Hannes Santahuhta

EXAMINING THE USE OF A SOFT-STARTER FOR THE THRUSTER UNIT’S LUBRICATION AND CONTROL PUMP

Electrical Engineering

2016

samk
Satakunnan ammattikorkeakoulu
Satakunta University of Applied Sciences

EXAMINING THE USE OF A SOFT-STARTER FOR THE THRUSTER UNIT'S LUBRICATION AND CONTROL PUMP

Santahuhta, Hannes
Satakunta University of Applied Sciences
Degree Programme in Electrical Engineering
May 2016
Supervisor: Tuomela, Jorma
Number of pages: 32
Appendices: 5

Keywords: thruster unit, soft-starter, lubrication and control pump, current spikes

---

The purpose of this thesis was to examine the use of a soft-starter and its advantages in the thruster unit's lubrication and control pump. It was made as an assignment for Rolls-Royce Oy Ab Rauma. The work included examining the possible use of the soft-starter for the problems found when starting the thruster unit's lubrication and control pump. The problem had been, very high current spikes when starting the pump.

This thesis mainly focused on explaining the thruster unit's lubrication and control pump and different starting methods which leads to examining the soft-starter. Lastly the content presents the final proposal for the use of soft-starter. This thesis concentrates especially on the benefits of the soft-starter, its use with the lubrication and control pump and the methods that apply to that.

The information in this thesis was gathered from the component manufacturers, Rolls-Royce Oy Ab database and from the workers of Rolls-Royce Oy Ab.

PEHMOKÄYNNISTIMEN TUTKIMINEN POTKURILAITTEEN VOITELU JA OHJAUSPUMPUN KÄYTÖSSÄ

Santahuhta, Hannes
Satakunnan ammattikorkeakoulu
Sähkötekniikann koulutusohjelma
Toukokuu 2016
Ohjaaja: Tuomela, Jorma
Sivumäärä: 32
Liitteitä: 5

Asiasanat: potkurilaite, pehmokäynnistin, voitelu ja ohjauspumppu, virtapiikki

---

Tämän opinnäytetyön tarkoituksena oli tutkia pehmokäynnistimen toiminnallisuutta potkurilaitteen voitelu ja ohjauspumpun käytössä. Toimeksiantajana työlle oli Rolls-Royce Oy Ab Rauma. Työssä tutkittiin pehmokäynnistimen mahdollisuutta potkurilaitteen pumpussa ilmeneviin käynnistys ongelmien ratkaisuun. Ongelmana oli suuret virtapiikit pumpun käynnistyksessä.

Aluksi opinnäytetyössä perehdyttiin potkurilaitteeseen, voitelu ja ohjauspumppuun, erilaisiin käynnistystapoihin sekä pehmokäynnistimeen. Lopuksi työssä esitettiin saatu ehdotus pehmokäynnistimen käytöstä. Erityisesti työssä perehdyttiin pehmokäynnistimen tuomiin etuihin ja sen käynnistys/kytkentätapoihin.

Tietoja opinnäytetyöhön kerättiin laitevalmistajilta, Rolls-Royce Oy Ab:n tietokannasta sekä Rolls-Royce Oy Ab:n työntekijöiltä.

ACKNOWLEDGEMENTS

I would first like to thank Rolls-Royce Rauma for the opportunity to write this thesis for their company. I would also like to show my gratitude for all the help and support they have provided me during the past 4 years while I was a Trainee Electrical Designer at their firm. I would like to especially thank, Mikko Knuuti and Sampsa Siivonen for the guidance and direction, they showed me during my position at Rolls-Royce. The work ethic and skills learned at the company will remain with me as I move forward in my career.

Secondly, I would like to thank my college, Satakunta University of Applied Sciences (SAMK), for giving me the opportunity to study my chosen field at their college. The education and skills that I have learned as an Electrical Engineer student over the past four years at the institution, will be the foundation of my future career. I would also like to thank my supervising teacher Jorma Tuomela at SAMK for all the support and assistance he gave me during the creation of this thesis.

CONTENTS

1 INTRODUCTION 6
2 ROLLS-ROYCE OY AB 7
2.1 Rolls-Royce Finland 7
2.2 Rolls-Royce Rauma 7
2.2.1 Azimuth thrusters 8
3 RULES FOR CLASSIFICATIONS 9
3.1 Det Norske Veritas Germanischer Lloyd 9
4 INDUCTION MOTOR STARTING METHODS 13
4.1 Direct-on-line starting (DOL) 13
4.2 Star-delta starting 15
4.3 Soft-starter 16
4.4 Frequency converter 20
5 CONNECTING THE SOFT-STARTER 22
5.1 Direct connection 22
5.2 Delta connection 23
5.3 Location of the main contactor 24
5.4 2- and 3-phase adjustment 25
6 SELECTING A SOFT-STARTER 27
6.1 Existing options 27
6.1.1 Drawing 7362768 27
6.1.2 Drawing 7363013 28
6.1.3 Drawing 7360716 29
7 CONCLUSION 30
REFERENCES 31
APPENDICES 33

1 INTRODUCTION

The intention of this thesis was to examine the use of a soft-starter in the thruster unit's lubrication and control pump. This thesis was assigned by Rolls-Royce Rauma, to explore and research the usage of the soft-starter in an existing issue. The thesis was written in English as it is the most primarily used language within Rolls-Royce. I also wanted to demonstrate my own improved fluency in the English language as part of my degree programme.

The issue mentioned above was the recurrent problem of too high current spikes in the lubrication and control pump when the motor was re-started with all the other equipment running simultaneously. This in some cases can cause major problems on the old vessels that in recent years were updated and more equipment had been installed. This has caused the current consumption to rise. During trial runs, vessels were left completely out of power. As a result of the loss of power, this could lead to the vessel drifting dead at sea.

Due to this malfunction in the thruster unit's lubrication and control pump in older vessels, the soft-starter was evaluated as a possible solution to the existing issue described above. Therefore, this thesis will analyze the use of the soft-starter in the thruster unit's lubrication and control pump with the aim of providing knowledge of the soft-starter's, best suited to rectifying the current spike problems.

2 ROLLS-ROYCE OY AB

Rolls-Royce has a world-leading range of capabilities in the marine market, encompassing the design, supply and support of power and propulsion systems for offshore oil and gas, merchant and naval vessels.

Right now they have some 650 Rolls-Royce designed and equipped vessels operating in the offshore oil and gas sector. And they have a significant presence in the naval market, powering 70 navies worldwide. All told, Rolls-Royce has 2,500 marine customers and equipment installed on over 30,000 vessels. (Rolls-Royce web-pages, 2016)

2.1 Rolls-Royce Finland

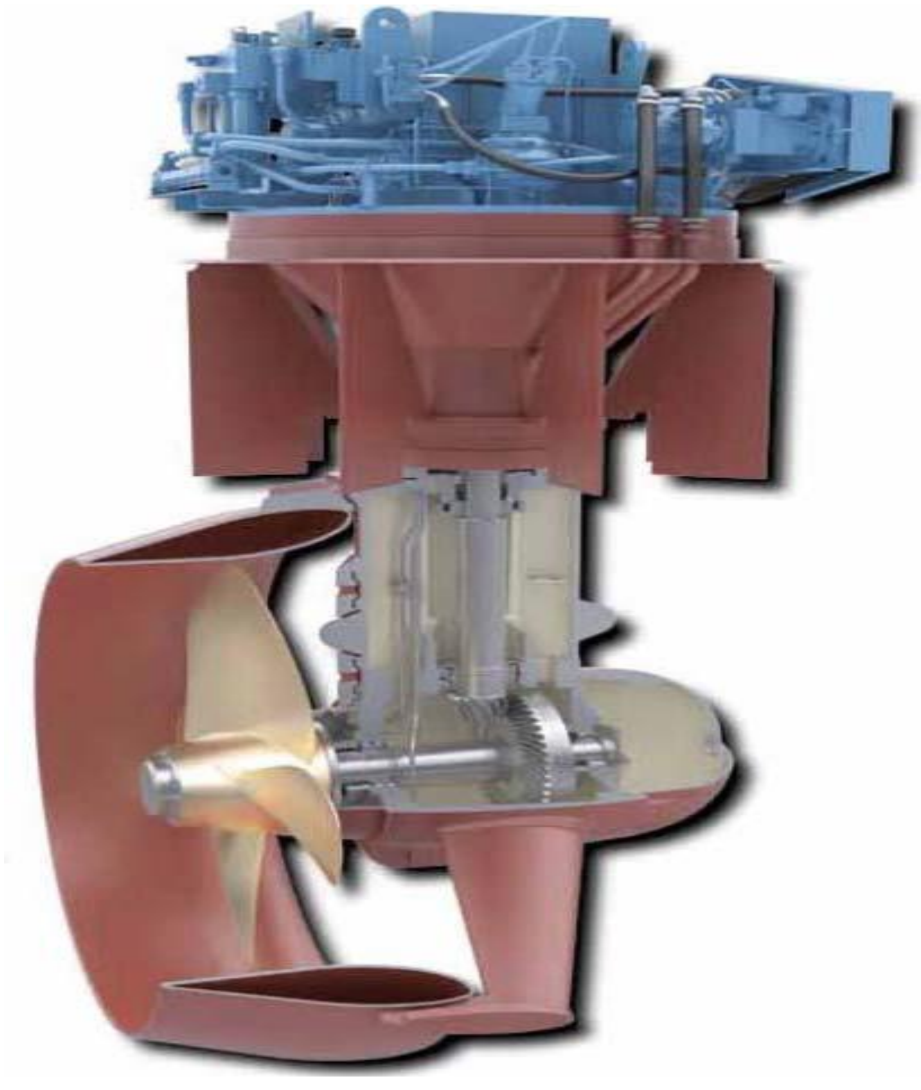
In addition to their sales office in Helsinki, Rolls-Royce has factories in Rauma Kokkola, where they design, market, and manufacture marine equipment. Our production selection in Finland includes azimuth thrusters, winch systems and water jets for variety of vessel types. Rolls-Royce employs 600 people in Finland, all whom enjoy an exciting, challenging and friendly working environment. Every role requires different qualities, but they particularly value reliability, foreign language skills and the ability to collaborate well with others. (Rolls-Royce web-pages, 2016)

