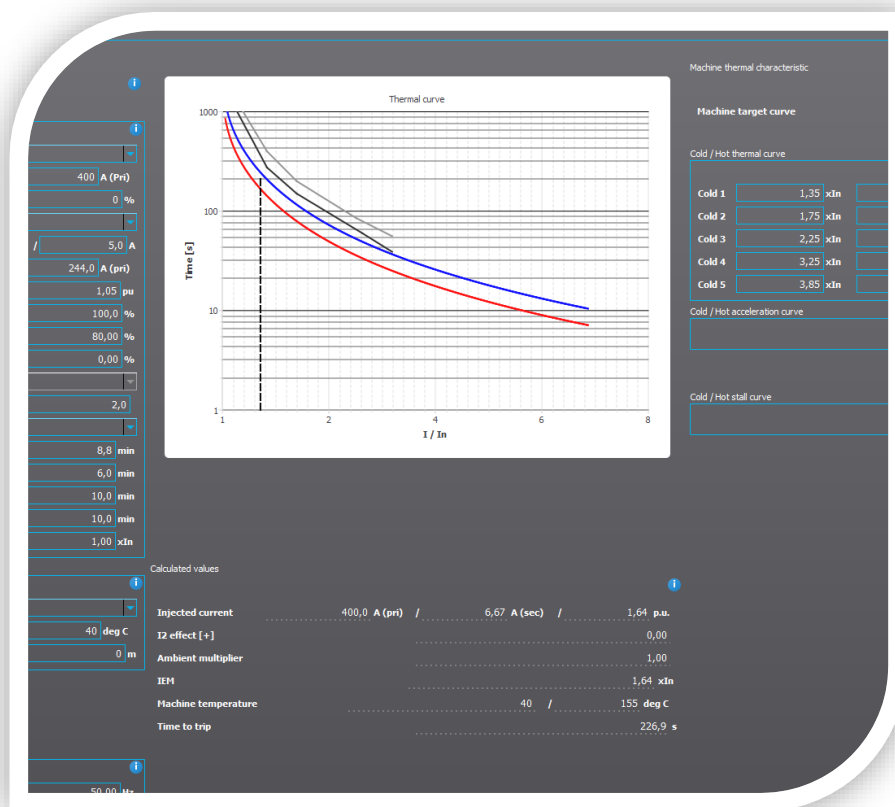


Motor Wizard

Instruction booklet



Revision	1.0
Date	10 May 2021
Changes	- The first revision of the booklet.
Revision	1.1
Date	2 May 2023
Changes	<ul style="list-style-type: none">- Updated the booklet visually.- Updated the document title to be consistent with other Wizard instruction booklets.- Added a cover image.- Added the all chapters except Chapter 5.- Added sources.

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1 INTRODUCTION

The Motor Wizard is an advanced setting tool integrated into the AQtivate 200 setting and configuration tool. The Wizard can be used to generate settings for a thermal replica of both induction and synchronous motors with an Arcteq protection relay (for example, AQ-M215 and AQ-M257A). A variety of motor-related information, such as its name plate values and data sheets as well as the system configuration, is the basis that the Wizard uses to build a suitable thermal replica to your relay.

Using the Motor Wizard offers various benefits:

- It is easy to install and easy to use.
- It has a built-in user manual in AQtivate 200.
- It makes it easy for you to write a thermal replica of the protected motor to your relay.
- It allows for fast commissioning of motor protection relays.

The basic function of the Motor Wizard is to provide a protected motor a fitting thermal replica based on given input values. Even though a motor thermal replica should be set according to the manufacturer's thermal curve presented in the motor's data sheet, this is rarely the case. More often than not, the thermal replica is made by copying the settings from the previous replica as well as possible. Alternatively, a single point is selected from the motor's actual thermal curve and used as the basis for commissioning. Neither of these methods can guarantee that the relay curve functions correctly at all times.



For additional information on the Wizard, please read the white paper written by our Senior Application Engineer Jani Vainionpää. The paper is available on our website at arcteq.fi/documents-and-software, and can be found under *Application notes and white papers* in the "AQ 200 series" section.

2 GETTING STARTED

2.1 Requirements

In order to download and upload configurations into and from your device, you first need to establish communication with it. This requires that you have a standard RJ-45 cable as well as at least one (1) free Ethernet port in your PC. Please make sure that your firewall and anti-virus protection programs allow AQtivate 200 to connect to the PC and freely use its Ethernet ports.

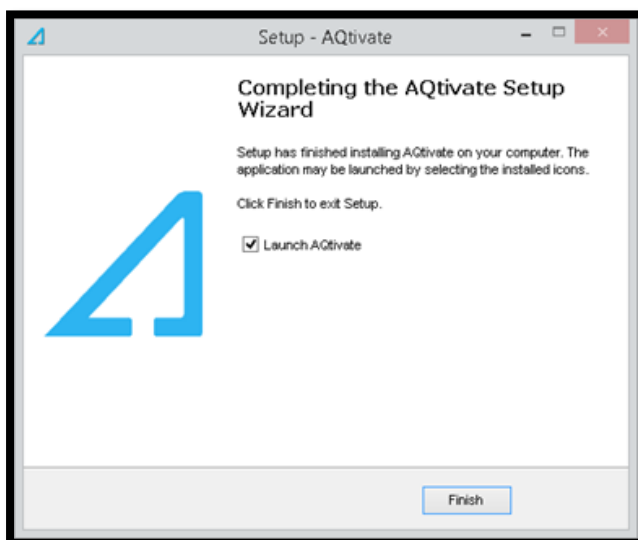
2.2 Installing the AQtivate 200 software suite

First, download the latest software installation file for AQtivate 200 from our website at arcteq.fi/documents-and-software, from the "Software" section. The software suite is free of charge. Please note that downloading requires that you log in to the Arcteq website. If you do not have a username to log in, you can create one at the top-right corner of our website. This is also free of charge.

When you have downloaded the installation files, launch the AQtivate Offline Installer .exe file (please note that this requires you to have administrator rights to the PC). First, the installer asks you to select the language that you would like to use during the installation process. Next, follow the step-by-step instructions provided by the AQtivate Setup Wizard to finish installing the software: select a destination for the software, select a place for the program's shortcuts, choose whether you want a desktop icon, and finally start the installation process by clicking **Install**.

When AQtivate 200 has been successfully installed, a pop-up window (*Figure 2-1*) will appear to prompt you to finish the installation process by clicking the **Finish** button in the window.

Figure 2-1. Finishing the AQtivate 200 installation process.



Please note that the installation process may be halted by your cybersecurity protections! If they detect the software suite, select to allow the connection to the PC. You may also manually whitelist AQtivate 200 on a list of programs allowed to have a connection to the PC.

3 CONNECTING TO A DEVICE

You can establish a connection between AQtivate 200 and your device by typing the relay's IP address to the Connect field at the top of the AQtivate 200 window (*Figure 3-1*) and then clicking **Connect**.

Figure 3-1. Connecting AQtivate 200 to a relay.



You do not have to be connected to a device in order to use the Transformer Wizard as it can also be used offline. You can store and open any project at any time. However, when you want to write your settings to the relay, you must have a connection between AQtivate 200 and your device.



Please note that establishing a connection to your protection device with the AQtivate 200 setting tool requires that the following ports must be open: 20, 21, and 1551. If the software cannot connect to your device, please check the settings in your firewall and anti-virus software suites.



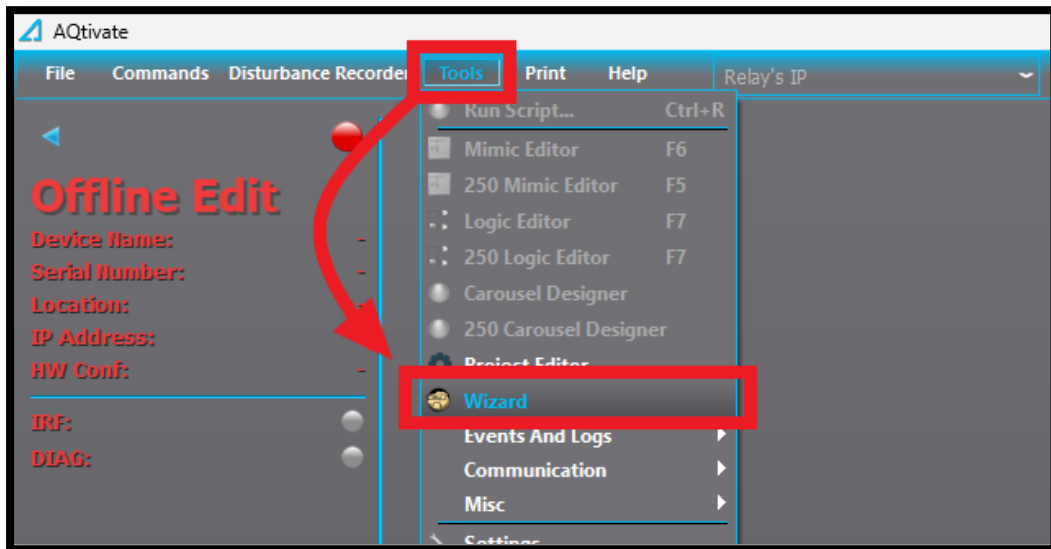
Each Arcteq protection relay is equipped with two (2) RJ-45 ports: one is at the front of the device, the other at the back. Both can be used to connect the relay to AQtivate 200. Please note that only the back port can be used for upgrading the device's firmware and for communication protocols. For more information on the ports, please refer to Chapter 3.3 in the AQtivate 200 instruction manual!

