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# Motor control panel configurator tool

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<p>This engineers' thesis was made for ABB, motors and generators divisions' sales team. The subject for the thesis was creating an easy to use, excel based sales configurator. The configurator tool is used to create simple, yet descriptive technical specifications for the customer as a part of a sales offer of a motor control panel. The configurator is intended to be used for the new MCP 300 series motor control panels.</p> <p>The basic electromotor theory that is necessary for understanding the operation and purpose of the motor control panels is explained in this report. Additionally, a description of the creation process of the configurator tool and the purpose of the thesis is included in this report.</p> <p>The requirements for the configurator were defined in co-operation with ABB sales engineers, and the different versions of the tool were discussed with the sales personnel in order to achieve maximal functionality for the tool.</p> <p>Due to long delivery times of connection diagrams, a full version of the tool remains to be completed. However, ABB now has a fully functional tool for easy creation of technical specifications, and detailed instructions for updating the tool to the full version when the connection diagrams are delivered.</p>	
Keywords	Synchronous motor, Excitation, Sales, Configurator, Excel

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Appendix 1. UNITROL 1000 – Compact and powerful Automatic Voltage Regulators

Appendix 2. Product life cycle management EA10

## List of Abbreviations

ABB	Asea Brown Boweri; The company produces electrical motors, robotics, drives and other industrial solutions.
AVR	Automatic voltage regulator. Regulates the excitation current of a synchronous motor. The model in use in MCP 300-series panels is UNITROL 1020-Automatic voltage regulator.
AC	Alternating current; Electric current that changes direction periodically.
DC	Direct current; Electric current that flows constantly to one direction.
MCP	Motor Control Panel; Used to feed excitation current to synchronous motors.
MCP 300	A product family of ABB's motor control panels. Features four different models for different excitation purposes: MCP 310, MCP330, MCP 350 and MCP 370.
MF	Magnetic field
SM	Synchronous motor. One of two types of AC-motors. Synchronous motors run in synchronism with the grid.
SLD	Single-Line diagram. A simplified electrical blueprint.
STT	Specification tool-tab. The tab with all the user input fields and options in the configurator tool.
VSD	Variable speed drive; Frequency transformer. Can be used to start synchronous motors that operate in conditions that prevent DOL starting.
IECO	International Electric Co.; Company that manufactures and designs electronics. Sub-contractor for ABB. Manufactures MCP 300-units.
PLM	Product life cycle management



## **1 Introduction**

ABB is an automation and industrial manufacturer. ABB has approximately 136 000 employees worldwide in 100 different countries. In Finland, ABB is one of the largest industrial employers with 5200 employees, 1 000 of the personnel work in research and development.

ABB is divided into several different divisions. This thesis was commissioned by Motors and Generators - Product Management, under the Robotics and motion division.

The goal of the thesis was to produce a Microsoft Excel-based technical configurator for the MCP 300 product family. The configurator is meant for sales' purposes in early stages of a project. The configurator tool is to be used for easy creation of a technical specification for MCP 300-products. By filling out required parts of the configurator tool, the tool creates a print area with the required information to make an offer to the customer.

This particular topic for this Bachelor's thesis was selected for the author due to the authors' previous experience and knowledge obtained with the MCP 300-series during his summer internship at ABB product management during the summer of 2017. The author was assigned to create a machine description document regarding the MCP 300-series products to support sales-personnel in describing the new product family to customers.

## **2 Methods and Resources**

The author of this thesis was granted access to ABB premises and a laptop with access to a company's email address and all relevant company training material. The thesis and this report was mostly created in ABB premises due to an easy access to supporting personnel. The making of this thesis work required frequent reviewing of the different versions of the configuration tool, and therefore it was convenient to work close to the people with the competence to give advice and feedback. The requirements for the configuration tool were defined by holding multiple meetings with Jari

Lindström, the representative of the Sales-department, Jouni Tervaskanto, the instructor of the thesis, and Sami Karttunen, the After sales-departments' representative.

As the subcontractor for ABB, IECO, the company that manufactures the MCP 300-product family, was also involved in this thesis work. Janne Vepsäläinen, the representative from IECO will deliver the Single line diagrams (SLD) that were used in the excel tool.

The kick-off meeting for the thesis work was held with the instructors. During the kick-off meeting it was agreed that a suitable date for the completion of a rudimentary draft of this report was set to 15.11.2017. This rudimentary draft would contain approximately 75% of the content of the final report.

During the creation of the configuration tool, the author relied on internet sources, ABBs' internal and public training material and the expertise of the ABB and IECO personnel.

### **3 Theory: Synchronous motors**

In order for the reader to grasp the purpose of the MCPs, the reader needs to have some basic knowledge on synchronous motors and electrical excitation. The contents of this chapter are the authors' best attempt of explaining the basics of synchronous motors in near layman's terms.

Firstly, it is necessary to explain the basics of electric magnets and how they can be used for producing mechanical work in an electric motor. Secondly, the reader needs to know the variables that affect an AC-motor and how the AC-motor affects the power grid that it draws power from. Thirdly, excitation of the rotor field coils, and how it can be used to force the motor to spin at a synchronous speed with the grid frequency.

After explaining the basics, the report examines the basic functions of MCPs and how it regulates the excitation current based on measured variables.

### 3.1 Basics of AC-motors

The electric motor is a machine that converts electric energy into mechanical energy by using electromagnets. Electromagnets are devices that produce a magnetic field (MF) when an electric current passes through them. The most common kind of electromagnet is a copper coil that is spun around a ferromagnetic core, usually made of steel or iron. (Figure 1) When an electric current is conducted through the copper wire, the wire produces a MF according to Amperes' law and magnetizes the core, amplifying the MF. [2]

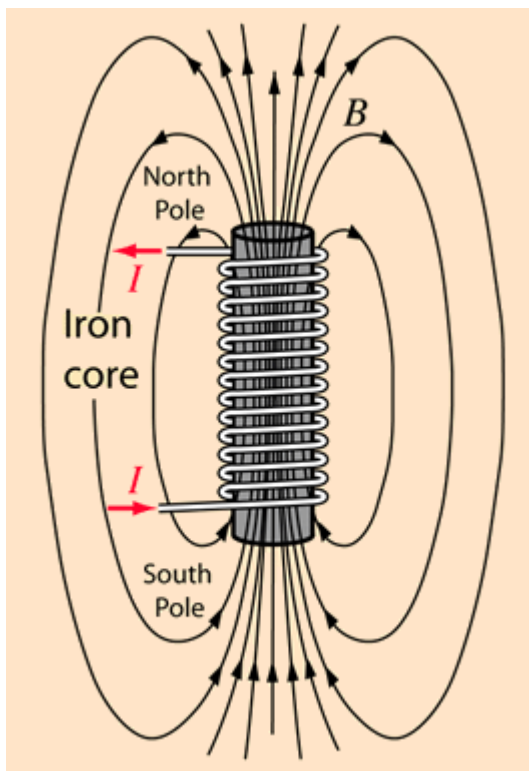


Figure 1. Electromagnet that consists of a copper wire and a ferromagnetic core and its MF [3]

The direction of the MF depends on the direction of the electric current. Electric magnets like this are dipoles, which means that they have a north and a south pole as seen in figure 1. Therefore, when used in a grid that uses alternative current (AC) the direction of the MF is constantly changing on a pace that is dependent on the frequency of the grid. [4]

When two or more dipole magnets interact together, the south pole of one magnet attracts the north pole of another magnet and vice versa. Additionally, the south pole of a magnet repels another magnets' south pole [5]. In an electric motor, there are multiple



electromagnets that are used to create a magnetic force between the two basic parts in an electric motor: the rotor and the stator. (Figure 2) Usually the rotor is spun inside the stator. This is done by turning the stator coils into electromagnets by conducting an electric current into. The rotor has a group of electromagnets in the outer rim of the cylinder that have their poles oriented outwards, towards the poles of the electromagnets in the stator.

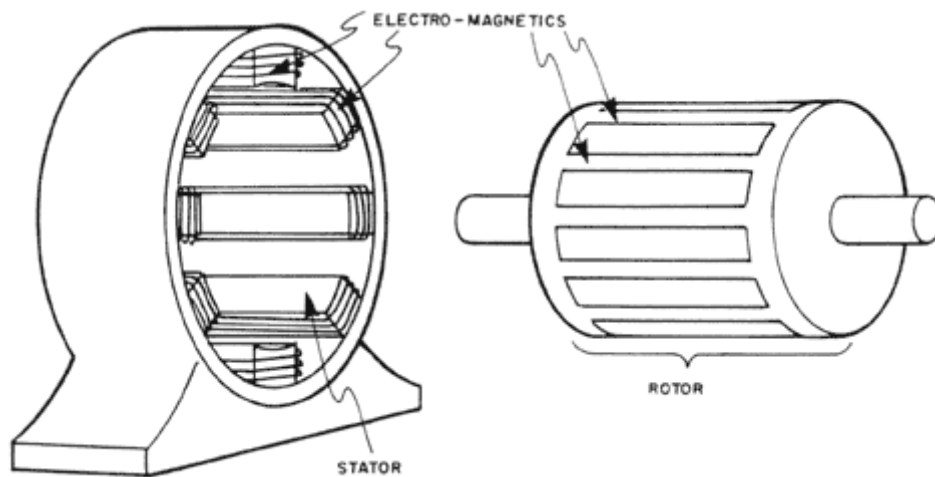


Figure 2. A simplified image of an electric motor [6]

When the stator coils are magnetized, the change in the MF around the rotor causes electromagnetic induction in the rotor coils, causing an electric current to flow through them. As the induced current flows, the rotor coils are magnetized as well.

Because the stator coils of synchronous motors are usually fed by a three phase AC grid, the direction of the MFs that are generated are constantly rotating. As mentioned before, the south pole of the rotor and north poles of the stator attract each other and vice versa, also south poles repel south poles and north poles repel north poles. This causes the stator coil MFs to create a tangential magnetic force to the coils on the outer rim of the rotor, therefore causing torque to the motor shaft [6].

The coils, also known as poles are always in pairs in the motor. They are often referred to as pole pairs. The connection of the pole pairs of a 6-pole 3-phase motor is displayed in figure 3. The south, and north poles of the pole pairs are on opposite sides of the motor.

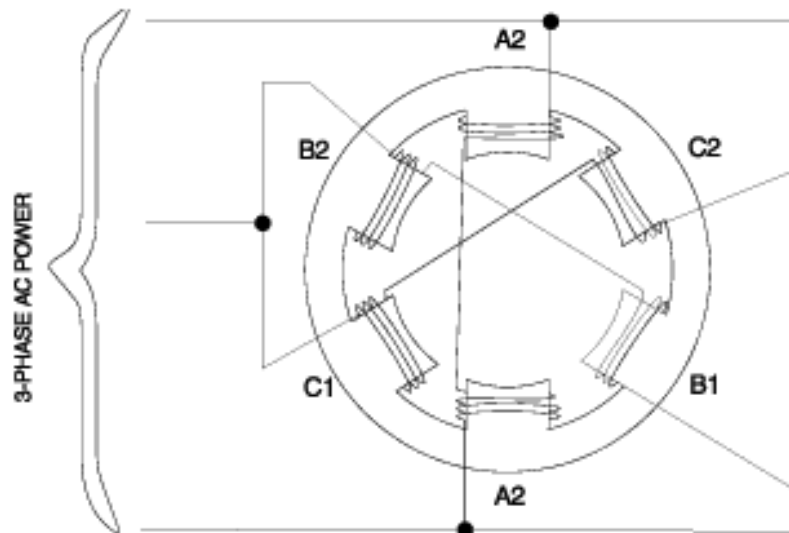


Figure 3. Connection of the poles in a 3-phase 6 pole motor [6]

The poles are at a 60 degree angle from each other. The 3-phase grid guarantees that there are always 2 poles with a current flowing in the positive direction, 2 poles with a negative current, and 2 poles with no current at all. Figure 4 illustrates how the poles interact with the rotor winding at four different times. The direction of the torque is displayed as a curved arrow. [6]

