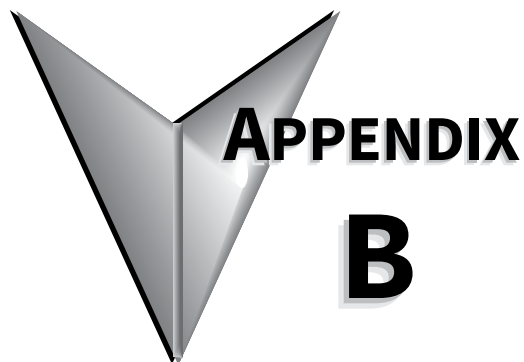


# SOFT STARTER APPLICATION CONSIDERATIONS

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# APPLICATIONS

## MOTOR SUITABILITY AND ASSOCIATED CONSIDERATIONS

The Stellar® SR35 soft-starter is a microprocessor-based optimizing soft-starter, designed for use world-wide in critical and non-critical systems. The design has proven to be both reliable and adaptable, and provides a powerful mechanism with which to control fixed-speed induction motors. However, due to the intrinsic differences between electronic and electro-mechanical starting systems, there are a number of simple rules and observations to follow when using the Stellar® SR35 soft-starter. This section introduces guidelines for the user and those incorporating the unit as part of their system design.

### **SUITABILITY**

In principle, any induction motor can be started by a soft-starter. Normally, the breakaway torque of the load should be less than the full-load torque of the motor, unless a motor with a high locked rotor torque characteristic is employed. As a quick assessment, any load which has a low or no-load start with a moderate starting time, or which can be started with a star-delta starter, auto transformer or other forms of reduced-voltage starting, can be considered to be a potential application for a soft-starter.

### **INDUCTION MOTOR CHARACTERISTICS**

Induction motors are required to provide sufficient torque to accelerate the motor and its load from standstill to full speed and to maintain full speed efficiently at all torque levels up to the design full load torque. Most modern induction motors have characteristics that are wholly suitable for use with soft starters, however, the characteristics vary considerably between different manufacturers and design types. It is important that the motor is capable of providing sufficient torque to drive the load at all speeds between standstill and rated speed, to enable the Stellar® SR35 to function properly. It is particularly important that the motor to be soft started does not have a low pull-up or saddle torque otherwise the load may not be accelerated correctly.

The primary function of the soft-starter is to act as a torque-regulating device. It cannot apply a torque greater than that which the motor generates. For this reason, problematic applications for which many different starting methods have been tried but failed, may need analysis of the motor or load performance before a soft-start can be successfully applied.

### **RATING**

For most applications, except high inertia loads, the starting demands and the inertia of the rotating masses are small enough to be insignificant. This means that no special consideration needs to be given to the rating of the soft-starter, other than to ensure that it is equal or marginally greater than the rated voltage and current of the controlled motor.

Alternatively, if the number of poles of the motor and the moments of inertia of the load ( $J_{load}$ ) and motor rotor ( $J_{motor}$ ) are known, a soft-starter will be suitable if the figures comply with the criteria given in the bottom row of following table:

|   |      |      |      |     |
|---|------|------|------|-----|
| <b>Number of Poles</b>  | 2    | 4    | 6    | 8   |
| <b>Synchronous Speed (rpm) Hz</b>                                 | 3000 | 1500 | 1000 | 750 |
| <b>(<math>J_{load}</math>)/(<math>J_{motor}</math>) less than</b> | 5    | 15   | 20   | 25  |

***MAXIMUM MOTOR CABLE LENGTH***

The length of the cable between the output terminals of the starter and the motor should not normally be greater than 100 meters.

***POWER FACTOR CORRECTION CAPACITORS***

Power factor correction capacitors applied to a single motor **MUST** always be connected by a separate contactor placed on the SUPPLY side of the Stellar® SR35 soft-start. Capacitors should be switched in after top-of-ramp (full line voltage) is reached and switched out of circuit before a stop is initiated.

It is important that any total system PFC scheme that automatically corrects for a range of inductive loads is not operated in such a way as to leave it heavily over compensated since this might introduce oscillations leading to damaging over-voltages.

***LIGHTLY LOADED, SMALL MOTORS***

Lightly loaded, small-sized (less than 2kW), star connected motors can produce high voltages at the motor terminals when shut down by simply opening the line contactor. As these voltages can damage the soft-starter, it is safer to control the opening of the line contactor with the soft start run relay contacts.

***MOTORS FITTED WITH INTEGRAL BRAKES***

Motors that include an integral, electrically operated brake, internally connected to the motor input terminals, can only be soft-started when the brake is re-connected to the supply through its own contactor.

