Motors | Automation | Energy | Transmission & Distribution | Coatings

Soft Starter

User's Guide

SOFT-STARTER APPLICATION GUIDE

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AUTHORS

This ‘Soft-Starter Guide’ was written by Rogério Ferraz, who was responsible for coordinating the guide and developing chapters 1, 4, 5, 6, 7, 8 and Annex II, as well as by Enivaldo C. do Nascimento, who helped develop chapter 4.

Chapters 2 and 3 and Annexes I and III were based on the WEG Variable Frequency Guide.

CONTENTS

1 INTRODUCTION

The need to accelerate, keep moving and stop machines is present in the development of our society.

In the past, solutions from animal power to water wheels, windmills and steam mills were used to try to obtain more comfort, greater safety and better results in performance.

***Figure 1.1**: Windmill*

The current stage of electric driven equipment development concentrates the results of an extensive period of testing and discoveries, in various areas of knowledge, to run increasingly sophisticated and demanding machines.

Today, Soft-Starters are well established alternatives for starting and stopping three-phase induction motors. Process and machine evolution has created an environment that allows for smooth, controlled starts with several features made available through digital controls.

Besides this, there is increasing consciousness about the need for conservation, which makes the Soft-Starter a piece of equipment in sync with the present energy scenario, contributing to rational installation use.

The Soft-Starter market is strongly represented by a Brazilian company whose name is synonymous with quality in all five continents, WEG.

This guide will surely be very useful to technicians, engineers and entrepreneurs who work with WEG to build a future in the global market.

1.1 MOTOR STARTING METHODS

As will be seen in chapter 2 (**Induction Motor Operation**), current and torque peaks are inherent to starts at full voltage in three-phase motors.

Frequently, there is a need to limit the current value drained from the power supply as to avoid:
1) Disruptions in the power supply or
2) Increases in the demand of electricity.

In the case of disruptions in the power supply, the objective is to reduce the voltage drop (or even its interruption). With regards to increases in demand, the objective is to meet the limits defined by power supply utility companies, since not complying with these limits is penalized with elevated charges.

Although a reduction in current always accompanies a torque reduction in the motor, this torque reduction is not always harmful. In fact, this is one of the aspects that needs to be carefully examined to reach the best sizing of the motor + starting system set.

1.2 TRADITIONAL MOTOR STARTING METHODS

Three-phase motor starting methods can be grouped in the following way:
1) Those in which the voltage applied to the motor is the full power supply voltage (direct on-line start)
2) Those in which the voltage applied to the motor is the full voltage, but the motor winding connection leads to a lower voltage in each winding (star-delta and series-parallel switching)
3) Those in which the voltage applied to the motor is actually reduced (auto transformer starters and Soft-Starters)

The items above are better explained in the following chapters.

1.2.1 Motor Starting with Gears

The basic objective of using gears during the acceleration of asynchronous motors is to allow for a start with practically no load and the shortest starting current time possible. This presents advantages in both the power supply and the motor.

Another point is that the motor is able to reach its maximum torque in a momentary deceleration process (during gear coupling), while in other methods this maximum torque is reached at full speed.

Maintenance needs and greater complexity of the mechanical set assembly are some of the restrictions to using gears.

1.2.2 Hydraulic Transmission

In a hydraulic assembly system, the energy is transferred by using a fluid to control a linear movement or an output shaft.

There are two main types of hydraulic transmissions:
1) Hydrokinetic (with hydraulic couplings), which use the kinetic energy of a fluid;
2) Hydrostatic, which use the pressure energy of a fluid.

1.2.3 Hydraulic Coupling

The working principle of a hydraulic coupling can be explained by comparing it to a pumping system. In the pumping system, a centrifugal oil pump is run by an electric motor. A turbine, whose shaft drives the machine, is run by the oil displaced by the pump.

Both parts share the same casing, with no mechanical connection between them and the energy is transmitted by the fluid (oil) between the parts.

From the very beginning of the motor motion, there is a tendency for the “moving part” (shaft that drives the machine) to move. When the torque transmitted to the shaft that drives the machine is the same as the frictional torque, the machine begins to accelerate.

This is a starting method that is historically associated with high inertia load starts, like mills or cranes.

The graph below illustrates the evolution of the torque on the output shaft of the coupling.

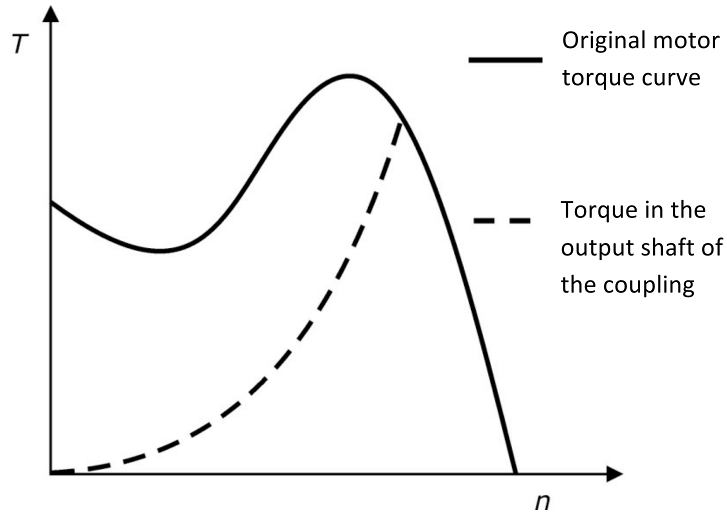


Figure 1.2*: A hydraulic coupling follows the principle of centrifugal machines. The torque transmitted to the output shaft is proportional to the square of the speed.*

Physically, the hydraulic coupling is installed between the motor and the machine.

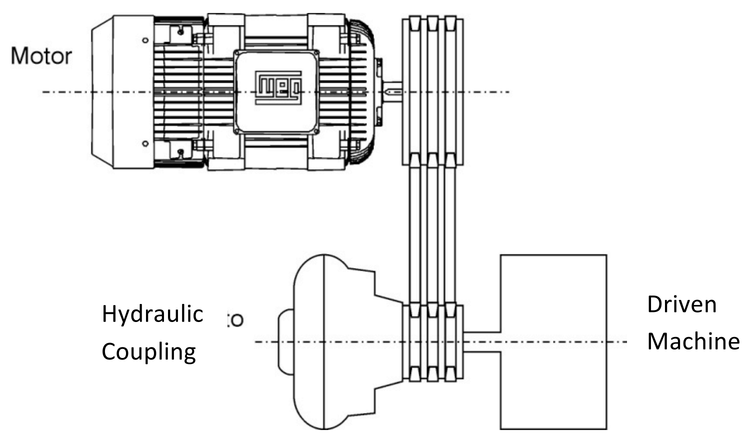


Figure 1.3*: Example of hydraulic coupling with pulley assembly*

The hydraulic coupling requires maintenance, to check the oil level and load, which can be a more or less difficult task, depending on its assembly (with pulleys, axial to the motor shaft, with reducers, etc).

Inadequate maintenance or oil leakage can damage the system.

1.2.4 Wound Rotor Motor

Wound rotor motors are defined by their ability to alter torque and current curves by inserting resistances that are outside the motor's rotor circuit.

STARTERS OF THREE-PHASE MOTORS WITH RING ROTOR AND RHEOSTAT

STARTING THREE-PHASE, WOUND ROTOR MOTORS WITH RHEOSTAT

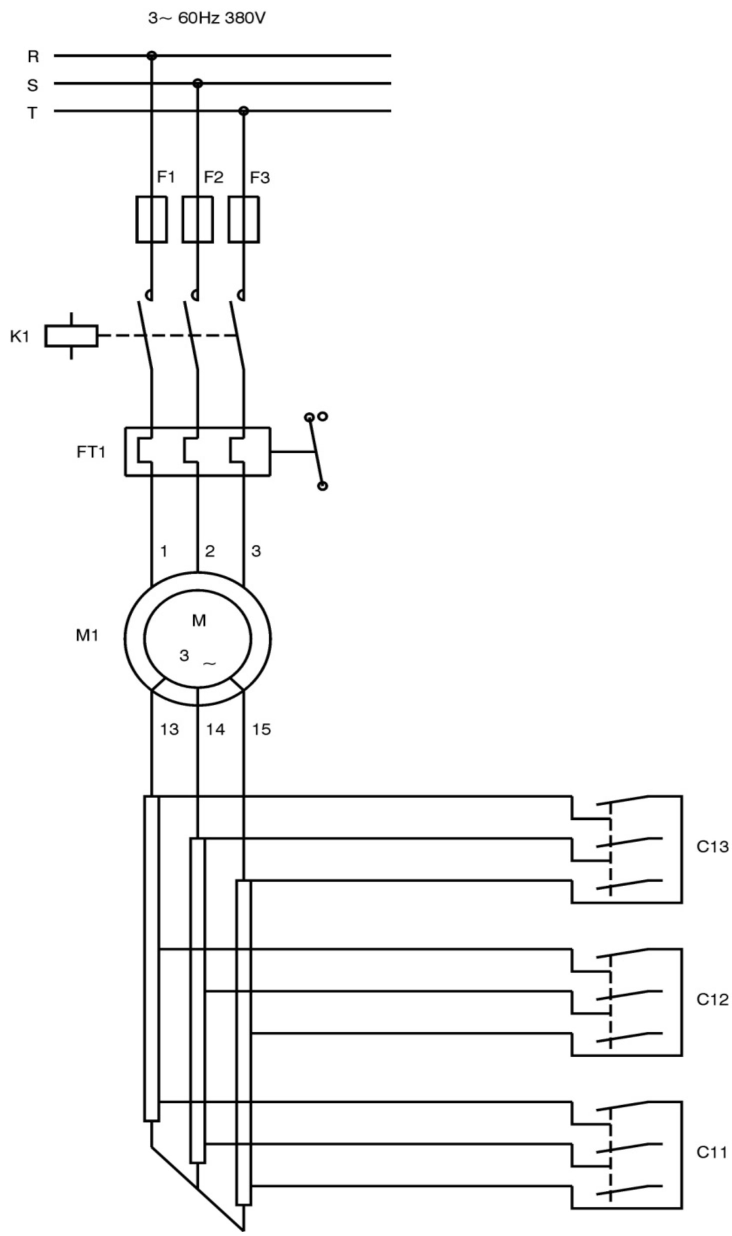


***Figure 1.4**: Example of a slip ring motor power circuit*

This motor curve alteration makes it very convenient to use a wound rotor motor to accelerate machines with high frictional torque at low rotations, as can be seen in the figure below:

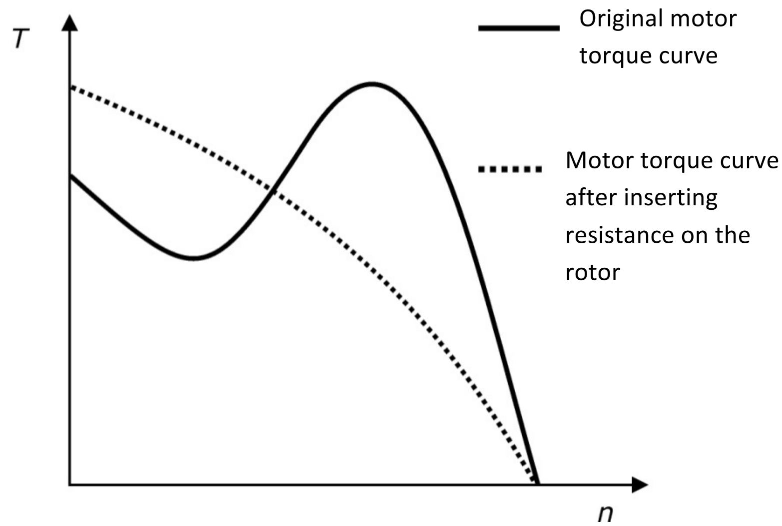


Figure 1.5*: Wound rotor motor start. Insertion of the appropriate resistors in the rotoric circuit takes the maximum motor torque to the very beginning of the start.*

Wound rotor motors have also been applied in machines that need speed variation and current reduction at the start.

However, the use of Variable Frequency Drives (VFDs) has narrowed the use of wound rotor motors to only very specific situations.

Pay special attention when sizing VFDs used for driving loads with high starting torques. The operation cycle and the demanded current must be analyzed for both Motor + VFD, for correct thermal sizing of the system.

1.2.5 Variable Frequency Drives as Starting Methods

Although the main function of a Variable Frequency Drive is that of speed variation, it is impossible to ignore its virtues with regards to machine starting and stopping.

In all starting methods, what is sought after are ways of dealing with starting overshoots (electrical and mechanical), to successfully reach stable system operation with the lowest disturbances possible.

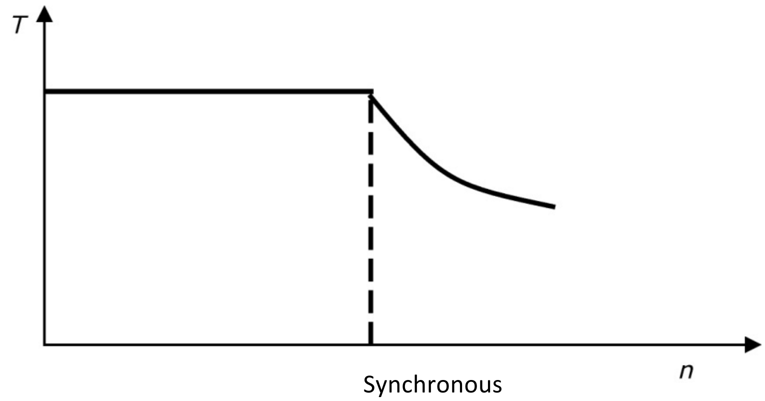


***Figure 1.6**: Torque - speed curve of a three-phase motor driven by a Vector Drive. As long as it is supplied with adequate ventilation, the three-phase motor driven by a VFD can apply its rated torque even at low speeds, for as long as is necessary.*

With a Variable Frequency Drive, these overshoots are practically eliminated, or at least greatly reduced.

For example, in loads with high inertia, the torque and the acceleration ramp can be adjusted to reach the smoothest acceleration possible. This happens because the Variable Frequency Drive “leads” the system from the beginning of acceleration.

When deceleration control is needed, with or without braking, the greatest number of alternatives are found through the VFD, with which it is possible to obtain smooth deceleration and stop of a pump, as well as a braking torque for lowering a load (overhead crane).

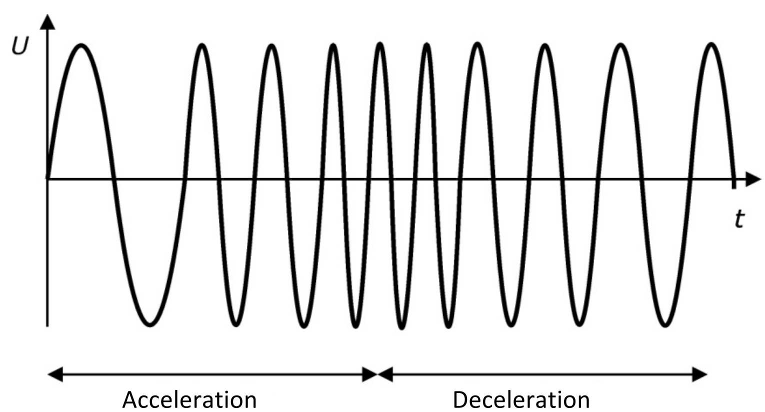


***Figure 1.7:** Phase fundamental at the VFD output during an acceleration process followed by a deceleration. With an adequate speed increase rate (acceleration ramp), along with new vector control technologies like Vectrue®, the starting overshoots can practically be eliminated in some applications.*

It is necessary, however, to state that each machine requires specific care when sizing the drive and any possible accessories (braking resistor, rectifier type, etc).

Figure 1.8: *CFW-09 Series Variable Frequency Drives. Low maintenance is one of the main differentiators of VFDs and Soft-Starters.*

2 HOW INDUCTION MOTORS WORK

To understand how a Soft-Starter or Variable Frequency Drive works, it is necessary to first understand how an induction motor works. To start, the basic physics principles of how electrical energy is converted to mechanical energy will be explained.

2.1 BASIC WORKING PRINCIPLES

A current circulating through a conductor produces a magnetic field, represented in figure 2.1 by the circular lines called magnetic induction lines. The conductor is located in the center of the figure and the circular lines around it are an illustration of the magnetic field generated by the current.

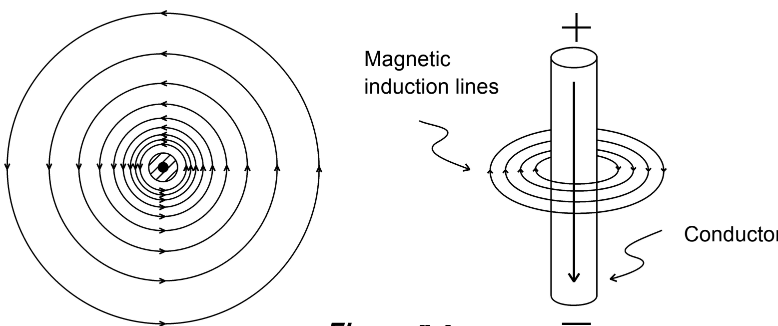


Figure 2.1

If a conductor is moved within a magnetic field, an induced voltage proportional to the number of induction lines cut per second (figure 2.2) will appear between the conductor terminals. If the mentioned conductor forms a closed circuit, an electrical current will circulate through it.

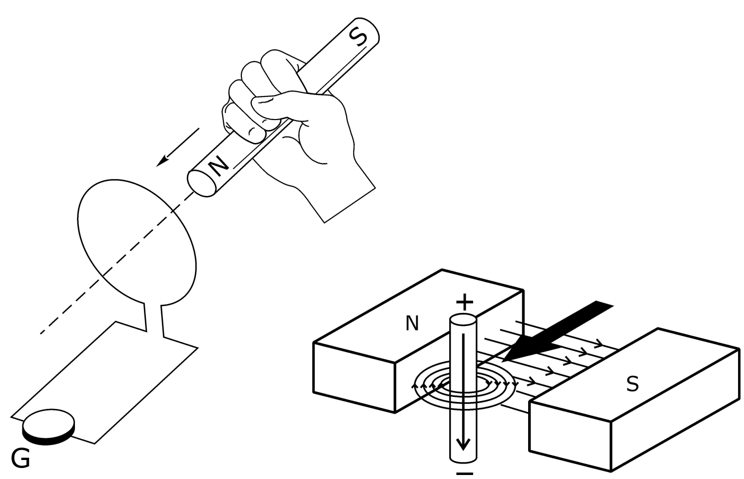


Figure 2.2

Two adjacent conductors (a and b), through which an electric current (i_a and i_b) circulates, each produce a magnetic field (Item 1). The interaction between these two magnetic fields will produce a force of attraction or repulsion (f) between the conductors (figure 2.3) proportional to the current that circulates through both conductors and the distance (d) between them.

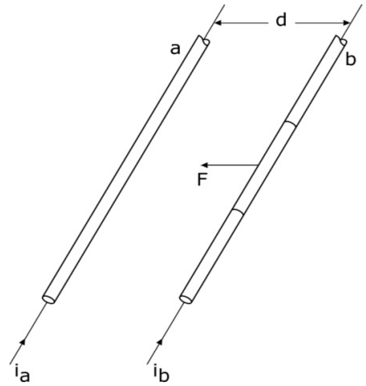


Figure 2.3

A multi-phase winding, like the one shown in figure 2.4, supplied by a three-phase voltage system (figure 2.5), will produce a rotating magnetic field (figure 2.6). This principle is similar to that seen in figure 2.1, but here the magnetic field is stationary.

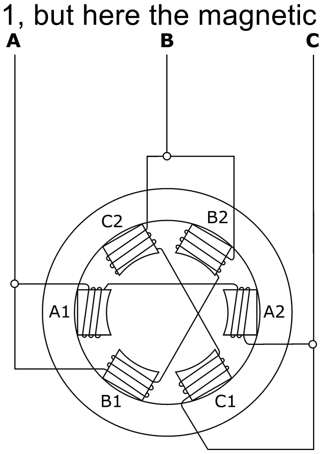
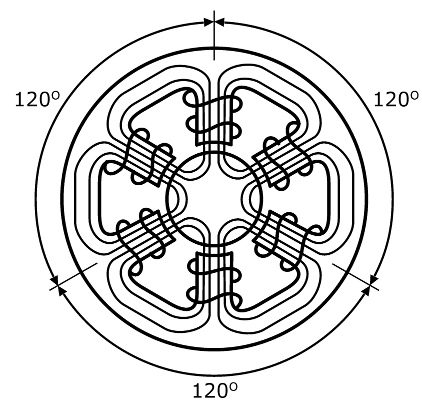


Figure 2.4



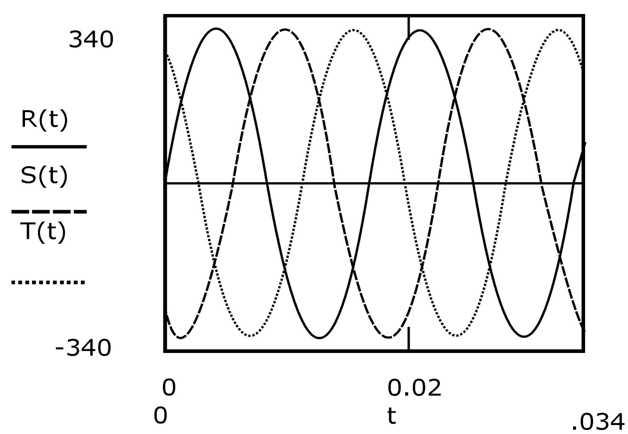


Figure 2.5

In figure 2.6, the points identified with numbers 1, 2, 3, 4, 5, 6, and 7 correspond to the moments when the voltage of one of the three phases is equal to zero. As such, it is easier to compose the magnetic induction vectors for each instant. The figure illustrates that the value resulting from these vectors is rotating (rotating field) with a speed that is proportional to the frequency and the number of motor poles.

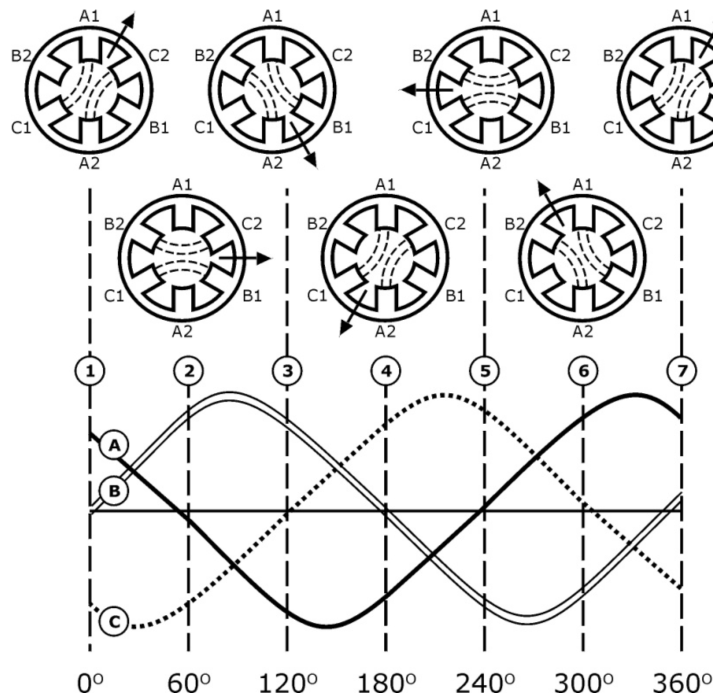


Figure 2.6

6. Torque: The torque (also called moment or binary) is the measurement of the effort needed to spin a shaft. It is known, through experience, that to lift weight in a process similar to that of water wells – see figure 2.7 – the force F that must be applied to the crank depends on the length of this crank. The longer the crank, the less force is needed. If the length of the crank is doubled, the necessary force F will decrease by half.

In figure 2.7, if the bucket weighs 20kgf and the diameter of the axle is 20cm, the rope will transmit a force of 20kgf on the surface of the axle, that is, at 0.1m (10cm) from the center of the axle.

To counterbalance this force, 10kgf is needed on the crank, if the length of “a” is 0.2m (20cm). If “a” is doubled, that is 0.4m (40cm), force F will be half, therefore 5kgf.

As can be seen, it is not enough to define the force used to measure the effort needed to spin the axle. It is also necessary to state the distance between the axle and the applied force. This “effort” is measured by the torque, which is a product of **F x a (the “force” by the “distance”)**.

In figure 2.7, the torque value is:

M = 20kgf x 0.1m = 10kgf x 0.2m = 5kgf x 0.4m = 2mkgf

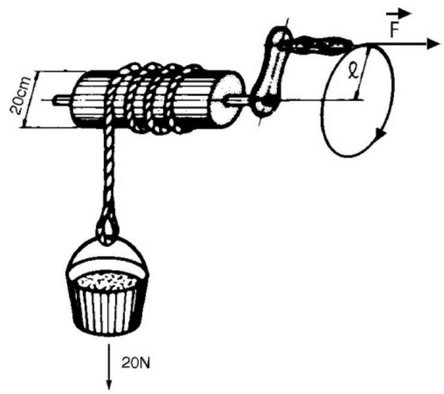
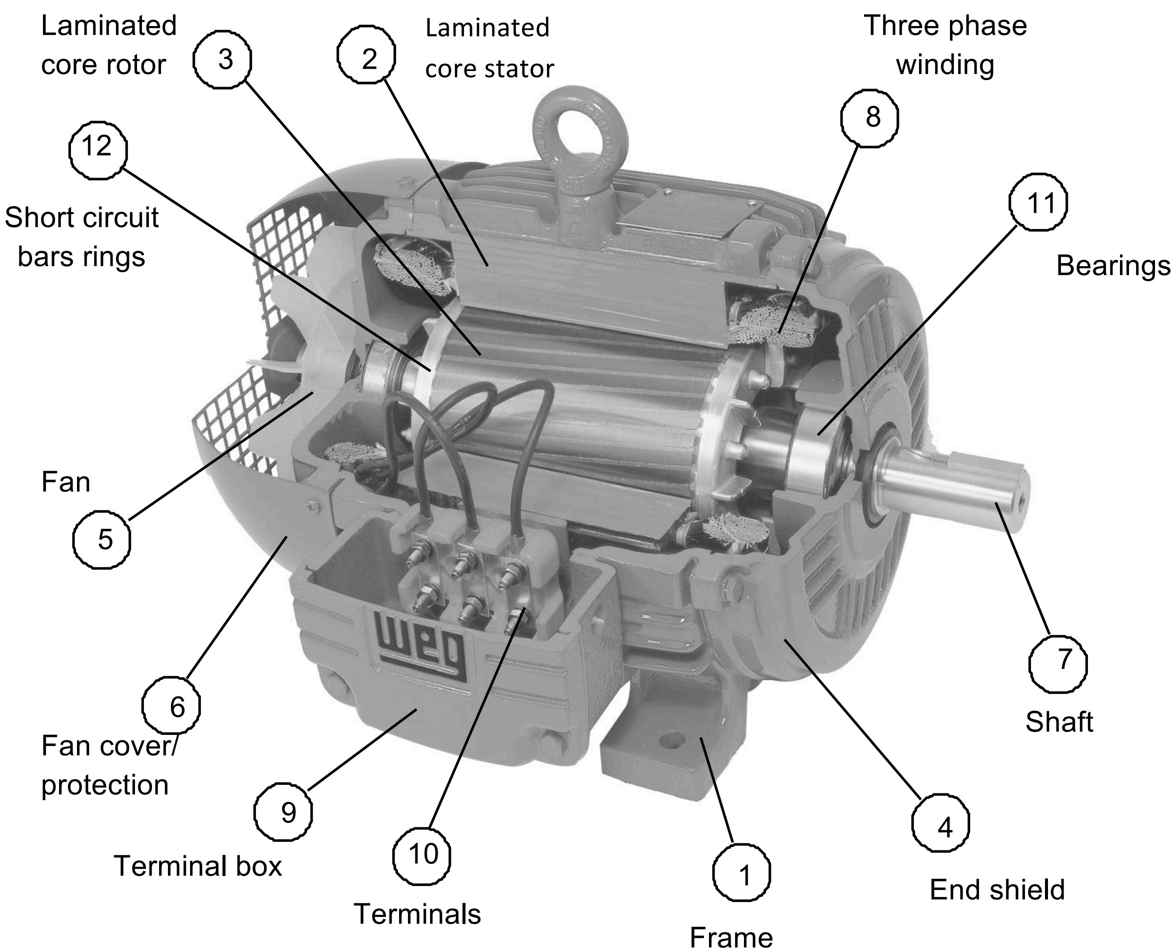


Figure 2.7

The most commonly used induction motors for industrial purposes are called three-phase squirrel cage motors (figure 2.8 – rotor and stator).



STATOR: Frame (1), laminated core stator (2), Three-phase winding (8)
ROTOR: Shaft (7), Laminated core rotor (3), Short circuit bars and rings (12)
OTHER PARTS: End shield (4), Fan (5), Fan cover/protection (6), Terminal box (9), Terminals (10) and Bearings (11).
In these motors, the rotor is manufactured with short circuited coils forming an actual cage. The stator is made up of three windings (three-phase winding), with pairs of poles in each phase.

2.2 OPERATIONAL ANALYSIS

An induction motor can be considered a transformer in an operational analysis, where the primary winding of the transformer is formed by the stator and the secondary winding by the rotor. The name "induction motor" comes from the fact that all the energy required by the rotor to generate torque is "induced" by the primary of the transformer (stator) and in the secondary (rotor). Since there are two magnetic fields, one in the stator and another in the rotor, a force will appear between the rotor and the stator that will make the rotor spin, as described in item 3. Only the rotor can move because it is mounted with bearings. This movement will make mechanical energy (torque) available in its shaft. To make this easier to understand, the study of how induction motors work will be divided into three hypothetical cases:

Case 1

First, a two pole motor with a "locked rotor" is considered, which means that the use of some type of mechanical device can keep the motor shaft (rotor) from spinning. In this condition, if a three-phase voltage with a frequency of 60Hz is applied to the stator windings terminals, a spinning magnetic field with a speed of 3600 rpm will be produced (item 5). The induction lines of this magnetic field will "cut" the rotor coils at maximum speed, inducing the maximum voltage in the rotor coils, and because they are in short circuit, the maximum current will also circulate through them. Since all the energy produced in the rotor must be "induced" by the stator, an elevated current will circulate in its winding (6 to 8 times greater than the rated motor current).

If this condition is maintained for more than a few seconds, the wires of the stator winding will overheat. This can damage (burn) the winding because it was not designed to support this greater current for an extended period of time.

Case 2

Now, another extreme will be presented. Suppose that the motor rotor can spin at exactly 3600 rpm. In this case, the induction lines of the rotational magnetic field produced in the stator "will not cut" the coils of the rotor because the two are spinning at the same speed. Therefore, there will be no induced voltage, no current and no magnetic field generation.

To produce mechanical energy (torque) in the motor, it is necessary to have two magnetic fields; otherwise, there will be no torque in the motor shaft.

Case 3

Now, suppose that, under the same conditions as Case 2, the speed of the motor rotor is reduced to 3550 rpm. The spinning magnetic field has a speed of 3600 rpm. The induction lines of the stator's spinning magnetic field will "cross" the coils of the rotor at a speed of 50 rpm, (3600 rpm – 3550 rpm = 50 rpm), producing a voltage and an induced current in the rotor. The interaction between the two magnetic fields that of the stator and rotor, will produce a force, which in turn will produce torque in the motor shaft.

The difference between the synchronous speed (3600 rpm) and the rotor speed is known as "slip".

Slip = synchronous speed – rotor speed

$$S = \frac{(Ns - N)}{Ns}$$

Now that these three conditions are described, it is possible to imagine what really happens to an induction motor.

Something similar to what is described in case 1 happens during the start. However, different than the locked rotor in case 1, this motor can spin freely. Therefore, an elevated current will circulate in the stator winding (6 to 8 times greater than the rated motor current), decreasing as the motor speed increases.

When the rotor speed comes closer to the synchronous speed (case 2), the torque that is produced will decrease, also decreasing the rotor speed. Then there will be a point of balance between the motor load and the rotor speed (case 3).

If the load on the motor shaft increases, the rotor speed will tend to decrease and the slip will increase. If the slip increases, the speed at which the induction lines of the rotor's magnetic field "cut" the stator increases, also increasing the induced voltage and current in the rotor. If the current is greater, the magnetic field generated will also be greater, thus increasing the available torque on the motor shaft, once again reaching equilibrium. If the torque required by the load is greater than the rated value of the motor, and if this condition is maintained for an extended period, the motor current will be greater than the rated value and the motor will be damaged.

2.3 CHARACTERISTIC CURVES OF INDUCTION MOTORS

2.3.1 Torque x Speed

This curve shows the relationship of the torque vs. the motor speed. During the start, when the motor is connected across the line, the locked rotor torque will be approximately 2 to 2.5 times its rated torque, decreasing as the speed increases until it reaches a value of 1.5 to 1.7 times the rated torque at approximately 30% the rated speed. As the speed increases, the torque increases, until it reaches the breakdown torque at 80% of the rated speed, decreasing until it reaches its rated torque at the rated speed. This can be seen by the torque curve in figure 2.9.

2.3.2 Current x Speed

This curve shows the relationship between the current consumed by the motor and its speed. The figure shows that during the start, when the motor is connected directly to the power supply, the current circulating through it is 5 to 6 times greater than the rated current, decreasing as the speed increases until it reaches a stationary value determined by the load coupled to the motor. If the load is rated the current will also be rated.

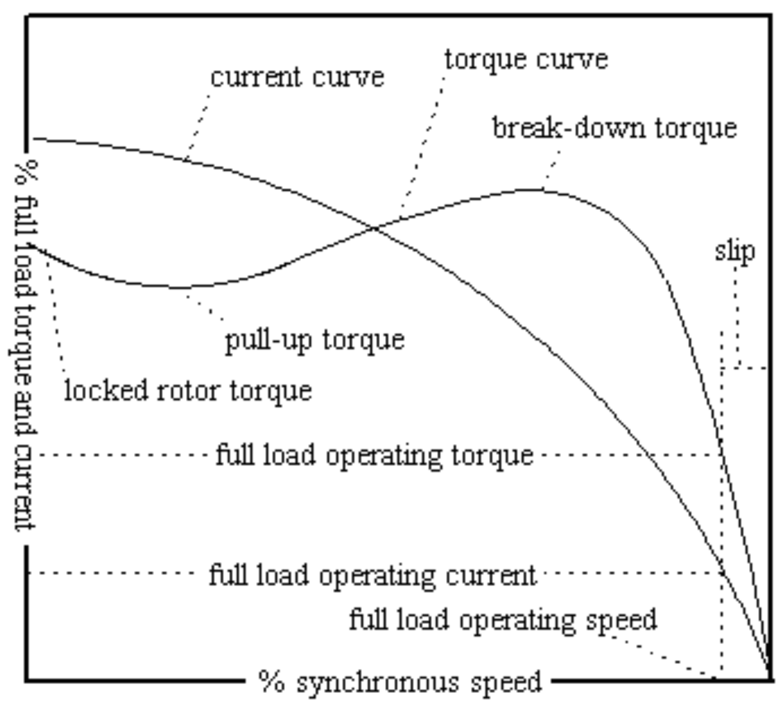


Figure 2.9: *Torque x Speed and Current x Speed curve for squirrel cage induction motors supplied with constant voltage and frequency*

2.4 POWER AND LOSSES

In the motor nameplate, there is a parameter called efficiency, which is identified by the Greek letter η. This parameter is a measure of the quantity of electrical power that is transformed by the motor into mechanical power. The power transmitted to the load by the motor shaft is lower than the electrical power absorbed from the power supply, due to losses in the motor. These losses can be classified into:

- Losses in the stator winding (losses in the copper);
- Losses in the rotor;
- Losses due to friction and ventilation;
- Magnetic losses in the nucleus (losses in the iron).

2.5 TEMPERATURE CHARACTERISTICS – THERMAL INSULATION CLASSES

Since an induction motor is a robust machine of simple construction, its lifetime depends almost exclusively on the lifetime of the winding insulation and the mechanical lifetime of the bearings. The lifetime of the insulation refers to its gradual wear, no longer withstanding the applied voltage and producing short circuits between the coils of the winding. For normative purposes, insulation materials and insulation systems (each one formed by the combination of various materials) are grouped into IISULATION CLASSES. These classes are defined by the respective temperature limit, that is, the greatest temperature that the material can continuously withstand without affecting the lifetime. The insulation classes used in electrical machines and their respective temperature limits according to norm NBR-7094, are shown in the table below:

Table 2.1 - Insulation classes

Class	Temperature
A	105
E	120
B	130
F	155
H	180

Classes B and F are the most commonly used.

The conventional motor insulation system, which has been successfully used in sinusoidal power supply (50/60Hz) may not comply with the necessary requirements if supplied by another type of wave form. This is the case in motors supplied by variable frequency drives. Currently, with generalized use of Variable Frequency Drives, there is a problem of insulation rupture caused by high voltage peaks, dV/dt and high switching frequencies due the PWM wave forms generated by the drive. This has made it necessary to implement improvements in the insulation of the wires and in the impregnation system, as to guarantee the lifetime of the motors. These motors with special insulation are called “Inverter Duty Motors”.

2.6 LOCKED ROTOR TIME

Locked rotor time is the time needed for the motor winding to reach its limit temperature when applied its rated current at normal operation conditions and room temperature at maximum value.

This time is a parameter that depends on the machine design. It is normally found in the catalog or in the manufacturer's data sheet. The table below shows the locked rotor temperature limits, according to NEMA and IEC norms.

Table 2.2 - Locked rotor temperature limits

Insulation Class	**Maximum Temperature**		**ΔT_{max} (ºC)**
	NEMA MG1.12.53	**IEC 79.7**	
B	175	185	800
F	200	210	100
H	225	235	125

For reduced voltage starts, the locked rotor time can be redefined as follows:

$t_{rb} = t_b \times (U_n / U_r)^2$ Where:

t_{rb} = Locked rotor time with reduced voltage
t_b = Locked rotor time with rated voltage
U_n = Rated voltage
U_r = Reduced voltage

Another way of redefining the locked rotor time is by using the current applied to the motor, as in the following:

$t_{rb} = t_b \, . \, (I_{pn} / I_{pc})^2$ Where:

t_{rb} = Locked rotor time with reduced current
t_b = Locked rotor time with rated current
I_{pn} = Direct on-line start current of the motor
I_{pc} = Motor starting current with reduced current

Generally, I_{pn} is obtained from catalogs and has a value of around 6 to 8 times the rated motor current, and I_{pc} depends on the motor starting method. If this start is star-delta, the value of the current will be approximately 1/3 that of the starting current.

3 COMMAND METHODS OF INDUCTION MOTORS

Induction motor command methods are implemented with electromechanical, electrical and electronic equipment. These kinds of equipment allow for the acceleration (starting) and deceleration (breaking) of motors, according to needs determined by the load, safety, electricity utility company, etc.

3.1 STARTING CATEGORIES

Three-phase squirrel cage induction motors are classified in categories, according to their characteristics of torque in relation to the starting current and speed. Each of these categories pertains to a type of load and is defined in norm NBR 7094. They are as follows:

a) Category N
This category includes most of the motors found in the market which are used for starting normal loads like pumps, tooling machines and fans.

b) Category H
Used for loads that require greater starting torque, like sieves, transporters, conveyers, loads with high inertia, crushing machines, etc.

c) Category D
Used in eccentric presses and other similar machines, where the load presents periodic peaks. Also used in elevators and loads that require very high starting torques and limited starting currents.

Table 3.1: *Characteristics of direct on-line start categories*

Starting Categories	Starting Torque	Starting Current	Slip
N	Normal	Normal	Low
H	High	Normal	Low
D	High	Normal	High

The torque x speed curves of the different categories are shown in figure 3.1.

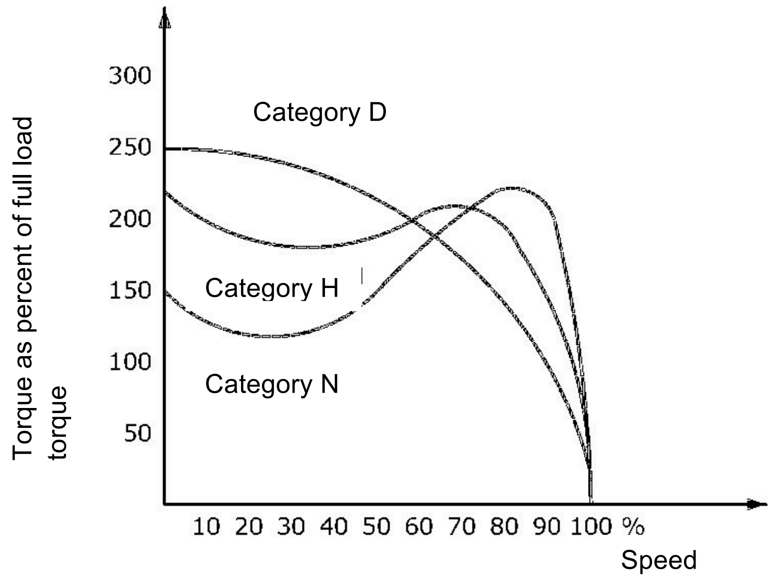


Figure 3.1: *Characteristic torque curves for each motor category (direct on-line start).*

3.2 STARTING METHODS

3.2.1 Direct On-Line Start

The easiest way to start and induction motor is called a direct on-line or across the line start. In this start, the motor is connected to the power supply directly through a contactor (see figure 3.2). However, it is important to note that for this type of start there are restrictions. As seen before, the starting current of an induction motor is 5 to 6 times greater than the rated current when directly connected to the power supply voltage. For this reason, and as a basic rule for large motors, a direct on-line start is not used.

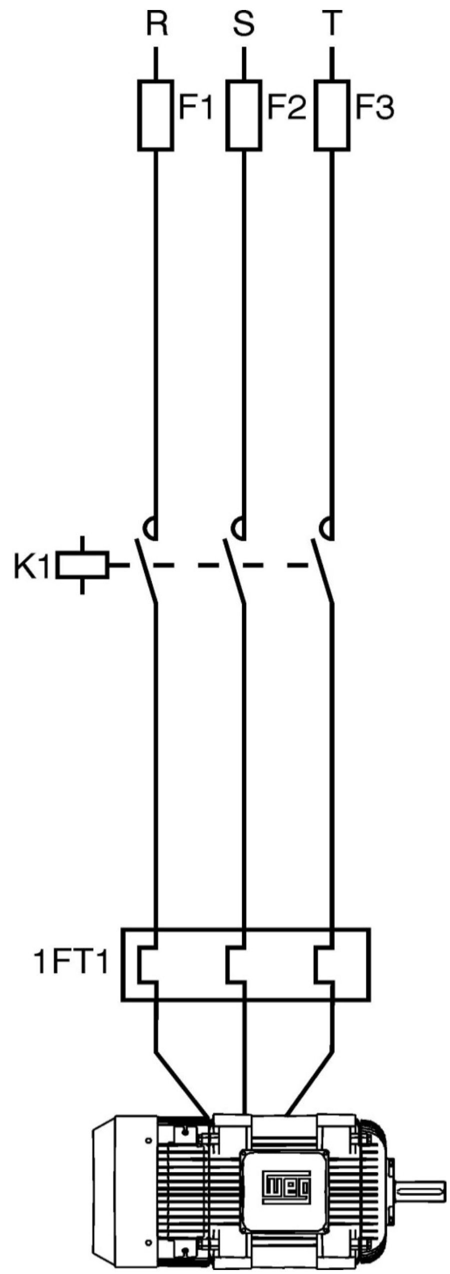


***Figure 3.2**: Direct on-line start*

3.2.2 Star-Delta Start (Y- Δ)

This type of start can only be used in motors with a six lead connection (for example 3 x 380 V and 3 x 220 V). The lower voltage must be equal to the power supply voltage and the other must be 1.73 times greater. This start is implemented with two contactors, as shown in figure 3.3. During the start, the motor is connected to the higher voltage, which allows a reduction of up to 1/3 the motor starting current, as seen in figure 3.4.

A star-delta start can be used when the motor torque curve is high enough to guarantee the acceleration of the machine with a reduced current, that is, the frictional torque of the load must not be greater than the motor torque when the motor is in star connection.

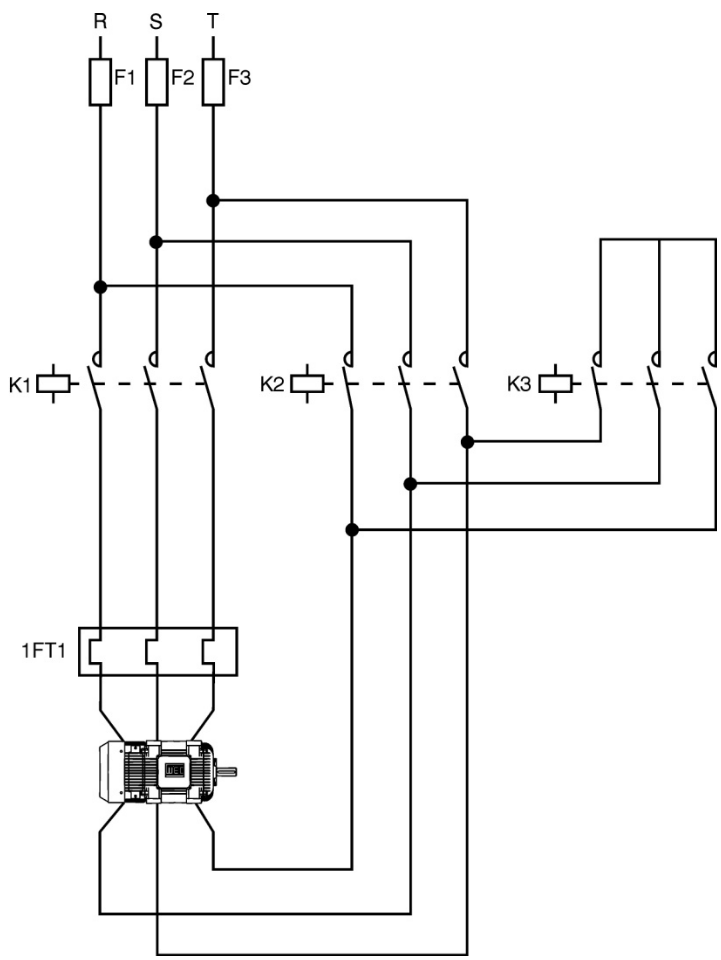


***Figure 3.3**: Star-delta start*

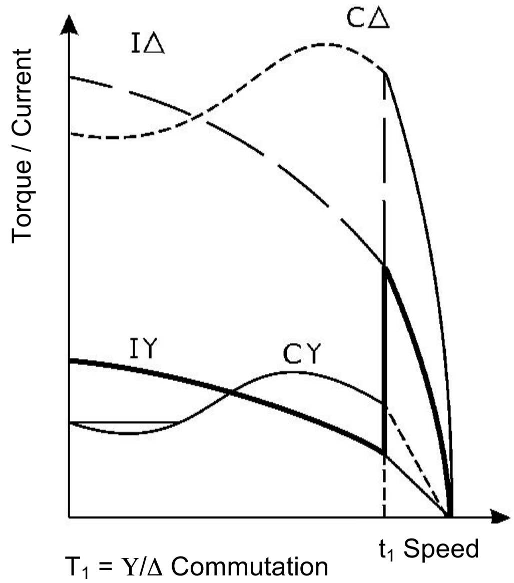


Figure 3.4*: Characteristic torque and current curve, motor with star-delta start*

3.2.3 Electronic Starter (Soft-Starter)

This will be explained in depth in the following chapter.

Besides the benefit of current control during the start, electronic switching also presents the advantage of not having moving parts.

Also, as an additional feature, the soft-starter allows for smooth deceleration of loads with low inertia.

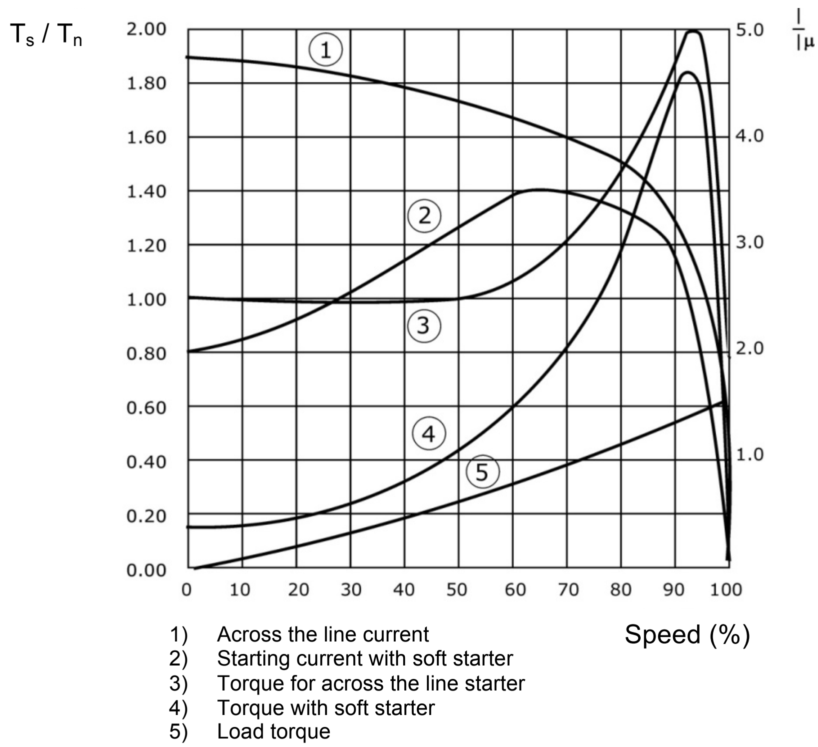


Figure 3.5: *Characteristic torque and current curve, motor with a smooth start (soft-starter).*

3.2.4 Series-Parallel Starter

This type of start must only be used in motors that can be connected in double voltage. The lower of the two voltages must be equal to the power supply voltage and the higher one must be double that value.

For example: 220V-440V and 380V-760V, or other power supply voltage values that follow this rule: 230V-460V, etc.

For this, the motor must have 9 to 12 connection terminals (leads), to allow for delta series-parallel connections (figures 3.6 and 3.7) or star series-parallel connections (figures 3.8 and 3.9).

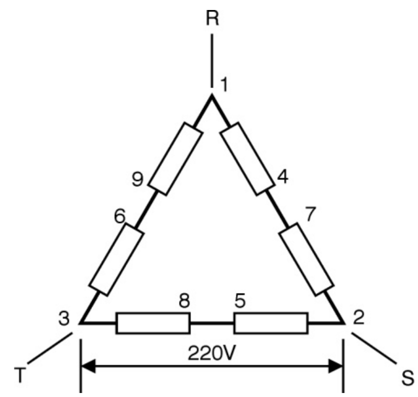


Figure 3.6: *Delta series connection: reduced voltage is applied as the “series-parallel” working principle.*

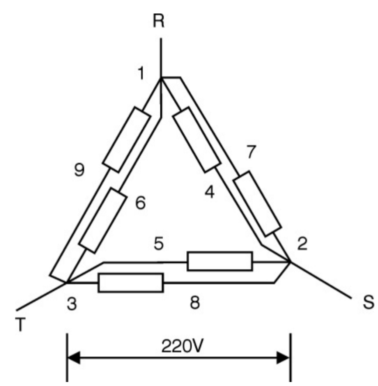


Figure 3.7: *Delta parallel connection: capable of receiving reduced voltage and actually applying reduced voltage; the motor develops its rated characteristics.*

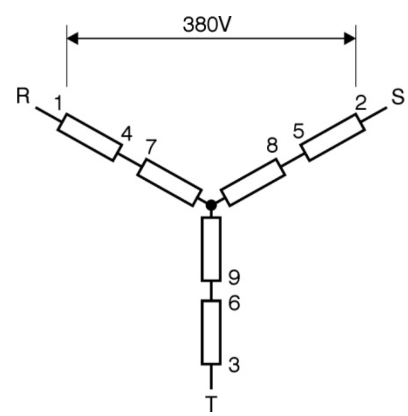


Figure 3.8: *Star series connection: reduced voltage is applied as the “series-parallel” working principle.*

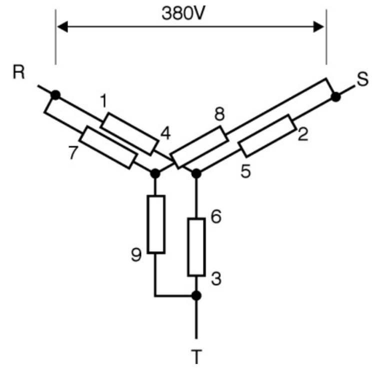


***Figure 3.9**: Star parallel connection: capable of receiving reduced voltage and actually applying reduced voltage. The motor develops its rated characteristics.*

At the starting moment, the current is reduced to 25 to 33% of the direct on-line current. The same happens to the torque, however, limiting the use of this starting method with no loads.

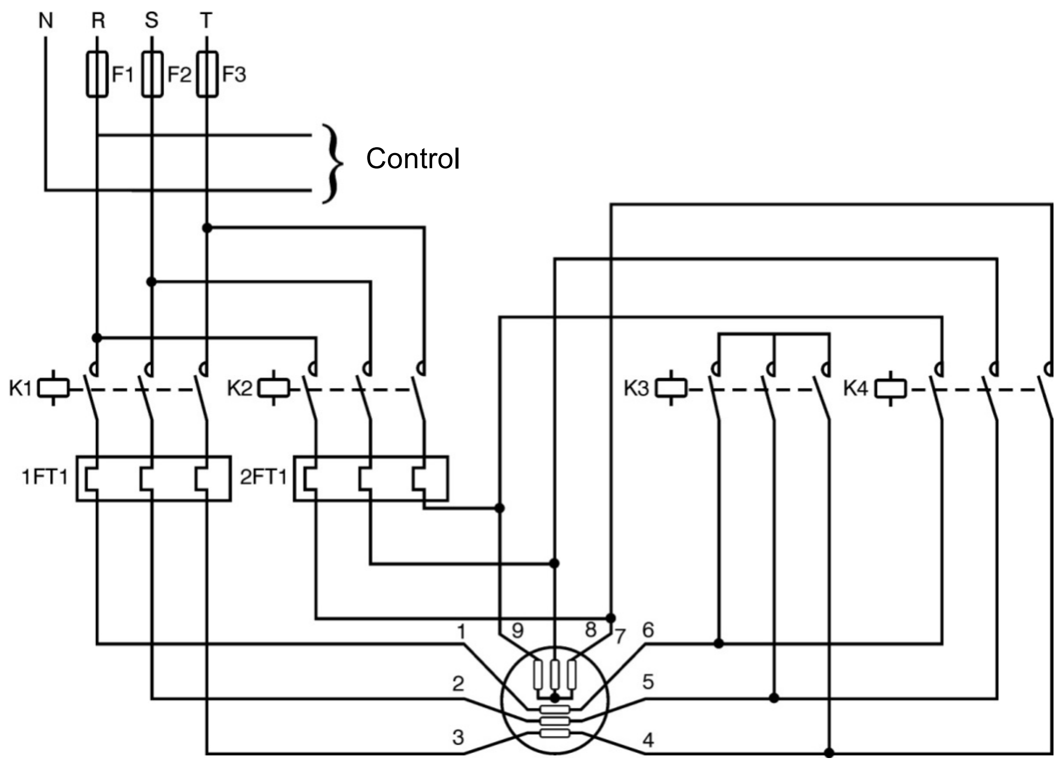


***Figure 3.10**: Series-parallel switch, using nine motor cables.*

3.2.5 Reduced Voltage Auto-Transformer Starter

This starting method supplies the motor with reduced voltage in its windings, during the start.

Voltage reduction in the windings (only during the start) is done by connecting an autotransformer in series with them. After the motor accelerates, the windings begin receiving rated voltage.

Current reduction depends on the TAP in which the transformer is connected.

TAP 65%: Reduction to 42% its direct on-line start value.

TAP 80%: Reduction to 64% its direct on-line start value.

A reduced voltage auto-transformer starter can be used for motors that start with a load. The frictional torque must be lower than the torque provided by the motor while starting with voltage reduced by the auto-transformer.

The motors can have a single voltage and just three available cables.

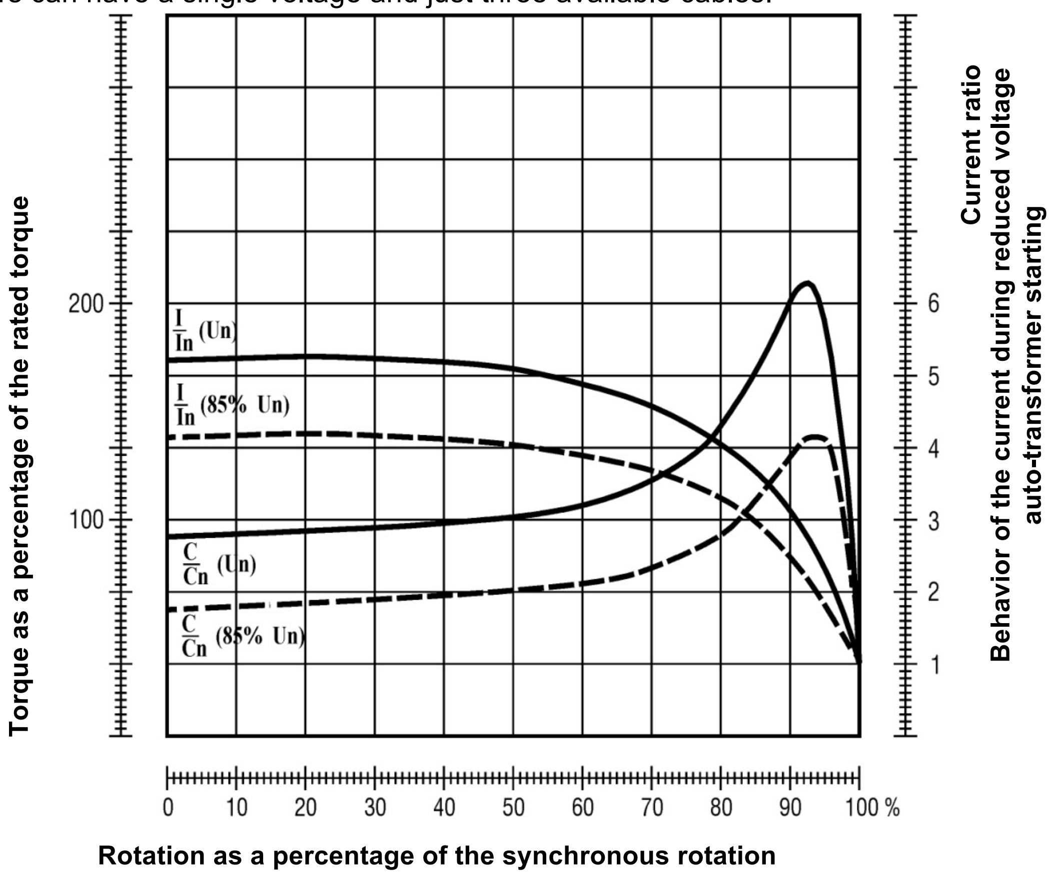


***Figure 3.11**: Characteristic curves of three-phase motors starting with a reduced voltage auto-transformer starter, TAP 85%*

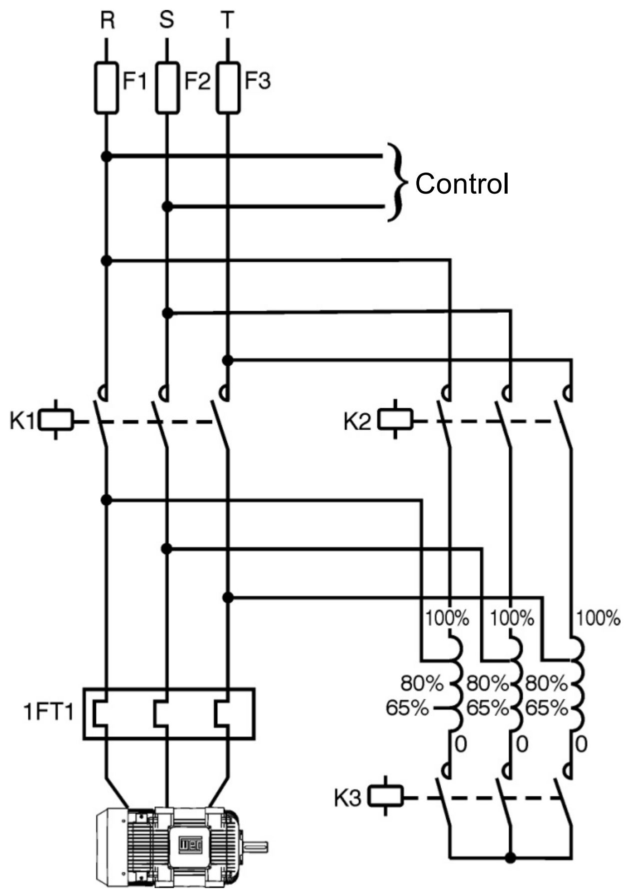


Figure 3.12: *Reduced voltage auto-transformer starter*

3.3 BRAKING

Induction motors have several forms of braking, that is, if s < 0. Below can be seen two electric braking methods.

