TOL3Dev
Three-Phase Thermal Overload Protection for Devices

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1. Introduction

1.1 Features

- Three-phase thermal protection for motors, generators and transformers
- Current measurement with conventional current transformers or Rogowski coils
- The thermal model applied uses two time constants and the TRUE RMS current measuring principle
- The function block protects both the stator and the rotor in motor protection
- Adjustable percentual temperature limits for tripping, prior alarm and restart inhibit
- Estimate in seconds for the tripping of the function block
- Estimate in seconds on the time required for the object to cool below the set restarting limit
- Ambient temperature compensation by external temperature sensor(s) or by parameter setting
- Temperature sensor supervision
- Delayed trip output for the circuit-breaker failure protection (CBFP) function
- Reduced cooling rate for motor at standstill

1.2 Application

This document specifies the function of the three-phase thermal overload protection function block TOL3Dev used in products based on the RED 500 Platform, e.g. motor, generator and transformer protection relays.

Table 1 . Protection diagram symbols used in the relay terminal

ABB	IEC	ANSI
TOL3Dev	3Ithdev>	49M/G/T

For IEC symbols used in single line diagrams, refer to the manual “Technical Descriptions of Functions, Introduction”, 1MRS750528-MUM.

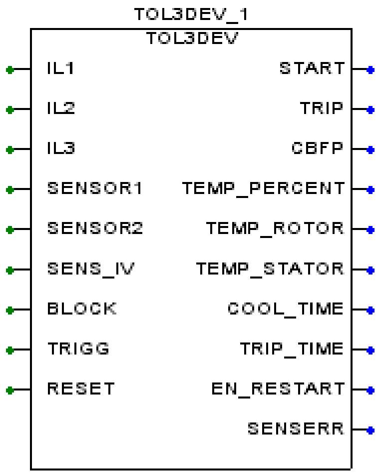


Figure 1.2.-2 Function block symbol of TOL3Dev

1.3 Input description

Name	Type	Description
IL1	Analogue signal (SINT)	Input for measuring the RMS-value of the phase current I_{L1}
IL2	Analogue signal (SINT)	Input for measuring the RMS-value of the phase current I_{L2}
IL3	Analogue signal (SINT)	Input for measuring the RMS-value of the phase current I_{L3}
SENSOR1	Analogue signal (REAL)	External temperature sensor 1 for ambient temp. measurement
SENSOR2	Analogue signal (REAL)	External temperature sensor 2 for ambient temp. measurement
SENS_IV	Digital signal (BOOL, active high)	Signal indicating a sensor fault, i.e. an invalidity input for sensor measurement
BLOCK	Digital signal (BOOL, active high)	Signal for blocking the tripping of the function block
TRIGG	Digital signal (BOOL, pos. edge)	External control signal for triggering the registers
RESET	Digital signal (BOOL, pos. edge)	Input signal for resetting the trip signal, sensor error signal and registers of TOL3Dev

1.4 Output description

Name	Type	Description
START	Digital signal (BOOL, active high)	Prior alarm signal
TRIP	Digital signal (BOOL, active high)	Tripping signal
CBFP	Digital signal (BOOL, active high)	Delayed trip signal for circuit-breaker failure protection (CBFP)
TEMP_PERCENT	Analogue signal (REAL)	Calculated temperature of the device, percentage of the maximum allowed temperature rise of the device
TEMP_ROTOR	Analogue signal (REAL)	Temperature of the rotor, percent value from the maximum allowed temperature rise of the rotor
TEMP_STATOR	Analogue signal (REAL)	Temperature of the stator, percent value from the maximum allowed temperature rise of the stator
COOL_TIME	Analogue signal (DINT)	Time in seconds which should be waited before restarting is possible
TRIP_TIME	Analogue signal (DINT)	Estimated time to the trip in seconds under present current level
EN_RESTART	Digital signal (BOOL, active high)	Restart enable signal
SENSERR	Digital signal (BOOL, active high)	Signal for indicating a sensor error

2. Description of operation

2.1 Configuration

Phase currents can be measured via conventional current transformers or Rogowski coils. The measuring devices and signal types for the analogue channels are selected and configured in a special dialogue box of the Relay Configuration Tool included in the CAP 505 Tool Box. Digital inputs are configured in the same programming environment (the number of selectable analogue inputs, digital inputs and digital outputs depends on the hardware used).

When the analogue channels and digital inputs have been selected and configured in the dialogue box, the inputs and outputs of the function block can be configured on a graphic worksheet of the configuration tool. The phase currents I_{L1}, I_{L2} and I_{L3} are connected to the corresponding I_{L1}, I_{L2} and I_{L3} inputs of the function block. The measuring principle for the current inputs is defined as TRUE RMS current measurement. The sensor inputs are connected to the inputs of TOL3Dev by means of the temperature measurement variables found on the global variables sheet of the configuration tool. The variables indicating the invalidity of sensor measurement are connected to the input SENS_IV as presented in Figure 2.1.-1 below.

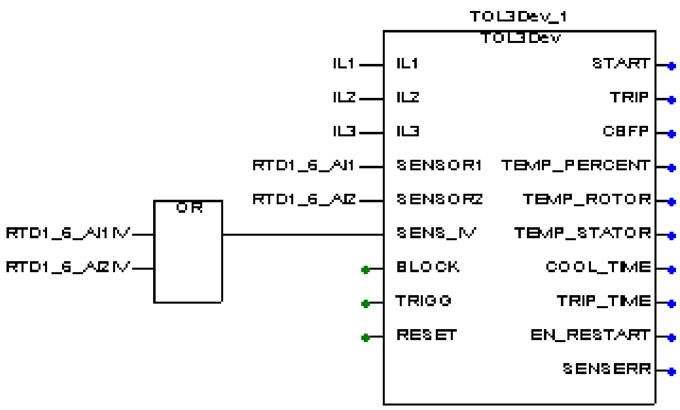


Figure 2.1.-1 Example for the connection of the SENS_IV input that indicates the invalidity of sensor measurement

Provided the sensor measurement is not used for compensating the ambient temperature, the SENS_IV, SENSOR1 and SENSOR2 inputs can be left unconnected.

Digital inputs are connected to the Boolean inputs of the function block and in the same way, the outputs of the function block are connected to the output signals.

2.2 Setting the rated values of the protected unit

A separate scaling factor can be set for each analogue channel. The factors enable differences between the ratings of the protected unit and those of the measuring device (CTs, VTs, etc.). A setting of 1.00 means that the rated value of the protected unit is exactly the same as that of the measuring device. For more information, refer to the technical reference manual of the product in question.

2.3 Measuring mode

The calculation of the thermal model is based on the TRUE RMS measuring principle. The thermal load is calculated by means of the highest phase current value.

2.4 Operation criteria

2.4.1 Principle of the thermal model applied

TOL3Dev applies the thermal model of two time constants for temperature measurement. The basic formula applied in calculating the temperature rise in degrees Celsius above the ambient temperature is presented below.

$$\Delta\Theta = [p * (I / I_n)^2 * \Delta\theta_n] * (1 - e^{-t/TC1}) + [(1-p) * (I / In)^2 * \Delta\theta_n] * (1 - e^{-t/TC2}) \quad (1)$$

where

$\Delta\Theta$	calculated temperature rise (°C) in the stator or the rotor
p	weighting factor for the short time-constant
I	the measured phase current with the highest TRUE RMS value
I_n	rated current of the protected object
$\Delta\theta_n$	temperature rise (°C) with the rated current under sustained load (=setting parameter Rise(°C),I=In)
TC1	the short heating / cooling time-constant
TC2	the long heating / cooling time-constant

2.4.2 TRIP output

The TRIP output is activated if TEMP(%), i.e. the temperature-rise calculated in percent, exceeds the value of the “Trip temperature” parameter that can be set in the range 80% to 120%.

The so-called delayed trip is set in use by giving the “Trip temperature” parameter a value higher than 100% and the “Trip delay” parameter a nonzero value. For example, the trip temperature can be set to 120% and the trip delay to 60 min, in which case the function block trips when the calculated temperature remains above 100% for 60 minutes but does not exceed 120%. If the temperature exceeds 120% during trip delay, the function block trips immediately.

If the TRIP output is chosen not to be used, the parameter is set as follows: ...\Control setting\Trip & Start = Disabled. The temperature-rise is however calculated normally.

If the TRIP output has been activated, it will remain active until the temperature values calculated for the stator and the rotor have both fallen below the limit value set for the “Restart inhibit” parameter.

2.4.3 START output

The START output becomes active when the calculated temperature exceeds the setting of the “Prior alarm” parameter that can be given a value in the range 40% to 100%. If the START output is chosen not to be used, the parameter is set as follows: ...\Control setting\Trip & Start = Disabled. The temperature-rise is however calculated normally.

The START output is useful in situations where the temperature of the protected object approaches the tripping temperature and the alarm is needed beforehand.

2.4.4 TEMP(%), STATOR(%) and ROTOR(%) outputs

The calculated temperature rises TEMP(%), STATOR(%) and ROTOR(%) can be monitored in the following three ways:

1 Via the HMI of the relay, in the view MAIN MENU / Protection lib. / TOL3Dev / Output data

2 Via LON communication provided the event E8 has not been excluded via the “Event mask” control parameter of TOL3Dev. Note that only the percentual temperature rise TEMP(%) is sent with the event.

3 Via the MIMIC view of the relay provided the connection presented in Figure 2.4.4.-1 below has been configured with the Relay Configuration Tool

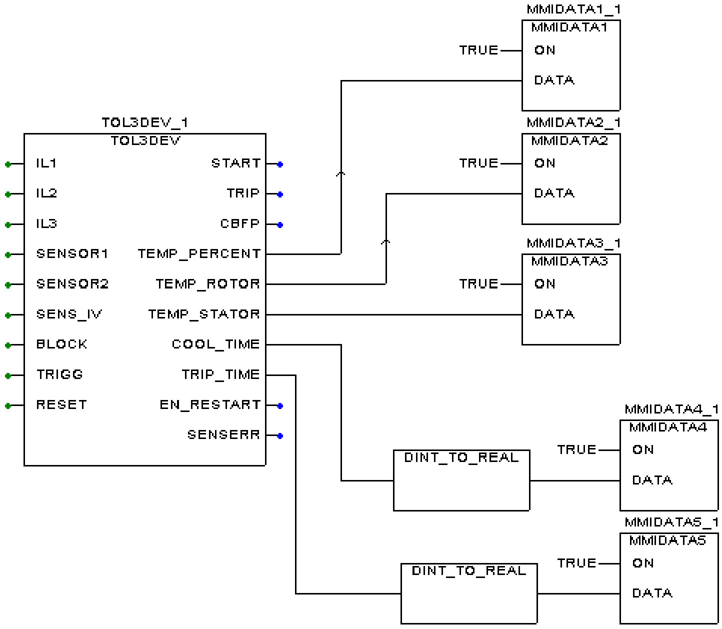


Figure 2.4.4.-1 Graphic representation of the TEMP(%), ROTOR(%) and STATOR(%) outputs in the MIMIC view of the relay

TOL3Dev sends an event containing the percentual temperature rise of the object to serial communication once every minute. However, if the change in the object temperature is less than 0,5% of the previous value sent, no event is sent to serial communication even though one minute has passed since the previous event.

If the parameter “Device type” is set to be MOTOR I, II, III, IV, the temperature rises ROTOR(%) and STATOR(%) are both calculated and the higher of the two values is shown in the TEMP(%) output. If the protected object is a generator or a transformer, the temperature rise ROTOR(%) is not calculated.

2.4.5 COOL_TIME output

The COOL_TIME output indicates in seconds the time required for the object to cool below the set temperature limit, i.e. the value of the “Restart inhibit” parameter. The cooling time left (s) can be monitored in the following three ways:

1. Via the HMI of the relay, in the view MAIN MENU / Protection lib. / TOL3Dev / Output data
2. Via LON communication provided the event E9 has not been excluded via the “Event mask” control parameter of TOL3Dev
3. Via the MIMIC view of the relay provided the connection has been configured with the Relay Configuration Tool. For an exemplary connection, see Figure 2.4.4.-1 above.

The COOL_TIME output will show the value 0 if the calculated temperature is below the set "Restart inhibit" level. When temperature is over the restart inhibit level and the value is still rising, the COOL_TIME output will show the value "99999". If the calculated temperature is over the “Restart inhibit” level and the value is decreasing, the value of COOL_TIME output will indicate the time when the thermal capacity value will drop below the “Restart inhibit” level with actual load (stopped or running).