***OLDER MOTORS***

The action of the fully-controlled soft-starter introduces harmonic currents and voltages to the motor. It is therefore, important to ensure that the motor employs techniques such as rotor skewing in its construction to suppress the effects of harmonic fluxes and avoid rough starting. This is rarely a problem with modern motors because nearly all motors designed in the last 20 years employ these techniques.

***WOUND-ROTOR OR SLIP-RING MOTORS***

Slip-ring induction motors **ALWAYS** need some resistance in the rotor circuit to ensure that sufficient rotational torque is generated to overcome any alignment torque, which is present at start-up. The resistance can be safely shorted out in the normal fashion with a contactor controlled by the programmable relay set as 'top-of-ramp' contacts.

***ENCLOSURES***

Thyristors are not perfect conductors, and the passage of current through them causes heat dissipation in the body of the device, which in turn causes the heatsink temperature to increase. As a rough guide, the heat generated is 1 watt/amp/phase when energy saving, which equates to a dissipation of 30 watts from the heatsink for a line current of 10 amps. Therefore, all cabinets or enclosures that house soft-starters should have adequate ventilation (refer to the Mechanical Installation Procedures, section for more detailed information).

***EU COMPLIANCE WITH THE EMC DIRECTIVE***

When considering the use or fitting of any Soft Starter, users and installers in European countries must comply with the EMC Directive 89/336/EEC. The manufacturer of the soft starter has a statutory obligation to provide a guide for compliance with this directive. For Stellar® SR35, this guidance is given in the EMC guide which is A3 of this manual. It is essential that users and installers understand

and comply with the requirements described in these sections.

### ***FUSES***

Circuit protection fuses should be rated at twice the motor rated current for normal low inertia applications. See also section relating to high inertia loads. Semiconductor fuses are available for the short circuit protection of the thyristors in Stellar® SR35. See Electrical Installation section for fuse recommendations.

## **RULES FOR SPECIFIC APPLICATIONS**

### ***HIGH INERTIA LOADS***

High inertia loads such as centrifugal and axial fans, grinders, flywheel presses, etc., may require a larger size of soft-start than the motor. For example, a 75kW starter may be needed for a 55kW motor. This is necessary due to the extra heat produced by the thyristors due to the extended start times and/or higher over-currents. If very high inertia loads are involved, then an analysis of the starting characteristics should be made. This will require accurate data about the motor speed-torque and speed-current characteristics as well as the load characteristics. For further information, consult your supplier. Consideration must also be given to thermal overload and fuse protection systems when extended start times are involved. This must be as for heavy duty starting, as a standard thermal overload will trip under these conditions. A heavy-duty start thermal overload or an electronic overload with dual settings for start and run is recommended. Modern HRC motor fuses will allow for some overload during the start, but the fuse curve, giving time/current data, will give an indication of suitability for the particular application.

### ***FREQUENT STARTING***

High starting frequencies require careful consideration of the soft-start thermal capabilities. In many cases a standard sized Stellar® SR35 may be suitable as start times are generally shorter for this type of application. If this is not the case then a larger soft-start may be required.

### ***SOFT-STOPPING***

Soft-stopping can reduce positive surge pressures in pipelines on shutdown. It is necessary to make sure that the ramp-down time is long enough to remove the energy from the fluid before the firing of the thyristors is stopped, otherwise the surge pressure may still be present. Soft-stopping can also be successfully applied to loads such as conveyor belt systems where sensitive items such as bottles are being transported.

### ***REVERSING CONFIGURATION***

Stellar® SR35 soft-starters used in conjunction with contactor controlled reversing and plug-braked motors show considerable benefits to the user by reducing mechanical and electrical stresses, particularly when utilizing the current limited start feature. It is required, with this type of application, to insert a 150 to 350 millisecond delay between the opening of one contactor and the closing of the other, to allow any residual flux in the rotor to die away.

### ***REPLACEMENT OF FLUID COUPLINGS***

Soft-starters can replace fluid couplings yielding benefits of higher efficiency running and lower costs to the user. If the coupling is used to magnify the available breakaway torque, it may be necessary to replace the fitted motor with another of a larger size or one with a high starting torque characteristic before a soft-start can be employed.

**TWO-SPEED MOTOR APPLICATIONS**

Two speed motors, whether Dahlander connected or with dual windings, can be soft started at each speed, provided that the start is initiated when the actual motor speed is less than the synchronous speed for the winding selected. This is particularly important when changing from high to low speeds.

Overhauling Loads

Certain applications can over-speed the motor as part of normal operation. Power flow is then from the motor to the supply. It is important that the optimizing is disabled during the over-speed condition and reinserted during normal conditions.