4 BASIC OPERATIONS

4.1 Opening the Motor Wizard

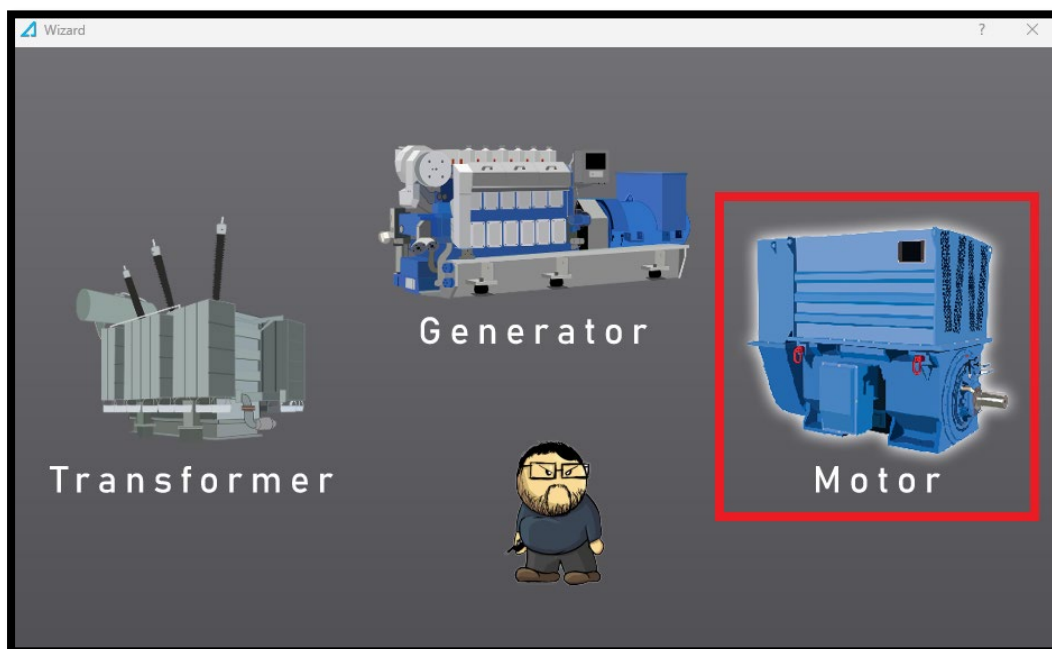
You can open the Motor Wizard tool from the AQtivate 200 software. Open the *Tools* menu on the software's main toolbar and select "Wizard" (Figure 4-1).

Figure 4-1. Opening the Wizard selection window.



This opens the wizard selection window, allowing you to choose which integrated wizard tool you want to use. For the Motor Wizard, select "Motor" (Figure 4-2).

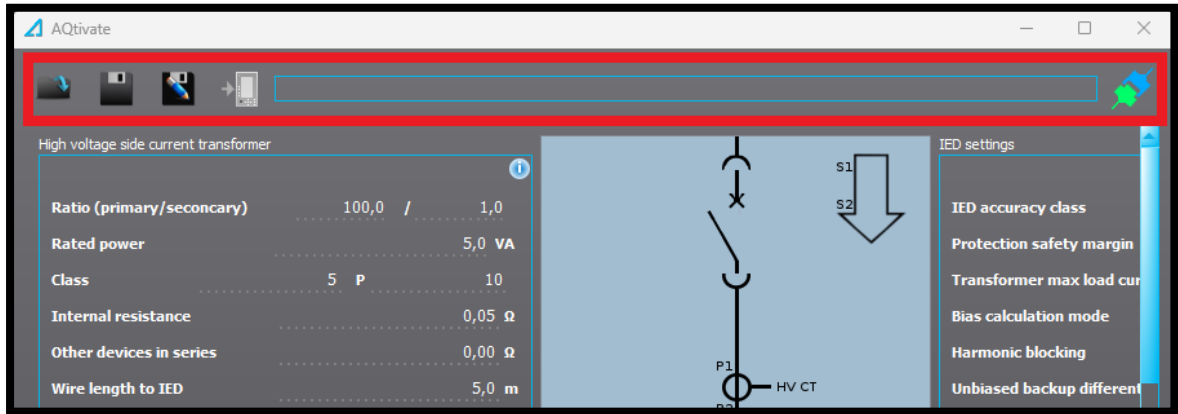
Figure 4-2. Selecting the Transformer Wizard.



4.2 Toolbar buttons

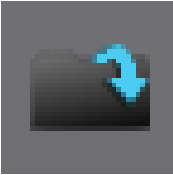
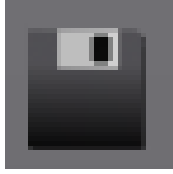

The Motor Wizard window's default view includes a toolbar at the top of the window (*Figure 4-3*).

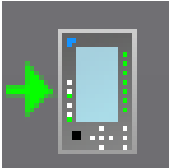


Figure 4-3. The main toolbar.



The buttons in the toolbar are explained in *Table 1* below.

Table 1. The toolbar buttons and their descriptions.

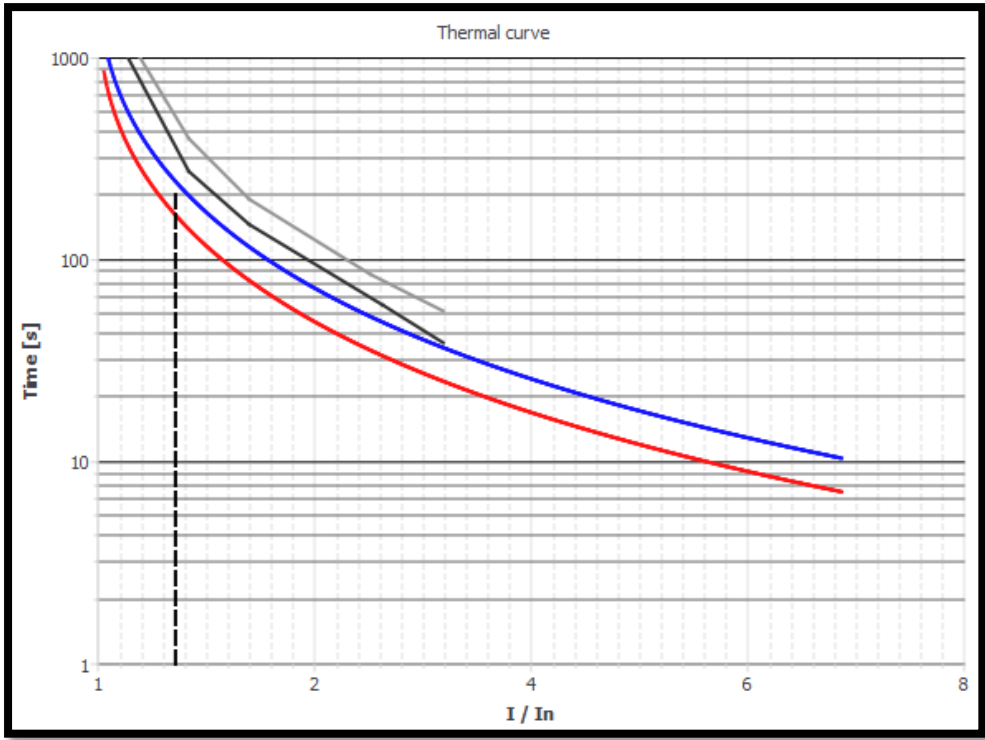
Toolbar icon	Name	Description
	Open	Open an existing wizard file (*.aqwz).
	Save	Save changes.
	Save as...	Save a wizard file (*.aqwz) to the selected location under the selected name.

	Write into relay	Write the calculated values of the Wizard into the connected relay. If you are <u>not</u> connected to a relay, this icon is colored in grayscale!
	Connect	Connect to a relay.
	Disconnect	Disconnect from the connected relay.

4.3 Visualization of the thermal curve

The Motor Wizard has a diagram for the thermal replica curve resulting from the current setting parameter values (*Figure 4-4*) at the center of the Wizard window. It follows the application settings, and makes it easier for you to get a fuller picture of your transformer protection.

Figure 4-4. Diagram of the thermal replica curve.



5 SETTING PARAMETERS

5.1 Parameters for the machine thermal image

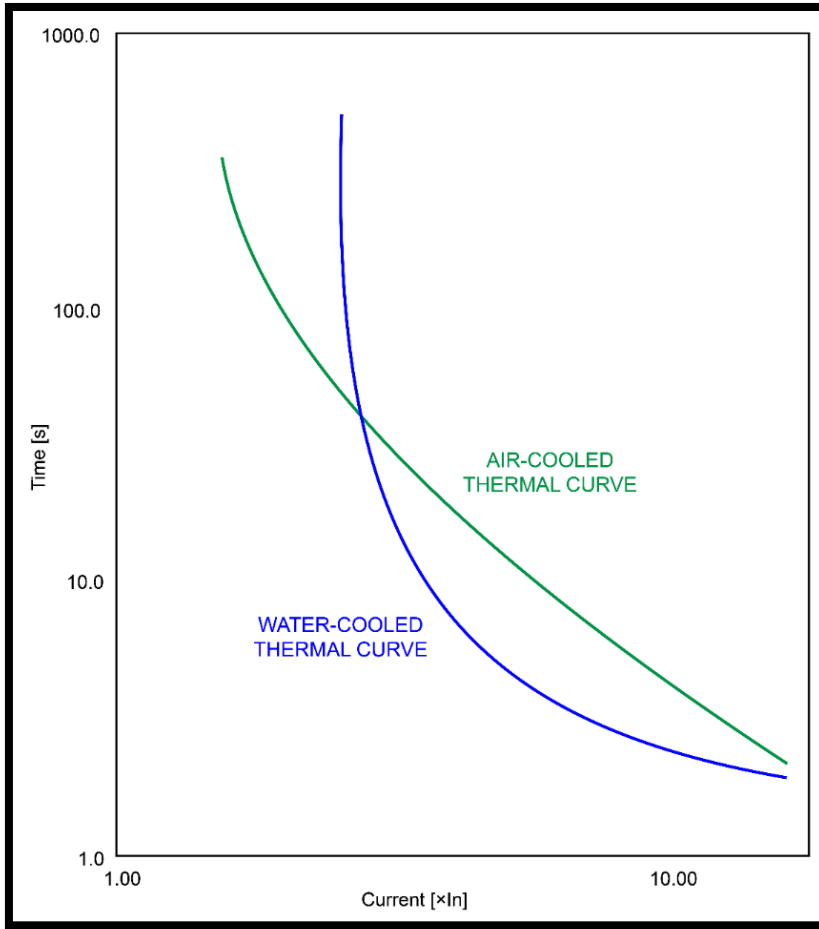
Table 2. Setting parameters for the machine thermal image.

