MAGNASTART

Slip Ring Motor Starter

APPLICATION AND INSTALLATION HANDBOOK V1.5

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This Handbook is written to give guidance as to the application and use of the Magnastart in normal circumstances. Whilst ever endeavor is made to ensure accuracy in its content, no liability can be assumed for errors or omissions.

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CONTENTS

1. INTRODUCTION

Magnastart is a unique Inducer system for starting asynchronous slip ring induction motors, offering considerable improvements in maintenance, reliability and cost-effectiveness. The Magnastart product line consists of a range of steel cored Inducers from 37 to 370kW, each individual model spanning a variety of machine sizes. When built into rotor starter systems, the Magnastart acts as the current-limiting rotor impedance during starting, and is bypassed by a shorting contactor when near full speed is reached.

Magnastart was originally supplied by ADWEL International Ltd. In 2007 ADWEL merged into Iris Power LP, and is now supplied from the Iris Power UK.

2. STARTING SLIP RING MOTORS

Most industrial electric motors now manufactured are induction motors, and whilst the great majority are of squirrel cage construction, a significant proportion are slip ring motors. Slip ring induction motors, whilst more expensive, have three main advantages over the more common squirrel cage type:

- They can be more efficient when running.
- Torque and Speed control is possible by altering the rotor circuit.
- They are capable of producing an exceptional starting torque and rapidly starting loads with a large inertia.

To start a system driven by an induction motor, an amount of electrical energy, approximately equal to the mechanical starting energy, has to be dissipated by the rotor circuit. With a squirrel cage motor, this would appear in the rotor itself. A slip ring rotor enables this energy to be absorbed in external equipment, thus avoiding overheating the rotor.

To start with maximum efficiency, the rotor requires a resistive load that reduces as the motor accelerates. Practically, this can be achieved in a number of ways. The most common is the resistance bank, which has a number of fixed value resistors progressively shorted out by time switches. Common variations of this method are liquid starters, where plates are mechanically lowered into a bath of electrolyte, and vapour starters where the resistance drops due to the liquid-vapour transition of electrolyte within the starter. All of these methods have major drawbacks:

- The changing resistance is set by timers and physical design parameters and does not take account of varying load conditions.
- Each starter has to be individually designed to suit the motor and once installed, its starting characteristics are not easily altered to suit changing load requirements.
- By virtue of the large number of contactors and other moving parts, resistance banks are bulky, complex and liable to malfunction.
- Liquid and vapour starters require regular ‘topping up’, anti-freeze, and other forms of maintenance, and can have a limited repetitive starting capability.

Magnastart achieves the same objectives, but in a radically different manner. It is similar in construction to a three-phase transformer, but operates in an entirely different manner. When the motor is first started, the frequency on the rotor is 50/60 Hz (supply frequency). As the motor speeds up, this (slip) frequency falls and because the impedance of the Magnastart is frequency dependent, the impedance also reduces. Consequently, under any load condition, Magnastart will always give the right impedance at all times during starting. It can be used additionally for inching, reversing and plug breaking.

3. PRINCIPLES OF MAGNASTART OPERATION

The Magnastart Inducer consists of 3 (primary) coils wound on specially shaped steel cores. The secondary windings are the steel cores themselves, which are constructed to maximize their eddy current losses. Eddy currents in these cores are reflected in the windings as an impedance which is dependent on rotor frequency, and will reduce as the frequency reduces. A selection of taps on the coils makes it possible to match the Magnastart impedance to the rotor for a wide range of motors and loads. It is connected across the rotor windings on starting in Fig 1.

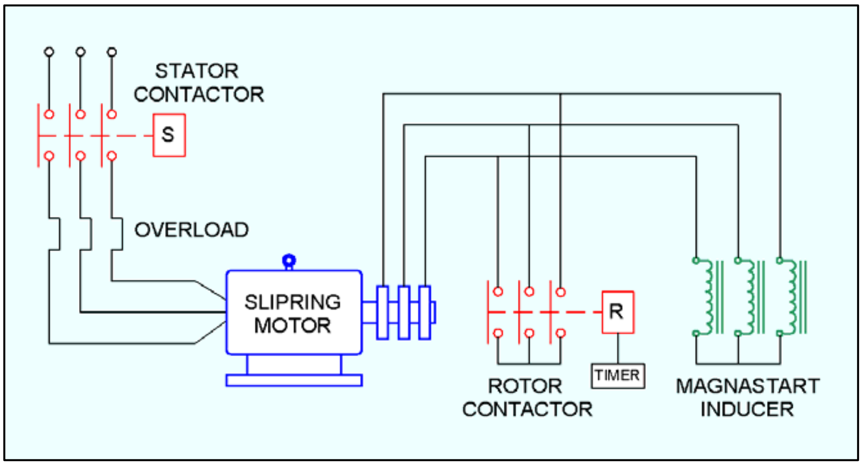


Fig 1

When power is applied to the stationary motor, the frequency in the rotor is the same as the stator, resulting in the maximum Magnastart impedance. As the motor accelerates, the rotor frequency (the slip frequency) and Magnastart impedance decreases. This results in a smooth acceleration to nearly full speed at which point the rotor is short circuited by the rotor contactor. This is contrasted with the result of using switched resistances in Fig. 2 below.

