

# NP800 – NP800R

## Application Guide

Multifunction Digital Relays



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## FOREWORD

The current guide aims at presenting the applications and features for the multifunction protections in the range **NP800** and **NP800R**. The NP800R series are especially dedicated to replacing CEE protection relays in the 700 and 7000 series. The NP800R mainly differ from the NP800 in their casing. The following table summarizes the available features:



This guide is the substitute of A0331E1E. (APPLICATION GUIDE NP800)

Protection features	NPI 800 NPI800R	NPID 800 NPID800R	NPIH 800 NPIH800R	NPIHD800 NPHD800R	NPU 800 NPU800R	NPUH 800 NPUH800R	NPM 800 NPM800R	NPG 800 NPG800R	NPSC 800- NPSC800R	NPW 800- NPW800R
Inhibition of hot start function [5]							x			
Minimum of impedance [21]								x		
Flux control [24]								x		
Synchronism check [25]									x	
Undervoltage [27]					x			x		x
Minimum of positive sequence voltage [27P]					x					
Reverse active power [32RP]								x		
Maximum of active power [32P]								x		x
Maximum of reactive power [32Q]								x		x
Loss of load – no-load operation [37]							x			
Single phase undercurrent [37]**			x							
Minimum of active power [37P]								x		x
Minimum of reactive power [37Q]								x		x
Loss of excitation [40]								x		
Maximum of negative phase sequence current [46]	x	x					x	x		

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Detection of broken conductor [46BC]	x	x								
Maximum of negative phase sequence voltage [47]					x					
Too long start [48] and locked rotor [51LR]							x			
Cable thermal image / transformer [49]	x	x								
Motor thermal image [49]							x	x		
Instantaneous phase overcurrent [50]	x	x					x	x		
Phase overcurrent [51]	x	x						x		
Instantaneous max of zero sequence current [50N]	x	x	x	x						
Max of zero sequence current [51N]	x	x	x	x			x			
Circuit breaker failure monitoring [50BF]	x	x					x			
Circuit breaker failure monitoring [50NBF]	x	x	x	x			x			
Circuit breaker failure monitoring [BF]								x		x
Voltage restrained overcurrent [50V] [51V]								x		
Power factor management [55]										x
Overvoltage [59]					x			x		x
Max of zero sequence voltage [59N]					x	x		x		x
Stator earth fault [64]								x		
Limitation and spacing of number of starts [66]							x			
Directional phase overcurrent [67]		x								
Directional Max of zero sequence voltage overcurrent [67N]		x		x						
Trip-circuit supervision of circuit breaker [74TC]	x	x	x	x	x	x	x	x		x
Under frequency and over frequency [81]					x			x		x
Latching of the output relays [86]	x	x	x	x	x	x	x	x		x

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Load reclosing function	x	x	x	x						
Logic selectivity	x	x	x	x						
Load shedding by external input and high speed restarting							x			
$\phi$ [Q/P] management of tangent										x
[ $\Sigma$ P] max of active integrated power										x
[ $\Sigma$ Q] max of reactive integrated power										x
Recloser	*	*								

\* recloser feature (NPIR800 and NPIDR800)

\*\* single phase undercurrent (NPIH800-NPIH800R). Consult us.

The current application guide is made of three chapters dealing each with the elements of an electrical network requiring protection:

- ◆ Incomers, cable feeders, and transformers,
- ◆ Generators,
- ◆ Induction motors.

The required protection features for these network elements are performed by the following NP800 – NP800R:

- ◆ NPI800-NPI800R and NPID800-NPID800R
- ◆ NPIH800-NPIH800R and NPIHD800-NPIHD800R
- ◆ NPU800-NPU800R-NPU800RE
- ◆ NPUH800-NPUH800R
- ◆ NPW800-NPW800R
- ◆ NPSC800-NPSC800R-NPSC800RE
- ◆ NPG800-NPG800R
- ◆ NPM800-NPM800R-NPM800RE

In addition to their protection functions, the NP800-NP800R also performs monitoring, measuring and recording of the various network electrical data. Their settings, reading and measurements are also available locally via an RS232 link on the front panel, or remotely via an RS485 link.

The following data are available for all protection functions of the NP800-NP800R range:

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- Function presentation and flow chart,
- Setting characteristics table,
- Setting advices.

The current document provides technical information on the NP800-NP800R range products, which complements the following documents:

- The sales brochures give an overview of the functions of each protection, their physical features, and environmental standards compliance.
- The “Installation guide” detail setting up operations for the NP800-NP800R range protections.
- The “Setting software user guide” describes the available configuration tool and its use on a PC or in connection with an electrical SCADA, as well as the description of the communication protocols.
- The “User's guide” for each kind of relay present the local Human Machine interface available through display and keyboard.
- The “First handling guide” describe the data required to put into service and operating the NP800-NP800R range protections, as well as their connection mode, and a series of recommended tests.

Unless otherwise specified, the protection and operation functions described in the following chapters can be set up locally or remotely via the configuration software.

The following symbols highlight important information or summarize key facts:



→ For more information, please contact your sales representative



→ Additional information



→ Important information

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# 1 Introduction

Electrical networks are a building brick of our economic life. Generation, transmission, distribution and use of the electrical energy in safe conditions are fundamental for the growth of cities and industries.

Perfect control over the electrical networks, from production to final use is an important issue. It is based upon cost control for production and maintenance.

Faced with ever more demanding expectations, **ICE** chose to design, produce and distribute a complete range of equipment's supporting the implementation of the intelligence and connections required, for a fully optimized management of electrical networks.

Because it uses the most advanced digital technologies for local information processing, field buses for transmission, the most powerful industrial computers to drive and supervise the electrical networks, **ICE** demonstrates via its accomplishments in the field of industrial reliability how it can apply its technologies to the other fields of the electrical energy industry management.

## 2 Warning

All technical characteristics presented in this guide apply to the specific NP800-NP800 range protections. You are however required to pay attention to the following warnings, in order to provide for proper working conditions of these protections.

### 2.1 Operating time

The present guide refers to inverse time curves as specified in the IEC 60255-4 and ANSI-IEEE standards. Setting the protections allows for a choice of working points on these curves by selecting the required value (using the setting step).

The protections own operating time (measurement and chain of trips) accounts for 20ms. In order to obtain the real tripping time of a protection, you must consequently add 20ms to the calculated time. The curves provided in this document are given for illustration purposes only. To obtain an optimized accuracy, please use the original curves or make use of the formulas.

### 2.2 Permanent and short duration performance

Phase input: if the threshold is higher than  $3 \times I_n$ , it is necessary to check that the value of the time delay or choice of the curve is not prejudicial to the thermal withstand of the phase input:  $3 \times I_n$  permanent,  $24 \times I_n$  20 s,  $100 \times I_n$  1s. ( $80 \times I_n$  1s NP800R series)

Earth-fault input: if the earth threshold is higher than  $2 \times I_{n0}$  with residual connection, it should be checked that the value of the time delay or choice of the curve is not prejudicial to the thermal withstand of the earth-fault input:  $2 \times I_{n0}$  permanent,  $10 \times I_{n0}$  20 s,  $40 \times I_{n0}$  1s. For NPI800-S1 and NPID800-S1 see phase input withstand.

### 2.3 Polarization of the digital inputs

For voltage up to 125 VDC, it is necessary to use an additional resistance. The maximum ohmic value of this additional resistance is defined by the following equation, which can be performed according to the standard E24 series:

$$R_{add} < \left( \frac{0.8 * V_{dc} - V_{min}}{I_{min}} \right) \text{ with:}$$

$V_{dc}$ : value of the auxiliary DC voltage

$V_{min}$ : minimum value of the voltage required to operate the logic input

$I_{min}$ : minimum current required to operate the logic input

**Note:** choose the resistance as RW (vitreous) type

## WARNING

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Range for the auxiliary voltage NP800-NP800R	
19 – 70 Vdc	85 – 255 Vdc
$R_{.add} < \left( \frac{0.8 * V_{dc} - 12}{0.01} \right)$	$R_{.add} < \left( \frac{0.8 * V_{dc} - 33}{0.004} \right)$

## 2.4 Configuration of the output relays

The protection functions described below do not alone perform a correct setting for tripping relays. After activation and setting of these functions, you must finalize the protection setting by assigning the matrix of the output relays, taking into account their interrupting capacity. For more information, read the dedicated section.

## 2.5 Measuring voltage (Un)

For all protections concerned, you must set the range of the measuring voltage (Un) taking into account the connection of the secondary voltage of voltage transformers, as well as the rated value of the secondary tension. (Ex: 100/√3, 110/√3, 100, 110 ...)

Setting function of the below described characteristics:

Setting range for the rated value of the measuring voltage (Un)	33 V to 120 V (with 0.1 V steps)
---	----------------------------------

### 3 Protection of Incomers, cable feeders and transformers

Electrical protection devices contribute to a large extent to the safe operation of industrial networks, since they are central to providing the best possible electrical supply quality.

In this chapter, we will examine how to best protect incomers and cable feeders as well as power transformers for the various network configurations (parallel production or transformation units setup, neutral grounding...).

This chapter prescribes use of various types of multifunction protections in the **NP800 – NP800R** range.

### 3.1 Phase to phase fault protection

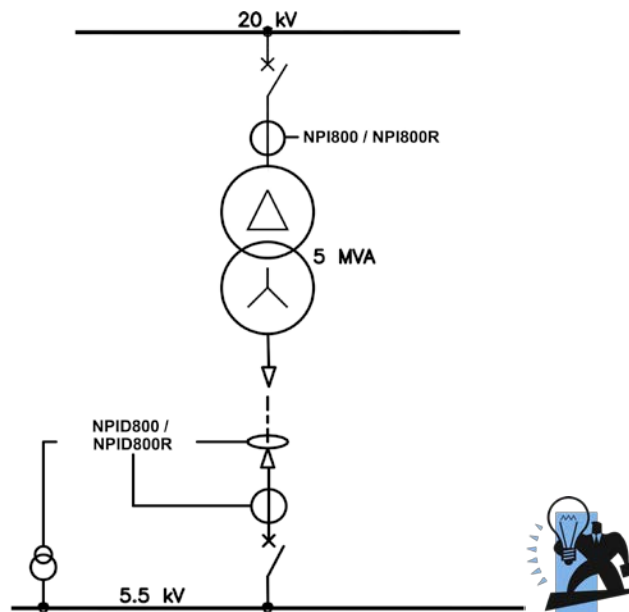
Overcurrent protection constitutes the basic protection of a network. It must be both responding and quick, as to limit (electrodynamic and heat) constraints applied to the electrical devices during a fault condition. Further, it must be selective, i.e. capable to isolate only the faulty element, and to keep the safe elements electrically supplied.

#### 3.1.1 Overcurrent functions [50] [51] NPI800-NPI800R and NPID800-NPID800R

##### 3.1.1.1 Presentation [50] [51] NPI800-NPI800R and NPID800-NPID800R

Overcurrent functions eliminate phase to phase or short circuit type faults. The **NPI800-NPI800R** and **NPID800-NPID800R** devices perform these functions using three threshold values:

- 1 “very high” threshold [50]  $I_{>>>}$  instantaneous or associated with an definite time delay (whose response time does not depend on the current)
- 1 “high” threshold [51-2]  $I_{>>}$  with 8 modes of time delay: definite time, IEC or ANSI inverse time delay (whose response time depends on the current), or customized curve (please contact us)
- 1 “low” threshold [51-1]  $I_{>}$  with 8 modes of time delay: definite time, IEC or ANSI inverse time delay, or customized curve (please contact us)

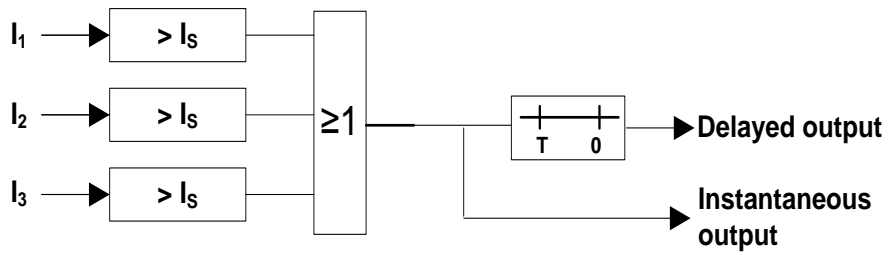


**Fig. 1:** Example of a protective system for a power transformer

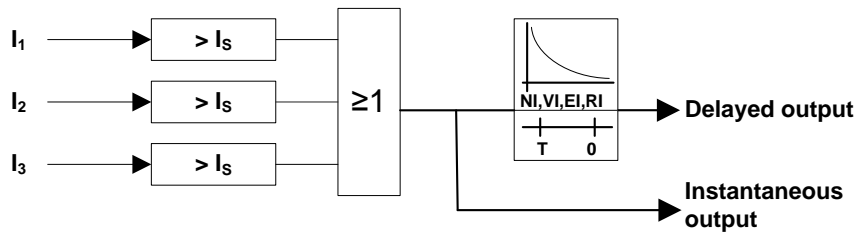


NPI800R, NPID800R, to replace CEE 700 or 7000 protection relays.

3.1.1.2 Flow charts [50] [51] NPI800-NPI800R and NPID800-NPID800R



**Fig. 2:** [50] [51-1] [51-2] functions with Definite time-delay



**Fig. 3:** [50] [51-1] [51-2] functions with inverse time delay

3.1.1.3 Setting characteristics [50] [51] NPI800-NPI800R and NPID800-NPID800R

[51-1] AND [51-2] FUNCTIONS THRESHOLDS	Setting
Low threshold - $I > [51-1]$	0.3 to 24.0 In with a 0.01 In step
High threshold - $I >> [51-2]$	
[51-1] AND [51-2] FUNCTIONS THRESHOLDS	Setting
Definite time-delay $t(I >) t(I >>)$	0.04 to 300 s step: refer to *
IEC 60255-4 compliant inverse time curve: inverse, very inverse, extremely inverse $t(I >) t(I >>)$	T++: 0.03 to 3 s with a 0.01 s step
ANSI/IEEE compliant inverse time curve: slightly inverse, very inverse, extremely inverse $t(I >) t(I >>)$	
RI Relatively inverse time curve $t(I >) t(I >>)$	0.1 to 20 s with a 0.01 s step
[50] FUNCTION THRESHOLD	Setting
Very high threshold - $I >>>$	0.3 to 24.0 In with a 0.01 In step
[50] FUNCTION DELAY	Setting
Definite time-delay - $t(I >>>)$	0.04 to 300 s step: see *
CHARACTERISTICS	Value
Instantaneous output response time	60 ms

\*: between 0.04 and 9.99 s step value of 0.01 s, between 10.0 s and 29.9 s step value of 0.1 s, between 30 and 300 s step value of 1s

For detailed characteristics of the inverse time tripping curves, please refer to the chapter “3.5 Tripping curves for [46] [51] [51N]”.

**3.1.1.4 Setting advices [50] [51] NPI800-NPI800R and NPID800-NPID800R**

**3.1.1.4.1 Selecting the time/current characteristic [50] [51] NPI800-NPI800R and NPID800-NPID800R**

Overcurrent protections are mainly defined by their time/current ratio characteristics.

Several types are available:

- With Definite time-delay,
- With inverse time: inverse / very inverse / extremely inverse, according to IEC 60255-4 standard,
- With “R” relatively inverse curve (electromechanical),
- With slightly inverse / very inverse / extremely inverse curves, according to ANSI/IEEE,
- With thermal overload protection according to the IEC 60255-8 standard.

It is not possible to define general rules to apply for choosing between the various protections.

You should however prefer inverse time protections in the following cases:

- There is an important risk of short duration high overloads on the premises,
- Inrush or energizing current may be high during several tenth of a second when powering on,
- Protective action must be coordinated with a great number of fuses.

On the contrary, use of Definite time-delay is recommended when short circuit currents are very high, or when they can fluctuate a lot at the same place (for example, when a network includes small generators whose short-circuit currents may quickly decrease).

As a general rule, apart from these technical criteria, we can say that in continental Europe, there is a clear tendency to use definite time-delay protections whereas in Anglo-Saxon countries inverse time protections are customary.

Time delayed overcurrent protections allow for chronologic selectivity. One disadvantage is that fault clearance time is longer when you come closer to the source, where short-circuits are even stronger.

It is therefore highly recommended to keep selective time measuring differences low when implementing two cascading time delay protections in a radial network.

The value of the selective interval used for electronic protections is usually of 300ms; this value being obtained by adding the following durations:

- Circuit-breaker fault clearance time,
- Time delay errors for both protections,
- Upstream protection overshoot (memory after fault clearance),
- A safety margin of about 100ms.

We remind you that for the protection of a transformer feeder, you should use a high instantaneous threshold, **set at value higher than the secondary short-circuit current**, as this will decrease the response time of the upstream protections, whilst limiting short-circuit current cable exposure.

If necessary, for time delays lower than 1 second, you may reduce this interval to 250ms for highly stable time delays (as with NP800-NP800R).

### 3.1.1.4.2 Example of threshold configuration [50] [51] NPI800-NPI800R and NPID800-NPID800R

Depending on the value you obtained through a co-ordination or a setting table study, the thresholds [50] and [51] to set on the protection must be adapted to the rate current of the current transformers, and possibly corrected according to the step of the setting range. Let us examine the following values as an example:

- $CT = 250/5 \text{ A}$
- $I_n \text{ protection} = 5 \text{ A}$
- Tripping value in the event of a short circuit = 2470 A with an instantaneous response time,
- Tripping value in the event of an overload = 380 A with a definite time delay of 4.5 s.

Calculation of the thresholds, and parameters to be set on the protection:

- For short circuit detection, use function [50] with the following settings:  
 $I_{>>>} = 2470/250 = 9.88$  and taking into account step values:  $9.9 \times I_n \text{ TC}$ .  
Time delay  $t(I_{>>>})$  will be set to 0.04 s.
- For overload unit, function [51-1] will be used with the following setting:  
 $I_{>} = 380/250 = 1.52$  and taking into account step values:  $1.5 \times I_n \text{ TC}$ .  
Definite time will be selected with a delay set to 4.5 s.

### **3.1.2 Phase overcurrent and directional function [67] NPID800-NPID800R**

#### **3.1.2.1 Presentation [67] NPID800-NPID800R**

The functions [67] of the **NPID800 – NPID800R** control phase shifts between the fundamental currents and voltages. Thanks to these functions, the protections remain stable and selective even on networks that are highly polluted by many harmonics.

Since the time delay for directional protections is selective for upstream protections, it is possible to obtain the loop opening and tripping of the sole faulty link (as to shorten fault clearance time, you may use a mutual tripping device between upstream and downstream circuit breakers).

The directional function does not require chronometric selectivity steps with the other network protections. Its time delay value must however be sufficient to avoid risks of tripping because of transients. If you allow for sensitive settings, you will benefit from the inverse time characteristics to counterbalance these phenomena.

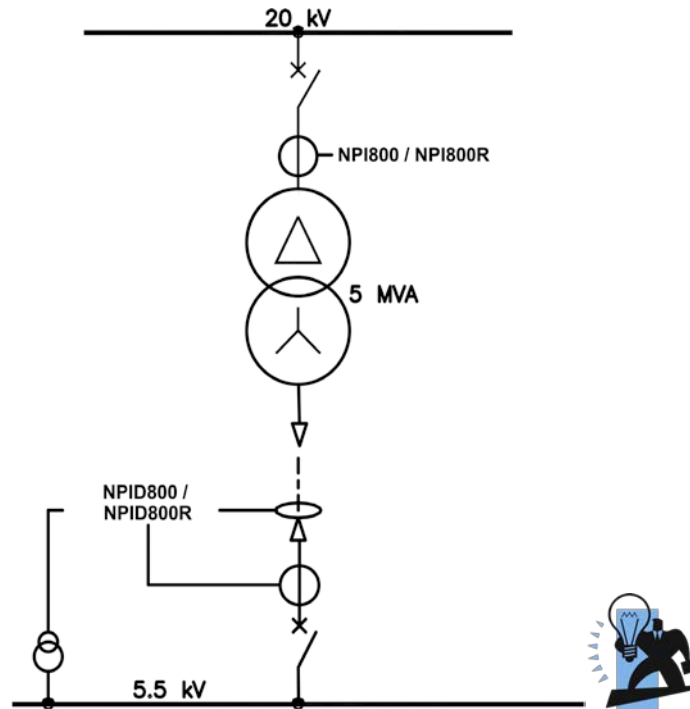
In order to perform these applications the directional function phase [67] of the **NPID800 – NPID800R** uses:

- Functions with an overcurrent value [50] [51-1] [51-2],
- A phase comparator to detect the direction of the fault current.

Therefore, fault detection is subject to two criteria:

- Intensity threshold has been reached by one of the overcurrent functions [50] [51-1] [51-2] for a time higher to the set time delay or according to the selected curve,
- The fault current is in the tripping zone.

Thanks to the phase comparator, it is possible to determine the direction of the fault current, by measuring the phase shift between current and the associated phase to phase voltage: I1/U23 and I3/U12. Please note that in case of close faults, the voltage of the fault phase is weak and cannot therefore be used for the measurement.

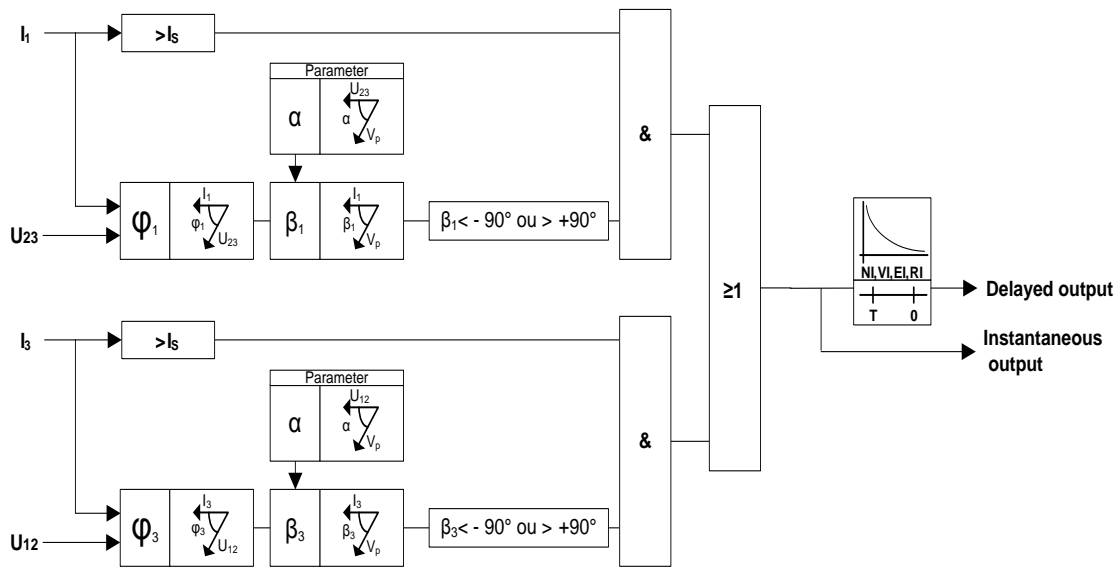


**Fig. 4 :** Example of a protection for a power transformer's incoming feeder

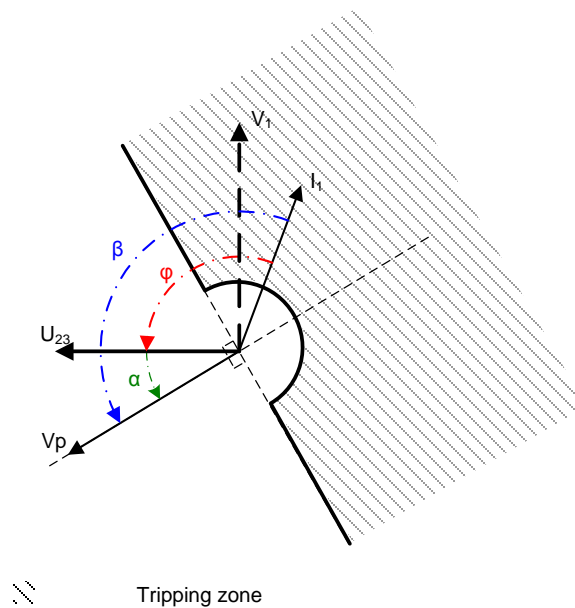


The **NPID800 – NPID800R** are overcurrent phase and earth fault protections with a directional criterion. In order to standardize the protections on the same site, it is possible to use these protections in place of the NPI800 – NPI800R, provided you deactivate their directional criteria. Additional advantages of using these protections are their I/O extension card and their additional available measurements (P, Q, Cos  $\varphi$  ...).

3.1.2.2 Flow chart [67] NPID800-NPID800R



$\varphi$  : Measurement of phase shift from current to associated voltage (phase to phase)  
 $\beta$  : Measurement of phase shift from current to polarizing voltage ( $\beta = \varphi + \alpha$ )  
 $\alpha$  : Settable angle from phase to phase voltage to polarizing voltage which determines the tripping zone



The current direction is determined from the measurement of its phase in relation to a polarisation value. This polarisation value ( $V_p$ ) is set with respect to the phase to phase voltage associated in quadrature with the considered phase:

- Current I1  $U_{23}=V_3-V_2$
- Current I3  $U_{12}=V_2-V_1$

**Fig. 5:** Phase overcurrent *directional function* [67]

**3.1.2.3 Application examples [67] NPID800-NPID800R**

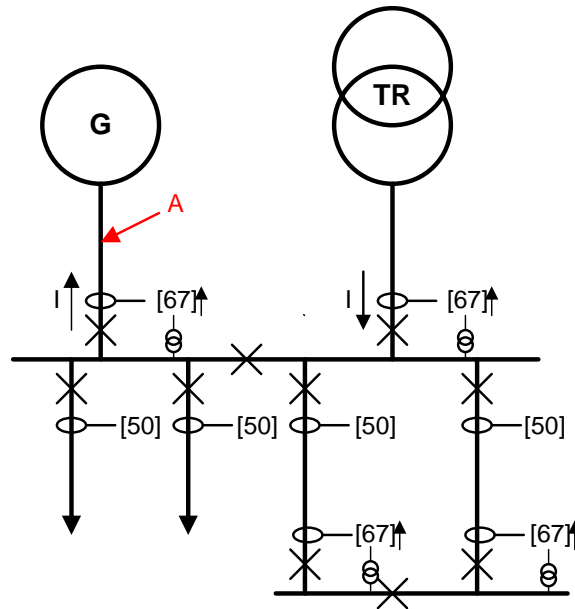
When substation is electrically supplied with by two cables or two parallel transformers, the protections located upstream on the outgoing feeders will trip simultaneously for any fault on only one of them. In order to obtain selective protection, it is possible to use directional protections.

Case # 1:

In case of fault located in “A” in the network represented on figure 7, the currents measured by the protections on the incoming feeders “TR” and “G” have the same amplitude but opposite directions.

In order to eliminate the “G” generator and let the “TR” transformer supply the network, a directional criteria [67] is required.

[67]↑: the arrow shows the direction of the protection tripping zone.



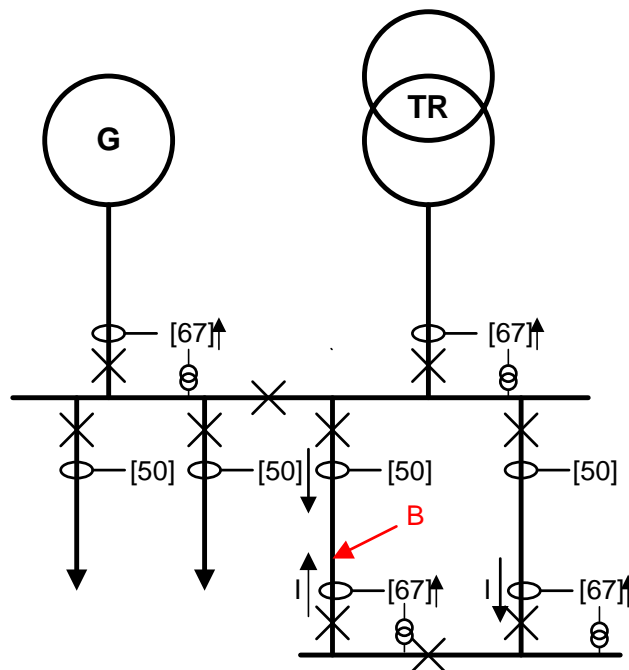
**Fig. 6:** Example of a network fitted with directional phase protection (1)

Case # 2:

In case of a fault located in “B” in the network represented on figure 8, the currents measured at the protections of the incoming feeders of the downstream busbar, supplied by two parallel cables, have the same amplitude but opposite directions.

In order to isolate the faulty cable, the incoming feeder protections need directional criteria [67]. In this case the fault will first be cleared by the protection [67], then thanks to time selectivity, by the upstream protection, thus enabling the network supply via the healthy cable.

[67]↑: the arrow shows the direction of the protection tripping zone.



**Fig. 7:** Example of a network fitted with directional phase protection (2)

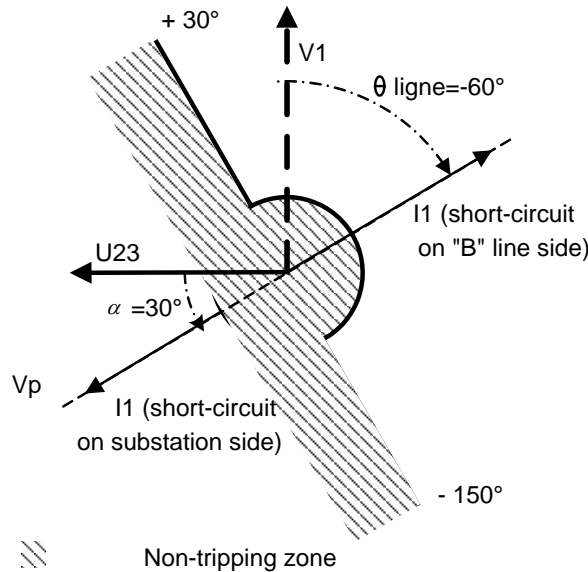
Directional overcurrent protections of the type **NPID800 – NPID800R [67]** will be installed on each incoming feeder.

The directional function of these protections monitors phase shifts between current and voltage and allows the overcurrent unit operation if this phase shift is the result of a current direction change.

3.1.2.4 Measurement principle [67] NPID800-NPID800R

From the reference voltage  $U_{23}$  (associated with the measuring current  $I_1$ ), the polarisation voltage  $V_p$  creates a non-tripping zone. The vector representing this voltage is located in the centre of a surface with  $180^\circ$  amplitude defining the tripping and non-tripping zones.

In order to modify the position of this zone, you can change the set of the  $\alpha$  angle value.



**Fig. 8:** Principle of measurement for a directional function [67]

According to the application example (2), if  $\theta_{line}$  (the line argument) corresponds to an inductive line with a current  $I_1$  lag by about  $60^\circ$ , the angle characteristic  $\alpha$  will be set to  $+30^\circ$  (see table in Setting characteristics). In this case, the protection will be allowed to trip for currents out of phase by  $+30^\circ$  to  $-150^\circ$ .

In normal operating conditions, the current  $I_1$  will be located in the non-working zone, and will be lag on  $V_1$ .

During a short-circuit, the current will be located in the tripping zone for a line side short-circuit in "B", in other words out of phase with  $V_p$ , and it will be in the non-working zone for a substation side short-circuit. The principle is identical for  $I_3$  and  $V_3$  in relation to  $U_{12}$ .

### **3.1.2.5 Operating modes [67] NPID800-NPID800R**

If the polarizing voltage is low, it is not possible to measure the angle of the directional function with accuracy. In this case, the working mode of the protection depends on the selected operating mode:

#### **Permission mode**

If the voltage is lower than the polarisation threshold, the protection does not react on the directional criteria [67] any more, and trip by one of the overcurrent functions [50] [51-1] [51-2] that have been associated with this criteria.

#### **Block mode**

If the voltage is lower than the polarisation threshold, tripping by one of the overcurrent functions [50] [51-1] [51-2] that have been associated with the directional criteria [67] is impossible.

#### **Memory phase (from V3.10 embedded version)**

In case of polarizing voltage lower than the polarizing threshold (3% of  $U_n$ ), the relay use a voltage memory in order to determine, with reliability, the fault direction by using the phase angle stored before the fault. This allows, during the fault, the calculation of the phase shift between the phase angle of the voltage memory and the current flowing. The application of this system is justified for three-phase faults close to the substation where the voltage is almost zero.

This new function only available for phase function, involves two different settings for the operating mode of the directional function [67].

### **3.1.2.6 Complementary function of NPID800-NPID800R: Phase voltage control**

When the relay is in abnormal situation, resulting of the loss of one or several phase(s) or fuse(s) blown for its polarizing voltage, the directional function [67] can be put out of service. To identify this type of fault, a two phase-phase voltages and residual voltage  $V_r$  functions are used. Thus, the threshold of the phase-phase voltage function is made to detect the lack of voltage and the threshold of the residual function is used to indicate abnormal voltage for one or two phases.

The anomaly appears when voltage:

- $V_r > V_p$  in case of unbalance or loss of phase
- $U_{12}$  and  $U_{23} = 0$  ( $>3\%U_n$ ) in case of a blown fuse

This voltage anomaly disappears when:

- $U_{12}$  or  $U_{23} > 50\%$
- $V_r = 0$  ( $<V_p$ )

### 3.1.2.7 Setting characteristics for NPID800-NPID800R

Characteristics	Values
Characteristic $\alpha$ for the angle	Between $-180^\circ$ and $+180^\circ$ steps of $1^\circ$
Polarisation threshold	3% of $U_n^*$
Polarizing voltage monitoring	Active or Inactive
Time delay for lack of voltage	0.04 to 300 s with a 0.01 s step

\* for details on the equipment's rated voltage ( $U_n$ ) , please refer to paragraph [2.5 Measuring voltage \( \$U\_n\$ \)](#)

### 3.1.2.8 Setting advices [67] NPID800-NPID800R

As indicated in the two above paragraphs, the selected value for the angle characteristic  $\alpha$  must enable the monitored fault current to be out of phase with polarisation voltage  $V_p$ .

In this manner, the fault current is located in the centre of the protection tripping zone and the maximum sensitivity is obtained.

Three parameters allow to act on the  $\alpha$  angle:

- the direction of the tripping zone required for the protection
- the  $\theta$  argument (value without sign) corresponding to the line impedance (usually inductive)
- the type of fault: three-phase or two-phase.

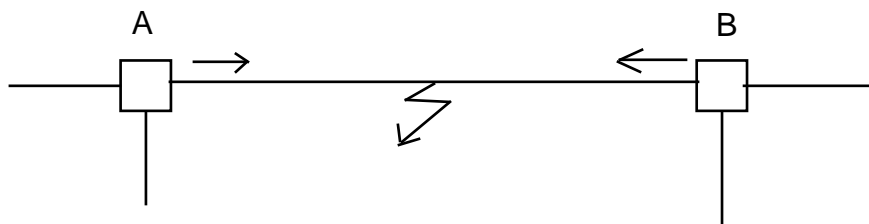
This last parameter is usually not being taken into account, since it has little influence on the setting for the  $\alpha$  angle.

The optimum  $\alpha$  angle is rule by the following relation:

- "Line side" direction:  $\alpha = 90^\circ - \theta$
- "Substation side" direction:  $\alpha = - (90^\circ + \theta)$ .

Argument $\theta$ corresponding to the line's inductive impedance	Setting for $\alpha$ according to the monitored direction	
	Towards line side	Towards substation side
$\theta = 75^\circ$	+ 15 °	- 165 °
$\theta = 60^\circ$	+ 30 °	- 150 °
$\theta = 45^\circ$	+ 45 °	- 135 °
$\theta = 30^\circ$	+ 60 °	- 120 °

The sole conditions to take into account are the ones existing when the fault arises. So, if we consider a line AB in a meshed network, when the fault occurs between A and B, the two ends become sources and the current direction is as indicated on the following flow chart. The two currents at each end of the line oppose out of phase and merge towards the fault.



In this example, if at each end A and B, we install a directional protection dedicated to trip their circuit breaker in case they locate a fault between A and B, we say that both directional protections are "line side" oriented. They will both work for a fault located downstream of them, since when the fault occurs, the A and B ends both behave like sources. For a fault located left of A, A directional protection sees it as upstream, and B downstream. This situation reverts for a fault located right of B.

For certain types of bar protections in the A substation, it is possible to install, for example, directional protections on the three lines converging to A, and to declare it as a bar fault if the three directional protections see the fault as "substation side". In this case, the directional protections are said to be "substation oriented".

The  $\alpha$  angle, as defined in the above "Setting characteristics" paragraph, enables you to set the monitoring direction of the directional protection to "line side" or to "substation side", and this independently of the energy flow direction in normal operating mode. You define the orientation of a directional protection according to the conditions of the currents and voltages as they occur during the fault situation.

## 3.2 Protection against earth faults

### 3.2.1 Protection of a network according to neutral connection

There are three ways to deal with the neutral point of an industrial network and these three possibilities must be examined separately: isolated neutral, impedance earthed neutral, solidly earthed neutral (or low impedance).

Depending on the case, you can use **NPIH800-NPIH800R**, **NPIHD800-NPIHD800R** and/or **NPUH800-NPUH800R** which, through their respective functions, max of zero sequence current, max of zero sequence current & directional, max of zero sequence voltage, performs fault detection and clearance between phase and ground.

#### 3.2.1.1 Network with isolated neutral

In networks with isolated neutral, ground fault currents are limited to the value of zero-sequence currents capacitive currents for the entire equipment. However, these kinds of faults always move the neutral point of the installation.

This is why you should implement an isolation monitoring device, so that after fault detection, it can be cleared as quickly as possible, as to avoid the risk of a second fault occurring before its clearance.

This function can be performed by a max of zero sequence voltage protection, like the **NPUH800-NPUH800R**, electrically supplied by three VT.

In some cases, use of sensitive protections with residual overcurrent **NPIH800-NPIH800R [50N] [51N]**, electrically supplied by a CBCT including the three cable phases can eliminate automatically and selectively any faults when they occur.

The value of the setting for these protections must amount to at least 1.5 the own capacitive current for the monitored output feeder. As a matter of fact, when a fault affects a neighbouring output, the own capacitive current of the healthy feeder "goes up" and feeds the fault, possibly leading to spurious tripping of the protection monitoring it, if the chosen threshold is too low.

On the other hand, in order to obtain a sufficient sensitivity for resisting faults, the total value of the capacitive current for the network must be higher than 5 times the same value for the longest feeder, in other words equal to 3 times the highest setting used on any protection of the installation.

If this condition cannot be met due to a too long outgoing feeder, you can use a directional zero-sequence current protection from the type **NPID800-NPIHD800R [67N]** or **NPIHD800-**

**NPIHD800R [67N]** with a current threshold located below the own capacitive current value without generating improper tripping.

Please note that this kind of protection can only be satisfactory if the number of outgoing feeders in operation (and subsequently the phase-to-earth capacitor) varies little over time; it however is very difficult to perform selective detection when the network has loops.

Sometimes, you can use other solutions, like temporarily performing an impedant grounding of the neutral (for about 2 seconds) using the zero-sequence voltage protection of a **NPUH800-NPUH800R [59N]**.

This allows zero-sequence current overcurrent protections to reliably detect and clear earth faults affecting the installation.

The above mentioned protections are being presented in the following paragraphs.

### **3.2.1.1.1 Function Max of zero sequence voltage [59N] NPUH800-NPUH800R and NPU800-NPU800R-NPU800RE**

#### **3.2.1.1.1.1 Presentation [59N] NPUH800-NPUH800R and NPU800-NPU800R-NPU800RE**

This function detects zero-sequence faults that can lead to a neutral point shift on networks with isolated neutral.

For the NPUH800-NPUH800R, an alternative that you must specify when ordering the protections allows to measure the zero-sequence voltage:

- Measured voltage: using a direct input of the residual voltage, by broken delta VT (measurement of  $V_r = 3 V_o$ ) or by neutral point VT (measurement of  $V_o$ ). You can choose either method when installing the protection.
- Calculated voltage: using vector calculation from the three-phase voltage  $V_1+V_2+V_3+N$ .

For the NPU800-NPU800R-NPU800RE, this functions activation depends on the wiring of the phase voltages:

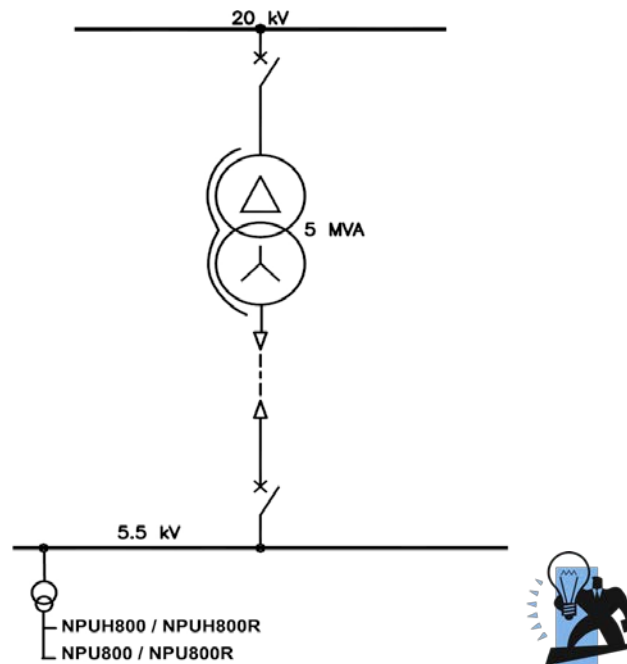
- Calculated voltage: using vector calculation from the three-phase voltage  $V_1+V_2+V_3+N$ .
- Measured voltage: if the terminals A5-A6 (NPU800) and T1-10/T1-11(NPU800R) are not being used for phase voltage measurement, it is possible to measure the zero-sequence voltage by connecting these terminals to the secondary of broken delta VT (measurement of  $V_r = 3 V_o$ ) or to the secondary of a VT with a neutral point (measurement of  $V_o$ ). You can choose either method when connecting the protection.



$V_r$  is calculated when connecting the three phases + Neutral and  $V_r$  is measured if the terminals A5 and A6 (NPU800) and T1-10 and T1-11(NPU800R) are available.

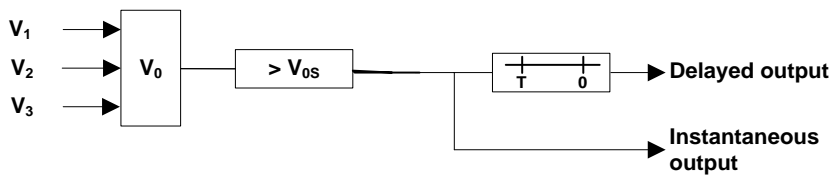
The protection monitors zero-sequence voltage by comparing it to a low and to a high threshold. You can activate or deactivate each threshold during the configuration operation.

When the voltage value reaches one of the set thresholds, an alarm is generated (instantaneous output) and a time delay is simultaneously launched. Upon expiry of the time delay, the time-delayed output is activated.

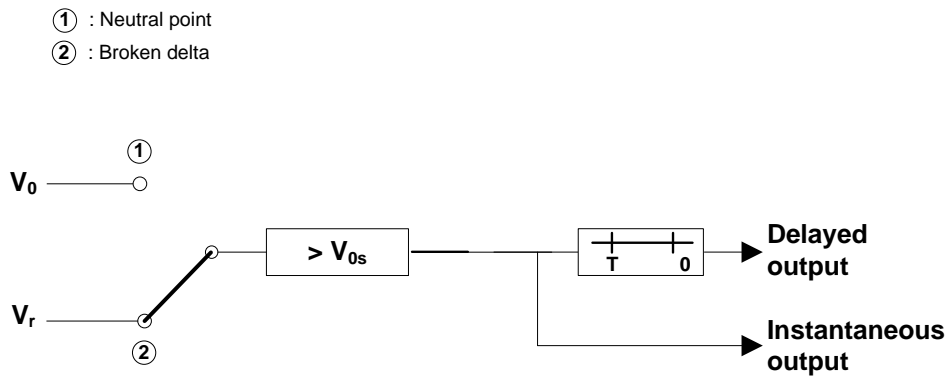


**Fig. 9:** Example of zero-sequence voltage protection on a busbar

### 3.2.1.1.1.2 Flow charts [59N] NPUH800-NPUH800R and NPU800-NPU800R-NPU800RE



**Fig. 10:** Function Max of zero sequence voltage [59N] (calculated mode)



**Fig. 11:** Function Max of zero sequence voltage [59N] (measured mode)

**3.2.1.1.1.3 Setting characteristics [59N] NPUH800-NPUH800R and NPU800-NPU800R-NPU800RE**

Time delay and thresholds for this function [59N]	Setting
Definite time-delay $t(V_0 >) - t(V_0 >>)$	0.04 to 300 s step: see *
Low threshold $V_0 >$	0.02 to 0.80 $U_n$ with steps of 0.01 $U_n$
High threshold $V_0 >>$	
Characteristics	Values
Response time for the instantaneous outputs	60 ms
Setting range for the rated value of the measuring voltage ( $U_n$ )	33 V to 120 V (with steps of 0.1 V)
Wiring choice to measure $V_0$	Setting
Wiring to measure $V_0$	Broken delta / neutral point

\* between 0.06 and 9.99 s with steps of 0.01 s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1 s.

**3.2.1.1.1.4 Examples of settings [59N] NPUH800-NPUH800R and NPU800-NPU800R-NPU800RE**

Depending on the value found from co-ordination or setting study, you must adapt the thresholds [59N] to set on the protection for taking into account the rated voltage of the measurement reducers (VP) and using the setting steps.

Depending on the application and on the type of protection, the zero-sequence voltage  $V_0$  is calculated from the result of the measurement of the phase to neutral voltages  $V_1, V_2, V_3$  or it is measured from the residual voltage  $V_r$  from a connection of three voltage transformers in broken delta or neutral point.

Note: the residual voltage  $V_r$  equals three times the value of the zero-sequence voltage  $V_0$ .

**Example of setting using the measured mode**

Let us examine the following data as an example:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3} \rightarrow U_{n_{rel}} = 57.7 \text{ V}$
- Tripping value calculated for the first threshold in case of zero-sequence fault: 10% of the phase to neutral voltage with a definite time delay of 1 s.
- Tripping value calculated for the second threshold in case of zero-sequence fault: 20% of the phase to neutral voltage with a definite time delay of 0.5 s.

Calculating the thresholds to enter on the protection (broken delta configuration):

- The low threshold  $V_0 >$  for the function [59N] will be used with the following setting:  
  
Since the VTs are mounted in star/broken delta, the voltage applied to the protection will be equal to three times the zero-sequence voltage (i.e.  $V_0$ )  
 $V_0 > = 0.1 \times 3 \times U_{n_{rel}} = 0.3 U_{n_{rel}}$   
The time delay  $t(V_0 >)$  will be set to 1 s.
- The high threshold  $V_0 >>$  for the function [59N] will be used with the following setting:  
  
Since the TP are mounted in star/broken delta, the voltage applied to the protection will be equal to three times the zero-sequence voltage.  
 $V_0 >> = 0.2 \times 3 \times U_{n_{rel}} = 0.6 U_{n_{rel}}$   
The time delay  $t(V_0 >>)$  will be set to 0.5 s.

Calculating the thresholds to enter on the protection (neutral point configuration):

- For the first threshold, the low threshold  $V_{o>}$  for the function [59N] will be used with the following setting:  
Since the VT is located in the star point of the generator, the voltage applied to the protection will be equal to the measured voltage. (i.e.  $V_o$ )  
 $V_{o>} = 0.1 \times U_{n_{rel}}$   
The time delay  $t(V_{o>})$  will be set to 1 s.
- For the second threshold, the high threshold  $V_{o>>}$  for the function [59N] will be used with the following setting:  
Since the TP is located in the star point of the generator, the voltage applied to the protection will be equal to the measured voltage.  
 $V_{o>>} = 0.2 \times U_{n_{rel}}$   
The time delay  $t(V_{o>>})$  will be set to 0.5 s.

### **Example of setting using the calculated mode**

Let us examine the following data as an example:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3} \rightarrow U_{n_{rel}} = 57.7 \text{ V}$
- Tripping value calculated for the first threshold in case of a zero-sequence fault: 10% of the phase to neutral voltage with a definite time delay of 1 s.
- Tripping value calculated for the second threshold in case of a zero-sequence fault: 20% of the phase to neutral voltage with a definite time delay of 0.5 s.

Calculating the thresholds to enter on the protection:

- The low threshold  $V_{o>}$  for the function [59N] will be used with the following setting:  
 $V_{o>} = 0.1 \times U_{n_{rel}} = 0.1 U_{n_{rel}}$   
The time delay  $t(V_{o>})$  will be set to 1 s.
- The high threshold  $V_{o>>}$  for the function [59N] will be used with the following setting:  
 $V_{o>>} = 0.2 \times U_{n_{rel}} = 0.2 U_{n_{rel}}$   
The time delay  $t(V_{o>>})$  will be set to 0.5 s.

**3.2.1.1.2 Function with earth fault overcurrent [50N] [51N] NPIH800-NPIH800R, NPI800-NPI800R and NPI800-S1**

**3.2.1.1.2.1 Presentation [50N] [51N] NPIH800-NPIH800R, NPI800-NPI800R and NPI800-S1**

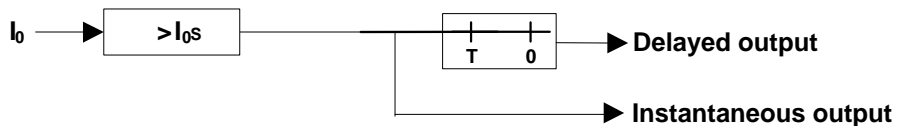
The function with earth fault overcurrent clears faults between phase and ground. Two settings ranges (low and high) with CT's and one range with CBCT are available with for each one, two thresholds:

- 1 "high" threshold [50N]  $I_0 >>$  instantaneous or associated with Definite time-delay
- 1 "low" threshold [51N]  $I_0 >$  with 8 time delay modes: definite time, IEC or ANSI inverse time delay, or factory setting (please contact us)

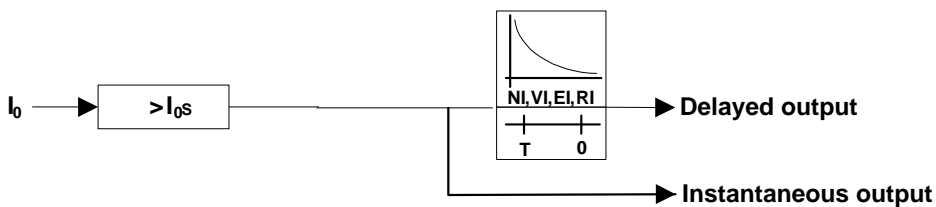
The **high measurement range** (0.3 to 24  $I_{n0}$ ) on CT's can be required for some applications of single-phase protection, such as the tank earth detection of a transformer. This range is available for **NPIH800-NPIH800R**. It is also available for NPI800 and NPID800, which gives rise to each, to a specific protection: **NPI800-S1** and **NPID800-S1**.

The input measurement withstand 100  $I_n$  - 1 s is assured.

**3.2.1.1.2.2 Flow charts [50N] [51N] on NPIH800-NPIH800R, NPI800-NPI800R and NPI800-S1**



**Fig. 12:** Functions with earth fault overcurrent [50N] [51N] with definite time



**Fig. 13:** Function with earth fault overcurrent [51N] with inverse time

**3.2.1.1.2.3 Setting characteristics [50N] [51N] NPIH800-NPIH800R and NPI800-NPI800R**

THRESHOLDS FOR THE FUNCTIONS [50N] [51N]	Setting
Thresholds $I_{o>}$ - $I_{o>>}$ connection CT (low range) <i>(except NPI800-S1)</i>	0.03 to 2.40 $I_{n0}$ with steps of 0.005 $I_{n0}$
Thresholds $I_{o>}$ - $I_{o>>}$ connection CT (high range) <i>(except NPI800-NPI800R)</i>	0.3 to 24.0 $I_{n0}$ with steps of 0.01 $I_{n0}$
Threshold $I_{o>}$ - $I_{o>>}$ CBCT connection** - ICE (primary)	0.6 to 48 A with steps of 0.1 A
TIME DELAYS FOR THE FUNCTIONS [50N] [51N]	Setting
Definite time-delay $t(I_{o>}) - t(I_{o>>})$	0.04 to 300 s Step: see*
Curves with inverse time, very inverse, extremely inverse according to IEC 60255-4 - $t(I_{o>})$	T++: 0.03 to 3 s with steps of 0.01 s
Time curves which are moderately inverse, very inverse, extremely inverse ANSI/IEEE - $t(I_{o>})$	T++: 0.03 to 3 s with steps of 0.01 s
RI inverse time curves $t(I_{o>})$	100 ms to 20 s with steps of 0.1 s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60 ms

\*: between 0.04 and 9.99 s steps of 0.01 s, between 10.0 s and 29.9 s steps of 0.1 s, between 30 and 300 s steps of 1s

\*\* 100/1 CBCT, and with adapter case model BA800 for 1500/1 CBCT

Accurate characteristics for tripping curves with inverse time are given in the chapter «[3.5 Tripping curves for \[46\] \[51\] \[51N\]](#)».

**3.2.1.1.2.4 Setting advices [50N] [51N] NPIH800-NPIH800R, NPI800-NPI800R and NPI800-S1**

Depending on the value found through co-ordination or setting study, you must adapt the thresholds [50N] and [51N] to set on the protection to take into account the rated current of the measurement reducers (CTs), and possibly modified according to the setting steps.

Let us consider the following three cases as an example:

Measurements of the zero-sequence current value in the residual connection of the 3 phase CTs:

- CT = 250/5 A
- In protection = 5 A (earth range = phase range)
- Tripping value in case of an earth fault = 25 A with a definite time delay of 0.5 s.

Calculating the thresholds and parameters to display on the protection:

- To detect earth faults, function [51N] will be used with the following settings:  $I_{0>} = 25/250=0.1$ . As a operating characteristic, choose definite time with a time delay of 0.5 s.

Measurement of the zero-sequence current value by a CBCT – 100 turns:

- CBCT ICE TF 80-1
- In protection = 0.2 A (specific earth range for CBCT connection)
- Tripping value in case of earth fault = 16 A with a definite time delay of 0.5 s.

Calculating the thresholds and parameters to display on the protection:

- To detect earth faults, function [51N] will be used with the following settings:  $I_{0>} = 16/20=0.8$ . As a operating characteristic, choose definite time with a time delay of 0.5 s.

**Note:** 20 = coefficient which takes into account the transformation ratio 100/1 of the CBCT and the earth range of 0.2 A.

Measurement of the zero-sequence current value by a CBCT – 1500 turns:

- CBCT CEE TF 80-15 associated with a BA800
- In protection = 0.2 A (specific earth range for CBCT connection)
- Tripping value in case of earth fault = 1 A with a definite time delay of 0.1 s.

Calculating the thresholds and parameters to display on the protection:

- To detect earth faults, function [51N] will be used with the following settings:  $I_{0>} = 1/20=0.05$ . As a operating characteristic, choose definite time with a time delay of 0.1 s,

**Note:** 20 = which takes into account the transformation ratio of the CBCT 1500/1 and the BA800 and the earth range of 0.2 A.

**3.2.1.1.3 Function of directional earth-fault overcurrent [67N] NPIHD800-NPIHD800R and NPID800-NPID800R**

**3.2.1.1.3.1 Presentation [67N] NPIHD800-NPIHD800R and NPID800-NPID800R**

This type of protection is used in two main cases:

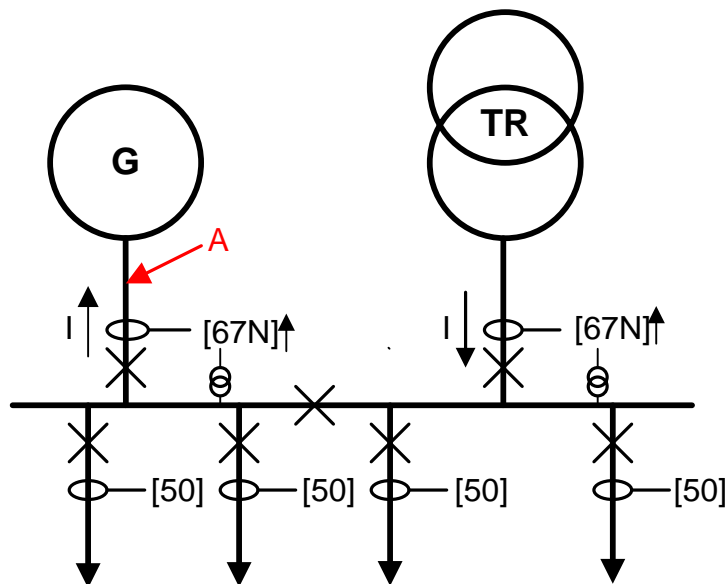
- as a complement to a phase directional protection, in order to identify and eliminate a faulty zero-sequence current element when several sources supply the same busbar
- on outputs for radial networks which are strongly capacitive, in case the neutral is isolated or impedant, as to obtain a sensitive zero-sequence current protection without risk of spurious tripping due to zero-sequence currents capacitors.

Application example #1:

In case of a fault located in "A" on the represented network, the currents measured by the incoming protections "TR" and "G" have identical amplitude but opposite directions.

We must use directional criteria [67N] in order to eliminate the generator "G" and let the transformer "TR" supply the network.

[67N]↑: the arrow indicates the orientation of the protection's tripping zone.



**Fig. 14:** Example of a network fitted with a directional zero-sequence current protection (1)

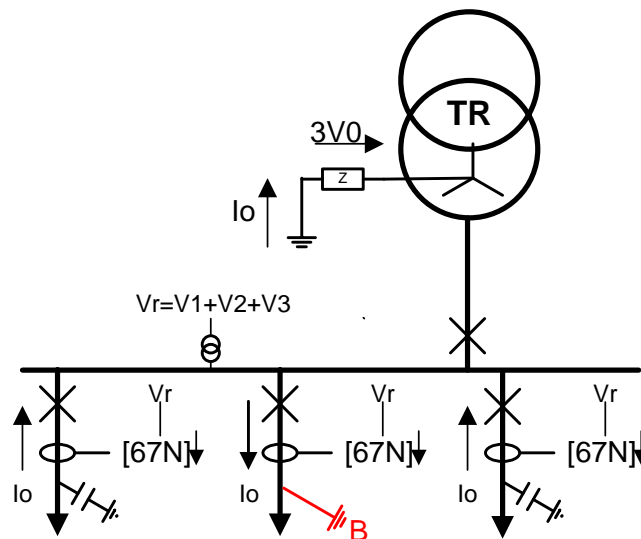
Application example #2:

In case of a fault located in “B” on the represented network, the zero-sequence current value of the default output is equal to the sum of all currents going up through the grounding impedance of the neutral, and through the zero-sequence currents capacitors of the healthy phases of the other outputs.

The fault current measured at a healthy feeder increases proportionally to its zero-sequence current capacitor and to the grounding impedance value.

In order to obtain a sensitive zero-sequence current protection, you must add directional criteria, as to eliminate only the faulty feeder and let healthy feeders supply the network.

[67N]↑: the arrow indicates the orientation of the protection's tripping zone.



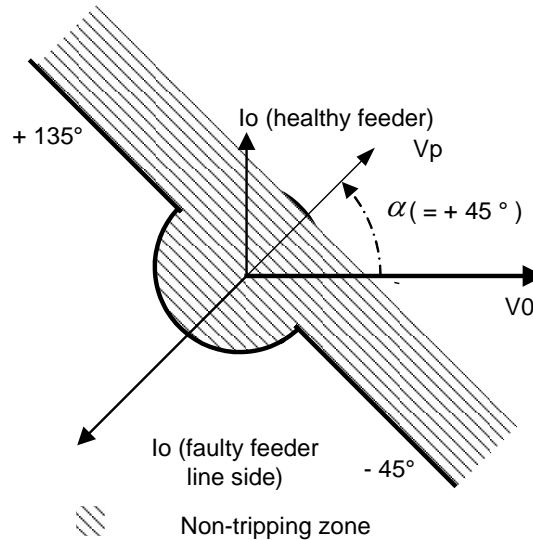
**Fig. 15:** Example of a network fitted with a zero-sequence current directional protection (2)

Depending on the application and on the type of protection, zero-sequence voltage Vo is calculated from the measurement of the phase to neutral voltages V1, V2, V3 or it is measured from the residual voltage Vr from a connection of three voltage transformers in broken delta.

**Note:** the value of the residual voltage Vr equals three times the value of the zero-sequence voltage Vo.

In addition to this, a polarisation threshold enables to neglect the residual voltage due to the natural unbalance of the network in the absence of any fault and to phase shifts generated by the VTs.

In relation to the zero-sequence voltage  $V_0$ , the polarisation voltage  $V_p$  defines a non-tripping zone. The vector showing this tension is located in the centre of a zone with a  $180^\circ$  amplitude which determines the tripping and non-tripping zones.



In order to modify the position of this zone, you can change the setting of the  $\alpha$  angle value.

According to our application example application #1, network with isolated neutral, if  $\theta_0$  the argument of the characteristic angle is  $45^\circ$ , which is a value corresponding to a current  $I_0$  lead of about  $90^\circ$  compare to the zero-sequence voltage, the  $\alpha$  angle characteristic will be set to  $+45^\circ$  (see the help table setting characteristics ). This setting allows tripping for zero-sequence current between  $+135^\circ$  and  $-45^\circ$ .

**3.2.1.1.3.2 Operating modes [67N] NPIHD800-NPIHD800R and NPID800-NPID800R**

If the polarisation voltage is low, it is not possible to measure with accuracy the angle of the directional function. In this case, the working mode of the protection depends on the selected operating mode:

**Permission mode**

If the voltage is lower than the polarisation threshold, the protection does not react on the directional criteria [67N] any more, and trip by one of the overcurrent functions [50N] [51N] that have been associated with this criterion.

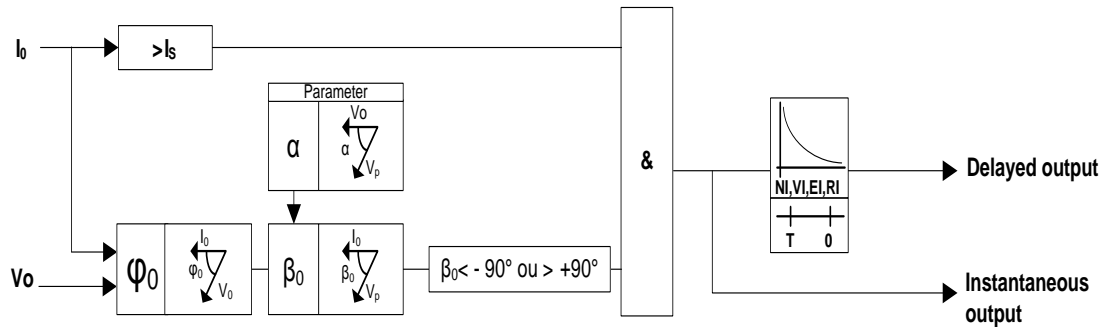
**Blocking mode**

If the voltage is lower than the polarisation threshold, tripping by one of the overcurrent functions [50N] [51N] that have been associated with the directional criteria [67N] is impossible.

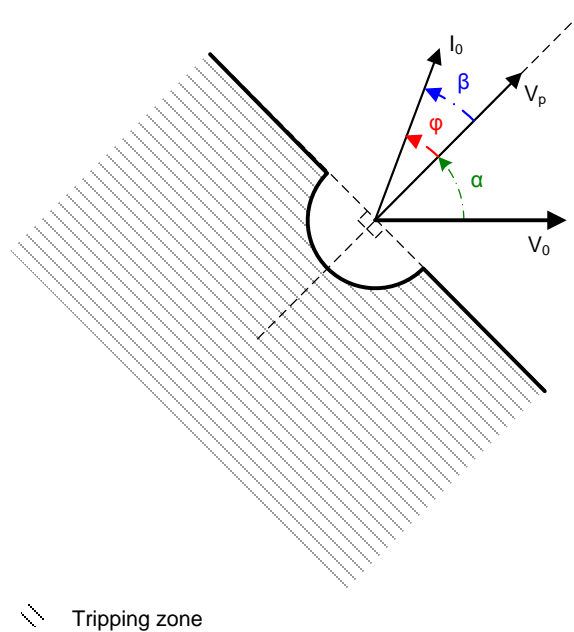
### 3.2.1.1.3.3 Inhibiting the function [67N] on NPIHD800-NPIHD800R and NPID800-NPID800R

You can temporarily inhibit the directional function by one “All or Nothing” input, or via digital communication.

### 3.2.1.1.3.4 Flow chart [67N] NPIHD800-NPIHD800R and NPID800-NPID800R



- $\varphi$  : Measurement of phase shift between current and voltage
- $\beta$  : Measurement of phase shift between current and polarizing voltage ( $\beta = \varphi + \alpha$ )
- $\alpha$  : Settable angle which determines the tripping zone



**Fig. 16:** Directional function with maximum of zero sequence overcurrent [67N]

**3.2.1.1.3.5 Setting characteristics [67N] NPIHD800-NPIHD800R and NPID800-NPID800R**

Characteristics	Values
Polarisation threshold for $V_0$	3 % to 20 % $U_n$ with steps of 1 %
Setting angle characteristic $\alpha$	-180° to +180° with steps of 1°

**3.2.1.1.3.6 Setting advices [67N] NPIHD800-NPIHD800R and NPID800-NPID800R**

Similarly to the directional function phase, in order to obtain the maximum sensitivity, setting the  $\alpha$  angle characteristic must be such as zero-sequence current due to a ground fault be as much as possible in opposite phase the with polarisation voltage  $V_p$ .

Two essential parameters allow choosing the  $\alpha$  angle:

- The tripping zone orientation required for the protection,
- The  $\theta_0$  argument function for the neutral connection of the installation (isolated neutral, impedant or directly grounded) and of the capacitive current of the dedicated network.

The optimum  $\alpha$  angle is ruled by the following relation:

- "line side" orientation:  $\alpha = \theta_0$
- "substation side" monitored fault:  $\alpha = \theta_0 \pm 180^\circ$ .

The following table applies:

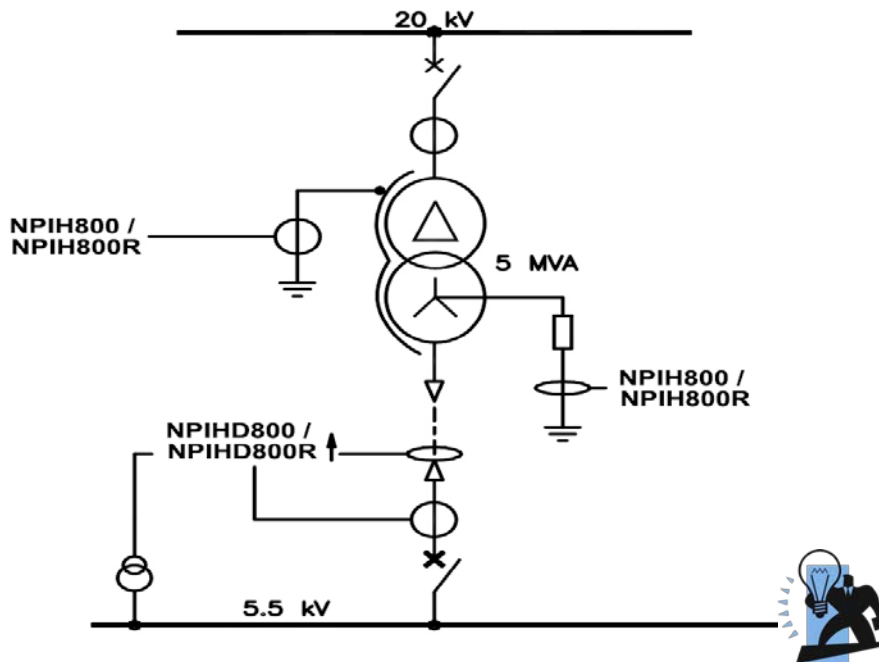
Neutral connection	Argument $\theta_0$ of the relevant angle	Setting of $\alpha$ according to the monitored direction	
		Direction «line side»	Direction «substation side»
Capacitive network with isolated neutral or connected to the earth via a high impedance	+ 45 °	+ 45 °	- 135 °
Network with neutral connected to the earth via a resistance or impedant	+10 °	+10 °	- 170 °
Network with solidly earthed neutral (or low impedance)	- 20 °	- 20 °	160 °

**3.2.1.2 Network with impedance earthed neutral**

On these networks, fault ground current is limited to a set value which can amount from ten to about one thousand amps. The various feeders must be fitted with a zero-sequence overcurrent protection **NPIH800-NPIH800R [51N]\***, fed via a CBCT or a residual connection of the line 3CTs. In the late case, the threshold must not be set below 6% In CT. As a matter of fact, in case of a phase to phase short-circuit, measurement reducers are likely to enter saturation in a dissymmetrical manner and to cause spurious tripping of a protection whose threshold would have been set too low.