**APPLICATION TABLE**

The table on the following page shows many common motor applications that suit the Stellar® SR35 soft-starter. It lists typical breakaway torque requirements as a percentage of motor full-load torque (FLT). For the most satisfactory soft-start in a given application, the motor should have a full-voltage locked-rotor-torque (LRT) that is at least twice the breakaway torque (E.g. For a reciprocating compressor the FLT is normally in the region of 50% motor LRT). As a general rule, the higher the motor LRT is above the load breakaway torque, the greater the control over the starting process.

| Application   | Breakaway Torque (%FLT) | Remarks  |
|---|-------------------------|--|
| <b>Agitator</b>                                       | 35                      | –  |
| <b>Air compressor - rotary, unloaded start</b>        | 25–35                   | –  |
| <b>Air compressor - reciprocating, unloaded start</b> | 50–100                  | –  |
| <b>Air compressor - screw type, unloaded start</b>    | 30                      | Usually two-pole motor                           |
| <b>Ball mill</b>                                      | 30–50                   | Eccentric load, needs high starting torque motor |
| <b>Carding machine</b>                                | 100                     | Often high inertia                               |
| <b>Centrifuge</b>                                     | 50–90                   | Usually high inertia                             |
| <b>Centrifugal fan - dampers closed</b>               | 10–25                   | Usually high inertia                             |
| <b>Centrifugal fan - dampers open</b>                 | 10–25                   | Usually high inertia, very long ramp times       |
| <b>Centrifugal blower - valve closed</b>              | 25–35                   | –  |
| <b>Centrifugal blower - valve open</b>                | 30–40                   | Can have long ramp time                          |
| <b>Conveyor - horizontal, unloaded</b>                | 10–50                   | –  |
| <b>Conveyor - horizontal, loaded</b>                  | 100–150                 | –  |
| <b>Conveyor - vertical lifting, unloaded</b>          | 50–85                   | –  |
| <b>Conveyor - vertical lifting, loaded</b>            | 100–175                 | –  |
| <b>Conveyor - vertical lowering, unloaded</b>         | 10–40                   | –  |
| <b>Conveyor - vertical lowering, loaded</b>           | 10–25                   | –  |
| <b>Crusher (not rock) - unloaded</b>                  | 25–75                   | Can be high inertia                              |
| <b>Drilling machine - unloaded</b>                    | 10                      | –  |
| <b>Fan, axial-flow propeller</b>                      | 20–40                   | –  |
| <b>Feeder - screw</b>                                 | 100–175                 | Needs high starting torque motor                 |
| <b>Feeder - vibrating, motor driven</b>               | 100–150                 | Needs high starting torque motor                 |
| <b>Grinder - unloaded</b>                             | 10–25                   | Usually high inertia                             |
| <b>Hammer mill</b>                                    | 20–125                  | Eccentric load, needs high starting torque motor |
| <b>Mills - flour etc.</b>                             | 30–50                   | –  |

| Application                                      | Breakaway Torque (%FLT) | Remarks   |
|--|-------------------------|---|
| <b>Mixer - dry contents</b>                      | 35–75                   | –   |
| <b>Mixer - fluid contents</b>                    | 10–40                   | –   |
| <b>Mixer - plastic contents</b>                  | 75–125                  | High torque motor offers advantage                |
| <b>Mixer - powder contents</b>                   | 75–125                  | High torque motor offers advantage                |
| <b>Pelletizers</b>                               | 50–100                  | –   |
| <b>Press, flywheel</b>                           | 50–150                  | Needs high starting torque motor                  |
| <b>Pump - centrifugal</b>                        | 10–25                   | Soft stopping useful                              |
| <b>Pump - positive displacement, piston type</b> | 100–175                 | Needs high starting torque motor                  |
| <b>Pump - vane type, positive displacement</b>   | 100–150                 | Needs high starting torque motor                  |
| <b>Rolling mill</b>                              | 30–50                   | –   |
| <b>Saw, band</b>                                 | 10–35                   | –   |
| <b>Saw, circular</b>                             | 25–50                   | May be high inertia; Plug brake may be useful     |
| <b>Screen, vibrating</b>                         | 30–60                   | –   |
| <b>Transformers, voltage regulators</b>          | Nil                     | Change firing mode                                |
| <b>Tumblers</b>                                  | 30–100                  | Can be eccentric load, may need high torque motor |
| <b>Rolling mill</b>                              | 30–50                   | –   |
| <b>Saw, band</b>                                 | 10–35                   | –   |
| <b>Saw, circular</b>                             | 25–50                   | May be high inertia; Plug brake may be useful     |
| <b>Screen, vibrating</b>                         | 30–60                   | –   |
| <b>Transformers, voltage regulators</b>          | Nil                     | Change firing mode                                |
| <b>Tumblers</b>                                  | 30–100                  | Can be eccentric load, may need high torque motor |

## CONCEPTS AND PRINCIPLES OF FIXED-SPEED INDUCTION MOTOR STARTING AND CONTROL

Since its invention one hundred years ago, the standard 3-phase induction motor has become one of the most familiar items of industrial equipment ever known. Due to its simplicity of construction, low cost, reliability and relatively high efficiency, it is likely to remain the prime source of mechanical energy for the foreseeable future.