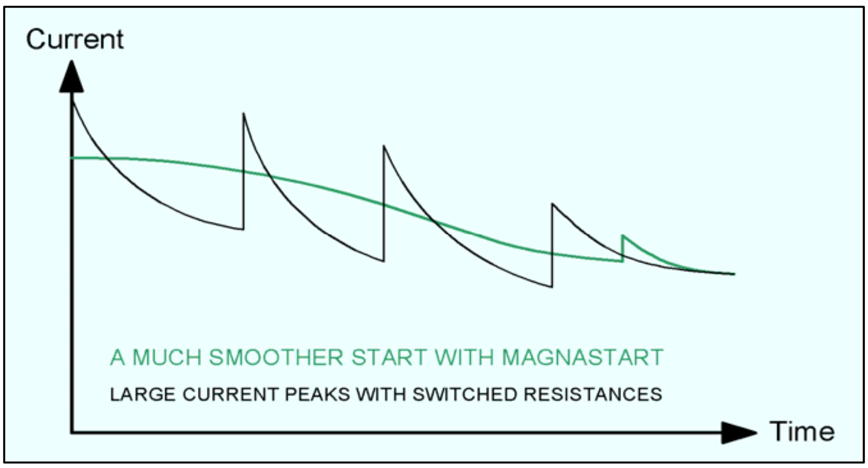


Fig 2

The starting energy

using Magnastart is dissipated in the heavy mass of the steel cores, which can absorb a considerable amount of energy. Advanced thermal insulation protects the coils which remain relatively cool, and several consecutive starts may be obtained on drives with high inertial loads.

Each of the coils has four connection taps brought out to studs on the front panel. By using various star and delta combinations, up to 17 different starting impedances are available, to provide the best starting characteristics on a wide range of motors.

4. CONSTRUCTION

The Magnastart chassis consists of two rectangular steel plates. Between these are sandwiched the three specially shaped, hollow steel cores, in a triangular array. The cores are specially shaped to give the special electrical characteristics required. On each core is wound a coil. On the smallest model, this is wound directly onto the core. On all other models the coil is supported at top and bottom by six heat-resistant supports. There is a 5mm air gap between the coil and the core to thermally insulate the coil from the core, where most of the heat is dissipated.

Each coil is tapped at 84% and 56%, and all the connections are brought out to the front panel in a rectangular array.

Magnastart is built to have a large mass. The large weight of steel not only gives improved electrical performance, but also a high thermal capacity. Consequently, it is capable of absorbing the energy from a number of starts in succession.

5. ELECTRICAL CHARACTERISTICS

Each coil has two intermediate taps, one at 56% and one at 84%. The Magnastart is supplied with a set of links, which can be used to make up to 17 different connections on the front panel. Each tapping has a different impedance at 50Hz. Motors with different rotor parameters can be accommodated by the same Magnastart model, and by using different tappings on the same motor, different starting characteristics can be obtained. A lower impedance tapping will generally give a high torque and draw a large starting current to produce a shorter start time, although at very low impedances, torque can decrease again. A higher impedance tap can be used to limit the starting current at the expense of starting torque and a longer start time.

A linear characteristic of impedance change with frequency is desired to give a constant current and torque during starting, and this is substantially achieved by Magnastart Inducers. The result for the model M175 is given in Fig. 3 below.

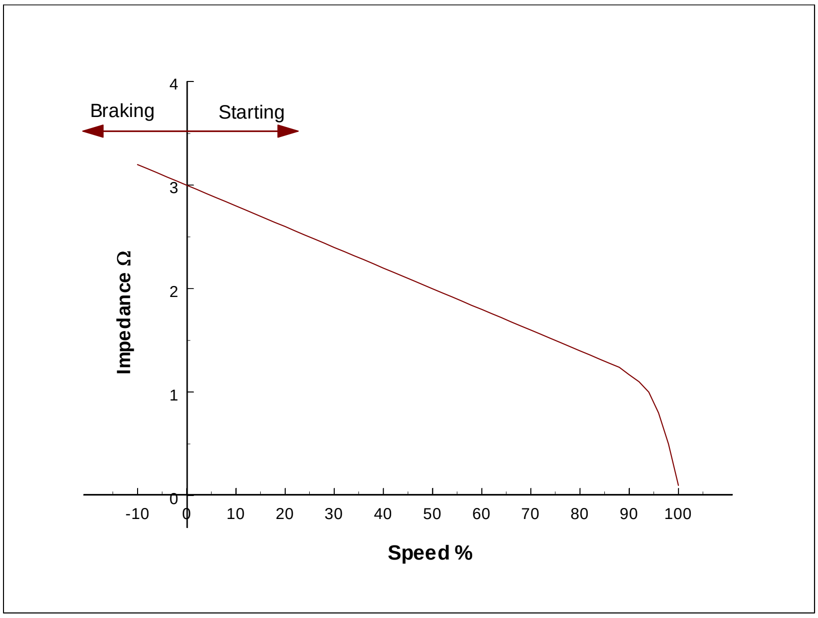


Fig 3

From this it can be seen that operation at 60Hz is little different, as the characteristic impedance is increased by only about 12%.

