Document number: 1SFC132392M0201
Revision: 2
Released: December 20, 2018
Updated: April 8, 2019

DECEMBER, 2018

Performance comparison between 2- and 3-phase controlled softstarters

ABSTRACT

A comparison between 2- and 3-phase controlled softstarters provides important insight into the differences and similarities between the two technologies. In this paper and associated research, it is concluded that from a performance, safety and reliability standpoint there is no significant difference between softstarters controlled using 2-phase or 3-phase technology.

The current imbalance that arises during starting does not affect the performance of the softstarter and therefore doesn't impact the quality or accuracy of the voltage or torque ramp. The widely discussed DC component generated by traditional 2-phase controlled softstarters is effectively eliminated with a DC compensation algorithm. Speed and acceleration performance are not bound to the number thyristors inside the softstarter and equal starting performance is easily achieved. When it comes to electrical isolation and reliability, it has been concluded that there is no significant difference, in design or outcome in case of failure, between the two different softstarter technologies.

Contents

1 Introduction

The purpose of this document is to provide a general overview of both 2-phase and 3-phase softstarter control, and to evaluate the differences between the two technologies.

A softstarter is a motor control device that ramps up a 3-phase squirrel cage induction motor from stand still to full speed in a controlled way. There are two main categories of softstarters, 2- and 3-phase controlled, that have either two or three sets of thyristors to control the motor voltage during start or stop.

There is a great deal of confusion regarding the performance of 2-phase controlled softstarters. Early 2-phase control generated what is now the infamous “DC component” and is responsible for a number of misconceptions regarding this technology. This paper will evaluate the DC component and if can it be eliminated. 2-phase vs. 3-phase control also poses questions regarding current imbalance and differences in component performance, safety and reliability.

Prior to getting a better understanding of the differences and similarities between these technologies, it’s first necessary to understand the basics and the different types of motor starting solutions.

2 Motor starting and softstarter technology

2.1 Motor starting solutions: Direct or soft start

2.1.1 Direct motor start

The traditional motor starting method is the "direct online" (DOL), or "across the line", which is a contactor start. When given a start signal the contactor closes and gives the motor full voltage instantly whereby the motor draws whatever current it needs to get it up to full speed. During this sequence there are two main type problems that arises: electrical and mechanical.

Depending on the load, the initial current (called locked rotor current) can be as high as 8 times the motor nominal current (FLA), which could have a negative impact on the upstream electrical system with tripping breakers or fuses blown.

The second problem, the mechanical, occurs on the motor and application side. A motor's starting torque is in the range of 2-2.5 times to the nominal, which in most applications would be excessive and can result in mechanical wear and tear. In a conveyor belt application, a slipping or even a snapped belt would be such a problem.

The solution to these, and similar problems, is to control the output voltage and current so that the starting sequence is softer, like a soft start.

2.1.2 Softstarter start

A softstarter controls the forwarded voltage to the motor by using thyristors (more about them later). The voltage is slowly increased allowing the motor to reach full speed with a fraction of the current needed in a DOL start.

In Figure 1, the softstarters initial voltage is set to 50% and then it's slowly increased to 100%. The initial current will then be about 50% of the locked rotor current, i.e. 4 times the nominal, instead of 8. The red line in Figure 2 represents this lower current. Since the torque is proportional to the voltage times the current, the motor torque when using a softstarter is reduced to about 25% (red line) of the DOL torque (black line), which is shown in Figure 3.

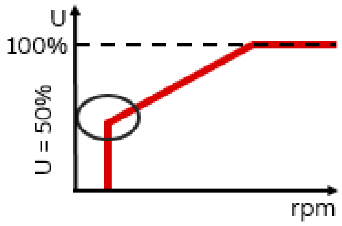


Figure 1: Voltage during softstarter.

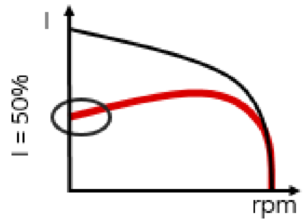


Figure 2: Current during start with (red) softstarter and DOL (black).

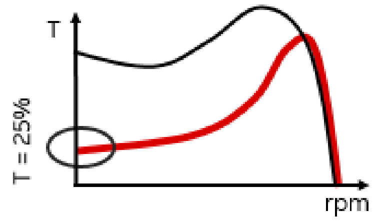


Figure 3: Torque during ramp with softstarter (red) and DOL (black).

The reduced torque and current achieved with a softstarter can eliminate many of the issues that comes with the DOL starter. Now the question is how the softstarter makes this happens.

2.2 Softstarter technology and topology differences

The power components of a softstarter are the thyristors, also called Silicon Controlled Rectifiers (SCRs). A softstarter consists of either two or three sets of anti-parallel thyristors pairs. When the terms '2-phase'- or '3-phase'- 'controlled softstarter' are used, it refers to the number of sets of thyristors that are being used. This is illustrated in Figure 4 and Figure 5.

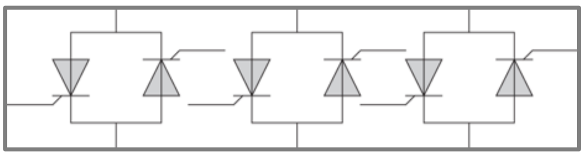


Figure 4: Thyristor topology of a "3-phase softstarter": 3 sets of anti-parallel thyristors.

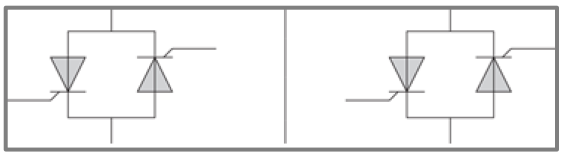


Figure 5: Thyristor topology of a "2-phase softstarter": 2 sets of anti-parallel thyristors.

The thyristor is a solid-state component that has two different states: blocking or conducting. In its standby state it's in blocking state which means that no current, nor voltage, is forwarded. The thyristor is controlled via a gate signal: when the thyristor receives a pulse to the gate, the thyristor starts to conduct, and it continues doing so until the voltage crosses the zero line (called *zero crossing*). The pulse is controlled from the softstarters PCBA and the timing depends on the time from the last zero crossing.

The bottom part of Figure 6 shows the sine wave and when the thyristor is conductive (filled red) and blocking (filled white) respectively. The distance between the zero-crossing and the triggering is called the firing angle and is usually denoted as α. The time α determines the amount of voltage that is forwarded to the motor. A half-filled half cycle represents 50% voltage and a completely filled represents 100%.