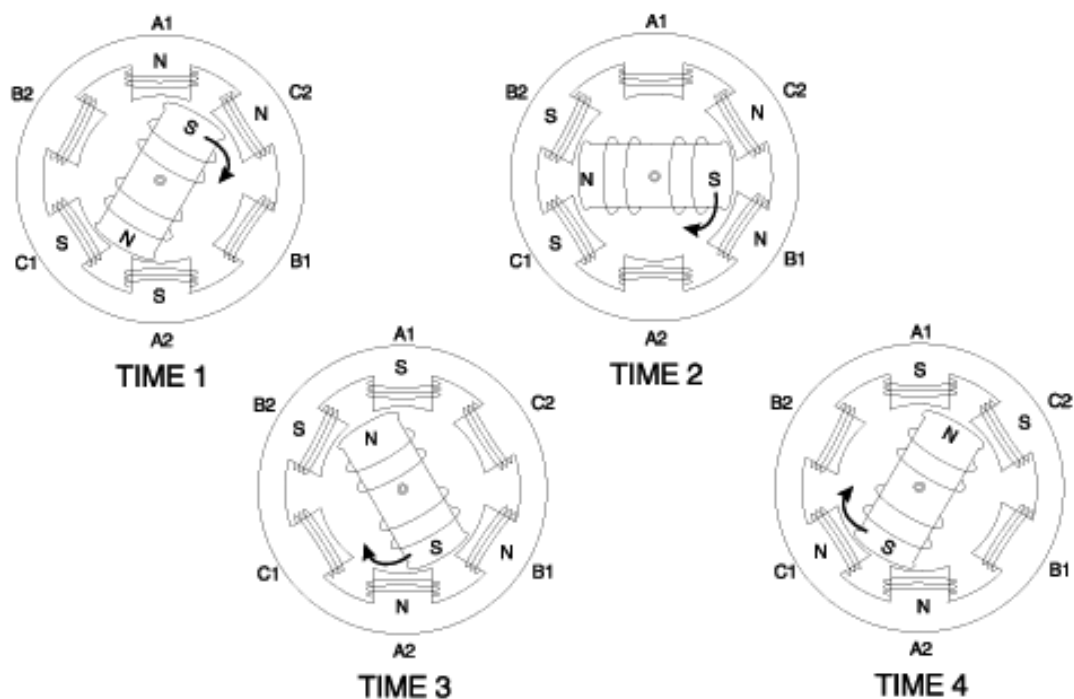


Figure 4. Stator windings, their polarities and rotor torque displayed [6]

A 3-phase system can be described to have the the current in three different branches with a 120 degree phase angle between them. Figure 5 displays the current differences with the current in amperes as a function of time. [6]

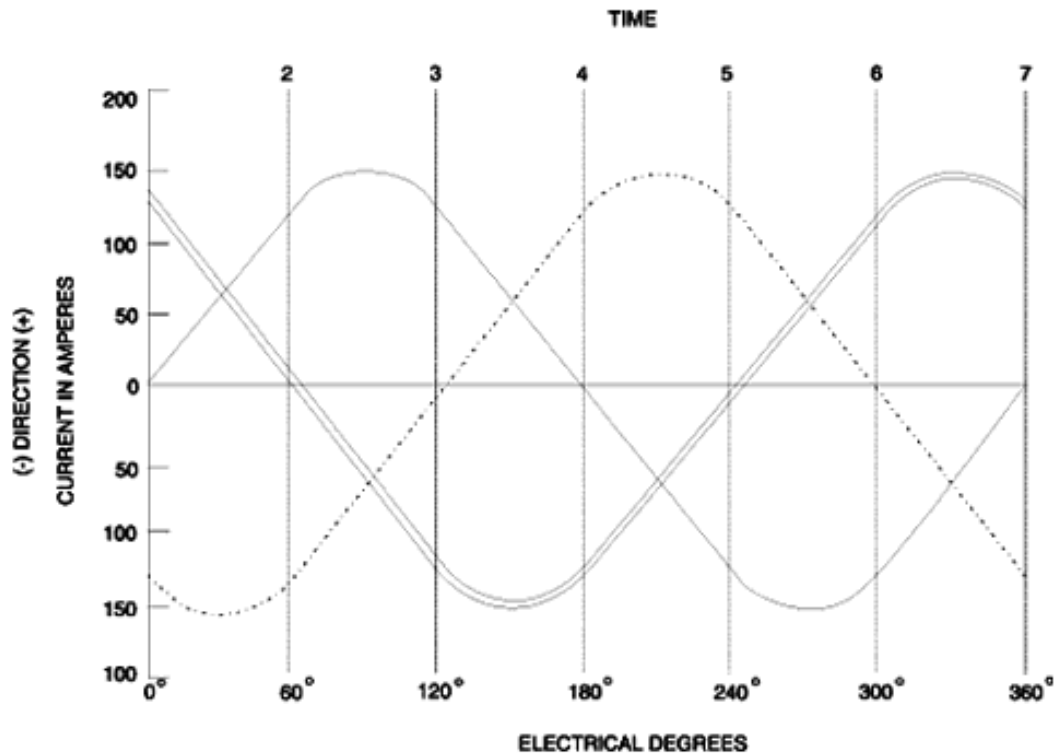


Figure 5. Three phase system and its' phase angles [6]

Figure 6 shows the relation of the MF of the stator and the phase angles. As mentioned before, the direction of the MF depends on the direction of the current. As seen in Figure 5, the direction of the current changes as time passes, but the phase angle remains the same. This means that the MF rotates at a constant speed according to the frequency of the AC current. This is called a rotating MF. [6]

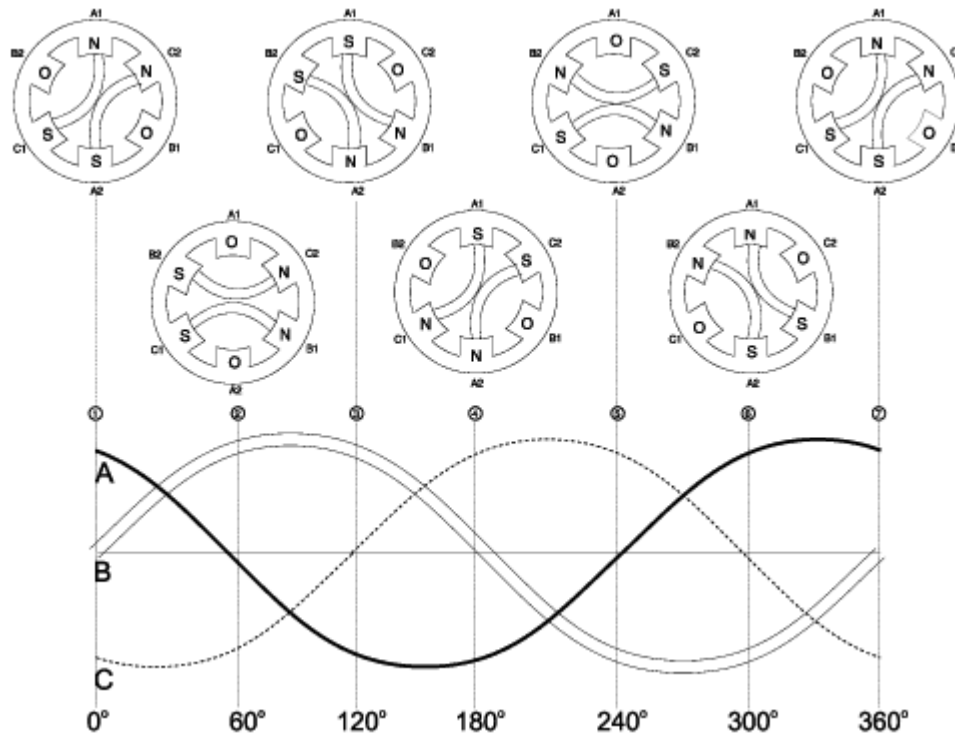


Figure 6. Magnetic fields in the stator as they change with the AC frequency [6]

It is important to note that there are motors with more or less poles than 6. The rotational speed of the motor is dependent on the frequency of the grid and the number of poles.

There are two different kinds of AC motors: Induction motors and synchronous motors.

In induction motors, the rotor speed should never quite reach the speed of the stator field (also known as synchronous speed). As the rotor catches up to the stator, the relative speed of the rotor and the stator slows down. As mentioned before: it is the change in MF around the rotor that induces the current that magnetizes the rotor poles. Therefore, the magnetization disappears when the rotor speed reaches the stator speed as the relative MF is no longer changing constantly. No speed difference and therefore, no torque. This speed difference that is required by induction motors is known as the slip.

The rotor speed of the SM however does reach, and remains at the stator speed. This is achieved by conducting or inducing a separate current to the rotor coils. This current is known as the excitation current, and can be fed to the rotor coil either by electromagnetic induction, or through slip rings and brushes. The rotor can remain at a syn-

chronous speed because the rotor coils are magnetized externally. This eliminates the need of the speed difference between the rotor speed and the speed of the rotating MF of the stator.

The excitation current is controlled with an MCP. The process and the principles of excitation are described in more detail in chapter 3.3 Excitation. Because this report is about a configuration tool for MCPs that are used to control SMs, it is not necessary to focus any more on induction motors. Therefore, the rest of this theory section is dedicated strictly to SM related issues.

There are two different main methods of starting a SM. Direct-on-line (DOL) start and variable speed drive (VSD) start.

When DOL-starting the motor, the motor is fitted with a squirrel cage in the rotor, and it is started as an induction motor. The excitation is switched on when the slip is minimized. DOL-starting the motor causes large inductive loads in the grid and may lead to a voltage drop in the grid. VSD can be used when the grid is too weak for DOL-starting the motor.

During VSD start, the excitation is switched on, and the stator field is controlled by a VSD. The VSD increases the frequency of the motor from 1Hz upwards until the grid frequency is reached. The motor is then synchronized with the grid. This starting method minimizes the speed difference of rotor and stator fields during start, therefore causing minimal voltage drop in the grid.

To sum up the basics of AC motors:

1. A constantly changing AC-current is fed to stator coils in order to create a MF
  2. Change in MF induces an electric current to the rotor poles
  3. Rotor poles are magnetized due to the induced current.
  4. The rotating MF of the stator interacts with the MF of the rotor poles
  5. Torque is generated. The motor spins.
- Two different types of AC-motors are SM and induction motors.
    - Induction motors never reach synchronous speed, but have a simpler build due to no additional connections that are needed for excitation.

- SMs operate at a synchronous speed but require a power source for excitation current, a MCP, exciter installed to the rotor which increases the mass of the rotor and makes it harder to rotate, or slip-rings and brushes that wear down in use and need to be replaced eventually.

### 3.2 P/Q-Diagram and variables of a synchronous motor

In addition to the excitation current and grid frequency, there are other variables in an AC-grid that affect the operation of a SM. In order for the reader to understand the principles behind the operation of a MCP and the need to control the excitation current, it is necessary to familiarize some of these variables. Additionally, to properly illustrate the connection between the variables, the P/Q-Diagram is also explained. The P/Q diagram is a tool for reading and understanding the operation of a SM and the MCP.

When an electromagnet is used to create a MF in an AC-circuit, the current in the wire coil keeps changing direction. When the current changes direction, the polarity of the MF also changes. When the MF changes, it induces a secondary current to the wire coil. This electric current flows to the opposite direction as the primary current that is initially used to create the MF, therefore resisting the change of current in the circuit according to the Lenz's law. [7]

Electromagnets and other elements that cause the same effect are known as inductive loads. In short: inductive loads cause the change of current lag behind the change of voltage. [7]

Figure 7 shows how the relationship between the current, voltage and power of the circuit looks like in a purely resistive AC-system, where there are no inductive loads connected. Vertical axis shows the change in the magnitude of the variables and the horizontal axis represents time.

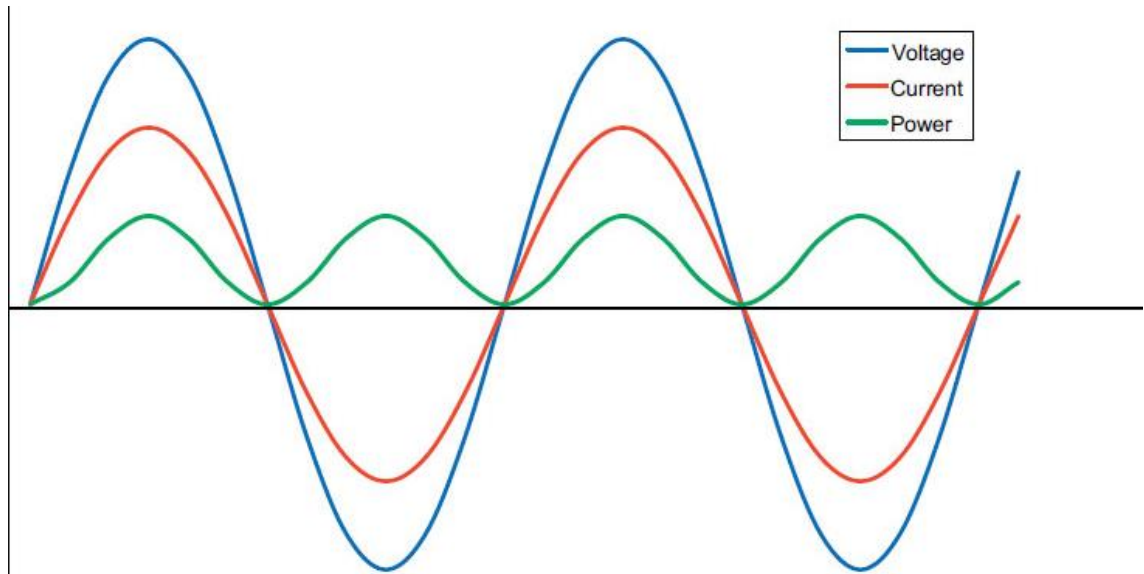


Figure 7. Voltage and current are in sync in a purely resistive system. [8]

Figure 8 displays how an inductive load affects the diagram. This is a purely inductive load, which means that the current is lagging 90 degrees in relation to the voltage. This causes the power to have negative half-cycles.