The power factor remains constant over the whole range at about 0.8. It should be noted that all times the impedance is greatly in excess of the D.C. resistance of the coils. Consequently during normal operation, the heating in the copper is small in relation to heating in the iron, keeping the coils relatively cool even if the Magnastart is subjected to a heavy duty cycle.

6. PERFORMANCE

The Magnastart's linear impedance characteristic means that the stator current drawn on start remains almost constant during three-quarters of the starting cycle. This has considerable advantages when supply restrictions are in force, as it enables the fastest possible start to be obtained within a given current limit.

Typical torque and current to speed characteristics are given in the charts below to illustrate the benefits of using a Magnastart Inducer as a rotor starter, compared to direct on line starting. (The impedance values 1-6 are nominal, and only reflect the typical range of impedances achievable from a Magnastart, not any particular tapping). Fig. 4 shows the variation in starting torque as a proportion of Full Load Torque (FLT) with impedance.

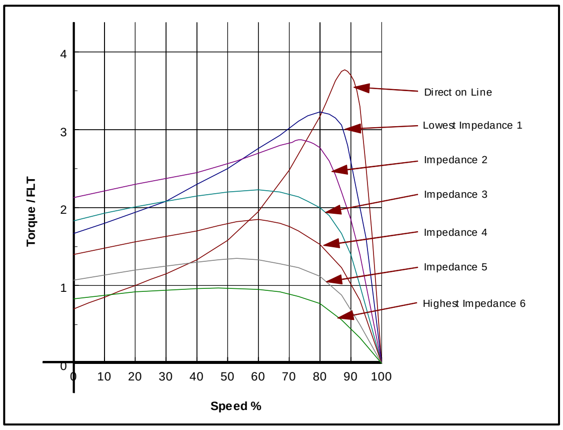


Fig. 4

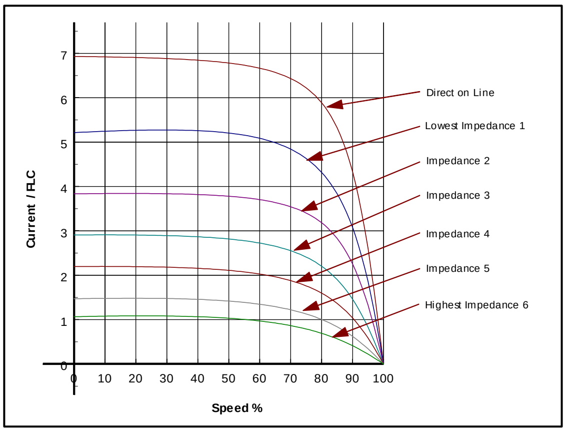


Fig. 5

As can be seen, direct on line starting will give the least starting torque, and there is an optimum impedance for maximising starting and run-up torque, with higher impedances generally depressing both values (though reducing starting current). On most motors this maximum starting torque occurs between 3 and 4 times the full load rotor current. Magnastart is most efficient, starting fan loads and large flywheels, at 2 times full load rotor current.

Fig. 5 shows the effect of the various impedances on starting line current, as a proportion of normal full load current (FLC), and illustrates that the starting current can be maintained at low levels if high starting torque is not a key requirement. (As is normal, current and torque both reduce to zero at 100% synchronous speed, ie no slip).

Section 9 gives details of tappings and relative impedances achieved.

7. RATING AND SELECTION OF MODEL

The size of a Magnastart required is decided solely by the motor size and starting duty required. Factors to be used in determining 'starting duty' are:

- The number of starts per hour.
- The starting period.
- The starting current as a factor of full load rotor current.

The rating of the required Magnastart is determined by the motor's full electrical power rating in kW/HP. It is not normally determined by the running mechanical load, since during start-up the motor will draw the maximum power possible (usually well in excess of the normal running power) to accelerate the machinery's mass.

The ratings have been calculated on a basis of 15 second starts, with near-full-speed being reached in ~10 seconds and being shorted in 15 seconds, generating a maximum of 1.5 times the full load torque at start. For other starting conditions, the units can be up-rated or de-rated in proportion.

In addition the motor's rotor voltage and current ratings should be considered to make sure these do not exceed the Magnastart's rating. Only very rarely do motors exceed the Magnastart ratings for rotor voltage or current. However, if the maximum rotor starting current or voltage is exceeded, a larger Magnastart is needed. Note that the Magnastart rotor ratings allow a wide range of voltage and current capacity, but these must not be used in conjunction beyond the maximum power rating of the Magnastart.

The chart in Section 9 provides a selection of front panel tappings and their relative impedances. This is used to select the right tapping. If the impedance needed is not known (which is quite often), the right tapping can be found by attempting a start with a high impedance tapping, then progressively trying lower impedance tappings until the right starting characteristics (line current vs time) are obtained. During the setting up operation, the rotor current should also be measured on each attempted start. This ensures that the Magnastart and motor rating is not exceeded and gives a guide to the additional torque that might be obtained on lower impedance tappings.