2.4.6 TRIP_TIME output

The TRIP_TIME output indicates the operate time of the function block in seconds when the current remains at the present level. The time estimate can be monitored in the following three ways:

1. Via the HMI of the relay, in the view MAIN MENU / Protection lib. / TOL3Dev / Output data
2. Via LON communication provided the event E22 has not been excluded via the “Event mask” control parameter of TOL3Dev
3. Via the MIMIC view of the relay provided the connection has been configured with the Relay Configuration Tool. For an examplary connection, see Figure 2.4.4.-1 above.

The TRIP_TIME output will show the value 99999 if the current is so low that the tripping temperature limit is not expected to be exceeded. The value 99999 is also shown if the BLOCK input is activated or the parameter “Trip & Start” is set to “Disabled”. After a trip command, the TRIP_TIME will remain zero as long as the TRIP output is active, or if the trip signal is latched, as long as the EN_RESTART is active.

2.4.7 EN_RESTART output

The EN_RESTART output is TRUE when the calculated temperature TEMP(%) is below the set value “Restart inhibit”. When the calculated temperature exceeds the set value, the EN_RESTART output turns to FALSE.

2.4.8 Compensation of ambient temperature

The influence of ambient temperature is compensated by the parameter “Ambient temp” in the Basic settings menu that can be either a set value or one measured by temperature sensors. Compensating the ambient temperature is important for the correct function of the thermal model since the environmental conditions of protected objects may vary considerably.

The principle of ambient temperature compensation is defined via the control setting parameter “Operation mode”. When no external sensors are used for measuring the ambient temperature, the “Operation mode” parameter is given the value 1 (=ON; no sensors). In this case the temperature value applied in the thermal model is the one set for the “Ambient temp” parameter. It is important to note that TOL3Dev smoothes stepwise on-line changes to the "Ambient temp" parameter. This means that the set changes are taken into use by exponential model having a time constant of 60 minutes. On the other hand, when external sensors are used, the “Operation mode” parameter is given the value 2 or 3. When the value 2 (=Sensor 1) is set for the parameter, one temperature sensor is used which is connected to the SENSOR1 input of the function block. The value 3 (=Sensors 1&2) means that two sensors are used for measuring the ambient temperature, in which case the function block applies the higher of the two temperature values in the thermal model for compensating the ambient temperature.

At any time, the ambient temperature value used in the thermal model can be checked via the HMI or via serial communication in the menu ... / TOL3Dev / Control setting / Ambient temp.

2.4.9 Temperature sensor supervision

Provided the temperature measurement value is not within the allowed range of -40 to +70 degrees, the function block sends a “Sensor error” event (E13) and activates the SENSERR output. The same is done also if TOL3Dev detects a rapid change of more than 5 degrees in the measured temperature. The SENSERR output is always latched and must be reset as presented in chapter 2.9.

When TOL3Dev detects an error in a sensor measurement, it applies the set temperature value for compensating the ambient temperature.

2.4.10 BLOCK input

If the BLOCK input is active, the TRIP output cannot be activated, but TOL3Dev still continues calculating the temperature of the protected object. Thus, activating the BLOCK signal prevents neither temperature calculation nor activation of the START output.

2.5 Application examples

2.5.1 Motor protection

2.5.1.1 Asynchronous motors

TOL3Dev is well suited for protecting squirrel-cage motors. The function block protects a motor from both short-duration overloadings and long-time overloadings. The start situation is a good example of short-duration overloadings since particularly at start-up the rotor is in danger to be overloaded by the starting current, which can be in the range of five to seven times the rated current of the motor. The start-ups of the motor also load the stator windings. The stator may constitute a limitation regarding thermal protection especially when a warm motor is restarted.

Because the function block calculates the temperature rise for both the stator and the rotor individually, the motor can be fully protected by means of proper settings. Furthermore, the thermal model of two time constants (formula 1) enables detecting both the short-time and long-time overloadings.

The Figure 2.5.1.1.-1 below shows an example of the thermal calculations in the loading situation of an asynchronous motor.

The parameter values applied in the example are the following:

Device type	= MOTOR IV		
Ambient temp	= 40 °C		
S: $\tau 1$	= 16.5 min	R: $\tau 1$	= 4.1 min
S: $\tau 2$	= 66.0 min	R: $\tau 2$	= 66.0 min
S: p-factor	= 0.6	R: p-factor	= 0.5
S:Rise(°C), I=In	= 90 °C	R:Rise(°C), I=In	= 90 °C
S:Maximum temp	= 155 °C	R:Maximum temp	= 210 °C

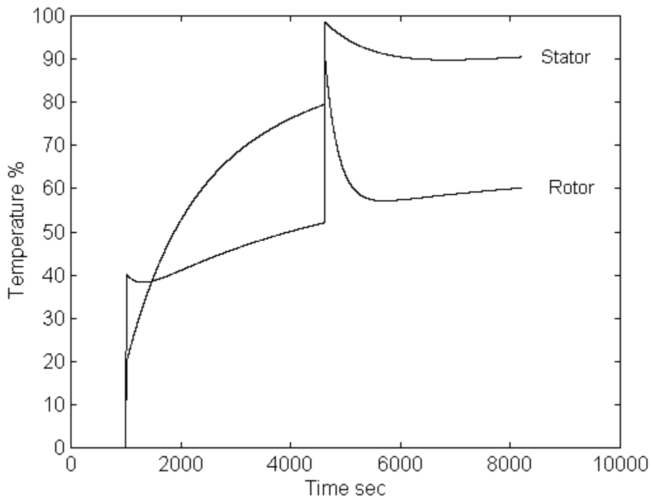


Figure 2.5.1.1.-1 Example of thermal calculations when the loading sequency is: 1) Start situation 10 seconds I=6 x In, 2) Loading 60 minutes I=1.1 x In, 3) Start situation 10 seconds I=6 x In 4) Loading 60 minutes I=1.1 x In

The cooling of the motor depends on its structure as well as on the cooling system applied. In squirrel-cage induction motors the cooling fan is usually installed on the shaft of the motor, i.e. the motor is self-cooled. Consequently, when the motor stops, the circulation of cooling air is interrupted as well. As a result the stopped motor cools down considerably slower than the rotating one. Provided the manufacturer does not state any other value, the cooling time-constant can be set to 3 x the heating time-constant for fully closed motors with surface cooling and to 4 x the heating time-constant for through-ventilated motors. For motors with a separate cooling system, the cooling time-constant is the same as the heating time-constant, and the cooling τ is set to 1 x τ.

Note! When the device type in motor protection (asynchronous or synchronous) is MOTOR I, MOTOR II, MOTOR III or MOTOR IV, the parameter “Gen&Trafo τ” has no effect and does not need to be set.

2.5.1.2 Synchronous motors

If a synchronous motor is started connecting it directly to the mains, TOL3Dev can also be used as back-up protection for the rotor, in which case the thermal curves designed mainly for squirrel-cage motors can be used for the synchronous motor as well. Especially the thermal curve of MOTOR II is suitable in this kind of a situation.

Provided the synchronous motor is started by means of a transformer or a reactor, the starting current usually remains below 2.5 x the rated current of the motor, in which case GENERATOR I is the best choice for the parameter “Device type”. However, if the motor tolerates only little overloading, the device type should be defined to be GENERATOR II.

Provided the manufacturer does not state any other value, the cooling time-constant of the synchronous motor can be set to 3 x the heating time-constant.

2.5.2 Generator protection

By means of the thermal model of two time constants (formula 1), TOL3Dev protects generators from both short- and long-time overloadings. In generator protection, only the temperature of the stator is calculated.

The thermal curve GENERATOR I is suitable for hydro generators and for small air-cooled turbine generators, whereas the thermal curve GENERATOR II is best suited for large turbine generators.

Provided the manufacturer does not state any other value, the heating time-constant, i.e. the parameter “Gen&Trafo τ”, can be set to 13 min for GENERATOR I and to 7 min for GENERATOR II.

Note! When the device type in generator protection is GENERATOR I or GENERATOR II, the parameters “Starting current”, “Starting time” and “No of starts” have no effect and do not need to be set.

2.5.3 Transformer protection

TOL3Dev protects a transformer mainly from short-time overloadings. From long-time overloadings the transformer is protected by the oil temperature detector included in its equipment.

The thermal curve of two time constants is typical for a transformer. Provided the manufacturer does not state any other value, the heating time-constant, i.e. the parameter “Gen & Trafo τ”, can be set to 50 min for a distribution transformer and to 73 min for a supply transformer.

Note! When the device type in transformer protection is TRANSFORMER, the parameters “Starting current”, “Starting time” and “No of starts” have no effect and do not need to be set.

2.5.4 Starting temperatures at initialization

After a relay reset and an auxiliary power failure, the starting value of the temperature rise for the stator is 80% and that for the rotor 30%. If the protected unit is not a motor but a transformer or a generator, the temperature rise calculation is set to 80% at the reset.

If the push-buttons C+E are pressed simultaneously for 5 s within 90 s from the reset, the starting values of the temperature rise calculation are reset to zero for both the stator and the rotor, which may be useful at testing. Note that pressing the push buttons later than within 90 s from the reset will have no effect on the temperature rise calculation.

If the tripping temperature limit has been set below 100%, the calculation of the temperature rise of the stator is started with the tripping temperature limit - 20%.

2.5.5 Lowering the calculated temperature during operation

If required, the temperature TEMP(%) calculated by the relay can be lowered during operation by setting the maximum temperature allowed for the stator (and the rotor) higher via the menu “Advanced settings” of TOL3Dev.

2.6 Settings

2.6.1 Setting groups

The two setting groups available for TOL3Dev are basic settings and advanced settings. Furthermore, the parameters used by the thermal model are shown under the heading “Actual setting”. If the user is only able to set the basic settings, the suggestions made by the relay for the advanced setting parameters are shown under actual settings, i.e. the relay is able to internally calculate the advanced setting parameters. The suggestions made by the relay are also presented in advanced settings.

Advanced settings include more setting parameters than basic settings, and by means of the advanced setting parameters the function of the thermal model can be set to be more accurate. If the user knows e.g. that the short heating time-constant for the rotor is three minutes, the particular parameter in advanced settings can be set by the user, after which the relay will show the new set value for the short time-constant under the heading “Actual setting”. Therefore, setting a parameter in advanced settings will always overrule the suggestion the relay has made for the concerned parameter. The remaining advanced setting parameters, i.e. those unknown by the user, are computed by the relay.

All the parameters used by the thermal model are shown under the heading “Actual setting”. However, these are read-only parameters and can thus not be set by the user.

2.6.2 Setting the function block via basic settings alone

The function block TOL3Dev can be set even if only the basic knowledge of the motor is available. In other words, the information about the motor starting is sufficient for setting the protection. These settings are meant to be simple, and although the extra knowledge from the motor is not known, the basic settings suffice to confirm the adequate function of overload protection.

For instance, the relay calculates one time constant from the motor start-up information and then internally converts the result into two time constants separately for the rotor and the stator, depending on the type of the device to be protected. Unless the type of the device is MOTOR I, II, III or IV, only the temperature of the stator is calculated.

2.6.3 Setting parameters

Device type: The parameter specifies the protected object. There are four motor types, two generator types and one transformer type available. The motor and generator types are described below.

MOTOR I	through-ventilated, rated power < 1500 kW
MOTOR II	through-ventilated, rated power > 1500 kW
MOTOR III	surface cooling, rated power < 500 kW
MOTOR IV	surface cooling, rated power > 500 kW
GENERATOR I	hydro generators and small air-cooled turbine generators
GENERATOR II	large turbine generators

There is a relation between the cooling process described in detail in the IEC standard 60034-6 and the motor types described above. For example, motors with the cooling system IC 00, IC 01, IC 03, IC 06, IC 11 or IC 31 should be set to MOTOR I or MOTOR II. Correspondingly, motors with e.g. the cooling system IC 00 41, IC 01 41, IC 01 51, IC 01 61, IC W37 A71 or IC W37 A81 belong to the category MOTOR III or MOTOR IV.