### INTRODUCTION

Energy conversion, from the electrical supply to rotating mechanical energy, is a characteristic of all motors. To regulate energy flow, most motor circuits require a mechanism to connect and disconnect them from their electrical power source; electro-mechanical switches, known as ‘Contactors’, are the standard means of achieving this control. Even today, more than one hundred years after their introduction, contactor-based systems remain the most widely used method of motor control. Nevertheless, there is a definite trend towards more sophisticated electronic systems of control being applied to fixed-speed motor drives. This section will discuss these newest forms of control - namely, electronic, microprocessor-controlled, optimizing soft-starters such as Stellar® SR35.



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*NOTE: Since there is a wealth of detailed literature available in the technical press, it is not proposed to dwell too heavily on the specifics of realizing the electronic control system, but rather, to offer an outline of its various capabilities.*

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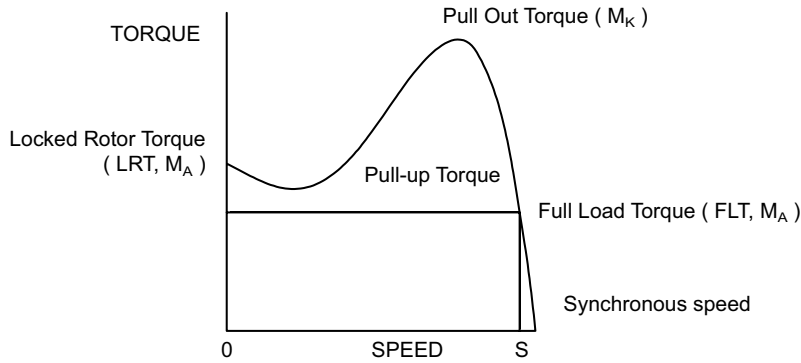
### THE INDUCTION MOTOR

In order to appreciate the benefits of using an electronic controller, it is important to have some understanding of the characteristics and limitations of the induction motor and the electro-mechanical systems currently used to control them. The standard, fixed-speed induction motor fulfills two basic requirements:

- To accelerate itself and its load to full speed (or speeds with multi-speed motors)
- To maintain the load at full speed efficiently and effectively over the full range of loadings

Due to the constraints of materials and design, it can be difficult to achieve both objectives effectively and economically in one machine. So, how does a motor start in the first place? As mentioned earlier, motors convert electrical energy drawn from the power supply into a mechanical form, usually as a shaft rotating at a speed fixed by the frequency of the supply. The power available from the shaft is equal to the torque (moment) multiplied by the shaft speed (rpm). From an initial value at standstill, the torque alters, up or down, as the machine accelerates, reaching a peak at about two thirds full speed, finally to become zero at synchronous speed. This characteristic means that induction motors always run at slightly less than synchronous speed in order to develop power - the 'slip speed' and, hence the term asynchronous. The following graph is of an induction motor torque/speed curve and illustrates this most important characteristic:

**TORQUE/SPEED CURVE – INDUCTION MOTOR**

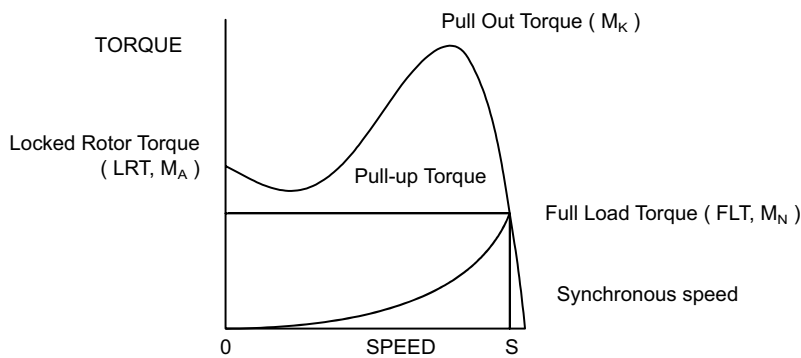


Torque/Speed Curve – Induction Motor

As for each type of motor, so each load coupled to an induction motor has its own speed/torque curve.