8. INSTALLATION

8.1. Enclosure and Mounting

The Magnastart should be installed in a suitable metallic enclosure, protected from human access. This need not be ventilated but reasonable space should be left either side of the Magnastart to allow circulation of air around the coils. The heat energy dissipated in the Magnastart during a start is approximately the same as the stored kinetic energy in the motor and load.

If it is mounted in the base of a control cubicle, ensure that enough ventilation or natural cooling through the body of the cubicle is provided to prevent the heat generated during starting cycle(s) adversely affecting other equipment (eg PLC). Extra or forced ventilation may be required in case of either a particularly compact housing or very arduous duty.

During operation the top and bottom plates (and cores) of the Magnastart may become very hot as a natural part of the starting process. Make sure that heat sensitive components, especially connection cables etc are not sited or routed close to these areas.

On the M30B, M45, M90, M125 and M175 the mounting channels can be removed and the Magnastart mounted on the M8 studs protruding from the bottom of the rubber mounts. This allows these Magnastarts to be mounted in a 400mm deep enclosure.

The mechanical dimensions and weight are given in the Specification in Section 11.

8.2. Connections

The connections should be all made to the front panel in flexible cables since there is considerable vibration during starting.

Ensure the cables are rated for the specified motor current. If the Magnastart and its shorting contactor is distant from the motor, consider over-sizing the rotor cables to minimize running losses in the cables.

The Magnastart need not be earthed for safety, as no part of its construction or circuitry should be exposed to risk of human contact. However some installers may wish to make an earth connection for overall earth integrity, in which case one of the bolts holding the connection panel may be used, ensuring the paint underneath is cleaned off first.

8.3. Voltage, Current and Frequency ratings

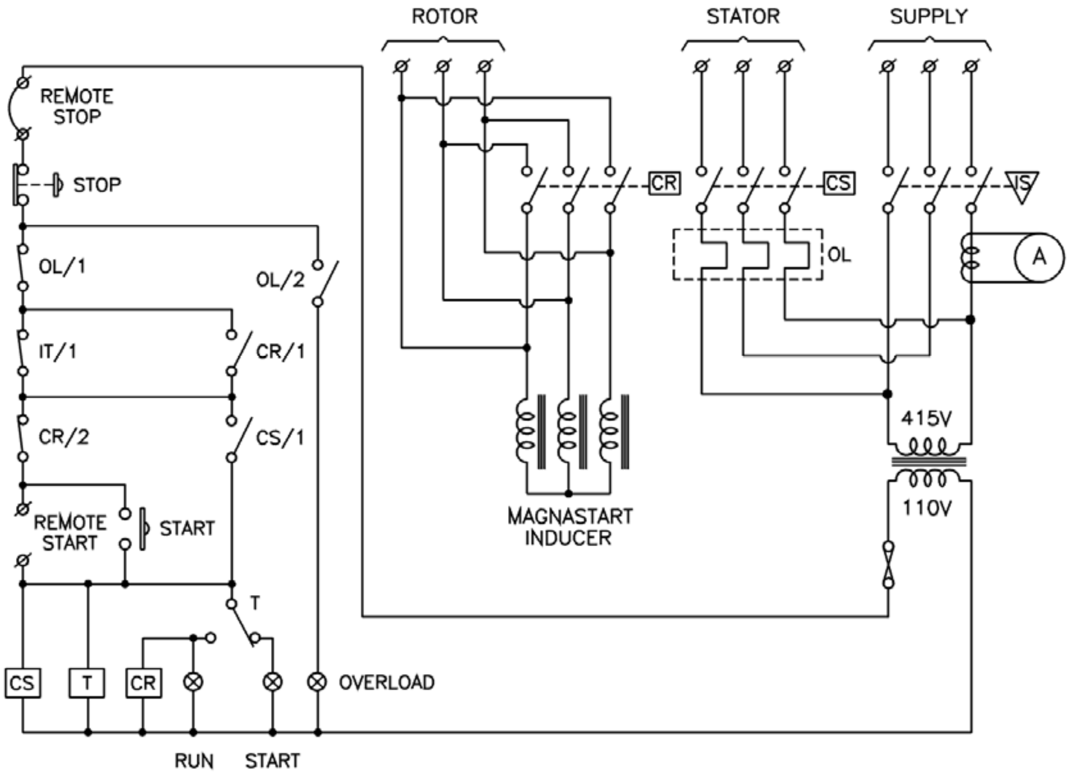
The motor’s rotor voltage and current ratings should not exceed the Magnastart’s rating. The stator voltage is normally not relevant to the installation unless any stator high voltage circuitry is installed in the vicinity when correct insulation co-ordination is required.

Operation is possible at 50Hz or 60Hz, and has the effect that the Magnastart impedance at 60Hz is increased by 10-15% over its nominal 50Hz rating. This is less than the difference between each impedance tap, and is thus usually not noticeable (in a few circumstances it may lead to the user choosing a slightly lower tap than the identical system at 50Hz).