Name	Range	Default
Thermal curve selector	1: I ² curve 2: Water cooled	1: I ²
Injected current amplitude	0...100 000 A (Pri)	400 A (Pri)
Injected I ₂ component	0...50 %	0 %
Phase CT input selection	1: CT1 2: CT2 3: CT3	1: CT1
CT ratio	1.0...25 000.0 / 0.2...10.0 A	300.0 / 5.0 A
Nominal current	1.0...25 000.0 A (pri)	244.0 A (pri)
Pick-up current	0.00...40.00 p.u.	1.05 p.u.
Trip level	0.0...150.0 %	100.0 %
Machine Cold/Hot limit	0.00...100.00	80.00 %
Used thermal capacity	0.00...200.00 %	0.00 %
NPS biasing in use	1: Yes 2: No	1: Yes
NPS bias factor	1.0...10.0	2.0
Time constant	1: Single 2: Multiple	2: Multiple
Cold curve Tau	0.0...500.0 min	8.8 min
Hot curve Tau	0.0...500.0 min	6.0 min
Machine running & cooling Tau	0.0...500.0 min	10.0 min
Machine stopped Tau	0.0...500.0 min	10.0 min
Machine service factor	0.01...5.00 × I _n	1.00 × I _n

5.1.1 Thermal curve selector

This setting parameter selects which type of thermal curve is used. Select the setting option “I² curve” for air-cooled machines (such as squirrel cage motors) and “Water cooled curve” for water-cooled machines (such as synchronous machines and generators). Please note that the thermal replica of water-cooled machines may differ from the regular logarithmic thermal replica (that is, the I² curve) of air-cooled machines. *Figure 5-1* on the following page shows how different the water-cooled thermal curves (in blue) are from regular air-cooled thermal curves (in green).

Figure 5-1. The difference between an air-cooled thermal curve and a water-cooled thermal curve.



The water-cooled curve provides a more accurate calculation of the time to trip when the machine operates above the normal load condition (see the pick-up settings). When the load is within its normal range and when the operating current is normal, a logarithmic operating characteristic is used and the separate time constants for heating and cooling are set.

With Equations (1)–(3) you can calculate the heating time in minutes based on how long it takes for the machine to reach the nominal temperature while on nominal load. The cooling time constant is usually two to three times longer in regular air-cooled applications whereas it usually takes less time for a water-cooled machine to decrease its core temperature.

$$\theta_t = \theta_{t-1} + e^{\frac{t}{T_{wc}}} \quad (1)$$

$$T_{wc} = \frac{M_L \times k}{I_{EM}^{M_H-1}} \quad (2)$$

$$I_{EM} = \frac{I_{RMS} + I_{2eff}}{k_{AMB}} \quad (3)$$

The thermal curve for a water-cooled application is not simple to set, and it typically requires the use of external tools such as a dedicated tool offered by the manufacturer or a spreadsheet software (e.g.,

Excel). The curve's low end and high end are adjusted separately by using their own factors. The curve's vertical position in the logarithmic scale is set via the curve weighing factor k .

5.1.2 Injected current amplitude

With this setting you can check the actual primary pick-up setting of the thermal replica. You can also see the expected operating time of the relay with certain current amplitudes. The primary value of this setting parameter is scaled to a per-unit value as well as secondary ampere values below the graph (please refer to [Chapter 6: Calculated values](#) of this manual).

5.1.3 Injected I^2 component

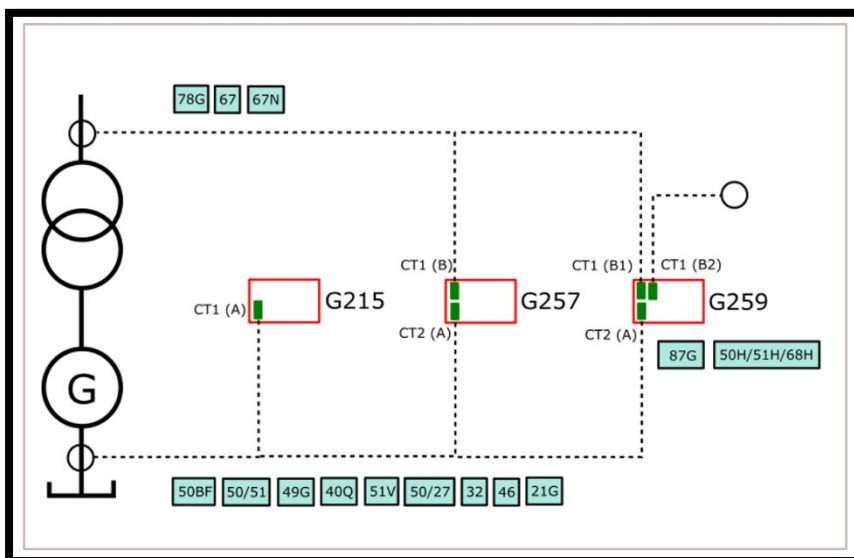
This setting parameter is a percentage of the injected current amplitude value. For example, when the I^2 component is set to 50 %, one half of the injected current amplitude is the negative sequence current I^2 and the other half is the positive sequence current I_1 . In a three-phase system, when one phase is missing during a symmetric load, the positive sequence current drops from 1.00 p.u. to 0.67 p.u., while the negative sequence current increases from 0.00 p.u. to 0.33 p.u.. In this condition the I^2 component amplitude would be 50 %.

The current component of the negative phase sequence heats up the protected machine twice as much as that of the positive sequence current. Therefore, I^2 directly affects the relay's pick-up threshold as well as its calculated operating time, causing the relay to trip faster.

5.1.4 Phase CT input selection

This setting parameter selects which physical current transformer card is used in the thermal protection of the machine. Please note that simple relays are equipped with only one CT card and therefore the selection is always "CT1" for them. However, relays with differential protection allow you to use either "CT1" or "CT2" for thermal protection. "CT3", on the other hand, is usually only available in three-winding differential relays and not used for thermal protection. See *Figure 5-2* for a visual representation of the various CT options.

Figure 5-2. The different CT options for thermal protection.



5.1.5 CT ratio

This setting parameter defines the current transformer's ratio in the application. For example, when the ratio is set to "400:5 A", the primary current of 300 A is scaled to 3.75 A on the relay side (the CT's secondary side). The relay/secondary side scaling is calculated by dividing the primary current by the set ratio.

5.1.6 Nominal current

As the name suggest, this setting parameter defines the nominal current of the protected machine. Please note that when a generator relay or a transformer relay is used, both the nominal MVA and voltage ratings must be set manually. This parameter only sets the nominal current of a motor relay automatically.

Typically, you can find the nominal current in the machine's name plate (see *Figure 5-3*) as defined by the manufacturer.

Figure 5-3. Nominal current in the name plate of an induction motor.

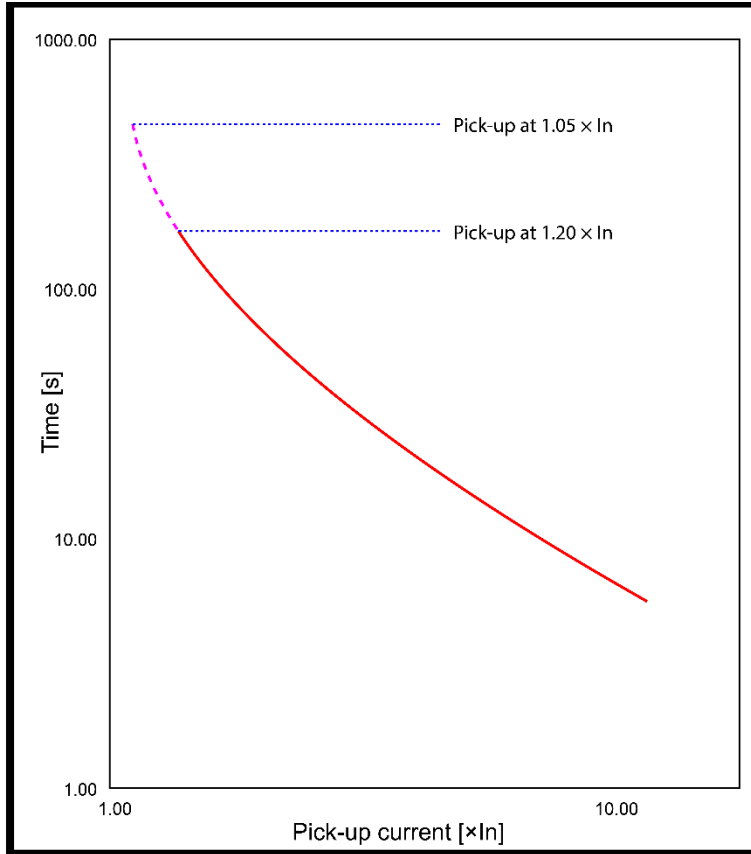
SIEMENS									
PE • 21 PLUS™					PREMIUM EFFICIENCY				
ORD.NO.	1LA02864SE41				E NO.				
TYPE	RGZESD				FRAME	286T			
H.P.	30.00				SERVICE FACTOR	1.15		3 PH	
AMPS	34.9				VOLTS	460			
R.P.M.	1765				HERTZ	60			
DUTY	CONT					40 °C AMB.		DATE CODE	
CLASS INSUL	F	NEMA DESIGN	B	K.V.A. CODE	G	NEMA NOM.EFF.	93.6		
SH. END BRG.	50BC03JPP3				OPP. END BRG.	50BC03JPP3			
MILL AND CHEMICAL DUTY QUALITY INDUCTION MOTOR									
Siemens Energy & Automation, Inc. Little Rock, AR							MADE IN U.S.A.		SA

5.1.7 Pickup current

This setting parameter determines when to start the calculation of the operating time to trip. In engine protection applications, the pick-up setting tends to be set above the maximum load current ("Maximum current" in most name plates). Please note that the pick-up setting should only be exceeded during engine starting, engine overload, or during fault conditions. In general, the overload or thermal protection tripping range is between 1.05...1.20 x FLA (the full-load current), as per the IEC 60947-4-1: 2018 standard [1].

Typically, you can find the FLA value in the machine's name plate. Note that the pick-up current setting alters the activation point of the thermal characteristics curve according to the diagram below (*Figure 5-4*).

Figure 5-4. The pick-up current setting changes the activation point of the thermal curve.

