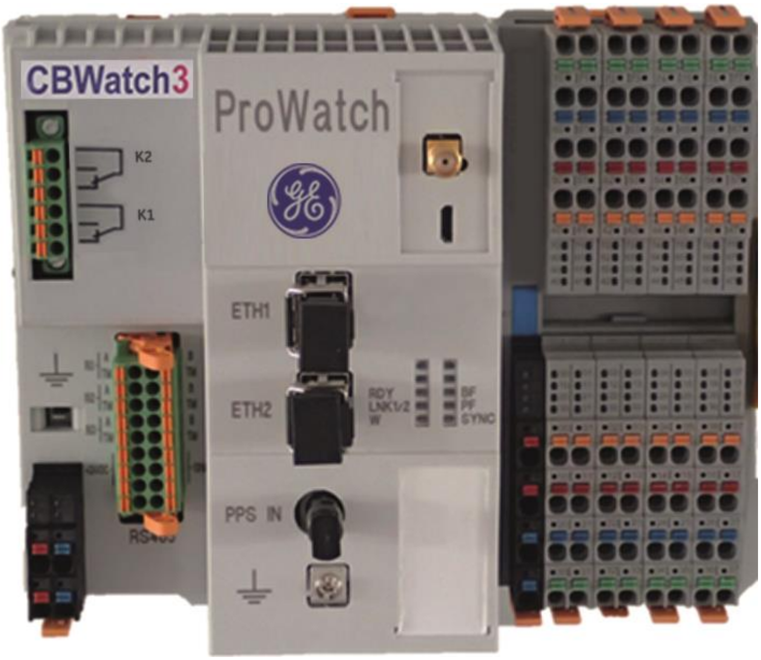
GE
Grid Solutions

CB Watch 3

Circuit Breaker Monitoring System

User Manual



imagination at work

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1 INTRODUCTION

1.1 Product Overview

The CB Watch 3 system (often abbreviated as CBW3 in this manual) is a monitoring system for high voltage circuit breakers. It monitors the following aspects:

- Operation timing
- SF6 gas leakage
- Arcing contact wear
- Coil circuits
- Stored energy system (spring or pump)
- Cabinet / tank heater temperature

A web server HMI is provided to both configure the system and review the data but various communication protocols are also available to transmit the data to a Historian or another software system.

1.2 Document Scope

This User Manual is intended to explain the various monitoring functionalities of the CBW3 and how they can be used to monitor a high-voltage circuit breaker. All outputted information is detailed as well as all the possible alarms that can be set. Communication and system settings are also covered.

Please refer to the CBWatch3 Installation Manual for information on the various modules and sensors comprising the CBW3 system. It provides all the necessary information to install and connect them together and configure the system.

All the available CBW3 monitoring options are detailed in this user manual. Depending on which configuration has been purchased and installed, all the functionalities described in this document may not be available.

1.3 Abbreviations & Definitions

Abbreviation	Meaning
CBW3	CB Watch 3 System
CT	Current Transformer
HV	High Voltage
AC	Alternating Current
DC	Direct Current
HMI	Web-page based interface
IPO	Independent Pole Operation

2 SYSTEM DESCRIPTION

2.1 Modules

The CBW3 system is comprised of both modules and sensors. The modules comprise the processor module and the various I/O modules. They receive and process the signals obtained from the sensors.
For more detailed information, please refer to the CBW3 Installation Manual.

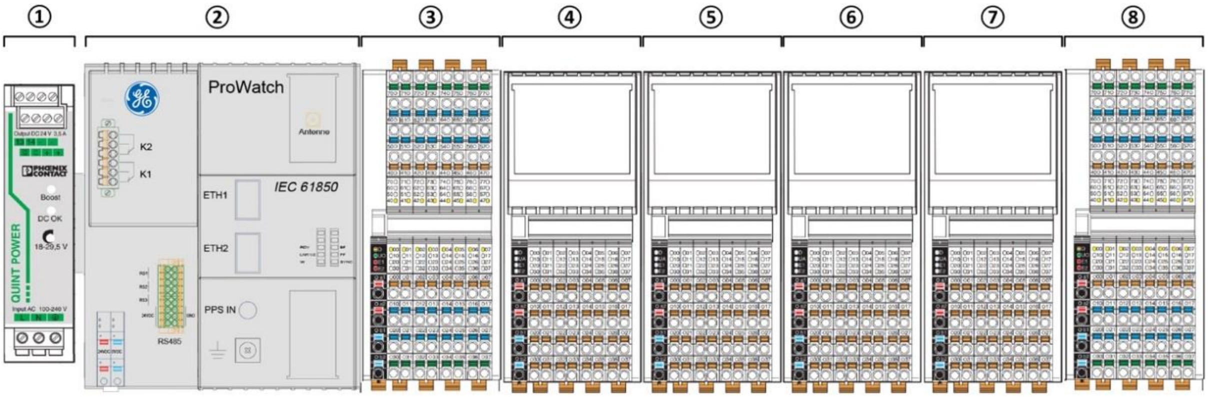


Figure 1 – CBW3 Modules

1	Power supply	5	AI8-2 Module
2	ProWatch Module	6	AI8-3 Module
3	DI16 Module	7	RTD8 Module
4	AI8-1 Module	8	DO16 Module

2.2 Sensors

Depending on your CBW3 configuration, various sensors are connected to the modules, either directly or through terminal blocs. These sensors acquire the data from the circuit breaker so that it can be received by the corresponding I/O modules and processed in the main ProWatch module. Please refer to the Installation Manual for details on sensors.

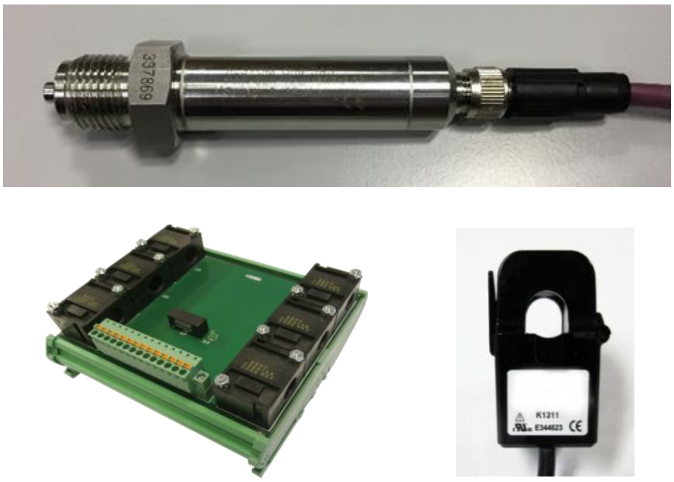


Figure 2 – examples of sensors used

3 HUMAN MACHINE INTERFACE (HMI)

3.1 Introduction

The CB Watch 3 does not require the user to load a special software to connect to it and access the information it captures. The CBW3 has a built-in web server and an integrated Human Machine Interface (HMI) which is accessible from any web browser,

The HMI lets the user configure the system, set alarms and visualise all the measured parameters, the alarm status and the curves/graphs recorded in memory.

3.2 TCP/IP configuration

Before you can access the CBW3's HMI, you must first configure your network adapter accordingly. Open Network Connections by clicking the Start button, and then clicking Control Panel. In the search box, type adapter, and then, under Network and Sharing Center, click View network connections. And then click "change adapter settings"

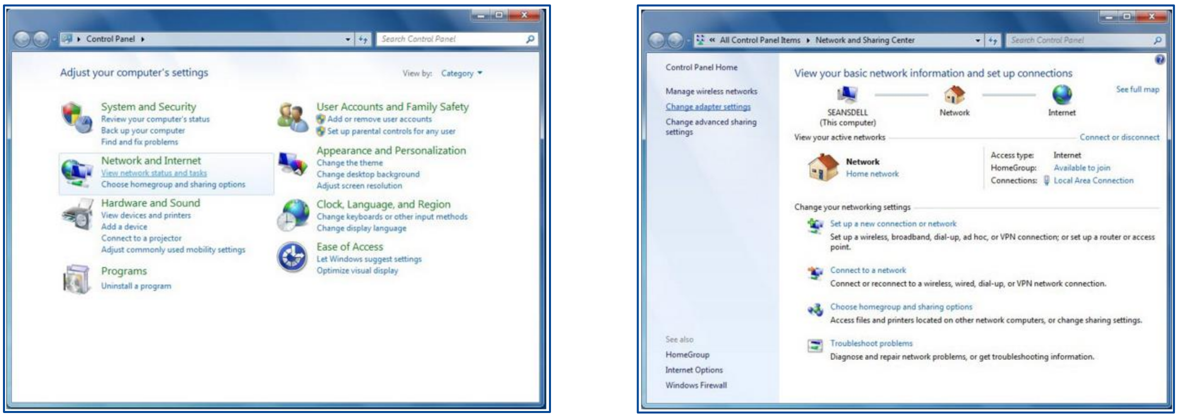


Figure 3 – Network card configuration step 1

Right-click the connection that you want to change, and then click Properties. If you're prompted for an administrator password or confirmation, type the password or provide confirmation.

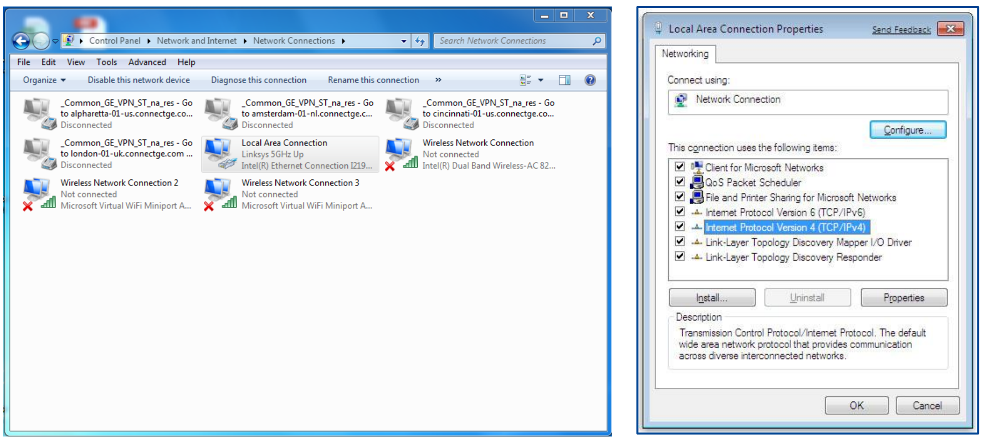


Figure 4 – Network card configuration step 2

In the window, select IPv4 IP address settings and click properties.
A new window (as shown below) will appear:

By default, the IP address of the CBW3 is set in the factory to: **192.168.5.22**
But your particular IP address will have been set during the installation process. We will use the default IP address here, purely as an example.

To communicate with the CBW3, you will need to set your network adapter to another address on that network, for example: 192.168.5.30
The last number 30 could be between 1 and 254, with the exception of 22 (which is the CBW3 address)

To do that, select “Use the following IP address” and enter:

- The IP address 192.168.5.30
- The sub-net mask 255.255.255.0

and then click OK

You can leave the DNS server settings blank

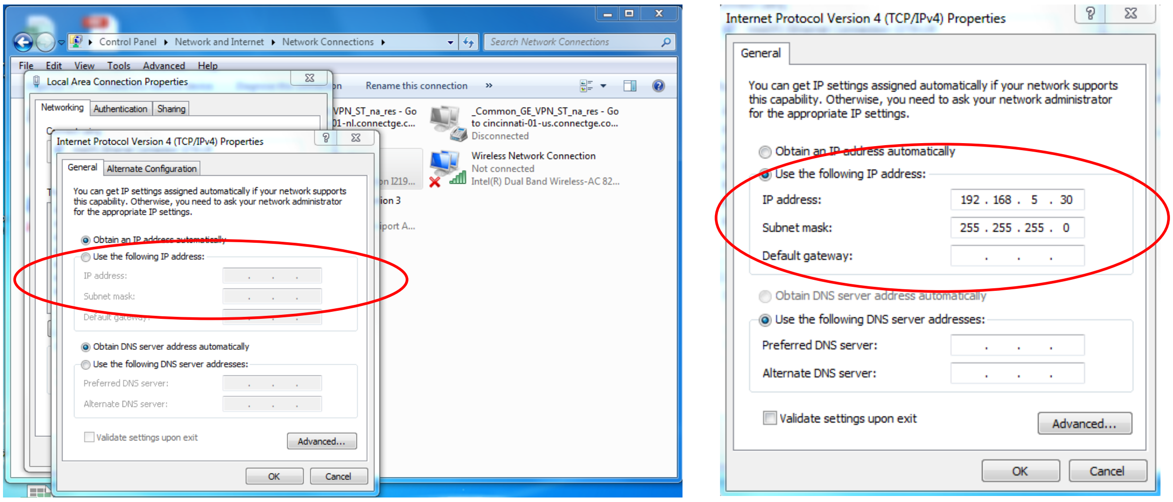


Figure 5 – Network card configuration step 3

Here is an example of a network connection layout. It is possible to have one or several CBW3 connected on the same network in a substation.

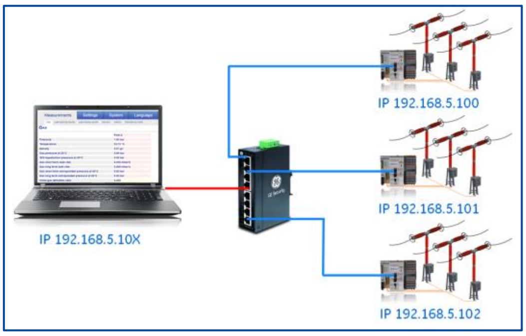


Figure 6 – CBW3 network connections

3.3 Connecting to the CBW3

Normally the CBW3 is fitted with a Fibre Optic (FO) LAN connection SFP module with LC connector. To connect directly your laptop to the CBW3 you should either go through a FO/RJ45 converter, a FO/USB converter or replace the FO SFP module by a suitable RJ45 SFP module (see picture below).

Warning: Standard 1Gbs RJ45 SFP modules will not work ! Only certain 100Mbs SFP module actually work. Please contact GE to acquire a correct and tested SFP module.

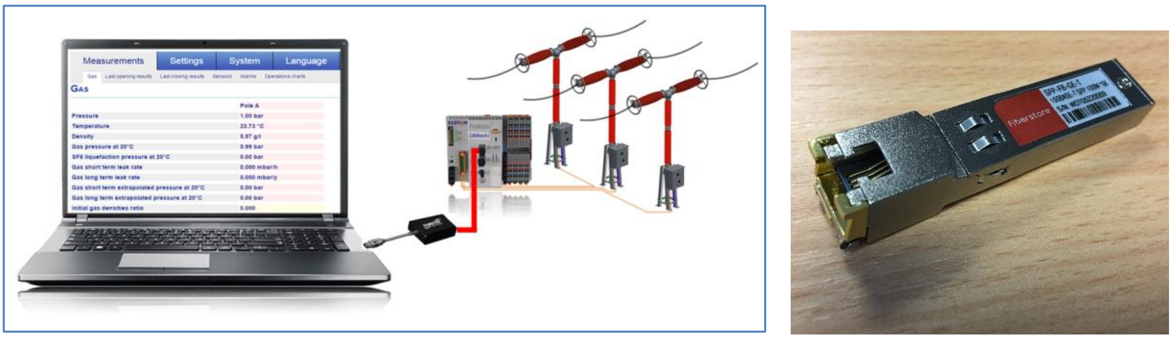


Figure 7 – Connection to the CBW3

Alternatively connect onto (or VPN into) the same network as the one the CBW3 is on.

Launch any Internet browser (for example: “Google Chrome” or “Mozilla Firefox”, (but preferably not “Internet Explorer” which is old and has compatibility issues) and enter the CBW3’s IP address in the address line.

192.168.5.22

Because the CBW3 uses “https” secure encrypted communication and your browser will not recognise the SSL security certificate, it will give you a warning that the communication may be dangerous and unsecured.