8.4. Control and Power Circuitry

The Rotor and Control circuitry should be wired to the general principles described below. Fig 6 shows a typical system wiring diagram for a basic starter. It should be stressed that this is intended as a base for the designer to use and adapt for his/her own purposes. It does not include any operating safety interlocks or extra controls for inching, supply protection arrangements, earthing, etc. It is common to use a Programmable Logic Controller (PLC) to perform the overall control and interlocking function.

The actual connections to the Magnastart are dependent on the Impedance setting required, covered in Section 9 below.



KEY	
CS	Stator Contactor
CR	Rotor Contactor
IS	Isolator
OL	Stator Overload
IT	Magnastart Cut–out
T	Timer
A	Ammeter

Fig. 6 Basic Starter Wiring Diagram

8.5. Setting the Timer

It is vital the Magnastart and rotor is shorted after starting to take the Magnastart out of circuit. The Magnastart coils are not rated to withstand the rotor current indefinitely, and should not exceed a start time before shorting of 15 seconds at their maximum rated current. As the heating effect is proportional to I^2, then for example at 50% of their rated current, a maximum start time of 1 minute would be permitted.

The timer should be set to close the rotor contactor after the motor has accelerated to a steady speed. If the current surge on closing is too large, then a lower impedance tapping may be required to get the motor nearer to full speed before closing. The speed can be checked with a tachometer if it is not easy to discern the speed or high accuracy is required. If the motor has to start under varying load conditions, an additional allowance should be made on the starting time to allow for a 'worst case' start. Setting the timer a little too long will not affect the starter's performance or reduce its starting capacity, as the Magnastart core dissipation is low once the motor reaches near full speed.

Other controls (eg current or tachometer) may be used to determine the correct time to short the rotor contactor. However since a varying load or operating defect could delay the shorting time indefinitely, a time-out should still be used to either force a rotor short or trip the drive, to protect the Magnastart from being in circuit indefinitely and thus overloaded. Please note that the cut-outs DO NOT detect overheating in the coils, thus a fault which causes continuous high currents in the Magnastart coils during running will lead to premature failure.

8.6. Inching and Speed Control

The Magnastart Inducer is suitable for inching and the same impedance may used as for normal starting. An interlock should be included to extend the rotor contactor closing time during inching operations. No matter at what speed the inch button is pressed or released, the Magnastart will always provide the correct torque for efficient operation automatically. If the inching operations are expected to be intensive, then either extra ventilation and/or a larger model should be chosen, as this is equivalent to extended starting duty.

The Magnastart Inducer is NOT suitable for speed control. The automatic reduction of impedance as the motor accelerates prevents a stable speed being achieved for a given load, and the Magnastart rating is only for the intermittent duty of starting, not continuous running.

8.7. Reversing

By fitting a reversing contactor into the stator circuit, the Magnastart can be used for reversing. The same Magnastart tapping would normally be used as for normal starting. Again the rotor contactor must be interlocked to extend rotor shorting closure time. The reversing torque will be at least the torque on start. If exceptionally heavy braking is required a lower impedance tapping may be required (though be aware that very low impedances can result in reduced torque).

The use of the Magnastart to reverse a running motor will cause at least a double duty cycle (run-down and back up again), and this will impact the number of duty cycles. In addition, the maximum rotor voltage must be evaluated since at point of reverse the slip frequency will be 2x supply.

8.8. Thermal Overload Cut-Out Protection

Each Magnastart is fitted with three thermal Cut-out switches (one per core in series) except on the M45 which has only one. These have normally closed contacts, which sense the core temperature (the part that heats up in normal use) and open at 150˚C. Connection is through the two smaller studs on the front panel. It MUST be wired into the control circuit to shut the motor down if the Cut-out contact opens during any of the starting, acceleration, inching or reversing periods.

The thermal Cut-out is intended to protect the Magnastart from overheating due to malfunction of drive or operator misuse, and it is vital that it is wired into the protection circuits. However since it is connected into the control system to achieve its effect, and senses the core (not the coil) temperature, it is not guaranteed to protect the Magnastart from damage in case of all overloads. It always remains the responsibility of the user to not exceed the Magnastart's ratings.

If the motor has been repeatedly started, sometimes the Cut-out can open after starting has completed (even though there is no current in the Magnastart) due to thermal inertia in the Magnastart, and may thus trip the motor. To avoid this problem, interlock the Cut-out with a N/O contact on the rotor contactor (as shown in the typical wiring diagram above).

8.9. Initial Use

The steel cores in the Magnastart are protected in manufacture with an oil coating. In initial use this may burn off and thus emit a small amount of smoke. This is normal and not an indication of damage, though all smoke emission should be investigated to make sure that there is no other problem.