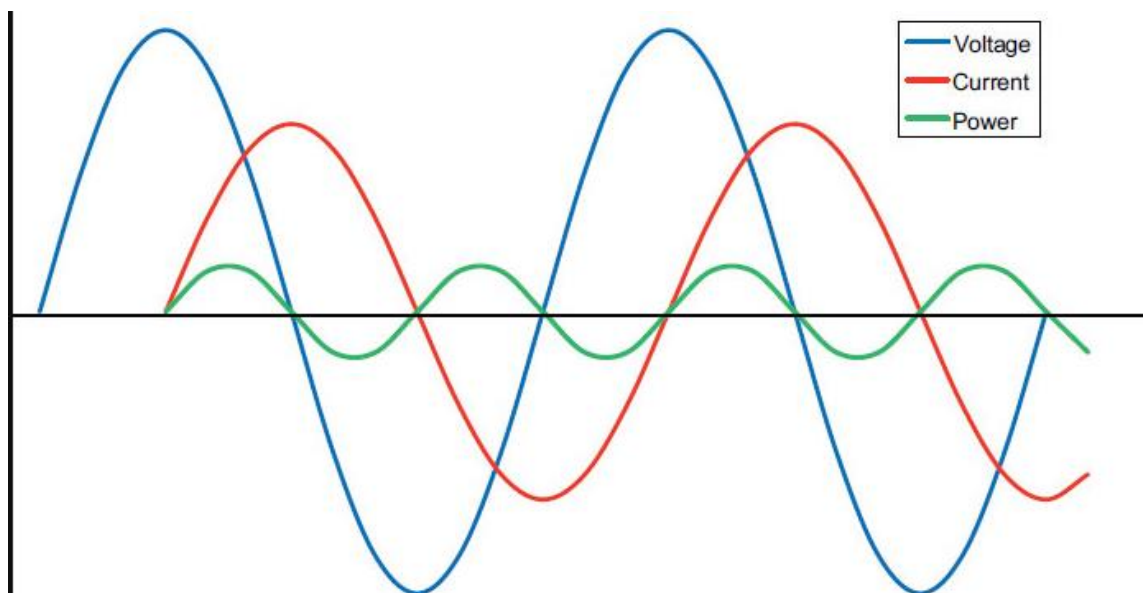


Figure 8. Fully inductive system. Current lags 90 degrees behind voltage. [8]

In a fully inductive system, during the positive half cycles the current is consumed to induce the MFs that cause the rotor rotation in a motor. During the negative half-cycles the power is returned to the grid.

This example can only work in theory. It would require a motor that has a 100% efficiency, which means that no current would be consumed in heating the coils or other forms of waste energy. In reality, a system is never fully inductive. There are always resistive loads in addition to the inductive loads that lower the current by the means of electrical resistance.

Figure 9 shows the total current in relation to the voltage as a function of phase degrees, the current that is used to induce the MFs (magnetic current), and the current that is consumed by resistive loads (load current). In this example, the load current is in the same phase as the voltage, with a 0 degree phase difference. The magnetic current is at a 90 degree phase difference. Total current is the sum of these currents, and therefore is at a 45 degree phase difference in relation to the voltage. In this example, to clarify the subject, the load current and the magnetic current are at the same magnitude. In real AC-motors that are working at a full load, the load current is significantly higher than the magnetic current. [9]

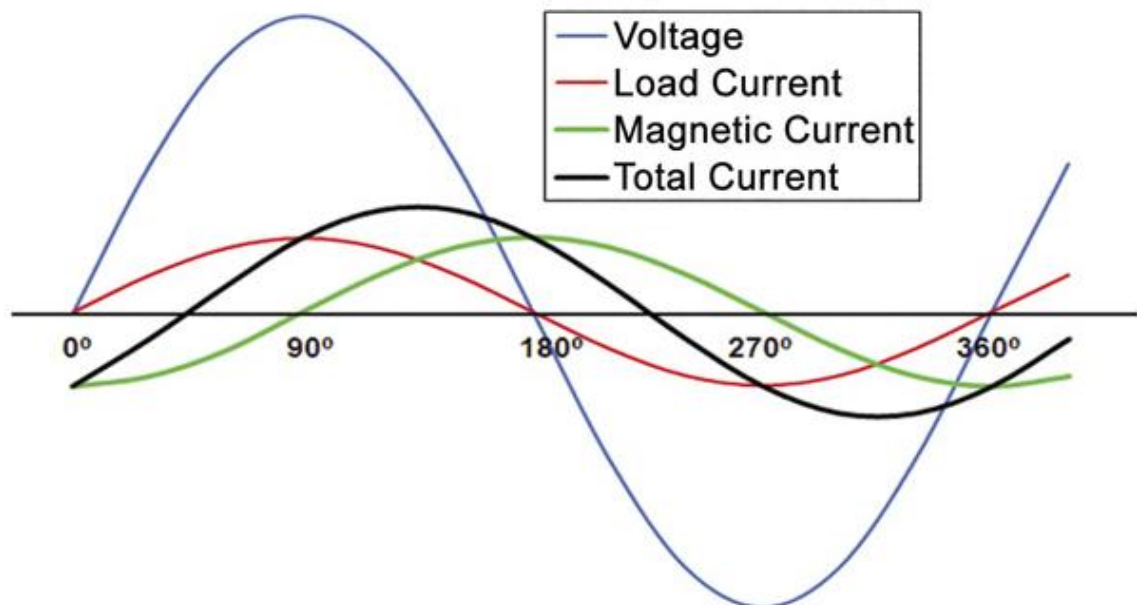


Figure 9. A more realistic representation of an inductive load with its resistive component. [9]

This cosine of this angle between the voltage phase and the total current phase is the first important variable. The mathematical sign that is used for this angle is usually  $\phi$  and the cosine of this angle ( $\cos \phi$ ) is known as the power factor (PF).



In the example above, the power factor is calculated as:

$$\cos \varphi = \cos(45^\circ) = 0,707$$

In the simplest terms: PF is the relation of the part of the current that does actual work in the system and the power that is applied to the system.

To sum up power factor:

- Inductive loads resist the change of current and cause a delay in the change of the current in relation to the change of voltage.
- Total current has two components: Load current and magnetic current.
- Power factor is the cosine of the angle of the phase difference of total current and voltage

After explaining what causes power factor, it is time to discuss how the magnetic current component of the total current affects the motor operation.

In an AC-circuit, active power, the element that describes how much energy is used for work (or generating torque) in a measure of time, can be calculated as [10]:

$$P = V \cdot I \cdot \cos(\varphi)$$

Where  $V$  is the average voltage of the sinusoidal wave form that is present in AC-circuits,  $I$  is the total current that is described above and  $\cos(\varphi)$  is the power factor.  $P$  is active power. Active power is measured in watts. Watts are described as joules per second. Joule is the unit of energy, which means that power is the amount of energy transferred per second. (or work). [10]

As mentioned above, in a purely resistive circuit power factor is 1. Therefore, power factor does not affect the power of the system. Partly inductive loads however make the power factor smaller because the power factor approaches 0 as inductive load is increased. [10]

So when there are inductive loads present, the active power is smaller. The input voltage and the input current aren't changed, but the output power is diminished. [10]

As discussed above, when inductive loads are present, a part of the power is returned to the grid instead of being dissipated as work in the system, making the system less power-efficient. The part of the input power that is returned is called reactive power. The mathematical sign of reactive power is  $Q$  and its unit is volt-amperes-reactive (VAR). [10]

The total input power is referred to as apparent power. The mathematical symbol of apparent power is  $S$ , and its unit is volt-amperes (VA).

When applying this to a synchronous motor:

Apparent power is what enters the motor from the grid as VA. Part of the VA gets returned to the grid as VAR due to inductive loads that are present, and the rest is active power that is used to generate the MFs that cause the rotor to rotate. This process is displayed in figure 10.

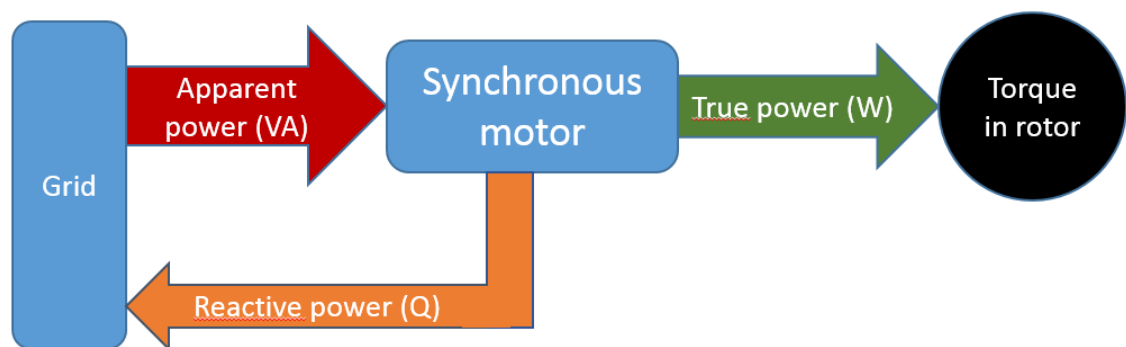


Figure 10. The different components of power in a synchronous motor [Self-made]

The relationship between the magnitudes of apparent power, active power, reactive power and the angular phase difference between the current and voltage can be described with the power triangle (figure 11).

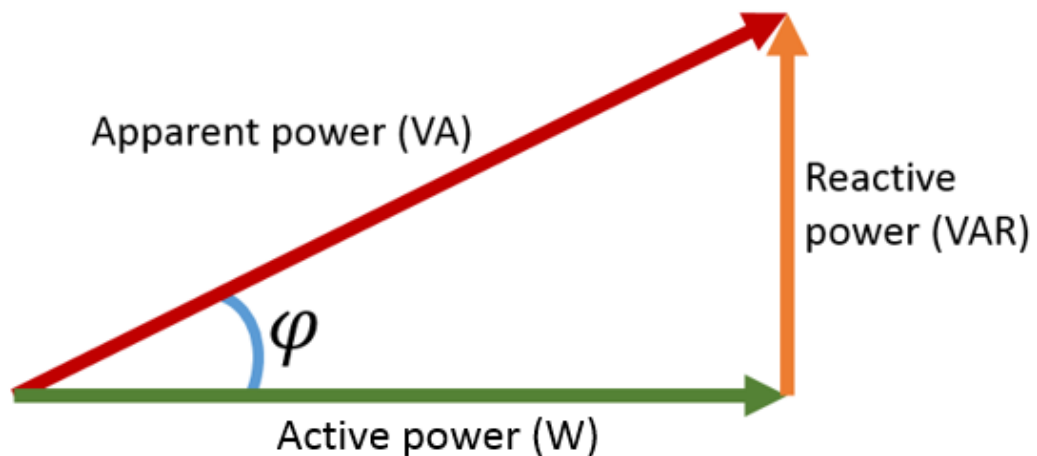


Figure 11. Power triangle: different power components and their relationships. [Self-made]

As can be seen from figure 11, the power triangle is a right triangle with apparent power as its hypotenuse and active and reactive powers as its catheti. As a right triangle, its sides and angles can be calculated with basic trigonometry. This means that the power factor can be used to calculate the sides when one of the power components is known. Additionally, Pythagorean Theorem can also be used to solve an unknown side of the triangle when two sides are known. Pythagorean Theorem is described below. [10]

$$a^2 + b^2 = c^2$$

Where a and b are the catheti (In this case, magnitudes of active power and reactive power), and c is the hypotenuse (Magnitude of Apparent power).

The lag in the current does not stay in the motor, and is present in the grid where the motor is connected as well. This means that the whole grid has the same amount of reactive power as the motor. Therefore the whole grid is operating at a sub-optimal power efficiency when large inductive loads are present. Large plants and industrial facilities that have multiple large motors must compensate for the inductive loads to ensure the proper operation of the grid. [10]

Starting SMs is often done by running the SM as an induction motor until it is feasible to switch excitation current on. This means that during start, the great rotational speed

difference between the MF of the rotor and the rotating MF of the stator, causes a considerable inductive load to the grid. Therefore starting large SMs can cause the power factor of the grid to fall momentarily. This can be compensated by adjusting the excitation of other motors in the grid. This method will be discussed in more detail later in this report.

Components of power summed up:

- Apparent power (Mathematical sign:  $S$ . Unit: VA) is supplied to a motor from the grid
- The currents generated by the MFs (inductive load) in the electromagnets cause the current to change slower in relation to voltage, this results in a lag between current and voltage phases.
- Reactive power (Mathematical sign:  $Q$ . Unit: VAR) is the part of the power that is returned to the grid due to the lag of the current. Reactive power is waste power that does not cause rotor torque.
- Active power (Mathematical sign:  $P$ . Unit: W) is the part of the power that is transformed from electrical energy to mechanical energy by the magnets that generate torque in the motor.
- Power factor ( $\cos \varphi$ ) is the electrical efficiency of the motor. It is used to calculate the amount of energy that is wasted in a motor as reactive power.

P/Q diagram (Figure 12) is a slightly different way of looking at the power triangle. It is a useful tool for deciphering the relation between the power components, and power factor. It can also be used to display certain functions of the MCP that will be discussed later in this report.