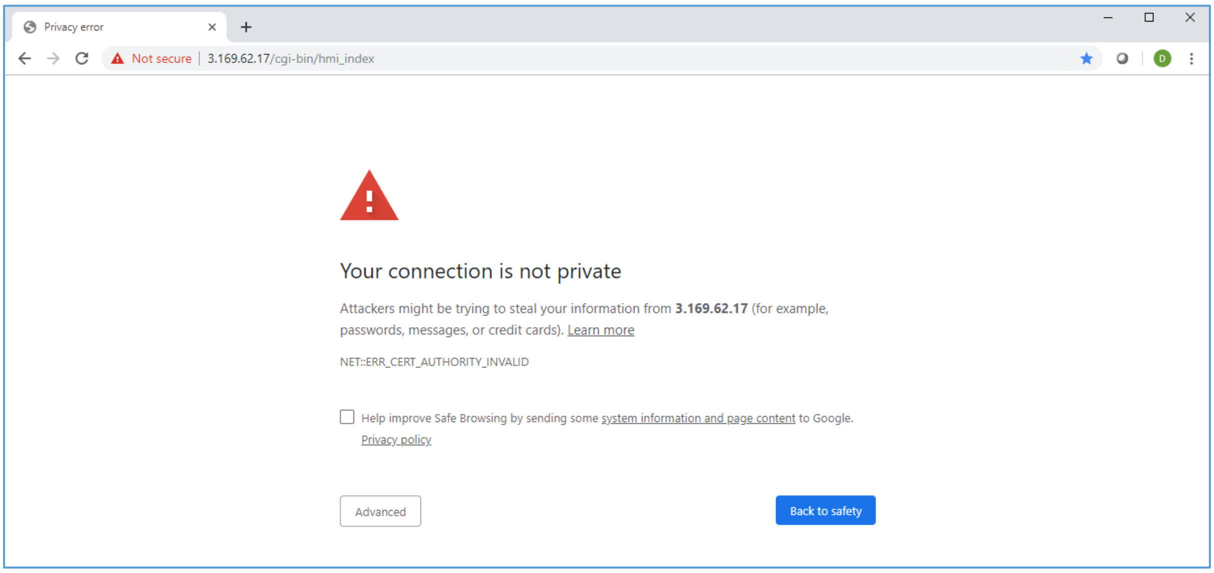


Figure 8 – Connection warning

Disregard and press the "Advanced" button which will reveal a "Proceed anyway" option.

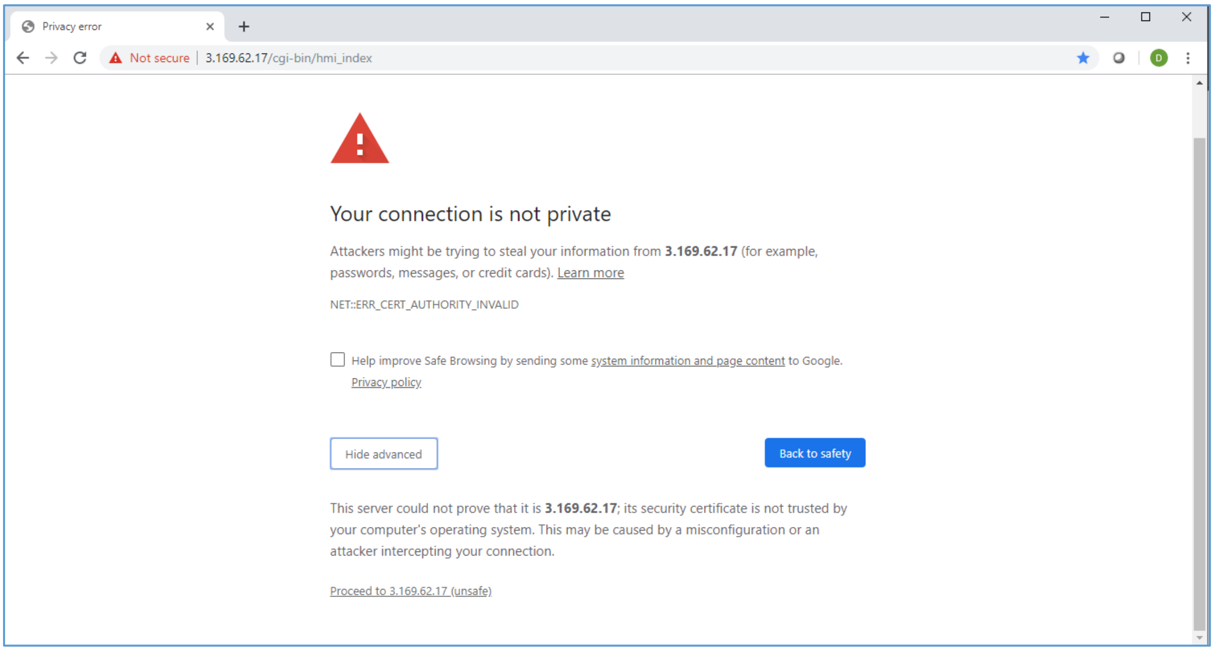


Figure 9 – Connection advanced page

Please disregard the "unsafe" warning and proceed anyway to the IP address that you know.

It is possible to save the IP address into your browser and tell it that it is trusted so that the message will no re-appear the next time.

You will then get to the CBW3 welcome page which will ask you for authentication

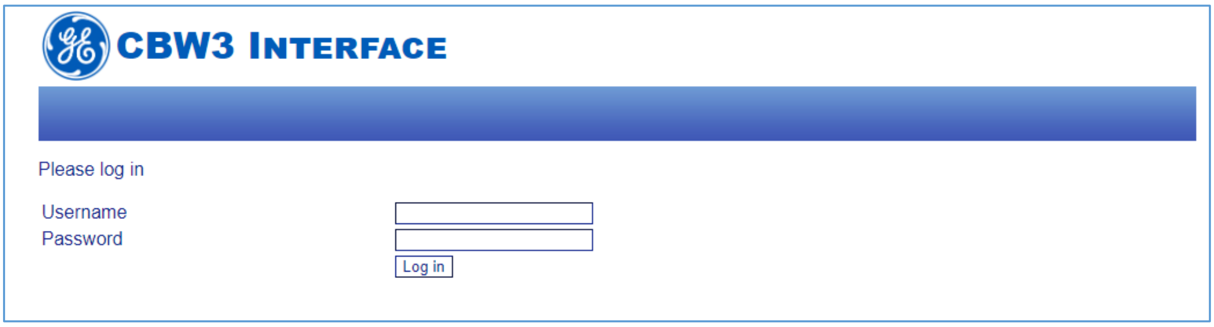


Figure 10 – HMI CBW3 log in

3.4 Access Levels

Access to the HMI and the data is restricted according to several username login levels, each protected by passwords. The various increasing levels of access are listed below. Each next level has the rights of the preceding level plus those listed:

1 Username: "user" Default password: leave blank

Access to all measurements and parameters is read-only
It is possible to change the language of the HMI

2 Username: "supervisor" Default password: "supervisor"

Only parameters for setting alarms are adjustable
It is possible to download parameters file

3 Username: "specialist" Default password: "specialist"

All of the parameters relative to the application are adjustable
In particular all those required for setting up the system

3.5 Language

Once you have access to the HMI of the CBW3, the language tab enables you to select the language that the HMI will use. Click on the required flag first and then click on any section of the top toolbar, the language will automatically change.

Figure 11 – HMI language selection

3.6 Navigation

Navigation through the menus is done by:

(1) Selecting one the menu **section** in the toolbar
- Measurements
- Settings
- System
- Overview
- Language

(2) Selecting one of the **tabs** in the secondary menu/toolbar:

Figure 12 – HMI secondary toolbar for System section

From now on in this user manual, the steps needed to reach any screen shown will be highlighted in black above the screen as per the example below:

As an example, if you wanted to visualise the firmware versions being used, you would select the “System” section first and then the “Product info” tab.

HMI: System / Product Info

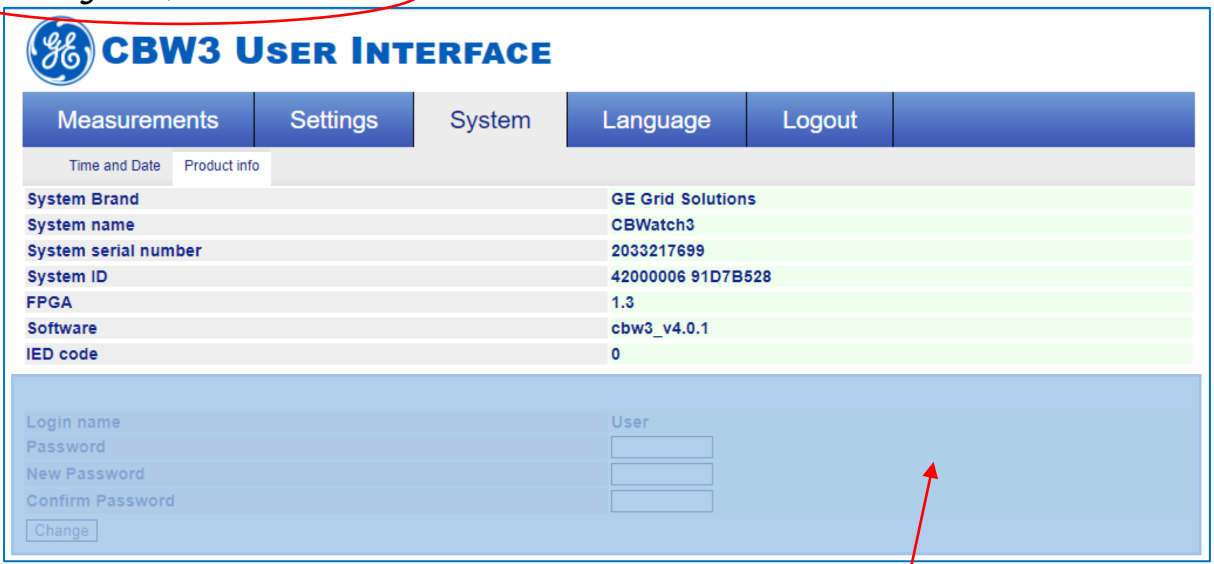


Figure 13 – CBW3 product information

Also in this user manual, we will often (as in the example above) mask part of the page displayed with a blue screen in order to focus attention on the relevant part of the page.

When changing any setting in the HMI, please note that before the adjustment of a parameter can take effect, it first needs to be validated and stored by pressing the "Set" or “Change” button in the corresponding sub-section.

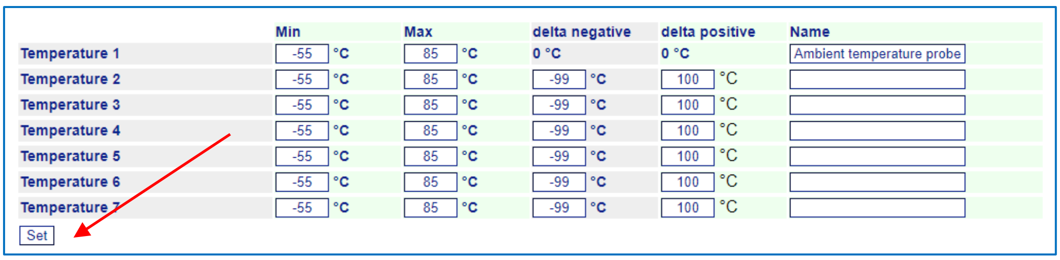


Figure 14 – Set button example

3.7 Software version

Please note that this User Manual assumes that the firmware/software version being used is at least:

Version 4.0 or above

And therefore, the HMI screen shots and some of the features described in this manual reflect what is available in this latest version. Please refer to an older version of the User Manual if there are discrepancies with what is described here.

3.8 Changing Passwords

Passwords can be changed for each username access level by:

- Logging in at the desired access level
- Going to the System / Product Info page
- Entering the current password for that access level
- Entering twice the new password that you want to set
- Pressing change

HMI: System / Product Info

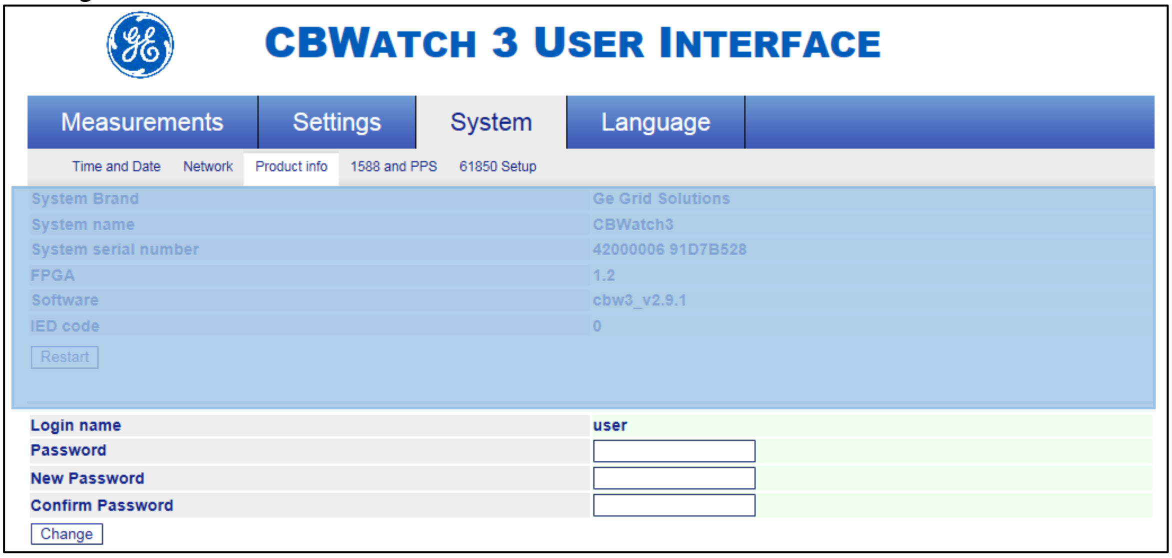


Figure 15 – Changing password

Please take good note of any new password after your change.

4 OPERATION/TIMING MONITORING

4.1 Introduction

The monitoring of the dynamic parameters during the operations of a circuit breaker (operating time, speed etc.) allows for a diagnostic to be made of any mechanical issue or significant drift in its speed of operation.

- Without a travel sensor installed in the CB (which represents the vast majority of cases found in the field), auxiliary position contacts (52a and 52b) are used to ascertain position and provide change of status timing.
- With a travel sensor installed (during the manufacturing of the CB as difficult to retrofit afterwards), more precise position data becomes available without relying on the auxiliary contacts. This unlocks additional functionalities.

Both options will be outlined although the first is, by far, the most common:

4.2 Functionalities available Without Travel Sensor

4.2.1 Number of operations

For each pole, the following information is recorded:

- date and time of the last opening and closing operation
- time elapsed since the corresponding previous close/open operation
- cumulative number of opening and closing operations performed

HMI: Measurements / Last opening results or Last closing results

LAST OPENING OPERATION DATA

	Pole A	Pole B	Pole C
Last operation date and time	Sun Jan 0 00:00:00 1900		
Time elapsed since previous closing operation	0.0 s	0.0 s	0.0 s
Opening operation counter	0	0	0

LAST CLOSING OPERATION DATA

	Pole A	Pole B	Pole C
Last operation date and time	Sun Jan 0 00:00:00 1900		
Time elapsed since previous opening operation	0.0 s	0.0 s	0.0 s
Closing operation counter	0	0	0

Figure 16 – Number of opening/closing operation

Traditionally the mechanical counter in a CB only counts opening operations and there is always a corresponding closing operation which is not counted. So it always counts a pair of operations. The numbers of opening and closing operations recorded in the CBW3 match the mechanical counter and usually show the same value or are out by one.

The number of operations already performed when retrofitting a CBW3 can be entered in the opening and closing operations counters during commissioning, to match the mechanical counter present on the circuit breaker.

HMI: Settings/Opening and Settings/Closing

OPERATION COUNTER AND ELECTRICAL WEAR		
Set opening operation counter	0	Set

OPERATIONS COUNTER THRESHOLD 2		
set closing operation counter	0	Set

Figure 17 – Initial setting of number of operations

An alarm can be set against both the number of opening and closing operations if they exceed a set threshold. This can be used for maintenance purposes.