2.2 Rolls-Royce Rauma

Rolls-Royce is the world’s leading manufacturer of azimuth thrusters. These can perform both the propulsion and steering duties for a vessel. In Rauma the majority of their workforce is involved in producing azimuth thrusters, mainly for use on offshore vessels, tugboats and ferries. Their azimuth product range covers the power spectrum from 300kW to 7,500kW. The Rauma facility also manages a range of anchoring, mooring and towing winch systems. In 2016, Rolls-Royce Rauma site employes about 450 people and 99% of the production is exported. The company’s turnover in 2014 was 614M€. (Seasideindustry web-pages, 2016; Kauppalehti web-pages, 2016)

2.2.1 Azimuth thrusters

Rolls-Royce is a global leader in the supply of azimuth thrusters. In an azimuth thruster the propeller rotates 360° around the vertical axis so the unit provides propulsion, steering and positioning thrust for superior maneuverability. Designs have been developed for propulsion and dynamic positioning in response to market requirements. As a result, there is a design available to suit virtually any application. Simple and robust construction provides high operational reliability together with simple maintenance for low through life costs. Units can be supplied for diesel or electric drive together with a remote control system. Rolls-Royce has a big range of different thrusters from a normal US type thruster to Swing-up/combi type. (Rolls-Royce web-pages, 2016)



Picture 1. Here you can see the Rolls-Royce Azimuth Thruster (US Type). (Rolls-Royce company presentation 2014)

3 RULES FOR CLASSIFICATIONS

3.1 Det Norske Veritas Germanischer Lloyd

All electrical equipment serving essential or important functions shall be delivered with DNV Product Certificate or DNV Type Approval Certificate as required, see Appendix 5. (DNV GL Pt.4 Ch.8 Sec.1 B301 2011)

There shall be component redundancy for main sources of power, transformers and power converters in the main power supply system so that with any source, transformer or power converter out of operation, the power supply system shall be capable of supplying power to the following services:

- those services necessary to provide normal operational conditions for propulsion and safety
- starting the largest essential or important electric motor on board, except auxiliary thrusters, without the transient voltage and frequency variations exceeding the limits
- ensuring minimum comfortable conditions of habitability which shall include at least adequate services for cooking, heating, domestic refrigeration (except refrigerators for air conditioning), mechanical ventilation, sanitary and fresh water
- for a duplicated essential or important auxiliary, one being supplied non-electrically and the other electrically (e.g. lubricating oil pump No. 1 driven by the main engine, No. 2 by electric motor), it is not expected that the electrically driven auxiliary is used when one generator is out of service
- For dead ship recovery. (DNV GL Pt.4 Ch.8 Sec.2 B101 2011)

Each motor shall normally be provided with at least the following control gear, functioning independent of control gear for other motors:

- each motor rated 1 kW or above: a multipole circuit breaker, fused circuit breaker or contactor, with overcurrent release, if necessary combined with a controller for limiting the starting current. (DNV GL Pt.4 Ch.8 Sec.2 H401 2011)

Electrical parameters

- Unless otherwise clearly stated by the purchaser, equipment shall be rated for continuous duty.
- All accessories shall be of such size as to be capable of carrying, without their respective ratings being exceeded, the current which can normally flow through them. They shall be capable of carrying anticipated overloads and transient currents, for example the starting currents of motors, without damage or reaching abnormal temperatures. (DNV GL Pt.4 Ch.8 Sec.3 C101 2011)

Harmonic distortion

- All equipment shall be designed to operate at any load up to the rated load, with a supply voltage containing the following harmonic distortion:
  - total harmonic content not exceeding 8% of voltage root mean square value
  - no single harmonic being greater than 5% of voltage root mean square value (DNV GL Pt.4 Ch.8 Sec.3 C103 2011)

Electromagnetic compatibility (EMC)

- Equipment producing transient voltage, frequency and current variations shall not cause the malfunction of other equipment on board, neither by conduction, induction or radiation. (DNV GL Pt.4 Ch.8 Sec.3 C105 2011)

Maximum operating temperatures

- The temperature rise of enclosures and their different exterior parts shall not be so high that fire risk, damage to the equipment, adjacent materials or danger to personnel occurs. The temperature rise shall not exceed 50°C. Exemptions may be considered for equipment that is especially protected against touching or splashing of oil. (DNV GL Pt.4 Ch.8 Sec.3 C200 2011)

Mechanical strength

- Equipment shall have sufficient mechanical strength to withstand the strains they are likely to be exposed to when installed. (DNV GL Pt.4 Ch.8 Sec.3 D101 2011)
- Enclosures shall be resistant to weather, oil and chemicals and have sufficient mechanical strength when intended to be installed in an area where risk of mechanical damage exists. (DNV GL Pt.4 Ch.8 Sec.3 D102 2011)
- Electrical equipment shall be constructed of durable non-hygroscopic materials which are not subject to deterioration in the atmosphere to which it is likely to be exposed.
- Electrical equipment shall be constructed of at least flame retardant materials. (DNV GL Pt.4 Ch.8 Sec.3 D103 2011)

Cooling and anti-condensation

- Where electrical equipment depends on additional cooling, the following shall be complied with:
  - an alarm shall be initiated when auxiliary cooling or ventilation motors stop running. Alternatively, a flow monitoring alarm shall be initiated.
  - the windings in the cooled equipment for essential services shall be equipped with temperature detectors for indication and alarm of winding temperature.
  - the windings in the cooled equipment for important services shall be equipped with temperature detectors for alarm at high winding temperature.
- Where the cooling of electrical equipment depends upon general room ventilation only, temperature detectors in the equipment are not required. (DNV GL Pt.4 Ch.8 Sec.3 D201 2011)

System operation and maintenance

- Start-ups and restarts shall be possible without specialized system knowledge. On power-up and restoration after loss of power, the system shall be restored and resume operation automatically.

- Testing of essential systems and alarm systems shall be possible during normal operation. The system shall not remain in test mode intentionally, and an active test mode shall be clearly indicated on the operator interface. (DNV GL Pt.4 Ch.9 Sec.3 B100 2011)

Additional requirements for computer based systems

- Where a computer based system is part of an essential function, back-up or emergency means of operation shall be provided, which to the largest extent possible shall be independent of the normal control system, with its user interface. (DNV GL Pt.4 Ch.9 Sec.4 A200 2011)

4 INDUCTION MOTOR STARTING METHODS

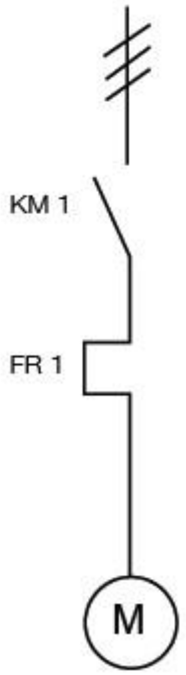
Next we look briefly at the most common ways to start the induction motors. This section will provide a short summary of the benefits and problems when the motor is started in these ways.

From the moment the first electrical motor was developed, electrical and mechanical problems have been occurring when starting the motor. Problems arise when high inrush current and current spikes as well as excessive mechanical wear exists. Traditional way to avoid these problems is to use a star delta starter. This method is used in many applications insufficient, as problems with current spikes and torque peaks will remain. Also, this method does not provide any way to perform a soft stop if it is needed. On the other hand, a soft-starter will provide far better performance during the start-up and also the possibility to soft stop the motor. (ABB web-pages)

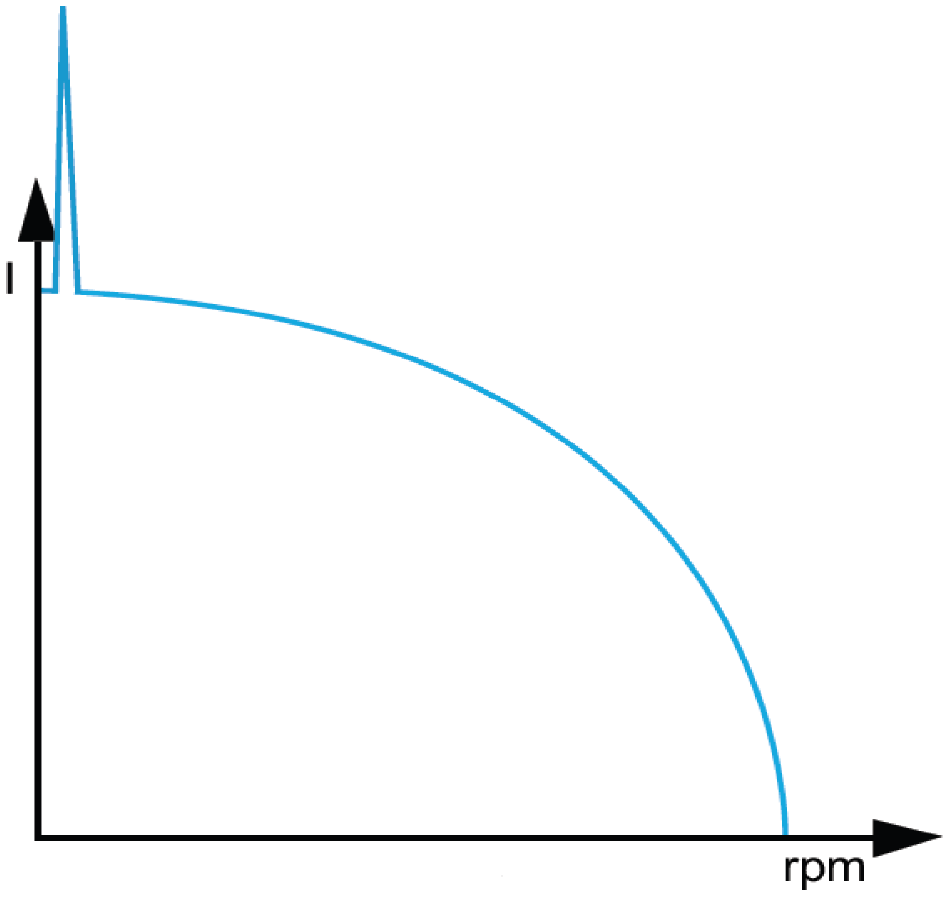
4.1 Direct-on-line starting (DOL)

This is the most common way for the motor start-up, because it is small in size and an easy solution for start-up. The starting equipment consists of only a main contactor and thermal or electronic overload relay. The disadvantage of this method is that the start-up current is the highest possible. The normal value for the starting current is 6-8 times the rated motor current however, the values can reach up to 10 times the rated current.