3.3.1 Reverse Current Braking

Reverse current braking is obtained by inverting two phases of the power supply voltage of the stator winding (see figure 3.7), to reverse the rotational direction of the rotor's rotating field while it is still spinning in the initial direction. This way, the rotor rotation is now contrary to a torque that works in the opposite direction (see figure 3.6) and starts to decelerate (brake). When the speed drops to zero, the motor must be de-energized, otherwise, it will start operating in the opposite direction. For this type of braking, the induced currents produced in the rotoric windings are of high frequency (twice the stator frequency) and elevated intensity. This is due to the motor producing an elevated torque, where there is absorption of electricity from the power supply with a current greater than the rated value, causing the motor to overheat.

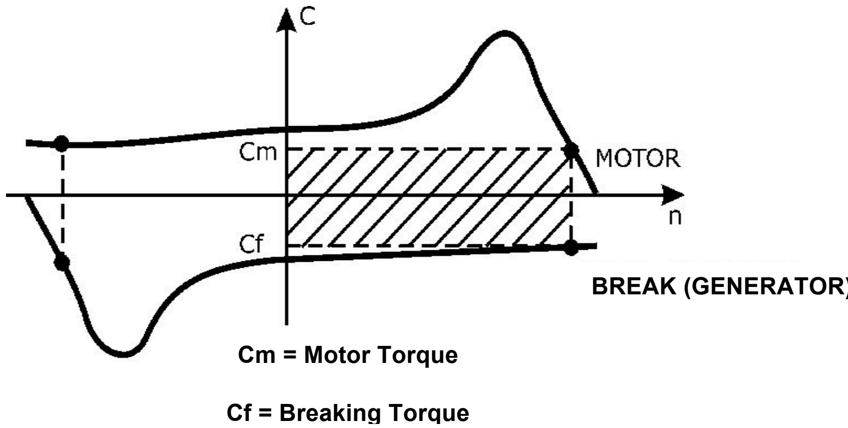


Figure 3.13: *Torque x speed curve in reverse current braking*

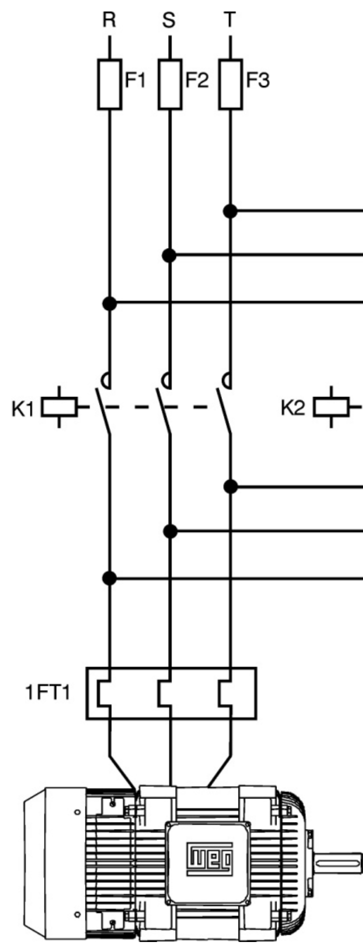


Figure 3.14*: Reverse current braking*

3.3.2 Direct current injection braking (DC Braking)

This is obtained by disconnecting the stator from the power supply and then connecting it to a DC source (see figure 3.9). The direct current sent to the stator winding establishes a stationary magnetic flux with a distribution curve showing a sinusoidal fundamental. The rotation of the rotor in its field produces a flux of alternating current in itself, which also establishes a stationary magnetic field with regards to the stator. Due to the interaction of the resulting magnetic field and the rotoric current, the motor develops a braking torque (see figure 3.8) with a magnitude that depends on the intensity of the field, the resistance of the rotoric circuit and the rotor speed.

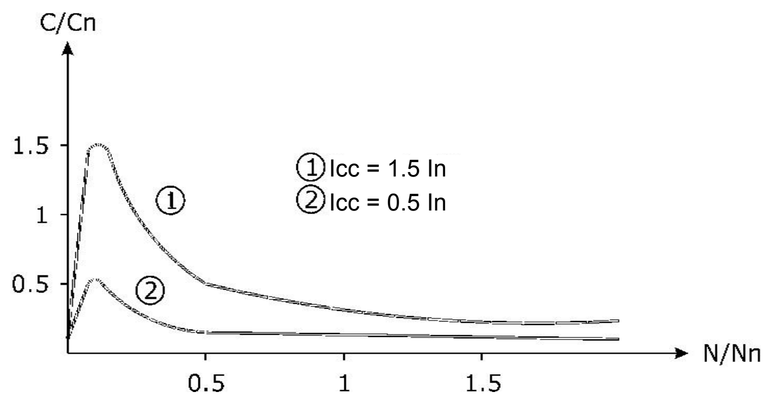


Figure 3.15: *Torque x rotation curve during DC braking*

In reality, DC braking has limited use due to the fact that all the braking energy is dissipated in the motor itself, which can cause it to overheat. Thus, DC braking is used with continuous voltages limited to approximately 20% of the rated AC voltage of the motor, so the motor lifetime is not jeopardized.

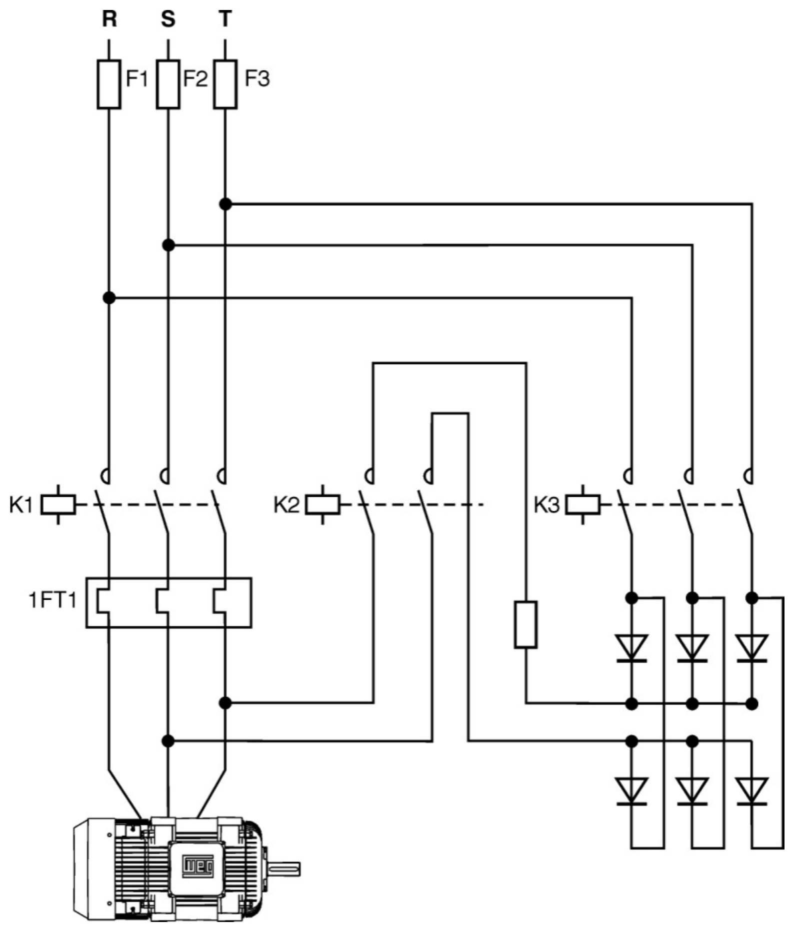


Figure 3.16: *Braking by DC injection*

3.4 ADVANTAGES AND DISADVANTAGES OF THE STARTING METHODS

3.4.1 Direct On-Line Start

Advantages

- Lowest cost of all
- Very simple to implement
- High starting torque

Disadvantages

- High starting current, causing a voltage drop in the power supply, which can cause interference in other equipment connected to the same installation
- Need to oversize cables and contactors
- Limitation in the number of starts/hour
- Torque peaks

3.4.2 Star-Delta Start

Advantages

- Reduced cost
- Starting current is reduced to 1/3 when compared to a direct on-line start
- No limitation in the number of starts/hour

Disadvantages

- Reduction in starting torque to approximately 1/3 the rated value
- Requires motors with six terminals
- If the motor does not reach at least 90% the rated speed, the current peak in the commutation from star to delta is equivalent to that of a direct on-line start
- High cost if the motor and the starting switch are very distant from each other, due to the need for six cables

3.4.3 Soft-Starter

Its advantages and disadvantages will be discussed in depth in the next chapter.

3.4.4 Series-Parallel Starter

Advantages

- Lower cost
- The starting current is reduced to ¼ when compared to a direct on-line start

Disadvantages

- Reduction in the starting torque to approximately ¼ the rated starting torque
- Motors with at least 9 terminals are needed (that is, winding connection possibility at a voltage equal to twice the power supply voltage)
- If the motor does not reach at least 90% the rated speed, the current peak during the connection commutation is equivalent to that of a direct on-line start
- Due to the need for nine cables, the installation cost increases if the motor and the starter are very distant from each other.

3.4.5 Reduced Voltage Auto-Transformer Starter

Advantages

- Capacity of starting with a load
- Possibility of adjusting the starting voltage, selecting (connecting) the transformer TAP
- Only three terminals need to be available in the motor
- When passing from reduced voltage to power supply voltage, the motor is not switched off and the second peak is greatly reduced

Disadvantages

- Size and weight of the autotransformer
- Limited number of starts per hour
- Additional cost of the autotransformer

3.5 MOTORS

3.5.1 General Information

Loads made up of electric motors present peculiarities that differentiate them from the rest.

a) The current absorbed during the start is much greater than that of regular operation with a load

b) The power absorbed in operation is determined by the shaft mechanical power that is required by the driven load, which can result in a power supply overload if the motor is not adequately protected

Due to these peculiarities, motor installation, besides the other instructions in this Norm, must meet the requirements listed below.

3.5.2 Limitation of Disturbances Caused by Motor Starts

To avoid unacceptable disturbances of the distribution power supply in the installation itself and in other loads connected to the motor installation, one must:

a) Observe the motor start limitations imposed by the local power supply company
NOTE: For direct on-line start of motors with powers exceeding 3.7kW (5CV), in installations fed by low voltage public distribution power supplies, the local power supply company must be consulted.

b) Limit the voltage drop in other loads, during the motor start, to the values defined in 6.2.6.1.
To meet the limitations described in items a) and b) above, <u>it may be necessary to use starting devices which limit the absorbed current during the start</u>.

> **NOTE!**
> In installations containing many motors, the probability of simultaneously starting several motors should be considered.

As can be observed in the text above, the reduction of motor starting currents is a requirement stipulated in norms.

There are various ways to reduce the starting current, and the following chapters will address the most effective way, presenting an excellent cost/benefit ratio for most applications: the SOFT-STARTER.

4 SOFT-STARTER

4.1 INTRODUCTION

To understand how a Soft-Starter works it is important to build a solid knowledge base, from which the equipment user can develop his/her product application capacity.

Special attention will be paid to the principle power component of the Soft-Starter: the SCR – *Silicon Controlled Rectifier*. Understanding SCR operation is crucial to understanding Soft-Starter operation. In the text below, a logical sequence will be used based on analogies with other phenomena and other components, thus allowing full understanding of the SCR.

4.1.1 Semiconductors and Electronic Components

Semi-conductor materials, like silicon, are elements with intermediate current conduction capacities. That is, the natural capacity of permitting electric current flux is intermediate when compared to that of actual conductors and that of insulating materials.

The way in which a semiconductor deals with electric loads depends on how impurities were added to its composition, a process called **doping**. There are two types of doping: P and N, each with complementary behavior in regards to the conduction of electric loads.

Example: a diode is an electronic component that has two different semiconductor parts, forming a P-N junction. The conductive properties only allow electric current flux in one direction on the diode, which is a situation defined as **directly polarized**. The same diode, if **inversely polarized**, acts as an insulator.

The conditions that influence the electric behavior of an electronic component vary with the level of voltage or current, the presence of an external electric signal, or even with visible or infrared light, etc.

4.1.2 Most Important Characteristic of Thyristors

Thyristors are components that exhibit a striking characteristic: in general, they do not return to their original state after the disappearance of what caused its change in state.

A simple comparison is the mechanical action of a light switch: when the switch is activated, it changes position and remains like this even after the cause of the movement disappears (that is, even after a person takes his/her hand off the switch). In comparison, a doorbell returns to its original position after the external stimulus ends.

Bipolar transistors and IGBTs also do not “lock” in a determined state after being stimulated by a current or voltage signal. For any input signal the transistor will exhibit a predictable behavior, according to its characteristic curve.

Back to Thyristors: they are semi-conductor components that tend to remain on, once turned on, and remain off, when turned off. A momentary event is capable of turning them on or off, and this is how they will remain, even if the event that caused the change of state is eliminated.
Before analyzing the thyristor itself, it is good to analyze its historic predecessor: the **gas discharge valve**.

4.1.3 Introduction to Gas Discharge Valves

A storm is a good opportunity to observe interesting electrical phenomena. Wind and rain cause the accumulation of static electricity charges between the clouds and the earth, as well as among the clouds themselves. The difference in charge manifests itself as high voltages, and when the electrical resistance of the air can no longer withstand these high voltages, current surges occur between the opposite poles of electric charges. This phenomenon is called lightning or atmospheric discharge.

Figure 4.1*: Atmospheric discharge*

Under normal conditions, air has a very high electrical resistance, generally treated as infinite. Its resistance decreases with the presence of water and/or dust, but is still good insulation for most situations. When a sufficiently high level of voltage is applied through a distance of air, its electrical properties are altered: electrons are yanked from their normal positions around the nucleus of their atoms and are released to make up an electric current. In this situation the air is considered to be ionized, being defined as plasma, and has a much lower electrical resistance than non-ionized air.

As the electric current moves through the air, energy is dissipated in the form of heat, which keeps the air in a plasma state. The low resistance of this state helps maintain lightning even after some reduction in the voltage. The lightning bolt remains until the voltage drops to below a level that is insufficient to maintain enough current to dissipate the heat. At the end of this process there is not enough heat to keep the air as plasma, which then goes back to normal and ceases to conduct current, allowing the voltage to increase again.

Observe how the air behaves in this cycle: when it is not conducting it remains as an insulator until the voltage passes a critical level. Then, once it changes state, it stays as a conductor until the voltage falls below a minimum level. This behavior, along with wind and rain, explains the existence of lighting as quick electrical discharges.

4.1.4 Thyratron

Behavior similar to that of the air with lightning can be observed in thyratron valves, the difference being that the valve can be triggered by a small signal.

A thyratron is basically a gas filled valve that can conduct current with a small control voltage applied between the grid and the cathode, and can be turned off by reducing the plate-cathode voltage.

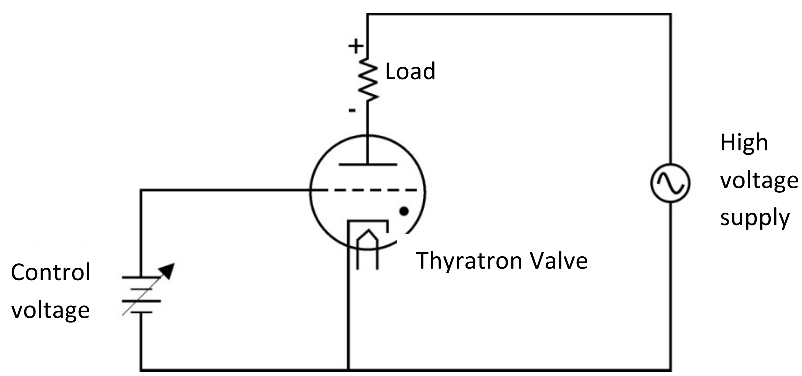


Figure 4.2*: Simplified thyratron control circuit*

In the circuit above, the thyratron valve permits current through the load in one direction (note the polarity through the resistive load) when triggered by the small DC control voltage connected between the grid and the cathode.

The “dot” inside the circuit of the illustration indicates that it is full of gas, contrary to the vacuum present in other valves.
Observe that the power supply of the load is alternating, which gives a hint as to how the thyratron is turned off after being triggered. Since the AC voltage passes through zero volts every half cycle, the current is interrupted periodically.

This quick interruption allows the valve to cool down and return to the “off” position. Current conduction can only proceed if there is enough voltage applied by the AC supply and if the DC control voltage allows it. An oscilloscope would indicate the voltage on the load according to figure 4.3.

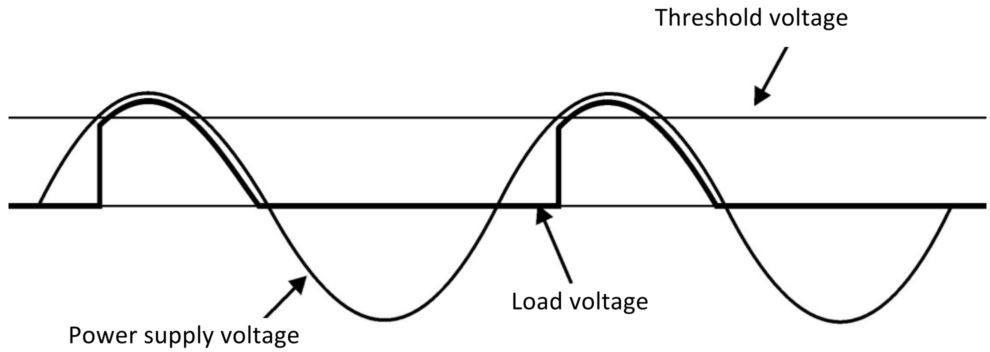


Figure 4.3

While the voltage supply increases, the voltage on the load remains zero until the threshold voltage is reached.

At this point the valve starts to conduct, according to the supply voltage until the next phase of the cycle. The valve remains “on”, even after the voltage is reduced to below the threshold voltage. Since thyratrons are one-way, there is no conductivity in the negative cycle. In practical circuits, several thyratrons could be arranged to form a complete wave rectifier.
Thyratrons became obsolete with the invention of thyristors. Today they are only used in very specific applications, due to their possibility of working with very high voltage and current values.

4.1.5 SCR (Silicon Controlled Rectifier)

Shown below are SCR representations:

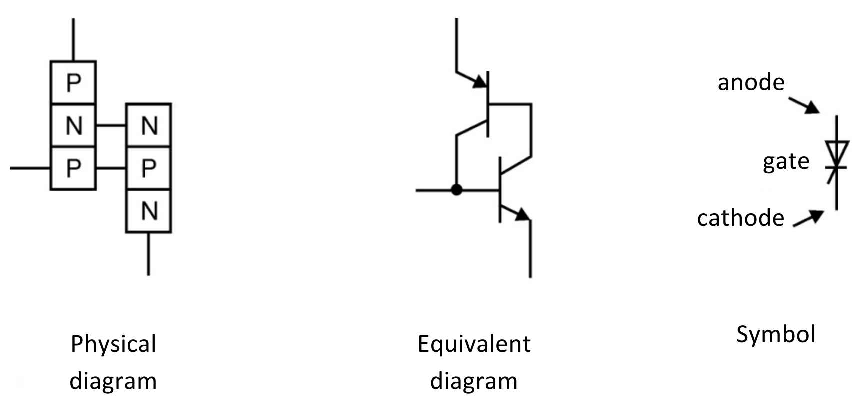


Figure 4.4

As seen above, the SCR is similar to two interconnected bipolar transistors, one PNP and the other NPN.

There are three ways to "trigger" it:

- By suddenly changing the voltage
- By passing the voltage limit
- By applying voltage between the gate and the cathode

The last way is actually the only applicable one. SCRs are normally chosen with a much higher breakover voltage value than is expected in the circuit.
A SCR test circuit is excellent for understanding its operation.

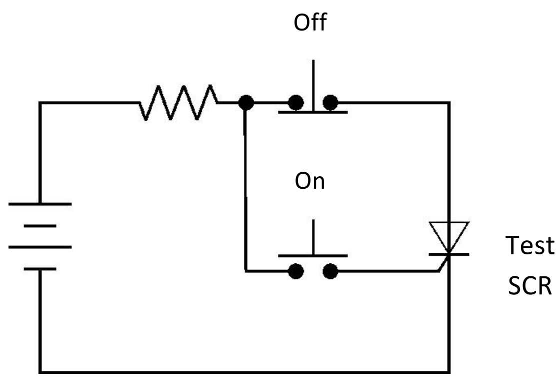


***Figure 4.5**: SCR test circuit*

A DC supply is used to energize the circuit, while two push buttons are used to "trigger" and to "de-energize" the SCR.

Pressing the "on" button (normally open) connects the gate to the anode, allowing current to flow from a battery terminal through the PN junction of the cathode-gate, by way of the button contact, through the resistive load and back to the other battery terminal.

This gate current must be enough for the SCR to be "sealed" in the "on" position because the SCR must keep conducting even after the button is released.

Pressing the "off" button (normally closed) cuts the current and forces the SCR to turn off.
If in this test the SCR does not "seal", the ohmic value of the load may be the problem. The SCR needs a minimum load current value to keep conducting.
Most SCR applications are AC controlled, even though SCRs are inherently DC (unidirectional).

If a bidirectional circuit is needed, several SCRs can be used (one or more in each direction) to deal with the current of both cycle phases, positive and negative.

The main reason for using an SCR in AC power circuits is its response to AC waves. It is a component that, after being stimulated, continues conducting (like its predecessor, the thyratron) until the load current passes through zero.

4.1.6 Understanding SCR Trigger

By connecting the correct control circuit to the SCR gate, the sine curve can be cut at any point as to control the energy delivered to the load.
The following circuit serves as an example:

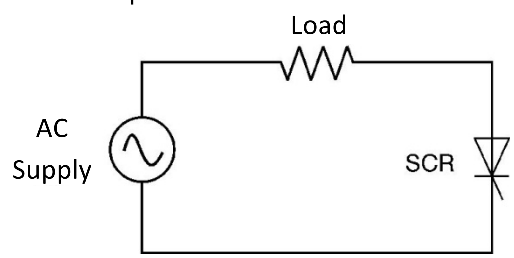


Figure 4.6: *AC Power supply, SCR and resistive load in series connection*

In the example above, an SCR is inserted in a circuit to control energy of an AC power supply fed to the load. Because it is unidirectional, half a wave can be delivered to the load, at the most. However, this circuit is used to demonstrate the basic control concept because is easier to understand than one controlling a whole sine curve, requiring two SCRs.

Without triggering the gate, and with the AC supply lower than the breakover value, the SCR will never start conducting.
Connecting the gate to the anode through a normal diode will almost immediately trigger the SCR at the beginning of any positive phase of the cycle.

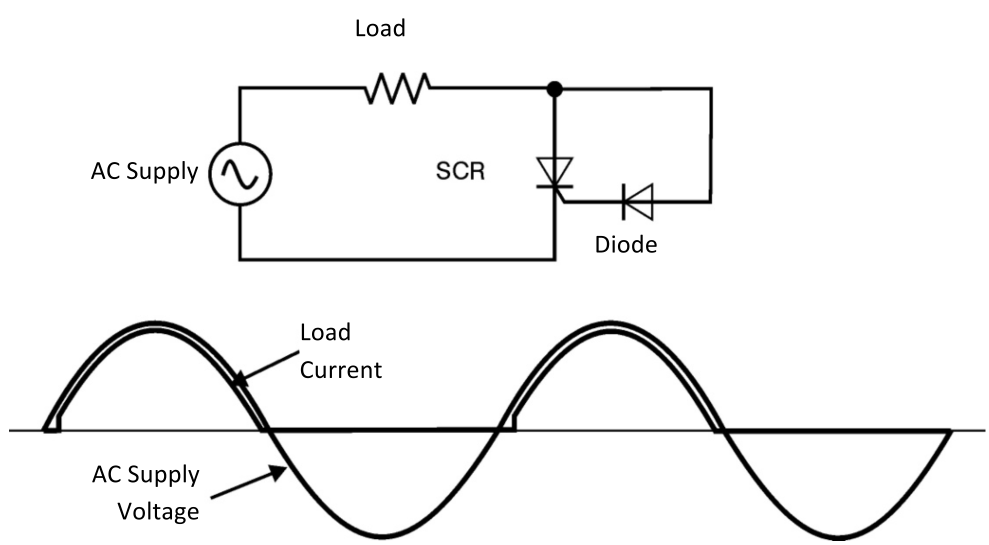


Figure 4.7: *Gate connected to the anode through a diode*

It is possible, however, to delay the trigger by inserting a resistance in the gate trigger circuit, thus incrementing the quantity of voltage needed for it. In other words, if it is more difficult for electrons to move through the gate, the AC voltage will need to reach a higher value for there to be enough current to start the SCR.

Result:

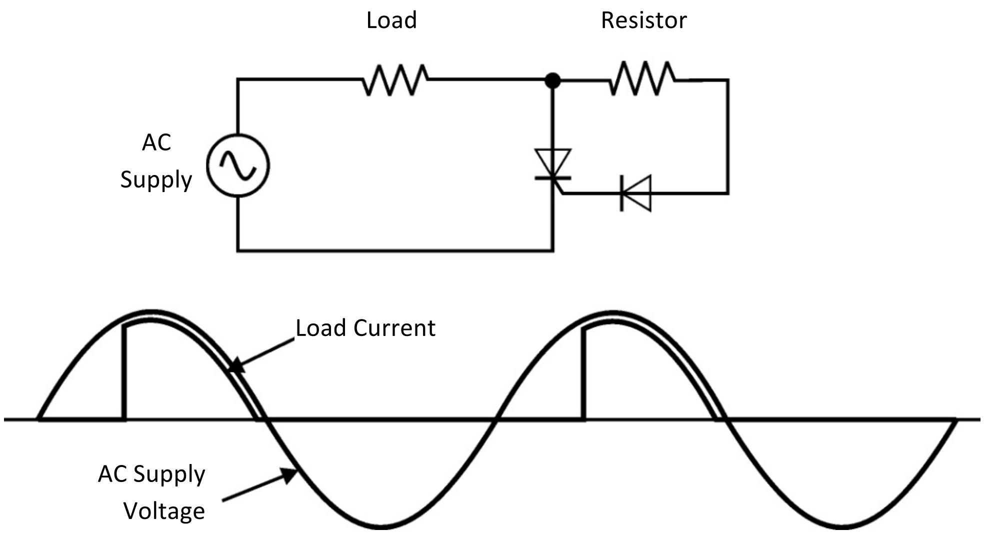


Figure 4.8: *Resistance inserted in the gate circuit*

With the half wave being cut at a higher level by the “late” SCR trigger, the load receives less energy because the load remains connected to the supply for a shorter period.
By making the gate resistor variable, adjustments to the supplied energy can be made:

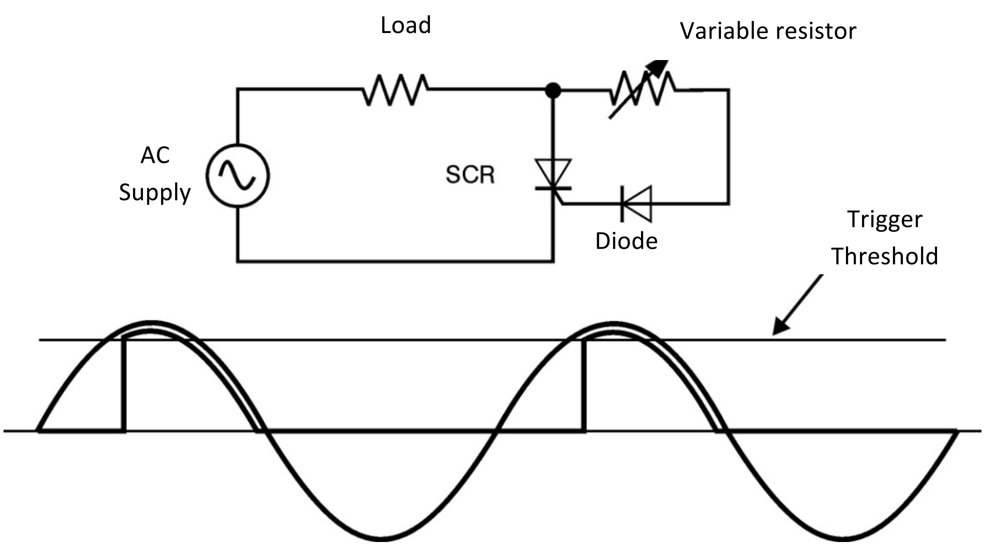


Figure 4.9: *By varying the resistance, the SCR trigger point varies (the greater the resistance, the greater the trigger point, or angle)*

Unfortunately, this control diagram is significantly limited. By using the AC supply to trigger the SCR, the control is limited to half the positive phase of the cycle, in other words, there is no way to delay the trigger to after the peak. This limits the minimum energy level to the energy obtained from the SCR trigger at the wave crest (at 90 degrees). Elevating the resistance to a higher value would not permit the circuit to ever trigger.
A solution to this is to add a phase shifting capacitor to the circuit.

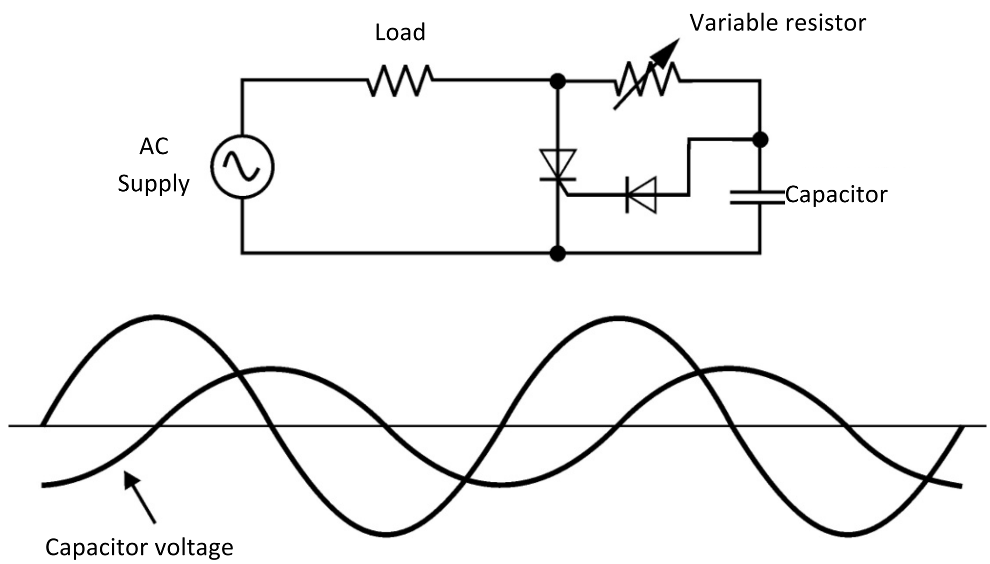


Figure 4.10*: The wave form with the lowest amplitude is the capacitor voltage*

To illustrate this, suppose that the control resistance is high, that is, the SCR is not triggering without a capacitor and there is no current through the load, except the small quantity of current through the capacitor and the resistor.
The capacitor voltage can be phase shift from 0 to 90° in relation to the AC supply. When this phase shift voltage reaches a high enough value, the SCR can be triggered.
Supposing that periodically there is enough voltage in the capacitor terminals to trigger the SCR, the resulting current wave form will be as follows:

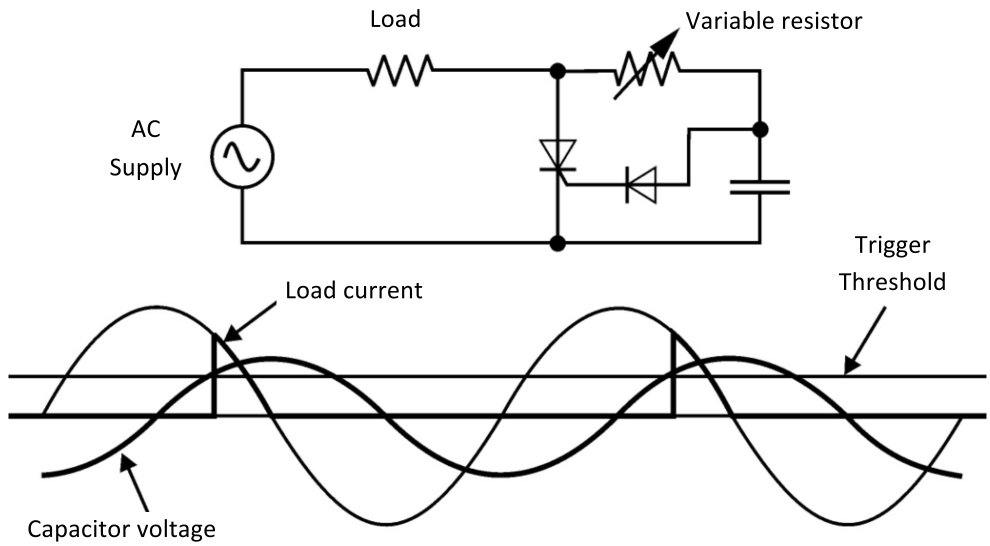


Figure 4.11*: The thyristor is fired after the maximum peak, due to the chosen capacitor*

If the capacitor wave form is still rising after the power supply sine curve peak, it is possible to trigger it after the peak; cutting the current wave and allowing less energy for the load.

SCRs can also be used by more complex circuits.
Pulse transformers are used to couple the trigger circuit to the SCR gate/cathode to provide electrical insulation between the trigger and power circuits:

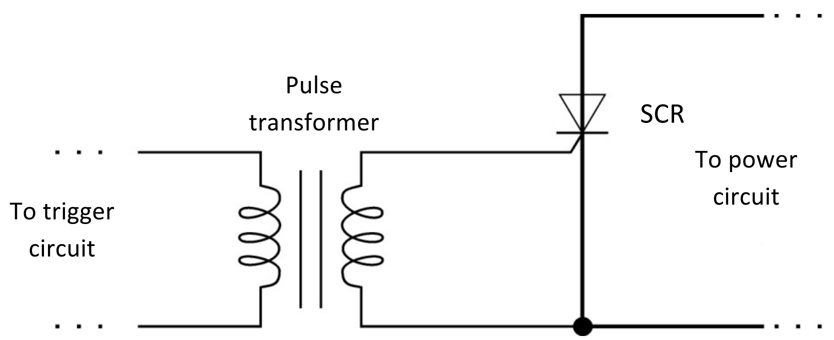


Figure 4.12*: Trigger with phase shifting transformer*

When multiple SCRs are used for power control, the cathodes are not electrically identical, making it difficult to use a single trigger circuit for all the SCRs.
An example of this is a controlled rectifying bridge:

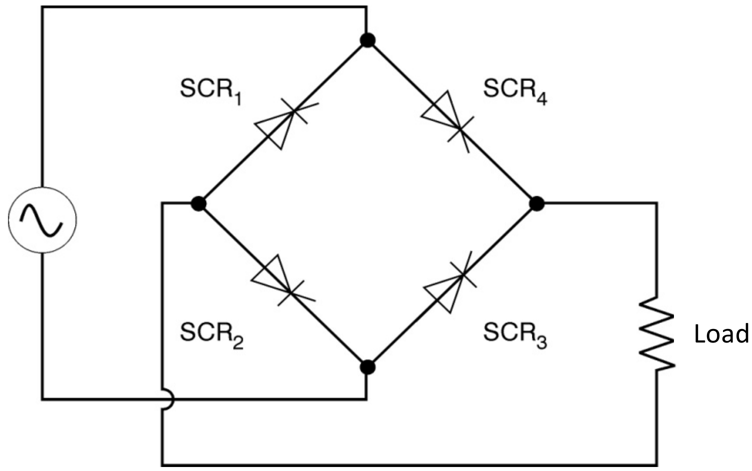


Figure 4.13: *Controlled rectifying bridge*

As in any rectifier, opposite elements must conduct simultaneously. SCR 1 and 3 & SCR 2 and 4. Since they do not share a cathode connection, it is necessary to use pulse transformers, as shown in figure 4.14:

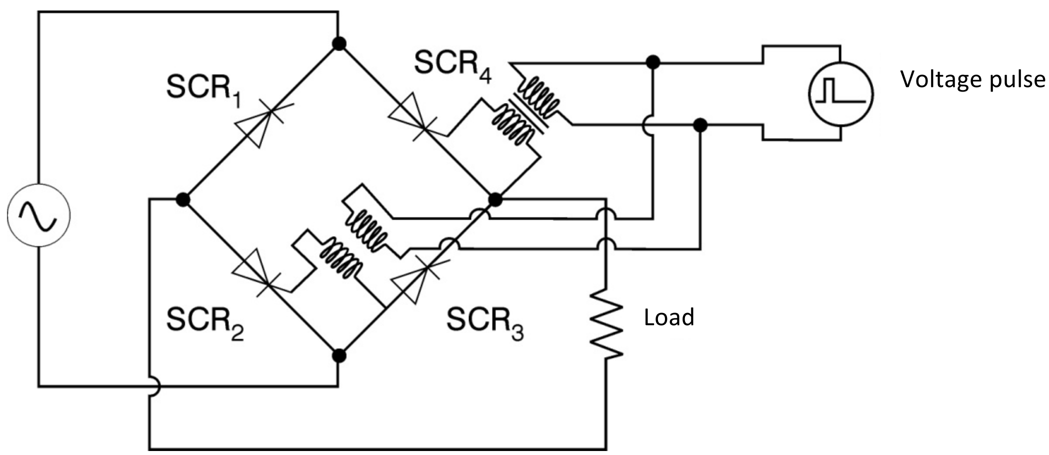


Figure 4.14: *Use of pulse transformers (simplified circuit for two thyristors for easier understanding)*

In the circuit above, the SCR 1 and 3 pulse transformer was omitted to make the illustration clearer. Naturally, the control circuits are not limited to a single-phase circuit, and as in the Soft-Starter, the control circuit may be three-phase. A three-phase rectifier with omitted trigger circuits looks like the following:

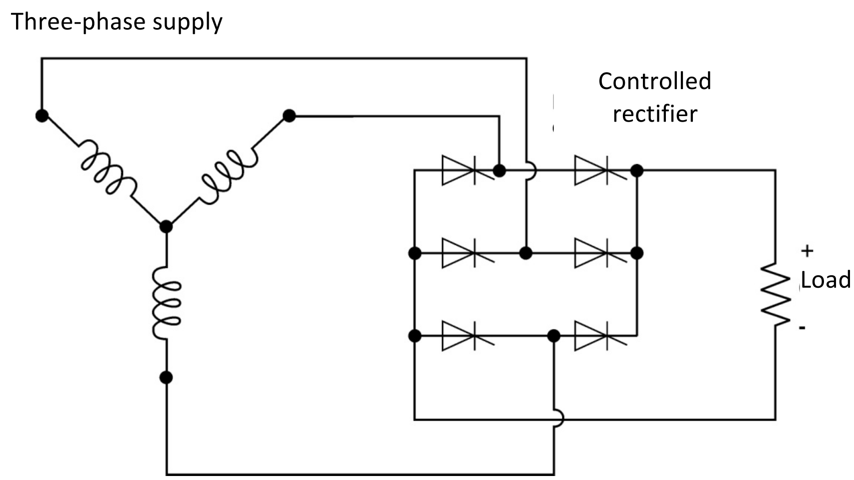


__Figure 4.15__: Three-phase rectifier (trigger circuit omitted)

4.2 SOFT-STARTER WORKING PRINCIPLE

Soft-Starter operation is based on the use of a thyristored bridge (SCRs) in anti-parallel configuration, commanded by an electronic control board with the objective of adjusting the output voltage, according to the programming done earlier by the operator. This structure is presented in figure 4.16.

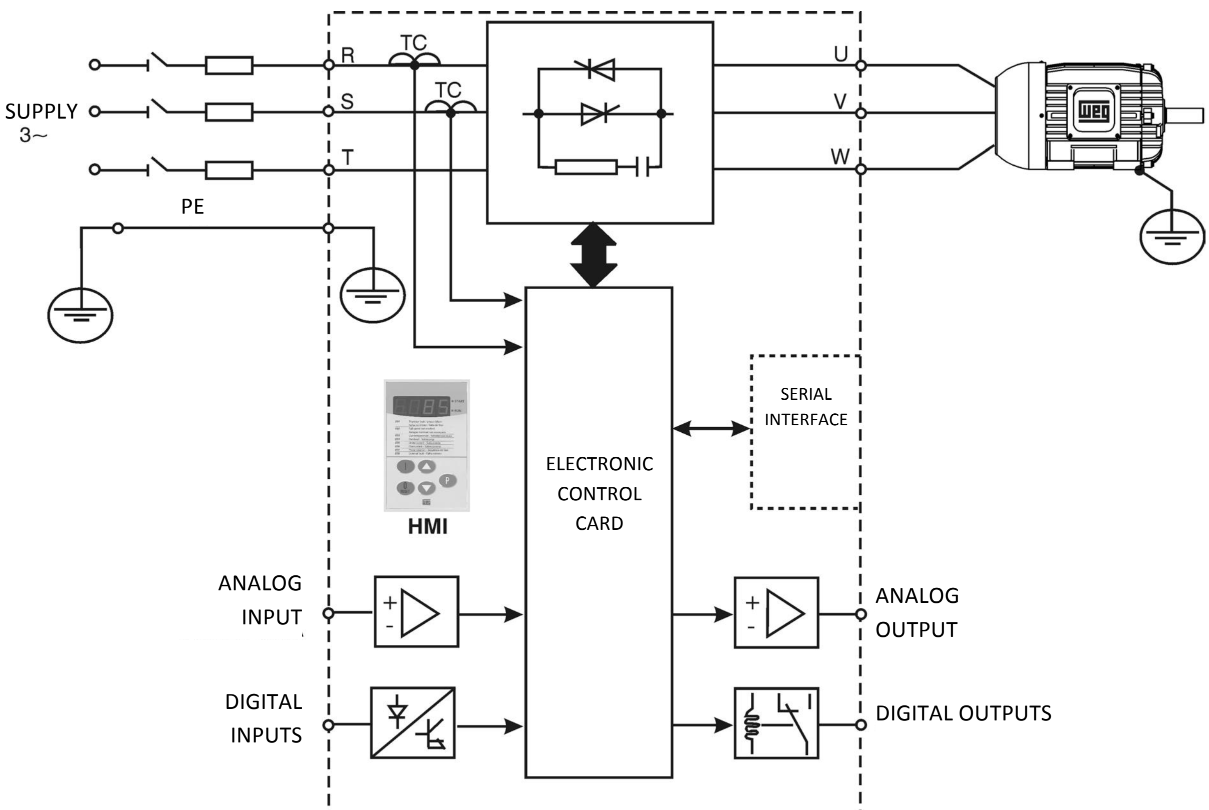


__Figure 4.16__: Simplified block diagram

As can be seen, the Soft-Starter controls the power supply voltage through a power circuit. This circuit is made up of six SCRs, where, by varying their trigger angles, the effective voltage value applied to the motor can be varied. A more comprehensive analysis of each of the individual parts of this structure will be made below since it is clear that the structure can be divided into two parts: the power circuit and the control circuit.

4.2.1 Power Circuit

SCR (Silicon Controlled Rectifier) thyristors are the main components of the Soft-Starter power stage.
By controlling the SCR trigger angle, the average voltage applied to the load can be controlled, thus controlling its current and power.

In a Soft-Starter, voltage control must be done in both directions of the current. An anti-parallel configuration of two SCRs per phase must be used, as indicated in the figure below.

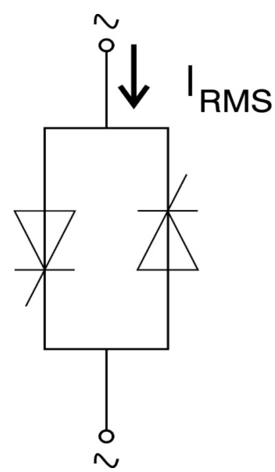


Figure 4.17*: Two anti-parallel thyristors*

In this case, there is voltage control in both halves of the cycle, by means of trigger in the gates derived from the control circuit.
Figure 4.18 shows a simplified diagram of a Soft-Starter power circuit, where the use of thyristor (SCR) pairs in anti-parallel can be observed in each circuit phase.

Through a thyristor trigger control circuit, the voltage applied on the motor can grow linearly, controlling, as such, the motor starting current.
At the end of the motor start, the motor will almost have supply voltage on its terminals.

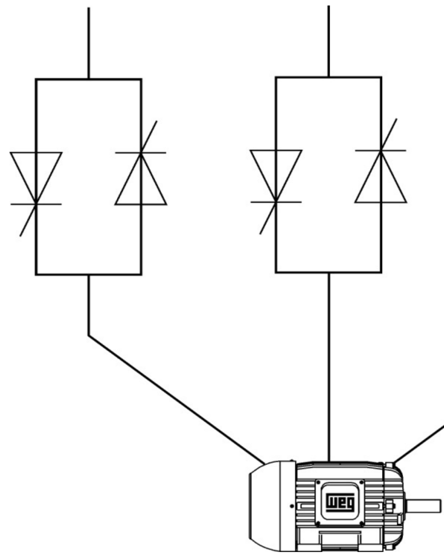


Figure 4.18: SCRs in the motor power circuit ("outside" the motor delta connection)

Below is an illustration of the voltage wave form in one of the motor phases at four moments. Note that when the SCR trigger angle is reduced, the voltage applied on the motor is increased, increasing its current.

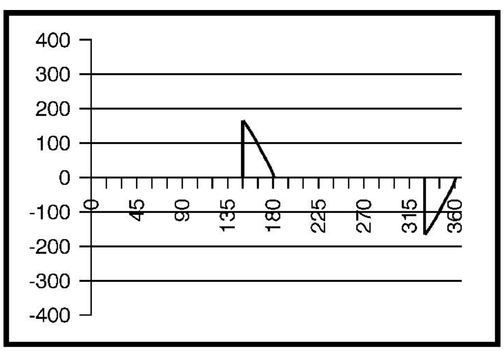


***Figure 4.19 a**: Trigger at 150°*

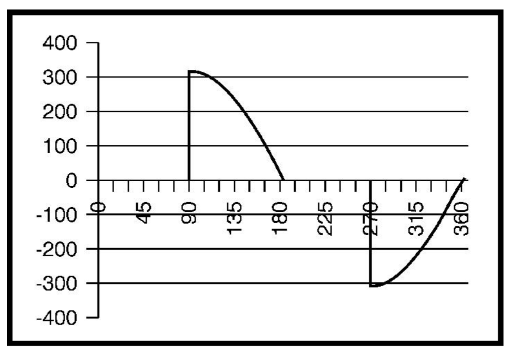


***Figure 4.19 b**: Trigger at 90°*

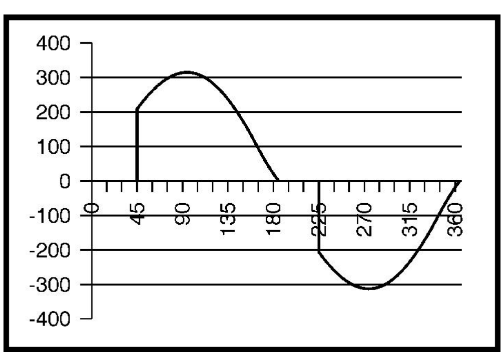


***Figure 4.19 c**: Trigger at 45°*

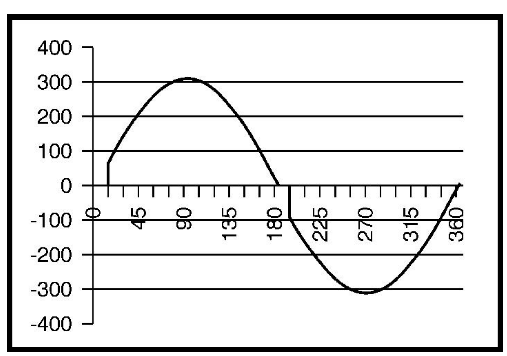


***Figure 4.19 d**: Trigger at 15°*

To avoid accidental SCR firing, a capacitor and a resistor are installed parallel to the SCR, as shown in figure 4.20. This auxiliary circuit is called a snubber and has the objective of avoiding SCR firing bv dV/dt (abrupt voltage variation in a small time interval).

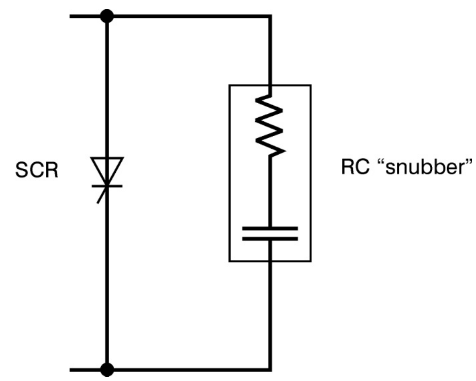


***Figure 4.20**: Snubber*

Current transformers are installed to monitor the current in the Soft-Starter output. This allows the electronic control to protect and maintain the current value at pre-defined levels (activated current limitation function).

4.2.2 Control Circuit

This is where the electric circuits responsible for commanding, monitoring and protecting the power components are located. It is also the location of the circuits used for command, communication and the HMI, which will be set by the operator based on the application.

4.3 MAIN CHARACTERISTICS

Although CHAPTER 5 of this guide is dedicated to the detailed description of Soft-Starter functions (parameters), it is interesting to present a different approach to the main Soft-Starter functions at this point.
Value ranges will not be detailed here, but practical aspects will be mentioned, like, if a function is more adequate for a load with high inertia or not, etc.

4.3.1 Main Functions

4.3.1.1 Voltage ramp during acceleration

Soft-Starter switchers have a very simple function. It is to generate an effective voltage in the thyristor bridge output, by controlling the trigger angle variation of the bridge, that is gradual and rises continuously until the rated voltage or the power supply is reached. This can be observed in figure 4.21.

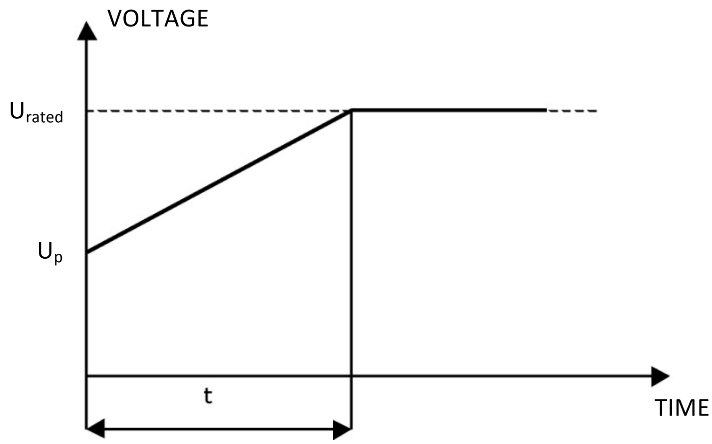


Figure 4.21*: Voltage ramp applied to the motor during acceleration*

Be aware of the fact that if ramp time and starting voltage (pedestal) values are set, it does not mean that the motor will accelerate from zero to its rated speed in that pre-defined time. In reality, this time will depend on the dynamic characteristics of the motor/load system, like for example: coupling system, load moment of inertia reflected on the motor shaft, activation of the current limitation function, etc.

Both the voltage pedestal and the ramp time are values that can be set within a range that varies from manufacturer to manufacturer.

There is no exact rule that can be applied to define what time value should be set and which would be the best pedestal voltage value for the motor to guarantee the acceleration of the load. The best approximation can be reached by calculating the motor acceleration time, which will be shown later.

- Voltage ramp during deceleration

There are two possibilities for stopping the motor, by inertia or controlled. When using inertia, a Soft-Starter takes the output voltage directly to zero, not allowing the motor to produce any kind of torque on the load. As a result of this, the load will lose speed until all the kinetic energy is dissipated. Equation (1) shows how this form of energy can be expressed mathematically.

$$K = \frac{1}{2} J \cdot \omega^2 \qquad (1)$$

where, K = kinetic energy (Joules)
J = total moment of inertia ($kg.m^2$)
Ω = angular speed (rad/s)

In the controlled stop, the Soft-Starter gradually reduces the output voltage until reaching a minimum value at a pre-defined time. This can be seen graphically in figure 4.22.

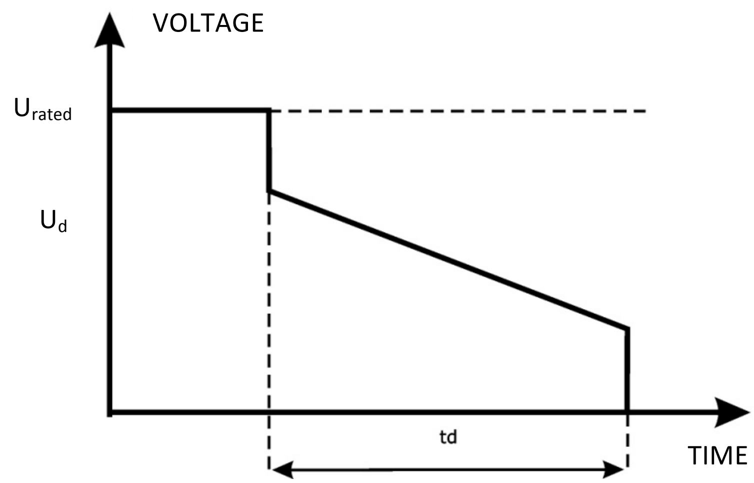


***Figure 4.22**: Deceleration voltage profile*

What occurs in this case can be explained in the following manner: by reducing the voltage applied to the motor, it will lose torque, which reflects on an increase in the slip, causing the motor to lose speed. If the motor loses speed, so will the driven load. This type of feature is very important in applications that require a smooth stop from a mechanical perspective. Centrifugal pumps and conveyors can be cited as examples of this.

In the specific case of centrifugal pumps, this feature minimizes the “water hammer” effect, which can cause serious damage to the entire hydraulic system, jeopardizing components like valves and piping, as well as the pump itself.

4.3.1.2 Water Hammer

“Water Hammer” is a “peak in pressure” resulting from the rapid speed reduction of a liquid. It can happen when a pumping system suffers an abrupt stop. In the context of Soft-Starter applications, the occurrence of water hammer is related to a fast stop in the pump motor, although it may be caused by other events, like the quick closing of a valve.

The pressure “peak” in these conditions can be several times greater than that expected for the system, damaging even the pump. When the Soft-Starter is enabled to stop the motor smoothly (Pump Control), the chance of water hammer occurring at the motor stop is reduced.

4.3.1.3 Kick Start

There are load types that require an extra effort from the drive at the starting moment, due to the high resistant torque. In these cases, the Soft-Starter normally needs to apply a greater voltage to the motor than that set at the acceleration voltage ramp. This is possible by using a function called “Kick Start”. As can be seen in figure 4.23, this function makes a voltage pulse with programmable amplitude and duration be applied to the motor so that it can develop enough of a starting torque to overcome the friction, and therefore accelerate the load. This function requires a great deal of caution because it must only be used in cases where it is absolutely necessary.

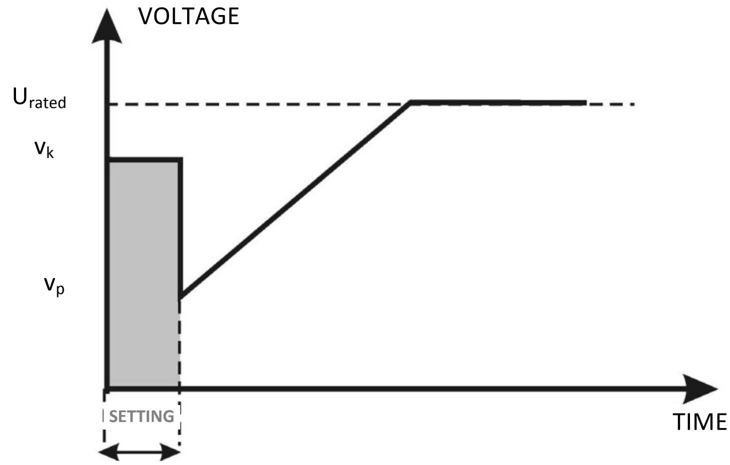


***Figure 4.23**: Graph of the Kick Start function*

Some important aspects related to this function must be observed, since it may be misused and may jeopardize the driven system itself.
Because the starting voltage can be set near the rated voltage, even if for a short period of time, the starting current will reach values that are very close to those registered in the motor catalog or data sheet. This is clearly undesirable because the use of Soft-Starters in these cases derives from the need to guarantee a smooth start, be it electrically or mechanically. This way, this feature can be considered one that should be used as a last resort, or when a heavy duty starting condition is very clear.

4.3.1.4 Current limitation

In most cases where the load presents elevated inertia, a function called current limitation is used. This function makes the power supply/Soft-Starter system only supply the motor with the necessary current to accelerate the load. A graph of how this function is executed can be seen in figure 4.24.

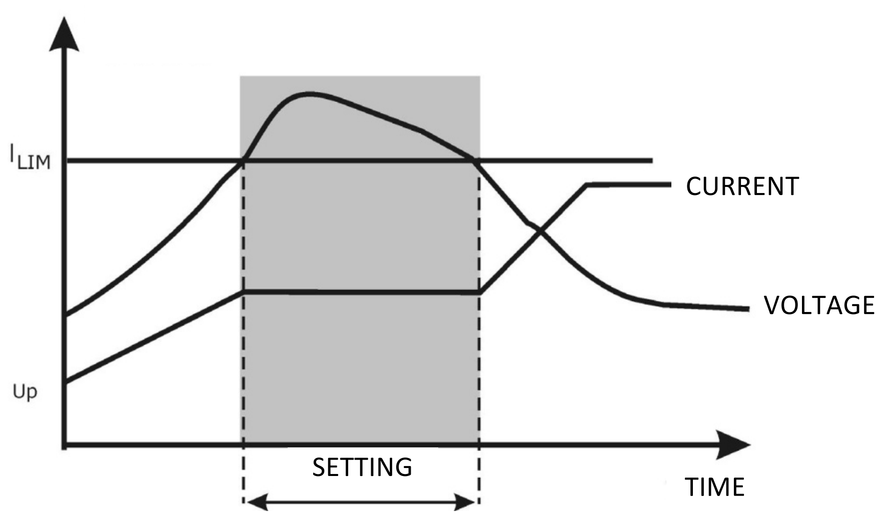


***Figure 4.24**: Current limitation*

This feature is always very useful because it guarantees a really smooth starting, and better yet, makes it viable to start motors in locations where the power supply is at its limit of capacity.

Normally, in these cases, the current condition at the start causes the installation protection system (circuit breaker), preventing normal operation of the whole installation. This creates the need to impose a starting current limit value to allow the equipment, as well as the rest of the installation, to run.

Current limitation is also frequently used for starting motors with loads that have higher moments of inertia. In practice, one can say that this is the function that should be used after not being successful with a simple voltage ramp. It can also be used when, for the motor to accelerate the load, it is necessary to set a voltage ramp in such a way that the starting voltage (pedestal) is near the levels of other starting systems, like for instance, reduced voltage auto-transformer starter. This is in no way a prohibitive factor in choosing the starting system.

4.3.1.5 Pump control

This function is especially used in Soft-Starter applications with pumping systems. It is in fact a specific configuration (pre-defined) that is designed for this type of application, where it is normally necessary to establish a voltage ramp during both acceleration and deceleration and also necessary to enable protections. The deceleration voltage ramp is activated to minimize the water hammer effect, harmful to the system as a whole. Immediate undercurrent and phase sequence protections are also enabled (to avoid cavitation).

Cavitation is the formation of “bubbles” inside the pump. In centrifugal pumps, cavitation can occur when the suction value is sufficiently high inside the pump. When these bubbles pass through the pump, a large quantity of energy is liberated, causing damage.