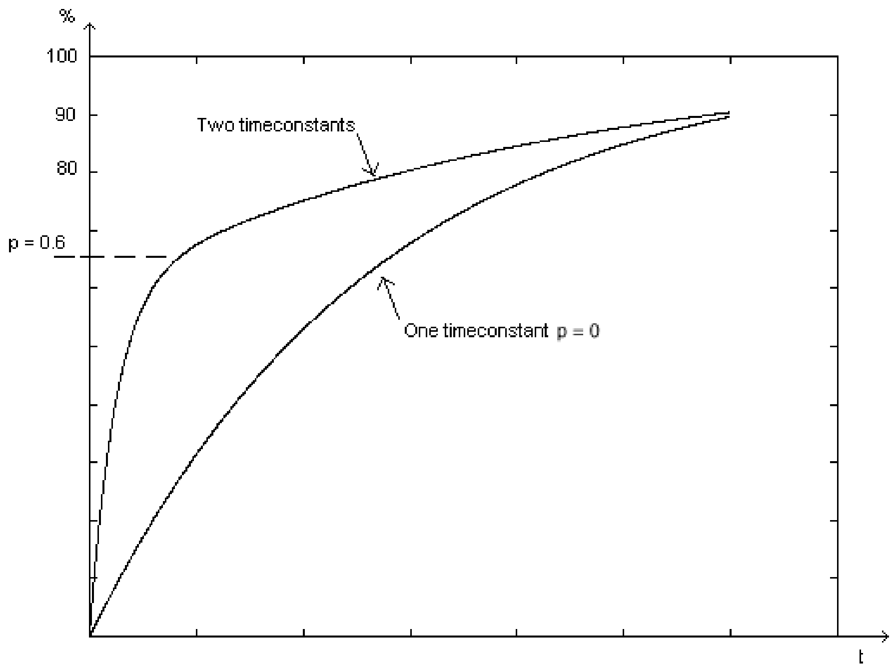
No of starts: The setting parameter defines how many times the motor is allowed to be started from initial cold condition state.

Cooling τ: If all the phase currents of the motor fall below 12 % of the rated current, the motor is presumed to be stopped. Typically, the cooling of the stopped motor is slower than that of the rotating one since the cooling device installed on the motor shaft, e.g. an air fan, will be stopped as well. The parameter “Cooling τ” is designed to compensate the difference in cooling properties. The long time-constants of the stator and the rotor are separately multiplied with the set value.

τ1: In the thermal model (formula 1) τ1 is the short time-constant that describes the warming of the windings with regard to iron.

τ2: In the thermal model τ2 is the long time-constant utilized to describe the warming of the iron with regard to cooling air.

p - factor: p - factor is the weighting factor for the short time-constant τ1. The figure below describes the difference in the heating curves between the one time-constant model and the two time-constant model. Using the two time-constant model, the relay is able to follow both fast and slow changes in the temperature of the protected object. As the Figure 2.6.3-1 shows, the higher the p - factor is, the larger is the share of the steep part of the heating curve. The warming and cooling following the two time-constant thermal curve is characteristic for motors, generators and transformers. If the p-factor is set to zero, the thermal image will correspond to the one time-constant



model.

Figure 2.6.3.-1 Effect of the p - factor and the difference between the two time-constant and the one time-constant models

Rise(°C), I=In: The parameter defines in degrees Celsius how much the motor, generator or transformer will warm up above the ambient temperature when loaded by the rated current. The setting of the rated current is described in chapter “Configuration”.

The rated power of ABB motors, for example, is usually based on a temperature rise of the insulation class B. However, the insulation of the motors is usually made to withstand class F temperatures. Therefore the default value of the parameter "S: Rise(°C),I=In" is 90 °C, i.e. in accordance with the insulation class B.

When the object to be protected is a transformer, the default value of the parameter "S: Rise(°C),I=In" is 78 °C, i.e. in accordance with the IEC standard 60354.

Max temperature: The maximum temperature value allowed for a stator or a rotor. For instance, the default maximum temperature of the stator is 155 °C when the "Device type" parameter is set to be MOTOR or GENERATOR. The value 155 °C corresponds to the insulation class F according to the norm IEC 60085.

When the protected object is a transformer, the default maximum temperature is 105 °C. This value is chosen, since even though the IEC standard 60354 recommends 98 °C as the maximum allowable temperature in long-time loading, the standard also states that a transformer can withstand the emergency loading for weeks or even months, which may produce the winding temperature of 140 °C. Therefore 105 °C is a safe maximum temperature value for a transformer.

2.7 Test mode

The digital outputs of the function block can be activated with separate control settings for each output either locally via the HMI or externally via the serial communication. When an output is activated with the test parameter, an event indicating the test is generated.

The protection functions operate normally while the outputs are tested.

2.8 START, TRIP and CBFP outputs

The output signal START is always pulse-shaped. The minimum pulse width of the START and TRIP output signals is set via a separate parameter on the HMI or on the serial communication. If the start situation is longer than the set pulse width, the START signal remains active until the start situation is over.

The output signal TRIP may have a non-latching or latching feature. If the start situation is longer than the set pulse width and the non-latching mode has been selected, the TRIP signal remains active until the start situation is over. When the latching mode has been selected, the TRIP signal remains active until the output is reset even if the operation criteria have reset.

The circuit-breaker failure protection function provides a delayed trip signal, CBFP, after the TRIP signal unless the fault has disappeared during the set CBFP time delay. An unsuccessful breaker operation is detected from the phase currents. If any of the phase currents remain above 1% p.u. for the set CBFP operate time, the CBFP trip is activated. The CBFP output can be used to operate a circuit breaker in front of the circuit breaker of the feeder.

Note! The control parameter "Trip pulse" also sets the pulse width of the CBFP output signal. The CBFP signal resets when the set pulse width elapses, even if the start situation is still active. Therefore, if the CBFP function is used, a setting value of 200ms or longer for the control parameter "Trip pulse" is recommended.

The default value for the control parameter “CBFP time” is 0.00 s, which means that the circuit breaker failure protection is not in use.

2.9 Resetting

The TRIP output signal, SENSERR output signal and registers can be reset either via the RESET input or over the serial bus or the local HMI.

The operation indicators, output signals and recorded data can be reset as follows:

	Operation indicators	Latched trip & sensor err.	Recorded data
RESET input of the function block 1)		X	X
Parameter F048V013 1)		X	X
General parameter F001V011 2)	X		
General parameter F001V012 2)	X	X	
General parameter F001V013 2)	X	X	X
Push-button C 2)	X		
Push-buttons C + E (2 s) 2)	X	X	
Push-buttons C + E (5 s) 2)	X	X	X

1) Resets the latched trip signal, sensor error signal and recorded data of this particular function block.
2) Affects all function blocks.

3. Parameters and events

3.1 General

- Each function block has a specific channel number for serial communication parameters and events. The channel for TOL3Dev is 48.
- The data direction of the parameters defines the use of each parameter as follows:

Data direction	Description
R, R/M	Read only
W	Write only
R/W	Read and write

- The different event mask parameters (see section “Control settings”) affect the visibility of events on the HMI or on serial communication (LON or SPA) as follows:

Event mask 1 (FxxxV101/102)	SPA / HMI (LON)
Event mask 2 (FxxxV103/104)	LON
Event mask 3 (FxxxV105/106)	LON
Event mask 4 (FxxxV107/108)	LON

For example, if only the events E3, E4 and E5 are to be seen on the HMI of the relay terminal, the event mask value 56 (8 + 16 + 32) is written to the “Event mask 1” parameter (FxxxV101).

In case a function block includes more than 32 events, there are two parameters instead of e.g. the “Event mask 1” parameter: the parameter “Event mask 1A” (FxxxV101) covers the events 0...31 and “Event mask 1B”(FxxxV102) the events 32...63.

3.2 Setting values

3.2.1 Actual settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
S: τ1	S1	0.1...999.0	min	14.0	R/M	Short time-constant for the stator
S: τ2	S2	0.1...999.0	min	69.0	R/M	Long time-constant for the stator
S: p-factor	S3	0.00...1.00	-	0.50	R/M	Weighting factor of the S:τ1
S: Rise(°C),I=In	S4	50.0...350.0	°C	90.0	R/M	Temperature rise of the stator when loaded by the rated current
S: Maximum temp	S5	50.0...350.0	°C	155.0	R/M	Maximum temperature allowed for the stator
R: τ1	S6	0.1...999.0	min	4.0	R/M	Short time-constant for the rotor
R: τ2	S7	0.1...999.0	min	69.0	R/M	Long time-constant for the rotor
R: p-factor	S8	0.00...1.00	-	0.25	R/M	Weighting factor of the R:τ1
R: Rise(°C),I=In	S9	50.0...350.0	°C	100.0	R/M	Temperature rise of the rotor when loaded by the rated current
R: Maximum temp	S10	50.0...350.0	°C	200.0	R/M	Maximum temperature allowed for the rotor

3.2.2 Basic settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Starting current	S41	0.10...10.00	x In	6.0	R/W	Starting current of the motor set as a multiple of the rated current
Starting time	S42	0.1...120.0	s	12.0	R/W	Maximum starting time permitted for the motor
No of starts	S43	1...3	-	2	R/W	Number of starts allowed from the cold state
Device type	S44	0...6 [1)]	-	0	R/W	Type of the device to be protected
Trip temperature	S45	80.0...120.0	%	100	R/W	Tripping temperature, percent value
Prior alarm	S46	40.0...100.0	%	90	R/W	Prior alarm temperature, percent value
Restart inhibit	S47	40.0...100.0	%	60	R/W	Temperature limit for the successful restarting
Ambient temp	S48	-50.0...100.0	°C	40.0	R/W	Setting value for ambient temperature
Cooling τ	S49	1.0...10.0	x τ	4.0	R/W	Cooling time multiplier for motor at standstill
Gen&Trafo τ	S50	1...999	min	20	R/W	Heating time-constant for generator or transformer

[1)] Device type: 0 = MOTOR I; 1 = MOTOR II; 2 = MOTOR III; 3 = MOTOR IV;
4 = GENERATOR I; 5 = GENERATOR II; 6 = TRANSFORMER

3.2.3 Advanced settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
S: τ1	V71	0.0...999.0	min	0.0	R/W	Short time-constant for the stator
S: τ2	V72	0.0...999.0	min	0.0	R/W	Long time-constant for the stator
S: p-factor	V73	0.00...1.00	-	0.00	R/W	Weighting factor of the S:τ1
S: Rise(°C),I=In	V74	0.0...350.0	°C	0.0	R/W	Temperature rise of the stator when loaded by the rated current
S: Maximum temp	V75	0.0...350.0	°C	0.0	R/W	Maximum temperature allowed for the stator
R: τ1	V76	0.0...999.0	min	0.0	R/W	Short time-constant for the rotor
R: τ2	V77	0.0...999.0	min	0.0	R/W	Long time-constant for the rotor
R: p-factor	V78	0.00...1.00	-	0.00	R/W	Weighting factor of the R:τ1
R: Rise(°C),I=In	V79	0.0...350.0	°C	0.0	R/W	Temperature rise of the rotor when loaded by the rated current
R: Maximum temp	V80	0.0...350.0	°C	0.0	R/W	Maximum temperature allowed for the rotor

3.2.4 Control settings

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Operation mode	V1	0...3 [1)]	-	1	R/W	Selection of operation mode
Ambient temp	V2	-50.0...100.0	°C	0.0	R/M	Ambient temperature value
Trip signal	V6	0 or 1 [2)]	-	1	R/W	Selection of latching feature for TRIP output
Trip pulse	V7	100...1000	ms	100	R/W	Minimum pulse width of TRIP and CBFP
Trip delay	V8	0...60000	min	0	R/W	Operate time of the delayed trip
CBFP time	V9	0.00...100.00	s	0.00	R/W	Operate time of Circuit-Breaker Failure Protection
Trip & Start	V10	0 or 1 [3)]	-	1	R/W	Indicates whether the START and TRIP outputs are enabled or not
Reset registers	V13	1=Reset	-	0	W	Resetting of latched trip signal and registers
Test START	V31	0 or 1 [4)]	-	0	R/W	Testing of START
Test TRIP	V32	0 or 1 [4)]	-	0	R/W	Testing of TRIP
Test CBFP	V33	0 or 1 [4)]	-	0	R/W	Testing of CBFP
Event mask 1	V101	0...8388607	-	4177983	R/W	Event mask 1 for event transmission (E0 ... E22)
Event mask 2	V103	0...8388607	-	4177983	R/W	Event mask 2 for event transmission (E0 ... E22)
Event mask 3	V105	0...8388607	-	4177983	R/W	Event mask 3 for event transmission (E0 ... E22)
Event mask 4	V107	0...8388607	-	4177983	R/W	Event mask 4 for event transmission (E0 ... E22)

[1)] Operation mode 0 = Not in use; 1= ON: no sensors; 2= ON: Sensor 1; 3 = ON: Sensors 1&2
[2] Trip signal 0 = Non-latching; 1 = Latching
[3] Trip & Start 0 = Disabled; 1 = Enabled
[4] Testing 0 = Do not activate; 1 = Activate