During a direct start-up, the starting torque is very high and is usually unnecessary for most applications. This causes an unnecessarily high burden on driving belts, couplings and driven equipment. Naturally, there are cases where this starting method works very well and no other start-up methods are needed. If the motor has a direct way to start, the only way to stop the motor is a direct stop. (ABB web-pages)



Picture 2. Direct start-up schematic (ABB web-pages)

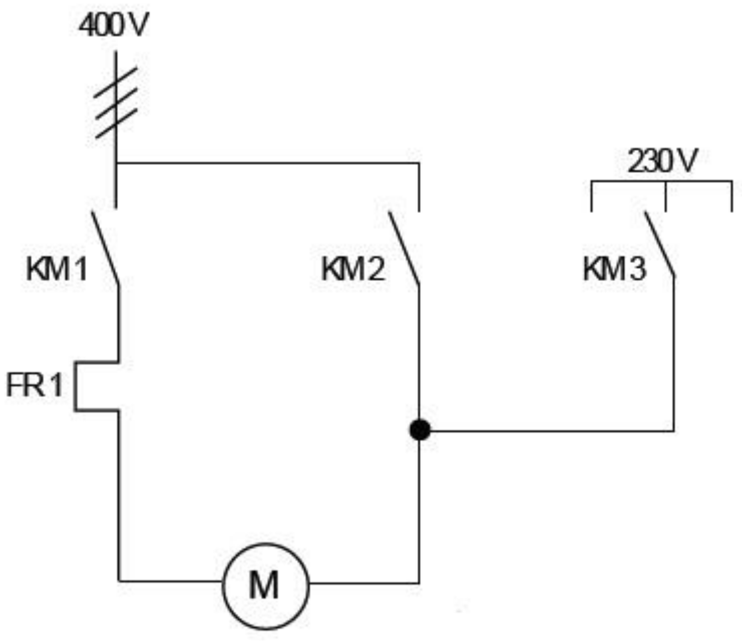


Picture 3. Current graph for DOL start-up (ABB web-pages)

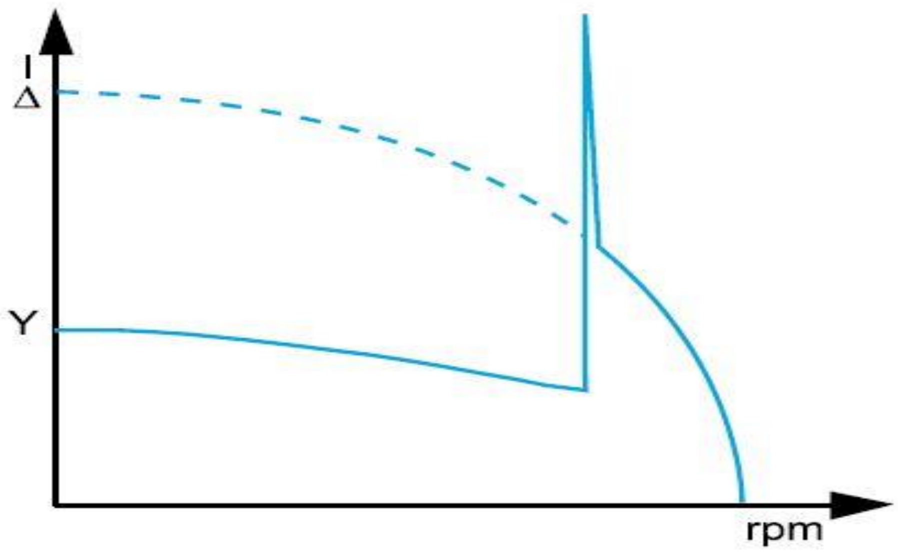
4.2 Star-delta starting

Star-delta starter normally consists of three contactors, an overload relay and a timer. This starting method requires that the motor is in the continuous use of delta connection. The basic idea of delta starting is that during the first phase of the acceleration, the motor windings are at star connection and producing lower current. After a predetermined time, the connection is changed to the delta connection which gives full power and full torque. As result, the star connection has 33% current compared to the delta connection.

The biggest problem with star-delta starting occurs, for example, when starting the pumps. The motor will accelerate to about 80-85 per cent of the rated speed before the load torque is equal to the motor torque and the acceleration stops. To achieve its rated speed, it requires a transition to the delta connection. This transfer often results in high transmission and current spikes. In some cases, the power peaks are even higher than those in direct starting. As in direct start-up, the only way to stop star-delta is a direct stop. (ABB web-pages)



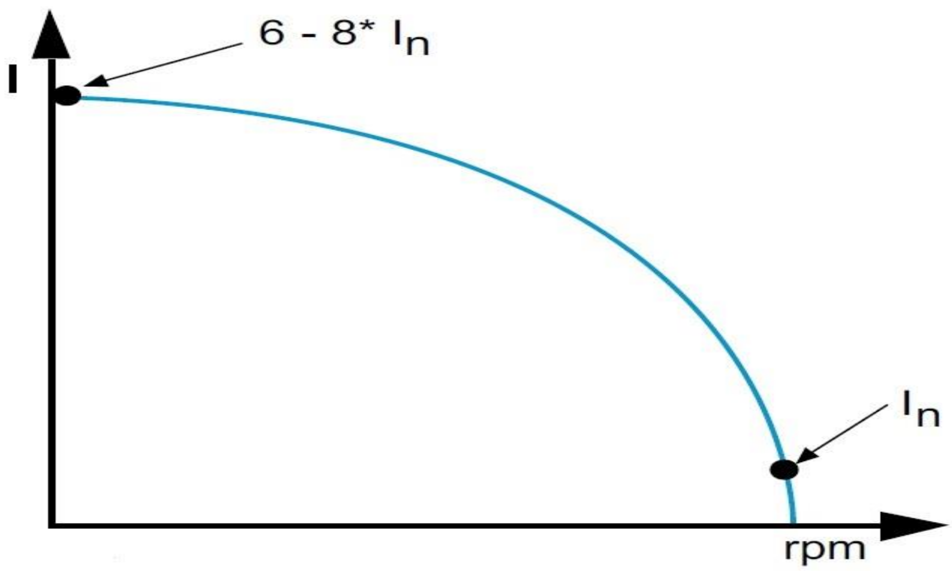
Picture 4. Star-delta start-up schematic (ABB web-pages)



Picture 5. Current graph for Star-delta start-up (ABB web-pages)

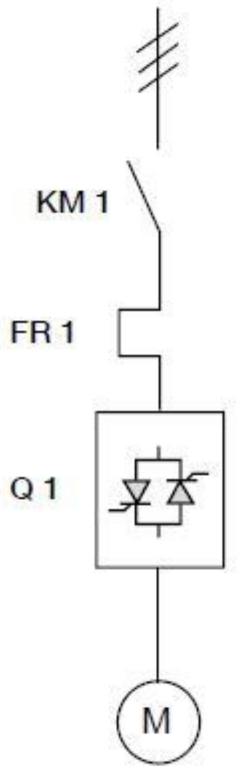
4.3 Soft-starter

The typical scenario where the soft-starters are used in motors are in conveyors, pumps, blowers, and compressors of all sizes. They all have one common quality; they take a large amount of current when they are started. Normally the motor without the soft-starter takes 6-8 times its rated current at the start-up, but it may be in some cases up to ten times. This is clearly seen in the next picture where the start-up takes up to 6-8 times the rated current. (ABB web-pages)



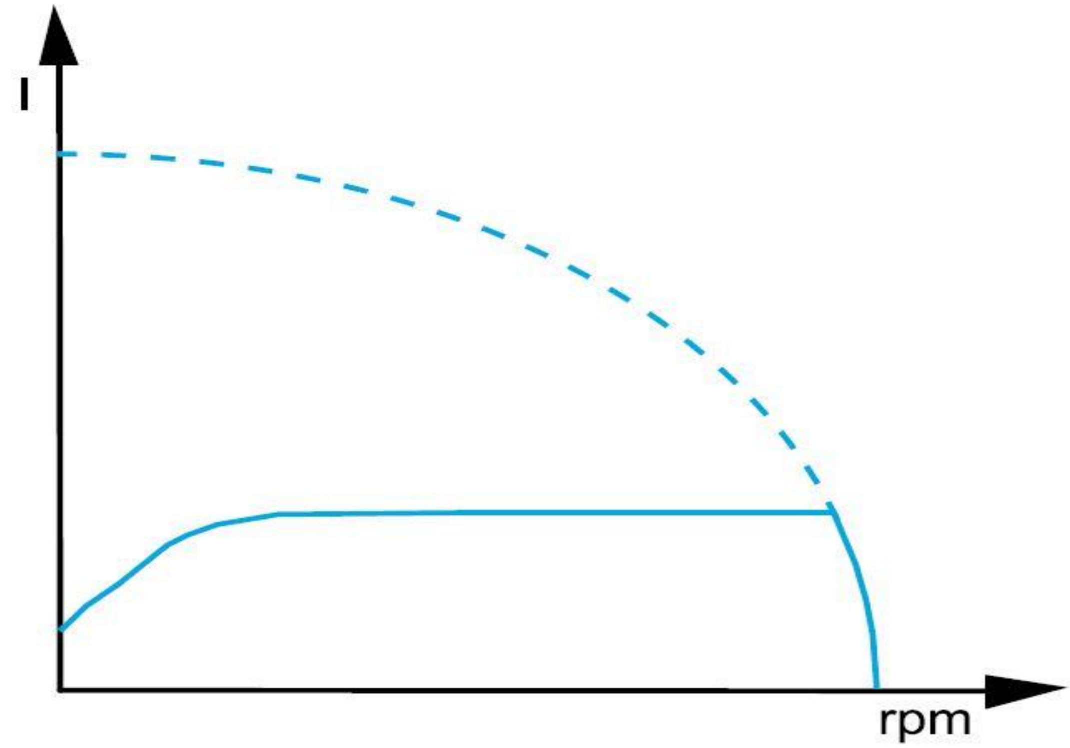
Picture 6. Current taken at start-up. (ABB web-page)