HMI: Settings/Opening and Settings/Closing

max number of opening operations	50
Max number of closing operations	1000

Figure 18 – Setting operation counter alarms

4.2.2 52a/52b 52a/52b contacts status

The 52a/52b auxiliary contacts are proximity switches that are there to reflect a direct image of the circuit breaker position and indicate the status of the circuit breaker:

- 52a aux. contact: is ON when circuit-breaker is CLOSED, and vice-versa
- 52b aux. contact: is OFF when circuit breaker is CLOSED, and vice-versa

HMI: Measurements/Sensors

POSITION 52A/52B CONTACTS			
Previous operation type	-----	-----	-----
52a (ON=CB Closed, OFF=CB Open)	OFF	OFF	OFF
52b (ON=CB Open, OFF= CB Closed)	OFF	OFF	OFF

Figure 19 – Auxiliary contact status

In an IPO CB, if the 52a or 52b contacts do not show the same value for all 3 poles for longer than the "pole discrepancy timeout" set, then a "Pole discrepancy" alarm is raised. This alarm can serve as a reminder of a temporary phase imbalance in an IPO CB and that the situation should not be maintained for a long time.

HMI: Settings/Operations Monitoring

Number of drives	1	3	Travel curve sensor presence	Yes
Pole discrepancy timeout	1.0 s		Aux. contacts timeout	200 ms

Figure 20 – Pole discrepancy timeout threshold

In both a ganged and an IPO CB, if for any one pole, the 52a and 52b contacts have the same value for longer than the "pole discrepancy timeout" set, then a "Pole discrepancy" alarm is also raised. It can alert to the fact that there is a problem with the 52a and 52b contacts for one pole and that the position of the CB for that pole might be incorrect.

HMI: Measurements/Alarms

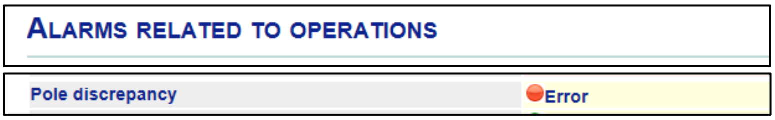


Figure 21 – Pole discrepancy alarm

4.2.1 Previous operation

The type of operation that was just performed is indicated as “previous operation type”. This can be Open (O), Closed (C) or a combination operation (CO, OC, OCO).

During each operation, data acquisition is performed from all the sensors for a period defined in the settings under « Acquisition duration »: 0.3s (300ms) is the default.

HMI: Settings/Operations monitoring

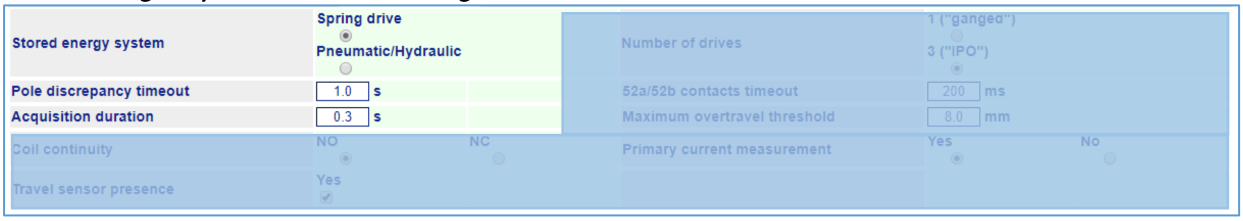


Figure 22 – Setting operation counter alarms

When a current flowing to the coil is detected, the system then samples every 0.4ms for the acquisition duration, we get a total number of sample of 300 / 0.4 = 750. By analysing the data from the 52a and 52b contact during this sampling period, we determine the type of operation that has occurred using the following rules:

If the system sees a Closing operation first, it will check for another Opening operation during the sampling time
- If it does not see one, then it declares a simple Closing operation “C”
- If it does see one, then it declares a Closing-Opening operations “CO”

If the system sees an “Opening” operation first, it will check for another Closing operation during the sampling time
- If it does not see one, then it declares a simple Opening operation “O”
- If it does see one, then it continues to see if there might be a third operation during the sampling period
  - If it does not see one, then it declares an Opening-Closing operation “OC”
  - If it does see one, then it declares an Opening-Closing-Opening operation “OCO”

4.2.2 52a/52b contacts switching time

All timing starts from the detection of the open or close command (rising edge of the current detected on the open or close coil circuit). The auxiliary contact switching time is measured for each operation:

HMI: Measurements/Last opening results or Last closing results

Auxiliary contact 52a switching time	0.0 ms	0.0 ms	0.0 ms
Auxiliary contact 52b switching time	0.0 ms	0.0 ms	0.0 ms

Figure 23 – Auxiliary contact timing

- Auxiliary contact 52a switching time: Time elapsed between open/close command received and the 52a contact changing status
- Auxiliary contact 52b switching time: Time elapsed between open/close command received and the 52b contact changing status

A graph is available showing the contact status change for each pole:

HMI: Measurements/Operations Charts/Opening and Closing

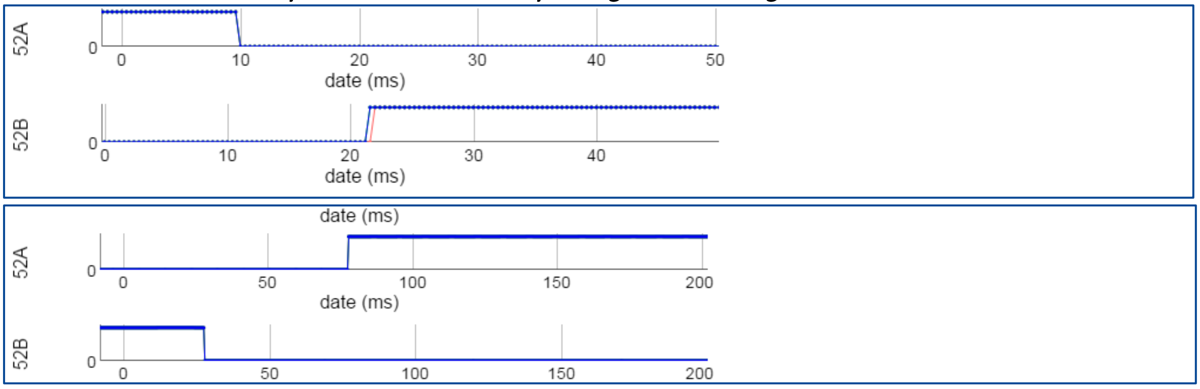


Figure 24 – Auxiliary contact opening and closing graphs

An “Aux contacts timeout” maximum threshold value can be entered during setup under.

HMI: Settings/Operations Monitoring

Number of drives	1 ○	3 ◉	Travel curve sensor presence	Yes ☐
Pole discrepancy timeout	1.0 s		Aux. contacts timeout	200 ms

Figure 25 – Auxiliary contacts switching threshold

An alarm is raised if, after an operation request has been detected, the 52a/52b contacts do not switch status before the auxiliary contact timeout threshold has been exceeded. This could indicate a faulty contact or an inability for the CB to respond to an operation command (“order rejection”).

HMI: Measurements/Alarms

	Pole A	Pole B	Pole C
Circuit breaker position contact 52a	No Error	No Error	No Error
Circuit breaker position contact 52b	No Error	No Error	No Error

Figure 26 – Monitoring the auxiliary contacts

4.2.3 Operating times

For each opening operation and for each of the poles, a recording is made of:
- The date and time of the appearance of the open command on the control circuit,
- The "Reaction time" (t1) between the appearance of the open command and the moment where the circuit breaker leaves the "closed" position and the 52a auxiliary contact changes status
- The "Operation time" (t2) between the appearance of the open command and the moment where the circuit breaker arrives in the "open" position and the 52b auxiliary contact changes status

Similarly, for each closing operation, for each of the phases, a recording is made of:
- The date and time of the appearance of the close command on the control circuit,
- The "Reaction time" (t1) between the appearance of the close command and the moment where the circuit breaker leaves the "open" position and the 52b auxiliary contact changes status
- The "Operation time" (t2) between the appearance of the close command and the moment where the circuit breaker arrives in the "closed" position and the 52a auxiliary contact changes status

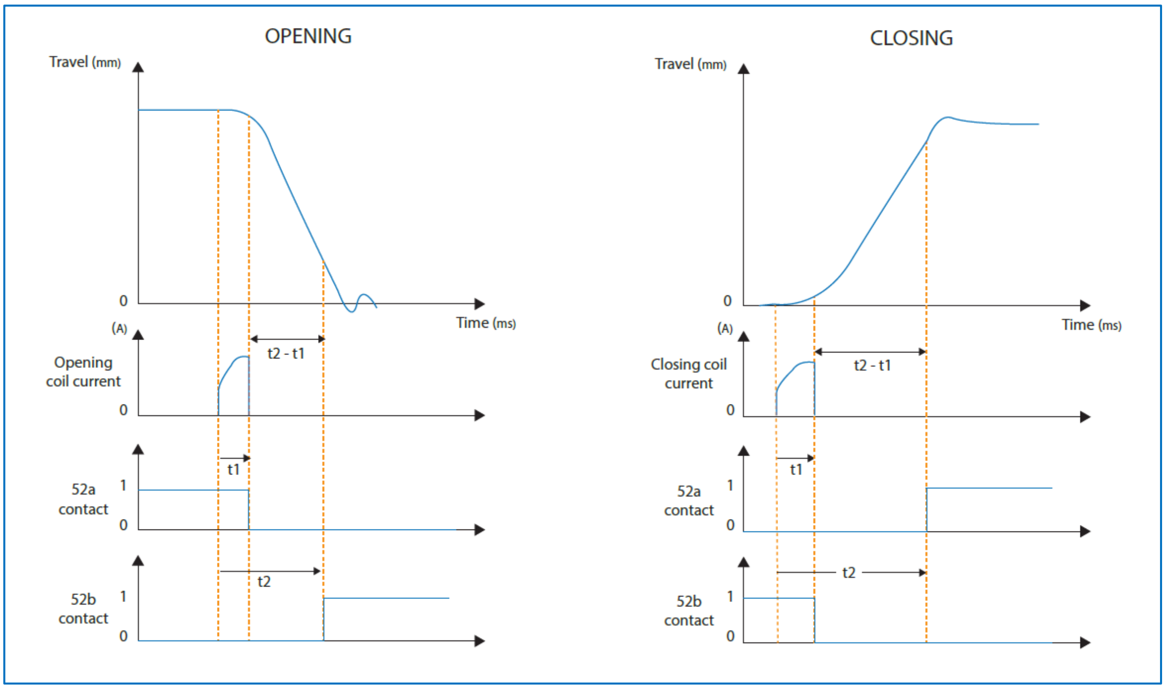


Figure 27 – Operating time measurement

The system can then calculate the "Travel time" (t2-t1) when the circuit breaker moves, during both opening or closing operations.

The system also calculates the opening contact separation time (ts) which it the "reaction time" t1 plus the contact separation offset to the 52a contact entered in the setup (time from 52a to contact separation) – see section 6.3 further on.

HMI: Measurements/Last opening and closing results

LAST OPENING MEASUREMENTS

	Pole A	Pole B	Pole C
Record Date	Thu Nov 9 16:41:52 2017		
Opening operations counter	633	633	633
52A contact switching time	15.2 ms	14.0 ms	15.2 ms
Opening reaction time (t1)	15.2 ms	14.0 ms	15.2 ms
52B contact switching time	26.8 ms	26.8 ms	28.0 ms
Opening operation time (t2)	26.8 ms	26.8 ms	28.0 ms
Opening travel time (t2-t1)	11.6 ms	12.8 ms	12.8 ms
Contacts separation time	16.7 ms	15.5 ms	16.7 ms
Contact separation speed	12.9 m/s	11.7 m/s	11.7 m/s
Overtravel	0.0 mm	0.0 mm	0.0 mm
Coil circuit voltage 1	1.00 V		
Ambient temperature	0.0 °F		
Time elapsed from previous closing operation	1011.0 s	1011.0 s	1011.0 s

LAST CLOSING MEASUREMENTS

	Pole A	Pole B	Pole C
Record Date	Thu Nov 9 16:25:01 2017		
Closing operations counter	632	632	632
52B contact switching time	56.8 ms	56.8 ms	57.2 ms
Closing reaction time (t1)	56.8 ms	56.8 ms	57.2 ms
52A contact switching time	94.4 ms	99.6 ms	100.4 ms
Closing operation time (t2)	94.4 ms	99.6 ms	100.4 ms
Closing travel time (t2-t1)	37.6 ms	42.8 ms	43.2 ms
Contact touching speed	4.0 m/s	3.5 m/s	3.5 m/s
Overtravel	0.0 mm	0.0 mm	0.0 mm
Coil circuit voltage 2	1.00 V		
Ambient temperature	0.0 °F		
Time elapsed from previous opening operation	5222.0 s	5222.0 s	5222.000 s

Figure 28 – Last operation measurements

4.2.4 Discordance between poles

When all poles are operated simultaneously in an IPO CB, the opening and closing operation timing are compared for each pole and any differences are highlighted.

- The “discordances” are the timing differences pole to pole (A-B, A-C, C-B),
- The maximum discordance is also recorded (also referred to as “discrepancy”)

There will always be small differences pole-to-pole, but these should be kept small as high values may lead to large voltage spikes being generated that could potentially damage network and equipment.

HMI: Measurements/Last opening and closing results

TIME DISCORDANCE BETWEEN POLES

	|A-B|	|A-C|	|C-B|
Reaction time discordances (t1)	1.2 ms	0.0 ms	1.2 ms
Reaction time discrepancy (t1)	1.2 ms		
Operation time discordances (t2)	0.0 ms	1.2 ms	1.2 ms
Operation time discrepancy (t2)	1.2 ms		
Travel time discordances (t2-t1)	1.2 ms	1.2 ms	0.0 ms
Travel time discrepancy (t2-t1)	1.2 ms		

TIME DISCORDANCE BETWEEN POLES

	|A-B|	|A-C|	|C-B|
Reaction time discordances (t1)	0.0 ms	0.4 ms	0.4 ms
Reaction time discrepancy (t1)	0.4 ms		
Operation time discordances (t2)	5.2 ms	6.0 ms	0.8 ms
Operation time discrepancy (t2)	6.0 ms		
Travel time discordances (t2-t1)	5.2 ms	5.6 ms	0.4 ms
Travel time discrepancy (t2-t1)	5.6 ms		

Figure 29 – Operating time discordances

Note that even though the discrepancy value is shown under pole A, it does not indicate that the maximum of the three discordance values is associated with pole A.

4.2.5 Separation speed & touching speed

A CB must operate at a specific speed in order to build up adequate pressure to allow for a cooling stream of air, oil or gas (depending on the type of breaker) to extinguish the arc that is generated after the contact separation and until the next zero crossing.

To enable speed calculations, the system requires two key distances to be entered during setup, measured in mm from the fully open position which is 0mm. In this example:

O	Start of open position = location of 52b sensor	15mm here
C	Start of close position = location of 52a sensor	120mm here

HMI: Settings/Opening and Settings/Closing

TRAVEL CURVE

Separation of contacts	36.000 mm		Start of open position	15.000 mm	
	max	min			
Open position limits	5.000 mm	-5.000 mm			

TRAVEL CURVE

	closed position max	closed position min	Limit for beginning of closed position	120.00 mm
Closed position limits	140.00 mm	130.00 mm		

Figure 30 – Entry of key distances

The distance (C-O), in this example: 120-15=105mm, is assimilated to the travel distance and the contact “separation speed” is calculated by dividing this distance by the “opening travel time” (t2-t1) which has been recorded.

