- The inverter will be damaged by corrosive atmospheres.
- Protect the unit from dust; dust can build up inside the unit, damage the fans, and prevent proper cooling. Conductive dust, such as metal dust, will damage the unit.
- Give due consideration to Electromagnetic Compatibility (EMC), such as:
  - Will the inverter be protected from the effects of power equipment such as Power Factor Correction equipment, Resistance Welding Equipment etc.?
  - Will the inverter be well grounded?
- How will the inverter and any control equipment (contactors, PLCs, relays sensors etc.) interact?

IF IN DOUBT, consult the guidelines and specification information in the Operating Instructions, or see section 6.1.

4 Getting Started with an Inverter

4.1 Mounting the Inverter

Mount the inverter using the mounting holes provided as described in the Operating Instructions. Ensure the correct torque ratings for the fixing bolts are not exceeded.

The unit may be mounted horizontally or vertically without derating. Do not mount the units upside down or sideways, as the fan cooling will oppose natural convection cooling.

4.2 Cooling

Many inverters will operate in a temperature of 50° C without de-rating.

Make sure that the inlet and outlet ducts are not blocked, for example by cables.

It is very important to ensure that the maximum operating temperatures are not exceeded inside a cubicle. When installing an inverter in a cabinet, it is necessary to calculate the heat rise:

1. Calculate total heat loss (P_{loss}) for all units inside the cabinet . Use manufacturers' data or assume 3% loss.
2. For a sealed cabinet, calculate temperature rise using the formula:
   $T_{rise} = P_{loss}/(5.5 \times A)$
   Where A is the total exposed area of the cabinet in square metres.

   For a fan cooled cabinet, calculate temperature rise using the formula:
   $T_{rise} = (0.053 \times P_{loss})/F$
   Where F is the air flow in cubic metres /minute.
3. Add the Temperature rise to the external ambient temperature. If this is greater than the operating temperature of the drive, additional cooling will be needed, or the units must be de-rated.

It will also be necessary to de-rate at altitudes above 1000 m. Typical de-rating is as follows:

2000 m	85% of full load rating.
3000 m	75% of full load rating.
4000 m	65% of full load rating.

For more information consult the inverter supplier.

4.3 Wiring up the Inverter

Warning

This Equipment must be Earthed

Note the warning guidelines in the Operating Instructions, and ensure all safety regulations are complied with.

Follow the wiring instructions in the Operating Instructions, including the EMC guidelines.

If the supply is connected to the motor/output terminals, the inverter will be damaged.

Check the wiring before switching on. In particular, is the unit connected to the correct supply, (low voltage units will be damaged if connected to a higher voltage) and is the protective earth connected?

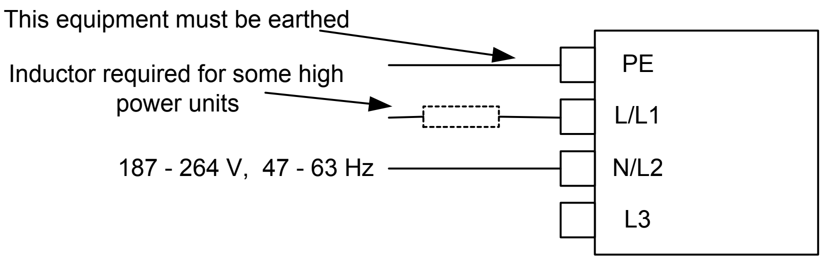


Figure 4-1 Input Wiring. Single-Phase Supplies

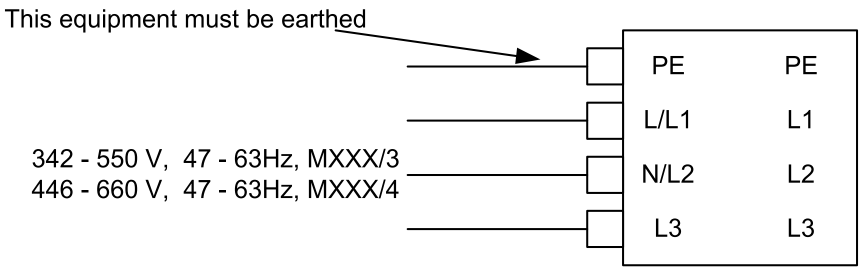


Figure 4-2 Input Wiring. Three-Phase Supplies

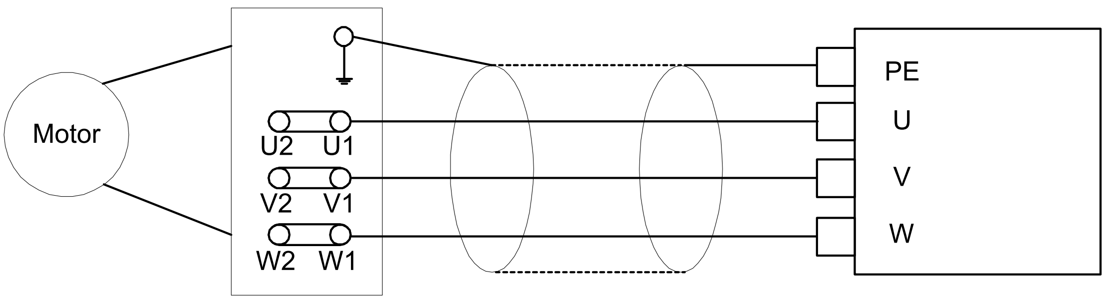


Figure 4-3 1AC or 3AC, 230 V Input. (Motor usually Delta Connected)

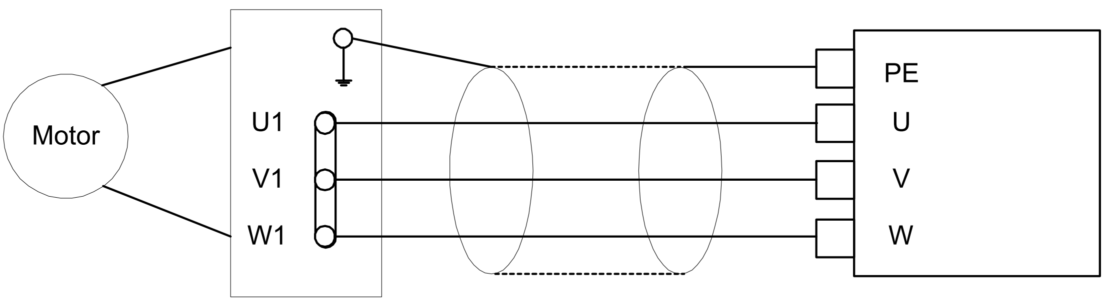


Figure 4-4 3AC, 400 – 575 V Input. (Motor usually Star Connected)

4.3.1 A Typical Installation

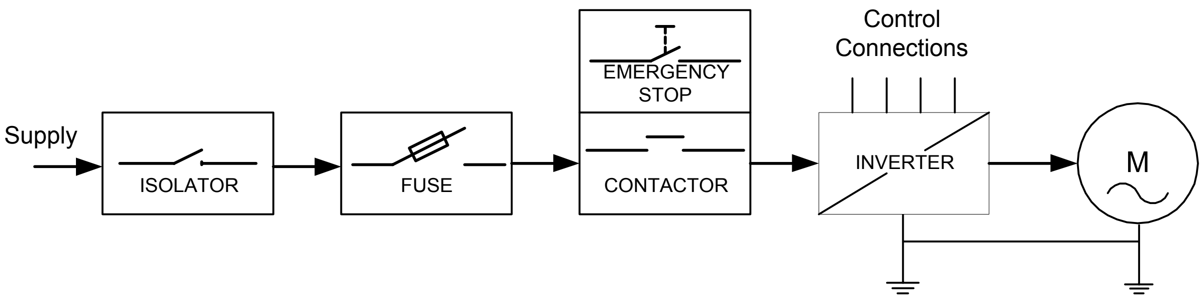


Figure 4-5 Typical Installation

Supply The supply may be either single or three phase, depending on the inverter type. The recommended wire sizes are stated in the manual.

Isolator An isolator is usually required for safety reasons.

Circuit Breaker or Fuses. The protection rating is based on the input current as stated in the manual. The input current is higher than the output current because the form factor of the current is high. Do not use fast acting circuit breakers or semiconductor fuses. Motor Circuit Breakers are usually recommended for use with inverters.

Inrush currents on the latest inverters are typically equal to, or less than the full load current, so nuisance tripping is less of a problem.

Contactor A contactor, with an emergency stop function connected may be required both for auxiliary control and safety isolation. Do not use the contactor as a stop start function This will cause unnecessary wear on the contactor and there will always be a slight delay while the inverter initialises. Use the control terminals or push buttons to do this. It is not permitted to use the Run/Stop control of the inverter as an emergency stop function. It is not recommended to fit a contactor between the output of inverter and the motor.

Motor As shown in previous diagrams, many motors, particularly at low powers, are designed for low voltage (230 V) or high voltage (400 V) operation. The voltage is usually selected by fitting links at the motor terminals. Instructions for low voltage (star) connection or high voltage (delta) connection are usually shown on the inside of the terminal cover. Clearly an inverter with a low voltage single or three phase input will produce a low voltage three phase output, and the motor should be connected accordingly. See also section 3.3

4.4 First Switch On

The Getting Started Guide or Operating Instructions that are supplied with the inverter will give detailed instructions on how to start and set up the inverter. However, some general points are worth noting:

- The inverter will usually operate a standard motor and load without changing the factory settings.

- To optimise performance, and for special applications, the factory settings may be changed. This is usually achieved by adjusting *parameters,* which are programmable settings that control various characteristics of the inverter. Parameters are usually set via a keypad or computer, and are normally stored by the inverter even after the power is switched off. The procedure for changing parameters is described in the the Operating Instructions.

- If too many parameters are changed, and performance is not as required, it may be advisable to reset all parameters to the factory setting and start again.

- ‘Quick set up’ or ‘Commissioning’ programmes may simplify programming and parameter setting. Check the ‘Getting Started Guide’.

- If there is a problem with the inverter or its settings, the display will usually flash or otherwise indicate a fault or warning. The handbook will suggest a trouble shooting procedure.

- If the motor goes in the wrong direction, switch off at the supply, wait five minutes for the internal capacitors to discharge, and swap any two motor connections. Of course, the motor can also be reversed using the front panel controls, digital inputs etc.

- If the motor is heavily loaded, or if the parameters have not been correctly set it may not turn. Set the motor parameters as described in the Operating Instructions.

5 Applications and Possibilities

Most inverters used in industry are controlled via the control terminals, not the front panel. This section describes some simple control possibilities using these inputs, and some of the programmable features that may prove useful. The following descriptions include terminal numbers and parameter values which are valid for MICROMASTER MM420 inverters. If other products are used please check the terminal numbers in the Reference Manual supplied with the inverter.

5.1 Using a Potentiometer with the Analog Input

Connect a potentiometer (between 5 kΩ and 100 kΩ) to the analog input as shown in Figure 5-1. The Potentiometer is wired as shown:

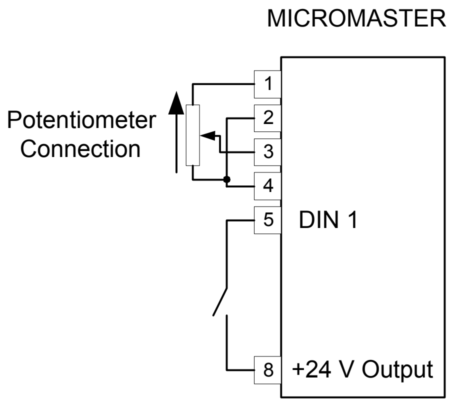


Figure 5-1 Using a Potentiometer with the Analog Input

Connect a switch between terminals 5 and 8 in order to apply a 'RUN' command to digital input 1.(DIN 1) The default parameter settings of the MM420 will permit operation using this simple arrangement.

The default maximum and minimum settings for the analog input are 50 and 0 Hz respectively, so the inverter will run at a frequency somewhere between these frequencies, depending on the potentiometer position.