When the Soft-Starter is adequately enabled for undercurrent protection (Pump Control), the pump is protected from prolonged cavitation.

4.3.1.6 Energy savings

Soft-Starters that include energy optimization characteristics simply alter the operation point of the motor. This function, when activated, reduces the voltage applied to the motor terminals so that the energy necessary to supply the field is proportional to the load demand.

When the motor voltage is at its rated value and the load requires the maximum torque for which the motor was designed, the operation point will be defined by point A, according to figure 4.25. If the load decreases and the motor is supplied by a constant voltage, the speed (rotation) will increase quickly, the current demand will decrease and the operation point will move along with the curve to point B. Since the developed motor torque is proportional to the square of the applied voltage, there will be a torque reduction with a voltage reduction. If this voltage is properly reduced, the operation point will become point A’.

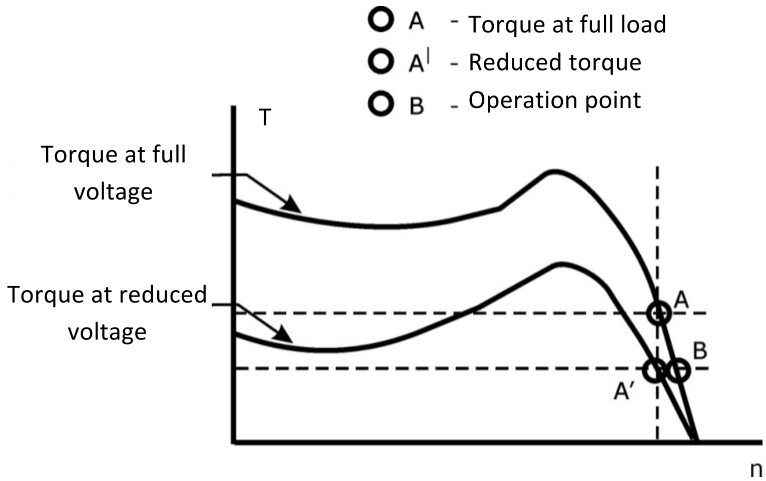


***Figure 4.25**: Balance between torque and voltage*

In practical terms, optimization with significant results can only be observed when the motor is operating with loads lower than 50% the rated load. Needless to say, this is very hard to find because it would be the case of extremely oversized motors, which is avoided at all costs, due to growing concerns with the waste of energy and power factor.

It is important to highlight that this type of energy optimization has some inconvenient characteristics, especially the generation of harmonic voltages and currents and power factor variations. Harmonics can cause problems related to damage and lifetime reduction of the capacitors used for power factor correction, transformer overheating and interference in the electronic equipment.

4.3.2 Protections

An important differential of WEG Soft-Starters are the protections that are available. See item 5.5 of this guide for a detailed description of the protections for the SSW-03 and SSW-04 series Soft-Starters.

4.3.3 Typical Starting Methods

Shown below are some typical starting methods, ranging from simple circuits used only for starting motors, to more sophisticated applications with reversal speed direction, by-pass, etc.

- Basic / Conventional

All commanding, reading and status monitoring is done via HMI.

4.3.3.1 Two wires control using digital inputs

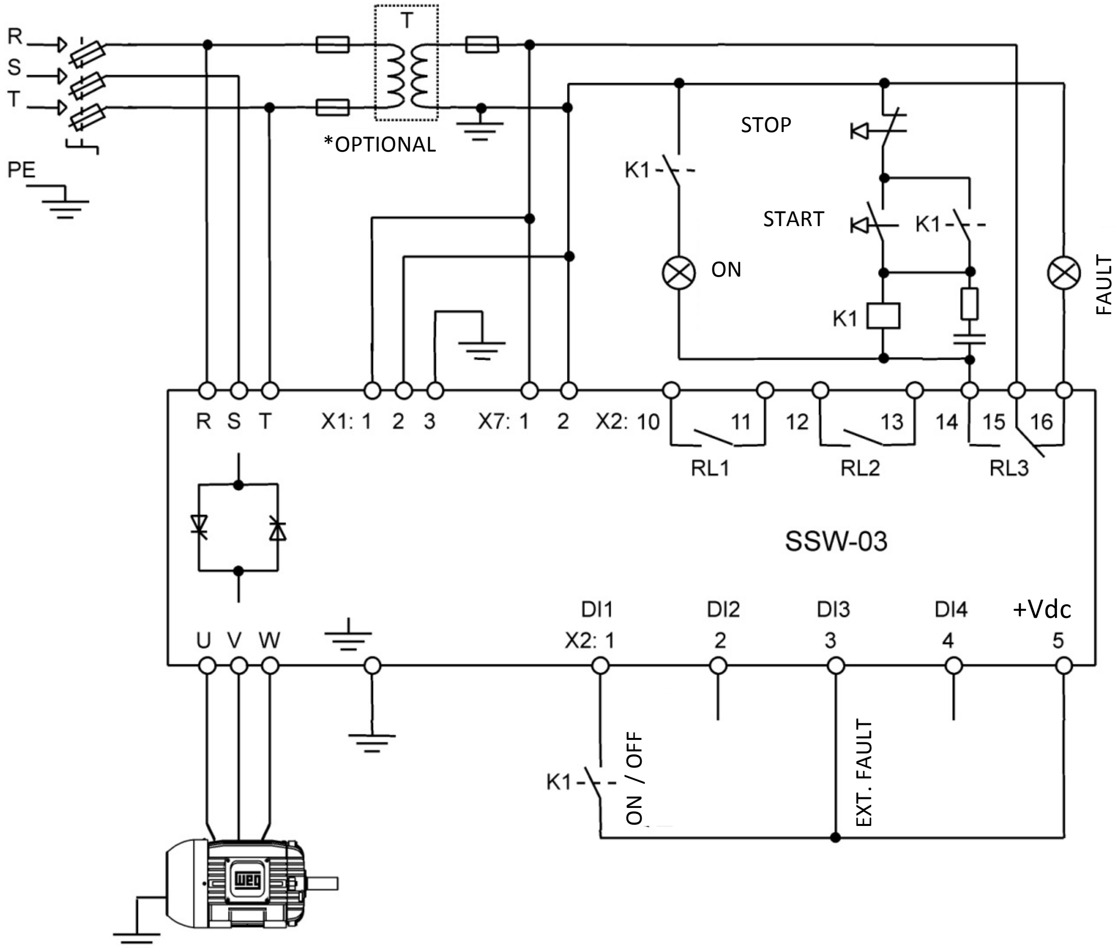


***Figure 4.26**: Simplified diagram of a basic starter*

Parameter	Programming
P53	1
P54	2
P55	Off
P61	Off

*Factory default

- Reversing Direction of Rotation

4.3.3.2 Three wires control using digital inputs

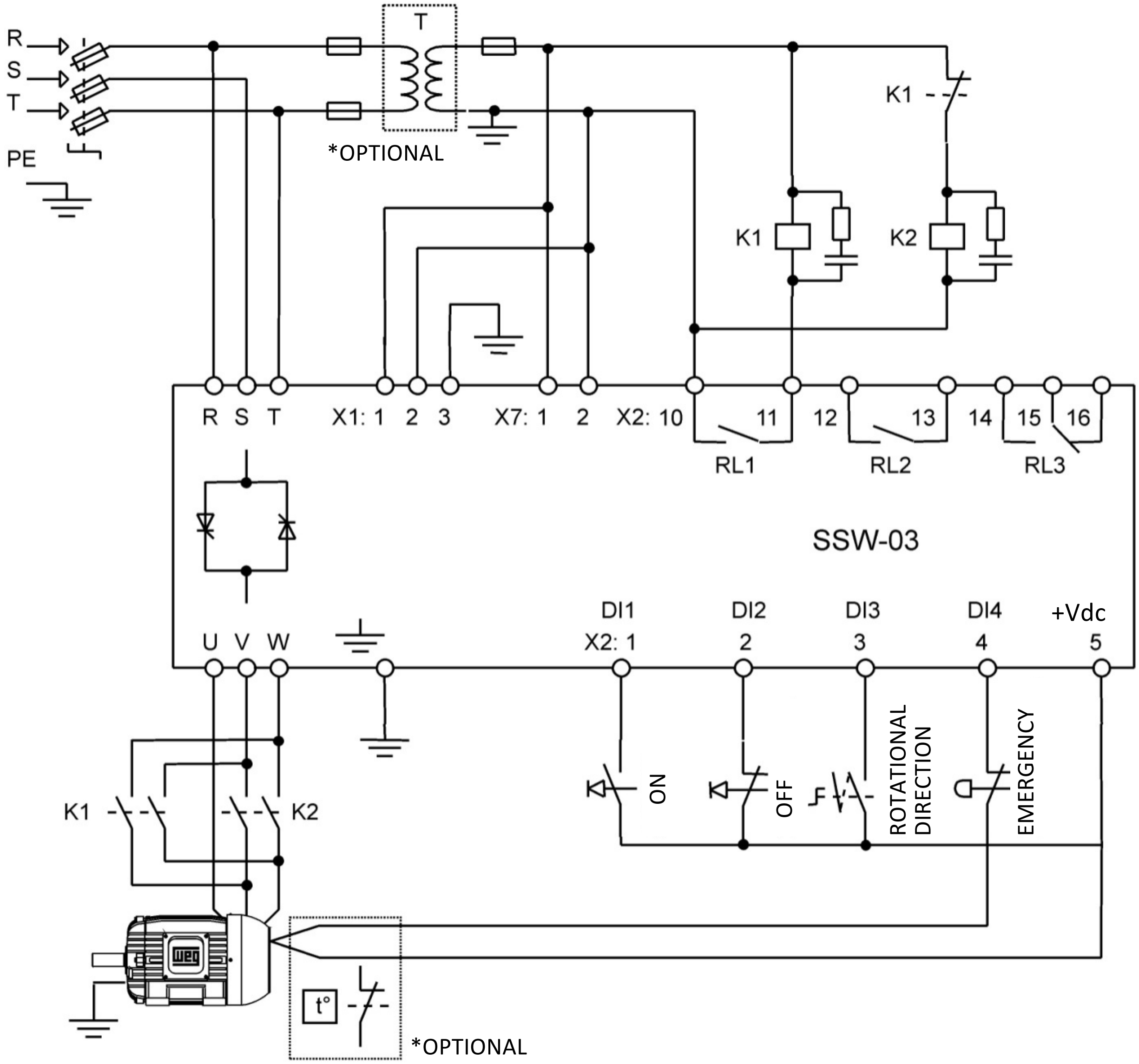


Figure 4.27*: Diagram of a soft starter reversing direction of rotation*

Parameter	Programming
P04	Off
P51	3
P53	4
P54	4
P55	3
P61	Off

- Braking by direct current injection

4.3.3.3 Starter with commands through three wire digital inputs and DC braking

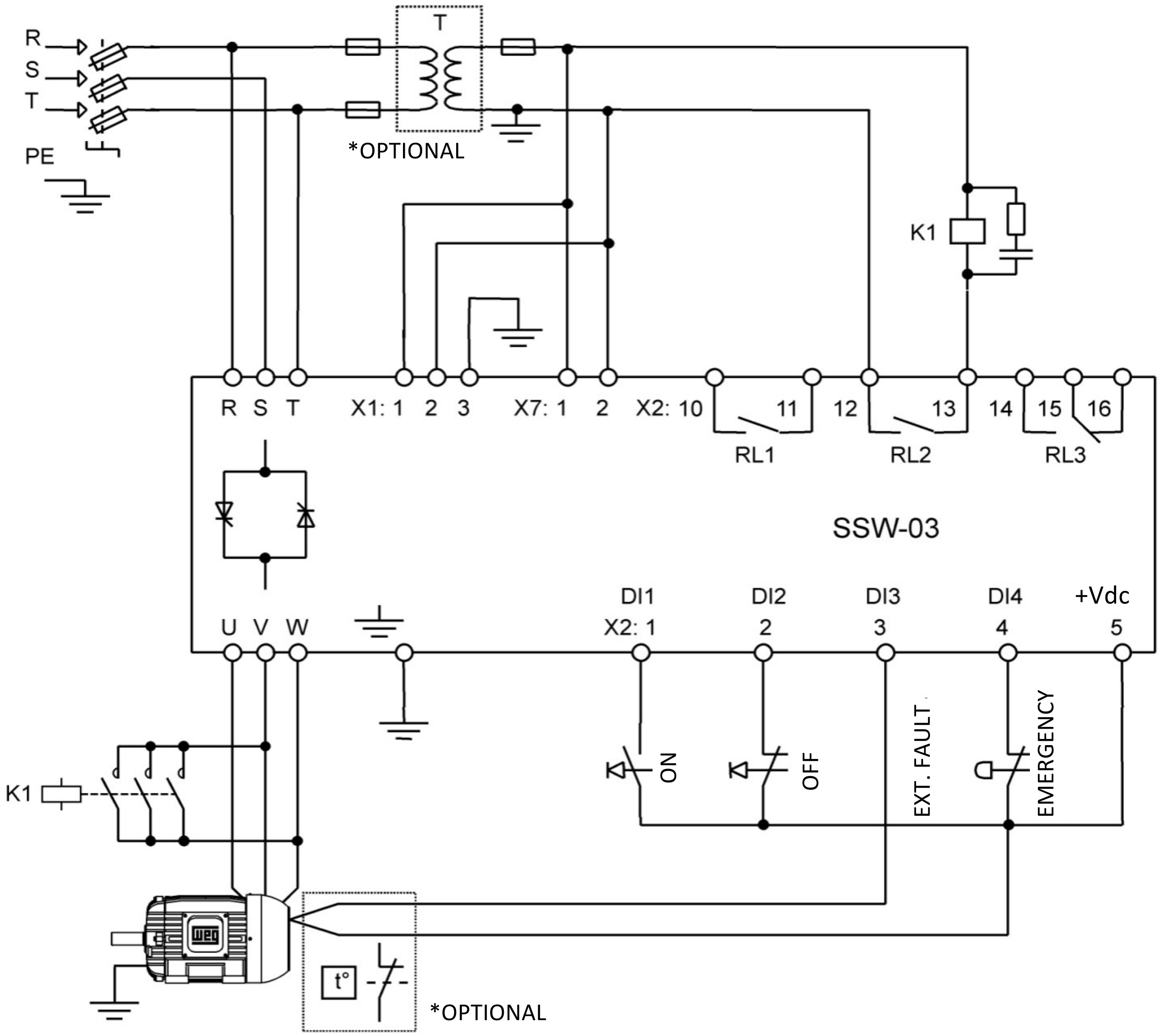


***Figure 4.28**: Diagram of a soft starter with DC braking*

Parameter	Programming
P34	Time (s)
P35	% of full Voltage
P52	3
P53	4
P54	2
P55	3
P61	Off

- By-pass

4.3.3.4 Starter with commands through three wire digital inputs and by-pass contactor

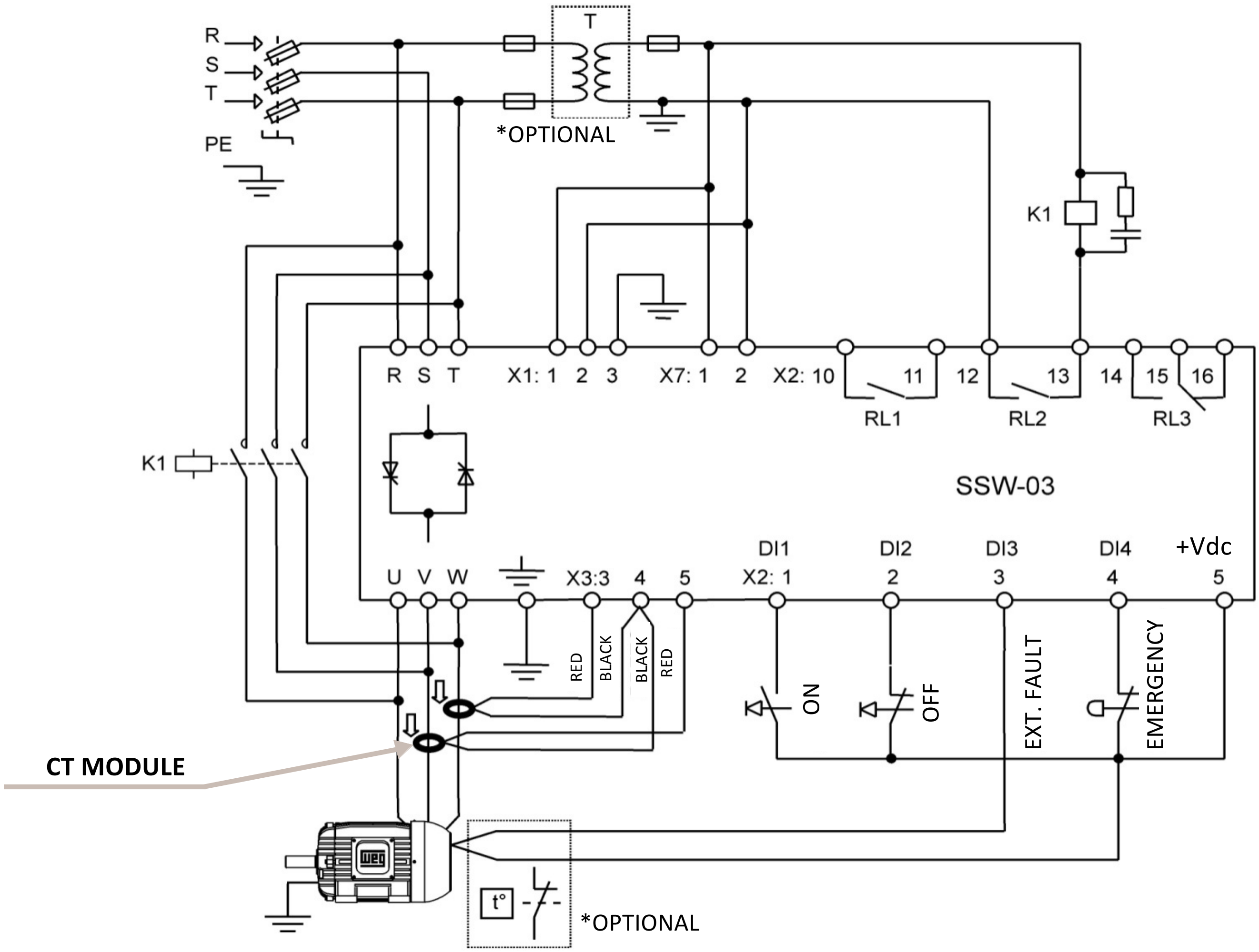


Figure 4.29*: Diagram of a starter with by-pass switch*

Parameter	Programming
P43	On
P52	2
P53	4
P54	2
P55	3
P61	Off

4.3.4 MAC Module

This optional feature is used to maintain the protections related to the motor when the SSW-03 Plus is used with a by-pass contactor. This module provides the measurements of current necessary for the Soft-Starter protection circuits and algorithms to continue protecting the motor, even during a by-pass.

- Multi-motors / Cascading start

4.3.4.1 *Three motors starting with one soft starter with the sequence control through digital inputs*

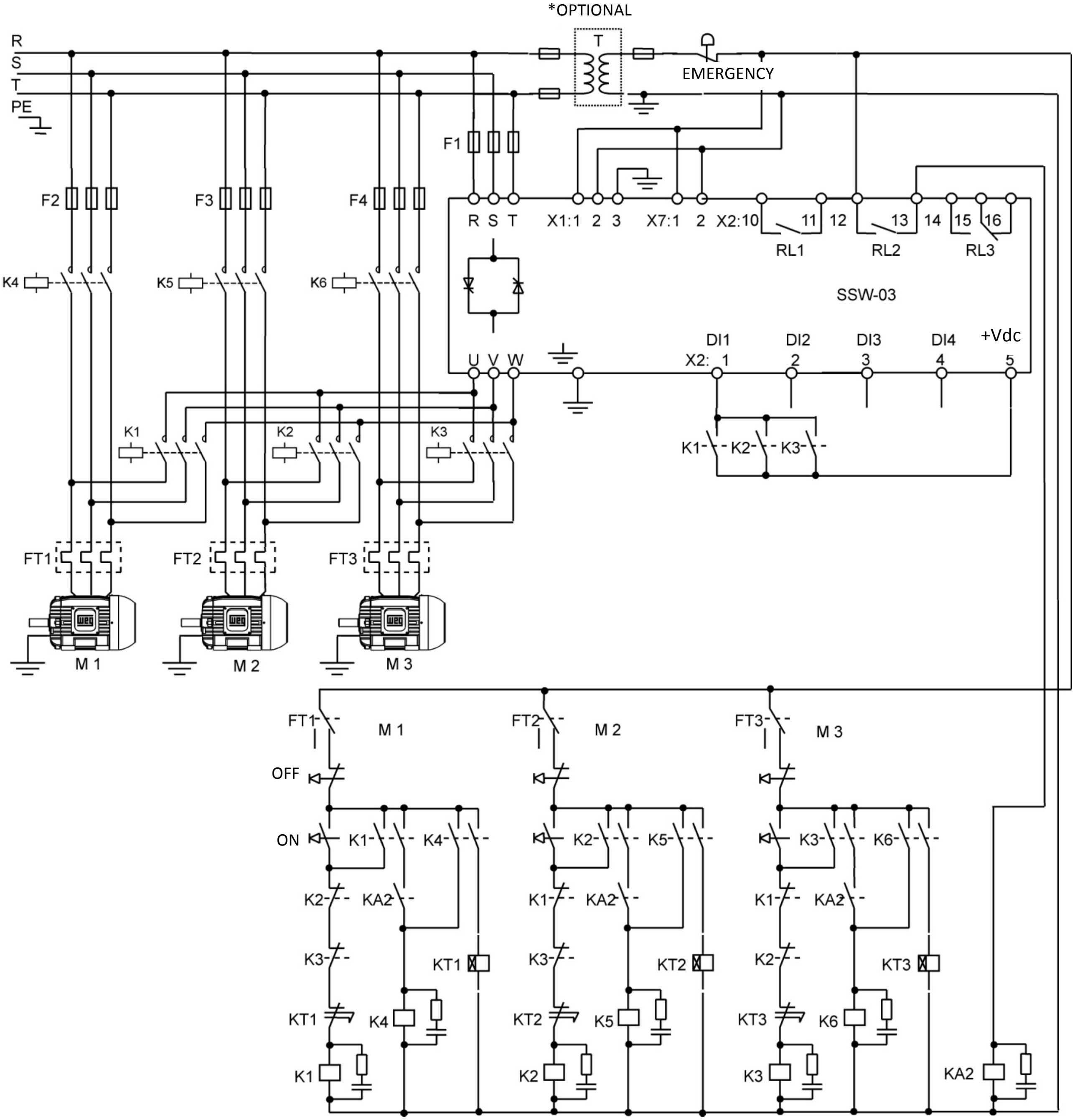


***Figure 4.30**: Diagram of a multi-motors starter*

5 SOFT-STARTER PARAMETERS

Soft-Starter parameters are read or write values, through which the operator may access program values that show, adjust or adapt the behavior of a Soft-Starter and a motor in a specific application. Simple examples of parameters:

- Read Parameter P73: Shows current consumed by the motor
- Programmable Parameter P01: Sets the initial voltage step (%) that will be applied to the motor

IMPORTANT: Always observe the equipment manual for parameter setting, which depends on the software version.

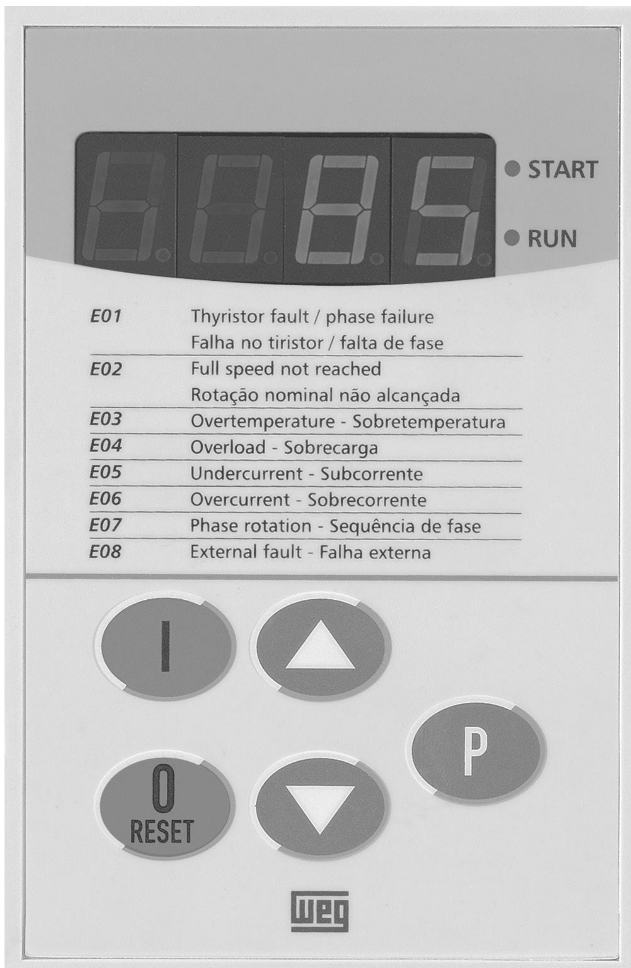


***Figure 5.1**: Human Machine Interface*

Practically all Soft-Starters available on the market have similar programmable parameters. These parameters are accessible through an interface called a Human Machine Interface (HMI), made up of a digital display and a keypad, see figure 5.1.

To make it easier to describe, the parameters will be grouped by their characteristics:

- Read parameters
- Regulation parameters
- Configuration parameters
- Motor parameters
- Special parameters

5.1 READ PARAMETERS

Read parameters, as their name suggests, allow values that were programmed in the regulation, configuration, motor and special parameters to be seen. For example, in the WEG Soft-Starter line, read parameters are identified from P71 to P77, as P82 and from P96 to P99. These parameters do not allow the programmed values to be edited, only read.

EXAMPLES:

P72 – Motor current

Indicates the Soft-Starter output current as a percentage of its rated current (%IN) (accuracy of ±10%)

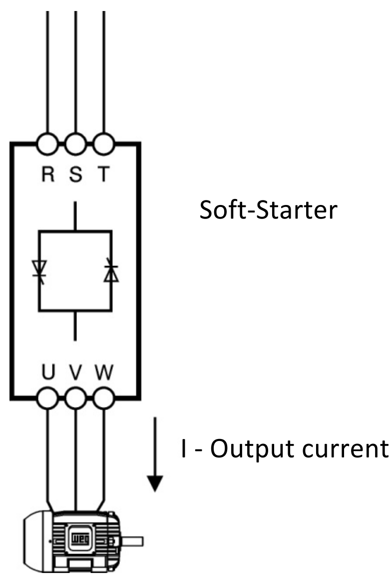


Figure 5.2: *P72 and P73 indicate the output current*

P73 – Motor current

Indicates the Soft-Starter output current directly in Amps (accuracy of ±10%)

P74 – Active power

Indicates the active power required by the load, values in kW (accuracy of ±10%)

> **NOTE!**
> "OFF" is shown when full voltage or energy savings function is used

P75 – Apparent power

Indicates the apparent power required by the load, values in kVA (precision of ±10%)

P76 – Power factor of the load (Cos ϕ)

Indicates the load power factor without considering the harmonic currents generated by the load switching (precision of ±5%).

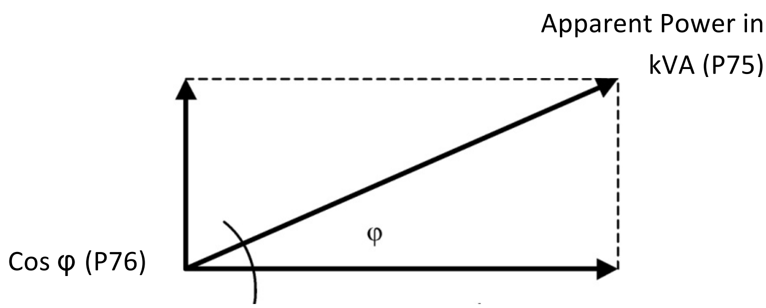


Figure 5.3: *Indications of P74, P75 and P76*

P82 – Motor thermal protection status

Indicates the status of the motor thermal protection as a percentage (0 … 250%) – 250% being the motor thermal protection activation point, indicating E04.

P96 – Last hardware fault that occurred

P97 – Second to the last hardware fault that occurred

P98 - Third to the last hardware fault that occurred

P99 – 1st of the last 4 fault that occurred

5.2 REGULATION PARAMETERS

These are values that can be set for Soft-Starter function use.

EXAMPLES:

P01 – Starting voltage

Sets the starting voltage (% of the power supply voltage) that will be applied to the motor

P02 – Acceleration ramp time

Defines the time of the voltage increment ramp, as shown in figure 5.4, as long as the Soft-Starter does not go into current limitation (P11)

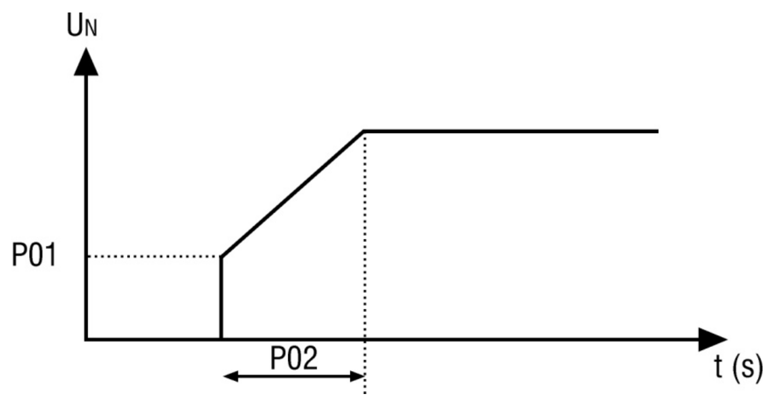


***Figure 5.4**: Acceleration ramp time*

P11 – Soft starter current limitation

Sets the maximum current value that will be supplied to the motor (load) during acceleration.

Current limitation is used for loads with high or constant starting torque.

Current limitation must be set to a level in which motor acceleration can be observed, otherwise,

the motor will not start.

NOTE!

1) If full voltage is not reached by the end of the acceleration ramp time (P02), error E02 will be enabled, turning the motor off.
2) Thyristor thermal protection, even during current limitation, is done by sensors in the soft-starter (switch) itself.

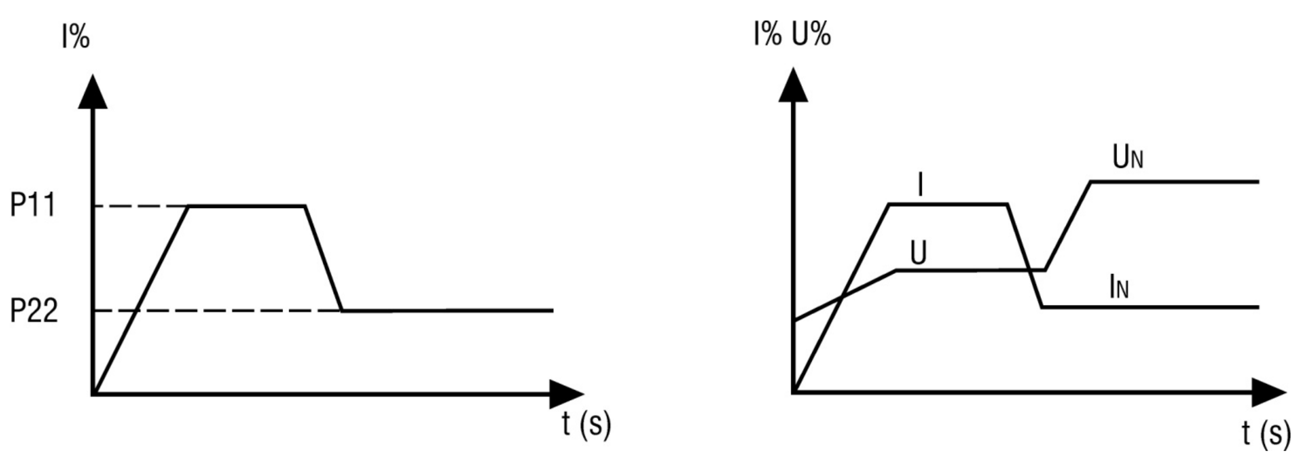


***Figure 5.5**: Current limitation during acceleration*

P11 – Example of the calculation for current limitation setting

Limit the current to 2.5x the motor current

I_n of the switch = 170A
I_n of the motor = 140A

I_{LIM} = 250% the I_n motor

2.5 x 140A = 350A

$$\frac{350A}{I_n \text{ switch}} = \frac{350A}{170A} = 2.05 \times I_n \text{ switch}$$

P11 = 205% the I_n of the switch = 2.5 x I_n of the motor

Where: I_n = rated current

Obs.: This function (P11) is not activated if the voltage pulse at the start (P41) is enabled.

P12 – Immediate overcurrent (% I_n switch)

Sets the instant overcurrent that the motor or Soft-Starter permits, during a time that is pre-set at P13, after which the switch turns off, indicating E06. Shown in figure 5.6.

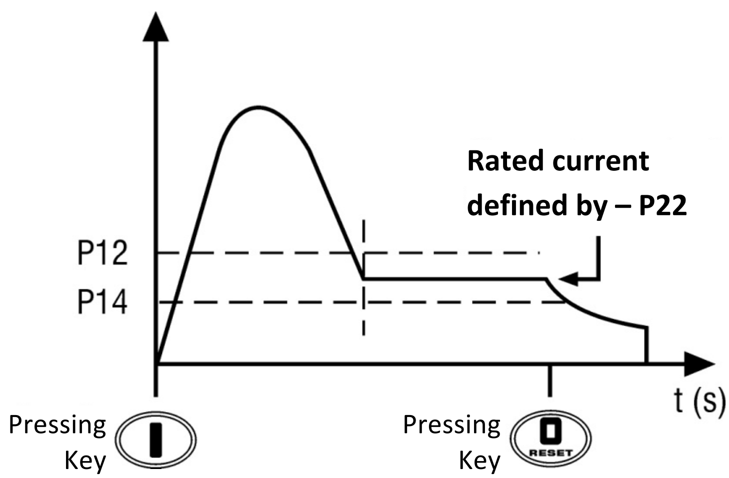


***Figure 5.6**: Immediate overcurrent: the value of P12 will be greater than the rated current defined in P22*

NOTE!
This function is only activated at full voltage, after the motor start.

P12 - Example of the calculation for immediate overcurrent setting

Maximum current value equal to 1.4x the motor current

I_n of the switch = 170A

I_n of the motor = 140A

1.4 x 140A = 196A

$\frac{196A}{I_n \text{ switch}} = \frac{196A}{170A} = 1.15 \times I_n$ switch

P12 = 115% the I_n of the switch = 140% the I_n of the motor

Where: I_n = rated current

P13 – Immediate overcurrent time (s)

This parameter is used to determine the maximum time that the load can operate with an overcurrent, as set at P12.

P14 – Immediate undercurrent (% I_n switch)

Sets the minimum undercurrent level in which the motor + load can operate with no problems. This protection is activated when the load current (figure 5.6) drops to a level lower than that set at P14; and for a time that is equal or greater than that set at P15. Error E05 is indicated.

> **NOTE!**
> This function is only activated at full voltage, after the motor start.

P14 - Example of the calculation for immediate undercurrent setting

Minimum current value equal to 70% that of the motor current

I_n of the switch = 170A
I_n of the motor = 140A

70% x 140A = 0.7 x 140A = 98A

$\frac{98A}{I_n \text{ switch}} = \frac{98A}{170A} = 0.57 \times I_n$ of the switch

P14 = 57% the I_n of the switch = 70% that of the motor

Where: I_n = rated current

P15 – Immediate undercurrent time (s)

This parameter is used to determine the maximum time that the load can operate with an undercurrent, as set at P14. A typical application of this function is in pumping systems, to avoid pump damage when running dry or in case of cavitation (page 73).

P22 – Rated current of the switch (A)

Its function is used to set the software to specific hardware conditions, serving as a base for the following functions: starting current limitation (P11); immediate overcurrent in operation (P12); undercurrent in operation (P14).

P23 - Rated voltage of the switch (A)

Used to indicate the power supplied to the load.

P31 – Phase sequence (ON = R-S- T also known as L1-L2-L3; OFF = any sequence)

This can be enabled or disabled. When enabled, its function is to protect loads that cannot operate in two rotational directions.

> **NOTE!**
> The phase sequence is only detected the first time the power is turned on, after the electronics are energized. Therefore, a new sequence will only be detected by turning off or resetting the electronics.

P33 – Voltage level of the JOG function

Executes the acceleration ramp up to the set JOG voltage value, during which time the digital input (DI4) is closed. After opening, the DI4 input executes the deceleration via ramp, as long as this function is enabled in P04.

The JOG function allows the motor to spin with a reduced torque, while someone/something (an operator, a PLC, etc) sends a digital signal to the Soft-Starter.

This function is useful to observe the behavior of the machine running for the first time (as a test of the general mechanical situation). Like this, it is possible to correct an incorrect assembly without the hassle of putting the machine into full speed during the first operation.

Another application is for positioning of material inside the machine. The JOG function “gives a little push” while the operator holds the JOG button (N/O dry contact connected to the input, programmed for JOG, of the Soft-Starter), making it so that the material to be worked on (or any machine element) can be adjusted at the beginning of the process.

> **NOTE!**
> 1) The maximum activation time of the JOG function is determined by the time set at P02. After this time runs out, error E02 is activated and the motor is disabled.
> 2) For this P55 = 4

P34 – DC Braking time (s)

Sets the DC braking time, as long as P52=3.

This is only possible with the help of a contactor that must be connected according to the item “Typical connection diagrams” in this guide.

This function must be used when one wishes to reduce the deceleration time established by the load on the system.

> **NOTE!**
> Whenever this function is used, a possible thermal overload in the motor windings must be taken into consideration. The SSW overload protection does not work with DC braking.

P35 – DC Braking voltage level (% UN)

Sets the grid voltage value, converted directly to Vdc, applied to the motor terminals during braking

P41 – Voltage pulse at the start (Kick Start)

When enabled, the voltage pulse at the start defines the time in which this voltage pulse (P42) will be applied to the motor, so that it can overcome the initial frictional torque and inertia of the load reflected to the motor shaft, according to figure 5.7.

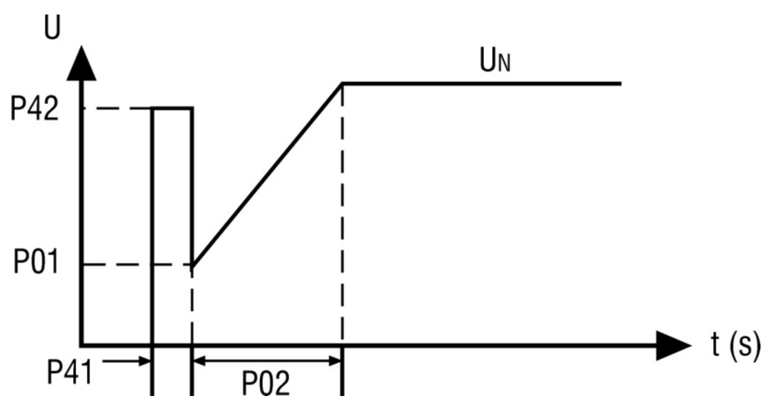


***Figure 5.7**: Kick-Start: helps start loads with elevated inertia*

> **NOTE!**
> Only use this function for specific applications where there is an initial resistance to the movement.

P45 – Pump control

Every WEG soft starter has a special algorithm for applications in centrifugal pumps. This special algorithm is intended to minimize the water hammer effect, overshoots in the hydraulic piping, causing ruptures or excessive wear.

Upon switching P45 to “On” and pressing the “P” key, the display will indicate “PuP” and the following parameters will automatically be set:

- P02 = 15s (acceleration time)
- P03 = 80% (starting voltage level during deceleration)

- P04 = 15s (deceleration time)
- P11 = Off (current limitation)
- P14 = 70% (switch undercurrent)
- P15 = 5s (undercurrent time)

All other parameters maintain their previous values.

NOTE!
Although automatically set values meet the majority of applications, they may be altered to better meet the needs of a specific application.
Below is a procedure to improve the performance of pump control.

Fine tuning of the pump control function:

NOTE!
This adjustment must only be made to improve pump control performance when the motor-pump is already installed and ready to operate at full rating.

1) Switch P45 (pump control) to "On".
2) Set P14 (undercurrent) or switch P15 (undercurrent time) to "Off" until the end of the adjustment. Afterwards re-program it.
3) Check the correct rotational direction of the motor, indicated on the pump frame.
4) Set P01 (initial voltage % U_N) to the level needed to start spinning the motor without any trepidation.
5) Set P02 (acceleration time [s]) to the starting time required by the load. Using the piping manometer, check the increase in pressure. This should be continuous until it reaches the maximum required level, with no overshoots. If there are any, increase the acceleration time until these pressure overshoots are reduced as much as possible.
6) Use P03 (voltage level % U_N) to cause an immediate or more linear pressure drop in the deceleration of the motor-pump.
7) Use P04 (deceleration time), with a manometer, to decelerate the motor. There must be a continuous pressure drop until the minimum level is reached without causing a water hammer effect while closing the retention valve. If it happens, increase the deceleration time until the oscillations are reduced as much as possible.

NOTE!

- If there are no observation manometers in the hydraulic piping, water hammers can be identified through the pressure relief valves.
- Excessively high acceleration and deceleration times cause motors to overheat. Program the lowest times necessary for the application.

P47 – Auto-reset time (s)

When an error occurs (except E01, E02 and E07 or E2x), the Soft-Starter can reset automatically, after the time programmed at P47 has passed.

If P47=Off, auto-reset will not occur. After the auto-reset, if the same error reoccurs three times consecutively (*), the auto-reset function will be disabled. Therefore, if an error occurs four

consecutive times, it will continue being indicated permanently and the Soft-Starter will be blocked from starting.
(*) An error is considered to be reoccurring if it is repeated up to 60 seconds after its last occurrence.

5.3 CONFIGURATION PARAMETERS

P43 – By-pass relay

When enabled, this function allows for full voltage indication to be used through RL1 or RL2 (P51 or P52) to activate an external by-pass contactor.

The main function of a by-pass is to eliminate losses in the form of heat caused by the Soft-Starter.

NOTE!
1) This function should always be programmed whenever a by-pass contactor is used.
2) Current transformers must be placed outside the connection with the by-pass contactor through the MAC-0x module so that the protections that refer to motor current reading are not lost.
3) When P43 is "On", parameters P74 and P76 are inactive, "Off".

P44 – Energy savings

Can be enabled or disabled. If enabled, its function is to decrease losses in the motor frame, when little or no load is present.

NOTE!
1) Total energy savings depend on the motor load.
2) This function generates undesirable harmonic currents in the power supply due to the firing SCR angle for voltage decreases.
3) When P44 is "On", parameters P74 and P76 are inactive, "Off".
4) This cannot be enabled with a by-pass (P43=On).
5) The "Run" led keeps blinking when the energy savings function is enabled.

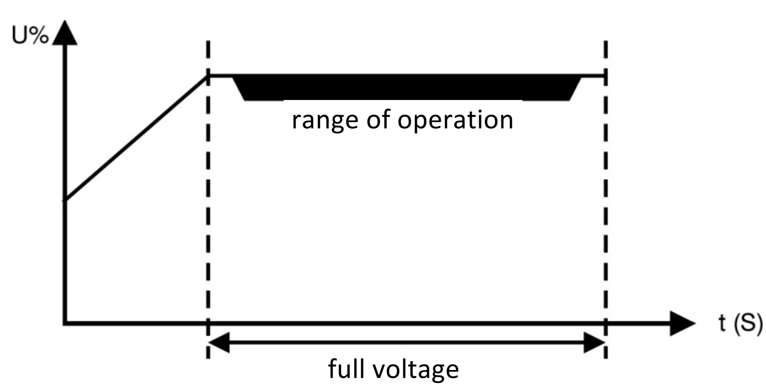


***Figure 5.8**: Energy savings*

P46 – Default values (loads factory parameters)

When “On”, this function forces Soft-Starter parameter setting according to factory values, except for parameters P22 and P23.

P50 – RL3 Relay programming

Enables relay RL3 to operate according to description below:

1) Closes the N.O. contact whenever the SSW-03 is not in ERROR mode.
2) Only closes the N.O. contact when the SSW-03 is in ERROR mode.

P51 – RL1 Relay function

Enables the RL1 relay to operate according to the following parameter setting:

1) “Operation” function – the relay is instantly switched on with a Soft-Starter start command. It is only switched off when the Soft-Starter receives a stop command (P04=Off), or by ramp when the voltage reaches 30% UN (P04=Off). Shown in figure 5.9.

2) “Full Voltage” function – the relay is only switched on after the Soft-Starter reaches 100%. It is switched off when the Soft-Starter receives a stop command. Shown in figure 5.9.

> **NOTE!**
> When the Full Voltage function is used to activate the by-pass contactor, parameter P43 must be “On”.

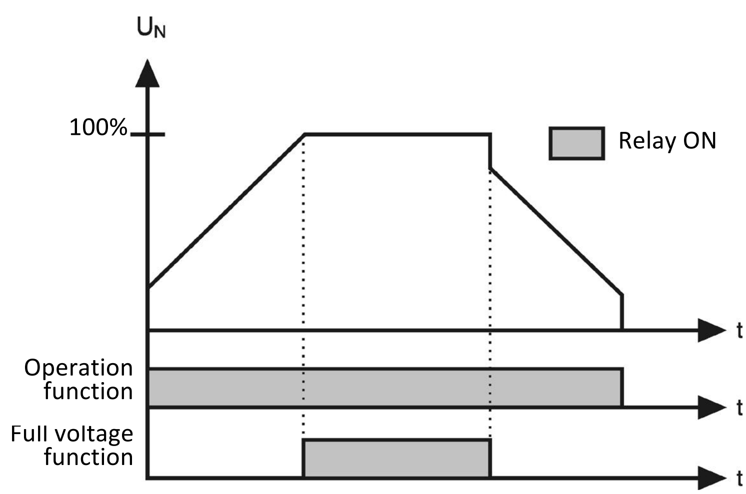


***Figure 5.9**: “Operation” and “Full Voltage” functions*

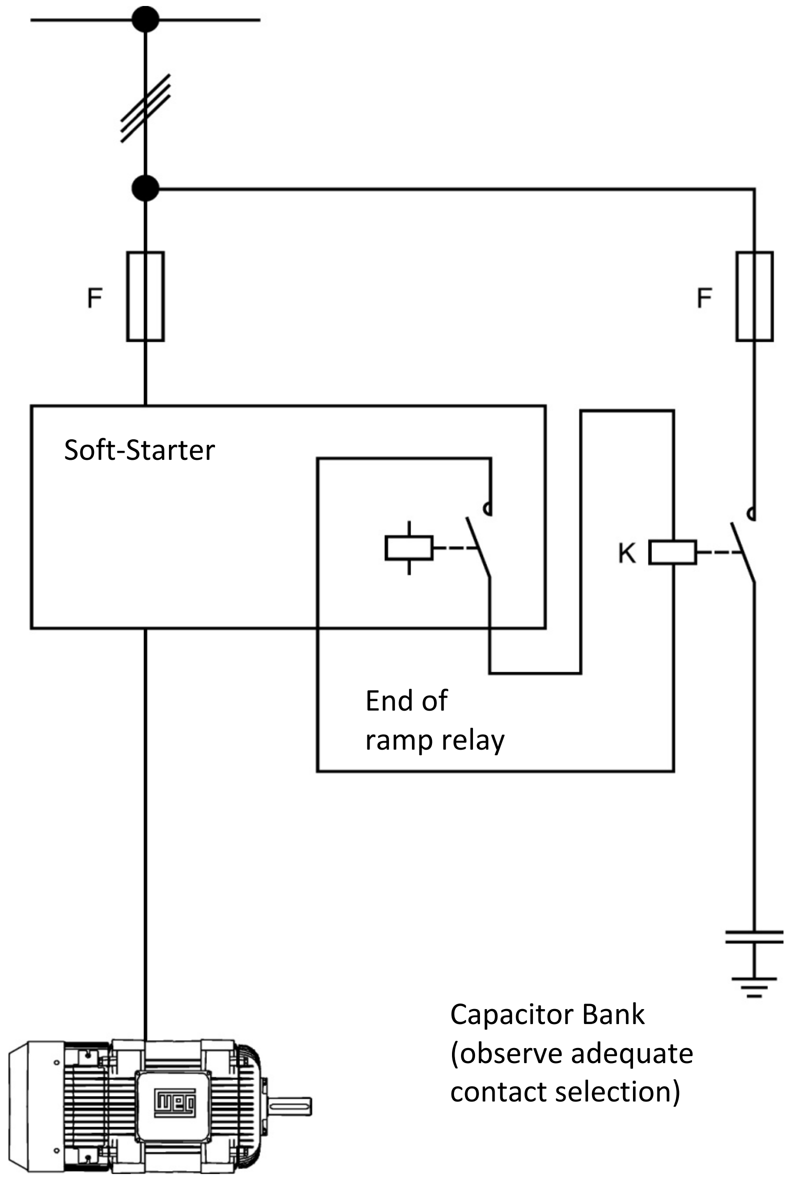


***Figure 5.10**: Simplified illustration of a relay application with ramp end function to connect a power factor correction bank.*

3) "Direction of Rotation" function – the relay is "on" when the digital input (DI3) is kept closed, and "off" when open. Relay RL1 will only command a contactor connected to the SSW-03 output, which will reverse 2 motor supply phases. As seen in figure 5.11.

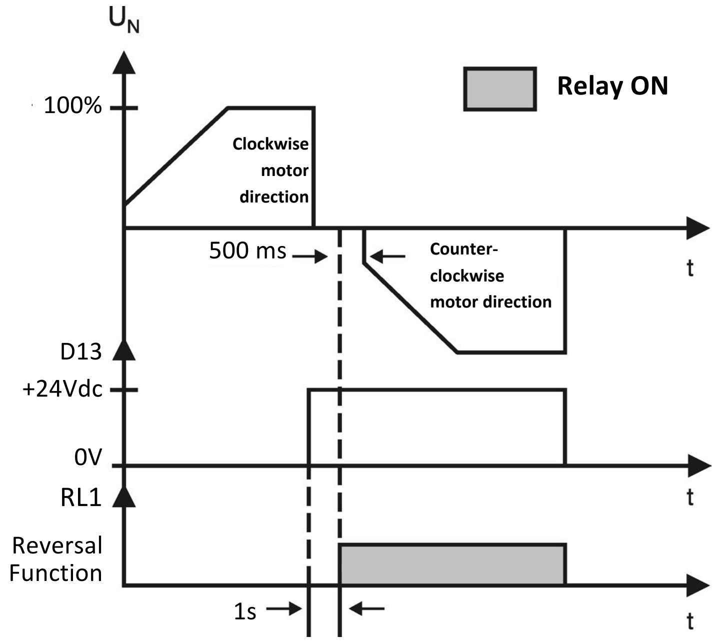


***Figure 5.11**: "Rotational Direction" function*

P52 – RL2 Relay function

1-2) Enable relay RL2 to operate.

3) "DC Braking" function – the relay is switched on when the Soft-Starter receives a command to stop. A contactor must be used for this function. According to figure 5.12.

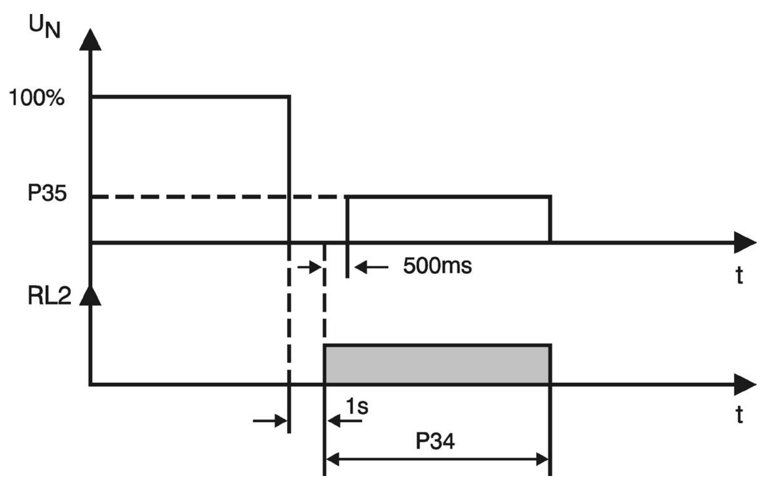


***Figure 5.12**: Relay for DC Braking function*

> **NOTE!**
> When programmed, both P51 and P52 will be executed independently, if the contactors are connected externally. Therefore, before executing the program, complete all necessary external connections.

P53 – Programming of digital input 2

Enables digital input 2 (terminal X2:2) to operate according to the codes described below:

OFF = "W/O Function"

1) "Error Reset" – resets an error status every time the DI2 input is in +24Vdc (X2:5).

2) "External Error" – can serve as additional load protection, activated when the input is open.

Ex.: Motor thermal protection through dry contact (free of voltage) of a protection relay (thermostat).

3) "General Enable" – input DI2 can be used as a Soft-Starter emergency. For this, terminal X2:2 must be connected at +24Vdc (X2:5).

4) "Three Wire Control" – allows the Soft-Starter to be commanded through two digital inputs. DI1 (X2:1) as start input and DI2 (X2:2) as stop input. Like this, a two key button can be used. See item "Typical connection diagrams" in this guide.

P54 – Programming of digital input 3

Enables digital input 3 (terminal X2:4) to operate according to the codes described below:

OFF = "W/O Function"

1) "Error Reset"

2) "External Error"

3) "General Enable"

4) "Direction of Rotation" – enables digital input 3 (DI3) when connected at +24Vdc (X2:5). Activate relay RL1 (according to item 6.4.5) and execute the motor direction of rotation reversal function with help from a reversing contactor connected to the Soft-Starter output. See item "Typical connection diagrams" in this guide.

NOTE!
Parameter P51 must be programmed at "3" for this function.

P55 – Programming of digital input 4

Enables digital input 4 (terminal X2:4) to operate according to the codes described below:

OFF = “W/O Function”

1) “Error Reset”

2) “External Error”

3) “General Enable”

4) “JOG Function” – enables digital input 4 (DI4) when connected at +24Vdc (X2:5). Makes the Soft-Starter apply the JOG voltage (P33) to the motor.

P56 – Analog output programming

Enables the 8 bit digital output (X2:8 and X2:9), value at voltage 0…10Vdc (adjustable gain P57), to indicate the following codes:

OFF = “W/O Function”

1) “Current” – proportional to the current circulating through the soft starter as % of full current (I_N).
2) “Voltage” – proportional to the output voltage of the soft starter as % of full voltage (U_N).
3) “Power Factor” – proportional to the power factor of the load w/o considering harmonic currents.
4) “Motor thermal protection” – proportional to the thermal status of the motor in %.

P57 – Analog output scaling factor

Sets the scaling factor at the analog output defined by parameter P56.

NOTE!

The following conditions apply to gain 1.00:
P56 = 1 output 10 Vdc when at 500% of the Soft-Starter rated current (I_N);
P56 = 2 outputs 10 Vdc when at 100% the of the Soft-Starter output full voltage (U_N);
P56 = 3 outputs 10 Vdc when the load power factor is equal to 1.00;
P56 = 4 outputs 10 Vdc when the motor thermal protection status (P82) is equal to 250%.

P61 – Command enabling

Commands	P61 = Off	P61 = On		Description
	Digital Input	HMI	Serial	
I/O	X	X	X	Digital Input or HMI/Serial
JOG Function	X		X	Digital Input 4 (DI4) or Serial
Rotational Direction	X		X	Digital Input 3 (DI3) or Serial
General Enable	X		X	Digital Inputs 2, 3, 4 or Serial

Commands that depend on P61 setting

- I/O (On/Off): When P61 = Off, allows the motor to start and stop via digital inputs (DI1 or DI1/DI2).
- When P61 = ON, allows the motor to start and stop via HMI-3P and serial only. When P61 = ON, digital input “DI1” has no function.

NOTE!
To execute this selection through HMI-3P/Serial or Digital Input, the motor must be off. Even when the change is from HMI-3P/Serial to Digital Input (DI1), the Digital Input must be open. If it is closed, the parameter setting will not be processed and the display will indicate E24.

- **JOG function:** can be programmed at the digital input (DI4) if P61 = Off. If P61 = ON, its operation is via serial.

- **Reversal of rotational direction function:** can be programmed at the digital input (DI3) if P61 = Off. If P61 = ON, its operation is serial.

- **General enable:** can be used as an “Emergency Command” because it can be programmed for any of the digital inputs (DI2, DI3 or DI4) and also via serial (as long as P61 = ON). If more than one digital input is programmed for this function, the first one to open will work as the emergency. If the command is also enabled for serial (P61=ON), all the digital inputs programmed for general enable must be closed.

Commands	Digital Input	HMI	Serial	Description
External Error	X			Only via digital inputs 2, 3 or 4
Error Reset	X	X	X	Available in all

- **External error:** can be programmed for any one of the digital inputs (DI2, DI3, or DI4). If it is not programmed, it is not executed. If more than one digital inputs are programmed for “External Error”, any one of them will be activated when disconnected from +24Vdc (X2:5).

- **Error reset:** it is accepted via HMI-3P, Serial and Digital Inputs DI2, DI3 or DI4, when programmed. When more than one digital input is programmed, any one of them can reset an error status, only needing to receive a +24Vdc (X2:5) pulse.

P62 – Soft-Starter address in the communication network

Defines the address in which the Soft-Starter will respond in the communication network among all the equipment connected there.

5.4 MOTOR PARAMETERS

P21 – Motor current setting (% rated current: I_N of the soft starter)

Sets the motor current value as a percentage of the rated value of the soft starter.

Supervises the overload conditions according to the thermal class curve selected at P25, thermally protecting the motor from overloads applied to its shaft.

When the overload time defined by the thermal protection class is exceeded, the motor is shut off and error E04 will be indicated in the HMI-3P display.

The following parameters are part of the thermal protection: P21, P25, P26 and P27.
P21=Off to disable the thermal protection.

Example: How to set P21:
I_n of the switch = 170A
I_n of the motor = 140A

$\frac{140A}{170A} = 0.823$ P21 = 82.3%

Obs.: Even if the CPU is reset, the motor overload error, E04, will keep the overload value in its memory. When the CPU is turned off, the last value is memorized. The value is only erased when the soft starter is ON and the motor has a load that is lower than the rated value, or when it is turned off.

P25 – Thermal classes for motor overload protection

Determines the activation curves of the motor thermal protection according to IEC 947-4-2, shown in the graph below:

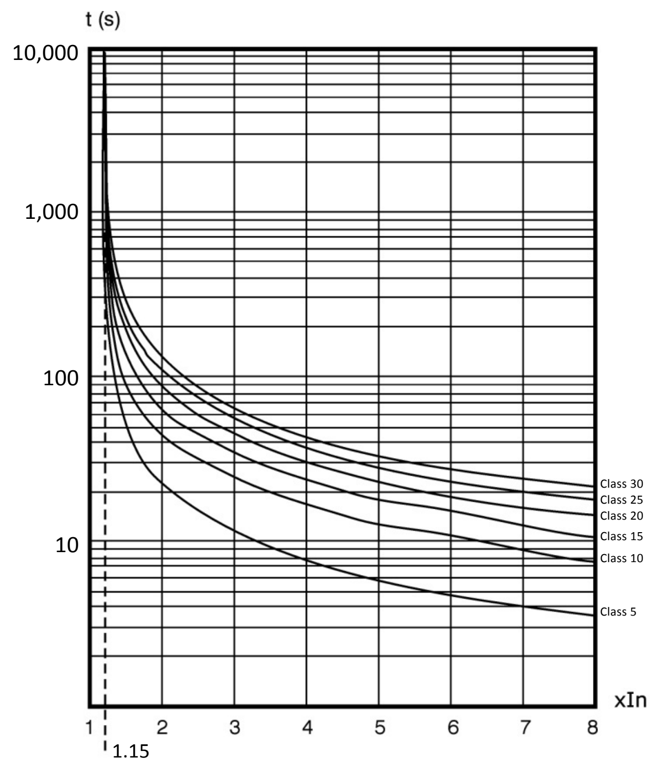


Figure 5.13*: Thermal classes*

> **NOTE!**
> When the motor is hot, the curve times are reduced by the factors shown in the table below. These factors are applied to motors with symmetric three-phase loads.

Classes 5 to 30.