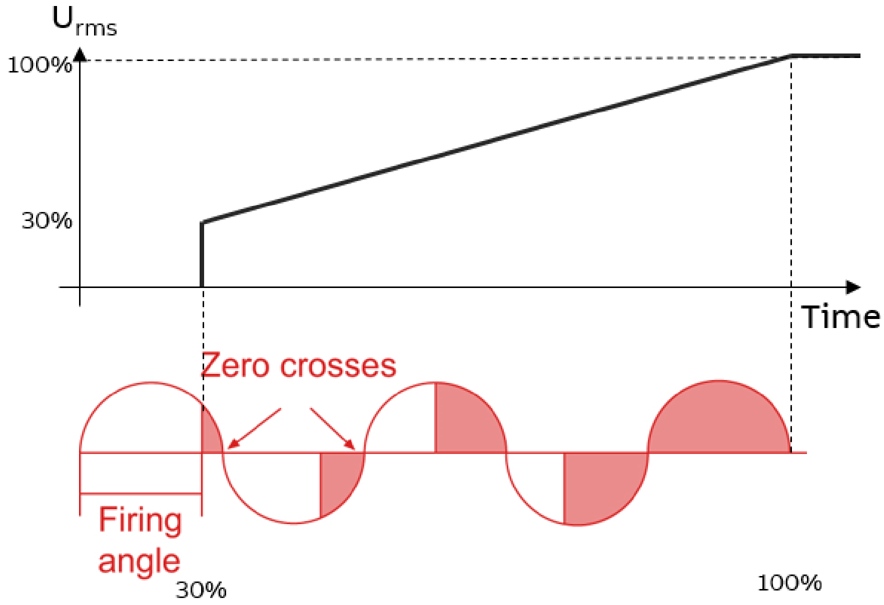


Figure 6: RMS voltage and thyristor triggering process relative to 50/60 Hz sine wave during softstarter starting sequence.

This means that the softstarter's way to control the voltage and current is to let only certain parts of the incoming voltage through.

The control method is equal for both 2- and 3-phase control, but what differences are there then? The RMS voltage increase shown in the figure above will not significantly differ between the two methods, but there will be some differences in the currents, which will be discussed next.

3 Current imbalance and the DC component

3.1 What is current imbalance and where does it come from?

The first thing noted when starting a 3-phase motor with a 2-phase controlled softstarter is that the currents in the phases are not equal. Typically, the controlled phases have approximately 30-50% lower current relative to the uncontrolled. The two controlled phases have similar current readings with a discrepancy up to approximately 20%. This can be seen in Figure 7 and Figure 8 below which shows current measurements from a 2-phase controlled start with and without current limit.

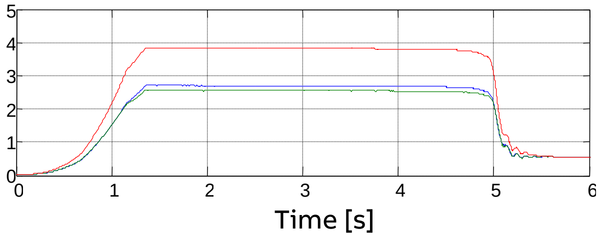


Figure 7: RMS current with 2-phase control with current limit.

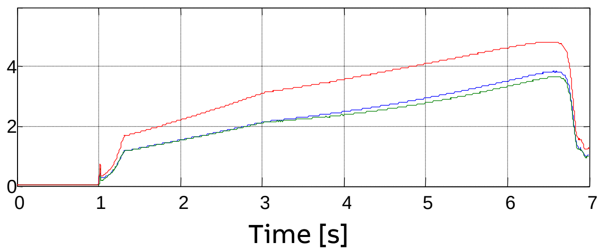


Figure 8: RMS current with 2-phase control without current limit.

Conceptually, this phase current discrepancy originates from the fact that each phase is conducting current different amount of time. In the controlled phases the thyristors control the current to the motor by switching on during the half cycle of the sine wave, and then switching off (entering a non-conductive state) at the zero crossing. This means that the controlled phases conduct only part of time, while the uncontrolled phase is always available for conducting, and provides a return path for the current.

To visualize this, Figure 9: The three phase currents when triggering angle is 5 ms. shows the discrepancies between the individual phase currents when L1 and L3 triggered with 5 ms firing angle (for 50 Hz). This triggering angle corresponds to approximately 50% voltage. The sum of the three currents must be zero, L2 = -L1-L3. From Figure 9 it is clear that L2 (red line) is conductive more time than L1 and L3.

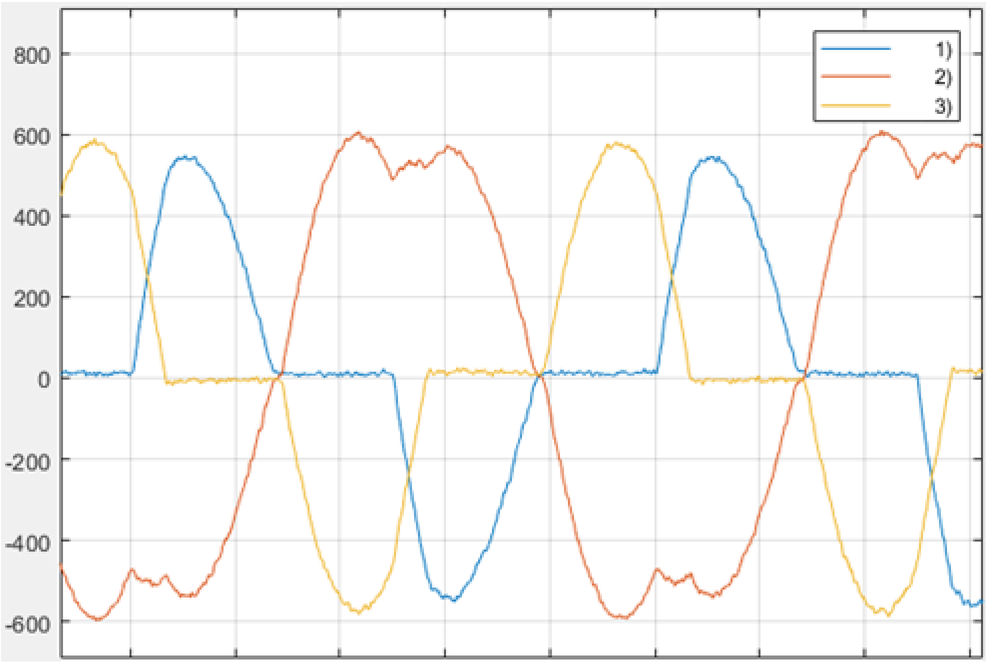


Figure 9: The three phase currents when triggering angle is 5 ms. The distance between vertical lines represent 4 ms.

3.2 Implications from current imbalance

3.2.1 The imbalance's impact on the motor temperature

Current imbalance between the phases can cause slightly disproportional heating of the motor windings during the start ramp time which lowers the motor's efficiency. The extent of the problem depends on the motor and load characteristics.

When it comes to motor heating, fortunately, the ramp time is usually less than 10 seconds which means that the impact of the current imbalance would be limited to a very short time. This in combination with the fact that motors are very resilient against temporary temperature rise concludes that the resulting efficiency impact on the motor is negligible.