The idea behind the soft-starter is to gradually allow the motor current to rise until the motor reaches its steady state. With this, the current at start-up is reduced but it also reduces the motors start-up torque. The soft-starters adjust the motor voltage with the use of back-to-back thyristors or triacs in each ac supply line to the motor. The thyristors actuated during the start-up phase is such that their turn-on is successively delayed less by each ac half cycle. The delayed switching ramps up the average ac voltage effectively to the motor until the motor exceeds full voltage. Once the rated speed is reached in the motor, the thyristor circuit may be bypassed. From the picture below you can see how the two thyristors are used per one phase to make the soft-start. (ABB web-pages)

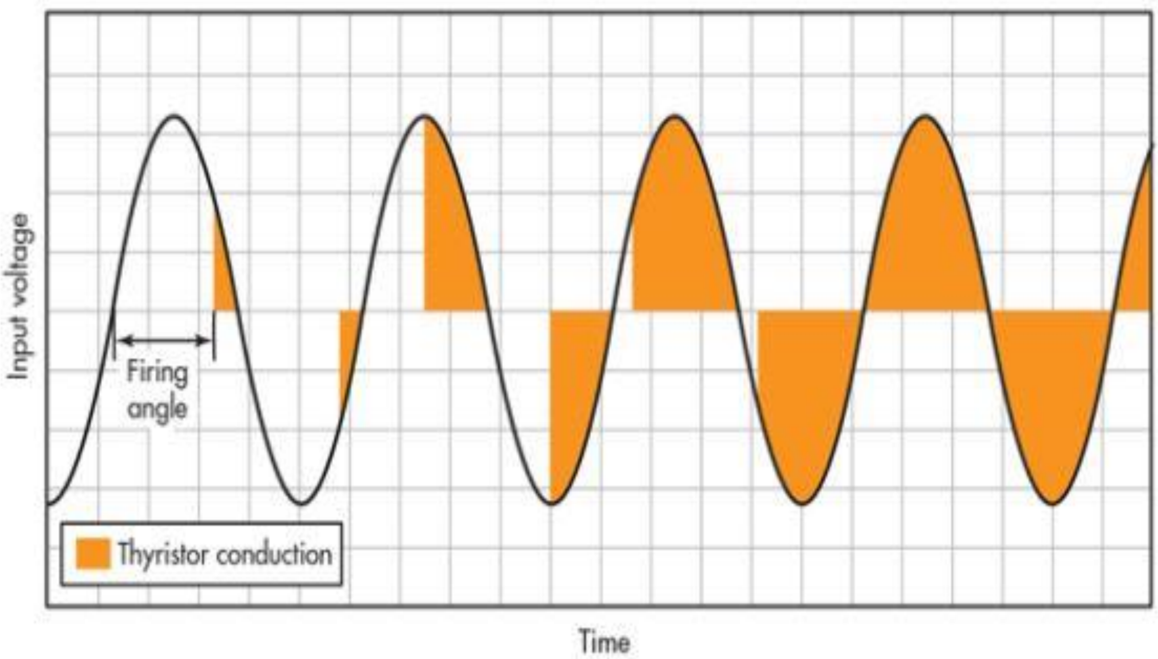


Picture 7. Soft-starters start-up schematic. A soft-starter has thyristors in its main circuit by which it adjusts the motor voltage. (ABB web-pages)

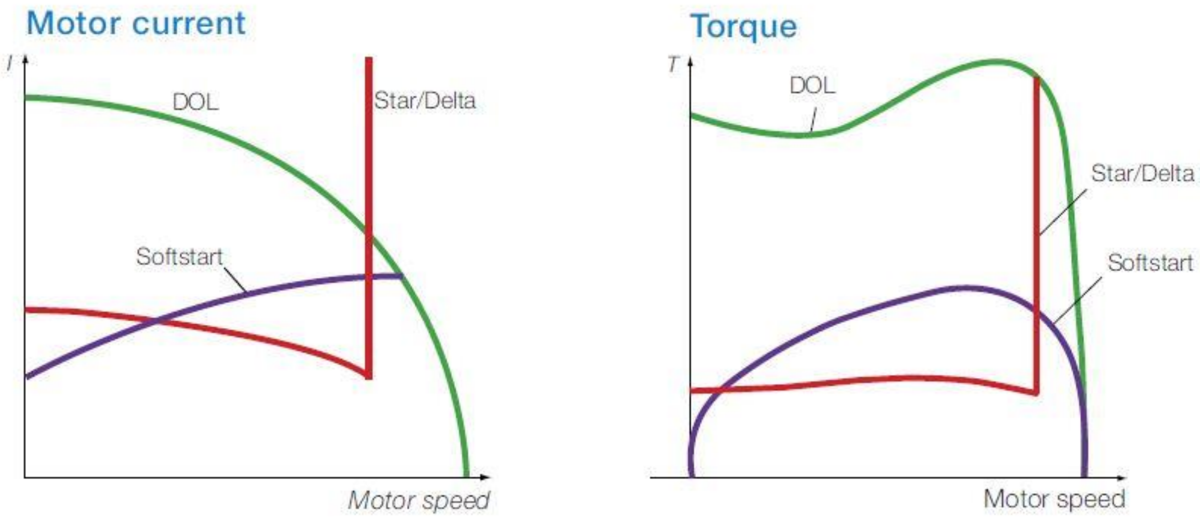
After the soft-starter is installed and is in use, it can be used as a frequency converter. It is capable to do the soft-start and soft-stop. Using the soft-starter, reduces starting current, starting torque and the stress on the mechanical components, which therefore, reduces the need for service and maintenance. (ABB web-pages)



Picture 8. Graph showing the starting current when using the soft-starter. (ABB web-pages)



Picture 9. Thyristors in the soft-starter let part of the voltage through at the beginning of the starting sequence and gradually increases it according to the set ramp time. The thyristors can also typically implement a soft-stop by reducing the motor voltage according to a set ramp time. (Machinedesign web-pages)



Picture 10. These graphs show the basic difference between direct-on-line starting (DOL), star-delta starting and soft-starting in terms of the motor current (I) and motor torque (T) (ABB web-pages)

Depending on how the AC motor is installed, unnecessary and unwanted torque and current spikes become an everyday problem with motor start-ups all over the world. This causes damage in multiple ways. These damages are as follows:

- Electrical problems due to voltage and current transients arising from Direct-On-Line or Star-Delta starts. Such transients may overload the local supply network and cause unacceptable voltage variations that interfere with other electrical equipment connected to the network.
- Mechanical problems that address the entire drive chain, from the motor to the driven equipment. As a result, this causes an increased need for additional service and repair, as well as unwanted down time.
- Operational problems, such as damage to products on conveyor belts.
- Water hammering and pressure surges in pipe systems when starting and stopping pumps.

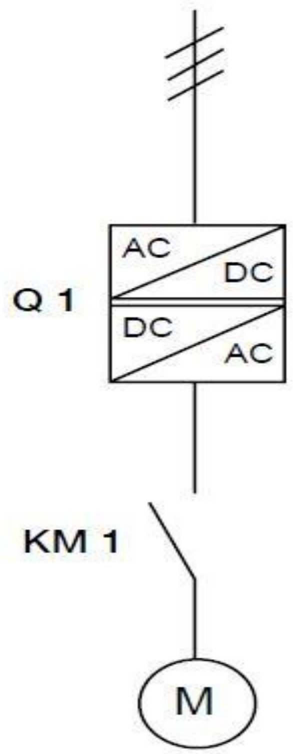
The financial costs are considerable; every technical problem and every breakdown costs money in terms of repairs as well as lost production due to down time. (ABB web-pages)