Table: *Multiples for starts with a hot motor*

IP / IN	O	20%	40%	60%	80%	100%
= P26	1	1	1	1	1	1
> P26	1	0.84	0.68	0.51	0.35	0.19

Example:
A motor is being operated with 100% I_n and is turned off.
It is immediately turned back on. The thermal class selected at P25 is 10. The starting current is 3 x I_n. The activation time is approximately 23s. The adjustment factor in the table for 100%of x I_n is 0.19.

The final activation time will be 0.19 x 23s = 4.3s.

P26 – Motor service factor

Sets the motor service factor (S.F.) according to the motor nameplate. This value defines the load that the motor withstands.

P27 – Thermal image auto-reset

Sets the thermal image auto-reset time of the motor.

The motor thermal image simulates the motor cooling time. The algorithm that executes this simulation is based on Standard WEG motor and according to the power programmed in the Soft-Starter parameters. For applications needing several starts per hour, the thermal image auto-reset can be used.

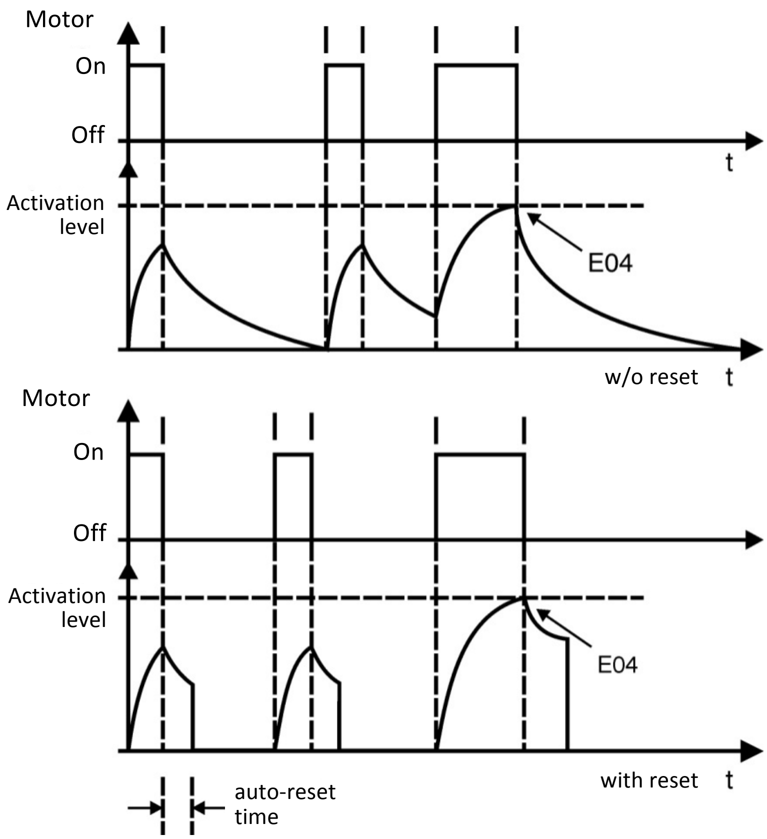


***Figure 5.14**: Thermal image auto-reset*

> **NOTE!**
> It is important to remember that, by using this function, the lifetime of the motor winding may be decreased.

5.5 ERRORS AND THEIR POSSIBLE CAUSES

A Soft-Starter can indicate the following errors:

- Incorrect programming error (E24);
- Serial error (E2X);
- Hardware error (E0X).

5.5.1 Programming error (E24)

An incorrect programming error (E24) does not allow the value that was incorrectly altered to be accepted. This error occurs when a parameter is altered with the motor Off and in the following conditions of incompatibility among parameters.

P11 current limitation with P41 kick start
P41 kick start with P55=4 at Jog
P43 by-pass with P44 energy savings
P61 at Off with ED1 or P55 Jog at On

To exit this condition of error just press the P, I, O keys.

Serial communication error (E2X)

Serial communication errors (E2X) do not allow the value that was altered or sent incorrectly to be accepted. For more details, see the SSW-03 Serial Communication Manual. To exit this condition of error just press the P, I, O keys.

5.5.2 Hardware error (E0X)

Hardware errors (E0X) block the Soft-Starter. To exit this condition of error, switch off the power supply and switch it back on. The push button  can also be used as reset. The error must be resolved before switching on again.

NOTE!
How error functions work:
All hardware errors E01…E08 turn off the RL3 relay and block the thyristor firing pulses, besides indicating the error in the display.

Obs.: Connection cables between the Soft-Starter and the motor that are too long (greater than 150m) or are shielded can present a high capacitance. This can cause the Soft-Starter to be blocked due to error E01.

Solution: Connect a three-phase reactance in series with the motor power supply grid. In this case, please consult the manufacturer.

Hardware errors

ERROR	RESET	PROBABLE CAUSES
E01	■ Switch electronics off and switch it back on ■ Or through the reset key ■ Or through the digital input programmed to reset ■ Or through the serial port	■ Phase failure in the three-phase power supply ■ Short-circuit or failure ■ Motor not connected ■ Power supply frequency with variation above 10%
E02		■ Programmed acceleration ramp time lower than the real acceleration time because the current limitation is on
E03		■ Ambient temperature greater than 40°C and elevated current ■ Start time with current limitation greater than that specified by the switch ■ Elevated number of successive starts ■ Blocked or defective fan
E04		■ P21, P25 and P26 set too low for the motor used ■ Load on the motor shaft too high ■ Elevated number of successive starts
E05		■ Pump working on dry ■ Load not coupled at the motor shaft
E06		■ Short-circuit between phases ■ Locked motor shaft (blocked)
E07		■ Inverted input power supply phase sequence
E08		■ Open wiring on terminal X2.3 and X2.5 (not connected to 24Vdc)

Possible hardware errors and their solutions

PROBLEM	POINT TO CHECK	SOLUTION
Motor does not spin	Incorrect wiring	1. Check all the power and command connections. For example: check the external error digital input that must be connected at 24Vdc.
	Incorrect programming	1. Check if the parameters have the correct values for the application.
	Error	1. Check if the Soft-Starter is not blocked due to a detected condition of error (see previous table).
Motor rotation oscillates (floats)	Loose connections	1. Turn the Soft-Starter and the power supply off, and tighten all the connections. 2. Check to see if all the internal connections of the Soft-Starter are tightly fastened.
Motor rotation too high or too low	Nameplate data	1. Check if the motor used is appropriate for the application.
Display is off	HMI connections	1. Check the HMI connections to the Soft-Starter (CCS1.1X card)
	Power supply voltage X1.1 and X1.2	1. Rated values must be within the following: For 220/230 Vac For 110/120 Vac Vmin = 187 Vac Vmin = 93.5 Vac Vmax = 253 Vac Vmax = 132 Vac
Cogging during pump acceleration	Soft-Starter parameter setting	1. Reduce time set at P04.

6 SIZING THE MOTOR + SOFT-STARTER SYSTEM

6.1 INTRODUCTION

At the end of this chapter two important objectives will have been reached.

1) The first and most important objective is to learn the difference between a simple application and a demanding application.

Note that "demanding" applications are being considered, not only those with heavy duty operation and load cycles. Demanding applications include those where the environment or the electric power supply have unfavorable characteristics.

It will be possible to identify a demanding application by learning which characteristics to analyze and with this, safely lead to correctly choosing the Soft-Starter.

2) The other objective is to see how easy it is to choose the correct Soft-Starter, for most common applications.

A Soft-Starter is a flexible and user friendly piece of equipment with several settings used to reach the best starting condition for a series of applications. Tips and generic comments will be given on many applications, which will be useful for the reader of this chapter when he/she is putting the acquired knowledge in practice.

Although the information presented here is the basis for Soft-Starter application, if there are any questions, the same information is available through the SDW – WEG Sizing Software (annex 2). Use the SDW along with this guide.

6.1.1 Definitions

Motor – Whenever *motor* is mentioned generically in this section, unless specifically stated otherwise, it will be referring to an alternating current, asynchronous, induction motor with a squirrel cage rotor.

Starter – Here the word *starter* means the set made up by the motor and its starting system, plus any other electronic control device that might be involved (such as a drive).

Load – The word *load* means the set of machine components that moves, or other components that are in contact and influence those parts, starting from the motor shaft end.

Torque – *Torque* can be defined as "the necessary force to spin a shaft". It is given by the product of the tangential force **F** (N) by the distance **r** (m) from the force application point to the center of the shaft. The SI (International System) unit of torque is the Nm (Newton-meter).

Inertia – *Inertia* is the resistance that a body offers to a modification in its state of movement. Any "body" with mass has inertia. A mass at rest requires torque (or force) to put it in movement. A mass in movement requires torque (or force) to change its speed or to put it to rest. The *mass moment of inertia* **J** (kgm^2) of a body depends on its mass **m** (kg) and the distribution of the mass around the spinning shaft, that is, its geometry. Annex 1 lists the formulas used to calculate the mass moment of inertia of several common bodies.

6.1.2 Basic Concepts

Torque

Torque **T** (Nm) is a product of the force **F** (N) necessary to spin a shaft by the distance **r** (m) of the force application point to the center of the shaft.

$$T = F * r \qquad \textbf{(6.1)}$$

This is the torque necessary to overcome the internal friction of a stopped machine, and that is why it is called *static frictional torque*, $T_{e\ at}$.

The torque needed to put a machine in movement can be determined by measuring the force, for example, using a wrench and a coil dynamometer, as seen in figure 6.1.

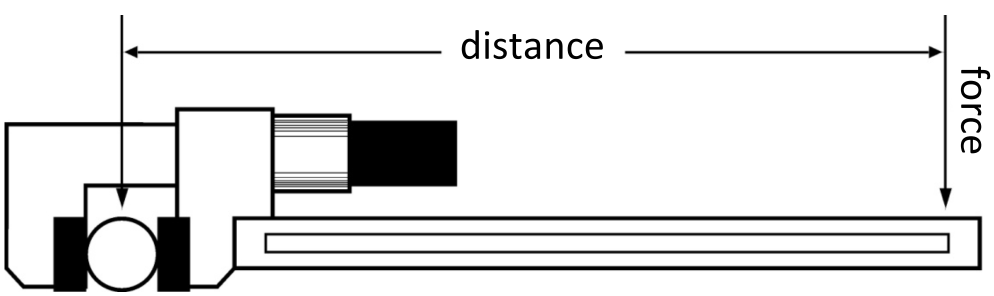


Figure 6.1: *Torque measurement*

Example:

If there is a force reading of 75 N (≈7.6 kgf) at 0.6 m (600 mm) from the center of the input shaft, the torque will be (equation 6.1):

$T_{e\ at} = 75 * 0.6 = 45.0$ Nm

Power

Power **P** is given by the product of the torque **T** (Nm) by the rotational speed **n** (rpm). The unit for power is the Watt. (Remember that 1000 W = 1 kW).

$$P = (2 * \pi/60) * T * n \qquad \textbf{\textit{(6.2)}}$$

Example:

If the machine requires the same 45.0 Nm at a rotation speed of 1,760 rpm, then the power will be (equation 6.2):

$$P = (2 * \pi/60) * 45.0 * 1{,}760 = 8{,}294 \text{ W } (\approx 8.3 \text{ kW})$$

Acceleration (deceleration)

Torque **T** required to accelerate (or decelerate) a load with a mass moment of inertia (or simply inertia) **J** (kgm^2), from a rotation speed $\mathbf{n_1}$ (rpm) to $\mathbf{n_2}$ (rpm), in a time **t** (s), is given by:

$$T_{d\,ac} = (2 * \pi/60) * J * (n_2 - n_1) / t \qquad \textbf{\textit{(6.3)}}$$

This torque is called dynamic acceleration torque, $T_{d\,ac}$. If $n_2 > n_1$ (acceleration), $T_{d\,ac}$ is positive, meaning that its direction is equal to the direction of rotation. If $n_2 < n_1$ (deceleration), $T_{d\,ac}$ is negative, meaning that its direction is opposite the direction of rotation.

Example:

A solid aluminum cylinder, with diameter **d** = 165 mm and length **l** = 1,200 mm, and therefore with a mass **m** of approximately 69.3 kg, has a mass moment of inertia **J** of (equation A1.1, annex 1):

$$J = 1/8 * 69.3 * 0.165^2 = 2.36E10^{-1} \text{ kgm}^2$$

If the body must accelerate from 0 to 1,760 rpm in a time of 1.0s, then the acceleration torque will be (equation 6.3):

$$T_{d\,ac} = (2 * \pi/60) * 2.36E10^{-1} * (1{,}760 - 0) / 1.0 = 43.5 \text{ Nm}$$

Adding the acceleration torque above and the frictional torque calculated in the first example, the torque is:

$$T = 45.0 + 43.5 = 88.5 \text{ Nm}$$

And the power (equation 6.2):

$$P = (2 * \pi/60) * 88.5 * 1{,}760 = 16{,}303 \text{ W } (\approx 16.3 \text{ kW})$$

Effect of a mechanical transmission
Mechanical transmission is understood as a speed reducer (or multiplier), like a gear reducer, reduction by pulleys and V-belt or timing belt. A mechanical transmission has two important parameters for sizing the starter, which are: (a) the transmission ratio i_R and (b) the efficiency η_R. In the case of gear reducers, these parameters are supplied by their manufacturer, and in the case of transmission by pulleys or belts, the parameters can be calculated from the transmission parameters (ratio of the effective diameters or ratio of the number of teeth).

Speed reducers are used, for example, for starting machines with low speeds and are placed between the motor shaft and the machine input/inlet shaft. The motor rotation speed is reduced proportionally to the transmission ratio i_R. The motor torque is multiplied by the same proportion. Besides this, part of the energy that enters is consumed by internal losses (friction, noise, etc.), which is quantified by the efficiency η_R. Thus, the torque needed at the input of a reducer T_1 (Nm) as a function of the torque demanded at the output T_2 (Nm) is given by:

$$T_1 = T_2 / (i_R * \eta_R) \qquad (6.4)$$

Example:
If example 4, with T_2 = 88.5 Nm, had a 1 stage gear reducer with a transmission ratio of i_R = 1.8 and efficiency η_R = 0.85, torque T_1 would be (equation 6.4):

T_1 = 88.5 / (1.8 * 0.85) = 57.8 Nm

The maximum motor speed would then be:

N_1 = 1,760 * 1.8 = 3,168 rpm

And the power (equation 6.2):

P = (2 * π/60) * 57.8 * 3,168 = 19,179 W (≈19.2 kW)

6.2 INTERACTION BETWEEN PROCESS, MACHINE MOTOR AND STARTER

6.2.1 The Importance of the Process/Machine

First comes the process. For entrepreneurs who need to pump water, grind grains, activate transporters, use compressed air, ventilate an area, or whatever else, the use of an electric motor is a consequence.
That is, the entrepreneur’s main focus is not in the technological restrictions that exist in running the process.

There are many driving solutions for a specific machine or process. It is the entrepreneur's responsibility (or that of the engineers/technicians) to choose the best solution for a given scenario, made up of the type of machine/process and by the available resources.

This is why the person responsible for applying a starter with an electric motor must, before all else, understand the process, that is, the requirements of the machine.

For example, suppose there is a small rural business that produces a certain type of grain and also has a byproduct that is a result of the grain's grinding process.

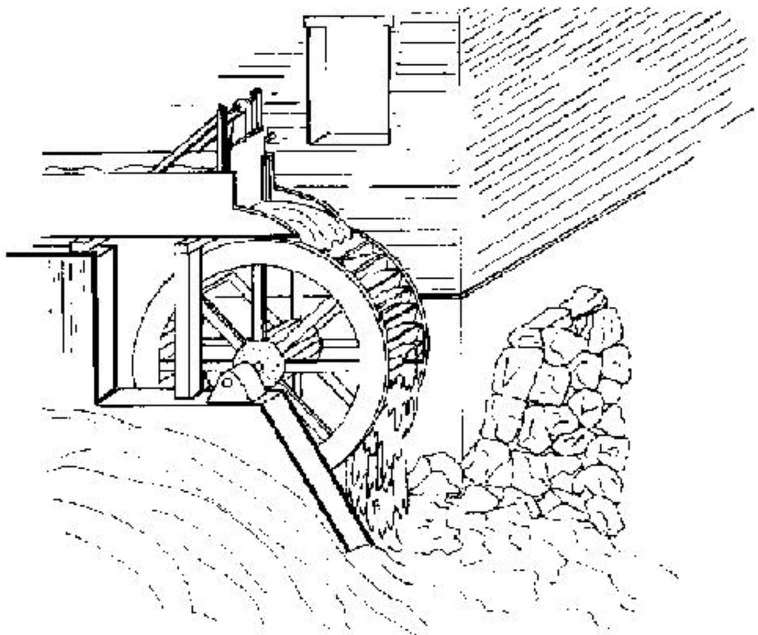


Figure 6.2*: Water mill. The solution to process motorization has not always counted on the flexibility of electric motors. The solution in itself is not as important as understanding the process needs.*

For a small production (or individual use) the business owner can use his/her own power, that of employees, water wheels, animals, etc. The process comes first, and afterwards comes the driving solution.

For production at a commercial level, it is necessary to use some kind of motorization that reaches the objectives while better utilizing the resources. It must be more efficient.

Within a universe of options for driving the process (grinding in the example), the entrepreneur chooses a three-phase electric motor. The machine he/she will acquire for the process will probably already be equipped with an installed motor.

Why would the manufacturer of the grinder supply a machine with an electric motor and not a diesel motor, for example? Or a DC motor? Or a turbine?

An AC electric supply is more convenient to work with than any other (diesel, DC energy, vapor, water, etc.).

Its use is widespread and its maintenance is easier. More professionals understand its characteristics and **especially its restrictions**.

Now, why should the manufacturer of the grinder or the entrepreneur use a Soft-Starter to drive the motor?

***Figure 6.3**: SSW-03 and SSW-04. Increasing machine and process sophistication, as well as greater consciousness of the need for preserving resources and installations, has created an environment that is well suited for the smooth driving of machines.*

Because they want driving that:

1) Causes less mechanical wear, and consequently, requires fewer stops for maintenance;
2) Causes less disruption in the electrical power supply, maintaining the stability for other equipment;
3) Uses the energy supply of that area better, making it easier to work with demand restrictions.

> **NOTE!**
> To keep the example simple, appropriate analysis of the application (mill) was omitted.

6.2.2 Electrical Starter Applications – Typical Problems

Inadequate application of the different types of electrical starting systems is a source for problems.
As seen in chapter 1, a slip ring motor and a motor with a squirrel cage rotor have individual characteristics that must be taken into consideration. Not only are the torque characteristics different, but there are also considerable differences in cost, starting options, frame dimensions, etc.

Therefore, it is necessary to understand how the motor interacts with the control system, and how both the motor and the system interact with the machine that is being driven, as well as the power supply.

Sizing is based on the torque that the load requires.

Thus, one can say that it is necessary to know the machine that is being driven very well. It is very important to ask as many questions as possible, even regarding things that are apparently insignificant. It is impossible to ask too much, and the more an application is understood, the better.

It is also necessary to understand the relations of power, torque, speed and acceleration/deceleration, as well as the effect of a mechanical transmission in the context of machine motorization.

6.3 WHAT A LOAD REQUIRES

Before continuing, it is important to remember the definition of the word *load*, section 6.1.1. In this material, load means: “the set of machine components that moves, or other components that are in contact and influence those parts, starting from the motor shaft end”.

To begin, one must pay attention to the load, and not the motor or drive. To correctly decide on the best starting system for a machine, it is necessary to consider that machine first. If one does not know the machine in detail, he/she will not be able to make the correct decisions regarding how it is driven.

A check-list containing possible questions is a great help. Questions regarding the performance and demands of the machine should be asked. Is the load constant or variable? Is fast acceleration necessary? In this case, what is the maximum admissible acceleration time? Is the service duty continuous or interrupted and repeated in intervals? See annex 3 of this guide for a sample check-list.

From here on out, the focus will be on determining the torque demanded by the load.

6.3.1 Types of Loads

Normally, the information of the torque demanded by the load is presented in the form of a "*torque versus speed*" graph. This does not have to be an impeccable graph, with perfect, colored lines. What is important is that it is a good size (not too small) and in scale. It can very well be hand-drawn.

Loads generally fall into one of the following categories:

- Constant torque
  The torque demanded by the load presents the same value throughout all the speed ranges. Hence, the power demand grows linearly with the speed (figure 6.4a). A conveyor belt moving a 1 ton load at 0.1 m/s, for example, requires approximately the same torque as if it were at 1.0 m/s. Other examples of loads with this type of behavior are: hoisting equipment (cranes and elevators), laminators, extruders and positive displacement pumps (piston, gear and helicoidal pumps).

- Constant power
  The initial torque is high and decreases exponentially with an increase in speed. The power demanded remains constant throughout all the speed ranges (figure 6.4b). This is normally the case in processes where there are variations in diameter, like in winding and unwinding machines and three axis tool machines. When the diameter is at its maximum, maximum torque is demanded at low speeds. As the diameter decreases, so does the torque demand, but the rotation speed must increase to keep the peripheral speed constant.

- Linear torque
  The torque grows linearly with the increase in speed, and therefore, the power grows in a quadratic manner (figure 6.4c). An example of a load with this behavior is a press.

- Quadratic torque
  The demanded torque increases with the square of the rotation speed, and the power increases with the cube (figure 6.4d).
  Typical examples are machines that move fluids (liquids or gases) through dynamic processes, like, for example, centrifugal pumps, fans, exhausts and centrifugal mixers. These applications present the greatest energy savings potential because the power is proportional to the speed raised to the cube.

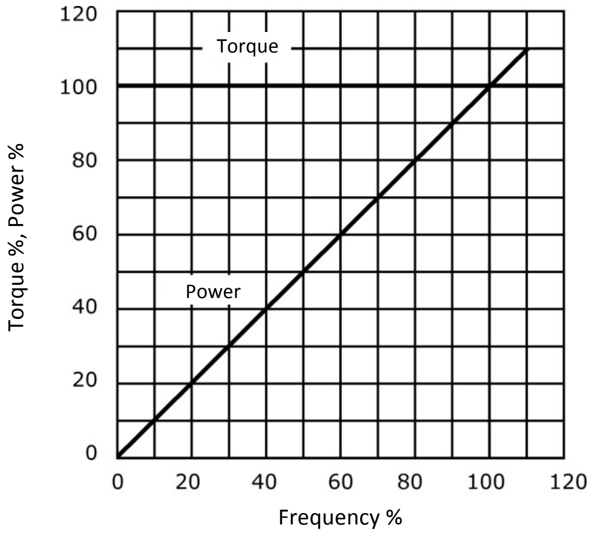


__Figure 6.4a__: Typical loads (constant torque)

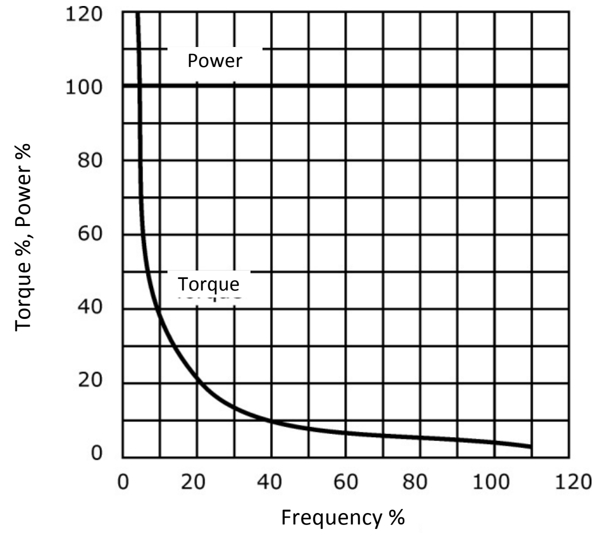


__Figure 6.4b__: Typical loads (constant power)

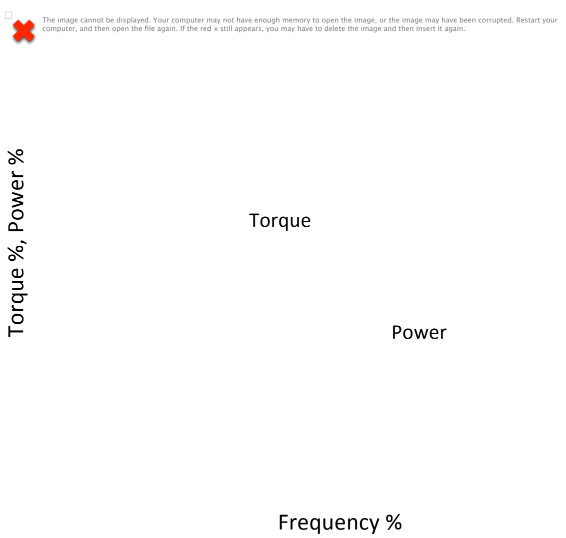


__Figure 6.4c__: Typical loads (linear torque)

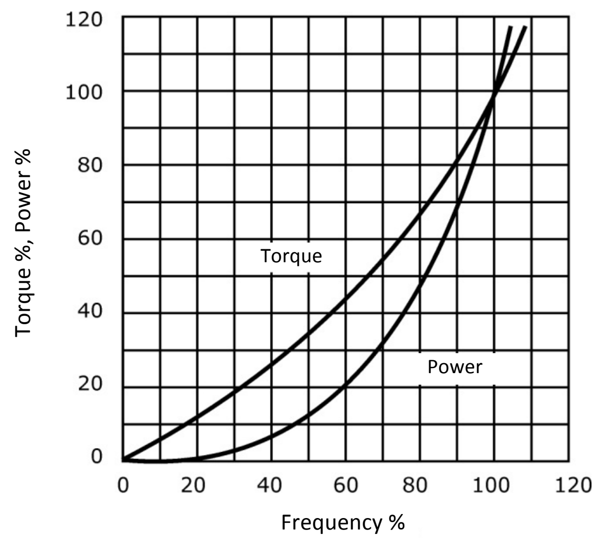


__Figure 6.4d__: Typical loads (quadratic torque)

6.3.2 Load Peak

The torque peak is different for each type of machine and needs to be identified correctly. In some cases the starting torque is too high, like in a very heavy conveyor. A load with high inertia that requires very fast acceleration will also have a high torque demand during the acceleration. Other applications present their maximum demand in operation, and not at the start, with sudden overloads appearing periodically.

6.3.3 Estimating Loads

It is sometimes necessary to determine the torque demanded by an existing machine, with an AC motor supplied directly by the power supply. The electric current consumed by the motor is a good indicator of the demanded torque. If it is possible to measure the current values in each of the operating conditions of the machine, a good approximation of the torque demanded by it can be reached. The current should be measured in one of the motor phases during the start, acceleration, normal operation and even in eventual overload situations. It is also important to determine the duration of each of these conditions within the machine cycle.

Next, the rated current value is checked on the motor nameplate.

Example:
A 15kW motor, 1760 rpm, 220V has a rated current of 52.0 A. The efficiency of this motor at 100% of the rated power is 89.8%. This means that 89.8% of 52.0 A = 46.7 A will produce torque. The other 52.0 – 46.7 = 5.3 A will make up for the losses and produce motor magnetizing.

The rated motor torque can be calculated from the rated power and the rated speed, as seen in equation 6.2.

$T = 15000 / [(2\pi/60) \times 1760] = 81.4$ Nm

One can say that the motor will develop:

81.4 Nm / 46.7 A = 1.743 Nm/A

Hence, at a current reading of 20 A, for example, the corresponding torque will be:

$(20-5.3) \times 1.743 = 25.6$ Nm

This logic is valid up to the rated speed. The torque of an AC motor operating with a variable frequency drive above the rated speed varies inversely to the square of the speed. In other words, at a speed equal to double the rated speed, the motor produces ¼ of the rated torque.

6.4 SELECTING A STARTER (MOTOR / SOFT-STARTER)

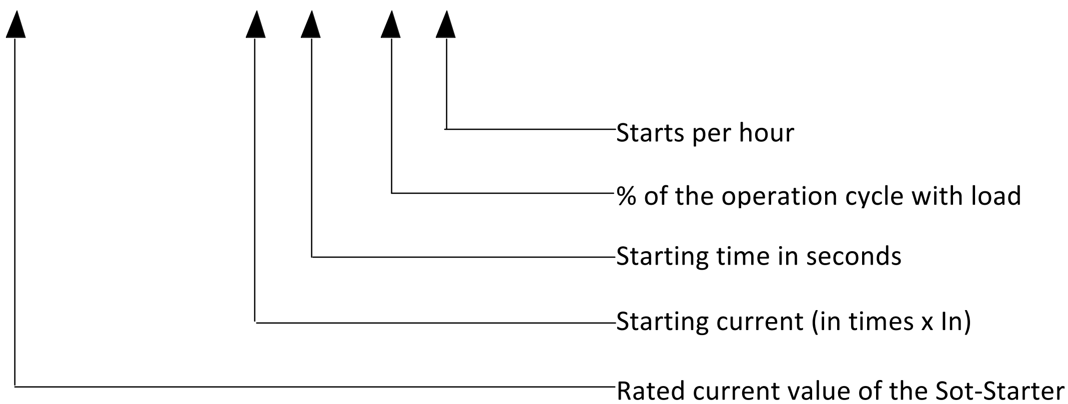
Items 5 and 6 of norm IEC 60947-4-2 specifies, among other subjects, AC53 categories, describing how the parameters define rated values of a Soft-Starter. There are two AC53 codes:

6.4.1 Categories AC53a and AC53b

- **AC53a**: for Soft-Starters used without by-pass contactors

For example, code AC53a below describes a Soft-Starter capable of supplying an operation current of 340 A and a starting current of 3 x 340 A for 30 seconds, 10 times per hour, with the motor operating for 60% of each cycle.

340 A: AC53a 3 30 60 10



- **Rated current value of the Soft-Starter**: maximum rated value for the rated current of the motor connected to the Soft-Starter, obeying the operation parameters specified by the other items in code AC53a.

- **Starting current**: the maximum current that will be drained during the start.

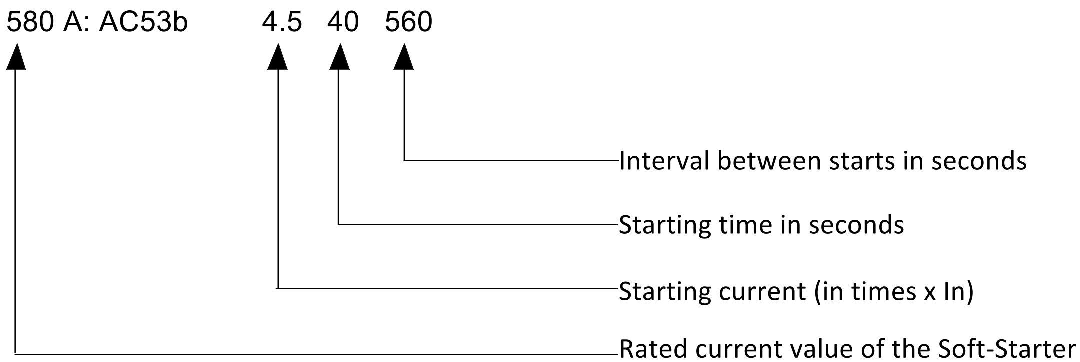
- **Starting time**: the time the motor takes to accelerate.

- **Work cycle with load**: the percentage of each operation cycle in which the Soft-Starter will be activated.

- **Starts per hour**: the number of operation cycles per hour.

- **AC53b**: for Soft-Starters used with by-pass contactors

For example, code AC53b below describes a Soft-Starter that, when used with a by-pass circuit, is capable of supplying an operating current of 580 A and a starting current of 4.5 x In for 40 seconds, with a minimum of 560 seconds between the end of a start and the beginning of the next one.



Therefore, one can say that a Soft-Starter has "several" rated current values. These values depend on the starting current and the requirements of the process/application.

To compare rated current values of different Soft-Starters, it is important to make sure the various parameters involved are identical.

6.4.2 Soft-Starter Thermal Capacity

The maximum rated value of a Soft-Starter is calculated in a way that the junction temperature of the power module (SCR) does not exceed 125°C.

Listed below are five operation parameters, besides the ambient temperature and the altitude, that affect the SCR junction temperature:

- Motor operation current;
- Current required at the start;
- Duration of the start;
- Number of starts per hour;
- Rest interval between starts.

The rated specification of a Soft-Starter must consider all these parameters. A single rated current value is not enough to describe the characteristics of a Soft-Starter.

Item 6.4.3 below will describe the procedure, using the five parameters above, to quantify how much a process demands from a Soft-Starter.

The calculation procedures of the RMS current demanded in a cycle and the calculation procedures of the RMS current capacity of a Soft-Starter are analog.

6.4.2.1 RMS Current in a Cycle (I_{RMS})

The RMS (Root Mean Square) value of a set of values is the square root of the mean of the square of this set of values. It is a common concept used to calculate effective values of electrical measurements.

According to IEC 61000-4-30: "**r.m.s**. value is the square root of the mean of the squares of the instantaneous values of a quantity taken over a specified time interval."

This definition is helpful in understanding the description of starter categories AC53a and AC53b.

The practical formula used to calculate the RMS value of the current in a machine operation cycle is the following:

$$I_{RMS} = \sqrt{\frac{\sum_{i=0}^{n} (I_i)^2 \cdot t_i}{\sum_{i-0}^{n} t_i}} \qquad \textbf{(6.5)}$$

That is:

$$I_{RMS} = \sqrt{\frac{(I_1)^2 \cdot T_1 + (I_2)^2 \cdot t_2 + \ldots + (I_N)^2 \cdot t_N}{T_{Total}}} \qquad \textbf{(6.6)}$$

With:
I_{RMS} – RMS current in the cycle
I_1 – current in path 1 of the cycle
t_1 – duration of path 1 of the cycle
I_2 – current in path 2 of the cycle
t_2 – duration of path 2 of the cycle
I_N – current in path N of the cycle
t_N - duration of path N of the cycle

Example:
Imagine the following operation cycle of a machine:

During time interval (a) the machine accelerates until its working speed, remains at that set speed during period (b) and then goes back to rest, decelerating during period (c). The operation consumes 60% of the cycle.

For this cycle, suppose that the Soft-Starter, under typical acceleration conditions for the inertia and overcoming the frictional torque, found the best motor start according to the following current cycle:

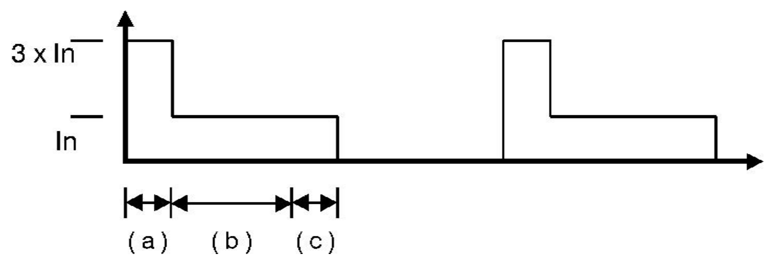


***Figure 6.6**: Current x time graph for the motor supplying load "X"*

Completing the example above, suppose that the following values can be applied:

(a) = 30.0 sec.
(b) = 329.0 sec.
(c) = 1.0 sec.
In = 100 A
3 x In = 300 A

Below, the EMS current value is calculated only in the cycle path with a load, that is, segments (a), (b) and (c).

$$I_{RMS} = \sqrt{\frac{(3 \cdot 100)^2 \cdot 30 + (100)^2 \cdot 330}{360}} = 129$$

Note that the value obtained is between the starting current (300A) and the rated current (100A). This indicates the characteristic of “mean” that the RMS value has. The effective current value at this stage of the cycle is 129 A.

It is important to remember, however, that there is a resting period until the next start. If this rest is considered, the effective current (RMS) will only be 74 A. The value of 74 A is lower than the value of the current in operation (100 A), which means that the cycle has a relatively low thermal demand.

$$I_{RMS} = \sqrt{\frac{(3 \cdot 100)^2 \cdot 30 + (100)^2 \cdot 330 + (0)2 \cdot 240}{600}} = 74$$

This explains why IEC 60947 includes the resting time period between starts (or the % of time in operation) as a parameter of categories AC53a and AC53b.
But can just any resting period be used to calculate the RMS value, therefore reaching a lower value? No.

A safe way to do this is to choose the most demanding six minutes of the cycle, calculating the effective current for this time interval.

In an analog manner, it would be necessary to calculate the effective current of the Soft-Starter to compare it to the cycle to which it is subjected. The current and time data needed to calculate the effective current of a Soft-Starter are its rated current and the overload cycle to which it will be subjected. The formula and the calculation procedure are the same as those already described for the operation cycle.

The effective current values (RMS) of the cycle and the Soft-Starter are now known. With this information, a Soft-Starter whose effective current is greater than the effective current demanded by the motor should be selected, with the addition of the respective temperature and altitude correction factors. Therefore:

$I_{ef\,SS} < K \times I_{ef}$ ***(6.7)***

K is the representation of the temperature and altitude influence on the sizing, as well as an eventual safety gap.

6.4.3 Special Cases

The admissible power of a Soft-Starter is determined by considering the following:

- Altitude at which the Soft-Starter will be installed

- Temperature of the cooling medium

NBR 7094 defines the following as usual service conditions:
a) Altitude no greater than 1000 m above sea level;
b) Cooling medium (ambient air) with a temperature no greater than 40°C.

In cases where the Soft-Starter must work with cooling air temperatures at rated power (greater than 40°C and/or at an altitude greater than 1000 m above sea level) the following reduction factors must be considered:

- Ambient temperature effect

The rated power (current) reduction of the variable frequency drive, due to the rise in ambient temperature, above 40°C and limited to 50°C, is given by the graph below:

Reduction factor = 2% / °C

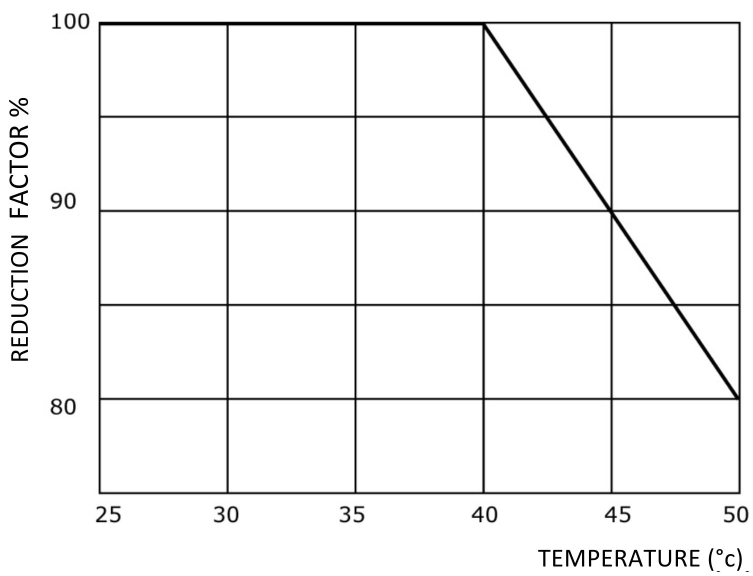


***Figure 6.7**: Rated power reduction curve as a function of the temperature increase*

- Altitude effect

Drives operating at altitudes above 1000 m, present problems with heating caused by air rarefaction and, consequently, decreased cooling ability.
Insufficient exchange of heat between the drive and the surrounding air leads to a need for reduction in losses, which also means a power reduction. Heating in drives is directly proportional to the losses, and these vary, approximately, in a quadratic ratio with the power.
According to norm NBR 7094, temperature elevation limits must be lowered in 1% for every 100 m above the altitude of 1000 m.
The rated power (current) reduction of variable frequency drives, due to a rise in altitude above 1000 m and limited to 4000 m, is given by the graph below:

Reduction factor = 1% / 100m

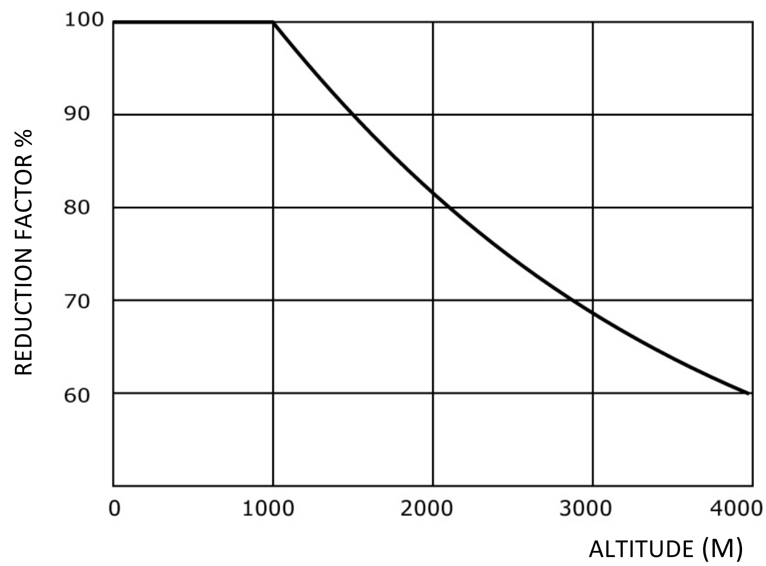


Figure 6.8*: Rated power reduction curve as a function of an increase in altitude*

6.4.4 Motor Locked Rotor Time

This is defined as the maximum time admitted by the motor under locked rotor current, that is, under starting current.
In practice, this time is adopted as the maximum starting time that the motor withstands.
However, this time increases as the current the motor demands from the power supply during the start is limited.

An extreme example of this situation is a start with a variable frequency drive using a ramp that allows for an acceleration consuming only one time the rated motor current. The maximum starting time in this example would be infinite, since the motor would be consuming rated current during the “start”, as long as the motor is equipped with the necessary ventilation.
The following equation is used as a practical rule to calculate the “locked rotor time” for the Soft-Starter:

$$t_{LR_{SS}} = t_{LR_m} \cdot \left(\frac{I_A/In}{I_L}\right)^2 \qquad \textbf{(6.8)}$$

Where:
$t_{LR_{SS}}$ = locked rotor time for a specific current limitation with the Soft-Starter
t_{LR_m} = Catalog locked rotor time
I_A/I_n = Ratio between the starting current and the rated current of the motor (catalog)
I_L = Soft-Starter limitation current

For example, a motor with a locked rotor time of 7.2 seconds and starting current of $I_A = 7 \times I_n$. If this motor starts a load with a current limitation of 4.5 x I_n, the maximum starting time that this motor withstands is increased to 17.42 seconds.

$$t_{LR_{SS}} = 7.2 \cdot \left(\frac{7}{4.5}\right)^2 = 17.42$$

6.4.5 Acceleration Time

Calculating the acceleration time is possible in a scenario with ideal application information. For this, the motor and load torque curves, motor and load moments of inertia and the reduction ratio are necessary.

Note that in the following example, to keep it simple, the voltage drop caused by the motor start will not be considered, that is, the power supply would present an infinite short circuit current. Item 6.5 below defines a voltage drop and its influence on the motor start.
It is known that, for an electric motor to withstand the starting condition, the following ratio must be respected:

$$t_a \leq 0.80 \times t_{LR} \qquad \textbf{\textit{(6.9)}}$$

Where,
t_a - Acceleration time
t_{LR} - Locked rotor time

The condition above should take into account the blocked rotor time corrected as a function of the current or voltage correction factor. This information can be obtained from the motor catalog or from the data sheet, which considers that rated voltage is being applied to the motor.
To calculate the acceleration time, the following equation is used:

$$t_a = 2\pi \cdot \Delta n \cdot \left(\frac{J_T}{M_A}\right)$$
(6.10)

Where,
t_a- Acceleration time
Δn - Speed
J_T or WK^2 – Total moment of inertia
M_A- Accelerating torque

The total moment of inertia is calculated by:

$$J_T = J_{motor} + J_{load} \quad \textbf{(6.11)}$$

Where,
J_{motor} – Moment of inertial of the motor
J_{load} - Moment of inertial of the load referred to the motor shaft

To calculate the accelerating torque, it is necessary to calculate the area defined by the characteristic motor and load torque curves (figure 6.9). This area can be calculated in the following ways: analytically, numerically or graphically. For analytical calculation, it is necessary to know the equations for the two curves so that they can be integrated between the desired limits. Although a little hard, the load curve equation can be interpoled, whereas that of the motor is too difficult to reach because it would be necessary to obtain extremely detailed information about the electrical characteristics of the motor. The following equation can be considered a very reasonable and valid approximation of this.

$$M_{motor} = \frac{A - Bn}{Mn^2 - Dn + E} \quad \textbf{(6.12)}$$

Where A, B, C, D and E are integer and positive constants that depend on the motor characteristics.

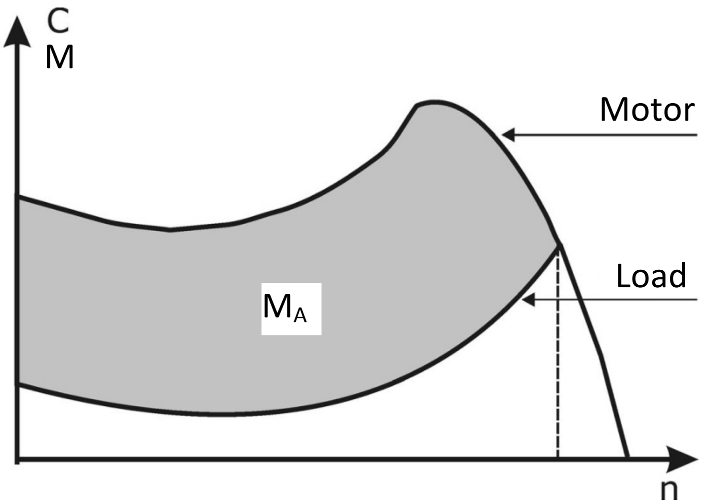


***Figure 6.9**: Graph of the accelerating torque*

Thus, the area represented in the figure above could be calculated by solving the following generic equation:

$$M_A = \int_0^n \frac{A - Bn}{Mn^2 - Dn + E}\, dn - \int_0^n M_{RT}(n)dn$$
(6.13)

M_{RT} (n) depends on the load torque characteristics, which, as seen before, can be classified into one of the specific groups (constant, quadratic, linear, hyperbolic or undefined). It is easier to find another way of calculating this area without going into complex integration techniques.

An interesting way to do this would be to calculate the area through a numeric integration technique. Because of its simplicity, the technique of integration through trapezoids will be used. This technique consists of dividing the integer interval in N equal parts and calculating the area of the trapezoid formed in each of the Δn subintervals. The torque points are read directly from the curve (see figure 6.10). It is clear that there will be a margin of error in the calculated value, but in this case it is perfectly tolerable.

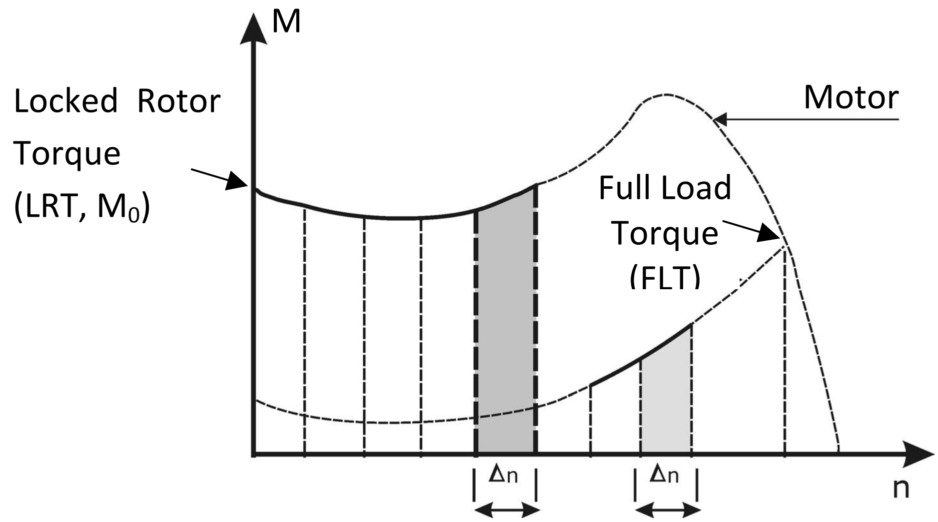


***Figure 6.10**: Technique of numeric integration through trapezoids*

Although time consuming, depending on the number of subintervals, this technique is very effective and simple. It allows the accelerating torque to be calculated for any torque characteristic of the motor and load. Let it be clear, however, that before applying this technique, the motor torque curve must be corrected based on the applied voltage variation, through reduction factors. Consider that the voltage variation applied to the motor obeys the following equation:

$$V(n) = \left(\frac{V_{rated} - V_p}{n_{rated}}\right) \cdot n + V_p \qquad \textbf{(6.14)}$$

Where,
V_p - Starting voltage
V_{rated} - Rated voltage
n_{rated} - Rated speed

The equation above would be valid if there were a closed loop speed system, where the Soft-Starter would receive the motor speed reading and then the voltage ramp would be applied.

Anyway, for sizing purposes, this will not get in the way because it is a satisfactory approximation. Figure 6.11 illustrates this consideration.

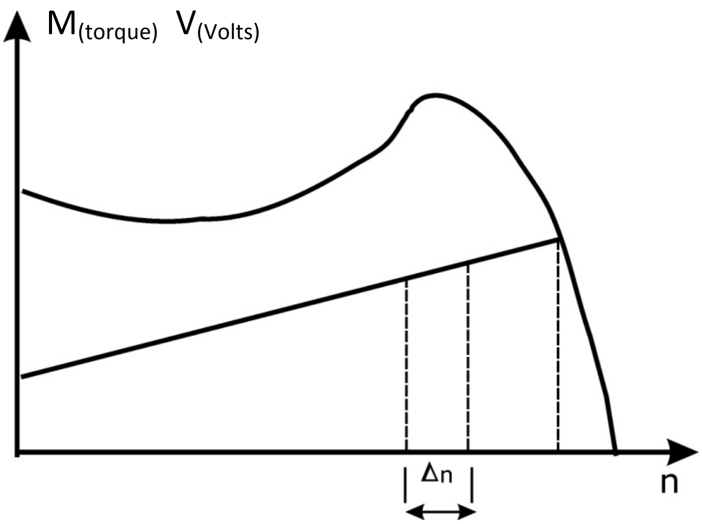


***Figure 6.11**: Voltage ramp applied to the motor during the start*

Thus, these values can be put into a table to make it easier to visualize the results obtained from the procedure described above.

***Table 6.1:** Torque values*

Speed (%)	M / M_N (motor)	M_{RC} / M_N	M_A / M_N
n_0	M_0	M_{R0}	$\frac{M_0 + M_1}{2} - \frac{M_{R0} + M_{R1}}{2}$
n_1	M_1	M_{R1}	$\frac{M_1 + M_2}{2} - \frac{M_{R1} + M_{R2}}{2}$
n_2	M_2	M_{R2}	$\frac{M_2 + M_3}{2} - \frac{M_{R2} + M_{R3}}{2}$
...	...	...	...
n_{rated}	M_N	M_N	$\frac{M_{N-1} + M_N}{2} - \frac{M_{RN-1} + M_N}{2}$

NOTE!
All the torque values in the table above were referenced to the rated motor torque because it is easier to work with values referenced in this manner.

By applying these values to the acceleration time equation, it is possible to calculate the partial acceleration times for each of the subintervals. All that has to be done afterwards is to add these partial values, thus obtaining the total acceleration time of the motor. We can express this mathematically through the following equation:

$$t_a = \sum_0^N t_{an} \quad \textbf{(6.15)}$$

The value found from the equation above must follow what is defined by expression 6.9. If this checks out, one can be sure that the chosen motor meets the starting condition.

This procedure will now be applied to a practical example based on a real application. The following information is provided:

- Load torque curve;
- Motor data sheet;
- Motor current and torque characteristics curve.

Observation:
See annex 1.

This example considers the data of a 25HP, 4 pole motor driving a centrifugal pump (quadratic torque). The pump moment of inertia value J (or WK^2) is stipulated at $0.023Kgm^2$ and the motor moment of inertia (catalog data) is $0.11542Kgm^2$.
The torque curves as a function of the rotation, of the pump and the motor, provide the demanded torque value in ten different rotation points. These values are listed in the table below.

Table 6.1a

Frictional torque points		Motor torque
Speed (% of n_{rated})	M_{RES} (N.m)	M_{motor} (N.m)
0	20.0	229.54
10	15.0	210.4117
20	14.0	197.6594
30	16.0	191.2833
40	23.0	193.8338
50	30.9	204.0356
60	39.9	216.7878
70	50.9	229.54
80	63.9	255.0444
90	75.8	184.9072
100	89.8	99.8

The motor torque values must be corrected for the voltage variation that will be applied. Here, it is considered that the motor will reach the rated voltage at the end of the ramp applied by the Soft-Starter. It is known that the motor torque varies according to the square of the applied voltage. As such, it is possible to determine the corrected torque values for each of the points provided, since the voltage ramp is known.
This is represented in the following table.

Table 6.1b

Motor torque values must be corrected through the following equation: $M_{motor} = (V/100)^2 \times M_{motor}$ (from table 6.1a)		
Speed (% of n_{rated})	Voltage (% of V_{rated})	M_{motor} (N.m)
0	35	28.1
10	41.5	36.2
20	48	45.5
30	54.5	56.8
40	61	72.1
50	67.5	93.0
60	74	118.7
70	80.5	148.7
80	87	193.0
90	93.5	161.6
100	100	99.8

With the corrected torque values it is now possible to fill in a table like table 6.1. This table will present the minimum accelerating torque values for each one of the defined rotation intervals. This new table is shown below.

Table 6.1c

Speed (% of n_{rated})	M_{motor} (N.m)	M_{RES} (N.m)	$M_{A\ medium}$ (N.m)
0	28.1	20.0	8.2
10	36.2	15.0	21.3
20	45.5	14.0	31.6
30	56.8	16.0	40.8
40	72.1	23.0	49.2
50	92.0	30.9	62.0
60	118.7	39.9	78.8
70	148.7	50.9	97.8
80	193.0	63.9	129.2
90	161.6	75.8	85.8
100	99.8	89.8	10.0

With the minimum accelerating torque values for all of the rotation intervals, it is possible to calculate the partial acceleration times for each one of them (through equation 6.10).
To calculate the total acceleration time, just use equation 6.15.
By substituting the values in the respective equations, the following result is reached for the total acceleration time: $t_a = 1.05$ s.

One can see that this motor can easily accelerate the load because the acceleration time is very low when compared to the locked rotor time (corrected). See item "6.4.5 – Motor locked rotor time", in this guide.
Remember that the procedure used in the example above does not consider the activation of the "current limitation" function of the Soft-Starter. When this function is active, factors to correct the motor current and torque curves must be applied.

A valid alternative would be to consider a current limitation value, and calculate the voltage that should be applied from there. The torque will be corrected according to the following equation:

$$M_A = \left(\frac{I_{Lim}}{I_n}\right)^2 \cdot M_n - M_{Rn} \qquad (6.16)$$

Note that the relation between the limitation and the motor current value provides us directly with the ratio of the applied voltage in relation to the rated voltage. As such, it is possible to attribute a value to the I_{Lim} and check if the voltage value applied to the motor is valid or satisfactory.

To guarantee the motor start, the effective current value must be calculated for the motor starting duty using the limit current and the total acceleration time values. See item 6.4.3 in this guide to calculate the effective current of the cycle and of the Soft-Starter.

6.5 VOLTAGE SAG OR MOMENTARY VOLTAGE DROP

The concept of “momentary voltage drop” is related to starting heavy loads (like large motors), and is therefore related to Soft-Starters.

According to norm IR+EC61000-4-30:
Voltage dip: (definition used for the purpose of this standard). A sudden reduction of the voltage at a point in the electrical system, followed by voltage recovery after a short period of time, from half a cycle to a few seconds.

According to norm IEEE 1159:
Voltage sag: A decrease to between 0.1 and 0.9 pu in rms voltage at the power frequency for durations of 0.5 cycle to 1 min.

Observe that the European norm used the term “voltage dip” while the American norm uses “voltage sag”. The term “voltage drop” is used in both markets. Although the definitions are slightly different, the described phenomenon is the same, that is:

The phenomenon that interests us (voltage sag) is a reduction in the voltage value in a point of the electrical system followed by its recovery after a short period of time, from half a cycle to a few seconds.

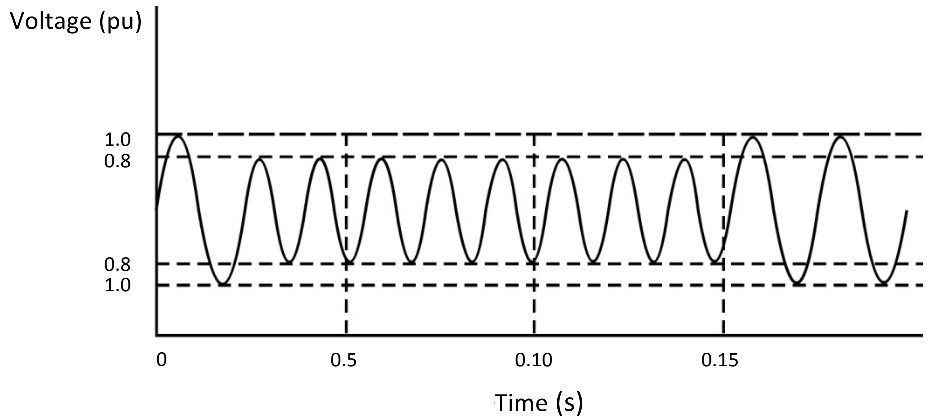


Figure 6.12*: Voltage drop. Observe the reduction in amplitude of the wave form from the second positive semi-cycle to approximately 0.15 seconds.*

The term “voltage drop” is also used for the drop that occurs in cables, especially in long distances.

From this point on, in this item, when the term “voltage drop” is mentioned, it will refer to the momentary phenomenon defined as a voltage dip or voltage sag in norms IEC61000-4-30 and IEEE 1159, described above.

Disturbances of less than half a cycle fit into the definition of “low frequency transient”, while disturbances greater than a few seconds can be called “power supply undervoltage”.

Impedance in power supply systems is different from zero. As such, any increase in current causes a corresponding voltage reduction. During normal power supply, these variations remain within acceptable limits, but when there is a very large current increase, or when the impedance of the system is high, the voltage can drop significantly. Thus, conceptually, there are two causes for voltage drops:

- Substantial current increase
- System impedance increase

From a practical point of view, what actually causes a voltage drop is an increase in current.

Imagine the following simplified single line diagram.

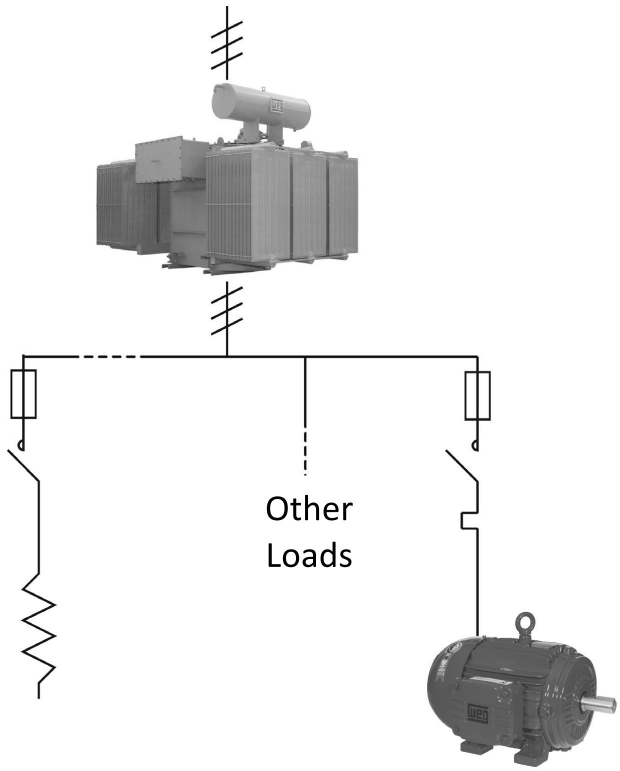


Figure 6.13*: An event that causes a voltage drop in the resistor terminal will cause a voltage drop in the transformer, and consequently, in the motor.*

It is obvious that any voltage drop in the transformer terminal will cause a voltage drop in the circuit below.

A short circuit in a distant busbar can also cause a drop in the transformer terminal. Thus, even faults in distant parts of the circuit can cause a voltage drop in all loads.