3.3 Measurement values

3.3.1 Input data

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Current IL1	I1	0.0...20000.0	A	0.0	R/M	Phase current I_{L1}
Current IL2	I2	0.0...20000.0	A	0.0	R/M	Phase current I_{L2}
Current IL3	I3	0.0...20000.0	A	0.0	R/M	Phase current I_{L3}
IL1 (%)	I4	0.0...1000.0	% In	0.0	R/M	Phase current I_{L1} in percent
IL2 (%)	I5	0.0...1000.0	% In	0.0	R/M	Phase current I_{L2} in percent
IL3 (%)	I6	0.0...1000.0	% In	0.0	R/M	Phase current I_{L3} in percent
Temp SENSOR1	I7	-50.0...100.0	°C	0.0	R/M	Temperature value from sensor 1
Temp SENSOR2	I8	-50.0...100.0	°C	0.0	R/M	Temperature value from sensor 2
Input SENS_IV	I9	0 or 1 [1)]	-	0	R/M	Signal indicating sensor fault
Input BLOCK	I10	0 or 1 [2)]	-	0	R/M	Blocking signal
Input TRIGG	I11	0 or 1 [2)]	-	0	R/M	Signal for triggering the registers
Input RESET	I12	0 or 1 [2)]	-	0	R/M	Signal for resetting the output signals and registers of TOL3Dev

[1)] Input SENS_IV 0 = Valid;1 = Invalid
[2)] Input 0 = Not active; 1 = Active

3.3.2 Output data

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Output START	O1	0 or 1 [1)]	-	0	R/M	Status of start signal (prior alarm)
Output TRIP	O2	0 or 1 [1)]	-	0	R/M	Status of trip signal
Output TEMP(%)	O3	0.0...1000.0	%	0.0	R/M	Calculated temp. of the device, maximum from the stator and the rotor
Output ROTOR(%)	O4	0.0...1000.0	%	0.0	R/M	Temperature of the rotor, percent value from the maximum allowed temperature rise of the rotor
Output STATOR(%)	O5	0.0...1000.0	%	0.0	R/M	Temperature of the stator, percent value from the maximum allowed temperature rise of the stator
Output COOL_TIME	O6	0...99999	s	0	R/M	Waiting time for the successful restart
Output TRIP_TIME	O7	0...99999	s	0	R/M	Estimated time to the trip
Output EN_RESTART	O8	0 or 1 [2)]	-	0	R/M	Restart enable signal
Output SENSERR	O9	0 or 1 [1)]	-	0	R/M	Status of sensor error signal

[1)] Output 0 = Not active; 1 = Active
[2)] Output EN_RESTART 0 = Disabled; 1 = Enabled

3.3.3 Recorded data

3.3.3.1 General

The information required for later fault analysis is recorded when the function block starts or trips, or when the recording function is triggered via the external TRIGG input.

No recordings are done if trip and start outputs are disabled via control setting "Trip & Start". However, the TRIGG input is functional.

The data of the last three events are stored into Recorded data 1...3, beginning from Recorded data 1. These registers are updated in a cyclical manner, where the values of the most recent event overwrite the oldest recorded data. If recorded data has been reset or the relay has been restarted, the first event is again stored to Recorded data 1.

3.3.3.2 Parameter values

Date and time	The time stamp indicates the rising edge of the START, TRIP or TRIGG signal.
Output TRIP	Status of the TRIP signal.
Input TRIGG	Signal for triggering the registers externally.
Trip delay	The elapsed time is recorded as a percentage of the set trip delay. The time starts accumulating when the temperature rise exceeds 100%.
Primary current	The measured primary current value (TRUE RMS) at the moment of recording.
Output ROTOR(%)	Temperature value of the rotor at the moment of recording. For recordings caused by the START output, ROTOR(%) shows the maximum temperature value of the rotor between the rising and the falling edge of the START signal.
Output STATOR(%)	Temperature value of the stator at the moment of recording. For the recordings caused by the START output, STATOR(%) shows the maximum temperature value of the stator between the rising and the falling edge of the START signal.
Ambient temp	Ambient temperature value used in the thermal model.

3.3.3.3 Priority

The priority of the recording function is the following:

1 Tripping

2 Starting

3 External triggering,

which means that if the function block has started, it will neglect an external triggering request.

3.3.3.4 Recorded data 1

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V201	YYYY-MM-DD	-	-	R/M	Recording date
Time	V202	hh:mm:ss.mss	-	-	R/M	Recording time
Output TRIP	V203	0 or 1 [1)]	-	0	R/M	Status of TRIP output
Input TRIGG	V204	0 or 1 [1)]	-	0	R/M	Status of TRIGG input
Trip delay	V205	0.0...100.0	%	0.0	R/M	Elapsed trip delay in percent
Primary current	V206	0.0...20000.0	A	0.0	R/M	RMS current value (maximum of I_{L1},I_{L2} & I_{L3})
Output ROTOR(%)	V207	0.0...1000.0	%	0.0	R/M	Temperature of the rotor, percent value from the maximum allowed temperature rise of the rotor
Output STATOR(%)	V208	0.0...1000.0	%	0.0	R/M	Temperature of the stator, percent value from the maximum allowed temperature rise of the stator
Ambient temp	V209	-50.0...100.0	°C	0.0	R/M	The ambient temperature used for the calculation of the thermal load

[1)] Status 0 = Not active; 1 = Active

3.3.3.5 Recorded data 2

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V301	YYYY-MM-DD	-	-	R/M	Recording date
Time	V302	hh:mm:ss.mss	-	-	R/M	Recording time
Output TRIP	V303	0 or 1 [1)]	-	0	R/M	Status of TRIP output
Input TRIGG	V304	0 or 1 [1)]	-	0	R/M	Status of TRIGG input
Trip delay	V305	0.0...100.0	%	0.0	R/M	Elapsed trip delay in percent
Primary current	V306	0.0...20000.0	A	0.0	R/M	RMS current value (maximum of I_{L1},I_{L2} & I_{L3})
Output ROTOR(%)	V307	0.0...1000.0	%	0.0	R/M	Temperature of the rotor, percent value from the maximum allowed temperature rise of the rotor
Output STATOR(%)	V308	0.0...1000.0	%	0.0	R/M	Temperature of the stator, percent value from the maximum allowed temperature rise of the stator
Ambient temp	V309	-50.0...100.0	°C	0.0	R/M	The ambient temperature used for the calculation of the thermal load

[1)] Status 0 = Not active; 1 = Active

3.3.3.6 Recorded data 3

Parameter	Code	Values	Unit	Default	Data direction	Explanation
Date	V401	YYYY-MM-DD	-	-	R/M	Recording date
Time	V402	hh:mm:ss.mss	-	-	R/M	Recording time
Output TRIP	V403	0 or 1 [1)]	-	0	R/M	Status of TRIP output
Input TRIGG	V404	0 or 1 [1)]	-	0	R/M	Status of TRIGG input
Trip delay	V405	0.0...100.0	%	0.0	R/M	Elapsed trip delay in percent
Primary current	V406	0.0...20000.0	A	0.0	R/M	RMS current value (maximum of I_{L1},I_{L2} & I_{L3})
Output ROTOR(%)	V407	0.0...1000.0	%	0.0	R/M	Temperature of the rotor, percent value from the maximum allowed temperature rise of the rotor
Output STATOR(%)	V408	0.0...1000.0	%	0.0	R/M	Temperature of the stator, percent value from the maximum allowed temperature rise of the stator
Ambient temp	V409	-50.0...100.0	°C	0.0	R/M	The ambient temperature used for the calculation of the thermal load

[1)] Status 0 = Not active; 1 = Active

3.3.4 Events

Code	Weighting coefficient	Default mask	Event reason	Event state
E0	1	1	START signal from TOL3Dev	Reset
E1	2	1	START signal from TOL3Dev	Activated
E2	4	1	TRIP signal from TOL3Dev	Reset
E3	8	1	TRIP signal from TOL3Dev	Activated
E4	16	1	CBFP signal from TOL3Dev	Reset
E5	32	1	CBFP signal from TOL3Dev	Activated
E6	64	0	BLOCK signal of TOL3Dev	Reset
E7	128	0	BLOCK signal of TOL3Dev	Activated
E8	256	0	Calculated temperature	-
E9	512	0	Cooling time for the successful restart	-
E10	1024	0	Test mode of TOL3Dev	Off
E11	2048	0	Test mode of TOL3Dev	On
E12	4096	0	Sensor error signal from TOL3Dev	Reset
E13	8192	0	Sensor error signal from TOL3Dev	Activated
E14	16384	1	START from TOL3Dev <= STATOR	Reset
E15	32768	1	START from TOL3Dev <= STATOR	Activated
E16	65536	1	TRIP from TOL3Dev <= STATOR	Reset
E17	131072	1	TRIP from TOL3Dev <= STATOR	Activated
E18	262144	1	START from TOL3Dev <= ROTOR	Reset
E19	524288	1	START from TOL3Dev <= ROTOR	Activated
E20	1048576	1	TRIP from TOL3Dev <= ROTOR	Reset
E21	2097152	1	TRIP from TOL3Dev <= ROTOR	Activated
E22	4194304	0	Estimated trip time from TOL3Cab	-

4. Technical data

Operation accuracies	Current measurement: f/f_n = 0.95...1.05: ± 1.0%, I = 0.1...10.0 x I_n
Operate time accuracy	±2% or ±0.5s
Reset ratio	TRIP: (TEMP(%) - 0.1) / Trip temperature START: (TEMP(%) - 0.1) / Prior alarm EN_RESTART: (TEMP(%) - 0.1) / Restart inhibit
Configuration data	Task execution interval (Relay Configuration Tool): 60 ms at the rated frequency f_n = 50 Hz

Technical revision history	
Technical revision	**Change**
C	-
D	- operation of the COOL_TIME output has been changed
E	- the value range of COOL_TIME and TRIP_TIME parameters in output data has been corrected

5. Appendix: Tripping curves

5.1 Setting values used in the tripping characteristics

Tripping curves (Figures 5.1.-1 – 5.1.-28) are based on the following setting values.

Device type	S: τ1	R: τ1	S:Rise(°C), I=In	R:Rise(°C), I=In	S:Maximum temp	R:Maximum temp	S: p-factor	R: p-factor	Trip temperature
Motor I	τ2 / 4	τ2 / 16	90 °C	100 °C	155 °C	200 °C	0.5	0.25	100 %
Motor II	τ2 / 4	τ2 / 16	90 °C	100 °C	155 °C	200 °C	0.5	0.35	100 %
Motor III	τ2 / 4	τ2 / 16	90 °C	100 °C	155 °C	200 °C	0.6	0.15	100 %
Motor IV	τ2 / 4	τ2 / 16	90 °C	100 °C	155 °C	200 °C	0.6	0.5	100 %
Generator I	τ2 / 16		90 °C		155 °C		0.6		100 %
Generator II	τ2 / 16		90 °C		155 °C		0.8		100 %
Transformer	τ2 / 16		78 °C		105 °C		0.4		100 %

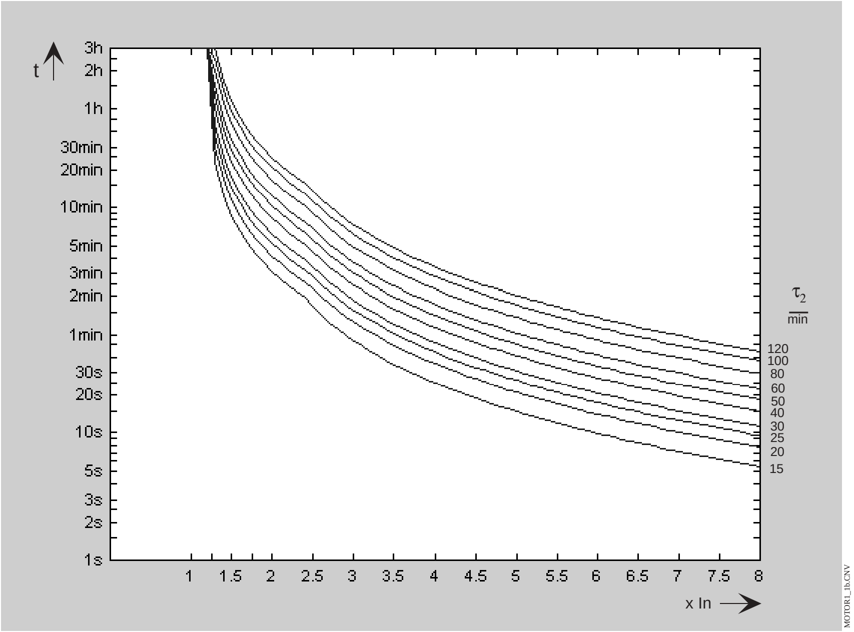


Figure 5.1.-1 Motor I: Ambient temperature = 20 °C; Initial condition: Cold motor, no preloading