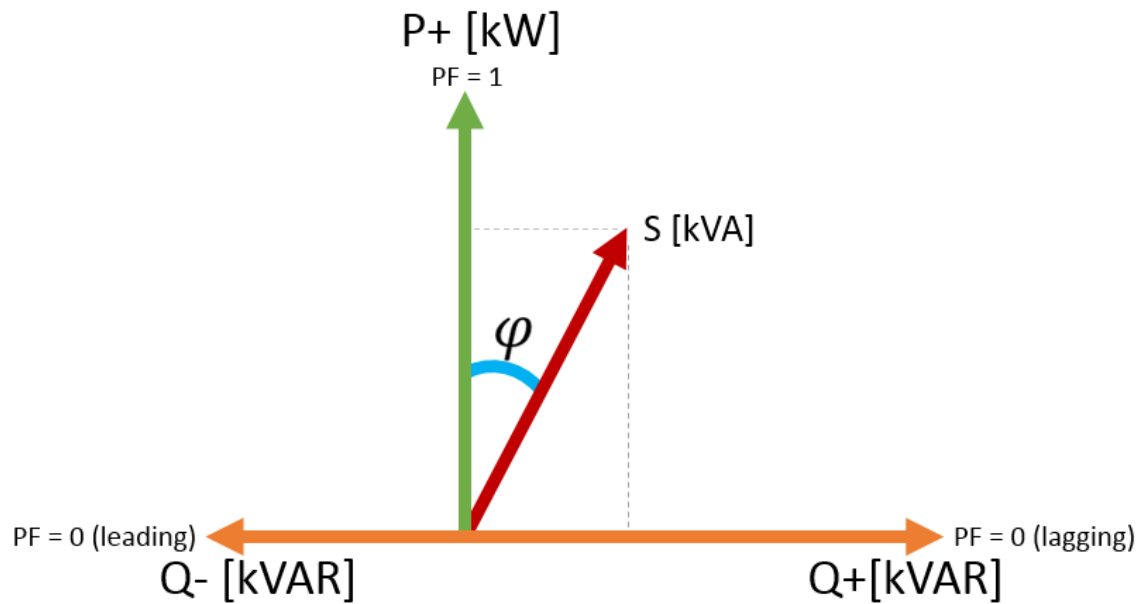


Figure 12. P/Q-Diagram in its' simplest form. [Self-made]

As seen in figure 12, the apparent power-vector of the synchronous motor can lean to either side of the vertical axis, and on the extremity of both directions, PF is 0. When the power factor is on the negative side of the horizontal axis, it means the machine is under excited, and when it is on the positive side, the motor is over-excited. This distinction is explained further in chapter 3.3 Excitation.

### 3.3 Excitation

This chapter examines the different methods of exciting a synchronous motor, the benefits of excitation, and how excitation of the rotor affects the P/Q diagram that is described above. When discussing excitation in this chapter, the SM is always assumed to have a full load unless mentioned otherwise.

The main distinction between an induction motor and SM is that a SM has an additional MF in the rotor coils. The MF in the rotor is provided to the motor by an excitation current (also known as a field current. Mathematical symbol:  $I_e$ ) that is introduced to the system by either electromagnetic induction (brushless excitation), or by direct conduction via brushes and slip rings (Static excitation).

The field current is DC current, which means that the magnetized coils in the rotor do not switch polarity according to grid frequency. Instead the polarities of the coils are static.

When brushless excitation (Figure 13) is used, the excitation current is first induced in an exciter, which is practically a small reverse generator on the rotor where the magnetic field is provided to the stator, and the output current is induced to the rotor. The output current at this stage is AC and has a frequency that is dependent to the number of poles in the exciter and the rotational speed of the rotor. The current is then converted into DC by a diode bridge or a thyristor bridge in the exciter and supplied to the rotor field coils.

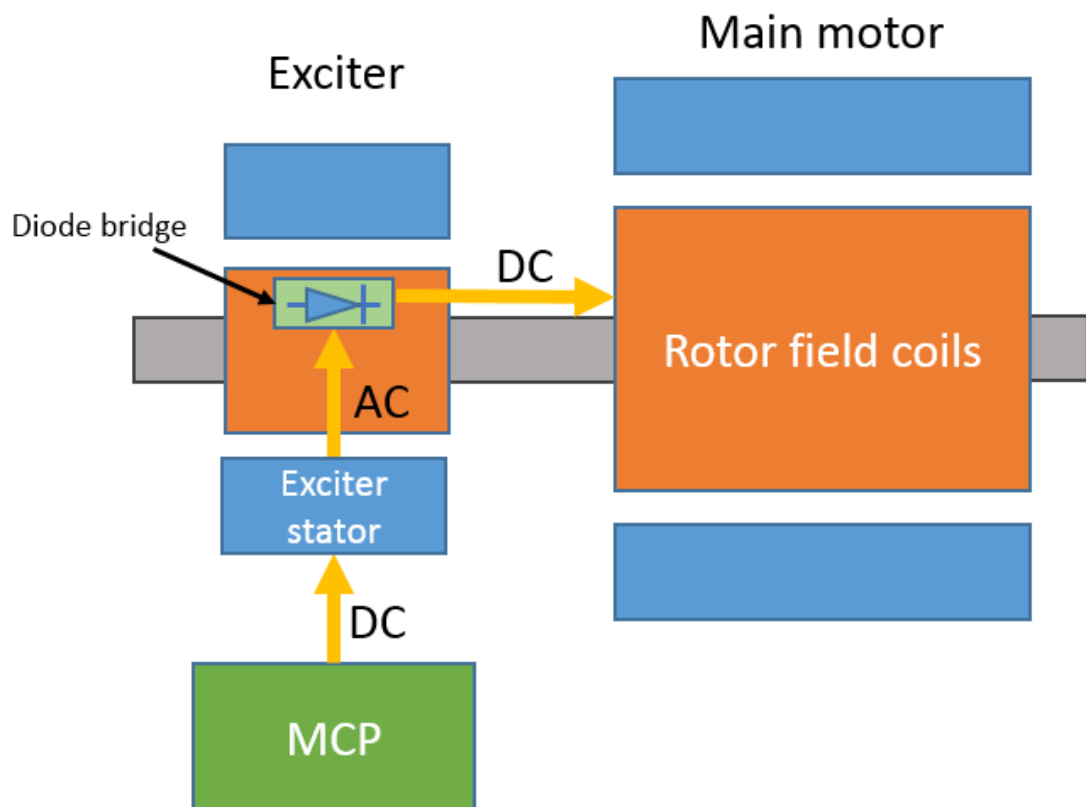


Figure 13. Simplified diagram of a brushless excitation system. Yellow arrows depict the stages of conversion in the flow of electricity [Self-made]

When using static excitation, (Figure 13), the AC current is converted into DC by a thyristor bridge which is located in the MCP or its vicinity. The DC current is then conducted directly to the rotor field coils through brushes and slip rings. The advantage of brushed excitation is that the changes made in the excitation current in the MCP skip

the delay of induction and conversion reach the field coils faster. Additionally, less additional mass needs to be attached to the motor shaft as is the case with brushless excitation. On the other hand, the slip rings and brushes create friction as the brushes chafe the slip rings. This leads to wear in the brushes and therefore additional maintenance requirements. This is why brushless excitation systems are much more common than static excitation systems.

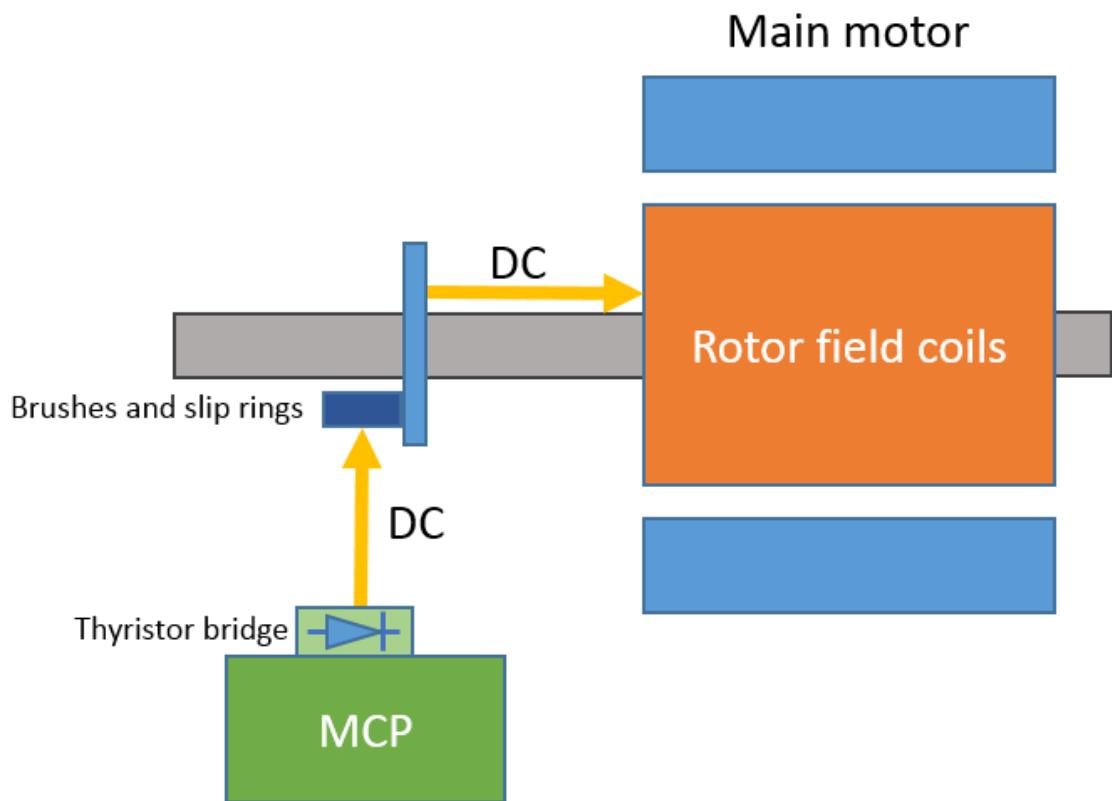


Figure 14. Simplified diagram of a static excitation system. [Self-made]

Feeding a rotor with an excitation current causes the field windings in the rotor to magnetize and create a stronger MF. This gives the rotating MF of the stator something to grab properly and eliminate the slip in the motor. [11]

As mentioned before, a magnetic flux between the rotor and stator induces a current into the stator coils. This current causes the reactive power in the system. In a SM, this magnetic flux can be controlled by raising or lowering the excitation current. Therefore, when adjusting excitation current, the power factor of the motor is adjusted as well. [12]

As explained above, adjusting excitation current can be used to regulate the power factor of a motor to a certain degree. Increasing the excitation current causes a motor to produce more reactive power, (leading), and decreasing the excitation current, the reactive power is decreased as well (lagging). When power factor is close to 1, the motor is considered to run in unity. This is when apparent power and real power are very close to each other, therefore the efficiency of the motor is as its peak. [12]

This means that increasing the excitation current can be used to compensate for heavy inductive loads on the grid. This could be useful, for example, when DOL-starting other motors in the grid. As mentioned before, starting a large motor creates heavy inductive loads to the grid. If there are motors running in the grid already, the excitation current of one or more of these motors can be decreased, so they consume less reactive power from the grid. This enables the motor that is being started to receive that reactive power, and start without causing a large voltage drop in the grid.

Basics of excitation theory summed up:

- Excitation current is provided to the system via electromagnetic induction (brushless excitation) or via brushes and slip rings (static excitation)
- Exciting the rotor coils magnetizes them and eliminates slip in the motor.
- Excitation current is controlled by a MCP.
- Adjusting excitation current can be used for adjusting power factor of a motor.

### 3.3.1 Operation of a motor control panel

This chapter addresses the various functions that a MCP uses to control the excitation current of a SM. The MCP 300-series panels use a UNITROL 1020 automatic voltage regulator (AVR) to control the excitation current. The technical specification of the UNITROL 1020 can be reviewed in appendix 1. The AVR receives measurement data from the grid and the motor and uses the data to regulate the excitation current.

The MCP receives measurement data (real time voltage and current values) from the grid and the motor. The received data is used to calculate the required current. The current is regulated by two different functions: control functions, and limiter functions. The control functions are selected from a switch in the MCP. Limiter functions on the other hand, are selected and adjusted during MCP commissioning. The limiter func-



tions are always motor specific, and there are seldom reasons to change them after the commissioning. Limiter functions are inbuilt software safety functions in the AVR. The limiters protect the SM from unsafe operations, such as overheating and falling out of step (losing the synchronous speed). The limiter functions and the safe operating zone of the SM can be displayed in the P/Q- diagram.

The most commonly used control modes, limiter functions and their most common uses are explained below in more detail.

### **Control modes**

There are four different control models featured by the UNITROL 1020 [Appendix 1. page 6]:

- Power factor control
- Reactive power control
- Automatic voltage regulation
- Manual control.

The two most commonly used modes are power factor, - and reactive power control. These two will be discussed more closely in this document.