In industrial power supply networks, most voltage drops originate in the installations themselves. The most common causes are:

- **Starting an elevated load**

Like a motor or a resistive furnace. Electric motors starting with full voltage can consume more than 600% their rated current during the start, depending on how they were projected. Electric furnaces typically require 150% their current until fully heated.

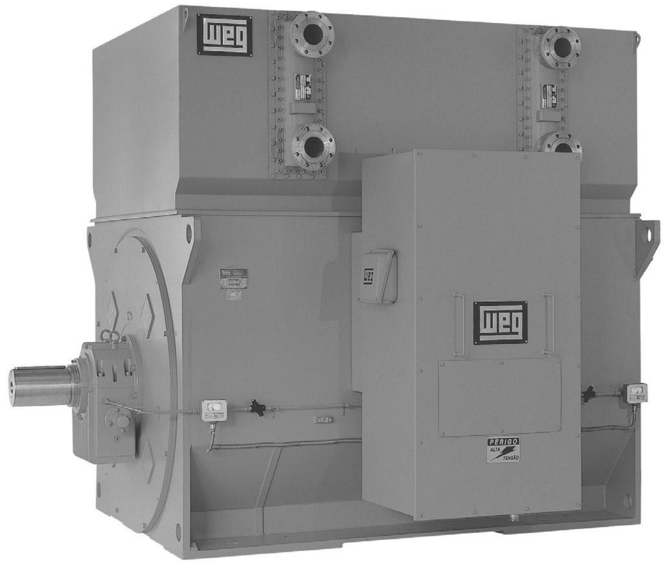


***Figure 6.14**: MASTER line motor – WEG motors can demand more than 600% the rated current, if starting at full voltage. The voltage drop can be considerable during the start of a large motor at full voltage.*

- **Defective or loose connections**

Like connectors that are not tightened to the wires. This increases the impedance of the system and increases the current increase effect.

- **Faults or short circuits**

Anywhere in the factory. Although a fault is quickly insulated by fuse or circuit breaker, it will "pull" the voltage down until the protection device goes on, which may take from a few cycles to a few seconds.

Voltage drops can also originate outside the consumer's installation. The most common are:

- **Faults in distant circuits**

Cause a corresponding reduction in the consumer's power supply. Devices in the utility company's power supply network normally correct the fault, which may last up to a few seconds. In general, the voltage drop will depend on the quantity and characteristics of the transformers between the consumer's power supply and the fault point.

- **Fault in the power supply company's voltage regulator**

These are rare. Power supply companies have automatic systems to adjust the voltage (transformers with automatic tap changes or automatic capacitor banks spread throughout the power supply network).

***Figure 6.15**: Voltage drops may originate from the utility company's power supply network*

The most important thing is to understand what caused the voltage drop before attempting to eliminate it.

6.5.1 Consequences of a Momentary Voltage Drop

If there is not enough voltage in the power supply, the equipment connected to it can turn off or jeopardized the operation. This can happen even if the voltage drop is for a short period and with a limited intensity.

There are loads that have a tendency of suffering more with voltage drops. These are normally circuits with DC supply, like computers, telephones, PLCs, etc.

It is also possible for undercurrent protection relays to cause unnecessary interruptions because of incorrect settings.

In a similar manner, it is possible for an unnecessary disconnection to occur due to a relay protecting against phase imbalance. On the other hand, motors and transformers can overheat and become damaged when operating during a phase imbalance, which makes the use of relays very important.

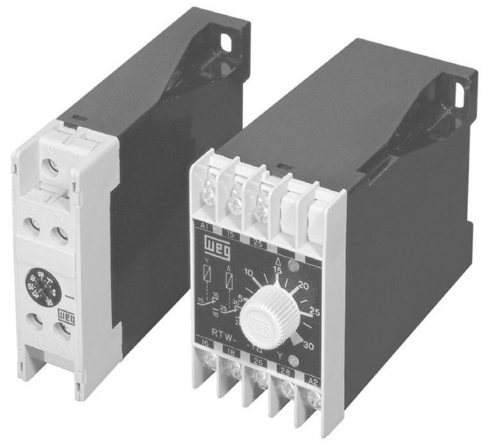


***Figure 6.16**: Protection relays must be correctly set to avoid unnecessary trips*

The most subtle problems occur in electronic equipment. There are circuits that are designed to activate during a voltage rise edge and are typically activated by the start function. During a voltage drop, the device operates perfectly, but can reset when the voltage drop ends.

6.5.2 Comments on Solutions to Momentary Voltage Drops

It is best to always design the system appropriately from the very beginning because corrections can bring about undesirable results. This is due to the fact that the various parts of the system are interdependent, and changing one part can have consequences on another. Below are some examples of possible adjustments in problematic systems.

6.5.2.1 Change the DC supply voltage settings

If the problem is manifesting itself only in a load supplied by a DC voltage source, some of these sources allow for adjustments that can provide a greater range to help overcome momentary voltage drops.

6.5.2.2 Reduce the load on the power supply grid

Partly loaded electric power supplies always accept better current wave forms (less harmonic distortion); however, distributing the loads in several transformers can improve the power supply quality.

6.5.2.3 Increase the power supply capacity

If redistributing the load is impossible, it will be necessary to use a power supply with greater capacity. This means a larger transformer, which will take up more space and more financial resources, and will alter the short circuit levels of the installation. It can also require alterations in the transformer output cables, as well as in the installation.

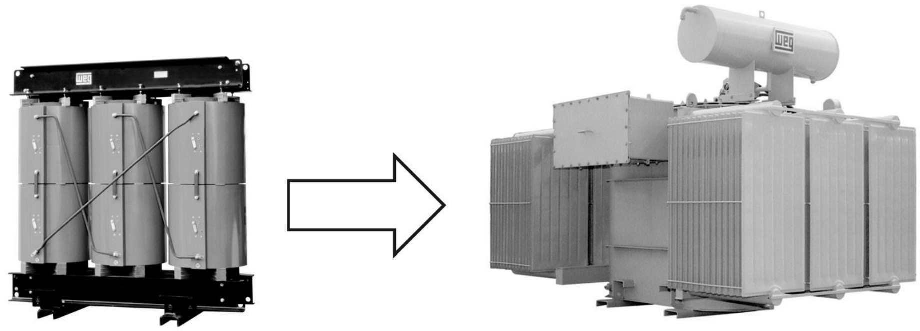


***Figure 6.17**: Switching to a larger transformer can bring about complications due to alterations in the short circuit capacity, as well as require changes to the cables and physical installation. In the figure above, for illustrative purposes, the transformer on the left side is dry and the other oil filled, although large dry transformers also exist.*

6.5.2.4 Alter the protection settings

If it is possible to identify a protection device that is not well adjusted (like a phase balance relay, undervoltage relay or an internal protection device), a new setting may be considered. Note, if a device was set in a specific way, the system's project probably determined that this was the appropriate way. Remember that it is not good to eliminate a system's protections. Depending on the protection device, adjusting it can be as simple as turning a knob or it may require component substitution or firmware adjustment.

6.5.2.5 Install a fast acting voltage regulator or UPS

There are several types of technologies used to increase the reliability of voltage supplying a sensitive point of the installation (UPS, static voltage compensator, etc.). This kind of equipment requires proper application engineering to appropriately solve the problem, and since this represents additional costs, it is wiser if only used to supply small loads that are very sensitive to voltage drops.

6.5.3 Relative Capacity of the Power Supply Network

When an electric motor starts, it will drain current from the power supply. Therefore, a voltage drop during the start and even during operation (although lower) is a phenomenon that is part of the system's operation. What can be done is to use strategies to reduce this voltage drop, like using a Soft-Starter.

But, is it possible to easily identify a circuit that will supply a new load as being potentially problematic, in terms of voltage drops caused by motor starts?

Described below are how power supply network characteristics influence load starts. The orientation is simplified and can help in Soft-Starter application.

This concept is particularly important in large load starts.

6.6 SHORT CIRCUIT CAPACITY CALCULATION

The short circuit capacity calculation is used in several situations:

- Transformer sizing
- Selection of circuit breakers and fuses as a function of the rupture capacity, determining if a power supply reactance is necessary for a variable frequency drive, etc.

The objective of this part of the guide is to explain how the short circuit capacity is important in sizing an electric starting system, and consequently, in deciding on a Soft-Starter or any other starting method.

An example of transformer sizing will be used to illustrate this concept.

Cable impedances and their respective voltage drops will be ignored here to simplify the example, as well as to provide the engineer, technician or entrepreneur with a fast way of evaluating a new load or re-evaluating an existing problem.

The following calculations will determine the “extra power” demanded by a transformer used to supply a single motor.

Two situations will be analyzed, called “A” and “B”. The first has a limited short circuit power in the primary, and the second has energy supply in the primary with a much lower and defined capacity.

Situation “A”:
Transformer connected to the power supply grid with limited short circuit capacity.

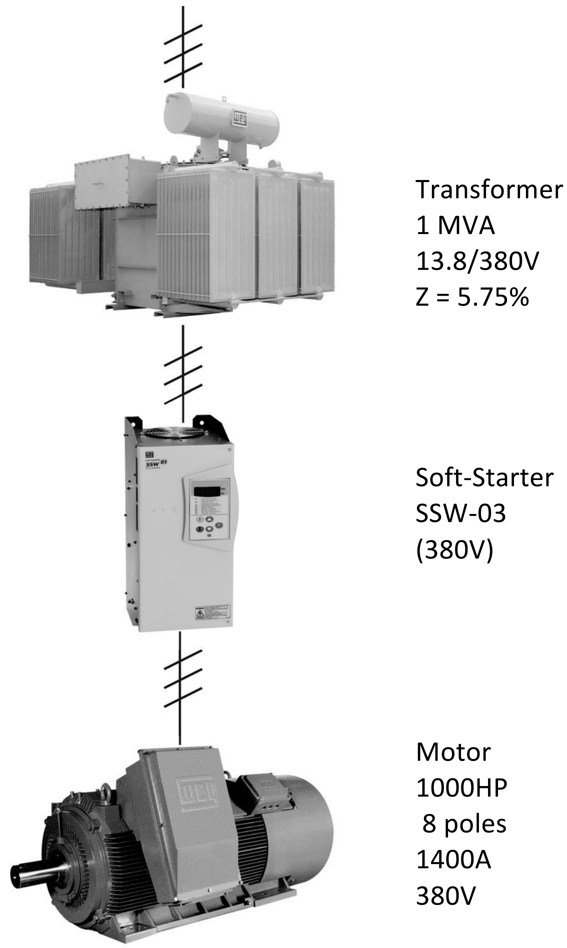


***Figure 6.18**: Illustration of system “A”*

Imagine a **1000 kVA** transformer with **380V** rated voltage in the secondary and **5.75%** impedance.

The rated output current at full load would be:

$$\frac{1000\text{kVA}}{380\text{V} \cdot \sqrt{3}} = 1521\text{A}$$

The value of 5.75% impedance indicates that there will be **1521 A** (rated current) if the secondary is short circuited and the voltage in the primary is elevated to a value of 5.75% the rated voltage in the secondary, that is, **21.8 V** appear in the secondary.

Thus, the impedance of the transformer secondary can be calculated as:

$$\text{Z} = \frac{\text{V}}{\text{I}} = \frac{21.85\text{V}}{1521\text{A}} = 0.01436\Omega$$

Imagine that the transformer will be connected directly to the utility company's power supply, and that it has a limited short circuit capacity. Note that the power supply company can supply this data upon request.

With limited short circuit power in the utility company's power supply, the short circuit current that the transformer can deliver at the secondary is:

$$\frac{380\text{V}}{0.01436} = 26{,}452\text{A}$$

Another alternative for calculating the short circuit current is:

$$\frac{1{,}521\text{A} \cdot 100}{5.75} = \frac{1521}{0.0575} = 26{,}452\text{A}$$

Finally, there is also the alternative of consulting the manufacturer.

Now, the connection of the motor to the transformer secondary will be analyzed.

The voltage drop caused by the current demanded at the motor start needs to be calculated.

In this example, observe how the transformer only supplies this motor, and therefore, if the voltage drop does not cause a torque reduction that enables it to start the load, oversizing the transformer is not necessary. It is important to remember, however, that this approach neglects any orientation of operation voltage ranges in the motor specifications or restrictions in norms.

Continuing with the example, imagine that the transformer will supply a motor that demands a rated current of 1400A, which will consume practically all of the transformer's capacity. As such, it can be said that the motor represents:

$$380\text{V} \cdot 1{,}400\text{A} \cdot 1.73 = 902\text{kVA}$$

Assume that the Soft-Starter limits the current to **3 x In** of the motor, which it will drain from the transformer.
Also assume that a voltage drop of **7.5%** is desired.

$$380\text{V} \cdot 1{,}400\text{A} \cdot 300\% \cdot 1.73 = 2{,}761\text{kVA}$$

The momentary voltage drop during the start will be proportional to the load represented by the motor, and can be expressed as a percentage of the load represented by the motor in relation to the maximum capacity of the transformer.

The transformer has a short circuit power that can be calculated as:

$380V \cdot 26{,}452A \cdot \sqrt{3} = 17{,}390kVA$

The voltage drop at the motor start will be:

$$\frac{2{,}761\text{kVA}}{17{,}390\text{kVA}} = 0.1587 = 15.87\%$$

As seen in item 6.4.6 (Acceleration Time), the motor torque is proportional to the square of the voltage, and therefore, it is necessary to check if this voltage drop leads to a motor torque reduction below the torque demanded by the load or if the motor torque reduction leads to an acceleration time that exceeds the thermal limit of the motor or the Soft-Starter.

However, as stated at the beginning, the voltage drop must remain at 7.5%.

That is, the transformer needs to be sized for a capacity of:

$$\frac{2{,}761\text{kVA}}{0.075} = 36{,}813\text{kVA}$$

Thus, the short circuit current of the transformer should be:

$$\frac{36{,}813\text{kVA}}{380\text{V} \cdot \sqrt{3}} = 55{,}998\text{A}$$

First, a slightly larger transformer will be observed. Suppose it has **2,000 kVA** and impedance of **6.5%**. This transformer would still not meet the requirements, since the short circuit current is **46,749 A**.

Imagine a transformer of **Z = 7.5%,** it would be necessary to have a transformer with a current value at full load equal to **4,200 A**, that is, approximately **3MVA**. That is approximately 3 times the power represented by the motor in operation.

Observe the increase in impedance as a function of the increase in power of the transformer.

Situation "B":
Insulation transformer connected to a step down transformer with a defined short circuit capacity.

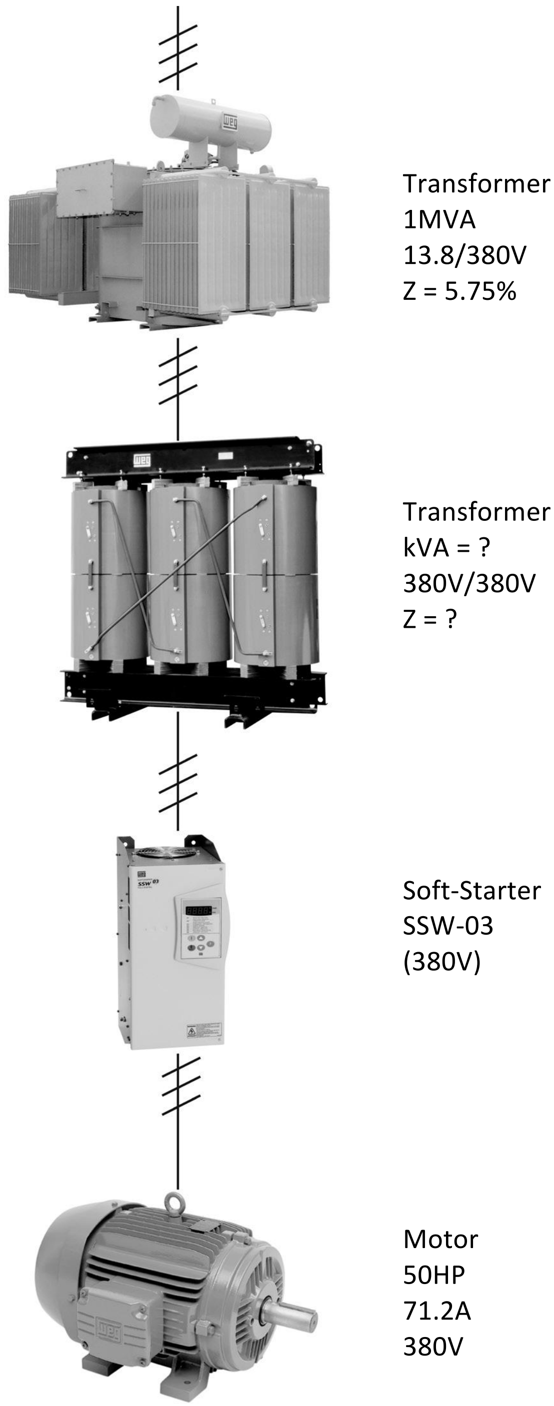


***Figure 6.19**: Illustration of system "B"*

Analyzed now is a situation considering a determined short circuit current capacity in the primary of the transformer supplying the motor.

Suppose there is a terminal that derives from a 1,000kVA transformer, equal to the one mentioned at the beginning of situation “A” above. In this terminal, a second transformer is connected directly to the terminals of the 1,000kVA transformer.

To simplify the example, supply cables between the two transformers are eliminated, and their respective impedance is not taken into consideration.

The second transformer, which has both the secondary and the primary in 380V in this example, will be used to supply a motor with 50hp, 3 phases, 380V, In = 71.2 A, Ip/In = 6.6.

Suppose a Soft-Starter will be used for starting a “heavy duty” application which will demand at least 4 times the rated motor current to start, that is, 4 x 71.2 = 284.8 A. This motor will be the transformer’s only load and the voltage drop must be limited to 7.5%.

In operation, the motor represents a load of:

$$380V \cdot 71.2A \cdot \sqrt{3} = 46.8kVA$$

At the start, the load represented by the motor will be:

$$380V \cdot 71.2A \cdot 400\% \cdot \sqrt{3} = 187.2kVA$$

First, imagine a **60kVA** transformer to supply this motor. The transformer will have an impedance of 3% and an output current of **91.3 A** at full load.

The short circuit current that can be supplied to the 60kVA transformer by the 1000kVA transformer is equal to **26,452 A**, that is, **17,390 kVA**.

The short circuit current of a transformer with a limited short circuit capacity in its primary is:

$$\frac{\textbf{Current at full load}}{(\textbf{Z of the 2}^{\textbf{nd}}\textbf{ transformer } + \textbf{ Z of the 1}^{\textbf{st}}\textbf{ transformer “seen” by the 2}^{\textbf{nd}})}$$

Where:

$$\textbf{Z of the 1}^{\textbf{st}}\textbf{ transformer “seen” by the 2}^{\textbf{nd}} = \frac{\textbf{power of the second (kVA)}}{\textbf{short circuit power available in the primary}}$$

Thus, the value of the short circuit current in the secondary of the 60kVA transformer is:

$$\frac{91.3\text{A}}{3\% + \left(\frac{60\text{kVA}}{17{,}390\text{kVA}}\right)} = \frac{91.3}{0.03 + 0.00345} = 2{,}729\text{A}$$

During the motor start, the voltage drop in the transformer output will be:

$$\frac{\textbf{Load represented by the motor at the start}}{\textbf{Short circuit power}}$$

That is:

$$\frac{187.2\text{kVA}}{380\text{V} \cdot 2729\text{A} \cdot \sqrt{3}} = 0.1043 = 10.43\%$$

The 60kVA transformer is too small, since the voltage drop exceeds the 7.5% specified at the beginning of this example.

However, for a 100kVA transformer, K = 3%, the short circuit current would be:

$$\frac{152.1\text{A}}{3\% + \left(\frac{100\text{kVA}}{17{,}390\text{kVA}}\right)} = 4{,}254\text{A}$$

And therefore, the voltage drop would be:

$$\frac{187.2\text{kVA}}{380\text{V} \cdot 4{,}254\text{A} \cdot \sqrt{3}} = 0.0669 = 6.69\%$$

This transformer meets the voltage drop needs.

More could be mentioned about this, after all, voltage drop is an extremely important subject. Some observations have not been made, like that during a voltage drop, some loads with energy regeneration tendencies will increase the short circuit current. For example, imagine that at the start of motor “A” there is a motor “B” driving an inertia flywheel. During this start, a voltage drop in the busbar occurs. Motor “B”, connected to the same busbar, will have a tendency of reducing its speed, due to the lower available torque. Since the load on “B” has a high inertia, the motor will start operating as a generator, contributing to the increase of short circuit current in the system.

The bibliography at the end of this guide indicates the books that deal with this subject in depth. For Soft-Starter applications, the concepts explained up to now will help to safely choose the necessary equipment. Leading the way for those who wish to deepen their knowledge on the subject.

In conclusion, some comments will be made about the use of transformers in overload situations.

6.6.1 TRANSFORMERS: OPERATION IN OVERLOAD

For electric systems to operate effectively, transformers are sometimes overloaded to meet operation circumstances. Naturally, in these cases, it is important for the customer and the transformer manufacturer to discuss and be conscious of the overload that the transformer can withstand without reducing its lifetime.

The main problem that must be dealt with is heat dissipation. If a transformer is overloaded by a determined factor, suppose 20% beyond its rated capacity for a short period of time, it is possible that the heat developed in the windings will easily be transferred to the surrounding air. Consequently, the overload is overcome with no problems.

However, in more intense overloads, or for longer periods of time, the internal temperature will increase, wearing down the insulation and possibly causing damage.

6.6.2 Comments on Voltage Drops and their Influence in Motor Starts

As has already been seen, the motor torque is proportional to the square of the voltage.
If there is a 10% voltage drop, the motor will have 81% of the torque available.

In a worst case scenario, the motor may not develop the necessary torque to accelerate the load before reaching the thermal limit of some of the components in the starting system (motor, Soft-Starter, etc.), if attention is not given during sizing.

On the other hand, hypothetically, if for a specific load at least 81% of the voltage is needed to start, and the power supply network itself already provides this condition, it is not necessary to use a starting method with reduced voltage.

Although these concepts were mentioned throughout this chapter, two systems ("A" and "B") will be simulated below by the *WEG Sizing Software – SDW* (see annex 2 in this guide).

The systems are identical, except for the voltage drop. They deal with the same motor, same load, etc. However, in system "A" the voltage drop during the start is 2.5% and in system "B" the voltage drop is 10%.

MOTOR

- Rated power: 220 kW
- Number of poles: 4
- Rated voltage: 380 V
- Rated current: 399.83 A
- Locked rotor time: 35 s
- Moment of inertia: 6.33814 kg.m^2
- Category: N
- M_A/M_N: 2 pu
- M_{max}/M_N: 2.2 pu
- I_A/I_N: 7pu

GENERAL

- Power supply voltage: 380 V
- Voltage drop at the start: 2.5 %
- By-pass: No
- Motor connection: Standard
- Temperature: 40 °C
- Altitude: 1000 m

LOAD

- Application: Centrifugal fan
- Rated torque (Cn): 55 % the motor
- Moment of inertia: 35 times J
- Number of starts per hour: 3
- Interval between starts: 20 min

Observe some relevant differences below, resulting from just the biggest voltage drop.

	System “A”	System “B”
Load	Fan (high inertia)	Fan (high inertia)
Voltage drop	2.5%	10%
Voltage pedestal	86%	99%
Acceleration time with voltage ramp	29.76 sec	30.36 sec
Current limit	614%	691%
Acceleration time with current limitation	29.97 sec	30.20 sec
Soft-Starter model	SSW-03 670/220-440	SSW-03 800/220-440

Observe that the voltage pedestal used by the Soft-Starter for system “B” is practically full voltage (99%). This is because the power supply itself is already reducing the voltage in the motor supply, and therefore, the motor is already being subjected to a “reduced” voltage.

Also observe that the current limitation increases, to compensate for the voltage drop. In reality, the algorithm used in the SDW is somewhat conservative in dealing with critical situations like starting with a voltage drop. In practice, a slightly lower limitation can be reached, depending on the dynamics of the electric system and its interaction with the machine.
Consequently, the thermal demand (RMS current) for starting system “B” is much greater, which creates the need for a much larger Soft-Starter.

Staying on this line, if exactly the same system were simulated for a 15% voltage drop, it would be apparent that the motor itself would not be able to start the fan! The voltage drop would be so great that the motor would not be able to develop enough torque to overcome the inertia of the fan.

Finally, a load with high inertia was chosen in this example to highlight the influence of a voltage drop.

If the same example were used to accelerate a centrifugal pump or a screw compressor (light loads), there would be no significant change attributed to the voltage drop.

6.7 TYPICAL APPLICATIONS

This item highlights the main functions used in starting typical machines. The objective is not to provide a foolproof recipe, but to present aspects that are typically relevant in these applications.

Note! The correct torque curve is always the one that is most appropriate for starting the machine, for example, fans with closed dampers, refineries with no load, conveyors with no load, etc.

6.7.1 Machines with Light Duty Starts

6.7.1.1 Centrifugal Pump

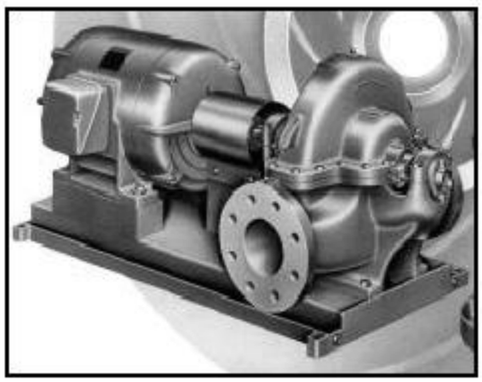


***Figure 6.20**: Centrifugal pump*

Torque type: Quadratic
Moment of inertia: Low
Starting current: Typically 2.5 to 3 x the motor FLA

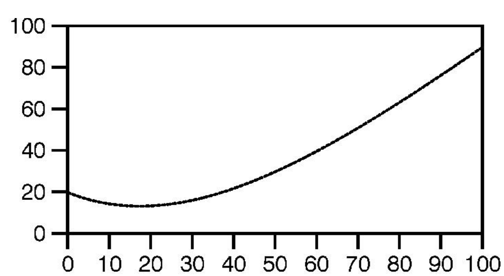


***Figure 6.21**: Torque curve of a centrifugal pump*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Starting too fast	“Pump Control” function
Stopping too fast	“Pump Control” function
Water hammer	“Pump Control” function
High current peak	“Pump Control” function
Pump running in the wrong direction	Phase reversal protection
Pump running dry (accentuated cavitation)	Undercurrent protection
Pump overload due to solid mass inside (accentuated cavitation and lubricant deterioration)	Overcurrent protection

6.7.1.2 Compressor

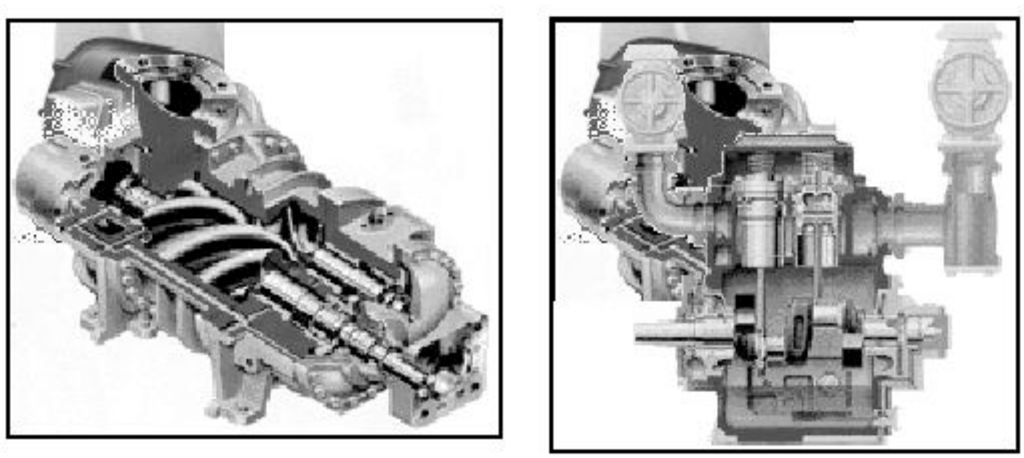


***Figure 6.22**: Compressor*

Torque type: Constant (reciprocating)
Moment of inertia: Low
Starting current: Typically 3 to 5 x the motor FLA

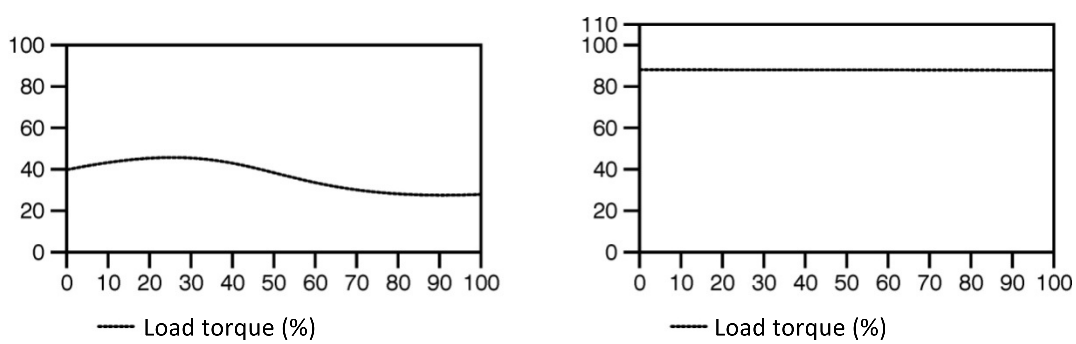


***Figure 6.23**: Torque curve of a compressor (screw on the left and reciprocating on the right)*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical cogging in the motor, transmission and compressor	Current limitation
Compressor running in the wrong direction	Phase reversal protection

6.7.1.3 Paper Refiner

Torque type: Constant and low (starting with no load)
Moment of inertia: Low
Starting current: Typically 2.5 to 3 x the motor FLA

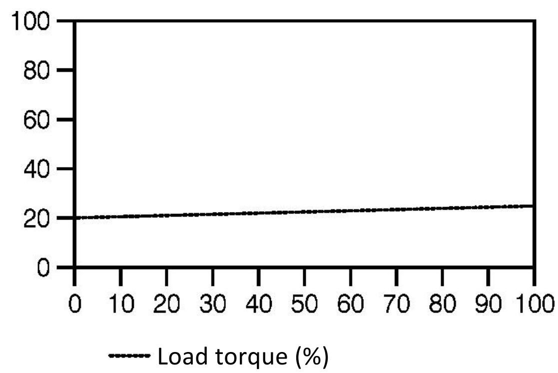


Figure 6.24*: Torque curve of a refiner*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical cogging in the motor, transmission and refiner	Current limitation
High current and voltage drop in the grid, due to significant load on the paper machine of a small factory	Current limitation
Need to control the closeness of the disks as a function of the load	Analog output (4-20mA) to use in the process regulator
Refiner running in the wrong direction	Phase reversal protection

6.7.1.4 Vacuum Pump (Blade)

Torque type: Parabolic
Moment of inertia: Low
Starting current: Typically 2.5 to 3 x the motor FLA

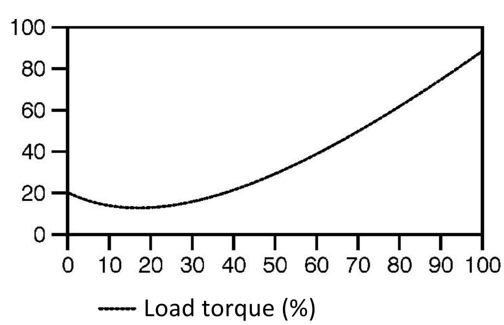


Figure 6.25*: Torque curve of a blade vacuum pump*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical cogging in the motor, transmission and pump	Current limitation
High current and voltage drop in the grid, due to the significant load on the paper machine	Current limitation
Pump running in the wrong direction	Phase reversal protection

6.7.1.5 Hydropulper Pump

Torque type: Quadratic
Moment of inertia: Medium
Starting current: Typically from 3 to 4.5 the motor FLA

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical cogging in the motor, transmission and hydropulper	Current limitation
Hydropulper running in the wrong direction	Phase reversal protection

6.7.2 Machines with Heavy Duty Starts

6.7.2.1 Vacuum Pump (Piston)

Torque type: Constant
Moment of inertia: Low
Starting current: Typically 4 to 5 x the motor FLA

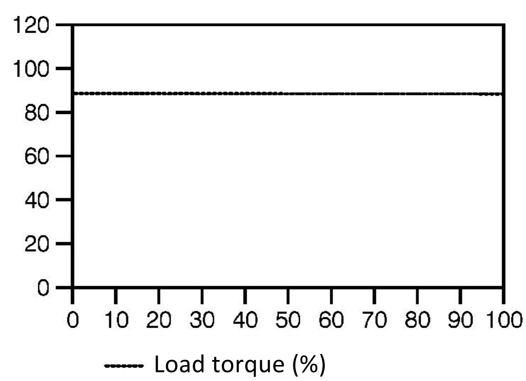


Figure 6.26*: Torque curve of a piston vacuum pump*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical cogging in the motor, transmission and pump	Current limitation
High current and voltage drop in the grid, due to the significant load on the paper machine	Current limitation
Pump running in the wrong direction	Phase reversal protection

6.7.2.2 Fan / Exhaust

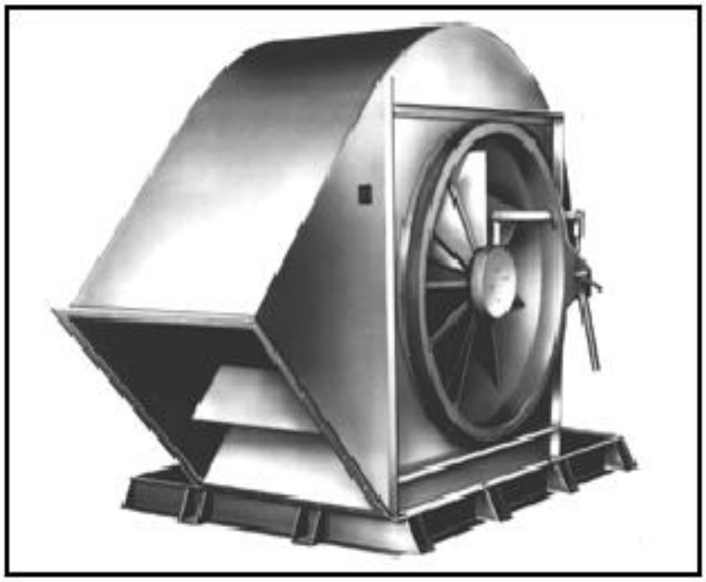


***Figure 6.27**: Fan*

Torque type: Quadratic
Moment of inertia: Medium to High
Starting current: Typically from 3 to 5 x the motor FLA

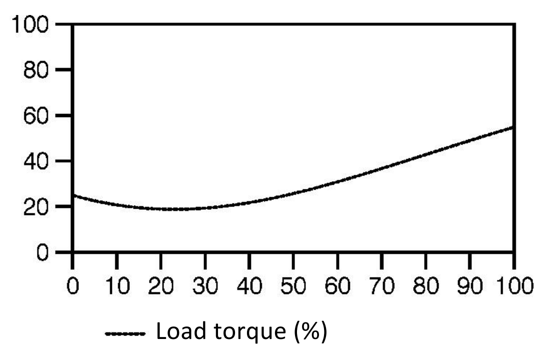


***Figure 6.28**: Torque curve of a fan*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
High current peak	Current limitation
Broken belt or coupling	Undercurrent protection
Blocked filter or closed damper	Overcurrent protection

6.7.2.3 Crusher

Torque type: Constant
Moment of inertia: High
Starting current: Typically 3.5 to 5 x the motor FLA

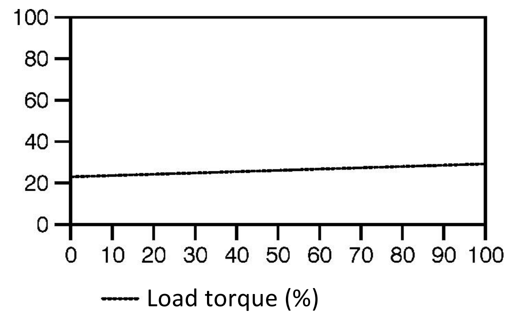


Figure 6.29: *Torque curve of a crusher*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Load with high inertia and high torque demands	Current limitation
Heavy start when starting with a load	"Kick Start" function
Inadequate material in the mill	Overcurrent protection
Broken coupling	Undercurrent protection
Vibrations while stopping	DC Braking

6.7.2.4 Centrifuge

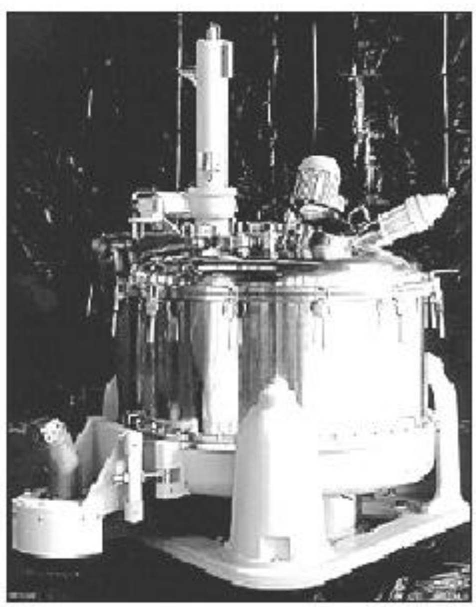


Figure 6.30: *Centrifuge*

Torque type: Linear
Moment of inertia: High
Starting current: Typically 3.5 to 5 x the motor FLA

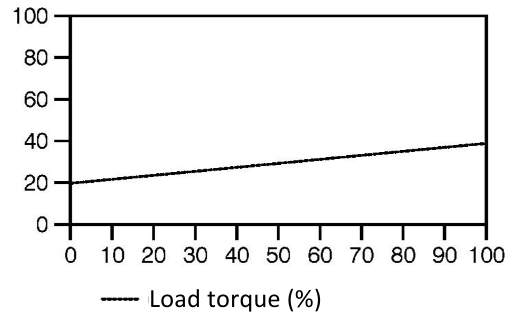


Figure 6.31*: Torque curve of a centrifuge*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Load with high inertia	Current limitation
Controlled stop	DC Braking
Load too heavy or out of balance	Overcurrent protection
Broken coupling	Undercurrent protection

6.7.2.5 Erator

Torque type: Constant
Moment of inertia: High
Starting current: Typically from 3.5 to 5 x the motor FLA

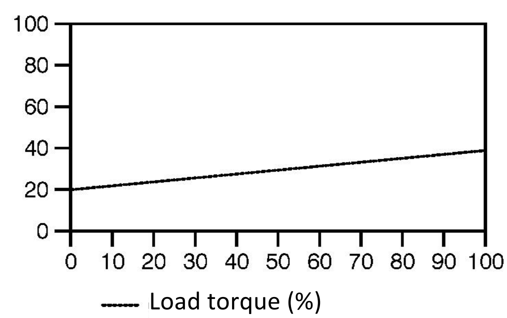


Figure 6.32*: Torque curve of an erator*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical cogging in the motor, transmission and erator	Current limitation
Erator running in the wrong direction	Phase reversal protection
Clogged erator	Overcurrent protection

6.7.2.6 Mixer

***Figure 6.33**: Mixer*

Torque type: Constant
Moment of inertia: High
Starting current: Typically from 3 to 5 x the motor FLA

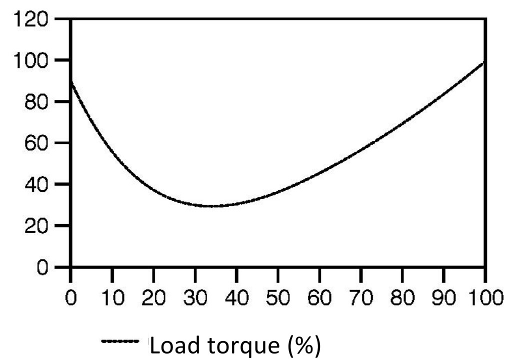


***Figure 6.34**: Torque curve of a mixer*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Different material to process	Current limitation
Feedback needed for the control circuit to regulate the viscosity	Analog output proportional to the current
Load too heavy or out of balance	Overcurrent protection
Broken or worn blades	Undercurrent protection

6.7.2.7 Mill

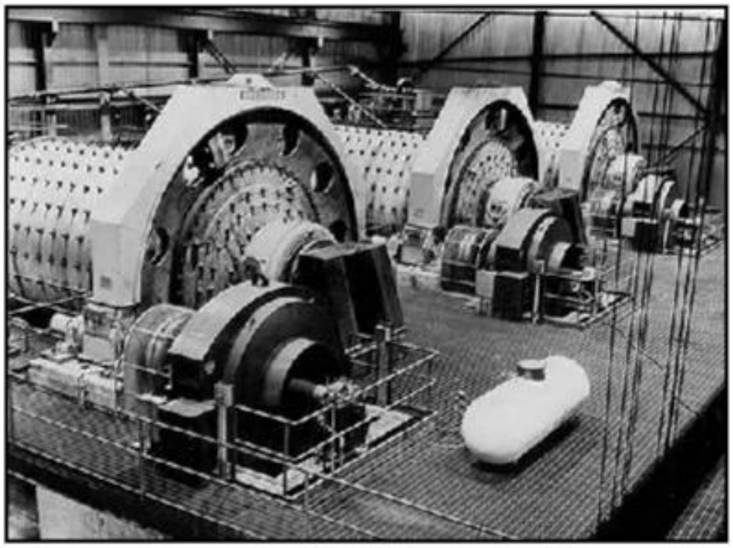


Figure 6.35: *Mill*

Torque type: Linear
Moment of inertia: High
Starting current: Typically from 3 to 5 x the motor FLA

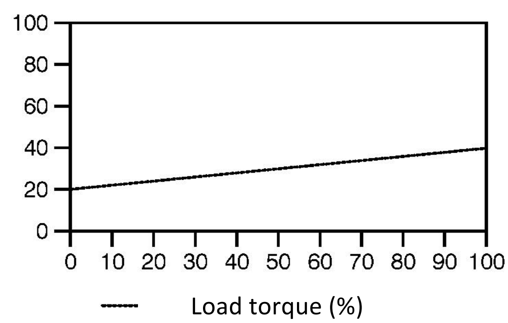


Figure 6.36: *Torque curve of a mill*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Heavy load with high inertia	Current limitation / Kick start function
Feedback needed for the control circuit to regulate the viscosity	Analog output proportional to the current
Locking	Overcurrent protection
Fast stop	DC Braking

6.7.2.8 Conveyor

***Figure 6.37**: Conveyor*

Torque type: Linear
Moment of inertia: High
Starting current: Typically from 3 to 5 x In of the motor

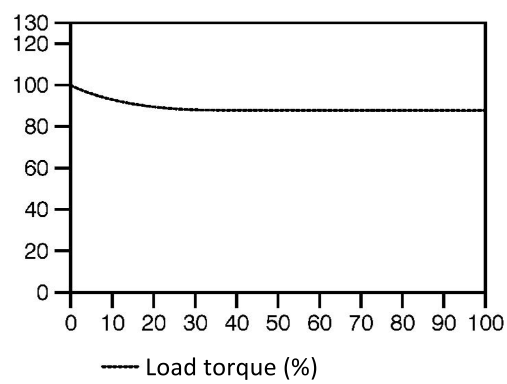


***Figure 6.38**: Torque curve of a conveyor*

Problem	Solution with SSW-03, SSW-04, SSW-06 or SMV-01
Mechanical jam in the motor, transmission or transported goods	Current limitation
Conveyor belt blocked	Overcurrent protection
Conveyor belt blocked	Locked rotor protection
Conveyor belt is off but the motor is still running	Undercurrent protection
Starting after conveyor belt blocking	JOG in reverse and then start forward

6.8 PRACTICAL SIZING RULES

In reality, it is frequently hard to obtain all the data needed for Soft-Starter sizing.
Other times the data is available, but the application is not severe (heavy duty) and the power network has a good supply capacity, so it does not make sense to spend time on unnecessary calculations.
Still other times, it is necessary to have a fast and practical rule that provides a good estimate with a good safety margin.

The table below represents this practical rule.
Although it may look obvious, it is worth mentioning that the table is based on the idea that the motor has enough torque to accelerate the load in operation.
It must also be mentioned that typical power supply network conditions were considered (short circuit power).

As in any practical rule, there is risk in attempting to generalize a process. Through experience however, the risk has been observed as relatively low, especially when the person applying the rule is aware of potentially problematic situations that create need for more in-depth analysis.

Table 6.2: *Sizing Criteria*

Application	Load	Inertia	Factor
Centrifugal Pumps	Low	Low	1.0
Screw Compressors	Low	Low	1.0
Reciprocating Compressors	Medium	Low	1.0
Fans	Quadratic	Medium/High	1.2 up to 25 HP
			1.5 above 25 HP
Mixers (Pulpers)	Medium	Medium	1.5 – 1.8
Mills	Medium/High	Medium	1.8 – 2.0
Conveyors	Medium/High	High	1.8 – 2.0
Centrifuges	Low	Very high	1.8 – 2.0

NOTE!
The values above are valid for normal duty, that is, with no more than 10 starts per hour. The inertia and frictional torque of the load reflected to the motor shaft are also considered above.

Examples:

Consider a WEG motor with 175 hp – IV poles – 380 Volts – 60Hz

1. Running a **centrifugal pump** at a water treatment station

- Consider the rated motor current
- In the motor catalog, this information is listed as I_{rated} = 253.88 A

- Using the criteria in table 6.2, factor 1.0 must be considered
- Therefore, the Soft-Starter indicated in this case is the SSW-03.**255**/220 – 440/2 (see catalog)

2. Running a **fan** in a cooling chamber

- Consider the rated motor current
- In the motor catalog, this information is listed as I_{rated} = 253.88 A
- Using the criteria in table 6.2, factor 1.5 must be considered
- As such, the value that will be considered is 1.5 x 253.88 A = 380.82 A
- Therefore, the Soft-Starter indicated in this case is the SSW-03.**410**/220 – 440/2 (see catalog)

3. Running a **continuous conveyor** in a mining company

- Consider the rated motor current
- In the motor catalog, this information is listed as I_{rated} = 253.88 A
- Using the criteria in table 6.2, factor 2.0 must be considered
- As such, the value that will be considered is 2.0 x 253.88 A = 507.76 A
- Therefore, the Soft-Starter indicated in this case is the SSW-03.**580**/220 – 440/2 (see catalog)

There is no doubt that this way of sizing Soft-Starters is much easier, but it is vulnerable to errors. It is difficult to guarantee the starting system because of the lack of information. In these cases, it is always wise to consult the Soft-Starter manufacturer so that the manufacturer may better evaluate the situation, indicating the most appropriate solution.

7 SOFT-STARTER INSTALLATION

7.1 INTRODUCTION

The objective of this chapter is to present the general components and information needed to install a Soft-Starter. Use of each component will depend on the specific case.

Also refer to the manual of the Soft-Starter that will be installed, following the specific recommendations presented there.

Figure 7.1: *Soft-Starters must be installed by qualified professionals, following the applicable norms and procedures.*

Item 7.2 describes the Soft-Starter connection between the motor and the power supply, in low voltage. The recommendations and circuits presented in this item are especially applicable to WEG SSW-03 and SSW-04.

In item 7.3, the Soft-Starter connection inside the motor delta will be explained. Because it decreases the total cost of the installation – depending on the distance between the motor and the panel – this type of connection is already the preferred choice among designers. This connection is possible with the SSW-03 Plus Soft-Starter.

The end of the chapter will bring individual characteristics of the SSW-05 micro Soft-Starter electrical installation. Comments will also be made about the SMV-01 Medium Voltage Soft-Starter.

7.2 STANDARD CONNECTION BETWEEN THE POWER SUPPLY AND THE MOTOR

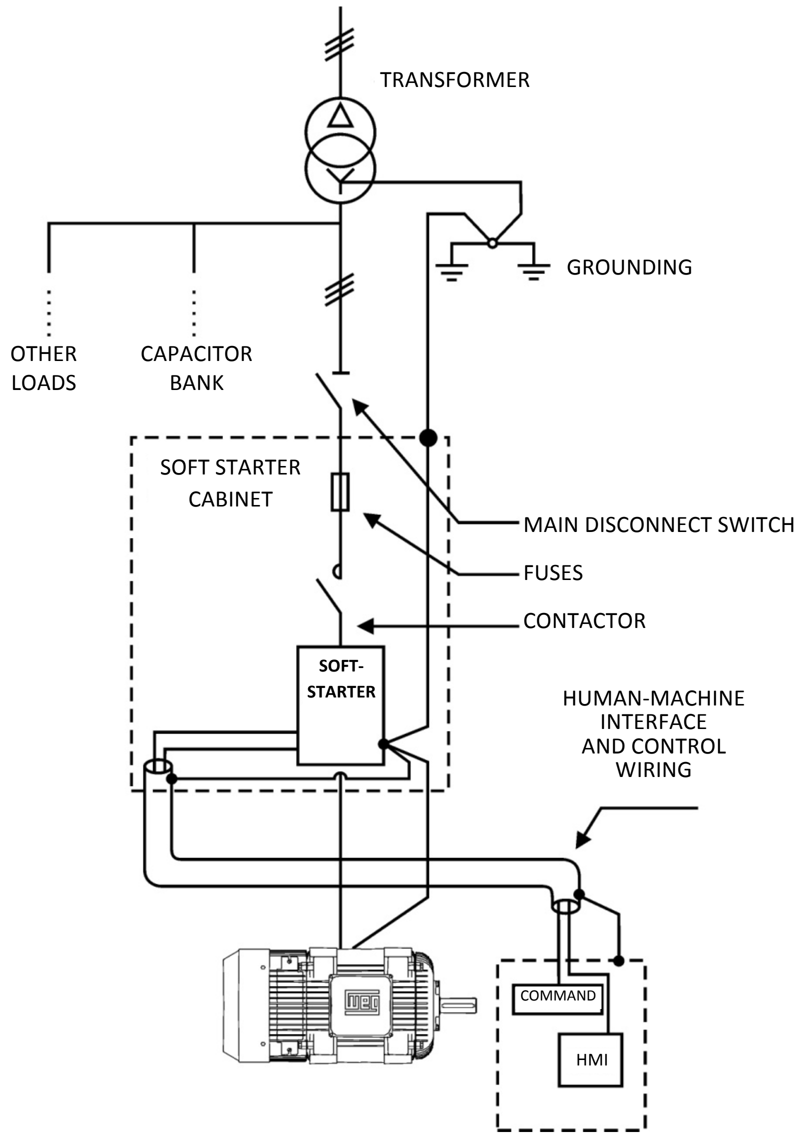


Figure 7.2: *Typical Soft-Starter installation between the power supply and the motor (low voltage)*

Figure 7.2 illustrates and complements the following comments:

7.2.1 Sectioning Switch

Sectioning switches (isolation contactors) are used for safety reasons to allow Soft-Starter de-energizing during maintenance.

7.2.2 Fuses or Circuit Breakers

To protect the installation, it is recommended to use time delay fuses or circuit breakers at the input.
Semiconductor high speed fuses may be used to protect Soft-Starter thyristors, but are not mandatory.

7.2.3 Contactor

Contactors are recommended in equipment needing emergency Stop.

Item 3.1.1 of standard IEC 60947-4-2 includes a note that should be considered when deciding whether or not to use a contactor:

NOTE!
Because dangerous levels of leakage currents (see 3.1.13) can exist in a semiconductor motor controller in the OFF-state, the load terminals should be considered live at all times.

Summarizing: the load terminals must be considered energized even when the Soft-Starter is OFF because dangerous levels of leakage current may exist.

Contactor use or non-use, therefore, determines different maintenance, safety and operation procedures and needs.

7.2.4 Control and Human-Machine Interface (HMI) Wiring

Control and remote HMI wiring must always be installed in exclusive metallic conduits (separated from other circuits) and grounded. When crossing power cables, they must also meet at an angle of 90°.

7.2.5 Power Factor Correction

Whenever possible, the power factor should be corrected directly in the motor with a capacitor bank driven by contactors controlled by the end of ramp relay (RL or R1). In this way, the Soft-

Starter guarantees that during voltage switching (acceleration and deceleration - moments when harmonics are generated), the capacitors are out of the circuit.

When it is not possible to correct the power factor directly at the motor, this must be done in the closest point possible to the transformer.

Never connect capacitor banks to Soft-Starter outputs or motor terminals if they are not controlled by the Soft-Starter. Failure to observe this can lead to significant damage to the installation and to the Soft-Starter, due to the resonance caused by harmonic distortions that occur during the start or stop.

7.2.6 Grounding

Soft-Starters absolutely must be grounded. Check the product manual to see the cable cross section that needs to be used. They should be connected to a specific grounding rod or to the general grounding point (resistance <10 ohms). The grounding wiring must not be shared with other equipment operating with high currents (ex.: high power motors, welding machines, etc.).

Observe the figure below when several Soft-Starters are used.

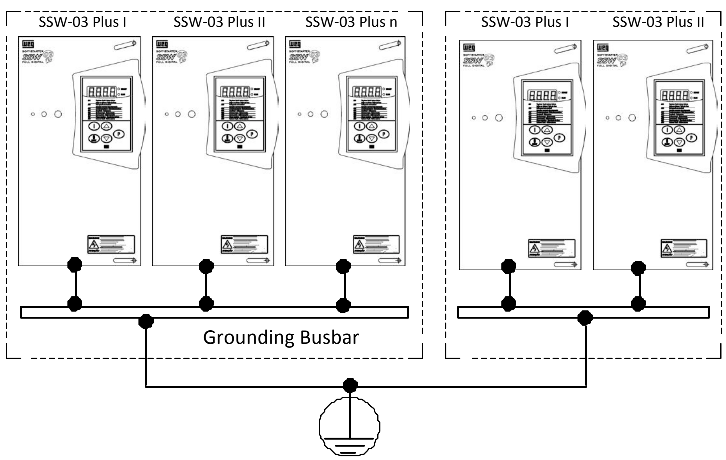


Figure 7.3: *Example of how to ground several Soft-Starters*

7.3 INSIDE THE MOTOR DELTA CONNECTION

7.3.1 1 Introduction

The advantage of connecting a Soft-Starter inside the motor delta is the reduction in current through semiconductors, and consequently, making it possible to use a Soft-Starter with a lower power.

Remember that all the Soft-Starter switch functions and protections remain active.

A standard connection requires less output wiring than an inside delta connection, which requires double the wiring. On the other hand, the inside delta connection requires a smaller cross section. Because of this, an inside delta connection will normally be a less expensive option for short distances, when considering the Soft-Starter + motor + wiring.

Here is an example:
Suppose there is a three-phase motor with rated current of 100 A. A 100 A Soft-Starter will be used to drive this motor, connected between the motor and the power supply, according to figure 7.4 below. Other variables that may influence Soft-Starter sizing (load, power supply, etc.) will be ignored here, to keep the example simple. Observe that the current passing through the semiconductors is the current demanded by the motor from the power supply network.

a) **Standard connection with three cables: Soft-Starter input grid current equal to the motor current.**

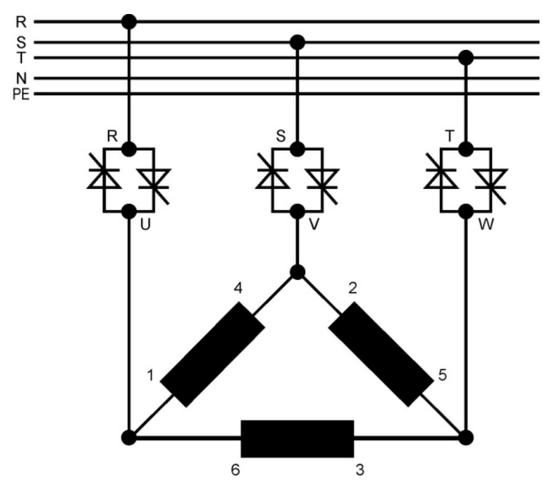


Figure 7.4: *Soft-Starter installation between the power supply and the motor*

On the other hand, imagine a Soft-Starter semiconductor inside the motor delta connection, according to figure 7.5. Notice that the current that will pass through the semiconductors is √3 times lower than the current demanded from the power supply. However, during the start, harmonic currents will be present, not generating motor torque but contributing to increase losses. Due to this, the current during the start is 67% the rated current throughout the Soft-Starter, while in operation the current is 58% the rated motor current.

b) Inside the motor delta connection with six cables: Soft-Starter input grid current equal to approximately 58% of the motor current (in operation) and 67% of the motor current (during the start).

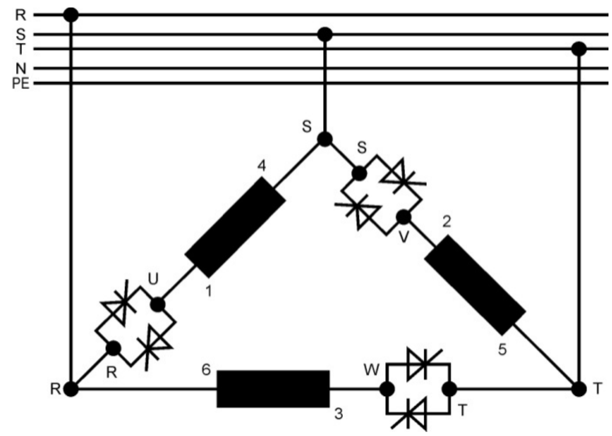


Figure 7.5: *Soft-Starter installation inside the motor delta connection*

SSW-03 Plus Soft-Starter parameters can be set to the following connection alternatives:

7.3.2 Connection Example of the SSW-03 Plus Inside the Motor Delta Connection

In an inside the motor delta connection, it is necessary to have access to six motor terminals, and the power supply voltage must coincide with the delta connection voltage (typical situation for motors prepared to start with star delta switching), as suggested in the figure below:

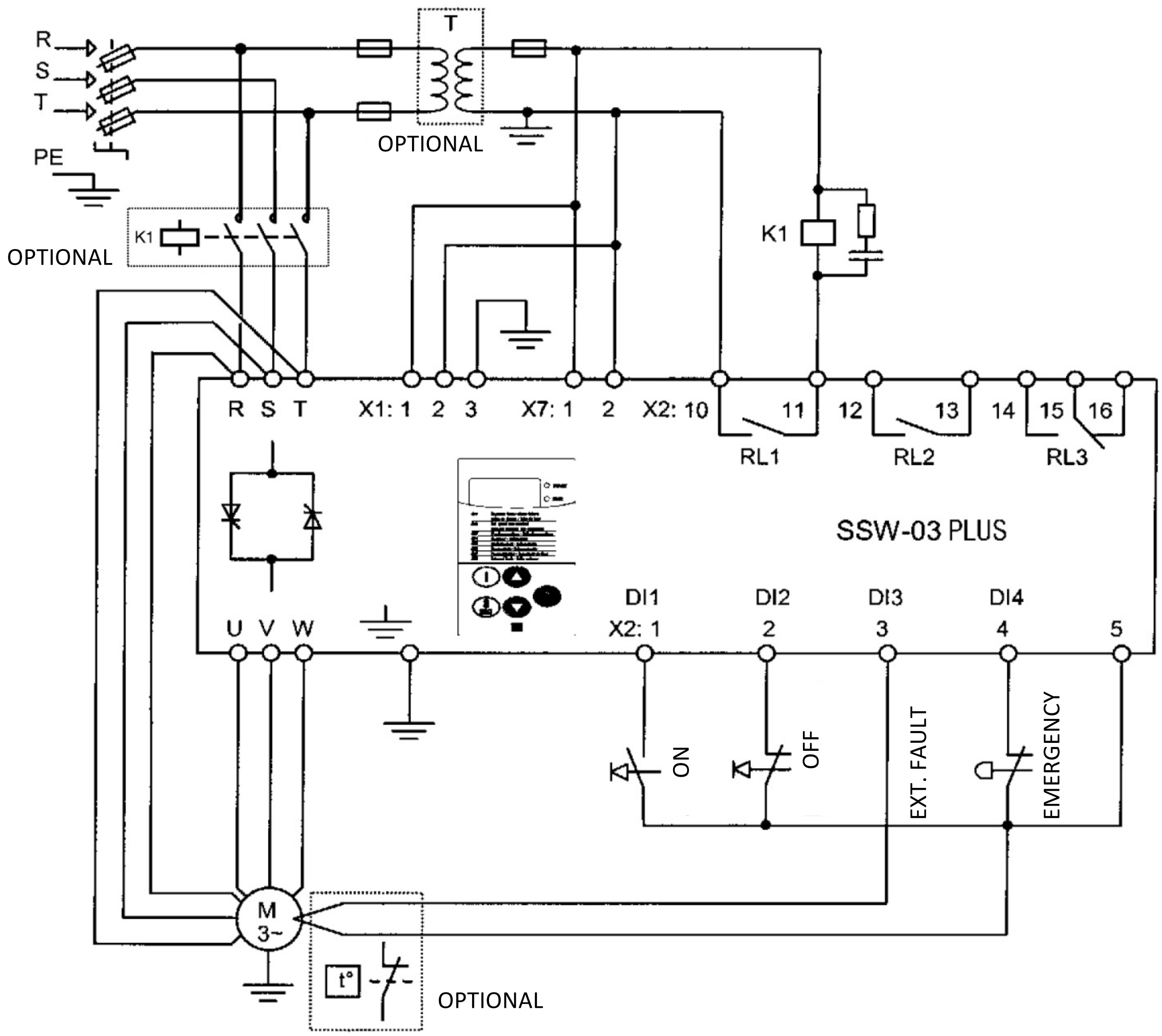


Figure 7.6: *Soft-Starter installation inside the motor delta connection*

> **NOTE!**
> It is also possible to connect the Soft-Starter with a by-pass, inside the motor delta connection.