A similar calculation is done for the closing contact “touching speed” by using this travel distance and the “closing travel time” (t2-t1)

HMI: Measurements/Last opening and closing results

LAST OPENING MEASUREMENTS

	Pole A	Pole B	Pole C
Contacts separation time	16.7 ms	15.5 ms	16.7 ms
Contact separation speed	12.9 m/s	11.7 m/s	11.7 m/s

LAST CLOSING MEASUREMENTS

	Pole A	Pole B	Pole C
Contact touching speed	4.0 m/s	3.5 m/s	3.5 m/s

Figure 31 – Separation and touching speed

All speeds are expressed in meters per second (m/s)

4.2.6 Timing alarms

Alarm thresholds can be set for the following measured items:

Opening

- Minimum and maximum Reaction time (t1), per pole
- Maximum t1 pole to pole discrepancy
- Minimum and maximum Operation time (t2), per pole
- Maximum t2 pole to pole discrepancy
- Minimum and maximum Travel time (t2-t1), per pole
- Maximum t2-t1 pole to pole discrepancy
- Minimum contact separation speed, per pole

Closing

- Minimum and maximum Reaction time (t1), per pole
- Maximum t1 pole to pole discrepancy
- Minimum and maximum Operation time (t2), per pole
- Maximum t2 pole to pole discrepancy
- Minimum and maximum Travel time (t2-t1), per pole
- Maximum t2-t1 pole to pole discrepancy

The threshold values can be entered during setup here:

HMI: Settings/Opening and Settings/Closing

OPERATIONS TIME

	max t1	min t1		max t2	min t2
Opening reaction time t1	15.0 ms	8.0 ms	Opening operation time t2	30.0 ms	15.0 ms
Max opening reaction time t1 discrepancy	1.0 ms		Max opening operation time t2 discrepancy	5.0 ms	
Max opening travel time t2-t1 discrepancy	5.0 ms		Minimum time since last closing	300.0 ms	
	max t2-t1	min t2-t1			
Opening travel time t2-t1	8.0 ms	15.0 ms	Min separation speed	2.50 m/s	

OPERATIONS TIME

	max t1	min t1		max t2	min t2
Closing reaction time t1	40.0 ms	20.0 ms	Closing operation time t2	85.0 ms	75.0 ms
	min rewind	max rewind		t2-t1 max	t2-t1 min
Spring reload time	3.0 s	8.0 s	Closing travel time t2-t1	60.0 ms	40.0 ms
Max closing reaction time t1 discrepancy	5.0 ms		Max closing operation time t2 discrepancy	5.0 ms	
Max closing travel time t2-t1 discrepancy	5.0 ms		Minimum time since last closing	300.0 ms	

Figure 32 – Operation timing alarms thresholds

An alarm is raised if, for any of the poles, the measured/calculated value during an opening or closing operation is found to be beyond the thresholds set (i.e. below the minimum value or above the maximum value set):

HMI: Settings/Operations Monitoring

Alarms related to operations

	Pole A	Pole B	Pole C
Reaction time t1 (open)	Alarm	Alarm	Alarm
Operating time t2 (open)	Alarm	Alarm	Alarm
Reaction time t1 (close)	Alarm	Alarm	Alarm
Operating time t2 (close)	Alarm	Alarm	Alarm
Travel time t2-t1 (open)	Alarm	Alarm	Alarm
Travel time t2-t1 (close)	Alarm	Alarm	Alarm
Contact separation speed (open)	OK	OK	OK
Circuit breaker position contact 52a	OK	OK	Alarm
Circuit breaker position contact 52b	OK	OK	Alarm
Reaction time t1 discrepancy (open)	OK	OK	OK
Operation time t2 discrepancy (open)	OK	OK	OK
Travel time t2-t1 discrepancy (open)	OK	OK	OK
Reaction time t1 discrepancy (close)	OK	OK	OK
Operation time t2 discrepancy (close)	OK	OK	OK
Travel time t2-t1 discrepancy (close)	OK	OK	OK

Figure 33 – Alarms related to operation timing

4.3 Additional Functionalities With Travel Sensor*

*The presence of a travel sensor fitted to the circuit breaker by the manufacturer is required for all the following additional functionalities.

4.3.1 Travel Distances

Certain physical distances associated with the CB contact movement need to be entered into the system (in mm) to understand the exact position of the contacts and to enable more precise timing and speed measurements. These are entered during settings:

All measurements start from the fully open position which is indicated as 0mm. In this example:

A	Open position	0mm
B	Open position limits	-5 to +5mm
C	Start of open position	15mm
D	Separation of contact	36mm
E	Start of close position	120mm
F	Closed position limits	130 to 140mm
G	Closed position	135mm

HMI: Settings/Opening and Settings/Closing

TRAVEL CURVE

Separation of contacts	36.000 mm		Start of open position	15.000 mm
	max	min		
Open position limits	5.000 mm	-5.000 mm		

TRAVEL CURVE

	closed position max	closed position min	Limit for beginning of closed position	120.00 mm
Closed position limits	140.00 mm	130.00 mm		

Figure 34 – Entry of distances

4.3.2 Using the travel sensor information

Because we have a travel sensor, we get real time information on the position of the contacts during opening and closing operations. As the sensor passes one of the pre-defined position (setup in the section above), then the system records the time and uses this value for calculations

For each opening operation and for each of the poles, a recording is made of:

- The "Reaction time" (t1) between the appearance of the open command and the moment the travel sensor shows moving away from the "closed" position [E]
- The "Operation time" (t2) between the appearance of the open command and the moment the travel sensor shows arriving at "open" position [C]

Similarly, for each closing operation, for each of the phases, a recording is made of:

- The "Reaction time" (t1) between the appearance of the close command and the moment where the travel sensor shows moving away from "open" position [C]
- The "Operation time" (t2) between the appearance of the close command and the moment where the travel sensor shows arriving at "closed" position [E]

4.3.3 Operation Graphs

A distance /vs/ time graph is recorded during each operation and stored:

HMI: Measurements/Operations charts/Opening

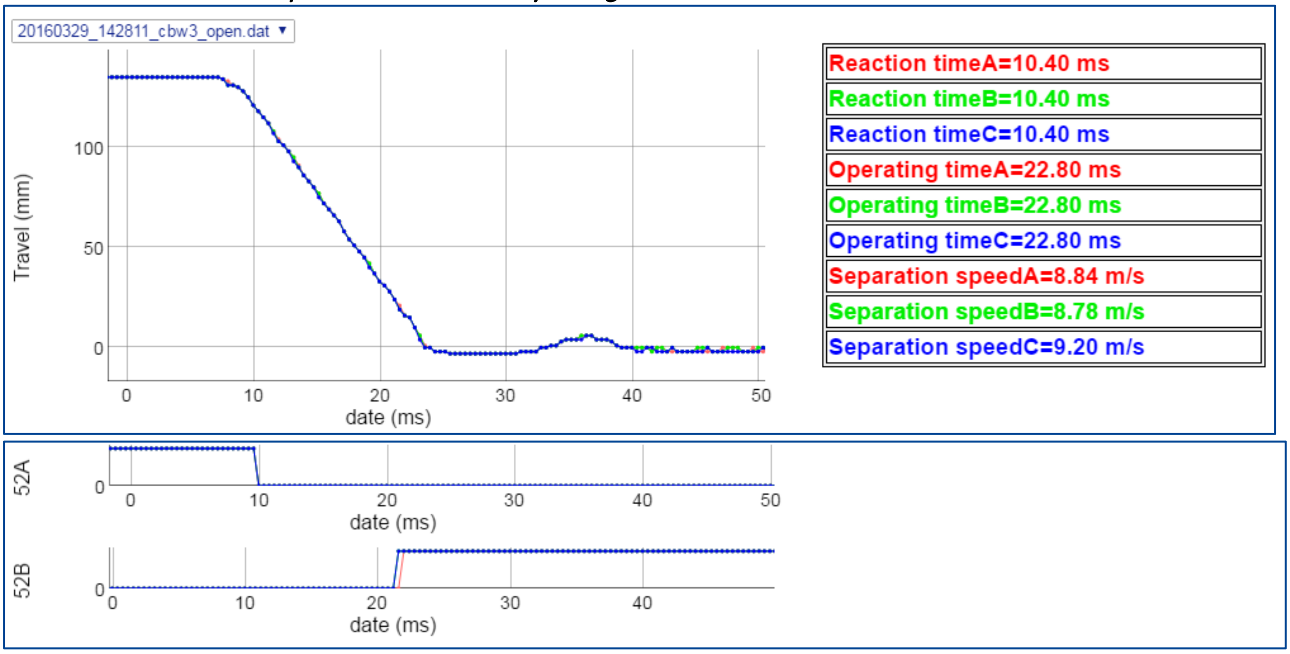


Figure 35 – Operation graphs for opening

HMI: Measurements/Operations charts/Closing

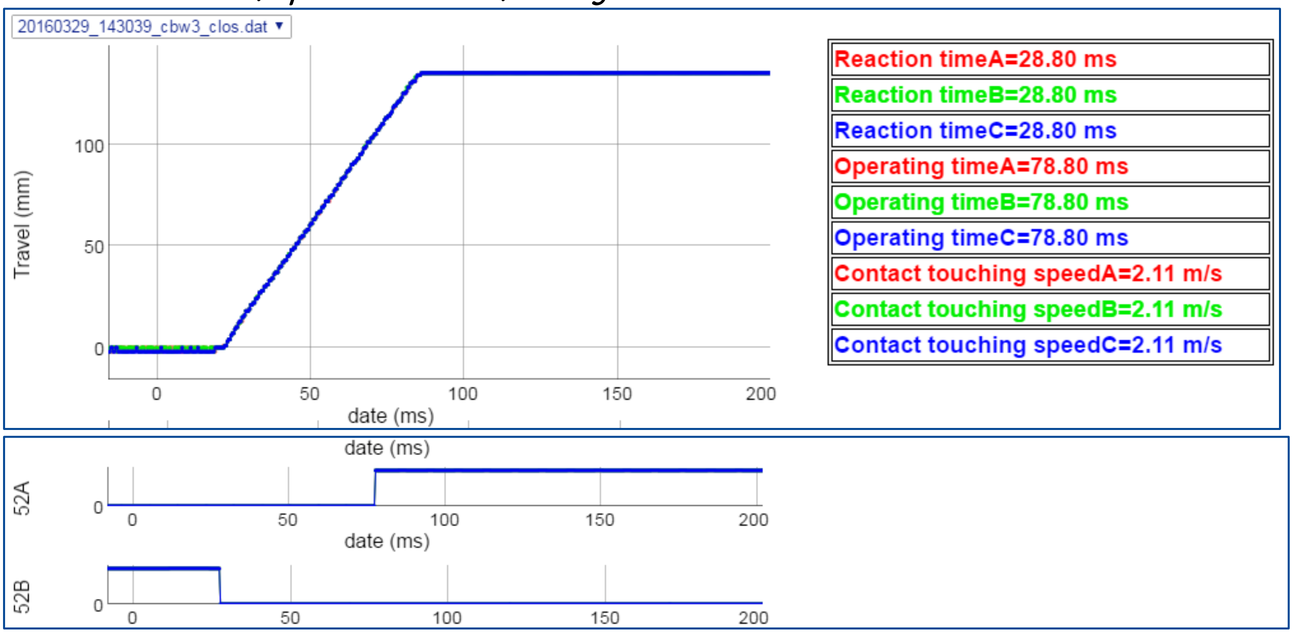


Figure 36 – Operation graph for closing

4.3.4 Auxiliary contact supervision

Because we have a travel sensor, when we get the signal from the 52a and 52b auxiliary contacts that the CB has opened or closed, we can check the corresponding position of the travel sensor (which should be within the pre-defined min and max positions) to confirm that the CB has physically moved to the correct position.

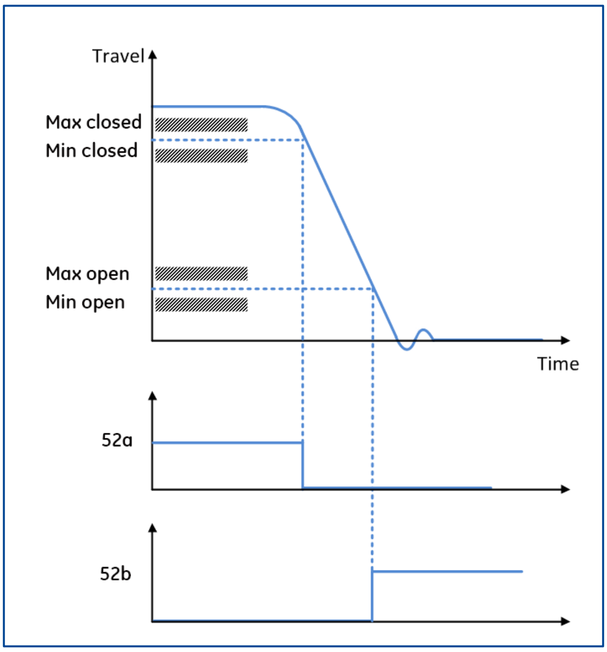


Figure 37 – Monitoring the auxiliary contacts

Since the travel sensor displacement limits (min and max in mm) for the physical open and closed positions have been entered (with tolerances) in the setup, an alarm is then raised if the travel sensor position is not within these limits.

HMI: Measurements/Alarms

ALARMS RELATED TO OPERATIONS

	Pole A	Pole B	Pole C
Reaction time t1 (open)	No Error	No Error	No Error
Operating time t2 (open)	No Error	No Error	No Error
Reaction time t1 (close)	No Error	No Error	No Error
Operating time t2 (close)	No Error	No Error	No Error
Spring reload time	No Error	No Error	No Error
Close position	No Error	No Error	No Error
Open position	No Error	No Error	No Error

Figure 38 – Monitoring the auxiliary contacts

- Close position alarm: Despite what 52a auxiliary sensor indicates, travel sensor indicates that CB is outside defined closed min/max positions
- Open position alarm: Despite what 52b auxiliary sensor indicates, travel sensor indicates that CB is outside opened defined min/max positions

4.3.5 Overtravel

The overtravel is also monitored for each operation. This is defined as the difference (in mm) between these two measured values:

- The maximum travel point reached during the operation
- The final resting position at the end of the operation

as measured by the travel sensor and shown on the travel curve

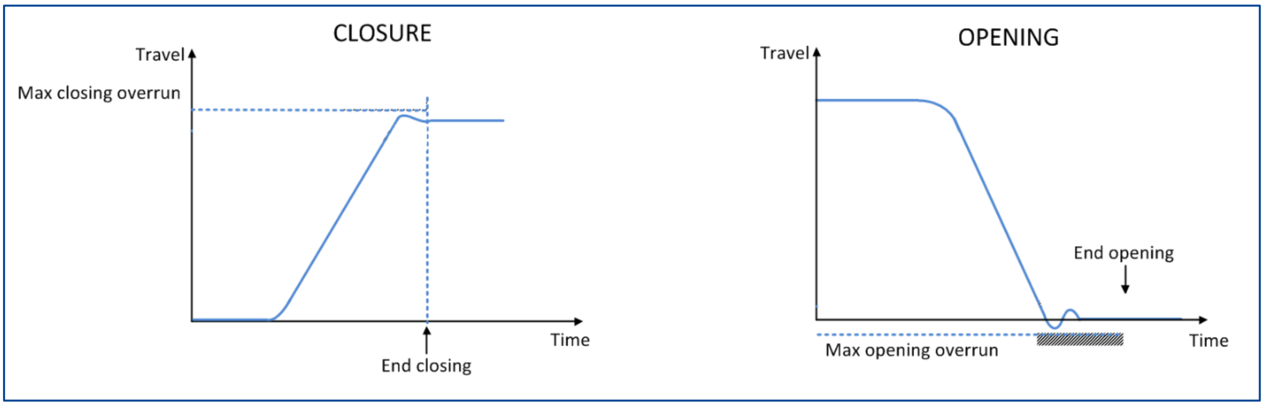


Figure 39 – Monitoring the overtravel

HMI: Measurements/Last opening results and Last closing results

LAST OPENING MEASUREMENTS

	Pole A	Pole B	Pole C
record date	Sun Jan 0 00:00:00 1900		
Opening operations counter	0	0	0
Opening reaction time (t1)	0.0 ms	0.0 ms	0.0 ms
Operation time (t2)	0.0 ms	0.0 ms	0.0 ms
Contacts separation time	0.0 ms	0.0 ms	0.0 ms
Contact separation speed	0.0 m/s	0.0 m/s	0.0 m/s
Opening travel time	0.0 ms	0.0 ms	0.0 ms
Overtravel	**0.0 mm**	**0.0 mm**	**0.0 mm**

LAST CLOSING MEASUREMENTS

	Pole A	Pole B	Pole C
record date	Sun Jan 0 00:00:00 1900		
Closing operations counter	0	0	0
Closing reaction time (t1)	0.0 ms	0.0 ms	0.0 ms
Closing operation time (t2)	0.0 ms	0.0 ms	0.0 ms
Auxillairy contacts 52a switching time	0.0 ms	0.0 ms	0.0 ms
Closing travel time	0.0 ms	0.0 ms	0.0 ms
Contact touching speed	0.0 m/s	0.0 m/s	0.0 m/s
Overtravel	**0.0 mm**	**0.0 mm**	**0.0 mm**

Figure 40 – Displaying overtravel

An alarm threshold can be entered for the maximum overtravel:

HMI: Settings/Operations monitoring

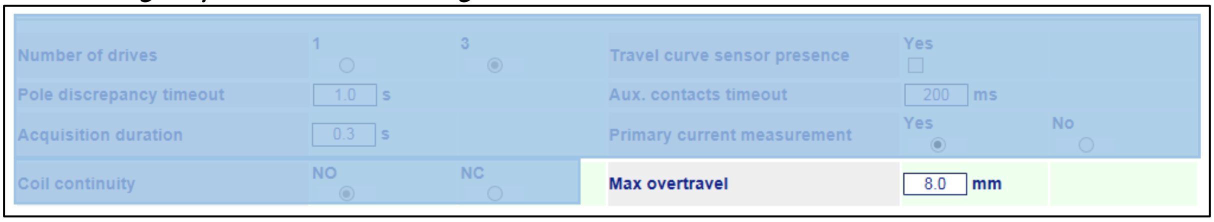


Figure 41 – Overtravel threshold

An alarm is raised if, during an opening or closing operation, the overtravel value measured exceeds the "Max overtravel" threshold entered.