The acceleration of a motor-load system is caused by the difference between the developed torque (motor) and the absorbed torque (load), and is shown by the shaded area in the next figure:

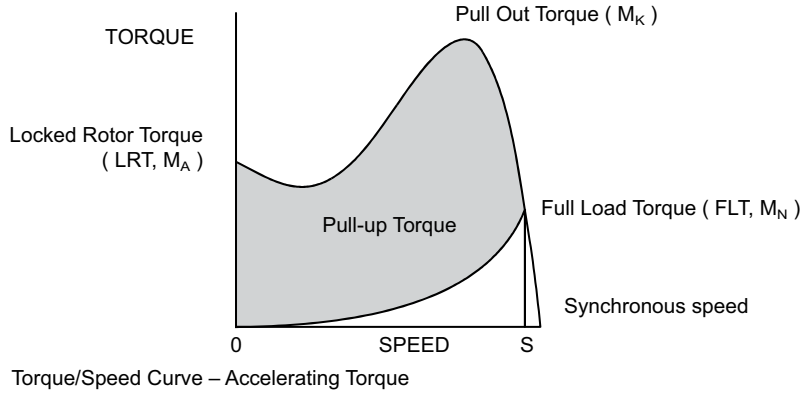
**TORQUE/SPEED CURVE – COUPLED LOAD**



Torque/Speed Curve – Coupled Load



**TORQUE/SPEED CURVE – ACCELERATING TORQUE**

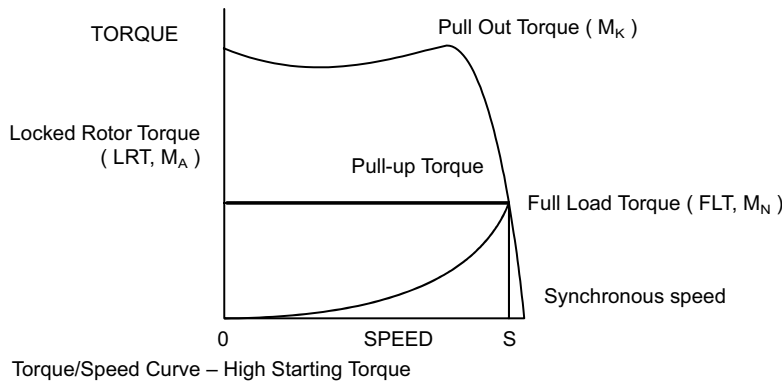


Obviously, the larger the difference, the faster the acceleration and the quicker full speed is reached - and, coincidentally, the greater the stresses experienced by the supply and drive systems during the acceleration process. An “ideal” start would accelerate the load with just sufficient force to reach full speed smoothly in a reasonable time, and with minimum stress to the supply and drive mechanisms.

Broadly speaking, the motor speed/torque characteristic is controlled by the rotor resistance - a motor with high rotor resistance can generate its peak torque (pull-out torque) at standstill giving the high break-away torque characteristic, which reduces steadily as the speed increases and becoming zero at synchronous speed. At the other end of the scale, a motor with a very low rotor resistance will produce a low starting torque but will generate its peak torque closer to the synchronous speed. Consequently, this type of motor runs at full power with higher operating efficiency and low slip speed. It is possible to combine the twin requirements of high starting torque and efficient full-speed operation within a single motor by techniques such as double-cage or deep bar design, and this, usually, is the motor characteristic chosen for lifting and hoisting applications.

However, most induction motors are designed to have a “standard” characteristic that provides a compromise between starting torque and operating efficiency. To summarize, an induction motor will only start and accelerate when it produces more torque than the connected load absorbs. This is true for all speeds - including standstill and full speed.

**TORQUE/SPEED CURVE – HIGH STARTING TORQUE**



## **STARTING INDUCTION MOTORS**

Starting a demagnetized induction motor from standstill is a demanding and complex process. At the instant of switching all the energy necessary to magnetize the motor, to provide the acceleration force, and to supply the kinetic energy of the rotor and load, must be present together with the energy to overcome the mechanical and electrical losses. To do so at full supply voltage places considerable stresses on the supply, the motor windings, and the iron cores of the stator and rotor. Excessive acceleration of a rotor when the mechanical load is small can produce torque oscillations in the shaft causing severe wear to transmissions, gears and drives. Excessive acceleration when the load inertia is high such as in centrifugal fans, causes belts to slip in the pulleys, producing rapid wear and early failure.

### **ELECTRO-MECHANICAL METHODS OF STARTING**

#### **METHOD A: DIRECT-ON-LINE**

The most simple means of controlling energy flow to an induction motor is to interrupt the power supply by a single, solenoid operated, 3-phase switch, known as a contactor. Very widely applied, the method is known variously as “direct-on-line”, “across-the-line”, “direct” etc., and is the usual form of control where low cost is the first, and most important consideration. As a result, it is most often used on small motor sizes (up to approx. - 22kW), or where the supply is strong enough to withstand the inrush and starting current surges without causing unacceptable voltage drops.