Changing parameters such as P0758 and P0760 will change the range of the potentiometer accordingly, but remember the absolute maximum and minimum settings are set by parameters P1080 and P1082. Note that many parameters cannot be changed while the inverter is running. The display will flash if this is attempted.

5.2 Using all the Digital Inputs

The digital inputs on the inverter are programmable and many different functions can be selected. The digital inputs have default settings which are used below, but can be easily changed.

With the potentiometer still connected, connect two more switches as shown below. The first switch will run the inverter as before, the second switch will now reverse the direction (providing a 'RUN' signal is already present from the first switch. The third switch can be used to reset any faults should they occur. These are the default settings for controlling the MICROMASTER MM420.

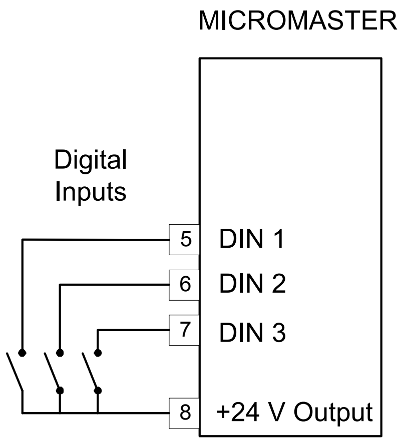


Figure 5-2 Using all the Digital Inputs

5.3 Selecting and Using the Fixed Frequencies

The digital inputs can be used to select fixed frequencies. Set parameter P1000 to 3 (select fixed frequency operation), and set parameters P0701, 2,and 3 to 16. These switches can now be used to select fixed frequencies 1, 2 and 3 (default values 0, 5 and 10 Hz). By setting P0701 etc. to 16, a 'RUN' signal is automatically generated when a fixed frequency is selected.

Closing more than one switch will simply add the two fixed frequencies together.

Other fixed frequencies (including reverse – negative – values) can be selected by changing the value of parameters P1001, 2, 3 etc.

5.3.1 More Complex Uses of Fixed frequencies

If the corresponding digital inputs are reprogrammed from 16 to 17, the inputs will selected fixed frequencies in binary coding, allowing the three inputs to select up to 8 digital inputs. However, a separate 'ON' command will be required

The fixed frequencies can be added or scaled to the fixed frequencies by changing parameter P1000 and P1071.

Please consult the Parameter List for additional details.

5.4 Using other digital input features

All the digital inputs have many different functions, which can be programmed by setting parameters P0701-3, The analog input can even be programmed as a digital input using parameter P0704. Simple uses include:

001 Run right
002 Run left
012 Reverse
010 Jog right.

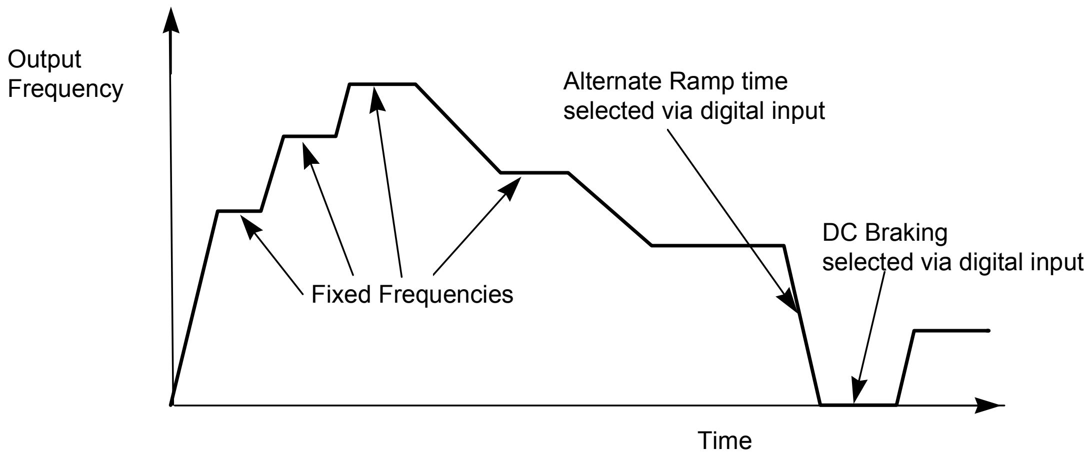
Other settings that may prove useful:

016 Select fixed frequency + on (see above)
012 Fault reset
029 External trip.

Advanced Features:

025	Enable DC brake. The DC brake feature can be enabled to provide a holding torque if required. See section 8.2.
013/014	Increase/decrease frequency (Motor Potentiometer function).
099	BiCo Functionality. Many complex functions are possible.

Please consult the Parameter List for additional details.



Possible control cycle using fixed frequencies, DC Braking, and Variable Ramp Rates

Figure 5-3 Composite Control Cycle

5.5 Using the control outputs

There are several control outputs, which can be used to control external indicators or warn of potential problems.

5.5.1 Analog Output (MICROMASTER MM440 only).

The analog output may be set to give several different indications as described in parameter P0771. The output is 0-20 mA, but can be easily converted to a voltage by fitting a resistor (500 ohms for 0-10 V for instance), and to 4-20 mA using the scaling parameters such as P0778.

5.5.2 Relays

An indicator relay is provided which may be programmed to give a variety of indications using parameter P0731. The relay is often used to indicate set point reached (P731=52.8), warning active (P731=52.7), output current exceeding a set value (P731=53.3).

The relays can be used to control an external brake. A timer function can be used to start the inverter and release the brake as described in parameter P1216. In this case, the relay must be suppressed and a contactor used to switch the brake itself. See section 5.8.6.

The relay contacts should be suppressed where inductive loads such as contactor coils or electromagnetic brakes are switched.

5.6 Current Limit and Protection Systems

The inverter must protect itself, the motor and system from overload and possible damage. Current limit now operates very rapidly, limiting the current and preventing a trip occurring.

Most inverters have several levels of current limiting:

Electronic Trip.	This is a very fast current limit which operates if there is a short circuit (line to line or line to earth) on the output. It is a fixed level trip and operates within a few microseconds.
Overload Limit.	This is a fast limit, which operates within a few microseconds, and removes some of the output pulses to limit the current and protect the inverter. If this pulse dropping occurs during overload, the operating condition will usually recover and the motor continue to operate without tripping.
Long Term Overload limit.	This is a slower limit, which allows an overload of at least 60 seconds when the current lies above the motor limit, but below the instantaneous limit values described above.
Continuous Limit.	This is the level set as the maxiumum continuous motor current. The inverter will control the current to this level after the overloads described above have timed out.

For further details refer to the Operating Instructions and Reference Manual.

5.7 Other Protection Features

5.7.1 I^2t Protection

When the motor is running at low speed and high load, the built in cooling fan may not provide enough cooling and the motor may overheat. Parameters can be set to calculate the motor temperature, based on a motor model and operating history such that the inverter will take action to protect the motor under these conditions. Further information is given in the Reference Manual.

5.7.2 PTC Resistor Protection

Many motors are available with a PTC (Positive Temperature Coefficient) resistor built into the windings. The resistance of the PTC rises rapidly at a particular temperature, and this change can be detected by the inverter. The input terminals of the inverter may be configured to accept a PTC signal and trip the inverter in the event of overheating.

5.7.3 Overvoltage

If the inverter is connected to a high voltage, or if the internal voltage is forced high by energy from an external load, then the inverter will trip. Overvoltage usually occurs as a result of a braking or regenerative load. See section 8.2. If the supply voltage is too high the inverter may be damaged even if it trips.

5.7.4 Internal Overtemperture

The inverter is protected from overheating. The heatsink temperature is monitored using a PTC and if the maximum temperature exceeded the inverter will trip.

Overtemperature in the inverter is usually caused by a high ambient temperature, a faulty or blocked fan, or blocked air inlet or outlet.

5.8 Some Additional Features

The MICROMASTER has many useful features built into the software and available for the user. Some of these are briefly described below. The manual gives details of how to select and use these features. Advanced features such as Serial Interface, Closed loop Control, Braking operation etc. are described section 8.

5.8.1 Display Mode

The display normally shows the output frequency, but output current, motor speed etc. can be selected instead.

5.8.2 Ramp Smoothing

The rate of change of ramp can be limited to limit ‘jerk’. The smoothing is calculated from the ramp up time, so if the ramp down time is very different smoothing will not be so effective during ramp down. Smoothing is not effective at ramp rates of less than 0.3 seconds. Smoothing has the effect that if the inverter is ramping up and a stop signal given, there will be a delay before the inverter begins to ramp down again. This effect can be optionally disabled using parameter .

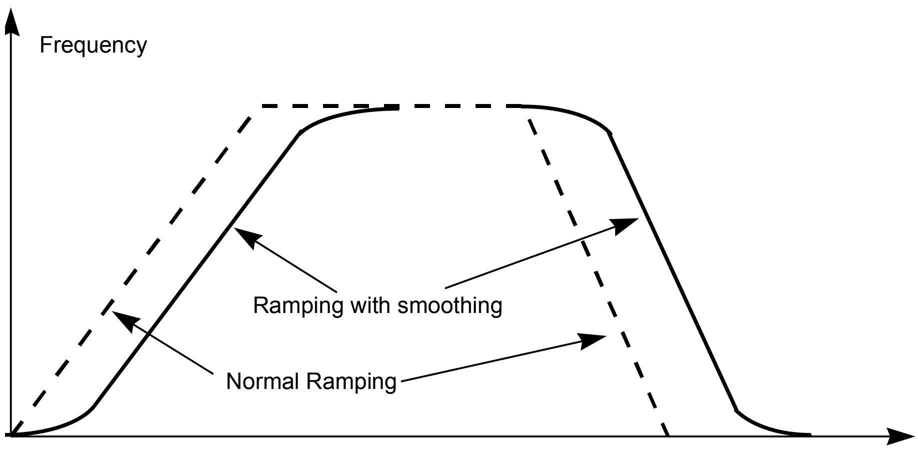


Figure 5-4 Smoothing applied to UP and DOWN ramps

5.8.3 Display Scaling

The value in display can be scaled to match the process and show ‘Litres per minute’ or ‘Metres per second’ etc.

5.8.4 Skip Frequencies etc.

If these frequencies are set, the inverter will not run at these output frequencies. Resonance problems can be avoided using this feature.

The bandwidth can be adjusted by setting the appropriate parameter.

5.8.5 Start on the Fly

Normally if the inverter attempts to start a motor that is already rotating it will current limit, stall or slow the motor down. If Start on the Fly is selected it will sense the speed of the motor and ramp the motor from that speed back to the set point. This is useful if the motor is already turning for some reason, such as following a short input supply break.

Start on the fly can operate when the load is rotating in the reverse direction, for instance when a fan is rotating due to reverse pressure. In this case, the motor direction is tested at low torque in forward and reverse directions. This can have the undesirable effect that the motor rotates in both directions at start up.

5.8.6 Electro-Mechanical Brake Control

The relays can be programmed to control a separate brake and a delay set (using appropriate parameters) so the motor can be energized prior to relay release. During the time set in the delay parameters, the inverter runs at its minimum frequency while the brake is energized, so that when the brake is released the motor will move immediately.

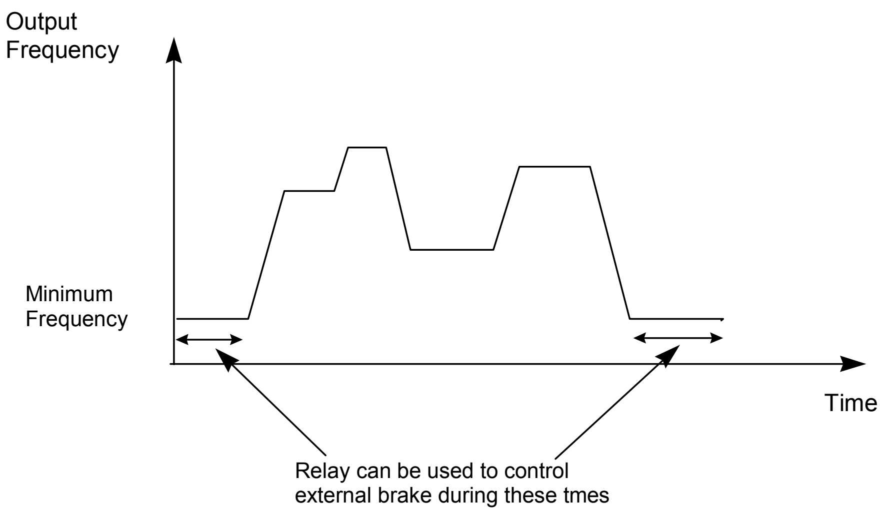


Figure 5-5 Possible control cycle using brake control relay and times

5.8.7 Slip Compensation

The motor speed is reduced depending on the load, due to the slip as described earlier. Slip can cause a speed regulation by as much as 10% with small motors. The inverter can compensate for this by increasing the output frequency slightly as the load increases. The inverter measures the current and increases the output frequency to compensate for the expected slip. This can give speed holding of better than 1%.