HMI: Measurements/Alarms

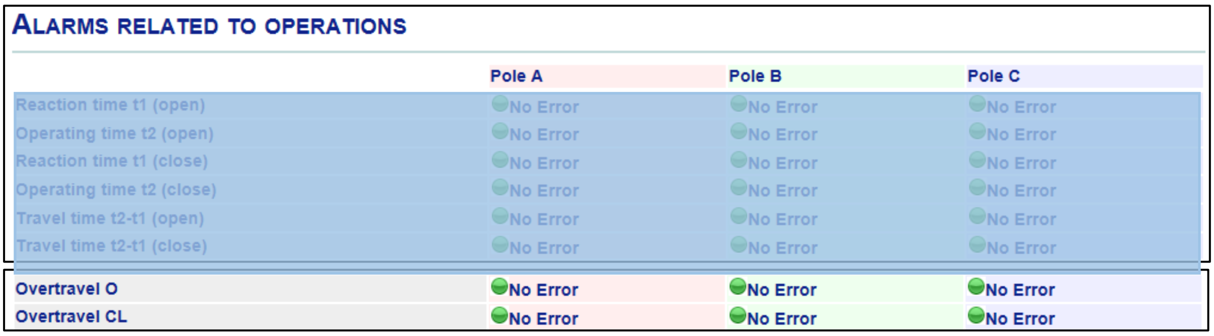


Figure 42 – Overtravel alarm

4.4 Timing Compensation

4.4.1 Introduction

The operating time of a circuit breaker varies depending on:

- the ambient temperature (greater friction in the mechanical movement at low temperature). This affects travel time.
- the voltage made available to the coil (lower DC voltage will mean that the coil takes longer to energise to the required level). This affects reaction time.

These variations do not reflect any issue with the circuit breaker and therefore should be compensated for before triggering an alarm to avoid false alarms.
These compensations can be activated or not, both for opening and closing operations, depending on the availability of the necessary compensation information.

The information required is detailed below and requires filling in a table during setup. Data for compensation should be made available from the CB manufacturer, but if it isn't available, then this table can be built up over time by reviewing the data of operations performed at different voltages and temperatures during the year.

HMI: Settings/Opening and Settings/Closing

Figure 43 – Timing compensation

4.4.2 Temperature compensation

The temperature compensation uses the ambient temperature value and a compensation table that can be customised for that CB type during setup.
It requires the presence of an outside ambient temperature value, either from a dedicated temperature sensor or from the gas sensor(s).
The temperature compensation is computed by shifting the timing alarm thresholds based on the change induced by the recorded ambient temperature when the operation took place compared to nominal 20°C. The change is extrapolated from the table.

Example below: the time threshold was entered for an ambient temperature of 20°C. At lower temperatures, extra time needs to be allowed so the compensating time should be 0ms for 20°C and +3ms at -25°C in the first example.

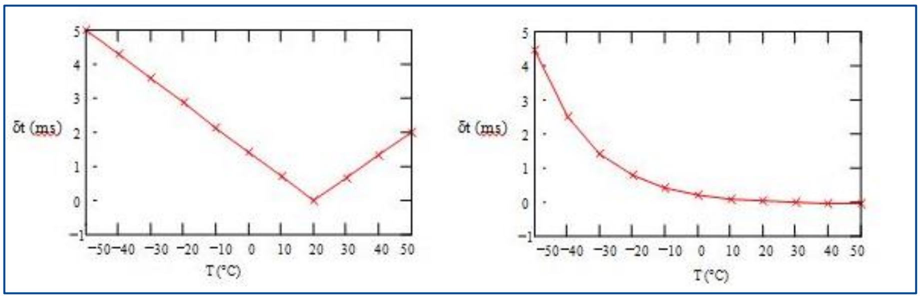


Figure 44 – Two examples of operating time temperature compensation values

4.4.3 Voltage compensation

The control line voltage compensation depends on the actual DC voltage being supplied to the coil when the command is sent compared to the nominal DC voltage.
It requires the presence of the DC voltage measurement sensor to provide the measured DC voltage information required.
The coil voltage compensation is computed by shifting the alarm thresholds based on the percentage change (up or down) of the coil voltage measured when the operation took place compared to the nominal voltage.

Example below: the time threshold was entered for a nominal DC voltage of 125V, at lower voltage extra time needs to be allowed so the compensating time should be 0ms for 0% and an increasing positive value of 6 milliseconds for a voltage of 90V DC (72% of nominal). Conversely, an increasing negative value is used as the voltage gets higher.

6. CONTACT TIMING TEST
Contacts timing were measured with Doble TR3100.

6.1 Closing Operation

SER. No.	CONTROL VOLTAGE (V DC)	CLOSING TIME (sec.)	VARIANCE BETWEEN PHASES (sec.)
201	90	0.0991	0.0019
	125	0.093	0.0021
	140	0.0913	0.001
TOLERANCE	125	LESS THAN 0.150	WITHIN 0.004

Figure 45 – Example of closing operating time changes with voltage changes

4.5 Setting Alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

4.5.1 Alarm Summary

This table summarises all the alarms that can be set in terms of operation timing monitoring.

Without travel sensor present:

Data obtained from CBW3	Thresholds		Alarms available	
	Min Alarm	Max Alarm	Digital	Relay
Number of opening operations, per pole	No	Yes	Yes	Yes
Number of closing operations, per pole	No	Yes	Yes	Yes
Pole discrepancy	No	Yes	Yes	Yes
52a contact switching time, per pole	No	Yes	Yes	Yes
52b contact switching time, per pole	No	Yes	Yes	
Opening reaction time (t1), per pole	Yes	Yes	Yes	Yes
Opening operation time (t2), per pole	Yes	Yes	Yes	Yes
Opening travel time (t2-t1), per pole	Yes	Yes	Yes	Yes
Opening reaction time (t1) discordance	No	Yes	Yes	Yes
Opening operation time (t2) discordance	No	Yes	Yes	Yes
Opening travel time (t2-t1) discordance	No	Yes	Yes	Yes
Opening contact separation speed, per pole	Yes	No	Yes	Yes
Closing reaction time (t1), per pole	Yes	Yes	Yes	Yes
Closing operation time (t2), per pole	Yes	Yes	Yes	Yes
Closing travel time (t2-t1), per pole	Yes	Yes	Yes	Yes
Closing reaction time (t1) discordance	No	Yes	Yes	Yes
Closing operation time (t2) discordance	No	Yes	Yes	Yes
Closing travel time (t2-t1) discordance	No	Yes	Yes	Yes

Additional alarms with travel sensor present:

Data obtained from CBW3	Thresholds		Alarms available	
	Min Alarm	Max Alarm	Digital	Relay
Open position issue (travel sensor vs 52a)	Yes		Yes	Yes
Close position issue (travel sensor vs 52b)	Yes		Yes	
Opening overtravel	No	Yes	Yes	Yes
Closing overtravel	No	Yes	Yes	Yes

4.5.2 Required data (without travel sensor present)

As seen in Section 4.2.5, the following distances (in mm) are required by the system to calculate the contact separation speed:

O	Start of open position	~ location of 52b sensor (ON when CB is OPEN)
C	Start of close position	~ location of 52a sensor (ON when CB is CLOSED)

Look at old timing test charts to ascertain how far they are located (travel distance when 52b contact changes state). Typically, O will be between 10-15mm (~10% of the total travel stroke) and C will be at ~90% of total travel stroke. Example: if stroke 135mm, C: ~120mm.
The difference (C-O) will be equivalent to ~80% of the total travel stroke and will determine the “distance travelled” during the opening or closing operation used to calculate the contact separation and touching speed:
Contact separation speed = distance travelled / opening travel time
Contact touching speed = distance travelled / closing travel time

4.5.3 Required data (with travel sensor present)

When a travel sensor is present and used, the following distances (in mm) are required by the system. The timing is measured when the travel sensor reaches these positions:

A: Open position	Always “0mm” as we start measuring from that position It is not required to enter that value
B: Open position limits	Tolerance on the open position Usually set to -5mm (min) and +5mm (max)
C: Start of open position	Same as in previous section above
D: Separation of contact	From open position to middle of arcing contact wipe range. Found in the CB manual. Example: 25mm
E: Start of close position	Same as in previous section above
F: Closed position limits	Found in the CB manual. Example 195-202mm. Mid-point is 198 -3mm/+4mm The mid-point becomes the closed position and the tolerances become the closed position limits
G: Closed position	Full stroke of CB

4.5.4 Threshold values

Maximum number of operations
Related to a requirement for a maintenance or inspection operation.

Pole discrepancy
It is set by default to 1s but can be customised. This means an alarm is generated if one pole remains in a different state for more than 1 second.

Maximum auxiliary contact 52a/b switching time
Maximum switching time is set by default to 200ms, but it can be customised.

Opening/Closing Reaction time (t1), per pole
Opening/Closing Operation time (t2), per pole
Opening/Closing Travel time (t2-t1), per pole
The nominal values of t1 and t2 are usually available from the CB User Manual or from the Factory Acceptance Test of the CB or from the latest test results.
The minimum values are the important ones

Opening/Closing Reaction time discordance
Opening/Closing Operation time discordance
Opening/Closing Travel time discordance
Data is usually available from the CB User Manual. A typical discordance threshold value would be <3-5ms, but it depends on the CB type and state.

Opening contact separation speed, per pole
Data is usually available from the User Manual or FAT. Typical values would be between 2 and 5m/s, but it depends on the CB type. Note that the result is heavily influenced by the distances set in the previous section above.

Open/Closed position issue
No thresholds are required as it only compares information from 52a/b sensors and travel sensors and an alarm is raised if they do not concur

Opening/Closing overtravel
Data is usually available from the CB User Manual. Typical values would be between 5 and 10mm, but it depends on the CB type. It is set by default to 8mm.

5 SF6 GAS MONITORING

5.1 General Description

If the circuit breaker being monitored uses SF6 gas (or gas mixture) to extinguish the arc, then the CBW3 can monitor the gas tanks for leaks.

During commissioning, a circuit breaker is filled with gas to its nominal filling density. The performance and even operation of a circuit breaker can be severely affected if the density of the gas contained in the circuit breaker falls too low. During the CB's life, it is therefore necessary to monitor the density of the gas not only to alert maintenance that a re-fill operation is needed before the CB locks itself (preventing operation) but also to detect any gas leak early so as to reduce cost, avoid penalties and save the environment.

5.1.1 Measurement principle

Because gas pressure varies with temperature (see figure below), pressure values cannot be compared over time unless they are temperature compensated. The variation of pressure with temperature is linear in the range of service (-25ºC to +50ºC). Comparisons are therefore made using either "pressure normalised at 20ºC" or "density" (expressed in kg/m3 or gr/l) which is independent.

The gas pressure and gas temperature are measured by the sensor and then the gas density is calculated using the Beattie-Bridgeman equation to take into account the thermodynamic laws of the gas (or gas mixture) used,.

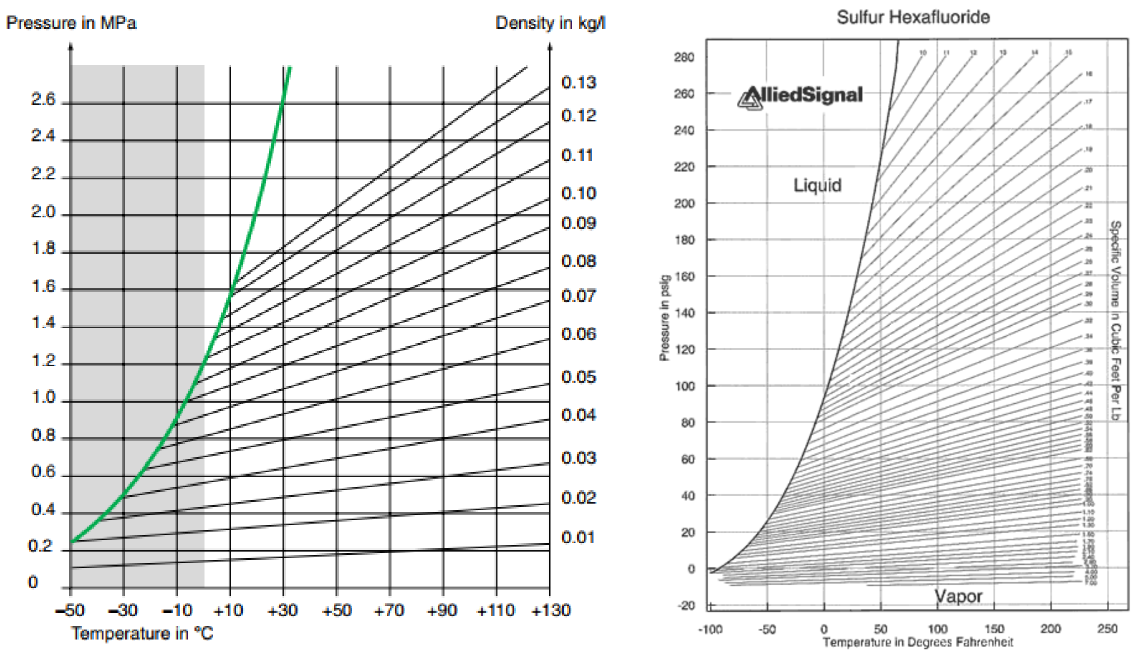


Figure 46 – Thermodynamic law applied to SF6 gas

These diagrams show lines of equivalent density where, along each line, the gas has the same density for various temperature/pressure combinations.