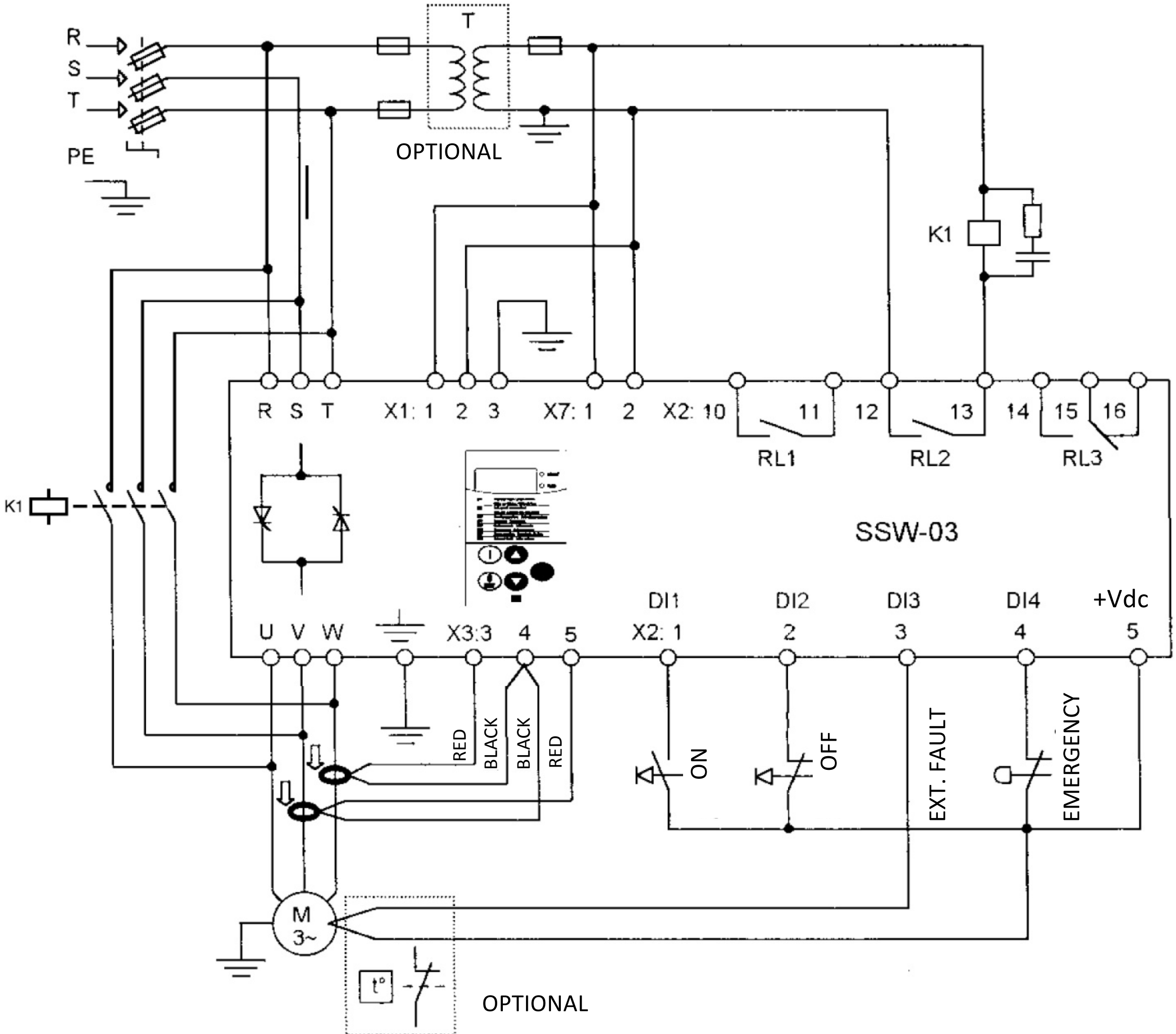


Figure 7.7: *Soft-Starter installation inside the motor delta connection*

In the inside the motor delta connection, the connection cables from the Soft-Starter to the power supply, and/or the power supply insulation contactor, must withstand the rated motor current. The connection cables of the Soft-Starter to the motor, and/or by-pass contactor connection, must withstand 58% the rated motor current (in operation) and 67% the motor current (during the start).

In this case, the use of copper bus bars in the connection between the Soft-Starter and the power supply is also suggested, due to the large currents involved and the cable cross-sections.

Along with the SSW-03 Plus, an extension bus bar is supplied as an accessory to allow for more cables to be connected to the SSW-03 Plus input bus bars.

When using a bus bar to connect the SSW-03 Plus to the power supply, do not use this extension bus bar.

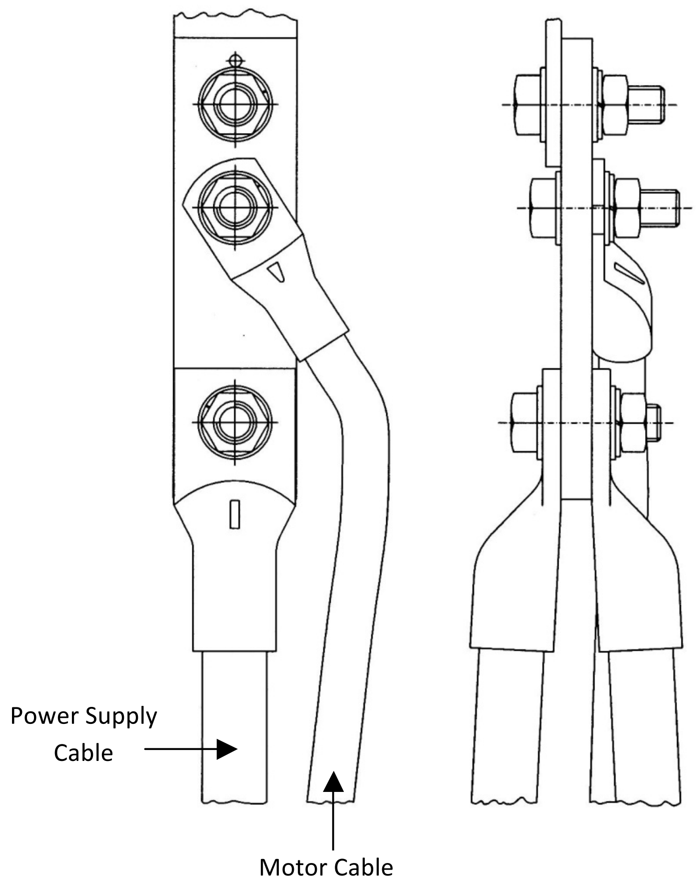


Figure 7.8: *Extension bus bar for the SSW-03*

7.3.3 Motor Terminal Connection with Multiple Voltages

Most motors are supplied with restarting winding terminals, as to be able to operate in power supply grids with at least two different voltages. The main restarting types of motor terminals for operation in more than one voltage are:

a) Series-parallel connection

The winding of each phase is divided into two parts (remember that the number of poles is always even, always making this type of connection possible).
By connecting the two halves in series, each half will remain with half the rated phase voltage of the motor.

By connecting the two halves in parallel, the motor can be supplied with a voltage equal to half the previous voltage, without altering the voltage applied to each winding. See the examples in figures 7.9 and 7.10.

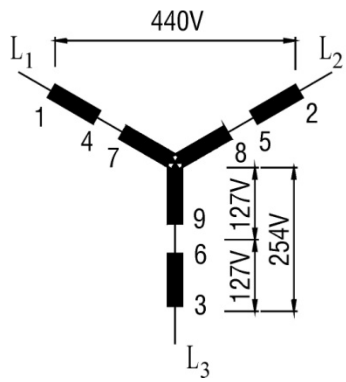


Figure 7.9: *Series-parallel connection Y*

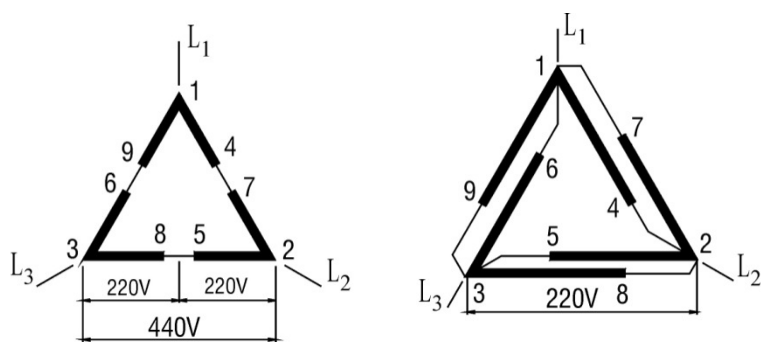


Figure 7.10: *Series-parallel connection* ∆

This type of connection requires nine motor terminals and the most common rated voltage (double) is 220/440V. This means the motor is connected in the parallel connection when supplied with 220V and in the serial connection when supplied with 440V. Figures 7.9 and 7.10 show the normal terminal numbering and the connection diagram for these types of motors, for motors connected in star as well as in delta.

The same diagram serves for any other two voltages, as long as one is double the other (for example: 230/460V).

b) Star-delta connection

Each phase winding has both terminals outside the motor.

If the three phases are connected in delta, each phase will receive the grid voltage (ex: 220V – figure 2.6). If the three phases are connected in star, the motor can be connected to a power supply with voltage equal to 220 x √3 = 380 volts, without altering the winding voltage, which continues to be equal to 220 volts per phase.

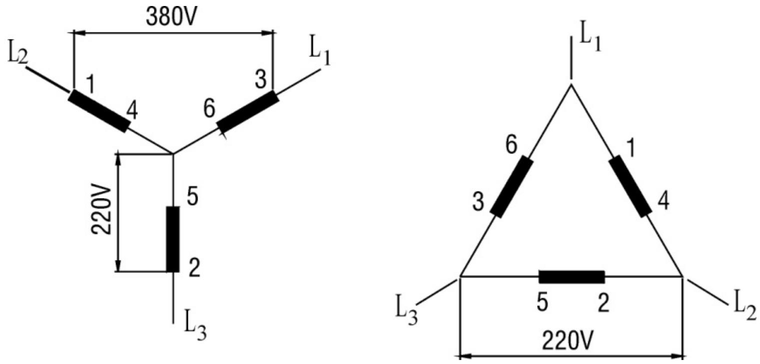


Figure 7.11: *Star-delta connection Y - Δ*

This type of connection requires six motor terminals and serves for any double rated voltage, as long as the second is equal to the first times √3.

Examples: 220/380V – 380/660V – 440/760V

In examples 380/660V and 440/760V, the greater declared voltage only serves to indicate that the motor can be started through a star-delta starting switch.

Motors with rated operation voltage above 660V must be equipped with a special insulation system, appropriate for this condition.

c) Triple rated voltage

The two cases above can be combined: the winding in each phase is divided in two halves for a series-parallel connection. Besides this, all the terminals are accessible so that the three phases can be connected in star or delta. As such, there are four possible rated voltage combinations.

1) Delta-parallel connection
2) Star-parallel connection, equal to √3 times the first
3) Delta-series connection, equal to double the first
4) Star-series connection, equal to √3 times the third

But, since the voltage above would be greater than 600V, it is only indicated as a star-delta connection reference.

Example: 220 / 380 / 440 (760) V

This type of connection requires 12 terminals, and figure 7.12 shows the normal terminal numbering and the connection diagram for the three rated voltages.

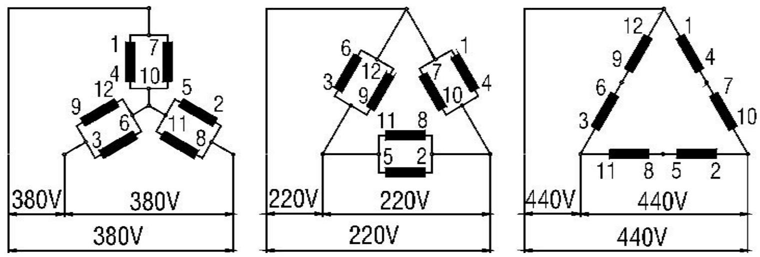


Figure 7.12: *"Multi-voltage" motor*

7.3.4 SSW-03 Plus Connection Possibilities as a Function of the Motor Closing

Standard connection with three cables: P28=OFF, Soft-Starter line current is equal to the motor current.

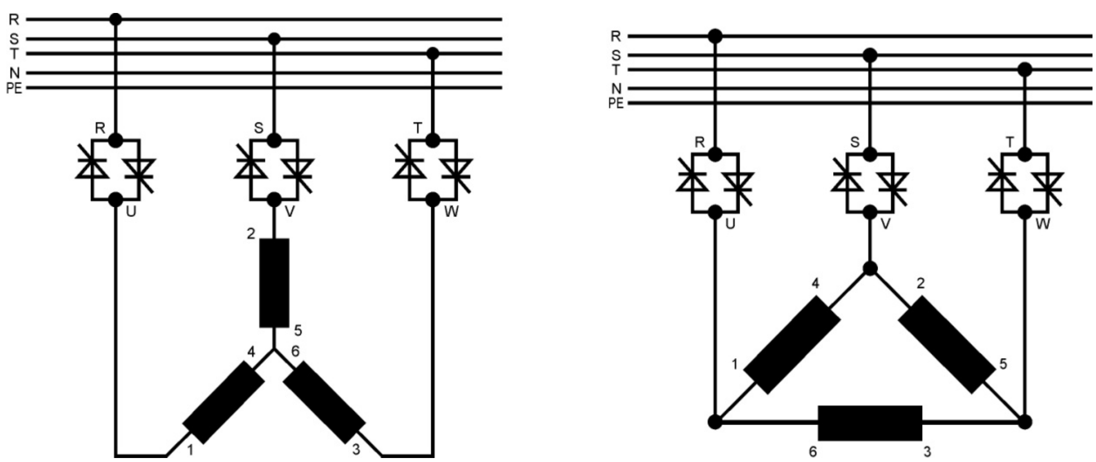


Figure 7.13: *Soft-Starter input grid current equal to the motor current*

Inside the motor delta connection with six cables: P28=ON, Soft-Starter input grid current is equal to approximately 58% the motor current (in operation) and 67% the motor current (at the start).

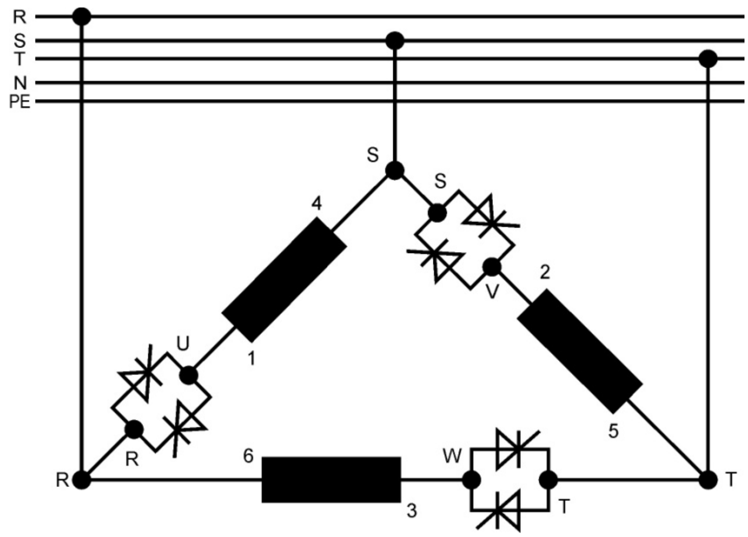


Figure 7.14: *Soft-Starter input grid current equal to approximately 58% the motor current*

Inside the motor delta connection with two delta windings connected in series.

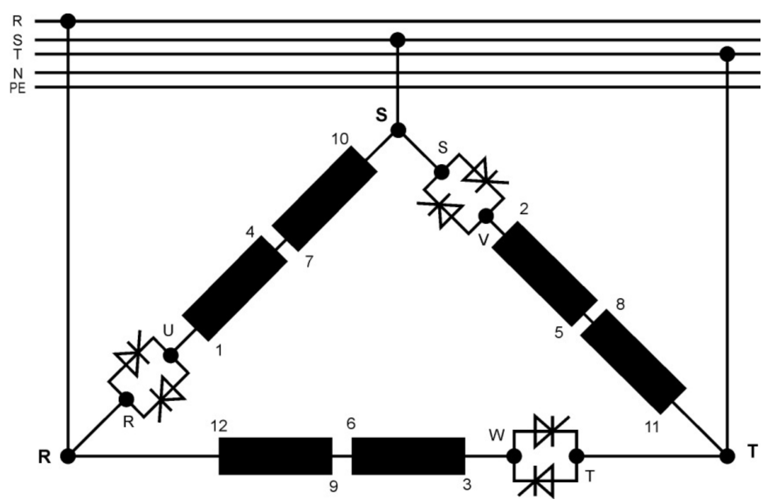


Figure 7.15: *Soft-Starter "inside the motor delta" and two delta windings connected in series*

Inside the motor delta connection with two delta windings connected in parallel.

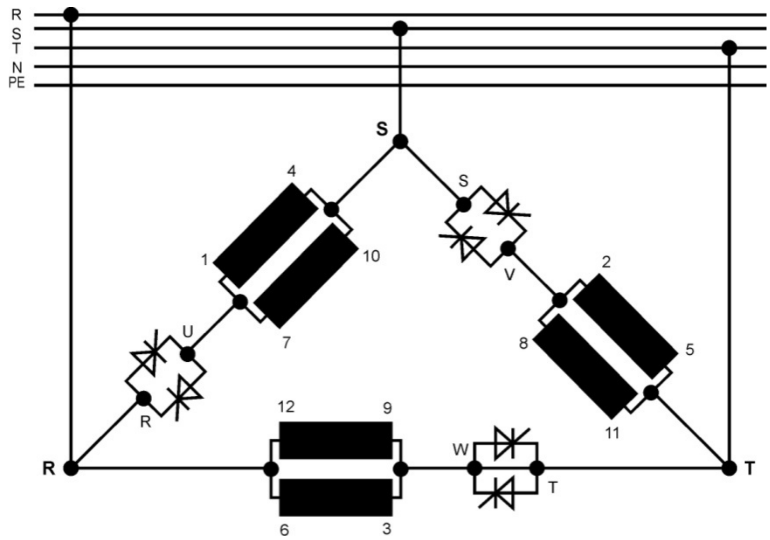


Figure 7.16: *Soft-Starter "inside the motor delta" and two delta windings connected in parallel*

7.4 SSW-05 (MICRO SOFT-STARTER)

The SSW-05 micro Soft-Starter connection differs in several ways from that of a conventional Soft-Starter. This is due to being developed with a focus on starting small motors that drive light loads, like pumps and compressors.

This Soft-Starter operates with the principle of voltage control in two phases. One of the phases passes directly and is connected to the motor. The voltage of the other two phases is controlled by thyristors connected in anti-parallel. After the start, the thyristors are short circuited by an internal relay (by-pass).

As such, the micro Soft-Starter must necessarily be used with a device that guarantees the physical opening of the power supply of all the phases (input contactor or circuit breaker), besides using fuses.

The table below lists WEG contactor + fuse sets indicated for each rated current value of the SSW-05.

SSW-05 Plus Current	Contactor (K1)	Fuse (F1, F2, F3)	Fuse (F11, F12, F21)
3A	CWM09	Type D 10A	Type D 6A
10A	CWM12	Type D 16A	
16A	CWM18	Type D 25A	
23A	CWM25	Type D 35A	
30A	CWM32	Type D 50A	
45A	CWM50	Type D 63A	
60A	CWM65	Type NH 100A	
85A	CWM95	Type NH 125A	

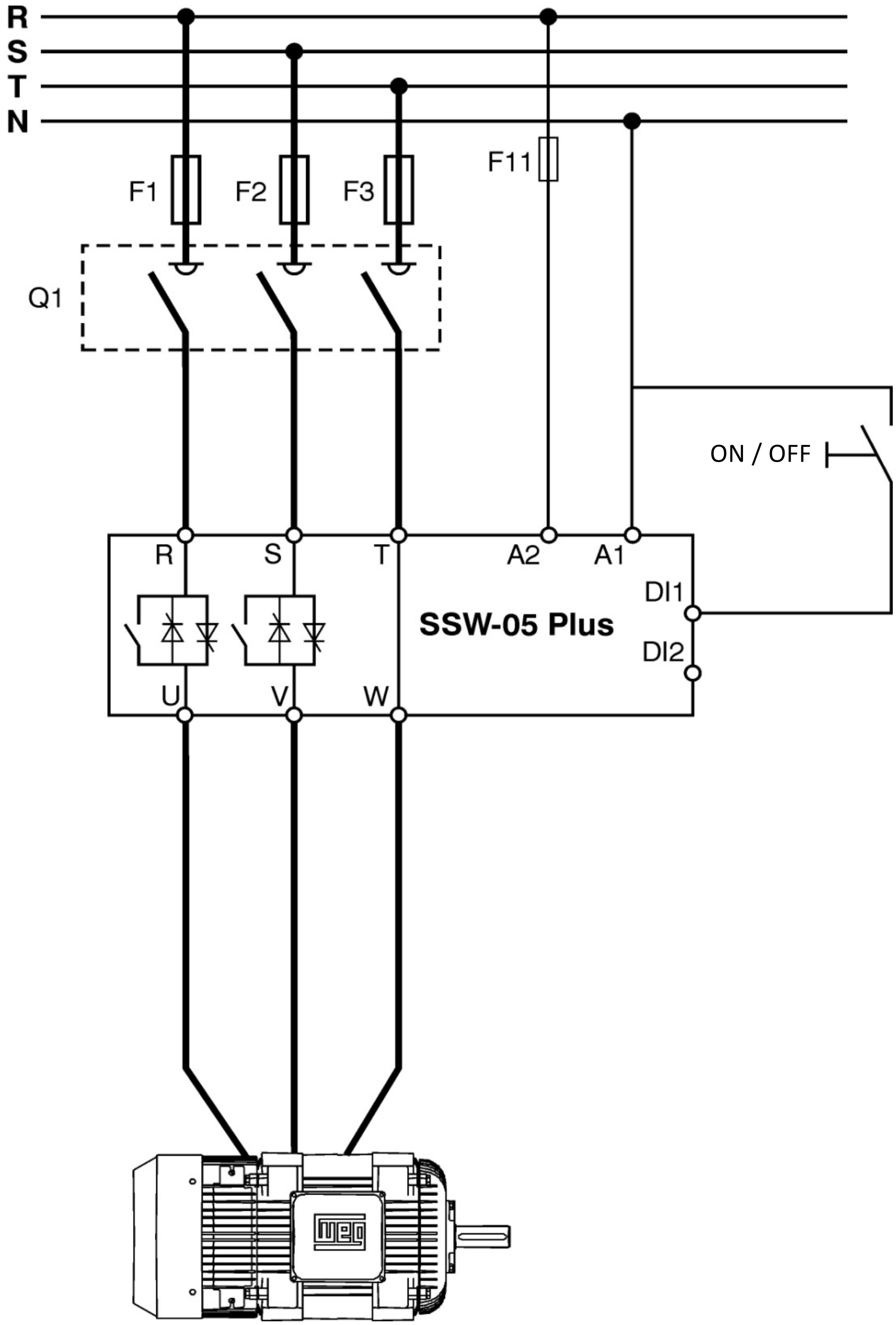


Figure 7.17: *Simplified SSW-05 micro Soft-Starter (two wires control and input disconnect switch)*

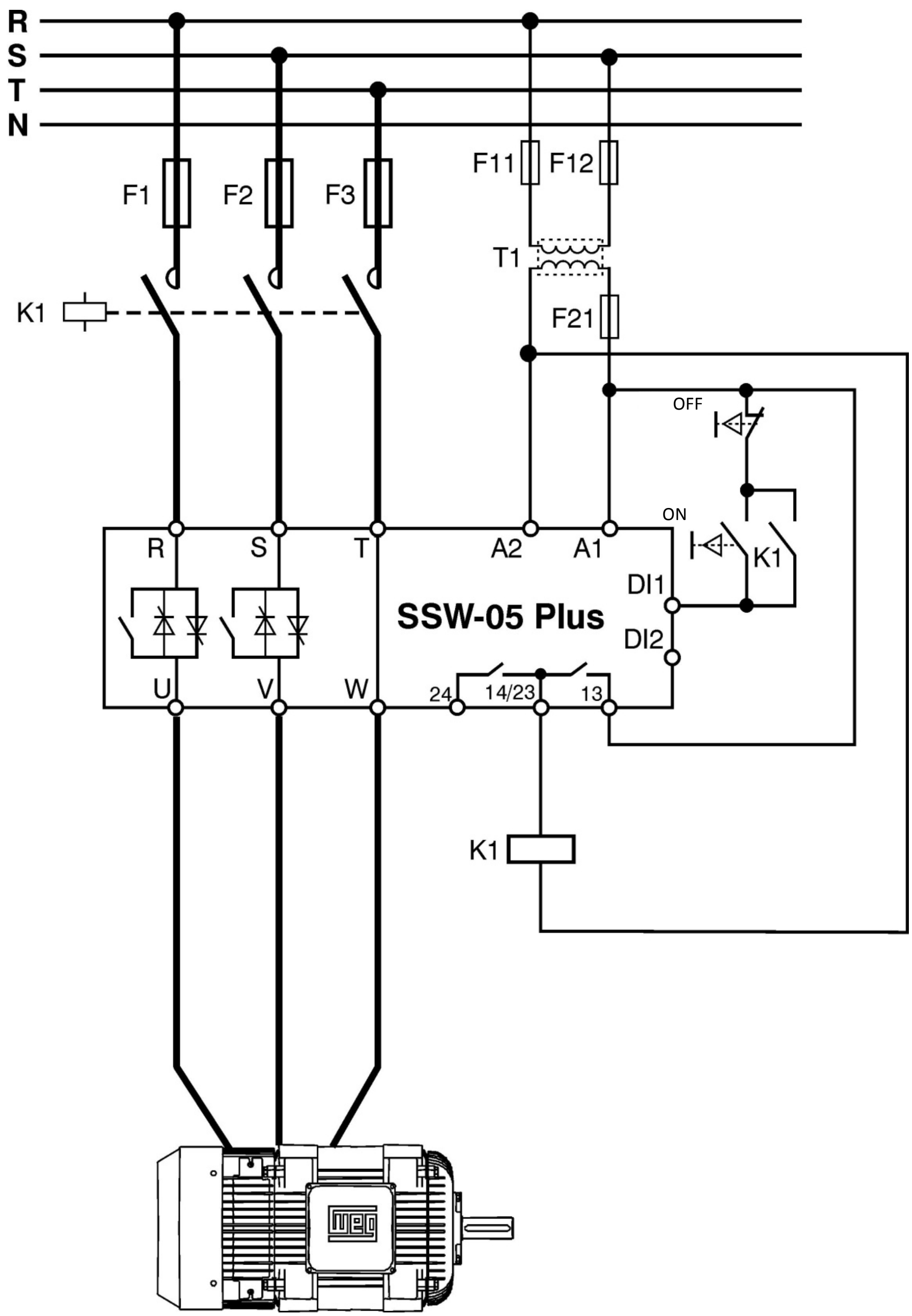


Figure 7.18: *SSW-05 micro Soft-Starter (control using I/Os and input contactor)*

7.5 SMV-01 CONNECTION (MEDIUM VOLTAGE SOFT-STARTER)

The SMV-01 is a complete starting system developed by WEG to start medium voltage motors.

The standard circuit is made up of an Input Sectioning Switch, Ultra-Fast Fuses, a Vacuum Input Contactor and a Vacuum By-Pass Contactor, as well as the Soft-Starter itself.

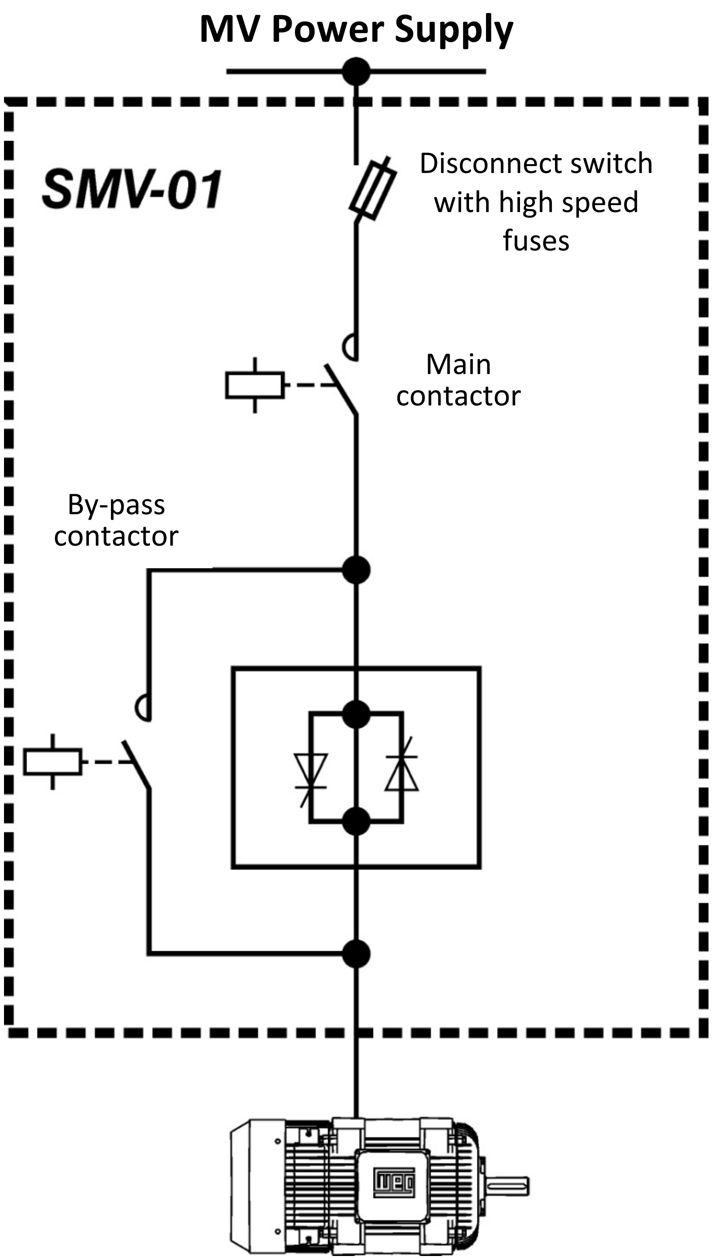


Figure 7.19: *Typical starting system with an SMV-01*

WEG application engineers and technicians, working with the client, develop the best installation solution for each specific application.

SSW-05

Micro Soft-Starter

- Compact
- Digital – DSP
- Easy operation
- High efficiency
- Built-in by-pass

SSW-05 Micro Soft-Starter

Soft-Starters are static starting switches designed for the acceleration, deceleration and protection of three-phase induction motors, which do so by controlling the voltage applied to the motor.
SSW-05 Plus Micro Soft-Starters, with DSP control (Digital Signal Processor) were designed for superior performance during electric motor starting and stopping, with an excellent cost/benefit ratio.
The Interface allows easy parameter setting, simplifying start-up and daily operation.
The SSW-05 Plus Micro Soft-Starters are compact, optimizing electrical panel space.
The SSW-05 Plus incorporates all electric motor protections.

Benefits

- Significant stress reduction on couplings and other transmission devices during the start (gear boxes, pulleys, gears, belts, etc.).
- Lifetime extension of the motor and the mechanical components of the driven machine due to reduced mechanical shocks.
- Easy operation, programming and maintenance.
- Simple electrical wiring.
- Operation in environments up to 55°C (122°F).

Some Applications

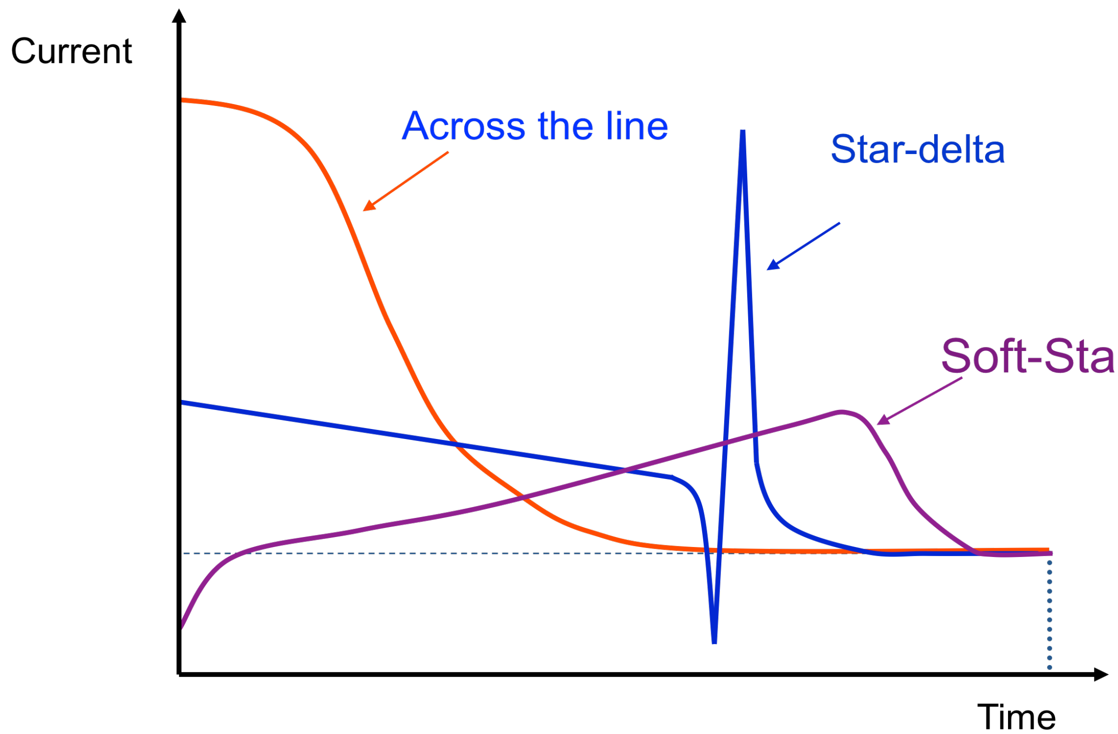
This soft starter is especially recommended for applications in:

- Vacuum Pump with blades
- Centrifugal Pumps
- Calenders / Roller Tables (starts w/o loads)
- Screw Compressors
- Mixers
- Paper Refiners
- Axial Fans (low inertia – light load)

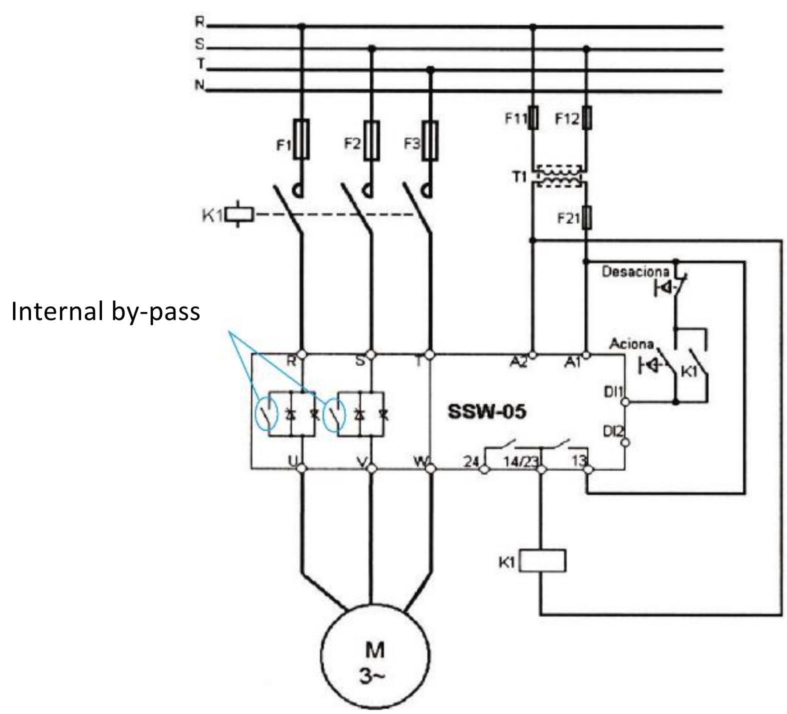
Other applications are possible upon analysis. If necessary, consult the manufacturer or an authorized dealer.

Certifications

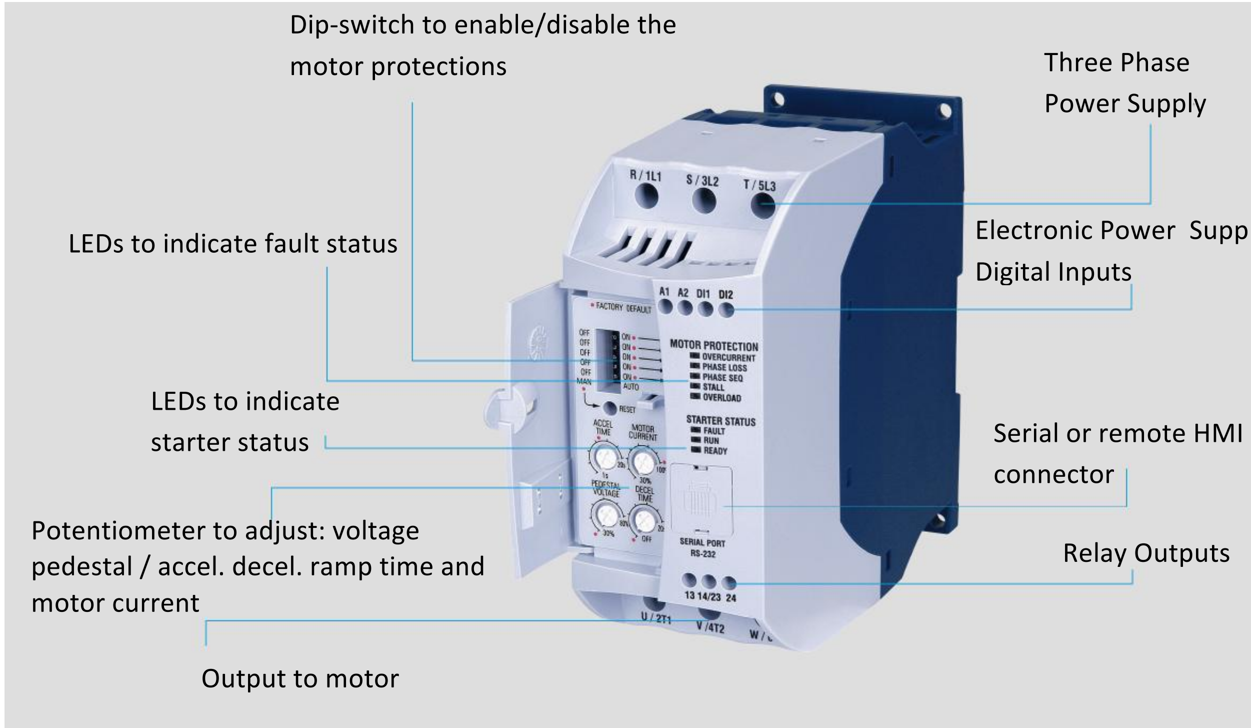
Starting method comparison



SSW-05 Plus Soft-Starter Connection

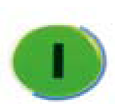


Settings and Indications



SSW-05 - Human-Machine Interface

Remote Human-Machine Interface for remote operation on panel door or machine console. The HMI has an incorporated copy function, allowing parameters to be copied from one soft-starter to another, providing fast and reliable set-up of identical starters.



Starts the Soft-Starter

Stops the Soft-Starter. Resets the Soft-Starter after a fault trip has occurred

Scrolls up parameters or increases parameter value

Scrolls down parameters or decreases parameter value

Selects (commutes) display between parameter number and value (position/content)

Model	Description	Item
CAB-RS-1	Remote keypad cable – 3.3 ft	10050268
CAB-RS-2	Remote keypad cable – 6.6 ft	10190951
CAB-RS-1	Remote keypad cable – 10 ft	010211478
HMI-SSW05-RS	Remote HMI to use with CAB-RS cable up to 3m	10193351

SUPERDRIVE Programming Software

Superdrive is a windows-based software for controlling, monitoring and setting parameters in SSW-05 Plus Soft-Starters.

It allows parameters to be set on-line, directly on the Soft-Starter and parameters files to be edited off-line and stored in the computer.

It is possible to store parameter files of all SSW-05 Plus in the installation.

The software also has built-in functions to transfer a set of parameters from the computer to the Soft-Starter, and vice versa.

The communication between the Soft-Starter and the computer is provided through RS-232 serial interface.

Models

3 to 30 Amps

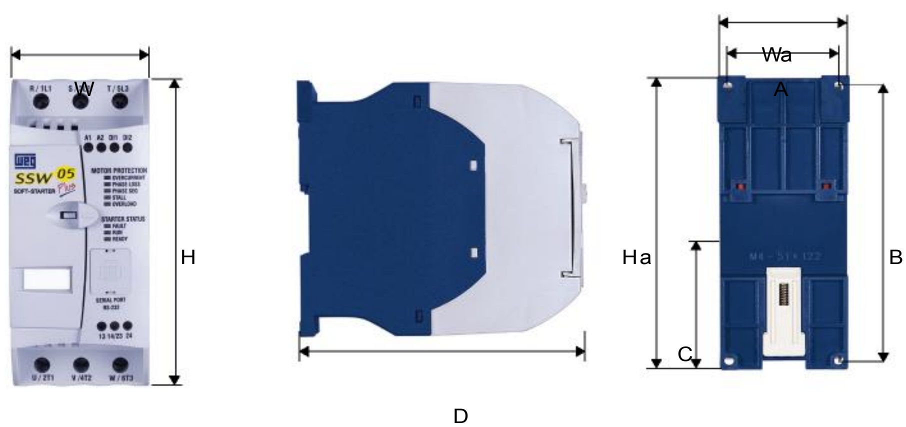
45 to 85 Amps

Specification Table

Supply Voltage	Item	SSW-05 Plus Micro Soft-Starter		Maximum Applicable Motor			Dimensions (MM)			Weight (kg)
		Model	I_{rated} (A)	Voltage (V)	Power HP	Power kW	Height	Width	Depth	
220/230/380/400/415/440/460 V	10413826	SSW-05.03	3	220V	0.75	0.55	130	59	145	0.74
	10413820	SSW-05.10	10		3	2.2				
	10413821	SSW-05.16	16		5	3.7				
	10413822	SSW-05.23	23		7.5	5.5				
	10413823	SSW-05.30	30		10	7.5				
	10413824	SSW-05.45	45		15	11	185	79	172	1.67
	10328754	SSW-05.60	60		20	15				
	10413825	SSW-05.85	85		30	22				
	10413826	SSW-05.03	3	380V	1.5	1.1	130	59	145	0.74
	10413820	SSW-05.10	10		6	4.5				
	10413821	SSW-05.16	16		10	7.5				
	10413822	SSW-05.23	23		15	11				
	10413823	SSW-05.30	30		20	15				
	10413824	SSW-05.45	45		30	22	185	79	172	1.67
	10328754	SSW-05.60	60		40	30				
	10413825	SSW-05.85	85		60	45				
	10413826	SSW-05.03	3	440V	2	1.5	130	59	145	0.74
	10413820	SSW-05.10	10		7.5	5.5				
	10413821	SSW-05.16	16		12.5	9.2				
	10413822	SSW-05.23	23		15	11				
	10413823	SSW-05.30	30		20	15				
	10413824	SSW-05.45	45		30	22	185	79	172	1.67
	10328754	SSW-05.60	60		40	30				
	10413825	SSW-05.85	85		60	45				
460/480/500/ 525/575 V	10052025	SSW-05.03	3	480V	2	1.5	130	59	145	0.74
	10686569	SSW-05.10	10		7.5	5.5				
	10686571	SSW-05.16	16		12.5	9.2				
	10686572	SSW-05.23	23		15	11				
	10686573	SSW-05.30	30		25	18.5				
	10686576	SSW-05.45	45		30	22	185	79	172	1.67
	10584471	SSW-05.60	60		50	37				
	1052026	SSW-05.85	85		75	55				

NOTE: The power ratings shown on the table are for loads such as centrifugal pumps and compressors (for starting without load), based on WEG
IV pole – 60 Hz motors. Access the site (www.weg.net) and use the SDW software for Soft-Starter sizing.
Sizing is based on the load curve data, number of starts/hour and type of load.

Mechanical Dimensions



Frame Size	Width (mm)		Height (mm)		Depth D (mm)	Dimension A (mm)	Dimension B (mm)	Dimension C (mm)	Dimension	Weight (kg)
	W	Wa	H	Ha						
1	59	60.4	130	130.7	145	51	122	61	M4 Bolt / Rail	0.74
2	79	80.4	185	185.7	172	71	177	99	M4 Bolt / Rail	1.64

Dimension Wa, Ha (mounting only with bolts)

Technical Characteristics

Model		SSW-05 Plus
Power Supply	Power voltage	220 – 460 Vac (-15%, +10%)
		460 – 575 Vac (-15%, +10%)
	Frequency	50 / 60 Hz
	Electronics	Electronic switching power supply (90 – 250 Vac)
Degree of Protection	Injected plastic	IP00
Control	Method	Voltage variation on load (motor)
	CPU	DSP type micro-controller
Starting Curve	Normal	300% (3xI_{rated}) during 10s, 4 starts/hour
Inputs	Digital	1 input for start and stop
		1 input for error reset
Outputs	Digital	1 relay output for full voltage indication (By-Pass) or defect (programmable)
		1 relay output for operation indication
Communication	Serial interface	RS-232
Safety	Protections	Motor overload
		Phase sequence
		Phase loss
		Locked rotor
		Overload
		Overcurrent
		Internal fault

Functions/Options	Initial voltage	30 – 80% Rated voltage
	Acceleration ramp time	1 – 20 s
	Deceleration ramp time	Off – 20s
	Ratio between motor In and switch In	30 – 100%
Ambient Conditions	Temperature	0 … 50°C – Normal operating conditions under rated current
	Humidity	0 … 90% w/o condensation
	Altitude	0 … 1000 m – normal operating conditions at rated current
		1000 … 4000 m – with current reduction of 1% / 100 m above 1000 m
Finishing	Color	Ultra matte grey (cover) and ultra matte blue (base) / WEG standard
Installation	Mounting method	Mounted with bolts or assembled on DIN 35 mm rails
Conformity/Norms	Safety	UL 508 Norm – Industrial control equipment
	Low voltage	IEC 60947 – 4 – 2
	EMC	EMC directive 89 / 336 / EEC – Industrial environment
Certification	UL (USA) and cUL (Canada)	Underwriters Laboratories Inc. / USA
	CE (Europe)	SGS / England
	IRAM (Argentina)	Instituto Argentino de Normalización
	C-Tick (Australia)	Australian Communications Authority

Sizing Software

Use the WEG Sizing Software (SDW) for Soft-Starters, which is available on the site www.weg.net or request a CD version through the e-mail: *automacao@weg.net*.

SSW05 0010 T 2246 P P -- -- Z

1 2 3 4 5 6 7 8 9

1 - Soft-Starter line SSW-05

2 - Rated output current:
0003 = 3 A
0010 = 10 A
0016 = 16 A
0023 = 23 A
0030 = 30 A
0045 = 45 A
0060 = 60 A
0085 = 85 A

1 - Input power Supply voltage:
T= Three-phase

4 - Power supply voltage:
2246 = 220 ... 46 0 V
46 57 = 46 0 ... 575 V

5 - Product manual language
P = Portuguese
E = English
S = Spanish
G = German

6 - Product version
P = Plus

7 - Special hardware
Blank = Standard (not available)
Hx = Optional version x (H1 ... Hn)

8 - Special software
Blank = Standard (not available)
Sx = Optional version x (S1 ... Sn)

9 - Code end
Z = Digit indicating code end

Ex.: SSW05 0060 T 4657 EPZ

SSW-06

Soft-Starter

- Voltage protections
- Torque control
- Built-in by-pass
- Built-in soft PLC
- LCD HMI
- Oriented start-up

SSW-06 Soft-Starter

WEG SSW-06 series Soft-Starters are static starting switches designed to accelerate, decelerate and protect three-phase induction motors. By controlling the voltage applied to the motor, depending on the thyristor trigger angle setting, it is possible to obtain smooth starts and stops. With the appropriate variable settings, the produced torque is adjusted to the load needs, and as such, the demanded current is as low as needed to start.

WEG SSW-06 series Soft-Starters have microprocessor technology and are fully digital. These are products with state-of-the-art technology, designed to guarantee the best starting and stopping performance in induction motors. They provide a complete solution, at a low cost. The HMI allows easy programming during commissioning and operation. The built-in “Pump Control” function gives optimized preset pump application parameters, avoiding “Water Hammer”.

Benefits

- Memory back-up for voltage, current and Soft-Starter status in case of a fault
- Programmable fault activation
- Exclusive Soft PLC function – built-in
- 32-bit RISC high performance microcontroller
- Built-in electronic motor protection
- Built-in electronic thermal relay
- Removable Human Machine Interface with double display (LED/LCD)
- Fully programmable control methods
- Totally flexible torque control
- “Kick-start” function for high breakaway torque
- “Pump control” function for intelligent control of pumping systems, avoiding “water hammer”
- Current peak limits on the power supply
- Voltage drop limits during starting
- Universal voltage (220 to 575 Vac)
- Control board power supply with EMC filter (94 to 253 Vac)
- Built-in bypass (85 to 820A) providing size reduction and energy savings
- Back-up memory of motor protection I^2t thermal image
- Over/undervoltage protection
- Voltage/current imbalance protection
- Protection of motor overload caused by over /undercurrent and over/underpower
- Motor PTC input
- Elimination of mechanical shocks
- Reduction of stress on couplings and transmission devices (gearboxes, pulleys, belts, etc.)
- Increased lifetime of the motor and mechanical equipment of the driven machine
- Easy operation, programming and maintenance via HMI
- Simplified electrical installation
- Oriented start-up
- Possibility for standard (3 cables) or inside the motor delta (6 cables) connection
- All protections and functions available for both types of connections (unique in the market)
- Serial or Fieldbus communication error protection functions
- Reversal of direction of rotation
- JOG function in frequency for both direction of rotation, without a contactor
- Three braking methods for a faster motor / load stop, with or without a contactor
- Operation in environments up to 55°C (with current reduction for model range 85A to 820A)

Applications

Chemical and Petrochemical
- Fans / Exhausts
- Centrifugal pumps
- Dosing / Process pumps
- Centrifuges
- Stirrers / Mixers
- Compressors
- Soap extruders

Plastic and Rubber
- Extruders
- Injection / Blowers
- Mixers
- Calenders
- Grinders

Pulp and Paper
- Dosing pumps
- Process pumps
- Fans / Exhausts
- Stirrers / Mixers
- Rotary filters
- Rotary kilns
- Wood chip conveyors
- Calenders
- Coaters
- Papers refiners

Sugar and Alcohol
- Fans / Exhausts
- Process pumps
- Conveyor belts

Juice and Beverages
- Centrifugal pumps
- Mixers
- Roller tables
- Conveyor belts
- Bottling lines

Cement and Mining
- Dosing / Process pumps
- Sifting Machines / Rotating tables
- Dynamic graders
- Conveyor belts
- Dosing machines
- Rotary Kilns

Food and Ration
- Dosing / Process pumps
- Fans / Exhausts
- Mixers
- Dryers / Furnaces
- Pellet mills
- Conveyors

Textile
- Mixers
- Dryers / Washers

Siderurgy and Metallurgy
- Fans / Exhausts
- Conveyor belts
- Drilling & Grinding machines
- Winding/unwinding machines
- Pumps

Ceramic
- Fans / Exhausts
- Dryers / Furnaces
- Rotary Kilns
- Ball / Hammer mills
- Roller tables
- Conveyor belts

Glass
- Fans / Exhausts
- Dryers / Furnaces
- Ball / Hammer mills
- Roller tables
- Conveyors belts

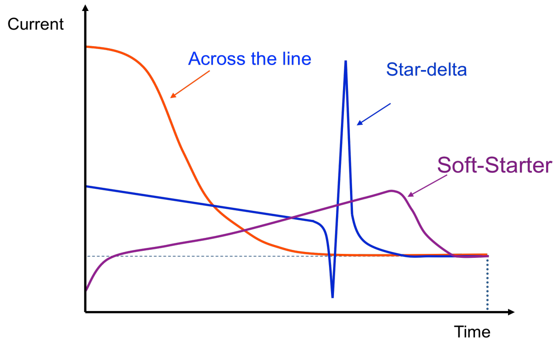
Refrigeration
- Process pumps
- Fans / Exhausts
- HVAC
- Screw / Piston Compressors

Wood
- Slicing Machine
- Sanding Machine
- Cutting machines
- Wood chippers
- Saws / Planes

Waste treatment
- Centrifugal pumps
- Axial flow pumps

Load transportation
- Conveyors / Belts / Chains
- Roller tables
- Monorails / Hoists
- Escalators
- Baggage conveyors (airports)

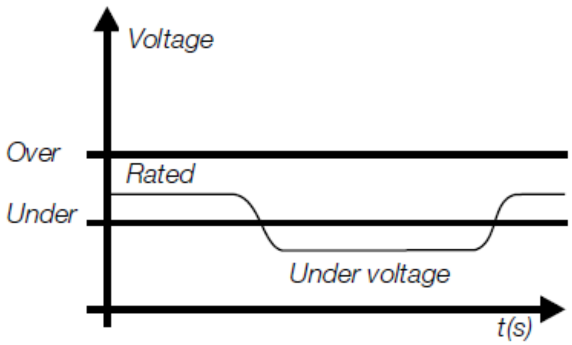
Comparison for different starting methods

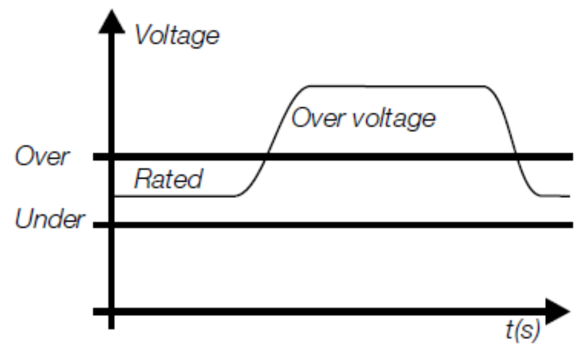


Voltage and Current Protections

Under and Overvoltage

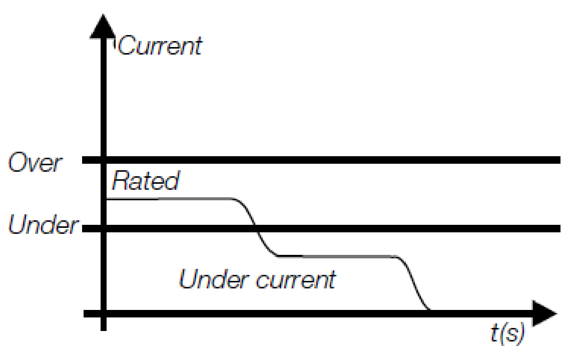
Allows under and overvoltage limits to be adjusted for full motor protection. Available in both motor connection types.

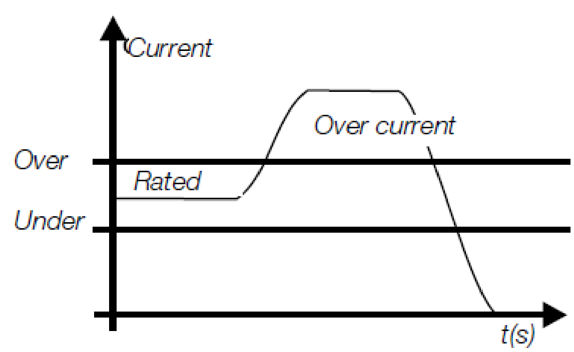




Under and Overcurrent

Allows under and overcurrent limits to be adjusted for full motor protection

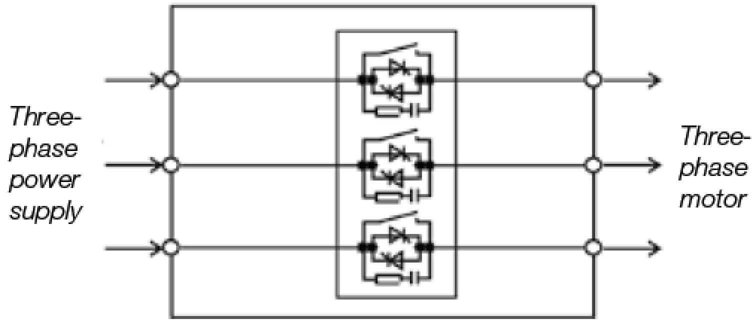




Built-In By-Pass

Under and Overvoltage

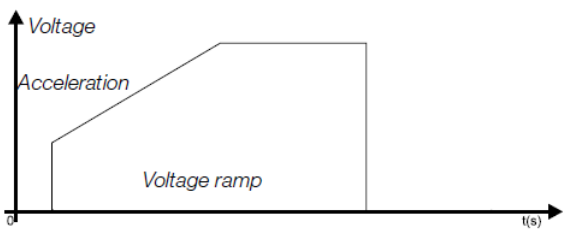
Built-in by-pass reduces power and heating losses in the thyristors, providing size reduction and energy savings. Available in models ranging from 10 to 820A.



Starting Methods

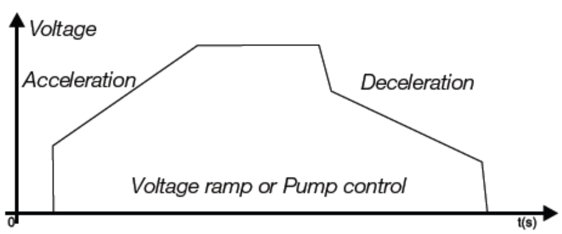
Voltage Ramp

Provides smooth acceleration and / or deceleration via voltage ramps.



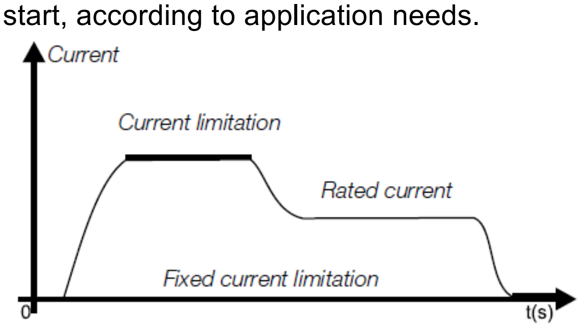
Pump Control

Pump control provides smooth deceleration, avoiding “water hammer”.