Slip compensation has no effect during Sensorless Vector Operation, as compensation is inherent.

Slip compensation is a positive feedback effect (increasing load increases output frequency), and too much compensation may cause slight instability. It is set up on a trial and error basis.

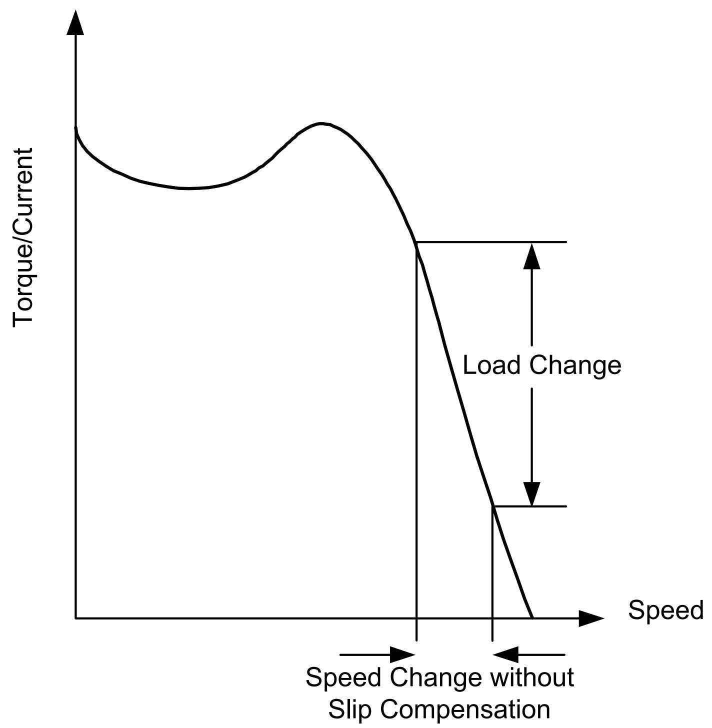


Figure 5-6 Slip Compensation

5.8.8 Pulse Frequency selection

The switching, or pulse width modulation frequency does not change with output frequency. See section 1.2. The switching frequency of the inverter can be selected between 2 and 16 kHz. A high switching frequency has higher losses and produces more Electromagnetic Interference (EMI). A lower switching frequency may produce audible noise. The switching frequency can be changed to suit the application, but some derating (as described in the Reference Manual), may be necessary on certain units.

The acoustic noise generated has a frequency of twice the switching frequency, except at light loads, where there is some fundamental frequency content. Therefore a switching frequency of 8 kHz will often be inaudible.

5.8.9 Boost. P1310, 11 and 12.

At low output frequencies the output voltage is low to keep the flux level constant, as described earlier. However, the voltage may be too low to overcome losses in the system. The voltage can be increased using parameter P1310. Parameter P1311 will only produce boost during ramping, and is therefore useful for additional torque during acceleration. If the boost is only required following a start command, P1312 will apply this. Boost has no effect during vector operation because the inverter calculates continuously the optimum operating conditions. Parameter P1310 is set to 50% as factory default.

The sum of P1310, 11 and 12 is limited to 250%.

The amount of boost is calculated from the stator resistance value and the Nominal Current setting.

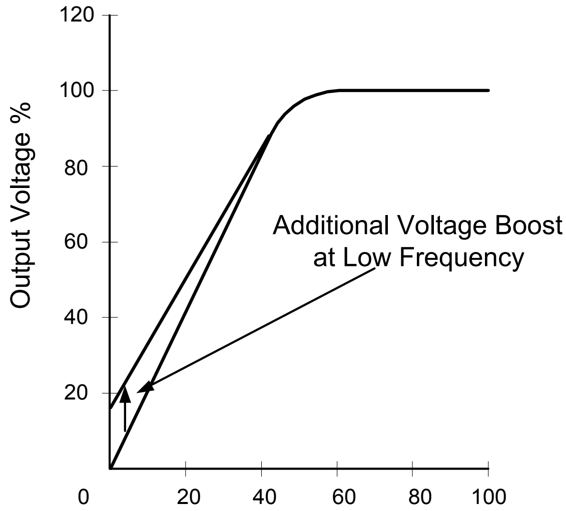


Figure 5-7 Voltage Boost

5.8.10 Serial Interface

The inverter can be controlled via a serial interface using terminals 14 and 15.

6 Electromagnetic Compatibility (EMC)

6.1 What is EMC?

All electronic and electrical equipment generate unwanted signals. These signals can be emitted from the product either via cables that are connected to the product (Input, output, signal etc.) or via electromagnetic radiation ‘radio transmission’. These signals can be received by other products (via the same routes) and can interfere with the correct operation of the product.

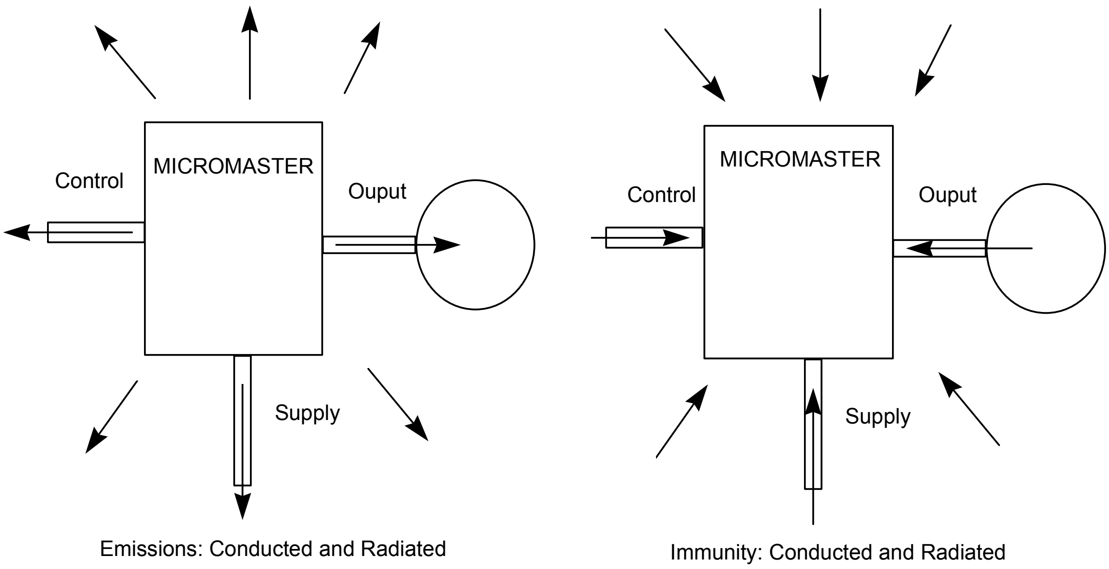


Figure 6-1 EMC. Emissions and Immunity

Any particular product gives out a certain level of emissions, and has a certain level of immunity to incoming signals from other products. If the immunity of all products is higher than their emissions, all is well. If this is not the case, severe problems can occur, causing quality problems, damage, or in extreme cases injury.

Electromagnetic Compatibility concerns how equipment works together. Electromagnetic Interference (EMI) refers to the unwanted signals themselves.

EMI has become a more serious problem recently as more electronic systems (which may prove to have low immunity) are used in industrial applications, and as power electronic products such as drives, generate high frequency signals which can produce high levels of interference.

6.2 Minimising the problem of EMI

EMI and EMC are much better understood than a few years ago, and most manufacturers of electronic equipment take care during design and installation to minimize emissions and maximize immunity. Siemens inverters are carefully designed with this in mind, and optional filters can be specified (either built in or as an external option) to reduce the emissions in the supply.

Before describing the practical solutions to EMI, it is important to understand the practical problems associated with EMC and inverters.

- The output of all inverters generates high frequency, high voltage switching waveforms in the output cables between the motor and inverter.

- A lot of EMI occurs at high frequency. At high frequencies the shape and length of the cable has a big effect on its impedance. Therefore short, thick, braided leads will be most effective in grounding, and high quality screened cable, grounded at both ends, will be needed to limit effects on signal leads.

- If equipment is badly grounded, high levels of EMI may connect from the power part of equipment into the control connections. Similar effects can occur when badly grounded equipment is connected together and EMI is conducted via the control cables.

- Particular care is needed when equipment is used with low signal sensors such as load cells and capacitive sensors.

- Conducted interference is more likely to cause problems than radiated interference.

- The signal and control leads in any electronic system are generally low voltage, high impedance, and are therefore particularly sensitive to the high level of EMI present in industrial systems.

- Switching inductive loads, such as electro-mechanical brakes, relay and contactor coils generate severe EMI.

6.2.1 Immunity and Immunity testing

Immunity is very important as damage and nuisance tripping will cause failure and service costs irrespective of where the fault lies. Therefore the tests carried out during product development are quite severe, and represent conditions encountered in industry.

Tests include:

- Electrostatic Discharge testing of all exposed surfaces, terminal and buttons using high voltage discharge gun. This simulates the effect of discharge from a human body electrostatically charged from a carpet for example.

- High voltage very high frequency discharges capacitively coupled into the control lines. This simulates the interference that couples from power switching (contactors etc.) into control leads.

- Similar discharges directly into the supply leads, line to line and line to ground. This simulates conducted interference from arcing contacts in other equipment.

- High energy, lower frequency interference in the supply leads, line to line and line to earth. This simulates lightning strike interference and similar supply disturbance.

6.2.2 EMC Guidelines

The guidelines for installation and wiring are detailed in the Operating Instructions, but the key points are as follows:

1. Ensure all equipment in the cubicle is well earthed, using thick, short earthing cable. Earth control equipment in the same way to the same earth point. Star point grounding, shown in Figure 6-2, is ideal, but a solid busbar is acceptable provided it is well grounded.

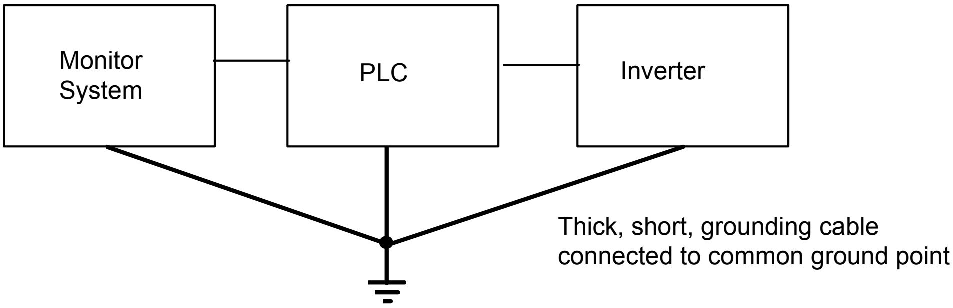


Figure 6-2 Star Point Grounding

2. Use screened leads for connections to the control circuitry. Ground the screen at both ends.

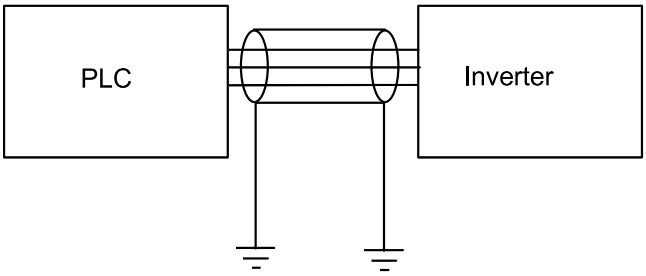


Figure 6-3 Screening of Control Cables

3. Separate the control cables from the power connections (e.g. supply and motor connections) as much as possible, using separate trunking etc.