If the protection is fed via a CBCT, you can set the threshold to 1.5 the value of the zero-sequence current capacitive of the feeder (an order of size would be 3 A/km for high voltage cables).

When several neutrals are simultaneously grounded as indicated on figure 18, you must use zero-sequence directional current protections like **NPID800-NPID800R [67N]** or **NPIHD800-NPIHD800R [67N]** (refer to **3.1.2 Phase overcurrent and directional function [67]** **NPID800-NPID800R** and **3.2.1.1.3 Function of directional earth-fault overcurrent [67N]** **NPIHD800-NPIHD800R and NPID800-NPID800R**) in order to selectively isolate one of the zero-sequence current source in case of a fault.



**Fig. 17:** Zero-sequence current protections on a network with earthed neutrals

In case of a network with one or several generators producing directly on the main busbar, you may perform grounding either on the neutral point of a generator, or on the busbar

using a Zig Zag coil or a star transformer with grounded neutral and secondary triangle closed by a resistor. (Broken delta connection)

The first option is not recommended, since the zero-sequence current protection installed on the neutral point must offer features that are sometimes incompatibles:

- Low threshold and quick operating time to efficiently protect the generator,
- Threshold and time delay values allowing for selectivity with the network's zero-sequence current protections.

The second option, on the contrary, provides favourable ground for a sensitive and quick protection of the generators against ground faults, generators being considered feeders for zero-sequence currents.

\* or the zero-sequence current unit of multifunction three phase + earth protections according to **[51N]** such as **NPI800-NPI800R**.

### 3.2.1.3 Network with solidly earthed neutral or low impedance

Grounding is generally performed on the neutral of an input delta-star transformer.

When this neutral is not accessible, the zero-sequence current generator is made of a Zig Zag coil or of a delta-star transformer connected to the main busbar.

The ground fault current is though only limited by the zero-sequence current reactance of the transformer or of the coil and its maximum value will be of the same order of magnitude as three phases short-circuits values.

It is thus possible to obtain a good sensitivity with the protection **NPIH800-NPIH800R [51N]** (or the zero-sequence current unit of multifunction three phase + earth protections **[51N]** such as **NPI800-NPI800R**) fed by a residual connection of the line 3 CTs.

### 3.2.2 Zero-sequence current protection for transformers

Except in some cases with Yyn coupling or with autotransformers, zero-sequence currents cannot “travel” from the primary to the secondary of a transformer.

It is therefore necessary to implement distinct protections on the primary and secondary sides against single-phase faults occurring inside the transformer or on a link cable.

#### 3.2.2.1 Single-phase faults at primary level

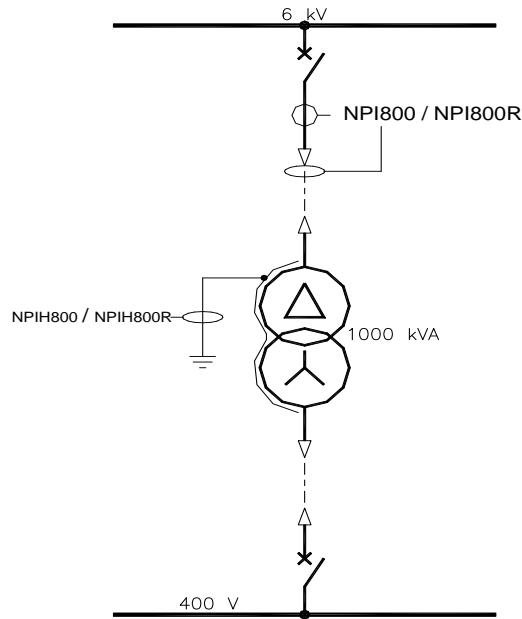
On the primary side, measuring the residual current is often performed using the three phase CTs fitting the feeder. It is the case for zero-sequence currents units [50N] [51N] for protections **NPI800-NPI800R** (see "**3.2.1.1.2 Function with earth fault overcurrent [50N] [51N] NPIH800-NPIH800R, NPI800-NPI800R**")

The protection must then fulfil one of the following two conditions:

- It must be slightly delayed, as to avoid spurious tripping caused by the flow of an artificial zero-sequence current following a temporary saturation of the measurement reducers (downstream inrush current or fault current). A threshold value of at least 6% is suitable in this case.
- It must be instantaneous, but the threshold value should not be less than 15 or 20 % InCT. Often, this constraint leads to a high setting values in comparison to the maximum fault current, and consequently to a lack of sensitivity.

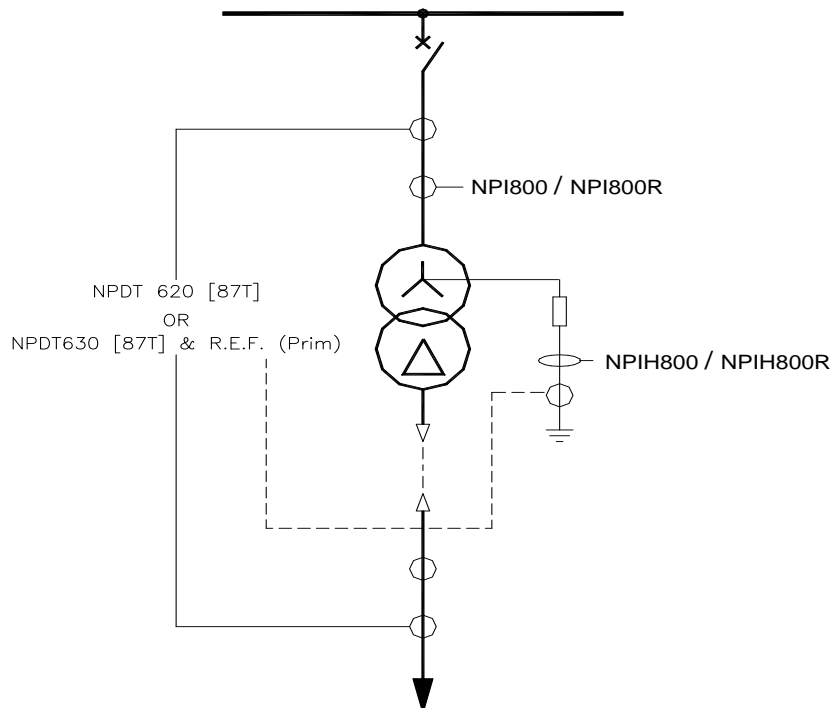
Using a CBCT around the 3 phases to measure the residual current allows for a both sensitive and quick protection. It is the case for zero-sequence currents units [50N] [51N] on **NPI800-NPI800R**.

When mounting such a measurement reducer is not possible, you can, provided cable length is small, link their ground braid to the transformer tank. In this manner, the tank-earth protection (see figure 19) will also apply to the cable “area”.



**Fig. 18:** Example of transformer protection HV/LV

As shown on figure 19, a simple earth overcurrent protection never guarantees satisfactory protection when coupled with star windings at the transformer primary, especially when the neutral is impedant. In order to improve the protection system, you can use a differential restricted earth fault protection; also called REF which can be integrated in the differential protection NPDT 630 (please contact us).



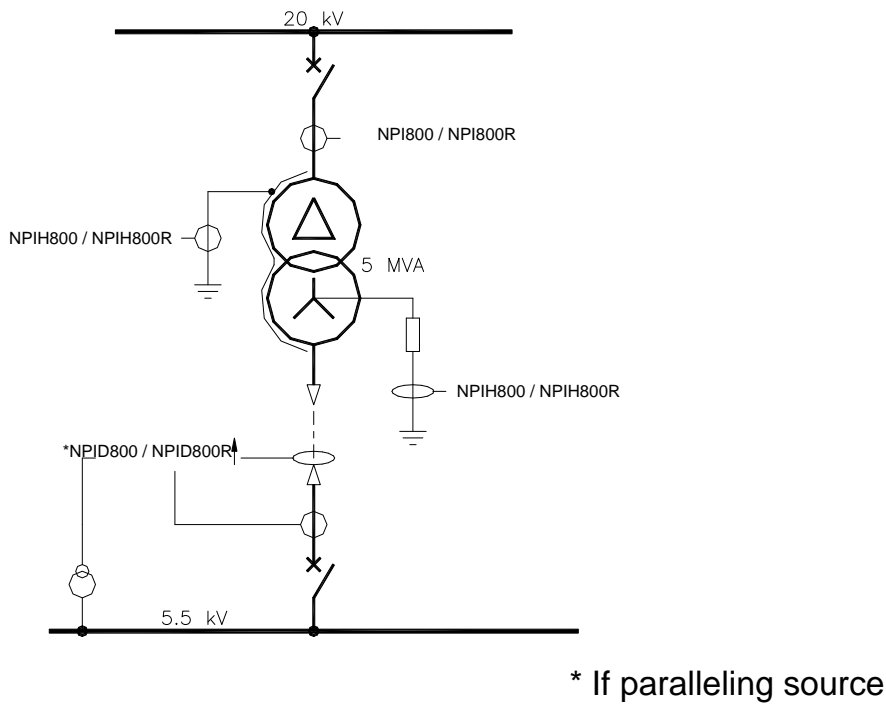
**Fig. 19:** Transformer HTB/HTA and REF at the primary

With this application, the residual current of the three line CTs is compared to the CT current of the neutral. This protection is working for all faults occurring in the CT area, in other words for earth faults on the winding. The protection remains stable for all faults outside this area.

**3.2.2.2 Single-phase faults at secondary level**

When the windings of a transformer on the secondary side are coupled in star and when their neutral point is grounded, you must install a single phase overcurrent protection in the connection between the neutral point and the ground and you must set it in a selective manner taking into account the zero-sequence currents protections located downstream in the network.

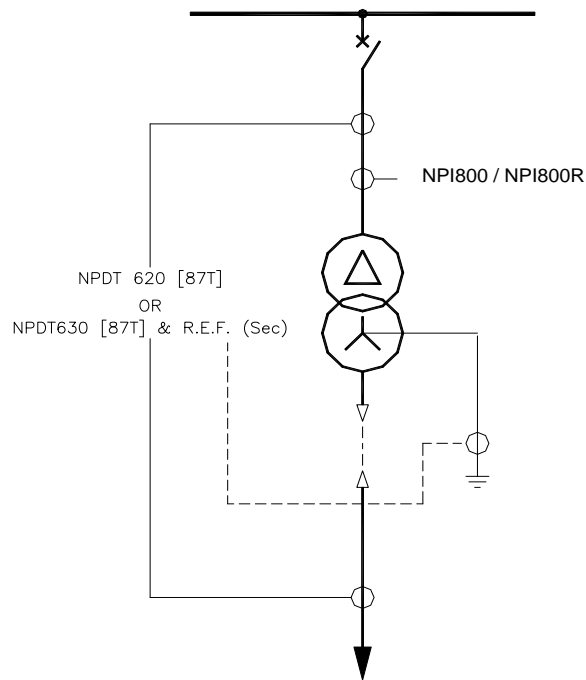
This protection is of the type **NPIH800-NPIH800R [51N]**, whether the measurement reducer be a CBCT or a CT coil. The influence of the third harmonics is eliminated in the zero-sequence current component, since only the fundamental current is measured (see figure 21).



**Fig. 20:** Example of HV/MV transformer protection

In order to improve the secondary winding protection of a transformer, for high values of fault currents, you can often use a restricted earth fault protection, also named REF (see figure 22) when the neutral is directly connected to the earth. In this case, you may use the

REF input on the NPDT 630 differential protections (please contact us). This function is more sensitive than differential protection, and it additionally measures the neutral point current, which protections cannot perform.



**Fig. 21:** Transformer HTB/HTA and REF on the secondary

### 3.2.2.3 Tank earth protection

The tank earth fault detection is a quick way to detect transformer internal faults.

If, as is often the case, this protection is not properly isolated from the ground, it should not be set below 10% of the maximum earth fault current, in order to avoid uncontrolled working due to an “errant” zero-sequence current (for example a ground fault current from a neighbouring output which is flowing in the circuit formed by the tank and its grounding).

It is recommended to apply a slight time delay to this protection (**NPIH800-NPIH800R [51N]**).

Associated with Buchholz gas detection relays, the instantaneous high threshold unit and with the zero-sequence current unit of the protection for the primary of the transformer, the tank earth protection provides quick detection and clearance of the faults affecting transformers.

### 3.3 Overload protection for cable and transformer

This function, also called **thermal image function [49]** provides cable and power transformer protection against prolonged overload. It is available on ranges **NPI800-NPI800R** and **NPID800-NPID800R**.

#### 3.3.1 Function of cable thermal image [49] NPI800-NPI800R and NPID800-NPID800R

##### 3.3.1.1 Presentation thermal cable [49] NPI800-NPI800R and NPID800-NPID800R

The cable thermal image function protects cables against prolonged overload. Calculation of the thermal image is performed on each phase.

The basic principle used by this protection relies on the heat production in a cable according to Joule losses  $R \cdot I^2 \cdot t$ . So by integrating the current value, it is possible to obtain a thermal image of the protected element.

The tripping time following detection of overload current is given by the following relation (IEC 60255-8 standard compliant):

$$t = C_{TE} * \ln\left(\frac{I^2 - I_{pre}^2}{I^2 - I_b^2}\right)$$

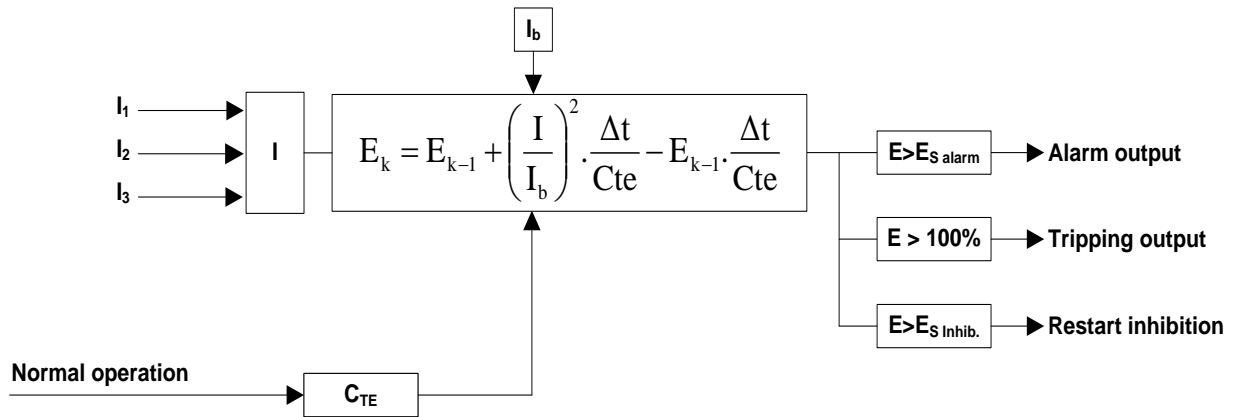
- $I$  = overload current.
- $t$  = tripping time after an overload detection.
- $C_{TE}$  = heating time constant and cooling parameter for the protected element.
- $I_{pre}$  = current before the overload.
- $I_b$  = base current for which the cable reaches a maximum thermal state of 100%.

The tripping occurs when the thermal state of the protected element reaches 100 %.

Thermal alarm is activated when the thermal state reaches the thermal alarm threshold which can be set between 80 and 100 % of the thermal state.

The curves, presented in paragraph 3.3.2.6.13.3.2.6.1 **Characteristics of the thermal image (cable and transformer)**, show the tripping time in relation to the preload current  $I_{pre}$ , for a time constant  $C_{TE} = 10$  min.

3.3.1.2 Flow chart for thermal cable [49] NPI800-NPI800R and NPID800-NPID800R



- E = Thermal state in %
- $E_k$  = Thermal state at K time
- $E_{k-1}$  = Thermal state at K – 1 time
- $E_{s\ alarm}$  = Thermal state threshold in %
- $E_{s\ inhib.}$  = Restart inhibition threshold in %

Fig. 22: Cable thermal image function [49]

3.3.1.3 Setting characteristics for thermal cable [49] NPI800-NPI800R and NPID800-NPID800R

THRESHOLDS FOR THE FUNCTION [49] CABLE	Setting
Thermal alarm threshold	80 to 100 % of thermal state with steps of 1%
Thermal tripping threshold $I_b$	0.4 to 1.3 $I_n$ with steps of 0.01 $I_n$
TIME CONSTANT FOR THE FUNCTION [49] CABLE	Setting
Time constant for heating $C_{TE}$	4 min to 180 min with steps of 1 min

**3.3.1.4 Setting advices for thermal cable [49] NPI800-NPI800R and NPID800-NPID800R**

Depending on the value found through co-ordination or setting study, you must adapt the thresholds [49] to set on the protection to take into account the rated current of the measurement reducers (CT) and possibly modified according to the setting steps. As an example, let us examine the following data to protect a cable:

- CT = 500/5 A
- In protection = 5 A
- Calculated tripping value of the thermal threshold\* = 565 A
- Time constant for heating = 60 min (manufacturer data).

\* depending on the cable manufacturer data:

- Maximum acceptable intensity for normal operation,
- Acceptable overload current.

Calculating the thresholds and parameters to set on the protection:

The tripping threshold  $I_b$  will be set to the following value:  $I_b = 565/500 = 1.13$ .

The heating time constant will be set to the required value: 60 min.

Implicitly, the cooling constant will also be set to 60 min.

As a complement, you can set the alarm threshold to 95% and so warn the operators before tripping occur.

### **3.3.2 Function of thermal image transformer [49] NPI800-NPI800R and NPID800-NPID800R**

#### **3.3.2.1 Introduction to thermal image transformer [49] NPI800-NPI800R and NPID800-NPID800R**

The thermal image transformer function provides protection against continuous overloads for power transformers when, in certain operating conditions, the power they absorbed is higher to their rated power.

Calculation of the thermal image is performed using negative and positive components of the current. This function allows for use of a cooling constant which differs from the heating constant.

This function is used to protect a power transformer against excessive temperature increase, due to a continuous overload.

When the calculated thermal state reaches 100 %, the transformer supply is switched off.

This state is obtained after a t time given by the following equation (IEC 60255-8 standard):

$$t = C_t * \ln \left( \frac{I_{\text{transf}}^2 - I_{\text{pre}}^2}{I_{\text{transf}}^2 - I_b^2} \right)$$

- $C_t$  = thermal time constant of the transformer
- $I_b$  = base current for which the transformer reaches a maximum thermal state of 100 % at steady state
- $I_{\text{pre}}$  = load current in the initial state
- $I_{\text{transf}}$  = real load current for the transformer at the "t" time

In order to give a more realistic image of the thermal constraints to which the transformer is exposed, we take into account the positive component of the current and its negative component weighted by a K factor (which accounts for the unbalance).

$$I_{\text{trans}} = \sqrt{I_{\text{direct}}^2 + K * I_{\text{inverse}}^2}$$

**The positive and negative sequences are calculated from the three phase currents (3 CTs required).**

A thermal alarm is generated when the thermal state reaches an alarm threshold which can be set between 80 and 100 %.

Tripping occurs for a thermal state of 100 %.

### 3.3.2.2 Value of the time constant $C_t$

The thermal time constant  $C_t$  of a transformer varies according to its working mode. To take this criteria into account, the thermal image of the NPI800-NPI800R and NPID800-NPID800R is calculated along three working modes:

#### 3.3.2.2.1 Reclosing mode

During the transformer power-on, the presence of inrush currents leads to quicker heating than working at normal operation. To integrate this phenomenon the heating time constant  $C_{TE}$  used in the protection calculation can be accordingly lowered.

In order to do so, starting with the activation of the dedicated “reclosing mode” the heating time constant  $C_{TE}$  is multiplied by a reclosing factor  $F_D$  with a value lower to 100%. The weighting takes the time set in the “reclosing mode” function.

→ Thermal time constant during reclosing:  $C_t = F_D * C_{TE}$

**Note:** to avoid the “reclosing mode” function reducing the calculation of the heating time constant of the thermal image  $C_{TE}$ , the factor  $F_D$  must be set to 100%.

#### 3.3.2.2.2 Normal operation mode

Normal operating mode is activated at the end of the “reclosing mode” time delay.

→ Thermal time constant in normal operation:  $C_t = C_{TE}$

#### 3.3.2.2.3 Cooling mode ( $I_{trans} < 0.15 I_n$ )

As soon as the transformer is not electrically supplied any more, the time constant increases due to the minor efficiency (or even the interruption) of the cooling system.

→ Thermal time constant for cooling:  $C_t = 1.0 \text{ to } 6.0 * C_{TE}$

3.3.2.3 Flow chart for thermal transformer [49] NPI800-NPI800R and NPID800-NPID800R

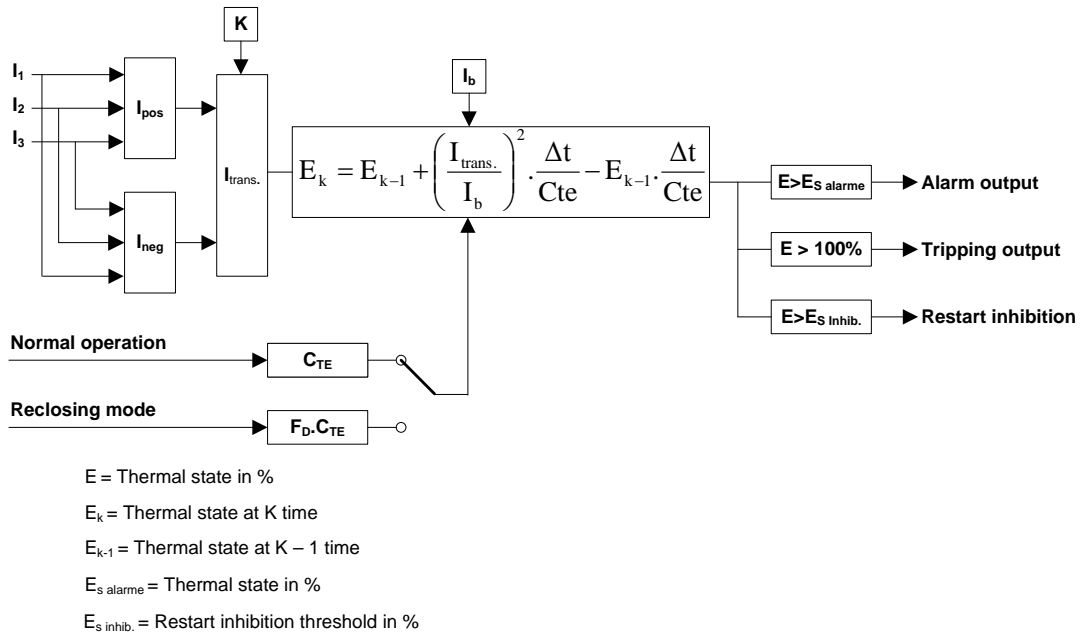


Fig. 23: Function thermal image for transformer [49]

3.3.2.4 Setting characteristics for thermal transformer [49] NPI800-NPI800R and NPID800-NPID800R

THRESHOLDS FOR THE FUNCTION [49] FOR TRANSFORMER	Setting
Negative component factor $K$	0 to 9 with steps of 1
Reclosing factor $F_D$	50 to 100 % with steps of 1%
Thermal tripping threshold $I_b$	0.40 to 1.30 $I_n$ with steps of 0.01 $I_n$
Thermal alarm threshold	80 to 100 % with steps of 1%
Thermal threshold reclosing inhibition ( if thermal trip)	40 to 100 % of thermal state with steps of 1%

TIME CONSTANTS FOR THE FUNCTION [49] FOR TRANSFORMER	Setting
$C_{TE}$ : heating time constant	4 min to 180 min with steps of 1 min
$C_{TR}$ : cooling time constant	1.0 to 6.0 $C_{TE}$ with steps of 0.1

### 3.3.2.5 Setting advices for thermal transformer [49] NPI800-NPI800R and NPID800-NPID800R

Depending on the value found through co-ordination or setting study, you must adapt the thresholds [49] to set on the protection to take into account the rated current of the measurement reducers (TC), and possibly modified according to the setting steps. Let us examine as an example the following data to protect a power transformer:

- CT = 250/5 A
- In protection = 5 A
- Rated current for the transformer = 210A

Heating time constant \* = 60 min. \* manufacturer data

- Transformer with oil natural and air natural circuit (ONAN)

Calculating the threshold and parameters to display on the protection:

The tripping threshold  $I_b$  will be set to the following value:  $I_b = (210/250) \times 1.07^{**} = 0.898$ , or taking into account the setting steps 0.90.

\*\* permanent overload factor

The heating time constant will be set to the required value: 60 min.

Depending on the cooling process (ONAN in this case), the cooling constant will also amount to 60 min ( $C_{TR} = C_{TE}$ ).

The restart inhibition thermal threshold will be set to the required value: 90%

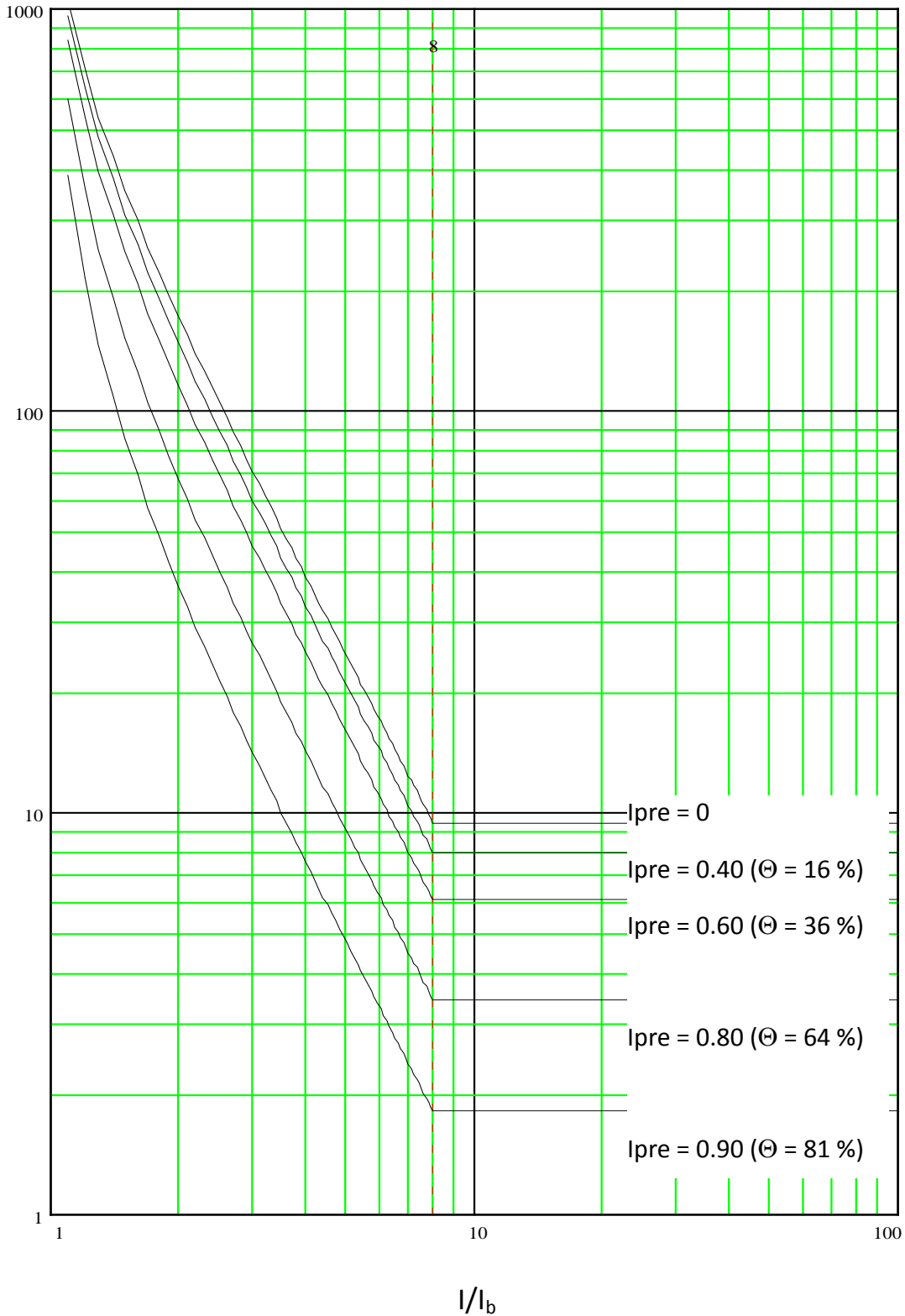
Since the installation is not subjected to great unbalanced currents, the negative sequence weighting factor will be set to 0. As a consequence, unbalances will not be taken into account for calculating the thermal image.

The reclosing factor will be set to 100%, so it does not have any effect on the heating constant. As a complement, you can set the alarm threshold to 90%, so the operating personal are warned before tripping for load shedding of no priority loads.

3.3.2.6 Thermal curves for NPI800-NPI800R and NPID800-NPID800R

3.3.2.6.1 Characteristics of the thermal image (cable and transformer)

The following curves are defined for a time constant  $\tau = 10$  minutes:



**3.3.2.6.2 Cooling curves (cable and transformer)**

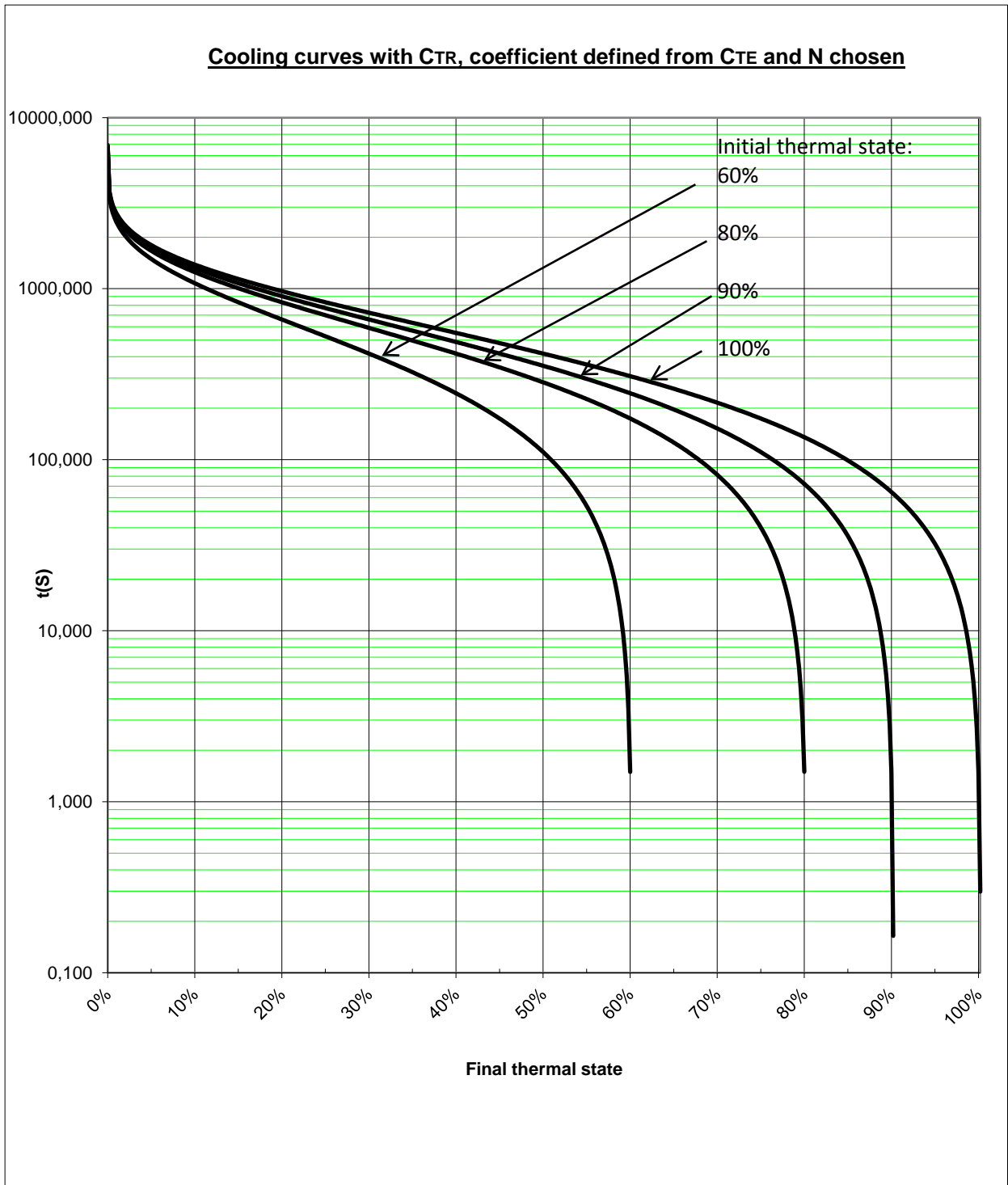
The following curve provides the time necessary for cooling, starting with a given thermal state.

For another value of time constant, multiply the indicated times on the curve by the value in minutes of the used time constant.

Equation cooling curves is as follows:

$$t = C_{TR} \cdot \ln\left(\frac{\theta_{thermal\_state}}{\theta_{trans}}\right) \text{ with } C_{TR} = N \cdot C_{TE}$$

C <sub>TR</sub>	Constant thermal cooling time (in minutes) to be converted in seconds for calculations
C <sub>TE</sub>	Constant thermal heating time (in minutes) to be converted in seconds for calculations
θ <sub>thermal_state</sub>	Coefficient of the initial thermal state of the machine (in %)
θ <sub>trans</sub>	Coefficient corresponding to the thermal state of the machine at the time t
N	Scale factor between the thermal time constant of cooling and heating



For example, the curves above are plotted with the following values:

CTE = 10 min

N = 1

### 3.4 Additional protections

Overcurrent digital protections of the **NP800-NP800R** range offer additional functions to their protection features:

#### 3.4.1 Function maximum of negative phase sequence current [46] NPI800-NPI800R and NPID800-NPID800R

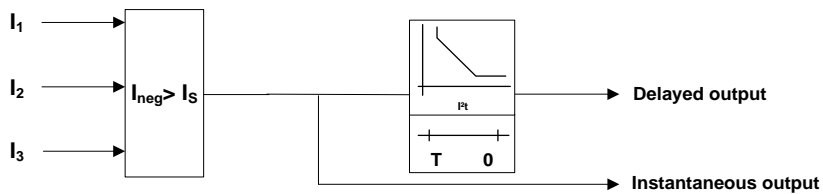
##### 3.4.1.1 Presentation [46] NPI800-NPI800R and NPID800-NPID800R

Any unbalance on an electrical network generates negative phase current. Due to its sensitivity, this function allows for detection of low amplitude current faults between phases as well as between a phase and earth, in network configurations for which standard overcurrent protections are inefficient:

- Phase inversion or phase loss
- Low amplitude two phased overcurrent's (great length outgoing feeders)
- Missing grounding (isolated neutral)
- Faults in the delta windings of the transformers.

This function offers a greater sensitivity than standard phase and earth current protections.

##### 3.4.1.2 Flow chart for [46] NPI800-NPI800R and NPID800-NPID800R



**Fig. 24:** Function maximum of negative phase sequence current [46]

### 3.4.1.3 Setting characteristics for [46] NPI800-NPI800R and NPID800-NPID800R

THRESHOLD FOR THE FUNCTION [46]	Setting
Threshold $I_{negative} I_{2>}$	0.1 to 2.4 In with steps of 0.01 In
TIME DELAY FOR THE FUNCTION [46]	Setting
Definite time-delay	0.04 to 300 s step: see *
Curves with inverse time, very inverse, extremely inverse time, IEC 60255-4 compliant	T <sub>++</sub> : 0.03 to 3 s with steps of 0.01 s
Curves with moderately inverse, very inverse, extremely inverse time, ANSI/IEEE compliant	
Curves with RI inverse time	0.1 to 20 s with steps of 0.1 s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60 ms

\*: between 0.04 and 9.99 s with steps of 0.01 s, between 10.0 s and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1s

For detailed characteristics of tripping curves with inverse time, please refer to the chapter "[3.5 Tripping curves for \[46\] \[51\] \[51N\]](#)".

### 3.4.1.4 Setting advices [46] NPI800-NPI800R and NPID800-NPID800R

Depending on the value found through co-ordination or setting study, you must adapt the thresholds [46] to set on the protection to take into account the rated current of the measurement reducers (CT), and possibly modified according to the setting steps. Let us examine as an example the following data:

- CT = 250/5A
- In protection = 5A
- Rated current for the equipment to protect: 225A
- Tripping value in case of phase negative component = 30% with a definite time delay set to 3 s.

Calculating the threshold and parameters to set on the protection:

- The unit with maximum negative-sequence current [46] will be used with the following setting:  $I_{2>} = (0,3 \times 225) / 250 = 0.27$  In CT, the threshold value remains unchanged, only taking into account the setting steps. The operating characteristics will be chosen definite time with a time delay of 3 s.

### 3.4.2 Detection of broken conductor function [46BC] NPI800-NPI800R and NPID800-NPID800R

#### 3.4.2.1 Introduction to [46BC] NPI800-NPI800R and NPID800-NPID800R

This function is even more sensitive than the maximum of negative phase sequence current function. The fault to detect corresponds to the opening of a strong current circuit, for example following the broken of a conductor.

This kind of fault does not produce a great overcurrent. Therefore, it cannot be detected by overcurrent functions [50] or [51]. In order to detect it, we use the unbalance factor, which corresponds to the ratio of the negative current on the positive current ( $I_2/I_1$ ).

During normal operation, the unbalance factor is low. On the contrary, after a conductor break, it changes and becomes high.

$$\text{unbalance.factor} = \frac{I.\text{negative.component}}{I.\text{positive.component}}$$

Measuring the unbalance factor allows to detect a circuit opening. It is only possible if the protection is connected to 3 phases CTs.

Negative current detection is little sensitive for low load lines.

Please note that the value of the unbalance factor varies according to the place where the fault takes place.

Function [46BC] is inhibited if the negative current component is lower than 8% of the rated current of the protection, in order to avoid any spurious tripping when the measured currents are low.

3.4.2.2 Flow chart [46BC] NPI800-NPI800R and NPID800-NPID800R

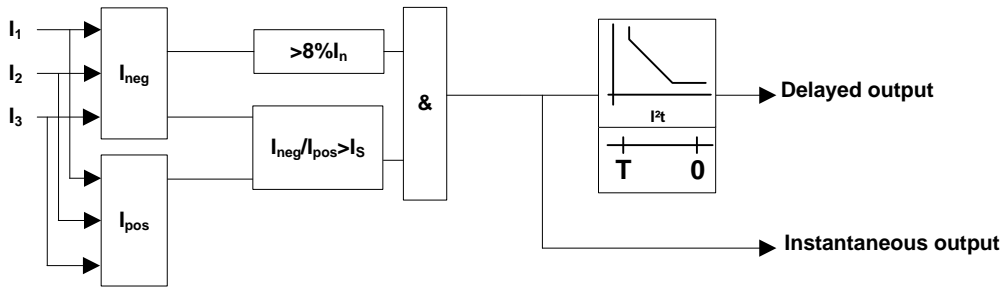


Fig. 25: Detection of broken conductor function [46BC]

3.4.2.3 Setting characteristics [46BC] NPI800-NPI800R and NPID800-NPID800R

THRESHOLDS FOR FUNCTION [46BC]	Setting
Thresholds $I_2/I_1 > - I_2/I_1 >>$ negative / positive component	10 to 250 %
TIME DELAY FOR FUNCTION [46BC]	Setting
Definite time-delay	0.04 to 300 s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60 ms
Minimum negative current to activate the function	$I_2 > 0.08 I_n$

3.4.2.4 Setting advices for [46BC] NPI800-NPI800R and NPID800-NPID800R

Let us examine as an example the following data:

- Calculated tripping value in case of broken conductor detection set to 25% with a definite time delay of 20 s.

Calculating the threshold to display on the protection:

The broken conductor detection unit [46BC] will be used with the following setting:  $I_2/I_1 = 0.25$ .

The operating characteristics will be definite time and the time delay set to 20 s.

### 3.4.3 Function single-phase undercurrent [37] NPIH800-NPIH800R

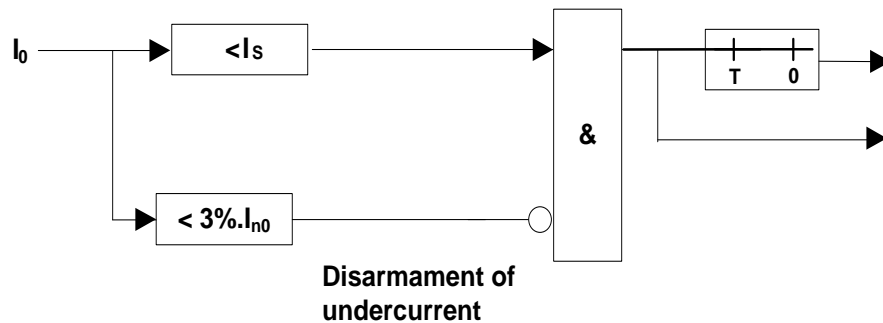
#### 3.4.3.1 Presentation [37] NPIH800-NPIH800R

This undercurrent function (single-phase) allows to check the presence or not of a current of a network component. As example, the function [37] can be used to check an open circuit of a self of compensation. It includes:

- 1 instantaneous threshold  $I_{0<}$  associated to a definite time delay
- 1 disarmament function, which inhibit the function when the circuit-breaker is open. The setting of the inhibition threshold, fixe to  $0.03 I_n$ , avoid any permanent trip order.

**NOTE:** This function is available only with CT connection, for high or low range.

#### 3.4.3.2 Flow-chart [37] NPIH800-NPIH800R



**Fig. 26 :** Single-phase undercurrent function [37] with definite time delay

#### 3.4.3.3 Settings characteristics [37] NPIH800-NPIH800R

THRESHOLDS FOR FUNCTION [37]	Setting
Thresholds $I_{0<}$ CT connection (low range $I_{0>}$ and $I_{0>>}$ )	$0.2$ to $2 I_{n0}$ with a $0.01 I_{n0}$ step
Thresholds $I_{0<}$ CT connection (high range $I_{0>}$ and $I_{0>>}$ )	$0.2$ to $2 I_{n0}$ with a $0.01 I_{n0}$ step
<b>THRESHOLD FOR FUNCTION 37 DISARMAMENT</b>  $I_0 < 0.03 I_{n0}$	On/Off
<b>TIME DELAY FOR FUNCTION [37]</b>	<b>Setting</b>

## PROTECTION OF INCOMERS, CABLE FEEDERS AND TRANSFORMERS

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Definite time delay $t(I_{o<})$	0.04 to 10 s with a 0.01 s step
<b>CHARACTERISTICS</b>	<b>Values</b>
Response time for instantaneous outputs	60 ms

### 3.5 Tripping curves for [46] [51] [51N]

#### 3.5.1 Definite time-delay [46] [51] [51N]

The phase and earth thresholds of NPI800-NPI800R, NPID800-NPID800R, NPIH800-NPIH800R and NPI800-S1 can be selected using a definite time characteristics. The time indicated by the time delay includes all the times from the fault processing to the output relay activation. Real tripping time of the protection equals the value of the time delay plus a delay of about 15ms.

#### 3.5.2 Inverse time delay for IEC standards [46] [51] [51N]

The phase and earth thresholds of NPI800-NPI800R, NPID800-NPID800R, NPIH800-NPIH800R and NPI800-S1 offer a choice of 3 curves with inverse time according to the IEC 60255-4.

##### 3.5.2.1 Equation IEC for [46] [51] [51N]

Here is typical equation for these curves:

$$t = T * \left( \frac{K}{(I/I_s)^\alpha - 1} \right)$$

- t      Tripping time
- I      Value of the measured current
- Is     Value of the set threshold
- α, K   Coefficients for the curve definition (inverse, extremely inverse, ...)
- T++   Time multiplier with a value between 0.03 and 3 s.

These curves are limited to the range of I values comprised between 1.1 Is and 20 Is.

Dynamic measurement:

- - Phase: from 0.05 to 24 In
- - Zero sequence on CT's: from 0.005 to 2.4 In<sub>0</sub>
- - Zero sequence on CT's: from 0.05 to 24 In<sub>0</sub>
- - Zero sequence on CBCT: from 0.1 to 48 A (primary of the CBCT)
- When the monitored value is greater than 20 times the threshold, the tripping time will never be higher than the value of 20 times the threshold. (Inverse time relay function with Definite Minimum Time)



- If the monitored value exceeds the measuring capacity of the relay inputs, i.e. 24 In for the phase current (18 In for NPG800 - NPG800R) or 2.4 In<sub>0</sub>, 24 In<sub>0</sub> and 48A for earth fault current, the trip time is function, based on the threshold setting, of the higher measured value i.e. 18, 24 In, 2.4 In<sub>0</sub>, 24 In<sub>0</sub> or 48A.

The real tripping time of the protection is equal to the calculated value, plus a delay of approximately 15 ms.

Types of time delay	Curve limits	T	K	$\alpha$
Inverse time	1.1 Is < I < 20 Is	Configurable between 0.03 and 3 s with steps of 0.01 s	0.140	0.02
Very inverse time			13.5	1
Extremely inverse time			80	2

### 3.5.2.2 Example of choice for an inverse time delay curve NPI800-NPI800R and NPID800-NPID800R

On a non-limiting example, figure 27 compares selectivity of a NPI800-1 (or NPI800R-1), protecting a power transformer, and NPI800-2 (or NPI800R-2) used to protect outgoing feeder at the secondary of this transformer.

The operating characteristic of the NPI800-2 (or NPI800R-2) has been set to definite time with two thresholds and two time delays [51] [50].

For function [51] of the NPI800-1 (or NPI800R-1), an IEC characteristic with inverse time has been chosen, which allows high overloads during short duration. The characteristic of unit [50] is definite time.

To ensure selectivity between the two protections a threshold setting value of 300 A has been chosen for [50], which corresponds to the threshold value for NPI800-2 (or NPI800R-2) and constitutes a stress point.

To select the curve T++ which is best adapted to the selectivity criteria of NP800-1 (or NPI800R-1), the following elements must be taken into account:

- curve going through 2s for a current of 300A
- setting value for the threshold [51] of NP800-1 (or NPI800R-1): 100A.

This choice has been made by using the following formula\*:

$$T_{++} = \frac{t \times \left[ \left( \frac{I}{I_s} \right)^{0,02} - 1 \right]}{0.140}$$

With:

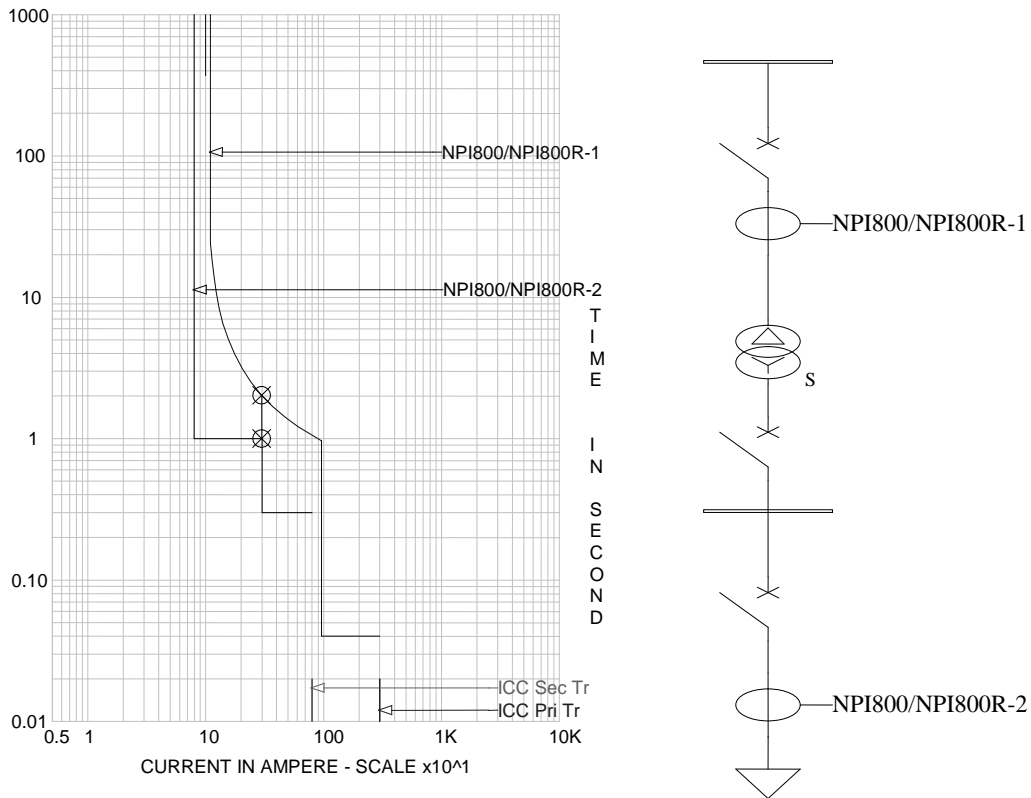
- T++ = curve to set on the protection
- I / Is = multiple of the threshold setting [51], depending on the current value
- t = theoretical value of the tripping time for the current value I/Is

In our example:

- $I/I_s = 3$  ( $I=300$  A and  $I_s=100$ A)
- $t = 2$  seconds

With a result of 0.317 and according to the setting steps of the protection the chosen T++ curve is: 0.32

\* extrapolated formula from IEC inverse time curves.



**Fig. 27:** Example of co-ordination study on a transformer

The following formulae\* can be used for the choice of:

- IEC curve with very inverse time:
- IEC curve with extremely inverse time:

$$T_{++} = \frac{t \times \left[ \left( \frac{I}{I_s} \right) - 1 \right]}{13,5}$$

$$T_{++} = \frac{t \times \left[ \left( \frac{I}{I_s} \right)^2 - 1 \right]}{80}$$

With:

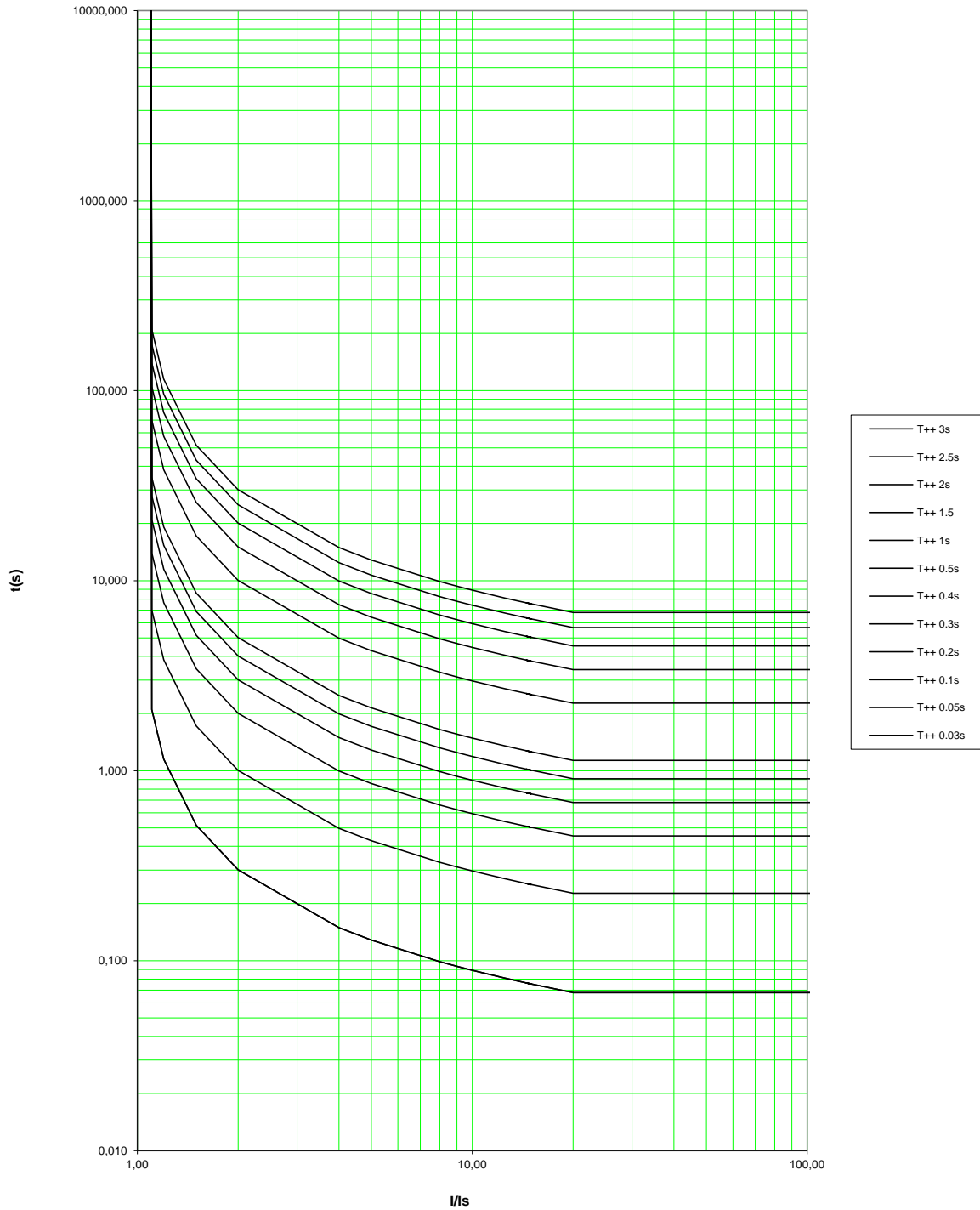
- $T_{++}$  = curve to set on the protection
- $I/I_s$  = multiple of the threshold setting [51], depending on the current value
- $t$  = theoretical value of the tripping time at the current value  $I/I_s$

\* extrapolated formula from IEC inverse time curves.

3.5.2.3 IEC compliant tripping curve with inverse time

$$t = \frac{0.140 T_{++}}{(I/I_s)^{0.02} - 1} \text{ Pour } 1.1I_s < I < 20I_s$$

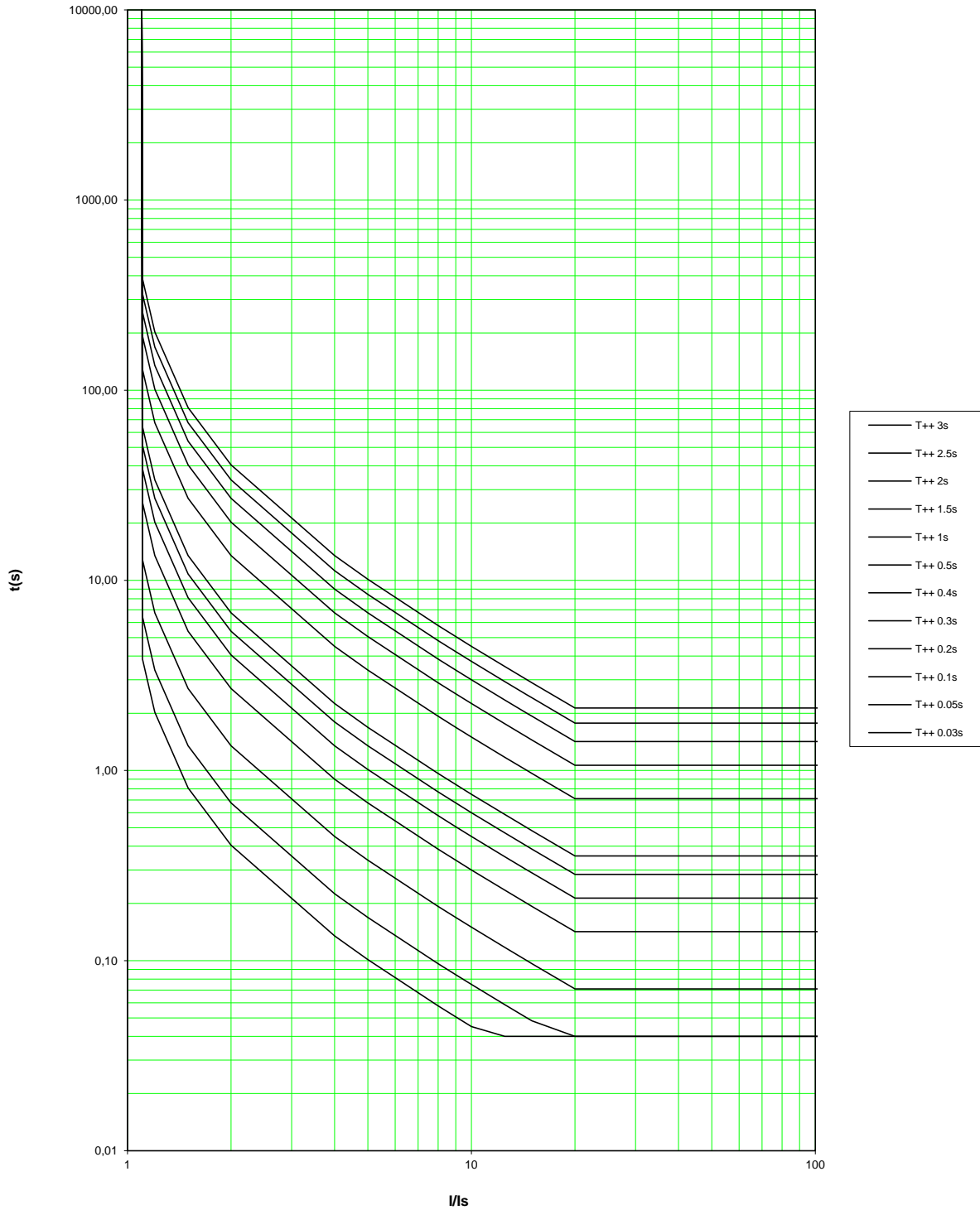
IEC inverse time curves



3.5.2.4 IEC compliant tripping curve with very inverse time

$$t = \frac{13.5 T_{++}}{(I/I_s) - 1} \text{ For } 1.1I_s < I < 20I_s$$

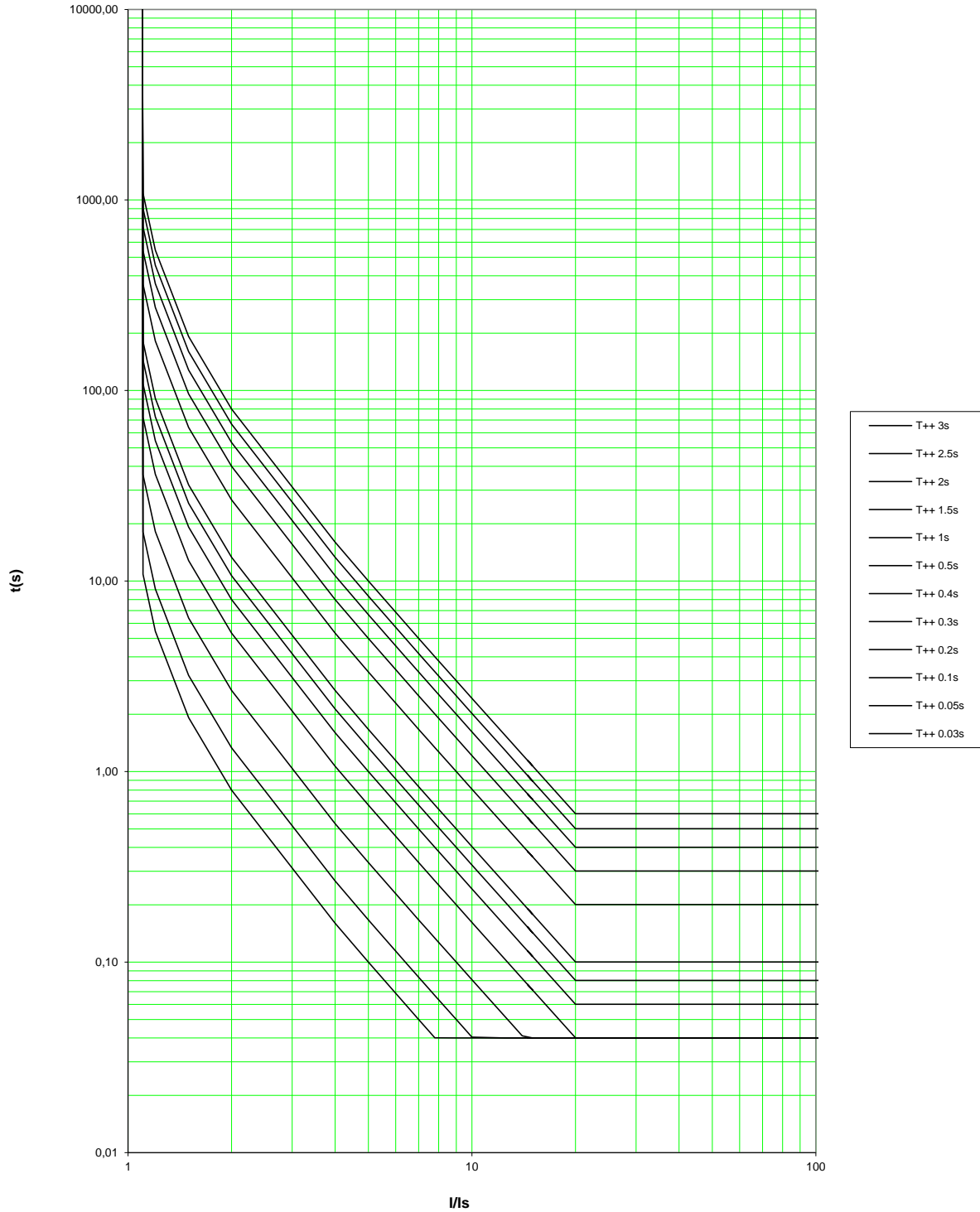
IEC curves with very inverse time



3.5.2.5 IEC compliant tripping curves with extremely inverse time

$$t = \frac{80 T_{++}}{(I/I_s)^2 - 1} \text{ Pour } 1.1I_s < I < 20I_s$$

IEC curves with extremely inverse time



**3.5.3 Inverse time delays for ANSI/IEEE standards [46] [51] [51N]**

The phase and earth thresholds of NPI800-NPI800R, NPID800-NPID800R, NPIH800-NPIH800R and NPI800-S1 offer a choice of 3 ANSI/IEEE compliant inverse time curves.

**3.5.3.1 ANSI/IEEE compliant equation of functions [46] [51] [51N]**

The equation for these curves is as follows:

$$t = T * \left( \frac{A}{(I/I_s)^\alpha - 1} + B \right)$$

- t                      Tripping time
- I                      Value of the measured current
- I<sub>s</sub>                    Value of the programmed threshold
- α, A, B              Definition coefficients for the curves (inverse, very inverse or extremely inverse)
- T ++                 Multiplying factor between 0.03 and 3 s.

All these curves are limited to a range of I values between 1.1 I<sub>s</sub> and 20 I<sub>s</sub>.

Dynamic measurement:

- - Phase: from 0.05 to 24 I<sub>n</sub>
- - Zero sequence on CT's: from 0.005 to 2.4 I<sub>n0</sub>
- - Zero sequence on CT's: from 0.05 to 24 I<sub>n0</sub>
- - Zero sequence on CBCT: from 0.1 to 48 A (primary of the CBCT)
- When the monitored value is greater than 20 times the threshold, the tripping time will never be higher than the value of 20 times the threshold. (Inverse time relay function with Definite Minimum Time)



- If the monitored value exceeds the measuring capacity of the relay inputs, i.e. 24 I<sub>n</sub> for the phase current (18 I<sub>n</sub> for NPG800 - NPG800R) or 2.4 I<sub>n0</sub>, 24 I<sub>n0</sub> and 48A for earth fault current, the trip time is function, based on the threshold setting, of the higher measured value i.e. 18, 24 I<sub>n</sub>, 2.4 I<sub>n0</sub>, 24 I<sub>n0</sub> or 48A.

The real tripping time of the protection is equal to the calculated value, plus a delay of approximately 15 ms.

Type of time delay	Limits of curves	T	A	$\alpha$	B
Moderately inverse time	1.1 Is < I < 20 Is	0.03 to 3 s with steps of 0.01 s	0.0515	0.02	0.1140
Very inverse time	1.1 Is < I < 20 Is		19.61	2	0.4910
Extremely inverse time	1.1 Is < I < 20 Is		28.2	2	0.1217

### 3.5.3.2 ANSI/IEEE compliant setting advices

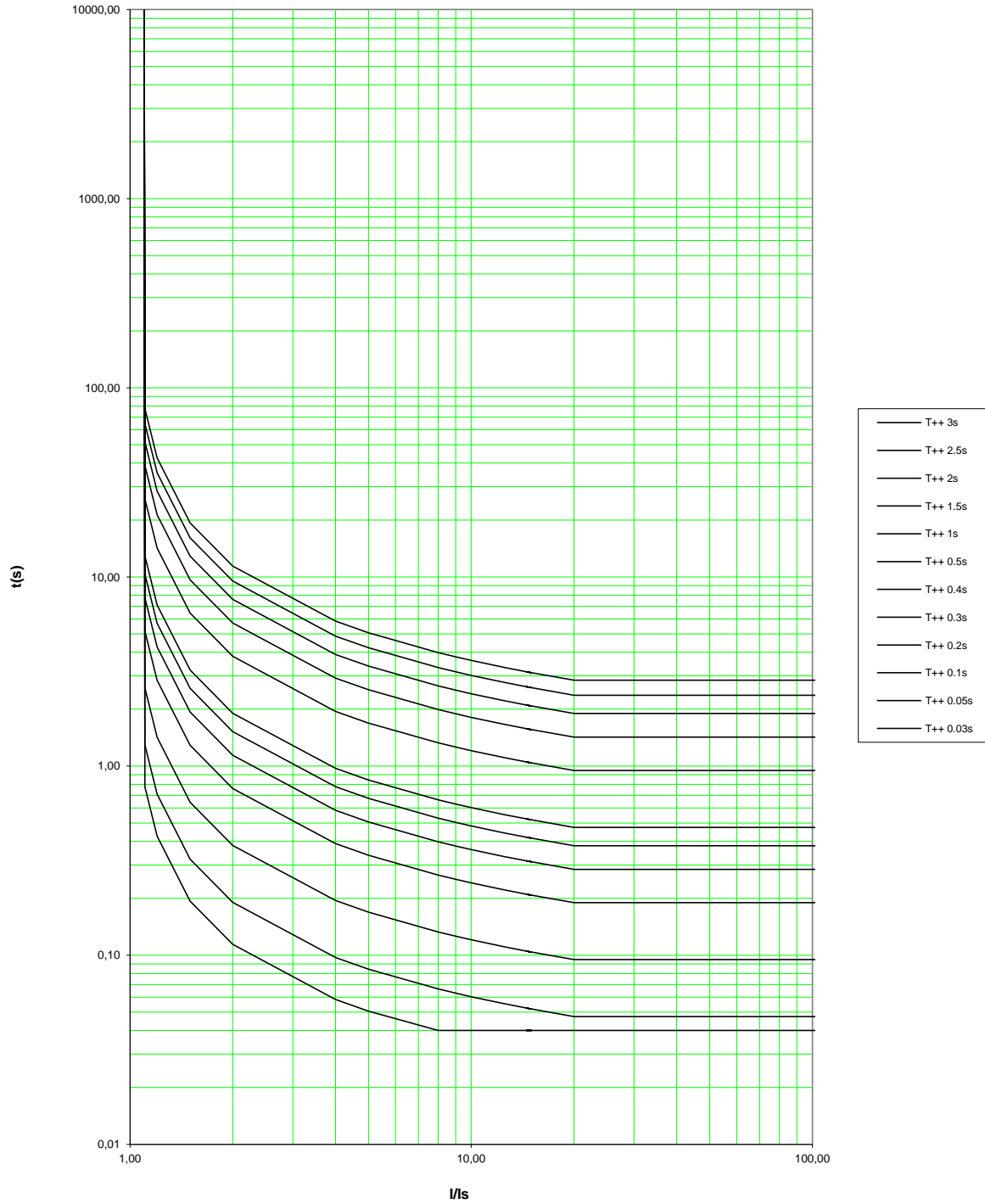


Please refer to the examples given for the IEC standard.