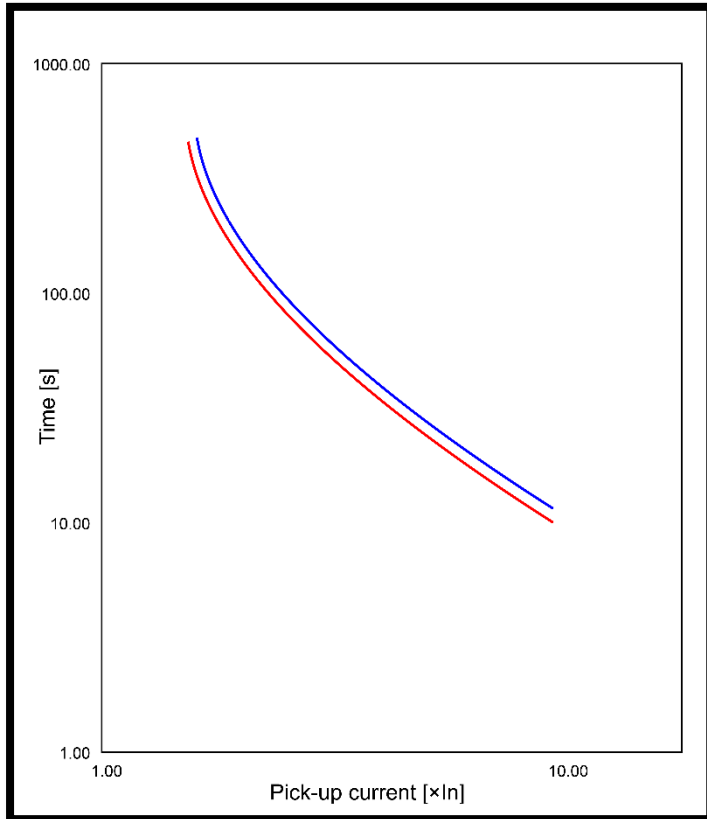


5.1.8 Trip level

This setting parameter defines the trip level of the resistance temperature detector (RTD), and it should be set at or below the maximum temperature rating of the insulation class. For example, when a motor with Class F insulation has a temperature rating of 155 °C, the stator RTD trip level could be set between 140...145 °C. The maximum value of this range is determined by subtracting the 10 °C hot spot from the motor's maximum temperature rating (i.e., 155 °C–10 °C = 145 °C).

As far as the Motor Wizard is concerned, the best way to adjust the thermal curve is to follow the values given in the protected machine's name plate. Instead, adjust the curve to below the desired level by using the trip level setting as well as the hot or cold curve tau time constant settings (see *Figure 5-5* on the following page).

Figure 5-5. Adjusting the thermal curve with trip level and hot tau curve settings.

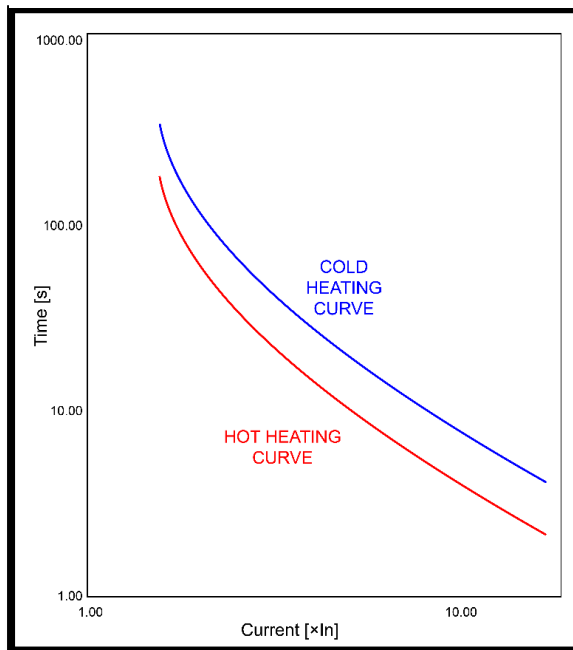


5.1.9 Machine Cold/Hot limit

The machine's cold and hot condition limits set the thermal points for the protected engine; when the temperature reaches this point the protected machine begins to follow the hot curve instead of the slower cold curve while heating up (see *Figure 5-6* on the following page). The hot curve trips the relay faster than the cold curve, and the tripping time is calculated based on both curves. Please note that the "Hot curve Tau" and the "Cold curve Tau" setting parameters are set separately from the machine's cold and hot condition limit parameters so that the former can follow the actual engine curves.

When a motor runs within the nominal current range for long enough, the engine reaches its nominal temperature. This temperature is commonly considered a hot condition. According to common practice the nominal temperature (and thus the hot condition) is reached when the temperature is 20 % below the actual thermal danger zone of the engine. This means that usually the hot condition limit is set to 80 % by default. Typically, there is no need to change this value.

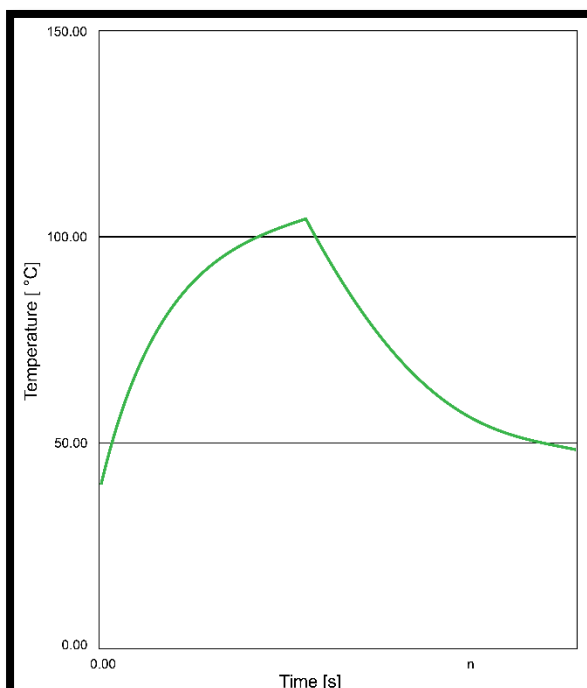
Figure 5-6. Once the hot condition limit is reached, Tau is changed to a faster one.



5.1.10 Used thermal capacity

When the projected machine is on or below the nominal ambient temperature zone, the used thermal capacity is 0 %. When the projected machine (like an induction motor) is turned on and run with a nominal load (nominal current), the thermal capacity begins to increase towards the nominal temperature and the hot condition theta limit is usually set to 80 %. Once this limit is reached, the engine's cold thermal curve tau changes to the hot thermal curve tau (Figure 5-7). If the motor is run with an overload, the thermal capacity can go up to 100 % or above, and eventually thermal protection might trip the relay.

Figure 5-7. Thermal curve of Class B motor for which the 80 % hot theta limit is 104 °C.



If the operating time from zero to the set trip limit is considered to take too long, you can test the relay in the commissioning mode with a pre-set thermal capacity (such as 60 %) for a faster trip time. The operating time function of the relay can be checked through the Motor Wizard: adding multiple test points allows you to create a test plan for the whole thermal curve.

5.1.11 NPS biasing in use & NPS bias factor

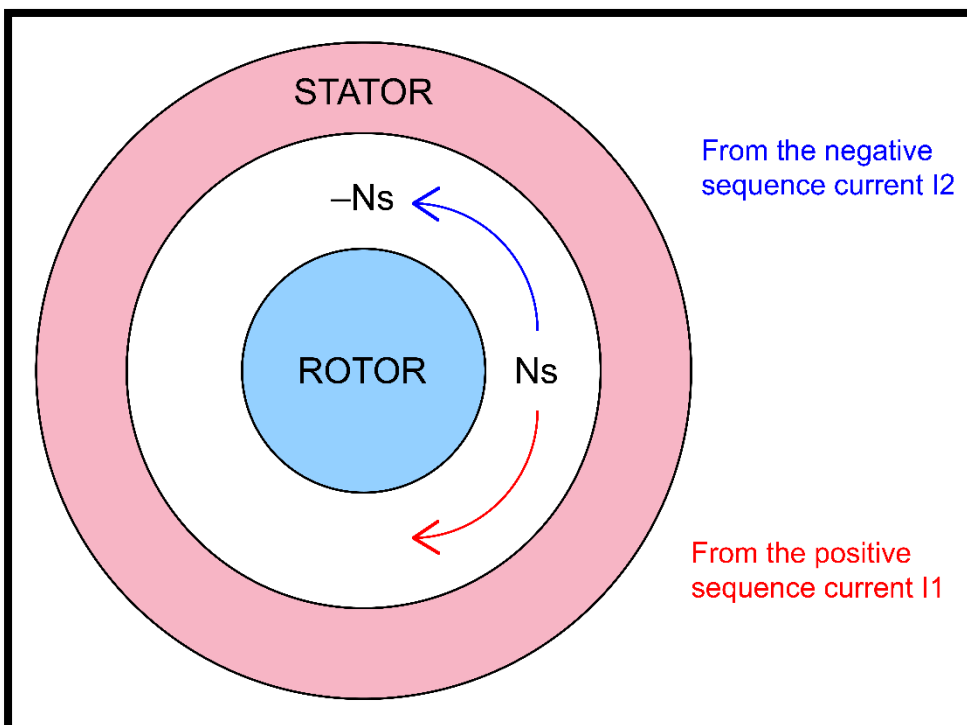
As mentioned previously in this manual, both water-cooled and air-cooled thermal replica formulas use the current calculation presented earlier in Equation (3).

The total current that heats the machine is based on multiple factors: current and harmonics (TRMS), the negative phase sequence current (I_2), the ambient temperature, and the installation altitude. This means that even when the relay has been set correctly and that the base current is slightly below the set pick-up value, thermal protection might still trip if a negative phase sequence current (I_2) is present, if the installation altitude is above 1,000 m, or if the installation temperature is above that of the normally rated temperature.

When it is a healthy condition, the rotor of an induction motor or a synchronous machine rotates at a stable speed. The rotating magnetic field (N_s) rotates around the rotor in a synchronous speed, and there is no speed difference between the rotor and the rotating magnetic field. When there is no speed difference, there is also no electromagnetic field (EMF) over the rotor, and no eddy currents which means there is no excessive heating in the rotor. In this condition the stator current is equivalent to the positive sequence current, as both the negative phase sequence current I_2 and the residual current I_0 are zero ($I = I_1 + I_2 + I_0$).

Unbalances can arise from many different sources: unbalanced loads, transmission line construction without transposition, faults, open phases, etc. The unbalanced condition changes things for the protected machine, as the stator current consists of both the negative and positive sequence currents (I_1 and I_2). The negative sequence current creates a reverse rotating magnetic field ($-N_s$) that tries to rotate the rotor in the opposite direction (*Figure 5-8*).

Figure 5-8. Opposite rotational current I_2 heats the machine twice as much.