The harsh, damaging effects described earlier are all imposed by direct-on-line starting and, as a control method, it is the most destructive of equipment. Its simplicity and apparent low cost, although attractive at first sight, hide large cost penalties in the shape of increased maintenance, reduced transmission equipment life and higher risk of motor failure, particularly when frequent starting and stopping is needed.

In larger sized motors special strengthening is necessary, at higher cost, before they can be safely used with direct-on-line starting. However, the shortcomings of the direct-on-line starter have been recognized ever since motors have been used and alternative systems have been developed over the years to reduce the damaging effects of this form of control.

#### **METHOD B: STAR-DELTA AND OTHER REDUCED VOLTAGE STARTING SYSTEMS**

Reduced voltage starting makes use of the fact that motor torque is proportional to the square of the terminal voltage; the most familiar type of reduced-voltage starter is the star-delta starter. Consisting of three contactors and a time switch (which can be mechanical, pneumatic, electrical or electronic), the star-delta starter changes the motor winding configuration from an initial star connection to a delta as the motor accelerates. The change-over or transition point is controlled by the time switch and is usually arranged to be approximately at 80% of full speed. The effect of starting in star is to alter the voltage across each stator winding to 58% of normal. This reduces the starting torque to a third of locked rotor torque (LRT) with a consequent reduction in starting currents and acceleration forces.

Although an apparent improvement over the direct system, significant disadvantages still remain. The transfer from star to delta momentarily removes the motor from the supply. During this time the motor is under the mechanical influence of the rotating load and, at the instant of disconnection, current will still flow in the rotor bars due to the time delay necessary for the magnetic flux to die away.

Therefore, there is a residual flux “frozen” on the surface of the rotating rotor, which cuts the stator windings, generating a voltage whose frequency depends on the rotor speed. If the load inertia is small, such as in a pump, or if the friction is high, there could be a significant loss of speed during the time the supply is disconnected.

In this case, when the reconnection to delta is made, a large phase differential can exist between the supply and the rotor fluxes. This can give rise to very large current surges (as much or more than full-voltage locked rotor current), together with massive transient torque oscillations, which can peak at levels in the region of fifteen-times full-load torque. Although the effects described are only present for a very short period of time (about one fifth of a second), they are sources of great stress and damage to the whole drive system, and where frequent starting is necessary, invoke high maintenance costs. The current surges, in the form of a very high level short duration “spikes”, are an increasing problem in these days of computer control systems and other “sensitive” electronic equipment. The voltage disturbance on the supply is very difficult to filter out and can cause severe problems, especially when larger motors are involved.

There are methods of control, for example, the Wauchope starter, which eliminate or reduce the reconnection transients. However, such starters are expensive and have reliability implications; for these reasons they are not widely applied.

The star-delta starter also has disadvantages due to the restricted starting torque available (if you need 40% LRT to break-away, you can only increase the motor size, or revert to direct-on-line). Combined with the severe effects of the re-switching surges, and the additional costs of bringing six conductors from the motor to the starter instead of only three, star-delta only offers an imperfect solution to the problem of starting the induction motor.

#### ***METHOD C: PRIMARY RESISTANCE STARTER***

It has long been recognized that the transition step in the star-delta system was a source of problems such as welded contactors, sheared drive shafts etc., and for many years a method of stepless control has been available in the form of the primary resistance starter. This type of controller inserts a resistance in one, or more often in each, of the phase connections to the stator at start-up, after which it is progressively reduced and shorted out at the end of the acceleration process. Frequently, the resistances are movable blades that are gradually inserted into an electrolyte liquid. The mechanism is usually large and expensive, both to purchase and to maintain, and considerable heat is created by the passage of current through the electrolyte resistor. This limits the starting frequency (because the electrolyte has to condense back to liquid before a new start can proceed), and these restrictions prevent this starter from being a popular option when selecting a control system. However, it has the distinction of being the smoothest and least stressful method of accelerating an induction motor and its load.

#### ***METHOD D: OTHER ELECTRO-MECHANICAL SYSTEMS***

Other control methods such as auto-transformer starting (popular in North America), primary reactance starting etc., are employed to a greater or lesser extent, to compensate for some of the disadvantages of each type of starter discussed. Nevertheless, the fundamental problems of electro-mechanical starters remain, and it is only in the last decade or two that their dominance has been challenged by the introduction of power semiconductors controlled by electronics.