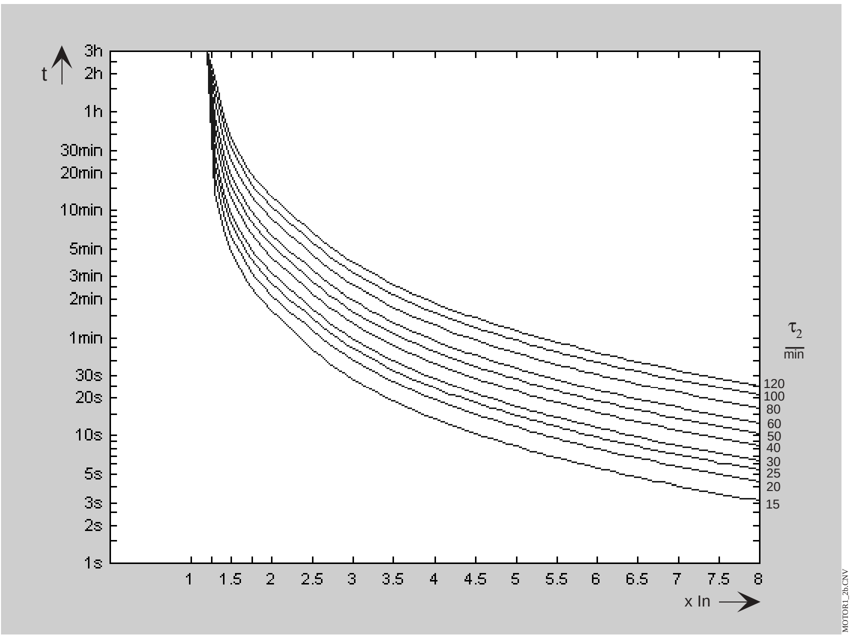


Figure 5.1.-2 Motor I: Ambient temperature = 20 °C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

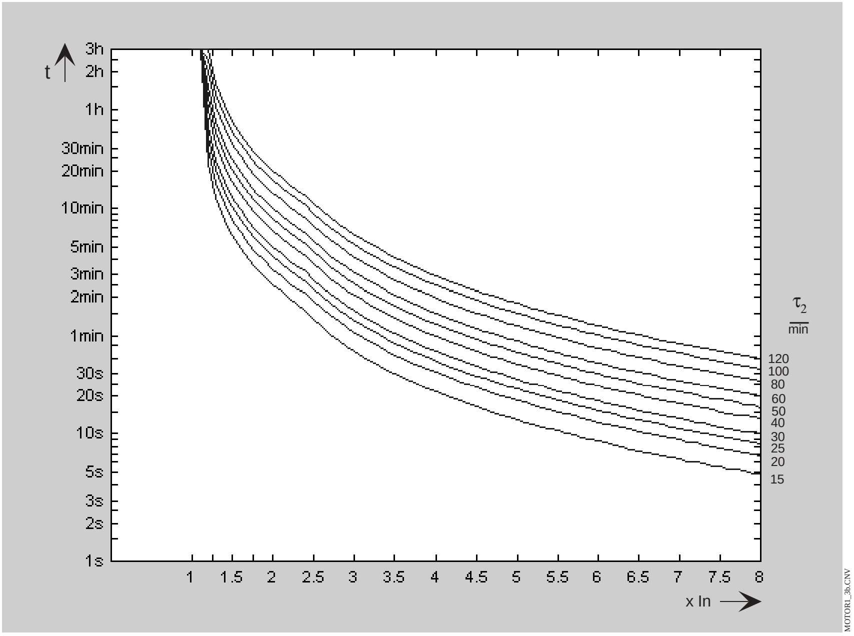


Figure 5.1.-3 Motor I: Ambient temperature = 40 ^{O}C; Initial condition: Cold motor, no preloading

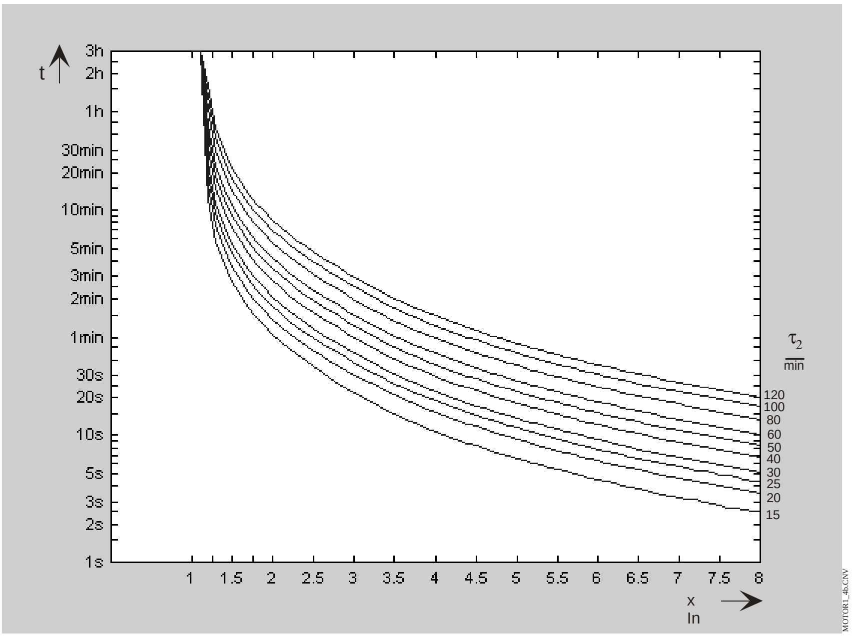


Figure 5.1.-4 Motor I: Ambient temperature = 40 ^{O}C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

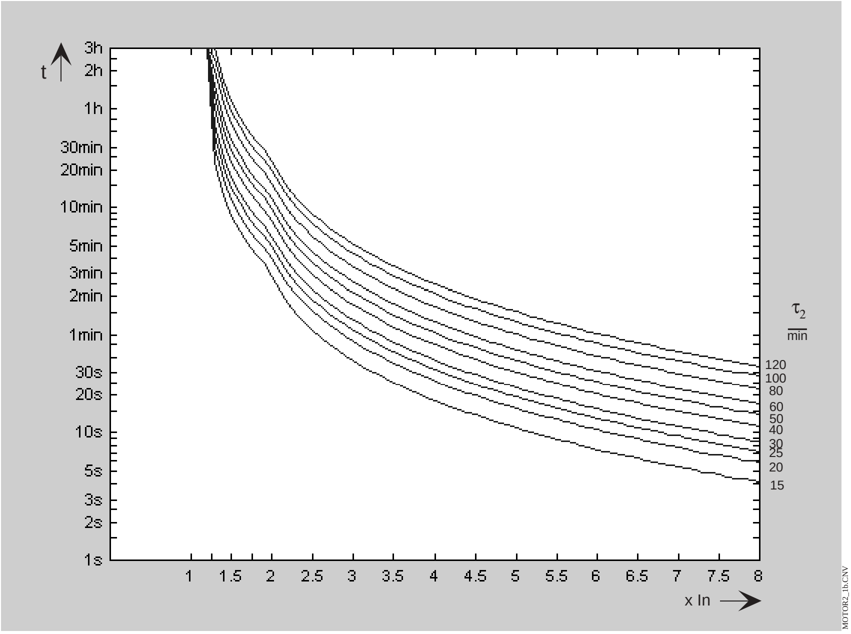


Figure 5.1.-5 Motor II: Ambient temperature = 20 °C; Initial condition: Cold motor, no preloading

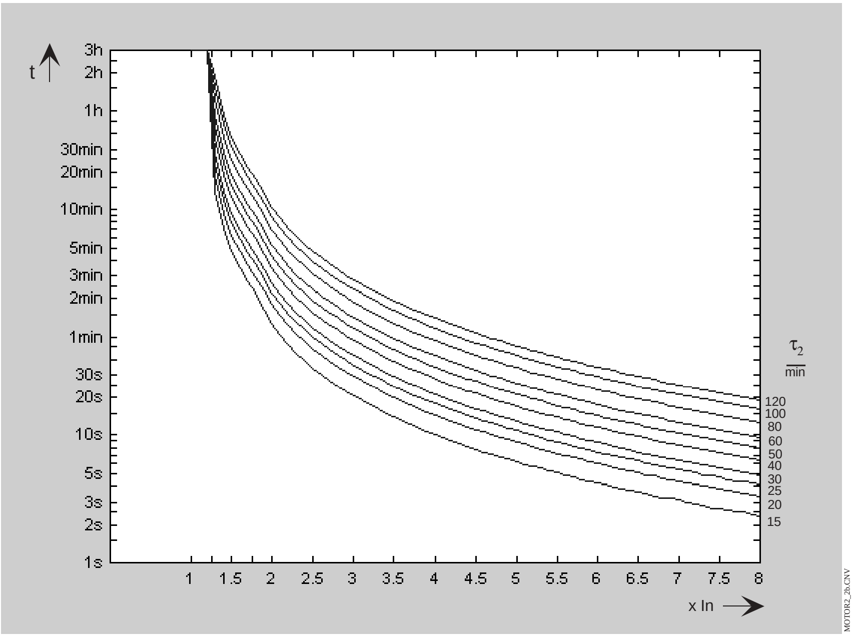


Figure 5.1.-6 Motor II: Ambient temperature = 20 °C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

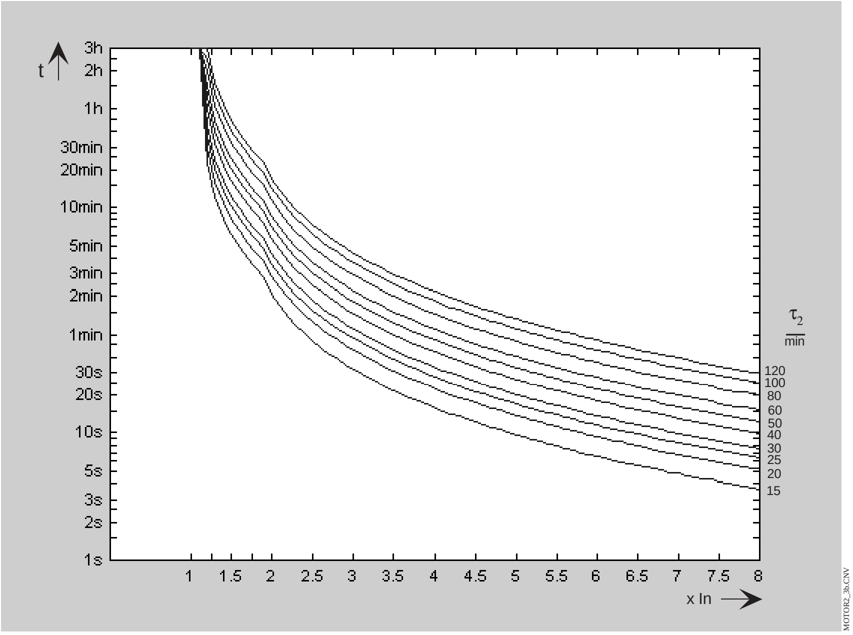


Figure 5.1.-7 Motor II: Ambient temperature = 40 °C; Initial condition: Cold motor, no preloading

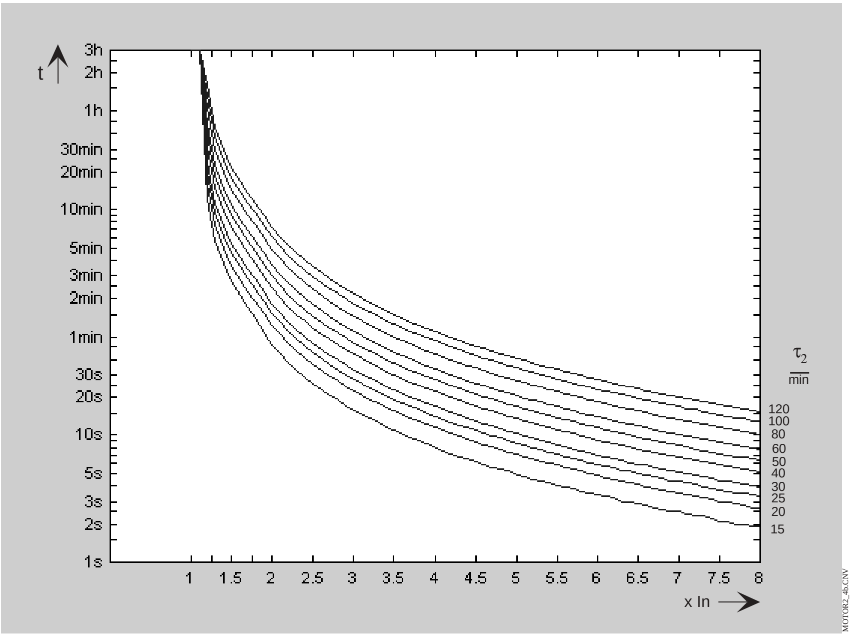


Figure 5.1.-8. Motor II: Ambient temperature = 40 °C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