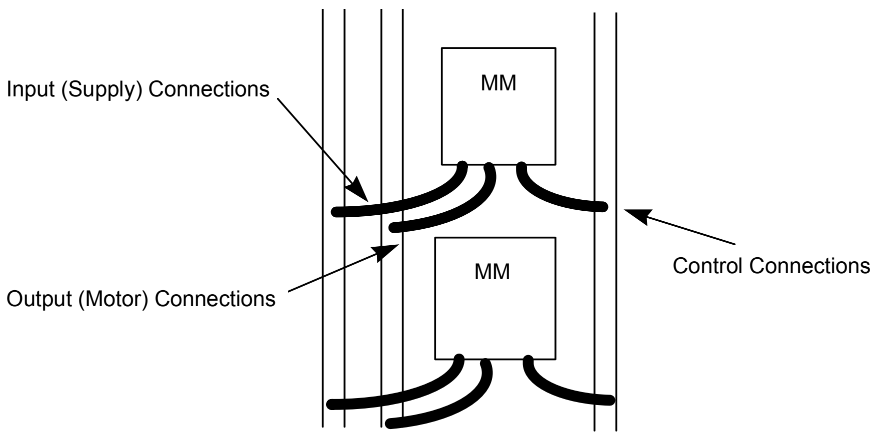


Figure 6-4 Separation of Control and Power Connections

4. Suppress relay, contactor coils etc. using R-C, flywheel diode, or varistor suppressers fitted at the coils.

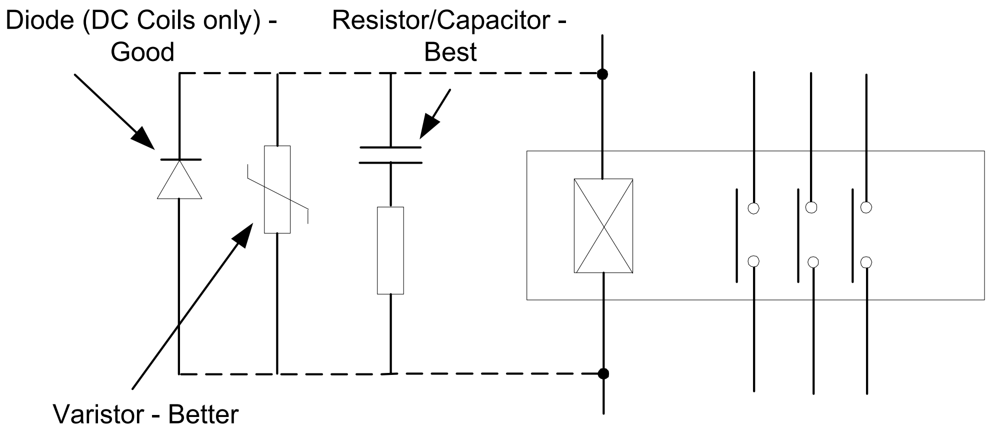


Figure 6-5 Suppression of Contactor Coils

5. Use screened or armoured cables for the power connections; ground the screen at both ends.

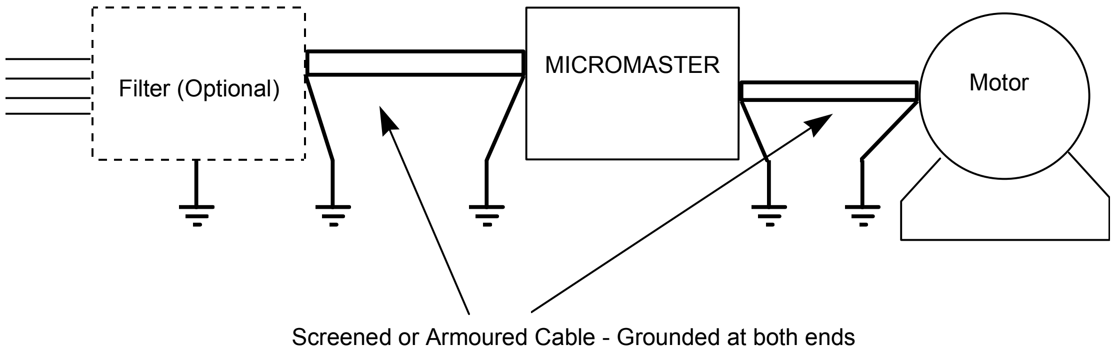


Figure 6-6 Use of Screened or Armoured Cables

6. Consider using an RFI filter in the supply to the converter.

7 Consider connecting the 0V of the inverter to the protective earth. This can often reduce noise in the 0V system.

6.3 EMC Rules and Regulations

The regulations concerning EMC are complex, changing and vary from country to country. The most important point to remember is that if there is no problem there is unlikely to be a legal issue, and in any case prevention is better - and cheaper - than cure.

6.3.1 European Regulations

The rules in Europe are complex, because they depend on the type of product, how it is sold, and who installs it.

Legislation, which came into force 1st January 1996, was designed to control emissions and immunity of many types of electrical and electronic equipment for both domestic and industrial applications. This is the EMC directive EEC/89/336, which refers to many Euronorms (such as EN55011, EN55022 etc.) to set the required levels.

However, separate EMC Product standard - EN 61800-3 has now been introduced which overrules these standards for drives products. This is also a complex regulation, but it does define two 'environments' - basically Domestic and Industrial, and two distribution methods - Restricted and Unrestricted. Restricted distribution means that the product is sold to a customer with some EMC competence. For Restricted distribution and Industrial installations there are essentially <u>no limits</u> on emission levels. For Domestic installations Class A1 or B1 levels apply, for Restricted and Unrestricted distribution respectively.

As the MICROMASTER is sold via restricted distribution for industrial applications, no limits for emissions apply. However, customers may require the MICROMASTER, or the final installation or equipment to meet other specifications such as the EMC directive. In practice the majority of low voltage MICROMASTERs are sold in Europe with a built in filter because of this.

7 Real Applications

The following examples are based on applications where Siemens Drives have been successfully applied. In some cases the circuitry and parameter settings have been simplified. The settings and parameters refer to Siemens MICROMASTER MM420s.

7.1 A Simple Fan Application

The Application uses a MIDIMASTER to control a ventilator fan in an application where the fan is manually adjusted. By using the Advanced Operator Panel, mounted on the cubicle door using the appropriate mounting kit, a simple control solution without additional cabling is achieved. The operator can then adjust the fan speed to suit ventilation requirements simply by pressing the buttons on the panel.

7.1.1 Advantages.

- At frequencies below 50 Hz there is significant energy saving. Power is proportional to the cube of speed, so a reduction in frequency to 45 Hz will result in a saving of about 30%. Mechanical systems offer little or no saving.
- Acoustic noise is reduced when the fan is run below base speed.
- The complete assembly can offer IP54 protection when the MICROMASTER is mounted in a suitable cubicle.
- The Advanced Operating Panel (AOP) offers a simple control solution; panel labelling, additional switches etc. are not needed.
- Closed loop control can be easily enabled using on board PI controller.

7.1.2 System Specifications

Motor:	18.5 kW 400 V 3-phase induction motor
Control System:	Advanced Operator Panel (AOP)
Drive:	MICROMASTER MM420 11 kW 400 V
Drive Control Interface:	Keypad control with start, stop and motorised potentiometer (reverse and jog functions disabled).

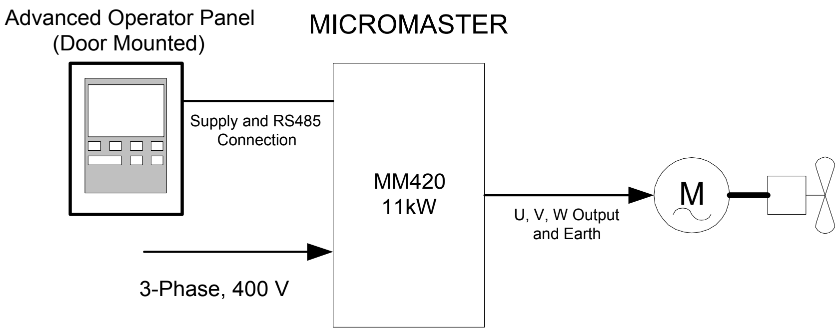


Figure 7-1 Fan Application

7.1.3 Key Parameter Details

Table 7-1 Fan Application with Manual Control

Number	Value	Meaning
P1000	1	Motorised potentiometer enabled. This allows the push buttons on the AOP to be used to control the speed.
P0003	3	Allows all parameters to be adjusted and set.
P1031	1	Motorised potentiometer settings stored on power down. The inverter will restart at the previous selected frequency.
P1200	34	Flying Start in forward direction enabled. This ensures that if the fan is rotating the inverter will sense it's speed and ramp back to the desired speed.
P1300	2	Quadratic V/F curve selected. Selecting the quadratic curve allows a higher continuous output, but limits the overload capability, which is not needed in this case. The quadratic curve also reduces the power consumption because it is optimised for fan and pump applications.
P1055	0	Jog Key disabled
P1032	1	Reverse direction disabled

Note.
The default settings of minimum and maximum speeds (0 – 50 Hz) are used in this case.

All required information such as speed, current and drive status is on the display.

If resonance is experienced in the system, it can be suppressed by using the skip frequency settings P1091- 1094.

7.2 A Closed Loop Controller using a Fan

The application uses an 11 kW MICROMASTER driving an 11 kW motor which operates the extractor fan in a chemical plant. The extractor maintains a constant flow rate by measuring flow downstream of a burner system. The MICROMASTER is installed in a cubicle close to the fan system, and a simple run/ stop signal used for control. The flow sensor is connected to the analog input to supply the necessary feedback signal. A resistor is fitted to the input to convert the current source to a voltage signal (2 to 10 V).

7.2.1 Advantages

- Very significant energy savings compared with fixed speed running.
- Improved process control - in this case, reduced pollution as burner operates at maximum efficiency.
- Built in PI means no additional controllers etc.
- No manual adjustment needed; simple run/stop commands.