3.2.2 Current imbalance and peak current

The current imbalance also impacts the highest inrush current. At normal start a 3-phase controlled softstarter requires about four times the nominal current. The current rating of the uncontrolled phase in a 2-phase softstarter is about 30% higher when compared to a 3-phase controlled softstarter meaning heavy applications in unreliable networks (for example a generator or transformer that under dimensioned for the motor) may experience problems. That having been said however, in normal situations this current imbalance is not a problem since a lower current limit will ensure a lower starting current without impacting the starting capability of the motor.

More importantly though, the implications related to current imbalance disappears when the softstarter reaches top-of-ramp (full speed), normally after only 10 seconds of ramping. During continuous full-speed operation the bypass contacts are closed and the softstarter does not cause any imbalance.

3.2.3 Relationship between current imbalance and voltage sag

The current inrush can also cause a sag in the main supply voltage. The sag magnitude is proportional to the inrush current and mainly depends on the transformer or generator power rating, impedance rating and short circuit current capability.

When using a softstarter instead of a DOL starter, the voltage sag will be much smaller in magnitude. If a 2-phase softstarter is compared to a 3-phase, the voltage sag will be slightly larger in the 2-phase controlled, but the difference is insignificant in a comparison the sag from a DOL start.

Additionally, most motors are designed so that they still can operate when the voltage has dropped to less than 90% of rated voltage, which means that the difference in voltage sag between the 2- and 3-phase softstarters would have limited to no differential impact.

3.3 Limited impact of current imbalance

The differences mentioned above can have an impact only during ramping. In a majority of applications, the ramp time with a softstarter is less than 10 seconds.

A quick calculation can be made based on an estimate of a normal application: If the start ramp time is set to be 12 seconds and the motor is started six times per hour, the ratio between motor starting and running time can be calculated with

$$\frac{12 * 6}{3600} = 0.02$$

This means that only 2% of the motor's lifetime is spent in a starting phase.

To conclude, the current imbalance differences between 2-phase and 3-phase control have no significant impact on performance in most applications because their effects are isolated only to the transient periods of ramp-up. Other issues that could result from a current imbalance can be limited to a few specific applications for which mitigation is possible through correct motor sizing.

4 The DC component and its origin

When the first 2-phase softstarters were developed, they had less torque that the corresponding 3-phase controlled. Soon it came clear that only controlling 2 of the 3 phases with the same control algorithm would be problematic: without any compensation algorithm, a traditional 2-phase controlled softstarter will create something called a DC component. This section explains what the DC component is, where it comes from, the implications, and how ABB have eliminated these issues.

4.1 What is the DC component?

With 2-phase control, there is a specific sequence of thyristors triggering where the current in one of the controlled phases will have an effect of the current on the other controlled phase. When this happens, the natural switch off point at the zero crossing is pushed out. This is illustrated in Figure 10 as the orange arrow. The half periods a and b are now not equal as they would be in a normal sine wave.

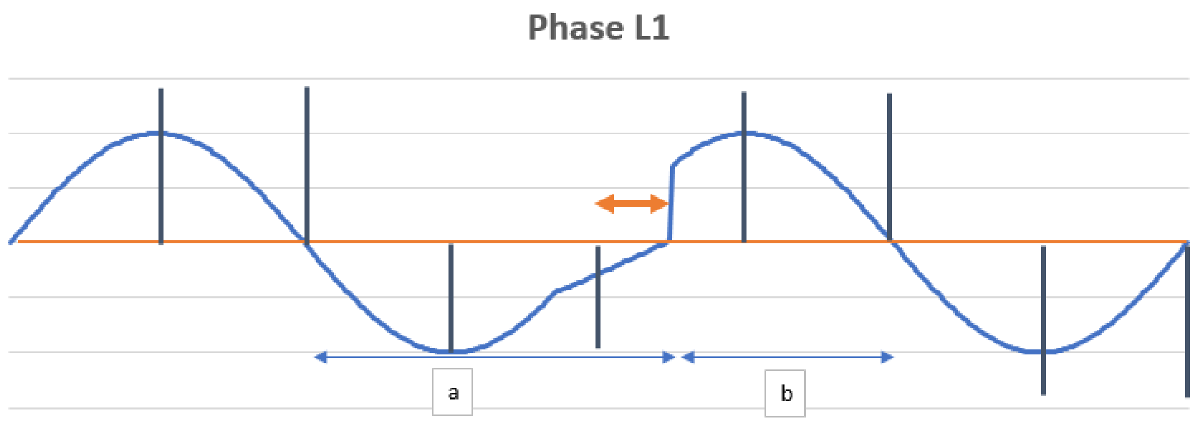


Figure 10: How the zero-crossing can have an offset during the ramp.

In this example the negative current will be active longer than expected. Because of this, the positive phase will now start later, but it will naturally stop at its actual zero-crossing. Altogether, the current will be more negative than positive during a full period which means that the current will have a negative offset from the 0. This offset is what give rise to the DC component.

In a normal balanced system, the voltage sine wave in is fluctuating around zero which means that the average value will be zero. On the other hand, a system where there is a DC component, the voltage has an offset from zero meaning that the average value is not equal to zero.

Mathematically this can be described as:

$$x(t) = A + B \times sin(2\pi \times f \times t)$$

where A is DC offset, B is the amplitude, f is the frequency, and t is the time. When $A \neq 0$, then there is a DC component.

4.2 One DC component per phase

The current during a normal start with a 2-phase controlled softstarter without DC compensation is shown in the top part of Figure 11.

In this situation, the DC component A from the equation above is not equal to zero. The DC component only exists during a specific interval of the ramp, which corresponds to about 40 - 60% voltage. This can be seen in figure below as the marked area.

The bottom part of the same figure shows the individual DC components for the three phases in the time span where they exist.

The red and blue lines represent the controlled phases, while the green is the uncontrolled phase. The controlled phases will have a positive DC offset, while the uncontrolled phase will have a negative offset. Since the sum of the DC components among the phases adds up to zero, the uncontrolled phase will have approximately twice as much DC component compared to the controlled phases.