4.4 Frequency converter

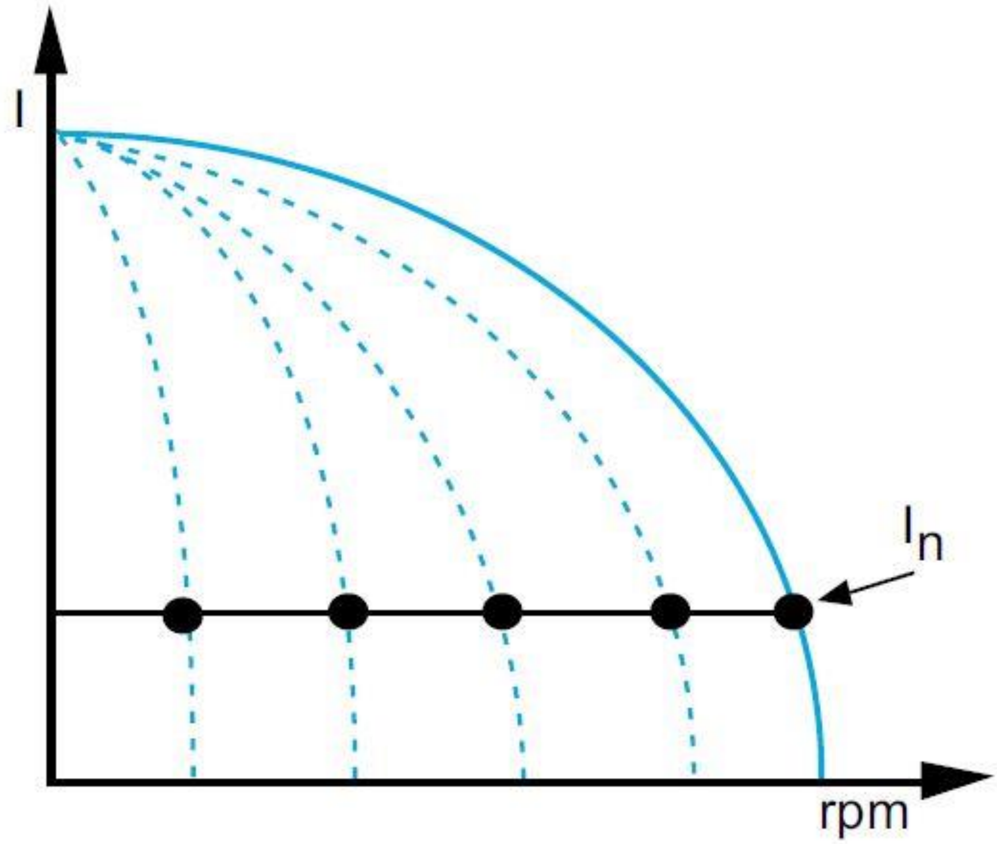
The frequency converter has two parts, one which converts Alternating current (AC) (50 or 60 Hz) to the Direct current (DC) and the other converts the DC back to AC. Frequency after the conversion may vary between 0-250 Hz. By adjusting the frequency, the frequency converter can adjust the speed of the motor.

During the start-up the frequency converter increases the frequency of zero Hz to the network frequency (50 or 60 Hz). When the frequency is increased gradually, the motor can be thought to run at the rated speed at the respective frequency. Since the motor can be thought of running at the rated speed, the motors rated torque is available right from the beginning of the start-up, and the current is approximately equal to the rated current. Normally, the frequency converter trips if the current exceeds the rated current of 1,5.

When the frequency converter is used to adjust the motor, the soft stop is possible. This is especially useful in stopping the pumps to prevent water hammering causing problems and it may also be useful for the belt conveyors. (ABB web-pages)



Picture 11. Frequency converter start-up schematic (ABB web-pages)



Picture 12. Current graph for Frequency converter start-up (ABB web-pages)

In many applications, the motor’s speed must be regulated continuously, in which the frequency converter is a very good solution. However, in many applications the frequency converter is used solely for starting and stopping the motor, even if the continuous regulation of the speed is not necessary. In this case, the solution is unnecessarily expensive, for example, when compared to the soft-starter.

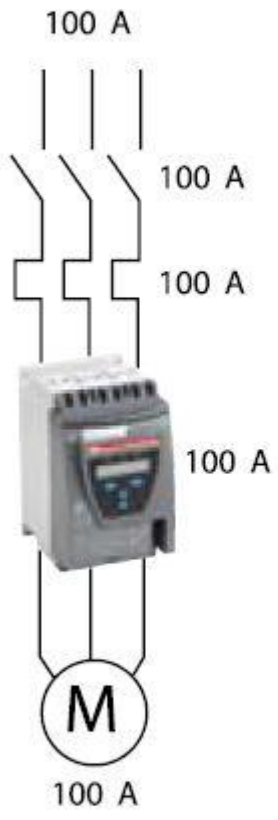
When comparing the soft-starter and the frequency converter, the frequency converter is physically larger and requires more space so that in many cases it is not possible to use. The frequency converter is also heavier than soft-starter, making it less suitable option for example, in ships, where weight and space is important. In addition, since the frequency converter changes the frequency and generates a sine wave, it will cause harmonics. The problems are reduced by using filters and shielded cables, but normally the harmonics cannot be eliminated completely. (ABB web-pages)

5 CONNECTING THE SOFT-STARTER

The soft-starter can be connected in two different ways: a direct connection, which is the most common method, and delta connection. The delta connection however, is not always suitable for all soft-starters.

5.1 Direct connection

Direct connection is the most common and the easiest way to connect the soft-starter. All three phases are connected in series with overload relay, the main contactor and other devices as shown in the picture below. In the direct connection, the equipment must be selected in such a way that they can withstand the full rated current of the motor. The motor itself may be a star or delta connection. For example: 100 ampere motor requires a 100 ampere soft-starter, 100 ampere main contactor etc. (ABB web-pages)



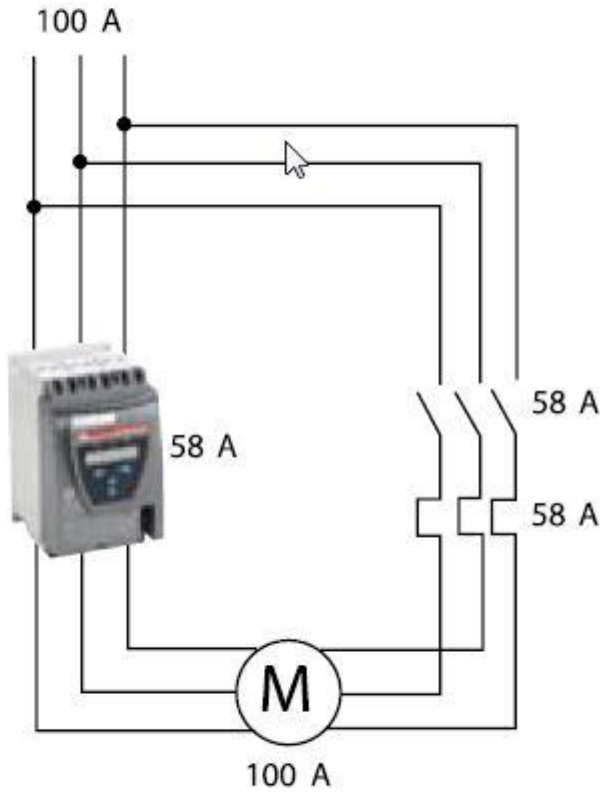
Picture 13. The soft-starter in direct connection with the motor (ABB web-pages)

5.2 Delta connection

With the delta connection, the soft-starter can be placed in the delta circuit, in which case it can be easily replaced by the star-delta starter. When the soft-starter is inside the delta connection, it only receives 58% ($1 / \sqrt{3}$) of the direct connections current. It is therefore possible to save costs by choosing smaller devices.

All the functions are the same regardless of whether the connection is in the direct or delta connection. The difference is that in the delta connection, between the soft-starter and motor, 6 cables are required. If the distance is long, a direct connection may be a cheaper solution.

Example: As in the picture below shows, a 100 ampere motor requires a 58 ampere soft-starter, 58 ampere main contactor for the triangle circuit etc. (ABB web-pages)



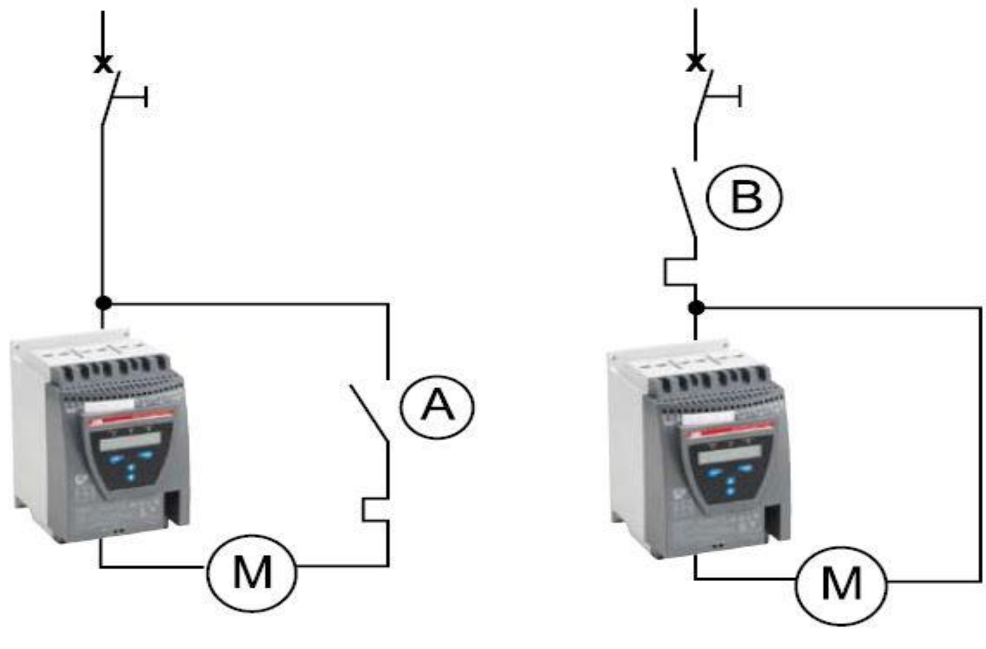
Picture 14. The soft-starter in the delta connection with the motor (ABB web-pages)

When the soft-starter is inside the delta connection, the motor must be able to delta-connect while running continuously. In the United States and some other countries, a special six-wire motor has to be ordered for this type of connection. The Soft-starter, which controls the voltage only in two phases out of three, cannot be used in the motors three phased triangle circuit.

5.3 Location of the main contactor

When using a soft-starter inside the delta connection, the main contactor can be placed in two ways: in the delta circuit or outside of it. In either case, the motor will stop, but in the alternative A, the motor is still considered to be live. In alternative B, the main contactor should be selected according to the motors rated current, while in the alternative A, the contactor will only receive 58% (1 / √3) of the motors rated current.