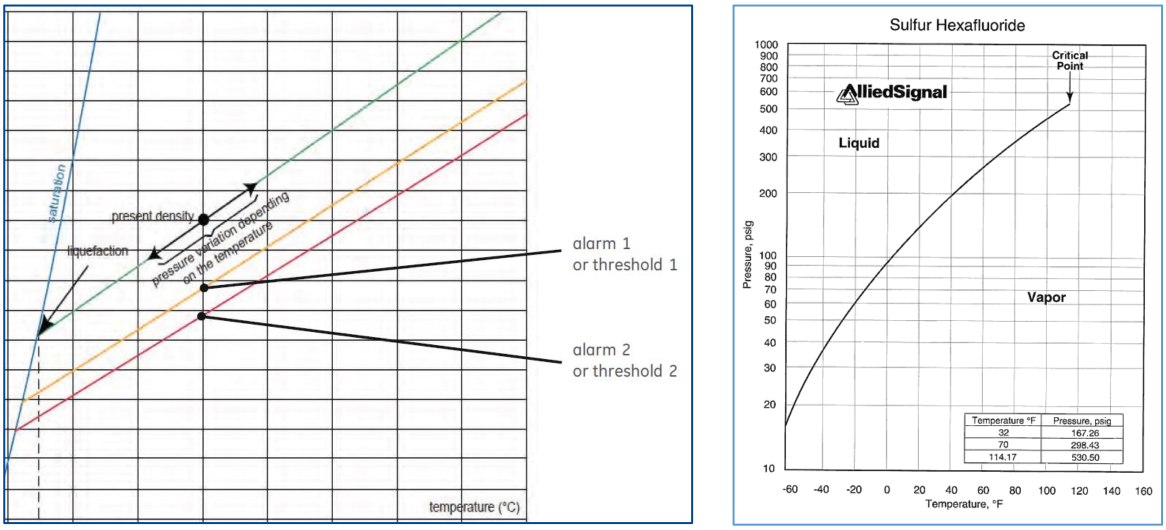


Figure 47 – Equivalent density lines and liquefaction curve

5.1.2 Gas sensors used

Two types of gas sensors are used depending on the options selected. Both output a digital signal (rather than an analogue signal) and measure the following parameters:

- Gas pressure and gas temperature
- Gas pressure and gas temperature + moisture level in gas

5.1.3 Sensor related alarms

In case the system loses communication with the gas sensor (for example if the cable has been cut) and therefore there is no answer from the digital sensor, then the sensor power supply is turned off and on again to reset the communication protocol and ensure that it is not a communication error. A counter is kept of the number of "no answer". The reset procedure may be repeated 3 times before the sensor is declared faulty and the "Sensor absence" alarm is raised.

HMI: Measurements/Alarms

ALARMS RELATED TO GAS

	Pole A	Pole B	Pole C
Threshold 1	No Error	No Error	No Error
Threshold 2	No Error	No Error	No Error
Threshold 3	No Error	No Error	No Error
Liquefaction	No Error	No Error	No Error
Short term extrapolation (threshold 2)	No Error	No Error	No Error
Long term extrapolation (threshold 1)	No Error	No Error	No Error
Sensor absence	No Error	No Error	No Error
Sensor data validity	No Error	No Error	No Error
Filling status of short term stack	Stack Not Enough	Stack Not Enough	Stack Not Enough
Filling status of long term stack	Stack Not Enough	Stack Not Enough	Stack Not Enough

Figure 48 – Gas sensor alarms

Whenever the sensor answers again, the "no answer" counter is reset automatically.

In case data is being received from the sensor but more than 50% of the digital data values received are incorrect or corrupted, then the "Sensor data validity" alarm is raised.

Data values are stored in "stacks" with the number of data values stored by the system corresponding to 2.5x times the short-term or long-term time horizon. This is to enable the calculation of an accurate long-term extrapolation:

- Short term stack: XXX minutes x 2.5 /10 values
- Long term stack: XXX days x 2.5 values

When there are not enough data points received to date to calculate the short or long-term trend, then the corresponding "stack not enough" alarm flag is set to indicate that the value in the register may not be accurate. The value is not displayed in the HMI and is replaced by a "-" instead.

5.2 Gas Measurements

5.2.1 Gas pressure/temperature/density

It is possible to visualise the following gas information in the HMI either for one of three separate tanks depending on the number of sensors installed:

HMI: Measurements/Gas

	Pole A
Serial number	110B0Z95
Gas pressure measured	0.09 psig
Gas temperature measured	26.01 °C
Gas density	1.19 g/l
Gas pressure at 20°C	-0.21 psig

GAS

	Pole A	Pole B	Pole C
Pressure	8.45 bar	8.58 bar	8.51 bar
Temperature	28.55 °C	28.45 °C	28.33 °C
Density	54.32 g/l	55.28 g/l	54.81 g/l
Gas pressure at 20°C	8.15 bar	8.28 bar	8.22 bar

Figure 49 – Gas measurements

The following information is available:

- Pressure: gas pressure in the tank measured by the sensor
- Temperature: gas temperature measured by the sensor
- Density: density computed from the pressure and temperature values measured for the gas or gas mixture used
- Gas pressure at 20°C: equivalent gas (or gas mixture) pressure calculated at a nominal 20°C temperature

As can be seen above, the display can be set (see setup instructions in the Installation Manual) to either show pressures in:

- Metric units: bar (absolute pressure in tank) or
- Imperial units psig (psi gauge, pressure relative to atmospheric pressure)

The gas sensor records the "absolute" value of the pressure inside the gas chamber and outputs it digitally in bar. This is what is shown in the HMI for metric units. If there is a gauge on the system, the gauge may show a "gauge pressure" (or pressure relative to atmospheric pressure) which is the difference between the absolute pressure measured and the atmospheric pressure at this altitude/temperature. Users will then experience a difference between the two readings of approximately 1 bar or 100 kPa (or 14.7 psi) .

<u>Warning</u>: Therefore take care when looking at the data or setting alarm limits. All metric pressures used in the CBW3 are "absolute" pressures in bar

The imperial unit output is different than for metric units. It is in psig (psi gauge) and it is a "relative" value as it is most often used in that way in non-metric regions. So, this is the same value as will be displayed by a gauge and there is no issue comparing them here.

5.2.2 Gas pressure alarms

Since all the nameplate values are usually given as gas pressures at 20°C, it is against this value that thresholds for alarms are entered. 3 standard thresholds are available:

- Threshold 1 "nearly too low": when the pressure falls below this threshold, the CB is still capable of fulfilling its function, but a gas refill action is required to prevent threshold 2 being reached.
- Threshold 2 "lock-out": when the pressure falls below this threshold, the CB is no longer capable of fulfilling its function. Depending on configuration, when this threshold is reached, the CB either is locked closed or opens automatically first.
- Threshold 3 "Overfilling": Used to indicate when the gas pressure in the CB is too high and there is a risk of overpressure at elevated temperature.

The threshold values are entered in the HMI under the settings section.

Each of these thresholds has a decreasing pressure threshold (minimum) and an increasing pressure threshold (maximum) to take care of hysteresis

HMI: Settings/Gas monitoring

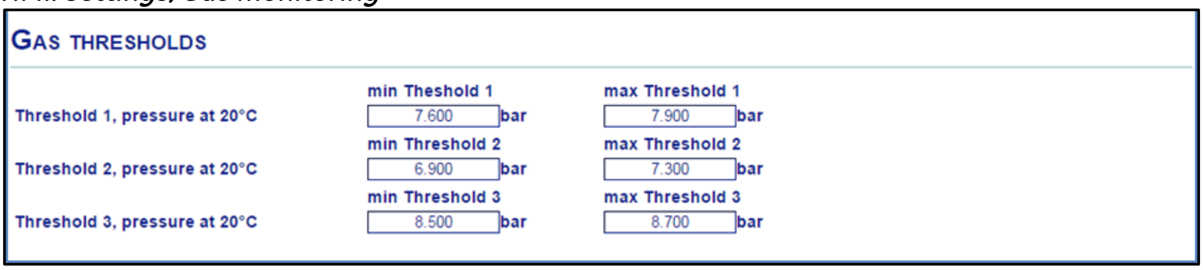


Figure 50 – gas pressure thresholds

The figure hereafter illustrates the passage of the various thresholds with their hysteresis during the change in gas density:

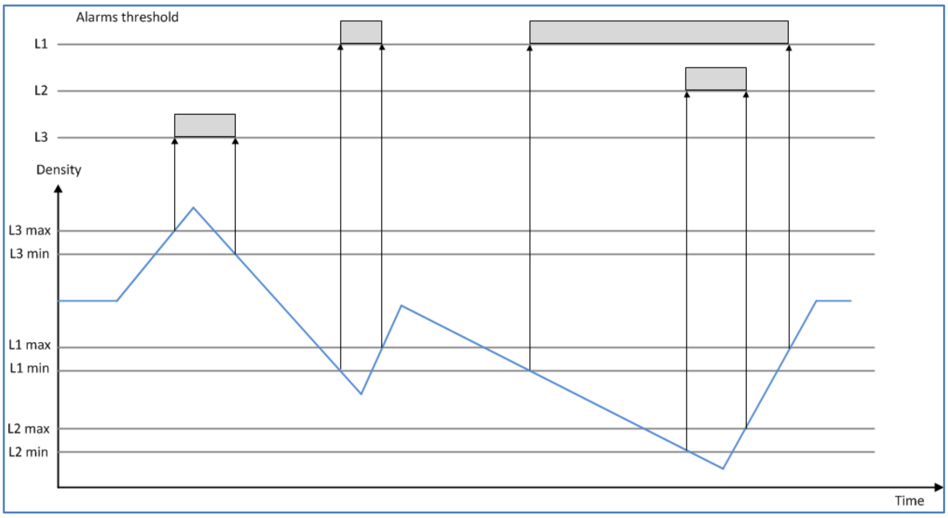


Figure 51 – Gas thresholds

A comparison is constantly made between the current gas pressure value normalised at 20ºC and the various thresholds (1, 2, 3) values set. If any is reached, then a threshold alarm is raised.

HMI: Measurements/Alarms

ALARMS RELATED TO GAS

	Pole A	Pole B	Pole C
Threshold 1	Alarm	OK	OK
Threshold 2	Alarm	OK	OK
Threshold 3	OK	OK	OK

Figure 52 – Gas alarms

5.2.3 Gas liquefaction risk

As seen in the graphs at the beginning of this section, the liquefaction curve indicates at which temperature and pressure the SF6 gas will change from gas phase to liquid phase. At normal ambient temperature, the liquefaction pressure is very high and is not a problem, but the curve drops rapidly, so that the liquefaction pressure gets closer to our operating pressure range when the temperature falls below freezing.

Therefore, if the gas temperature falls below 3ºC (37.4ºF), the liquefaction pressure for the gas (or gas mixture) at 20ºC is displayed so that it can be compared to the current gas pressure at 20ºC. Until the gas temperature reaches that point, a "-" value is displayed as it is not relevant to display it.

HMI: Measurements/Gas

Gas pressure at 20°C	-0.29 psig
SF6 liquefaction pressure at 20°C	-

Figure 53 – gas liquefaction pressure

If the current gas pressure value normalised at 20ºC falls below the known liquefaction pressure for the gas at 20ºC, then a liquefaction risk alarm is raised.

HMI: Measurements/Alarms

ALARMS RELATED TO GAS

	Pole A	Pole B	Pole C
Threshold 1	Alarm	OK	OK
Threshold 2	Alarm	OK	OK
Threshold 3	OK	OK	OK
Liquefaction	OK	OK	OK

Figure 54 – Gas alarms

5.2.4 Gas moisture level

The presence of a high level of moisture in the SF6 gas affects the dielectric withstand strength of the gas. Therefore, it is always desirable to test the moisture content of any gas being added to the CB before doing so. Failing that, the resulting gas moisture level can be measured as an option and displayed in the HMI. A special gas sensor is used that not only measures pressure, and temperature but also the moisture level in the gas.
The moisture level in the gas is continuously displayed in the HMI:

HMI: Measurements/Gas

Gas humidity measured	8581 ppmv

Figure 55 – Gas moisture level

The moisture level is indicated in ppmv: parts per million by volume.
This is the units most commonly used and quoted in the IEC standard 62271-1.
This value represents one million times the ratio of the volume of moisture (water vapor) present in the gas to the total volume of the gas (including water vapor).

An alarm can be set if the moisture level exceeds a maximum threshold:

HMI: Settings/Gas

GAS THRESHOLDS

	min Threshold 1	max Threshold 1
Pressure, Threshold 1 at 20°C	80.594 psig	87.266 psig
	min Threshold 2	max Threshold 2
Pressure, Threshold 2 at 20°C	70.441 psig	77.113 psig
	min Threshold 3	max Threshold 3
Pressure, Threshold 3 at 20°C	108.586 psig	111.487 psig
	Threshold H	Threshold HH
Long term gas % leak rate	0.00 %	0.00 %
Humidity, Excessive Threshold	0 ppmv	
Minimum time before alarm Excessive humidity	0.00 min	

Figure 56 – Moisture alarm threshold

Note: In order to avoid spurious alarms and because moisture measurements without averaging are notoriously variable and "spiky" in the short term (due to the influence of temperature), one can set a minimum time (in minutes) for the value to exceed the threshold before the alarm is raised.

HMI: Measurements/Alarms

ALARMS RELATED TO GAS

	Pole A	Pole B	Pole C
Threshold 1	Alarm	OK	OK
Threshold 2	Alarm	OK	OK
Threshold 3	OK	OK	OK
Liquefaction	OK	OK	OK
Short term extrapolation (threshold 2)	Alarm	OK	OK
Long term extrapolation (threshold 1)	Alarm	OK	OK
Sensor absence	OK	Alarm	Alarm
Sensor data validity	OK	Alarm	Alarm
Excessive humidity	Alarm	OK	OK

Figure 57 – Excessive moisture alarm

5.2.5 Short and long-term horizons

The rate of change of the pressure can be calculated using two sets of values:

- values in the "short-term" stack measured every 10 minutes
- values in the "long-term" stack measured every day

These values are used to calculate a linear extrapolation/forecast of the pressure in the future at the end of either the "short-term" or "long-term" time horizon.

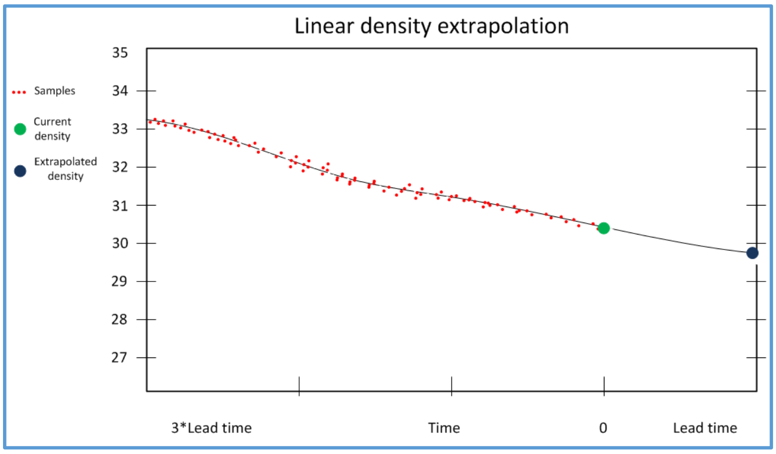


Figure 58 – Linear gas pressure extrapolation

- Short-term extrapolated pressure at 20°C: future value computed using linear regression and a history of 2.5x the short-term horizon
- Long-term extrapolated pressure at 20°C: future value computed using linear regression and a history of 2.5x the long-term horizon

Note: when there are not enough data points recorded to date to calculate the short or long-term trend, then the corresponding "stack not enough" alarm flag is set to indicate that the value in the register may not be accurate. The value is not displayed in the HMI and is replaced by a "-" instead.

The time horizons need to be defined first:

- The “short-term” time horizon can be set from 20 min to 1,200 minutes (20 hours)
- The “long-term” time horizon can be set from 20 days to 200 days

HMI: Settings/Gas monitoring

TIME EXTRAPOLATION

	Short-term (minutess)	Long-term (days)
Time projections	20 mn	20 j

Figure 59 – Time horizons setup

For “long-term” gas pressure trend calculations, the equivalent gas pressure at 20°C is recorded every night at 2AM . This allows for consistent conditions and the removal of external influences such as variations in line load or solar radiation.

For the “short-term” trend, the recordings are taken much more frequently and will show greater sensitivity to external influences. It is therefore much more difficult to calculate an accurate leakage rate by using a standard calculation.

When 3 independent gas volumes are monitored, by assuming that the leak will appear on only one volume, a reliable detection of relatively rapid leaks is carried out by comparing the measured extrapolated pressures of the three volumes taken two by two.

HMI: Measurements/Gas

	Pole A	Pole B	Pole C
Pressure	8.45 bar	8.58 bar	8.51 bar
Gas long term leak rate	0.000 mbar/y	0.000 mbar/y	0.000 mbar/y
Gas short term extrapolated pressure at 20°C	0.00 bar	0.00 bar	0.00 bar
Gas long term extrapolated pressure at 20°C	0.00 bar	0.00 bar	0.00 bar

Figure 60 – Forecasted gas pressure values

5.2.6 Gas leak rates

Whenever there is a leak in the gas system, this manifests itself as a drop in the gas pressure.