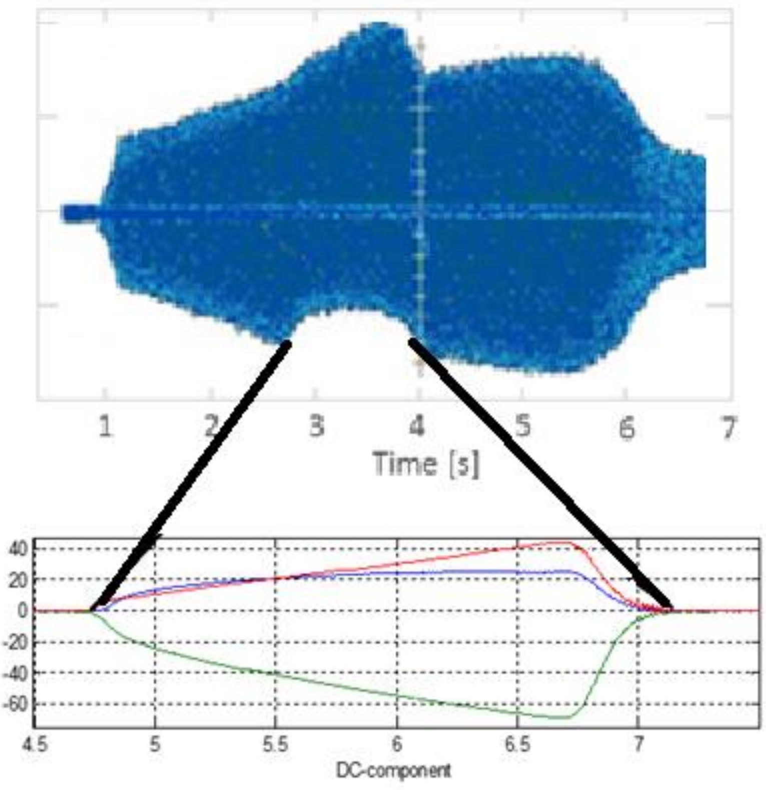


Figure 11: The DC component visualized, and how it's related to the individual phase currents.

4.3 The DC component's impact on the motor and application

It is now clear what the DC component is and where it comes from. The next questions are what impact this has.

Due to the DC component unwanted negative torque arises. This can cause torque oscillations, bad noise and unnecessary heating of the motor. In rare situations, there can also be a problem with accelerating the motor up to full speed due to increased current.

Even though the motor heating is very limited with a 2-phase softstarter compared to the 3-phase, it is still valuable to eliminate the DC component to ensure same performance for both. So how do we eliminate it and what's the result?

4.4 ABB eliminates the DC component with algorithm

ABB's 2-phase softstarters has an implemented DC compensation algorithm that effectively eliminates the DC component during the ramp and the starting current and torque profile is as smooth as it is when starting with a 3-phase controlled softstarter.

The algorithm is patented and is based on adjusting the control to compensate for the deviations of the zero-crossings. Since the half cycle time is known, and that the softstarter knows the time since the last crossing, the deviation can be determined and hence also be compensated for.

In Figure 12 and Figure 13 below the current with (left) and without (right) DC compensation are shown. The left figure shows how the DC current offset moves the current up from zero. In the right figure, it's clear that the DC compensation algorithm eliminates the offset and the current has the exact same form as the current from a 3-phase controlled softstarter has.

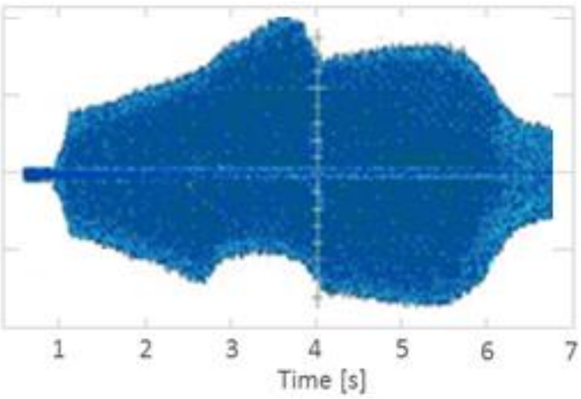


Figure 12: DC component from a 2-phase controlled softstarter without compensation algorithm.

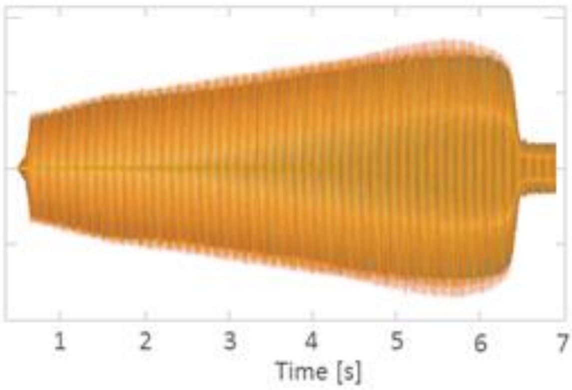


Figure 13: 2-phase controlled softstarter with compensation algorithm.

To summarize, there is a current imbalance, but the impact on the motor and starting performance is negligible. The DC component that arises is effectively eliminated with ABB's algorithm resulting in a perfectly balanced start. So, the difference between the 2- and 3-phase control is the current imbalance that occurs during the ramp, but what about other performance indicators?

5 Performance

5.1 What is performance?

Currents and DC component aside, what effect does softstarter solution have on the motor and application? In chapter 2 we discussed about the disadvantages having a direct start. Consider the conveyor belt again: a too high motor acceleration can potentially exert too much stress resulting in a slipping or a snapped belt. This type of wear and tear from harsh motor acceleration can have a negative impact on many different types of applications, and that's why one of the best motor starting performance indicator is the rotational motor speed [RPM].

ABB's softstarters have two main different starting ramp types: Voltage ramp and Torque control. The voltage ramp is a linear voltage increase from a starting voltage (usually 30%) to 100% voltage, where the motor speed profile will in most cases be a quadric-like, but changes with different type of loads.

On the other hand, the torque control increases the torque linearly, which means that the voltage and current will be irregular during the ramp. In most situations the motor speed during start will also be more linear compared to the voltage ramp (also load dependent.)

In the next two chapters, the voltage and torque ramp comparison between 2- and 3-phase is shown and discussed.

5.2 Voltage ramp

In Figure 14 below the speed-time curves are shown for both a 3-phase and a 2-phase controlled softstarter when the ramp time is set to 5 seconds, initial voltage 30% and the load is fairly light.

In the beginning of the ramp the performance from the two different softstarter types are indistinguishable. In this case, when the motor comes up to about 700 RPM, the control algorithms for the 2- and 3-phase acts different. From 2 seconds of ramping, the 2-phase softstarter ramp takes about 0.5 seconds longer to complete the ramp compared to the 3-phase type. The curves are equally smooth and the both are considered perfect starts.

Any start that have a similar speed profile that would be completed between 3 and 6 seconds for this load would be considered a very good start. Considering the motor and application, the best ramp can't be determined just reading from a chart; the only way is to fine-tune the softstarters parameters to match the applications performance requirements.