7.2.2 System Specifications

Motor	4 pole 11 kW 420 V 3-phase induction motor
Control System	Closed loop PI system
Sensor	4 –20 mA flow rate sensor
Drive	MICROMASTER 11 kW 400 V

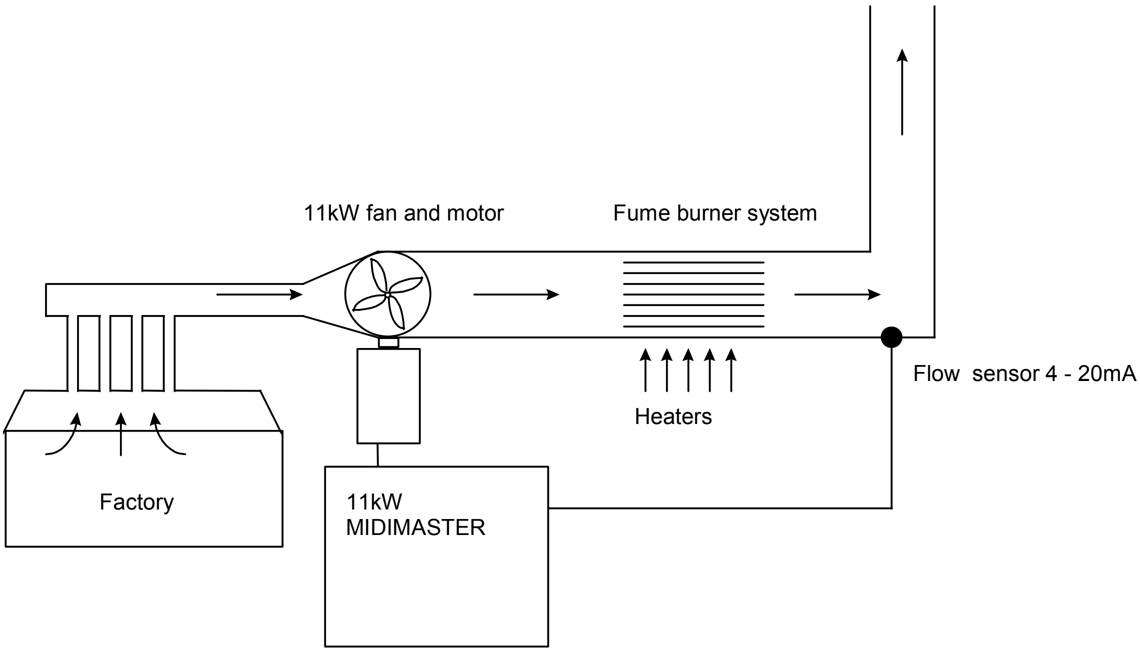


Figure 7-2 Extractor System using Closed Loop Flow Control

7.2.3 Key Parameter Details

Table 7-2 Fan Application with Closed Loop Control

Number	Value	Meaning
P1000	1	Digital set point preset in MIDIMASTER. Manual adjustment not normally required.
P1040	20	Nominal setpoint
P0003	3	Allows all parameters to be adjusted and set.
P1080	10	Minimum fan speed
P1082	30	Maximum fan speed
P0778	4.00	Analog output 4 – 20 mA indicating output frequency. This signal is used as part of the overall factory management system. Setting P0778 applies a 4 mA offset.
P1300	2	Quadratic V/F curve selected. Selecting the quadratic curve allows a higher continuous output, but limits the overload capability, which is not needed in this case. The quadratic curve also reduces the power consumption because it is optimised for fan and pump applications.
P0300-P0311	***	Settings to suit motor
P201	1	PID enabled. The following parameters give the best overall stability in this particular application.
P202	0.3	P Gain
P203	0.06	I Gain
P204	0	D Gain
P205	1	Sample Interval
P206	0	Sensor Filtering
P207	100	Integral capture range
P208	1	Sensor type
P211	25	0% set point
P212	80	100% set point
P220	1	Switch off at minimum frequency
P0761	2	PI analog input 4 –20 mA to suit flow transducer

7.3 Controlling Lift Door Operation

Lift doors need to close at varying speeds. Starting slowly, accelerating fast and slowing again as they approach closure. In this case, the doors are held closed by the motor running at low frequency at zero speed. The load can vary considerably due to mechanical changes as the lift moves, and variations in door weight as external doors are operated as well. A very good result has been obtained using micro switches to select the various speeds.

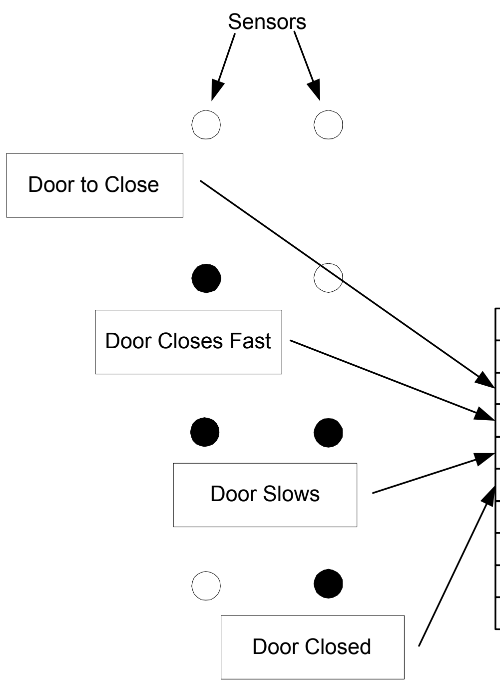
7.3.1 Advantages

- Very simple system provides the desired speed profile. Doors operate smoothly and silently.
- Torque at zero speed holds doors closed.
- Speed profile can be easily adjusted.

7.3.2 System Specification

Motor	4 pole 80 W 230 V 3-phase induction motor. Oversize with no external cooling fan - allowing zero speed operation
Control System	Two Microswitches selecting fixed frequencies; open/close signal on third digital input
Drive	MICROMASTER MM420 750 W 230 V

Note.
The following diagrams and tables refer to settings and parameters used on MICROMASTER MM420. Settings for MICROMASTER MM440 may be different.



DIN 1	DIN 2	DIN 3	Output	Function
Sensor 1	Sensor 2	Open/Close		
0	0	1	5 Hz	Close Slow
1	0	1	25 Hz	Close Fast
1	1	1	10 Hz	Slow Down
0	1	1	2 Hz	Hold Closed
0	1	0	- 6 Hz	Open Slow
1	1	0	- 15 Hz	Open Fast
1	0	0	- 5 Hz	Slow Down
0	0	0	Stop	Stop Open

Figure 7-3 Lift Door Operation

7.3.3 Key Parameter Details

Note.
Careful selection of the inputs is needed to ensure the correct combination of forward and reverse frequencies is possible.

Table 7-3 Key Parameters. Lift Door Operation

Number	Value	Meaning
P1000	3	Fixed Frequencies selected
P0003	3	Allows all parameters to be adjusted and set
P1001	- 5	Fixed Frequency 1. Setting the following parameters allows the complex selection of fixed frequencies, forward and reverse, to be selected using only the two microswitch inputs and the open/close signal
P1002	-6	Fixed Frequency 2
P1003	- 15	Fixed Frequency 3
P1004	5	Fixed Frequency 4
P1005	+25	Fixed Frequency 5
P1006	+2	Fixed Frequency 6
P1007	+10	Fixed Frequency 7
P0701-3	17	Binary selection of fixed frequencies
P0300-P0311	***	Settings to suit motor

7.4 A Conveyor Application using several MICROMASTERs

MICROMASTERs are used to control short conveyors. Each conveyor is used as a holding point while products are sorted. The products are moved forward by rapid acceleration of the conveyors under computer control.

7.4.1 Advantages

- Controlled acceleration rates ensure product is moved as fast as possible without damage.
- No direct on line switching of motor; no shock loading or current inrush.
- Drive status and parameters can be continuously monitored via serial link.
- Settings can be changed via serial link.
- Small size allows drive and control system to be mounted under conveyor and close to motor.

7.4.2 System Specifications

Motor	750W 400V 3 phase induction motor.
Control System	Custom computer system communicating with central controller.
Drive	MICROMASTER MM420 750W 400V
Drive Control Interface	Digital input control with 1 or 2 fixed frequencies, alternative ramp rate selection, output relays.

7.4.3 Application Details

Up to five inverters and motors are used in conjunction with five conveyors and a local computer controller. Three are shown below. The computer is used to set the parameters and to monitor drive operation. Actual control and fault monitoring is via the digital inputs and relay outputs. This example uses a BiCo (Binary Connector) function which connects digital input 3 to the 'Select Jog Ramp times' functions. For the second conveyor controller shown below the faster ramp times and second fixed frequency can be selected using digital inputs 3 and 2, connected to the control relays as shown in Figure 7-4.

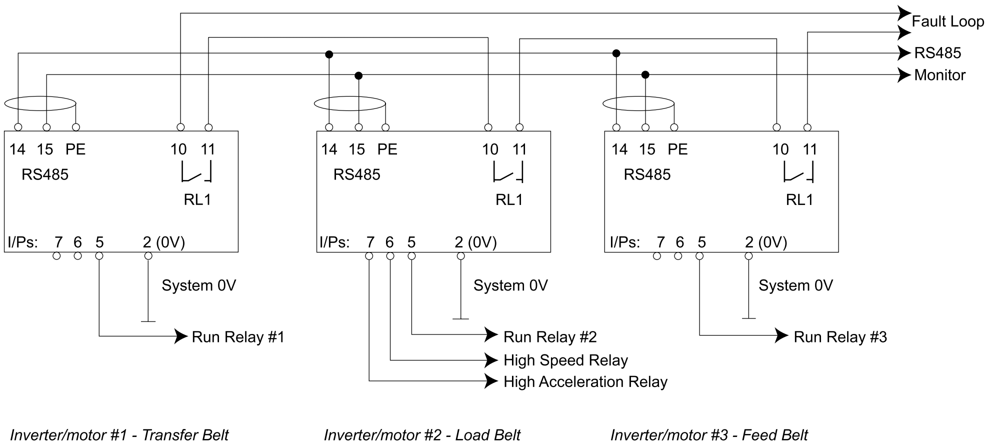


Figure 7-4 Conveyor Application

7.4.4 Key Parameter Settings

Table 7-4 Key Parameters. Conveyor Application

Number	Value	Meaning
P1120	0.6	Ramp up
P1121	0.6	Ramp down. Fast ramping possible with these settings
P1000	003	Fixed frequency operation
P0003	3	Allows all parameters to be adjusted and set.
P1082	110	Maximum Output Frequency. High speed operation possible in certain circumstances.
P1060	0.3	Jog (alternative) ramp up rate
P1061	0.3	Jog (alternative) ramp down rate
P1001	40	Fixed frequency 1
P1002	45	Fixed frequency 2
P0701	16	Run at fixed frequency 1
P0702	16	Run at fixed frequency 2
P1124	16722.2	Use jog ramp times BiCo Function
P0703	99	Enable BiCo function
P0300-P0311	***	Settings to suit motor

By setting P0701 and P0702 to 16, the drive starts and runs to the selected frequency.

7.5 A Material Handling Application

Several MICROMASTERs are used to handle sheets of large, fragile pieces of material. The system is controlled by a Programmable Logic Controller (PLC) using the digital and analogue inputs. Relays are used to control the DC Brake.

7.5.1 Advantages

- Electromechanical brake controlled directly from inverter with fail safe control.
- Analog and digital outputs from PLC easy to set up and monitor.
- An overtemperature switch is used to detect the overheating of the motor rather than a PTC.
- Boost during ramp up ensures good torque at low speed.
- Smooth operation with controlled ramp rates ensures material is not damaged during handling.

7.5.2 System Specifications

Motor	550 W 230 V 3-phase induction motor.
Control System	PLC
Drive	MICROMASTER MM420 550 W 230 V
Drive Control Interface:	Analog input control, brake control and Motor temperature protection

7.5.3 Application Details

Each machine is controlled by a PLC which controls the inverter via an analog input and digital controls.

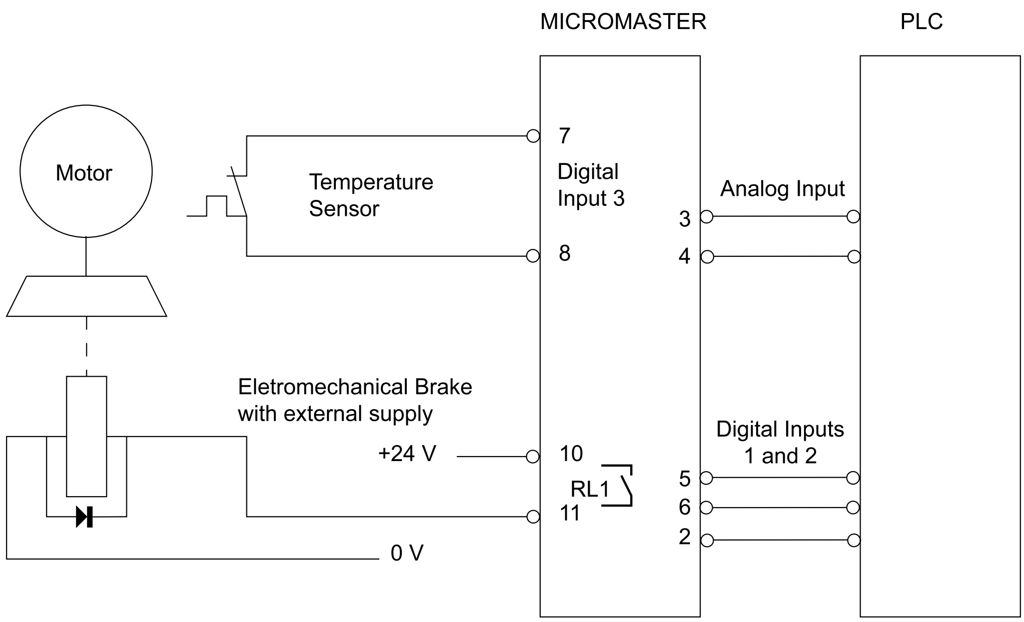


Figure 7-5 **Material Handling Application**

7.5.4 Key Parameter settings

Table 7-5 Key Parameters. Material Handling Operation

Number	Value	Meaning
P1120	0.3	Ramp up
P1121	0.3	Ramp down
P0003	003	Allows all parameters to be adjusted and set.
P1082	100	Maximum Output Frequency. This wide speed range is possible because torque requirements are not excessive at high speed.
P2000	100	Reference Frequency. Used for analog, serial I/O etc. 0-10 V now corresponds to 0-100 Hz
P0701	2	Run left
P0702	1	Run right
P0703	29	External Trip
P0731	52.3	Output Relay 1 Brake control. Here the brake control operates immediately as P1216 and P1217 are set to 0.
P1215	1	Enable brake control function
P1216	0	Brake release time
P1217	0	Brake stop time
P1310	0	Continuous boost. In this application starting boost (P1312) proved more useful than continuous boost.
P1312	100	Starting boost
P0300-P0311	***	Settings to suit motor

7.6 An Exercise Machine Application

A running machine uses a variable speed drive to control the running belt speed from a slow walk to a fast run.