The reverse rotating air gap flux and the rotor have a relative speed difference from one another, which generates a breaking torque. The relative speed is twice as big as the rotational velocity of the rotor (which also results in double frequency currents). The current induced into the rotor causes its surface to heat up, and the resulting heat can damage the rotor very quickly.

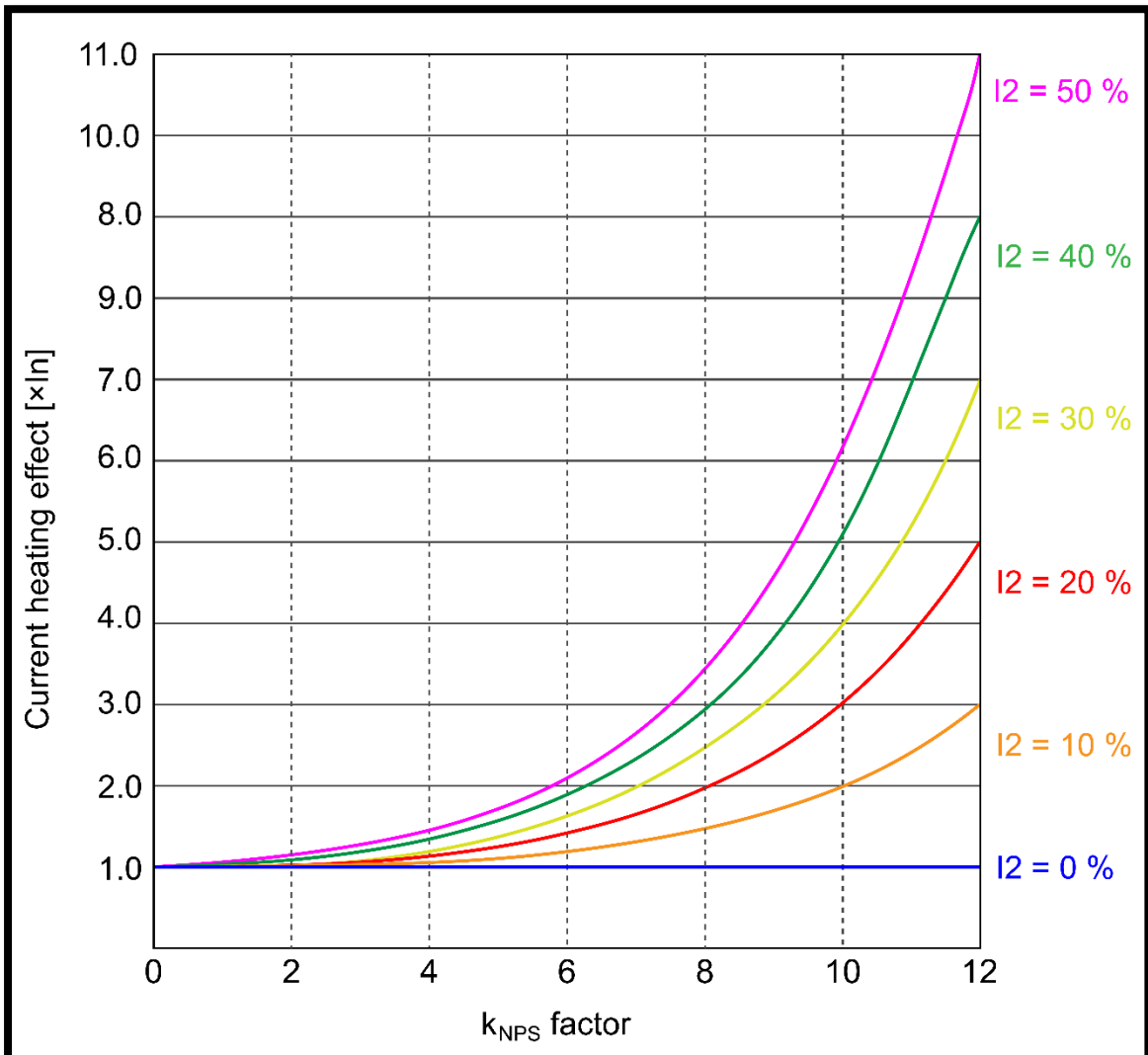
The "NPS bias factor" setting parameter is constantly proportional to the thermal capacity of the rotor, as seen in Equation (4) below:

$$\frac{I_{MEAS}}{I_N} \times \left(\frac{100 - I_2^2/I_1^2}{100} \right) + \frac{I_{MEAS}}{I_N} \times \left(\frac{I_2^2/I_1^2}{100} \right) \times NPS \quad (4)$$

By default, this setting parameter is set to 2.0 which represents the double frequency current multiplied by 2. When this setting parameter is set to 1.0, the status is disabled. The NPS bias factor also affects current amplitudes (Figure 5-9).

Please note that for this setting parameter to be in use, the "Negative phase sequence biasing" setting parameter must be set to "NPS biasing in use".

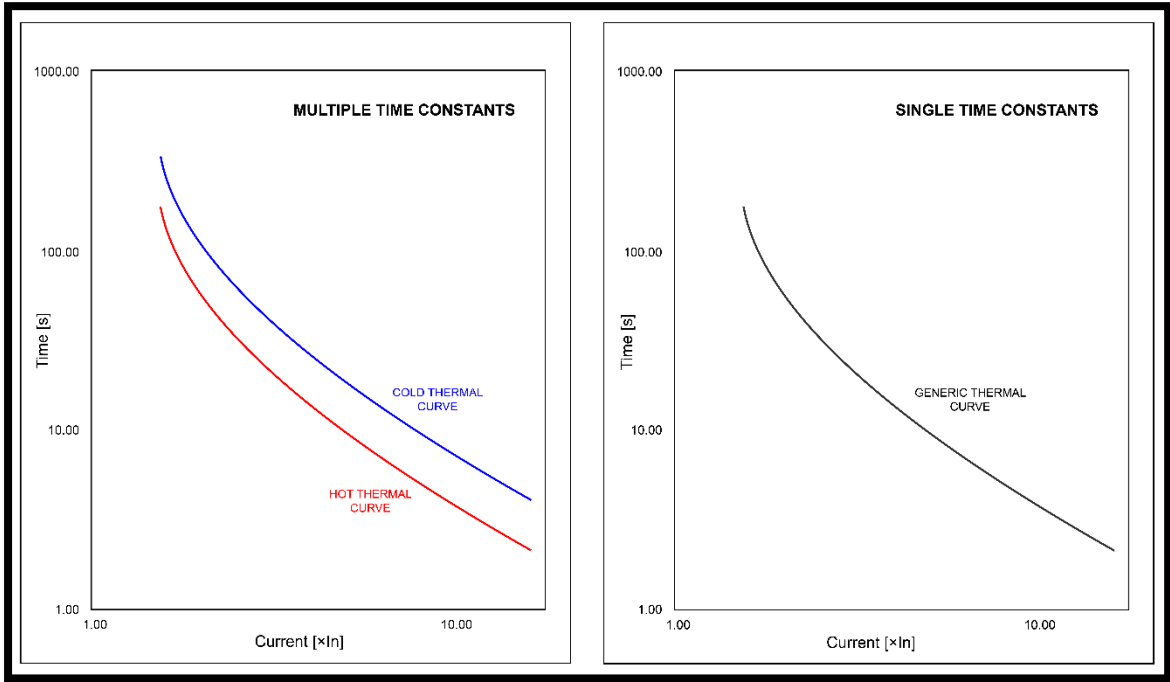
Figure 5-9. The effect of the NPS bias factor on current amplitudes.



5.1.12 Time constant

When this setting parameter is set to “Multiple”, you can set both the hot and the cold curve of the protected machine separately. However, many applications only provide one thermal curve (such as generator applications) in which case the “Single” time constant should be used. *Figure 5-10* below illustrates the difference.

Figure 5-10. Two thermal curves with multiple time constants (left), one thermal curve with a single time constant (right).



As far as the Motor Wizard is concerned, the best way to adjust the thermal curve is to follow the values given in the protected machine’s name plate. Instead, adjust the curve to below the desired level by using the trip level setting as well as the cold curve tau and the hot curve tau time constant settings.

5.1.13 Cold curve Tau & Hot curve Tau

The operating time of a logarithmic thermal replica is based on a specific time constant. When a single time constant has been selected in the time constant setting parameter, only the cold time constant (the "Cold curve Tau" setting parameter) is required; when multiple time constants have been selected, the hot time constant (the "Hot curve Tau" setting parameter) is also set. Both hot and cold time constants use the same equation in the I^2 mode, although the value of the tau is different. With multiple time constants the cold curve tau is changed to the hot curve tau once the machine has reached the set hot condition limit. Using multiple time constants reduces the tripping time because the hot curve tau is set to be faster than the cold curve tau. See Equation (5) below for the calculation of the trip time as affected by the measured current, the hot and cold curve taus:

$$Trip\ time = LN \frac{I_{EM}^2 - (\sqrt{\theta_{stat} \times k_{SF}})^2}{I_{EM}^2 - (\sqrt{\theta_{set} \times k_{SF}})^2} \times tau \times 60 \quad (5)$$

5.1.14 Machine running & cooling Tau, and Machine stopped Tau

The water-cooled thermal replica operates (that is, affects the machine's temperature) only when the measured current is above the set pick-up limit. While the measured current remains below the pick-up limit, the thermal calculation follows the regular I^2 equation, which requires that both the "Machine running&cooling Tau" and the "Machine stopped Tau" setting parameters be set separately. The cooling time constant is used when the temperature is between the pick-up limit and the "Machine stopped Tau" and when the engine is in the cooling state.

5.1.15 Machine service factor

The "Machine service factor" setting parameter is the percentage of overloading that the motor can deal with for short periods of time as long as it otherwise operates within the correct voltage tolerances. For example, the standard service factor for open drip-proof motors is 1.15, which means that a 10-MW motor with a 1.15 SF can provide 11.5 MW of power when required for a short while. Some fractional motors have a higher service factor, such as 1.25, 1.35, or even 1.50. The service factor directly affects the current pick-up limit of the I^2 equation: it increases the pick-up limit when set to higher than 1.0. Additionally, it affects the shape of the thermal curve.

The service factor can be used in to... [2]:

- 1) ...accommodate inaccuracy in predicting a system's occasional additional power needs.
- 2) ...increase the life of the used insulation by lowering the winding temperature at the rated load.
- 3) ...deal with intermittent overloads.
- 4) ...allow the ambient temperature to occasionally exceed 40 °C.
- 5) ...compensate for low or unbalanced supply voltages.