The power factor control mode keeps the power factor at a desired setting. This can be used when the motor needs to be run at maximum efficiency, or can be used to momentarily increase or decrease the power factor. This means that whenever there are changes in the power components in the grid power, the AVR delivers a different excitation current, so that the change in power factor is minimal. This means that the active and reactive power values of the motor can change in use. Power factor mode is displayed on a P/Q diagram on the left side of figure 15.

The reactive power factor control is used to keep the reactive power at a set value. When there are large induction motors in the grid, the inductive load they produce can be negated by adjusting the grids' reactive power. This can be achieved by adjusting the reactive power of a SM. Similarly to the power factor control, the AVR keeps the reactive power at a set point even if there are changes in the grid values. This means

that the active power and the power factor of the motor are variable values. Reactive power mode is displayed on a P/Q diagram on the right side of figure 15.

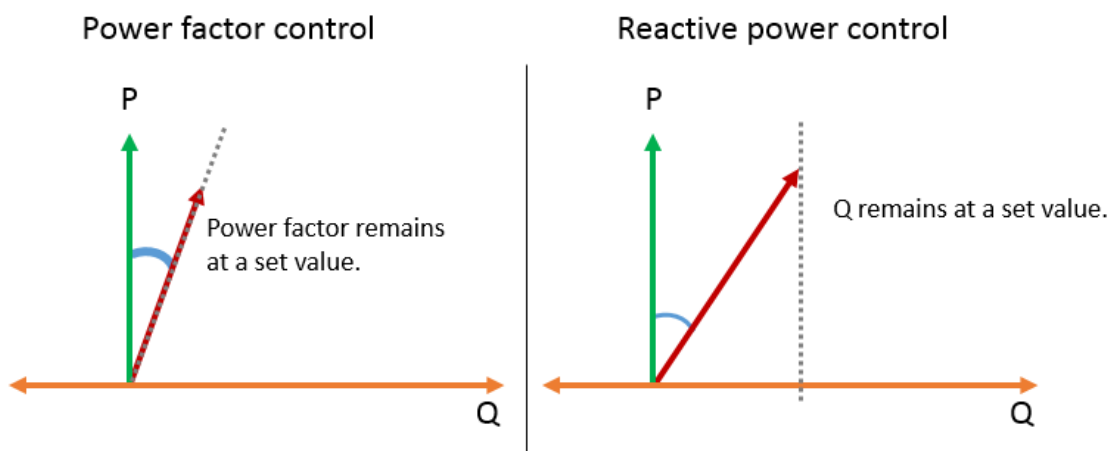


Figure 15. Power factor and reactive power control modes. The operating point is always set along the dashed line. The position of the line is adjustable. [Self-made]

### Limiter functions

The limiter functions are also software based functions. As the name suggests, the limiter functions limit the excitation current in order to keep it within safe limits. There are three main limiter functions that will be briefly discussed in this document.

The limiter functions can also be displayed in a P/Q-Diagram. Figure 16 shows how the limiter functions can be used to limit the operating point of the SM. The red area in the image is the safe zone for operation, and the lines of various colours represent the limiter functions. When the operating point reaches a limiter function line, the AVR decreases, or increases the excitation current accordingly, to keep the operating point within the allowed borders.

The main limiter functions are [Appendix 1. page 6]:

- Maximum field current limiter: Protects the rotor from overheating.
- Minimum field current limiter: Prevents the excitation from decreasing to a too small value. Protects from asynchronous operation.
- Under-excitation limiter: Also protects the motor from rotor overheating.

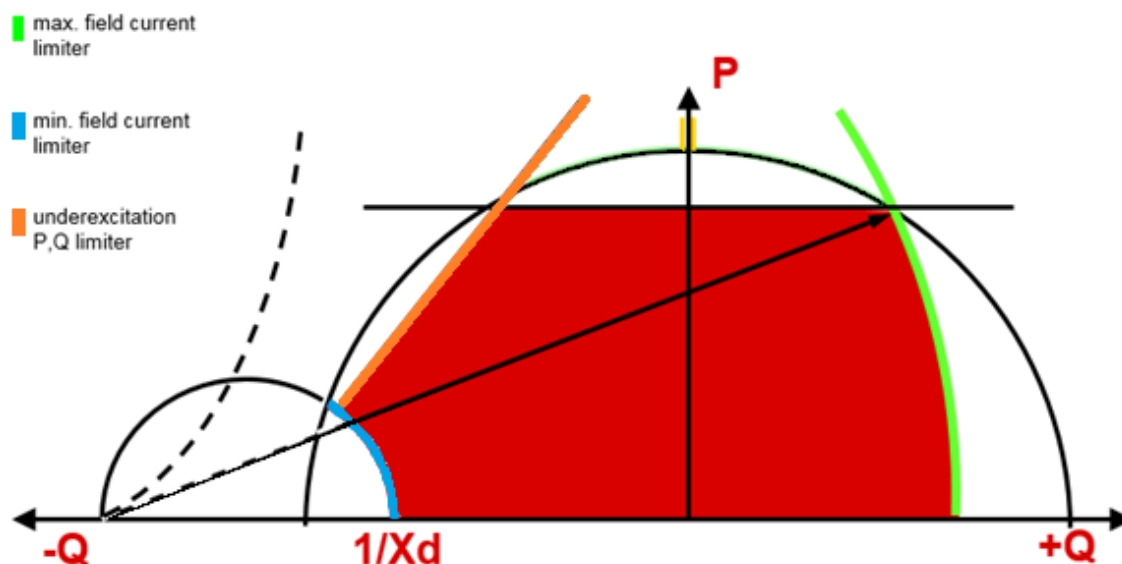


Figure 16. Limiter functions displayed in a P/Q-Diagram. [Self-made]

#### 4 MCP 300-Series

This chapter contains a brief introduction to the MCP 300 product family, and to the differences between the models. The main components of the panels are also discussed using enough details for the reader to understand what components are typically included in a MCP. Some components are selected through co-operation with the customer, and the rest are default components that are usually included in the cubicle.

MCP 300 product family has four different models for different excitation purposes. The models and their purposes are:

- **MCP 310:** The MCP 310 is the standard model control panel for DOL-started motors.
- **MCP 330:** the standard dual channel panel. Can be used with DOL-start with any start-current lowering methods.
- **MCP 350:** The MCP 350 is the standard model control panel when using VSD start. Can be fitted with dual channel operation.
- **MCP 370:** The go-to model for brush-excited motors. MCP 370 can be used with any starting method, and can be fitted with dual channel operation. With static excitation, the excitation current is converted from AC to DC by a thyristor bridge inside the MCP 370.

The model is selected together with the customer and is always application specific.

In addition to the AVR, the MCPs include the following main components

- **Control logic relays:** The start sequence of the motor is controlled with a set of solid state relays. The relays are responsible of tripping the motor if there is fault in the start that may cause damage to the motor.
- **Protective relays:** The control logic relays protect the motor during start. The protective relays protect the motor during operation. There are multiple relay options selectable for the MCP 300 units.
- **Speed switch:** The speed switch is used together with an inductive switch in the motor to measure the rotational speed of the rotor.
- **Measuring transducer:** The measuring transducer measures variables from the motor and the grid, and supplies them to the distributed control system.
- **Transformer:** There are multiple electronic components in the cubicle, therefore a transformer is required to feed the electronics the power they require.
- **Panel meters, switches and indications:** These are used to monitor and control the operation of the MCP.

## 5 The purpose of this thesis

Where there is a large ABB synchronous motor (SM), there is a motor control panel (MCP). The technology of the electronic components that are used in the construction of the MCPs develop at a faster rate than the parts of the SM. As the production of the MCPs is updated to incorporate newer and better components, the older MCP models become a liability for the customer support of ABB as there are old components in the customers' panels that are no longer used in production. As the technology that was used in producing the older models becomes outdated, the availability of the components diminishes and they become difficult to come by. Therefore it is relevant to keep the customers' MCP model-base in check, and keep upgrading the customers' panels in order to prevent them from going obsolete. This way ABB can maintain optimal life cycle support for the customers' MCPs.

ABB has set up a four phase product life cycle management (PLM) system for MCP products. [Appendix 2, page 1] The products are divided into four categories depending on the age and availability of the technology used in their production. The categories are Active, Classic, Limited, and Obsolete. The products in each category change as time passes. An MCP model in the Active-phase, may fall into the Classic-phase as the availability of an important component decreases.

A product in the Active-phase has a guaranteed PLM support from ABB. The product as a whole, and the parts used in its' construction are sold actively.

The products in the Classic-phase are no longer actively sold, but are available for spare parts and other PLM support.

In the Limited-phase, the PLM-support is available as long as spare parts and material exists, and for Obsolete-products ABB cannot guarantee PLM-support and therefore recommends updating to an Active-series product.

The MCP's are often sold as subsidiaries with new motors. The lifespan of an MCP is years shorter than the life cycle of the SM. Therefore, the MCP often needs to be changed during the life cycle of the SM.

When offering a customer a new MCP product as a subsidiary with a new SM, or as a replacement for an older MCP model, the salesperson usually has to provide a technical specification of the offered panel. The specification needs to include enough relevant information for the customer to be informative. Additionally, in order to be understandable to a customer with no background in electrical engineering, the specification needs to be clear and easy to read and simple for the salesperson to explain step-by-step. It is also often preferred to have a simplified connection diagram, also known as a single line diagram (SLD) in order to make the specification more describing of the product.

The purpose of this thesis, was to create a tool for the sales- and after sales teams for an easy preparation of the technical specification of the MCP. The tool was created in Microsoft Excel 2013-program. The reasons Excel was chosen were its' suitable functionalities, easy accessibility for ABB personnel and its widely known use across the world.

In order for the author to write a universally understandable description of the creation process of the tool, it was decided that this report is to be written in English.

## 5.1 Issues with MCP sales

In addition to selling new panels as subsidiaries with new synchronous motors, it is important to sell new panels to replace old panels in order to keep up optimal PLM support for the customers. Failing to do this results in customers having an old MCP product base and loss of revenue for ABB due to lack of sales of MCPs and spare parts. Selling new, substitutive MCPs requires the sales teams to be active in locating customers with old MCPs and selling new panels to them.

The sales team also needs to be informed and educated whenever a new MCP product comes to the market so they know the details of the new product to make selling more efficient. So far the sales teams have not been educated enough on the new MCP 300 series.

The sales teams also need appropriate tools to remain active. Filling out forms manually is tedious and repetitive work and therefore may discourage the personnel and affect sales. Before this configurator tool ABB has had no similar tool for MCP 300 series in widespread use among the sales teams.

## 5.2 Goals of this thesis

In order to increase sales of MCP 300 series, ABB has started to raise awareness of the new product family among the sales personnel. In the summer of 2017 the author of this report created a machine description document (MDD) that describes the functions and components of the MCP 300 series in greater detail. The document was written with the sales personnel in mind to help sales describe the product to customers. ABB has also held training lectures to sales personnel to bring them up to speed about MCP 300 series.

In addition to the training and the descriptive documents, ABB also needed an easy to use tool to create descriptive technical specifications. The specifications are used as a part of an offer for a new MCP for ABB personnel to describe the product to customers. This configurator tool was created to fill this need.

The goal of this engineers thesis work was to create a configuration tool for the MCP 300 series panels. The configurator tool must be easy to use and have enough functions to make descriptive technical specifications that are easy to read and simple to explain to a near-layman. The configurator tool should also attach three different diagrams to the technical specification to further describe the product.

## **6 The configurator tool**

This chapter includes a detailed description of the methods that were used during the creation process of the MCP 300 configurator tool. The author was requested to create the tool by using as much simple cell-logic functions as possible. The reasoning for this was that while the more complex Visual Basic and macro based functions would add more flexible options for creation and use, it would also make updating and troubleshooting more complicated. Therefore the Configuration tool was created to be completely VBA- and macro-free.

The configurator tool is an Excel worksheet with the following three tabs:

- Specification tool tab (STT)
- Diagrams tab
- Print area tab

The STT includes multiple text input-fields, check-boxes and option buttons. All user input is done on the STT. The STT is divided into 9 different sections, each of which specify certain components or options for the panel. The sections are numbered from 1-9, to guide the user from start to finish, and to prompt the user into filling the STT logically section by section. This way, all the intended information will be input into the STT.

The Diagrams-tab has all the relevant Single Line Diagrams (SLD). Print area-tab reads the inputs on the STT and imports the correct SLD for the panel. The SLDs are imported from the Diagrams-tab to the second, third and fourth page of the Print Area-tab by using a picture lookup.

The picture lookup uses INDEX and MATCH functions in a specified name, which is given to an initial Image in the print area pages. This process is explained in more depth in chapter: 6.1 Creation. The Diagrams-tab is used only as a place to store and recover the diagrams as needed. The user will never have a reason to open the tab except when updating or altering the tool.

The print area-tab takes input data from STT and the SLDs from the Diagrams-tab and fills out a technical specification that can be saved as a PDF-file or printed out for the customer for reviewing.

## 6.1 Creation

This part of the report addresses the creation process of the excel configurator tool. All individual parts and cell-formulas are not displayed or described, instead some parts were chosen to display the general idea behind the tool and the logic behind it. The operation of checkboxes, option buttons and text field inputs is explained in general, instead of explaining the use of each box and button.