3.5.3.3 ANSI/IEEE compliant tripping curves with moderately inverse time

$$t = T * \left( \frac{0.0515}{(I/I_s)^{0.02} - 1} + 0.1140 \right) \text{ Pour } 1.1I_s < I < 20I_s$$

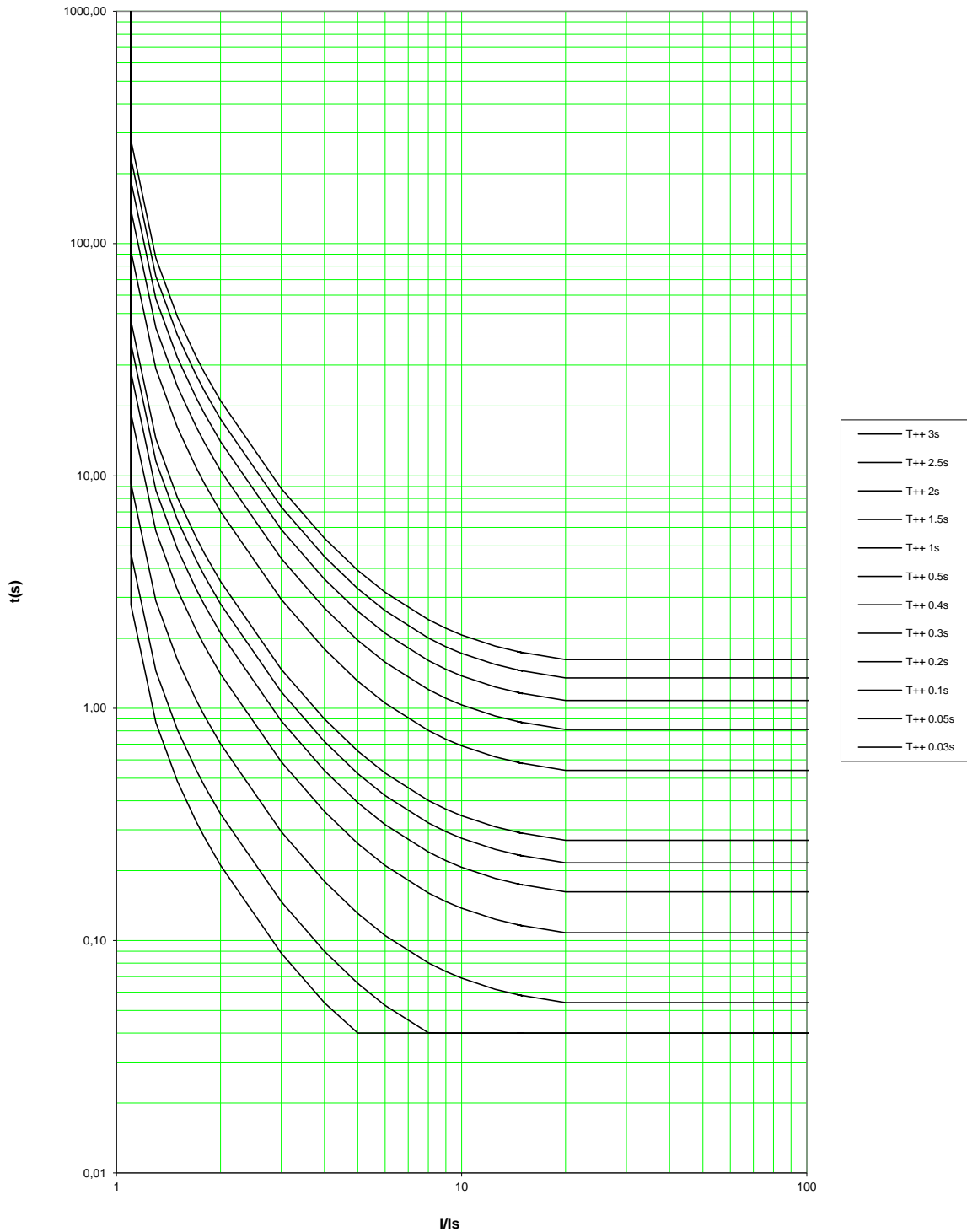
IEC curves - moderately inverse



3.5.3.4 ANSI/IEEE compliant tripping curves with very inverse time

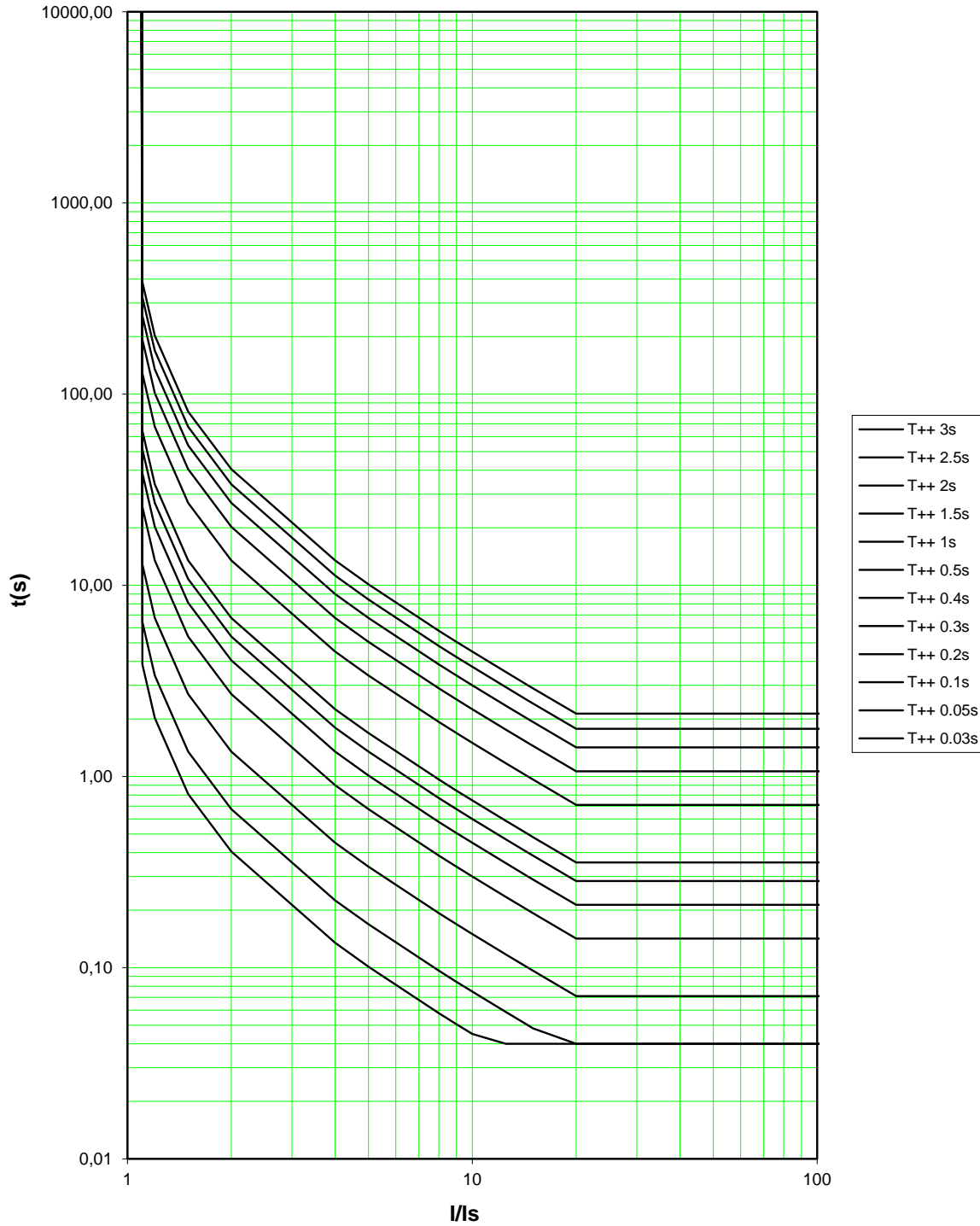
$$t = T * \left( \frac{19.6}{(I/I_s)^2 - 1} + 0.4910 \right) \text{ Pour } 1.1I_s < I < 20I_s$$

ANSI curves with very inverse time



3.5.3.5 ANSI/IEEE compliant tripping curves with extremely inverse time

$$t = T * \left( \frac{28.2}{(I/I_s)^2 - 1} + 0.1217 \right) \text{ Pour } 1.1I_s < I < 20I_s$$



**3.5.4 Inverse time delay with electromechanical type**

The phase and earth thresholds of NPI800-NPI800R, NPID800-NPID800R, NPIH800-NPIH800R and NPI800-S1 allows for selection of an RI inverse time curve with electromechanical type.

**3.5.4.1 RI Equation for NPI800-NPI800R and NPID800-NPID800R**

The typical equation for this curve is as follows:

$$t = \frac{T_{++}}{0.339 - \frac{0.236}{(I/I_s)}} \quad \text{Pour } 1.1I_s < I < 20I_s$$

- t                      Tripping time
- G                      Value of measured unit
- G<sub>s</sub>                    Value of the threshold for the programmed unit
- T<sub>++</sub>                    Multiplying factor between 0.03 and 3 s.

Dynamic measurement:

- - Phase: from 0.05 to 24 I<sub>n</sub>
- - Zero sequence on CT's: from 0.005 to 2.4 I<sub>n0</sub>
- - Zero sequence on CT's: from 0.05 to 24 I<sub>n0</sub>
- - Zero sequence on CBCT: from 0.1 to 48 A (primary of the CBCT)
- When the monitored value is greater than 20 times the threshold, the tripping time will never be higher than the value of 20 times the threshold. (Inverse time relay function with Definite Minimum Time)



- If the monitored value exceeds the measuring capacity of the relay inputs, i.e. 24 I<sub>n</sub> for the phase current (18 I<sub>n</sub> for NPG800 - NPG800R) or 2.4 I<sub>n0</sub>, 24 I<sub>n0</sub> and 48A for earth fault current, the trip time is function, based on the threshold setting, of the higher measured value i.e. 18, 24 I<sub>n</sub>, 2.4 I<sub>n0</sub>, 24 I<sub>n0</sub> or 48A.
- 

The real tripping time of the protection is equal to the calculated value, plus a delay of approximately 15 ms.

**3.5.4.2 RI application for NPI800-NPI800R and NPID800-NPID800R**

Use of this characteristic is recommended when selectivity with other network protections is not required.

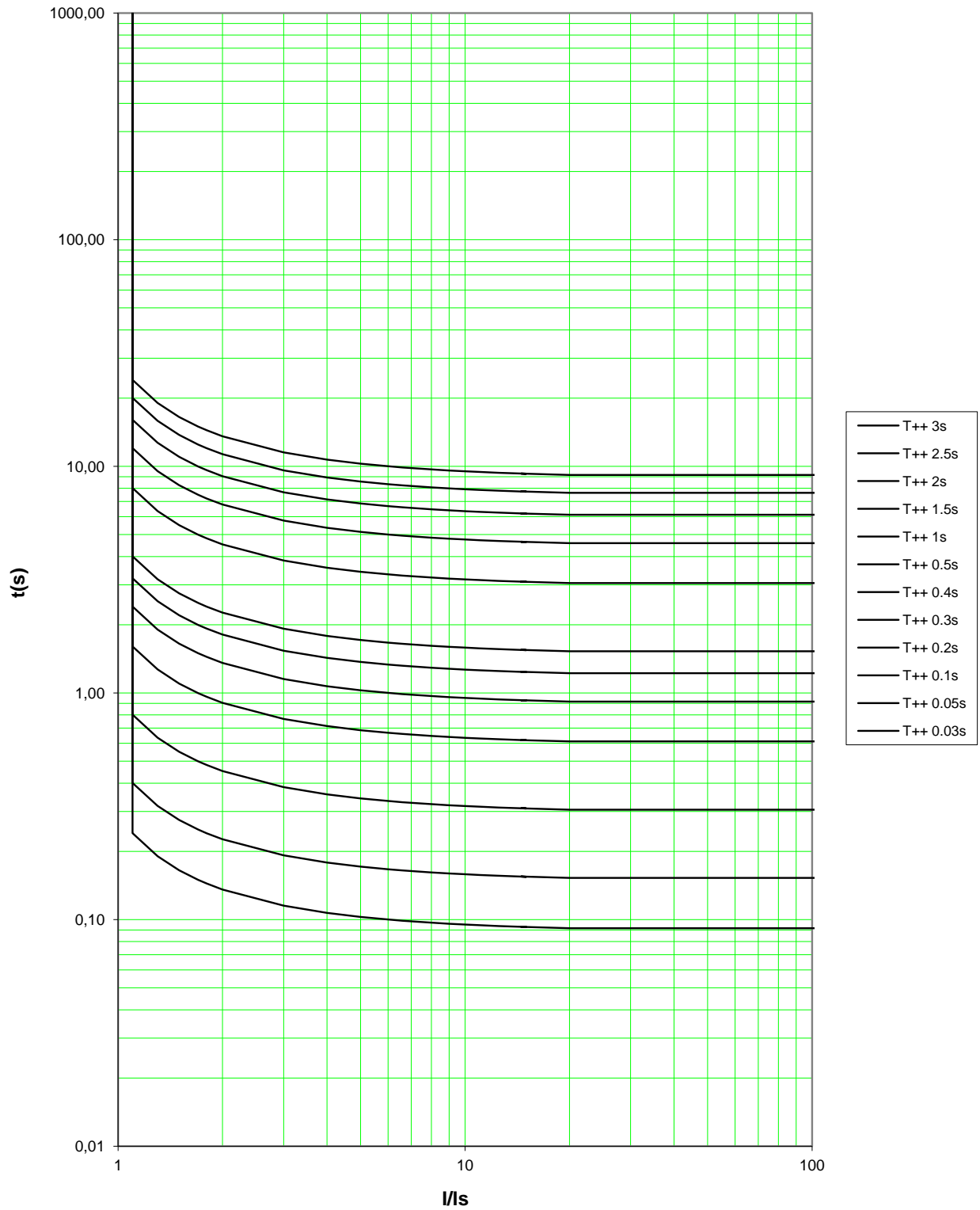
**3.5.4.3 RI setting advices for NPI800-NPI800R and NPID800-NPID800R**



Please refer to the examples provided with the IEC standard.

3.5.4.4 RI curve for NPI800-NPI800R and NPID800-NPID800R

RI inverse curves



### **3.5.5 Programmable inverse time delay for NPI800-NPI800R and NPID800-NPID800R**

The NP800-NP800R models are designed to work according to two configurable tripping curves with inverse time.

These curves are to be defined by the user, and then downloaded by ICE at the factory site. For more information, please contact us.

Like any other inverse time curves, these two characteristics can then be shared by the other protection functions, in the same way as IEC or ANSI/IEEE curves.

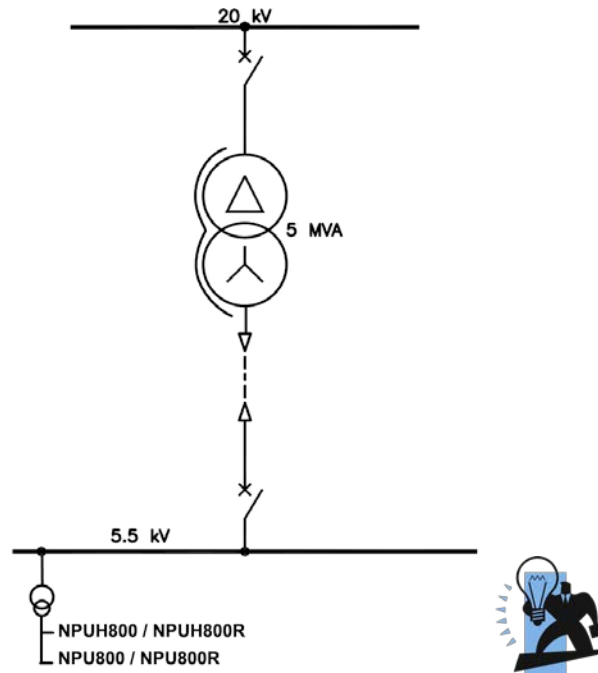
## 3.6 Monitoring and network management protections

### 3.6.1 Overview

The **NPU800-NPU800R-NPU800RE**, **NPW800-NPW800R** and **NPSC800-NPSC800R-NPSC800RE** models are mainly dedicated to electrical network monitoring and management functions.

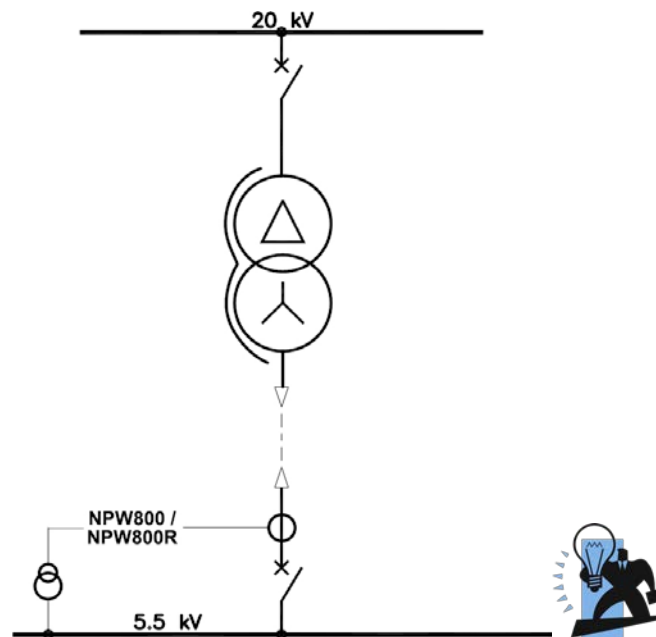
Digital voltage and frequency protections **NPU800-NPU800R-NPU800RE** perform voltage monitoring for electrical networks and/or islanding, or load shedding for no priority loads. So when the electrical supply of a switchboard is performed by two transformers feeding each a half-busbar, in case of a transformer failure, it is possible to perform automatic load transfer from a half-busbar to the other. Unless otherwise indicated, to achieve this, the following functions will be performed by the NPU800-NPU800R-NPU800RE:

- Starting transfer for lack of voltage
- Checking that the healthy incomer has not already been subjected to a transitional status during the few seconds before transfer initialisation.
- Checking that the recorded voltage drop is not the result of a downstream fault (using a current protection such as NPI800-NPI800R); since a transfer in this case would lead to a complete substation loss.
- Checking the residual voltage on the busbar that will be subjected to the transfer, if it supplies motors.
- Load shedding for rotating loads upon voltage drop.



**Fig. 28:** Example of voltage protection on a HV network

- ◆ Use of power digital protections **NPW800-NPW800R** allows for islanding of a production installation with its own production units in case of failure of the energy distribution line, when it also supplies other subscribers. In addition, these protections enable monitoring the direction of the energy flow, power factor management,  $\phi$  tangent, and they include NPU800-NPU800R-NPU800RE functions for network voltage and frequency monitoring.



**Fig. 29:** Power protection connected on a HV network

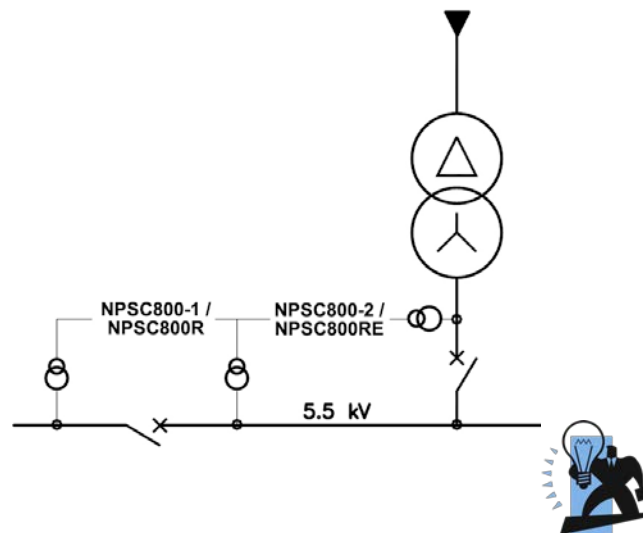
- ◆ The **NPSC800-NPSC800R** models perform synchronism check between two sources and they are commonly used to authorise closing command transmission towards a coupling circuit breaker. They are available in 2 alternatives:

- NPSC800-1 / NPSC800R: synchronism check [25]
- NPSC800-2 / NPSC800RE: synchronism check [25] with network management

NPSC800-1 or NPSC800R perform synchronism check between 2 sources and they are commonly used to allow closing command transmission towards a bus-tie circuit breaker.

NPSC800-2 or NPSC800RE also perform synchronism check, but they also allow network management in the four following situations:

- Line powered (Live Line) – busbars not powered (Dead bus): **LL-DB**
- Line not powered (Dead line) – busbars powered (Live bus): **DL-LB**
- Line not powered (Dead line) – busbars not powered (Dead bus): **DL-DB**
- Reconnection mode: coupling of two sections issued from the same source.



**Fig. 30:** Paralleling management of busbars with NPSC800-NPSC800R

### 3.6.2 Undervoltage function [27] NPU800-NPU800R-NPU800RE and NPW800-NPW800R



For NPU, implementing the undervoltage function [27] involves the automatic deactivation of the positive sequence undervoltage function [27P].

#### 3.6.2.1 Presentation [27] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

This function allows detection of voltage drop and it also allows for load shedding of no priority consumer networks during an overload or to check voltage before switching sources. With the NPU800-NPU800R-NPU800RE models, the undervoltage function offers 4 thresholds ( $U<$ ,  $U<<$ ,  $U<<<$  and  $U<<<<$ ) and with the NPW800-NPW800R models, this function offers three undervoltage thresholds ( $U<$ ,  $U<<$  and  $U<<<$ ), each of them associated with an inverse or definite time characteristic.

It enables monitoring of three phase or two phase voltages, phase-to-phase or phase to neutral, associated with a logic function “OR” or “AND”. When using the logic “OR”, as soon as the value of one of the monitored voltages is lower to one of the set thresholds (with the logic “AND”, all voltages are monitored), an alarm is generated (instantaneous output) and simultaneously a time delay is started. Upon expiry of the time delay, the time-delayed output is activated.

Using either logic “OR” and “AND”, when all voltages are higher again to the threshold of 3 % (reset percentage) the protection goes back to its initial state.

Threshold setting is performed using percentages of  $U_n$ , independently of the selected wiring mode (phase to neutral or phase-to-phase voltages).

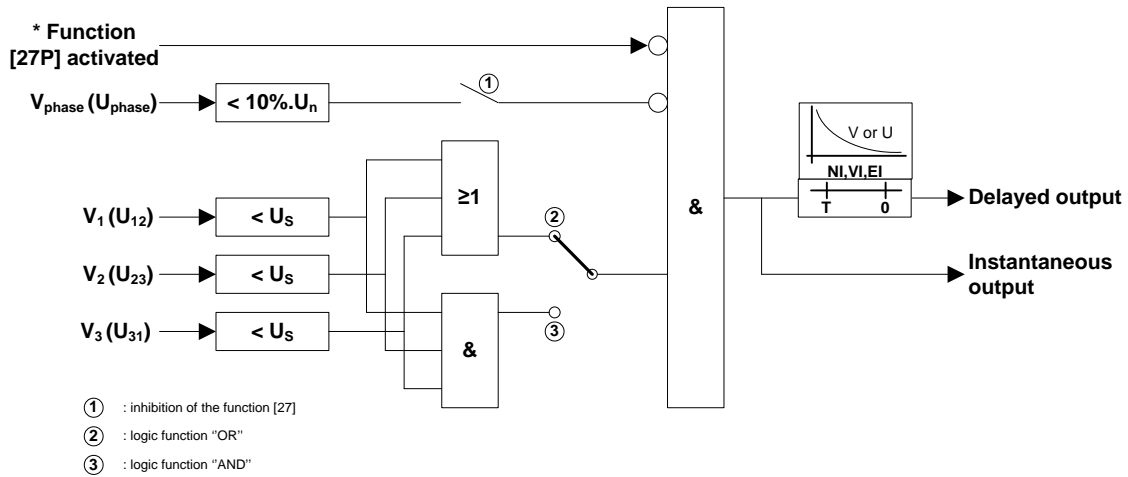
Example:

- Phase to neutral voltage mode:  
 $U_n = 63.3 \text{ V}$ , threshold = 40 %  $U_n$   
 $\Rightarrow$  Fault detection occurs for  $V_x < 0.4 * 63.3 = 25.3 \text{ V}$
- Phase-to-phase voltage:  
 $U_n = 110 \text{ V}$ , threshold = 40 %  $U_n$   
 $\Rightarrow$  Fault detection occurs for  $U_{xy} < 0.4 * 110 = 44 \text{ V}$ .

As to avoid tripping when powering on a protection on a non-powered network, it is possible to choose to deactivate the undervoltage function when all measured voltages are lower than 10 % of  $U_n$  (inhibition threshold), and this whatever logic function is being used (“OR” or “AND”). If inhibition is activated, the minimum setting available takes a value of 0.2  $U_n$ , to avoid a systematic inhibition of the function when the threshold is reached. As a

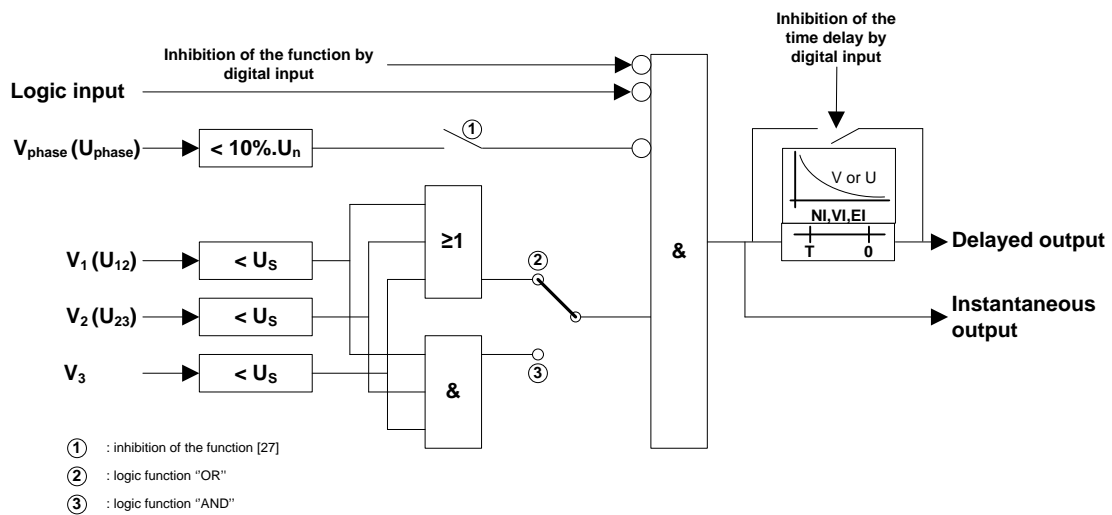
complement, for NPW800-NPW800R, it is possible to associate a digital input to the position of the coupling circuit breaker, thus allowing for temporary disconnection of the function or of the time delay block for this function.

**3.6.2.2 Flow chart [27] NPU800-NPU800R-NPU800RE**



**Fig. 31:** Undervoltage [27] function on NPU800-NPU800R-NPU800RE

**3.6.2.3 Flow chart [27] NPW800-NPW800R**



For the NPW800-NPW800R, the function can be inhibited using digital input. The time delay can be inhibited in a similar way.

**Fig. 32:** Undervoltage function [27] on NPW800-NPW800R

**3.6.2.4 Setting characteristics for [27] NPU800-NPU800R-NPU800RE and NPW800-NPW800R**

THRESHOLDS FOR THE FUNCTION [27]	Setting
Low threshold $U<$ - $U<<$ - $U<<<$ - $U<<<<^{**}$	0.05 to 1.20 $U_n$ steps of 0.01 $U_n$
TIME DELAYS FOR THE FUNCTION [27]	Setting
Definite time-delay: $t(U<)$ - $t(U<<)$ - $t(U<<<)$ - $t(U<<<<)^{**}$	0.04 to 300 s steps: see *
Inverse time curves CEI: inverse, very inverse, extremely inverse $t(U<)$ - $t(U<<)$ - $t(U<<<)$ - $t(U<<<<)^{**}$	T++: 0.03 to 3 s steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse $t(U<)$ - $t(U<<)$ - $t(U<<<)$ - $t(U<<<<)^{**}$	T++: 0.03 to 3 s steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Setting range for the rated value of the voltage measurement ( $U_n$ )	33 V to 120 V (steps of 0.1 V)
Blocking threshold for the undervoltage function [27]	10 % $U_n$

\* Between 0.04 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1s, between 30 and 300 s with steps of 1s.

\*\* threshold  $U<<<<$  only available on the NPU800-NPU800R-NPU800RE models.

**3.6.2.5 Setting advices for [27] NPU800-NPU800R-NPU800RE and NPW800-NPW800R**

Depending on the value you obtained through a co-ordination or a setting table study, the thresholds [27] to set on the protection must be adapted to the rate voltage of the measurement reducers (VT), and possibly corrected according to the step of the setting range.

Let us examine the following data as an example:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3}$
- tripping value calculated for the first threshold in case of voltage drop: 5.1 kV with a definite time delay of 1 s.
- tripping value calculated for the second threshold in case of voltage drop: 4.2 kV with a time definite time delay of 0.5 s.

Calculating the thresholds to set on the protection:

- For the first threshold, the low threshold  $U<$  of function [27] will be used with the following setting:  
 $U< = 5.1/6 = 0.85$   
Chosen operating characteristic will be definite time with a time delay set to 1 s.
- For the second threshold, the low threshold  $U<<$  of function [27] will be used with the following setting:  
 $U<< = 4.2/6 = 0.7$   
Chosen operating characteristic will be definite time with a time delay set to 0.5 s.
- The third threshold, the low threshold  $U<<<$  will be set out of service.
- The same applies to the fourth threshold  $U<<<<$  for the NPU800-NPU800R-NPU800RE.

### 3.6.3 Function positive sequence undervoltage of [27P] NPU800-NPU800R-NPU800RE



Implementing the function positive sequence undervoltage [27P] involves the automatic deactivation of the undervoltage function [27]. It requires a connection of the three phases.

#### 3.6.3.1 Introduction to [27P] NPU800-NPU800R-NPU800RE

Through measurement of the positive\* component, this function ensures a global monitoring of the three phases voltage system in temporary or permanent unbalanced working conditions (single phase reclosing) of the supply network. Calculation of the positive voltage is performed via phase to neutral or phase-to-phase measures on the three analogue inputs of the protection.

When the positive component of the voltage becomes lower to one of the set thresholds, an alarm is generated (instantaneous output) and simultaneously a time delay is launched. Upon expiry of the time delay, the time-delayed output is activated.

When the positive component of voltage is higher again to the threshold of 3 % (reset percentage) the protection goes back to its initial state.

\* measurement requiring the connection of the three phase inputs to a three-phase network.

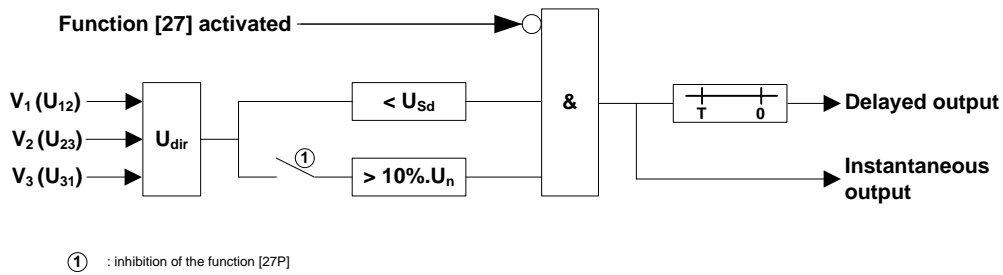
To set the thresholds, use percentages of  $U_n$ , independently of the wiring mode (phase to neutral voltage or phase-to-phase voltage).

Example:

- Phase to neutral voltage mode:  
 $U_n = 63.3 \text{ V}$ , threshold = 85 %  $U_n$   
 $\Rightarrow$  Fault detection is performed for  $V_d < 0.85 * 63.3 = 53.8 \text{ V}$
- phase-to-phase voltage mode:  
 $U_n = 110 \text{ V}$ , threshold = 85 %  $U_n$   
 $\Rightarrow$  Fault detection is performed for  $U_d < 0.85 * 110 = 93.5 \text{ V}$ .

This function can be deactivated when the measured positive voltage is lower than 10 % of  $U_n$  (inhibition threshold).

3.6.3.2 Flow chart for [27P] NPU800-NPU800R-NPU800RE



**Fig. 33:** Positive sequence undervoltage function [27P]

3.6.3.3 Setting characteristics for [27P] on NPU800-NPU800R-NPU800RE

Thresholds for the function 27P	Setting
Low thresholds $U_{d<} - U_{d<<} - U_{d<<<}$	0.05 to 1.20 $U_n$ with steps of 0.01 $U_n$
Time delay for the function 27P	Setting
Definite time-delay: $t(U_{d<}) - t(U_{d<<}) - t(U_{d<<<})$	0.04 to 300 s step: seer *
Characteristics	Values
Reset percentage	103 %
Response time for instantaneous outputs	60ms
Reset time	< 55ms
Range of setting for the rated value of the measuring voltage ( $U_n$ )	33 V to 120 V (with steps of 0.1 V)
Inhibition threshold for the function [27P]	10 % $U_n$

\* between 0.04 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1s, between 30 and 300 s with steps of 1s.

3.6.3.4 Setting advices for [27P] NPU800-NPU800R-NPU800RE

Depending on the value found through a setting study, you must adapt the thresholds [27P] to set on the protection to take into account the rated voltage of the measurement reducers (VT), and possibly modified according to the setting steps.

Let us examine as an example the following data:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3}$
- Tripping value calculated for the first threshold in case of positive voltage drop: 5.1 kV with a definite time delay of 1 s.
- Tripping value calculated for the second threshold in case of positive voltage drop: 4.2 kV with a definite time delay of 0.5 s.

Calculation of the thresholds to display on the protection:

- For the first threshold, the low threshold  $U_{d<}$  of the function [27P] will be used with the following setting:  
 $U_{d<} = 5.1/6 = 0.85$   
The time delay will be set to 1 s.
- For the second threshold, the low threshold  $U_{d<<}$  of the function [27P] will be used with the following setting:  
 $U_{d<<} = 4.2/6 = 0.7$   
The time delay will be set to 0.5 s.
- The third threshold, the low threshold  $U_{d<<<}$  of the function [27P] will be set out of service.

### 3.6.4 Function with maximum of negative phase sequence voltage [47] NPU800-NPU800R-NPU800RE

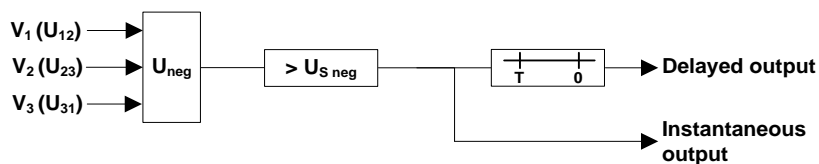
#### 3.6.4.1 Introduction to [47] NPU800-NPU800R-NPU800RE

The function with maximum of negative phase sequence voltage enables the detection of supply unbalances (order of succession of phases, loss of phases...) by monitoring the negative component of voltage, and preparing an alarm to warn the operator of a permanent voltage unbalance.



The negative voltage is calculated using a connection of the three phases.

#### 3.6.4.2 Flow chart for [47] NPU800-NPU800R-NPU800RE



**Fig. 34:** Function maximum of negative phase sequence voltage [47]

#### 3.6.4.3 Setting characteristics of [47]

Thresholds for the function 47	Setting
Thresholds $U_{neg>} - U_{neg>>}$	0.03 to 0.3 $U_n$ with steps of 0.01 $U_n$
Time delay for the function 47	Setting
Definite time-delay: $t(U_{neg>}) - t(U_{neg>>})$	0.04 to 300 s pas: see *
Characteristics	Values
Response time for the instantaneous outputs	60ms
Setting range for the rated value of the measuring voltage ( $U_n$ )	33 V to 120 V (with steps of 0.1 V)

### 3.6.4.4 Setting advices for [47] NPU800-NPU800R-NPU800RE

Let us examine as an example the following data:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3}$
- Tripping value calculated for the first threshold  $U_{neg>}$  in case of supply unbalance: 0.6 kV with a definite time delay of 10 s.
- Tripping value calculated for the second threshold  $U_{neg>>}$  in case of supply unbalance: 1.2 kV with a definite time delay of 0.5 s.

Calculating the thresholds to display on the protection:

- The threshold  $U_{neg>}$  for the function [47] will be used with the following setting:  
 $U_{neg>} = 0.6/6 = 0.1$   
The time delay  $t(U_{neg>})$  will be set to 10 s.
- Le threshold  $U_{neg>>}$  for the function [47] will be used with the following setting:  
 $U_{neg>>} = 1.2/6 = 0.2$   
The time delay  $t(U_{neg>>})$  will be set to 0.5 s.

### 3.6.5 Function overvoltage of [59] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

#### 3.6.5.1 Introduction to [59] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

This function ensures detection of abnormal overvoltage on a three phase network. It enables monitoring of three phase voltages, phase-to-phase or simple, associated with a logic function "OR" or "AND".

When setting into operation, you must specify the type and the number of voltages to monitor, according to the wiring of the protection:

- three phase-to-phase (or simple) voltages: U12 (V1), U23 (V2) and U31 (V3)
- two phase-to-phase (or simple) voltages: U12 (V1) and U23 (V2)
- one phase-to-phase (or simple) voltage: U12 (V1).

in case of monitoring of phase to neutral, you can define different tripping and signalisation relay for each phase.

The function presents two overvoltage thresholds ( $U>$  and  $U>>$ ), each of them being associated with a definite time or inverse time characteristic. To configure the thresholds, use percentages of  $U_n$ , whatever wiring mode (phase to neutral or phase-to-phase voltage) has been chosen.

Example:

- phase to neutral voltage mode:  
 $U_n = 63.3 \text{ V}$ , threshold = 110 %  $U_n$   
 $\Rightarrow$  Fault detection is performed for  $V_x > 1.1 * 63.3 = 70 \text{ V}$
- phase-to-phase voltage mode:  
 $U_n = 110 \text{ V}$ , threshold = 120 %  $U_n$   
 $\Rightarrow$  Fault detection is performed for  $U_{xy} < 1.2 * 110 = 132 \text{ V}$ .

Using the "OR" logic, as soon as the value of one of the monitored voltages reaches one of the thresholds set (all monitored voltages using the "AND" logic), an alarm is generated on the instantaneous output and simultaneously, a time delay is launched. Upon expiry of the time delay, the time-delayed output is activated.

Using the "OR" and "AND" logic, when all voltages are again lower than 3 % threshold (reset percentage) the protection returns to its initial state.

3.6.5.2 Flow chart for [59] NPU800-NPU800R-NPU800RE

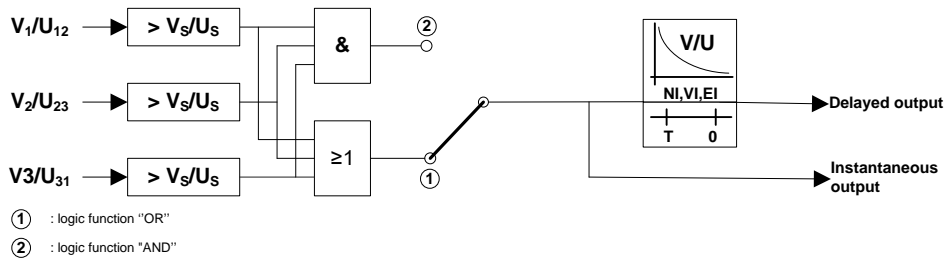
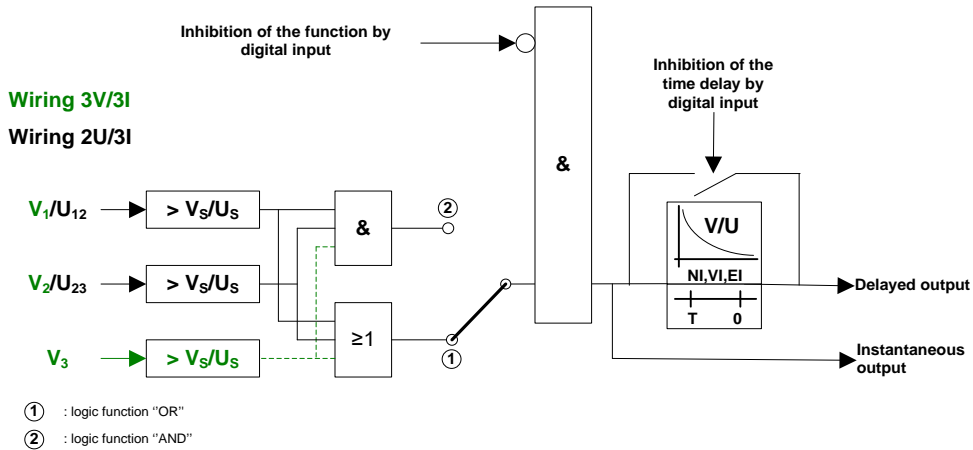


Fig. 35: Function of phase overvoltage [59] on NPU800-NPU800R-NPU800RE

3.6.5.3 Flow chart for [59] NPW800-NPW800R



For the NPW800-NPW800R models, the function can be inhibited using digital input. The time delay can be inhibited in a similar way.

Fig. 36: Function of phase overvoltage [59] on NPW800-NPW800R

### 3.6.5.4 Setting characteristics for [59] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION [59]	Setting
Thresholds U> - U>>	0.40 to 2.00 Un with steps of 0.01 Un
TIME DELAY FOR THE FUNCTION [59]	Setting
Definite time-delay: t(U>) - t(U>>)	0.04 to 300 s step: see *
Inverse time curves CEI: inverse, very inverse, extremely inverse t(U>) - t(U>>)	T++: 0.03 to 3 s with steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse t(U>) - t(U>>)	T++: 0.03 to 3 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60 ms
Reset time	< 55 ms
Setting range for the rated value of the measuring voltage (Un)	33 V to 120 V (with steps of 0.1 V)

\* between 0.06 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1 s.

### 3.6.5.5 Setting advices for [59] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

Depending on the value found through a setting study, you must adapt the thresholds [59] to set on the protection to take into account the rated voltage of the tension-reducing devices (TP), and possibly modified according to the setting steps.

Let us examine as an example the following data:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3}$
- calculated tripping value in case of overvoltage for the first threshold: 6.6 kV with a time definite time delay of 1 s

- tripping value calculated in case of overvoltage for the second threshold: 7.2 kV with a time definite time delay of 0.5 s.

Calculating the thresholds and parameters to display on the protection:

- The first threshold  $U>$  for the function [59] will be used with the following setting:

$$U> = 6.6/6 = 1.1$$

The time delay  $t(U>)$  will be set to 1 s.

- The second threshold  $U>>$  for the function [59] will be used with the following setting:

$$U>> = 7.2/6 = 1.2$$

The time delay  $t(U>>)$  will be set to 0.5 s.

### 3.6.6 Max of zero sequence voltage of [59N] NPW800-NPW800R

For the NPW800-NPW800R models, this function [59N] as for the NPU800-NPU800R-NPU800R, ensures the detection of ground faults, only through vector calculation of the three phase voltages independently of the selected power calculation method (2W or 3W). Except for the difference of voltage measurement method, the characteristics are identical.



*For the presentation, the flow chart, the characteristics and the setting advices, please refer to section "3.2.1.1.1 Function Max of zero sequence voltage [59N] NPUH800-NPUH800R and NPU800-NPU800R-NPU800RE".*

### 3.6.7 Function under frequency and over frequency of [81] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

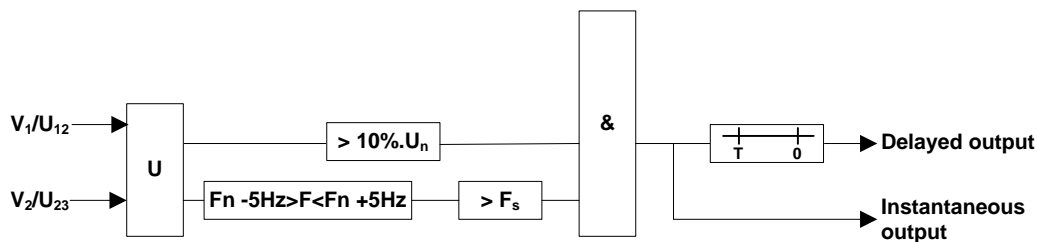
#### 3.6.7.1 Introduction to [81] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

The function with under frequency and over frequency [81U] and [81O] allows detection of abnormal low or high frequency of the network in comparison to the rated value, and for a better quality control of the supply, especially for production installations which are connected to the public distribution network.

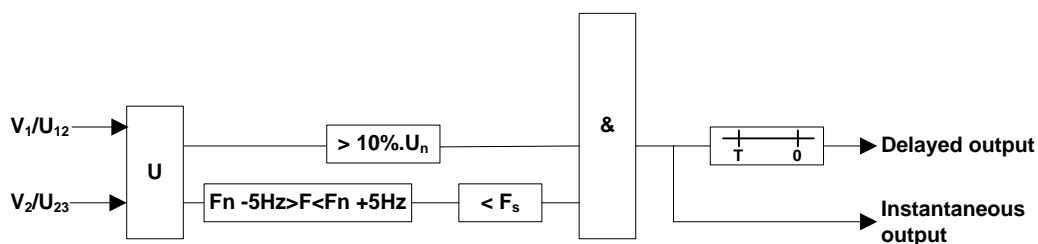
Both functions offer each four thresholds to be set:  $F > \dots F \gg \gg$  and  $F < \dots F \ll \ll$ .

Below 10% of the rated voltage  $U_n$ , the function is inhibited, as to avoid any spurious tripping.

#### 3.6.7.2 Flow charts for [81] on NPU800-NPU800R-NPU800RE



**Fig. 37:** Function of over frequency [81O]



**Fig. 38:** Function of under frequency [81U]

3.6.7.3 Flow charts for [81] NPW800-NPW800R

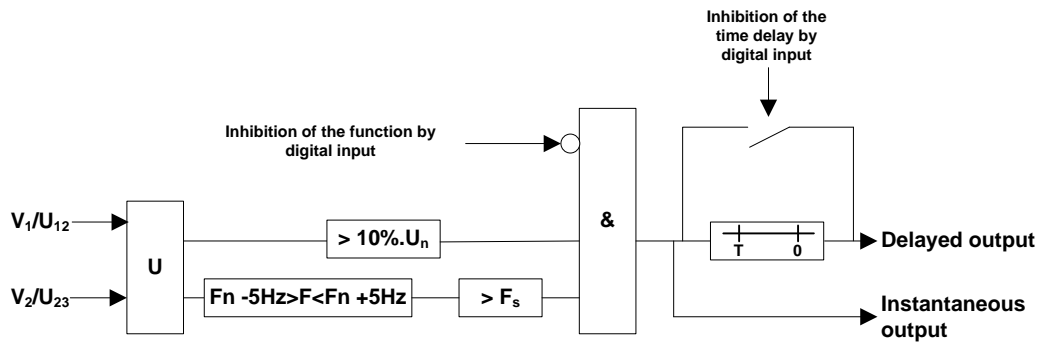


Fig. 39: Function of over frequency [81O]

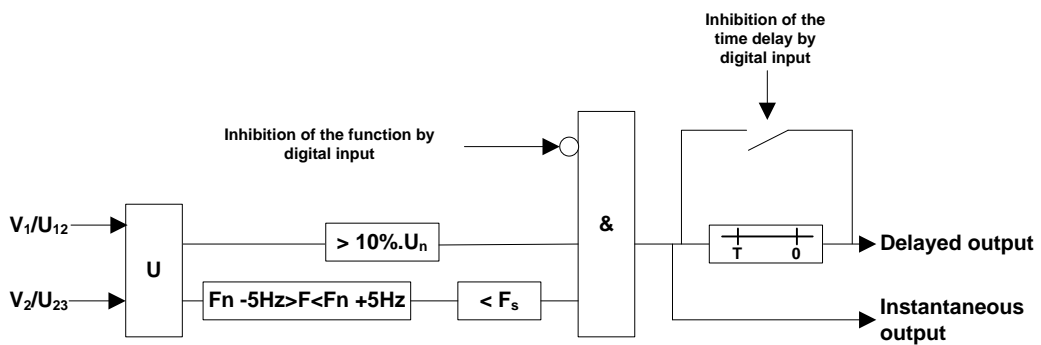


Fig. 40: Function of under frequency [81U]



For the NPW800-NPW800R models, the function can be inhibited using digital input. The time delay can be inhibited in a similar way.

3.6.7.4 Setting characteristics for [81] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION [81O] F>, F>>, F>>>, F>>>>	Setting
Threshold (Fn = 50 Hz)	50.05 to 54.0 Hz with steps of 0.01 Hz
Threshold (Fn = 60 Hz)	60.05 to 64.0 Hz with steps of 0.01 Hz

THRESHOLDS FOR THE FUNCTION [81U] F<, F<<, F<<<, F<<<<	Setting
Threshold (Fn = 50 Hz)	46.0 to 49.95 Hz with steps of 0.01 Hz
Threshold (Fn = 60 Hz)	56.0 to 59.95 Hz with steps of 0.01 Hz
TIME DELAY FOR THE FUNCTION [81O/81U]	Setting
Definite time-delay	0.08 to 10 s with steps of 0.01ms
CHARACTERISTICS	Values
Maximum response time for the outputs	< 150ms
Operating voltage	> 0.10 Un

Outside normal range of operation, the values cannot be guaranteed.

### 3.6.7.5 Setting advices for [81] NPU800-NPU800R-NPU800RE and NPW800-NPW800R

We will examine a production site connected to the supply network with a rated value of 50 Hz.

In order to isolate from perturbations on the network, the first thresholds are set to  $\pm 1\%$  of  $F_n$  with a time delay of 500ms.

$$F< = 49.5 \text{ Hz}$$

$$t(F<) = 0.50 \text{ s}$$

$$F> = 50.5 \text{ Hz}$$

$$t(F>) = 0.50 \text{ s}$$

As to avoid a loss of stability due to a load variation when switching to operation as a separate network, the second thresholds are set to the following values, with instantaneous response time.

$$F<< = 47.5 \text{ Hz}$$

$$t(F<<) = 0.08 \text{ s}$$

$$F>> = 51 \text{ Hz}$$

$$t(F>>) = 0.08 \text{ s}$$

### 3.6.8 Maximum of active power function of [32P] NPW800-NPW800R

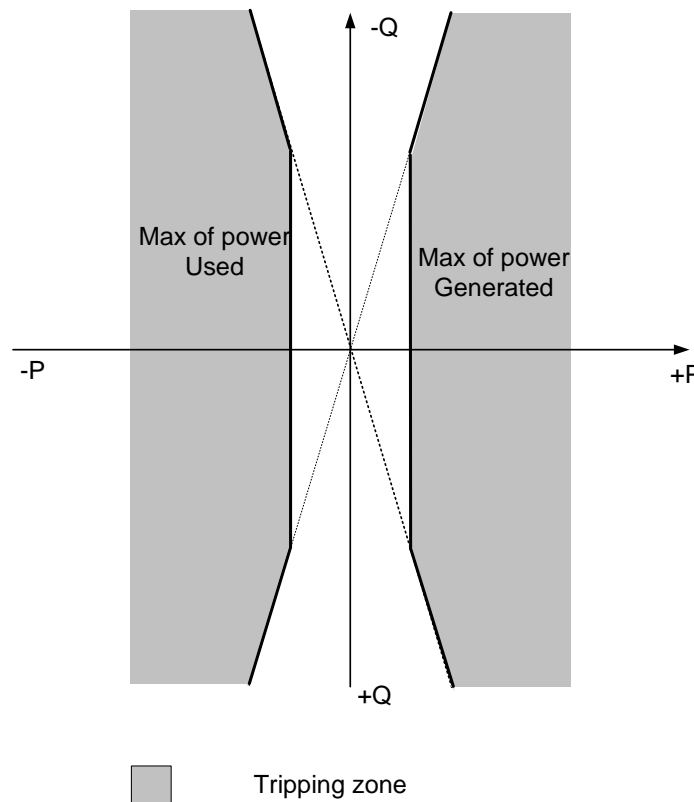
#### 3.6.8.1 Introduction to [32P] NPW800-NPW800R

The maximum of active power function is used to detect overload situations, and it provides for protection of the network elements by allowing load shedding actions.

Function [32P] offers two thresholds which can be set using 3 modes: active power generated (**Export**: P+) or used (**Import**: P-), or generated and used (**Export / Import**: P+/P-). The operating characteristic is definite time or inverse time. The value of the thresholds is expressed in percentage of the rated power.

This function relies on the method of the three or two wattmeter's, depending on the selected alternative.

Function [32P] is operational when the following condition is met:  $P \geq 3.1\% Q$ . In other words, for a threshold of active power of 1%, a break of the tripping characteristic at 0.32 Qn.



**Fig. 41:** Operating characteristics of the function [32P]

3.6.8.2 Flow chart for [32P] NPW800-NPW800R

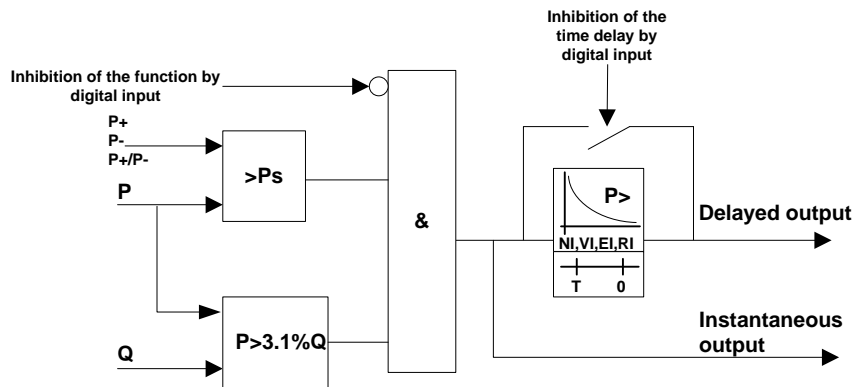


Fig. 42: Function maximum of active power [32P]

3.6.8.3 Setting characteristics for [32P] NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION [32P]	Setting
Thresholds P> - P>>	1 to 120 % of Sn
TIME DELAYS FOR THE FUNCTION [32P]	Setting
Definite time-delay: t(P>) - t(P>>)	0.04 to 300 s step: see *
Inverse time curves CEI: inverse, very inverse, extremely inverse t(P>) - t(P>>)	T++: 0.03 to 3 s with steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse t(P>) - t(P>>)	T++: 0.03 to 3 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Type of the direction on the thresholds of P P+ = exported power (provided) P- = imported power (used) P+/- = exported power / imported power	P+, P- or P+/-

\* between 0.04 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1s, between 30 and 300s with steps of 1s.

### 3.6.9 Maximum of reactive power function of [32Q] NPW800-NPW800R

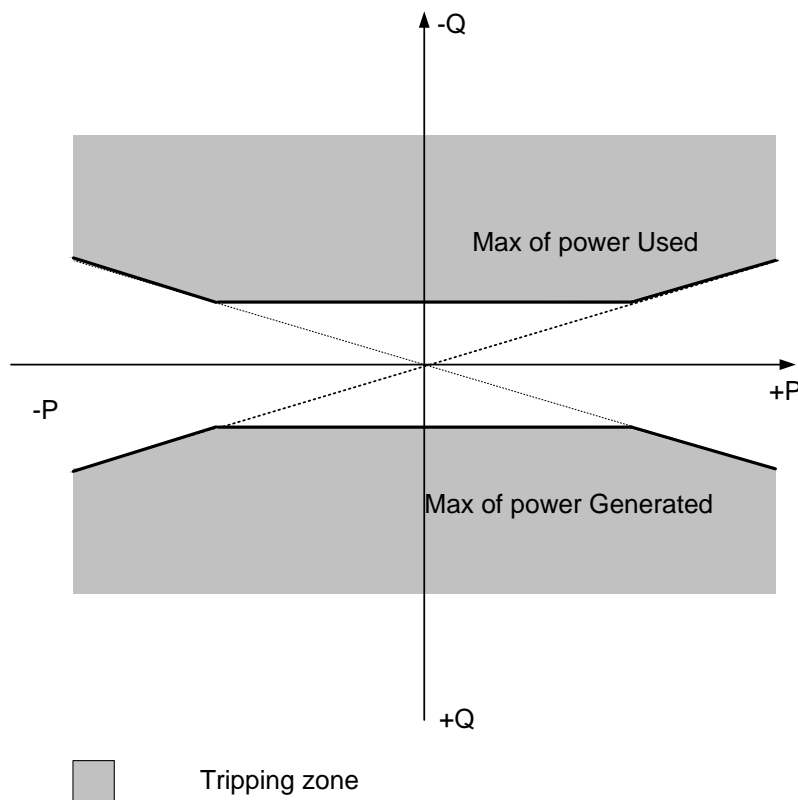
#### 3.6.9.1 Introduction to [32Q] NPW800-NPW800R

The maximum of reactive power function can be used to protect generators when they use reactive power in case of loss of excitation.

Function [32Q] offers two thresholds which can be set using 3 modes: active power generated (**Export**: Q+) or used (**Import**: Q-), or generated and used (**Export / Import**: Q+/Q-). The operating characteristic is definite time or inverse time. The value of the thresholds is expressed in percentage of the rated power.

This function relies on the method of the three or two wattmeter's, depending on the selected variant.

Function [32Q] is operational when the following condition is met:  $Q \geq 3.1\% P$ . In other words, for a threshold of active power of 1%, a break of the tripping characteristic at  $0.32 P_n$ .



**Fig. 43:** Operating characteristics of the function [32Q]

3.6.9.2 Flow chart for [32Q] NPW800-NPW800R

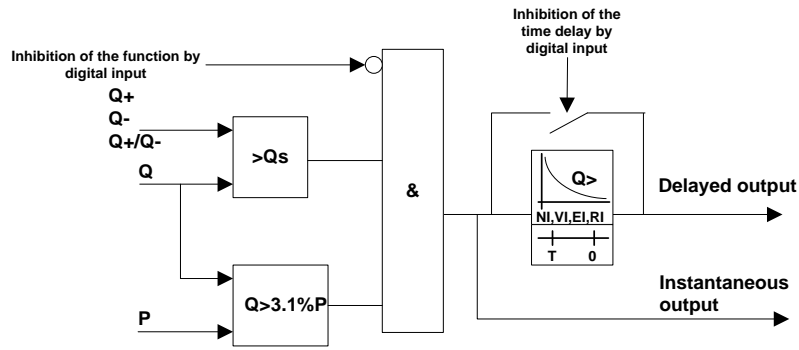


Fig. 44: Maximum of reactive power function [32Q]

3.6.9.3 Setting characteristics for [32Q] NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION [32Q]	setting
Thresholds Q> - Q>>	1 to 120 % of Sn
TIME DELAYS FOR THE FUNCTION [32Q]	setting
Definite time-delay: (Q>) - t(Q>>)	0.04 to 300 s step: see *
IEC inverse time curves: inverse, very inverse, extremely inverse t(Q>) - t(Q>>)	T++: 0.03 to 3 s with steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse t(Q>) - t(Q>>)	T++: 0.03 to 3 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Type of the direction on the thresholds of Q Q+ = exported power (provided) Q- = imported power (used) Q+/- = exported power / imported power	Q+, Q- or Q+/-

\* between 0.04 and 9.99 s with steps of 0.01 s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1 s.

### 3.6.10 Minimum of active power function of [37P] NPW800-NPW800R

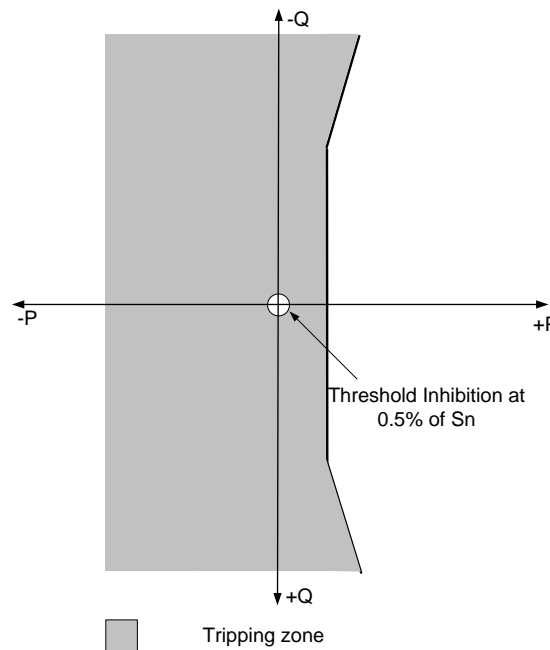
#### 3.6.10.1 Introduction to [37P] NPW800-NPW800R

The minimum of active power function is used to detect a drop in transit of active power in a network and to monitor the amount of sources working in parallel depending on the network load.

Function [37P] can be used as an alarm to detect the presence of a minimum of active power. This function offers two thresholds which can be set using 3 modes: active power generated (**Export**: P+) or used (**Import**: P-), or generated and used (**Export / Import**: P+/P-). The operating characteristic is definite time or inverse time. The value of the thresholds is expressed in percentage of the rated power. The function [37P] is inhibited at 0.5% of Sn.

This function relies on the method of the three or two wattmeter's, depending on the selected alternative.

Function [37P] is operational when the following condition is met:  $P \geq 3.1\% Q$ . In other words, for a threshold of active power of 1%, a break of the tripping characteristic at 0.32 Qn.



**Fig. 45:** Operating characteristics of function [37P]

3.6.10.2 Flow chart for [37P] NPW800-NPW800R

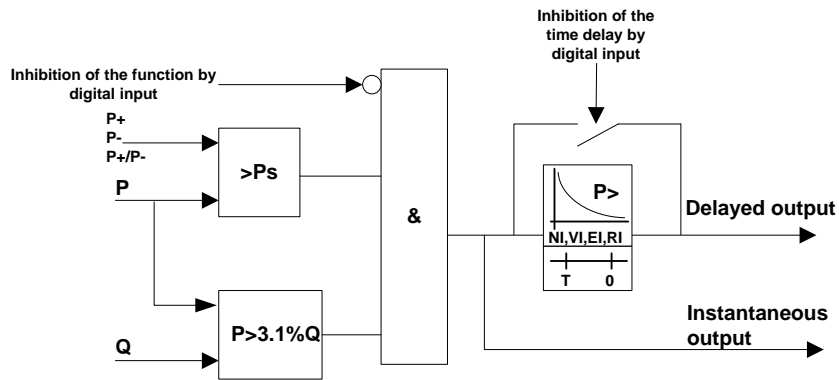


Fig. 46: Function minimum of reactive power [37P]

3.6.10.3 Setting characteristics for [37P] NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION [37P]	Setting
Thresholds P< - P<<	1 to 120 % of Sn
TIME DELAYS FOR THE FUNCTION [37P]	Setting
Definite time-delay: t(P<) - t(P<<)	0.04 to 300 s step: see *
IEC inverse time curves : inverse, very inverse, extremely inverse t(P<) - t(P<<)	T++: 0.03 to 3 s with steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse t(P<) - t(P<<)	T++: 0.03 to 3 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Nature of the direction for thresholds of P P+ = exported power (provided) P- = imported power (used) P+/- = exported power / imported power	P+, P- or P+/-

\* between 0.04 and 9.99 s with steps of 0.01 s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1 s.

### 3.6.11 Minimum of reactive power function of [37Q] NPW800-NPW800R

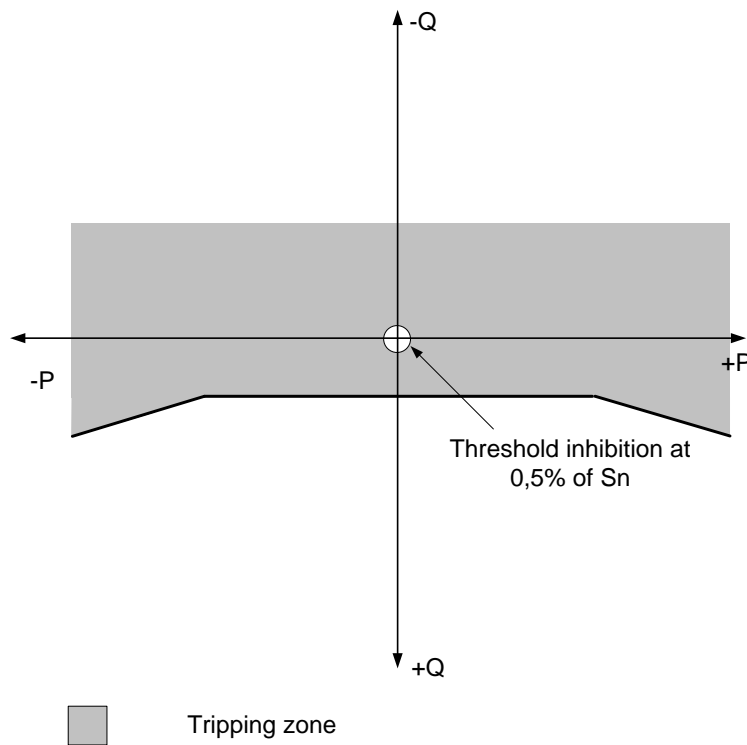
#### 3.6.11.1 Introduction to [37Q] NPW800-NPW800R

The function with minimum of reactive power is activated when the reactive power transiting on a network is lower to the set threshold.

Function [37Q] can be used as an alarm to detect the presence of a minimum of reactive power. This function offers two thresholds which can be set using 3 modes: active power provided (**Export**: Q+) or used (**Import**: Q-), or provided and used (**Export / Import**: Q+/Q-). The operating characteristic is definite time or inverse time. The value of the thresholds is expressed in percentage of the rated power. The function [37Q] is inhibited at 0.5% of Sn.

This function relies on the method of the three or two wattmeter's, depending on the selected variant.

Function [37Q] is operational when the following condition is met:  $Q \geq 3.1\% P$ . In other words, for a threshold of active power of 1%, a break of the tripping characteristic at 0.32 Pn.



**Fig. 47:** Operating characteristics for function [37Q]

3.6.11.2 Flow chart for [37Q] NPW800-NPW800R

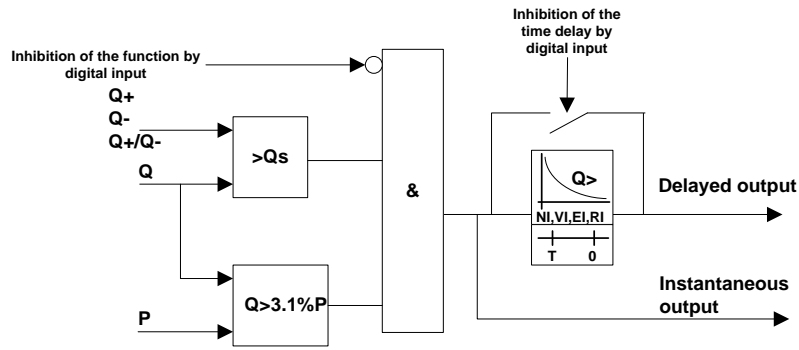


Fig. 48: Function with minimum of reactive power [37Q]

3.6.11.3 Setting characteristics for [37Q] on NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION [37Q]	Setting
Thresholds $Q<$ - $Q<<$	1 to 120 % of $S_n$
TIME DELAYS FOR THE FUNCTION [37Q]	Setting
Definite time-delay: $t(Q<)$ - $t(Q<<)$	0.04 to 300 s step: see *
IEC inverse time curves: inverse, very inverse, extremely inverse $t(Q<)$ - $t(Q<<)$	T++: 0.03 to 3 s with steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse $t(Q<)$ - $t(Q<<)$	T++: 0.03 to 3 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Nature of the direction on the thresholds of Q Q+ = exported power (provided) Q- = imported power (used) Q+/- = exported power / imported power	Q+, Q- or Q+/-

\* between 0.04 and 9.99 s with steps of 0.01 s, between 10 and 29.9 s with steps of 0.1s, between 30 and 300 s with steps of 1 s.

### 3.6.12 Power factor management of the network of [55] NPW800-NPW800R

#### 3.6.12.1 Introduction to [55] NPW800-NPW800R

The power factor management function or  $\cos \phi$  allows to measure the power factor of an installation at measurement location and to control the capacitors banks installed to compensate reactive power close to the loads.

The power factor, which is defined as the ratio between active power used over the apparent power, is a measurement of an installation's efficiency.

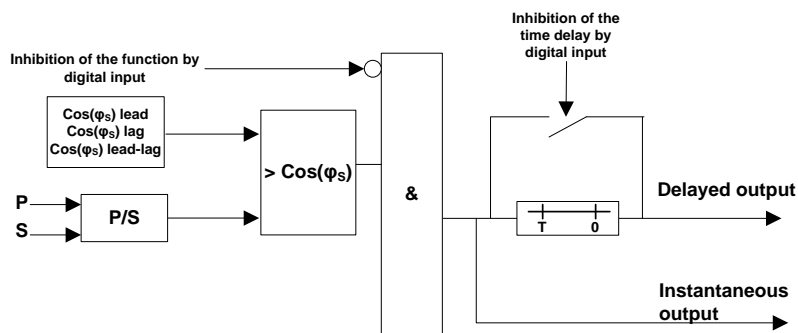
As a matter of fact, output in kW is related to the active power of electrical energy. A weak power factor, meaning close to 0, is usually the result of using an inductive load, for example transformers, lighting ballasts and induction motors, especially motors with insufficient load.

This function allows, depending on the measured power factor, to monitor the connection or the load shedding of the capacitors banks. This, in order to accurate the power factor, and to check if the loads of the feeders behave in an inductive or capacitive way. This way, the operator can be warned on a possible malfunction of the capacitors banks or on the necessity to compensate reactive energy at a certain place.

In order to perform this, 2 thresholds are available,  $FP <$  and  $FP <<$ , which can be set according to 3 modes: lead / lag / lead-lag using values between 0.1 and 0.99, for instantaneous output or with a time delay you can set between 40ms and 300 s.