#### ***THE SEMICONDUCTOR MOTOR CONTROLLER***

During the 1950's, much effort was put into the development of a four-layer transistor device which had the power to switch large currents at high voltages when triggered by a very small pulse of current. This device became known as the silicon controlled rectifier (SCR), or in Europe, the ‘Thyristor’; it is the basis on which all soft starting systems are built. The characteristic of most interest is the ability of the thyristor to switch rapidly (in about 5 millionths of a second) from “OFF” to “ON” when pulsed, and to remain “ON” until the current through the device falls to zero, - which conveniently, happens at the end of each half-cycle in alternating current supplies.

By controlling the switch-on point of a thyristor relative to the voltage zero crossing in each half

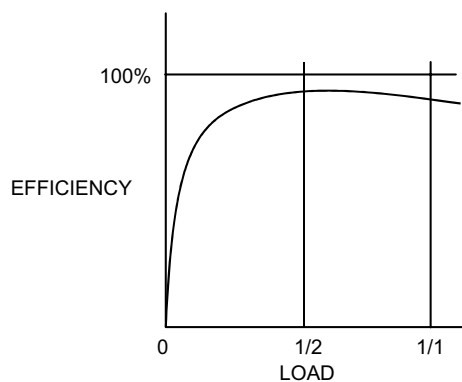
wave of an alternating current, it is possible to regulate the energy passing through the device. The closer the turn-on point is to the voltage zero crossing point, the longer the energy is allowed to flow during the half-cycle. Conversely, delaying the turn-on point reduces the time for the energy to flow. Putting two thyristors back-to-back (or anti-parallel) in each of the phase connections to a motor, and by precisely controlling their turn-on points, an electronic soft starter continuously adjusts the passage of energy from the supply so that it is just sufficient for the motor to perform satisfactorily.

So, for instance, by starting with a large delay to the turn on point in each half cycle, and progressively reducing it over a selected time period, the voltage applied to the motor starts from a relatively low value and increases to full voltage. Due to the motor torque being proportional to the square of the applied voltage, the starting torque follows the same pattern giving the characteristic smooth, stepless start of the soft-starter.

***RUNNING INDUCTION MOTORS***

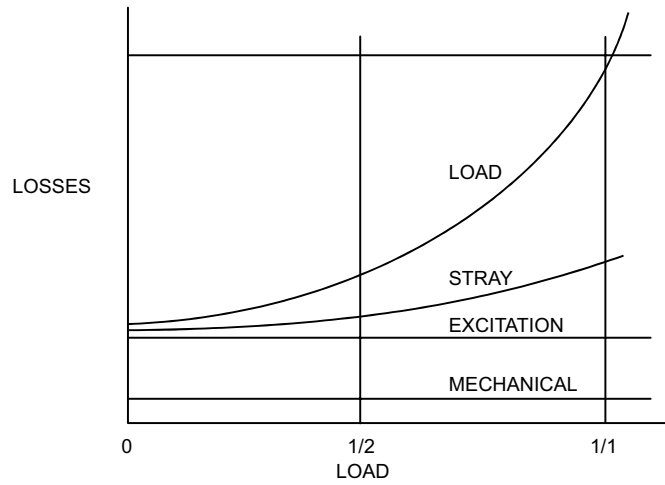
Once a start has been completed the motor operating efficiency becomes of interest. When working at or near full load, the typical 3-phase induction motor is relatively efficient, readily achieving efficiencies of 85% to 95%. However, as shown below, motor efficiency falls dramatically when the load falls to less than 50% of rated output.

In fact, very few motors actually experience consistent fully rated operation, the vast majority operate at much lower loads due to either over-sizing (a very frequent situation), or natural load variations. For Fan and Pumping applications, the affinity laws will allow the inverter drive to show very considerable energy savings over virtually all other methods of control through varying the speed of the motor in response to changes in load. Where motor speeds cannot be varied, an optimizing version of semiconductor motor controller, such as Stellar® SR35 will also produce energy savings in lightly loaded motors. Less sophisticated systems of soft-starter remain at full conduction and the motor then behaves as if it were connected directly to the mains supply. However, at light loads and mains voltages, induction motors always have excess magnetic flux, and efficiency loss and power factor degradation result. By detecting the load at any instant, and adjusting the motor terminal voltage accordingly, it is possible to save some of the excitation energy and load loss, and improve motor power factor when the motor is running inefficiently at light loads.