This chapter is also intended to act as a guide for the maintenance and upkeep of the tool. After reading this chapter, the reader should be informed enough about the creation process of the tool to make changes using the same functions and formulas.

Some data fields transfer data from an input-type text field directly from the STT to the Print area tab, and others use nested IF, AND, OR and all of the previous in different combinations. The text field type inputs have a grey background in the specification tool as indicators for input field (Figure 17), and the other logic functions take their input from check boxes and option buttons.



	B	C	D	E	F	G	H	I	J	
5	<b>1. Project details</b>									
6										
7	Project:	<input type="text" value="Example 12"/>				Order no.:	<input type="text" value="1234567890"/>			
8										
9	Customer:	<input type="text" value="EX Ample Oy."/>				Sales by:	<input type="text" value="Eric Xavier Amplee"/>			
10										
11	Motor:	<input type="text" value="Motor examplee"/>				Date:	<input type="text" value="14.10.2017"/>			
12										

Figure 17. Input text fields in the STT [Self-made]

### Use of check boxes and option buttons

Inputs from check boxes and option buttons work through linked cells. (Figure 18) The cells that are linked to checkboxes change their value from TRUE to FALSE depending on the status of the linked checkbox. Option buttons change the value of their linked cell from 1 to X, where X depends on the number of buttons in the group. The option buttons were grouped using the Group Box tool. If the buttons are not grouped, all the buttons in the worksheet will share the same linked cell, and cannot be used in different applications.

	F	G	H	I	J	N	O	
13	<b>4. Power supply</b>					13	<b>4.</b>	
14						14		
15	Supply voltage:	<input type="text" value="500"/>		[ AC DC ]		15	FALSE	
16	For AC: Frequency	<input type="text" value="50"/>		[ 1~ 3~ ]		16	TRUE	
17						17		
18	<input type="checkbox"/>	Redundant power supply for excitation					18	1
19	<input checked="" type="checkbox"/>	Redundant power supply for electronics					19	1
20	<input checked="" type="radio"/>	AC Redundant power supply for electronics: AC					20	1
21	<input type="radio"/>	DC					21	

Figure 18. Check boxes, option buttons and their linked cells. Linked cells and their values are on the right side with tan background. [Self-Made]

The cells that use the data from the checkboxes and option buttons manage the data by referring to one or more cells with user input data in the STT and using different formulas to change the value of the printed cell.

Example of check boxes and option buttons in action:

Option buttons are used in the STT (Figure 19) to determine the protective relay-option in the Print area.

	B	C	D	E		N	
22	<b><u>6. Protection</u></b>					23	<b>6.</b>
23						24	
24	<input type="radio"/> MRQ1 + MRR1					25	5
25	<input type="radio"/> Multilin SR469					26	FALSE
26	<input type="radio"/> Multilin SR489					27	FALSE
27	<input type="radio"/> ABB REM 543					28	
28	<input checked="" type="radio"/> ABB REM 545					29	
29	<input type="checkbox"/> Differential protection <input type="checkbox"/> Differential protection <input type="checkbox"/> 5A Secondary current (Default 1A)					30	
30						31	
31						32	

Figure 19. Protective relay option buttons in STT [Self-made]

The formula in the print area cell that displays the selected relay is presented in sample formula 1:

```
=IF(AND(OR('Specification tool'!E12;'Specification
tool'!E13);'Specification
tool'!J20=1);"MRQ1";IF(AND('Specification
tool'!E13=FALSE;'Specification tool'!E12=FALSE;'Specification
tool'!J20=1);"MRQ1 + MRR1";IF('Specification
tool'!J20=2;"Multilin SR469";IF('Specification
tool'!J20=3;"Multilin SR489";IF('Specification tool'!J20=4;"ABB
REM 543";IF('Specification tool'!J20=5;"ABB REM 545"))))))
```

**Sample formula 1:** Multiple nested IF-functions with AND- and OR functions. J20 is the linked cell for all of the option buttons

In addition to the option buttons, the cell also recalls data from two check boxes, E12 and E13. (Figure 20) This is done because the option MRQ1+MRR1 is not necessary when using excitation with brushes or VSD start. Instead the MRQ1 relay is used as a standalone protective relay when exciting via brushes or using VSD start.

	K	L	M	N
5	<b>2. Panel model information</b>			<b>2.</b>
6				
7	<input checked="" type="checkbox"/> Excitation with brushes			TRUE
8	<input type="checkbox"/> VSD Start		Model:	FALSE
9	<input checked="" type="checkbox"/> Dual channel		MCP 370	TRUE
10	IP class: IP54			
11				
12				

Figure 20. Additional checkboxes that affect the relay selection formula. [Self-made]

## Lists

There are three lists in the print area that are composed of multiple check-box selections. The lists were done by using three helper columns in the STT. Figure 21 shows the check-boxes and helper columns for a list. The helper columns are situated in columns O, P and Q.

	F	G	H	I	J	O	P	Q
22	<b>7. Meters</b>					22	<b>7.</b>	
23						23	FALSE	Excitation current
24	<input type="checkbox"/> Excitation current		<input type="checkbox"/> Active power			24	FALSE	Excitation voltage
25	<input type="checkbox"/> Excitation voltage		<input type="checkbox"/> Reactive power			25	TRUE	1 Motor current
26	<input checked="" type="checkbox"/> Motor current		<input checked="" type="checkbox"/> Power factor			26	TRUE	2 Motor voltage
27	<input checked="" type="checkbox"/> Motor voltage		<input type="checkbox"/> Frequency			27	TRUE	3 Apparent power
28						28	FALSE	Active power
29	<input checked="" type="checkbox"/> Apparent power					29	FALSE	Reactive power
30						30	TRUE	4 Power factor
31						31	FALSE	Frequency

Figure 21. Left: Check-boxes for printed list. Right: Helper columns in the STT. [Self-made]

First of the helper columns (columns O) consists of the linked cells of the check-boxes that are used as user input.

The second helper column (Column P) is a number-column that shows the order number of all the check-box options. If a check-box is not checked, its linked cell shows the value FALSE, and it is not numbered in the number-column. The number column only gives an order number for the checked check-boxes, and leaves the unchecked ones empty. The operation of the second helper column is described by sample formula 2.

```
=IF(O26=FALSE;"";COUNTIF($O$23:$O26;TRUE))
```

**Sample formula 2.** From cell P26, second helper column. First, the formula checks if its respective linked cell is valued TRUE or FALSE. If the value is false, the cell remains empty. If the check-box is checked, and the linked cell is valued TRUE, the COUNTIF function counts all the numbers in the second helper column, and gives a value to the cell. The given value is a number that follows the previous number in the column.

Table 1 displays all the formulas used in the P-column to further describe the example above.

Cell	Formula
P24	=IF(O24=FALSE;"";COUNTIF(\$O\$24;TRUE))
P25	=IF(O25=FALSE;"";COUNTIF(\$O\$24:\$O25;TRUE))
P26	=IF(O26=FALSE;"";COUNTIF(\$O\$24:\$O26;TRUE))
P27	=IF(O27=FALSE;"";COUNTIF(\$O\$24:\$O27;TRUE))
P28	=IF(O28=FALSE;"";COUNTIF(\$O\$24:\$O28;TRUE))
P29	=IF(O29=FALSE;"";COUNTIF(\$O\$24:\$O29;TRUE))
P30	=IF(O30=FALSE;"";COUNTIF(\$O\$24:\$O30;TRUE))
P31	=IF(O31=FALSE;"";COUNTIF(\$O\$24:\$O31;TRUE))
P32	=IF(O32=FALSE;"";COUNTIF(\$O\$24:\$O32;TRUE))

Table 1. List functions from column P.

The third helper column is a simple list of names with no formulas in it.

The operation of the list in the print area is described in sample formula 3.

```
=IFERROR(VLOOKUP(6;'Specification tool'!$P$23:$Q$31;2;0);"")
```

**Sample formula 3.** Cell I36 in the print area. The list uses the VLOOKUP function to create the printed list. VLOOKUP uses 2 columns in a worksheet. First it searches for a given number in the leftmost column in the selected area. The number in the sample formula is 6. Then it returns the value of the cell to the right of the number to the cell with the VLOOKUP. The VLOOKUP in the print area therefore scans the second helper column, and returns the names from the right side of the numbered cells.

If the VLOOKUP does not find the given number, it normally returns a #N/A-error. Therefore the IFERROR function is necessary. The IFERROR returns a given value if an error is detected. The given value in this case is an empty cell, in order to make the print area as easy to read as possible. This use of helper columns and VLOOKUP-function creates a list with no empty cells in between values.

Instructions on filling the STT appropriately are inserted as comments into each section of the STT. The instructions refer to the MDD that was written by the author of this report when further details are needed about a certain section.

### Picture lookup

As mentioned above, the appropriate diagrams are chosen by the logic print area cells in pages 2, 3 and 4. The method used for this application is called a picture lookup. The picture lookup uses INDEX- and MATCH functions that are defined in a name, which is given to a diagram. There is a single image per picture lookup on the print area with a given name. The name creator prompts the user to give the name something for the name to refer to. Figure 22 displays the name creator with the referred ranges.

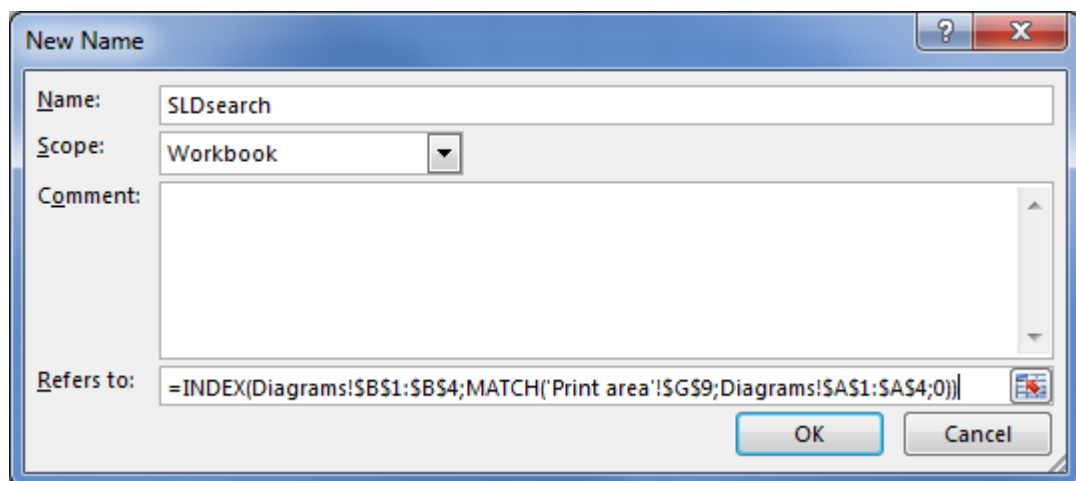


Figure 22. Name creation with the picture lookup formula.

The formula in the Refers to-field is observed closer in sample formula 4:

```
=INDEX      (Diagrams!$B$1:$B$4;      MATCH      ('Print      ar-
ea'!$G$9;Diagrams!$A$1:$A$4;0))
```

**Sample formula 4.** Formula required for a picture lookup. The formula is specified in a name instead of a cell. Then the name is given to a sample image in the print area tab. The sample image can initially be any image as long as it is given the right dimensions. The INDEX function returns a value from a table or an array from the intersection of a given row and a given column.

In this application, the INDEX function is used to return an image (a SLD) from a table that consists of two columns (Cells A1-A4 and B1-B4), one column (A) has the names of the available SLDs and the other (B) has the diagrams themselves. It is important to fit the images to the cells of the column properly and select move and size with cells-option from the format picture-options. This way the images are locked to the respective cells.

First the INDEX function is given the array from which it will search a value (The value is an image in this case.). That array is cells B1-B4. Second, the function is given a row that specifies which cell value will be returned from the array. The row in this case is selected with a MATCH function. The match function searches the print area for an MCP model (Print area cell G9) and returns a value from the array from a row that has the exact value that is specified in the print area. The picture lookup then copies the correct image from the index array to the named image on the print area tab.

## 6.2 Diagrams

This chapter addresses the different diagrams that will be attached to the technical specification. The configurator tool takes in the user input data from the STT and uses it to compile the technical specification in the print area. As a part of the print area, the configurator tool also chooses correct diagrams from the diagrams-tab and attaches them to the second, third and fourth pages of the print area.

Due to delays in the delivery of the up-to-date connection diagrams, the diagrams themselves were not implemented to the configuration tool during the making of this thesis. Instead, the author made clear instructions on how to implement the picture lookup for the diagrams.

As mentioned before in chapter 5.2 Goals of this thesis, there are three different diagrams that the configurator tool attaches to the print area. Each diagram takes one A4 page, and they are used to display certain things about the MCP and to make it clear to the customer what they are being offered. The diagrams and their purposes are as follows:

- Single Line Diagram (SLD)
- Panel layout diagram
- Door layout diagram

The SLD is the most complex diagram in the technical specification. It displays a simplified connection diagram for the main elements of the excitation system. The main components being:

- Motor control panel and its main components
- Power supply
- Distributed control system
- Exciter (with brushless excitation only)
- Synchronous motor

There will be six different SLD diagrams in the Diagrams tab of the tool. During the planning of the configurator tool it was decided that six options is sufficient for the specification tool to be informative enough, without making the configurator tool too complex. The selected SLDs depend on the model of the MCP. There are only four different models in the MCP 300 series, but it was decided that dual channel options for MCP 350 and MCP 370 should be displayed in the SLD.