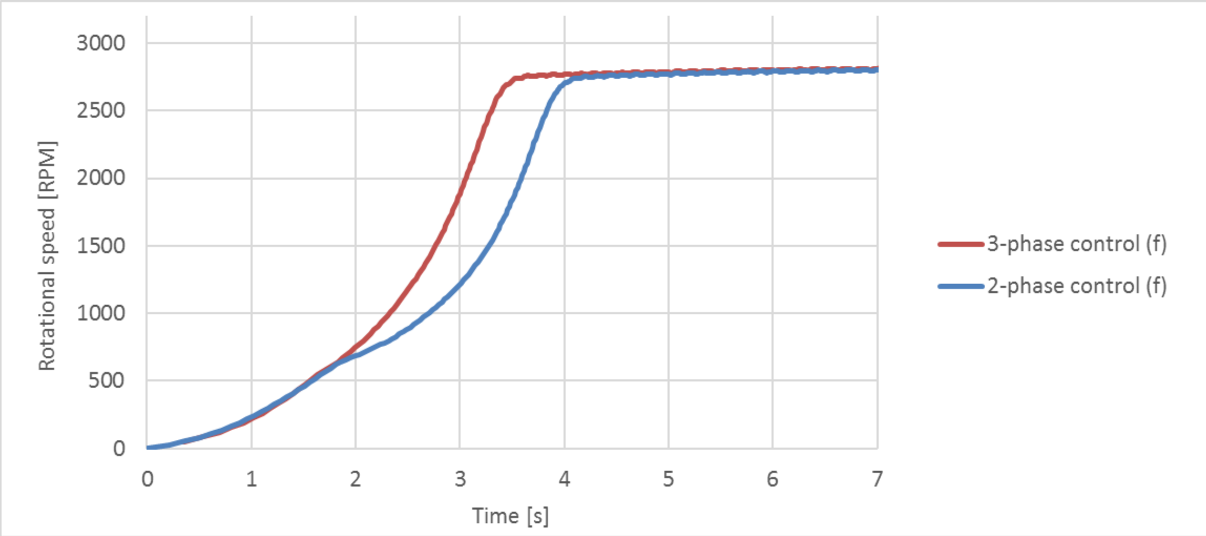


Figure 14: Rotational speed with voltage ramp with a light load for both 2- and 3-phase controlled softstarters with different acceleration times. Both ramps are equally good and the application would experience very similar behavior.

If the two ramps are studied more in detail between 2 and 4 seconds, it becomes clear that the result in the application would be inseparable if a 2- or 3-phase softstarter is used.

To compare the parts of the speed curves from 800 to 2800 RPM, the 2-phase has been time-shifted 0.5 seconds to match the 3-phase, which can be seen in Figure 15 below. The difference is diminutive, and it would've been impossible to differentiate between the two when considering the effect on motor and application. The curves have close to exact same form from 1300 to 2800 RPM.

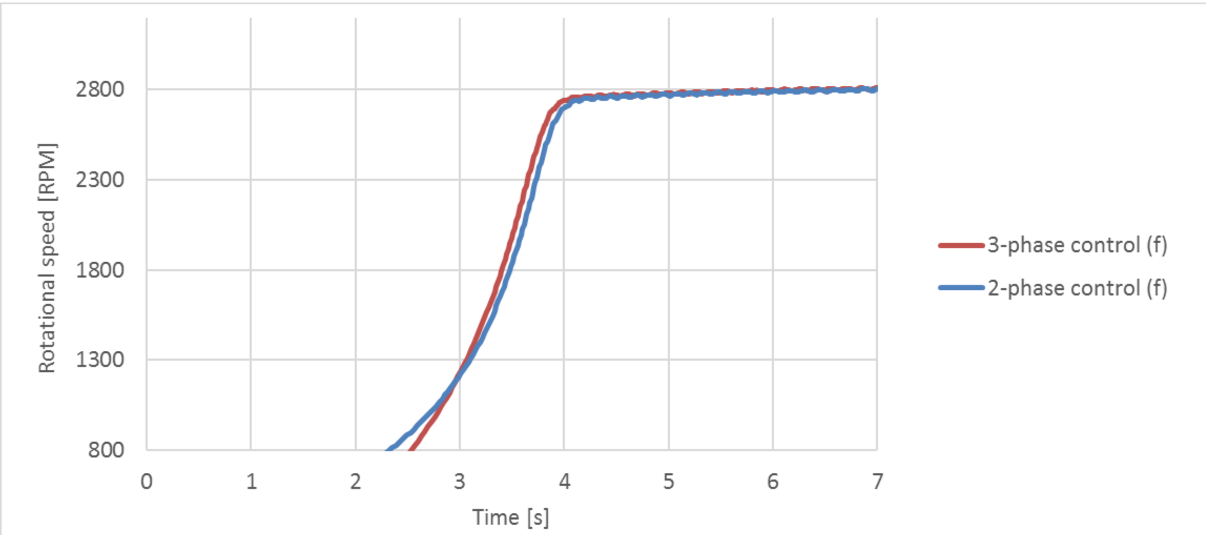


Figure 15: Time-shifted graph for comparison of ramps between 700 and 2800 RPM.

Taken together, when using a regular voltage ramp, the performance from a 2-phase controlled softstarter with DC compensation is the same as a regular 3-phase controlled softstarter. There is a ramp time difference comparing the two, but due to the ramp's shape similarities, the difference in time can easily be eliminated with a 0.5 second time reduction.

To put the comparison into a larger context, the DOL start curve has been added to the speed-time curve.

The DOL acceleration time is four times faster, but that also means that a much higher force is exerted on the application. As shown Figure 16 below, the DOL start is completed after one second, which should be compared to the softstarter starts that are finished after about 4 seconds.

More remarkable is that the maximum acceleration is approximately double as high compared to any of the softstarter technologies. The DOL peaks around 4500 RPM/s, while the softstarters have a maximum value right above 2000 RPM/s. This is visualized in Figure 17 where the accelerations (RPM/s) are plotted for the three ramps.

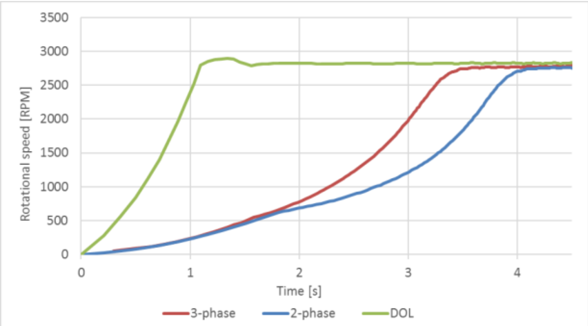


Figure 16: Speed comparison between DOL and the two softstarter technologies with voltage ramp. The DOL start is completed

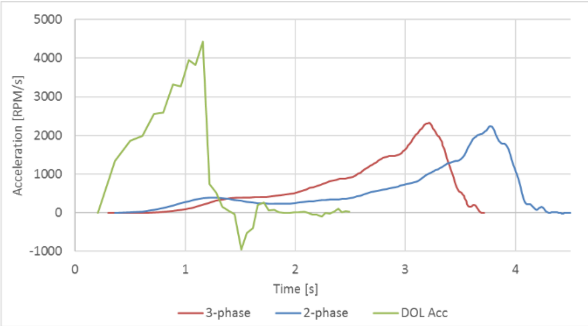


Figure 17: Acceleration comparison between DOL and the two different softstarter technologies with voltage ramp.

5.3 Torque control

Unlike the voltage ramp, torque control is designed to generate a linear torque during the ramp and depending on the load this linear torque can in turn generate a linear speed increase. With a linear speed the acceleration is generally kept at much lower level resulting in a smoother and longer starting ramp. A prolonged ramp is often beneficial for the application, and for the mechanical equipment the lower acceleration is the largest contributor to extended lifetime.