Despite the location of the main contactor, its classification has to be AC-3 with the current in question. This is to allow it to cut the power off and to stop the motor in case of an emergency. (ABB web-pages)

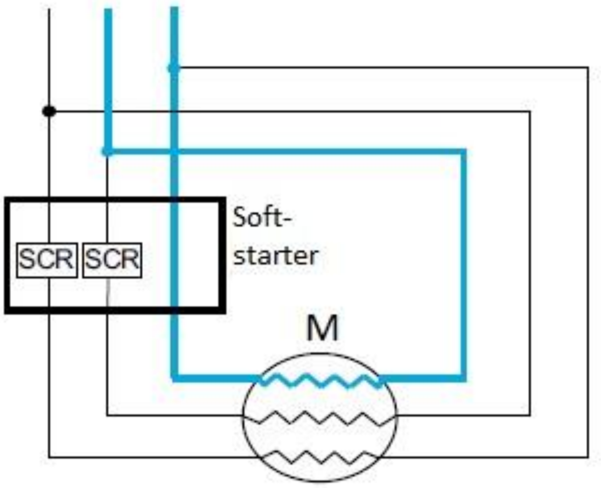


Picture 15. In alternative A, the main contactor is inside the delta connection and in alternative B, it is outside of the delta connection. (ABB web-pages)

5.4 2- and 3-phase adjustment

Normally in the soft-starter, 6 thyristors (two facing each other in all three phases) are used to adjust the motors output voltage. In order to reduce the number of parts and to minimize the soft-starters size, the 2-phase control is a possible solution. In this solution, only the third phase passes through a soft-starter without adjusting the voltage or the current. The 2-phase controlled soft-starter works as well as the 3-phase controlled soft-starter, with a few exceptions described.

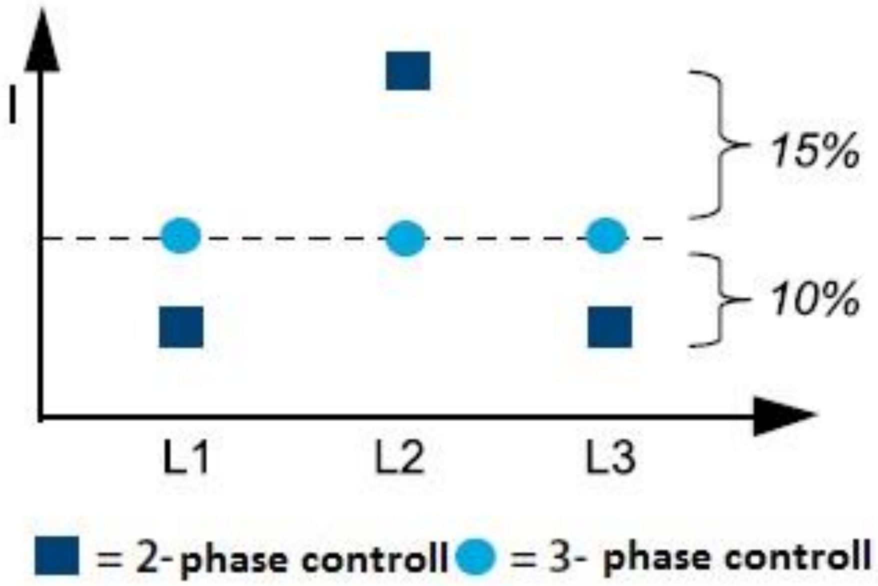
Delta connection is not possible because the soft-starter does not control one phase. The current of this phase passes through the starter without giving the start signal to the soft-starter. In this case, the motor will not start, but heats up and eventually gets damaged. This increase in temperature can be avoided with the main contactor in standby mode. However, the current does not decrease at the start-up which diminishes the main advantage of the soft-starter reducing the current. (ABB web-pages)



Picture 16. The 2-phase controlled soft-starter schematic (ABB web-pages)

Some of the 2-phase controlled soft-starters create a DC-component. When up and down ramping is controlled with only two phases, the DC-component is generated, which has a braking effect that weakens the torque. The result is a very noisy and a poor start. Only a very few 2-phase controlled soft-starters have the DC-component removing advanced algorithm. This algorithm is necessary if 2-phase controlled soft-starters are to be used with large motors. (ABB web-pages)

When using 3-phase controlled soft-starters, the start-up current can be balanced between all three phases. When the 2-phase controlled soft-starter is used, the current of the uncontrolled phase is greater than the current in other phases. This affects it so that the maximum current (in one phase) is greater in the 2-phase controlled soft-starter than in the 3-phase controlled soft-starter. This imbalance of the current occurs momentarily while in start-up and shut-down. During the continuous run the current will be balanced. (ABB web-pages)



Picture 17. The balance between 2-phase and 3-phase controls. (ABB web-pages)

2-phase controlled soft-starter is a good solution and works well:

- in most normal applications
- in all types of equipment
- when torque control is required
- with normal or heavy-duty start-ups
- and when small and cost-effective solution is needed

3-phase controlled soft-starter is more recommended when:

- the lowest possible starting current is required
- delta connection is required
- unbalanced load during the start-up and shut-down causes problems (ABB web-pages)

6 SELECTING A SOFT-STARTER

Selecting the right soft-starter for every case is hard and will take a lot of time and consideration. Every case and every vessel is different which makes the research difficult. Some pumps are bigger than others and some are smaller which is important to know when choosing the soft-starter in each case. Connecting the soft-starter to the system with various methods needs to be considered carefully since all the starting methods are not possible in all the cases.

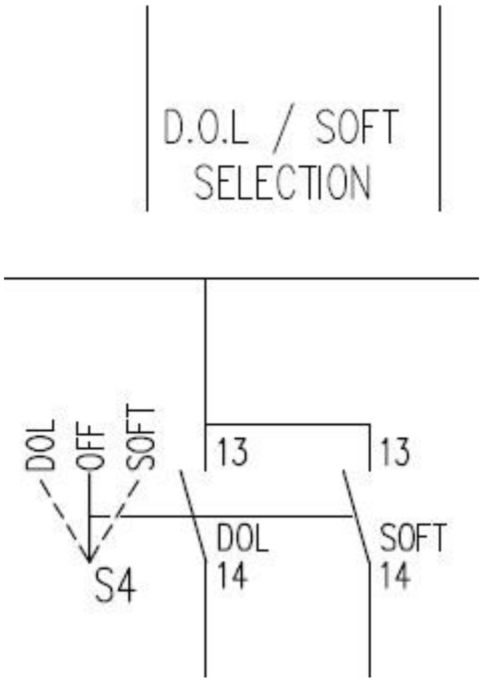
Problems occur when adding new technology and starting methods to the old installations with or without the old wirings and components. Old vessels and old installations make its own restrictions to the new installations. For example, the old electrical cabinets have their limited space, see appendix 4, for new components and new big size soft-starters cannot be fitted. New and bigger cabinet could be an option in some cases but it would make unnecessary extra costs and work to the company and its customer. Therefore, to find the best and the most cost-effective solution for the problem is highly important.

6.1 Existing options

There is already existing drawings and installations in some cases which I will go through in this section. Some of them have worked and yet some have displayed problems even after their installations.

6.1.1 Drawing 7362768

The idea behind this solution, see appendix 1, has been that the pump can be started in both ways, using the soft-starter or the normal direct-on-line starting (DOL). This works however, a lot of space in the electrical cabinet has been taken by having two different starting methods, which perhaps is not necessary. The starting method in use with the soft-starter is direct connection. The starting method to DOL or the soft-start can be chosen easily, as you can see from the picture below.



Picture 18. DOL and soft-starter selection. (Rolls-Royce archives)

The soft-starter is Schneider Electrics model ATS48C17Y that has motor power of 75kW and 140A starting current rating. Motors rated current is 135A. Specially for pumping and ventilation machines.

Since this method is already in use in the case seen above and working, I am not recommending any changes to the installation and starting method.

6.1.2 Drawing 7363013

The idea behind this solution, see appendix 3, has been that the pump can be started in the delta connection with the soft-starter.

The soft-starter is Siemens model Sirius 3RW4038-1BB14 that has motor power of 37kW and 72A starting current rating. Motors rated current is 59A. The 2- and 3-

phase control is possible with this soft-starter. Especially designed for hydraulic pumps, conveyors, escalators and small fans.

Since this method is already in use in the case seen above and working, I am not recommending any changes to the installation nor the starting method.

6.1.3 Drawing 7360716

In this drawing, see appendix 2, we can see that this project is without a soft-starter and needs a solution for further use. Current starting method is DOL which causes really high current spikes at the start-up.

For this kind of case, I would recommend based on the research conducted, that either a direct connected soft-starter or delta connected 2-phase controlled soft-starter to rectify the current spikes. I would further recommend using a soft-starter that can replace the overload relay which would become useless after the installation of the soft-starter.

7 CONCLUSION

In conclusion this thesis has explored and investigated the existing problem of high current spikes in the thruster unit's lubrication and control pump. Examining the issue in more detail, I discovered the main problem lies when starting the motor which causes high current spikes. To illustrate the possible solutions for this problem, I first began my thesis with the rules for classifications of vessel motor starters. Next I examined the induction motor starting methods which explains each starting method in detail. This section also outlines the advantages and disadvantages of their usage.

The next section of my thesis explored the possibility of using the soft-starter to eliminate the high current spikes issue. To do this, I examined the possible ways to connect the soft-starter which illustrates the many possibilities for using the soft-starter in the thruster unit's lubrication and control pump. Upon discovering the different means of connection, I evaluated several drawings which displayed different soft-starters abilities to decrease the current spikes. As a result of the evaluation of the drawings, I provided a recommendation for the suitable changes (if any), on the basis of the research conducted and the knowledge I obtained while doing this thesis.

During the course of this thesis, I have gained exceptional knowledge with regards to the soft-starter and its connection methods within the thruster unit's lubrication and control pump. Of course, before the creation of this thesis, I was aware of what a soft-starter was and its general capabilities, however researching the different types of soft-starters has helped me to understand their benefits and usage for the current spikes issue mentioned above. Writing this thesis has also taught me the importance of organization and discipline, two skills which I will bring forward in my career. Writing this thesis in English was no easy task, it was challenging to say the least however, I have learned that challenging circumstances will arise in life and I must have the confidence to pursue these challenges.