The logic behind choosing the correct SLD is displayed in figure 23. In situations with cross the selected SLD works so that it always favours the rarer option. Excitation with brushes is less commonly used than VSD start, therefore, the selected SLD has a brushed excitation system instead of a VSD start.

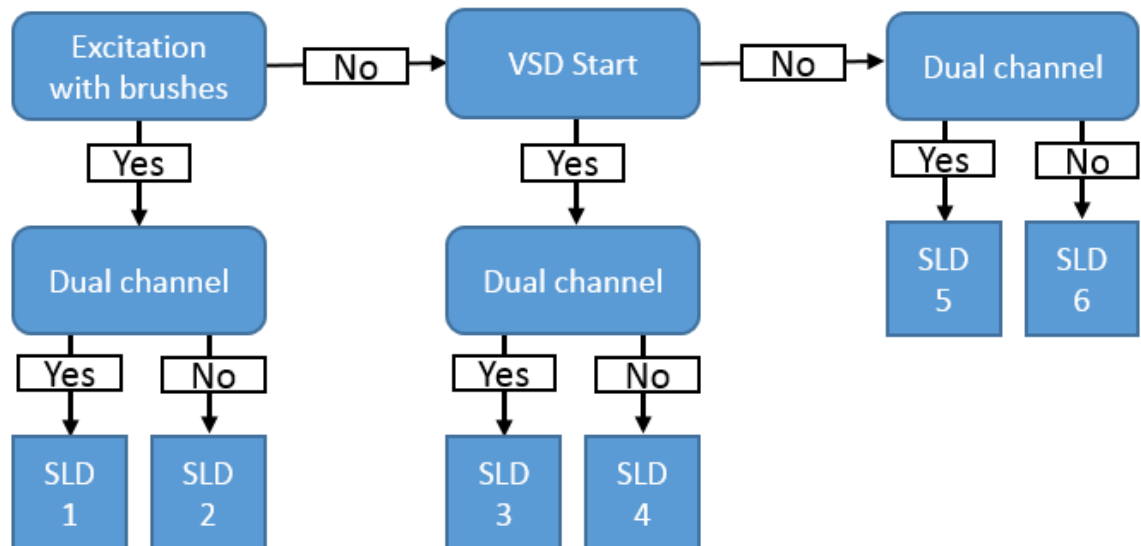


Figure 23. SLD selection logic. [Self-made]

In addition to the connection diagram, indication lamps, meters and switches in the panel door are also listed in the SLD. As there are only six different SLDs available in the diagrams-tab, therefore the SLD is not always absolutely correct. Instead it displays the default selections for the options that do not affect the SLD choice. The SLD does not take into account other choices that are made in the STT than the ones done in the Panel model information section, which was displayed earlier in figure 18.

The door layout diagram displays the place of the components on the door of the MCP cubicle. The diagram can be used as a cheat sheet when adjusting the MCP values or when briefing the customer about the product.

The panel layout diagram can be used when determining where the MCP will be installed. The diagram illustrates the physical dimensions of the cubicle, and is important when designing the technical space where the panel will be located.

## 7 Results and discussion

The objective of this thesis was to create a simple to use tool for sales personnel. The tool would create a technical specification according to the selected options. It was suggested by the personnel that the technical specification should only be a page long plus the required diagrams.



A meeting was held with instructors from ABB in. During this meeting the current version of the tool was closely reviewed by the attendees. Several suggestions about adding content and visual elements were made, but the tool was deemed to include everything relevant and to be simple and informative enough. Adding more than the suggested contents would have only made the tool more complicated to use, and the specification too long and complex for customers.

Due to delays in the delivery of the up-to-date connection diagrams, the diagrams themselves were not implemented to the configuration tool during the making of this thesis. Instead, the author made clear instructions on how to implement the picture lookup for the diagrams.

As a result of this thesis, ABB now has a simple excel-based tool for an easy creation of descriptive technical specifications for MCP 300 units, and the instructions for keeping it up to date.

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## Appendices

## UNITROL 1000 – Compact and powerful Automatic Voltage Regulators



## Product benefits



ABB is the world leading volume supplier of high quality UNITROL automatic voltage regulators (AVR) and static excitation systems (SES) that offers solutions for any type and size of power plant with high return on investment. UNITROL 1000 product family covers low power range applications and sets with respect to functionality, reliability and connectivity a new benchmark for the global industry.

UNITROL 1000 provides compact and reliable solutions. Various built-in control software functions, robust mechanical and electrical design enable a wide range of applications.

### Main features

- Compact and robust AVR for excitation current up to 40 A
- Separate communication and control processors
- Wide range of built-in control software functions
- Ethernet-based fieldbus interface
- Wide range of power input voltage, for AC and DC input
- Flexible and freely configurable measurements and inputs / outputs (I/Os)

### Wide range of applications

- Land-based power plants based on diesel engines, gas or steam turbines and hydro turbines
- Marine: electrical propulsion and auxiliary supply
- Traction: diesel electric locomotives
- Wind: based on direct connected synchronous machines
- Synchronous motors

## Key benefits

### + Stable and reliable control of your machine

Highly integrated and robust AVR for harsh industrial environment. Stable and accurate regulation even with highly disturbed voltages.

### + AVR for various applications

Fully configurable I/Os and measurement inputs and user-specific configurable field bus interface enable easy plant integration.

### + Easy operation, monitoring and maintenance of the system

Intuitive and user-friendly commissioning tool.

### + Full support for grid codes

Built-in Power System Stabilizer (option), simulation models and grid code studies available.

### + Efficient product life cycle management

Extended life time of your assets with minimum costs.

### + Professional technical help always within your reach

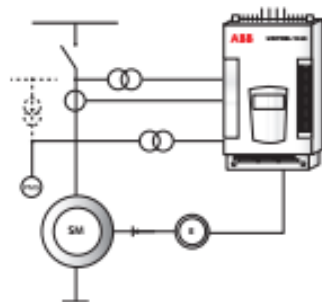
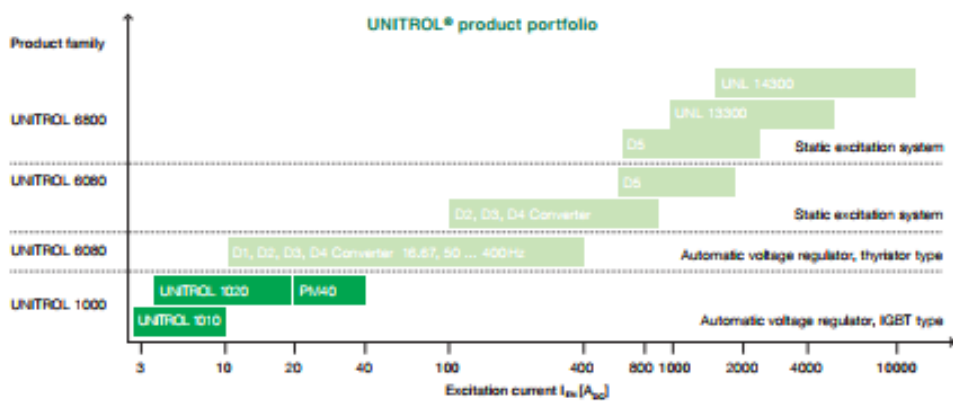
ABB's global excitation service network.

# Portfolio

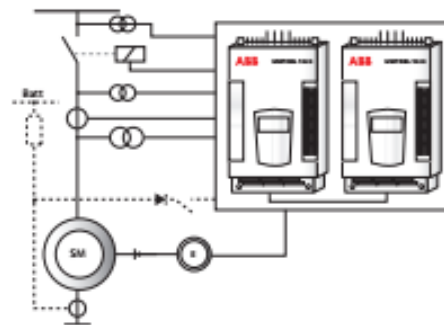
UNITROL 1020 and UNITROL 1010 are the latest products of the UNITROL 1000 family. For most reliable operation, the communication and control tasks are split in separate controllers. The non-volatile flash memory of the AVR stores events and data logs to enable fault analysis and fast trouble shooting. Time synchronization is done over Ethernet communication, and the events and data logs are time-stamped.

UNITROL 1000 is provided with modern communication ports like Ethernet and USB for connection of the PC-based commissioning tool CMT1000. Besides it is possible to power up the controller of the device via USB port. Thus the user can download files or configure the device even when no input power is available. AVR output stage is based on proven IGBT technology, which allows AC and/or DC voltage inputs from different sources.

UNITROL 1020 and UNITROL 1010 are designed for a wide range of ambient temperature and harsh environmental conditions and can be mounted directly on the machine.



Single channel generator or motor excitation with PMG supply.

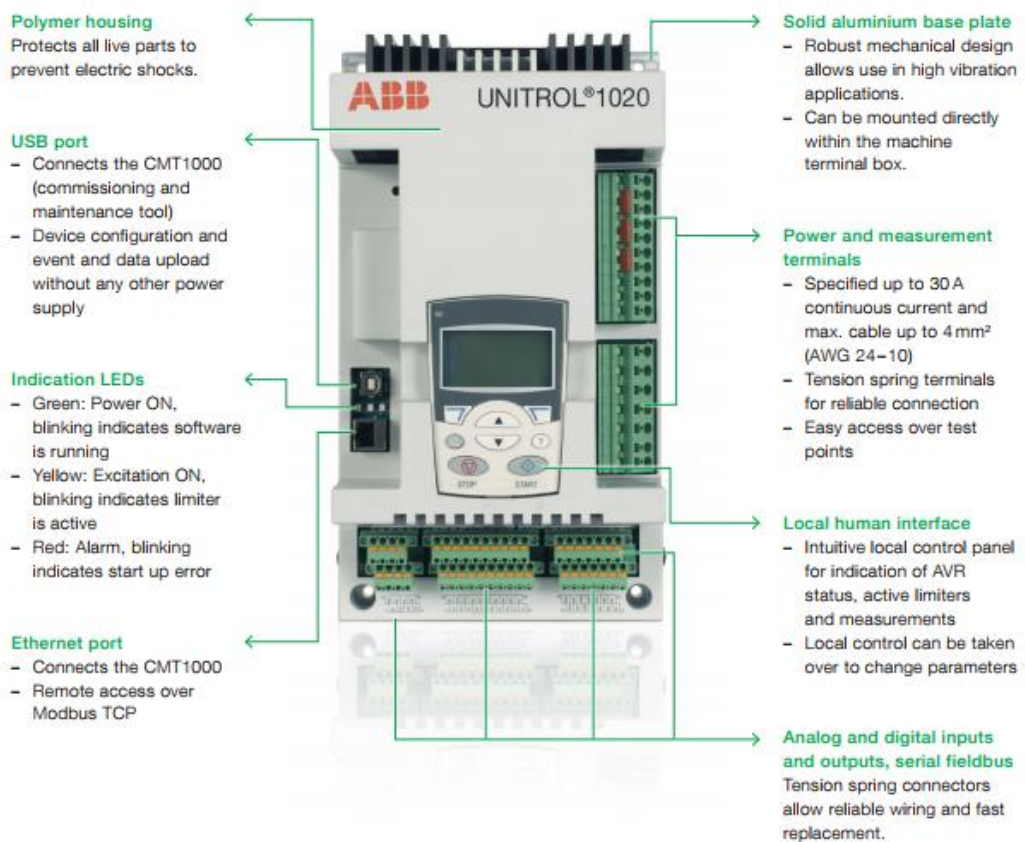


Dual channel generator or motor excitation with compounding and field flashing.

## Overview

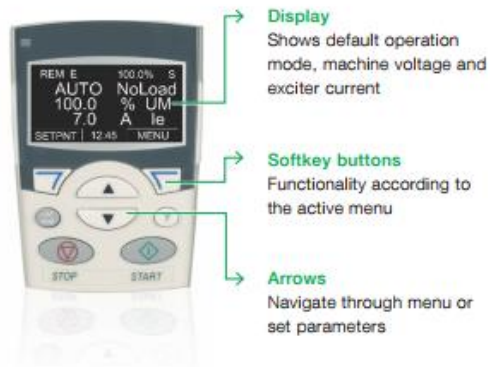
UNITROL 1020 combines high performance control and power circuits with a simple mechanical design. The construction provides a platform for a broad range of small applications, including those in highly demanding

environmental conditions. Furthermore, high levels of EMC immunity is achieved through separation of the power and measurement terminals from the I/O connectors.





Local human-machine interface provides immediate data on AVR status.



The UNITROL 1000 family has freely configurable measurement and analog or digital I/Os. The configuration is done via the local human-machine interface or CMT1000 software.