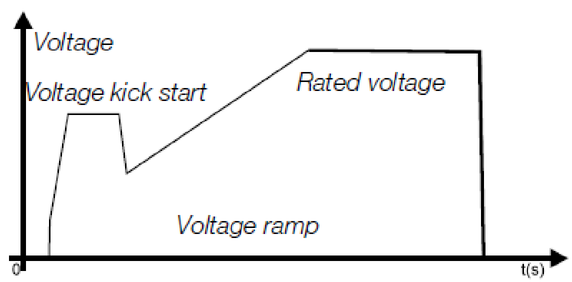
Current Limit

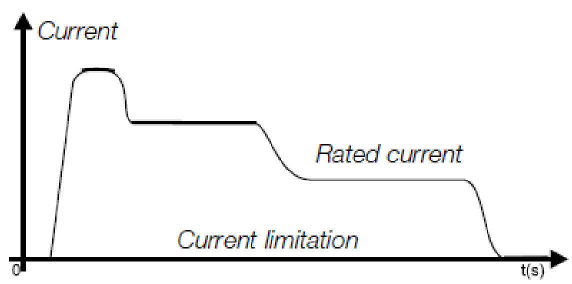
Allows a current limitation to be set at the start, according to application needs.



Voltage and Current Kick Start

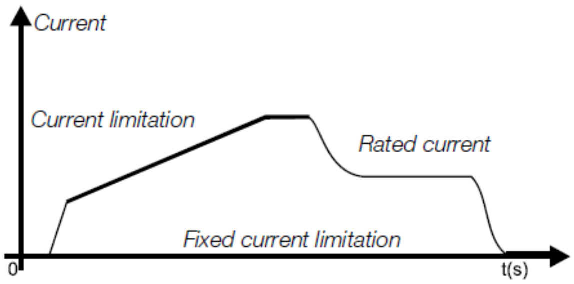
Provides an initial pulse of voltage or current that, when applied to the motor, provides an initial torque boost to start the motor. Required for loads with high breakaway torque.

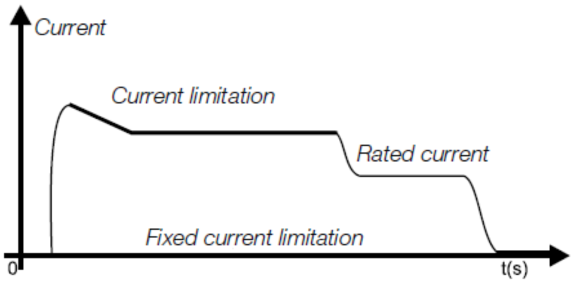




Current Ramp

Allows setting higher or lower current limits for the beginning of a start. Applied to loads with higher or lower initial torque.



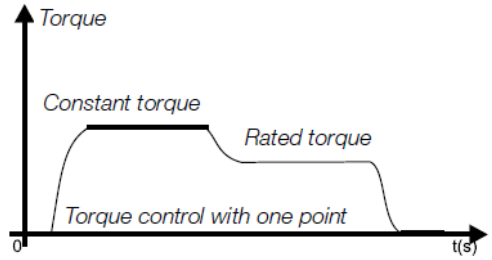


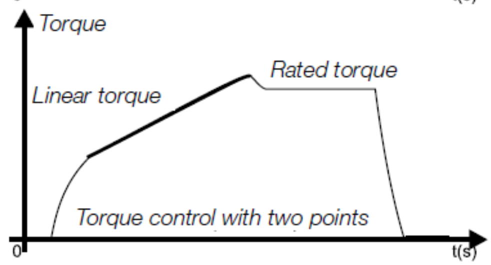
Torque Control

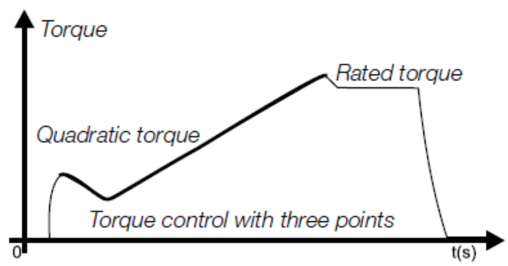
The SSW-06 has a totally flexible, high performance torque control algorithm that makes it possible to meet the needs of any application, for starting and stopping. Available in both motor connection types: standard (3 cables) or inside the motor delta (6 cables).

- 1 adjustment point - Constant torque
- 2 adjustment points - Linear torque ramp
- 3 adjustment points - Quadratic torque ramp

This type of control may allow acceleration and deceleration with linear speed ramp.







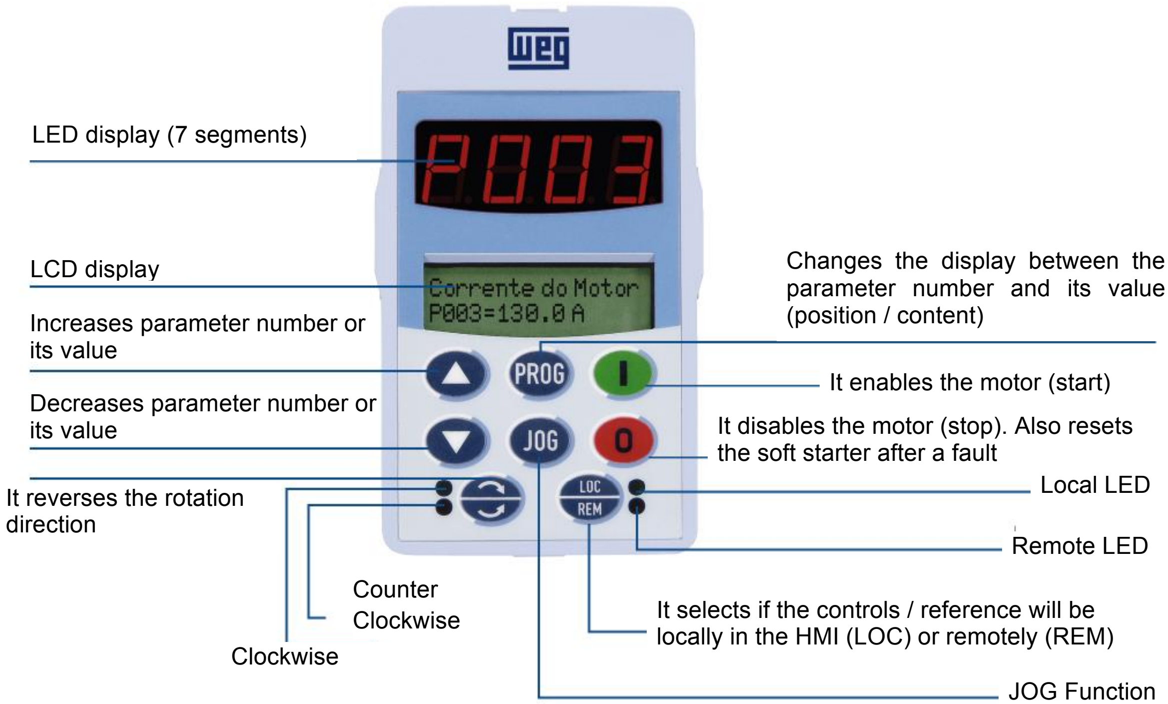
Human-Machine Interface

Intelligent Interface

Intelligent operation interface with double display, LED (7 segments) and LCD (2 lines of 16 characters), which allows excellent long distance visibility, with a detailed description of all parameters and messages via alphanumeric LCD (liquid crystal) display.

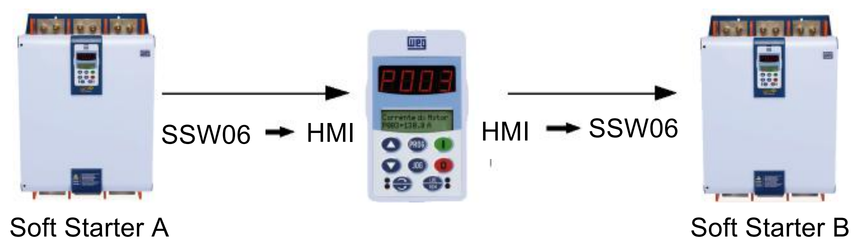
Selectable Language

The intelligent operation interface also allows the user to choose the language used for programming, reading and displaying parameters and alphanumeric messages on the LCD display.
The high hardware and software capacity level of the product offers the user many language options, such as Portuguese, English, German and Spanish, in order to adapt to any user around the world.



Copy Function

The intelligent interface also offers a "COPY" function that allows copying the parameters from one soft-starter to another, providing programming speed, reliability and repetition in similar applications.



Machines with serial production

Oriented Start-Up

Soft-Starters are designed for starting induction motors, and their adaptation and performance are directly related to the characteristics of the motor itself, as well as that of the power supply. SSW-06 series Soft-Starters have a specially developed programming option that simplifies the start-up. It uses an oriented and automatic sequence of parameters that guides the user through the sequential programming of the minimum characteristics needed to adapt the Soft-Starter to the driven motor and load.

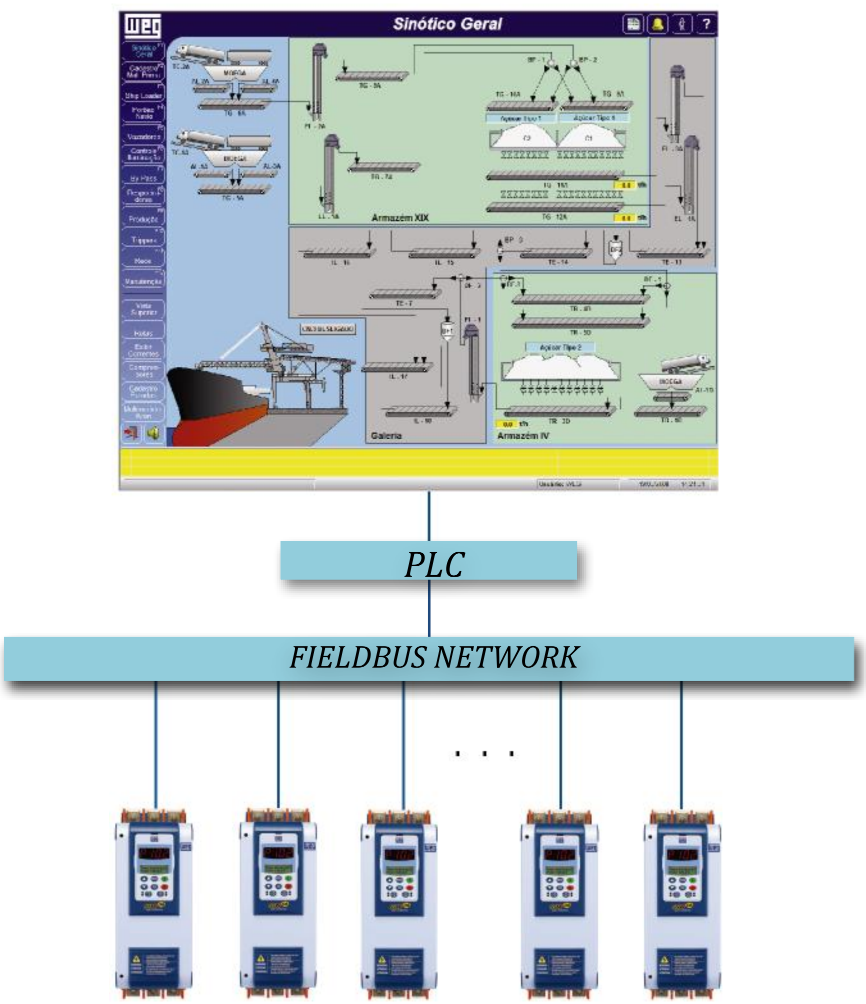
FIELDBUS Communication

SSW-06 Soft-Starters can be connected to Fieldbus fast communication networks through the most widely used standard protocols in the world. They are:

FIELDBUS →
- Profibus DP (optional)
- DeviceNet (optional)
- Modbus RTU RS-232 (built-in)
- Modbus RTU RS-485 (optional)

Mainly intended to integrate into large industrial automation systems in plants, fast communication networks offer many advantages in Soft-Starter supervision, online monitoring and controlling. The result is high performance and great operational flexibility, characteristics required in complex and/or integrated systems. For Fieldbus Profibus DP or DeviceNet communication network connections, SSW-06 Soft-Starters offer plug-in accessories that can be installed according to the desired protocol. For the Modbus RTU protocol, the connection can be done via RS-232 (built-in) or RS-485 (optional) interfaces.

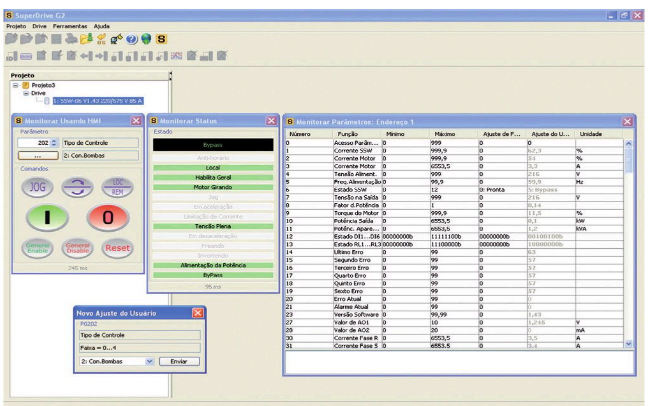
Beside the advantages in protection, monitoring and motor driving, digital inputs and digital / analog outputs can be used as remotes of the Fieldbus network master.

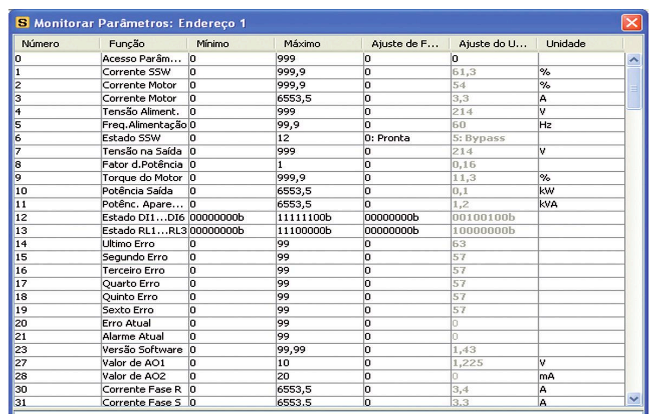


Superdrive G2

Software in Windows platform, for SSW-06 programming, controlling and monitoring.

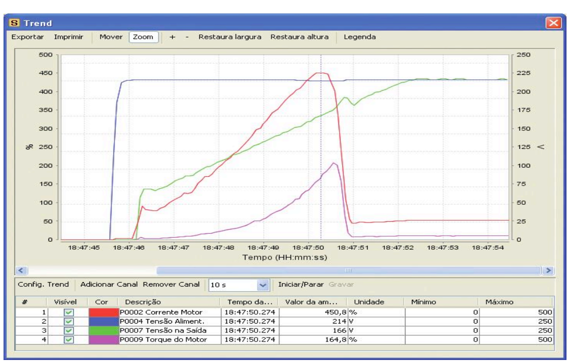
- Automatically identifies the SSW-06
- Reads SSW-06 parameters
- Writes SSW-06 parameters
- Edits parameters on-line in the SSW-06
- Edits parameters off-line in the PC
- Allows all application documentation to be created
- Easily accessible
- Superdrive G2 software allows SSW-06 parameter setting, command and monitoring
- Supplied with a 3m RS-232 serial cable with purchase of the Superdrive G2 software
- Free software on the site *www.weg.net*





Monitorar Parâmetros: Endereço 1

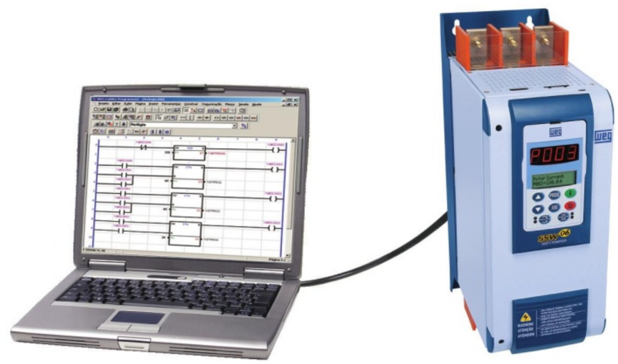
Número	Função	Mínimo	Máximo	Ajuste de F...	Ajuste do U...	Unidade
0	Acesso Parâm...	0	999	0	0	
1	Corrente SSW	0	999,9	0	61,3	%
2	Corrente Motor	0	999,9	0	54	%
3	Corrente Motor	0	6553,5	0	3,3	A
4	Tensão Aliment.	0	999	0	214	V
5	Freq.Alimentação	0	99,9	0	60	Hz
6	Estado SSW	0	12	0: Pronta	5: Bypass	
7	Tensão na Saída	0	999	0	214	V
8	Fator d.Potência	0	1	0	0,16	
9	Torque do Motor	0	999,9	0	11,3	%
10	Potência Saída	0	6553,5	0	0,1	kW
11	Potênc. Apare...	0	6553,5	0	1,2	kVA
12	Estado DI1...DI6	00000000b	11111100b	00000000b	00100100b	
13	Estado RL1...RL3	00000000b	11100000b	00000000b	10000000b	
14	Ultimo Erro	0	99	0	63	
15	Segundo Erro	0	99	0	57	
16	Terceiro Erro	0	99	0	57	
17	Quarto Erro	0	99	0	57	
18	Quinto Erro	0	99	0	57	
19	Sexto Erro	0	99	0	57	
20	Erro Atual	0	99	0	0	
21	Alarme Atual	0	99	0	0	
23	Versão Software	0	99,99	0	1,43	
27	Valor de AO1	0	10	0	1,225	V
28	Valor de AO2	0	20	0	0	mA
30	Corrente Fase R	0	6553,5	0	3,4	A
31	Corrente Fase S	0	6553.5	0	3.3	A

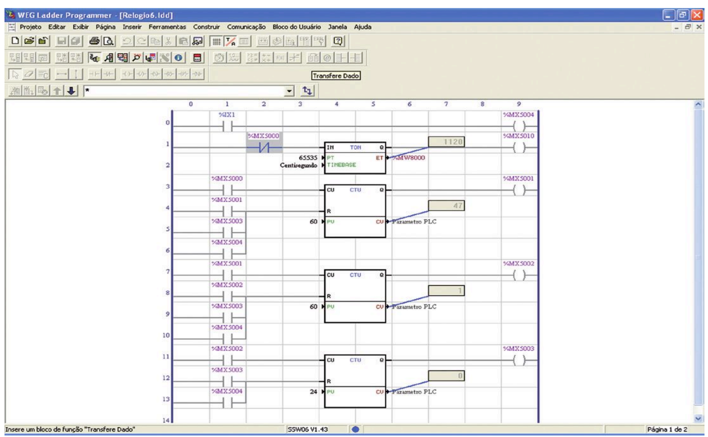


SOFTPLC Function

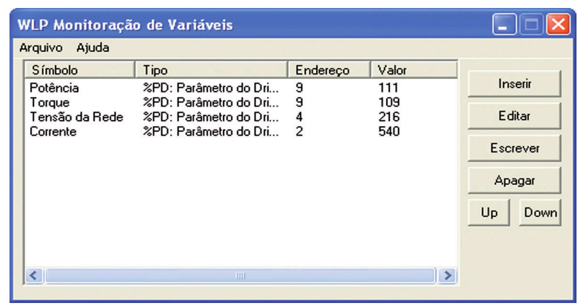
Equips the SSW-06 with PLC functions, providing the user with flexibility and the possibility of customizing user application programs.

- LADDER programming language – WLP Software.
- Access to all SSW-06 parameters and I/Os.
- PLC, math and control blocks.
- On-line download, upload and monitoring.
- Memory capacity of 1Kbytes.
- On-line help.
- 18 Parameters, 4 errors, 4 alarms (can be programmed individually)
- Free software on the site *www.weg.net*

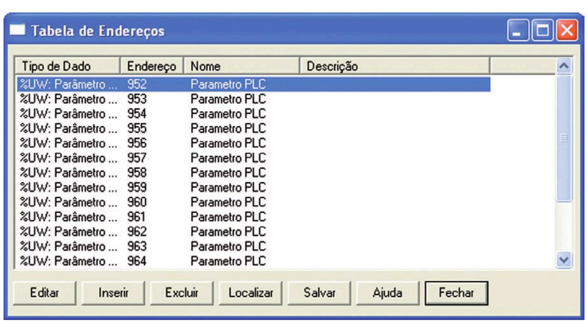




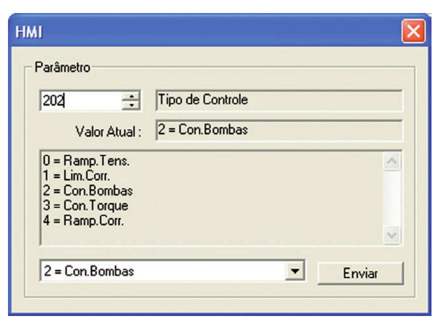
Easy programming – standard Ladder language



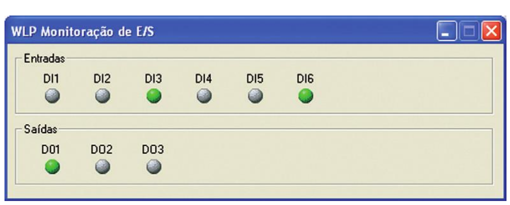
Online monitoring



User parameters



Virtual HMI allowing parameters changing



Digital Inputs and Outputs monitoring

Accessories and Options

HMI with double display

LED and LCD, with complete options via codes, alphanumeric text messages and COPY function.
For local: Soft-Starter cover; or remote: panel door installation. Maximum distance 16 ft (5m) without frame.

HUMAN-MACHINE INTERFACE
Complete version as standard
HMI-SSW-06-LCD

Installation frame / Interface mounting

Remote HMI mounting for Soft-Starter operation transfer to the panel door or to a machine console. Maximum distance 16ft (5 m). Degree of protection: NEMA1 / IP42.

REMOTE INTERFACE FRAME
KIT KMR – SSW-06

Cable length for HMI SSW-06 connection

Cable length (X) 1, 2, 3 and 5 m.

REMOTE INTERFACE
INTERCONNECTION CABLES
CAB – HMI SSW-06-X

Fieldbus cards

These cards enable SSW-06 control and data exchange in communication networks.

FIELDBUS OMMUNICATION KITS
Profibus DP → KFB-PD
DeviceNet → KFB-DN
Profibus DPV1 → KFB-PDPV1
DeviceNet Acyclic → KFB-DD

RS-485 communication

Enables an SSW-06 connection to a Modbus-RTU network via RS-485, with galvanic insulation.

RS-485 COMMUNICATION KIT
RS-485 → KRS-485

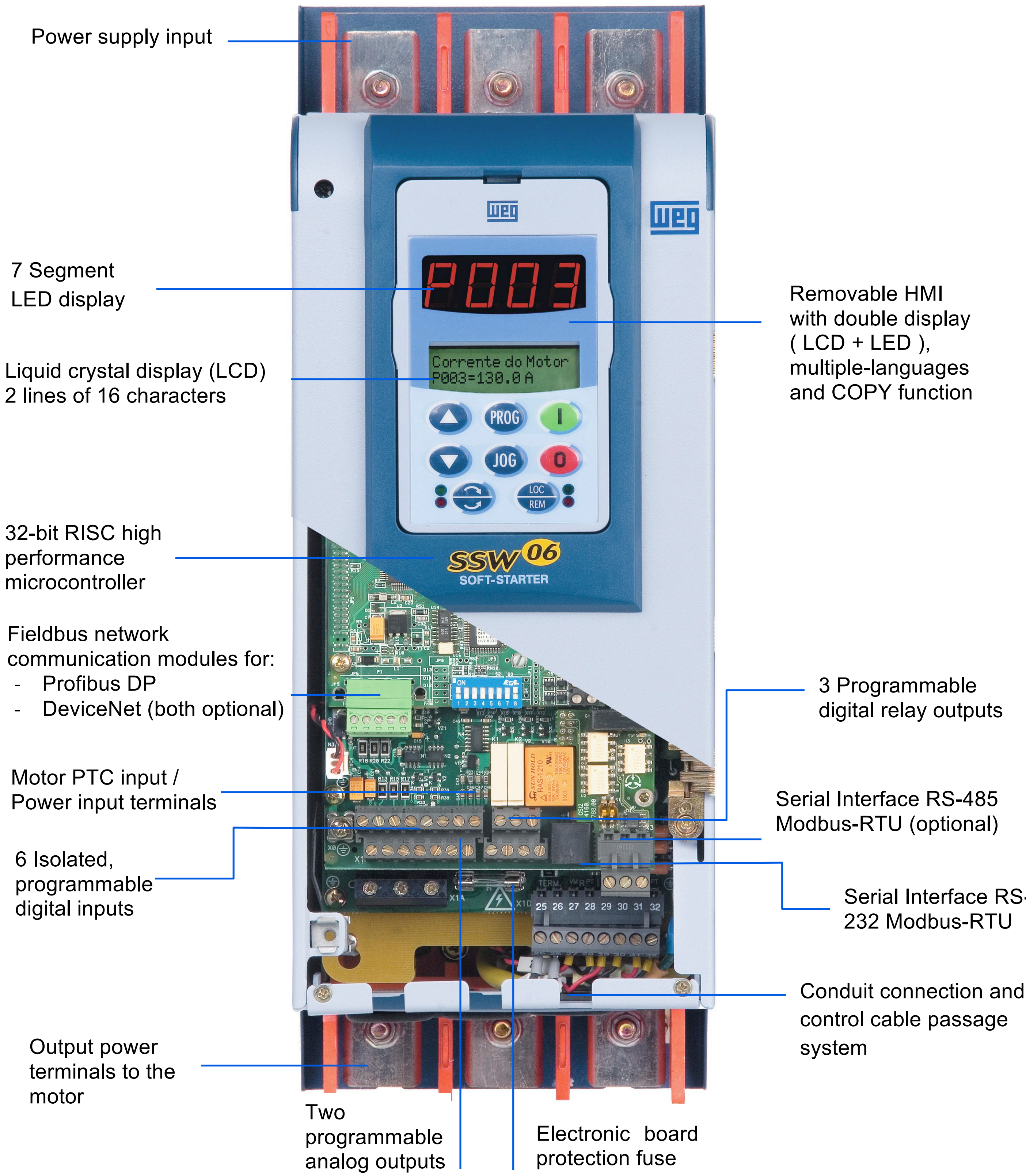
IP20 Kit

Protection of the power terminal blocks.

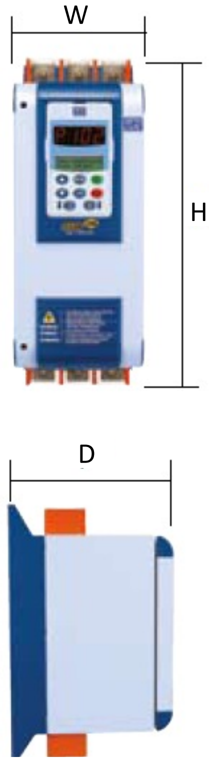
POWER TERMINAL PROTECTION KIT
(for models from 85A to 820A)

KIT IP20-M2 (85A to 130A)
KIT IP20-M3 (170A to 205A)
KIT IP20-M4 (255A to 36 5A)
KIT IP20-M5 (412A to 604A)
KIT IP20-M6 (670A to 820A)

SSW-06 - A flexible and compact product

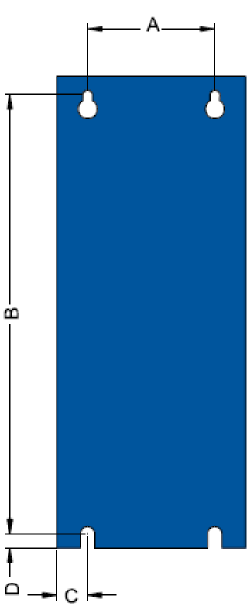


Dimensions and Weight



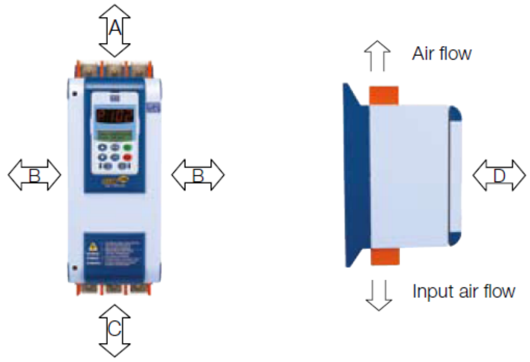
Model	Width "W" (mm)	Height "H" (mm)	Depth "D" (mm)	Weight (kg)	Frame Size
SSW-06.0010	130	256	182	3.3	1
SSW-06.0016					
SSW-06.0023					
SSW-06.0030					
SSW-06.0045	132	370	244	8.5	2
SSW-06.0060					
SSW-06.0085					
SSW-06.0130					
SSW-06.0170	223	440	278	18.6	3
SSW-06.0205					
SSW-06.0255	370	550	311	41.5	4
SSW-06.0312					
SSW-06.0365					
SSW-06.0412		650	347	55	5
SSW-06.0480					
SSW-06.0604					
SSW-06.0670	540	795	357	120	6
SSW-06.0820					
SSW-06.0950	568	895	345	107	7
SSW-06.1100	685	1235	433	217.5	8
SSW-06.1400					

Mounting



Model	A (mm)	B (mm)	C (mm)	D (mm)	Mounting Bolt	Frame Size
SSW-06.0010	75	239	28	8.5	M5	1
SSW-06.0016						
SSW-06.0023						
SSW-06.0030						
SSW-06.0045	75	350	28.5	8.5	M5	2
SSW-06.0060						
SSW-06.0085						
SSW-06.0130						
SSW-06.0170	150	425	36.5	5.9	M6	3
SSW-06.0205						
SSW-06.0255	200	527.5	85	10	M6	4
SSW-06.0312						
SSW-06.0365						
SSW-06.0412	200	627.5	85	10	M6	5
SSW-06.0480						
SSW-06.0604						
SSW-06.0670	350	775	95	7.5	M8	6
SSW-06.0820						
SSW-06.0950	400	810	84	10	M8	7
SSW-06.1100	500	1100	93	15	M8	8
SSW-06.1400						

Free Space for Ventilation



Model	A (mm)	B (mm)	C (mm)	D (mm)	Frame Size
SSW-06.0010 SSW-06.0016 SSW-06.0023 SSW-06.0030	150	30	150	50	1
SSW-06.0045 SSW-06.0060 SSW-06.0085 SSW-06.0130	150	30	150	50	2
SSW-06.0170 SSW-06.0205	150	30	150	50	3
SSW-06.0255 SSW-06.0312 SSW-06.0365	150	30	150	50	4
SSW-06.0412 SSW-06.0480 SSW-06.0604	150	30	150	150	5
SSW-06.0670 SSW-06.0820	150	30	150	50	6
SSW-06.0950	150	30	150	50	7
SSW-06.1100 SSW-06.1400	150	100	150	50	8

Technical Characteristics

POWER SUPPLY	Power	(220 to 575 Vac) (-15% to +10%) or (187 to 632 Vac)
	Control	(110 to 230 Vac) (-15% to +10%) or(94 to 253 Vac)
	Fan	Models from 255 to 820 A
		115 Vac (103.5 to 122) Vac / 230 Vac (207 to 253) Vac
		Model 950 A
		115 Vac (103,5 to 122) Vac / 230 Vac (207 to 243,8) Vac
		Models from 1100 to 1400 A
		230 Vac (207 to 243,8) Vac
	Frequency	50 to 60 Hz (+/- 10%), or 45 to 66 Hz
DEGREE OF PROTECTION	Metallic Cabinet	IP00
CONTROL	Control Method	Motor voltage variation on the load (Three phase induction motor)
	CPU	32-Bit RISC microcontroller
	Control Types	Voltage ramp
		Current limitation
		Current limitation ramp
		Pump control
		Torque control 1, 2 or 3 points
STARTING DUTY (3)	Standard connection	300% (3 x I rated) during 30 s for 3-cable connection
	Inside Delta	25 s for 6-cable connection
INPUTS	Digital	5 insulated programmable inputs 24 Vdc
		1 insulated programmable input 24 Vdc (for motor PTC)
OUTPUTS	Relay	3 programmable outputs 250 V / 2 A: (2 x NA) + (1 x NA + NC – Fault)
	Analog	1 Programmable output (10 bits) 0…10 Vdc
		1 programmable output (10 bits) 0...20 mA or 4...20 mA
SAFETY	Protections	Overvoltage
		Undervoltage
		Voltage imbalance
		Undercurrent
		Overcurrent
		Current imbalance
		Output overload (motor) – i^2t
		Overtemperature in thyristors / heat sink
		Overtemperature in motor / PTC
		Inverted Phase sequence
		External fault
		Open by-pass fault (1)
		Closed by-pass fault (1)
		Overcurrent in the by-pass (1)
		Undercurrent before by-pass (1)
		Power supply phase loss
		Output phase loss (motor)
		Thyristor fault
		CPU error (watch dog)
		Programming error
		Serial communication error
		Self-diagnosis error
		HMI-SSW06-LCD communication error
		Starting time exceeded
		Serial communication error
		Undervoltage in the control board
		Frequency out of range
		No grounding
		Incorrect motor connection
		Undertorque
		Overtorque
		Underpower
		Overpower
FUNCTIONS / FEATURES	Standard	Built-in (removable) human-machine interface with double display LED + LCD (HMI-SSW06-LCD)
		Programming access password
		HMI-SSW06-LCD language selection: Portuguese, English, Spanish and German
		Control type selection: Voltage ramp, current limitation, current limitation ramp, pump control and torque control
		Local/ Remote operation selection
		Fault self-check
		Oriented start-up according to the control type
		Standard or inside the motor delta connection
		All protections and functions available in both types of connection to the motor
		PUMP CONTROL function (protection against “water hammer” in pumps)
		COPY function (Soft-starter -> HMI or HMI -> soft-starter)
		Built-in by-pass for the models 10 to 820 A

		Serial interface RS-232 with built-in Modbus RTU. RS-485 optional.
		Input for motor PTC
		Fault self-check and auto-reset
		Reset to factory default programming or to user programming
		Special features: timer, Kilowattmeter
		Programmable over and undervoltage and voltage imbalance between phases
		Programmable over and undercurrent and current imbalance between phases
		Under and overcurrent before by-pass
		Programmable over and undertorque
		Programmable over and underpower
		Programmable rated power supply voltage
		Fully programmable voltage ramp
		Programmable current limitation
		Programmable current ramp
		Programmable pump control
		Fully flexible torque control
		Auto reset of the programmable thermal memory
		Programmable thermal class (motor overload) from class 5 to 45.
		Reversal of rotational direction
		JOG function in frequency for both rotation directions
		Reverse braking
		Optimal braking without contactor
		DC Braking
		Built-in SoftPLC
	Options/Accessories	Frame for remote HMI
		Cable interconnecting Soft-Starter with remote HMI 1, 2, 3 and 5 m
		RS-485 communication kit
		Profibus-DP and Profibus-DPV1 communication kit
		Acyclic DeviceNet communication kit
		IP20 kit for models from 85 up to 365 A
HUMAN MACHINE INTERFACE (HMI-SSSW06-LCD)	Control	On, Off / Reset and Parameter setting (main function programming)
	Supervision (Reading)	Scroll up and down parameters or their contents
		Motor current (% In of the Soft-starter)
		Motor current (% In of the motor)
		Motor current (A)
		Power supply frequency (0…99.9 Hz)
		Power supply voltage (0…999 V)
		Output voltage (0…999 V)
		Motor torque (% In of the motor)
		Load active power – (kW)
		Load apparent power – (kVA)
		Soft-starter status
		Status of digital and analog inputs and outputs
		Load Cos φ (0.00 … 0.99)
		Power on hours
		Enabled hours
		Energy consumption in kWh
		Analog output value
		SoftPLC status
		Last six error code back-up with voltage, current and status diagnosis
		Soft-starter software version
		Motor thermal protection – (0 … 250)
		Current indication in each phase R-S-T
		Voltage indication of R-S / S-T / T-R power supply
		Fieldbus communication card status
		Starting diagnosis
		Full load operation diagnosis
AMBIENT CONDITIONS	Temperature	0 to 55°C (models from 85 to 820 A) without rated current reduction
		0 to 40°C (models from 950 to 1400 A) without rated current reduction
	Humidity	20...90 %, w/o condensation
	Altitude	0... 1000 m: standard operation at rated current
		1000... 4000 m; with output current reduction of 1% / 100 m, over 1000 m
FINISHING	Color	Cover: ultra mat gray
		Cabinet: ultra mat blue
CONFORMITY / NORMS	Safety	UL 508 Standard – Industrial control equipment (2)
	Low Voltage	EN 60947-4-2 Standard; LVD 2006/95/EC – Low voltage directive
	EMC	EMC directive 89 / 336 / EEC – Industrial environment
	UL (USA) / cUL (Canada)	Underwriters Laboratories Inc. – USA (2)
	CE (Europe)	Certified by EPCOS
	IRAM (Argentina)	Instituto Argentino de Normalización (2)
	C-Tick (Australia)	Australian Communications Authority
	Gost	(Russia)

Notes: (1) Models from 10A to 820A
(2) Starting duty: 10 starts / hour for models from 10A to 820A
5 starts / hour for models from 950A to 1400A

Specification Table

SSW-06 SOFT-STARTER			MAXIMUM APPLICABLE MOTOR				Frame Size
Model (command: 94-253V) (fan: 110/220)(2)(3)	I_{rated} (A) Ta = 0 … 55°C(4)	Voltage (V)	Standard Connection (3 cables) Ta = 0 … 55°C(4)		Inside Delta Connection (6 cables) Ta = 0 … 55°C(4)		
			HP	kW	HP	kW	
SSW-06-0010 T 2257 PSZ	10	220	3	2.2	-	-	1
SSW-06-0016 T 2257 PSZ	16		5	3.7	-	-	
SSW-06-0023 T 2257 PSZ	23		7.5	5.5	-	-	
SSW-06-0030 T 2257 PSZ	30		10	7.5	-	-	
SSW-06-0045 T 2257 PSZ	45		15	11	25	18.5	2
SSW-06-0060 T 2257 PSZ	60		20	15	30	22	
SSW-06-0085 T 2257 PSZ	85		30	22	60	45	
SSW-06-0130 T 2257 PSZ	130		50	37	75	55	
SSW-06-0170 T 2257 PSZ	170		60	45	125	90	3
SSW-06-0205 T 2257 PSZ	205		75	55	150	110	
SSW-06-0255 T 2257 PSZ	255		100	75	175	130	4
SSW-06-0312 T 2257 PSZ	312		125	90	200	150	
SSW-06-0365 T 2257 PSZ	365		150	110	250	185	
SSW-06-0412 T 2257 PSZ	412		150	110	250	185	5
SSW-06-0480 T 2257 PSZ	480		200	150	350	260	
SSW-06-0604 T 2257 PSZ	604		250	185	450	330	
SSW-06-0670 T 2257 PSZ	670		250	185	500	370	6
SSW-06-0820 T 2257 PSZ	820		350	260	600	450	
SSW-06-0950 T 2257 PSZ	950		400	300	700	520	7
SSW-06-1100 T 2257 PSZ	1100		450	330	800	600	8
SSW-06-1400 T 2257 PSZ	1400		550	410	1050	775	

Specification Table

SSW-06 SOFT-STARTER			MAXIMUM APPLICABLE MOTOR				Frame Size
Model (command: 94-253V) (fan: 110/220)(2)(3)	I_{rated} (A) Ta = 0 … 55°C(4)	Voltage (V)	Standard Connection (3 cables) Ta = 0 … 55°C(4)		Inside Delta Connection (6 cables) Ta = 0 … 55°C(4)		
			HP	kW	HP	kW	
SSW-06-0010 T 2257 PSZ	10	440	5	7.7	-	-	1
SSW-06-0016 T 2257 PSZ	16		10	7.5	-	-	
SSW-06-0023 T 2257 PSZ	23		15	11	-	-	
SSW-06-0030 T 2257 PSZ	30		20	15	-	-	
SSW-06-0045 T 2257 PSZ	45		30	22	75	55	2
SSW-06-0060 T 2257 PSZ	60		40	30	100	75	
SSW-06-0085 T 2257 PSZ	85		60	45	125	90	
SSW-06-0130 T 2257 PSZ	130		100	75	175	130	
SSW-06-0170 T 2257 PSZ	170		125	90	200	150	3
SSW-06-0205 T 2257 PSZ	205		150	110	300	220	
SSW-06-0255 T 2257 PSZ	255		200	150	350	260	4
SSW-06-0312 T 2257 PSZ	312		250	185	450	330	
SSW-06-0365 T 2257 PSZ	365		300	220	500	370	
SSW-06-0412 T 2257 PSZ	412		350	260	600	450	5
SSW-06-0480 T 2257 PSZ	480		400	300	700	520	
SSW-06-0604 T 2257 PSZ	604		500	370	850	630	
SSW-06-0670 T 2257 PSZ	670		550	410	950	700	6
SSW-06-0820 T 2257 PSZ	820		700	520	1200	900	7

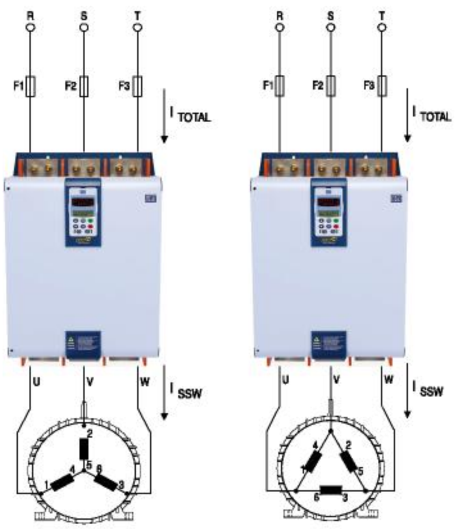
SSW-06-0950 T 2257 PSZ	950		800	600	1400	1030	
SSW-06-1100 T 2257 PSZ	1100		900	670	1600	1175	8
SSW-06-1400 T 2257 PSZ	1400		1200	900	2000	1475	

NOTES:
1) The maximum motor powers, in the table above, were calculated based on WEG 2 and 4 pole motors.
For motors with other poles (Ex.: 6 or 8 poles), other voltages (Ex.: 230, 400 or 460 V) and/or other manufacturers, base the Soft-Starter specification on the rated motor current.
2) In the 950 A model, the fan voltage must be specified as 110 or 220 Vac.
3) In 1100A and 1400A models, the only fan voltage is 220 Vac.
4) Ambient temperature (Ta) = 0… 55°C is only valid for 10A to 820A models; for 950A, 1100A and 1400A models, Ta= 0… 40°C (w/o rated current reduction)

Types of Connections from the Soft-Starter to the Motor

Standard (3 cables)

Motor in Y



$I_{Soft\text{-}Starter} = I_{Full\ Current}$

Inside the motor delta (6 cables)

Motor in Δ Soft-starter inside the motor delta

$I_{Soft-Starter} = \frac{I_{Full\ Current}}{\sqrt{3}}$	= 58% $I_{Full\ Current}$ (After starting)
$I_{Soft-Starter} = \frac{I_{Full\ Current}}{1.5}$	= 67% $I_{Full\ Current}$ (During Starting)

IMPORTANT:
- In the standard connection (3 cables) the motor can be connected either star (Y) or delta (Δ).
- In the inside the motor delta connection (6 cables), the motor can only be connected in delta. The table below shows the available voltages for standard motor types:

MOTOR	6 CABLE CONNECTION
220V – Δ / 380V – Y	220V – Δ
380V – Δ / 660V – Y	380V – Δ
440V – Δ / 760V – Y	440V – Δ
575V – Δ	575V – Δ
220V – Δ / 380V – Y/ 440V – Δ / 760V – Y	220V – Δ 440V – Δ

- For the same motor power, the inside the motor delta connection (6 cables) provides a reduction of 42% in the Soft- Starter current, when compared to the standard connection (3 cables).
- The inside the motor delta connection (6 cables) makes it possible to start a motor with a power 73% greater than in the standard connection (3 cables).
- The inside the motor delta connection requires 6 cables to the motor.
- During the start, the motor current can be 1.5 times greater than that of the Soft-Starter.
- After the start, at full voltage, the motor current can be up to 1.73 times greater than that of the Soft-Starter.

Part Number Specification

SSW06	0085	T	2257	P	O	--	SI	--	--	Z
1	2	3	4	5	6	7	8	9	10	11

1 - Soft-Starter line SSW-06

2 - Rated output current:

0010 = 10 A	0312 = 312 A
0016 = 16 A	0365 = 365 A
0023 = 23 A	0412 = 412 A
0030 = 30 A	0480 = 480 A
0045 = 45 A	0604 = 604 A
0060 = 60 A	0670 = 670 A
0085 = 85 A	0820 = 820 A
0130 = 130 A	0950 = 950 A
0170 = 170 A	1100 = 1100 A
0205 = 205 A	1400 = 1400 A
0255 = 255 A	

3 - Input power supply voltage: T= Three-phase

4 - Power supply voltage: 2257 = range 220 … 575 V

5 - Product manual language:
P = Portuguese
E = English
S = Spanish

6 - Product version:
S = Standard
O = with Options

7 – Degree of protection: Blank = Standard (see table of characteristics)

8 – Human Machine Interface (HMI):
Blank = Standard (with LED + LCD HMI)
SI = w/o HMI

9 - Special hardware:
Blank = Standard
H1 = Ventilation 115V (950 A model)
Ex.: SSW06 0085 T 2257 P S Z
H2 = Ventilation 230V (950 A to 1400 A models)
Ex.: SSW06 0950 T 2257 P S H1 Z

10 - Special software:
Blank = Standard
S1 = Optional with special software version

11 - Code end:
Blank = Standard
Z = Digit indicating code end

NOTE:
1 - Communication kits are optional.
2 – In models 950A to 1400A, the ventilation voltage must be defined (H1 or H2)

SSW-07

Soft-Starter

- Easy operation
- High efficiency
- Built-in by-pass
- Built-in protections
- Heavy duty
- Full control in all three phases

SSW-07

Soft Starters are static starting switches, designed to accelerate, decelerate and protect three-phase, electric induction motors by controlling the voltage applied to the motor.

The SSW-07, with DSP control (Digital Signal Processor), was designed to provide excellent performance in motor starts and stops, with an excellent cost / benefit ratio.

With easy set up, it simplifies start-up activities and daily operations.

The SSW-07 is compact, optimizing space in electric panels and already incorporates all electric motor protections.

It adapts to customer needs through its plug and play optional accessories, such as, HMI, communication interface or motor PTC input.

Benefits

- Significant reduction of mechanical stresses on the coupling and transmission devices (gearboxes, pulleys, gears, conveyors, etc) during the start.
- Increased lifetime of motor and mechanical equipment of the driven machine due to the reduction in mechanical stress.
- Easy operation, setup and maintenance.
- Simple electrical installation.
- Operation in environments up to 55°C (w/o current reduction for all models).
- Built-in electronic motor protection.
- Built-in electronic thermal relay.
- “Kick-Start” function for starting loads with high breakaway torques.
- Reduction of “Water Hammer” in pump applications.
- Voltage drop limitation during start.
- Universal voltage (220 to 575 Vac).
- Switched mode power supply with EMC filter for the control board (110 to 240 Vac).
- Built-in by-pass providing size reduction and energy saving (17 to 200 A).
- Voltage monitoring of control board, permitting a back-up of I x t values (thermal image).

Applications

Chemical and Petrochemical
Fans / Exhausts
Centrifugal Pumps
Dosing / Process Pumps
Stirrers / Mixers
Compressors
Soap Extruders

Plastic and Rubber
Extruders
Injectors / Blowers
Mixers
Calenders / Pullers
Granulators

Pulp and Paper
Dosing Pumps
Process Pumps
Fans / Exhausts
Stirrers / Mixers
Rotating Filters
Rotating Ovens
Wood Chip Conveyors
Roller Table
Calenders / Coaters
Paper Refineries

Sugar and Alcohol
Fans / Exhausts
Process Pumps
Conveyors

Beverages
Stirrers / Mixers
Roller Tables
Conveyors
Bottling Lines

Cement and Mining
Dosing / Process Pumps
Sifters / Vibrating Tables
Dynamic Separators

Food
Dosing / Process Pumps
Fan / Exhausts
Stirrers / Mixers
Driers / Continuous Ovens
Pelletizers
Conveyors / Monorails

Textile
Stirrers / Mixers
Driers / Washing Machines

Siderurgy and Metallurgy
Fans / Exhausts
Conveyors
Drills / Grinders
Wire Drawing
Pumps

Ceramics
Fans / Exhausts
Driers / Continuous Ovens
Ball / Hammer Mills
Roller Tables
Conveyors

Glass
Fans / Exhausts
Bottle Manufacturing Machine
Roller Tables
Conveyors

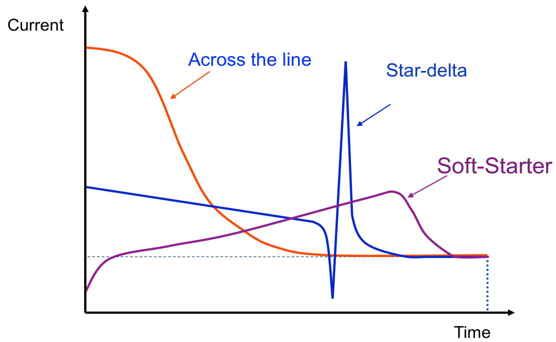
Refrigeration
Process Pumps
Fans / Exhausts
Air Conditioning Systems
Screw / Piston Compressors

Wood
Sanding Machines
Cutters
Wood Chippers
Saws / Plains

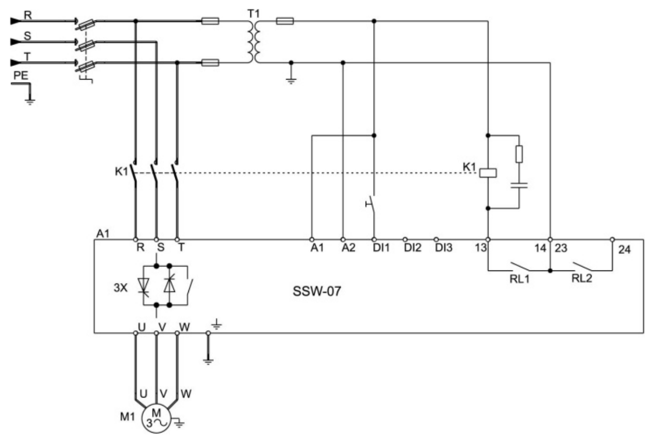
Sanitation
Centrifugal Pumps

Load Transportation
Conveyors / Belts / Chains
Roller Tables
Monorails
Escalators
Baggage Conveyors (Airports)

Starting Method Comparison



Typical Starter Connection Diagram



Settings

Three phase power supply

Setting trimpots

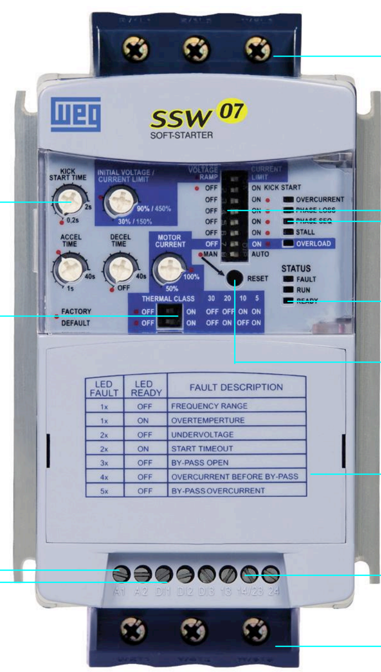
DIP switches to set and enable the protections and modes

SSW07 Status indication LEDs

DIP switch for thermal class setting

Reset

Cover for optional plug ins



Electronic power supply (A1 and A2)

Relay Output

Start/Stop motor (DI1) and Reset (DI2 and DI3)

Output / motor connection

SSW-07 Soft-Starters may be interconnected to Fieldbus fast communication networks through Modbus RTU, DeviceNet and PROFIBUS DP protocols.

Mainly intended to integrate to large industrial automation systems in plants, the communication networks offer many advantages in Soft-Starter supervision, monitoring and control, on-line and off-line. The result of this is high performance and great operational flexibility, characteristics required in complex and/or integrated systems.

For communication network interconnection, SSW-07 Soft-Starters offer plug-in accessories in the front part of the product. Optional modules (RS-232 or RS-485) are available for the DeviceNet and Modbus RTU protocols.

Human-Machine Interface (HMI)

The HMI with 7 segment LED display provides excellent long distance visibility.
The HMI has a built-in Copy function, which allows parameters to be copied from one soft-starter to another, permitting fast and reliable set-up of identical starters.

Local

Plug-in type HMI in the front of the product.

SSW-07 local HMI

Remote

Remote HMI for mounting on panel door or machine console.

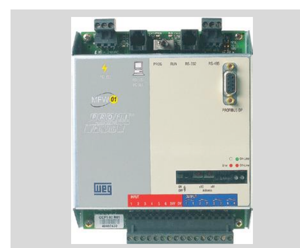
SSW-07 remote HMI
Cable for connecting HMI to SSW-07.
Cable lengths: 1, 2, 3, 5, 7.5 and 10 m.

Superdrive G2

Software in Windows platform for SSW-07 parameter setting, control and monitoring.

- Automatically identifies the SSW-07
- Reads SSW-07 parameters.
- Writes parameters in the SSW-07.
- Edits parameters on-line in the SSW-07
- Edits parameters off-line in the PC.
- Enables the creation of all application documentation.
- Trace function captures Soft-Starter information and presents them in graph format.
- Easily accessible.
- Enables parameter setting, control and monitoring of the SSW-07 via Superdrive G2 software.
- Supplied with a 3m RS-232 serial cable and RS-232 module, with purchase of the Superdrive G2 software.
- Free software available at the site *www.weg.net*

Accessories and Options



Modbus RTU – RS – 232
Optional Plug-in type module for Modbus RTU communication in RS-232.

Modbus RTU – RS – 485
Optional Plug-in type module for Modbus RTU communication in RS-485.

Communication Modules
DeviceNet
Optional Plug-in type module for DeviceNet communication with acyclic access.

IP20 Kit

For models from 130 A to 200 A, this kit guarantees protection against contact with energized parts.

Cable

For RS-232 connection
Cable length: 3 and 10m.

Motor PTC

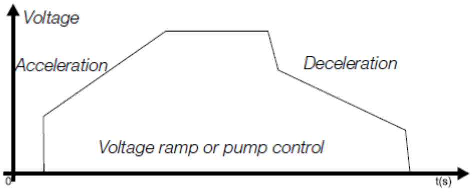
Optional module for motor PTC connection.

Ventilation Kit

For models from 45 A to 200 A. The ventilation kit is necessary for heavy duty starting cycles.

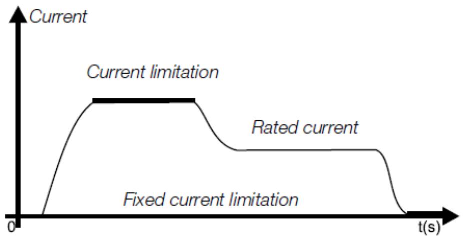
Programming Features

All programming necessary for starting any type of load is available through trimpots and dip-switches.



Voltage ramp

Provides smooth acceleration and/or deceleration, through voltage ramps.

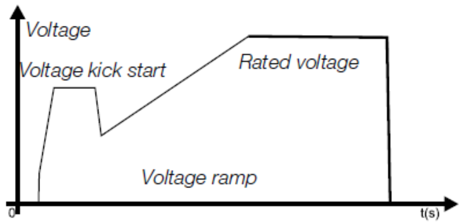


Current limit

Permits setting current limits during acceleration, according to application needs.

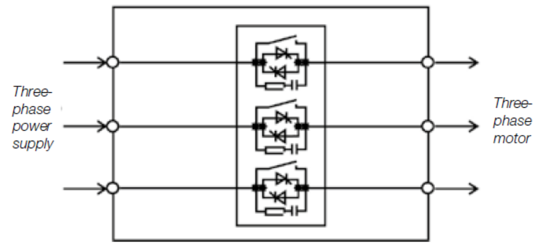
Voltage Kick Start

Enables an initial voltage pulse which provides an increase in the initial starting torque of the motor. This is required to start loads with high breakaway torques.



Built-In By-Pass

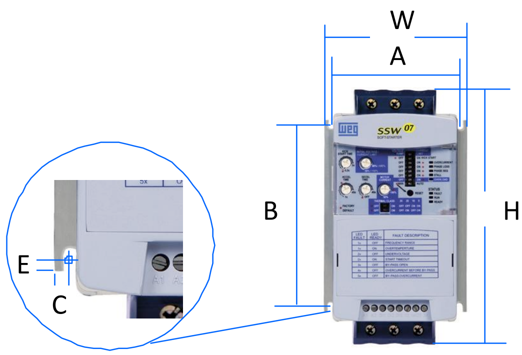
Built-in by-pass minimizes power losses and heat dissipation in the thyristors, providing size reduction and energy savings. Available in all models.



Dimensions and Weight

Model SSW-07	Height "H" mm (In)	Width "W" mm (In)	Depth "D" mm (In)	A mm (In)	B mm (In)	C mm (In)	E mm (In)	Mounting Bolt	Weight kg (lb)	Degree of Protection
SSW-070017 SSW-070024 SSW-070030	162 (6.38)	95 (3.74)	157 (6.18)	85 (3.35)	120 (4.72)	5 (0.20)	4 (0.16)	M4	1.3 (2.9)	IP20
SSW-070045 SSW-070061 SSW-070085	208 (8.19)	144 (5.67)	203 (7.99)	132 (5.2)	148 (5.83)	6 (0.24)	3.4 (0.13)	M4	3.3 (7.28)	IP20
SSW-070130 SSW-070171 SSW-070200	276 (10.9)	223 (8.78)	220 (8.66)	208 (8.19)	210 (8.27)	7.5 (0.3)	5 (0.2)	M5	7.6 (16.8)	IP00*

Table 3.1 Installation data in mm (In)
* IP20 with optional kit



Technical Characteristics

POWER SUPPLY	Power	220 to 575 Vac
	Control	110 to 230 Vac (-15% to +10%) or 94 to 264 Vac
	Frequency	50 to 60 Hz (+/- 10%), or 45 to 66 Hz
DEGREE OF PROTECTION	Injected Plastic	IP20 in models 17 to 85A
		IP00 in models 130 to 200 A (IP20 optional)
CONTROL	Control Method	Voltage variation on the load (three phase induction motor)
	CPU	DSP type microcontroller (Digital Signal Processor)
	Control Types	Voltage ramp
		Current limitation
STARTING DUTY (1)	Standard connection	300% (3 x I rated) during 30 s, 10 starts / hour (every 6 minutes)
INPUTS	Digital	3 insulated programmable inputs
OUTPUTS	Relay	2 relays with NA contacts, 240 Vac, 1A, programmable functions
SAFETY	Protections (Standard)	Overcurrent;
		Overcurrent before by-pass
		Phase loss;
		Inverted phase sequence
		Overtemperature in power heat sink
		Motor Overload (class 5 to 30)
		Locked Rotor
		Excess starting time
		Over/Under Frequency
		By-pass contact open
		Undervoltage in control supply
		Programming error
		Serial communication error
		HMI communication error
		Undervoltage in control power supply
	Protections (with accessories)	Undercurrent
		Current imbalance
		Overcurrent before By-pass
		External defects
		Programming error
		Serial communication error
		HMI communication error
		Overtemperature in motor PTC
FUNCTIONS / FEATURES	Standard	Voltage ramp (Initial voltage: 30% to 90%)
		Current limitation (150% to 450% of SSW-07 rated current)
		Starting time (1 to 40s)
		Kick Start (Off - 0,2 to 2s)
		Deceleration ramp (0 to 40s)
		Motor and SSW-07 current ratio (50% to 100%)
		Fault auto-reset
		Thermal memory auto-reset
		Factory standard reset
		By-pass built-into Soft-Starter
PROGRAMMING ACCEWSSORIES (HMI or SERIAL COMMUNICATION)	Control	On, Off / Reset and Parameter setting (function programming)
	Additional Functions / Features	Starting time up to 999s
		Deceleration time up to 999s
		Program enabling password
		Local / Remote operation selection
		COPY function (SSW-07 >>> HMI and HMI >>> SSW-07)
	Supervision (Reading)	Motor current (% Soft-Starter In)
		Motor current (% motor In)
		Motor current (A)
		Current indication in each phase R-S-T
		Power supply frequency
		Apparent power supplied to load (kVA)
		Soft-Starter status
		Digital input and output status
		Back up of last 4 errors
		Soft-Starter software version
		Heat sink temperature

		Motor thermal protection status
	Options	Plug-in type local HMI
		Remote HMI Kit
		Remote HMI interconnection cable (1, 2, 3, 5, 7.5 and 10 m)
		RS-232 Communication kit
		Interconnection cables for SSW-07 >>> PC Serial (RS-232); 3 and 10m
		RS-485 Communication kit
		Motor PTC kit
		DeviceNet communication kit
		Superdrive G2 kit
		Ventilation kit for frame size 2 (45 to 85 A)
		Ventilation kit for frame size 3 (130 to 200 A)
		IP20 kit for frame size 3 (130 to 200 A)
FINISHING	Color	Cover: ultra mat gray
		Cabinet: ultra mat blue
CONFORMITY / NORMS	Safety	UL 508 Standard – Industrial control equipment (2)
	Low Voltage	EN 60947-4-2 Standard; LVD 2006/95/EC – Low voltage directive
	EMC	EMC directive 89 / 336 / EEC – Industrial environment
	UL (USA) / cUL (Canada)	Underwriters Laboratories Inc. – USA (2)
	CE (Europe)	Certified by EPCOS
	C-Tick (Australia)	Australian Communications Authority
	Gost	(Russia)

(1) To withstand this cycle, models 45 to 200A must be fitted with a ventilation kit.