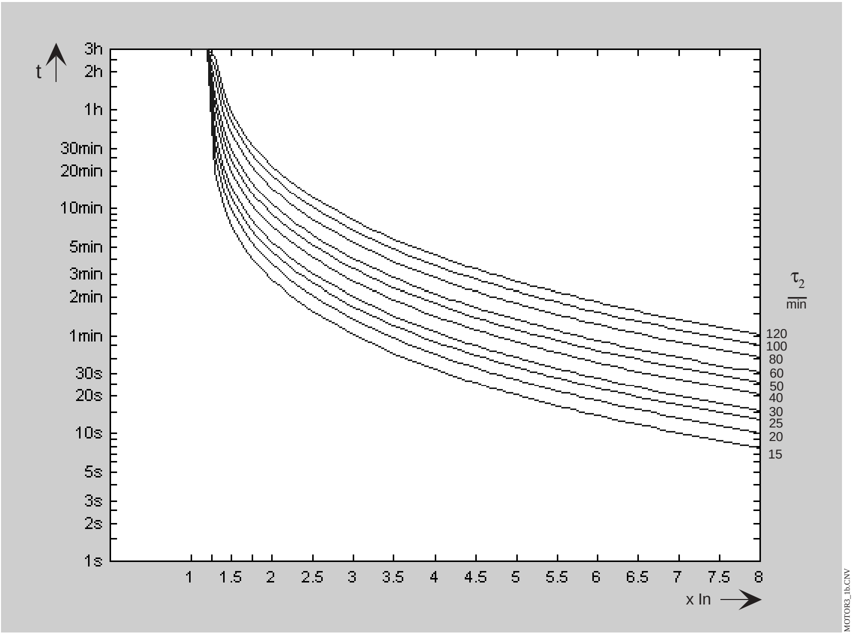


Figure 5.1.-9 Motor III: Ambient temperature = 20 ^{O}C; Initial condition: Cold motor, no preloading

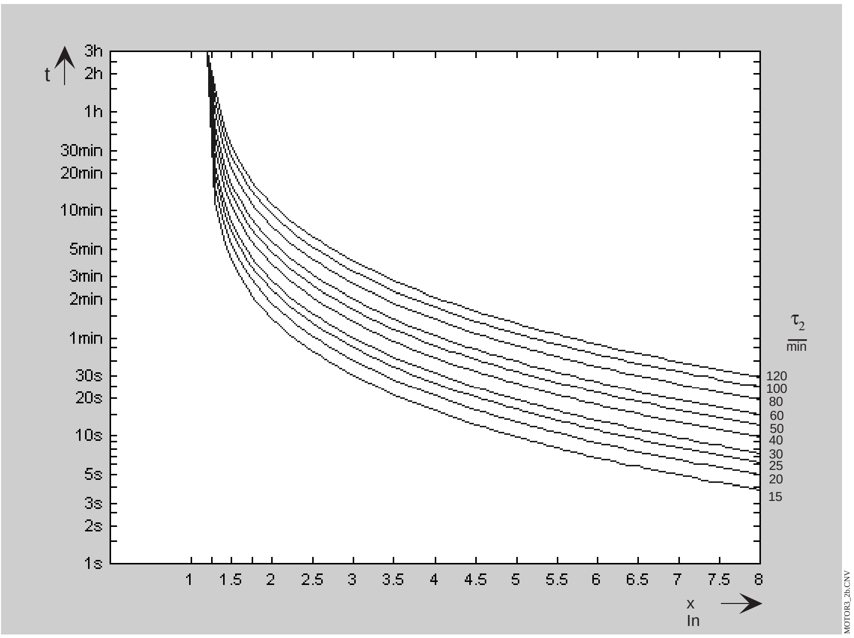


Figure 5.1.-10 Motor III: Ambient temperature = 20 ^{O}C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

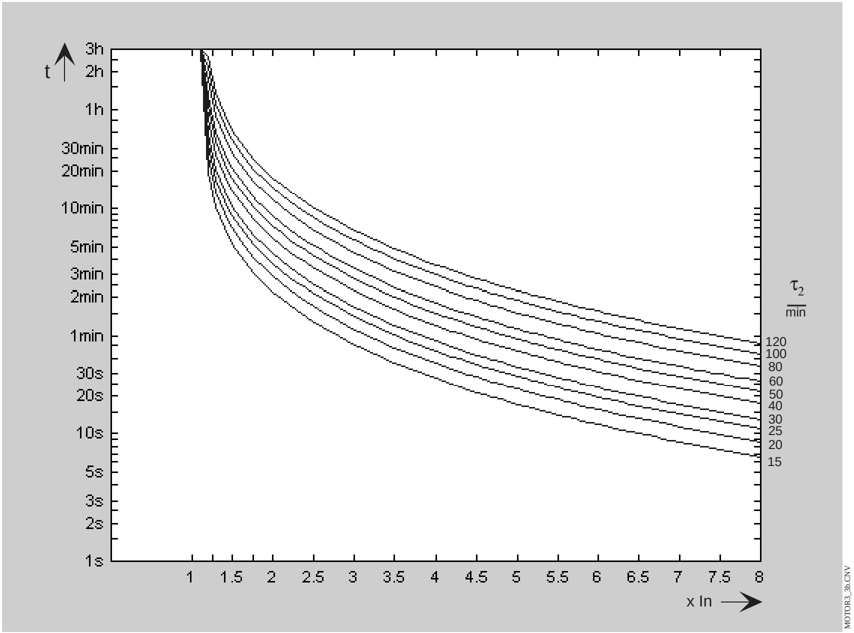


Figure 5.1.-11 Motor III: Ambient temperature = 40 °C; Initial condition: Cold motor, no preloading

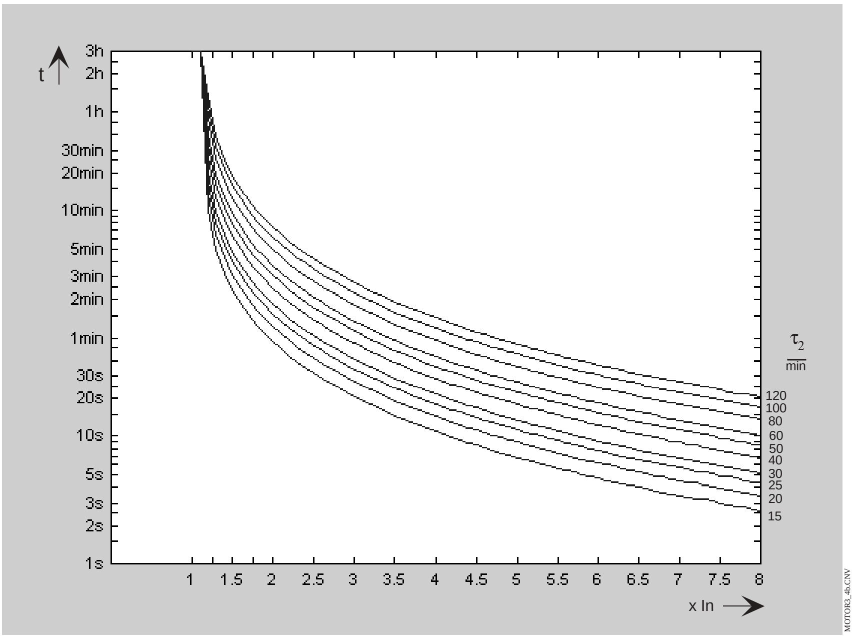


Figure 5.1.-12 Motor III: Ambient temperature = 40 °C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

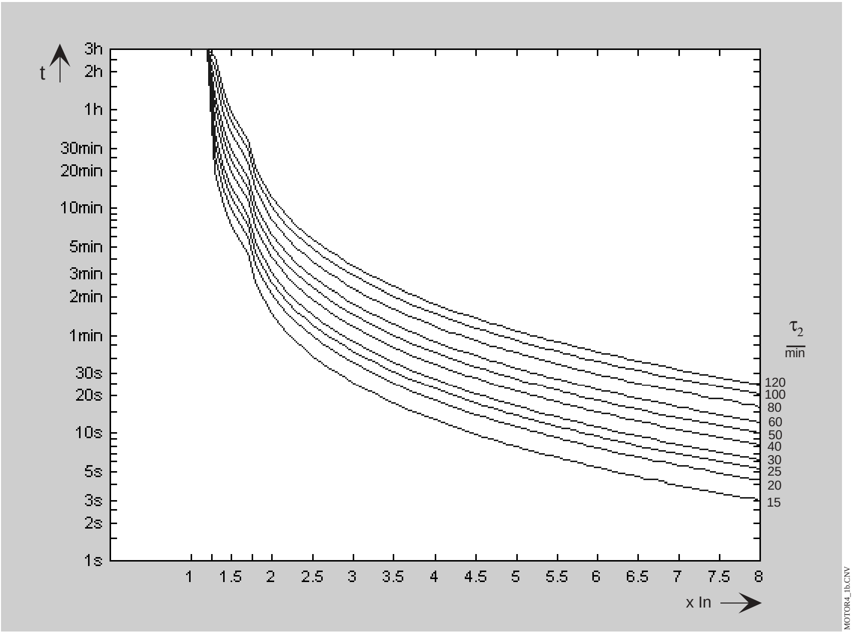


Figure 5.1.-13 Motor IV: Ambient temperature = 20 ᴼC; Initial condition: Cold motor, no preloading

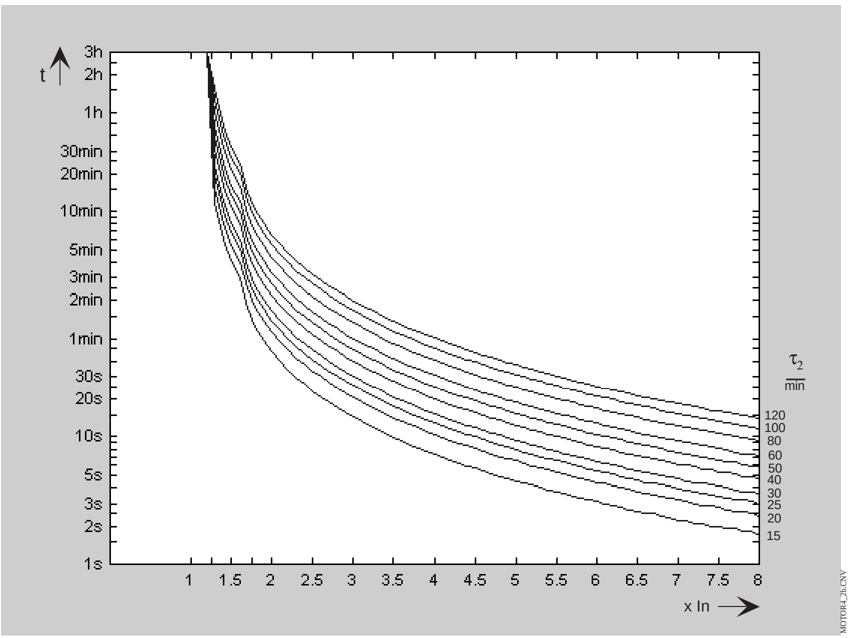


Figure 5.1.-14 Motor IV: Ambient temperature = 20 ᴼC; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

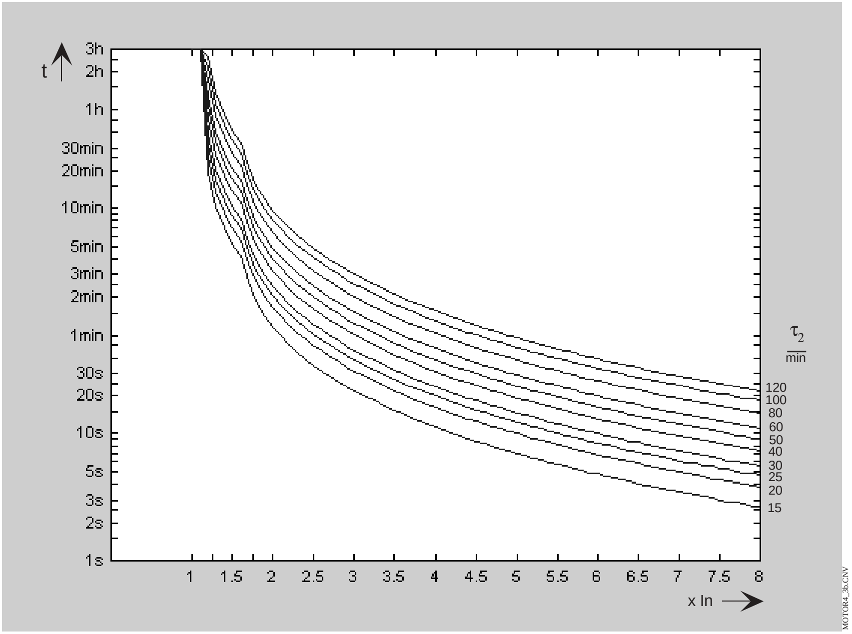


Figure 5.1.-15 Motor IV: Ambient temperature = 40 ^{O}C; Initial condition: Cold motor, no preloading