- Short-term pressure leak rate: in pressure unit per hour
- Long-term pressure leak rate: in pressure unit per year

It is possible to visualise the following gas information in the HMI either for one of three separate tanks depending on the number of sensors installed.
The leak rates calculated using the long-term horizon values are the most accurate.

The calculations use the following principles:

The short-term gas pressure leak rate = change in pressure at 20°C calculated using the values in the short-term stack, scaled to an hour (in pressure unit per hour)

The long-term gas pressure leak rate = change in pressure at 20°C calculated using the values in the long-term stack, scaled to a year (in pressure unit per year)

If not enough data is available to fill the short term or long term horizon set, then the value cannot be calculated and a "-" is displayed instead.

HMI: Measurements/Gas

Gas short term leak rate	0.021 psi/h
Gas long term leak rate (Value before refill)	-

Figure 61 – Gas leak rates (ganged CB)

	Pole A	Pole B	Pole C
Pressure	8.45 bar	8.58 bar	8.51 bar
SF6 liquefaction pressure at 20°C	0.00 bar	0.00 bar	0.00 bar
Gas short term leak rate	0.000 mbar/h	0.000 mbar/h	0.000 mbar/h
Gas long term leak rate	0.000 mbar/y	0.000 mbar/y	0.000 mbar/y
Gas short term extrapolated pressure at 20°C	0.00 bar	0.00 bar	0.00 bar
Gas long term extrapolated pressure at 20°C	0.00 bar	0.00 bar	0.00 bar

Figure 62 – Gas leak rates (IPO CB)

5.2.7 Gas alarms

Two alarms can be set on the extrapolated gas pressure values calculated. They rely on the thresholds set in section 5.2.2 above:

- The "long-term" alarm is raised if the extrapolated gas pressure at 20ºC is calculated to drop below the gas threshold 1 (nearly too low) that has been set
  - ➢ This means that the gas pressure/level will be below threshold 1 within the long-term horizon that has been set
- The "short-term" alarm is raised if the extrapolated gas pressure at 20ºC is calculated to drop below the gas threshold 2 (too low, lock-out) that has been set
  - ➢ This means that the gas pressure/level will be below threshold 2 within the short-term horizon that has been set

HMI: Measurements/Alarms

Alarms related to gas

	Pole A	Pole B	Pole C
Threshold 1	Alarm	OK	OK
Threshold 2	Alarm	OK	OK
Threshold 3	OK	OK	OK
Liquefaction	OK	OK	OK
Short term extrapolation (threshold 2)	Alarm	OK	OK
Long term extrapolation (threshold 1)	Alarm	OK	OK

Figure 63 – Gas alarms

5.2.8 Gas measurement history

On the HMI, you can view graphs displaying the history of the key gas parameters. Using the drop down menu, you can select either:

- Short term graphs: with resolution of 1 value every 10 minutes
- Long term graphs: with resolution of 1 value per day

HMI: Measurements/Gas

Figure 64 – gas graph selection

The “short term” selection displays the history of:

- Gas density
- Gas pressure at 20°C
- Gas temperature

The “long term” selection displays the history of:

- Gas density
- Gas pressure at 20°C
- Gas temperature
- Gas moisture

You can adjust the time span on all the graph’s X axis (narrow down the time-span to focus on a period) by selecting/highlighting it with your mouse.

HMI: Measurements/Gas/Short term

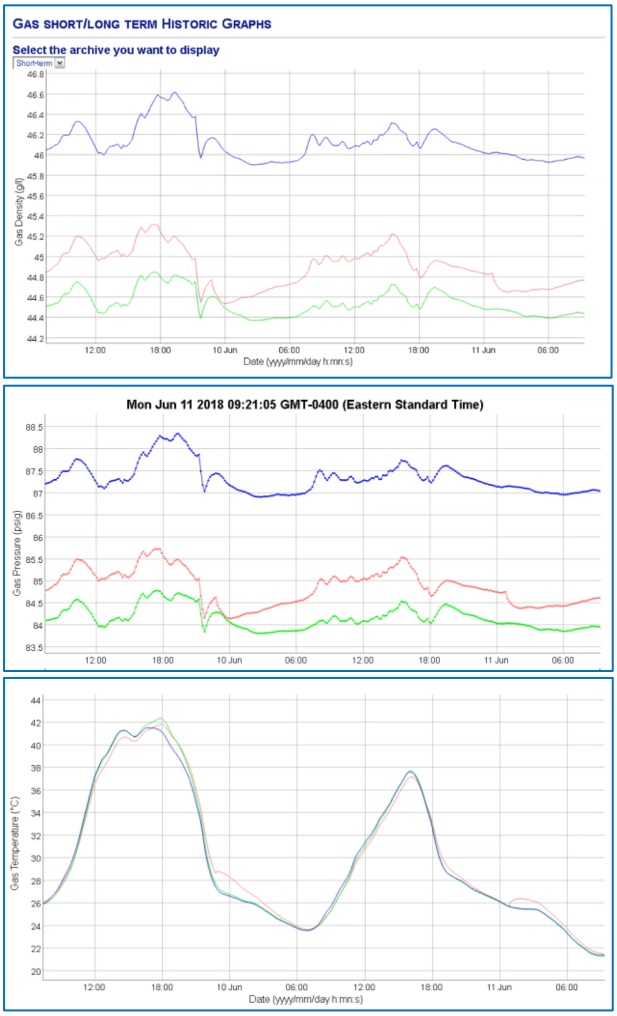


Figure 65 – Short-term gas graphs

HMI: Measurements/Gas/Long-term

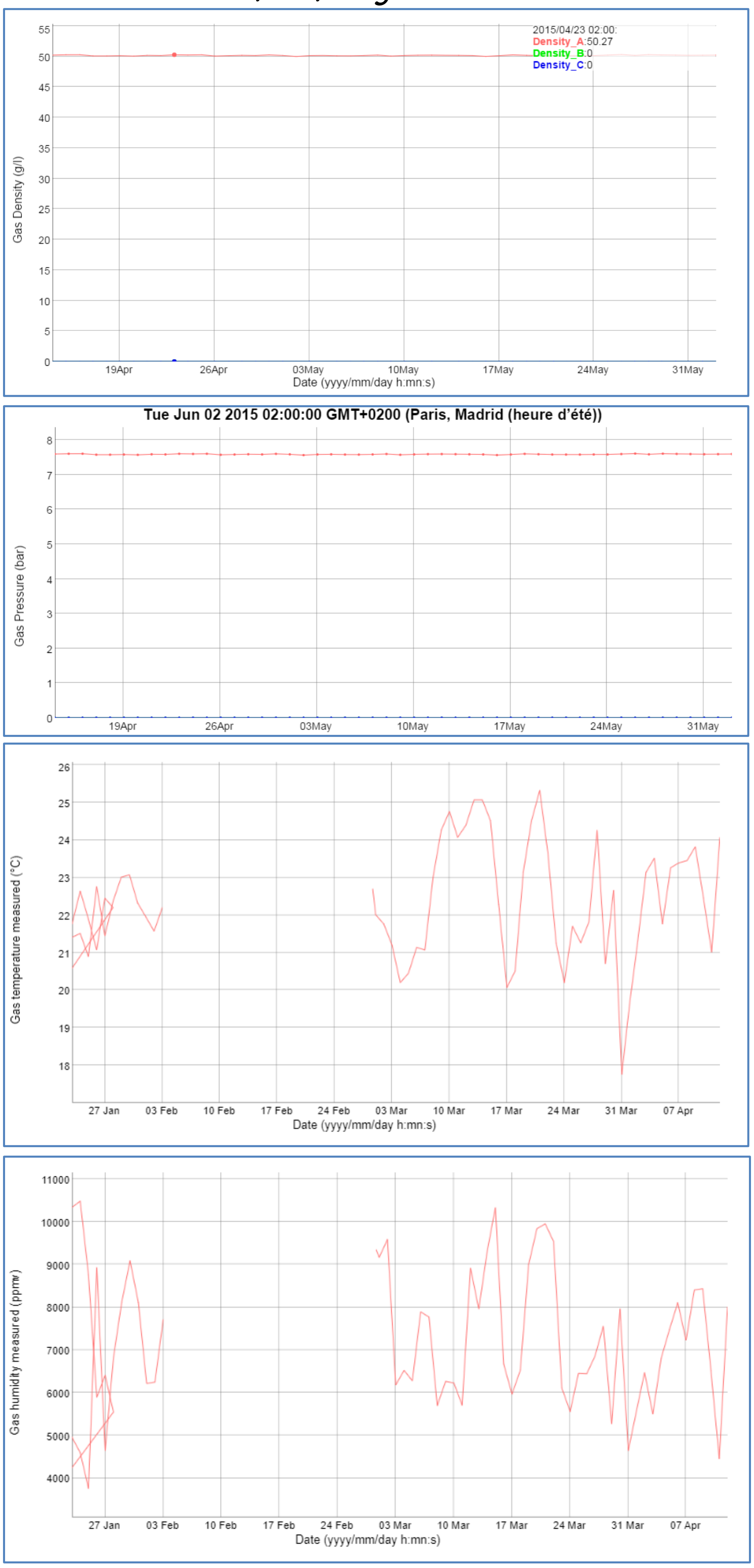


Figure 66 – Long-term gas graphs

5.3 Setting Alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

5.3.1 Alarm Summary

This table summarises all the alarms that can be set in terms of SF6 gas monitoring.

Data obtained from CBW3	Thresholds		Alarms available	
	Min Alarm	Max Alarm	Digital	Relay
Gas pressure at 20°C	Yes, 2x	Yes	Yes	Yes
Gas liquefaction risk	Yes	No	Yes	Yes
Gas moisture level	No	Yes	Yes	Yes
Gas short-term extrapolated pressure at 20°C	Yes	No	Yes	Yes
Gas long-term extrapolated pressure at 20°C	Yes	No	Yes	Yes

5.3.2 Required data

The data required to set alarm thresholds is readily available from the CB user's manual or from the CB's name plate:

63GDA-1-2-3: TEMP. COMP. PRESS. SWITCH-ALARM
SET AT 69 PSIG + or - 1.5 PSIG
63MTD-1-2-3-4-5-6 TEMP. COMP. PRESS. SWITCH-LOCKOUT
SET AT 62 PSIG + or - 2.5 PSIG

Figure 67 – Gas level data

The key bits of data required are:

- Nominal SF6 gas fill pressure at 20ºC — 75 psig in this example
- Minimum (T2 - lock-out) SF6 gas pressure at 20ºC — 62 psig in this example
- What level the low gas warning (T1) is set as — 69 psig in this example

5.3.1 Threshold values

Gas pressure level at 20ºC

The values for the different alarm thresholds (T1, T2, T3) are readily available from the CB user's manual or from the CB's name plate (as shown in the figures above).

If a key concern is to ensure that the CB does not run out of gas and remains operational, then the important thresholds could be:

- T2: The pressure at which the CB lock-out any operation and prevent any operation due to low SF6 gas pressure
- T1: A warning level a bit before that, to provide a warning that the system is getting close to lock-out pressure

If a key concern is to ensure that any gas leak is detected as early as possible so that it can be fixed before too much gas is lost, then the warning level threshold T1 above should be set to show:

- T1: A small decrease below nominal pressure to alert that there is a leak, closer to nominal and further away from the warning level of the density meter

In terms of tolerances (min/max values) for each threshold, we would suggest using from +/-3% to +/-5% around the nominal value. If the sensor is exposed to direct sunlight, larger tolerances should be set to avoid false alarms due to swings in sensor temperature rather than gas temperature.

Gas liquefaction risk

The gas liquefaction pressure is stored in memory so no need to enter any threshold.

Gas moisture level

CB manufacturers usually recommend a maximum level of moisture in ppmv. If no value is specified, then you can fall back on IEC 60376 standard recommendation: 120 ppmv.

Gas extrapolated pressures

The same thresholds 1 and 2 are used as for the gas pressures. If want earlier warning, then need to extend both the short term and the long-term horizon during setup.

6 CONTACT WEAR MONITORING

6.1 General Description

Most circuit breakers use special arcing contacts specifically designed to withstand the high energy that occurs during arcing when opening a circuit breaker. These have a finite service life and therefore need to be replaced when it has been reached.

With the appropriate sensors installed, the interrupted current during each CB opening operation can be monitored by enabling "Primary current measurement" in the setup:

HMI: Settings / Operations monitoring

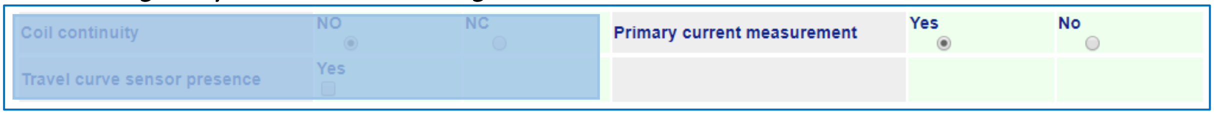


Figure 68 – Setting primary current measurement

The arcing time is measured and used to highlight any increase, showing degradation in the current interruption performance and possibly even a "non-interruption".

If we measure the current interrupted, square it and multiply it by the arcing time, we get the "I2T" measure of the energy that the contact has been subjected to. By keeping a cumulative total of this energy throughout the life of the contact, we can estimate the "contact wear" that has occurred due to electrical deterioration.

6.2 Interrupted Current

The AC current flowing through the breaker is monitored for each pole using the breaker's own primary current CTs (or nearby independent CTs) which are connected through further CTs to the CBW3 so that an image of its value can be recorded.

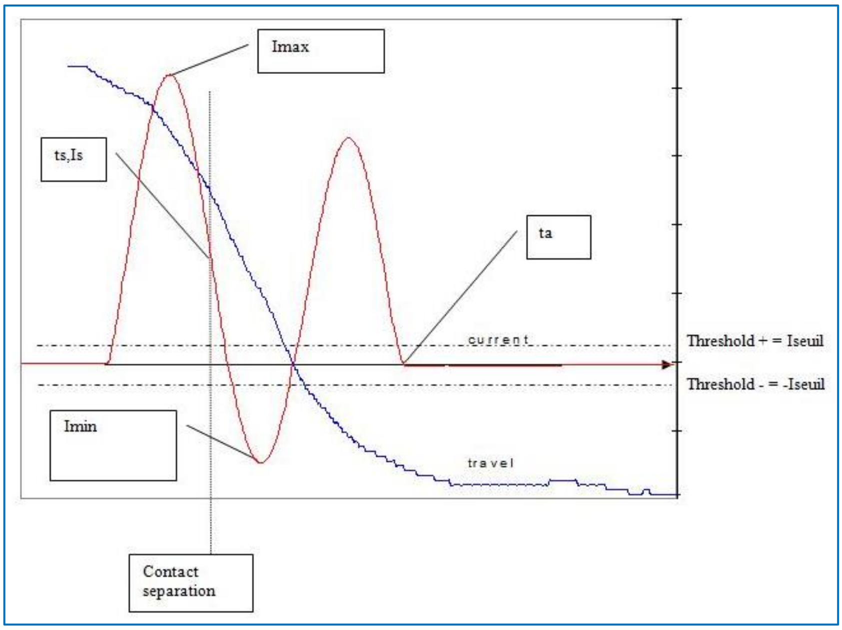


Figure 69 – Current before and during interruption

During the first 20 milliseconds following the command to the coil, the minimum and maximum peak current values (Imin and Imax) are determined. The value of the interrupted current is made using the equation: $Irms=(Imax-Imin)/2\sqrt{2}$.
This RMS interrupted current value for each pole is displayed in the HMI:

HMI: Measurements / last opening results

CONTACT WEAR

Interrupt current (RMS)	0.00 kA	0.00 kA	0.00 kA
Arcing time	0.00 ms	0.00 ms	0.00 ms
Cumulated Electrical Wear	0.00 kA^2.s	0.00 kA^2.s	0.00 kA^2.s

Figure 70 – Interrupted current value

A simplified current curve is displayed and archived with each operation (1 point every 400 micro seconds).