#### Power terminals

- 3 phase excitation power input
- 3 phase auxiliary power input (control power supply)
- Excitation output

#### Measurement terminals

- 3 phase machine voltage
- 1 phase network voltage
- 1 phase machine current

#### Analog I/O

- 2 outputs/3 inputs (configurable)
- +10 V/-10 V references output

#### Digital I/O

- 4 inputs only (configurable)
- 8 inputs/ outputs (configurable)
- 24 V output (600 mA) for external relay

#### Serial fieldbus

- RS485 for Modbus RTU or VDC communication
- CAN for dual channel communication

UNITROL 1010 is a compact device with limited functionality and is designed for excitation currents up to 10 A nominal. It supports the same interfaces and has the same mechanical footprint as UNITROL 1020.



UNITROL 1000-PM40 is the power module that extends the output current of the UNITROL 1020 up to 40 A.



## Control software

The UNITROL 1000's software has all the functions necessary for modern excitation systems. ABB offers three software-function packages out of the shelf.

### LIGHT

The **LIGHT** version covers essential functionality for cost sensitive applications where limited software functionality is required.

- Regulator control modes: Bumpless transfer between all modes
  - Automatic voltage regulator (AVR)
  - Field current regulator (FCR)
  - Power factor regulator (PF)
  - Reactive power regulator (VAR)
- Limiters: Keeping synchronous machines in a safe and stable operation area
  - Excitation current limiter (min./max.)
  - PQ minimum limiter
  - Machine current limiter
  - V/Hz limiter
  - Machine voltage limiter
- Soft start
- Voltage matching

### BASIC

The **BASIC** version covers all functionality of **LIGHT** in addition to the following:

- Modbus TCP
- Rotating diode monitoring
- Analog input to PID summing point for super imposed regulator.
- VDC mode: Reactive load sharing for up to 31 machines in island operation.
- Dual channel/monitoring: Enables the dual channel operation based on self diagnostics and setpoint follow up over CAN communication.

### Available software packages:

	Software function	UNITROL 1010	UNITROL 1020
<b>LIGHT</b>	AVR / FCR / PF / VAR		
	Limiters		
	Soft start		
	Voltage matching		
<b>BASIC</b> (Configurable SW)	Modbus TCP		
	Rotating diode monitoring		
	Input for closed loop control		
	VDC mode		
	Dual channel/monitoring		
<b>FULL</b> (Configurable SW)	Synchronization		
	Event logger		
	Data logger		
<b>OPTION</b>	Real-time clock		
	Power system stabilizer (PSS)		

### FULL

The **FULL** version covers all functionality of **BASIC** in addition to the following:

- Synchronization: Fast and reliable built-in synchronizer.
- Event logger: Up to 500 events are stored in a non-volatile memory.
- Data logger: A data log of 12 signals is saved automatically in the non-volatile memory.
- Real-time clock: For accurate time stamped events and data logs.

### Power system stabilizer (PSS)

The **FULL** software version can be complemented with the power system stabilizer function. Compliant with the standard IEEE 421.5-2005 2A/2B, the PSS improves the stability of the generator over the highest possible operation range.



# Technical data and order codes

## UNITROL 1010/UNITROL 1020

Power electronic input	
AC input voltage 3-phase (max., sinusoidal)	0 to 300 V <sub>AC</sub>
DC input voltage (max.)	0 to 420 V <sub>DC</sub>
Max. peak input voltage (not sinusoidal)	420 V <sub>p</sub>

Voltage regulation	
Accuracy at 25 °C	0.2 %
AVR response time (3-phase meas.)	< 20 ms
AVR response time (1-phase meas.)	< 50 ms
PWM limitation	0.5 to 99 %

Excitation output UNITROL 1020	
Continuous output current (40 °C)	20 A <sub>DC</sub>
(55 °C requires an external capacitor)	
Continuous output current (55 °C)	15 A <sub>DC</sub>
Overload current for 10 sec. (55 °C)	40 A <sub>DC</sub>

Excitation output UNITROL 1010	
Continuous output current (55 °C)	10 A <sub>DC</sub>
Overload current for 10 sec. (55 °C)	20 A <sub>DC</sub>

Auxiliary supply (controller) input	
AC input voltage 3-phase (max., sinusoidal)	9 to 300 V <sub>AC</sub>
AC input voltage 1-phase (max., sinusoidal)	16 to 300 V <sub>AC</sub>
DC input voltage (max.)	18 to 420 V <sub>DC</sub>
Max. peak input voltage (not sinusoidal)	420 V <sub>p</sub>

Exciter current measurements	
Full range	0 to 40 A
Accuracy	< 1 %
Resolution	< 100 mA

Measurements	
Machine voltage, 1, 2 or 3 phase	up to 500 V <sub>AC</sub>
Machine current, 1 phase	1 to 5 A <sub>AC</sub>
Network voltage, 1 phase	up to 500 V <sub>AC</sub>
Frequency range	10 to 150 Hz
Accuracy	< ± 1 %

24 V digital I/O, 4 inputs, 8 I/Os	
Digital input impedance	< 2 kΩ
Digital input threshold (low/high)	5 V / 13 V
Digital output, max. output current	150 mA

±10V analog I/O, 3 inputs, 2 outputs	
Analog inputs impedance	< 240 kΩ
Analog output impedance	100 Ω

Communication interfaces	
Ethernet (cable length < 100 m)	10 / 100 MBit/s
USB version (cable length < 3 m)	1.0; 1.1; 2.0
RS485 data rate (cable length < 500 m)	Configurable
CAN (cable length < 3 m)	Only for connections between UNITROL 1000 devices (UNITROL 1000-PM40 or dual channel configuration)

Environmental data	
Permissible ambient temperature	-40 to 70 °C
Maximum heat sink temperature	90 °C

Mechanical stability	
Vibration, IEC 60068-2-6	DNV class B
Shock and bump, IEC 60255-21-2	Class 2
Seismic, IEC 60255-21-3	Class 2

EMC standards	
Generic immunity standard EN 61000-6-2	
Generic emission standard IEC 61000-6-4	

Certifications	
CE certification	
cUL certifications according	
UL 508c (compliant with CSA)	
DNV certification according class B	

## UNITROL 1000-PM40

Power electronic input	
AC input voltage 3-phase (max.)	0 to 250 V <sub>AC</sub>
DC input voltage (max.)	0 to 300 V <sub>DC</sub>
Absolute max. peak input voltage	350 V <sub>p</sub>

Excitation output UNITROL 1000-PM40	
Continuous output current (55 °C)	40 A <sub>DC</sub>
Overload current for 10 sec. (55 °C)	80 A

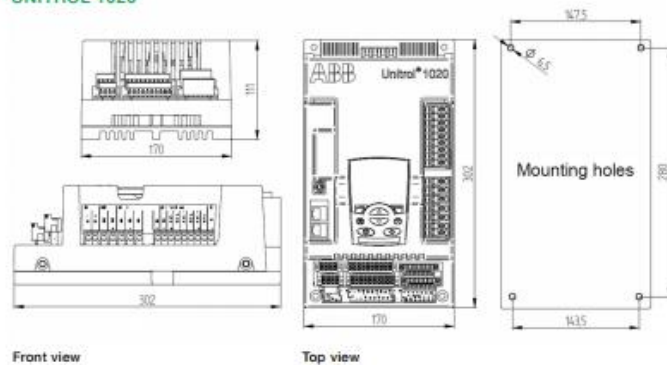
## Order codes

UNITROL 1010	
UNITROL 1010-0002 LIGHT	3BHE035301R0002
UNITROL 1010-0003 BASIC	3BHE035301R0003
UNITROL 1010-0004 BASIC + SYNC	3BHE035301R0004
UNITROL 1020	
UNITROL 1020-0003 BASIC	3BHE030579R0003
UNITROL 1020-0004 BASIC + SYNC	3BHE030579R0004
UNITROL 1020-0006 FULL	3BHE030579R0006
UNITROL 1020-0007 FULL + PSS	3BHE030579R0007
UNITROL 1000-PM40	
UNITROL 1000-PM40	3BHE015411R0001

Devices are shipped with a CD containing a CMT1000 commissioning and maintenance tool, a production test certificate and manuals.

## Mechanical dimensions

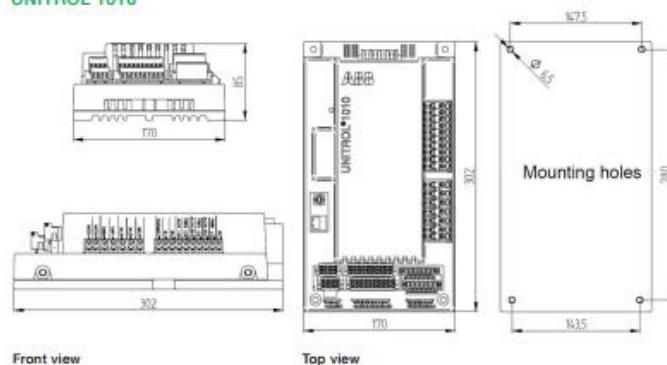
### UNITROL 1020



Front view

Top view

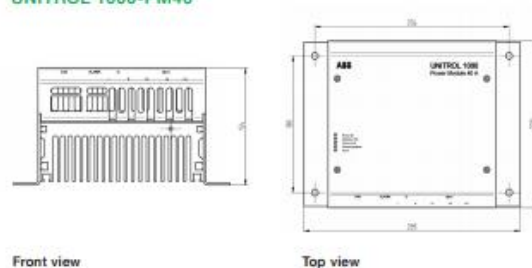
### UNITROL 1010



Front view

Top view

### UNITROL 1000-PM40



Front view

Top view

## Grid codes and UNITROL 1000 systems

### Grid codes

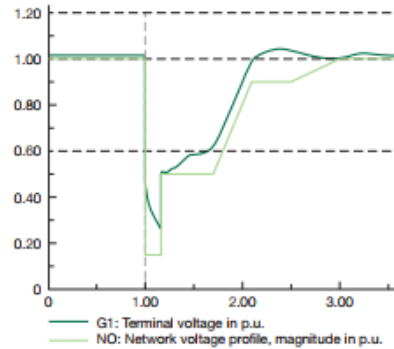
Built-in power system stabilizer and fast detection of voltage dips are prerequisites to meet any grid codes.

ABB provides detailed computer representation of internal control algorithm and IEEE models for system simulations.

In addition, ABB provides several levels of service:

- Calculation of PSS parameter
- Simulations of reference step responses
- Stability simulations for various different network conditions

ABB provides detailed questionnaires and provides results in a report.



Example of fault ride through defined grid code. ABB offers grid code compliant studies in order to prove stability under all circumstances.

### UNITROL 1000 systems

ABB provides over 100 years of experience in building project specific engineered systems for any applications.

ABB offers various systems depending on the need of the customer:

- Single channel systems
- Dual channel systems
- Mounting on a plate or in a cubicle

Systems include protection breaker and exciter field breaker. They are fully tested in the ABB factory and AVR setting can be ordered preset.

Ask our expert for more information about:

- Variable speed applications
- Multiple power input sources
- Synchronization of your machine
- I/O extension with external programmable logic controller over field bus



3D model of dual-channel system on a mounting plate.



## Service and support

For life cycle management or technical support, the worldwide network of UNITROL specialists is at your service.

### Installation and commissioning

The professionalism, extensive experience and multilingual skills of ABB's engineers ensure a satisfactory installation and commissioning.

### Training

ABB university offers standard and customized training courses for UNITROL excitation systems. On-site training options are also available. For a detailed training program, visit [www.abb.com/abbuniversity](http://www.abb.com/abbuniversity)

### e-Learning

With the UNITROL 1000 interactive e-learning program you decide where and when you learn. The program covers general excitation knowledge as well as detailed product handling know-how.

### UNITROL 1000 global support organization

A team of qualified engineers located in different ABB organizations worldwide are ready to support you with your most challenging enquiries and application requirements.

### Life cycle management

ABB's excitation systems life cycle management model helps the customers to extend and maximize the life cycle of their assets at minimum costs. Depending on the product's life cycle phase, the service specialists recommend necessary actions and approach the clients pro-actively to inform them on all maintenance, service and upgrade necessities.

### Examples of life cycle services:

- Technical support for optimized reliability
- Spare parts delivery
- Preventive and corrective maintenance
- Upgrade and modernization

For urgent technical assistance, please call the hotline:

+41 (0)844 845 845

(365 days / 24 hours)

or contact ABB by e-mail:

[unitrol1000support@ch.abb.com](mailto:unitrol1000support@ch.abb.com)



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## Product life cycle management EA10



### Current life cycle status

The EA10 motion controller is in the Limited phase since April 2016 according to the ABB life cycle model outlined above.

### Life cycle plan

It is planned to keep EA10 in the Limited phase at least until 30.6.2018, after which it will be transferred to Obsolete phase.

The ABB life cycle management model is designed to manage an orderly transition to new replacement products or to choose from various lifetime extending services. At the same time the model ensures access to continuing support for our customers.

### Recommended actions

It is recommended to replace the existing installation with compatible latest generation products.

### Further information

For more information on drives life cycle management and available services contact your local ABB organization or at [www.abb.com/drives](http://www.abb.com/drives).

### Product availability in Limited phase

The product is no longer available

### Service availability in Limited phase

Following services are available

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Spare Parts, availability limited

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Technical support available

4FFS1000065635, Rev.A, 10.10.2017

For more information please contact your local ABB  
representative or visit:

[www.abb.com/drives](http://www.abb.com/drives)

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