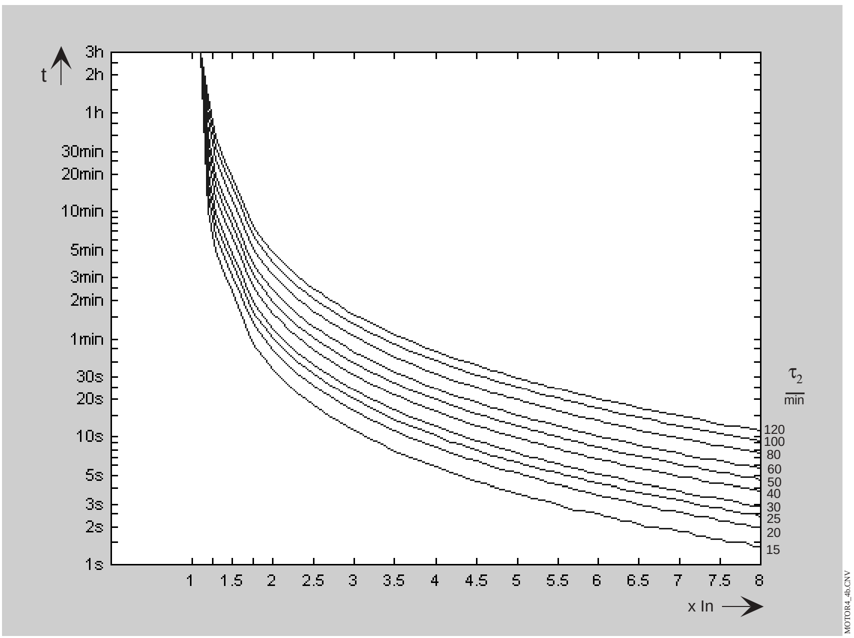


Figure 5.1.-16 Motor IV: Ambient temperature = 40 ^{O}C; Initial condition: Warm motor, long-time preloading with the current 0.883 x I_n

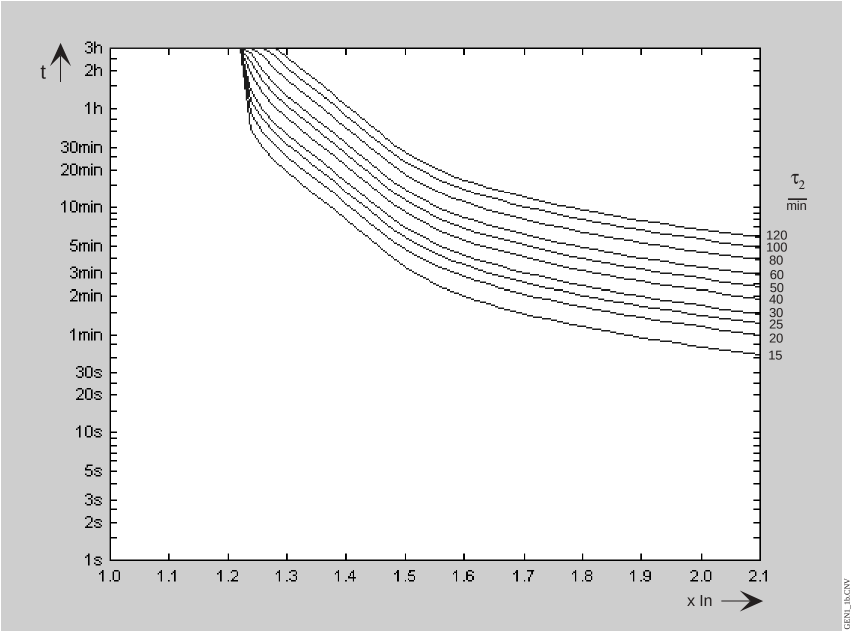


Figure 5.1.-17 Generator I: Ambient temperature = 20 °C; Initial condition: Cold ⇔ no preloading

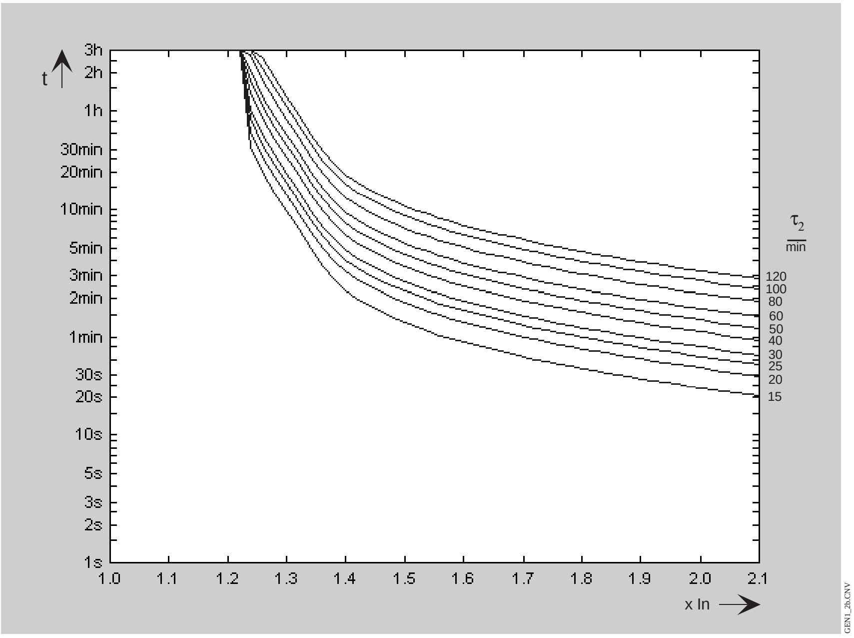


Figure 5.1.-18 Generator I: Ambient temperature = 20 °C; Initial condition: Warm ⇔ long-time preloading with the current 0.883 x I_n

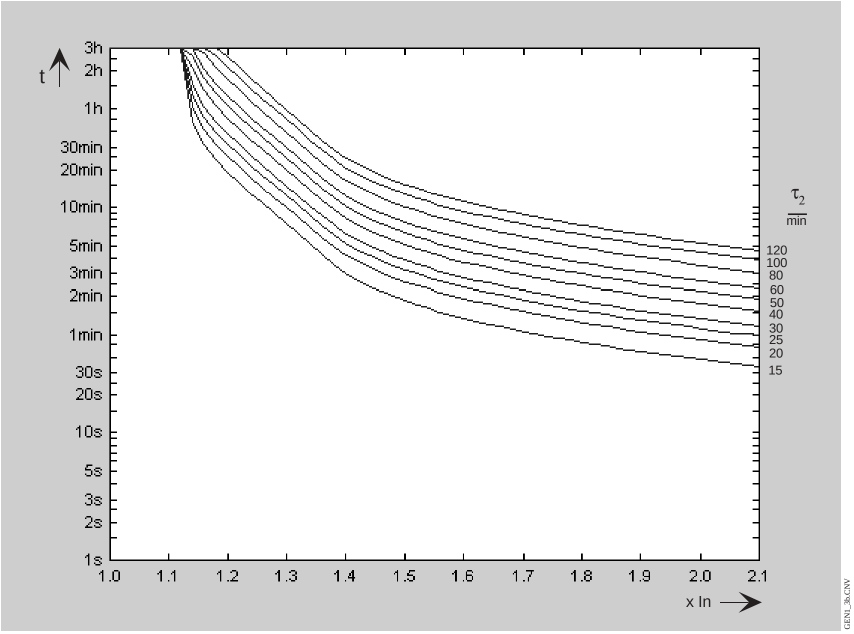


Figure 5.1.-19 Generator I: Ambient temperature = 40 °C; Initial condition: Cold ⇔ no preloading

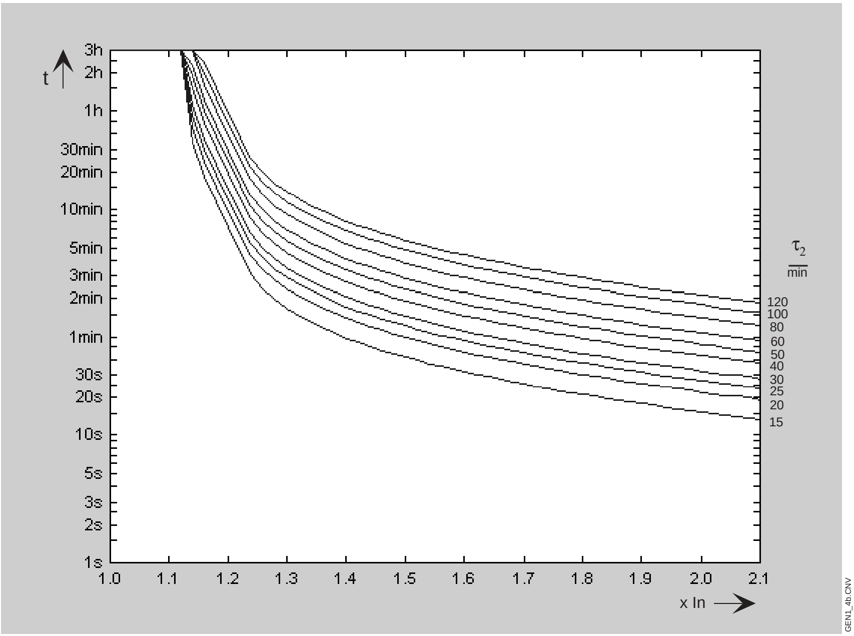


Figure 5.1.-20 Generator I: Ambient temperature = 40 °C; Initial condition: Warm ⇔ long-time preloading with the current 0.883 x I_n

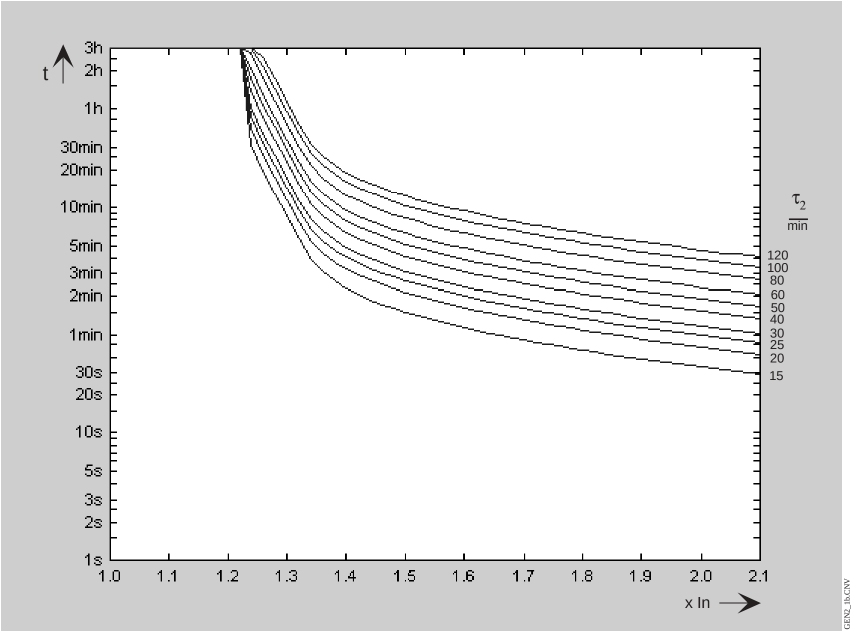


Figure 5.1.-21 Generator II: Ambient temperature = 20 °C; Initial condition: Cold ⇔ no preloading