The Reset percentage for these thresholds  $FP <$  and  $FP <<$  can be set between 0.1 to 0.99.

#### 3.6.12.2 Flow chart for [55] NPW800-NPW800R



**Fig. 49:** Function of power factor management [55]

**3.6.12.3 Setting characteristics for [55] NPW800-NPW800R**

THRESHOLDS FOR THE FUNCTION POWER FACTOR	Setting
Thresholds 1 (FP<) and 2 (FP<<)	0.10 to 0.99
TIME DELAYS FOR THE FUNCTION POWER FACTOR	Setting
Definite time-delay: t(FP<) – t(FP<<)	0.04 to 300 s step: see *
CHARACTERISTICS	Values
reset percentage	0.10 to 0.99
Response time for instantaneous outputs	60ms
Working mode of the threshold for the power factor FP: φ = lead (inductive) φ = lag (capacitive) φ = lead / lag	IND, CAP or IND/CAP

**3.6.12.4 Setting advices for [55] NPW800-NPW800R**

In France, reactive power is not invoiced to industrial users supplied with high tension if the tangent φ of their installation is lower than 0.4. This corresponds to a power factor of 0.93. The function of control of power factor can therefore be used to meet this condition.

The power factor function can allows managing a circuit breaker for capacitors banks. The Reset percentage must be set in such a way that when the capacitors banks are connected, the status of the output does not change.

Example:

The threshold (FP<) is set to 0.6. If this threshold is reached, a capacitors bank is connected. When this is the case, the power factor increases by at least 0,15. The Reset percentage must therefore be higher than at least 0.75.

### 3.6.13 Function of $\phi$ [Q/P] tangent management NPW800-NPW800R

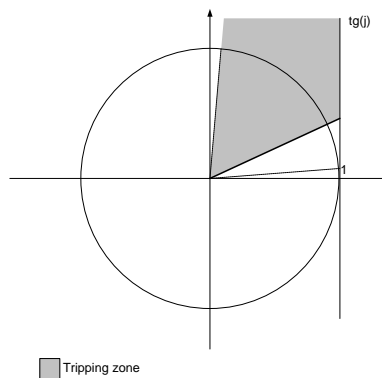
#### 3.6.13.1 Introduction to [Q/P] NPW800-NPW800R

This function allows managing the tangent  $\phi$  at a given point in the network. Tangent  $\phi$ , defined as the ratio of the reactive power over the active power (Q/P), is an indicator for reactive power usage transiting on part of an installation (transformer, feeder, ...).

In industrial processes using electrical energy, only the active energy is transformed by the production tool into useful energy, either mechanical, thermal or lighting... Reactive energy is used mainly to feed magnetic circuits of electrical engines (motors, autotransformers...). Further, some elements within electrical networks of transport and distribution (transformers, lines...) also use reactive energy in some situations. In order to compensate for reactive power used by these loads, you may install capacitors banks at immediate proximity of them.

In addition to this, depending on the subscription contract and during some time frames here it is limited, reactive energy used by industrial subscribers above a  $Tg \phi$  of 0.4 is usually charged by the energy provider according to the set rules and prices.

Function [Q/P] (reactive power / active power) can also be activated and so alert the subscriber on the instantaneous value of the network  $Tg \phi$  and also implicitly provide information on proper working of reactive power compensation devices. In order to do so, 2 thresholds,  $tg \phi >$  and  $tg \phi >>$ , which can be set between 0.1 and 9.99 (operational between  $6^\circ < \phi < 84.28^\circ$ ) can be used as instantaneous outputs or with a time delay that can be set between 40ms and 300 s. The reset percentage on these thresholds  $tg \phi >$  and  $tg \phi >>$  can be set from 0.1 to 9.99. Its operating characteristic is definite time.



**Fig. 50:** Operating characteristics of  $Tan \phi$  management

3.6.13.2 Flow chart of [Q/P] NPW800-NPW800R

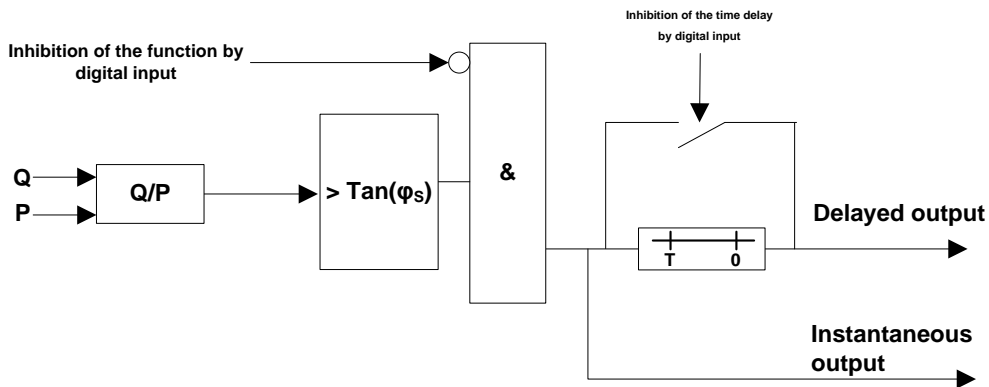


Fig. 51: Function of Tan φ management

3.6.13.3 Setting characteristics of [Q/P] NPW800-NPW800R

THRESHOLDS FOR THE FUNCTION TANGENT MANAGEMENT	Setting
Thresholds 1 tg(φ) and 2 tg(φ)	0.10 to 9.99
TIME DELAYS FOR THE FUNCTION TANGENT MANAGEMENT	Setting
Definite time-delay: t(FP<) - t(FP<<)	0.04 to 300 s step: see *
CHARACTERISTICS	Values
Reseting percentage	0.1 to 9.99
Response time for instantaneous outputs	60ms
Reset time	< 55ms
Working mode	6° < φ < 84,28°

\* between 0.04 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1 s.

### 3.6.14 Function of maximum of integrated active power $\Sigma P$ and reactive $\Sigma Q$ NPW800-NPW800R

#### 3.6.14.1 Introduction to $\Sigma P/\Sigma Q$ NPW800-NPW800R

The function of maximum of integrated power enables monitoring of the averaged value of active or reactive power used during a T time. This is a progressing average that is recalculated after each measurement in relation to the displayed T time.

Let p be the input quantity and  $\Delta t$  the integration time displayed on the protection (5 to 60 minutes).

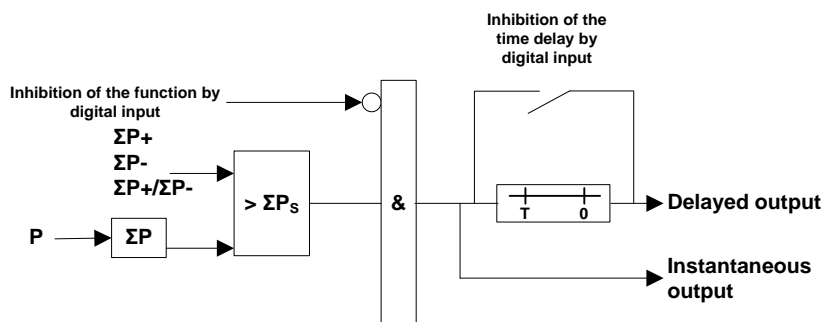
The integrated request on p will be:

$$\langle p \rangle = \frac{1}{T} \cdot \sum_{t-\Delta t}^T p(t) \cdot dt$$

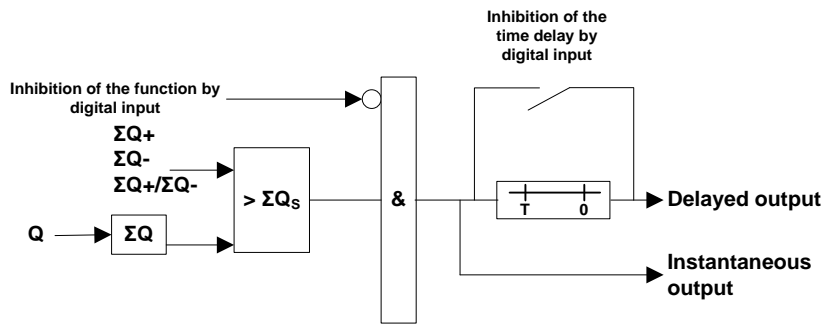
So at any t moment t multiple of 60 s, the protection calculates the average of the p power measures between the t instant and the t-  $\Delta t$  instant, which corresponds to the signal surface between these two moments. Every 60 seconds, the protection displays the calculated average.

The function of Maximum of integrated power  $\Sigma P$  and  $\Sigma Q$  offers a configurable threshold  $\Sigma P$  and a configurable threshold  $\Sigma Q$  using 3 modes: power provided (**Export**:  $\Sigma P/\Sigma Q+$ ) or used (**Import**:  $\Sigma P/\Sigma Q -$ ), or provided and used (**Export / Import**:  $\Sigma P/\Sigma Q +/-$ ). The operating characteristic is definite time. The value of the thresholds is expressed in percentage of the rated power.

#### 3.6.14.2 Flow charts for $\Sigma P/\Sigma Q$ NPW800-NPW800R



**Fig. 52:** Function of maximum of integrated active power  $\Sigma P$



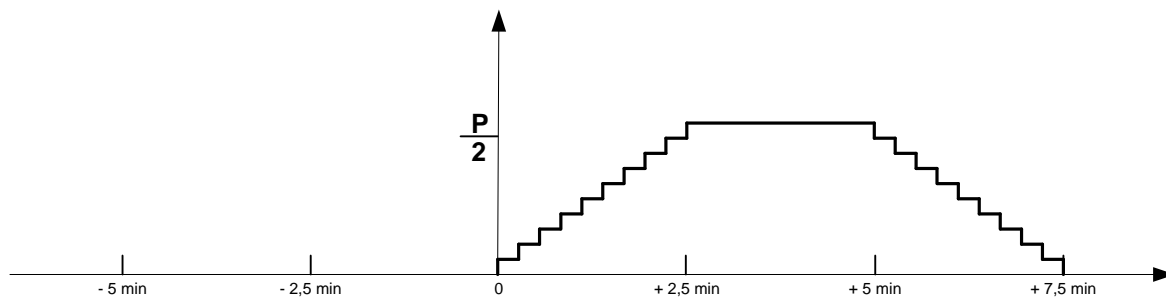
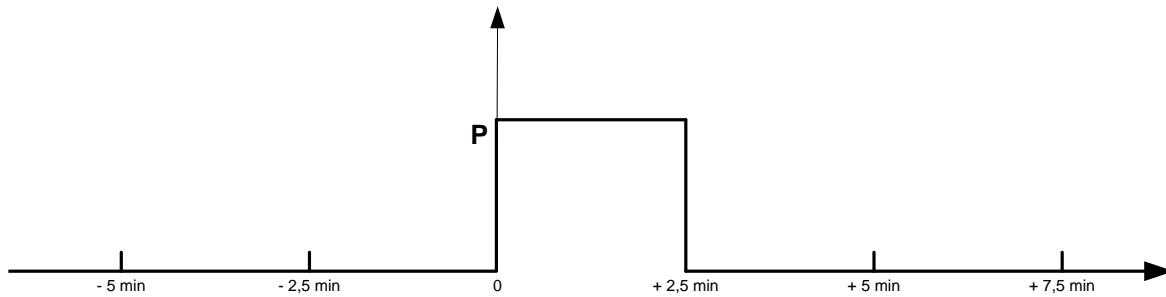
**Fig. 53:** Function of Maximum of reactive integrated power  $\Sigma Q$

**3.6.14.3 Setting characteristics for  $\Sigma P/\Sigma Q$  NPW800-NPW800R**

THRESHOLDS FOR THE FUNCTIONS $\Sigma P$ AND $\Sigma Q$	Setting
Threshold $\Sigma P >$	1 to 120 % of $S_n$
Threshold $\Sigma Q >$	1 to 120 % of $S_n$
Integration period (shared value)	5 to 60 min steps of 1 min
TIME DELAYS DES FUNCTIONS $\Sigma P$ AND $\Sigma Q$	Setting
Definite time-delay: $t(\Sigma P >) - t(\Sigma Q >)$	0.04 to 300 s step: see *
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Nature of the direction on the $\Sigma P$ and $\Sigma Q$ thresholds $\Sigma P/\Sigma Q + =$ exported power (provided) $\Sigma P/\Sigma Q - =$ imported power (used) $\Sigma P/\Sigma Q +/- =$ exported power / imported power	EXPORT, IMPORT or EXPORT/IMPORT

### 3.6.14.4 Setting advices for $\Sigma P/\Sigma Q$ NPW800-NPW800R

We will examine building an integrated request with an integration period set to 5 minutes, provided at the  $t = 0$  instant, the input quantity is null and stayed null for a period of time  $T > 5$  minutes.



The protection performs a calculation of the progressing average of the variable  $P$  over a period of 5 min.

- At instant  $T = 0$ , the current has been null since  $t - \Delta t = 5$  min, so  $\langle I \rangle = 0$ .
- At instant  $t = 2.5$  min, the protection calculated the averaged value of  $I$  between instant  $t = 2.5$  min and instant  $t - \Delta t = 2.5$  min  $\langle I \rangle = I/2$  (between instant  $t = 0$  and instant  $t = + 2.5$  min, the protection displays 10 intermediate results).
- Between instant  $t = + 2.5$  min and instant  $t = + 5$  min, the value  $\langle I \rangle$  remains unchanged and equal to  $I/2$ , since the average does not vary.
- At instant  $t = 7.5$  min, the value  $\langle I \rangle$  is back to null (after the display of 10 intermediate results).

### 3.6.15 Function of synchronism check [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE

#### 3.6.15.1 Presentation [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE

The function of synchronism check is mainly used for the interconnection of two parts of an electrical network, with no risk for the equipment's (*short-circuit, impact of charge, stress of the machines over the network*) while taking care of the protection of people and property. As described in section Overview of the current chapter, the synchronism check [25] function is common to both versions and provides with measurement of amplitude, angle and frequency differences for the voltage on either side (*busbar & line*) of a paralleling circuit breaker, in order to avoid any short-circuit or load impact during the paralleling operation. Activation of relay "C" is permanent as long as these conditions are met.

Synchro-check is performed when the two sections are powered, by checking the following four parameters.

◆ *Voltage difference ( $\Delta U$ )*

The device permanently measures the absolute value of deviation for both voltages inputs. When these conditions are met, in other words when voltage measurement difference is lower than the set ( $\pm U$ ), LED L1 lits on the front face. A last check on the minimum line voltage, also configurable, then allows or not the paralleling operation.

◆ *Angular difference ( $\Delta \varphi$ )*

The device permanently measures phase shift between both voltages on either side of the paralleling circuit breaker. When the appropriate conditions are met, in other words when angular difference measurement is lower than the set threshold, LED L2 lits on the front face.

◆ *Frequency difference ( $\Delta f$ )*

The device permanently measures the frequency of both voltage sources on either side of the paralleling circuit breaker. When the appropriate conditions are met, in other words when frequency difference measurement is lower than the set, LED L3 lits on the front face.

◆ *Rate of frequency change ( $\Delta f/dt$ )*

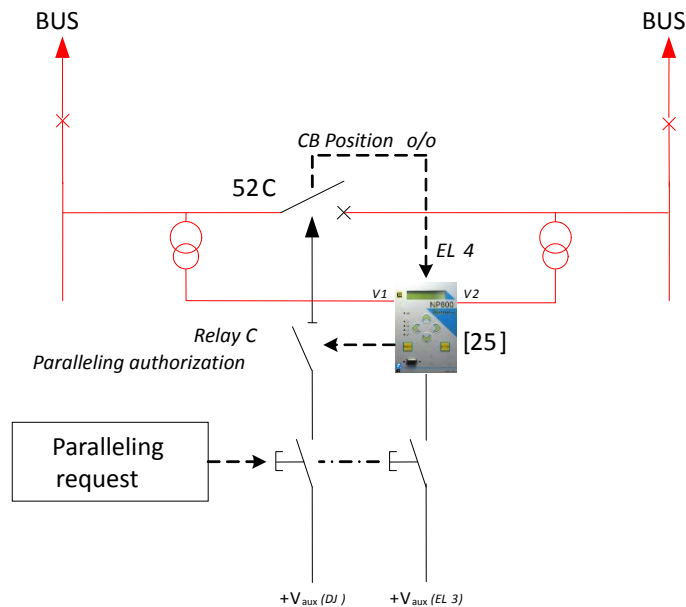
The device permanently monitors frequency variation between both voltage sources on either side of the paralleling circuit breaker. This function allows delaying of paralleling if this speed is out of the setting ranges (*acceleration / deceleration*).

When all above conditions are met, the L4 LED on the front face indicates that paralleling is allowed and that the “C” authorisation relay is activated.

For safety reasons a smoothing time delay allows to check stability of the measurements, and guarantees voltages are perfectly synchronised.

It is possible to inhibit activation of the device by activating the 2 dedicated inputs, via software (*SMARTSoft*) and digital (*EL2*). The paralleling enabling function is then no more in operation (*unit C inhibited*) and the device can then verify measurements.

This function is available on both versions (*NPSC800-1/NPSC800R & NPSC800-2/NPSC800RE*).



**Fig. 54:** Using a NPSC800 or NPSC800R with two busbars

◆ *Phase shift*

A parameter for phase shift (0 to 360°, with a step of 1°) is available on the NPSC800-1 - NPSC800-2 / NPSC800R-NPSC800RE models, and allows correcting possible phase shifts originated through the connection of a vector group from a power transformer, if this one is located between the two sets of measurement reducers.

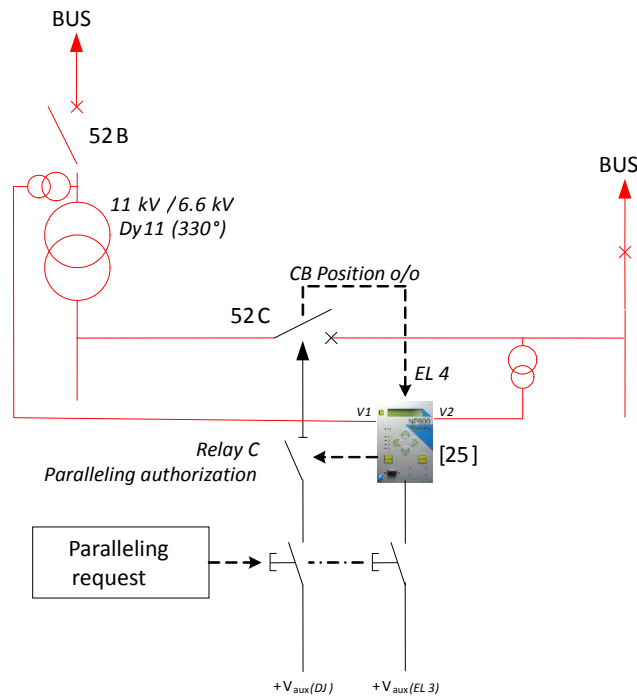


Fig. 55: Using a NPSC800 or NPSC800R with angle recalibration

3.6.15.2 Flow chart for [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE

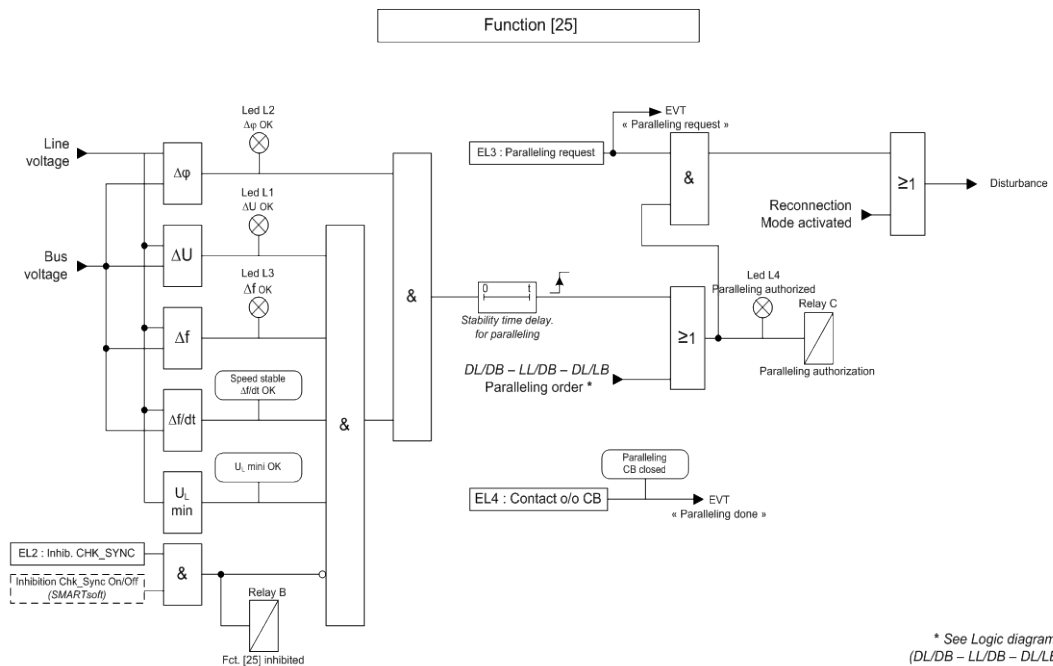


Fig. 56: Synchronism check function [25]

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**3.6.15.3 Setting characteristics for [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE**

THRESHOLDS FOR THE FUNCTION [25]	Setting
Threshold $U_{line}$ mini for authorisation	50 to 100% $U_n$ with steps of 5% $U_n$
Thresholds for voltage difference (+/-) $\Delta U$	1 to 15% $U_n$ with steps of 1% $U_n$
Thresholds for phase difference (+/-) $\Delta \phi$	1 to 20° with steps of 1°
Thresholds for frequency difference (+/-) $\Delta f$	0.01 to 1.5 Hz with steps of 0.01Hz
Thresholds for Rate of frequency change (+/-) $\Delta f/dt$	0.01 to 0.2 Hz/s with steps of 0.01Hz/s
TIME DELAY FOR THE FUNCTION [25]	Setting
Time lag before authorisation	0 to 300 s with steps of 0.01 s

**3.6.15.4 Setting advices for [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE**

**3.6.15.4.1 Principle of [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE**

The function of synchronism check is mainly used for the interconnection of two parts of an electrical network, with no risk for the equipment's (*short-circuit, impact of charge, stress of the machines over the network*) while taking care of the protection of people and property.

For overall application of safety rules, a smoothing time delay allows checking stability of the measurements, and guarantees voltages are perfectly synchronised.

However, when this coupling request has to be performed quickly (*automatic reclosing, for example*) this time delay can be very demanding in case it has been set between 10 and 20 seconds.

It is therefore possible to accelerate this operation. This solution implies that the paralleling authorisation will be given in non-synchronism conditions, with value shifts towards conditions slightly above ideal conditions.

The intrinsic relation between time, shift and closing angle that is kept over time is as follows:

$$S = \frac{D \times 1000}{180 \times T}$$

with: - **D** = Closing angle in degrees authorised

- **S** = Shift in mHz

- **T** = Total time in seconds

**3.6.15.4.2 Typical values [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE**

- Frequency shift or value difference:  $\pm 0.5$  Hz
- Phase shift: to be adjusted between  $\pm 10^\circ$
- Voltage difference:  $\pm 0.08 U_n$  (with  $U_n = 100$  V)

### 3.6.16 Function of network management NPSC800-2/NPSC800RE

#### 3.6.16.1 Introduction to the network management NPSC800-2/NPSC800RE

The network management function comes as a complement of function [25], synchronism check, since it enables taking into account the following situations:

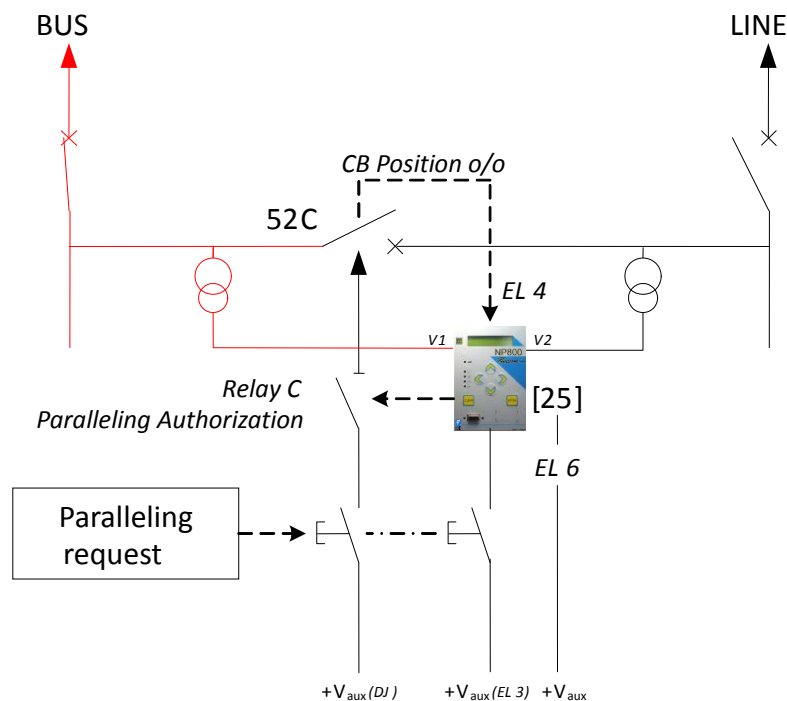
- Live line – dead bus: **LL-DB**
- Dead line – live bus: **DL-LB**
- Dead line – dead bus: **DL-DB**

This function is only available on the NPSC800-2 or NPSC800RE models.

It is possible to activate any one of these functions (in non-exclusive mode) by selecting the 2 dedicated inputs, via software (SMARTSoft) and digital (EL).

In the various applications, three situations where two network sections work in parallel may occur: paralleling of a powered section with an unpowered section, both sections unpowered, or one section powered and the other unpowered. NPSC800-2 or NPSC800RE can handle these situations.

Checking the presence of line and bus voltage is performed, for each voltage using an overvoltage threshold (dedicated to the presence of the voltage) and an undervoltage threshold (dedicated to control without voltage). For each of these configurations, both thresholds are associated with a definite time-delay, as to guarantee stable measurement. A paralleling authorisation can only be issued at the end of this time delay.



**Fig. 57:** Example for function DL-LB

3.6.16.2 Flow chart for network management NPSC800-2/NPSC800RE

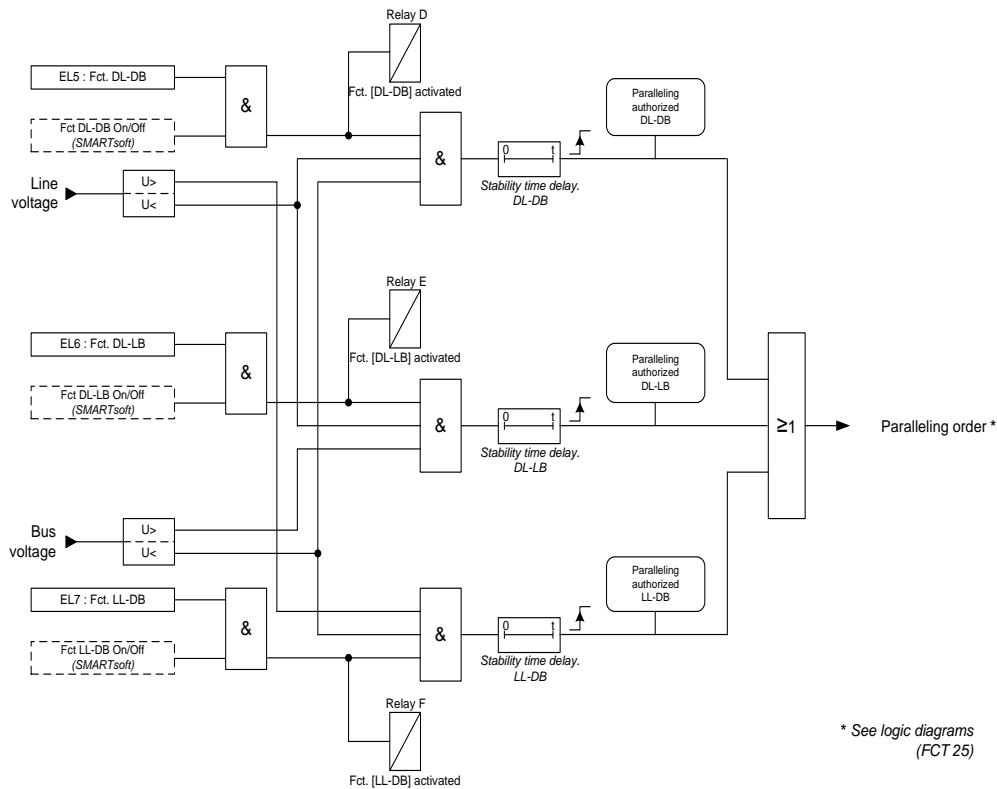


Fig. 58: Network management function (NPSC800-2/NPSC800RE)

3.6.16.3 Setting characteristics for network management NPSC800-2/NPSC800RE

THRESHOLDS FUNCTION FOR NETWORK MANAGEMENT	Setting
Threshold U> line powered (LL)	5 to 120% Un with steps of 1% Un
Threshold U< no voltage on line (DL)	5 to 120% Un with steps of 1% Un
Threshold U> bus powered (LB)	5 to 120% Un with steps of 1% Un
Threshold U< no voltage on bus (DB)	5 to 120% Un with steps of 1% Un
TIME DELAY FUNCTION NETWORK MANAGEMENT	setting
Time delay for (DL-DB / LL-DB / DL-LB)	0 to 300 s with steps of 10ms

These characteristics complement the ones of the synchronism check function (see 3.6.15 Function of synchronism check [25] NPSC800-1 / NPSC800R and NPSC800-2 / NPSC800RE)

3.6.16.4 Setting advices for network management NPSC800-2/NPSC800RE

The settings for voltage thresholds aim at identifying the following situations:

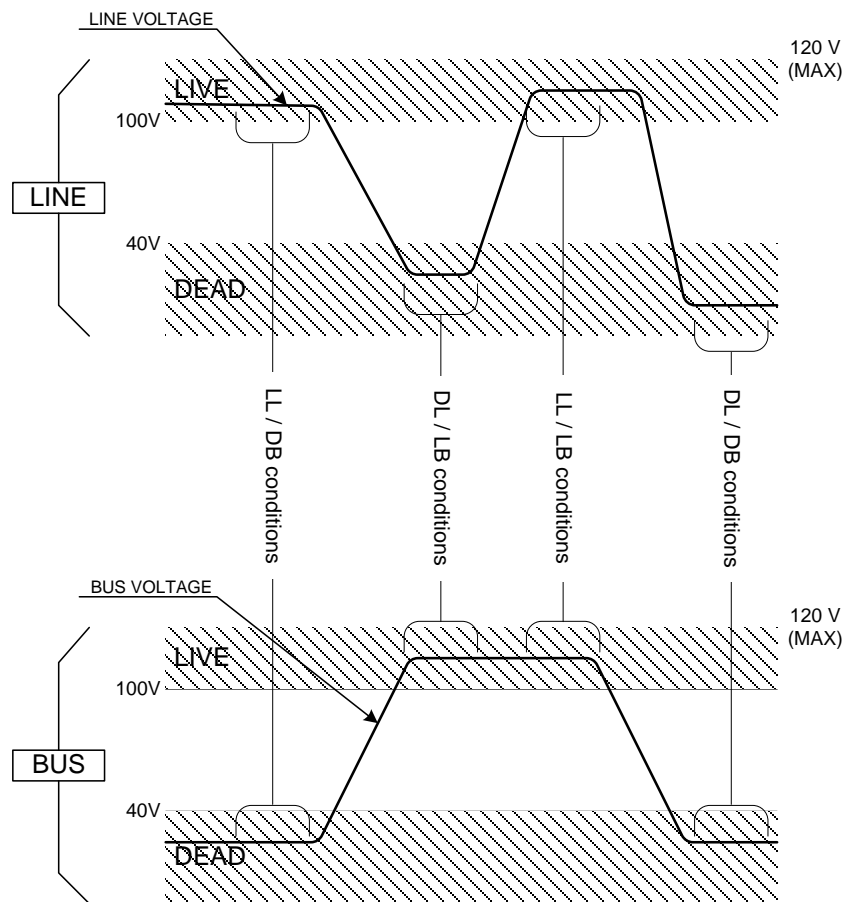
- Live line – dead bus: **LL-DB**
- Dead line – live bus: **DL-LB**
- Dead line – dead bus: **DL-DB**

Checking the presence of line and bus voltage is performed, for each voltage using an overvoltage threshold (dedicated to the presence of the voltage) and an undervoltage threshold (dedicated to control without voltage). For each of these configurations, both thresholds are associated with a definite time-delay, as to guarantee stable measurement. A paralleling authorisation can only be issued at the end of this time delay.

The recommended settings are as follows:

- Thresholds  $U >$  for line power (LL) and bus power (LB) set to 100 V.
- Thresholds  $U <$  for no voltage on line (DL) and no voltage on bus (DB) set to 40 V.

The following flow chart illustrates the situations which can occur according to the measured line and bus voltage.



**Fig. 59:** Different configurations of the network management function

### 3.6.17 Reconnection mode NPSC800-2 / NPSC800RE

#### 3.6.17.1 Introduction to the reconnection mode NPSC800-2/NPSC800RE

Reconnection mode is an extension for function [25], synchronism check, since it enables faster and/or automatic paralleling of two sections fed by the same source. If the reconnection mode is always used, function [25] can be inhibited.

This function is only available on the NPSC800-2 or NPSC800RE models.

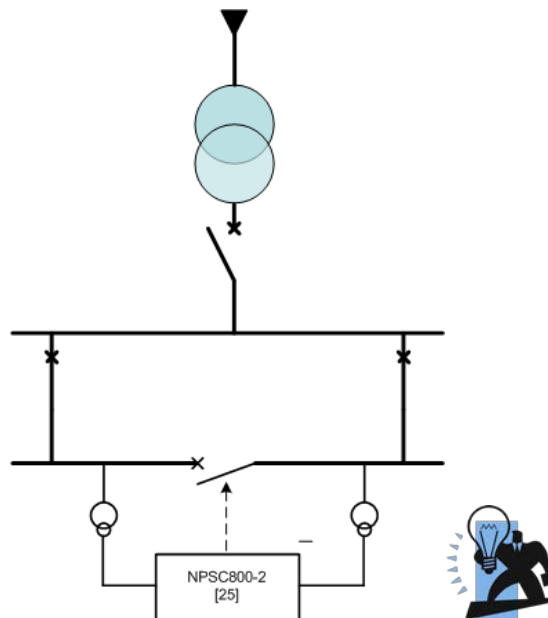
It is possible to activate this function by selecting the 2 dedicated inputs, via software (SMARTSoft) and digital (EL8).

In reconnection mode, checking synchronism is performed when both sections are powered by controlling voltage difference ( $\Delta U$ ) and angular difference ( $\Delta \varphi$ ).

When reconnection conditions are met, output relay G is activated, after a programmable time delay, as to allow the closing command for the paralleling circuit breaker.

The pulse time value for the relay G can be defined.

Note: Since both sections to connect will be supplied with the same source, it is not necessary to check for frequency difference.



**Fig. 60:** Example of reconnection

3.6.17.2 Flow chart for reconnection NPSC800-2/NPSC800RE

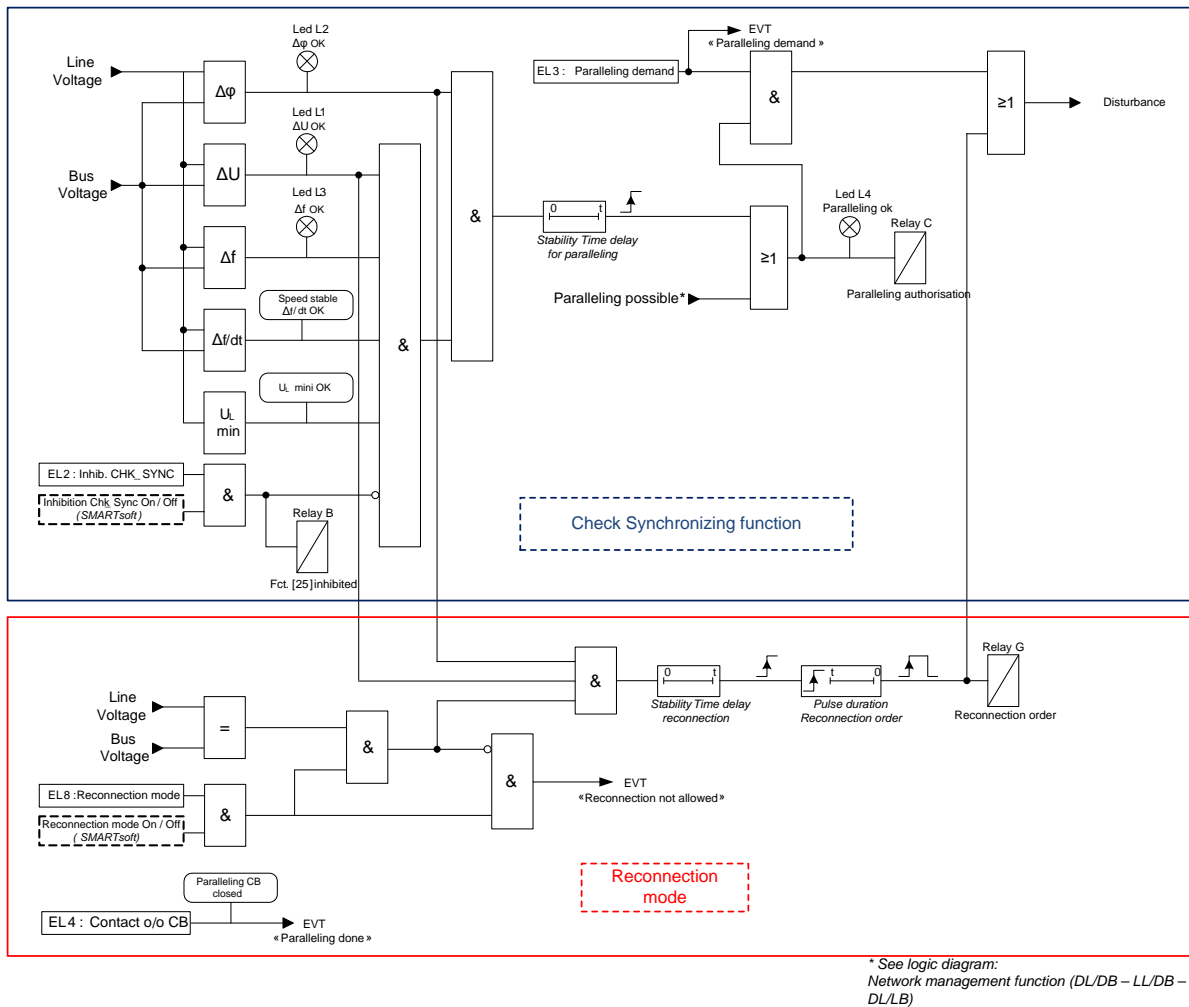


Fig. 61: Function of synchronism check with reconnection mode

3.6.17.3 Setting reconnection characteristics NPSC800-2/NPSC800RE

TIME DELAY FOR THE RECONNECTION MODE	Setting
Reconnection stability condition time delay	0.04 to 300 s with steps of 40ms
Paralleling relays pulse time	100ms to 500ms with steps of 10ms

Setting characteristics for the voltage difference ( $\Delta U$ ) and angular difference ( $\Delta \varphi$ ) thresholds are the same as function [25].

### 3.7 Tripping curves for [27] [27P] [37P] [37Q] and [32P] [32Q] [47] [59] [59N]

#### 3.7.1 Tripping curves for [27] [27P]

##### 3.7.1.1 Definite time-delay for [27] [27P]

The NPU800-NPU800R-NPU800RE and NPW800-NPW800R models allow selecting a definite time curve with a time delay which can be set between 40ms and 300 s.

The value of the time delay includes all fault processing times until the output relay activation.

The real tripping time for the protection is the sum of the time delay value and a delay of about 15ms.

##### 3.7.1.2 Inverse time delay for IEC [27] standard

###### 3.7.1.2.1 Equation for IEC [27]

The NPU800-NPU800R-NPU800RE and NPW800-NPW800R models allow the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the undervoltage [27] functions.

The typical equation for these curves is as follows:

$$t = \left( \frac{k \times (G / G_s)^\alpha}{1 - (G / G_s)^\alpha} \right) \times T_{++}$$

- t Tripping time
- G Value of the measured quantity
- G<sub>s</sub> Threshold value for the programmed quantity
- α, K Definition ratios for the curves (inverse, extremely inverse, ...)
- T<sub>++</sub> Multiplying factor between 0.03 and 3 s

These curves are limited to a value range of G between 0.2 and 0.9 G<sub>s</sub>.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

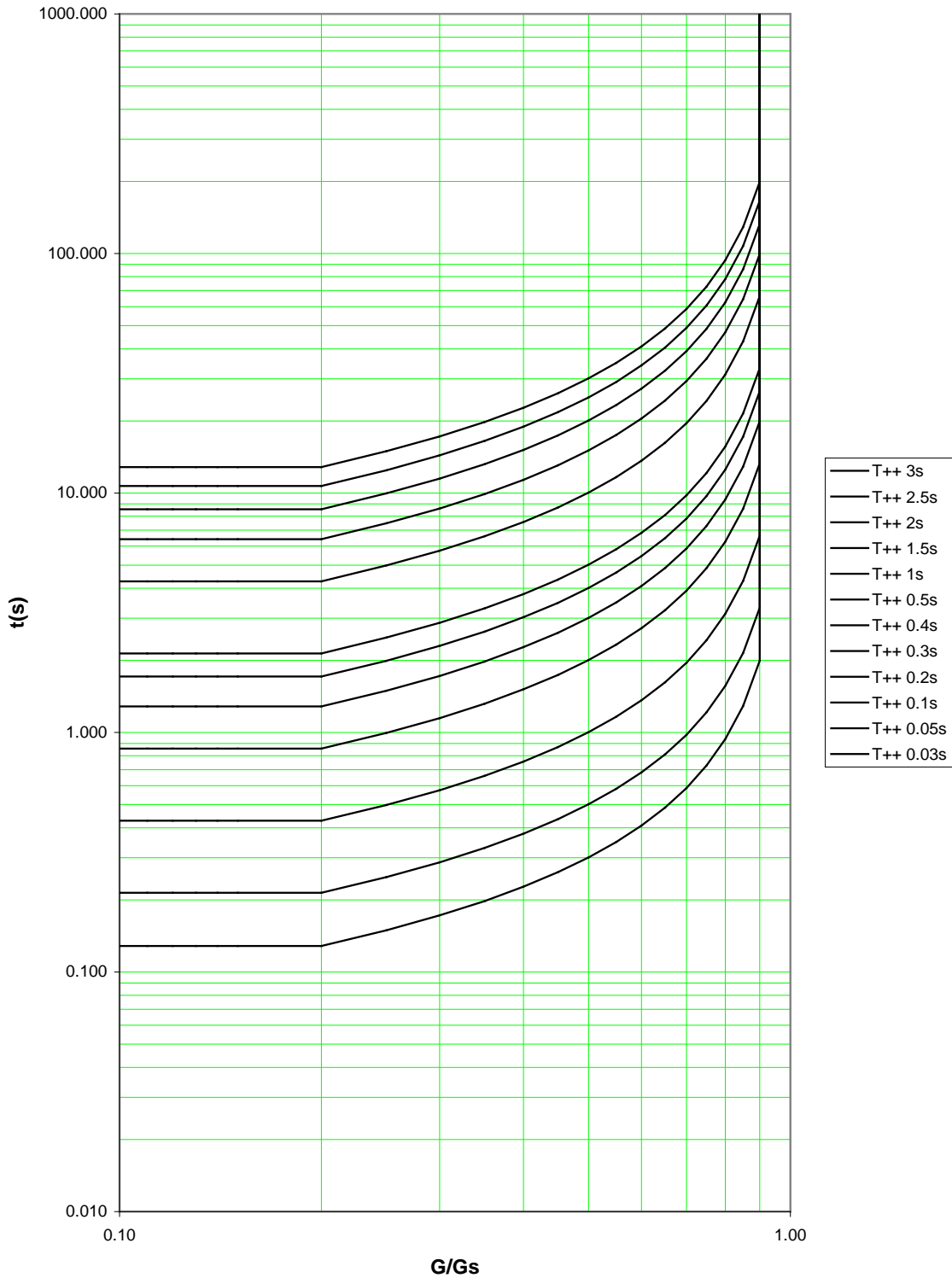
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Type of time delay	Limit of curves	T	K	$\alpha$
Inverse time	0.2 <G/Gs< 0.9	between 0.03 and 3 seconds	0.140	0.02
Very inverse time			13.5	1
Extremely inverse time			80	2

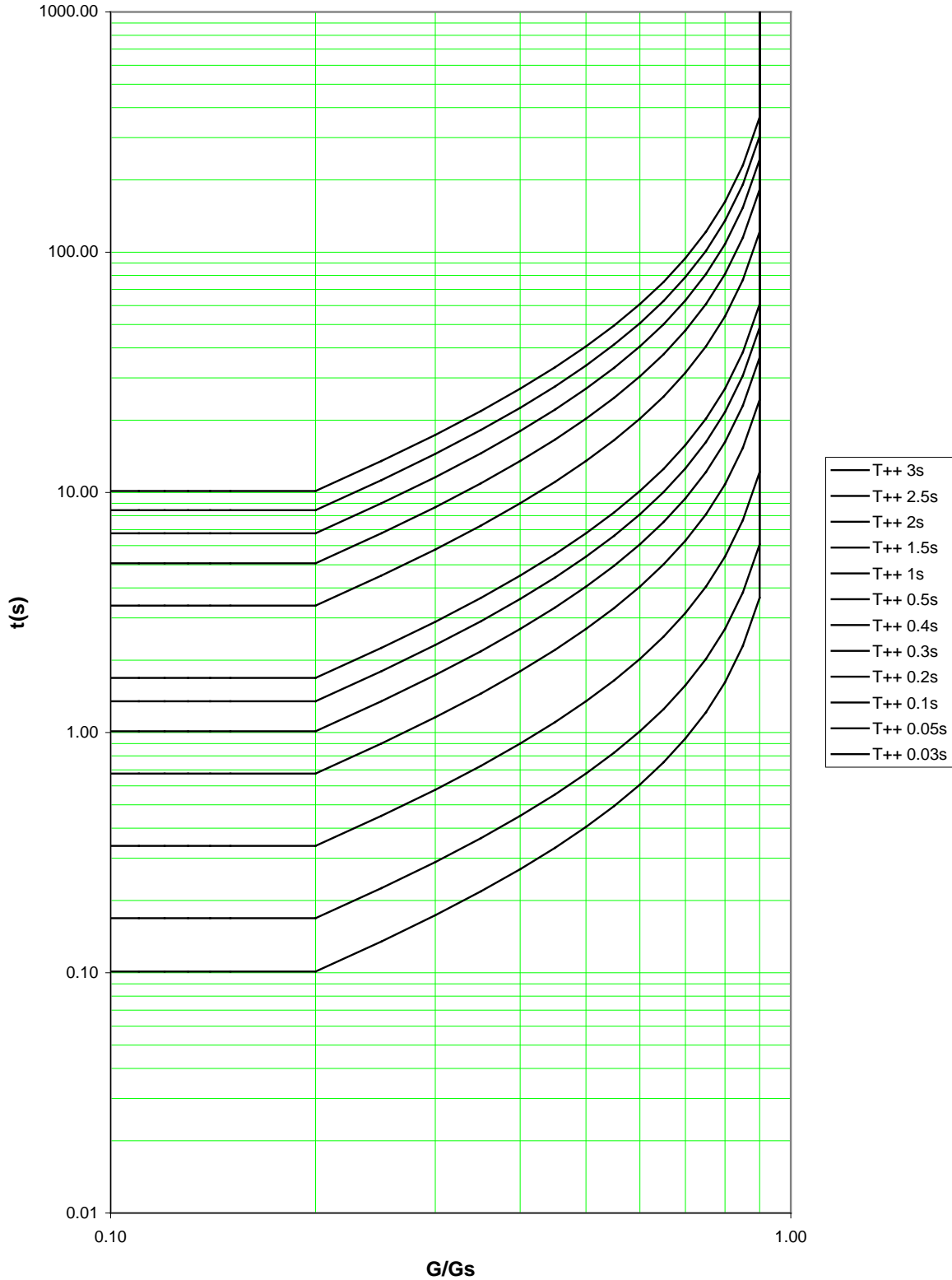
3.7.1.2.2 Tripping curves with inverse time for IEC [27]

$$t = \left( \frac{0.14 \times (G/G_s)^{0.02}}{1 - (G/G_s)^{0.02}} \right) \times T_{++} \quad \text{For } 0.2 < G/G_s < 0.9$$



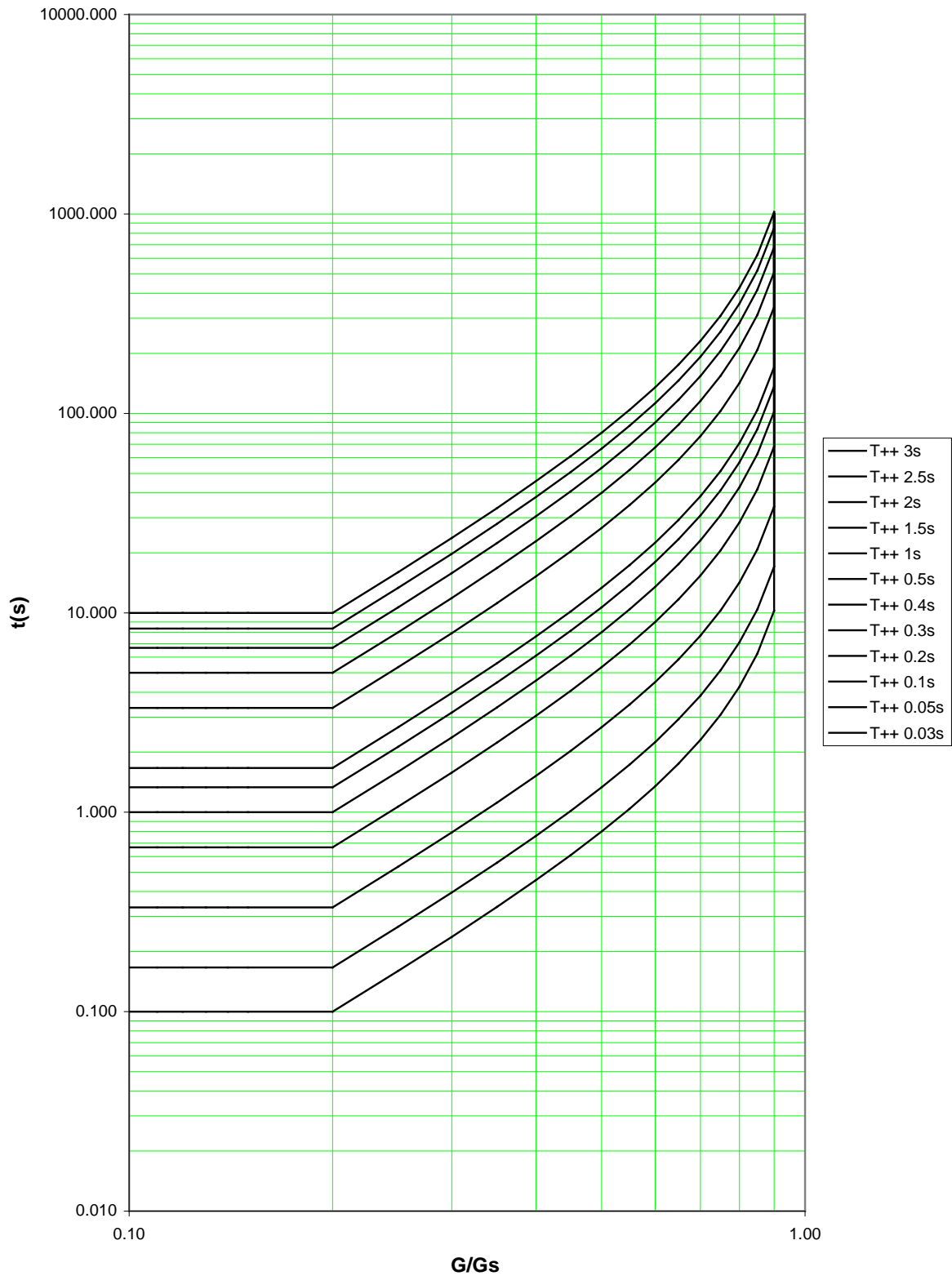
3.7.1.2.3 Tripping curves with very inverse time for IEC [27]

$$t = \left( \frac{13.5 \times (G/G_s)}{1 - (G/G_s)} \right) \times T_{++} \text{ For } 0.2 < G/G_s < 0.9$$



3.7.1.2.4 Tripping curves with extremely inverse time IEC [27]

$$t = \left( \frac{80 \times (G/G_s)^2}{1 - (G/G_s)^2} \right) \times T_{++} \text{ For } 0.2 < G/G_s < 0.9$$



**3.7.1.3 Inverse time delay for ANSI/IEEE [27] standard**

**3.7.1.3.1 ANSI/IEEE [27] [37P] [37Q] equation**

The NPU800-NPU800R-NPU800RE and NPW800-NPW800R models allow for the selection of 3 curves with inverse time according to the ANSI/IEEE standard for the undervoltage [27] functions.

The typical equation for these curves is as follows:

$$t = T + + * \left( \frac{A * (G / G_s)^\alpha}{1 - (G / G_s)^\alpha} + B \right)$$

- t                      Tripping time
- G                      Value of the measured quantity
- G<sub>s</sub>                    Threshold value for the programmed quantity
- α, A, B                Definition ratios for the curves (inverse, very inverse or extremely inverse)
- T ++                    Multiplying factor between 0.03 and 3 s.

These curves are limited to a range of values of G between 0.2 and 0.9 G<sub>s</sub>

Dynamic measurement from 1 to 240V for [27] function.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

Type of time delay	Limit of curves	T	A	α	B
Moderately inverse time	0.2 <G/G <sub>s</sub> < 0.9	Choose between 0.03 and 3 seconds	0.0515	0.02	0.1140
Very inverse time			19.61	2	0.4910
Extremely inverse time			28.2	2	0.1217

**3.7.1.3.2 Setting advices for ANSI/IEEE [27]**

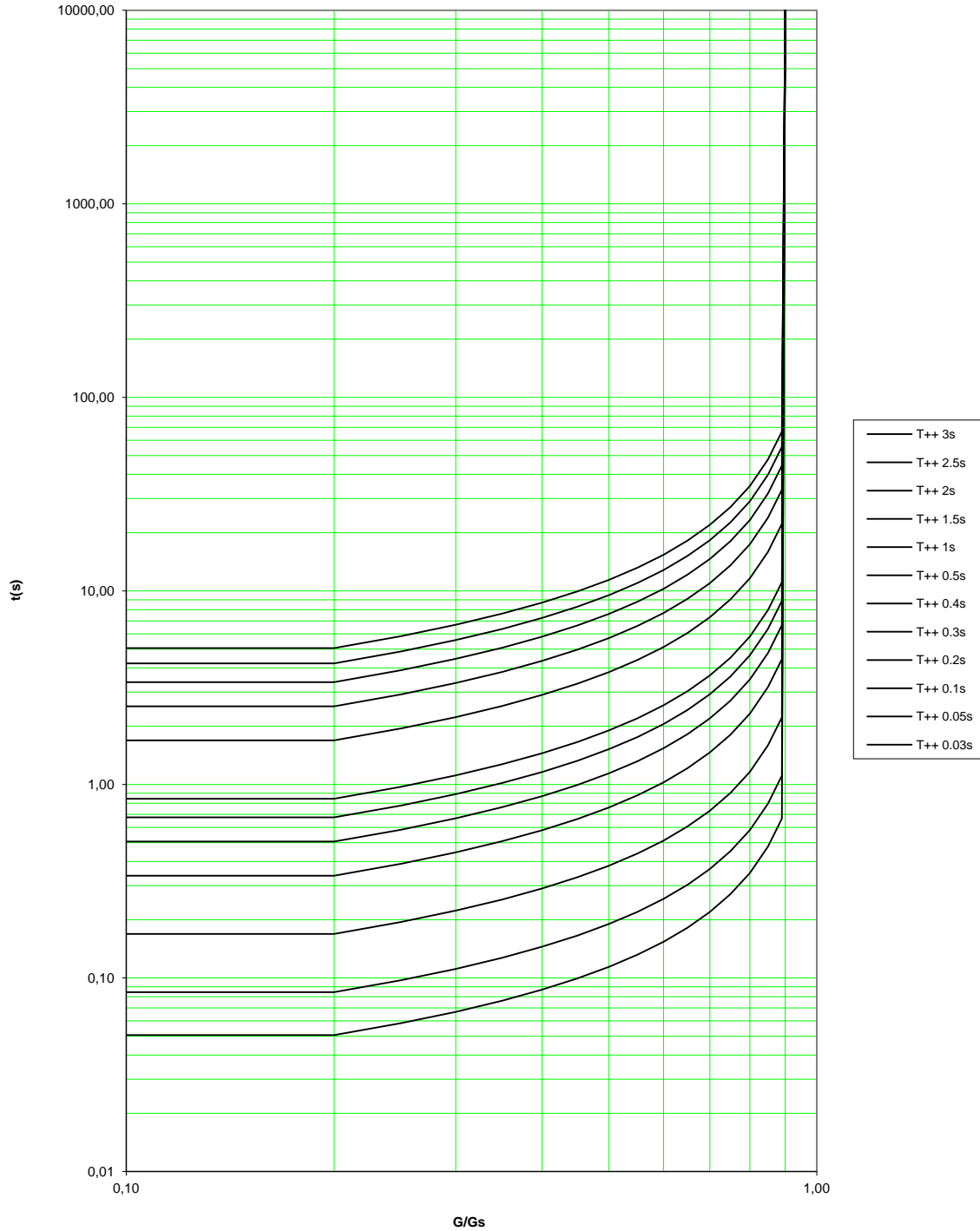


Please refer to the examples associated with the IEC standard.

3.7.1.3.3 Tripping curves with moderately inverse time for ANSI/IEEE [27]

$$t = T_{++} * \left( \frac{0.0515 * (G/G_s)^{0.02}}{1 - (G/G_s)^{0.02}} + 0.114 \right) \text{ For } 0.2 G_s < G < 0.9 G_s$$

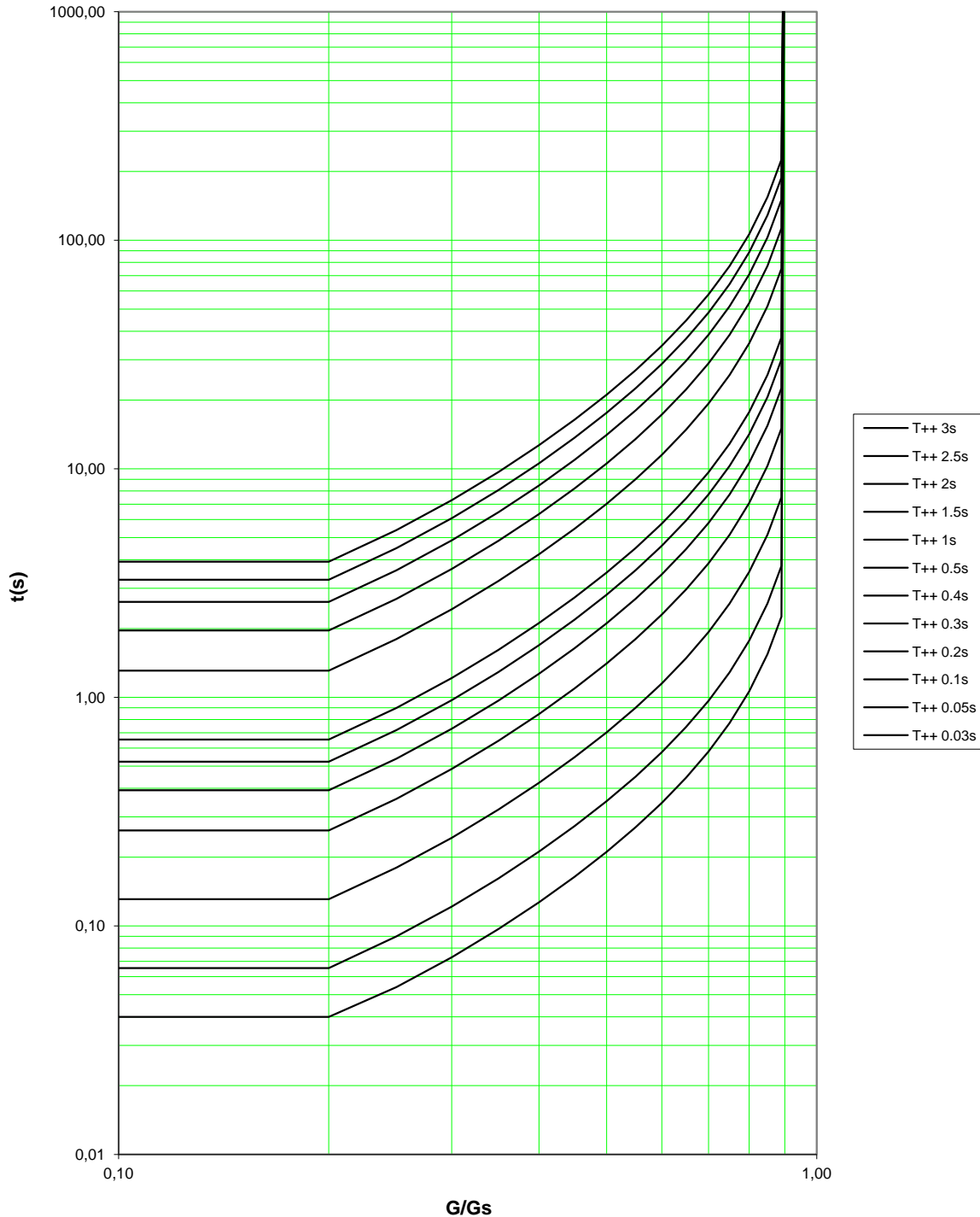
Ansi inverse min



3.7.1.3.4 Tripping curves with very inverse time for ANSI/IEEE ANSI/IEEE [27]

$$t = T_{++} * \left( \frac{19.61 * (G/G_s)^2}{1 - (G/G_s)^2} + 0.4910 \right) \text{ For } 0.2 G_s < G < 0.9 G_s$$

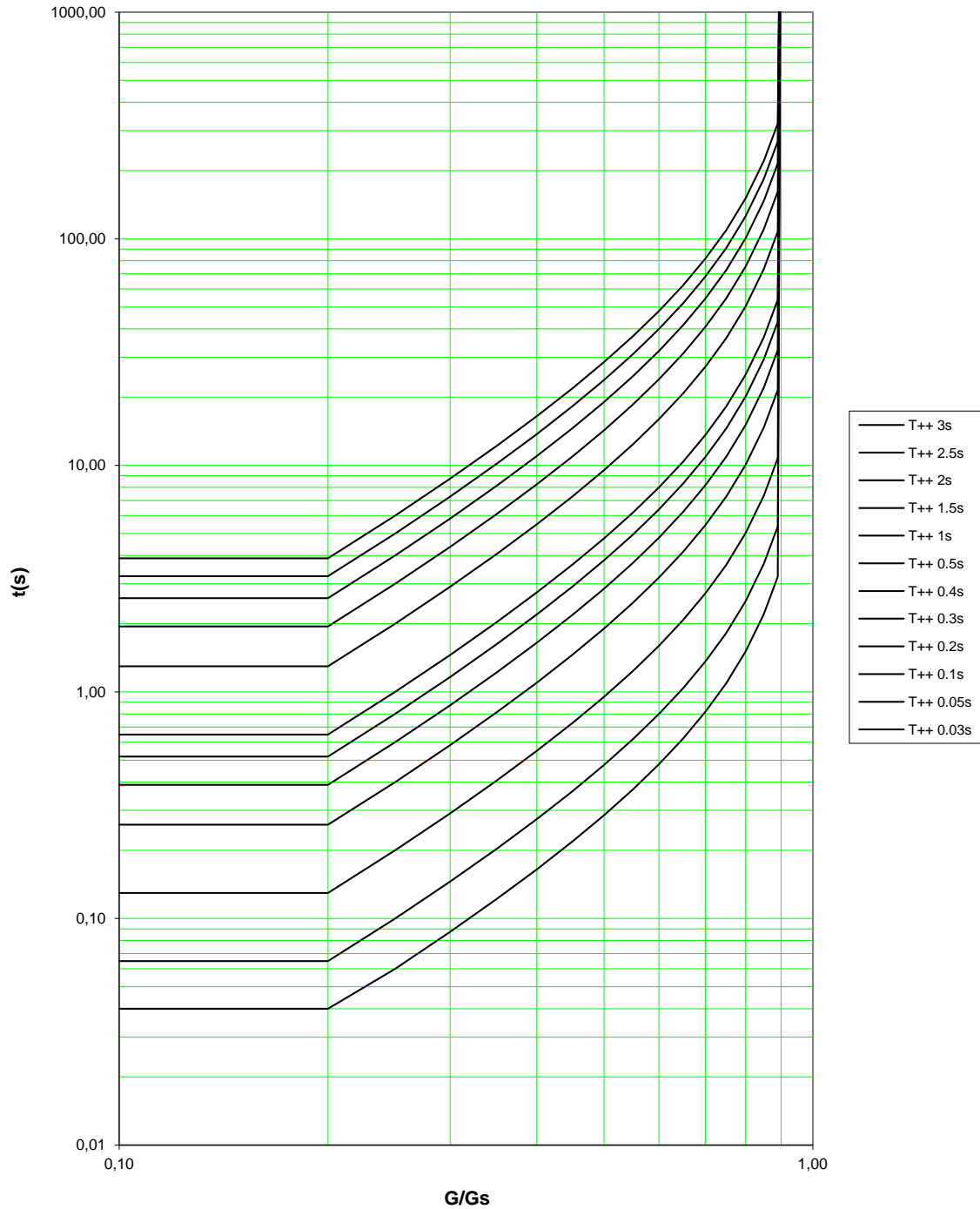
ANSI - Very inverse min



3.7.1.3.5 Tripping curves with extremely inverse time for ANSI/IEEE [27]

$$t = T_{++} * \left( \frac{28.2 * (G/G_s)^2}{1 - (G/G_s)^2} + 0.1217 \right) \text{ For } 0.2 G_s < G < 0.9 G_s$$

ANSI Extremely inverse (min)



### **3.7.1.4 Programmable inverse time delay**

As mentioned in section **3.5.5 Programmable inverse time delay for NPI800-NPI800R and NPID800-NPID800R**, the NP800-NP800R models are designed to work with two configurable tripping curves with inverse time.

These curves are to be defined by the user, and then downloaded by ICE at the factory. For more information, please contact us.

Like any other inverse time curves, these two characteristics can then be shared by the other protection functions, in the same way as IEC or ANSI/IEEE curves.

### 3.7.2 Tripping curves for [47] [59] [59N]

#### 3.7.2.1 Definite time-delay for [47] [59] [59N]

The **NP800-NP800R-NP800RE** and **NPW800-NPW800R** models allow for the selection of a definite time curve with a time delay between 40ms and 300s.

The value of the time delay includes all fault processing times until the output relay activation.

The real tripping time for the protection is the sum of the time delay value and a delay of about 15ms.

#### 3.7.2.2 Inverse time delay for IEC [59] standards

##### 3.7.2.2.1 Equation for IEC [47] [59]

The **NP800-NP800R-NP800RE** and **NPW800-NPW800R** models allow for the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the following functions:

- Overvoltage [59]

The typical equation for these curves is as follows:

$$t = T_{++} * \left( \frac{K}{(G/G_s)^\alpha - 1} \right)$$

- t Tripping time
- G Value of the measured quantity
- G<sub>s</sub> Value of the programmed quantity
- α, K Ratio to define the curves (inverse, extremely inverse, ...)
- T<sub>++</sub> Time multiplier value between 0.03 and 3 s.

These curves are limited to a range of values of G between 1.1 G<sub>s</sub> and 2 G<sub>s</sub>.