8.10. Replacing a Resistor or Liquid Starter

A common application of the Magnastart is to replace a failed resistance or liquid/electrolytic starter on an existing motor. There is normally no problem with this, and the simpler control system and robust, reliable construction with no maintenance requirements are a benefit. However the fact that the Magnastart power factor is not unity (typically 0.8) will cause a small reduction in the absolute maximum starting torque that the motor can achieve. If the original design had been such that there was no tolerance headroom, or the use has changed to expect the absolute maximum starting torque, then it is possible that the replacement starter will fail to start the motor against full load. This can be a problem with fully loaded ball mills, where it is natural to load the mill to the maximum possible. In this case the simplest remedy is to make a small reduction in the starting load.

If this is not possible, another strategy is to connect three power resistors in parallel with the Magnastart so that part of the starting impedance is the resistors. These will act to increase the power factor and thus maximum starting torque, but will not require any extra shorting contactors since the Magnastart impedance will still reduce down to a low level once started, becoming the dominant impedance.

9. CHOOSING THE IMPEDANCE TAPPING

A wide number of tapping arrangements are possible. The connection diagrams for the preferred values are given on the Preferred Impedance Tapping Chart in Fig. 7 below. The arrowhead connections are made to the rotor. The cross-connections can be made up with the set of cable links provided with each Magnastart.

If there is no other information available, such as calculations made from motor and load data or similar previous installations, the tapping required may be determined by trial, using Tapping 1 for the initial test. Set the timer to maximum and attempt to start. Since Tapping 1 produces minimum torque and current, the motor may not move or may fail to reach full speed. Measure the starting line current and refer to the impedance values on the impedance matching chart. For off-load starts 1x Full Load line Current should be sufficient. Starts against load may require 2x or 3x FLC.

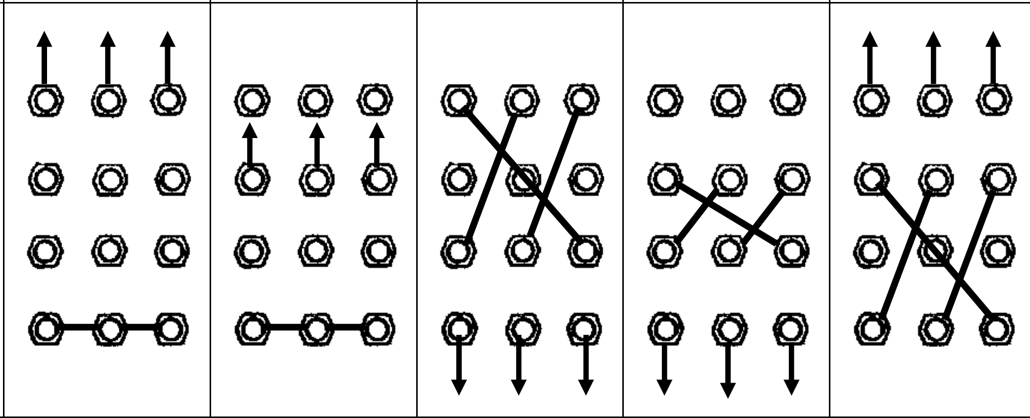
In general to increase the starting current and torque, choose a lower impedance tapping. To reduce them, choose a higher impedance tapping. The % impedance values will give an approximate indication of the change in starting current with different tappings though will never exceed the direct-on-line starting current (eg if impedance is reduced from 100% to 41%, starting current will increase by approximately 120%). Note that the energy that the Magnastart can absorb does not significantly vary with the tappings (unlike resistance starters), as the great majority of the starting energy is absorbed in the iron cores. Each starting trial will heat the Magnastart up, so do not test too many times in succession without allowing adequate cooling periods, else the cut-out may trip

A further seven Alternate Impedance Tapings are given in Fig. 7a below. These provide a fine-tuning ability if the required impedance is found to lie between two preferred tappings, or a very low impedance is required. It is rarely required to use these, and the lower impedances will also need to have the cable and rotor impedance taken into account.

In case that the motor is supplied from a generator or supply with limited overload capacity, the tapping will need to be chosen so that the supply voltage does not drop excessively due to the stator starting current. This is needed to ensure that no damage is done to the generator and the control systems operate correctly during starting. It may limit the motor starting capacity against load.

CHECK THE ROTOR CURRENT.
DO NOT EXCEED THE SPECIFIED MAXIMUM ROTOR CURRENT.

If the tapping chosen uses only some of each coil, it will act like an auto-transformer, and significant voltages will occur on unused terminals during starting. For most tappings this will not be a problem, but in the case of tapping 17 the voltages between the “0” terminals will be 525% of rotor voltage, thus limiting the rotor voltage this can be used with. The designer should consider this in the system insulation co-ordination, and may need to disallow certain tappings.