Part Number Specification

BR	SSW07	0017	T	5	S	--	--	--	Z
1	2	3	4	5	6	7	8	9	10

1 – Market / Manual: BR = Brazil
EX = Export

2 – WEG Soft-Starter line SSW-07

3 - Rated output current:

4 - Input power supply voltage: T= Three-phase

5 - Power supply voltage: 5 = range of 220 to 575 V

6 - Product version: S = Standard
O = with Options

7 – Degree of protection: Blank = Standard
IP = IP20 for models of 130 A to 200 A

8 - Special hardware: Blank = Standard

9 - Special software: Blank = Standard

10 - Code end: Z = Digit indicating code end

Specification Table

Model	SSW-07 Rated current	Voltage	Power	
SSW-07	(A)	(V)	(HP)	(kW)
SSW-070017	17	220	6	4.5
SSW-070024	24		7.5	5.5
SSW-070030	30		10	7.5
SSW-070045	45		15	11
SSW-070061	61		20	15
SSW-070085	85		30	22
SSW-070130	130		50	37
SSW-070171	171		60	45
SSW-070200	200		75	55
SSW-070017	17	380	10	7.5
SSW-070024	24		15	11
SSW-070030	30		15	11
SSW-070045	45		30	22
SSW-070061	61		40	30
SSW-070085	85		60	40
SSW-070130	130		75	56
SSW-070171	171		125	90
SSW-070200	200		125	90

Model	SSW-07 Rated current	Voltage	Power	
SSW-07	(A)	(V)	(HP)	(kW)
SSW-070017	17	440	12.5	9.2
SSW-070024	24		15	11
SSW-070030	30		20	15
SSW-070045	45		60	22
SSW-070061	61		50	37
SSW-070085	85		60	45
SSW-070130	130		100	75
SSW-070171	171		125	90
SSW-070200	200		150	110
SSW-070017	17	575	15	11
SSW-070024	24		20	15
SSW-070030	30		30	22
SSW-070045	45		40	30
SSW-070061	61		60	45
SSW-070085	85		75	55
SSW-070130	130		125	90
SSW-070171	171		175	132
SSW-070200	200		200	150

NOTES: The maximum motor power ratings above were calculated based on WEG 4 pole, IP55, standard motor at 55^{o}C ambient temperature.

SSW-08

Soft-Starter

SSW-08 Soft-Starter

- Used with light loads like:
  Centrifugal pumps;
  Small fans;

- Built in by-pass provides energy savings.

- Universal voltage:
  Control: 901-265 Vac, 94-264 Vac
  Power: 220-575 Vac

- Modern design, with extremely reduced size and weight, optimizing space in electric panels.

- Plug-and-play philosophy. SSW-08 automatically recognizes and configures optional accessories.

- Operates in environments up to 55°C without derating.

- Starting Duty:
  5 starts/hour with current limitation of
  3 x In, during 20s w/o ventilation kit.
  10 starts/hour with current limitation of
  3 x In, during 20s with ventilation kit.

Specifications

Model	SSW-08 Rated Current	Voltage	Power	
		(V)	(HP)	(kW)
SSW-080130	130		50	37
SSW-080171	171	220	60	45
SSW-080200	200		75	55
SSW-080130	130		75	55
SSW-080171	171	380	125	90
SSW-080200	200		125	90
SSW-080130	130		100	75
SSW-080171	171	440	125	90
SSW-080200	200		150	110

SSW-08 comes with the same accessories as the SSW-07 line.
Power of 50 to 220 HP and voltage of 220 to 575 V.
High starting curve.
Built-in motor, switching and by-pass protection.

8 ANNEX 1 – MASS MOMENT OF INERTIA CALCULATION

8.1 MOMENT OF INERTIA OF SIMPLE SHAPES

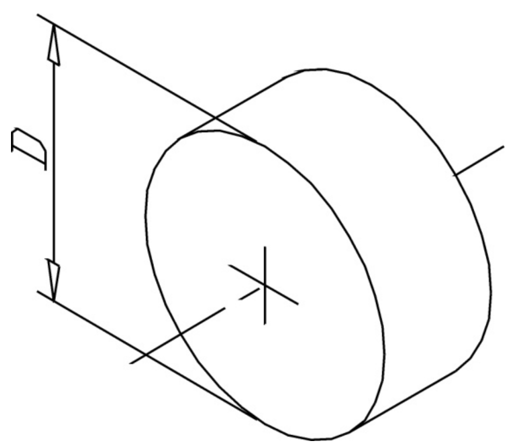
Listed below are the equations used to calculate the *mass moment of inertia* ***J*** [kgm^2] of simple geometric shapes, in relation to their barycentric axle, that is, the axle that runs through their center of gravity. All the units must be from the International System (SI).

The following symbols will be used in the equations:

m - mass [kg]
ρ - specific mass [kg/m3]
D - external diameter [m]
d - internal diameter [m]
D_b - diameter of the base [m]
l - length [m]
a, b - sides [m]

a) Solid disk or cylinder

The mass moment of inertia of a disk, or a solid cylinder, referred to its longitudinal shaft is:

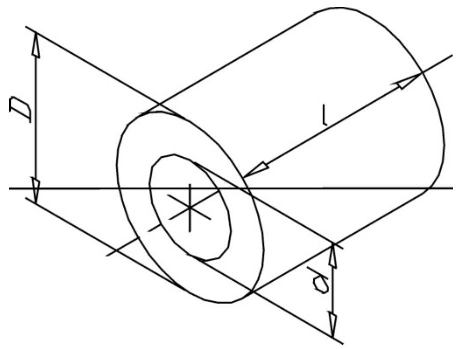


$$J = 1/8 * m * D^2 \ [kgm^2] \quad (A1.1)$$

or

$$J = \pi/32 * \rho * D^4 * l \ [kgm^2] \quad (A1.2)$$

b) Hollow cylinder

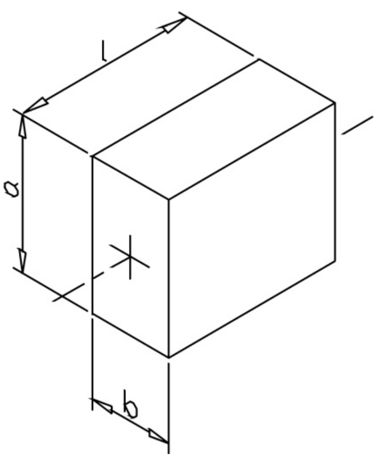


$J = 1/8 * m * (D^2 + d^2)$ [kgm²] (A1.3)

or

$J = \pi/32 * \rho * (D^4 - d^4) * l$ [kgm²] (A1.4)

c) Rectangular Prism

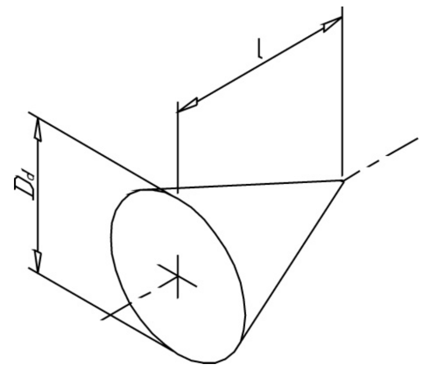


$J = 1/12 * m * (a^2 + b^2)$ [kgm²] (A1.5)

or

$J = 1/12 * \rho * (a^3 b + ab^3) * l$ [kgm²] (A1.6)

d) Solid Cone



$J = 3/40 * m * D_b^2$ [kgm²] (A1.7)

or

$J = \pi/160 * \rho * D_b^4 * l$ [kgm²] (A1.8)

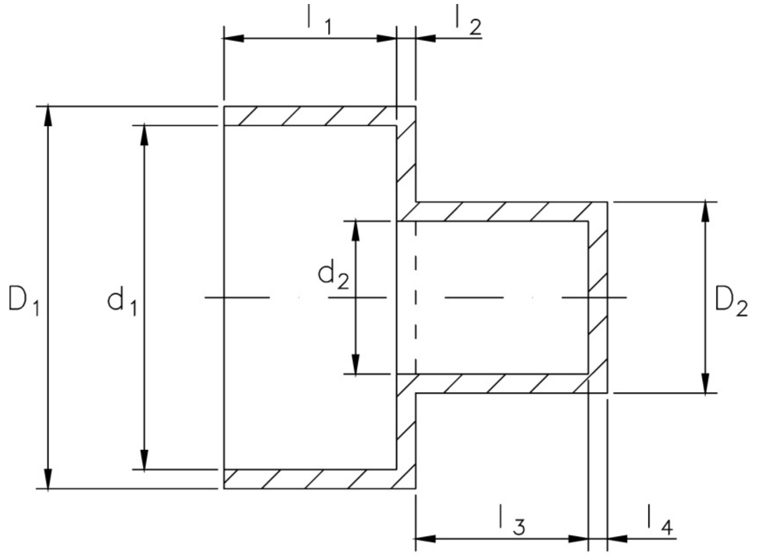
8.1.1 Parallel Axle Theorem

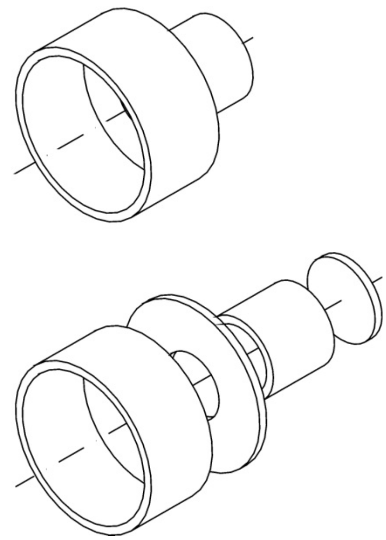
The mass moment of inertia ***J'*** [kgm^2] of a body in relation to an axle parallel to its barycentric axle is given by:

$J' = J + m * e^2$ (A1.9)

with:
e – distance between the axles [m], and
J – mass moment of inertia in relation to the barycentric axle

8.2 MOMENT OF INERTIA OF COMPOUND SHAPES





Example:

$$J_1 = 1/8 * m_1 * (D_1^2 + d_1^2)\ [kgm^2]$$

$$J_2 = 1/8 * m_2 * (D_1^2 + d_2^2)\ [kgm^2]$$

$$J_3 = 1/8 * m_3 * (D_2^2 + d_2^2)\ [kgm^2]$$

$$J_4 = 1/8 * m_4 * D_2^2\ [kgm^2]$$

or

$$J_1 = (\pi * \rho) / 32 * (D_1^4 - d_1^4) * l_1$$

$$J_2 = (\pi * \rho) / 32 * (D_1^4 - d_2^4) * l_2$$

$$J_3 = (\pi * \rho) / 32 * (D_2^4 - d_2^4) * l_3$$

$$J_4 = (\pi * \rho) / 32 * D_2^4 * l_4$$

$$J = J_1 + J_2 + J_3 + J_4\ [kgm^2]$$

where: m_1 – mass of each primitive i of the part [kg]

D_1, D_2 – external diameters [m]

d_1, d_2 – internal diameters [m]

l_i – length of each primitive i of the part [m]

8.3 MOMENT OF INERTIA OF LINEARLY MOVING BODIES

The mass moment of inertia **m** [kg] of a body that moves linearly is reflected in its driving axle in the following way:

8.3.1 Driving by movement screw (fuse)

$J = m * (p / 2\pi)^2$ [kgm^2] (A1.10)

where:

p – fuse step [m]

8.3.2 Driving by pinion/trammel, cable or roll/belt

$J = m * r^2$ [kgm^2] (A1.11)

where:

r – primitive radius of the pinion, or external radius of the roll [m]

8.4 MECHANICAL TRANSMISSION

The mass moment of inertia is reflected from the output shaft (2) to the input shaft (1) of a transmission, according to the following equation:

$J_1 = J_2 / i^2$ (A1.12)

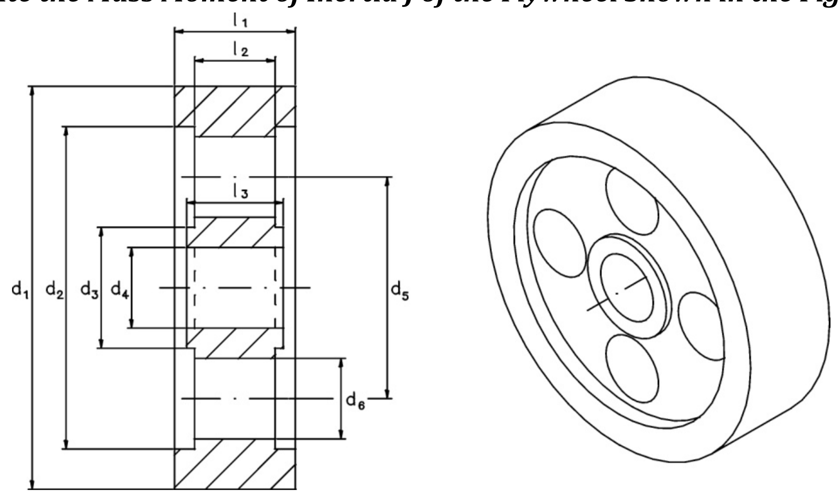
where:

J_2 – moment of inertia [kgm^2] in the output shaft (2), with rotation n_2 [rpm]
J_1 – moment of inertia [kgm^2] in the input shaft (1), with rotation n_1 [rpm]
i – transmission ratio ($i = n_1 / n_2$)

8.5 CALCULATION EXAMPLES OF MASS MOMENT OF INERTIA

8.5.1 Calculation Example 1

8.5.1.1 Calculate the Mass Moment of Inertia J of the Flywheel Shown in the Figure Below.



a) Moment of inertia of a solid flywheel

$J_1 = (\pi * \rho) / 32 * d_1^4 * l_1$

b) Moment of inertia of the side gaps (negative)

$J_2 = (\pi * \rho) / 32 * d_2^4 * (l_1 - l_2)$

c) Moment of inertia of the side spaces of the cube (positive)

$J_3 = (\pi * \rho) / 32 * d_3^4 * (l_3 - l_2)$

d) Moment of inertia of the cube hole (negative)

$J_4 = (\pi * \rho) / 32 * d_4^4 * l_3$

e) Moment of inertia of a hole in the core

$J_5 = (\pi * \rho) / 32 * d_5^4 * l_2$

f) Transposition of e) to the barycentric shaft of the flywheel

$J'_5 = [(\pi * \rho) / 32 * d_5^4 * l_2] = [(\pi * \rho) / 16 * d_5^2 * d_6^2 * l_2]$

$J'_5 = (\pi * \rho) / 32 * d_5^2 * l_2 * (d_5^2 + d_6^2)$

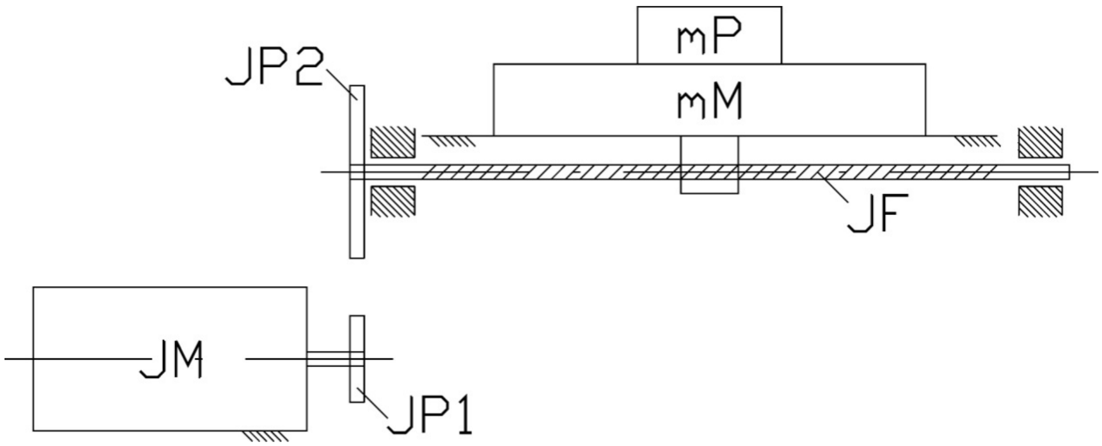
g) Mass moment of inertia of a flywheel

$J = J_1 - J_2 + J_3 - J_4 - (4 * J'_5)$

$$J = (\pi * \rho) / 32 * \{d_1^4 * l_1 - d_2^4 * (l_1 - l_2) + d_3^4 * (l_3 - l_2) - d_4^4 * l_3 - 4 * [d_5^2 * l_2 * (d_5^4 + 2 * d_6^2)]\}$$

8.5.2 Calculation Example 2

8.5.2.1 For the system shown in the diagram below, calculate the total moment of inertia referred to the motor shaft.



where:

J_M – mass moment of inertia of the motor rotor [kgm^2]
J_{P1} - mass moment of inertia of the moving pulley P_1 [kgm^2]
J_{P2} - mass moment of inertia of the moving pulley P_2 [kgm^2]
I – transmission ratio
J_F - mass moment of inertia of the recirculating sphere fuse [kgm^2]
p_F –thread step of the recirculating sphere fuse [m]
m_M – moving mass of the machine table [kg]
m_P – mass of the part [kg]

Therefore:
$J_{Tot} = J_M + J_{P1} + (1/I^2) * [J_{P2} + J_F + (p_F / 2\pi)^2 * (m_M + m_P)]$

9 ANNEX 2 – WEG SIZING SOFTWARE - SDW

9.1 INTRODUCTION

The objective of this software is to help size and specify WEG static starting switches.

Main functions and advantages of the SDW:

- Uses the WEG motor data base, helping to fill in the data;
- As a sizing option, presents the main applications with their respective characteristics to help complete the data;
- Allows switches to be sized according to various starting conditions; and
- Along with a model, the result presents a list of basic parameters to help during start-up.

9.2 ACCESSING

The Software is available through the internet and one way of obtaining it is to:

- Access the WEG site (*www.weg.net*)
- Click on Downloads and On-Line Systems
- Click on Soft-Starter Sizing Software - SDW

The Software guides the user, who must provide the requested information as the application analysis advances. The first step is to select the language and market location for which the starter is intended.

Figure A1: *Opening screen*

By clicking on the help key on this screen, an auxiliary window will appear with the following explanation:

Language: Portuguese, English and Spanish are available. By selecting one of the languages, the "market" field will automatically change according to the selection. Example: Portuguese – Brazil; English – North America; Spanish – Latin America.

Market: The following markets are available: Africa, North America, Latin America, Australia / New Zealand, Brazil and Europe. By selecting one of the markets, a list of the main motors supplied in this market will become available on the next page.
The market can be selected independently from the language.

Example:
Language: Portuguese
Market: North America

The next screen – which will appear after the 

key is pressed – has the following appearance:

Figure A2: *Initial motor data*

Following the example, a 350 HP, 4 pole, NEMA premium is chosen for a 460V, 60 Hz power supply grid.

The content of the help key in this screen is the following:

Motor/Line Type: The most common motors types are available in this field and correspond to the selected market. If your motor is not on this list, please select the “standard” motor and manually enter the data according to your motor.

Standard: This information cannot be modified and corresponds to the available motors in each market.

Number of Poles: Select the number of poles corresponding to the motor in use. This data will be used to define the motor speed. Standard motors are available in 2, 4, 6 and 8 poles. When selecting a higher number of poles, for example 12 poles, the software will not locate a corresponding WEG motor in the data bank. In this case, the motor data have to be enter manually.

Category: Select the category that corresponds to the motor used. This data will be used to define the shape of the torque vs. speed curve (T x n) of the motor. Standard motors are available in category N. If a different category is selected, for example D, the software will not locate a corresponding WEG motor in the data bank. In this case, some additional data will need to be filled in by the user.

Rated Frequency: The frequency in this field cannot be altered and corresponds to the motors available in each market. Unit: Hertz (Hz).

Rated Voltage: The available motor connection voltages are listed in this field. The voltage in which the motor will be connected must be chosen. Unit: Volt (V).

Rated Power: This field lists the powers that correspond to the type of motor selected. Important: if deemed necessary, before selecting a motor, select the power unit (kW or hp).

Since a 200 HP, 6 pole motor for a power supply of 380V, 60Hz was selected, the Software will search in its databank for the characteristics of this motor, and the following screen will appear when 

is clicked:

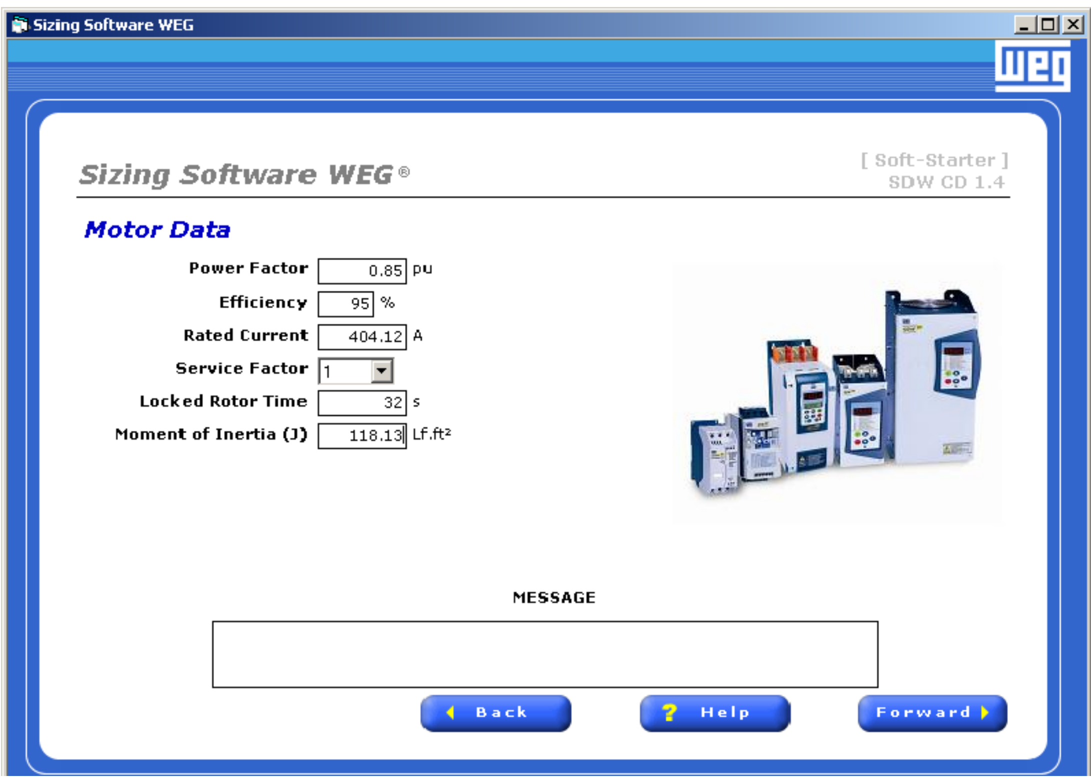


Figure A3: *This data (PF, efficiency, current, etc.) was retrieved by the Software from the WEG motor databank*

The contents of the help key in this screen are the following:

Power Factor: This value is automatically filled in according to the selected motor, if the motor is not found in the WEG databank, the Software will suggest a value, which should be checked with the motor nameplate. Important: this value is used to calculate the rated motor current.

Efficiency: This value is automatically filled in according to the selected motor, if the motor is not found in the WEG databank, the Software will suggest a value, which should be checked with the motor nameplate. Important: this value is used to calculate the rated motor current.

Rated Current: This value is calculated based on the data entered above (rated power, rated voltage, power factor and efficiency). This information is extremely important for Soft-Starter specification. Unit: Ampere (A)

Service Factor: This value must only be filled in according to the motor data if it is used, otherwise, the value should remain at 1 (one).

Locked Rotor Time: This value is automatically filled in according to the selected motor, if the motor is not found in the WEG databank, the Software will not suggest a value, which should then be filled in with a value that corresponds to the motor being used. It is important for this value to be filled in correctly because it is used to check if the motor is prepared to start the load that will be selected. Unit: seconds (s).

Moment of Inertia (J): This value is automatically filled in according to the selected motor, if the motor is not found in the WEG databank, the Software will not suggest a value, which should then be filled in with a value that corresponds to the motor being used. It is important for this value to be filled in correctly because it is used as a base to suggest inertia values in the various load options. Unit: kgm^2 or $lb.ft^2$, depending on the selected market.

Continuing with the example, suppose that this data does not need to be altered. That is, the motor used in the example will have the characteristics chosen by the Software.

By clicking on 

the following screen will appear:

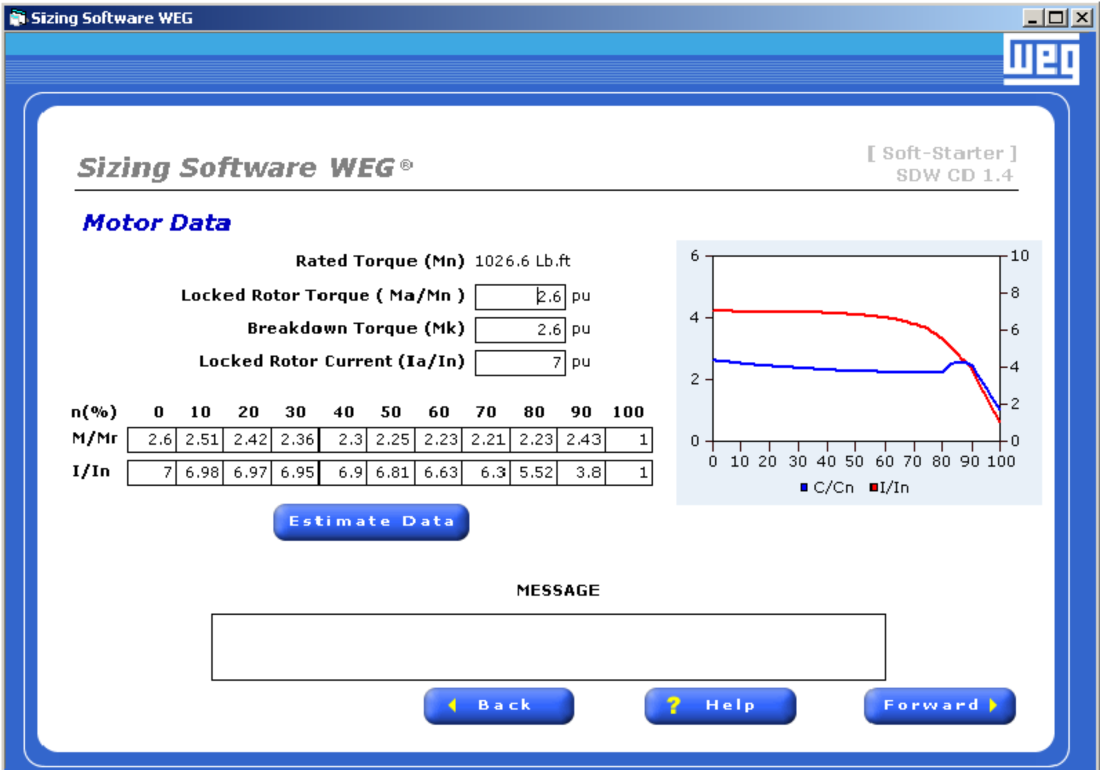


Figure A4: Torque and current curves may also be accessed from the WEG motor databank

The contents of the help key in this screen are the following:

Rated Torque (M_N): This value is automatically filled in according to the selected motor.

Torque with locked Rotor (M_A/M_N): This value is automatically filled in according to the selected motor. If the motor is not found in the WEG databank, the Software will not suggest a value, which should then be filled in according to the nameplate value of the motor being used.

Breakdown Torque (M_K/M_N): This value is automatically filled in according to the selected motor. If the motor is not found in the WEG databank, the Software will not suggest a value, which should then be filled in according to the nameplate value of the motor being used.

Important: The torque vs. speed (M/M_N) graph in this screen is drawn according to the values on the table. If necessary, these values may be altered.

Current with Locked Rotor (I_A/I_N): This value is automatically filled in according to the selected motor. If the motor is not found in the WEG databank, the Software will not suggest a value, which should then be filled in according to the nameplate value of the motor being used.

Important: The current vs. speed (I/I_N) graph in this screen is drawn according to the values in the table. If necessary, these values can be altered.

Torque vs. Speed (M/M_N) and Current vs. Speed (I/I_N) Tables: These tables are filled in according to the data obtained from the WEG databank. These values may be altered according to the motor being used.

Key:

This key must be pressed to update the graphs whenever one or more values are altered in this screen.

Continuing with the example, the curves will remain unaltered and the 

key may now be pressed.

The Application Data screen will open.

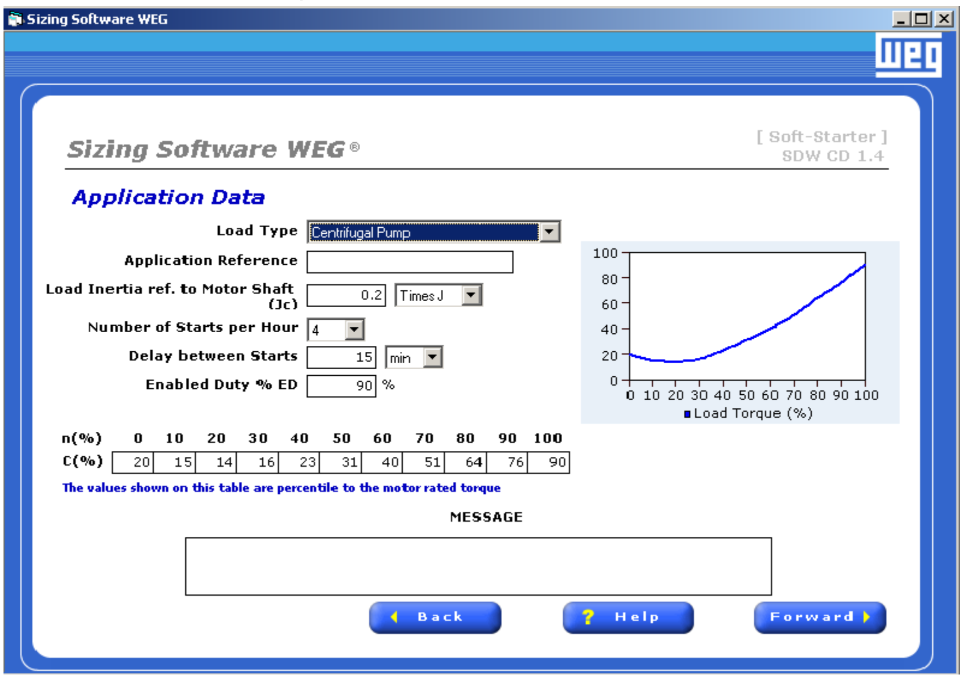


Figure A5: *Application data*

The application characteristics may now be entered into the Software (pump, compressor, extruder, etc.). One interesting advantage of the Software is that it suggests "typical" characteristics for the load, based on WEG experience with these applications.

Of course, it is always a good idea to compare the characteristics suggested by the Software to the real characteristics of the machine that will be started.
In the example, a centrifugal pump will be started and only the number of starts per hour will be altered from the value suggested by the SDW (the Software suggested 4 but only 1 start per hour will be executed).

The content of the help key in this screen is the following:

Type of Load: This involves a load databank, with the respective characteristics of each load. When a specific load is selected, the Software will suggest its characteristics, like torque vs. speed curve data and inertia referred to the motor shaft (Jc).

Application Reference: This field can be used to identify a specific application. Example: “TAG 563786” or “Factory II Fan”.

Load Inertia Referred to the Motor Shaft: Initially, the Software suggests a value according to the selected load. This value may be altered according to the desired application and each application has a minimum and maximum limit for this value. For example: the Software does not allow an inertia of 10 times the motor rated value to be filled in for a centrifugal pump, in the same way that it does not allow an inertia of 1 time the motor rated value to be filled in for a fan / exhaust.

NOTE!
Some machine manufacturers use the term “inertia” of a body as defined by other concepts, and not that of moment of inertia J. For example: GD2, where G is understood as weight (and not mass) and D is understood as the “rotation diameter” (or “diameter of inertia”). As such, for a solid cylinder with diameter d (and radius r) in relation to its shaft, there is:

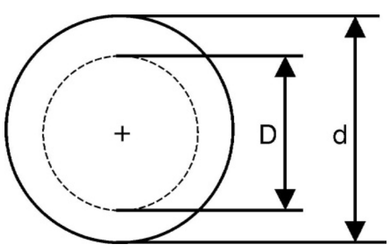


***Figure A7:** “Rotation diameter” D of a cylinder*

$$D = \frac{d}{\sqrt{2}}$$

$$GD^2 = \frac{Gd^2}{2} = \frac{G4r^2}{2} = 2Gr^2$$

Where, numerically:

$$\frac{GD^2}{J} = \frac{2Gr^2}{\frac{Mr^2}{4}} = 4 \rightarrow GD^2 = 4J$$

$J = \frac{GD^2}{4}$ (As long as GD^2 is expressed in $kgf.m^2$ and in $kg.m^2$)

NOTE!
Therefore, it is important to pay attention and observe if the inertia provided by the manufacturer is GD^2 or J. The SDW requires the information to be J and not GD^2!

Number of Starts per Hour: This value is suggested according to the selected load. It may be altered to any one of the pre-determined values. This is used to determine the effective current of the cycle and, therefore, must be as accurate as possible because it will affect the sizing.

Interval between Starts: This value is filled in according to the number of starts per hour. It may be altered if the interval between starts of the application is lower than the suggested value. Example: if the number of starts per hour is 10, this field will be filled in with “6 min” or “360 s”. This value is used to determine the effective current of the cycle and, therefore, must be as correct as possible because it will affect the sizing.

Usage Factor: This value corresponds to the operation time of a motor between one start and another. Example: if the interval between starts is 10 minutes and the usage factor is 60%, it means that the motor will operate during 6 minutes and be off during 4 minutes.

Click on 

to continue with the example.

Figure A8: *General data*

The Software asks the user to insert data about the ambient and the power supply.
In the example, the data suggested by the SDW will be maintained, as shown in the figure above.

The content of the help key in this screen is the following:

Ambient Conditions:

Altitude: Some fixed altitude values are available in this field, which should be selected according to the location in which the soft starter will be installed. Standard altitude is 1000 m, and it continues above this value until 4000 m. The Software considers a progressive derating factor in the output current of the SSW.

Ambient Temperature: In this field, some fixed ambient temperature values are available, which should be selected according to the location in which the soft starter will be installed. Standard temperature is 40°C, and above this value is 50°C. The Software considers a progressive derating factor in the output current of the SSW.

System Characteristics:

Three-Phase Power Supply Voltage: This field is filled in automatically with the motor voltage. This value may be altered if the power supply voltage is different from that of the motor. The Software only accepts power supply voltages greater than the motor voltage. Example: Motor voltage 440 V- Power supply voltage 480 V.

Voltage Drop during the Start: It is possible to define the voltage drop that will probably occur during the selected system start (motor / load) in this field. If the value is not altered, the Software will consider a voltage drop of 2.5%. This voltage drop means there will be a torque reduction in the motor.

Motor Connection: The SSW-03 Plus has two modes of operation: standard connection or inside the motor delta connection. In the standard connection, the motor is installed in series with the SSW through three cables.

In the inside the motor delta connection, the SSW is connected to each motor winding separately, through six cables. With this type of connection, only the current inside the motor delta will circulate through the Soft-Starter, that is, approximately 58% of the rated motor current. The motor must have six connection cables available and the power supply must correspond to the voltage of the motor delta connection.

Example:
Power supply: 220 V – motor ? – 220 / Y-380 V
Power supply: 380 V – motor ? – 380 / Y-660 V

Standard Connection with Three Cables:

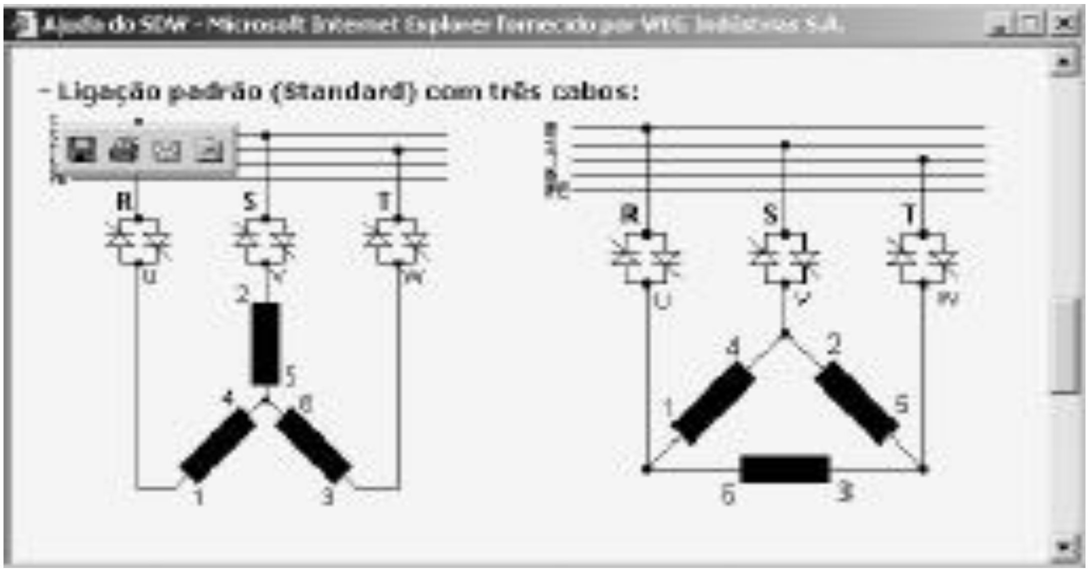


Figure A9: *Standard connection in the SDW "Help"*

Figure A10: *Inside the motor delta connection in the SDW "Help"*

Soft-Starters – 6 Cable Connection

ATTENTION!
To use the SSW-03 Plus Soft-Starter in a 6 cable connection (inside the motor delta connection), the secondary of the three-phase transformer supplying the electrical installation MUST NOT be connected in DELTA. It is MANDATORY for the secondary of this transformer to be CONNECTED IN STAR and to have its CENTRAL POINT (NEUTRAL) GROUNDED.

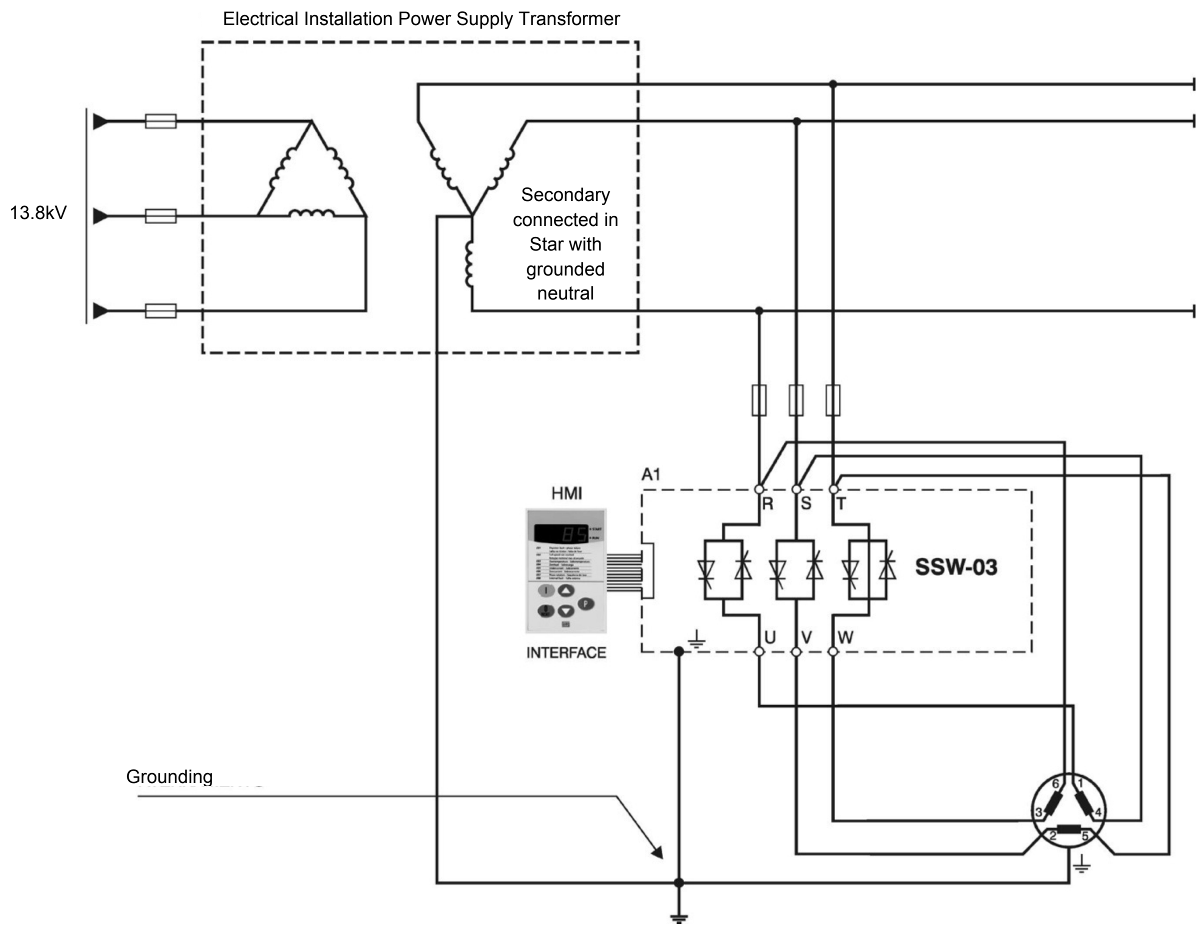


Figure A11: *Soft-Starter – 6 cable connection*

The motor will be connected directly to the power supply after starting (by-pass): The SSW may be used only at the start, transferring the motor directly to the power supply afterwards. In this case, the Software only considers the current during the start and the effective current of the cycle, which is calculated considering the current in operation with a value of zero.

Continuing with the example, click on the  key without altering any data.

The Software shows the result of the simulation data.

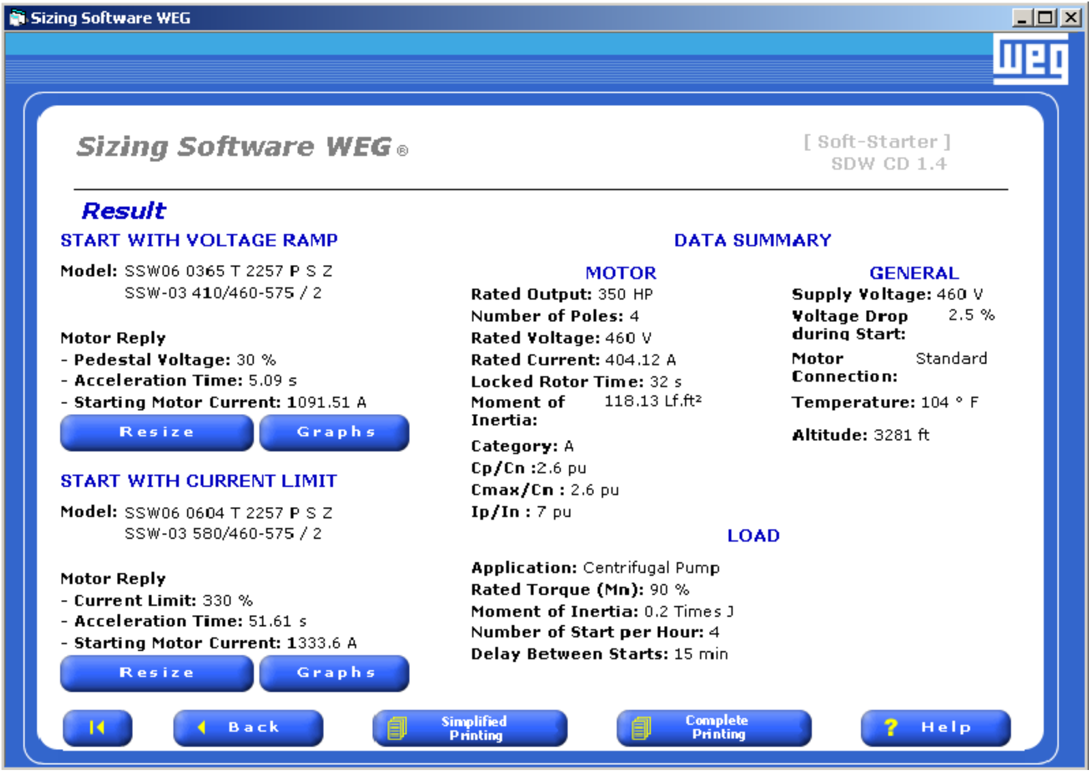


Figure A12: *Result*

The "Result" screen above presents a series of keys accessing different SDW resources, allowing the user to make several simulations.

This is an important characteristic that demonstrates to the user how the system behaves as a whole.

The content of the help key in this screen is the following:

Result: The Software provides two starting models, one for starting with a voltage ramp and another for starting with current limitation. When the suggested models are different, the larger model is used because the starting method that will be used, voltage ramp or current limitation, and depends on the characteristics of the load and the system. Normally, current limitation is used as the starting method in loads with high inertia and low frictional torque at the start. Example: crushers, fans and wood choppers. The voltage ramp is generally used in loads with low inertia and high frictional torque at the start. Example: reciprocating pump, piston compressor, conveyor belts, etc. (with the exception of centrifugal pumps, due to their low frictional torque).

Motor Response – starting with a voltage ramp: Motor behavior referring to the acceleration time and effective starting current for a specified voltage pedestal.

Motor Response – starting with current limitation: Motor behavior referring to the acceleration time and effective starting current for a specified current limitation.

Keys:

By clicking on this key, the voltage pedestal or the current limitation may be re-defined. The motor response and the appropriate model for this new starting condition can then be checked.

By clicking on this key, a screen with the following graphs will appear:

- Current vs. speed of the motor with direct on-line start and with SSW start;
- Output voltage vs. time; and
- Motor acceleration.

By clicking on this key, a report containing results, entered data and graphs will be printed.

The re-size key of the "Starting with voltage ramp" exhibits the following screen, which provides the option of altering the voltage pedestal:

Figure A13: *Re-sizing*

Resize

The re-size key of the “Starting with current limit” exhibits the following screen, which provides the option of altering the current limitation adopted by the soft starter:

Figure A14: *Re-sizing*

Graphs

Starting with voltage ramp graphs in the example will have the following appearance:

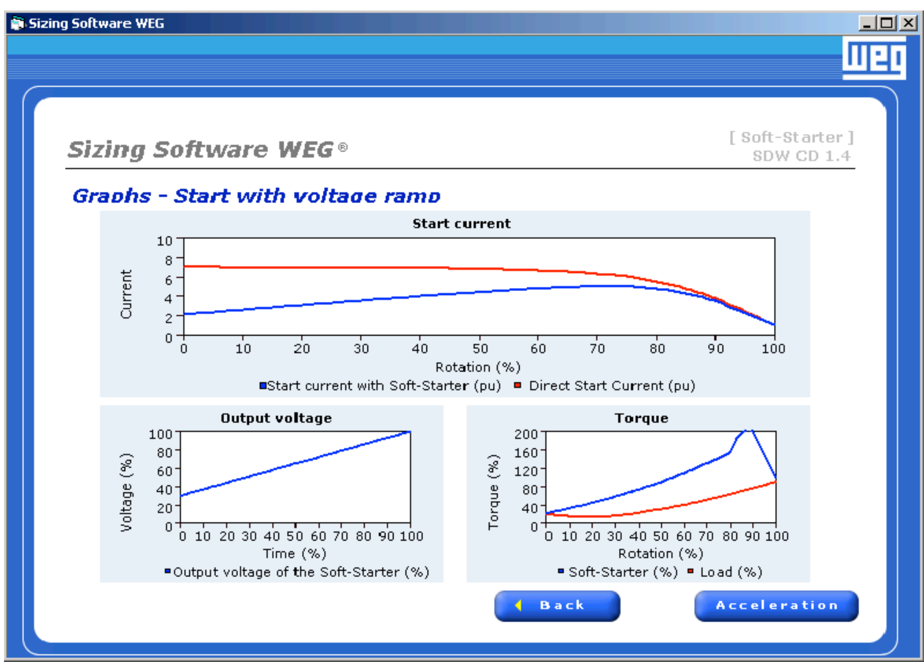


Figure A15: *Graphs*

By clicking on the “Acceleration” key in the Graph screen, the following data (with reference to starting with voltage ramp) will appear:

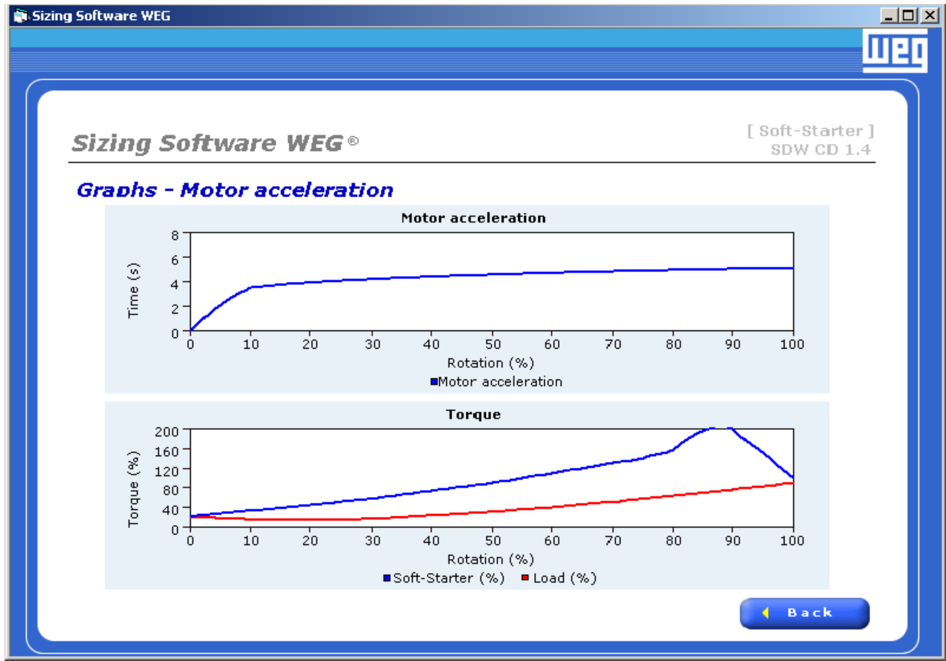


Figure A16: *Graphs - Acceleration*

Starting with current limitation graphs in the example will have the following appearance:

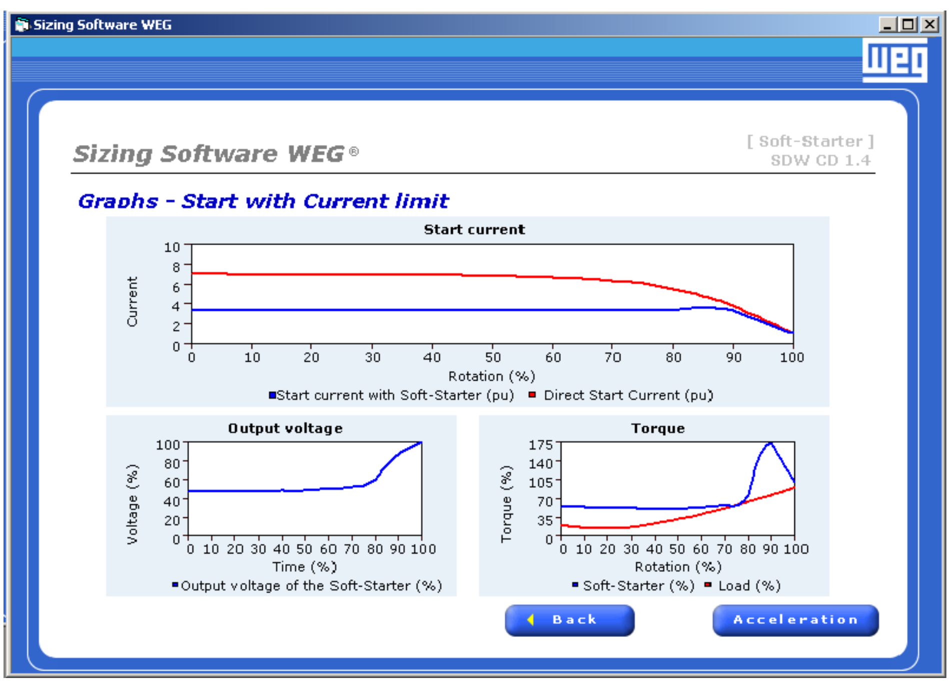


Figure A17: *Graphs*

By clicking on the “Acceleration” key in the Graph screen, the following data (with reference to starting with current limitation) will appear:

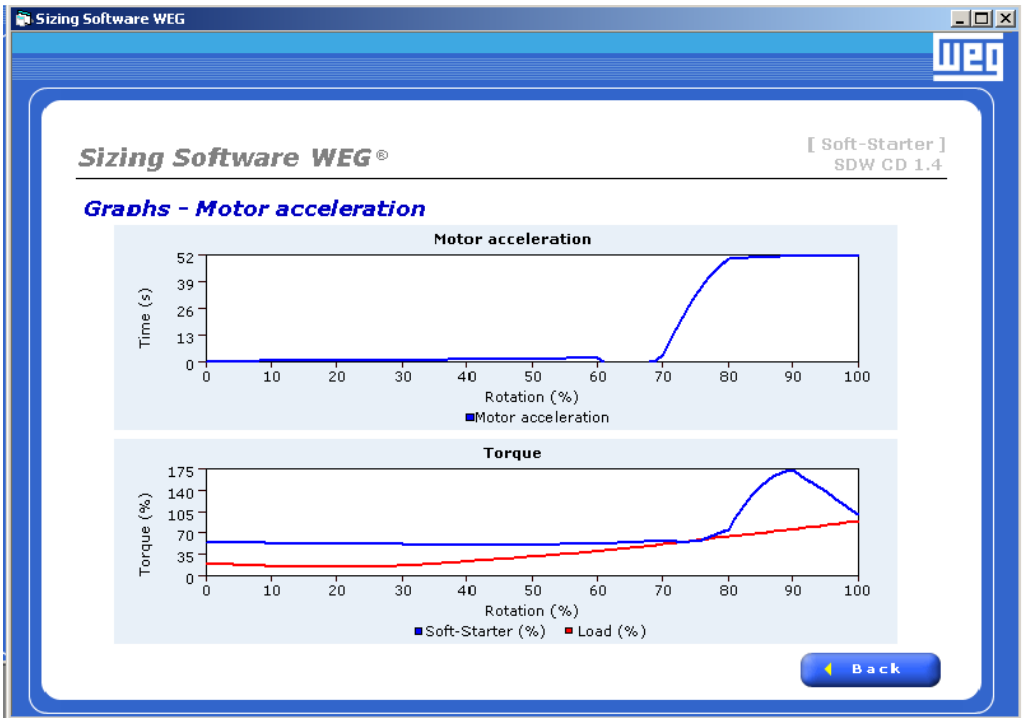


Figure A18: *Graphs - Acceleration*

9.3 LIMITS OF LIABILITY

The SDW provides a means for the user to execute an application analysis in a very easy way. All of the databank and the rules incorporated into the Software create an analytical tool, and the results of this tool must be certified by the user.

WEG recommends that this Software be used by qualified professionals who fully comprehend the information being requested and/or supplied by the Software.

WEG does not assume any responsibility for losses or damage caused by incorrect SDW application.

10 ANNEX 3 – DATA SHEET FOR SIZING SOFT-STARTERS

General Data	
Company:	Tel:
City / State:	Fax:
Contact:	E-mail:
Application / Load:	

Application Data

<table>
<tr><td rowspan="2">Motor</td><td rowspan="2">Rated Power: HP
Service Factor:
S.F. = ……………………………

Is it used?
[ ] No
[ ] Yes</td><td>Nr of Poles / Rates Speed:
[ ] 2 Poles (3600 rpm)
[ ] 4 Poles (1800 rpm)
[ ] 6 Poles (1200 rpm)
[ ] 8 Poles (900 rpm)
[ ] ... Poles (……. rpm)</td><td>Board Current and Voltage:
[ ] 220 V → …………. A
[ ] 380 V → …………. A
[ ] 440 V → …………. A
[ ] ………...V → ………. A</td></tr>
<tr><td>Desired Speed Range:
From ………… To ………... rpm</td><td>Number of Starts per Hour:
…………. Starts / Hour</td></tr>
<tr><td>Load</td><td>Load Type:
[ ] Pump
[ ] Centrifugal Pump
[ ] Piston Compressor
[ ] Screw Compressor
[ ] Fan and Exhaust
[ ] Mixer
[ ] Centrifuge
[ ] Other</td><td colspan="2">Frictional Torque of the Load Referred to the Motor Shaft:
……………………………..Nm
……………………………..kgfm

Load Inertia Referred to the Motor Shaft:
……………..……………..kgm²</td></tr>
<tr><td rowspan="2">Installation</td><td>Power Supply:
[ ] 220 V
[ ] 380 V [ ] 50 Hz
[ ] 440 V [ ] 60 Hz
[ ] ……………………….V</td><td colspan="2">Ambient Conditions for Installation:
Altitude: [ ] Up to 1000 m; [ ]……………..m (specify in Obs.)
Atmosphere: [ ] Normal; [ ] Aggressive
Temperature: [ ] Up to 40°C; [ ] ………..°C</td></tr>
<tr><td colspan="2">Degree of Protection Needed:
[ ] IP 00 (open w/o protection)
[ ] IP 20 (finger safe)
[ ] IP 54 (closed – panel mounted)
[ ] Outdoor (special panel for rain)
[ ] ………………………………… (specify in the Obs.)</td><td>Command Method:
[ ] I/O Buttons
[ ]Human Machine Interface
[ ] Analog Input</td></tr>
<tr><td colspan="4">Observations:

</td></tr>
</table>

If additional information must be supplied, please attach to this sheet.

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- MANUAL DE CHAVES DE PARTIDA WEG ACIONAMENTOS
- MANUAL DA SOFT- STARTER - Série: SSW-03 Plus WEG AUTOMAÇÃO
- MANUAL DA SOFT- STARTER WEG - Série: SSW-04 WEG AUTOMAÇÃO
- SSW-05 MANUAL DO USUÁRIO WEG - Série: SSW-05 Plus WEG AUTOMAÇÃO
- MANUAL DE INSTALAÇÃO E MANUTENÇÃO DE MOTORES ELÉTRICOS WEG MÁQUINAS

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Compressor Duty Motors
Farm Duty Motors
Poultry Fan Motors
Auger Drive Motors
IEEE 841 Motors
Stainless Steel Wash Down Motors
Saw Arbor Motors
Cooling Tower Motors
Commercial HVAC Motors
Pad Mounted Motors
Vector Duty Motors

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Low Voltage 3-phase motors up to 2,500HP

Motors up to 70,000HP and 13,200V

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Ex-n, Ex-e, Ex-p motors

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Complete line of options and accessories

Soft Starters

3-1500HP
Oriented start-up
Built-in bypass contactor

Universal source voltage (230-575V, 50/60Hz)

Network communications: Profibus-DP, DeviceNet, Modbus-RTU

Complete Line of options and accessories

MV Soft-starter 3.3kV, 41.6kV: up to 3500HP, Withdrawable Power Stacks, & 8x PT100 Temperature monitoring

Controls

Mini – Contactors
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Manual Motor Protectors
Molded Case Circuit Breakers
Smart Relays

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Timing & Motor Protection Relays
Terminal Blocks

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