7.6.1 Advantages

- Excellent low speed torque ensures smooth operation even at low belt speeds with a heavy step.
- Wide speed range makes good use of motor.
- External class B filter meets domestic and light industrial requirements.
- Automatic motor protection due to continuous current monitoring.

7.6.2 System Specifications

Motor	2.2 kW 230 V 3-phase induction motor
Control System	Microprocessor control system with display, keypad etc.
Drive	MICROMASTER MM420 2.2 kW 230 V
Drive Control Interface	Analog and digital input controls, fault indication via output relays

7.6.3 Application Details

A 2.2 kW motor drives a pulley and flywheel system via a toothed belt. The motor is controlled by a 2.2 kW inverter with an external input filter to reduce EMI. The inverter is connected to the main controller via an analog frequency control and digital inputs. The digital inputs are used to run, stop and reset invert faults.

The I^2t function will help protect the motor in this application. Continuous high load operation is unlikely, but the inverter will trip if the motor is in danger of overheating. This is acceptable in this application. The fault relay is used to alert the user of this condition.

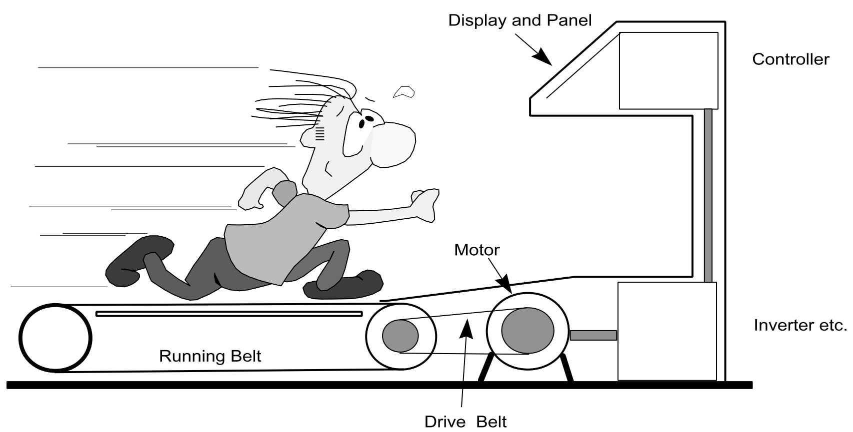


Figure 7-6 Exercise Machine

7.6.4 Key Parameter Settings

Table 7-6 Key Parameters. An Exercise Machine Operation

Number	Value	Meaning
P0003	003	Allows all parameters to be adjusted and set.
P1080	3	Minimum Output Frequency
P1082	83	Maximum Output Frequency
P2000	83	Frequency Reference for scaling.
P0701	1	Run right
P0702	9	Reset Fault
P0731	52.3	Output Relay Fault indication
P0640	130	Motor Overload Factor. This will limit the motor current and presumably has been selected to suit the motor and application.
P300-P0311	***	Settings to suit motor

8 Advanced Applications Information

8.1 Using Closed Loop Control

8.1.1 What is Closed Loop Control?

Closed loop control is widely used in industrial applications to control a broad variety of processes. Control engineering is a complex subject, but a simple closed loop control uses a feedback signal from the process (such as temperature, pressure, speed) a desired value from a set point (often set manually) and a control system that compares the two and derives an error signal. The error signal is then processed and used to control the inverter and motor (in this case) to try to reduce the error.

The error signal processing can be very complex because of delays in the system. The signal is usually processed using a Proportional, Integral and Differential (PID) calculator, and these parameters can be adjusted to optimize the performance and stability of the system. Once a system is set up and stable, very efficient and accurate control can be achieved.

8.1.2 Closed Loop Control using MICROMASTER MM420

A standard PI control loop function has been incorporated in the MICROMASTER MM420, requiring only the connection of a suitable feedback transducer, and configuration of parameters.

The control loop is not suitable for fast response control systems, but is ideal where the controlled variable changes slowly, or where transient errors are not critical (for example temperature or pressure control).

Note.
The system is not intended specifically for speed control but can be used in this way, provided fast response is not required. Where fast response and accuracy are critical, external PID control systems or higher performance Siemens inverters should be considered.

The following information relates to MM420 parameters and closed loop functionality.

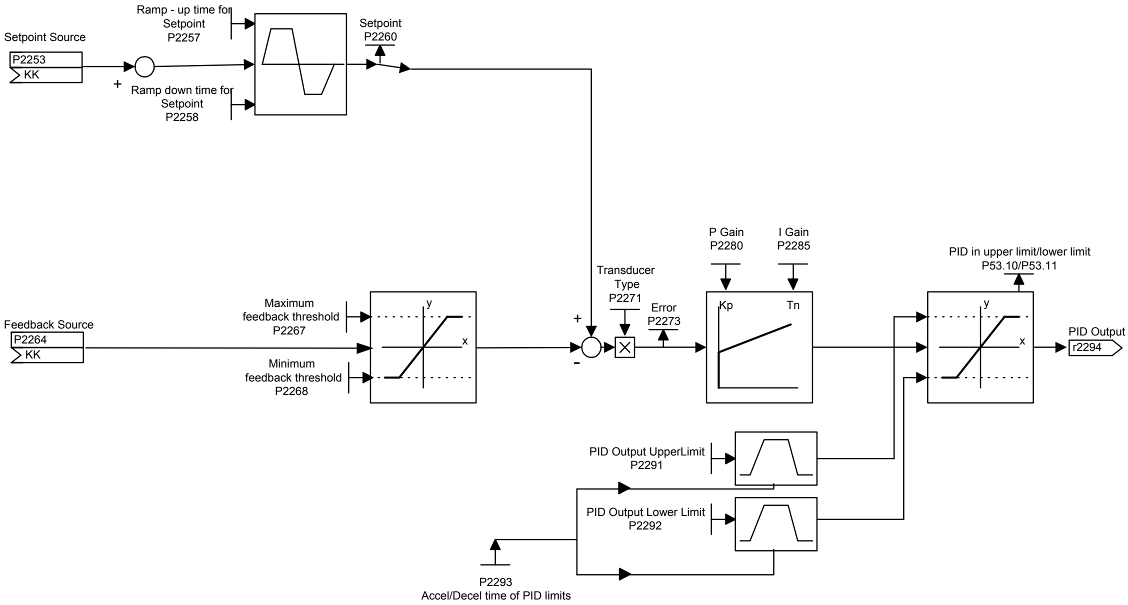


Figure 8-1 A Typical Closed Loop Controller

Figure 8-1 shows how the closed loop controller is implemented in the MM420.

Note..
That all setpoints are now expressed in percentage. When controlling a Setpoint, the frequency is not the desired quantity.

The setpoint usually derived from a fixed frequency has adjustable ramp rate that can be set before being compared with a feedback signal. The feedback signal, which is usually a 0-10 V or 4-20 mA signal derived from a transducer connected to the analog input, is also pre-processed with threshold limits. The difference between the set point and the feedback signal (the error) is then amplified and filtered using gain and integration constants. These are usually known as the P and I terms. In this case a differential term (D) is not included as it is rarely needed. Before the P and I processing the error signal is optionally corrected ("transducer type"). This correction is to determine whether to speed up, or slow down the motor to reduce the feedback signal. That is, increasing the speed of a vacuum pump will decrease pressure; increasing the speed of a compressor will increase pressure.

After processing with the P and I terms, the resulting signal is passed to the inverter which increases or decreases the output frequency as required, subject to certain limitations, such as acceleration and deceleration times.

8.1.3 Setting up a feedback control system

Some general points.

- Remember that once closed loop operation is enabled values such as the setpoint are displayed in percent of full scale.
- If possible run the drive open loop first, to check, in particular, the sensor feedback voltage or current.
- Check P2271 value for the correct 'sense' operation. Set P2271 according to the sensor/actuator types. If the feedback signal reduces as the motor speed increases, select P2271=1. Otherwise, use P2271=0.

- Start with the PID gains still on their factory settings - P_{gain} =1, no integral or differential action.

- Select fast ramp up and down times as otherwise these will limit closed loop performance.

- Make sure the scaling parameters match the feedback signal and the expected range of the transducer.

- Increase the P_{gain} (P2280) until the system starts to oscillate, possibly looking at the value of the feedback if the physical effects are not obvious. Reduce the value of P2280 to 35% of that where oscillation started.

- Increase the integral gain P2285 until the system oscillates again. Reduce the value to 50% of that where oscillation started. This quick setting method will give good results in most applications. More precise setting methods would normally involve using an oscilloscope to look at the sensor signal response to step changes in the setpoint.

- Note that systems such as fan cooling may require the motor to be 'off' most of the time. Set P220=1 in such cases to avoid excessive DC current heating of the motor.

8.2 Braking and Slowing down using Inverters

8.2.1 What happens when a motor is stopped?

When the output frequency of the inverter is reduced, the motor will slow down. If the output frequency of the inverter falls rapidly, the motor may no longer 'motor', but may act as a generator.

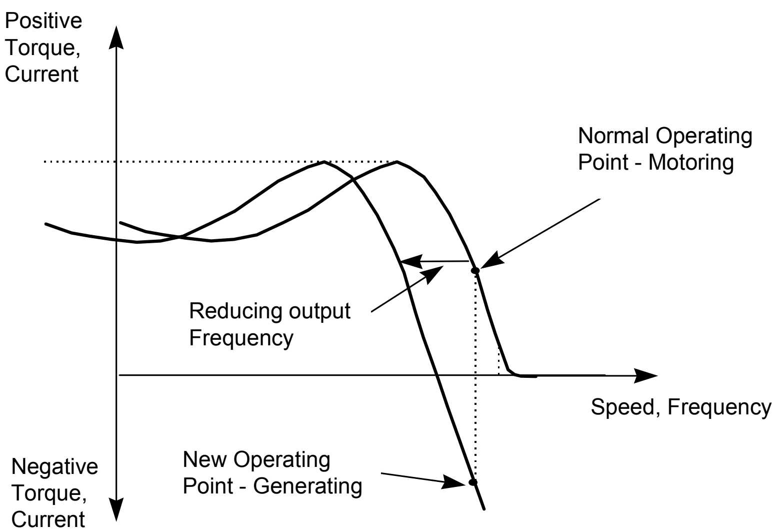


Figure 8-2 Graph showing the Motor acting as a Generator

If the motor and load have a high inertia, the motor will take longer to slow down so generation is more likely to occur. The generated energy returns to the inverter (i.e. regenerates) as a negative current. This is known as regeneration. The current is returned to the DC link, but cannot return to the supply because of the blocking action of the input rectifier. Therefore the current charges the DC link capacitors and if the DC link voltage becomes too high the inverter will protect itself from overvoltage by tripping. If the inverter trips there is no more motor flux, so it no longer regenerates and comes to an uncontrolled stop. However, there are several possibilities to control braking and stopping using an inverter.