In Figure 18, a comparison between the torque control ramp for 2- and 3-phase controlled softstarters are shown. The same motor and load as for the voltage ramp was used.

Both ramps are perfect. Regardless of the softstarter type the speed increases equally smooth with a close to linear acceleration. The difference in acceleration time between the softstarters is roughly 3 seconds, which originates from the fact that the control algorithms are optimized to control a linear torque rather than an exact ramp time. The same logic applies to any softstarter regardless of control type.

Critical to mention is that from the graph there is no way to determine which of the two that is the best ramp. From a performance standpoint they are equally good; it's the actual application that gives the input needed to fine-tune the parameters for the motor and application behavior.

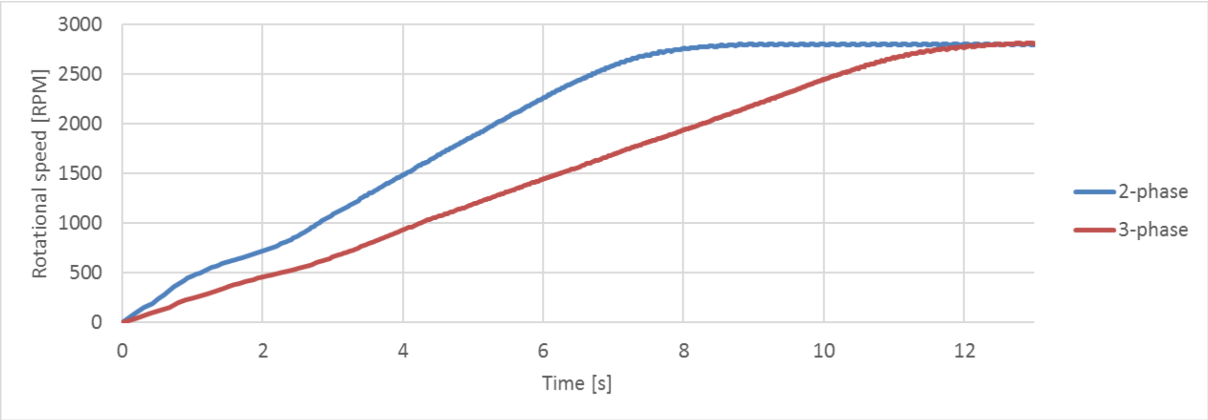


Figure 18: Rotational speed over time with torque ramp with a light load for both 2- and 3-phase controlled softstarters with different acceleration times. Both ramps are equally good but finishes the acceleration at different times.

Every application is different and heavily impacts the acceleration time, so adjusting ramp time is normal procedure for fine-tuning softstarter parameters to the application. In Figure 19 below the torque ramp time for the 3-phase controlled softstarter is reduced with about 3 second. This gives an accurate and easy comparison between the two ramps, and it verifies that the performances are equal.

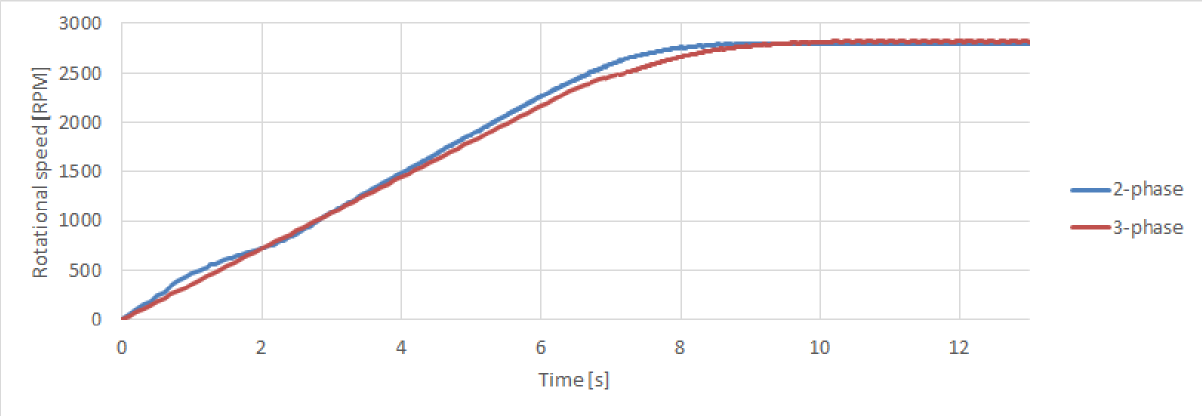


Figure 19: Rotational speed over time with torque ramp with a light load for both 2- and 3-phase controlled softstarters with the same acceleration times. The ramps are equally good: shape profile and acceleartion time coincides.

In Figure 20 below, the accelerations during the starts from Figure 18 above are plotted. Due to the high measurement accuracy and the scale of the figure, the accelerations below might first be interpreted as volatile, but comparing to the voltage ramp it becomes clear that the torque control's peak acceleration is only a third of voltage ramp's: 2100 RPM/s vs. 700 RPM/s.

Even more remarkable is when the same comparison is done between the acceleration of a DOL start from the above figure and the 2-phase controlled softstarter. The DOL start reaches about 4500 RPM/s and the torque control start 650 RPM/s, meaning that the difference is about seven times.

Lastly, worth commenting is the similarities in the acceleration spans and mean values of the two curves in the figure below. The profiles differ due to different ramping time, but both the spans and the mean are close to each other and shows that there is no distinguishable difference when it comes to 2- or 3-phase control.

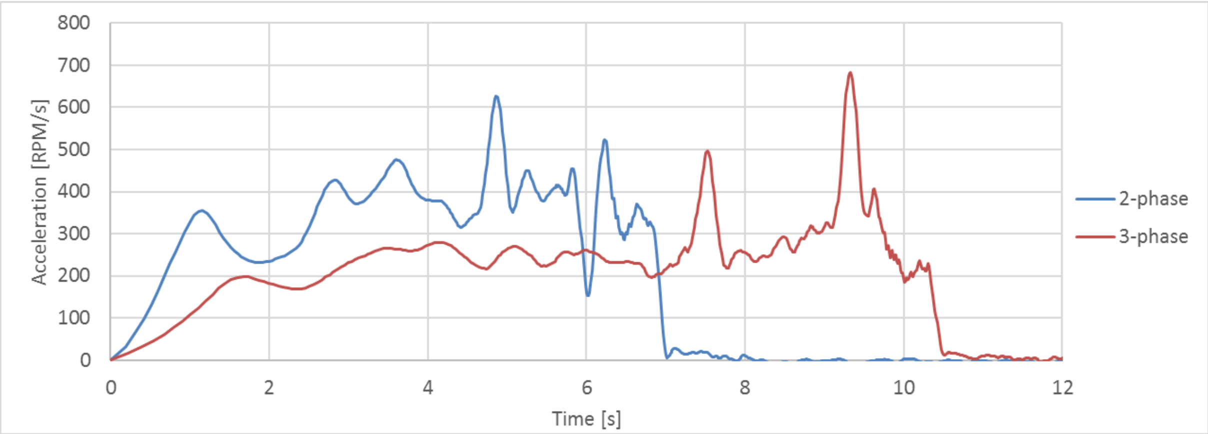


Figure 20: Acceleration comparison between 2- and 3-phase softstarters with torque control for the speed-time curves from Figure **Figure 18** above. Both accelerations are many times lower compared

to previously discussed values. The profile differs but the acceleration ranges and mean values are close.