REFERENCES

ABB.com. (2011). *Pehmokäynnistinopas*. [online] Available at: https://library.e.abb.com/public/d11f99611045fef8c125796e00473a8a/OPAS%20Pehmokaynnistys%201FI12_01.pdf [Accessed 22 May 2016].

ABB.com. (2011). *Softstarters*. [online] Available at: http://www02.abb.com/global/ilabb/ilabb012.nsf/0/4bce0ca0ff1672d6c1257913003778a1/$file/SOFT+STARTERS.pdf [Accessed 22 May 2016].

DNV GL. (2011). *SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT*. [online] Available at: https://rules.dnvgl.com/docs/pdf/DNV/rulesship/2011-01/ts408.pdf [Accessed 22 May 2016].

DNV GL. (2011). *SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT*. [online] Available at: https://rules.dnvgl.com/docs/pdf/DNV/rulesship/2011-01/ts409.pdf [Accessed 22 May 2016].

DNV GL (2011) *SHIPS / HIGH SPEED, LIGHT CRAFT AND NAVAL SURFACE CRAFT. Appendix 5.*

Kauppalehti.fi. (2014). *Rolls-Royce Oy Ab | Osakeyhti� | Kauppalehti.fi*. [online] Available at: http://www.kauppalehti.fi/yritykset/yritys/rollsroyce+oy+ab/10076287 [Accessed 22 May 2016].

Rolls-royce.com. (2016). – *Rolls-Royce*. [online] Available at: http://www.rolls-royce.com/products-and-services/marine/about-marine/products/thrusters.aspx [Accessed 22 May 2016].

Rolls-royce.com. (2016). *About marine*. [online] Available at: http://www.rolls-royce.com/products-and-services/marine/about-marine.aspx [Accessed 22 May 2016].

Drawings (appendix 1-4) taken from Rolls-Royce archives Rauma.

Schneider-electric.nu. (2016). *ATS48C17Y*. [online] Available at: http://pdf.schneider-electric.nu//files/partnumbers/ATS48C17Y_document.pdf [Accessed 22 May 2016].

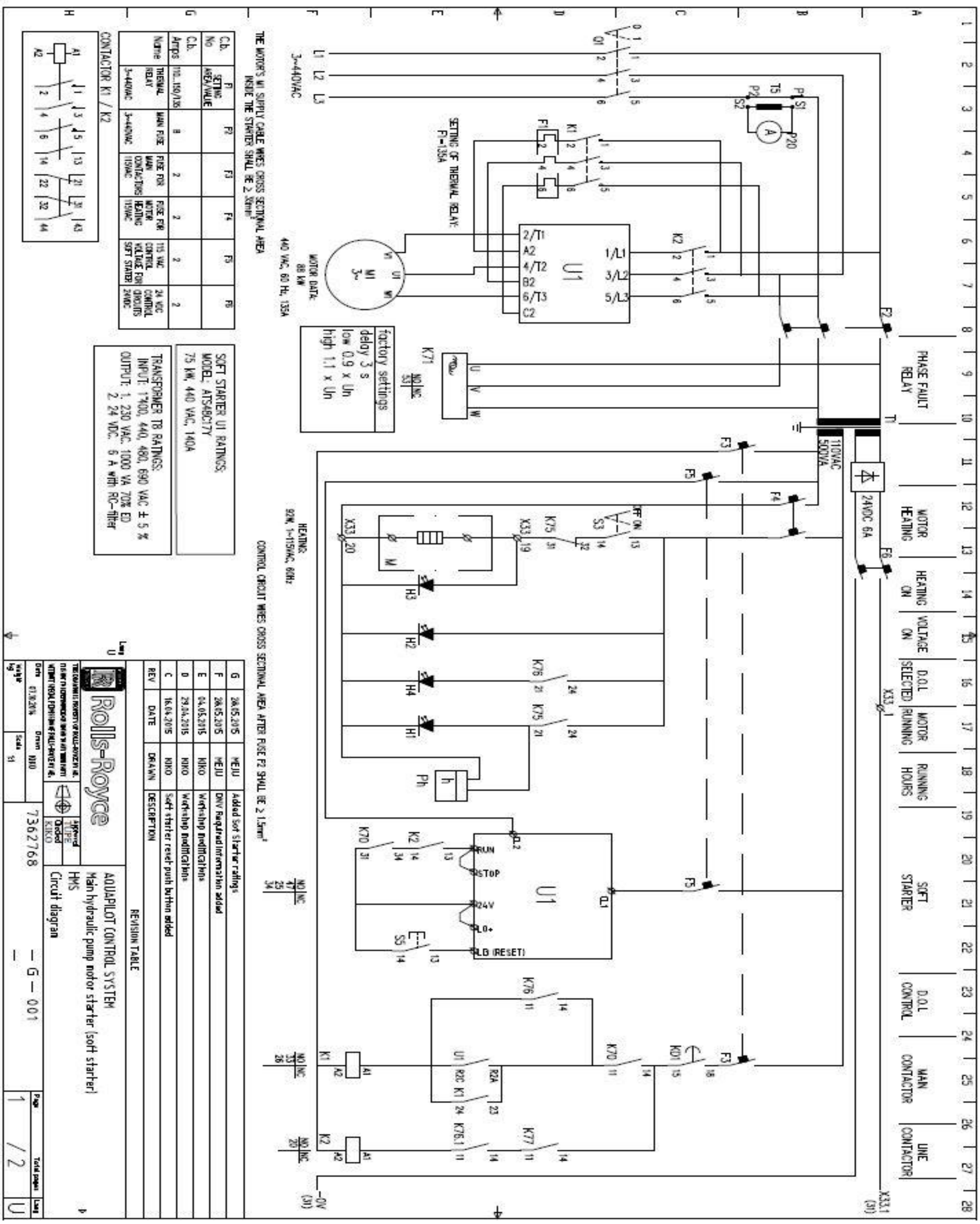
Seasideindustry.com. (2016). *Rolls-Royce | Seaside Industry Park Rauma*. [online] Available at: http://www.seasideindustry.com/rolls-royce [Accessed 22 May 2016].

Teschler, L. (2016). *Soft Starters*. [online] Machinedesign.com. Available at: http://machinedesign.com/engineering-essentials/soft-starters [Accessed 22 May 2016].

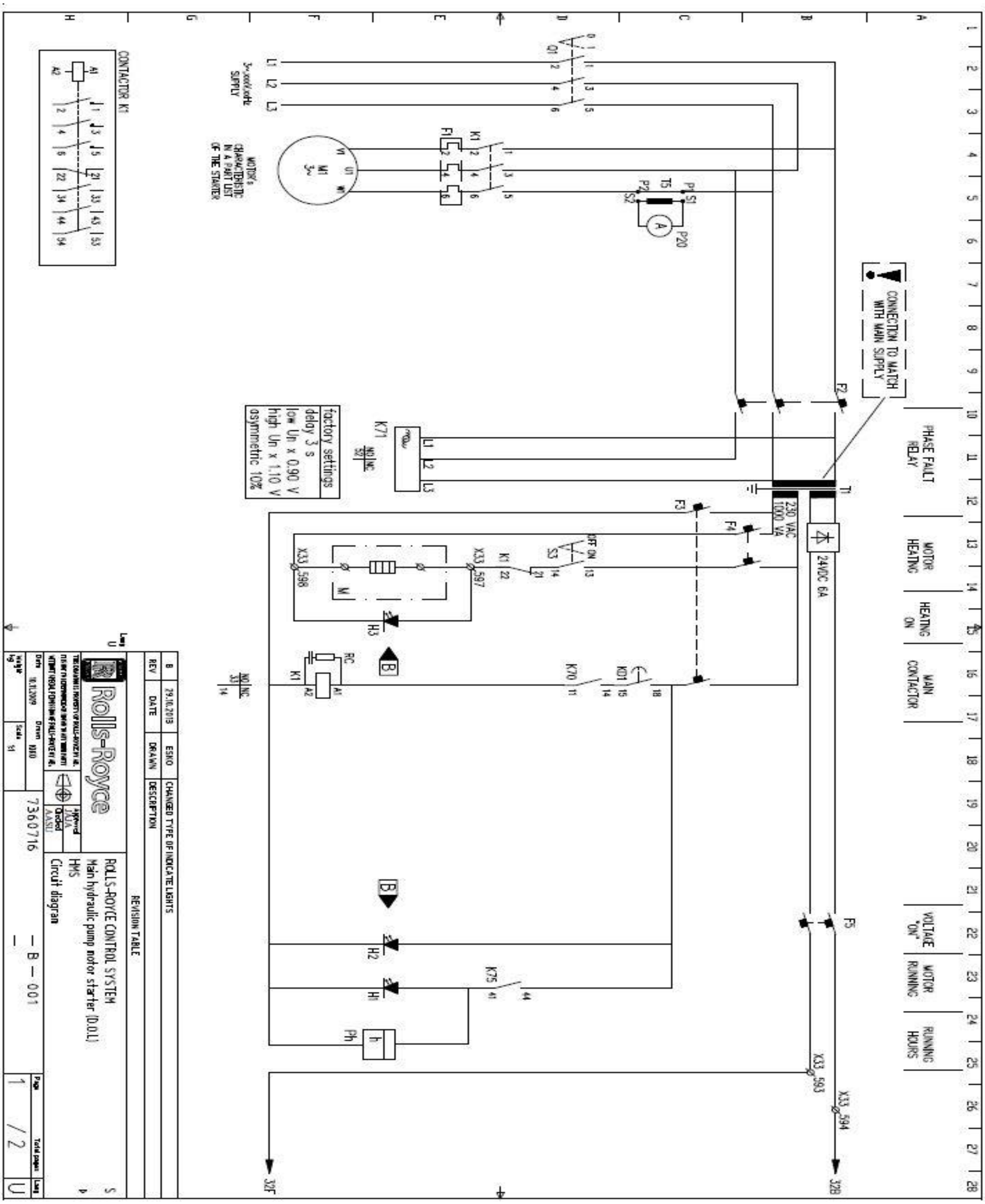
Uk.rs-online.com. (2016). *3RW4038-1BB14 | Siemens 72 A Soft Starter, IP00, 37 kW, 200 → 480 V ac | Siemens*. [online] Available at: http://uk.rs-online.com/web/p/soft-starts/0420524/ [Accessed 22 May 2016].