8.2.2 Braking and Stopping with an Inverter

Ramping Down and Braking

As stated above, if the inverter reduces the output frequency (i.e. Ramps down) the motor and load will slow down. If the load and motor inertia is high, regeneration will occur. In many cases there is insufficient regeneration to cause excessive voltage; in fact very fast ramp down rates can often be used in certain processes without problems. In many cases the energy is absorbed by other losses, such as gearbox or rolling friction. The ramp down time, controlled by the inverter allows predictable deceleration and stopping times.

Where regeneration does cause trips, several solutions are possible. An external brake, DC braking or Compound braking may be used. These are described in section 8.2.2.

However, a simple solution is to connect a resistor across the DC link of the inverter to dissipate the regenerated energy.

Some inverters incorporate a controller which switches the resistor on and off to maintain the DC link voltage at a constant level.

The MICROMASTER MM420 has no controller and the use of an external controller or resistor is not possible.

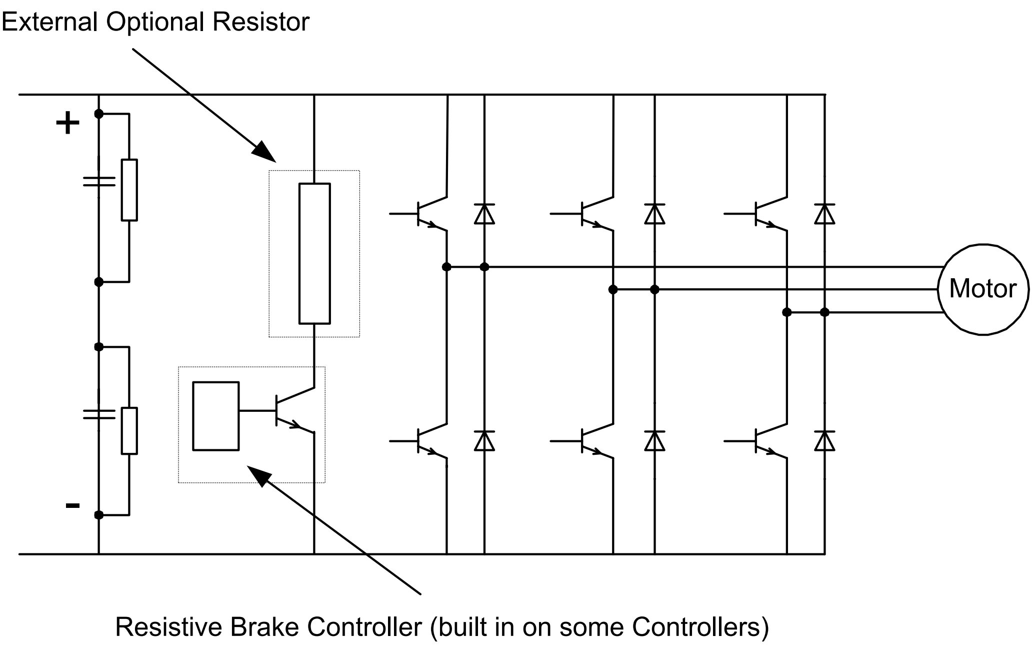


Figure 8-3 Absorbing Regenerated Current

DC Braking.

If a controlled DC voltage is applied to the motor, a braking and holding torque is produced in the rotor. During DC braking the stored energy of the motor and load is dissipated in the rotor itself, so there is no regeneration back to the inverter. However, because no frequency is applied, there is no control over motor speed, and it is not possible to predict the stopping time of the motor and load. The torque on the rotor is maintained even at standstill, so DC braking can be used to hold the rotor and load for short periods if required.

Parameter P1232 sets the level of DC Braking current, and braking will be applied for the time set in P1233 irrespective of the motor speed. The parameter value corresponds to a percentage of the full load current in the motor. In practice it is not possible to calculate the braking torque this will produce. Continuous use of the DC braking will cause overheating in the motor and suitable protection systems must be considered. The braking can also be activated by an external switch.

Compound Braking

If DC braking and regenerative braking are combined, braking with minimal regeneration but with controlled motor speed is possible. This consists of a reducing frequency with DC component added to it. This braking system, developed by Siemens for the MICROMASTER, is known as Compound braking. Compound braking can prove very effective, combining the best of DC braking and Regenerative braking. As with DC braking, the load energy is dissipated in the motor, and therefore excessive, frequent braking can lead to overheating. Parameter P1236 sets the level of compound braking.

The above braking methods are summarized in the Figure 8-4.

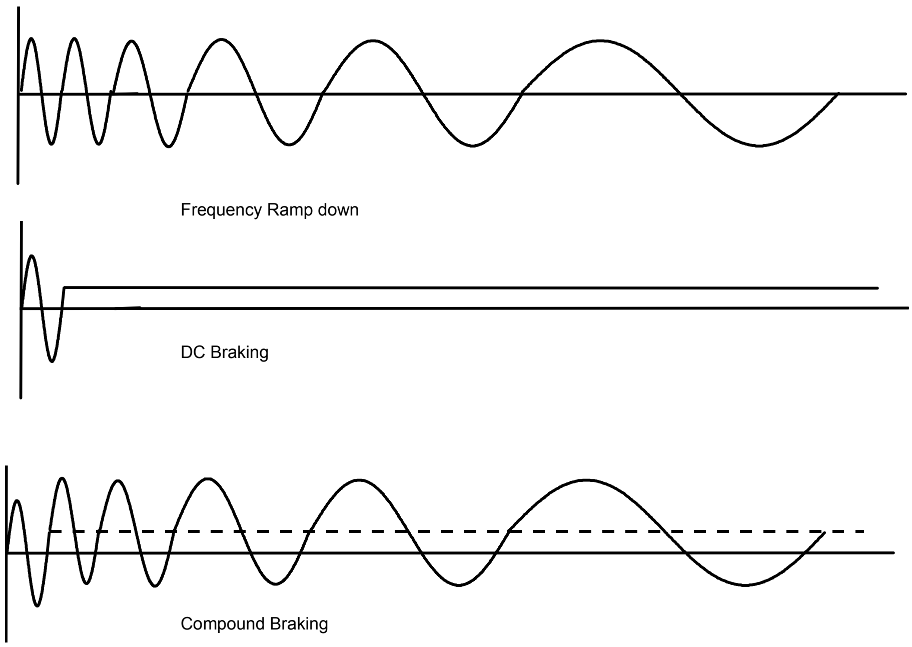


Figure 8-4 **Braking Methods**

8.3 Using the Serial Interface

All Siemens Drives include a serial interface as standard. The serial interface uses a RS485 two wire connection which is designed for industrial applications.

Up to 31drives may be connected on a single RS485 link, and drives addressed individually or with a broadcast message. A separate master controller is required, and the drives act as slaves.

A communications protocol known as the USS protocol has been developed by Siemens and is common to all Siemens drive products. Each inverter can be set up using parameters to receive and respond to USS protocol telegrams.

Using a serial interface has several advantages:

- Wiring can be greatly reduced.
- Control functions can be changed without re-wiring.

- Parameters can be set up and changed via the interface.
- Performance can be continuously monitored and controlled.

8.4 Using PROFIBUS

8.4.1 What is PROFIBUS?

PROFIBUS is an open standard communication protocol which has been designed and developed for use in general industrial applications. The standard is defined in EN50170 (volume 2) and has been developed, agreed and adopted by many manufacturers worldwide.

PROFIBUS control is now available for a wide variety of products, from many different companies such as drives, actuators, valves, as well as programmable logic controllers (PLCs) and other system controllers. PROFIBUS operates over a variety of hardware interconnections such as fiber optics and RS485.

There are three versions of PROFIBUS: FMS, DP and PA; these versions will work together. The most commonly used version is the DP version, intended for general industrial applications. This is the version supported by Siemens Drives.

8.4.2 Using PROFIBUS with Siemens Standard Drives

In order to connect to a PROFIBUS system a PROFIUS adapter module is required. This module mounts on the front of the drive in the same way as the AOP, and uses the RS485 serial port to communicate to the drive.

A nine way ‘D type’ connector, which is a PROFIBUS standard, is incorporated into the module.

The drive may be controlled and monitored via the main PROFIBUS system in a similar way to the USS. The PROFIBUS protocol is more complex than the USS protocol (in fact, the USS is a simplified version) and control programmes are best developed using proprietary software.

Although a PROFIBUS system is more complex than for instance, the USS Protocol, it offers the following advantages:

- Open, clearly defined system.
- Many different products from many different manufacturers.
- Well proven in many industrial applications.
- Reduced wiring; easy set up re-programming, monitor and control.
- Very fast; up to 12 Mbaud.
- Up to 125 slaves on one DP system.
- Single or Multi-master operation possible.
- One to one or braodcast communications.
- Support and development software available.

8.5 Vector and FCC Control

8.5.1 What is a Vector Drive?

Vector control is a complex mathematical control function that improves the performance of an AC drive. It is necessary to understand conventional Voltage to frequency control and Flux current control in order to understand Vector Control.

Voltage to Frequency Control

A simple inverter drive outputs a variable frequency and voltage to the motor, with an additional voltage boost (see section 5.8.9) to overcome losses and non linearity at low frequency. In this case, the voltage rises linearly as the frequency increases, which theoretically maintains the correct flux level in the motor up to the base frequency. For pump and fan applications the load is reduced at frequencies below base frequency, so a reduced voltage is acceptable. In these cases a quadratic (pump and fan curve) can be specified.

These voltage levels are suitable for many applications. However, for higher performance a better control strategy is needed. In particular, to offer the same capability as a DC drive and motor (fast response, torque control, low speed operation) complex mathematical models of the motor are needed. The processing power to achieve this has only become available recently at low cost. Siemens standard drives have offered different solutions such as Flux Current Control and now offer Sensorless Vector control in some variants.

8.5.2 What is Flux Current Control?

The Siemens Standard Drives have developed an improved current monitoring system which allows accurate measurement of the output current with reference to the motor voltage. This enables the monitoring system to separate the total output current into the real (load) and imaginary (flux) part.

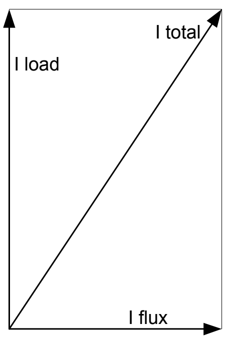


Figure 8-5 Vector Diagram. Load Current against Flux Current

The flux part can then be controlled, and therefore the flux on the motor optimized for all conditions. This is Flux Current Control (FCC). It has proved very successful in a wide variety of applications. It offers improved motor efficiency and better torque and transient response compared to standard Voltage to frequency operation. It is not as effective as full vector control or sensorless vector control.

Vector Control

Vector control is best understood by considering the operation of a DC machine. A DC machine consists of a field winding and armature winding. Therefore the armature Current (Torque) and field current (Flux) can be controlled independently. Independent control of the Flux and Torque producing currents permits optimum performance - Torque at zero speed, rapid response to load changes etc.

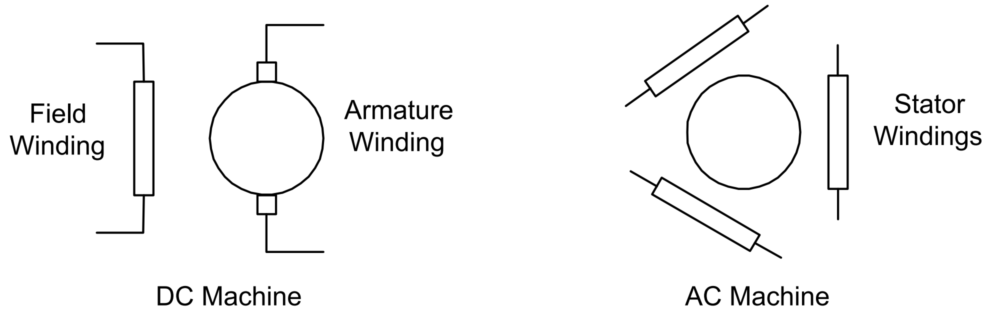


Figure 8-6 Comparison. DC Motor/AC Motor

In an AC Machine, the stator winding currents set the Flux and the Torque; therefore it is difficult to control the torque and flux separately. Hence it is necessary to control the magnitude and phase - *the Vector* - of the current. To control the phase with reference to the rotor, the rotor position must be known. For full vector control, an encoder **must** be used to tell the inverter the rotor position.