The American National Electrical Manufacturers Association (NEMA) [3] defines the service factor as a multiplier. When applied to the rated power, it indicates a permissible power loading which may be carried under the conditions specified for the service factor at rated voltage and frequency. Please note that NEMA gives some additional cautions for the service factor:

- 1) Operating at the service factor load for extended periods of time will usually reduce the motor speed, its life, and its efficiency.
- 2) The motor may not provide adequate starting, and it is possible to get pull-out torques and incorrect starter/overload sizing; these, in turn, affect the overall life span of the motor.
- 3) Do not rely on the service factor to carry the load continuously.
- 4) The service factor is affected when the operating conditions differ from the ones it was established for: the rated voltage, frequency, ambient and sea-level conditions.

The service factor is required to be printed on the machine's name plate only when it is higher than 1.0. When the service factor has not been specifically mentioned, you can assume it to be 1.0. The higher the service factor, the more current the engine can handle before the thermal replica's maximum limit is reached.

Figure 5-11. The service factor in the name plate of an induction motor.

SIEMENS									
PE • 21 PLUS™					PREMIUM EFFICIENCY				
ORD.NO.	1LA02864SE41				E. No.				
TYPE	RGZESD				FRAME	286T			
H.P.	30.00				SERVICE FACTOR	1.15		3 PH	
AMPS	34.9				VOLTS	460			
R.P.M.	1765				HERTZ	60			
DUTY	CONT				40 °C AMB.				DATE CODE
CLASS INSUL	F	NEMA DESIGN	B	K.V.A. CODE	G	NEMA NOM.EFF.	93.6		
SH. END BRG.	50BC03JPP3				OPP. END BRG.	50BC03JPP3			
MILL AND CHEMICAL DUTY QUALITY INDUCTION MOTOR									
Siemens Energy & Automation, Inc. Little Rock, AR									
MADE IN U.S.A.									

5.2 Parameters for the environmental settings

Table 3. Setting parameters for the environmental settings.

Name	Range	Default
Insulation glass (tmax)	1: A 2: B 3: F 4: H	3: F
Ambient temperature	–20...60 deg C	40 deg C
Installation altitude	0...4 000.0 m	0 m

5.2.1 Insulation glass (tmax)

The maximum temperatures for a motor winding insulation are rated using NEMA designations. *Table 4* below defines these insulation class ratings:

Table 4. The maximum temperature for NEMA designated insulation classes. [4]

Class designation	Maximum temperature
Class A	105 °C
Class B	130 °C
Class F	155 °C
Class H	180 °C

When a temperature threshold is exceeded, the insulation deteriorates at an increasing rate. For every 10 °C increase in temperature, the deterioration rate doubles (approximately). For example, a Class F insulation loses half of its mechanical strength after experiencing 20,000 hours at its rated temperature. Obviously, the insulation will not simply fail at this point, but it will have been significantly weakened.

The lower the temperature is, the longer the insulation lasts:

- 1) 80,000 hours (10 years) at 135 °C.
- 2) 40,000 hours (5 years) at 145 °C.
- 3) 20,000 hours (2.5 years) at 155 °C.
- 4) 10,000 hours (1.25 years) at 165 °C
- 5) 5,000 hours (less than 1 year) at 175 °C

Please note that the selected insulation class does **not** affect the calculations in the Wizard. However, the engine's temperature range can be combined with the thermal replica and then the current estimated temperature can be brought to a local display or to SCADA.

5.2.2 Ambient temperature & Installation altitude

The ambient temperature of a motor is defined as the temperature of the motor's surroundings. This is also the temperature of the motor when it is not currently in operation and has not recently been in operation. Because motors are not 100 % efficient, the power applied to a motor will cause it to generate heat and raise the motor's temperature. This temperature rise is the change in the motor's temperature when power is applied to it, and it is generally defined as the temperature difference between the ambient temperature and the temperature when the motor is at full load. The temperature rise is measured from the motor's windings because that is usually the hottest part ("hot spot") of a motor.

The insulation class of a motor defines how much the temperature is allowed to rise above the ambient temperature (with an allowance for a hot spot). Together the insulation class and the rated ambient – which is always 40 °C – give a specific maximum temperature to use when operating above this default ambient temperature. For example, for a Class F motor the maximum temperature is 155 °C which means that with an ambient temperature of 40 °C and a 10 °C hot spot the maximum temperature rise is 105 °C. However, if the ambient temperature is 60 °C, the maximum temperature rise can only be 95 °C at a hot spot and 85 °C otherwise.

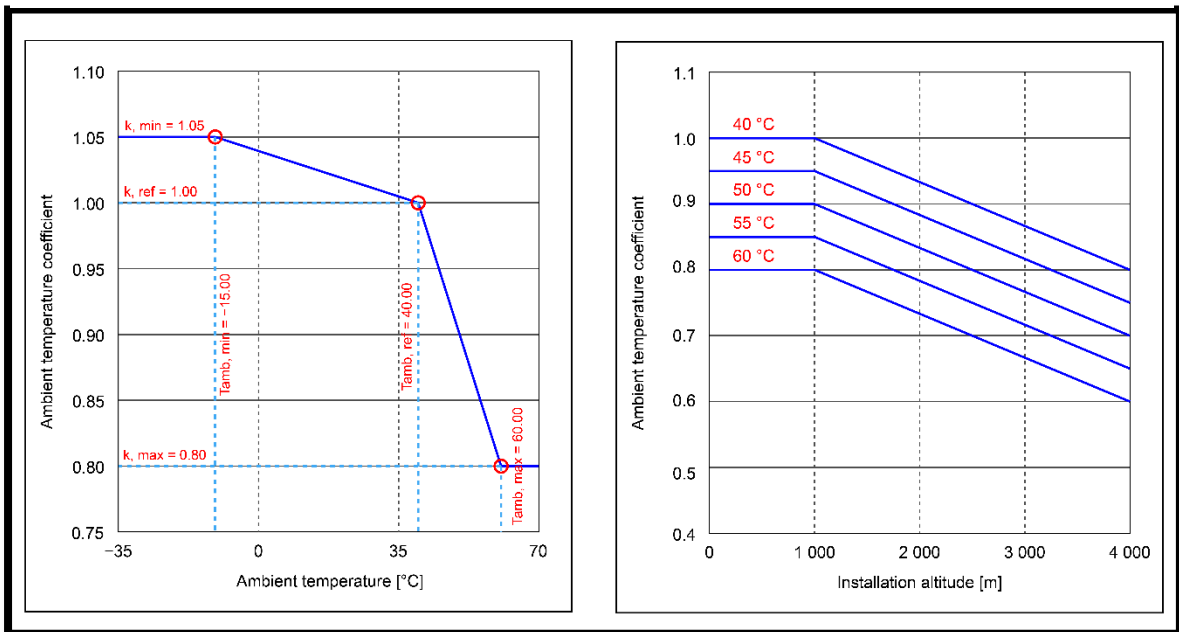
Please note that the ambient temperature factor (k_{AMB}) also affects the calculation of the thermal replica. The higher the temperature surrounding the protected object, the lower the current that is required to heat the object up to its maximum temperature. Similarly, when the temperature is below the ambient temperature limit (40 °C), the current can be higher before the maximum temperature limit is reached.

In addition to the ambient temperature, installation altitude also affects the operation of the thermal replica. When a motor is meant to operate in a place that is situated 1...4 kilometers (1,000...4,000 meters) above sea level or has an ambient temperature of +40...+60 °C, it is necessary to apply a corrective coefficient to the motor's power to allow it to maintain its thermal reserve (the maximum temperature is reached by the windings in normal operating conditions).

See *Figure 5-12* on the following page for an example graph regarding the corrective coefficient for different ambient temperatures (left) and altitudes (right). As it shows, installation altitude and ambient temperature affect the measured current directly, therefore also affecting the heating of the protected machine. However, the ambient temperature does **not** affect the shape of the thermal protection curve.

In AQtivate 200's "Environmental settings" section you can select whether ambient temperature is set manually or not. You can also define the maximums, the minimums, and the reference values for both the ambient temperature and the ambient temperature coefficient.

Figure 5-12. Both ambient temperature and installation altitude affect the motor's thermal withstand.



5.3 Parameters for the machine characteristic

Table 5. Setting parameters for the machine characteristic.

Name	Range	Default
Frequency	16.67...60.00 Hz	50.00 Hz
Curve AI	1: Disabled 2: Enabled	1: Disabled
Min. locked rotor current	0.10...40.00 $\times I_n$	4.10 $\times I_n$
Nominal starting current	0.10...40.00 $\times I_n$	6.00 $\times I_n$
Max. LR / curve current	4.00...40.00 $\times I_n$	7.15 $\times I_n$
Safe stall time cold (stator)	0.10...600.00 s	5.00 s
Safe stall time hot (stator)	0.10...600.00 s	4.00 s
Maximum scale time	1: 1k 2: 10k 3: 100k	1: 1k

5.3.1 Frequency

This setting defines the motor's frequency. The speed of electrical motors with 2, 4, 6, or 8 poles depends on the frequency (see *Table 6* on the following page).

Table 6. The number of poles and the frequency affect the motor's speed. [5]

Speed (rpm)				
Poles	Frequency (50 Hz)		Frequency (60 Hz)	
	Synchronous	Full load	Synchronous	Full load
2	3 000	2 850	3 600	3 450
4	1 500	1 425	1 800	1 725
6	1 000	950	1 200	1 150
8	750	700	900	850

The higher the frequency, the faster the engine rotates at the nominal speed. The frequency setting of the relay does **not** directly affect the thermal replica, but it does affect the accuracy of the current and voltage measurements which means that the protection relay must be set with the correct frequency parameter.

Figure 5-13. Frequency in the name plate of an induction motor.

SIEMENS									
PE • 21 PLUS™					PREMIUM EFFICIENCY				
ORD.NO.	1LA02864SE41				E NO.				
TYPE	RGZESD				FRAME	286T			
H.P.	30.00				SERVICE FACTOR	1.15			3 PH
AMPS	34.9				VOLTS	460			
R.P.M.	1765				HERTZ	60			
DUTY	CONT				40 °C AMB.			DATE CODE	
CLASS INSUL	F	NEMA DESIGN	B	K.V.A. CODE	G	NEMA NOM.EFF.	93.6		
SH. END BRG.	50BC03JPP3				OPP. END BRG.	50BC03JPP3			
MILL AND CHEMICAL DUTY QUALITY INDUCTION MOTOR									
Siemens Energy & Automation, Inc. Little Rock, AR								MADE IN U.S.A.	