APPENDICES

APPENDIX 1

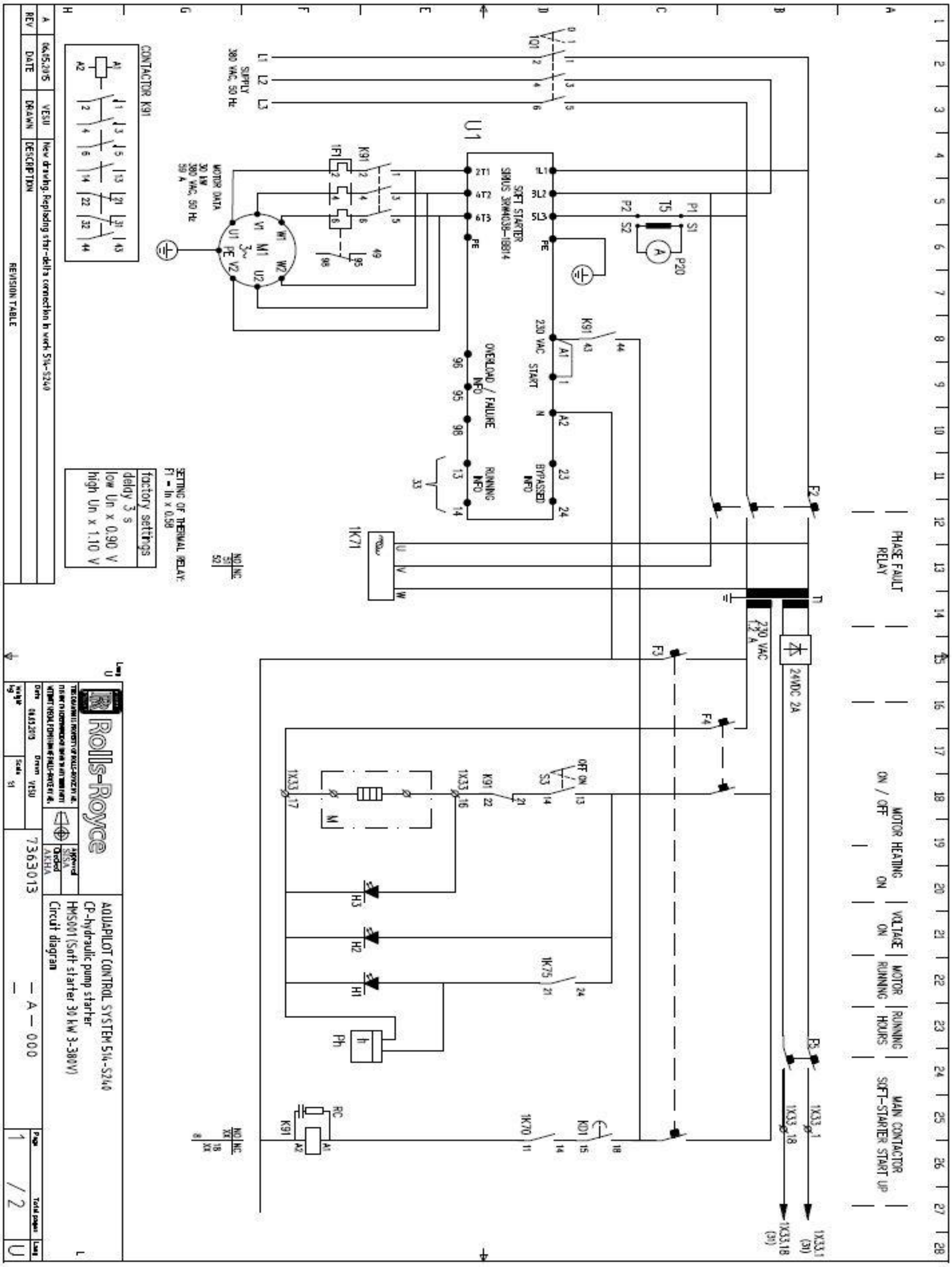


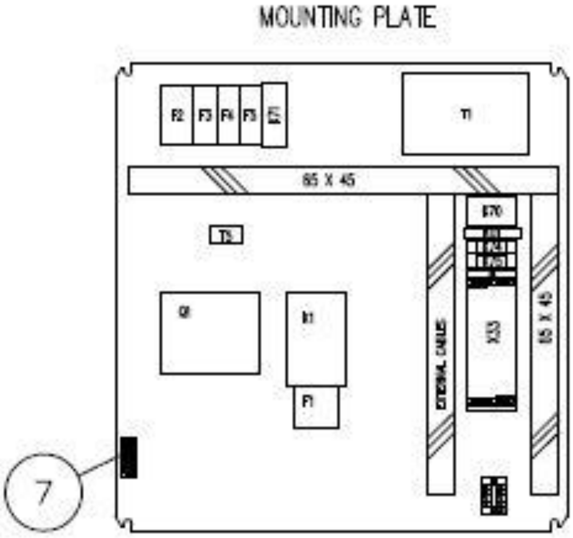
APPENDIX 2



PHASE FAULT RELAY
MOTOR HEATING
HEATING ON
MAIN CONTACTOR
VOLTAGE "ON"
MOTOR RUNNING
RUNNING HOURS
CONNECTION TO MATCH WITH MAIN SUPPLY
24VDC 6A
230 VAC
1000 VA
factory setings
delay 3 s
low Un x 0.90 V
high Un x 1.10 V
asymmetric 10%
CONTACTOR K1
MOTOR'S CHARACTERISTIC IN A PART LIST OF THE STARTER
CHANGED TYPE OF INDICATE LIGHTS
REV
DATE
DRAWN
DESCRIPTION
REVISION TABLE
Rolls-Royce
ROLLS-ROYCE CONTROL SYSTEM
Main hydraulic pump motor starter (D.O.L.)
HMS
Circuit diagram
7360716
- B - 001
1 / 2

APPENDIX 3


PHASE FAULT RELAY
MOTOR HEATING ON / OFF
ON
VOLTAGE ON
MOTOR RUNNING
RUNNING HOURS
MAIN CONTACTOR SOFT-STARTER START UP
SOFT STARTER SIRIUS 3RW4038-1BB14
CONTACTOR K91
SUPPLY 380 VAC, 50 Hz
MOTOR DATA 30 kW 380 VAC, 50 Hz 59 A
OVERLOAD / FAILURE INFO
RUNNING INFO
BYPASSED INFO
SETTING OF THERMAL RELAY: F1 = In x 0.58
factory settings
delay 3 s
low Un x 0.90 V
high Un x 1.10 V
230 VAC 1.2 A
24VDC 2A
A 06.05.2015 VESU New drawing. Replacing star-delta connection in work 514-S240
REV DATE DRAWN DESCRIPTION
REVISION TABLE
Rolls-Royce
AQUAPILOT CONTROL SYSTEM 514-S240
CP-hydraulic pump starter
HMS001 (Soft starter 30 kW 3-380V)
Circuit diagram
7363013
A 000
1 / 2



Rolls-Royce

AQUAPILOT CONTROL SYSTEM
Main pump starter
HMS2722.003 (D.O.L, 380-500V, 45-63A)
Assembly drawing

Date 07.11.2012	Drawn HALO	Approved JAJA	Checked KO	S K
Weight kg	Scale 1:10	7452722	— A — 003	Page 2 / 2 Total pages, Lang U

Table B3 Required certificates

Equipment	*Continuous rating*	*DNV product certificate*	*Works certificate* [1]	*DNV type approval certificate*
Main and emergency switchboards	all ratings	X		
Distribution switchboards, motor starters, motor control centres, etc.	≥100 kW/kVA	X		
	≥10 kW/kVA and <100 kW/kVA		X	
Generators [4] and transformers	≥300 kVA	X		
	≥100 kVA and <300 kVA [2]	X		
	≥10 kVA and <100 kVA		X	
Motors [4]	≥300 kW	X		
	≥100 kW and <300 kW [2]	X		
	≥10 kW and <100 kW		X	
Semi-conductor converters for motor drives	≥100 kW	X [7]		
	≥10 kW and <100 kW		X	
Semi-conductor converters/ assemblies for power supply	≥50 kVA	X [8]		
	<50 kVA		X	
Cables [3), 6]	all ratings			X
System for automatic start/stop of generator prime movers and automatic operation of breakers, Sec.2 H200 [5]	all ratings	X		

1) The definition of works certificate is given in Pt.1 Ch.1 Sec.4 of the Rules for Classification of Ships. Work certificate can be required when necessary for further information.

2) As an alternative to the acceptance based on DNV product certificate, the electrical equipment will also be accepted based on a DNV type approval certificate and work certificate.

3) All cables, except:

— cables for internal use in electrical assemblies
— short cable lengths on mechanical packages
— control, automation and communication cables for non-important equipment

4) Certificates for shafts shall be issued as required by Ch.4. This is only applicable for shafts part of the main mechanical propulsion line except generators in diesel electrical propulsion.

5) See Ch.9 for requirement to documentation and scope of testing.

6) Cables not having valid type approval certificate will also be accepted on the basis of a DNV product certificate. For manufactures having type approved cables, only routine tests according to Sec.9 H101 will be required.

7) Certification of semiconductor converters for motor drives may be partly based on type approval of power modules.

8) Semi-conductor converters/assemblies for power supply may be covered by a Type Approval certificate. This will be stated in the Type Approval certificate.

Note: Heat exchangers used in conjunction with certified electrical equipment, shall be certified as required for pressure vessels, see Ch.7.