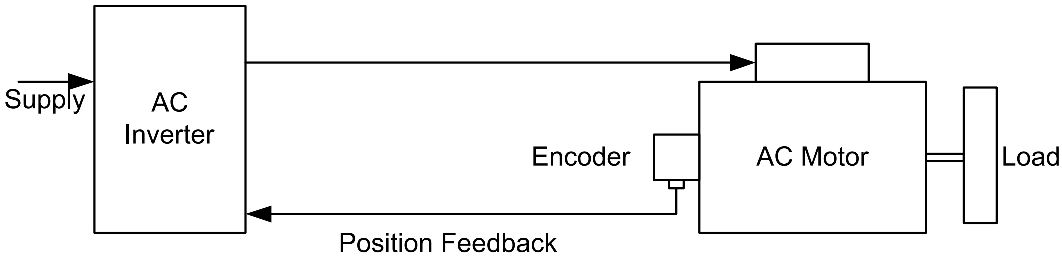


Figure 8-7 Position Fedback via a Motor Shaft Encoder

With the above arrangement, it is possible to achieve performance equal to that of a DC Machine provided the full parameters of the motor are known and the inverter is able to model its performance.

However, most AC motors are not fitted with encoders and the additional cost and complexity is an unnecessary expense.

Recent developments in motor control and modeling have allowed sensorless (that is without encoder feedback) vector operation to be possible. Sensorless Vector Control predicts the rotor position by mathematically modeling the motor. To do this the inverter must:

- Monitor the output voltage and current very accurately.
- Know the motor parameters (Rotor, Stator resistance, leakage reactance etc.).
- Know the motor history; that is, the previous load etc. in order to predict the motor temperature.
- Be able to calculate very rapidly.

At low speeds it is *very difficult* to predict the motor performance and the hence the rotor position. Siemens standard vector drives use a complex mathematical system, first developed for their engineered drives, which gives very good Sensorless Vector performance.

Flux Current Control and conventional voltage to frequency control is available in addition to Sensorless vector performance.

9 Options for Siemens Standard Drives

9.1 Introduction

Several options are available for use with Siemens Standard drives; some are described below. These are intended to assist product selection, installation and commissioning in certain applications.

9.2 Advanced Operating Panel AOP

The advanced operating panel consists of a control and display unit that fits directly on top of the MICROMASTER or MIDIMASTER Control panel. A socket connects directly onto the front of the unit, so the AOP can take power from and communicate with the drive via the RS485 interface.

The AOP offers the following features:

√ Many languages (Such as English, German, French, Italian, Spanish) for text operation with explanation of parameters, faults etc.

√ Diagnostics - help with fault finding.

√ Upread/download of parameter sets from units to AOP and back. This allows fast, reliable programming and copying of parameter sets.

√ AOP mounts directly on MICROMASTER and MIDIMASTER.

√ Optional Door mounting kit with IP54 protection included.

√ Optional AOP to computer connection kit for remote operation and off line programming.

The AOP has several practical uses; for example:

- The AOP may be mounted directly onto the inverter and used to control the drive directly.
- The AOP can be mounted on a separate panel (using an optional cable of up to 5m) to enable remote control and monitoring of the drive.
- If an external power supply is connected to the AOP, remote control over distances greater than 5m is permissible
- Parameter sets can be stored in the AOP and uploaded or downloaded as required. This is particularly useful where many inverters require programming in production.

9.3 Braking Modules and Braking Resistors

During regeneration (see section 8.2.2) it may be necessary to dissipate the energy that is returned to the inverter. MICROMASTER MM420 units do not have the capability to dissipate regenerated energy.

Some Siemens inverters have a built in ‘braking chopper’ and require only an external resistor to allow controlled dissipation. The resistors can be supplied as optional parts to the inverters, and fit alongside the inverters. They are specially designed to operate with the high voltages present in the DC link, and are of metalclad, IP54 design. Braking resistors for operation with earlier MICROMASTERs were designed to mount underneath the inverters. Other resistors can also be used, but care must be taken to ensure they are of adequate voltage and power rating.

9.4 EMC Filters

MICROMASTER inverters are designed to minimize conducted and radiated interference. However, they are power electronic products and generate significant levels of interference over a wide electromagnetic spectrum.

In many applications it is possible to operate without filters or with the built in filter. However, in order to achieve higher levels of attenuation an external filter may be required. In particular, an external filter will be needed in order to meet residential, commercial and light industrial levels.

The purpose of EMC filters is to reduce the conducted levels of interference from the inverter to the supply. It is not intended to reduce radiated interference or attenuate interference into the inverter. It should be fitted to the input supply to the inverter and will be damaged if installed in the inverter output.

The filters are designed to mount underneath the MICROMASTER to minimize space requirements. Full installation instructions and information concerning the appropriate filters are given in the Reference Manual.

9.5 PROFIBUS Module

Siemens Standard Drives incorporate an RS485 serial interface as standard. In order to operate on a PROFIBUS system a separate conversion module is required. The PROFIBUS module and the PROFIBUS system is described in section 8.4.2.

9.6 Input and Output Chokes

Chokes can be fitted to the input of the inverter to reduce harmonic distortion and to reduce the effect of supply disturbance on the inverter. Chokes are also recommended where supply impedance is less than 1%.

Chokes are fitted to the output of the inverter to allow operation with long cables. The choke compensates for the stray capacitance of the cables. Recommended chokes for different cable lengths and inverters are available.

A Environmental Protection Levels (IP rating)

Table A-1 gives the definitions of DIN40050, BS EN 60529 and IEC529. These refer to the IP numbers and the different levels of protection available.

Table A-1 Protection levels (IP Rating)

FIRST NUMBER		
0	No protection	No special protection of persons from direct contact with active or moving parts. No protection of the object from access of solid foreign matter.
1	Protection against large foreign bodies	Protection of persons from accidental large-area direct contact with active or internal moving parts (e.g. hand contact), but no guard against intentional access to such parts. Protection of the object from access of solid foreign matter larger than 50mm in diameter.
2	Protection against medium-size foreign bodies	Protection of persons from finger contact with active or internal moving parts. Protection of the object from access of solid foreign matter larger than 12mm.
3	Protection against small foreign bodies	Protection of persons from touching active or internal moving parts with tools, wires or similar foreign bodies thicker than 2,5mm. Protection of the object from access of solid foreign matter larger than 2,5mm.
4	Protection against very small foreign bodies	Protection of persons from touching active or internal moving parts with tools, wires or similar foreign bodies thicker than l mm.
5	Limitation of ingress of dust	Total protection of persons from touching voltage-carrying or internal moving parts Protection of the object from harmful deposit of dust. Although ingress is not completely prevented, dust will not enter in sufficient quantity to impair the operation or safety of the apparatus.
6	Prevention of ingress of dust	Total protection of persons from contacting voltage-carrying or internal moving parts. Total protection of the object from ingress of dust.

SECOND NUMBER		
0	No protection	No special protection.
1	Protection against water dripping vertically	Water drops falling vertically must not have any harmful effect.
2	Protection against water dripping non-vertically	Water drops failing at any angle up to 15' with the vertical must not have any harmful effect.
3	Protection against spray water	Water hitting the object at any angle up to 600 with the vertical must not have any harmful effect.
4	Protection against splash water	Water splashing against the object from all directions must not have any harmful effect.
5	Protection against jet water	A jet of water projected from a standard nozzle at 12.5 litres per minute against the object from all directions must not have any harmful effect.
6	Protection against powerful water jets	A water jet projected at 1 00 litres per minute from all directions shall have no harmful effect.
7	Protection against temporary submersion	If the enclosure is immersed between 0. 1 5 and 1 m in water for 30 minutes, water must not enter it in any harmful quantity.
8	Protection against continuous submersion	If the enclosure remains submerged in water, under agreed conditions which are more severe than those of IPX7, water must not enter it in any harmful quantity.

B Some Useful Formulae

B.1 Torque and Power Relationships

If the steady state torque is known, the power requirement can be calculated:

Power [kW] = (Torque [Nm] X Speed [rev/min])/ 9550
or
Torque [Nm] = (9550 X Power [kW])/ Speed [rev/min]

Acceleration Torque.

The amount of torque needed to accelerate (or decelerate) a rotating body is dependent on its moment of inertia:

Acceleration Torque [Nm] = Moment of Inertia [kg.m.m] X Acceleration [m/s.s] X $2\pi/60$.

Often it is necessary to calculate the total torque requirement in order to determine the motor type and inverter power.

Total Torque = Acceleration Torque + Steady State Torque

Moment of Inertia

The moment of inertia is often specified for motors, gearboxes etc. It can be calculated for simple bodies, for example:

Solid Cylinder, Radius R, Length l, Mass m:

Moment of inertia = $J = m.R^2/2$

If the cylinder is hollow, with inner radius r, outer radius R:

Moment of inertia = $J = m.(R^2 - r^2)/2$

Torque, Power and Moment of Inertia of Practical Assemblies

Gearbox

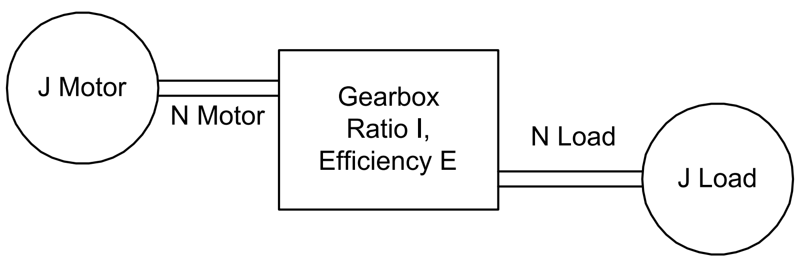


Figure B-1 Practical Assemblies. Gearbox

Gearbox Ratio I = Nmotor/Nload

Moment of Inertia

The load moment of inertia can be referred to the motor shaft

J*load = Jload/ I^2
or
J*load = Jload. $(Nload)^2$/ $(Nmotor)^2$

Output Power

Output Power = (Input Power) X (Gearbox efficiency)

Output Torque

Output Torque = (Input Torque) X (Gearbox efficiency)/ (Gearbox Ratio)

Conveyor Applications

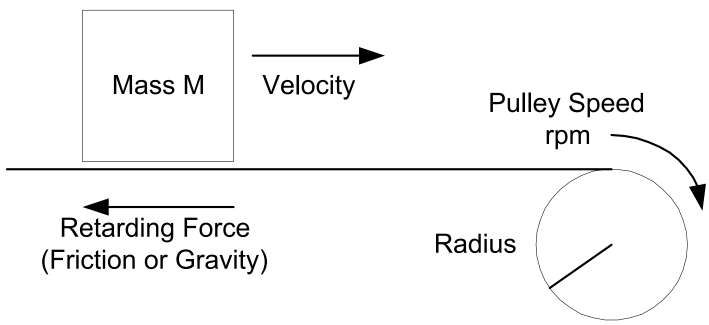


Figure B-2 Practical Assemblies. Conveyor

Accelerating Torque = Mass X Velocity
Steady state Torque = Retarding Force X Radius
Velocity = 2.π.Radius X Pulley Speed.
Power = Retarding Force X Velocity
Moment of inertia = Mass X $(Velocity)^2$ + Pulley etc.

Hoist Applications.

A hoist is a vertical conveyor where the Retarding force is gravity.

Steady state Torque = Retarding Force X Radius
= Mass X g X Radius.
Power = Mass X g X Velocity
Moment of inertia = Mass X $(Velocity)^2$ + Pulley etc

Index

Suggestions and/or Corrections

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