6 Reliability and Safety

When it comes to product reliability and safety for the comparison between 2- and 3-phase softstarter, there are two main things to consider: single phasing the motor and isolation capability. Except for these topics, due to the product similarities no significant differences in the design of the softstarter types affect other areas that might be of a major concern.

6.1 The impact from thyristor or bypass problems on 2- vs. 3-phase controlled softstarters

6.1.1 Softstarter main circuit topology

When it comes to the product reliability and the impact in case of failure should also be analyzed for 2- and 3-phase controlled softstarters. The components that controls the main power of a softstarter are the thyristors and the bypass, and they are also the most critical parts when it comes to reliability.

If we study the internal schematics of both 2- and 3-phase controlled softstarters, we can understand the potential failures that can occur in a clearer way. In Figure 21, the internal differences between these can easily identified.

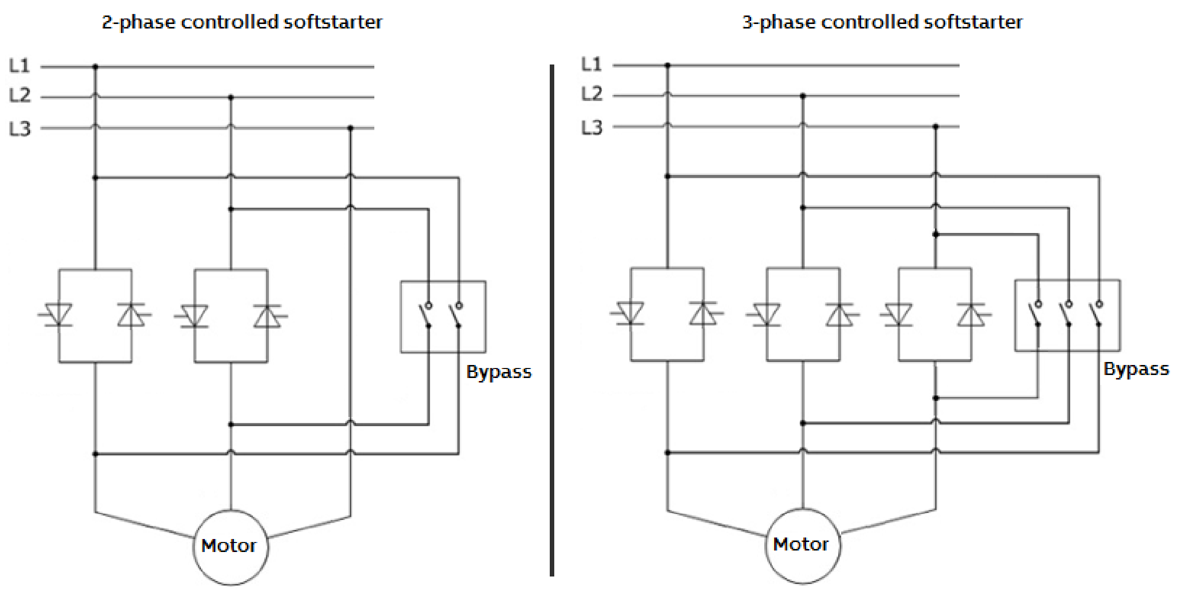


Figure 21: Softstarter main circuit topology comparison between 2- and 3-phase controlled softstarters. To the left two phases can be controlled with the thyristors and the bypass, where the third phase is connected directly to the motor. To the right, all phases can be controlled with thyristors and bypass.

The topology also provides great insight about potential sources of failure. In the 2-phase softstarter, there are 6 different components, 4 thyristors and 2 bypass contacts, that can fail. In the 3-phase softstarter there are instead 9 potential points of failure. For a failure of the 2-phase softstarter would occur, only one of the six components needs to fail the motor since there always is a return path for the current via the directly connected phase. On the other hand, single phasing the motor with a 3-phase softstarter requires two of nine shorted components.

To summarize, the risk of single phasing the motor is higher on the 2-phase softstarter, but since the 3-phase has 50% more points of potential failures, the total risk disparity is lower than expected. But what will happen in case one thyristor or bypass gets shorted? How will the system react and what are the consequences?

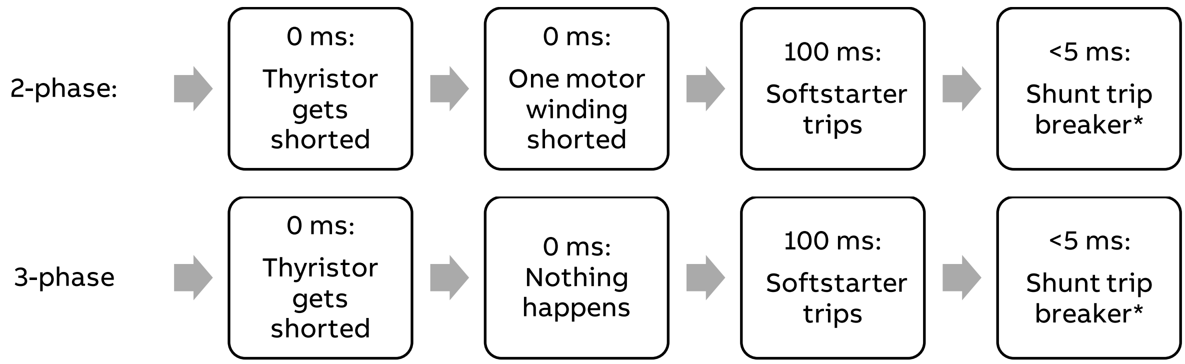
6.1.2 Shorted thyristor or bypass

Shorted thyristors or bypass means that full power to the motor without the ability to stop it without an external device, e.g. a breaker.

There are various reasons why a thyristor can get shorted, but the most common are due to overheating or a too high current, such as a system short circuit. High current or voltage, wear & tear, and low supply voltage are all reasons why a bypass can become welded. Regardless of the reason why, for most softstarters a shorted thyristor or bypass means a stop in production.