Dynamic measurement from 1 to 240V.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

## PROTECTION OF INCOMERS, CABLE FEEDERS AND TRANSFORMERS

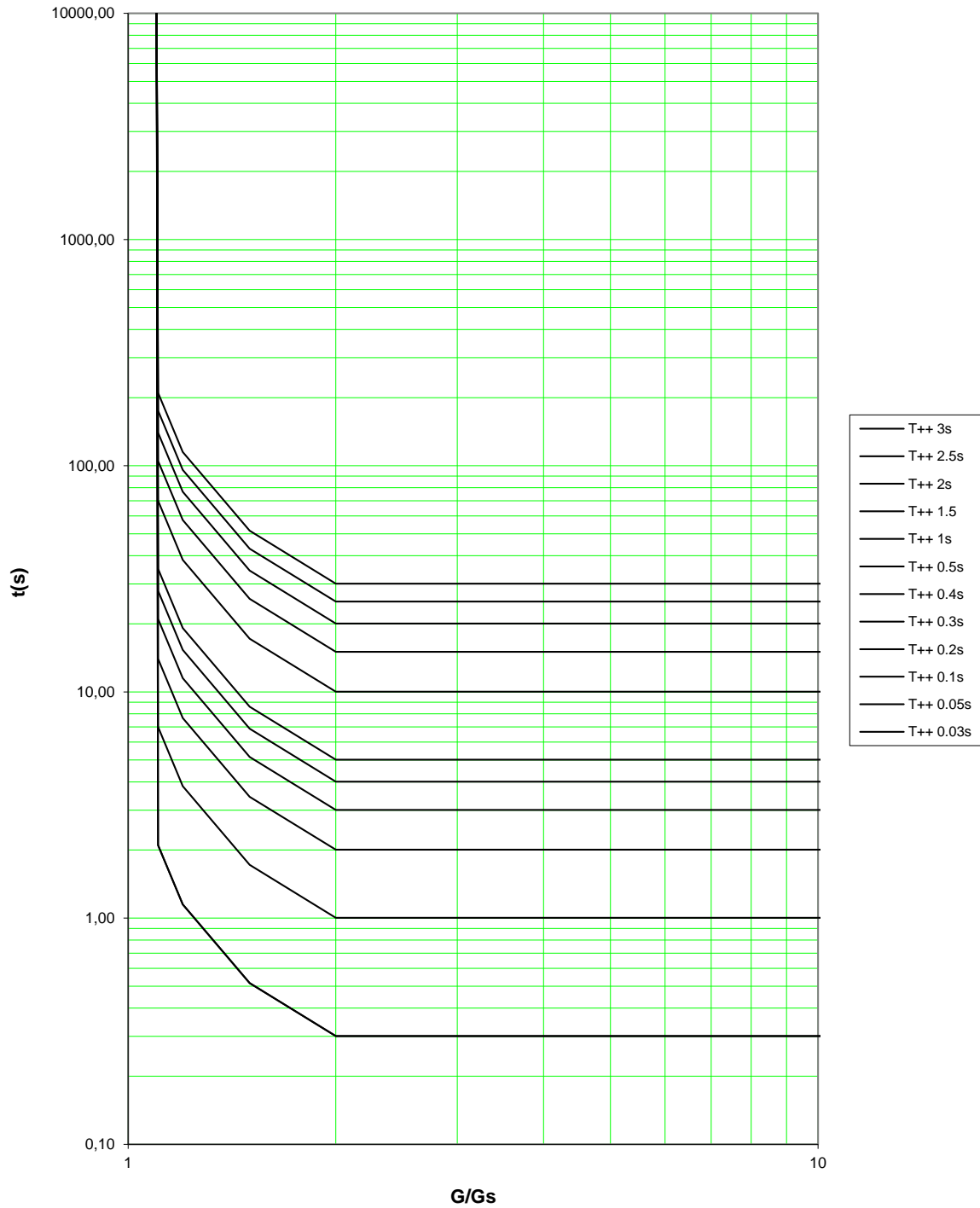
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Type of time delay	Limit for curves	T	K	$\alpha$
Inverse time	1.1 Gs < G < 2 Gs	Choose between 0.03 and 3 seconds with steps of 0.01 s	0.140	0.02
Very inverse time			13.5	1
Extremely inverse time			80	2

3.7.2.2 Tripping curves with inverse time for IEC [59]

$$t = \frac{0.140 T_{++}}{(G/G_s)^{0.02} - 1} \text{ For } 1.1G_s < G < 2 G_s$$

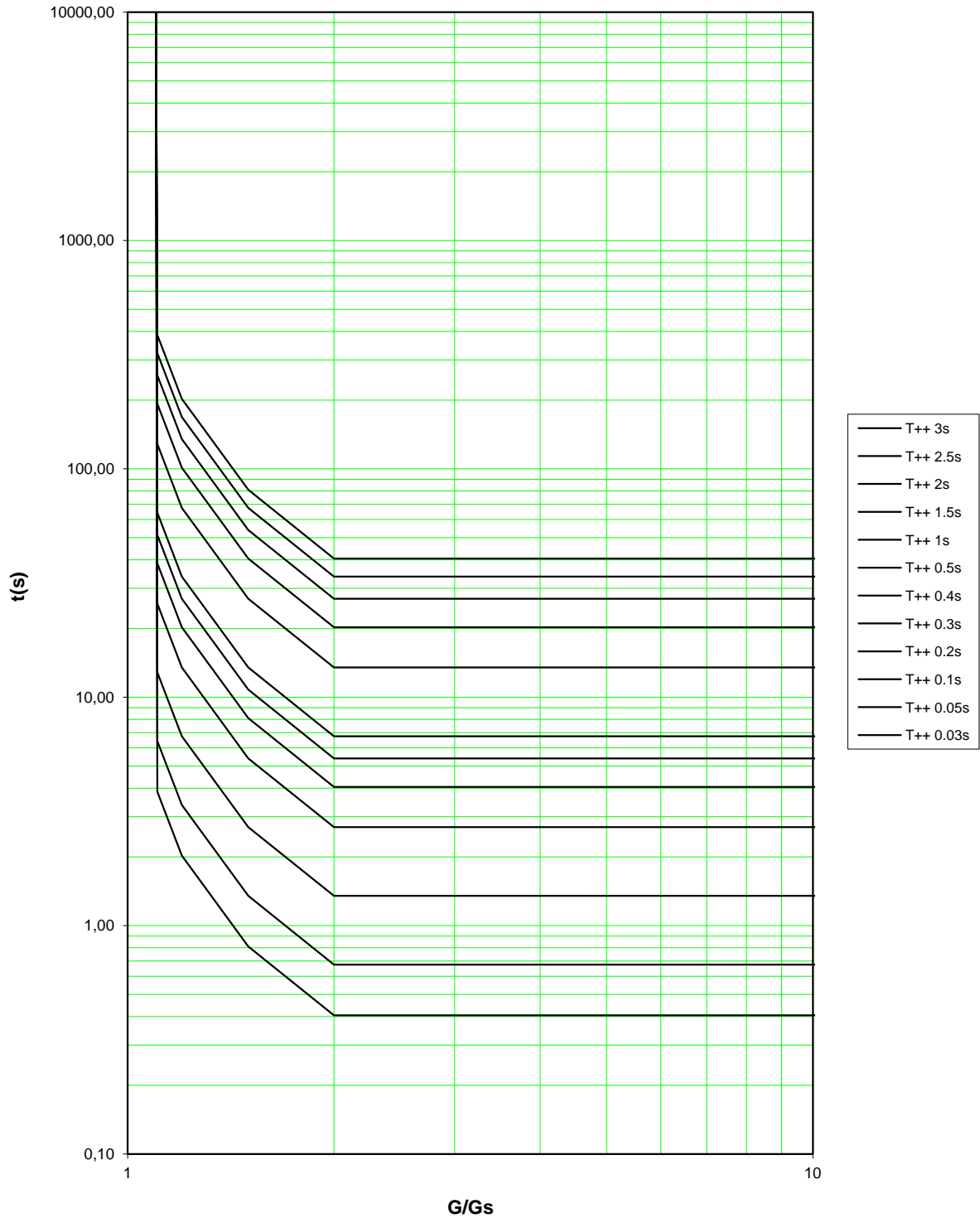
IEC curves with inverse time



3.7.2.2.3 Curves with very inverse time for IEC [59]

$$t = \frac{13.5 T_{++}}{(G/G_s) - 1} \text{ For } 1.1G_s < G < 2 G_s$$

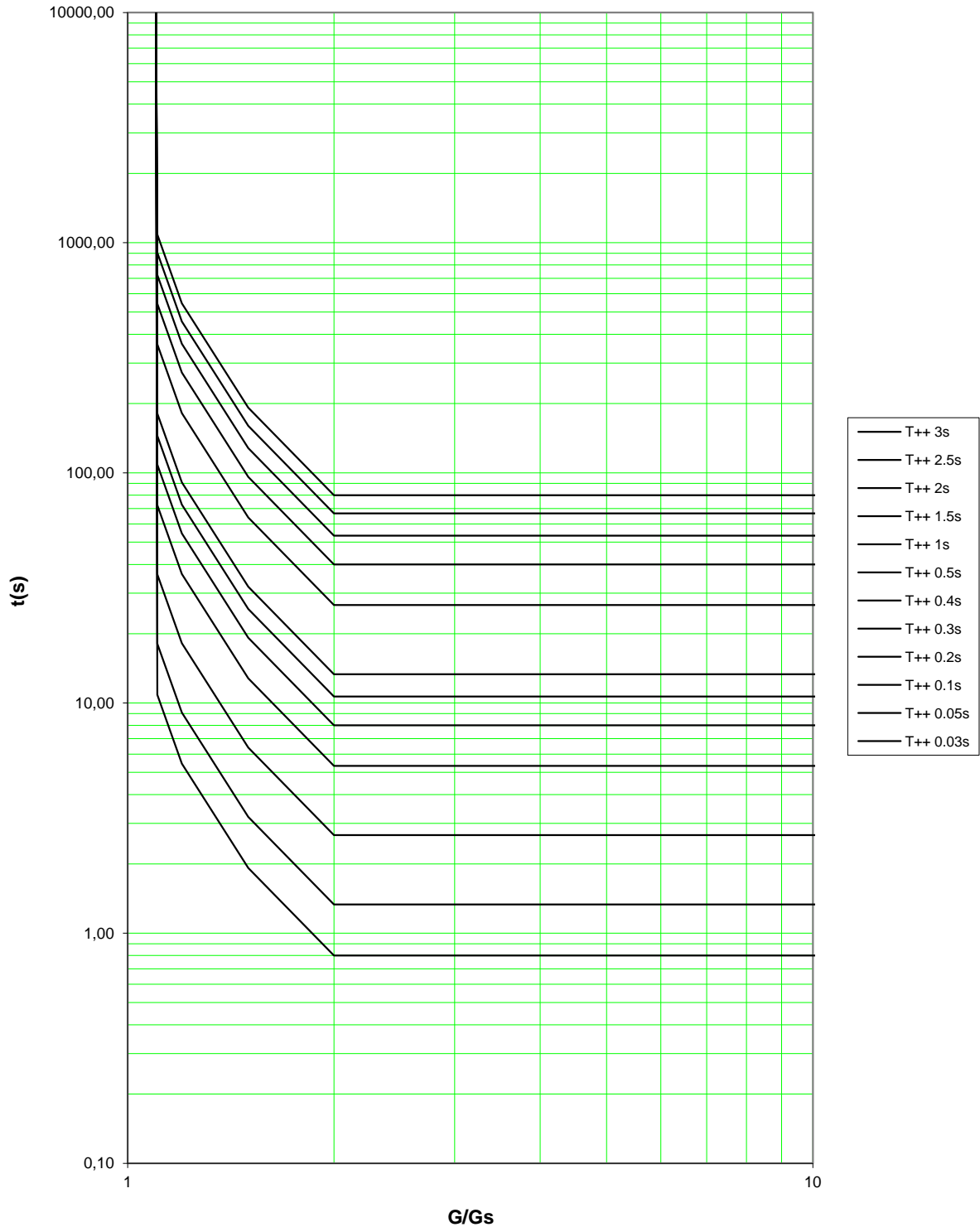
IEC curves with very inverse time



3.7.2.2.4 Curves with extremely inverse time for IEC [59]

$$t = \frac{80 T_{++}}{(G/G_s)^2 - 1} \text{ For } 1.1G_s < I < 2 G_s$$

IEC curves with extremely inverse time



**3.7.2.3 Inverse time delay for ANSI/IEEE [59] standards**

**3.7.2.3.1 Equation for ANSI/IEEE [59]**

The **NP800-NP800R-NP800RE** and **NPW800-NPW800R** models allow for the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the following functions:

- Overvoltage [59]

The typical equation for these curves is as follows:

$$t = T * \left( \frac{A}{(G/G_s)^\alpha - 1} + B \right)$$

- t                      Tripping time
- G                      Value of the measured quantity
- G<sub>s</sub>                    Threshold value for the programmed quantity
- α, A, B                Factors for curves definition (inverse, very inverse or extremely inverse)
- T ++                    Multiplying factor between 0.03 and 3 s.

These curves are limited to a range of values of G between 1.1 G<sub>s</sub> and 2 G<sub>s</sub>.

Dynamic measurement from 1 to 240V.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

Type of time delay	Curve limits	T	A	α	B
Moderately inverse time	1.1 < G/G <sub>s</sub> < 20	Choose from 0.03 to 3 s	0.0515	0.02	0.1140
Very inverse time			19.61	2	0.4910
Extremely inverse time			28.2	2	0.1217

**3.7.2.3.2 Setting advices for ANSI/IEEE [32P] [32Q] [59]**

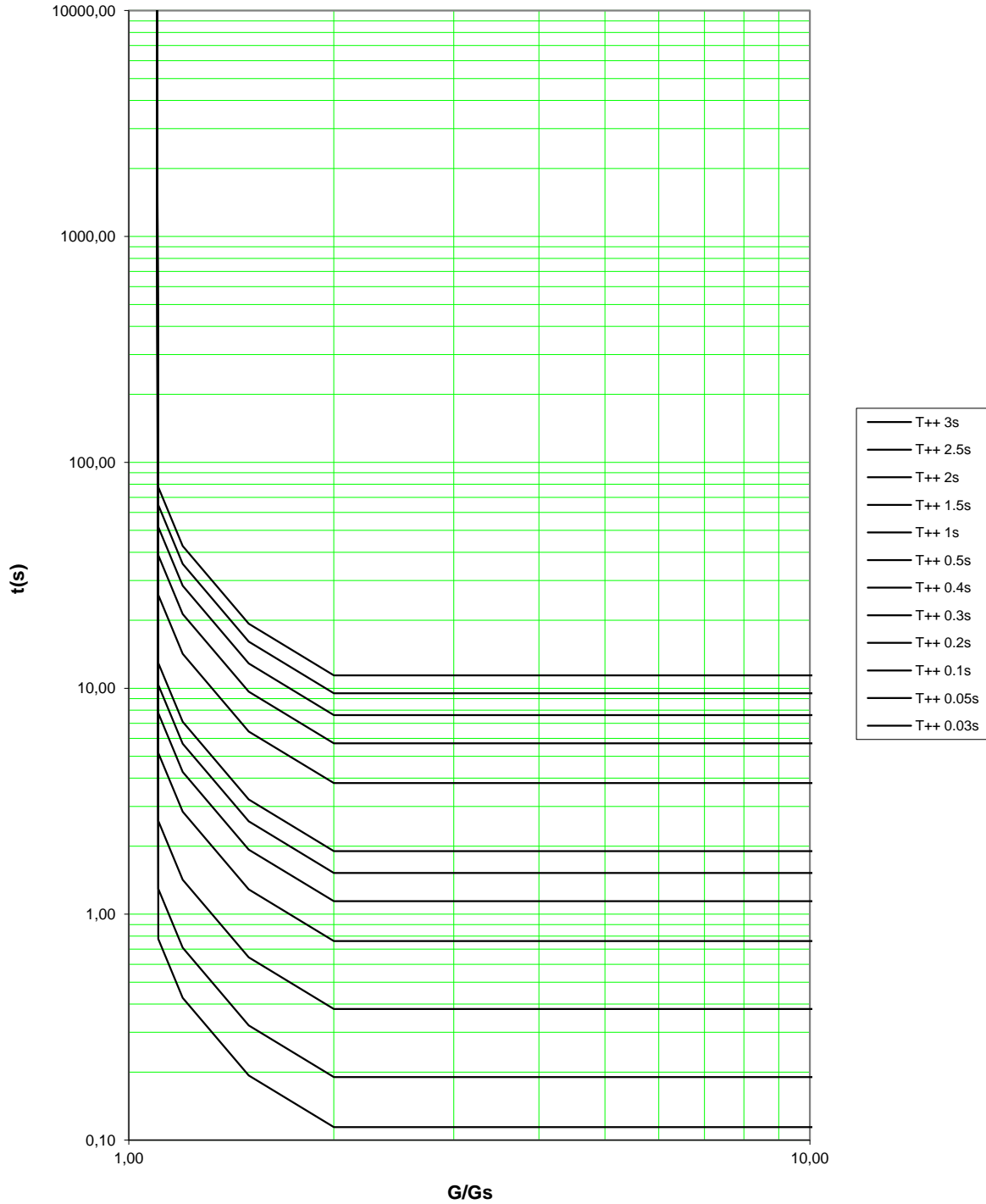


Please refer to the examples related to the IEC standard.

3.7.2.3.3 Tripping curves with moderately inverse time for ANSI/IEEE [59]

$$t = T_{++} * \left( \frac{0.0515}{(G/G_s)^{0.02} - 1} + 0.1140 \right) \text{ For } 1.1 G_s < G < 2 G_s$$

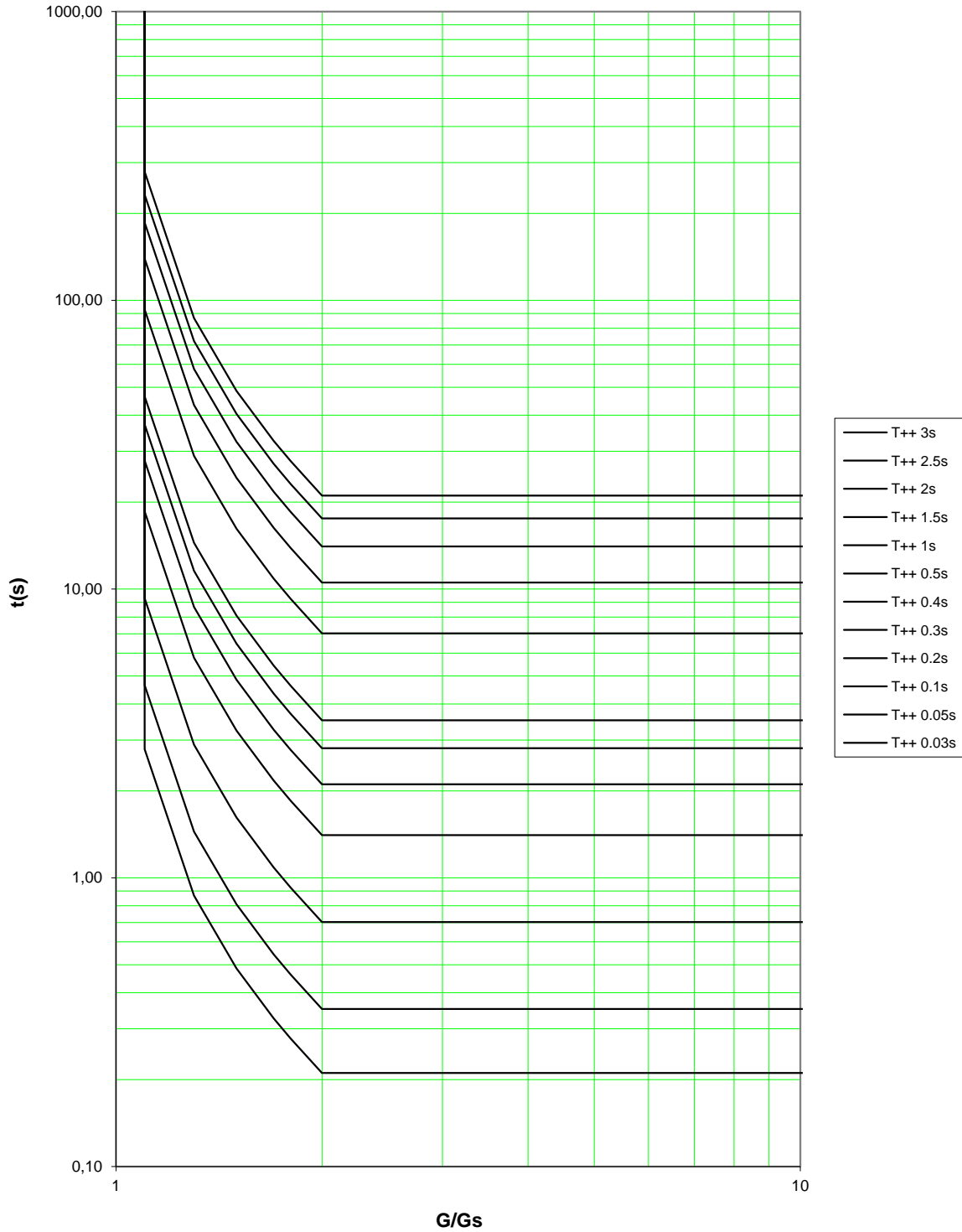
IEC curves - moderately inverse



3.7.2.3.4 Tripping curves with very inverse time for ANSI/IEEE [59]

$$t = T_{++} * \left( \frac{19.6}{(G/G_s)^2 - 1} + 0.4910 \right) \text{ For } 1.1 G_s < G < 2 G_s$$

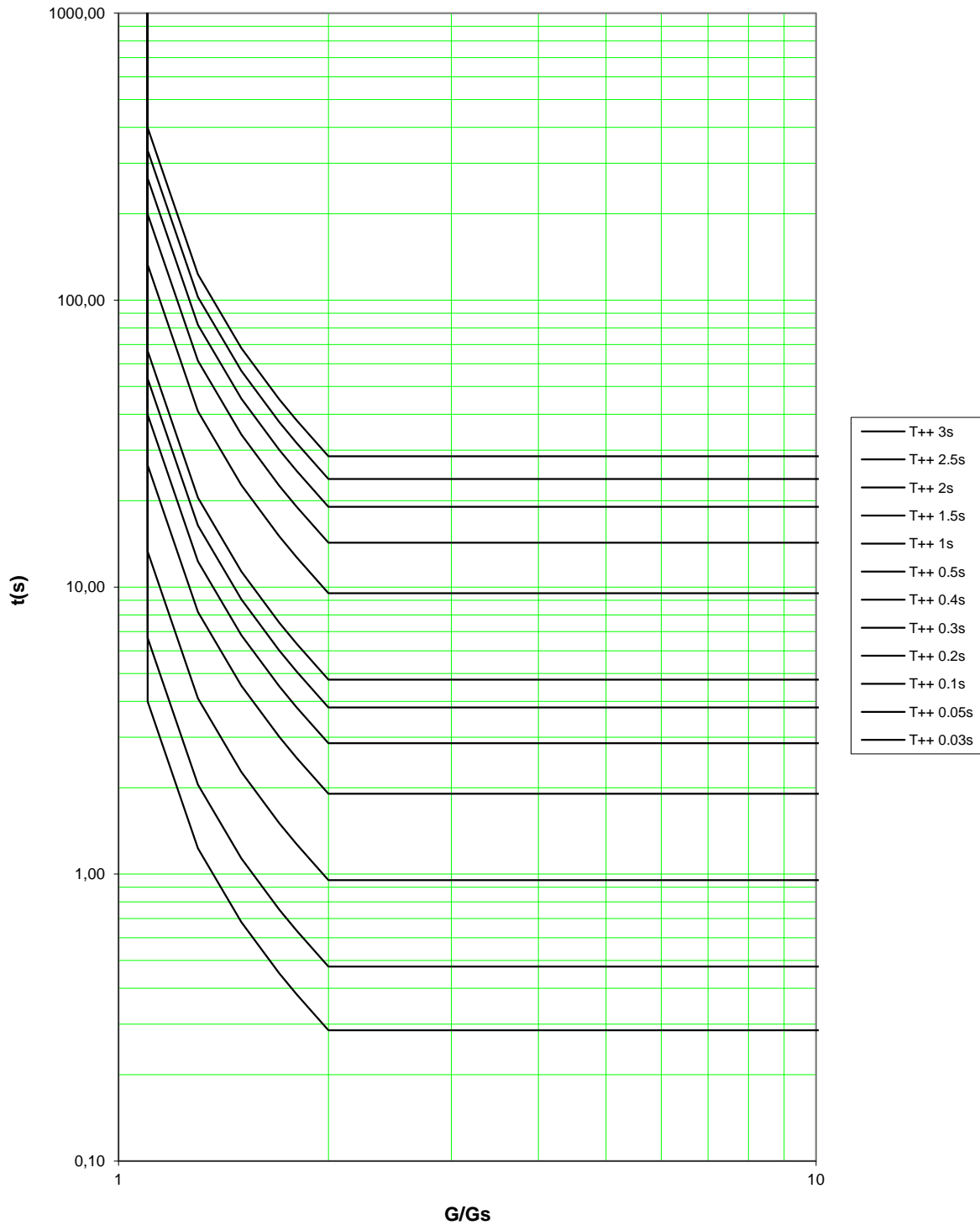
ANSI curves with very inverse time



3.7.2.3.5 Tripping curves with extremely inverse time for ANSI/IEEE [59]

$$t = T_{++} * \left( \frac{28.2}{(G/G_s)^2 - 1} + 0.1217 \right) \text{ For } 1.1G_s < G < 2 G_s$$

IEC curves with extremely inverse time



### 3.7.3 Tripping curves for [37P] [37Q]

#### 3.7.3.1 Definite time-delay for [37P] [37Q]

The NPW800-NPW800R models allow selecting a definite time curve with a time delay which can be set between 40ms and 300 s.

The value of the time delay includes all fault processing times until the output relay activation.

The real tripping time for the protection is the sum of the time delay value and a delay of about 15ms.

#### 3.7.3.2 Inverse time delay for IEC [37P] [37Q] standard

##### 3.7.3.2.1 Equation for IEC [37P] [37Q]

The NPW800-NPW800R models allow for the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the active power [37P] and reactive power [37Q] functions.

The typical equation for these curves is as follows:

$$t = \left( \frac{k \times (G / G_s)^\alpha}{1 - (G / G_s)^\alpha} \right) \times T ++$$

- t Tripping time
- G Value of the measured quantity
- G<sub>s</sub> Threshold value for the programmed quantity
- α, K Definition ratios for the curves (inverse, extremely inverse, ...)
- T ++ Multiplying factor between 0.03 and 3 s

These curves are limited to a value range of G between 0.2 and 0.9 G<sub>s</sub>.

Dynamic measurement from 0.01 to 18 In and 1 to 240V for [37P] and [37Q] functions.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

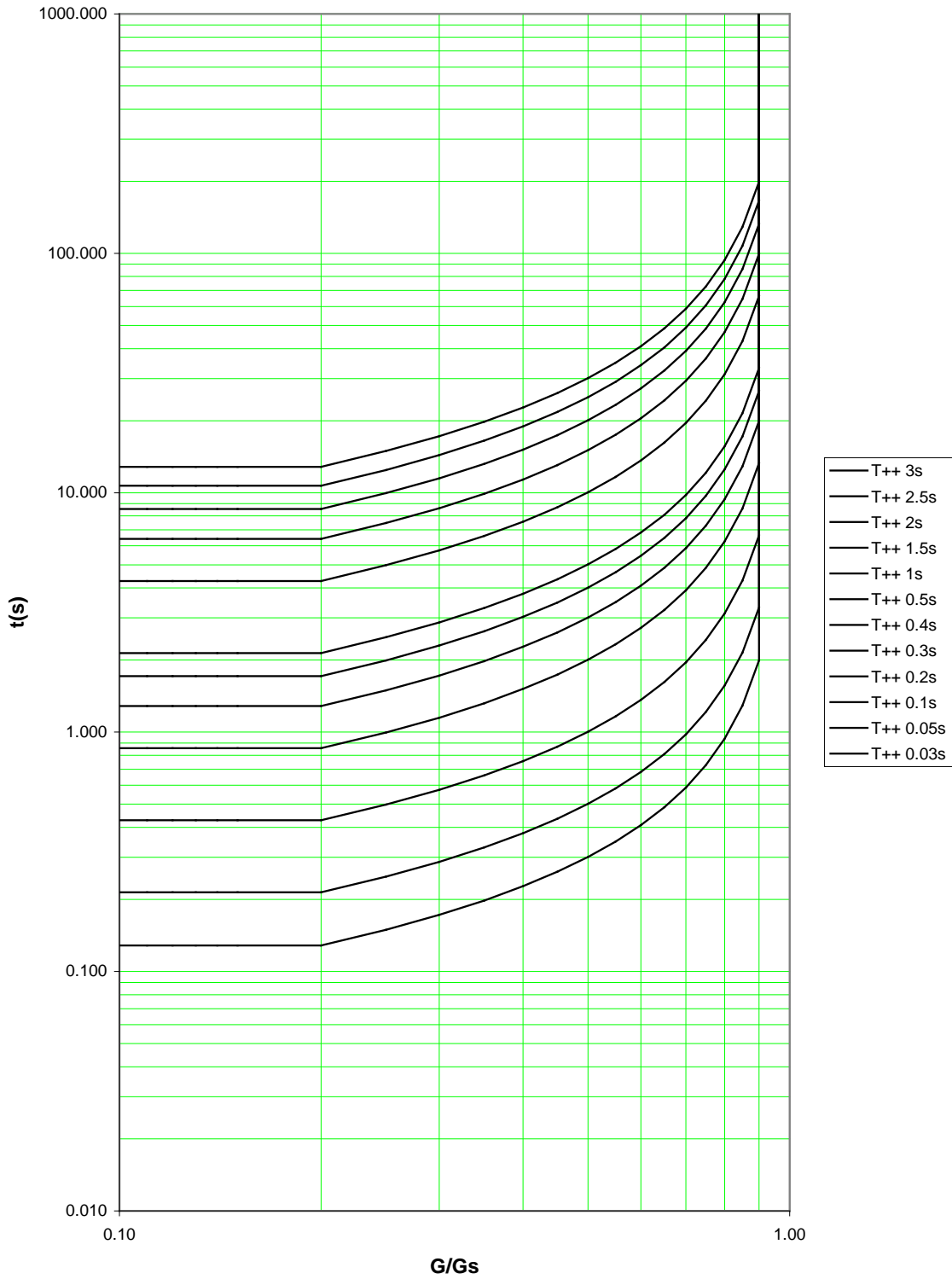
## PROTECTION OF INCOMERS, CABLE FEEDERS AND TRANSFORMERS

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Type of time delay	Limit of curves	T	K	$\alpha$
Inverse time	0.2 <G/Gs< 0.9	between 0.03 and 3 seconds	0.140	0.02
Very inverse time			13.5	1
Extremely inverse time			80	2

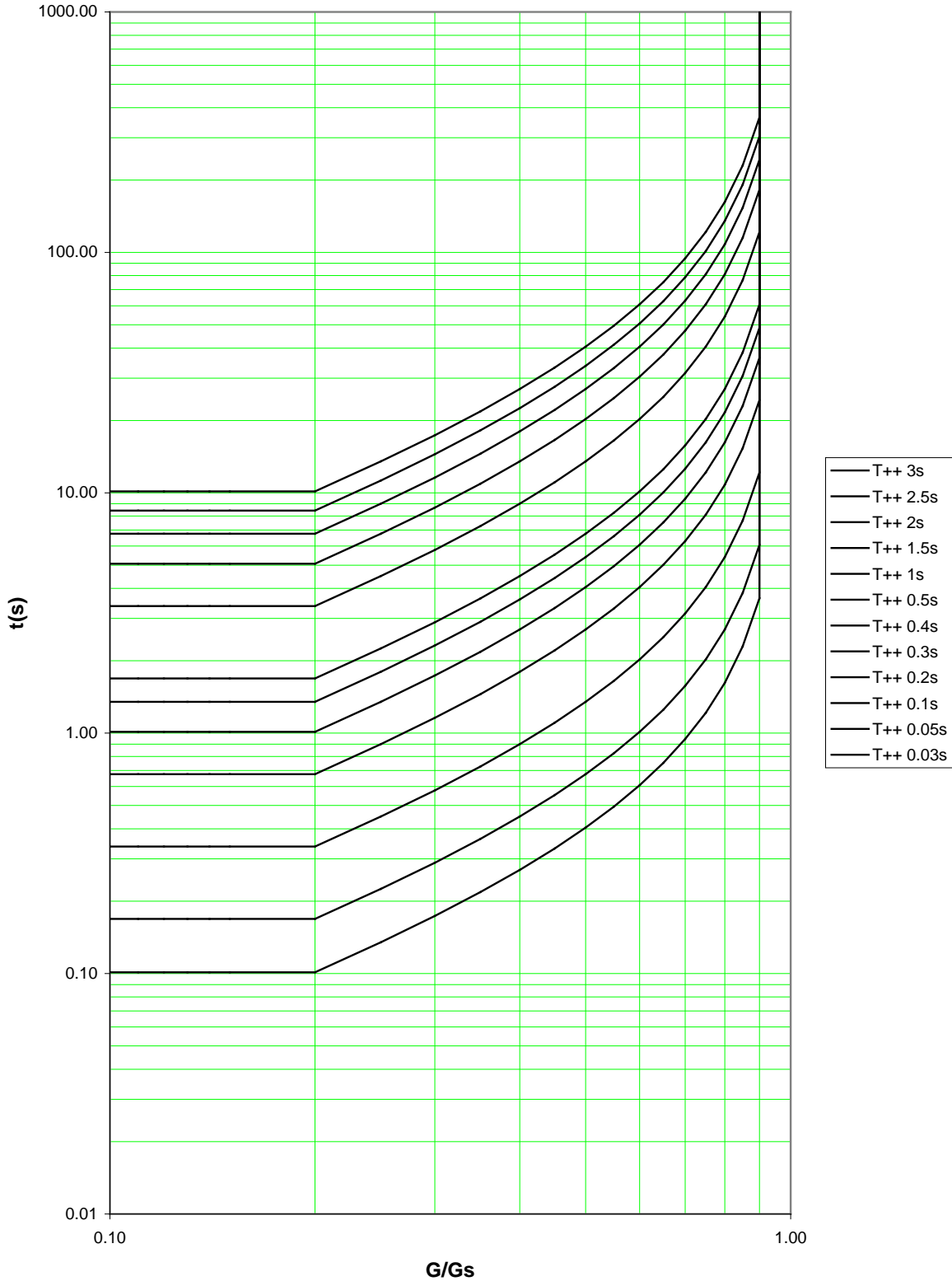
3.7.3.2 Tripping curves with inverse time for IEC [37P] [37Q]

$$t = \left( \frac{0.14 \times (G/G_s)^{0.02}}{1 - (G/G_s)^{0.02}} \right) \times T_{++} \quad \text{For } 0.2 < G/G_s < 0.9$$



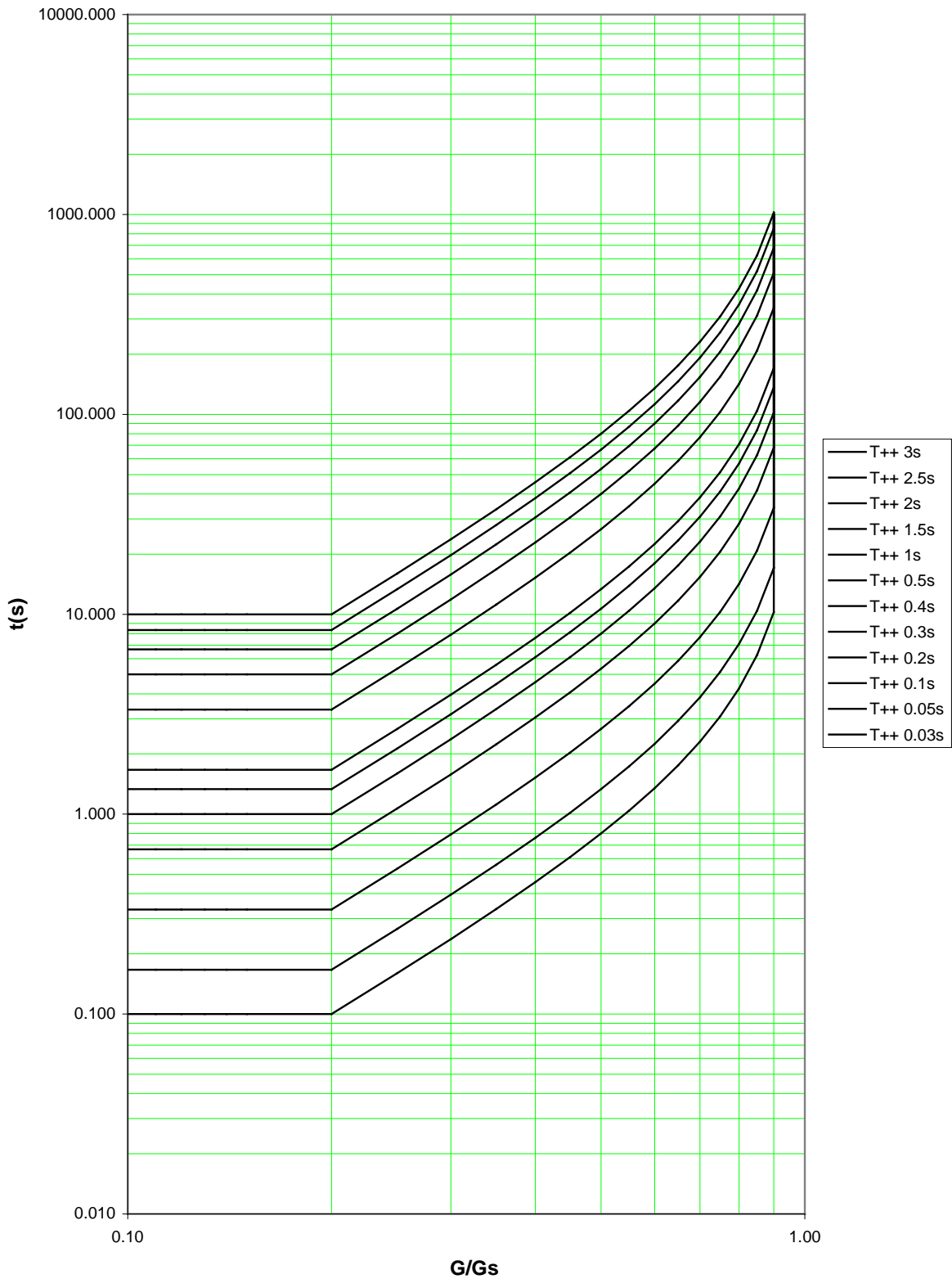
3.7.3.2.3 Tripping curves with very inverse time for IEC [37P] [37Q]

$$t = \left( \frac{13.5 \times (G/G_s)}{1 - (G/G_s)} \right) \times T_{++} \text{ For } 0.2 < G/G_s < 0.9$$



3.7.3.2.4 Tripping curves with extremely inverse time IEC [37P] [37Q]

$$t = \left( \frac{80 \times (G/G_s)^2}{1 - (G/G_s)^2} \right) \times T_{++} \text{ For } 0.2 < G/G_s < 0.9$$



**3.7.3.3 Inverse time delay for ANSI/IEEE [37P] [37Q] standard**

**3.7.3.3.1 ANSI/IEEE [37P] [37Q] equation**

The NPW800-NPW800R models allow for the selection of 3 curves with inverse time according to the ANSI/IEEE standard for the active power [37P] and reactive power [37Q] functions.

The typical equation for these curves is as follows:

$$t = T + + * \left( \frac{A * (G / G_s)^\alpha}{1 - (G/G_s)^\alpha} + B \right)$$

- t                      Tripping time
- G                      Value of the measured quantity
- Gs                     Threshold value for the programmed quantity
- α, A, B                Definition ratios for the curves (inverse, very inverse or extremely inverse)
- T ++                    Multiplying factor between 0.03 and 3 s.

These curves are limited to a range of values of G between 0.2 and 0.9 Gs

Dynamic measurement from 0.01 to 18 In and 1 to 240V.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

Type of time delay	Limit of curves	T	A	α	B
Moderately inverse time	0.2 <G/Gs < 0.9	Choose between 0.03 and 3 seconds	0.0515	0.02	0.1140
Very inverse time			19.61	2	0.4910
Extremely inverse time			28.2	2	0.1217

**3.7.3.3.2 Setting advices for ANSI/IEEE [37P] [37Q]**

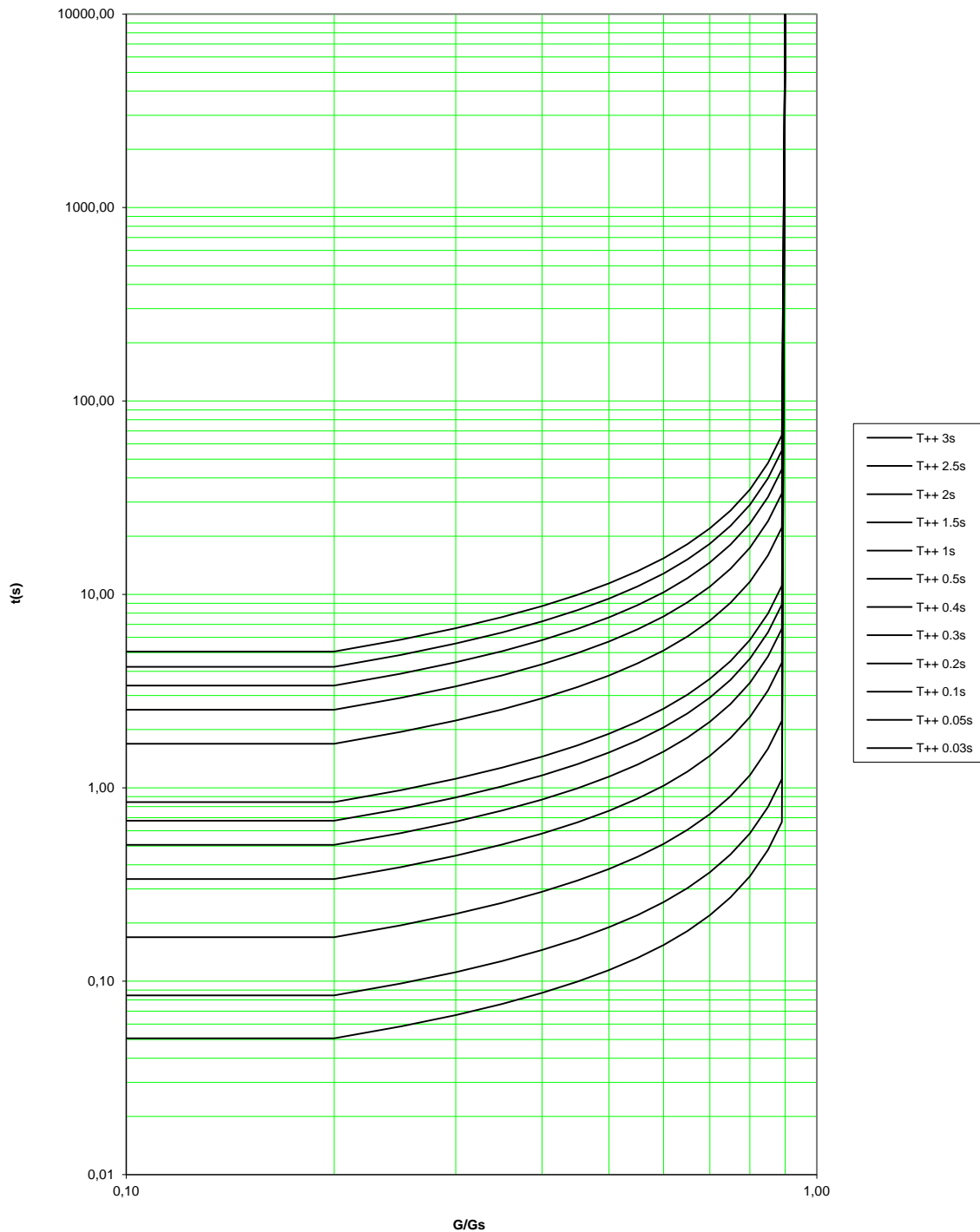


Please refer to the examples associated with the IEC standard.

3.7.3.3 Tripping curves with moderately inverse time for ANSI/IEEE [37P] [37Q]

$$t = T_{++} * \left( \frac{0.0515 * (G/G_s)^{0.02}}{1 - (G/G_s)^{0.02}} + 0.114 \right) \text{ For } 0.2 G_s < G < 0.9 G_s$$

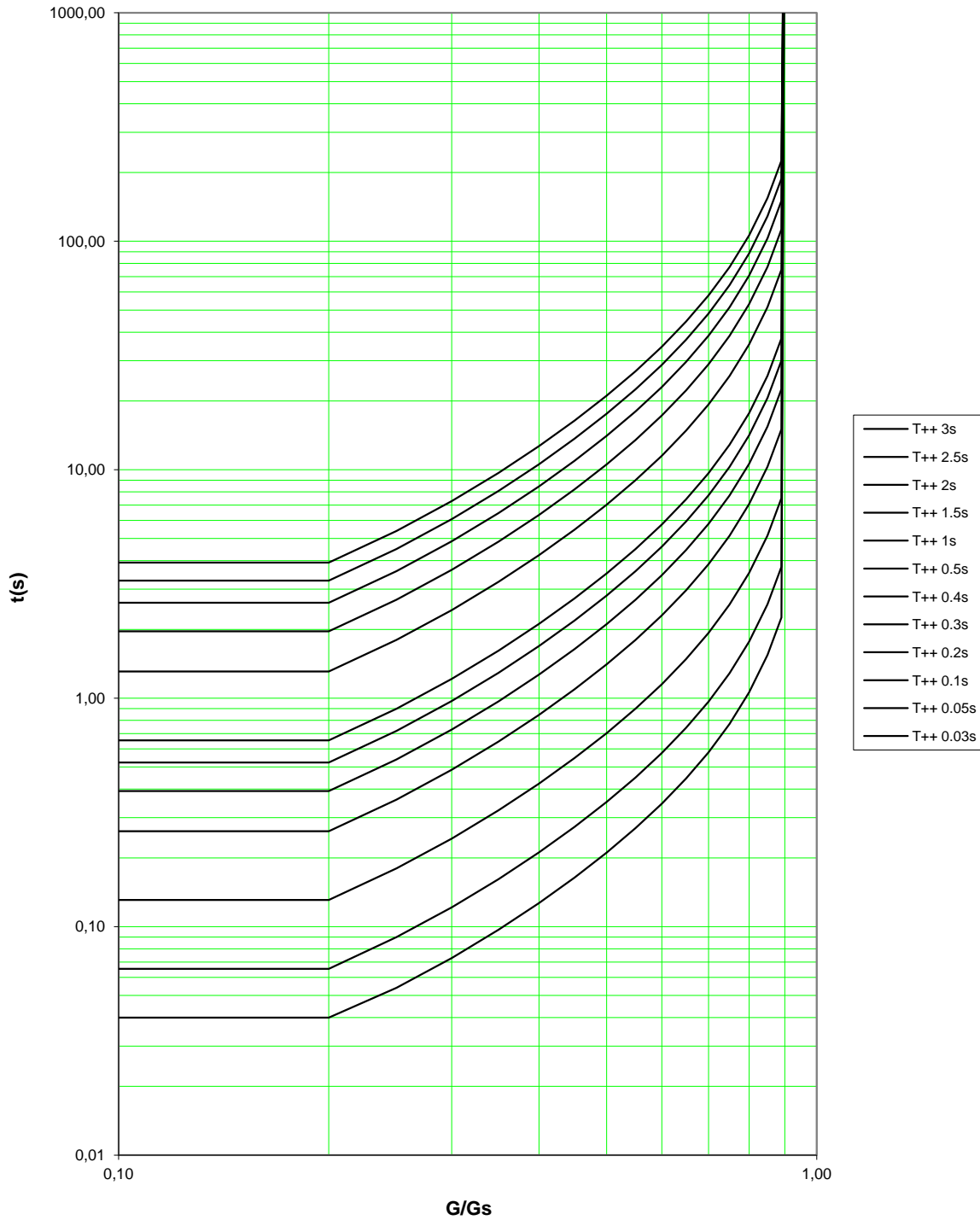
Ansi inverse min



3.7.3.3.4 Tripping curves with very inverse time for ANSI/IEEE ANSI/IEEE [37P] [37Q]

$$t = T_{++} * \left( \frac{19.61 * (G/G_s)^2}{1 - (G/G_s)^2} + 0.4910 \right) \text{ For } 0.2 G_s < G < 0.9 G_s$$

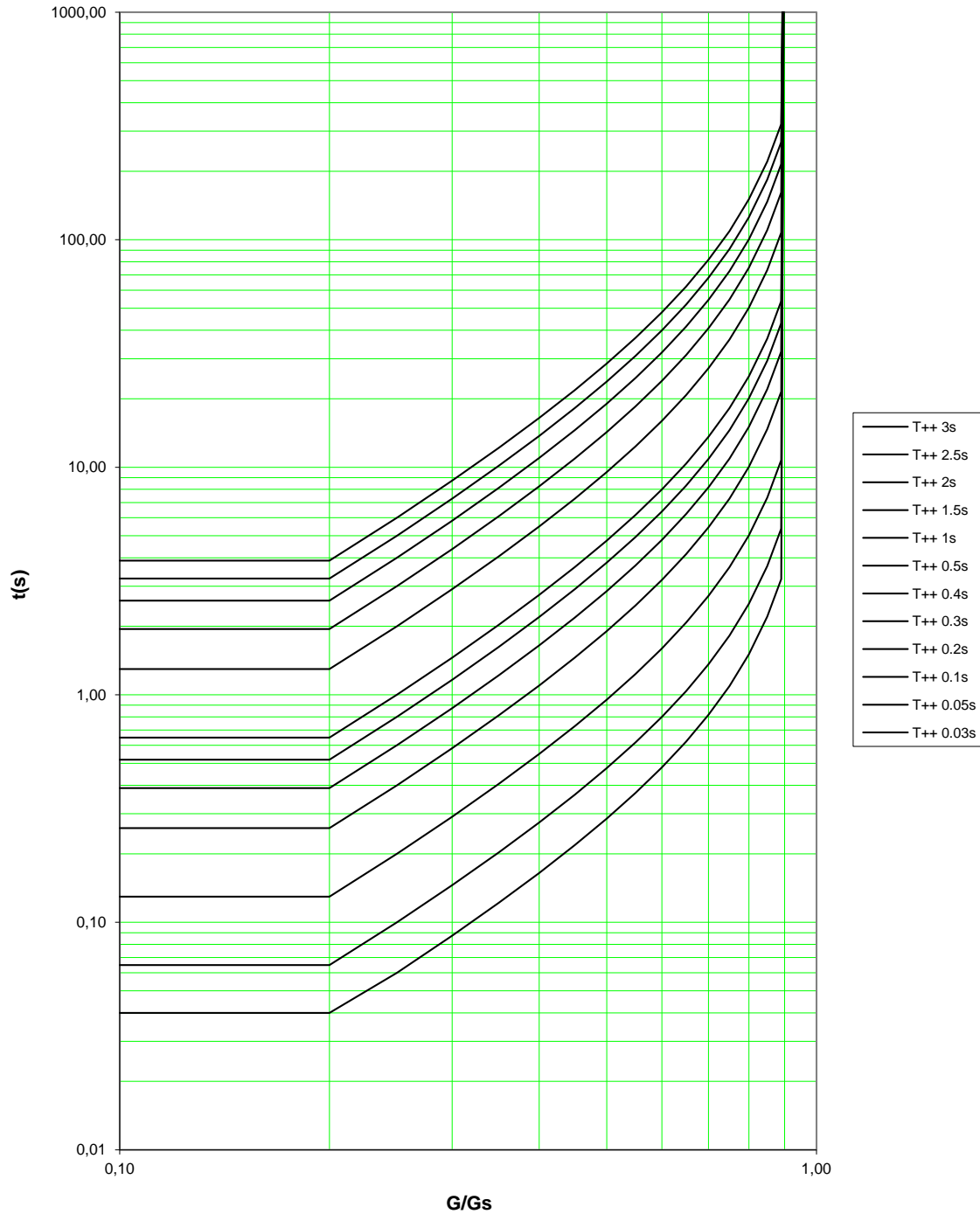
ANSI - Very inverse min



3.7.3.3.5 Tripping curves with extremely inverse time for ANSI/IEEE [37P] [37Q]

$$t = T_{++} * \left( \frac{28.2 * (G/G_s)^2}{1 - (G/G_s)^2} + 0.1217 \right) \text{ For } 0.2 G_s < G < 0.9 G_s$$

ANSI Extremely inverse (min)



### 3.7.3.4 Inverse time delay with electromechanical type for [37P] [37Q]

#### 3.7.3.4.1 Inverse time equation with electromechanical type for [37P] [37Q]

The NPW800-NPW800R models allow for the selection of an RI inverse time curve with electromechanical type for the following functions:

- minimum of active power [37P]
- minimum of reactive power [37Q]

The typical equation for this curve is as follows:

$$t = \frac{T_{++}}{0.339 - (0.236 \times (G/G_s))} \quad \text{For } 0.2 G_s < G < 0.9 G_s$$

- t                      Tripping time
- G                      Value of the measured quantity
- G<sub>s</sub>                    Threshold value for the programmed quantity
- T<sub>++</sub>                    Multiplying factor between 0.03 and 3 s.

Dynamic measurement from 0.01 to 18 In and 1 to 240V.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

#### 3.7.3.4.2 Application inverse time with electromechanical type of [37P] [37Q]

Use of this characteristic is recommended when selectivity with other network protections is not required.

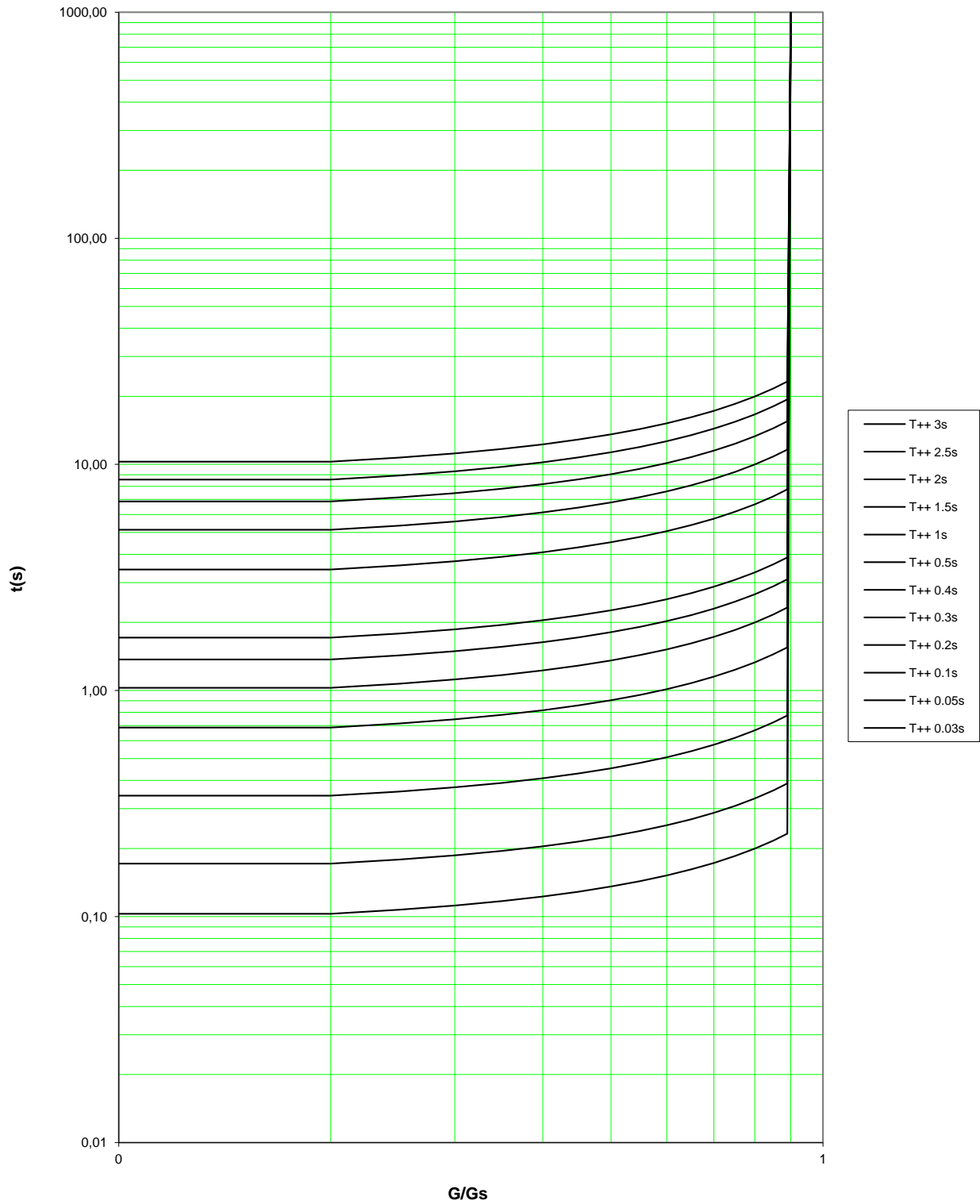
#### 3.7.3.4.3 Setting advices for inverse time with electromechanical type of [37P] [37Q]



Please refer to the examples related to the IEC standard.

3.7.3.4.4 RI curve of [37P] [37Q]

RI inverse (min)



### **3.7.3.5 Programmable inverse time delay**

As mentioned in section **3.5.5 Programmable inverse time delay for NPI800-NPI800R and NPID800-NPID800R**, the NP800-NP800R models are designed to work with two configurable tripping curves with inverse time.

These curves are to be defined by the user, and then downloaded by ICE at the factory. For more information, please contact us.

Like any other inverse time curves, these two characteristics can then be shared by the other protection functions, in the same way as IEC or ANSI/IEEE curves.

### **3.7.4 Tripping curves for [32P] [32Q]**

#### **3.7.4.1 Definite time-delay for [32P] [32Q]**

The **NPW800-NPW800R** models allow for the selection of a definite time curve with a time delay between 40ms and 300s.

The value of the time delay includes all fault processing times until the output relay activation.

The real tripping time for the protection is the sum of the time delay value and a delay of about 15ms.

#### **3.7.4.2 Inverse time delay for IEC [32P] [32Q] standards**

##### **3.7.4.2.1 Equation for IEC [32P] [32Q]**

The **NPW800-NPW800R** models allow for the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the following functions:

- Maximum of active power [32P]
- Maximum of reactive power [32Q]

The typical equation for these curves is as follows:

$$t = T_{++} * \left( \frac{K}{(G/G_s)^\alpha - 1} \right)$$

- t Tripping time
- G Value of the measured quantity
- G<sub>s</sub> Value of the programmed quantity
- α, K Ratio to define the curves (inverse, extremely inverse, ...)
- T<sub>++</sub> Time multiplier value between 0.03 and 3 s.

These curves are limited to a range of values of G between 1.1 G<sub>s</sub> and 20 G<sub>s</sub>.

Dynamic measurement from 0.01 to 18 In and 1 to 240V for [32P] and [32Q] functions.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

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Type of time delay	Limit for curves	T	K	$\alpha$
Inverse time	1.1 Gs < G < 20 Gs	Choose between 0.03 and 3 seconds with steps of 0.01 s	0.140	0.02
Very inverse time			13.5	1
Extremely inverse time			80	2

- When the monitored value is greater than 20 times the threshold, the tripping time will never be higher than the value of 20 times the threshold. (Inverse time relay function with Definite Minimum Time)

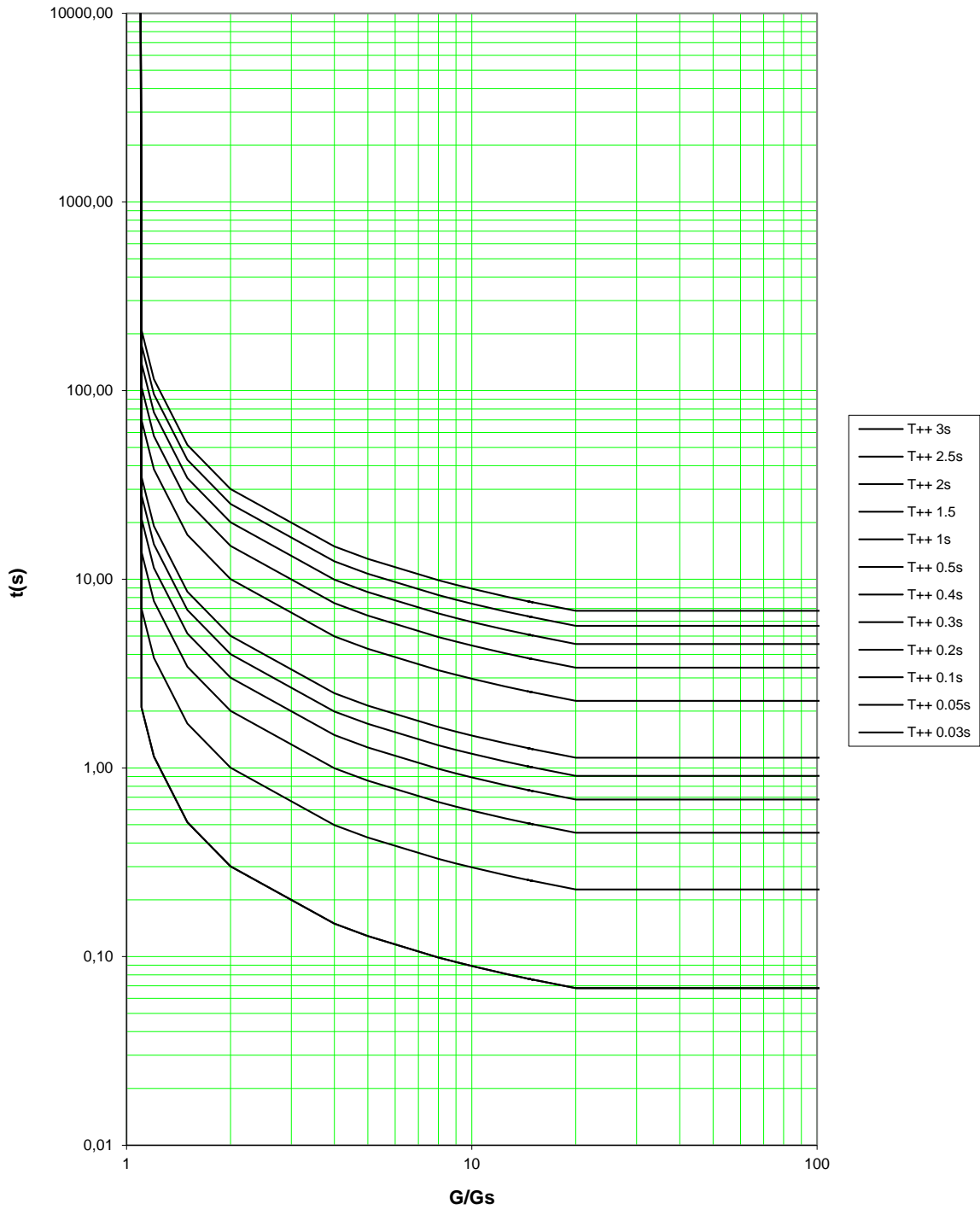


- If the monitored value exceeds the measuring capacity of the relay inputs, i.e. 18 In, the trip time, based on the threshold setting, will function of this value.

3.7.4.2.2 Tripping curves with inverse time for IEC [32P] [32Q]

$$t = \frac{0.140 T_{++}}{(G/G_s)^{0.02} - 1} \text{ For } 1.1G_s < G < 20 G_s$$

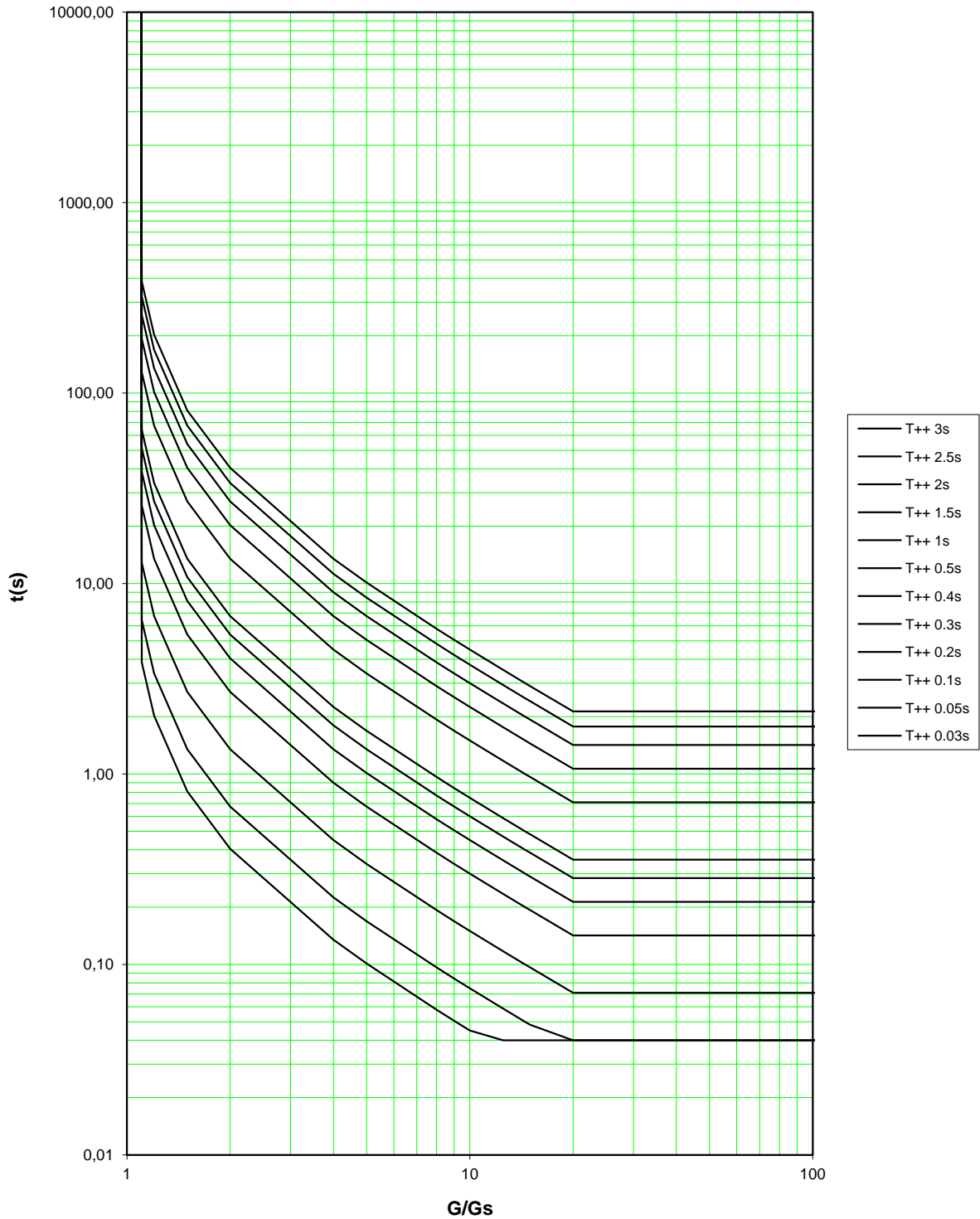
IEC curves with inverse time



3.7.4.2.3 Curves with very inverse time for IEC [32P] [32Q]

$$t = \frac{13.5 T_{++}}{(G/G_s) - 1} \text{ For } 1.1G_s < G < 20 G_s$$

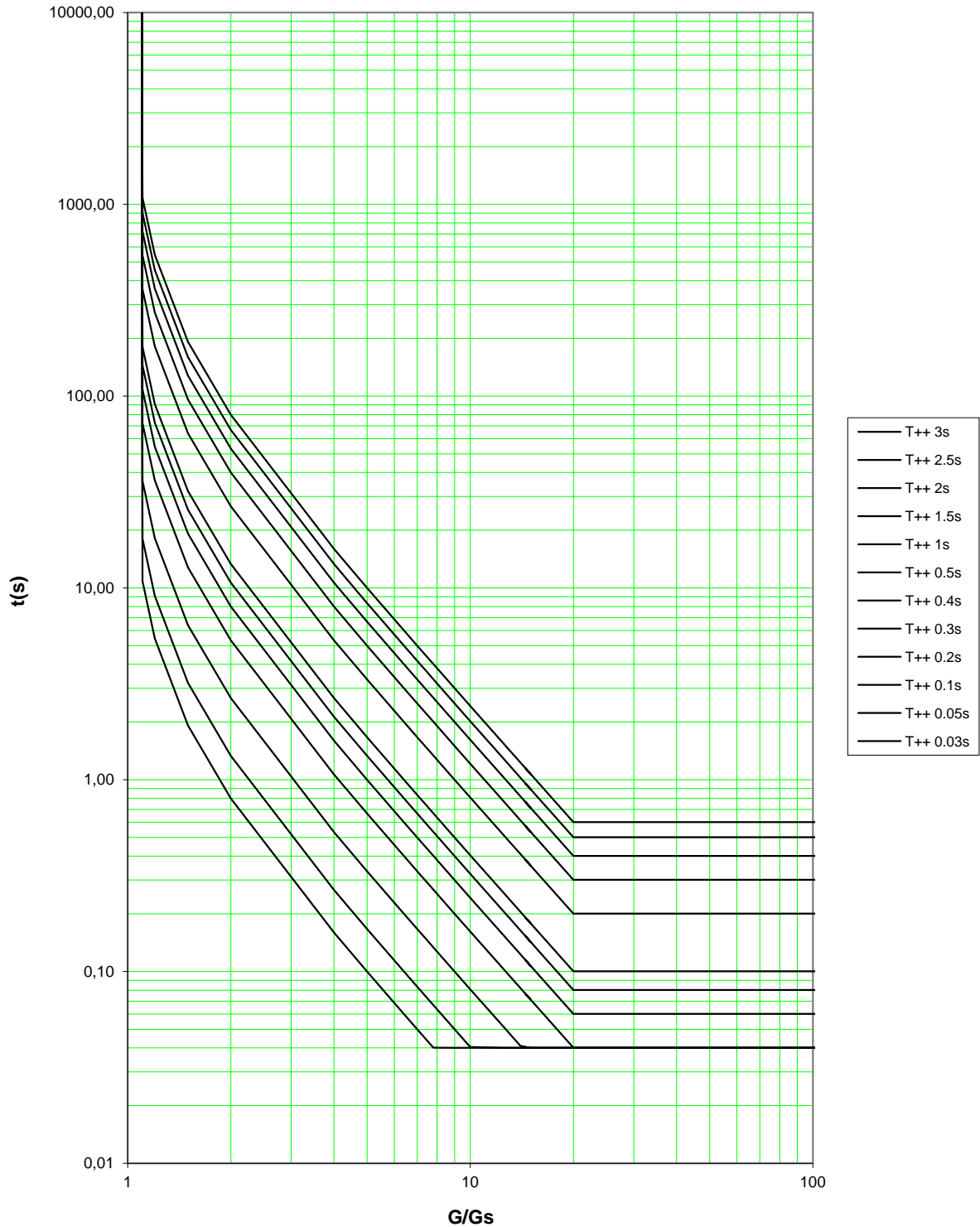
IEC curves with very inverse time



3.7.4.2.4 Curves with extremely inverse time for IEC [32P] [32Q]

$$t = \frac{80 T_{++}}{(G/G_s)^2 - 1} \text{ For } 1.1G_s < I < 20 G_s$$

IEC curves with extremely inverse time



### 3.7.4.3 Inverse time delay for ANSI/IEEE [32P] [32Q] standards

#### 3.7.4.3.1 Equation for ANSI/IEEE [32P] [32Q]

The **NPW800-NPW800R** models allow for the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the following functions:

- Maximum of active power [32P]
- Maximum of reactive power [32Q]

The typical equation for these curves is as follows:

$$t = T * \left( \frac{A}{(G/G_s)^\alpha - 1} + B \right)$$

- t                      Tripping time
- G                      Value of the measured quantity
- G<sub>s</sub>                    Threshold value for the programmed quantity
- α, A, B                Factors for curves definition (inverse, very inverse or extremely inverse)
- T ++                    Multiplying factor between 0.03 and 3 s.