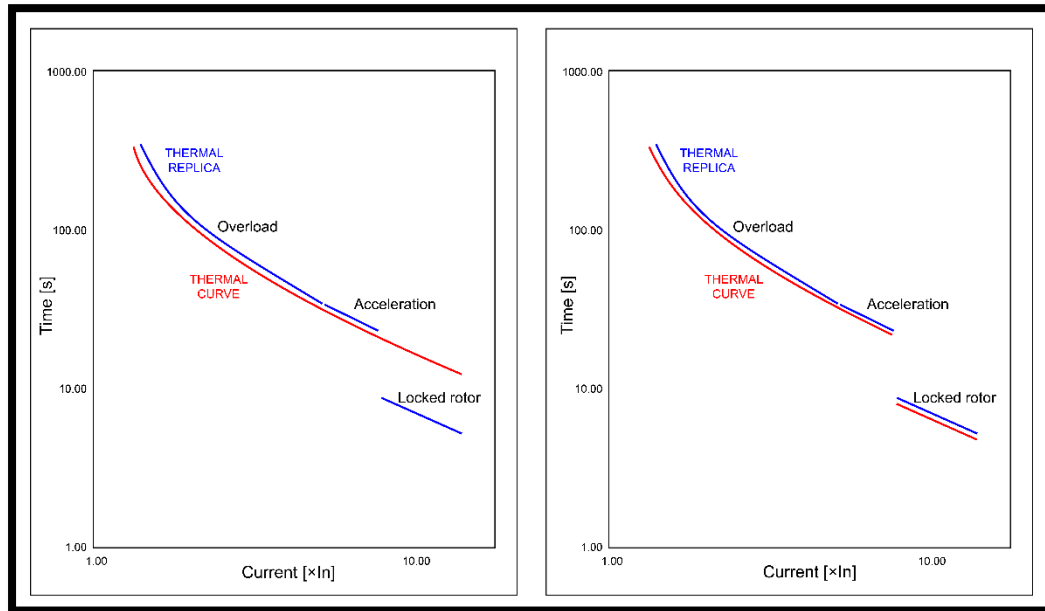
5.3.2 Curve AI

Some induction motors have a very specific thermal behavior that no single thermal replica can cover. This is normally caused by the locked rotor curve (which heats the engine more than usual) and the linear thermal curve. In such cases the "Curve AI" setting parameter (aka. the curve artificial intelligence setting parameter) can be used. Instead of following the linear thermal curve all the way, the thermal replica switches to follow the locked rotor curve once the minimum locked rotor setting has been reached, and the AI models a suitable tau for the situation. Usually, the locked rotor protection can deal with starts that take too long as well as with locked rotor situations; however, a regular thermal replica will not follow those situations accurately, and therefore the engine's actual temperature may be higher than what the thermal replica is calculating.

Figure 5-14 on the following page presents the operating principle behind the curve artificial intelligence. For simplicity's sake only one time constant is used. However, when multiple time constants are used, the thermal replica will use both the hot and cold locked rotor curves separately. With Curve AI you can create a thermal replica for the most complex thermal characteristics. Curve AI follows the actual I^2

thermal replica as well as the separate time constant(s) in the locked rotor area. Set the parameters "Min. locked rotor current", "Nominal starting current" and "Max. LR / curve current", and adjust the locked rotor area separately from the thermal replica by altering the values of the "Safe stall time cold (stator)" and "Safe stall time hot (stator)" parameters.

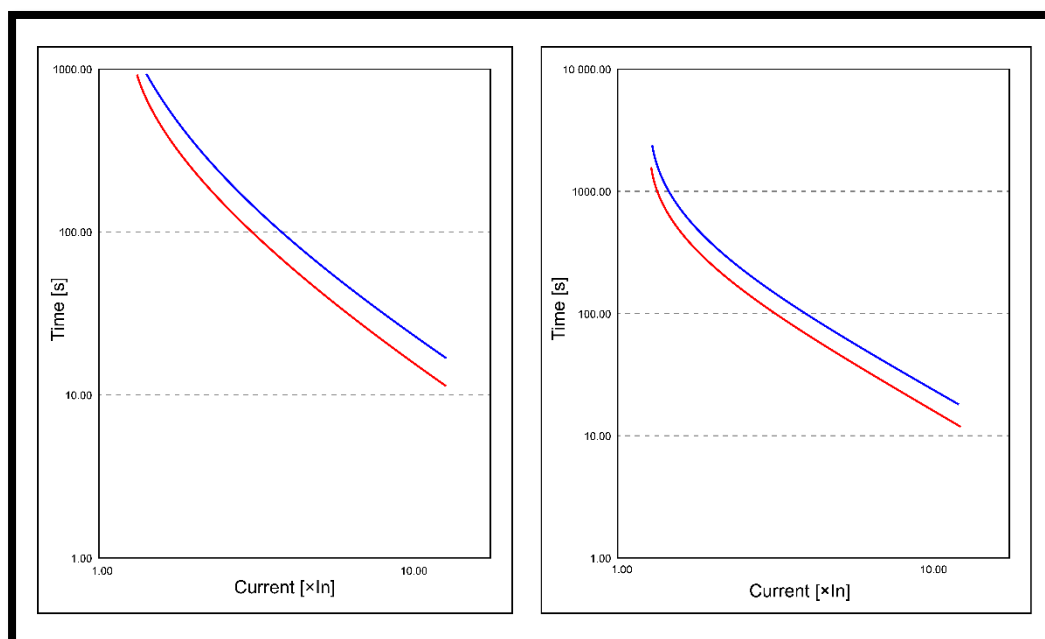
Figure 5-14. Operating principle of the Curve AI, with Curve AI enabled (left) and disabled (right).



5.3.3 Maximum scale time

With this setting parameter, you can select the scale of the thermal curve's logarithmic diagram. The logarithmic scale can be selected to be 1,000 ("1k") or 10,000 ("10k").

Figure 5-15. The presentation of the thermal curve depends on whether the selected maximum time scale is "1k" (left) or "10k" (right).



5.4 Parameters for the machine thermal characteristic, the Cold/Hot thermal curve, the Cold/Hot acceleration curve, and the Cold/Hot stall curve



Please note that the "Curve AI" setting parameter must be set to "Enabled" for the Cold/Hot acceleration curve and Cold/Hot stall curve setting parameters to be visible and changeable.

Please also note that the decimal separator in these parameters must be a comma, not a period (e.g. "0,12" instead of "0.12")! Otherwise, the Wizard does not acknowledge the change!

Table 7. Setting parameters for the machine thermal characteristic.

Name	Range	Default
Machine target curve	1: Hidden 2: Visible	2: Visible

Table 8. Setting parameters for the Cold/Hot thermal curve.

Name	Range	Default
Cold 1	0.01...10.00 $\times I_n$ 1...100 000 s	1.35 $\times I_n$ 1 000 s
Cold 2	0.01...10.00 $\times I_n$ 1...100 000 s	1.75 $\times I_n$ 400 s
Cold 3	0.01...10.00 $\times I_n$ 1...100 000 s	2.25 $\times I_n$ 200 s
Cold 4	0.01...10.00 $\times I_n$ 1...100 000 s	3.25 $\times I_n$ 85 s
Cold 5	0.01...10.00 $\times I_n$ 1...100 000 s	3.85 $\times I_n$ 56 s
Hot 1	0.01...10.00 $\times I_n$ 1...100 000 s	1.25 $\times I_n$ 1 000 s
Hot 2	0.01...10.00 $\times I_n$ 1...100 000 s	1.75 $\times I_n$ 275 s
Hot 3	0.01...10.00 $\times I_n$ 1...100 000 s	2.25 $\times I_n$ 150 s
Hot 4	0.01...10.00 $\times I_n$ 1...100 000 s	3.35 $\times I_n$ 60 s
Hot 5	0.01...10.00 $\times I_n$ 1...100 000 s	3.85 $\times I_n$ 39 s

Table 9. Setting parameters for the Cold/Hot acceleration curve.

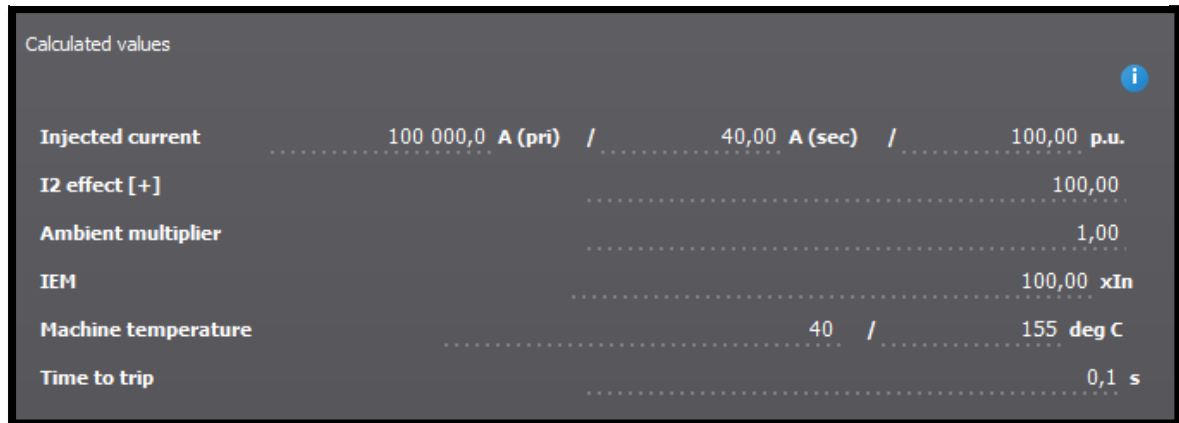
Name	Range	Default
Cold 1	0.01...10.00 $\times I_n$ 1...100 000 s	4.10 $\times I_n$ 51.00 s
Cold 2	0.01...10.00 $\times I_n$ 1...100 000 s	5.12 $\times I_n$ 33.00 s
Hot 1	0.01...10.00 $\times I_n$ 1...100 000 s	4.10 $\times I_n$ 35.00 s
Hot 2	0.01...10.00 $\times I_n$ 1...100 000 s	5.12 $\times I_n$ 22.00 s


Table 10. Setting parameters for the Cold/Hot stall curve.