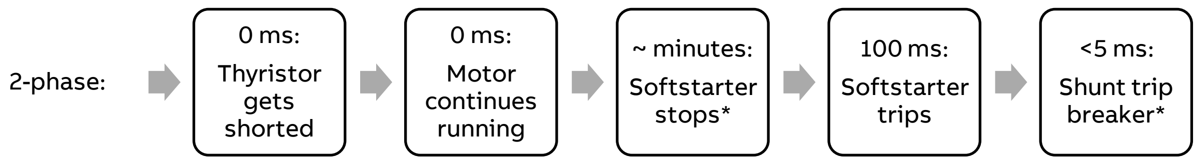
Below, the processes of what happens if a short circuit thyristor occurs during stand still, ramping or in full speed for both 2- and 3-phase controlled softstarters, are described. The shorted thyristor can also be a shorted bypass contactor; the same logic applies.

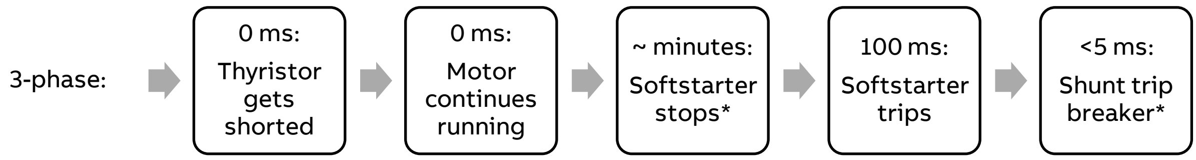
During stand still or ramp



** Shunt trip breaker, line contactor, manual motor starter or other disconnecting means to open the circuit and cut the power. Time depends on breaking device and overall system design.*

During full speed





** Since the voltage over the thyristor during full speed is zero, the softstarter can't detect shorted thyristor in full speed. Detection will first occur after stop signal, or at next start.*

Assuming that the electrical cabinet is designed in accordance with proper safety standards, the two above processes impact of any of the discussed failures, for either a 2- or 3-phase softstarter, will be equal. Regardless of the number of thyristors, the result from a shorted thyristor is always the same: first a trip followed by operation shut down by the disconnect device.

It can hence be concluded that there is no difference between the 2- and 3-phase controlled softstarter when it comes to result from a shorted thyristor or bypass.

6.2 Safety aspects

6.2.1 Electrical isolation – definition and product requirement

One common question about motor controller is whether the device is classified as an isolation disconnect, or not. Generally, there are two types of isolations that is important: electrical blocking isolation for the motor and isolation disconnect in combination with service work or other safety measurements.

Electrical blocking

The former, electrical blocking of the motor, means that the motor is not allowed to be run in standby state. Again, Figure 18 above shows the topology of the softstarter power circuit, and as discussed, the thyristors in the controlled phases are in a blocking state during standby. For a 3-phase softstarter there is no closed current path through any of the windings. Consequentially, the uncontrolled phase in the 2-phase softstarter is only conducting during ramping.

Hence, there is no difference between 2-phase and 3-phase softstarters in terms of how they block the current during standby. However, since thyristors are semiconductor-based switches, neither the 2-phase nor 3-phase softstarter can fully electrically isolate downstream equipment.

Isolation disconnect

An isolation disconnect is used to isolate the downstream circuit from electrical power. Prior to service work on equipment in the branch downstream from an isolator, proper safety measurements must be taken, including opening the isolator. Such work could for example involve replacing a broken contactor or repairs of the motor.

The main reason why the electrical circuit should be isolated from the power is to protect the person doing the service work. This means that the requirements of what is classified as an isolation disconnect is strictly defined. A product certified according to IEC/UL60947-1 (and its supporting and relevant standards and sub-standards) must when in “Open” position be able to isolate at a defined and rated withstand voltage and assure that the contacts of the main circuit of the switch gear will remain in open position.

This means that the pole-to-pole (phase-to-phase) and input (line side) to output (load side) isolation must be guaranteed at the products defined withstand voltage. To accomplish this the isolation device must, among other requirements, have a suitable space between contacts or poles to prevent ionization of air in this space. In general, the farther the distance the better isolation.

6.2.2 A motor control device is not an isolator

Most motor control devices are not classified, nor certified, as isolators. To realize the isolator functionality, a breaker with isolation function, a switch- or a fuse-disconnect that is certified according to relevant standards can for example be used.

Now, consider the softstarter that have two types of devices for controlling the main circuit: the thyristors and the bypass. The bypass (either relays or a contactor) and the thyristors are components that controls the main power, but none of them are classified as an isolator. Subsequently, as a whole the softstarter is not an isolator which means that any service work on the load side of the softstarter is not allowed unless an isolator is disconnected and set to open position, and all other proper safety measurements are considered.

6.2.3 Difference between a 2- and 3-phase controlled softstarter when it comes to isolation

The question about the isolation difference between 2- and 3-phase remains. However, since the softstarter isn’t an isolation device the answer is rather straightforward: there is no difference. It is true that there is one phase directly connected to the motor with a 2-phase controlled softstarter, as seen in Figure 21 above, but since no service work or human contact should occur on the load side of any softstarter without proper isolation, there is no difference between the two softstarter types regarding isolation capability.

7 Other comparisons and limitations

In this chapter, a few other positive notes and some limitations are brought up.

7.1 Other comparisons and comments

- **Less components equals less failure**: As a general concept, the fewer components in a product, the lower the risk for failures. Since the 3-phase device has about 50% more components, the risk for failure for a 2-phase device is greatly reduced.

- **A third less of harmonics during start**: During ramping the thyristors are active, and they generate some harmonics. Even though the harmonics generated from a softstarter seldom is a problem, it is still important to mention that a 2-phase softstarter generates one third less compared to the 3-phase softstarter since there is two instead of three thyristors.

- **Less current in the controlled phases**: As mentioned in chapter 3, the current is less in the two controlled phases in a 2-phase softstarter compared to the 3-phase version. This means that the thyristors will be exposed to less current which in turn means lower deterioration and longer life time.

- **Fewer components means smaller footprint:** When the number of major components is third of the 3-phase softstarter, the product footprint is heavily reduced. 2-phase softstarters offers a size down to a third of size of its 3-phase peers.

7.2 Limitations

- **Inside delta:** A softstarter connected inside delta means six leads to the motor, where three is connected to each side of the softstarter. This connection will place the thyristors in series with each other and the motor windings, and with the main circuit phases connected between each thyristor and winding pair (read separate documentation about inside delta for more information). With a 2-phase softstarter, a direct short circuit would be introduced, and the motor would be single phased when connected. Hence, 2-phase softstarters can’t be used with inside delta connection.

8 Conclusions

In this paper research and explanations have been provided to illustrate and clarify the differences between 2- and 3-phase softstarter technology. While there are some differences in applications and specific control mechanisms it has been shown that most of these are not related to the softstarter technology as much as they are to the different control algorithms among different softstarters. When compared to a traditional DOL starting method both 2- and 3-phase technologies show comparable improvements, and both offer similar magnitudes of mechanical and electrical efficiency.

What we can conclude is that what matters most, the performance, reliability and safety aspects of the solutions, do not differ significantly between the two softstarter technologies, and that in most applications the 2-phase softstarter can be used interchangeably with a 3-phase controlled unit.