Tapping	1	2	3	4	5
Coil Taps 100% 84% 56% 0					
Impedance	100%	71%	67%	54%	41%

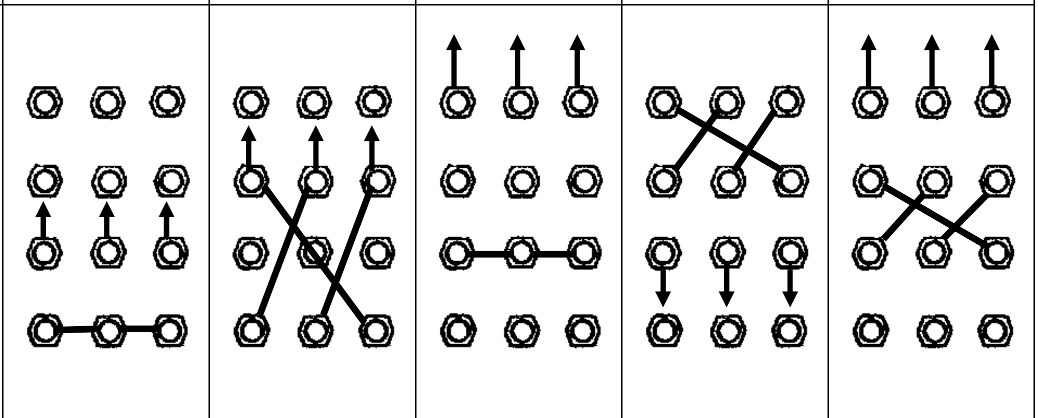
Tapping	6	7	8	9	10
Coil Taps 100% 84% 56% 0					
Impedance	31%	26%	20%	15%	11%

Fig. 7 Preferred Impedance Tappings

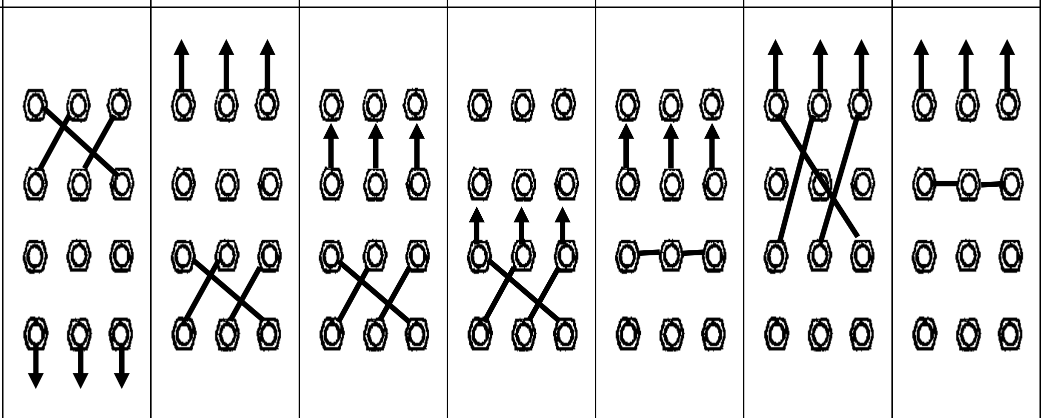
Tapping	11	12	13	14	15	16	17
Coil Taps 100% 84% 56% 0							
Impedance	91%	57%	37%	12%	7.8%	6.9%	2.6%

Fig. 7a Alternate Impedance Tappings

10. CONNECTING MAGNASTARTS IN PARALLEL

The maximum Magnastart rating is 370kW, but it may be desired to start a higher rated motor. In this case it is sometimes possible to connect 2 or more M350 Magnastarts in parallel to achieve a larger combined rating. This should only be considered for ratings above 370kW, it is normally more reliable (and more economic) to use a single, correctly sized Magnastart for lower ratings.

In case Magnastarts are connected in parallel the following criteria MUST be applied.

i) The Magnastarts are all tapped identically, and
ii) The Cut-outs on all units are wired in series, so that if any unit overheats, the system trips.
iii) The system is de-rated by 10% to allow for mismatch of individual units.
iv) The rotor voltage must not exceed the Magnastart rating.

It will be obvious that operating in parallel will reduce the combined maximum impedance, so this arrangement functions best with lower voltage rotors. If this is problematic, then a series/parallel combination could be considered, and must be designed specifically for the application by a competent Electrical Engineer.

Since the success of this use is very dependant on the motor and system design, IRIS POWERdoes not guarantee that parallel operation will be successful in all cases, and the user must satisfy themselves that the application is appropriate.