Motor Efficiency/Load Characteristic

All Stellar® SR35 soft-starters are microprocessor controlled, and this gives them a number of advantages. Firstly, there are no adjustments to be made for the energy saving function: all calculations necessary to find the best degree of phase-back of the thyristors for any load condition is made by the microprocessor. Secondly, the start always synchronizes with the supply voltage and a special structure of turn-on pulses virtually eliminates the inrush currents normally associated with motor start-up; this happens every time. Lastly, there is the absolutely stepless starting process, found only with the primary resistance or reactance electromechanical starters - but without the wasted energy, and with the opportunity to control the maximum current allowed to flow during the starting process. Other features such as soft stopping are included to give considerable control over all modes of induction motor operation.



Motor Efficiency/Loss Characteristic

**RELIABILITY CONSIDERATIONS**

An aspect of electronic controllers for induction motors which is of increasing concern is that of reliability. There is little point in installing an expensive item of electronic equipment to save potentially considerable amounts of money if the device is unreliable to the point that vital processes are constantly interrupted.

There are electronic products in the market place which appear to offer soft starting cheaply. They almost always rely on less advantageous technologies such as analogue control, or half-control, where one of the two thyristors in each phase is replaced with a diode. There are systems which only control the energy flow in one phase while the other two are directly connected. Owing to the variable quality and performance of many so-called inverters and soft-starters available to the unsuspecting purchaser, international standards for these products have been developed.

So far, IEC 60947-4-2 - 'AC Semiconductor Motor Controllers and Starters' defines the soft starter in every important respect, including thermal and overload performance as well as electromagnetic compatibility. By ensuring that any motor controller equipment purchased conforms to IEC 60947-4-2, a user should be reasonably safeguarded from shoddy or inadequate products when specifying equipment for future installations. A particular advantage of the use of the optimizing soft starter is its impact on the maintenance requirements of associated electro-mechanical equipment. Optimizing lowers the surface temperature of the motor by reducing the losses within the motor. This prolongs the motor life - and reduces heating of the surrounding atmosphere in the process. If the atmosphere is subject to air conditioning, reducing the heat input will reduce the air conditioning costs. Reduced starting and running currents reduces cable losses and, contactor switching operations are carried out under the most advantageous conditions. No current flows on switch-on since all switching is carried out by the thyristors - virtually eliminating the need for contact replacement.

Indeed, there are a growing number of installations where contactors are no longer employed, being replaced by controllable circuit breakers or isolators instead.

In summary, electronic controllers for most fixed-speed applications are opening new ways of increasing the efficient operation of induction motors, as well as offering significant benefits in control. Intending users need to ensure themselves of the quality and performance of any products they expect to fit and this can be reasonably expected if compliance with the appropriate IEC standards is demanded.

## APPENDIX B GLOSSARY OF TERMS

Breakaway Torque: The minimum torque required to achieve rotor movement for the motor with its load.

Current Limit: The current at which the ramp is held. For the SR35, current limit is only active during start-up where it contributes to the motor control function. This feature is particularly useful when starting high-inertia loads that require an extended start-up period. (See also Overload Level.)

Direct-On-Line (DOL): The direct connection and disconnection of a motor from the AC main supply by means of a contactor or switch. Acceleration and operation is at full mains voltage only.

iERS: Intelligent Energy Recovery System. An advanced motor control technology proven to reduce the energy consumed in fixed speed motor applications. It matches the power consumption to the load required by intelligently monitoring and regulating energy consumption, voltage, current, and power factor during the motor starting and running stages. iERS automatically bypasses itself when it is not needed, and continues monitoring to re-engage itself as needed.

Inrush Current or Locked Rotor Current: The current that flows at the instant of connection of a motor to the power source. It is limited by the impedance presented by a de-energized motor and the applied voltage. Usually expressed as a multiple of motor full-load current.

Kick-start Voltage: The percentage of supply voltage applied before commencing ramp-up when a load has a high breakaway torque and the standard settings of pedestal voltage may not allow sufficient torque to be developed by the motor to cause acceleration.

Locked Rotor Current: Same as Inrush Current (defined above).

Overload Level: The level of current at which the controller overload begins to integrate. For the SR35, the overload detector is always active and provides protection against prolonged over-current operation.

Pedestal Voltage: The voltage that the unit applies to the motor at start-up. It is expressed as a percentage of the rated supply voltage.

Power Factor: The ratio, expressed as a trigonometric cosine, of the real power consumption to the apparent power consumption.

Top of Ramp (TOR): The unit achieves Top of Ramp (TOR) when it completes the start-up stage of motor control. (This occurs when the voltage applied to the motor first equals the main supply voltage.)

Soft-start: The regulation, by electronic means, of the supply voltage from an initial low value to full voltage during the starting process. This over-comes the inherent drawbacks of a switched supply. The motor torque is modified in proportion to the square of the voltage applied.

Trip: A trip occurs when the unit removes power to the motor because its operation equals the limit imposed by one of its self-protection features.