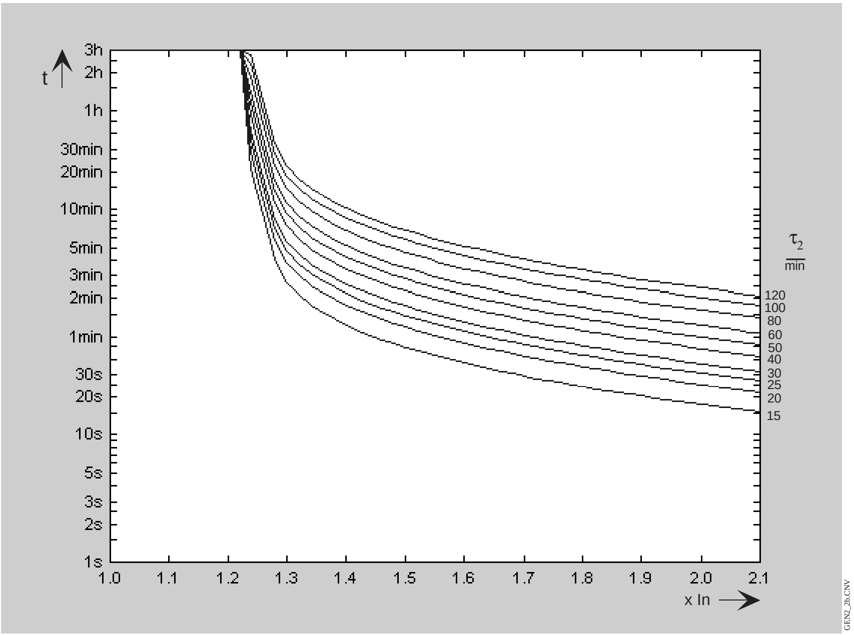


Figure 5.1.-22 Generator II: Ambient temperature = 20 °C; Initial condition: Warm ⇔ long-time preloading with the current 0.883 x I_n

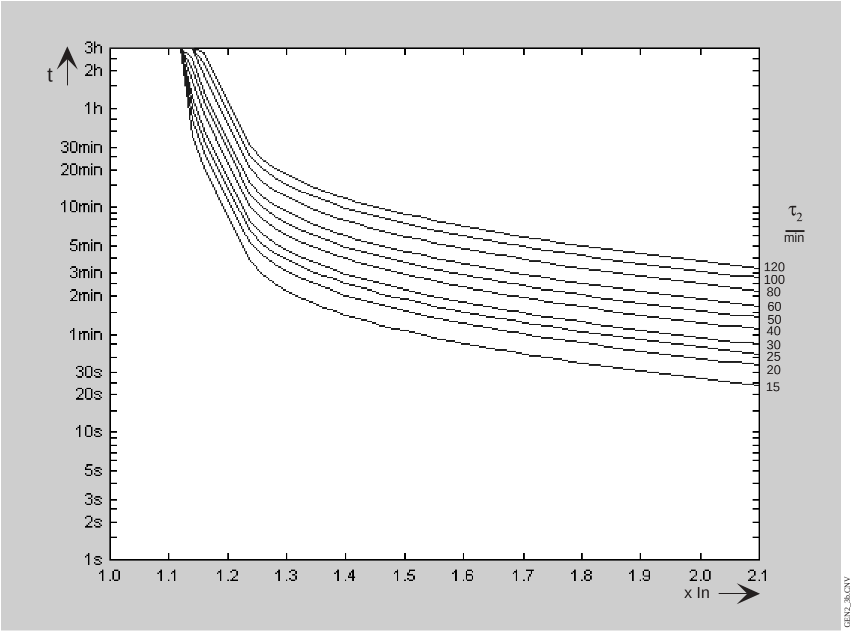


Figure 5.1.-23 Generator II: Ambient temperature = 40 ^{O}C; Initial condition: Cold ⇔ no preloading

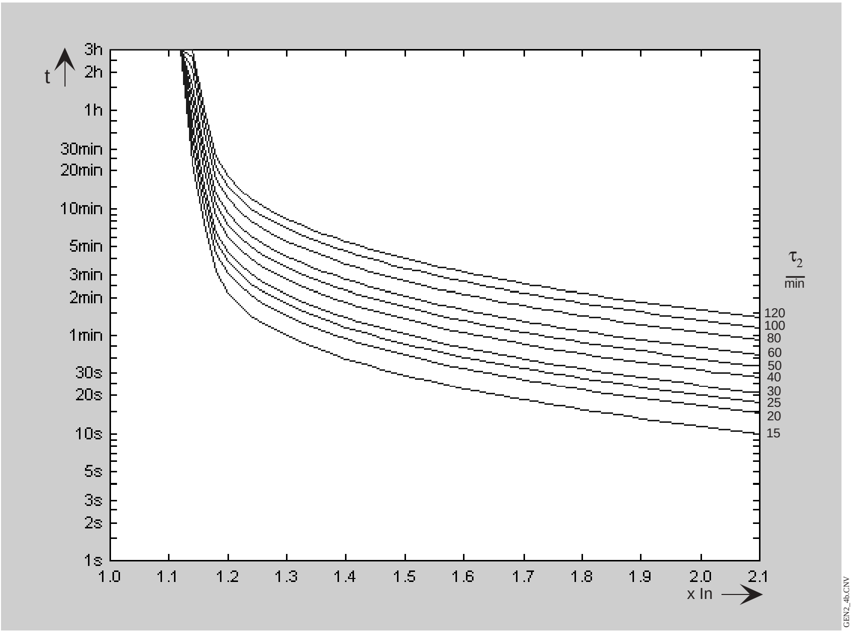


Figure 5.1.-24 Generator II: Ambient temperature = 40 ^{O}C; Initial condition: Warm ⇔ long-time preloading with the current 0.883 x I_n

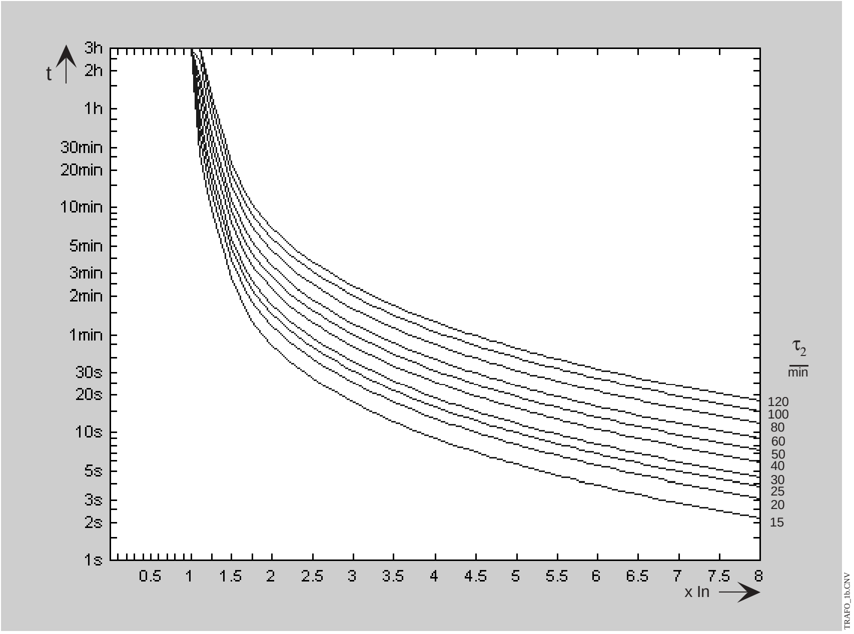


Figure 5.1.-25 Transformer: Ambient temperature = 20 ^{O}C; Initial condition: Cold ⇔ no preloading

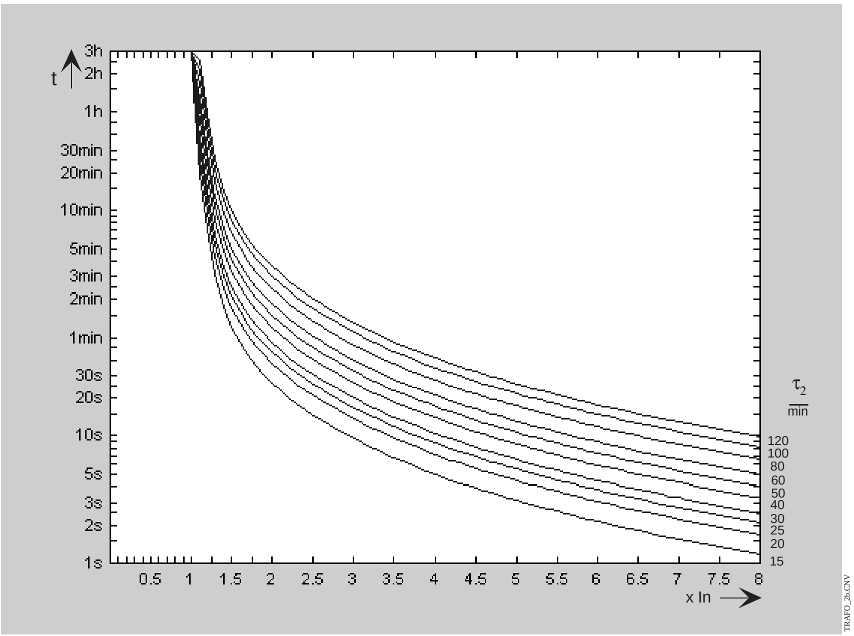


Figure 5.1.-26 Transformer: Ambient temperature = 20 ^{O}C; Initial condition: Warm ⇔ long-time preloading with the current 0.7 x I_n

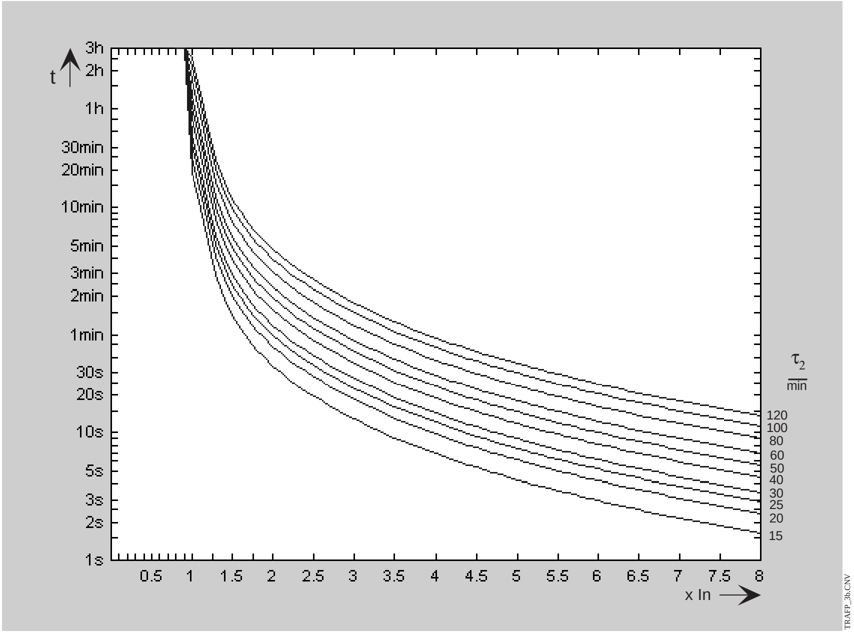


Figure 5.1.-27 Transformer: Ambient temperature = 40 ^{O}C; Initial condition: Cold ⇔ no preloading

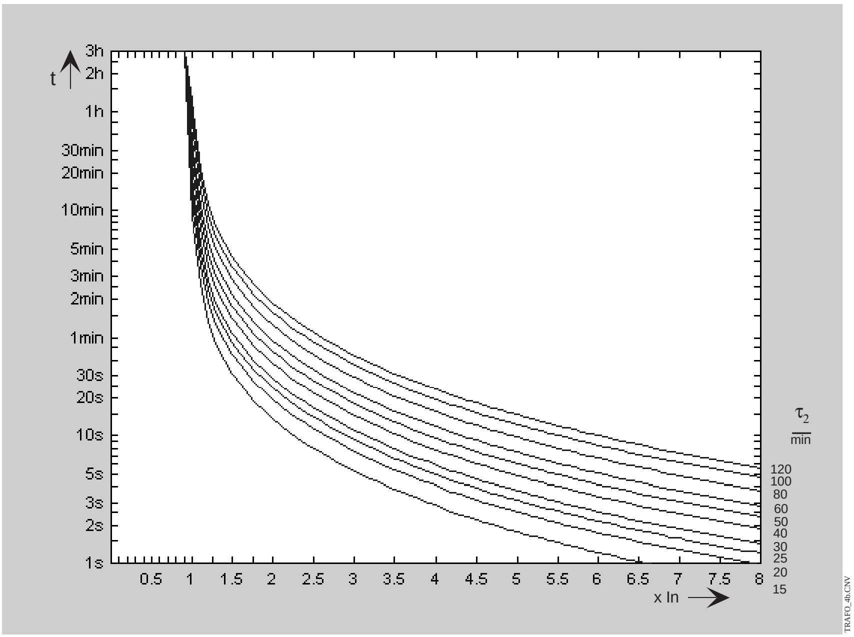


Figure 5.1.-28 Transformer: Ambient temperature = 40 ^{O}C; Initial condition: Warm ⇔ long-time preloading with the current 0.7 x I_n