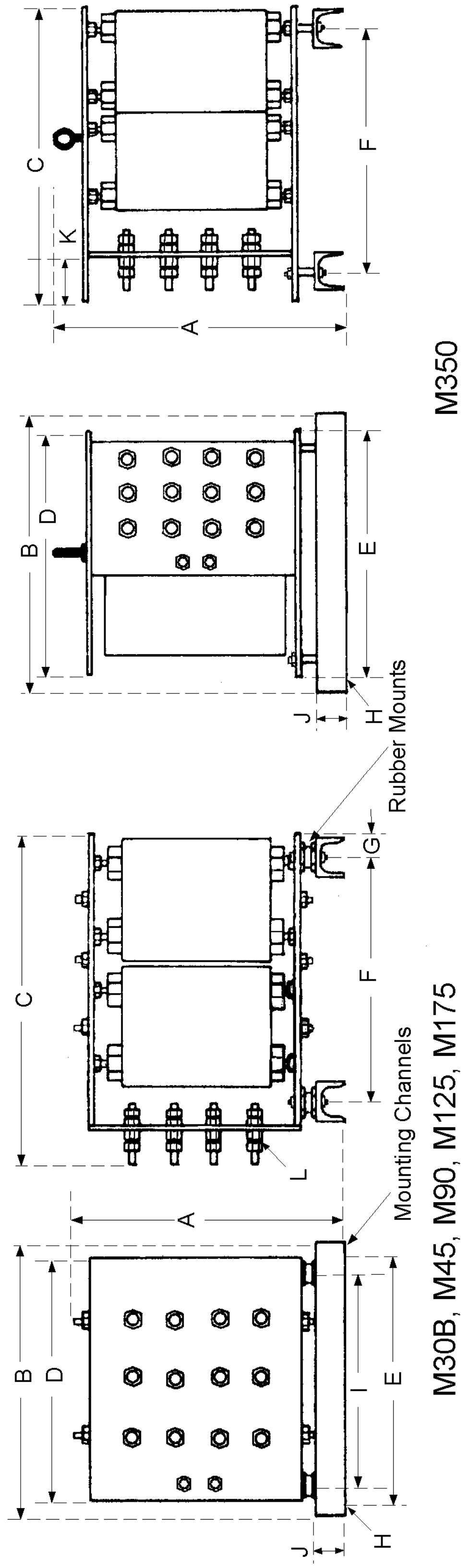
11. SPECIFICATIONS

Model No		M30B	M45	M90	M125	M175	M350
Max Motor Size [1]	kW HP	37 55	55 75	110 150	150 200	200 270	370 500
Max Starts/Hr [2]		9	7	6	7	5	4
Max Consecutive Starts [3]		4	4	4	5	4	4
Max Rotor Starting Current	Amps	140	275	425	525	625	1100
Max Rotor Voltage [4]	Volts	600	600	800	800	1000	1200
Max Rotor Voltage (HD) [5]	Volts	500	500	550	600	750	900
Impedance [6]	Ohms	7.0	4.0	3.5	2.5	3.0	2.3
Coil Insulation Rating		Class F (150°C), 4,000Vac winding-ground proof test					
Thermal Overload Cut-out [7]		250Vac, 10A or 30Vdc, 5A max Normally closed					
Dimensions [8]	mm	See Mechanical Outline drawing					
Height	A	250	260	255	360	360	430
Width	B	305	325	365	365	365	500
Depth	C	320	330	420	425	420	500
Body Width	D	250	270	320	320	320	420
Fixings Holes Side to Side	E	280	300	340	340	340	470
Fixings Front to Back	F	233	257	320	320	320	360
Rear Fixings	G	25	25	30	30	30	70
Fixing Hole Size	H	10	10	10	10	10	12
Fixing Studs Side to Side	I	215	247	285	285	285	370
Channel Height	J	37	37	37	37	37	37
Front Panel Inset	K	-	-	-	-	-	95
Load Studs	L	M8	M8	M10	M10	M12	M12
Overload Cut-out Studs	L	M6	M6	M6	M6	M6	M6
Weight [9]	kg	27	36	54	75	81	165
Operating Environment		-25°C to +50°C ambient, 0-95% RH (non-condensing)					

Notes:

1. With 50/60Hz, 3 phase supply. For other supply arrangements contact ADWEL.
   It may be possible to parallel models for greater capacity in particular circumstances. Please consult IRIS POWERwith specific details.
2. This is based on the maximum motor size starting against 1.5 x full load torque for 15 secs, mounted in a typical unventilated metallic enclosure. For heavier duties extra or forced ventilation may be required, or a larger Magnastart chosen.
3. Maximum consecutive starts are from cold. Note that the motor rating may also limit consecutive starts.
4. Normal starting duties, occasional inching in both directions.
5. Heavy inching, and plug braking.
6. Impedance is approximate per coil at 50Hz, full load, 100% tapping. Increase 12% for 60Hz. Typical PF is 0.8.
   Tappings at 84% and 56% per coil allow a choice of star and delta impedances from 100% down to 3% in 17 steps.
7. The Thermal Overload Cut-out should be wired to trip the starting system in case of overload (contacts open).
8. On the M30, M45, M90, M125 and M175 the mounting channels may be removed and the Magnastart mounted on the M8 studs protruding from the bottom of the rubber mounts. This allows these Magnastarts to be mounted in a 400mm deep enclosure.
9. Weight is without packing. For normal road shipment, the Magnastarts are mounted on 50 x 75 x 430mm wooden bearers (to allow fork-lift carriage) and shrink wrapped. For air/sea export, extra packing can be arranged.

Fig. 8 Mechanical Outline



12. CE DIRECTIVE CONFORMITY

Equipment intended to be sold or operated in the European Union needs to be compliant with the applicable CE Directives, which may include the Low Voltage Directive, EMC Directive and Machinery Directive. Magnastart cannot itself be compliant, since it is a component intended for incorporation into equipment by others. However if a Magnastart Inducer is built into starter equipment in conformity with applicable standards (such as EN60947), compliance may be declared.

Magnastart is not a Safety Component within the terms of the Machinery Directive.