Name	Range	Default
Cold 1	0.01...10.00 $\times I_n$ 1...100 000 s	5.20 $\times I_n$ 37.00 s
Cold 2	0.01...10.00 $\times I_n$ 1...100 000 s	7.15 $\times I_n$ 19.00 s
Hot 1	0.01...10.00 $\times I_n$ 1...100 000 s	5.20 $\times I_n$ 22.00 s
Hot 2	0.01...10.00 $\times I_n$ 1...100 000 s	7.15 $\times I_n$ 12.00 s

6 CALCULATED VALUES

Figure 6-1. Calculated values for the Motor Wizard.



Calculated values			
Injected current	100 000,0 A (pri) / 40,00 A (sec) / 100,00 p.u.		
I ² effect [+]			100,00
Ambient multiplier			1,00
I _{EM}			100,00 xI _n
Machine temperature	40 / 155 deg C		
Time to trip			0,1 s

The Motor Wizard tool calculates characteristic settings for the thermal curve, but it also produces some additional, informative data, as presented in *Figure 6-1*. The Wizard calculates the following values:

- 1) The injected current in amperes (both primary and secondary) and in per-unit values.
- 2) The positive I² effect (no unit).
- 3) The ambient multiplier (no unit).
- 4) The I_{EM} current in multiples of the nominal current.
- 5) The machine temperature in degrees Celsius.
- 6) The time to trip in seconds.

7 USING THE MOTOR WIZARD

The format of a settings file (or a "wizard file") from the Motor Wizard is *.aqwz. A single wizard file includes all the essential settings related to the thermal replica.



Please note that the breaker connections and I/O connections ("matrix") must be set separately using the AQtivate 200 software.

7.1 Saving and opening a wizard file

You can save a wizard file with the **Save** button or the **Save as...** button. You can also open an existing project with the **Open** button. Please refer to *Table 1* on page 9 for the respective icons of these buttons.



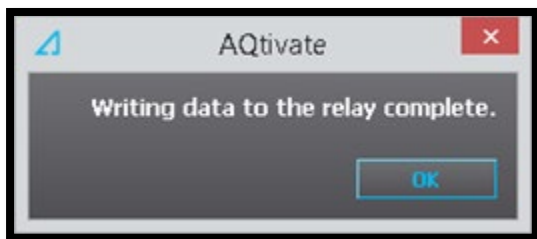
Please note that AQtivate 200 setting files (*.aqs) and wizard files (*.aqwz) are fully independent, and they must be saved and opened separately!

7.2 Writing settings into a device

You can write a selected .aqwz file into a relay by clicking the **Write to relay** button (see *Table 1* on page 9 for the icon of this button). You must be connected to the relay for this button to work. If you have not established a connection, the button is gray and will not function.

When the software has finished writing the setting values from the wizard file into the connected device, a separate window pops up to inform you of this (*Figure 7-1*). Click **OK** to proceed.

Figure 7-1. Writing process complete.



7.3 Changing setting parameters

All setting parameters which appear in blue text fields or drop-down menus in the wizard's main window can be modified. When one of these parameters appears in gray, it cannot be modified while the one or more parameters are defined the way they are at that moment. Its value is fixed and is only visible for informative purposes.

When you want to change the value of a setting parameter, place the cursor on top of the parameter box (either a text field or a drop-down menu). When you left-click the box, you can either type in a new value and press **Enter** (text fields) or select one of pre-set options (drop-down menus).

In *Figure 7-2* below, you can see an example of both types of changeable parameters. For example, the parameters "CT ratio" and "Trip level" are text fields, denoted by their white text and a unit to the right of the box. "Thermal curve selector" and "Phase CT input selection" are examples of parameters with a drop-down menu, denoted by the triangle to the right of the box. You can also see an example of a parameters in gray ("NPS biasing in use"), meaning that they cannot be changed.

Figure 7-2. Parameter type examples.

The screenshot shows a window titled "Machine thermal image" with a blue information icon in the top right corner. The window contains a list of parameters with their current values and units:

Parameter	Value	Unit
Thermal curve selector	I^2 curve	
Injected current amplitude	400	A (Pri)
Injected I2 component	0	%
Phase CT input selection	CT1	
CT ratio	300,0 / 5,0	A
Nominal current	244,0	A (pri)
Pickup current	1,05	pu
Trip level	100,0	%
Machine Cold/Hot limit	80,00	%
Used thermal capacity	0,00	%
NPS biasing in use	Yes	

7.4 Accessing the built-in user manual

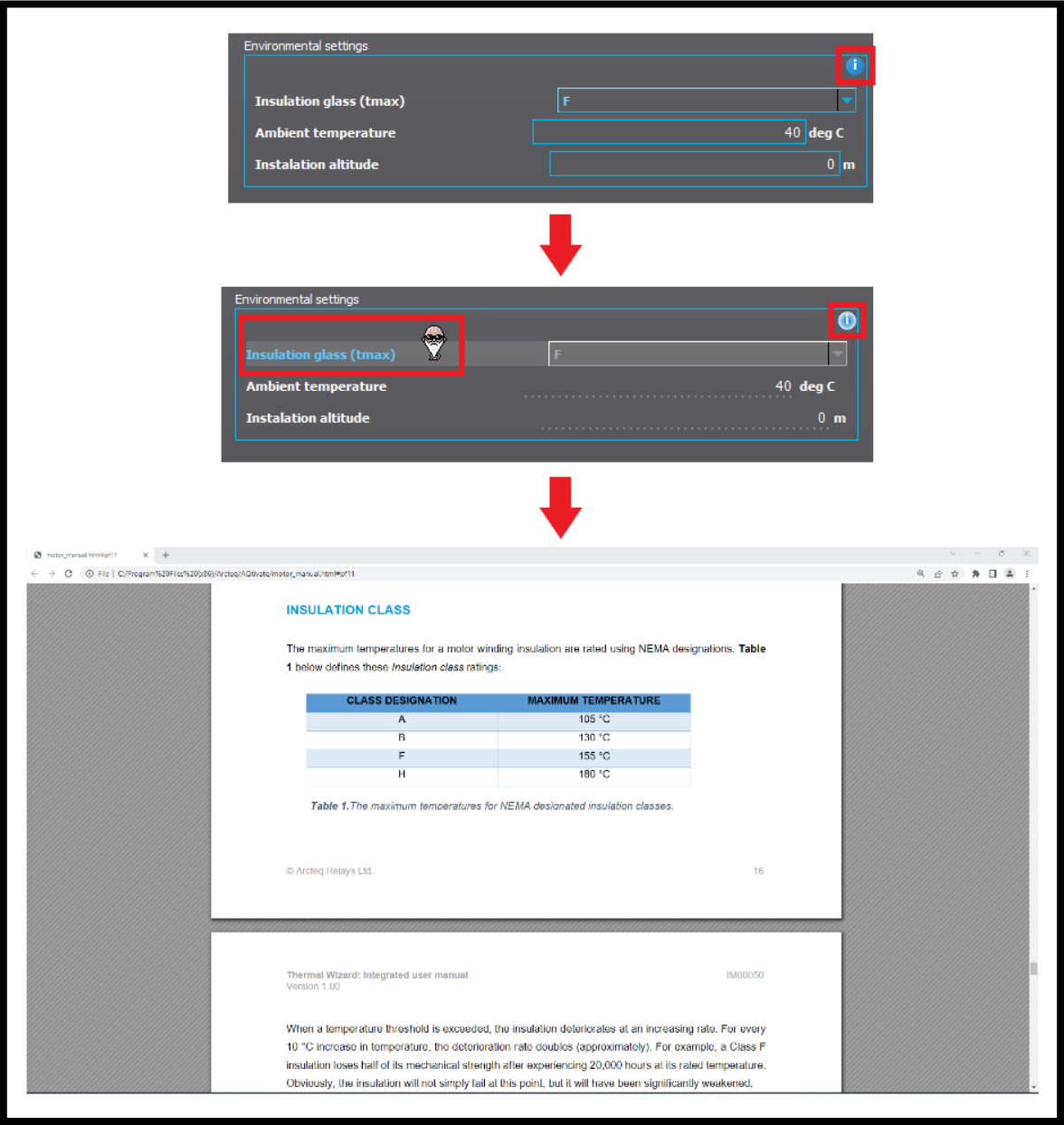
The Motor Wizard has a built-in user manual that provides a detailed description for all visible parameters. Please refer to [Chapter 5 \("Setting parameters"\)](#) of this instruction booklet for these descriptions.

All parameter groups with descriptions have a circular blue icon on their top-right corner. Enter the information mode by left-clicking the blue circle icon. The icon turns light blue, and your cursor becomes the face of a bearded wizard. Click the name of the parameter whose description you want to view to open a new tab in your web browser. This opens this Motor Wizard manual, and sets you straight on the correct chapter for the respective setting parameter you clicked in the Wizard. You can exit the information mode by clicking the circular icon again. See *Figure 7-3* on the following page for how to open a parameter description window.



Please note that you cannot change setting parameter values while in the information mode. You have to return to the default view mode to modify the parameters!

Figure 7-3. Opening the Motor Wizard manual from AQtivate 200.



SOURCES

- [1] IEC 60947-4-1 (2018). *Low-voltage switchgear and controlgear – Part 4-1: Contactors and motor-starters – Electromechanical contactors and motor-starters*. Edition 4.0. International Electrotechnical Commission.
- [2] Bhatia, A. (). *Understanding Motor Nameplate Information – NEMA vs. IEC Standards*. Continuing Education and Development, Inc. Available at:
<https://www.cedengineering.com/userfiles/Understanding%20Motor%20Nameplate%20Information%20-%20NEMA%20vs.%20IEC%20Standards.pdf>
- [3] ANSI/NEMA MG 1-2021 (2021). *Motors and Generators*. American National Electrical Manufacturers Association.
- [4] Toshiba (2020). *Motors & Drivers – Temperature Rise*. Toshiba International Corporation. Available at: toshiba.com/tic/datafiles/app_notes/Temperature_Rise_1605749858.pdf
- [5] Engineering ToolBox (2009). *Induction Motors – No. of Poles and Synchronous vs. Full Load Speed*. Available at: https://www.engineeringtoolbox.com/synchronous-full-load-speed-induction-motors-d_1448.html

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