These curves are limited to a range of values of G between 1.1 G<sub>s</sub> and 20 G<sub>s</sub>.

Dynamic measurement from 0.01 to 18 In and 1 to 240V for [32P] and [32Q] functions.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

- When the monitored value is greater than 20 times the threshold, the tripping time will never be higher than the value of 20 times the threshold. (Inverse time relay function with Definite Minimum Time)



- If the monitored value exceeds the measuring capacity of the relay inputs, i.e. 18 In, the trip time, based on the threshold setting, will function of this value.

Type of time delay	Curve limits	T	A	$\alpha$	B
Moderately inverse time	1.1 < G/Gs < 20	Choose from 0.03 to 3 s	0.0515	0.02	0.1140
Very inverse time			19.61	2	0.4910
Extremely inverse time			28.2	2	0.1217

**3.7.4.3.2 Setting advices for ANSI/IEEE [32P] [32Q] [59]**

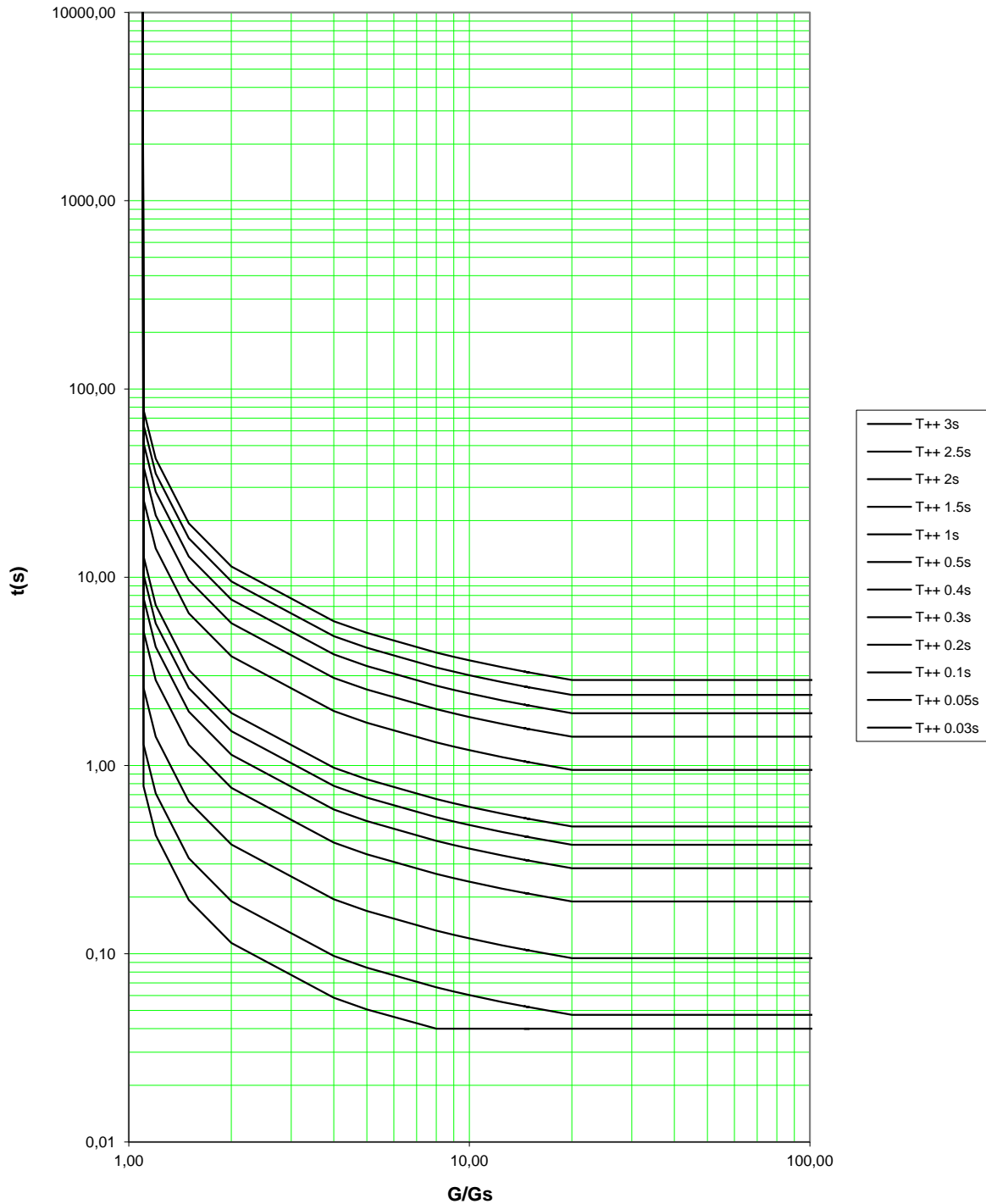


Please refer to the examples related to the IEC standard.

3.7.4.3.3 Tripping curves with moderately inverse time for ANSI/IEEE [32P] [32Q]

$$t = T_{++} * \left( \frac{0.0515}{(G/G_s)^{0.02} - 1} + 0.1140 \right) \text{ For } 1.1 G_s < G < 20 G_s$$

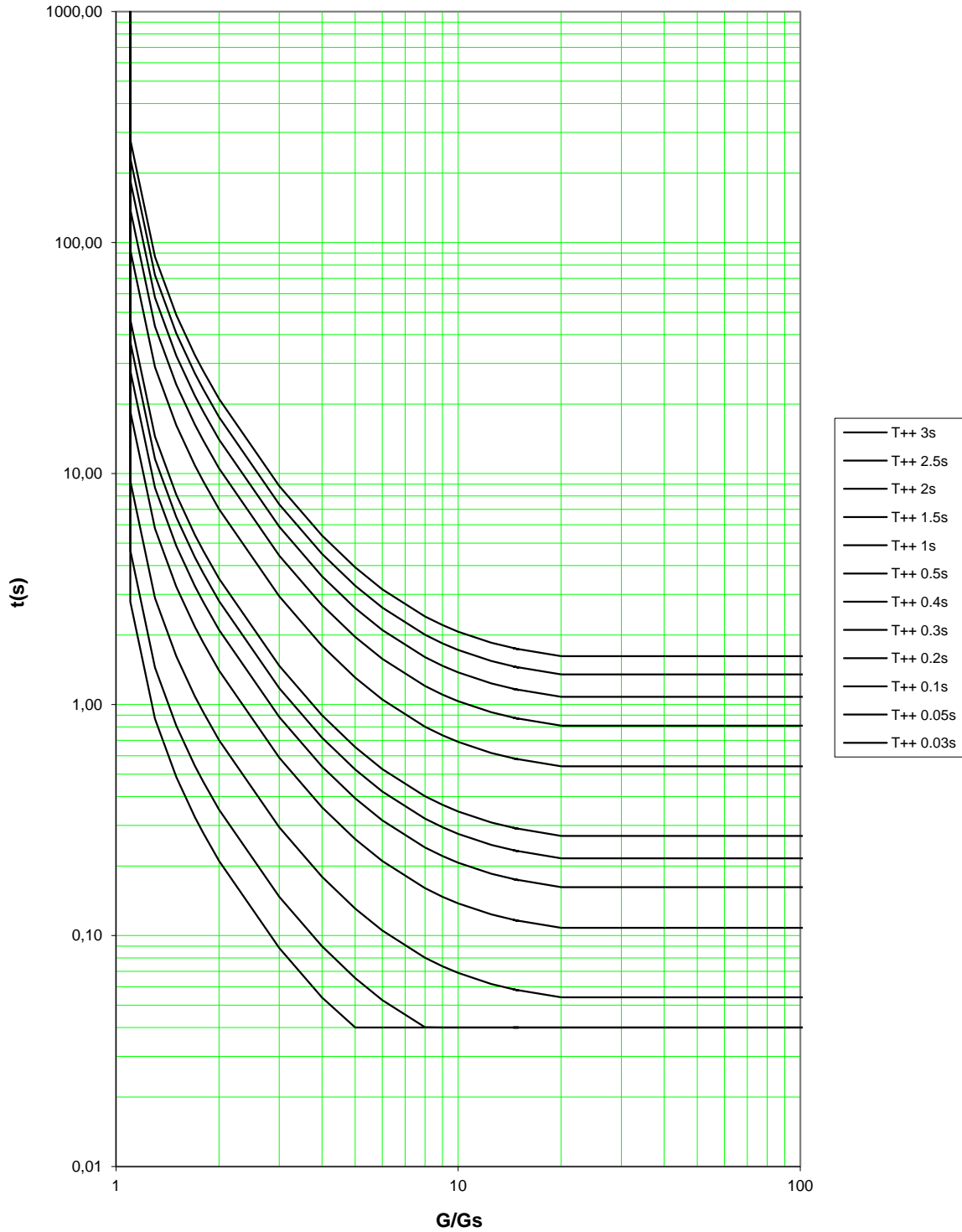
IEC curves - moderately inverse



3.7.4.3.4 Tripping curves with very inverse time for ANSI/IEEE [32P] [32Q]

$$t = T_{++} * \left( \frac{19.6}{(G/G_s)^2 - 1} + 0.4910 \right) \text{ For } 1.1 G_s < G < 20 G_s$$

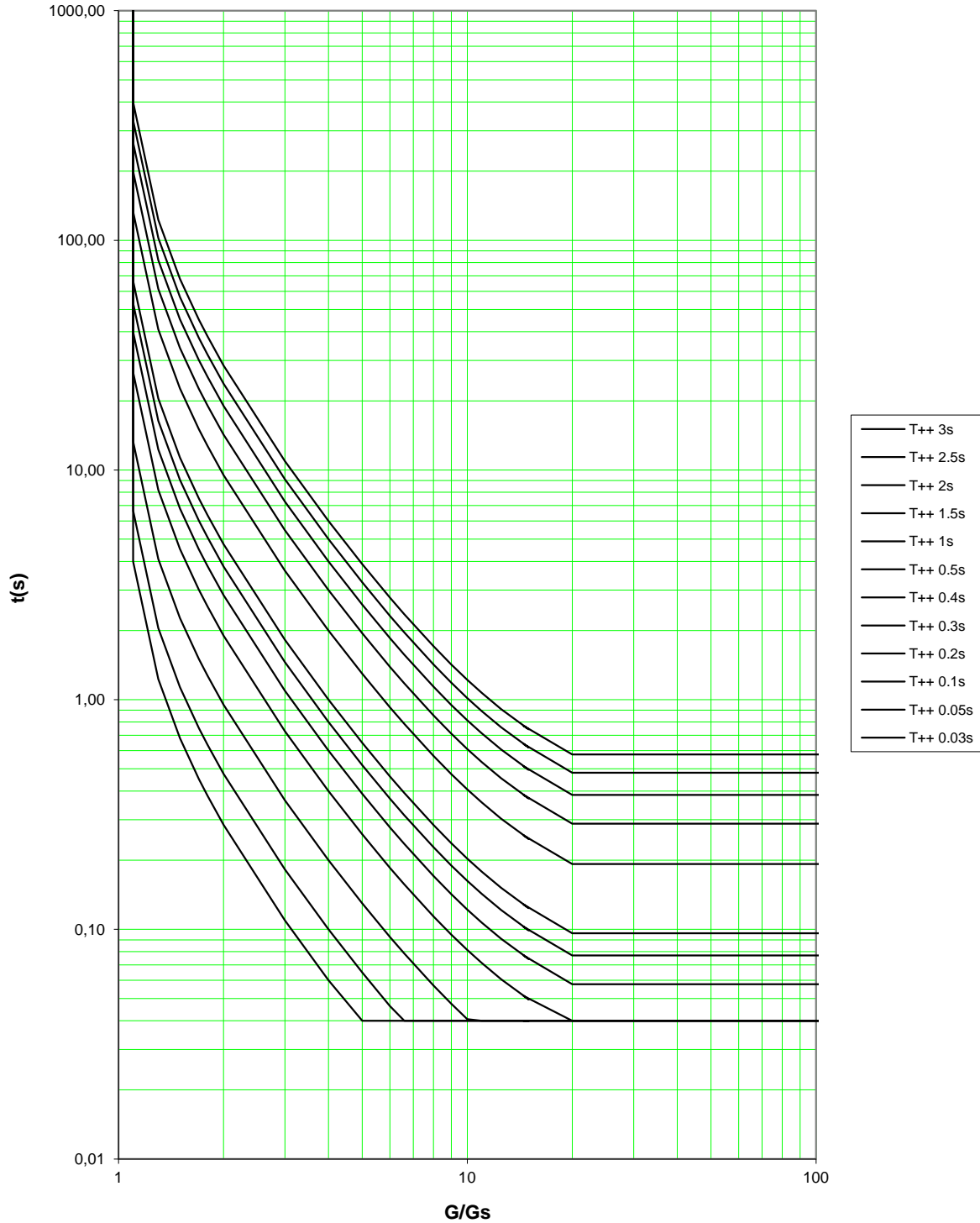
ANSI curves with very inverse time



3.7.4.3.5 Tripping curves with extremely inverse time for ANSI/IEEE [32P] [32Q]

$$t = T_{++} * \left( \frac{28.2}{(G/G_s)^2 - 1} + 0.1217 \right) \text{ For } 1.1G_s < G < 20 G_s$$

IEC curves with extremely inverse time



### 3.7.4.4 Inverse time delay with electromechanical type for [32P] [32Q]

#### 3.7.4.4.1 Equation inverse time with electromechanical type for [32P] [32Q]

The **NPW800-NPW800R** models allow for the selection of 3 curves with inverse time according to the IEC 60255-4 standard for the following functions:

- Maximum of active power [32P]
- Maximum of reactive power [32Q]

The typical equation for this curve is as follows:

$$t = \frac{T_{++}}{0.339 - \frac{0.236}{(G/G_s)}} \quad \text{for } 1.1 G_s < G < 20 G_s$$

- t                      Tripping time
- G                      Value of the measured quantity
- G<sub>s</sub>                    Threshold value for the programmed quantity
- T<sub>++</sub>                    Multiplying factor between 0.03 and 3 s.

Dynamic measurement from 0.01 to 18 In and 1 to 240V for [32P] and [32Q] functions.

The real tripping time of the protection is equal to the calculated value, plus a delay of 15ms approximately.

- When the monitored value is greater than 20 times the threshold, the tripping time will never be higher than the value of 20 times the threshold. (Inverse time relay function with Definite Minimum Time)



- If the monitored value exceeds the measuring capacity of the relay inputs, i.e. 18 In, the trip time, based on the threshold setting, will function of this value.

#### 3.7.4.4.2 Application inverse time with electromechanical type for [32P] [32Q]

Use of this characteristic is recommended when selectivity with other network protections is not required.

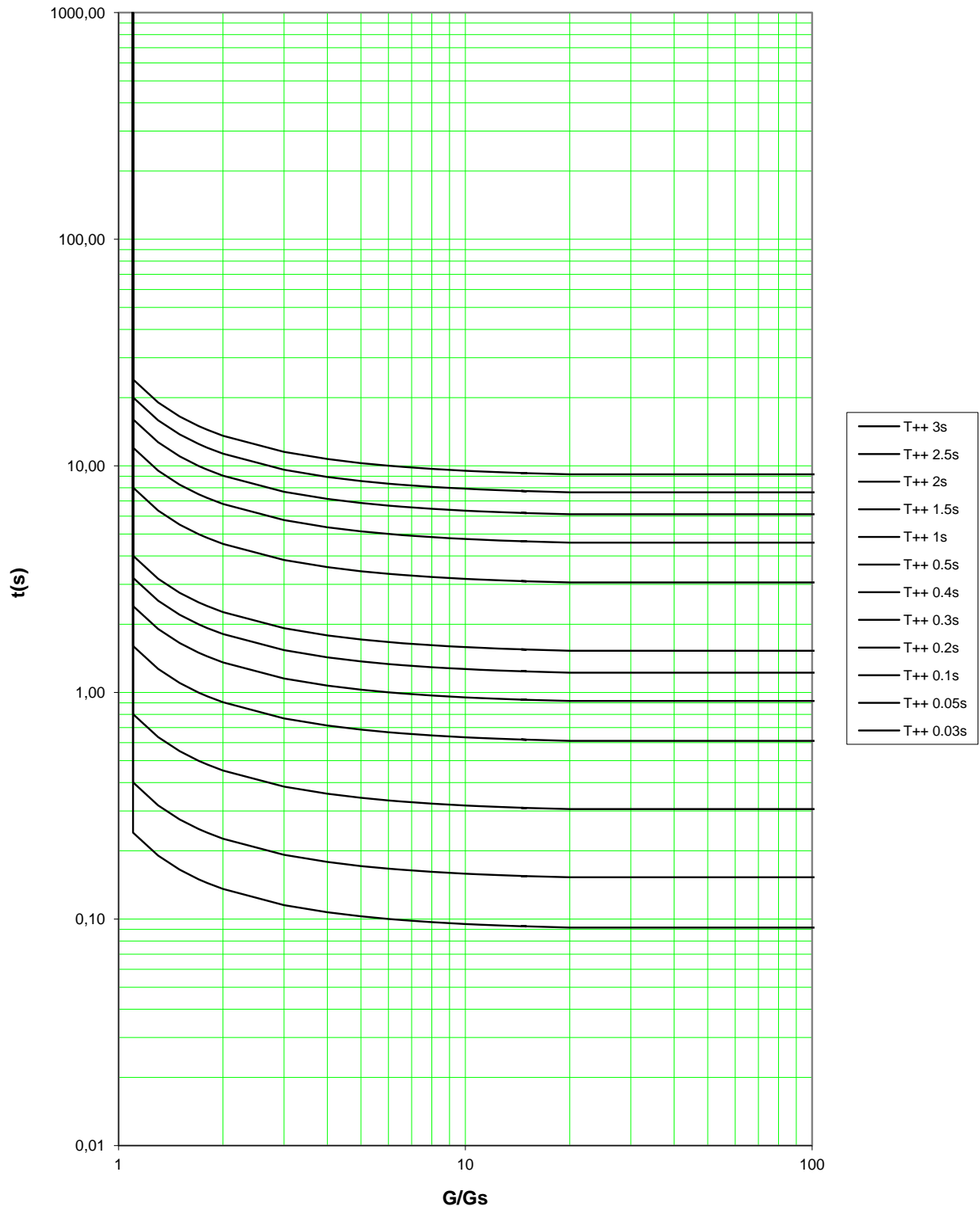
#### 3.7.4.4.3 Setting advices for inverse time with electromechanical type for [32P] [32Q]



Please refer to the examples related to the IEC standard.

3.7.4.4 RI curve for [32P] [32Q]

RI inverse curves



### 3.7.4.5 Programmable inverse time delay



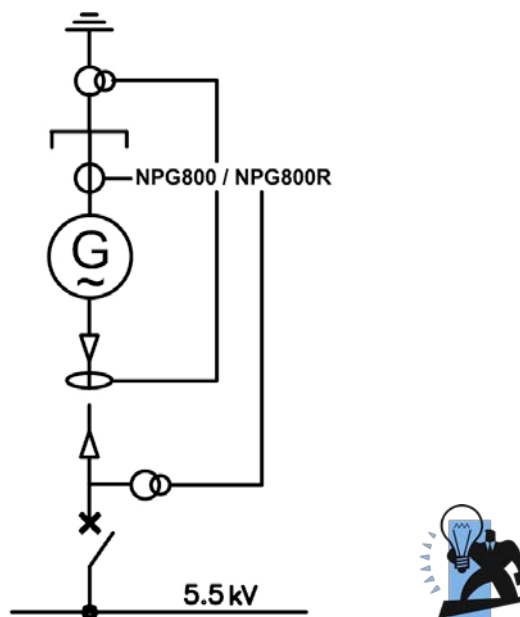
See "3.7.1.5 Programmable inverse time delay"

## 4 Protecting generators

Performances of a generator can be affected by faults in the device as well as by outside perturbations on the supply network it is connected to.

The **NPG800-NPG800R** multifunctional protections are designed to react as efficiently in the first and in the second case. They ensure protection for synchronous and asynchronous generators connected on three phase networks and moved by any type of machines: steam, hydraulic or gas turbine, diesel or gas engine. Their protection functions and measurement functionalities make them appropriate for machine-generator groups from a few hundred kVA to tens of MVA.

The current chapter presents parallel analysis of the various anomalies which can affect a generator and the protection functions of the **NPG800-NPG800R** range to be used in each of these cases.



**Fig. 62:** Example of generator protection with the NPG800-NPG800R

### 4.1 Protection against external and internal faults

When short-circuit occurs at the terminals of a generator with round rotor, the following phenomena's tend to occur:

- At first, stator currents are only limited by the direct axis subtransient reactance  $X''_d$ , and this during a period defined by the  $T''_d$  time constant (mainly conditioned by the dampers circuits).
- A few cycles after short-circuit begin, the dampers circuits being in operation, the currents are limited by the direct axis transient reactance  $X'_d$  and they decrease at a speed set by the time constant  $T'_d$  to reach a constant amplitude which is determined by the internal electromotive value  $E$  and the direct axis synchronous reactance  $X_d$ .
- Initially equal to ten times the rated current  $I_n$ , the amplitude of the short-circuit currents decreases to stabilise at a value usually lower to  $I_n$ , due to the high value of the synchronous reactance  $X_d$ . Implementation of voltage regulators allows sometimes to keep the fault current at a level above the rated current.

This type of fault can be detected by the overcurrent function with voltage restrained unit **[51V]** or by the function with minimum of impedance **[21]**, which are able to work despite the current decrease whilst offering a threshold higher to the rated current as regards to normal operation conditions, and a time delay compatible with the selectivity required by downstream protections.

The function with minimum of impedance **[21]** of the **NPG800-NPG800R** offers a solution for this use.

In the particular case where the permanent short-circuit current in the generator keeps a value mostly higher to  $I_n$ , we can make use of one or several of the overcurrent functions **[51-1]** **[51-2]** of the **NPG800-NPG800R**.

Fed by the CTs of phases on the neutral side of the windings, these protections also protect against all faults originating in the winding, these faults being responsible for generating currents of the same kind as outside faults.

The **NPG800-NPG800R** models are specialised in the protection of generators and they monitor a greater part of the windings than overcurrent protections. In order to obtain faster protection and to monitor nearly all windings of the machine, it is necessary to use a differential protection. This protection detects instantaneously, phase-to-phase faults occurring in the machine windings, sometimes producing low level currents which can remain undetected by other protections.

## **4.1.1 Function minimum of impedance of [21] on NPG800-NPG800R**

### **4.1.1.1 Introduction to [21] on NPG800-NPG800R**

The minimum of impedance function protects generators against short-circuit currents.

During low-impedance short-circuit at the terminals of a generator; a fault current is produced whose amplitude varies over time. This current is set by the subtransient reactance  $X''_d$  (transforming the total magnetic leakage between the stator, the inductor and the dumpers circuits), and reaches high level at first. It is then limited by subtransient  $X'_d$  reactance (transforming the total magnetic leakage between the stator and the inductor). As it keeps decreasing, it reaches a stable value set by the direct axis synchronous reactance  $X_d$ .

With an initial value of about 5 to 10 times the rated value  $I_n$ , the current amplitude stabilises to a value lower to it ( $I_n$ ). These phenomenon's are more or less strong according to the distance of the fault from the machine and to the type of automatic voltage regulator used (static, shunt, compound, pilot generator...).

The overcurrent protection [50] [51] alone is therefore not sufficient, since its delayed threshold, set above the rated current cannot detect permanent fault currents. Measurement of the quantity "impedance", independent of current value and of the voltage ensures therefore an adequate monitoring of the machine and its network against faults on several phases.

Apparent impedance calculation is performed as follows:

$$\vec{Z}_1 = \frac{\vec{V}_A - \vec{V}_B}{\vec{I}_A - \vec{I}_B}, \quad \vec{Z}_2 = \frac{\vec{V}_B - \vec{V}_C}{\vec{I}_B - \vec{I}_C}, \quad \vec{Z}_3 = \frac{\vec{V}_C - \vec{V}_A}{\vec{I}_C - \vec{I}_A}$$

In order to reach stability during faults occurring at the secondary of transformer blocs (in particular with star – delta coupling), the operating characteristic is represented by a circle which is centred on the origin of chart R-X. Two distinct thresholds ( $Z <$  and  $Z <<$ ) are available (see figure 57) for minimum of impedance (2 concentric circles). Each threshold is associated with a definite time characteristic.

To connect with phase-to-neutral voltages ( $3V/3I$ ), the function is activated when one of the three impedance vectors  $Z_1$ ,  $Z_2$  or  $Z_3$  enters one of the tripping circles. With phase-to-phase voltages ( $2U/3I$ ), only the impedance vectors  $Z_1$  and  $Z_2$  are involved.

The function is also secured thanks to a current threshold  $I_2 >$ , which can be set between  $0.1 I_n$  and  $0.4 I_n$ , authorising tripping.

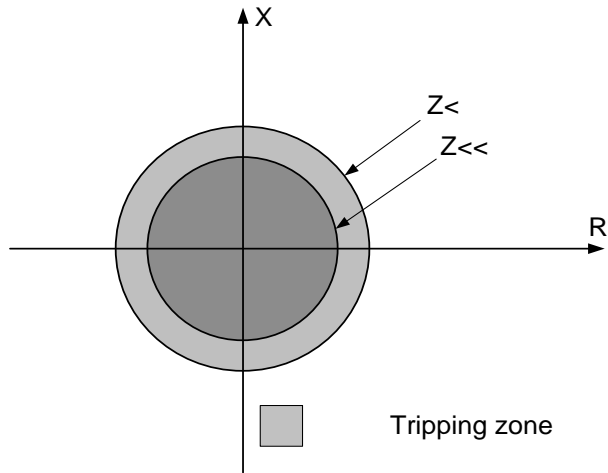


Fig. 63: Operating characteristics of the minimum of impedance function [21]

4.1.1.2 Flow chart for [21] NPG800-NPG800R

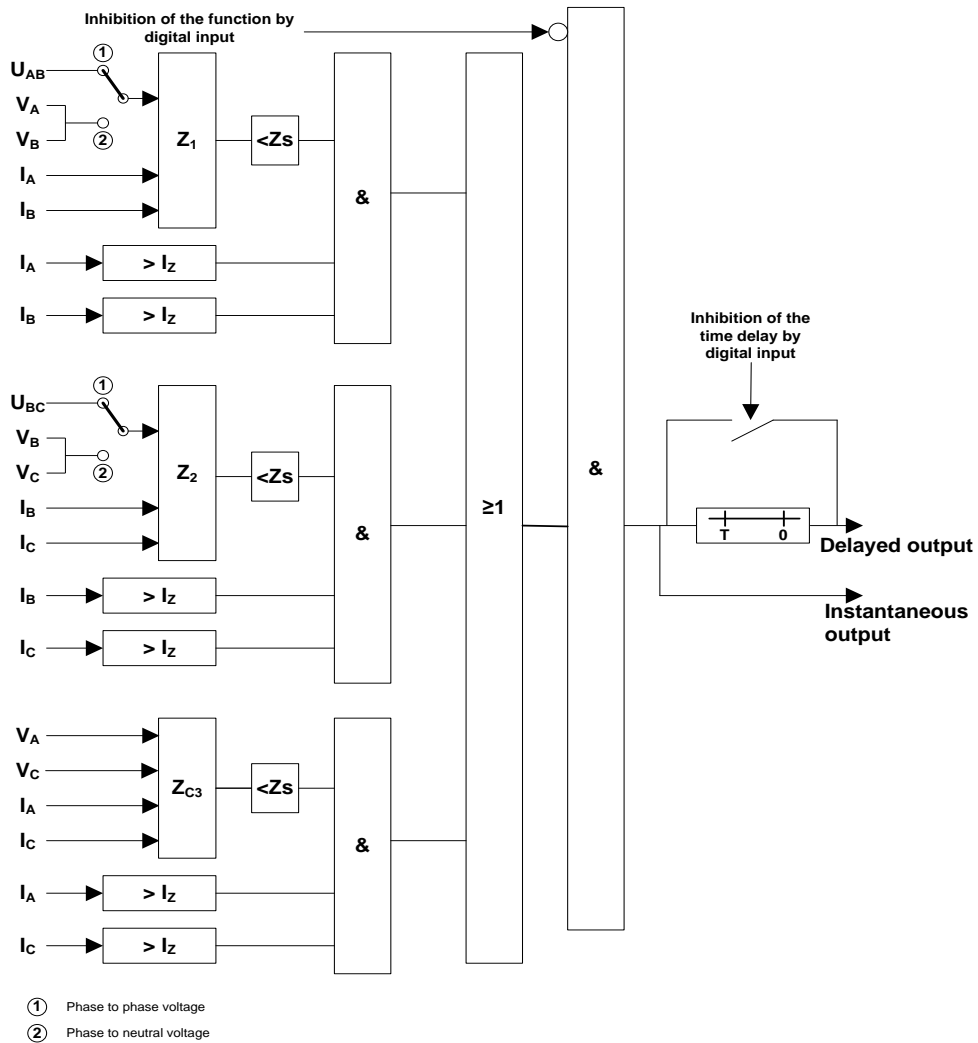


Fig. 64: Function minimum of impedance [21]

**4.1.1.3 Setting characteristics for [21] on NPG800-NPG800R**

THRESHOLDS FOR THE FUNCTION [21]	Setting
Thresholds Z< and Z<<	0.10 to 2.00 Zn with steps of 0.01 Zn
Threshold IZ>	0.10 to 0.40 In with steps of 0.05 In
TIME DELAY FOR THE FUNCTION [21]	setting
Definite time-delay - t(Z<) - t(Z<<)	0.04 to 300 s  step: see *
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms

**4.1.1.4 Setting advices for [21] on NPG800-NPG800R**

We will examine the case of synchronous generator with the following characteristics:

$$S_n = 8.2 \text{ MVA}$$

$$U_n = 6.6 \text{ kV}$$

$$I_n = 717 \text{ A}$$

$$\text{T.C.} = 750/5 \text{ A}$$

$$\text{T.P.} = 6600/\sqrt{3} / 100/\sqrt{3} \text{ V}$$

Since it is not a generator-transformer block, only the low threshold is set.

Low threshold Z< is set in relation to threshold [51].

Coordination study managed to setting threshold [51] to a value of 1.7 I<sub>n</sub> T.C.

The threshold has been adapted to take the setting steps into account.

$$Z < = \frac{0,8 \times Z_{[51]}}{Z_{relay}} = \frac{0,8 \times \frac{U_n}{\sqrt{3} \times 1,7 \times I_n}}{\frac{U_n}{\sqrt{3} \times I_n}} = 0,50$$

The time delay is set to be selective with downstream protections.

t(Z<) = 0.9 s on a network fault clearing is performed in 0.6 s.

Generator-transformer block:

For this specific application, you must use the minimum of impedance function to detect faults in the generator-transformer (as a backup of differential protection), and use the overcurrent function for co-ordination with downstream located protections. The low threshold of the minimum of impedance protection ensures the last backup for all other functions with a fairly long time delay.

**4.1.2 Function of overcurrent and with restrained voltage [50] [51] [50V] [51V] on NPG800-NPG800R**

**4.1.2.1 Introduction to [50] [51] [50V] [51V] NPG800-NPG800R**

The maximum of current function protects generators against overload currents [51] and short-circuit currents [50]. These functions can be associated with a voltage restrained criteria [51V] [50V].

During low-impedance short-circuit at the terminals of a generator; a fault current is produced whose amplitude varies over time. This current is set by the subtransient reactance X''d (transforming the total magnetic leakage between the stator, the inductor and the dumpers circuits), and reaches high level at first. It is then limited by subtransient X'd reactance (transforming the total magnetic leakage between the stator and the inductor). As it keeps decreasing, it reaches a stable value set by the direct axis synchronous reactance Xd.

With an initial value of about 5 to 10 times the rated value In, the current amplitude stabilises to a value lower to it (In). These phenomenon's are more or less strong according to the distance of the fault from the machine and to the type of automatic voltage regulator used (static, shunt, compound, pilot generator...).

The overcurrent protection alone is therefore not always sufficient, since its delayed threshold, set above the rated current cannot detect permanent fault currents; voltage at the

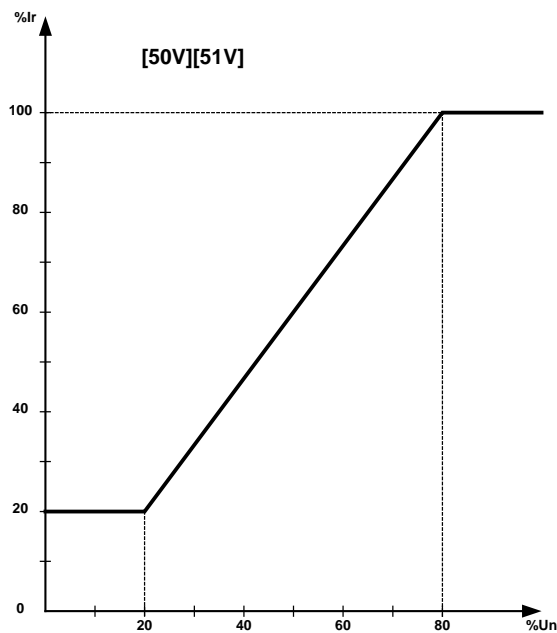
terminals of a generator being very weak during a fault. This is why the functions [50] and [51] can be associated with a voltage restrained criteria which allows correcting the overcurrent function threshold by also measuring the voltage and so obtaining the functions [50V] [51V].

This function has three distinct thresholds for the overcurrent with voltage restrained unit [51-1V] [51-2V] and [50V] functions linked with a definite or inverse time characteristic for thresholds [51-1V] and [51-2V]; threshold [50V] being associated with definite time characteristic.

The protection is activated when one of the currents reaches the current threshold adjusted by the voltage.

The current threshold is modified by the voltage as follows:

$$I_r = \frac{I_r}{3} \times \left( 4 \frac{U}{U_n} - 0.2 \right)$$



**Fig. 65:** Modification of the thresholds [51-1] [51-2] and [50] according to the voltage.

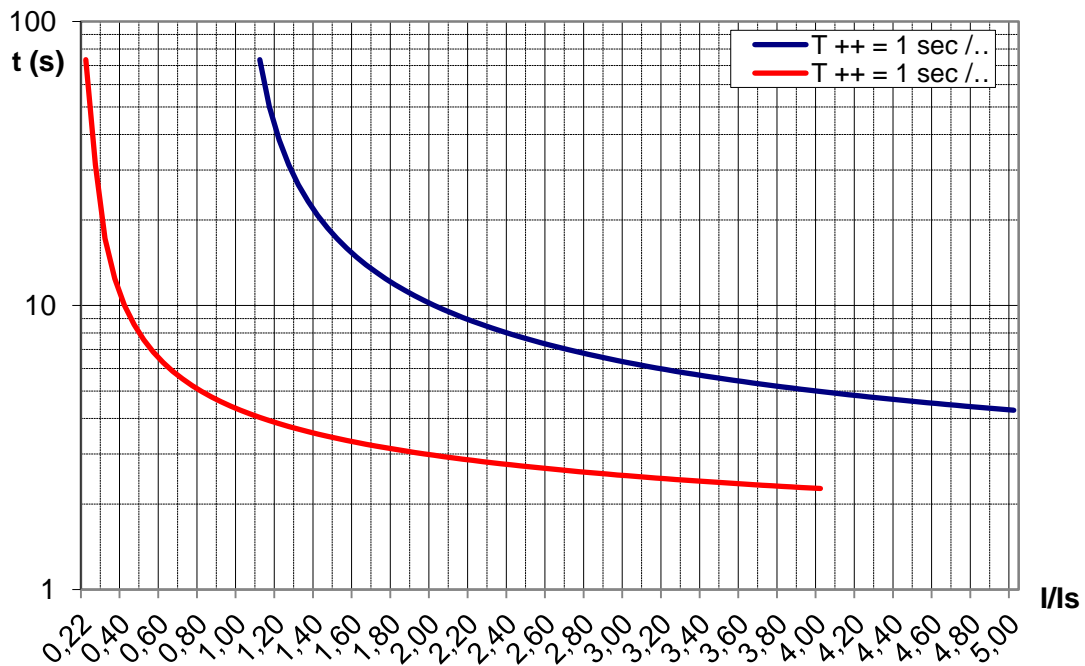
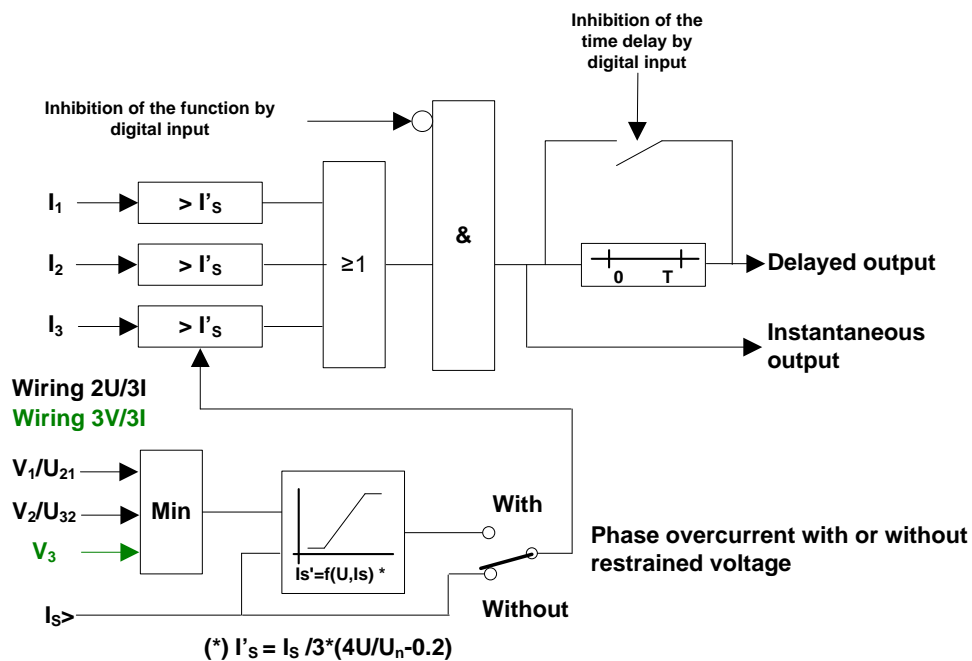
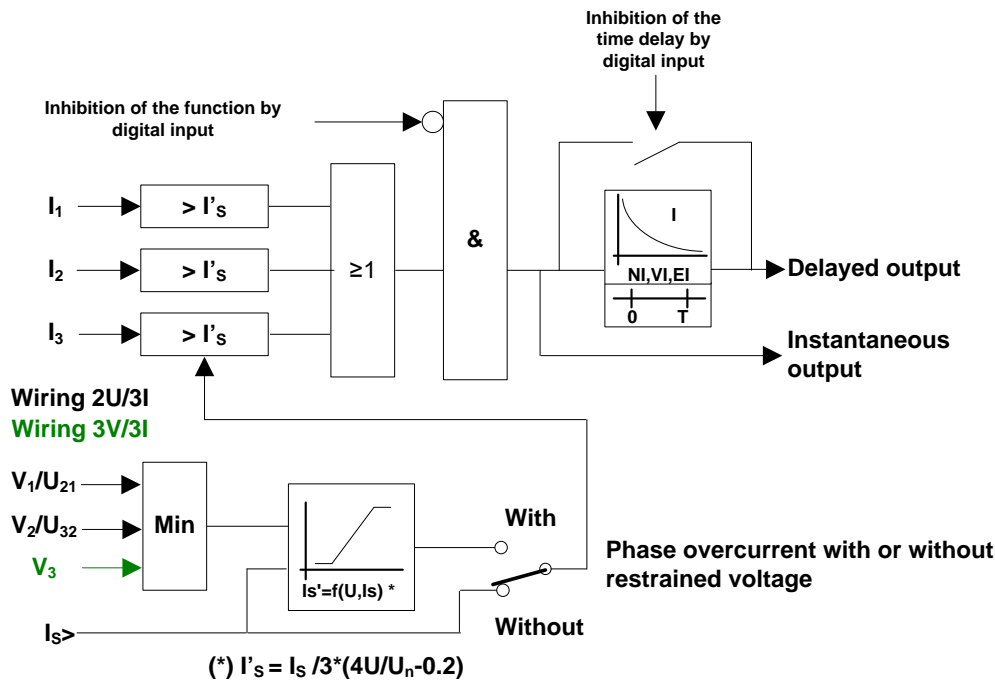


Fig. 66: IEC curve with inverse time depending on the measuring voltage.

4.1.2.2 Flow charts for [50] [51] [50V] [51V] on NPG800-NPG800R



**Fig. 67:** Overcurrent function with restrained voltage unit [50] [50V]



**Fig. 68:** Overcurrent function with restrained voltage unit [51] [51V]

**4.1.2.3 Setting characteristics for [50] [51] [50V] [51V] NPG800-NPG800R**

THRESHOLDS FOR THE FUNCTIONS [51][50]	Setting
Thresholds $I >$ [51-1] - $I >>$ [51-2]	0.3 to 10 $I_n$ with steps of 0.1 $I_n$
Threshold $I >>>$ [50]	0.3 to 10 $I_n$ with steps of 0.1 $I_n$
Thresholds modification depending on the voltage [51-1V] [51-2V] [50V]	
TIME DELAYS FOR THE FUNCTIONS [51] [50]	Setting
Definite time-delay - $t(I >)$ $t(I >>)$	0.04 to 300 s
$t(I >>>)$ [51-1] [51-2] [50]	step: see *
IEC** inverse time curve: inverse time, very inverse, extremely inverse with $t(I >)$ $t(I >>)$	T++: 0.03 to 3 s

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[51-1] [51-2]	with steps of 0.01s
ANSI/IEEE*** inverse time curve: normally inverse, very inverse, extremely inverse t (I>) t (I>>) [51-1] [51-2]	T++: 0.03 to 3 s with steps of 0.01s
<b>CHARACTERISTICS</b>	<b>Values</b>
Response time for instantaneous outputs	60ms

\*: between 0.04 and 9.99 s with steps of 0.01 s, between 10.0 s and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1s

\*\* : see section "**3.5.2.1 Equation IEC for [46] [51] [51N]**"

\*\* : see section "**3.5.3.1 ANSI/IEEE compliant equation of functions [46] [51] [51N]**"

**4.1.2.4 Setting advices for [50] [51] [50V] [51V] on NPG800-NPG800R**

These functions must guarantee selectivity with the electrical network protections, which has consequences on thresholds and time delays values. Therefore, the settings given below are only provided as examples.

The low threshold (I>) [51] for the protection is generally set to 1.2 In of the generator with a time delay (tI>) (definite time) of 1.6 second (as to let through, between other things, possible bumps during normal operation).

During high faults or low-impedance short-circuits at the terminals of the generator, currents reach initially several times the rated current of the machine, and they decrease to stabilise at a permanent short-circuit value usually lower to the rated current of the machine.

If the generator regulator is type "shunt with booster", it has a system which, during a short-circuit, keeps generally current up to values of around 3 In of the generator during 10 seconds per overexcitation. The setting for the high threshold I>>> [50] of the protection will be performed according to this "boosted" current and to the network protections to which the generator is connected.

As to protect from a possible automatic voltage regulator malfunction, it is strongly recommended to activate the restrained voltage function for current measuring functions [51V][50V] or even to use the minimum of impedance function [21]. Above a certain power, this protection is really necessary.

## 4.2 Overload protection [49] NPG800-NPG800R

Since overloads lead to overheating stator circuits, they must be eliminated before dangerous temperatures are produced inside the machine.

Depending on the power of the machine, overload protection can be performed by the overcurrent function, or by the thermal image function of models NPG800-NPG800R.

### 4.2.1 Introduction to [49] NPG800-NPG800R

This function protects generators against unusual heating of stator circuits which must be eliminated before dangerous temperatures are produced inside the machine.

For high power generators, like turbo-generators, you must prefer the thermal image function to the use of the low threshold, with a time delay, of the overcurrent function which has been calculated in the previous chapter for overload detection.

The thermal image integrated into the protection allow for accurate monitoring of machines thermal behaviour, as well during balanced as during slightly unbalanced operation.

This function offers two thresholds, a tripping threshold  $I_b$  and an alarm threshold.

The thermal state is given from the base current  $I_{gen}$  which is calculated from the symmetrical components  $I_{positive}$  and  $I_{negative}$  and this, with an exponential smoothing.

Tripping is commanded when the calculated thermal state reaches 100 %.

This state is obtained after a t time given by the following relation (IEC 60255-8 standard):

$$t = C_t * \ln \left( \frac{I_{gen}^2 - I_{pre}^2}{I_{gen}^2 - I_b^2} \right)$$

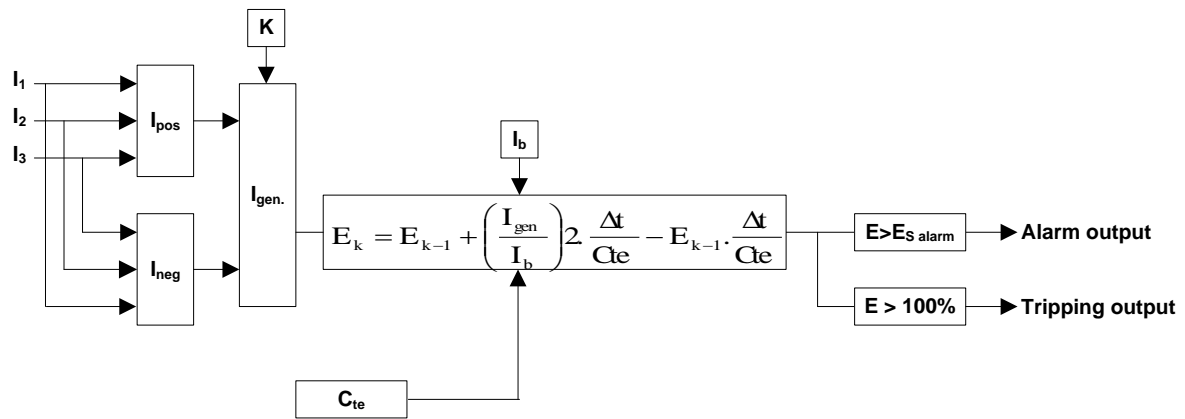
- $C_t$  : heating thermal time constant of the generator (in s).
- $I_b$  : base current for which the generator reaches a maximum thermal state of 100 % at steady state ( $I_b$  can be set in % of the rated current  $I_n$ ).
- $I_{pre}$  : load current of the generator in its initial state.
- $I_{gen}$  : real load current of the generator at instant "t".

As to obtain a more realistic image of the thermal constraints to which the generator is submitted, we take into account the positive component of the current and its negative component, reduced using a k factor (representative for the unbalance).

$$I_{gen} = \sqrt{I_{positive}^2 + K * I_{negative}^2}$$

Before tripping (for a thermal state of 100 %), a thermal alarm is generated when the thermal state reaches an alarm threshold which can be set between 80 and 100 %.

4.2.2 Flow chart for [49] on NPG800-NPG800R



E = Thermal state in %  
 E<sub>k</sub> = Thermal state at K  
 E<sub>k-1</sub> = Thermal state at K - 1  
 E<sub>s\_alar m</sub> = Thermal state threshold in %

Fig. 69: Function of thermal image [49]

4.2.3 Setting characteristics for [49] NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [49]	Setting
Current for thermal reference I <sub>b</sub>	I <sub>b</sub> = 0.40 to 1.30 I <sub>n</sub> steps of 0.01 I <sub>n</sub>
Thermal alarm threshold	80 to 100 % thermal θ steps of 1%
K: factor for negative component	0 to 9 steps of 1
TIME CONSTANTS FOR THE FUNCTION [49]	Setting
C <sub>TE</sub> : heating time constant	4 to 400 min steps of 1min
C <sub>TR</sub> : cooling time constant *	1.0 to 6.0 C <sub>TE</sub> with steps of 0.1

\* The setting for the cooling time constant C<sub>TR</sub> is active when the generator is considered to be stopped, meaning as soon as current I<sub>gen</sub> becomes lower to 0.5 % of I<sub>b</sub>. When current I<sub>gen</sub>

becomes higher to 0.5 % of  $I_b$ , the generator is considered in operation and in this case,  $C_{TR} = C_{TE} (1X)$ .

### 4.2.4 Setting advices for [49] on NPG800-NPG800R

Let us examine as an example the following data to protect a generator:

- CTs: 1000/5 A - 5VA 5P10
- In protection: 5 A
- Rated current for the generator: 900A
- Heating thermal time constant \* = 60 min
- Cooling of the generator with fan at the end of the shaft

\* manufacturer data

Adaptation of the rated current of the generator to the protection:

The rated current for the generator must be adapted, to take into account the measurement reducers (CTs), the steps of setting for the thermal basic current  $I_b$ , and the load factor for the generator "Fc". When a generator is used at its rated power, "Fc" must be set between 1.05 and 1.07 (value corresponding to a permanent overload of 5 to 7 % without reaching tripping through the thermal protection unit). This parameter must be determined during the setting study of the protection. (This is not a separate setting parameter of the protection.)

$$I_b = (I_n \text{ generator} / I_n \text{ CTs}) \times \text{"Fc"}$$

Calculation of the thermal threshold and parameters to set on the protection:

The base current  $I_b$  will be set to the following value:  $I_b = (900/1000) \times 1.07 = 0.963$ , and after integrating the setting steps: 0.96.

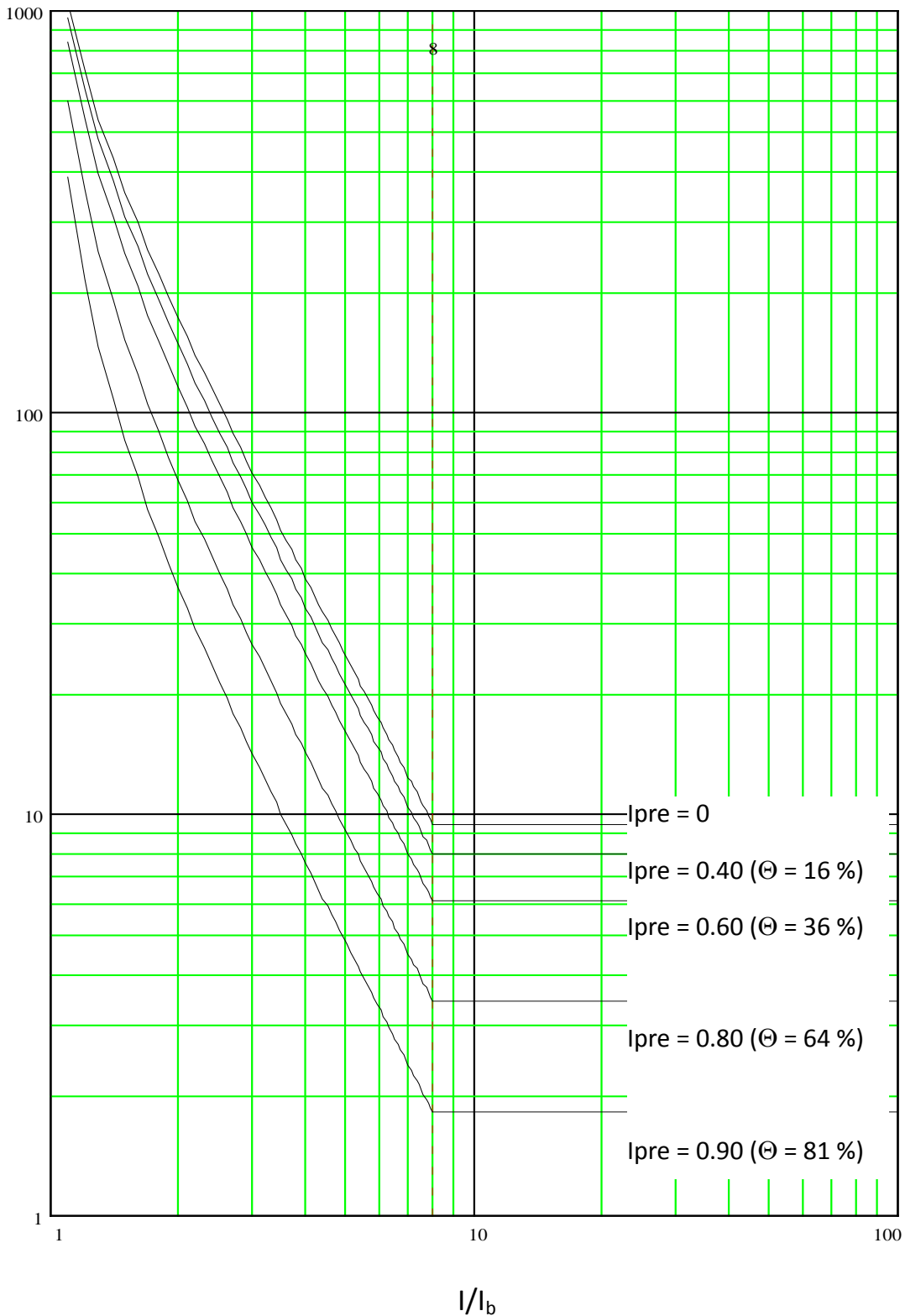
The heating time constant CTE will be set to the required value of: 60 min.

Given the cooling mode, the CTR constant will be set to twice (2) the heating constant.

4.2.4.1 Thermal curves for NPG800-NPG800R

4.2.4.1.1 Characteristics of the thermal image

The following curves are defined for a time constant  $\tau = 10$  minutes:



**4.2.4.1.2 Cooling curves**

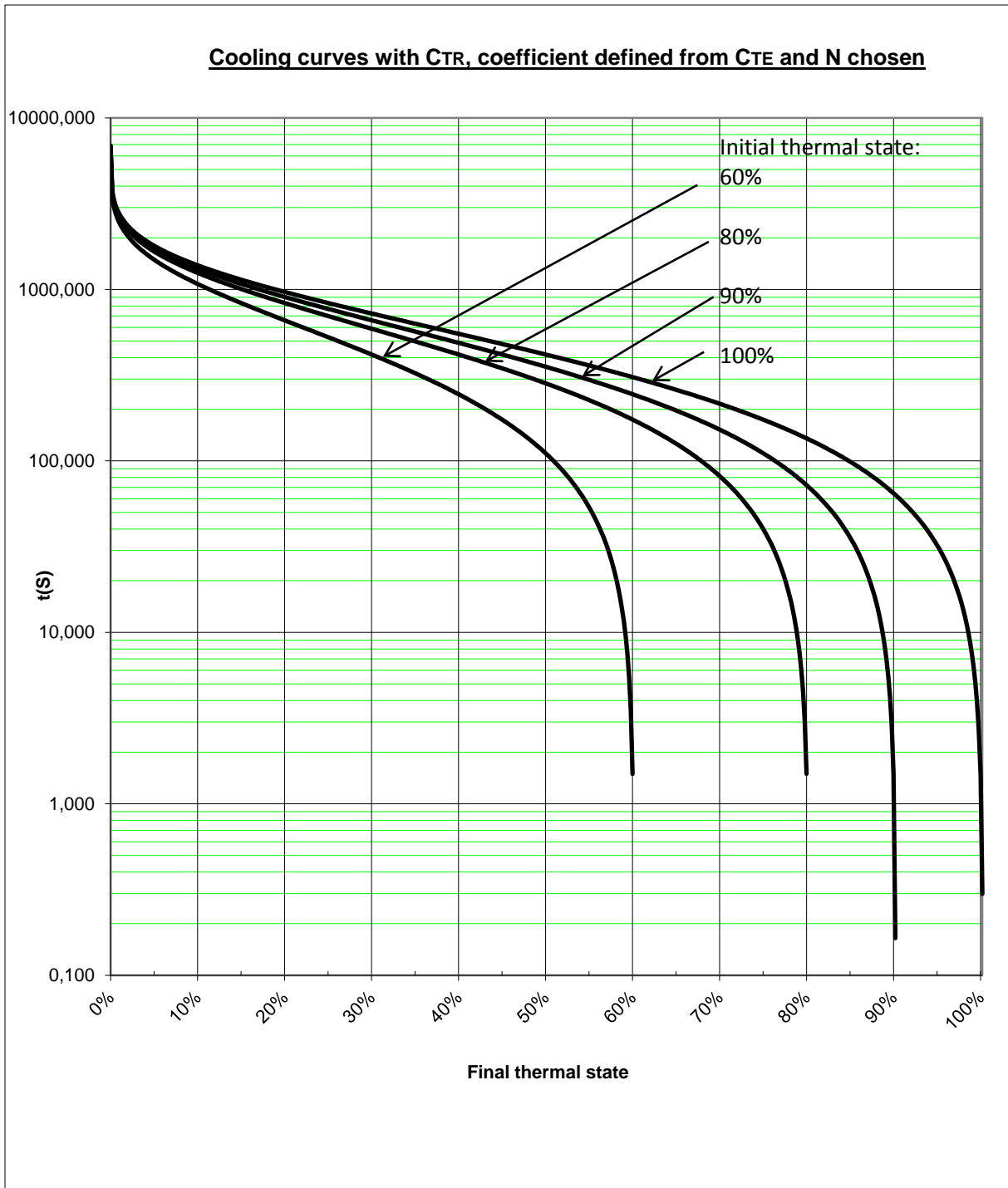
The following curve provides the time necessary for cooling, starting with a given thermal state.

For another value of time constant, multiply the indicated times on the curve by the value in minutes of the used time constant.

Equation cooling curves is as follows:

$$t = C_{TR} \cdot \ln\left(\frac{\theta_{thermal\_state}}{\theta_{trans}}\right) \text{ with } C_{TR} = N \cdot C_{TE}$$

C <sub>TR</sub>	Constant thermal cooling time (in minutes) to be converted in seconds for calculations
C <sub>TE</sub>	Constant thermal heating time (in minutes) to be converted in seconds for calculations
θ <sub>thermal_state</sub>	Coefficient of the initial thermal state of the machine (in %)
θ <sub>trans</sub>	Coefficient corresponding to the thermal state of the machine at the time t
N	Scale factor between the thermal time constant of cooling and heating



For example, the curves above are plotted with the following values:

CTE = 10 min

N = 1

### 4.3 Protection against unbalance [46] NPG800-NPG800R

#### 4.3.1 Introduction to [46] NPG800-NPG800R

The function maximum of negative phase sequence current [46] protects generators against the negative currents effects which circulate on unbalanced networks.

Dissymmetrical loads due to, for example to phase-to-earth or phase-to-phase faults leads to a dissymmetrical current system. Such system can be divided into a positive, a negative and possibly a zero-sequence current system.

Generators designed to produce balanced loads can only tolerate permanently a small unbalance factor. They must be disconnected from the network if this rate reaches a too high value, as not to be subjected to severe damages.

The negative system generates a field turning at the same speed as the rotor field but in the reverse direction, which means that in relation to the stator, it turns twice as fast. It induces Foucault currents in the mass of the rotor. If a fault lasts for too long, these currents lead to an exaggerated heating of the rotor and the bumpers circuits.

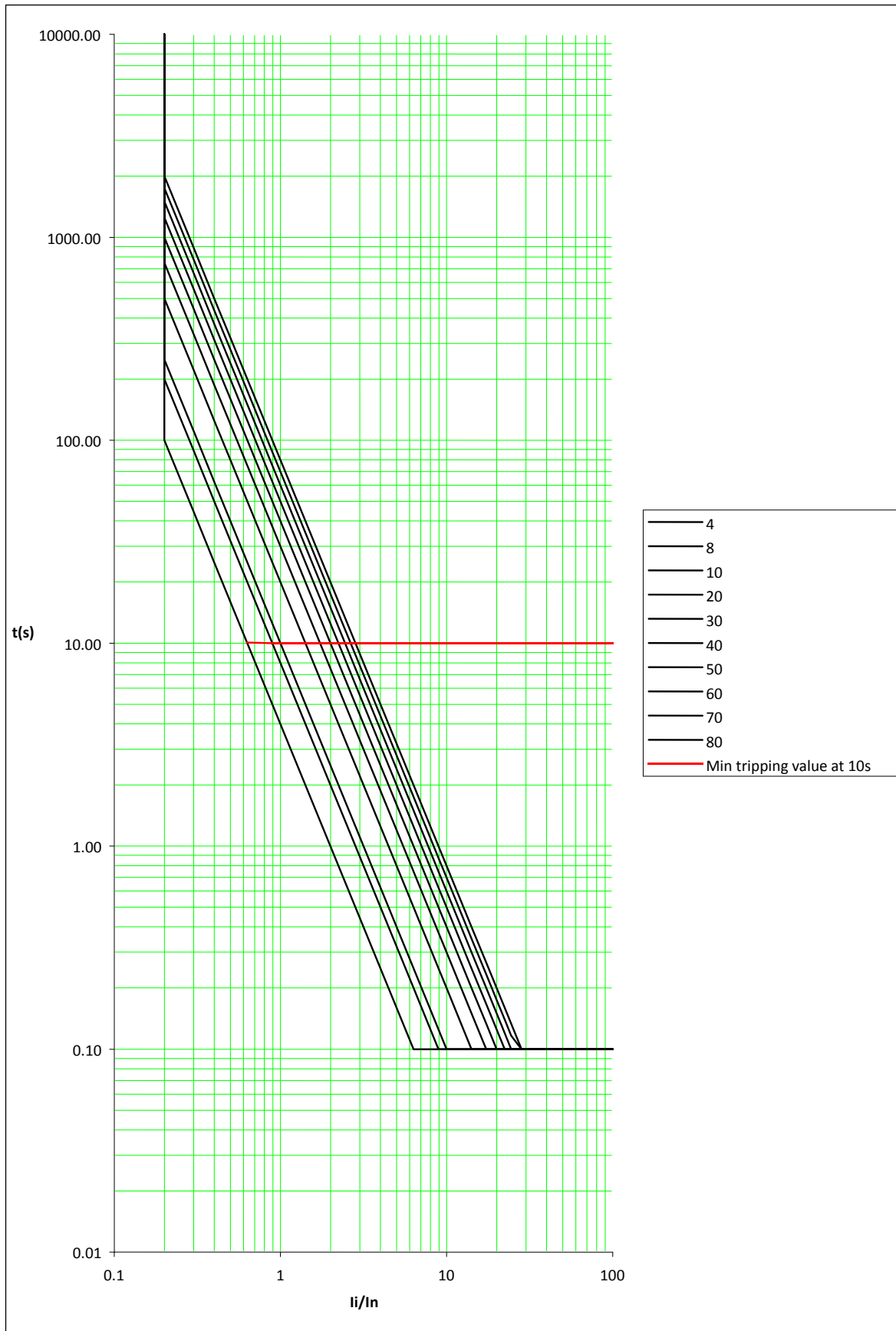
The value of the heating that a machine can withstand without severe damages is provided by the manufacturer. It is defined by a relation between the negative current  $I_i$  and the duration for which this current can be applied:

$$I_i^2 \cdot t = K \text{ where } K \text{ is a constant which depends on the machine}$$

This relation allows to adapt best the protection to the withstand of generators to negative currents, as defined in the applicable standards (IEC 6034-1).

Function [46] offers two configurable thresholds. The first one ( $I_2 >$ ) is used for the alarm and the second one ( $I_2 >>$ ) for tripping. Detection of unbalances is based on the measurement of the negative component of line currents. The tripping characteristic to choose for this negative component is inverse time (curve extremely inverse), the curve equation follows the type  $(I_i/I_n)^2 \cdot t = \text{constant}$ . These curves are defined to 100% of  $I_{neg}/I_n$ . Limitation of the curves can be set between 0.1 and 10 seconds.

The alarm characteristic for the negative component is definite time.



**Fig. 70:** characteristics  $I^2t$  for function [46]

4.3.2 Flow chart of [46] on NPG800-NPG800R

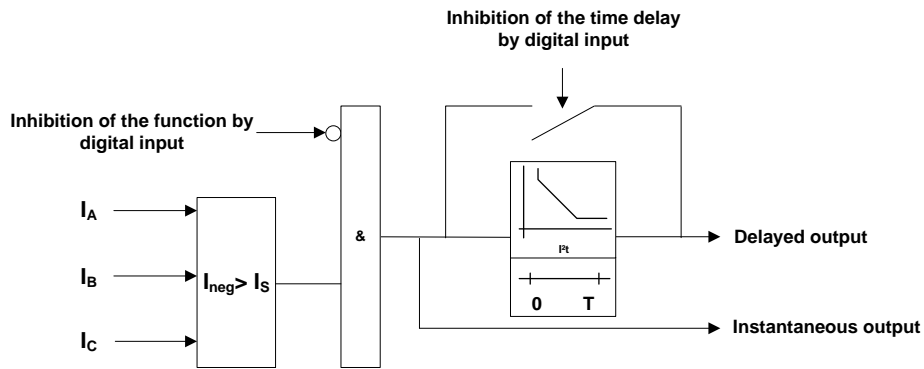


Fig. 71: Function maximum of negative phase sequence current [46]

4.3.3 Setting characteristics for [46] on NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [46]	Setting
Thresholds $I_{neg}/I_n$ : ( $I2>>$ ) and ( $I2>$ )	0.03 to 0.50 $I_n$ steps of 0.01 $I_n$
TIME DELAYS FOR THE FUNCTION [46]	Setting
Operating curves - $t(I2>>) / t(I2>)$ : Curves $I_i^2 \cdot t = K$ $K = \text{constant in s}$ Operation pour $I_{neg} = 100\% I_{neg}/I_n$	4 to 80 s** steps of 1 s
Minimum tripping duration	0.1 to 10 s step: see *
Definite time-delay - $t(I2>>) / t(I2>)$	0.04 to 300 s step: see *
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms

\*: between 0.04 and 9.99 s with steps of 0.01 s, between 10.0 s and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1s

\*\* : curves defined for 100% of  $I_{neg}/I_n$

### 4.3.4 Setting advices for [46] NPG800-NPG800R

In order to define the thresholds for function [46], you must know and take into account the following characteristics:

$I_n$	:	Rated current for the generator.
$I_{n\_CT}$	:	Primary rated current for the CTs.
$I_i \text{ perm}$	:	Permanent generator operation of the generator with negative component current depending on its rated value.
$K$	:	Time during which the generator can tolerate an negative component equal to its rated value.

We will examine a synchronous generator with the following characteristics:

$I_n$	:	1050 A
$I_{n\_CT}$	:	1000 A
$I_i \text{ perm}$	:	10 %
$K$	:	15 s

To protect this generator, we will use threshold  $I_{2>>}$  for tripping and associate it with the inverse time characteristic (curve extremely inverse), the equation for the curves is of type  $(I_i/I_n)^2 \cdot t = \text{constant}$ . Threshold  $I_{2>}$  will be used for alarm, associated with definite time delay.

Threshold  $I_{2>>}$  is used to trip the network generator when the duration and the level of negative current reaches the suitable limits for the generator. According to the rated current for the generator and for the CTs, the rate of negative component allowed and the setting steps, the threshold  $I_{2>>}$  is set at  $0.10 \cdot I_{n\_CT}$ . This setting allows to detect negative current lower to the permanent withstand of the machine. Constant C is set to 15 seconds, known value on the inverse current curve suitable for the generator. The minimum tripping duration is set to 2 seconds.

Threshold  $I_{2>}$ , used for alarm, is set to a lower level than threshold  $I_{2>>}$ . It indicates an alarm when negative current is equal to 80% of the permanent withstand, meaning a setting of  $0,08 I_{n\_CT}$  with definite time-delay set to 60 seconds.

### 4.4 Power protections

#### 4.4.1 Protection against reverse power of [32RP] on NPG800-NPG800R

In principle, generators working in parallel with other sources must, according to their manufacturer data, be protected against working as a motor by a reverse active power protection.

The required power for a generator to work as a motor varies from a few percentage of its rated value for steam powered generators to 20 % for Diesel powered generators.

##### 4.4.1.1 Introduction to [32RP] on NPG800-NPG800R

The reverse active power function aims at avoiding reverse working of a generator as a synchronous motor, though partly or entirely providing mechanical loss of the shaft line. Reverse power operation does not affect the generator but it can cause damages to the powering machine. Steam turbines are submitted to high temperatures and hydraulic turbines, to a cavitation phenomenon.

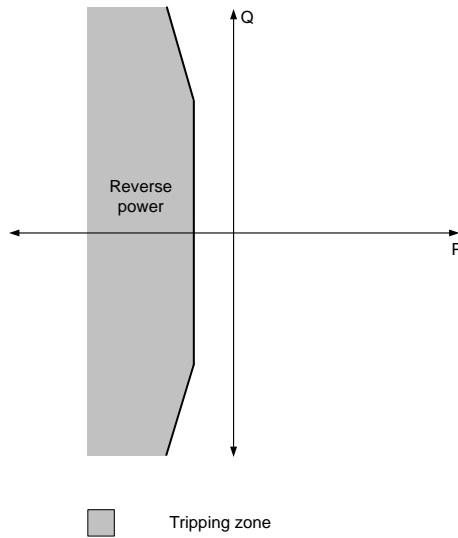
The protection must however be slightly be delayed, as to tolerate synchronising power exchange between the generator and the network during load variations or after fault clearance.

This function offers a threshold (RP>) for the reverse of active power associated with definite or inverse time characteristic. Its function is to send a tripping order when reverse power (the active component) reaches this threshold.

This threshold is expressed in percentage of the rated power and it is set according to the equipment it has to protect.

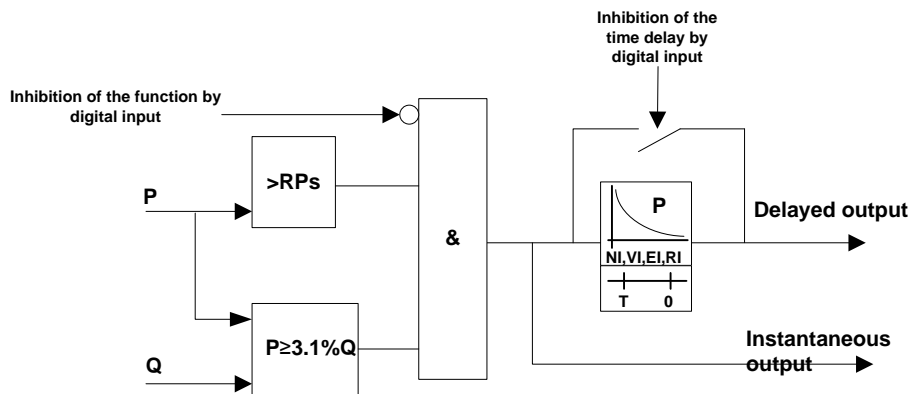
When mechanical losses are provided entirely at synchronous generator level, it applies to only a few percentage of the rating power, in case of turbines. When this loss is shared between the synchronous generator and the turbine, the absorbed electrical power becomes very little. It is therefore necessary to use a sensitive and precise detection function.

When working as a motor, the machine usually keeps providing the network with reactive power, whose amplitude is much higher than the active power amplitude, which can compromise measurement accuracy and directional character. With the NPG range, this directional stability is kept, thanks to a threshold correction when confronted with a high level of reactive power. In order to achieve that, the function operates when the following condition is met:  $P \geq 3.1\% Q$ . So for a threshold of active power of 1%, this means a break of the tripping characteristic at  $0.32 Q_n$ .



**Fig. 72:** Tripping zone for the minimum of active power function [32RP]

4.4.1.2 Flow chart for [32RP] on NPG800-NPG800R



**Fig. 73:** Reverse of active power function [32RP]

4.4.1.3 Setting characteristics for [32RP] on NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [32RP]	Setting
Instantaneous reverse active power RP>	1 to 120 % of Sn step: 0.1% of Sn
TIME DELAYS FOR THE FUNCTION [32RP]	Setting
Definite time-delay: t (RP>)	0.04 to 300 s step: see *
IEC inverse time curve: inverse, very inverse, extremely inverse t (RP>)	T++: 0.03 to 3 s with steps of 0.01s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse T (RP>)	T++: 0.03 to 3 s with steps of 0.01s
RI inverse time curves: t (RP>)	0.1 to 20 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms

\*: between 0.04 and 9.99 s with steps of 0.01 s, between 10.0 s and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1 s

\*\* : 0.5 % between 1 and 20%, 1 % between 20 and 40%, and 3% between 40 and 120%

The tripping curves characteristics for function [32P] are equivalent to the ones presented in section "[3.7.2 Tripping curves for \[32P\] \[32Q\] \[47\] \[59\] \[59N\]](#)".

### 4.4.1.4 Setting advices for [32RP] on NPG800-NPG800R

Selecting the sensitivity of the protection depends on the mechanical powering of the generator.

For example, for a steam turbine chooses a sensitivity of around 4 % of the rated power (mechanical no-load loss is very small). For diesel engines, choose a sensitivity of around 10 % of the rated power (mechanical no-load loss is very high).

We will examine a synchronous generator powered by a diesel engine with the following characteristics:

$$S_n = 8,2 \text{ MVA}$$

$$P_n = 6560 \text{ kW}$$

$$U_n = 6,6 \text{ kV}$$

$$I_n = 717 \text{ A}$$

$$\text{CTs} = 750/5 \text{ A}$$

$$V_T = 6600/\sqrt{3} / 100/\sqrt{3} \text{ V}$$

Given the high mechanical no-load loss, in a range of value of 25% for diesel engines, the threshold is set to 10 % of the rated power.

$$RP > = \frac{0,10 \times S_{n\_machine}}{S_{n\_relay}} = \frac{0.10 \times \sqrt{3} \times U_{n\_generator} \times I_{n\_generator}}{\sqrt{3} \times U_{n\_relay} \times I_{n\_relay}} = 0.09.S_n$$

The time delay is set to 5 s.

The protection will be active for a reverse power of 656 kW.

### 4.4.2 Protection of active power [32P/37P] - NPG800-NPG800R

The maximum of active power function [32P] is used to send an alarm to the operator or to contribute to certain logic functions upon reaching a given active power threshold. Function [37P] can be used as an alarm to detect a minimum of active power generated.



The operating and characteristics of threshold [32P] are absolutely identical to those of the NPW800-NPW800R as described in section "3.6.8

**Maximum of active power function of [32P] NPW800-NPW800R".** The operating and characteristics of threshold [37P] are also identical to those described in section "3.6.10 **Minimum of active power function of [37P] NPW800-NPW800R".**

### 4.4.3 Reactive power protections [32Q/37Q] NPG800-NPG800R

The maximum of reactive power function [32Q] can be used to protect generators when they start using reactive power in case of loss of excitation, or to send an alarm to the operator, or to contribute to certain logic functions upon reaching of a given reactive power threshold. Function [37Q] can be used as an alarm to detect a minimum of reactive power generated.



The operating and characteristics of the thresholds [32Q] are absolutely identical to these of the NPW800-NPW800R models described in section "3.6.9 **Maximum of reactive power function of [32Q] NPW800-NPW800R".** The operating and characteristics of threshold [37Q] are also identical to those described in section "3.6.11 **Minimum of reactive power function of [37Q] NPW800-NPW800R".**

## 4.5 Protection against frequency variations [81] NPG800-NPG800R

The maximum of frequency function [81.O] allows for detection of machine overspeed, following an islanding or load shedding operation. This can be dangerous because of mechanical constraints applied to the rotor, especially for high power generators. The minimum of frequency [81.U] can be used, par exemple, to activate a load shedding operation.



The operating and characteristics of the two thresholds [81O] and of the two thresholds [81U] are absolutely identical to these of the NPW800-NPW800R models described in section "3.6.7 **Function under frequency and over frequency of [81] NPU800-NPU800R-NPU800RE and NPW800-NPW800R".**

## 4.6 Protection against stator voltage disturbances on NPG800-NPG800R

### 4.6.1 Undervoltage function [27] NPG800-NPG800R

The undervoltage function provides for voltage loss detection due to malfunction of the automatic voltage regulator, to generator excitation loss, to network overload...

In addition to protecting the generator in case of voltage drop, the undervoltage function enables load shedding for non-priority consumer's networks during an overload, or voltage check before a sources transfer.



The operating and characteristics of the two thresholds [27] are absolutely identical to these of the NPW800-NPW800R models described in section "[3.6.2 Undervoltage function \[27\] NPU800-NPU800R-NPU800RE and NPW800-NPW800R](#)".

### 4.6.2 Overvoltage function [59] on NPG800-NPG800R

In case of separation of all or part of the load, voltage at the terminals of the generator suddenly increases to reach a value close to the internal electromotive force. Normally, the voltage regulator acts on excitation to counterbalances this voltage peak. It is however necessary to add a slightly delayed overvoltage protection to backup possible system failures. The overvoltage function [59] offers the features required for this application.



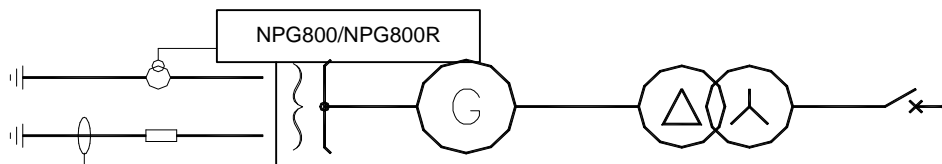
The operating and characteristics of the two thresholds [59] are absolutely identical to these of the NPW800-NPW800R models described in section "[3.6.5 Function overvoltage of \[59\] NPU800-NPU800R-NPU800RE and NPW800-NPW800R](#)".

### 4.7 Protection against earth faults and stator windings protection

When the generator is galvanically isolated from the network it is connected to via a delta-star transformer, you may choose the best solution for the earthing system responding best to the machine protection specifications.

Two solutions shown on figure 74 are commonly used:

- Isolated neutral and use of a Max of zero sequence voltage **[59N]** function to monitor displacement of the neutral point with the **NPG800-NPG800R** protection, fed by a VT to be installed between the neutral point of the machine and the earth.
- High impedant neutral and use of a current relays fed via a CBCT on the earthing connection. With function **[64]** of the **NPG800-NPG800R** models set to about 1 A, this solution protects 90 % of the windings for earthing limited to 10 A.



**Fig. 74:** Group-block

When a generator feeds directly the network, the place and nature of its connection to the earth are sometimes imposed by the network characteristics.

Flow chart on figure 75.a shows the case of a network with isolated neutral and VT between the neutral point of the generator and the earth:

If the generator is the sole supply source for the network, function **[59N]** of the **NPG800/NPG800R** is required. This function can also detect a fault circulating in the stator before the paralleling of the generator on the network.

On the contrary, if the network is wide enough, a selective protection can be obtained through use of a sensitive zero-sequence current protection like the **NPIH800/NPIH800R [51N]**, working on the capacitive current of the network. A Max of zero sequence voltage protection **NPUH800/NPUH800R [59N]** used to monitor neutral point displacement should in this case be fed by VTs connected to the busbars.

Flow chart on **figure 75.b** shows the case of impedant network and neutral point of the generator non-earthed:

With function **[59N]** the **NPG800/NPG800R** models can detect a fault circulating in the stator before the paralleling of the generator on the network.

If the network is large enough, a simple sensitive zero-sequence current protection **NPIH800/NPIH800R [51N]** allows rapid elimination of an internal fault whether or not the presence of parallel sources.

Flow chart on **figure 75.c** shows the case of the neutral point of the generator earthed:

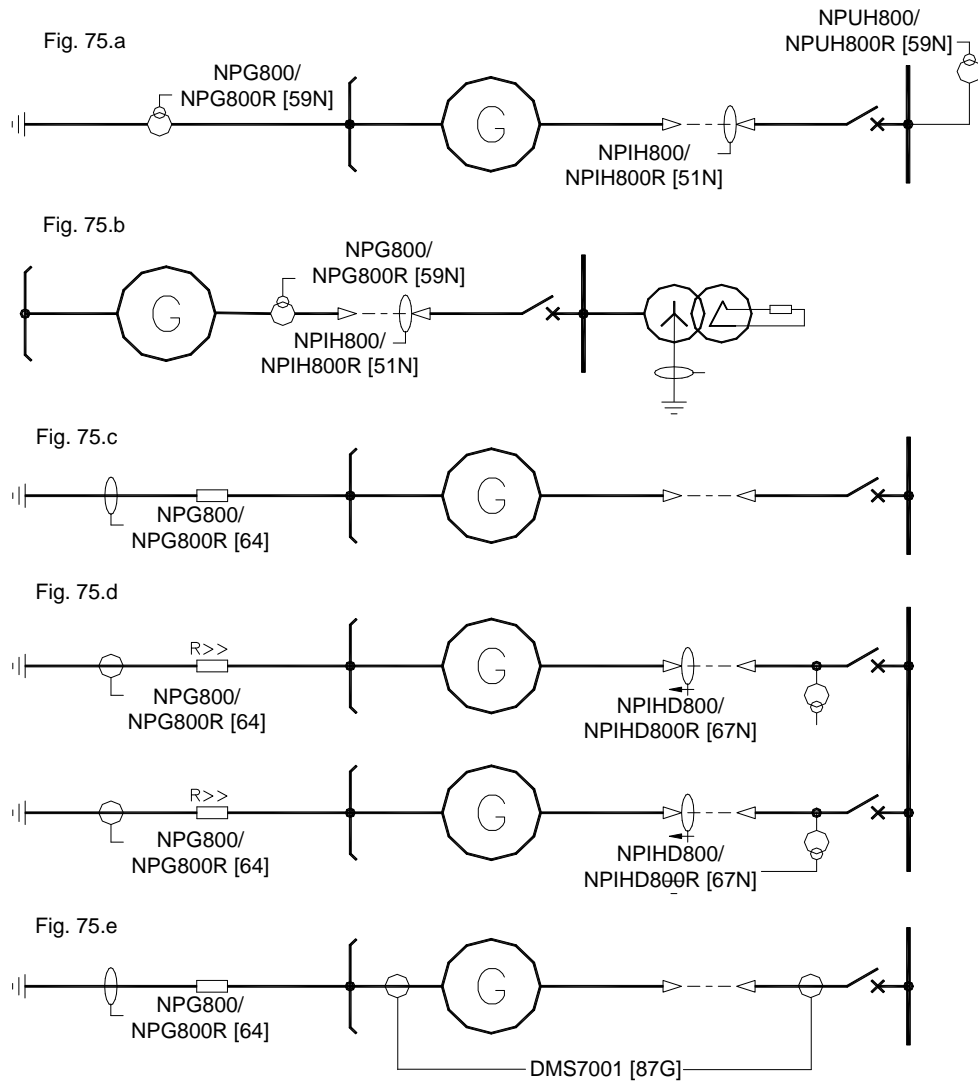
It is still possible to use function **[64]** of the **NPG800/NPG800R** range, fed by a CBCT installed in the earthing connection, provided this earthing is exclusive in the network and the value at which the earth fault current is limited is low enough to be supported by the machine during the protection time delay (this time delay being necessary for selective fault clearance in the network). In fact, this solution only applies to small size networks.

Flow chart on **figure 75.d** shows the case of several machines working in parallel or when the network offers several earthing system device:

This case when the earthing is done at machine level leads to implement an automatic switching system for these neutral points, so that only one is effectively in operation, or you may also use a sensitive directional zero-sequence current protection like types **NPIHD800/NPIHD800R [67N]**. These protections are usually fed via a CBCT, as to obtain a maximum sensitivity.

Particular point **Fig.75.e**:

Each time zero-sequence current fault current will not have been limited to a value lower than the rated current of the machine, you will implement a very quick action differential protection **DMS 7001 [87G]** ordering when an internal fault arises decoupling of the generator and the earthing device as well as a quick stop excitation of the machine. As a backup for this differential protection, we strongly recommend use of function **[64]** of the **NPG800/NPG800R** protections, which monitors faults circulating in the neutral point, and is not sensible to harmonics, especially these with rank 3.



**Fig. 75:** Stator protection against earth fault

## **4.7.1 Function Max of zero sequence voltage [59N] NPG800-NPG800R**

### **4.7.1.1 Introduction to [59N] NPG800-NPG800R**

Generators connected to networks with isolated neutral or fitted with a neutral point transformer loaded on a strong resistance, are likely to operate in a prolonged manner even when a fault affects either their stator or the electrical network. This function allows to signal this operation mode as to take appropriate action and plan a possible stop of the machine before a second fault on one of the phases that remained healthy, leads to the generation of a strong amplitude current in the laminated steel core.

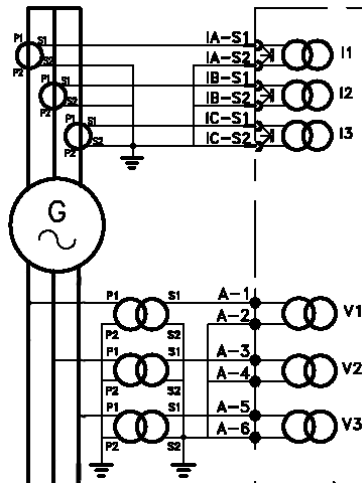
Protections NPG800/NPG800R offers a Max of zero sequence voltage function with two settable thresholds ( $V_{0>}$  and  $V_{0>>}$ ) associated with an definite time characteristic and performs detection using:

- Calculation of residual voltage  $V_r$  by summation of the three phase to neutral voltages provided by the voltage transformers connected to the terminal of the machine.
- Measurement of the residual voltage  $V_r$  through a special input which is fed with the residual voltage produced by the voltage transformers connected in broken delta.
- Measurement of the residual voltage  $V_r$  through a special input which is fed with the residual voltage produced by the zero-sequence voltage produced by a voltage transformer located in the star point of the generator.

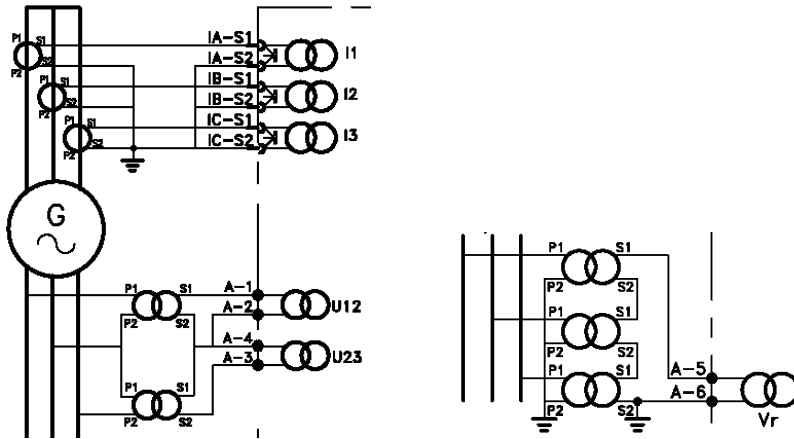
The 3 modes for measurement of the zero-sequence voltage depend on the type of wiring of the protection (see below).

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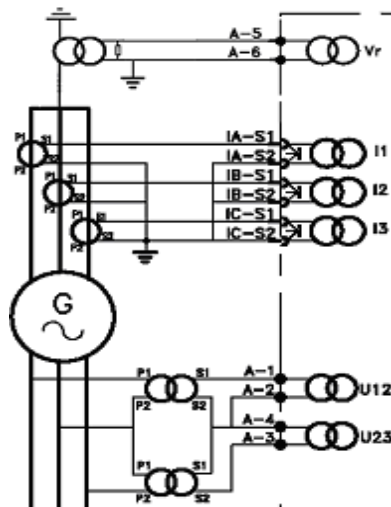
- 3V / 3I wiring - NPG800 (calculating residual voltage  $V_r$ )



- 2U / 3I wiring - NPG800 + broken delta (measurement of residual voltage  $V_r$ )



- 2U / 3I wiring - NPG800 + neutral point (measurement of residual voltage  $V_r$ )



4.7.1.2 Flow chart for [59N] on NPG800-NPG800R

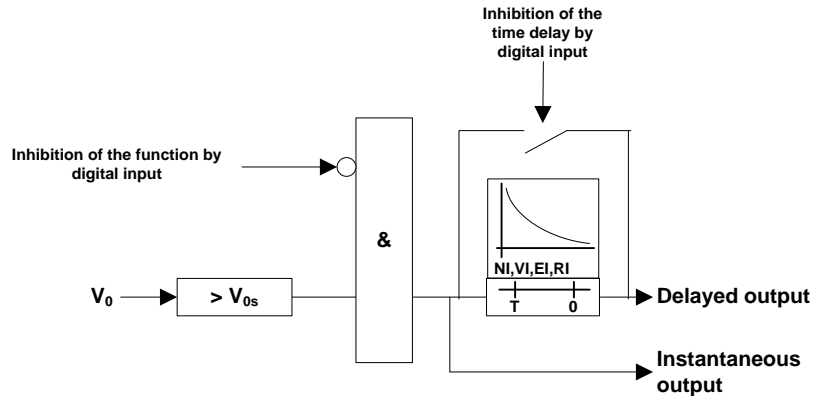


Fig. 76: Function Max of zero sequence voltage [59N]

4.7.1.3 Setting characteristics for [59N] NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [59N]	Setting
Thresholds $V_{0>}$ and $V_{0>>}$	0.02 to 0.80 $U_n$ with steps of 0.01 $U_n$
TIME DELAY FOR THE FUNCTION [59N]	Setting
Definite time-delay $t(V_{0>}) - t(V_{0>>})$	0.04 to 300 s step: see *
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms
Range of settings for the rated value of the measuring voltage ( $U_n$ )	33 V to 120 V (with steps of 0.1 V)

\* between 0.06 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1s.

### 4.7.1.4 Setting advices for [59N] on NPG800-NPG800R

Depending on the value found through coordination or setting study, you must adapt the thresholds [59N] to set on the protection to take into account the rated voltage of the measurement reducers (VT) and possibly modified according to the setting steps.

Depending on the application and on the type of protection, the residual voltage  $V_r$  is calculated which is the result of the measurement of the phase to neutral voltages  $V_1, V_2, V_3$  or it is measured from the residual voltage  $V_r$  from a connection of three voltage transformers in broken delta and the zero-sequence voltage  $V_0$  is measured from a voltage transformer located in the start point (neutral point) of the generator.

Note: the value of the residual voltage  $V_r$  equals three times the value of the zero-sequence voltage  $V_0$ .

#### 4.7.1.4.1 Example of setting in measured mode

As an example, let us examine the following data:

- 6 kV network
- $VT = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3} \rightarrow U_{on_{rel}} = 57.7 \text{ V}$
- Tripping value calculated for the first threshold in case of a zero-sequence fault: 10 % of the network phase to neutral voltage with a definite time delay of 1 s.
- Tripping value calculated for the second threshold in case of zero-sequence fault: 20 % of the network phase to neutral voltage with a definite time delay of 0.5 s.

Calculating the thresholds to set on the protection (broken delta wiring):

- For the first threshold, the low threshold  $V_0 >$  for function [59N] will be used with the following setting:  
According to the broken delta wiring of the VTs, the voltage applied to the protection will be three times the measured voltage. (i.e.  $V_r$ )  
 $V_0 > = 0.1 \times 3 \times U_{on_{rel}} = 0.3 U_{on_{rel}}$   
The time delay  $t(V_0 >)$  will be set to 1 s.
- For the second threshold, the high threshold  $V_0 >>$  for function [59N] will be used with the following setting:  
According to the broken delta wiring of the VTs, the voltage applied to the protection will be three times the measured voltage.  
 $V_0 > > = 0.2 \times 3 \times U_{on_{rel}} = 0.6 U_{on_{rel}}$   
The time delay  $t(V_0 >>)$  will be set to 0.5 s.

Calculating the thresholds to set on the protection (neutral point wiring):

- For the first threshold, the low threshold  $V_{0 >}$  for function [59N] will be used with the following setting:  
According to the VT install in the star point of the generator, the voltage applied to the protection will be equal to the measured voltage. (i.e.  $V_0$ )  
 $V_{0 >} = 0.1 \times U_{n_{rel}}$   
The time delay  $t(V_{0 >})$  will be set to 1 s.
- For the second threshold, the high threshold  $V_{0 >>}$  for function [59N] will be used with the following setting:  
According to the VT install in the star point of the generator, the voltage applied to the protection will be equal to the measured voltage.  
 $V_{0 >>} = 0.2 \times U_{n_{rel}}$   
The time delay  $t(V_{0 >>})$  will be set to 0.5 s.

### 4.7.1.4.2 Example of setting in calculated mode

Let us examine as an example the following data:

- 6 kV network
- $TP = 6 \text{ kV} / \sqrt{3} / 100 \text{ V} / \sqrt{3} \rightarrow U_{n_{rel}} = 57.7 \text{ V}$
- Tripping value calculated for the first threshold in case of zero-sequence fault: 10% of the network phase to neutral voltage with a definite time delay of 1 s.
- Tripping value calculated for the second threshold in case of zero-sequence fault: 20% of the network phase to neutral voltage with a definite time delay of 0.5 s.

Calculating the thresholds to display on the protection:

- For the first threshold, the low threshold  $V_{0 >}$  for function [59N] will be used with the following setting:  
 $V_{0 >} = 0.1 \times U_{n_{rel}} = 0.1 U_{n_{rel}}$   
The time delay  $t(V_{0 >})$  will be set to 1 s.
- For the second threshold, the high threshold  $V_{0 >>}$  for function [59N] will be used with the following setting:  
 $V_{0 >>} = 0.2 \times U_{n_{rel}} = 0.2 U_{n_{rel}}$   
The time delay  $t(V_{0 >>})$  will be set to 0.5 s.

### 4.7.2 Function Max of zero sequence current [64] NPG800 -NPG800R

#### 4.7.2.1 Introduction to [64] NPG800-NPG800R

When a network is linked to the earth, quick detection and elimination of single-phase faults is generally required, in order to ensure personal safety and to limit material damage. This protection is usually given to a Max of zero sequence current function.

Synchronous machines can contribute to the provision of earth fault current and/or be themselves affected by this fault (stator grounding). If this fault occurs outside of the machine, it can withstand it for a fairly long time within its thermal and mechanical limits. If this fault occurs in the stator, it must be detected and eliminated as soon as its amplitude reaches a few Amperes, as to avoid a prolonged machine stop as a consequence of this incident.

The various modes of earth connection for machines and network lead to many application cases for the NPG800 model. The application choice is done according to the type of measurement requested:

- network side measurement:
  - residual connection of 3CTs (Ino CT independent of InPh TC)
  - CBCT \* around all three phases
  
- star point side measurement:
  - CT (Ino CT independent InPh TC)
  - CBCT \*

\*for the CBCT choice, please refer to the 142941 drawing.

This function offers two thresholds to Max of zero sequence current ( $I_{0>}$  and  $I_{0>>}$ ), each of them associated with a definite or inverse time characteristic.

4.7.2.2 Flow chart for [64] on NPG800-NPG800R

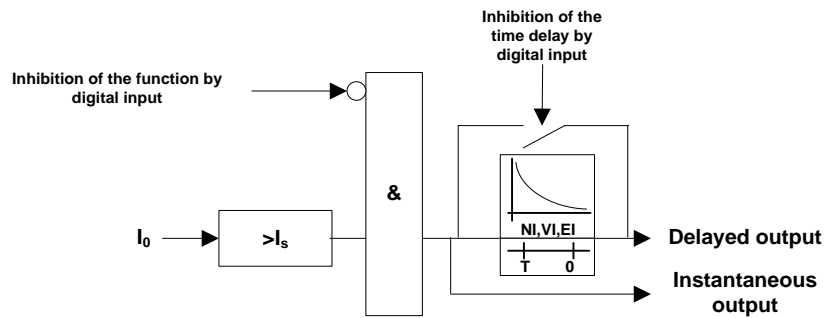


Fig. 77: Max of zero sequence voltage overcurrent function [64]

4.7.2.3 Setting characteristics for [64] NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [64]	Setting
$I_0$ thresholds > - $I_0 \gg$ CT connection	0.03 to $2.4 I_{n0}$ with steps of $0.01 I_{n0}$
Threshold $I_0 >$ - $I_0 \gg$ connection CBCT – ICE Primary range: 0.6 to 48 A, step: 0.1A	$0.03$ to $2.4 I_{n0}^{**}$ with steps of $0.01 I_{n0}$
TIME DELAYS FOR THE FUNCTION [64]	Setting
Definite time-delay $t(I_0 >)$ $t(I_0 \gg)$	0.04 to 300 s step: see *
IEC*** inverse time curve: inverse, very inverse, extremely inverse $t(I_0 >)$ $t(I_0 \gg)$	$T_{++}$ : 0.03 to 3 s with steps of 0.01s
ANSI/IEEE*** inverse time curve: normally inverse, very inverse, extremely inverse $t(I_0 >)$ $t(I_0 \gg)$	$T_{++}$ : 0.03 to 3 s with steps of 0.01s
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms

\* between 0.06 and 9.99 s with steps of 0.01s, between 10 and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1s.

\*\* to obtain the value to be set on the protection, divide the desired value at the primary by 20. This coefficient takes into account the transformation ratio 100/1 of the CBCT and the earth range for the protection 0.2 A.

\*\*\*: for the characteristics of function [64], see section: "[3.5 Tripping curves for \[46\] \[51\] \[51N\]](#)"

### 4.7.2.4 Setting advices for [64] on NPG800-NPG800R

We will examine a synchronous generator with the following characteristics:

- Limitation of fault current to 10A through a neutral point resistance.
- Measurement of the zero-sequence current fault is performed by an ICE CBCT, 100 turns, TF 50.1.
- Rated current for the protection is 0.2 A (specific range for CBCT)

As to provide maximum protection to the generator windings, this protection will be set at its minimum threshold (0.6 A) with a sensitive time delay of 100ms, knowing that with a threshold of 0.6 A the protection protects 94 % of the stator windings of the machine.

Calculating the thresholds and parameters to display on the protection:

- Function [64] will be used with the following setting:  $I_{o>} = 0.6/20=0.03$ .
- the operating characteristic will be definite time and the time delay set to 0.1 s.

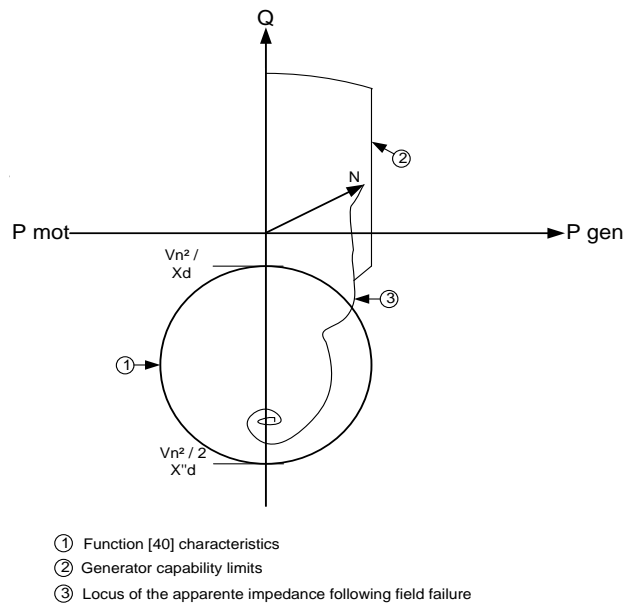
Note: 20 = coefficient which takes into account the transformation ratio 100/1 of the CBCT 100/1 and the earth range for the protection 0.2 A.

## 4.8 Protection against loss of field [40] NPG800-NPG800R

### 4.8.1 Introduction to [40] NPG800-NPG800R

When a generator loses its excitation, the reactive power necessary to its magnetisation is provided by the network. If a previous load exists, the machine loses its synchronism. Consequently, the network operation is disturbed (voltage drops, overloads...), even more if the generator is more powerful and on the other hand, at the faulty machine level, excessive heat is produced in the coil heads of the stator as well as circuits and rotor laminated steel core. Detection and elimination of such operating conditions is therefore necessary.

Analysis of the machine behaviour shows that impedance at its terminals varies between synchronous direct axis reactance  $X_d$  (machine which has kept its synchronism) and subtransient direct axis reactance  $X''_d$  (machine stopped). In reality, the generator keeps turning and the average apparent impedance at its terminals is slightly lower to the transient direct axis reactance  $X'_d$ .



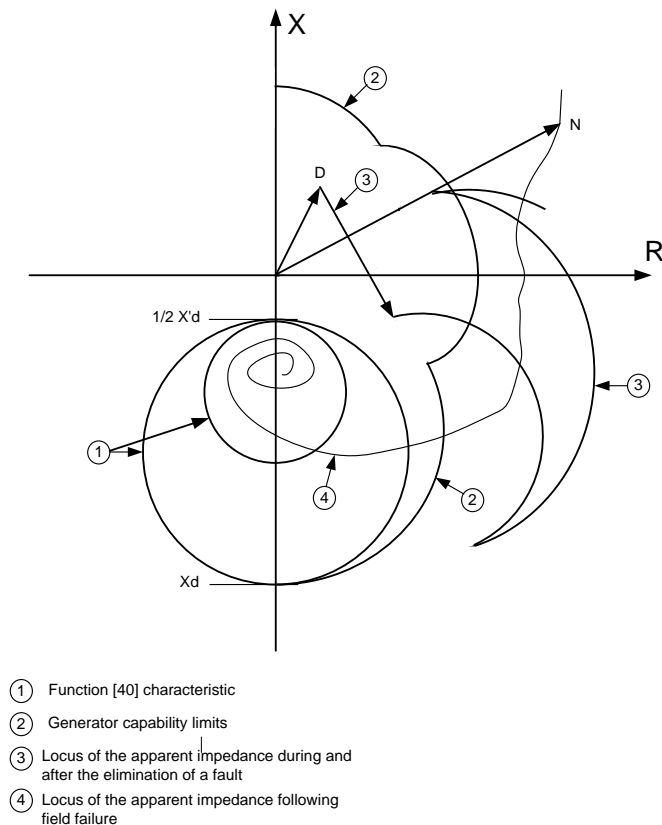
**Fig. 78:** Flow chart P-Q for the function loss of field [40]

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The protection uses measurement of the internal impedance of the generator. This protection is performed by an impedance function with shifted circular feature (MHO) in an R-X impedance flow chart. This function offers two thresholds ( $Y <$  and  $Y <<$ ) associated with a definite time characteristic.

This circular feature grants to the protection a great working safety as it authorises all permanent or transitional stable working conditions which come with violent oscillations of the active and reactive power with the network after fault clearance.

The time delay thresholds enables to oversee these power oscillation following the elimination of a violent network fault, whilst detecting the loss of excitation which is typical for absorption of reactive power during asynchronous operation.



**Fig. 79:** Flow chart R-X for the loss of field function [40]

4.8.2 Flow chart for [40] NPG800-NPG800R

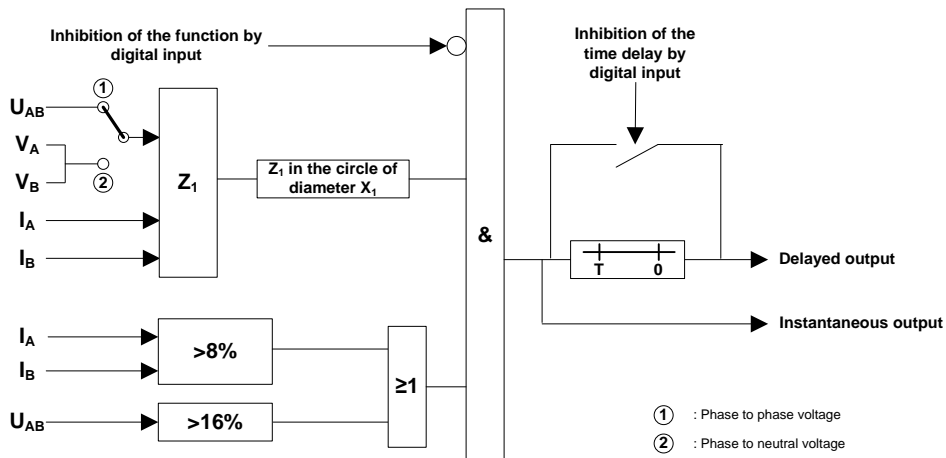


Fig. 80: Loss of field function [40]

4.8.3 Setting characteristics for [40] NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [40]	Setting
Circle shift: $X2 (Y<) - (Y<<)$	0.08 to 0.40 $Z_n$ steps of 0.01 $Z_n$
Circle diameter: $X1 (Y<) - (Y<<)$	0.50 to 5 $Z_n$ steps of 0.05 $Z_n$
Inhibition threshold: $U < 16\%$ of $U_n$ or $I < 8\%$ of $I_n$	
TIME DELAY FOR THE FUNCTION [40]	Setting
Definite time-delay - $t (Y<) - t(Y<<)$	0.04 to 300 s step: see *
CHARACTERISTICS	Values
Response time for instantaneous outputs	60ms

\*: between 0.04 and 9.99 s with steps of 0.01 s, between 10.0 s and 29.9 s with steps of 0.1 s, between 30 and 300 s with steps of 1s

**4.8.4 Setting advices for [40] on NPG800-NPG800R**

We will examine a synchronous generator (GTG) with the following characteristics:

$$S_n = 8.2 \text{ MVA}$$

$$U_n = 6.6 \text{ kV}$$

$$I_n = 717 \text{ A}$$

$$X''_d = 0.20 \text{ pu}$$

$$X'_d = 0.28 \text{ pu}$$

$$X_d = 2,204 \text{ pu}$$

$$CTs = 750/5 \text{ A}$$

$$VT = 6600/\sqrt{3} / 100/\sqrt{3} \text{ V}$$

The circle is set to start with the base impedance of the machine “translated” to the secondary of the measurement reducers.

The circle is shifted of  $X'_d/2$  from its origin.

1 – Correcting reactance’s “Xd” and “X’d” for the generator in function of the rated values of the NPG800 protection:

$$X_{d\_relay} = X_{d\_GTG} \times \frac{I_{n\_CT}}{I_{n\_GTG}} \times \frac{U_{n\_GTG}}{U_{n\_VT}} = 2.204 \times \frac{750}{717} \times \frac{6600}{6600} = 2.31 \times Z_{n\_relay}$$

$$X'_{d\_relay} = X'_{d\_GTG} \times \frac{I_{n\_CT}}{I_{n\_GTG}} \times \frac{U_{n\_GTG}}{U_{n\_VT}} = 0.28 \times \frac{750}{717} \times \frac{6600}{6600} = 0.293 \times Z_{n\_relay}$$

2 – Calculating the settings of X1 and X2 for the NPG800 1<sup>st</sup> threshold (Y<)

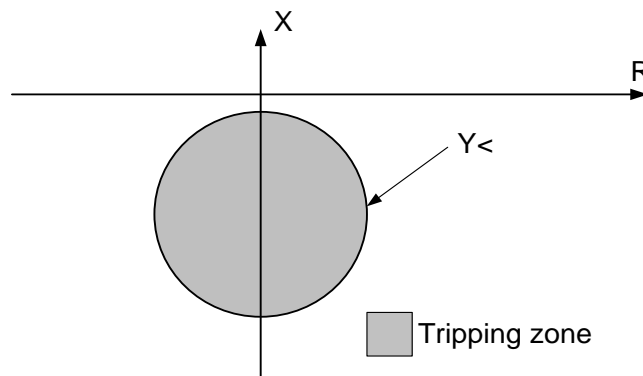
$$X_1(Y <) = X_{d\_relay} - \frac{X'_{d\_relay}}{2} = 2.31 - \frac{0.293}{2} = 2.15 \times Z_{n\_relay}$$

$$X_2(Y <) = \frac{X'_{d\_relay}}{2} = \frac{0.293}{2} = 0.15 \times Z_{n\_relay}$$

### 3- Setting the time delay for threshold $Y<$ :

The faults detected by the threshold  $Y<$  are excitation faults, so this threshold will be set between 1 and 3 seconds, as to avoid tripping's during the transitional periods (major fault on the network).

$$t(Y<) = 1 \text{ s}$$



**Fig. 81:** Operating characteristics of the loss of field [40]

## 4.9 Function of overfluxing [24] NPG800-NPG800R

### 4.9.1 Introduction to [24] NPG800-NPG800R

The aims of the function of overfluxing [24] is the protection of the magnetic circuits of rotating machines and transformers, in particular the machine-transformer block groups, by following the ratio  $U/f$ .

The relationship between voltage (E) at the terminals of a winding and the flux (B) induced in the magnetic circuit is defined by the Boucherot relation:  $E = 4,44.f.A.N.B$  where:

f = network frequency (Hz)

A = magnetic circuit section (m<sup>2</sup>)

N = number of turns in the coil

B = flux density (Tesla)

This can be written in the following form:  $B = K \cdot \frac{E}{f}$

The magnetic flux is therefore proportional to the ratio of the voltage over the frequency  $U/f$ .

For economic reasons, magnetic circuits are used to work with a maximum induction. Lowering frequency and increasing voltage lead to higher flux and saturation of the magnetic circuit. This translates into higher heating which can lead to destruction of the magnetic circuit.

A ratio E/f higher to the rated value leads heating at magnetic circuit level. We can say that the resulting temperature increase is a direct consequence of the ratio E/f.

The higher the threshold is exceeded, the greater the temperature increase will be, the shorter the action time must be. This is why it is interesting to use an inverse time characteristic, possibly completed with a second threshold with definite time.

Measurement is performed on phase-to-phase voltages  $U_{AB}$ ,  $U_{BC}$  or on phase-to-neutral voltages  $V_A$ ,  $V_B$  and  $V_C$  depending on the wired mode (3I-2U or 3I-3V).

4.9.2 Flow chart for [24] on NPG800-NPG800R

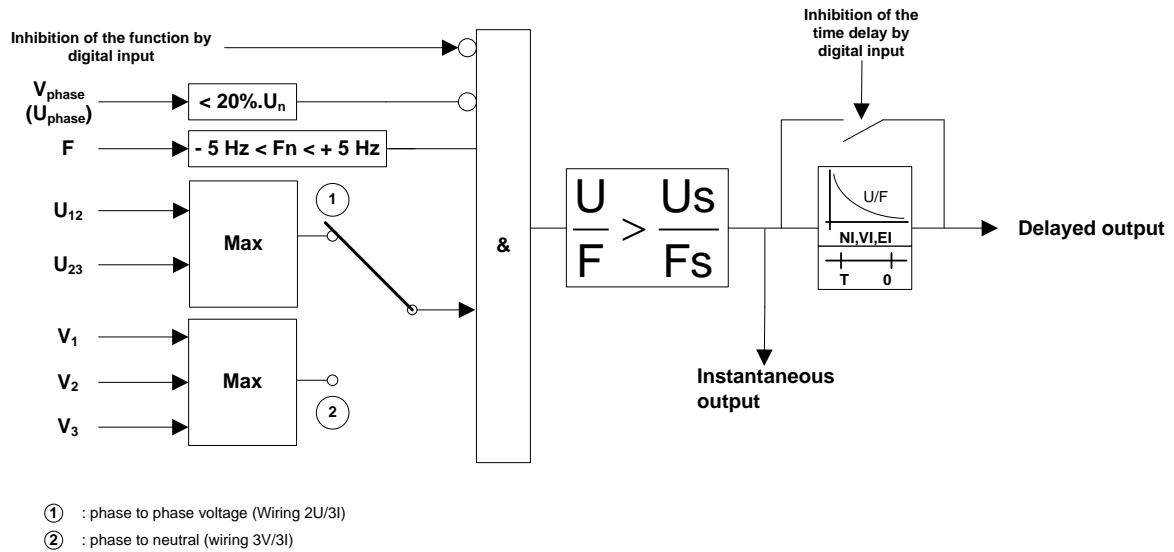


Fig. 82: Magnetic flux control [24] function

4.9.3 Setting characteristics of [24] NPG800-NPG800R

THRESHOLDS FOR THE FUNCTION [24]	Settings
Thresholds: $U/F >$ and $U/F >>$	80 % to 200 % $U_n/F_n$ steps of 0.01 $U_n/F_n$
TIME DELAY FOR THE FUNCTION [24]	Settings
Definite time-delay - $t(U/F >)$ $t(U/F >>)$	0.2 to 10 s step: see *
IEC inverse time curves: inverse, very inverse, extremely inverse - $t(U/F >)$ $t(U/F >>)$	T++: 0.03 to 3 s with steps of 0.01 s
ANSI/IEEE inverse time curves: moderately inverse, very inverse, extremely inverse - $t(U/F >)$ $t(U/F >>)$	T++: 0.03 to 3 s with steps of 0.01 s
CHARACTERISTICS	Settings
Measurement dynamic	45 to 55 Hz or 55 to 65 Hz
Response time for instantaneous outputs	60ms

### 4.9.4 Setting advices for [24] on NPG800-NPG800R

For generator-transformer block installations and as a complement to the overvoltage function [59], we use a maximum of magnetic flux protection, to avoid working under overexcitation conditions. Both U/F thresholds, used for tripping, allow for a good protection of synchronous generators by avoiding working under overexcitation conditions.

In order to do so, the first threshold, the low threshold U/F> of function [24] is set to 105 % of  $U_n/F_n$ . Its operating characteristic is selected with IEC inverse time. The value of T++ is set in order to obtain a trip at 1.1 U/F between 120 s ( $T_{++} = 1.64$ ) and 180 s ( $T_{++} = 2.46$ ) to allow overexcitations which belong to system stability and to the network operation. It is also possible to make use of a definite time characteristic.

The second threshold, the high threshold U/F>> is set to 120 % of  $U_n/F_n$ . Its operating characteristic is definite time and its time delay is set between 2 s and 5 s, to avoid overheating, which reduce the lifetime of equipment's.

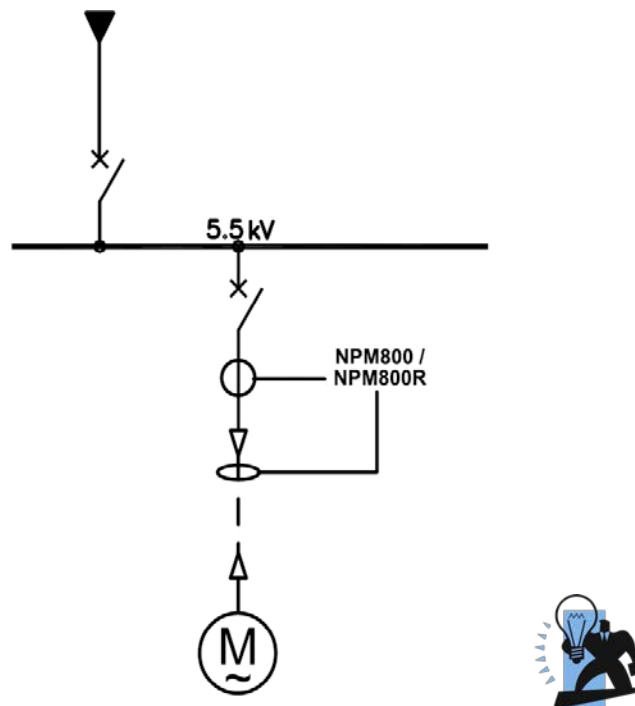
## 5 Protection of induction motors

Protection of medium and low voltage motors requires use of multifunction protections with at least the following elements:

- A thermal image function
- A unit sensitive to the negative component of currents,
- A unit allowing for quick elimination of all violent multiphase faults,
- Units for too long start or locked rotor,
- A function of start inhibition,
- A unit for Max of zero sequence current

This chapter details these basic functions, all integrated in the motor protections of range **NPM800-NPM800R-NPM800RE**, as well as their additional functions.

You can only choose between a unique (multifunction protection) or an combination of several protection systems (multifunction protection and additional protections) after a detailed study of the installation constraints, the start conditions and the thermal constant parameter for the motor to protect (its power alone is not a sufficient criteria to choose the type of protection).



**Fig. 83:** Example of motor protection using the NPM800-NPM800R-NPM800RE

## 5.1 Protection against balanced and unbalanced thermal overloads on NPM800-NPM800R-NPM800RE

### 5.1.1 Introduction to the thermal image of [49] NPM800-NPM800R-NPM800RE function

#### 5.1.1.1 Overview of [49] NPM800-NPM800R-NPM800RE

This function can be used to protect a motor against an excessive temperature increase, following a continuous overload. Permanent overload on a motor is the result of a growing resistive torque, of a subsequent loss of motor torque, or of a voltage drop.

If the overload is maintained, the high current value will lead to a temperature increase damageable for the life time of the machine (early ageing of the isolating material).

An unbalanced distribution of phase-to-neutral consumers or minor unbalances of the network lead to the production of negative currents which also participate in the heating of the machine rotor.

The thermal image unit [49] of the **NPM800-NPM800R-NPM800RE** range protections records any type of overload, whether balanced or unbalanced, and in the latest case, it takes into account the overheating of the rotor. The negative component for stator currents generates, indeed, an air gap electromagnetic field turning at synchronism speed in the reverse direction as the rotor.

Due to this fact, currents with a 100 Hz frequency originate in the rotor, concentrate on its surface via a skin effect and lead to important Joule loss, in other words overheating. In order to take this loss into account, the current value used to build the thermal image is the result of a combination of positive and negative currents, which are themselves calculated from real phase currents through a symmetrical components calculation. In this manner, the response time of the thermal image unit is lowered when a noticeable negative component rate is present in the supply system of the motors.

Their heating time constant can be set, to adapt to any kind of motor.

The **NPM800-NPM800R-NPM800RE** models offer a thermal alarm unit able to inform the operator of an overload operating condition of a motor before tripping, which is always damageable to industrial processes.

Evaluating the thermal state of a motor is performed using a NPM800 internal thermal image. When the calculated thermal image reaches 100 %, the tripping for this unit is initiated.

This thermal state is obtained after a given t time obtained through the following relation (IEC 60255-8 standard):

$$t = C_t * \ln\left(\frac{I_{mot}^2 - I_{pre}^2}{I_{mot}^2 - I_{ref}^2}\right)$$

- $C_t$ : thermal time constant (in seconds) for the motor, depending on the operating mode.
- $I_{ref}$ : rated current for which the motor reaches a maximum thermal state of 100 % in stabilised operation ( $I_{ref}$  is set in percentage of the rated current  $I_n$ ).
- $I_{pre}$ : load current of the motor at its initial state.
- $I_{mot}$ : real load current of the motor at instant t:

In order to gain a more realistic image of the thermal constraints to which the motor is submitted, we take into account the positive component of the current (representative of the motor torque) and the negative component weighted by a factor K (accounting for the unbalance). This K factor allows to take into account the heating created by the negative component which are, for a given current value, higher than those created by the positive component.

Before tripping (for a thermal state of 100 %), a thermal alarm is generated when the thermal state reaches is alarm threshold, which can be set between 80 and 100 %.

### 5.1.1.2 Time constant of [49] NPM800-NPM800R-NPM800RE

Time constant  $C_t$ , used by the thermal image varies according to three operation modes, depending on starting threshold  $I_{dem}$  and on the locked rotor function (please refer to the section dedicated to this function).

#### 5.1.1.2.1 Start mode ( $I_{mot} > I_{dem}$ – start threshold) [49] NPM800-NPM800R-NPM800RE

The start threshold  $I_{dem}$  is determined according to  $I_{ref}$ .

The start operation of the motor happens when current  $I_{mot}$  is higher to the set start threshold  $I_{dem}$ .

During the start period, heating is faster than with normal operating mode, as the motor has not yet reached its normal speed. The heating time constant can therefore be lowered.

In order to achieve this, we multiply constant  $C_{TE}$  by a start factor  $F_D$  lower to 1:

Start time constant  $C_t = F_D * C_{TE}$ .

**5.1.1.2.2 Normal operating mode ( $I_{mot} < I_{dem}$  – start threshold) of [49] NPM800-NPM800R-NPM800RE**

The motor is considered at normal operating mode, when current  $I_{mot}$  is lower to the start threshold  $I_{dem}$ .

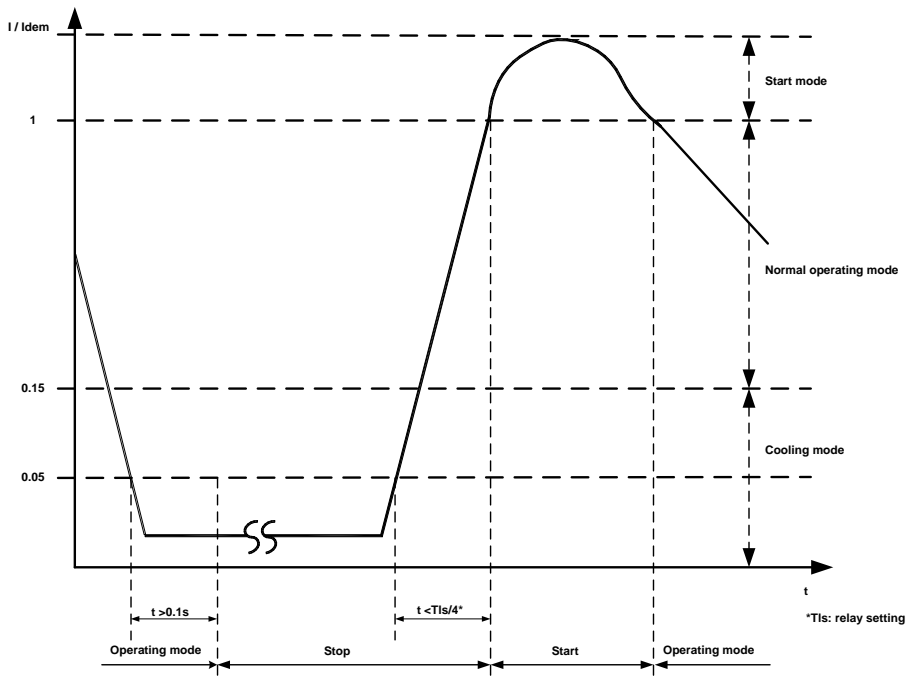
In this case, the motor heating time constant  $C_{TE}$  is not reduced:

$$C_t = C_{TE}$$

**5.1.1.2.3 Cooling mode ( $I_{mot} < 0.05 I_{dem}$  – start threshold) [49] NPM800-NPM800R-NPM800RE**

As to reflect the various cooling modes of motors, the **NPM800-NPM800R-NPM800RE** models offer a set cooling time constant (which is activated at machine stop).The motor is considered in stop state when current  $I_{mot}$  becomes  $< 0.05 I_{dem}$ . When a motor is not supplied any more, its speed rapidly decreases and the time constant increases, due to a reduced efficiency of the cooling system:

Cooling time constant  $C_{TR} = 1.0$  to  $6.0 * C_{TE}$ .



**Fig. 84** : State of the motor measured by NPM800-NPM800R-NPM800RE

**5.1.2 Introduction to the function inhibition of hot start according to [5-49]  
NPM800-NPM800R-NPM800RE**

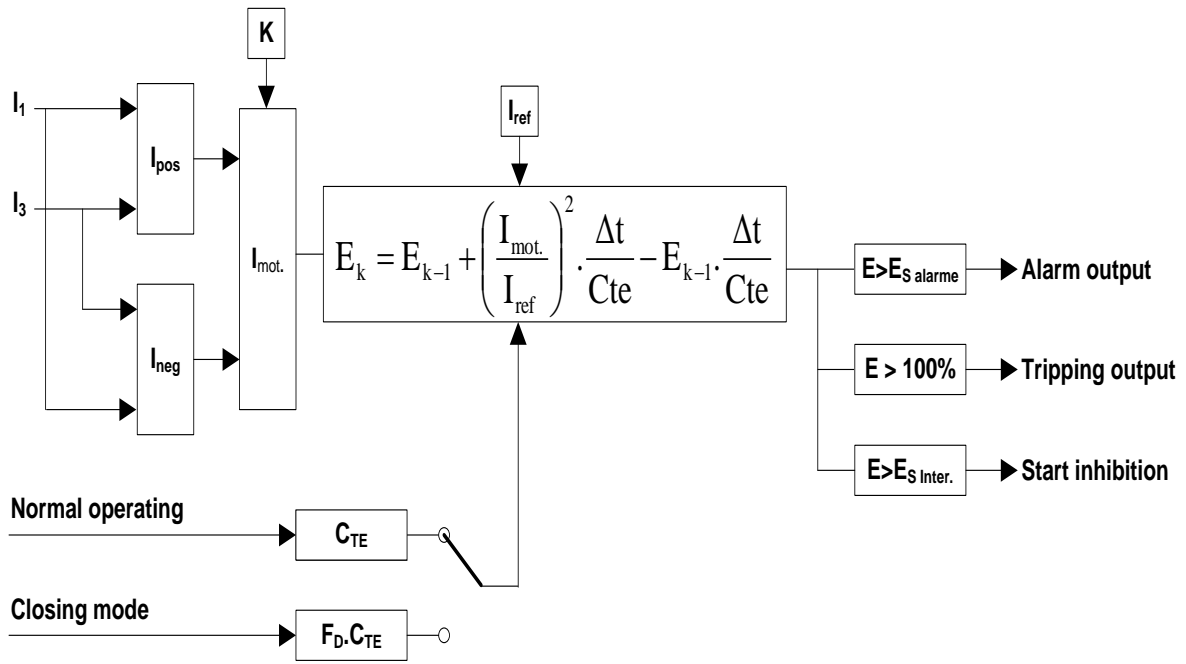
When the motor reaches a temperature close to the thermal tripping value, a new start could rapidly lead to thermal tripping. To avoid this situation, it is possible to forbid any new start of the motor as long as its thermal state  $\theta$  is not below a certain threshold.

This function orders a relay "START INHIBITION" which will be included in the control chain for motor start.

It is advised to use inverter relay C, which offers a contact normally closed when this relay is de-energised:

- cold motor ( $\theta <$  displayed threshold): the selected relay is de-energised (contact closed). Start is allowed.
  
- hot motor( $\theta >$  displayed threshold): the selected relay is activated (contact open). Start is inhibited.

5.1.3 Flow chart for [49] NPM800-NPM800R-NPM800RE



- $E$  = Thermal state in %
- $E_k$  = Thermal at  $K$
- $E_{k-1}$  = Thermal state at  $K - 1$
- $E_{S\ alar\ me}$  = Threshold of the thermal state in %
- $E_{S\ inter.}$  = Threshold of the start inhibition in %

**Fig. 85:** Motor thermal image function [49]

**5.1.4 Setting characteristics for [49] NPM800-NPM800R-NPM800RE**

Characteristics	Values
C <sub>TE</sub> : heating time constant	4 to 180 min with steps of 1min
C <sub>TR</sub> : cooling time constant	1.0 to 6.0 C <sub>TE</sub> with steps of 0.1
K: negative component factor	0 to 9 with steps of 1
F <sub>D</sub> : start factor	50 to 100 % with steps of 1%
I <sub>ref</sub> : thermal reference current	I <sub>ref</sub> = 0.40 to 1.30 I <sub>n</sub> with steps of 0.01 I <sub>n</sub>
Thermal alarm threshold	80 to 100 % $\theta$ thermal with steps of 1%
Thermal threshold for inhibition of hot start (If thermal trip)	40 to 100 % $\theta$ thermal with steps of 1%

**5.1.5 Setting advices for [49] on NPM800-NPM800R-NPM800RE**

Let us examine as an example the following data to protect an induction motor:

- CT = 100/5 A - 5VA 5P15
- I<sub>n</sub> protection = 5 A
- Rated current for the motor = 90A
- Load factor for the motor = 100%
- Start current for the motor = 450A (5 times I<sub>n</sub> motor )
- Start time for the motor = 4 s
- Heating time constant \* = 20 min
- Motor cooling by air fan on the shaft end.

\* manufacturer data

### Adapting the rated current of the motor to the protection:

The rated current of the motor must be adapted to take into account:

- the measurement reducers (CTs)
- the setting steps for thermal rated current  $I_{ref}$
- the load factor "Fc" for the motor. If the motor load factor is lower to its rated value, coefficient "Fc" is not used (case of an oversized motor). If the motor is to be used at its rated value, "Fc" must be included between 1.05 and 1.07 (these values correspond to a permanent overload of 5 to 7 % without reaching tripping via the thermal unit). This parameter must be determined during the setting study, and it is not a setting parameter for the protection.

$$I_{ref} = (I_n \text{ motor} / I_n \text{ TC}) \times \text{"Fc"}$$

### Calculating the thermal threshold and parameters to set on the protection:

The tripping threshold  $I_{ref}$  will be set to the following value:  $I_{ref} = (90/100) \times 1.07 = 0.963$ , so after taking account of the setting steps: 0.96.

The heating time constant  $C_{TE}$  will be set to the requested value: 20 min.

Given the cooling mode, constant  $C_{TR}$  will be set to twice (2) the heating constant.

### Calculating the restart inhibition thermal threshold:

In order to avoid penalising the process, this threshold, if possible, must be set to 90 % of the thermal state calculated by the protection. To this effect, we must check that the motor will not trip during a hot start with the equation which is used to calculate the thermal image according the characteristics of the motor:

$$t = C_{TE} * \ln \left( \frac{I_{mot}^2 - I_{pre}^2}{I_{mot}^2 - I_{ref}^2} \right)$$

Where:

- t = tripping time (in seconds) for the thermal protection when starting

## PROTECTING INDUCTION MOTORS

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- $C_{TE} = 1200 \text{ s (20min)}$
- $I_{mot} = 5 \text{ (450A/90A)}$
- $I_{ref} = 1.07$
- $I_{pre} = 1$

With a result of 7.26 s, taking account of the motor starting time (4 s), we can set 90 % for the restart inhibition thermal threshold.

### Weighting using the negative component:

Since the measurement reducers belong to class 5 P, and since the installation is not subjected to strong unbalanced currents, the negative sequence weighting factor will be set to 9. Therefore, unbalances lower to the operating threshold of the measurement unit of the negative component [46] will be taken into account for calculating the thermal image.

### Setting the starting factor

The starting factor will be set to 90 %, weighing the heating constant during starting periods.

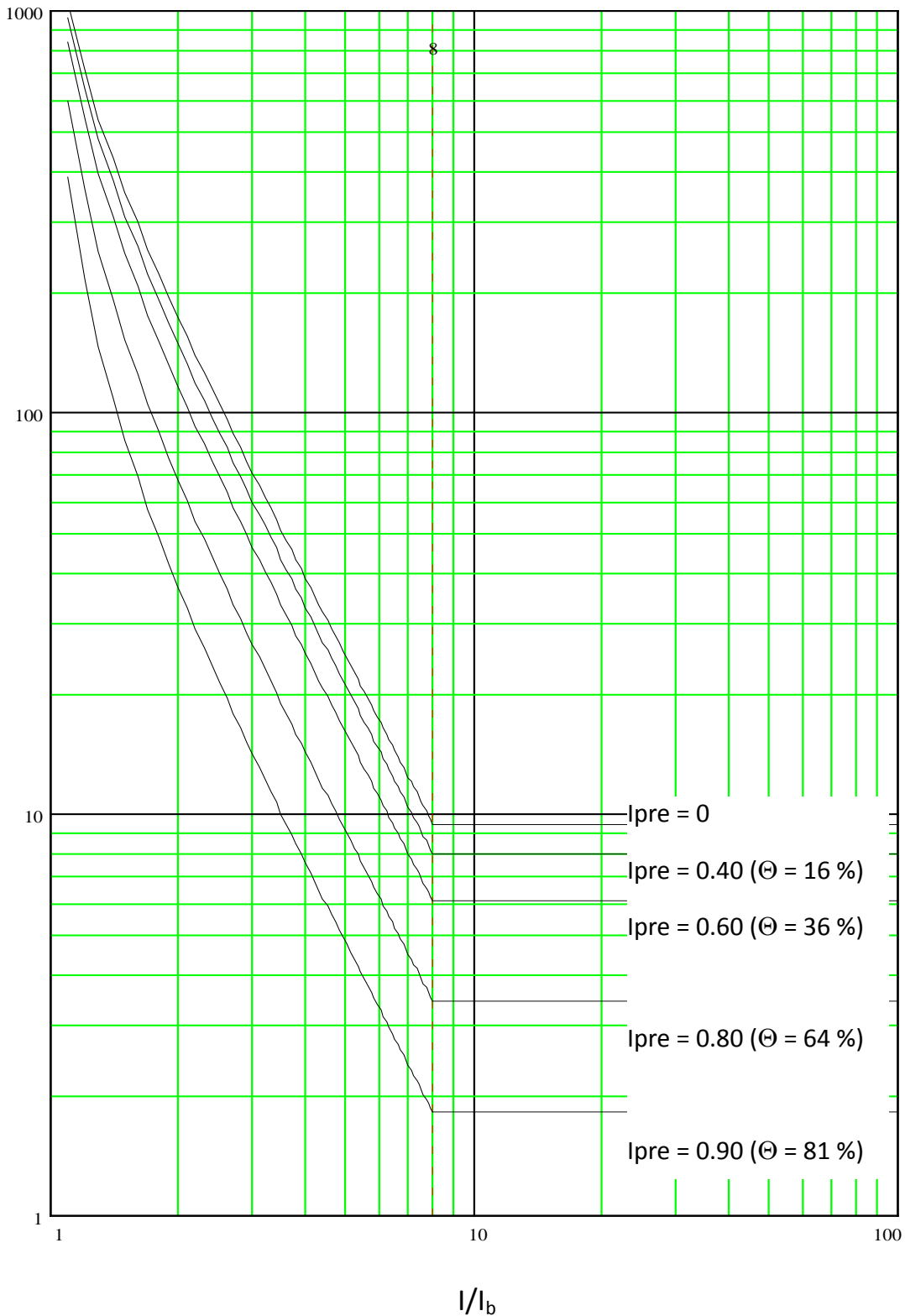
### Setting the alarm threshold

As a complement, you can set the alarm threshold to 95 %, so that operating persons are warned before tripping of the motor by the thermal unit.

5.1.5.1 Thermal curves for NPM800-NPM800R

5.1.5.1.1 Characteristics of the thermal image

The following curves are defined for a time constant  $\tau = 10$  minutes:



**5.1.5.1.2 Cooling curves**

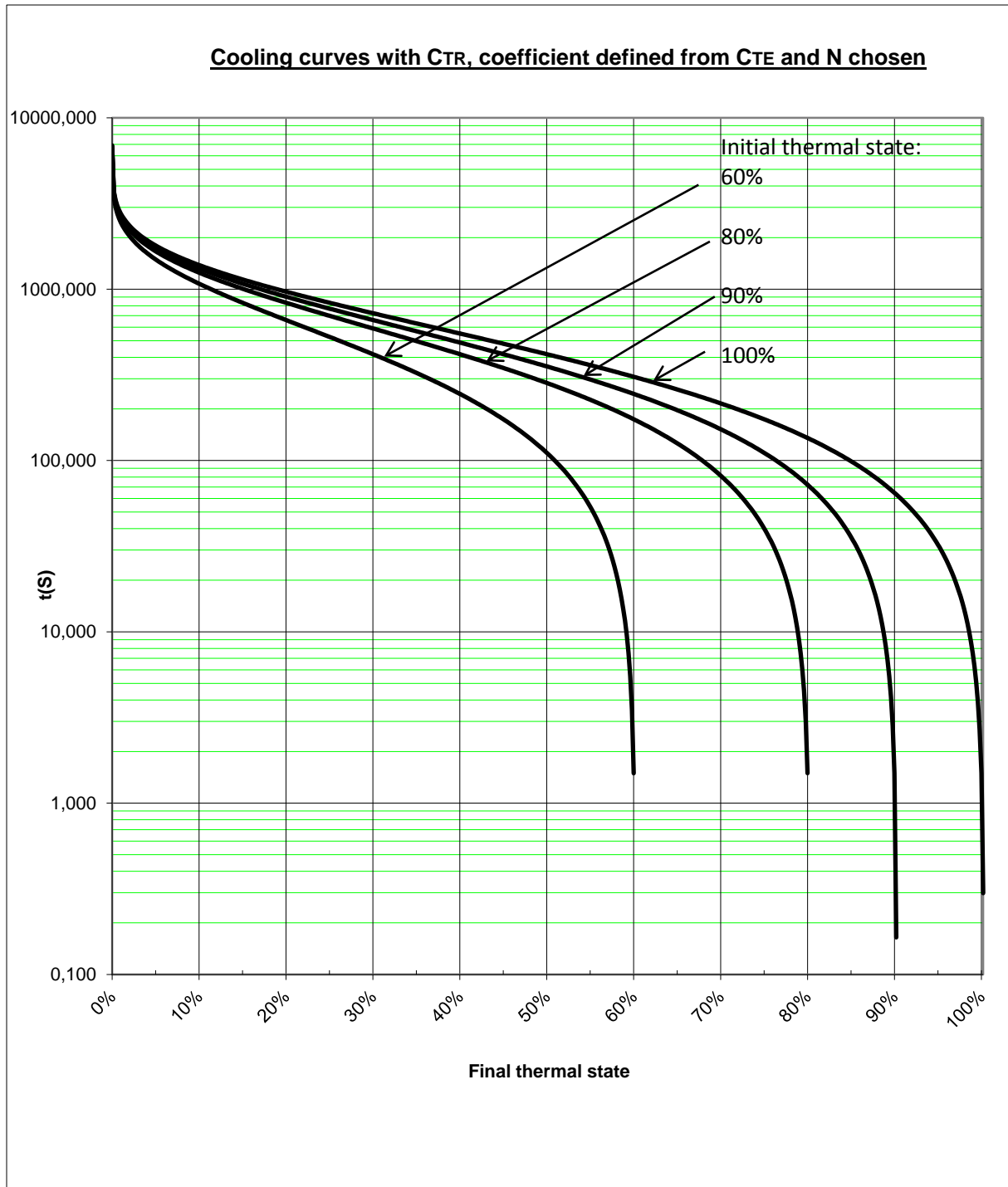
The following curve provides the time necessary for cooling, starting with a given thermal state.

For another value of time constant, multiply the indicated times on the curve by the value in minutes of the used time constant.

Equation cooling curves is as follows:

$$t = C_{TR} \cdot \ln\left(\frac{\theta_{thermal\_state}}{\theta_{trans}}\right) \text{ with } C_{TR} = N \cdot C_{TE}$$

$C_{TR}$	Constant thermal cooling time (in minutes) to be converted in seconds for calculations
$C_{TE}$	Constant thermal heating time (in minutes) to be converted in seconds for calculations
$\theta_{thermal\_state}$	Coefficient of the initial thermal state of the machine (in %)
$\theta_{trans}$	Coefficient corresponding to the thermal state of the machine at the time t
N	Scale factor between the thermal time constant of cooling and heating



For example, the curves are plotted with the following values:

CTE = 10 min

N = 1

## 5.2 Protection against unbalance for [46] NPM800-NPM800R-NPM800RE

### 5.2.1 Introduction to [46] NPM800-NPM800R-NPM800RE

Operation of a motor on an unbalanced network can be the result of a blown fuse, of the non-closing of a circuit breaker pole, or of a bad succession of phases of the network.

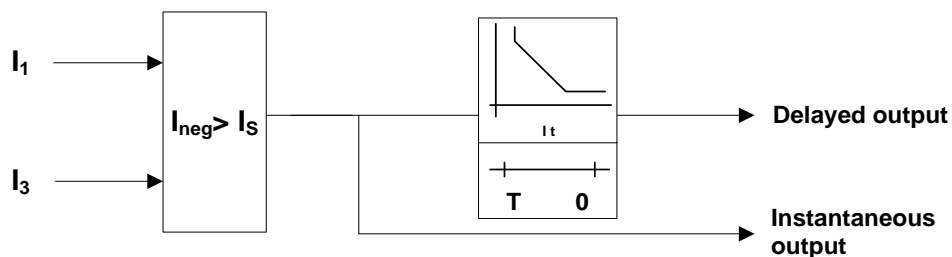
The **NPM800-NPM800R-NPM800RE** models offer a unit with maximum of negative phase sequence current [46] with inverse time. This function aims at avoiding damages due to unbalances, reverse of phases or phases open.

Detection of these unbalances relies on the measurement of the negative component of current, calculated from phase's currents  $I_1$  and  $I_3$ .

The characteristic of tripping of the negative component is inverse time. This allows to the protection not to trip on slight temporary unbalances, especially during start, but to trip very quickly for real phase reverse or phase open. The equation for the curves follows the type  $(I_{inv}/I_n) \times t = \text{constant}$ . These curves are defined for 100% of  $I_{inv}/I_n$ .

Please note that negative currents circulating in the transformer-motor bloc groups keep their amplitude when crossing the transformer (but without transformation ratio). Only their phase rotate by a multiple of  $30^\circ$ , depending on the clock index of the machine. As a consequence, a protection installed on the primary side will monitor the same amplitude of negative component as it would, if it was connected directly to the motor's terminals.

### 5.2.2 Flow chart for [46] on NPM800-NPM800R-NPM800RE



**Fig. 86:** Detection of unbalance function [46]

### 5.2.3 Setting characteristics for [46] NPM800-NPM800R-NPM800RE

Characteristics	Values
Inverse time curve (for $I_{inv} = 100\% I_{inv}/I_n$ )	1 to 10 s with steps of 1 s
Minimum duration of tripping	0.2 to 10 s with steps of 10ms.
Threshold for negative component $I_{inv}$	0.20 to 0.80 $I_n$

### 5.2.4 Setting advices for [46] NPM800-NPM800R-NPM800RE

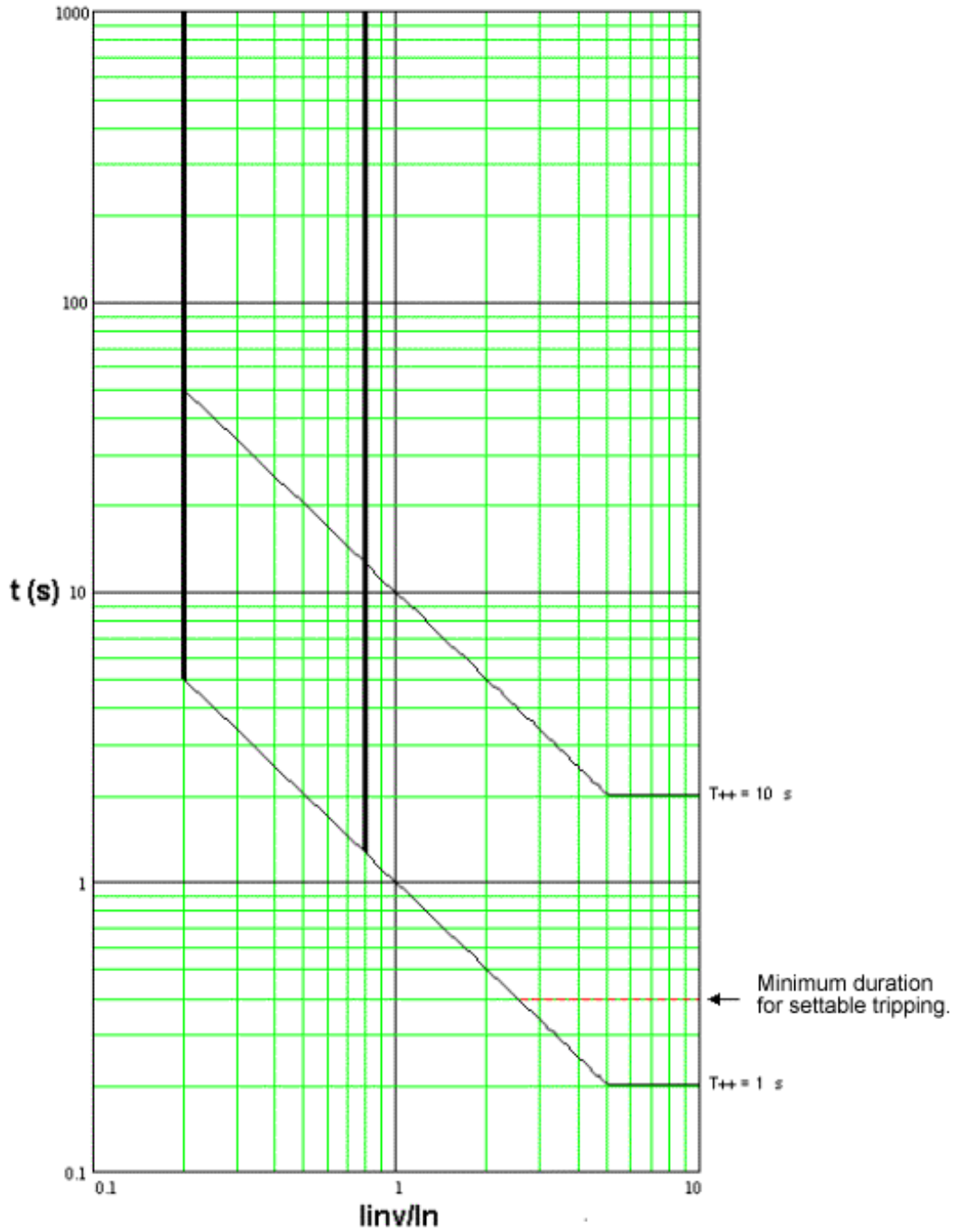
In order to ensure detection and elimination of single-phase operations or resistive two-phase faults, a setting of 20 % for function [46] (of the rated current for the motor, possibly modified to take into account the protection's setting steps) allows to detect the loss of a phase.

A curve set to 2 s allows to properly protecting the motor, avoiding spurious tripping during the start phases.

The setting of the minimum of tripping time delay must allow fuses\* to eliminate all violent unbalances before the associated contactor is activated. A setting of 0.5 s will usually fulfil this condition.

\* case of a fuses contactor

5.2.5 Tripping curve depending on the negative phase sequence current for [46] NPM800-NPM800R-NPM800RE



### 5.3 Protection against phase to phase short-circuits for [50] NPM800-NPM800R-NPM800RE

#### 5.3.1 Introduction to [50] NPM800-NPM800R-NPM800RE

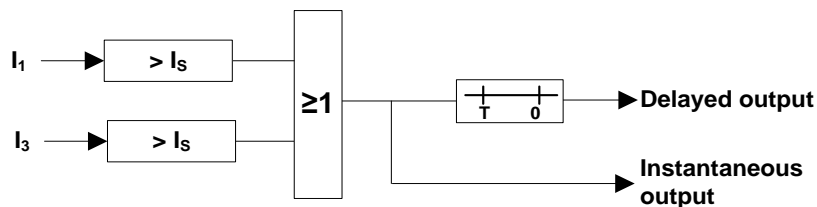
A phase to phase short-circuit, in the windings, at the terminals of the machine, or in the supply cables, sets free strong currents which can deteriorate the machine through heating and through the resulting electrodynamics forces.

As to eliminate short-circuits, the **NPM800-NPM800R-NPM800RE** models are fitted with a fast working unit [50]. This function has a threshold  $I_{s>}$ , which can have a Definite time-delay.

It can be deactivated in case the motor is controlled by a fuse contactor.

For all machines, the protection against short-circuits [50] is set to a value which is higher to the start current, which makes this protection nearly insensitive to internal faults close to the neutral point, in case high power machines are used. Under these conditions, an additional differential protection is necessary (**DMS7001**).

#### 5.3.2 Flow chart for [50] on NPM800-NPM800R-NPM800RE



**Fig. 87:** Detection of short-circuits function [50]

**5.3.3 Setting characteristics for [50] NPM800-NPM800R-NPM800RE**

Threshold for the function [50]	Setting
Threshold phase I>>	3.0 to 12.0 In with steps of 0.1 In
Time delay for the function [50]	Setting
Definite time-delay t(I>>)	0.04 to 3 s with steps of 0.01 s
Characteristics	Values
Response time for instantaneous outputs	60ms

**5.3.4 Setting advices for [50] on NPM800-NPM800R-NPM800RE**

Whether or not this function is activated usually depends on the breaking capacity of the motor's control device:

- with a fuses contactor, deactivate function [50]  
(fuses will eliminate short-circuits )
- with a circuit breaker, activate function [50]  
(this device provides the breaking capacity to eliminate short-circuit currents)

When function [50] is activated, its setting depends on the motor start current. To allow starts, threshold [50] must be higher to the motor's start current. A threshold set 40% above the start current is suitable.

In the selectivity chain, the short circuit detection unit [50] for motor protection is the function which is located in the most downstream position. Because of this, in order to isolate as quickly as possible the part of the network which is impacted by a fault and not to set additional time constraints, tripping will be instantaneous or only slightly time delayed.

Let us examine as an example the following data to protect an induction motor:

- CT = 100/5 A - 5VA 5P15
- In phase protection = 5 A
- ICE T0 105.1 CBCT
- In earth protection = 0.2 A (earth range is specific to CBCT wiring)
- Start current of the motor = 450A
- Motor control device = circuit breaker.
- Capacitive current downstream of the protection = 0.8 A

The tripping threshold of [50] will be set to the following value: I>> = (450x1.4)/100=6.3 In.

The tripping will be selected “instantaneous”.

## 5.4 Protection against earth faults for [51N] NPM800-NPM800R-NPM800RE

### 5.4.1 Introduction to [51N] NPM800-NPM800R-NPM800RE

Earth fault is the most frequent fault on asynchronous machines. Deterioration of the quality of the insulating material causes a fault current to circulate between the windings and the earth, through the sheets and the stator frame. The intensity of the fault current depends on the type of connection to the earth used for the installation. Like with phase-to-phase faults, a quick elimination is suitable to reduce damages and reparation costs.

Independently of the chosen neutral connection for the installation, the zero-sequence current component unit integrated in the **NPM800-NPM800R-NPM800RE [51N]** models ensures protection against earth faults. This unit connects on a CBCT or as a residual connection of the three phase CTS. In any case, it is recommended to supply this via a CBCT. This method allows for detection of resistive low amplitude fault currents. Furthermore, early detection of earth faults allows reducing cost of possible damage and of machine repair (rewinding of the motor instead of a complete replacement).

It is possible to temporarily deactivate the zero-sequence current protection function during the phase of detection of motor start. This avoids tripping on a false zero-sequence current, especially when using the phase CTs to calculate the residual component and not a CBCT (risk of saturation of one or several CTs during start).

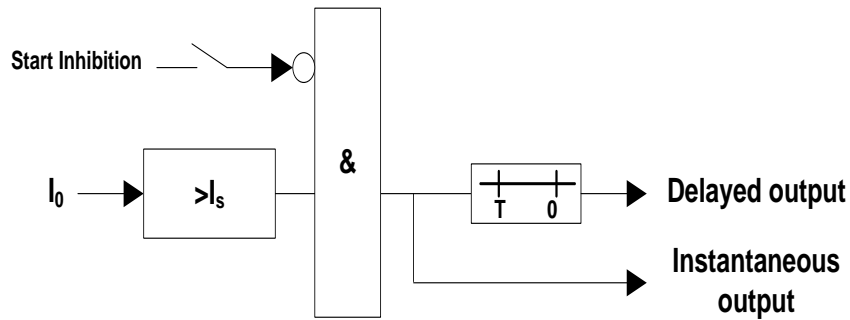
There is a lower limit of the threshold setting for the zero-sequence current unit. It is the rated capacitive current of the protected feeder which, if it accidentally feeds a fault on a neighbouring feeder, risks to spuriously activate the considered zero-sequence current unit. As a reference, the capacitive zero-sequence current value per kilometre of cable is generally, for 5-6 kV networks, of about 2 to 3 A. The minimum threshold for the zero-sequence current unit of the protections will be set to 1.5 times the capacitive current for the feeder: most of the time, this threshold will not be higher to 8 A.

In case of networks with isolated neutral, the zero-sequence current unit of the **NPM800-NPM800R-NPM800RE [51N]** models will perform selective elimination of earth, if the total capacitive zero-sequence current on the network is higher to 5 times the current of each of the feeders taken separately (if this ratio cannot be respected, you can add a directional zero-sequence current protection of type **NPIHD800-NPIHD800R [67N]**).

Signalling the fault must in all cases be performed with a Max of zero sequence voltage protection **[59N]**. This function is performed via a residual overvoltage protection like the **NPUH800-NPUH800R** (fed by three voltage transformers or in a broken delta). Further, even if a single-phase fault cannot be detected by the zero-sequence current unit **[51N]** of the **NPM800-NPM800R-NPM800RE** models, its use is justified by the fact that it provides the

most sensitive detection of double faults to the earth at two distant locations of the same network.

**5.4.2 Flow chart for [51N] NPM800-NPM800R-NPM800RE**



**Fig. 88:** Detection of earth fault function [51N]

**5.4.3 Setting characteristics for [51N] on NPM800-NPM800R-NPM800RE**

Threshold for the function [51N]	Setting
Inhibition of zero-sequence current threshold during start	Active/inactive
Definite time-delay	0.04 to 3 s with steps of 0.01 s
CT earth connection threshold	0.03 to 0.40 $I_{n0}$ with steps of 0.005 $I_{n0}$
Toroid earth connection threshold* - ICE (6 to 8 A)	0.03 to 0.40 $I_{n0}$ with steps of 0.005 $I_{n0}$
Time delay for the function [51N]	
Definite time-delay	0.04 to 3 s with steps of 0.01 s
Characteristics	Values
Response time for instantaneous outputs	60ms

\* 100/1 CBCT and with use of an adapter case BA800 for 1500/1 CBCT

**5.4.4 Setting advices for [51N] on NPM800-NPM800R-NPM800RE**

It is generally recommended, depending on the neutral connection of an electrical network feeding motors to protect an installation, to use the zero-sequence current measurement unit via CBCT. This method allows detection of weak currents typical for resistive earth faults. Detecting resistive earth faults will limit reparation cost (a rewinding may suffice instead of a complete motor replacement).

If measuring earth fault current via a CBCT cannot be done, use the unit Max of zero sequence overcurrent fed by a residual connection of 3 CTs. Possibly, you will have to set up an inhibition during the start period or its threshold will not be set below 0.15 to 0.2 In CT to avoid spurious tripping's.

There is a lower limit to set the threshold of the zero-sequence current unit. It is the rated capacitive current of the protected feeder which, if it feeds a fault on a neighbouring feeder, risks to spuriously activating the considered zero-sequence current unit. As a reference, the capacitive current value per kilometre of cable is generally, for 5-6 kV networks, of about 1 to 2 A.

If the control device of the motor is a circuit breaker, like for function [50], at selectivity chain level, the earth fault detection unit [51N] of a motor protection is the most downstream function. Because of this, and in order to isolate as quickly as possible the faulty network section, and not to set additional time constraints, tripping will be instantaneous. On the contrary, if the control device is a fuse contactor, a minimum operating time of 0.25 s to 0.5 s must be taken into account for the tripping of the unit and make it selective as regards to fuse fusion in case an earth fault current transforms into a two phase fault.

Threshold [51N] of the zero-sequence current unit for the protection will be set to 1.5 times the output own capacitive current value:

$$I_{o>} = 0.8 \times 1.5 = 1.2A. \text{ The threshold to set on the protection will be: } 1.2A / 20 = 0.06$$

Note: 20 = coefficient taking into account the CBCT 100/1 transformation ratio and the earth range. When using a 1500/1 toroid and a BA800 the coefficient will also have a value of 20.

When the control device is a circuit breaker, the selected tripping will be "instantaneous".

## 5.5 Start protections for [48] [51LR] [66]

### 5.5.1 Protection against too long start [48] and locked rotor [51LR] NPM800-NPM800R-NPM800RE

#### 5.5.1.1 Introduction to [48] [51LR] NPM800-NPM800R-NPM800RE

The too long start function [48] protects the motor in case of prolonged overcurrent exposure, after which its starting time is higher to its normal start time.

A too long start makes the machine rapidly heat, due to absorption of the start current with a defective cooling (ventilator at shaft end). This overload is too quick to be eliminated by the thermal unit, a better adapted protection must therefore be considered.

The **NPM800-NPM800R-NPM800RE** models integrate a delayed unit with definite time [48] which ensures an efficient protection of a too long start period. When starting occurs in normal conditions, currents (I1 or I3) become higher to the start threshold  $I_D$  during a given time and then they drop below  $I_D$ . Upon reaching  $I_D$ , a start time delay is activated.

If at the end of this time delay, the current is still higher to  $I_D$ , tripping via the function too long start is triggered.

In order to take into account voltage drops which often happen during the start of a motor, this unit can be set to a value lower to start current  $I_D$  (which is the setting of the locked rotor protection) and it can be delayed at a higher value than the starting time of the motor.

The function locked rotor [51LR] is set into operation after detection of an overcurrent above the start threshold  $I_D$  outside the start period. This function only starts three seconds after the start period is done, so when the measured currents (I1 or I3) become lower to the start threshold  $I_D$ .

5.5.1.2 Flow charts for [48] [51LR] on NPM800-NPM800R-NPM800RE

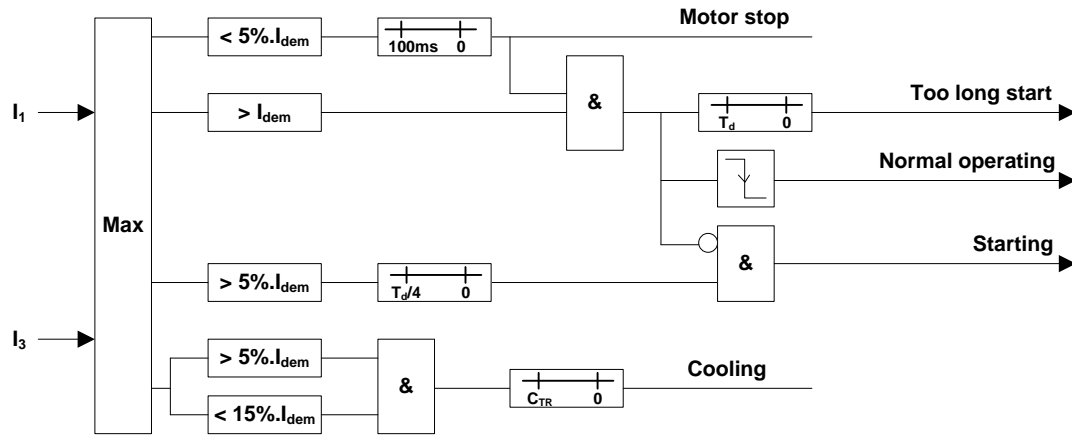


Fig. 89: Too long start function [48]

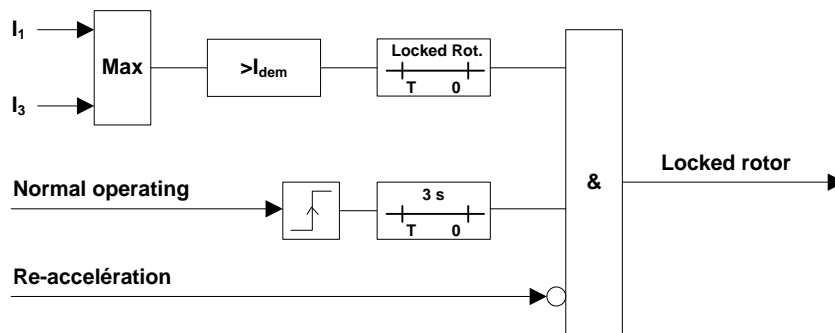


Fig. 90: Locked rotor function [51LR]

**5.5.1.3 Setting characteristics for [48] [51LR] on NPM800-NPM800R-NPM800RE**

Characteristics	Values
Start threshold and locked rotor threshold ( $I_D$ )	1 to 10 $I_{ref}$ with steps of 0.1 $I_{ref}$
Time delay for too long start [48]	2 to 200 s with steps of 1 s
Time delay for locked rotor [51LR]	0.2 to 10 s with steps of 0.1 s

**5.5.1.4 Setting advices for [48] [51LR] on NPM800-NPM800R-NPM800RE**

Let us examine as an example the following data to set up this function:

- CT = 100/5 A - 5VA 5P15
- $I_n$  protection = 5 A
- Rated current of the motor = 90A
- Start current of the motor = 450A (5 times the rated current)
- “Direct” start of the motor
- Start time for the motor = 4 s
- Stall time for the rotor (cold value) = 10 s.

Setting the start threshold and the locked rotor parameters:

Given the start current whose value is 5 times the motor rated current, the start threshold  $I_D$  will be set to 3 times the base current  $I_{ref}$ . This setting value will allow detecting a start independently of the network voltage value. On the other hand, since the current of locked rotor for an operating induction motor is close to its start current, the start threshold  $I_D$  which is set to 3 times the base current  $I_{ref}$  allows to detect this situation.

## PROTECTING INDUCTION MOTORS

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### Setting the time delay for too long start:

The time delay for too long start will be set the value of 4 s. Because of this, during start, if the motor current is higher to  $I_D$  during more than 4 s, the protection will trip.

### Setting the time delay for locked rotor:

For our application, the time delay, given its operating threshold and without knowledge of the hot characteristics of the rotor withstand, will be set to 1 s. This value allows possible short duration overloads during motor operation.

## 5.5.2 Protection by number of starts limitation for [66] NPM800-NPM800R-NPM800RE

### 5.5.2.1 Introduction to [66] NPM800-NPM800R-NPM800RE

This function [66] allows avoiding overheating of the motor due to too frequent starts. Depending on the application, it can also allow to avoid overheating of fuses and of the start system.

The **NPM800-NPM800R-NPM800RE** models control motor starts by counting them during a given period: a number of starts (N) is allowed over a chosen period ( $T_{nd}$ ). If the number of authorised starts has been reached, any new start will be inhibited for the duration ( $T_{int}$ ). This time delay ( $T_{int}$ ) must be set to a value higher (or equal) to  $T_{nd}$ , as to allow for sufficient cooling of the motor after a series of starts.

Note: In order to inhibit the closing order, you must include a contact for function [66] at the output unit into the closing chain of the circuit breaker or control contactor for the motor.

The number of restart(s) still authorised is indicated on the protection (menu measurement of the HMI).

The **NPM800-NPM800R-NPM800RE** models are fitted with a start authorisation unit [5-49], which depends on the thermal state of the machine. The contact for this unit, when inserted into the closing chain, will inhibit control execution as long as the thermal state of the motor will not be lower to the thermal state allowing restart.

Note: In order to simplify the control mode for motor start, it is recommended to use the same output unit as the one for function [66]; provided this function is being used.

5.5.2.2 Flow chart for [66] on NPM800-NPM800R-NPM800RE

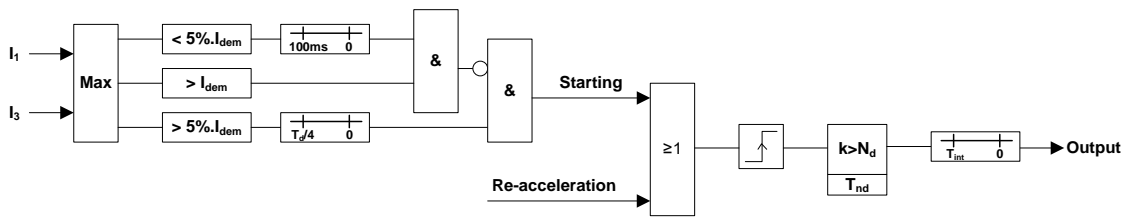
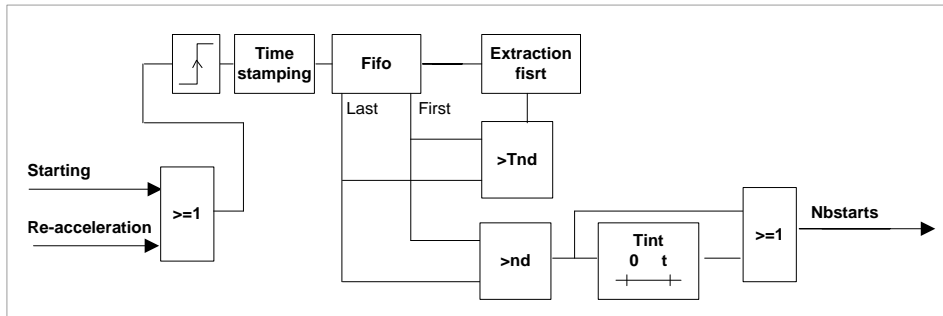


Fig. 91: Number of starts limitation function [66]

5.5.2.3 Setting characteristics for [66] NPM800-NPM800R-NPM800RE

Characteristics	Values
Maximum number(s) of start(s) during $T_{nd}$	1 to 4 with steps of 1
$T_{nd}$ : time delay for start counting	15 to 60 min with steps of 1 min
$T_{int}$ : time delay for start inhibition	15 to 60 min with steps of 1 min

#### 5.5.2.4 Setting advices for [66] on NPM800-NPM800R-NPM800RE

This function must be set according to the motor manufacturer data. For example, if 2 starts per hour are allowed:

- Number of starts = 2
- $T_{nd} = 60 \text{ min}$
- $T_{int} = 60 \text{ min}$

**Note:** The function start inhibition using the thermal image complements the number of starts limitation for hot motor control.

## 5.6 Protection against loss of load - no-load operation [37I] NPM800-NPM800R-NPM800RE

### 5.6.1 Introduction to [37I] NPM800-NPM800R-NPM800RE

NPM800 models includes an undercurrent unit [37I] which operates when the current absorbed by the motor reaches a current value close to unloaded motor operation for a duration higher to a set time delay.

This function is typical for a “pump unpriming” or transmission belt break. In order to authorise normal start for a motor, this unit can be set in operation after a set time delay or using an external input. However, it sometimes happens that the current criteria alone do not allow pump unpriming detection. It is then necessary to use a minimum of active power protection [37P].

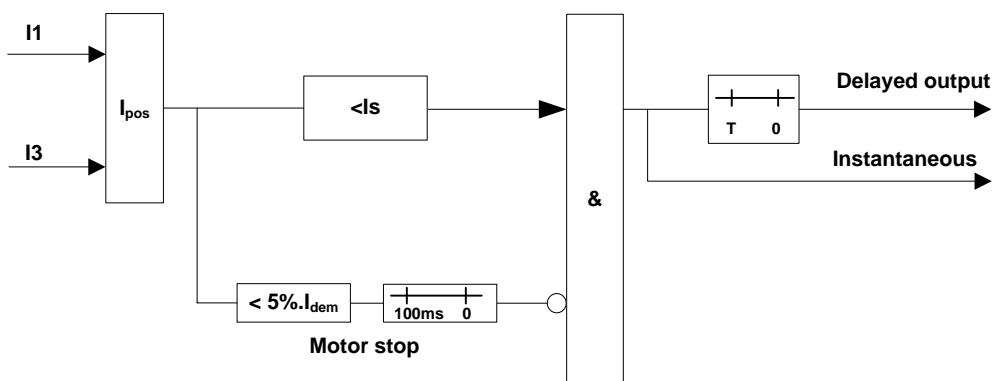
Detecting a current lower to a set threshold allows performing tripping when a pump unprimes or when a belt breaks.

The positive component for the current is used for this function. It is calculated from currents I1 and I3.

Fault clearance occurs when current ( $5\% I_{dem}$ ) disappears for at least 100ms.

Note: The motor is considered stopped when current  $I_{mot}$  becomes  $< 0.05 I_{dem}$ .

### 5.6.2 Flow chart for [37I] on NPM800-NPM800R-NPM800RE



**Fig. 92:** Loss of load – no-load operation function [37I]

### 5.6.3 Setting characteristics for [37I] on NPM800-NPM800R-NPM800RE

Characteristics	Values
Positive I minimum threshold	0.1 to 2.4In steps of 0.01 In
Tripping time delay for loss of load	0.05 to 120 s step: see *

\* between 0.05 and 0.99 s with steps of 0.01 between 1 s and 59.9 s with steps of 0.1 s, between 60 and 120 s with steps of 1s

### 5.6.4 Setting advices for [37I] on NPM800-NPM800R-NPM800RE

In order to detect a pump unpriming or a no-load operation, the threshold for function [37I] will have to be set according to the unloaded motor operation current, corrected with the setting steps of the protection. A value lower of 40 % to the rated current of a motor is usually a sign for no-load operation.

Let us examine as an example the following data to set this function:

- CT = 100/5 A
- In protection = 5 A
- Rated current for the motor = 90A
- Pump unpriming current = 16A

The pump unpriming threshold will be set in the following manner  $16/100=0.16$  In. The value for the time delay will be chosen according to process data, but it should not interfere with the start phase (no-load operation time for the motor before pump priming).

**Note:** sometimes the current criteria alone do not allow for pump unpriming or no-load operation detection; it is then necessary to use a minimum of active power protection.

## 5.7 Load shedding by external input and high-speed restarting on NPM800-NPM800R-NPM800RE

### 5.7.1 Introduction to load shedding high-speed restarting on NPM800-NPM800R-NPM800RE

In case of a fault on the network, such as a strong voltage or frequency drop, it is possible to perform a load shedding of the motor by using the All or Nothing "load shedding" input.

Tripping occurs upon a settable time delay expiry.

If the external order disappears before time delay expiry, the protection will not send the tripping command and it allows for re-acceleration for a duration equivalent to a start, though avoiding a tripping via the locked rotor function (51LR).

Note: For a re-acceleration application (high-speed restarting), a contact of a minimum voltage of the motor control panel must be directed to the "load shedding" input of the NPM800(s) whose motor (s) must be re-accelerated. No output relay of the NPM800 will be directed to the tripping of the opening device, which implicitly is the same as inhibiting the load shedding function. The "load shedding" time delay will be set to its maximum value.

### 5.7.2 Flow chart

See function [66]

### 5.7.3 Setting characteristics for load shedding high-speed restarting on NPM800-NPM800R-NPM800RE

Characteristics	Values
Time delay for load shedding	0.06 to 120 s  Steps: see *

\* between 0.06 and 2.99 s with steps of 0.01 s, between 3 s and 29.9 s with steps of 0.1 s, between 30 and 120 s with steps of 1s

### 5.8 Other functions required for motor protection

The **NPM800-NPM800R-NPM800RE** models offer the entire range of basic functions which are vital to the protection of induction motors. However, to ensure a better, much more comprehensive protection, additional voltage protections are often required:

- Undervoltage function [27]
- Positive sequence undervoltage function [27P]
- Overvoltage function [59]
- Function of balanced voltage [47]

These functions can be found in the **NPU800-NPU800R-NPU800RE** models.

#### 5.8.1 Undervoltage [27] and [27P]

Detecting voltage drops, single-phase, two-phase, or three-phase, provides better operating conditions for electrical equipment, and in particular for induction motors where torque motor is strongly affected by these faults. The undervoltage function **[27]** of the **NPU800-NPU800R-NPU800RE** models, supplied by the VT of the busbars is usually set to 0.7, in order to load-shed the induction motors which are about to stall.

Motor protection can also be increased by the use of a positive sequence undervoltage function **[27P]**. This function allows overall control of the three-phase voltage system or of the motor torque of rotating machines, in case of permanent or temporary unbalanced operation (single-phase reclosing on the downstream network). The **NPU800-NPU800R-NPU800RE** models also allow this application.

#### 5.8.2 Overvoltage [59]

It is important to detect overvoltage, whether single-phase, two-phase, or three-phase, since it leads to accelerated ageing or to disruption of the insulating material of electrical equipment and more specifically in the case of rotating machines.

The overvoltage function **[59]** of the **NPU800-NPU800R-NPU800RE** models, fed by the VT of the busbars is usually set to 1.3  $U_n$ , in order to load-shed the induction motors which are about to stall .

### **5.8.3 Balanced voltage [47]**

Detection of supply unbalances [47] (phases order, loss of phases...) is achieved by monitoring the negative component of voltage and it is normally used to activate an alarm warning operators of a permanent voltage unbalance. The **NPU800-NPU800-NPU800R** models allow this application.

## 6 Shared functions for the NP800-NP800R range

### 6.1 Maintenance of the circuit breaker

This function aims at monitoring the circuit breaker state, as to facilitate its maintenance. The sum of the cut square Ampere, as well as the number of “opening/closing” cycles is recorded. In order to use the data, please refer to the circuit breaker documentation.

The cumulated value of the cut  $kA^2$  is recorded when the following conditions are met:

- tripping commanded by the protection.
- current disappearance during the tripping period. This period corresponds to the minimum tripping time delay for the output relay, to which a definite time delay of 100ms is added. After this period, cumulating stop occurring.

The number of circuit breaker operations is incremented when:

- the protection orders tripping and the above conditions are met.

Characteristics	Range
Cut $kA^2$ alarm (over tripping)	1 to 64000000
Number of circuit breaker operations	1 to 10000

### 6.2 Monitoring the circuit breaker function [74TC] [BF]

#### 6.2.1 Trip-circuit supervision of the circuit breaker [74TC]

This function allows checking the continuity of the tripping circuit for a circuit breaker. In case lack of continuity is detected, an alarm “Coil circuit breaker” is generated. This function is inhibited when the tripping relay(s) is used.

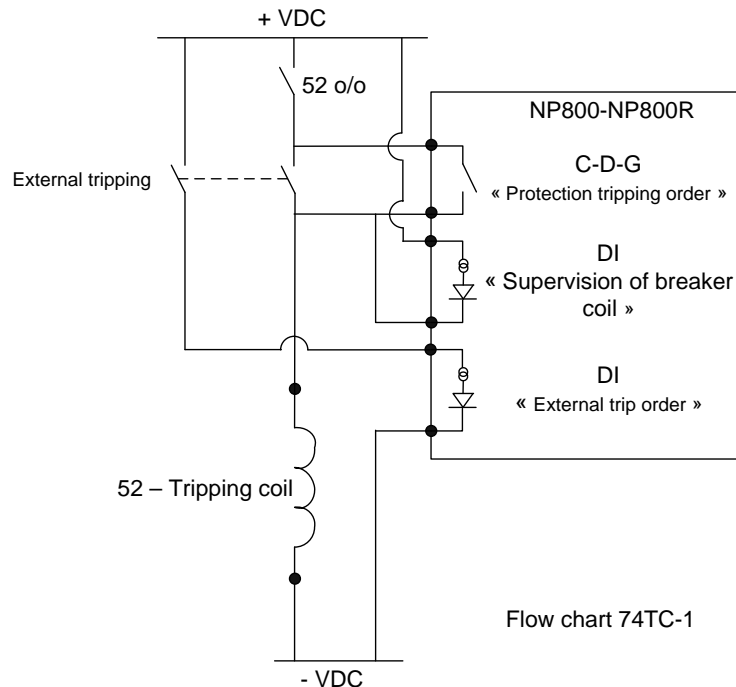
Setting this function must be performed via the configuration software; to choose the digital input, the tripping relay(s) (preferably C-D-G) and possibly, the alarm relays.

In case of a tripping order of the circuit breaker via external order of the protection, the message “Circuit breaker fail” appears at the HMI, since this command is interpreted by the protection as a closing of the circuit breaker tripping circuit. To avoid this phenomenon, it is required to forward the information “external order” to the protection via the digital input “External tripping order”, as to inhibit the trip-circuit monitoring function of the circuit breaker.

The following 3 application flow charts cover the common cases of circuit breakers control-commands.

Flow chart 74TC-1:

It is possible to have access to the terminals of the tripping coil. In this case, one o/o interlock allows checking continuity of the tripping circuit of the circuit breaker and this, independently of the circuit breaker position (Closed or Open). The polarisation current of the DI through the coil will be around 10 mA for the auxiliary voltage 19-70 VDC and around 4 mA for the 85-255 VDC range.



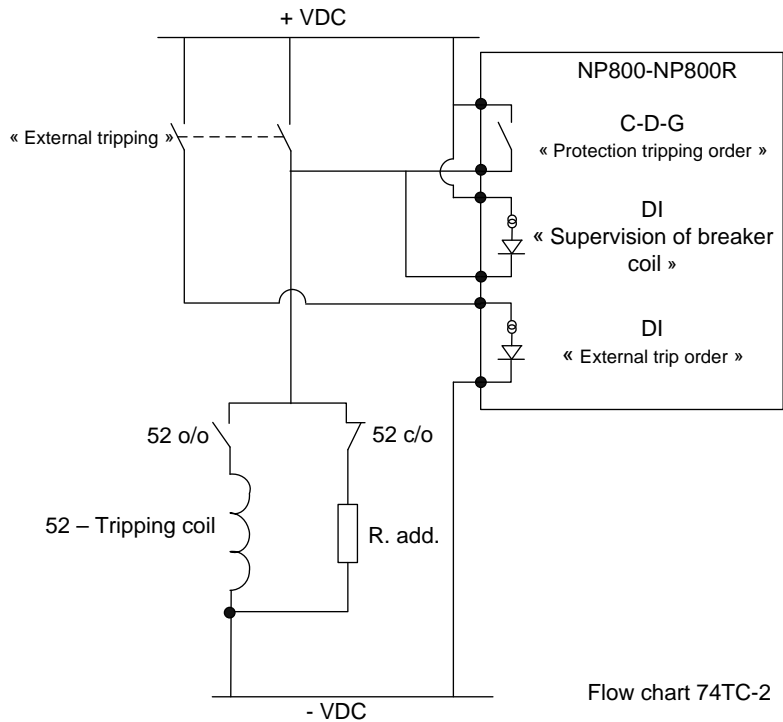
**Fig. 93:** Application flow chart #1 for function [74TC]

Flow chart 74TC-2:

It is not possible to have access to the terminals of the tripping coil. In this case, the o/o interlock wired serially with the tripping coil and c/o interlock allows verifying continuity of the tripping circuit when circuit breaker is closed and partially when it is open. The polarisation current of the DI through the coil will be around 10 mA for the auxiliary voltage 19-70 VDC and around 4 mA for the 85-255 VDC range.

An additional resistor\* is necessary to limit the current during activation, and in case of latching of the output relay(s) (C-D-G).

\* not provided with NP800-NP800R.



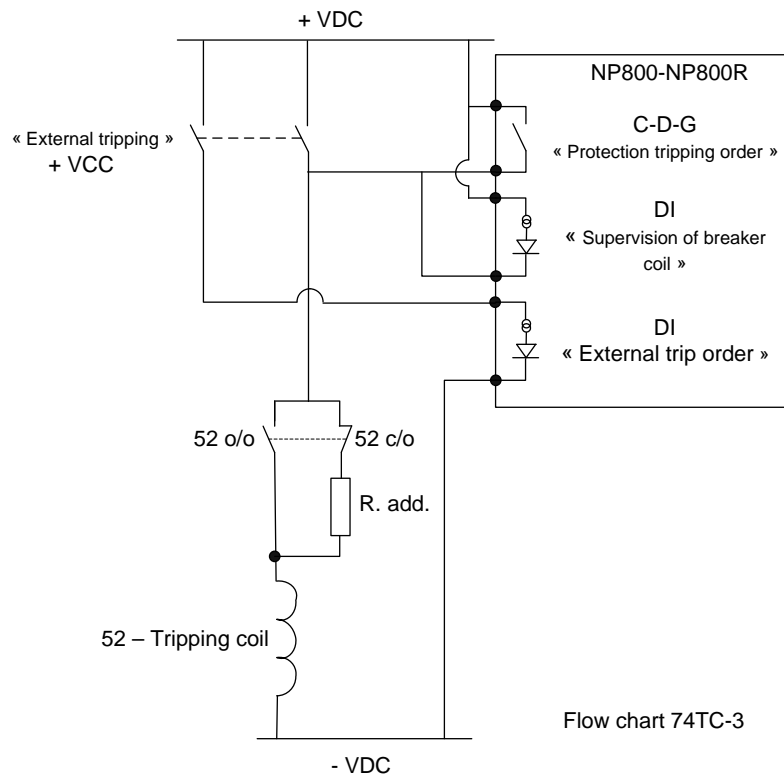
**Fig. 94:** Application flow chart #2 for function [74TC]

Flow chart 74TC-3:

It is not possible to have access to the terminals of the tripping coil, but the terminals of the serially wired o/o interlock are accessible. In this case, o/o interlock and c/o interlock allows checking the continuity of the total tripping circuit independently of the position of the circuit breaker (Closed or Open). The polarisation current of the DI through the coil will be around 10 mA for the auxiliary voltage 19-70 VDC and around 4 mA for the 85-255 VDC range.

An additional resistor\* is necessary to limit the current during activation, and in case of latching of the output relay(s) (C-D-G).

\* not provided with NP800-NP800R



**Fig. 95:** application flow chart #3 for function [74TC]

### 6.2.1.1 Calculating the additional resistance [74TC]

Since calculation depends on the application, take into account a minimum current value through digital input. This minimum value depends on the polarisation voltage of the digital input, in function of the auxiliary voltage of the protection.

#### Flow chart 74TC2:

The maximum ohmic value of the additional resistance, to be chosen in the E24 standard series, is defined by the following relation:

$$R_{add} < \left( \frac{0.8 * V_{dc} - V_{min}}{I_{min}} \right)$$

With:

$V_{dc}$ : value of the auxiliary voltage in direct current

$V_{min}$ : minimum value of the internal voltage required for the digital input operation

$I_{min}$ : minimum current value required for the digital input operation

## SHARED FUNCTIONS FOR THE NP800-NP800R RANGE

Range for the auxiliary voltage NP800-NP800R	
19 – 70 Vdc	85 – 255 Vdc
$R_{add} < \left( \frac{0.8 * V_{dc} - 12}{0.01} \right)$	$R_{add} < \left( \frac{0.8 * V_{dc} - 33}{0.004} \right)$

The power of the additional resistance (in Watt) is defined as follows:

$$Pr > 2 * \frac{(1.2 * V_{dc})^2}{R}$$

**NOTE:** The resistance to be chosen is RW type (vitreous) and according to standard power.

### Flow chart 74TC3:

The maximum ohmic value of the additional resistance is defined by the following relation:

$$R_{add} < \left( \frac{0.8 * V_{dc} - V_{min}}{I_{min}} \right) - R_{coil}$$

With:

$V_{dc}$ : value of the auxiliary voltage with direct current

$V_{min}$ : minimum value of the internal voltage necessary for the operation of the digital input

$I_{min}$ : minimum current value necessary for the operation of the digital input

$R_{coil}$ : resistance value of the tripping coil

Range of the auxiliary voltage NP800-NP800R	
19 – 70 Vdc	85 – 255 Vdc
$R_{add} < \left( \frac{0.8 * V_{dc} - 12}{0.01} \right) - R_{coil}$	$R_{add} < \left( \frac{0.8 * V_{dc} - 33}{0.004} \right) - R_{coil}$

The power of the additional resistance (in Watt) is defined as follows:

$$Pr > 2 * \frac{(1.2 * V_{dc})^2}{(R + R_{coil})}$$

### Note:

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When auxiliary relays are provided for anti-pumping in the tripping circuit, they must be taken into account when calculating the ohm value of the additional resistor.

For both applications, we assume that the maximum variation of the auxiliary voltage keeps within the range of +/- 20 %.

### 6.2.1.2 Working of the digital input [74TC]

**NP800 IUM group:** Fault detection of continuity in the tripping circuit for the circuit breaker is performed using the passage of level 1 to level 0 at the digital input; using the configurator, select “Negative logic” as the operation mode.

**NGP800 and NPW800:** Fault detection of continuity in the tripping circuit for the circuit breaker is performed using the passage of level 1 to level 0 at the digital input; using the configurator, select “Positive logic” as the operation mode.

### 6.2.1.3 Wiring the tripping circuit [74TC]

If several protections have been wired into the circuit breaker, function [74TC] must only be activated for one of these protections. To avoid spurious tripping, the circuit breaker will receive the tripping commands from the other protections through one of its generic inputs.

### 6.2.1.4 Characteristics of the function [74TC]

Characteristics	Values
Response time (faulty circuit coil )	0.5 s - fixed

## 6.2.2 Circuit breaker failure [50BF] [50NBF]

This function monitors the opening of the circuit breaker poles after the protection has sent a tripping order. (Order comes from a protection function or from remote control).

The function monitors the opening time of the circuit breaker. In order to do it, the protection checks that the phase currents and/or voltage between phases are lower to predefined thresholds at the end of the time delay of the circuit breaker failure.

If it is not the case, an alarm “Circuit breaker failure” is generated.

Setting this function and declaring the used tripping relay(s) as well as the optional alarm relay is only possible via the configuration software.

## SHARED FUNCTIONS FOR THE NP800-NP800R RANGE

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Characteristics	Values
Threshold for circuit breaker failure [50BF]	5 to 30% of $I_n$ with steps of 1 $I_n$
Threshold for circuit breaker failure [50NBF]	0.5% to 3% of $I_{n0}$ with steps of 0.1 $I_n$
Time delay for circuit breaker failure - tBF	0.06 to 1 s with steps of 0.01 s

### Notes:

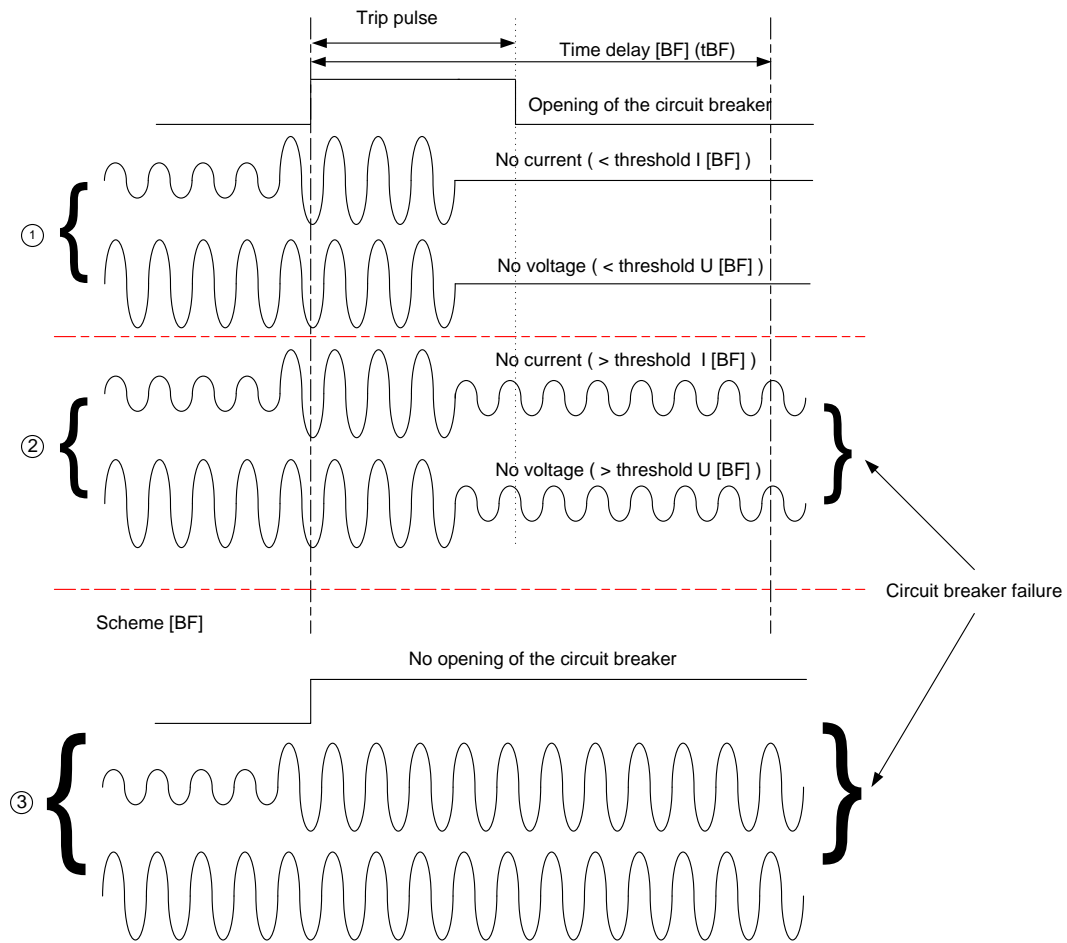
- The chosen value for the failure threshold has an indirect influence on the values measured by the protection (“noise” threshold).

The three graphics in the flow chart [BF] illustrate this function:

Curves ① represent normal operation of a circuit breaker with a tripping order followed by a current and voltage measurement, at the end of the tBF time delay, lower to the fault threshold(s) of the circuit breaker. (no current / no current or voltage.)

Curves ② represents a faulty operation of a circuit breaker with a tripping order followed by a current and voltage measurement, at the end of the tBF time delay, higher to the fault threshold(s) of the circuit breaker. (no current / no current or voltage.)

Curves ③ represents a faulty operation of a circuit breaker with a tripping order not followed by the opening of the circuit breaker poles. (no current / no current or voltage.)



**Fig. 96:** Operating curves of [BF]

## 6.3 Function of logic selectivity

### 6.3.1 Logic selectivity presentation

The logic selectivity function is used when the number of cascading protections becomes too important to allow use of time selectivity. In a radial network, during a fault, the protections located upstream of the fault point are solicited. On the contrary, the downstream protections are not. Because of this, there is a simple way to localise precisely the fault point, and to clearly define the only circuit breaker to order.

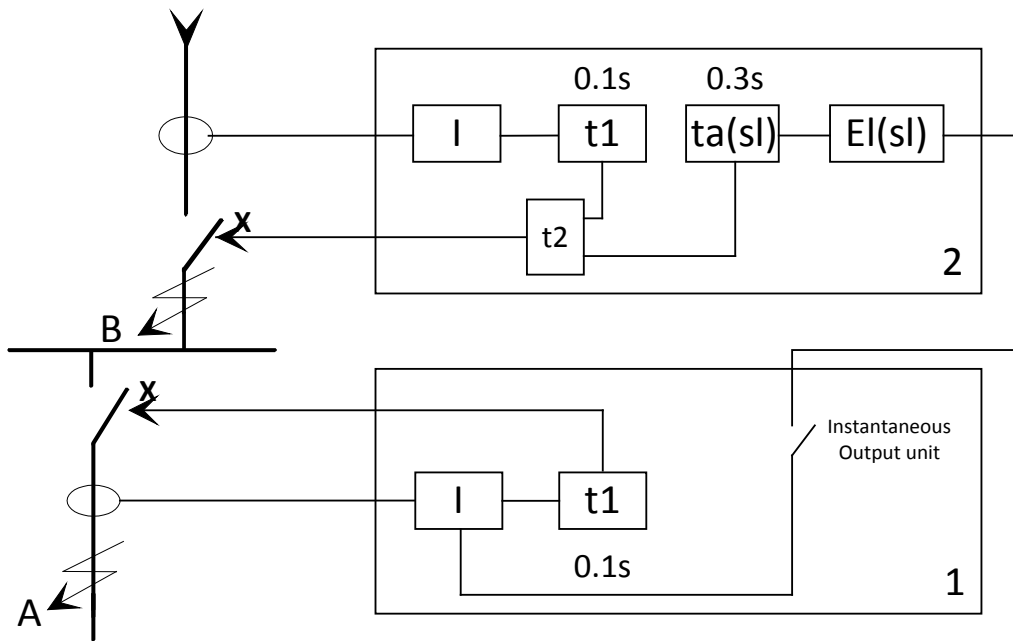
Each solicited protection must for the phase and zero-sequence current protection functions:

- Upon reaching the threshold for one of these functions, via an output relay used as an “instantaneous”, activate\* the logic selectivity input of the protection located immediately upstream to add a delay to its tripping time delay.
- Send a tripping order to the associated circuit breaker; tripping occurs if no delay order is received from the protection located immediately downstream.

\* thanks to pilot wire connection

The most downstream protection which is closest to the fault trips first. The upstream protections must provide assistance to the downstream protection.

As a conclusion, this function allows to reduce the time selectivity intervals between the various cascading protections and to globally set all these protections at a short operating time.



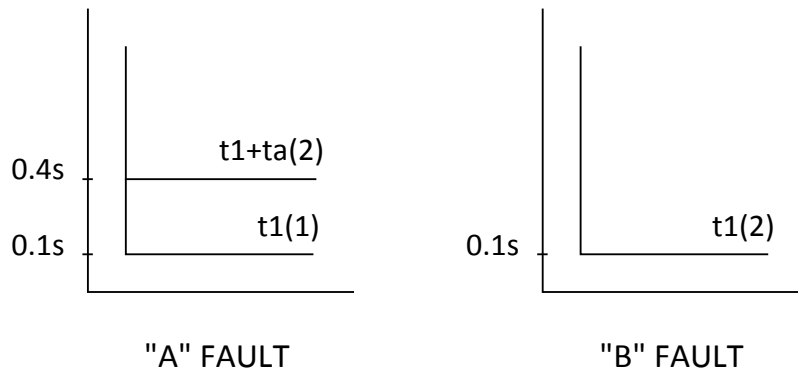
I = I fault

El(sl) = Digital input dedicated to the logic selectivity

1 = tripping time = t1

2 = tripping time if (sl) = 1 => t2 = t1 + ta(sl)

2 = tripping time if El(sl) = 0 => t2 = t1



**Fig. 97:** Logic selectivity implementation

### 6.3.2 Working mode for logic selectivity input

#### Positive true-data mode

The function is activated by a level 1.

In this case, an interruption of the pilot wires avoids activation of the function, but network protection is still performed.

#### Negative true-data mode

The function is activated by a level 0.

In this case, an interruption of the pilot wires is interpreted as a permanent selectivity request, but network protection is restored at the end of the selectivity time delay.

### 6.3.3 Setting characteristics

Characteristics	Values
Time delay logic selectivity thresholds [50] [50N]	0.06 to 3 s with steps of 0.01 s
Time delay logic selectivity thresholds [51] [51N]	0.06 to 120 s with steps of 0.01 s

## 6.4 Configuring the I/O relays – LEDs

### 6.4.1 Logic inputs

A series of functions can be associated with available logic inputs using the configuration software **SMARTsoft**.

The configuration software verifies that any input is associated with only one function and that active functions have all the inputs necessary to their proper operation.

For example, the remote control function requires the following entries:

- Interlock O/O: closed position of the circuit breaker
- Interlock F/O: open position of the circuit breaker
- Local/Distant: cell operation in local or remote mode.

It is possible to select the working mode for each input:

- Positive security: the input is active when it is polarised
- Negative security: the input is active when it is not polarised. You should use this mode if you want operation in case of interruption of a connection wire.

Level 0: <10 V range of auxiliary voltage of 19 to 70 VDC

<33 V range of auxiliary voltage of 85 to 255 VDC

Level 1: >20 V range of auxiliary voltage of 19 to 70 VDC

>37 V range of auxiliary voltage of 85 to 255 VDC

Polarizing current: < 20 mA

### 6.4.2 Output relay and latching output contacts [86]

Depending on the version, it is possible to associate one or several of the 3 or 7 output relays to a function of protection, and to select their working mode:

- Output unit is held after fault clearance, function [86]. Reset occurs by activating a digital input, or via the digital communication dedicated to this function, or by the local HMI. In case of lack of auxiliary voltage, the position of the assigned output relay(s) for function 86 is memorised in the flash memory of the protection. Consequently, upon return of the auxiliary tension, the output relay(s) find back the position they had before the supply switched off.
- Output unit reset if the fault has been cleared at the end of the pulse order.

### 6.4.2.1 Selecting the output relays

Relays A*, B*, E, F (signalisation circuit , relays coil with opening release)	double contact NO, 8 A permanent current making capacity 12 A / 4 s short-circuit current withstand 100 A / 30ms breaking capacity DC a L/R = 40ms: 50W breaking capacity AC a cos $\phi$ = 0,4: 1250 VA
Relays C*, D, G and WD (WD: watchdog) (control-command circuit, configurable to set CB coil with Opening Release or Under Voltage Release)	change over contact, 16 A permanent current breaking capacity 25 A / 4 s short-circuit current withstand 250 A / 30ms breaking capacity CC a L/R = 40ms: 50W voltage) breaking capacity CA a cos $\phi$ = 0.4: 1250 VA

Depending on their characteristics:

- Relays A\*, B\*, E, F will be assigned to signalisation functions
- Relays C\*, D, G will be assigned to control-command circuits

\* versions NP800, NP800R with 3 output relays

### 6.4.2.2 Working mode of the output relays

You can choose the working mode of the output relays C, D, G according to the type of the tripping coil of the switching device associated with the NP800-NP800R, to Opening Release or Under Voltage Release. You may also use this function to change the status of the contacts of an output relay. (In this case, a “NO” contact can be redefined in “NC” if it is associated with an output relay assignable as Under Voltage Release)

**Note:** the tripping relay use for remote control should be the same which is used for protection functions tripping.

### 6.4.3 LEDs

The protection has four programmable yellow LEDs which can be dedicated to:

- tripping by a protection function. This state is memorised until events acknowledgement via the local HMI local or through the PC configuration software **SMARTsoft**.
- tripping by a generic function (memorised state)
- remote controlled tripping or reclosing (state not memorised)
- any kind of tripping
- alarm state: maximum number of tripping's, non-complementarity O/O - C/O CB failure, local/remote discrepancy, circuit breaker fault (non memorised state)
- state of the inputs: O/O - C/O, Local - Remote (non memorised state)
- operating mode: group of setting 2, remote mode (non memorised state)
- Miscellaneous: Communication with PC, detection of network messages. (non memorised state)

## SHARED FUNCTIONS FOR THE NP800-NP800R RANGE

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You may choose operation with permanent lighting or flashing LEDs.

You can only choose the LED's attribution using the PC configuration software **SMARTsoft**.

## 6.5 Remote control function – load shedding - reloading

The remote control function enables, according to the Local and Remote inputs, control-command of the closing and tripping relays via the communication network\*:

- Voluntary tripping remote command
- Voluntary closing remote command
- Load shedding according to priority level
- Reloading.

### Operation:

In local mode local remote commands order are inhibited.

A “Remote mode” event is generated when switching mode.

**\* communication is optional, depending on the NP800 version**

### 6.5.1 Remote controlled tripping

When the protection receives a remote tripping command order, the following actions are executed:

- Activation of the output relay(s) associated with the remote command (A-B-C-D-E-F)
- Displaying the message: “Tripping by remote control” on the LCD
- Event generation: “Trip: remote control”

This command is taken into account unless there is a circuit breaker failure.

### 6.5.2 Remote controlled reclosing

When the protection receives a remote reclosing command, the following actions are executed:

- Activation of the output relay(s) associated with the remote command (A-B-C-D-E-F)
- Displaying the message: „*RECLOSING BY REMOTE CONTROL*” on the LCD
- Event generation: „*CLOSE: REMOTE CONTROL*”

This command is taken into account unless there is a circuit breaker failure.

### 6.5.3 Load shedding using priority levels

This command is executed if the load shedding level is higher or equal to the level, between 1 and 5, which was set in the protection. Priority level 6 which correspond to priority feeder, can therefore not be load shed.

When a protection receives a load shedding order and the circuit breaker is already open, it ignores this order and the following reloading command.

### 6.5.4 Reloading

This command is executed independently of any level, and only if the protection previously received a load shedding command. The reclosing command is given at reloading time delay expiry, which can be set independently for each protection.

In case of local mode switching, the reloading will not be executed.

Characteristics	Values
Time delay before reloading	1 to 120 s (with steps of 1 s)
Reclosing impulsion duration	100 to 500ms (with steps of 10ms)

## 6.6 Programmable generic functions

It is possible to configure up to 8 generic programmable functions with, for each function, the following possibilities:

- Putting in/out of service
- Operating mode of the generic functions (tripping / delay)
- Initiating time (tripping mode only)
- Identification of the function with a description made of a maximum of 14 characters
- Assigning the function to All of Nothing input
- Assigning one or more output relays.

In “**tripping**” mode, activating an input leads the start of the programmable initiating time. Upon expiry of this delay, an alarm or a tripping is activated.

A time stamped event indicating the function name is automatically added to the logbook.

In “**Report**” mode activating an input leads to recording an event with a time stamp in the logbook.

Characteristics	Values
Activation time	15ms
Initiating time delay	0.04 to 300 s with steps of 0.01 s

Application example: for a power transformer, processing the Buchholz contacts and the thermostat in order to time stamp events with redundant alarm circuits and tripping of these “direct” protections.

## 6.7 Setting up the protections

### 6.7.1 Setting groups 1 and 2

The NP800-NP800R models offer two parameter tables that can be switched for the protection and automatism functions.

It is possible to request use of group of settings 2 by activating:

- the input All or Nothing: GROUP 2
- the remote communication network
- the PC configurator, during commissioning

By default, group of settings 1 is active.

It is possible to read the values of the table currently in use using:

- the local HMI local: measurement menu
- the PC configurator (via the tabs Table 1 and Table 2 of the functions screens)
- the remote communication network

### 6.7.2 Priority management

The priority is given to the request of the use of settings group 2, whether this request comes from input All of Nothing or from an order on the communication network.

## 6.8 Events

### 6.8.1 Recording/acknowledgement

When a protection sends a tripping order, an event is automatically generated. The event function enables recording of the last 250 events, and of the last 200 in case of an auxiliary power failure. The oldest events are deleted first from the protection memory (FIFO stack).

You may program a LED to indicate that an event must be acknowledged. To perform acknowledgement locally, you must press the button CLEAR than ENTER on the protection. You may also use the **SMARTsoft** settings software or the digital communication link.

### 6.8.2 Contents of an internal event

- Type of event
- Appearance / disappearance (appearance in the simplified reading mode)
- Timestamp with a 10ms step
- Electrical values measured during the tripping
- Active setting group.

### 6.8.3 Event management mode

There are two modes of event management, to allow a simplified management or a more detailed fault analysis. You can only choose the mode via the menu "Operation" of the PC setting software **SMARTsoft**.

- Simplified mode: only events like tripping's and alarms are recorded. Use of this mode is recommended if the operator acknowledges events via the local HMI.
- Complete mode: tripping like events, instantaneous events and signalisation as well as their appearance/ disappearance are recorded. This mode is especially useful for equipment implementation or when a protection is linked to a supervisor and we want to have access to a logbook with all events related to this protection.

### 6.8.4 Time stamp

When it is powered on, a protection uses the relative time mode, the time reference is maintained using the time base clocked by the internal quartz of the protection.

The time is kept for at least 72 h in case of lack of auxiliary supply.

After having set the time at protection level using a PC or the communication network. The protection then switches to non-synchronous time.

When time stamped messages are sent at an interval lower to a minute, the protection works in synchronous time mode, which allows for events timestamp des events with accuracy at least equal to 10ms.

Characteristics	Accuracy
Relative time mode	<10 s/jour
Non synchronous time mode	<10 s/jour
Synchronous time mode	≤ 10ms

## 6.9 Disturbances

The disturbances function allows recording 4 disturbances, each of them of 52 cycles. The pre-time is programmable from 0 to 52 periods. The sampling frequency is of 12 points per cycle.

The format used is binary COMTRADE. The disturbances files can be read on the communication network MODBUS®.

The PC configuration software **SMARTsoft** allows making use of these disturbances: transfer, viewing, saving, printing, measurement of various times, measurement of instantaneous amplitudes and efficient amplitudes...

It is also possible to perform a manual tripping for disturbances, via the PC configuration software, a dedicated input or a network control-command.

## 6.10 Operating parameters

Setting the protections requires a certain number of operation parameters which can fluctuate from one protection to the other.

Here is a list of the parameters which are used by all protection functions:

- Choice of the language used for the local HMI
- Customization of the parameters file (identification of the s/station and the feeder)
- Rated value for the frequency of the network (Fn)
- Rated value for phase CT (InP)
- Rated value for phase VT and zero-sequence current (UnP and choice of range for UnS)
- Connection mode of the protection (3V/3I or 2U/3I)
- Connection mode of zero-sequence voltage input (2U/3I only)
- Event management (simplified or complete mode)
- Duration of the integration period for calculation of the averaged values of power, current and voltage
- Inhibition tension (<10% of Un)
- Duration of the minimum tripping pulse
- Duration of the closing pulse
- Response time of the circuit breaker (BF)
- Monitoring mode for the opening of the circuit breaker (BF)
- Load shedding level
- Reloading time delay
- Turning the remote control function on/off

## 6.11 Communication

The protection offers an optional network communication function RS485 on the rear panel of the protection. This function is independent from the RS232 communication interface on the front panel. The possible communication protocols available are as follows:

- MODBUS®
- IEC 870-5-103 (please contact us)

The data necessary for the setting of the communication parameters are the following:

- Slave number.
- Character transmission mode.
- Transmission speed in Baud.
- Transmission format.

Characteristics	Values
Slave number	1 to 255
Transmission speed	300, 600, 1200, 1800, 2400, 4800,9600, 19200, 38400, 57600 and 115200 bauds
ASCII format	8 bits without parity, 2 stops 8 bits without parity, 1 stop 8 bits even parity, 1 stop 8 bits odd parity, 1 stop 7 bits even parity , 1 stop 7 bits even parity, 2 stops 7 bits odd parity, 1 stop 7 bits odd parity, 2 stops 7 bits parity forced to 0. 2 stops 7 bits parity forced to 1. 2 stops
Binary format	8 bits without parity, 2 stops 8 bits without parity, 1 stop 8 bits even parity, 1 stop 8 bits odd parity, 1 stop

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