HMI: Measurements / Operations charts / Opening

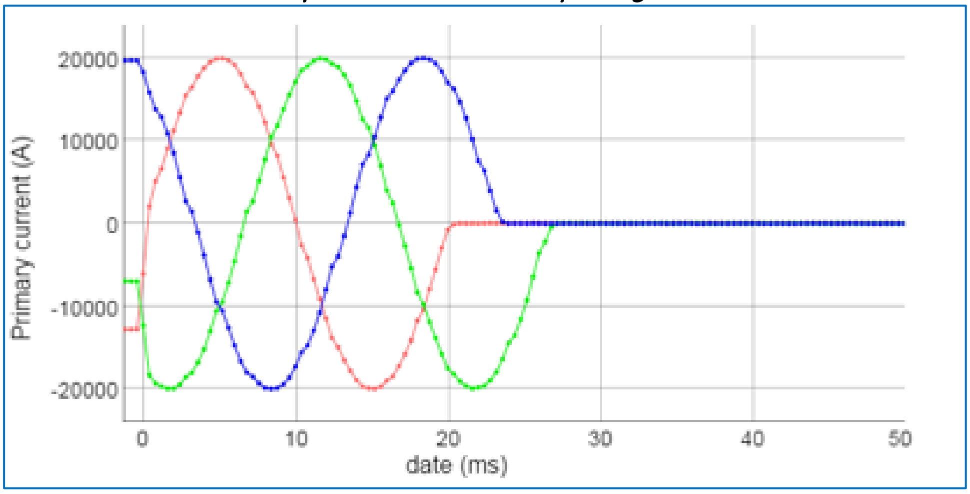


Figure 71 – Stored interrupted current curve

6.3 Arcing Time

6.3.1 Arcing time measurement

During an open operation, we are particularly interested in the "Arcing time". To calculate that, we need to know when the arcing starts, as we know that it finishes when the interrupted current CTs show a measured value of zero.

When there is a travel sensor present, we can determine exactly when the arcing contacts have physically separated (ts). We know the physical distance and know when it has been reached and therefore exactly when the arcing begins.

When a travel sensor is not present, we must estimate when the arcing begins. From the CB FAT and type tests, we know the original time-offset between when the CB starts to open (52a) and when the arcing contacts physically separate. We must rely on this separation time offset (ts-t1) which we input during the setup. It can be set differently per pole but is usually the same.

HMI: Settings / Opening

Start of open position	15.000 mm		
	A	B	C
Time from 52a to contact separation	1.0 ms	1.0 ms	10.0 ms

Figure 72 – Separation offset input

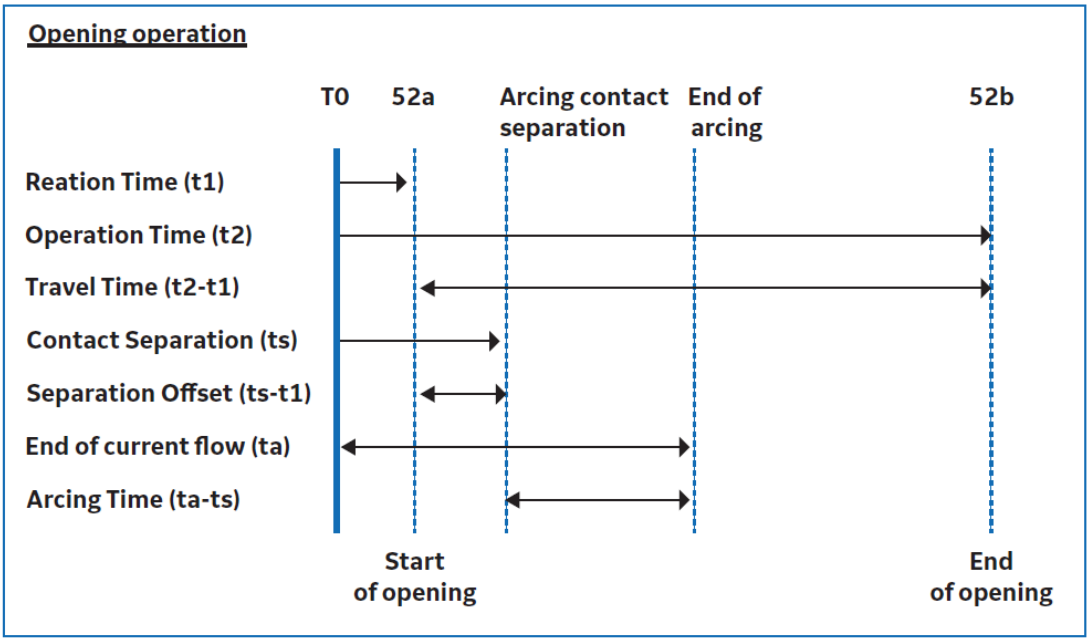


Figure 73 – Opening operation timing diagram

Using either of these two methods, the arcing time can be calculated and shown for each operation:

HMI: Measurements / last opening results

CONTACT WEAR

Interrupt current (RMS)	0.00 kA	0.00 kA	0.00 kA
Arcing time	0.00 ms	0.00 ms	0.00 ms
Cumulated Electrical Wear	0.00 kA^2.s	0.00 kA^2.s	0.00 kA^2.s

Figure 74 – Arcing time

6.3.2 Arcing time alarm

To receive a warning when the breaker is not interrupting the arc fast enough and the arcing time is too long, an alarm can be set against a maximum threshold:

HMI: Settings / Opening

ELECTRICAL WEAR

	threshold 1	threshold 2	Max number of opening operations	1000
Electrical wear thresholds	100.0 kA^2.s	150.0 kA^2.s	Max arcing time	0.0 ms

Figure 75 – Max arcing time threshold

Any alarm raised can be seen in the HMI:

HMI: Measurements / Alarms

ALARMS RELATED TO OPERATIONS

	Pole A	Pole B	Pole C
Excessive inrush current	OK	OK	OK
Excessive arcing time	OK	OK	OK

Figure 76 – Max arcing time threshold

6.4 Arcing contact wear

6.4.1 Contact electrical wear

During the period from the separation of the contacts (time Ts) and until definitive extinction of the current (time Ta), we cumulate the squared amps interrupted by the circuit breaker to estimate the electrical deterioration induced by the operation. We do that independently for each phase/pole.

$$\text{Electrical contact wear per operation} = \int f(\text{Irms}).(i(t))^2 dt$$

The function f above is set by default to: f(Irms)=1 for all Irms values.

The calculated value above represents the electrical deterioration for the operation under consideration. It is then added to the cumulative figure to obtain the total electrical wear per phase that the contact has endured so far.

$$\text{Cumulative electrical contact wear} = \Sigma \text{ Electrical contact wear per operation}$$

The cumulative electrical contact wear is displayed in the HMI after each operation:

HMI: Measurements / last opening results

CONTACT WEAR

Interrupt current (RMS)	0.00 kA	0.00 kA	0.00 kA
Arcing time	0.00 ms	0.00 ms	0.00 ms
Cumulated Electrical Wear	0.00 kA^2.s	0.00 kA^2.s	0.00 kA^2.s

Figure 77 – Contact electrical wear cumulative value

When the arcing contacts are replaced with new ones, the cumulative arcing contact wear needs to be reset to zero here:

HMI: Settings / Opening

OPERATION COUNTER AND ELECTRICAL WEAR

Set opening operation counter	0		Set
Set initial electrical wear	0.00	kA^2.s	Set

Figure 78 – Initial electrical wear setting

6.4.2 Contact wear alarm

To receive a warning when we are approaching the time when the arcing contacts need to be replaced due to wear, a comparison is made between the cumulative electrical wear and the maximum value specified by the manufacturer of the arcing contacts used.

Alarms can be set per pole and with two threshold values:

- Threshold 1: a warning level (approaching contact wear limit)
- Threshold 2: an alarm level (contacts need to be replaced)

HMI: Settings / Opening

ELECTRICAL WEAR

	threshold 1	threshold 2	
Electrical wear thresholds	100.0 kA^2.s	150.0 kA^2.s	max number of opening operations 1000

Figure 79 – Opening electrical wear thresholds

Any alarm raised can be seen in the HMI:

HMI: Measurements / Alarms

ALARMS RELATED TO OPERATIONS

	Pole A	Pole B	Pole C
Travel time t2-t1 discrepancy (close)	No Error	No Error	No Error
Electrical wear, threshold 1	No Error	No Error	No Error
Electrical wear, threshold 2	No Error	No Error	No Error

Figure 80 – Arcing contact electrical wear alarms

6.4.3 Non-linear contact wear

To account for the case where the electrical wear is not linear (higher wear at lower currents for examples), the function above can be modified and act as a magnifying (or reducing) factor for a given amp rating by entering a coefficient greater than 1.0 (or smaller) into a table. A spreadsheet can be used to upload the data.

HMI: Settings / Opening

ELECTRICAL WEAR WEIGHTING TABLE

coeff_0kA	1.00	coeff_2kA	1.00	coeff_4kA	1.00	coeff_6kA	1.00	coeff_8kA	1.00
coeff_10kA	1.00	coeff_12kA	1.00	coeff_14kA	1.00	coeff_16kA	1.00	coeff_18kA	1.00
coeff_20kA	1.00	coeff_22kA	1.00	coeff_24kA	1.00	coeff_26kA	1.00	coeff_28kA	1.00
coeff_30kA	1.00	coeff_32kA	1.00	coeff_34kA	1.00	coeff_36kA	1.00	coeff_38kA	1.00
coeff_40kA	1.00	coeff_42kA	1.00	coeff_44kA	1.00	coeff_46kA	1.00	coeff_48kA	1.00
coeff_50kA	1.00	coeff_52kA	1.00	coeff_54kA	1.00	coeff_56kA	1.00	coeff_58kA	1.00
coeff_60kA	1.00	coeff_62kA	1.00	coeff_64kA	1.00	coeff_66kA	1.00	coeff_68kA	1.00
coeff_70kA	1.00	coeff_72kA	1.00	coeff_74kA	1.00	coeff_76kA	1.00	coeff_78kA	1.00
coeff_80kA	1.00	coeff_82kA	1.00	coeff_84kA	1.00	coeff_86kA	1.00	coeff_88kA	1.00
coeff_90kA	1.00	coeff_92kA	1.00	coeff_94kA	1.00	coeff_96kA	1.00	coeff_98kA	1.00
coeff_100kA	1.00	coeff_102kA	1.00	coeff_104kA	1.00	coeff_106kA	1.00	coeff_108kA	1.00
coeff_110kA	1.00	coeff_112kA	1.00	coeff_114kA	1.00	coeff_116kA	1.00	coeff_118kA	1.00
coeff_120kA	1.00	coeff_52kA	1.00	coeff_124kA	1.00	coeff_126kA	1.00	coeff_128kA	1.00
coeff_130kA	1.00	coeff_132kA	1.00	coeff_134kA	1.00	coeff_136kA	1.00	coeff_138kA	1.00
coeff_140kA	1.00	coeff_142kA	1.00	coeff_144kA	1.00	coeff_146kA	1.00	coeff_148kA	1.00
coeff_150kA	1.00	coeff_152kA	1.00	coeff_154kA	1.00	coeff_156kA	1.00	coeff_158kA	1.00
coeff_160kA	1.00	coeff_162kA	1.00	coeff_164kA	1.00	coeff_166kA	1.00	coeff_168kA	1.00
coeff_170kA	1.00	coeff_172kA	1.00	coeff_174kA	1.00	coeff_176kA	1.00	coeff_178kA	1.00
coeff_180kA	1.00	coeff_182kA	1.00	coeff_184kA	1.00	coeff_186kA	1.00	coeff_188kA	1.00
coeff_190kA	1.00	coeff_192kA	1.00	coeff_194kA	1.00	coeff_196kA	1.00	coeff_198kA	1.00
coeff_200kA	1.00								

Browse... Upload

Figure 81 – Electrical wear weighting table

6.5 Setting Alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

6.5.1 Alarm summary

This table summarises all the alarms that can be set in terms of contact wear monitoring.

Data obtained from CBW3	Thresholds		Alarms available	
	Min Alarm	Max Alarm	Digital	Relay
Arcing time, per pole	No	Yes	Yes	Yes
Cumulative contact wear, per pole	No	Yes, 2x	Yes	Yes

Figure 82 – Contact wear alarm summary

6.5.2 Threshold values

Arcing time

In the absence of any other value, a maximum arcing time of one complete power cycle should be set (20ms for 50Hz in Europe/Asia, 17ms for 60Hz in NAM). This gives two chances for the arc to be extinguished when the current crosses the zero point.

Contact wear

Contact electrical wear thresholds T1 and T2 should be entered in accordance with the arcing contact manufacturer's recommendations and based on the operational planning lead-time required to purchase new ones and go replace them:

- T1 - approaching contact wear limit - for example 120 KA^2s
- T2 - contacts need to be replaced - for example 150 KA^2s

When installing on an already operational CB, we may need to enter during setup an estimate of the cumulative electrical wear to date. This is very tricky to do and should be avoided if possible as an incorrect guess may lead to an incorrect assumption as to the status of the contacts:

However, if the number of operations already performed is small and the history is known from the relays and fault recorders, you can rebuild the history and calculate the starting contact wear value.

As a last resort, a rough estimation can be made using a formula along these lines:

Multiplying the (standard line current x 2) squared, by the standard arcing time

The factor 2x is there to take into account that an estimated 1 in 10 operation will have been under extreme fault current 10x greater than normal. An even greater factor may be used (more conservative in terms of contact wear) depending on the operational history of the CB.

If not monitored

If this function is not being monitored and no sensors are present, then the threshold values should be set as such to avoid any erroneous alarm:

Figure 83 – Contact wear alarm summary

7 CONTROL CIRCUIT MONITORING

7.1 General description

This section covers monitoring the various CB command circuits and ensuring that any open or close command, sent manually or by a protection relay, can be executed.

7.2 DC Supply

7.2.1 DC supply level

While a circuit breaker will fail to receive any command if there is no DC voltage present or if it is extremely low, the time taken for the operation may be affected by the presence of a lower than nominal DC voltage (as has been explained in section 4.4.3). This can occur when the DC power is supplied by substation batteries not in optimal shape and when several operations are taking place at the same time.

With the appropriate sensor installed, the CBW3 can continually monitor DC voltage source 1 (and DC voltage source 2 if present) that supply the coil circuit voltage. The values are displayed in the HMI:

HMI: Measurement / Sensors

CIRCUIT BREAKER

Previous operation type	-----	-----	-----
Coil circuit voltage 1	0.0 V		
Coil circuit voltage 2	0.0 V		

Figure 84 – Continuous display of DC voltage for source 1 and 2

In addition, the voltage value at each opening or closing operation is stored with the operation data and is displayed with the other last operation values:

HMI: Measurements/Last opening and closing results

LAST OPENING MEASUREMENTS

	Pole A
Record Date	Thu Aug 22 12:19:40 2019
Coil circuit voltage 1	0.0 V
Coil circuit voltage 2	0.0 V
Ambient temperature	0.0 °C

LAST CLOSING MEASUREMENTS

	Pole A
Record Date	Thu Aug 22 12:20:39 2019
Coil circuit voltage 1	0.0 V
Ambient temperature	0.0 °C

Figure 85 – DC voltage in last operation measurements

7.2.2 DC supply alarm

An alarm can be set for each of the DC voltage sources with both a minimum and maximum threshold. Any alarm is displayed in the HMI.

HMI: Settings / Analogue channels

	type	low value	high value	DC min	DC max
DC voltage(X2)	0-10V	0.00	300.00	90	145

Figure 86 – DC voltage alarm thresholds

HMI: Measurements / Alarms

DC1 min voltage	Alarm
DC1 max voltage	OK
DC2 min voltage	Alarm
DC2 max voltage	OK

Figure 87 – DC voltage alarms

7.3 Coil Integrity

7.3.1 Coil current

With the appropriate CTs installed, the CBW3 can measure the current passing through each coil during an opening or closing operation. This is useful data to measure the integrity of the coil. Any partial reduction in the number of turns (reducing the ability of the coil to trip the latch) will change the impedance of the coil and will be detected through a resulting increase in the current used and a lengthening of the time to reach actuation level.

A small degradation of the coil can therefore be detected before it becomes problematic and the coil becomes open circuit, preventing the open/trip or close command from the protection relay being executed.

The following information is displayed in the HMI:

HMI: Measurement / Last opening results or last closing results

Coil Current

Mean coil current O1	0.0 A	0.0 A	0.0 A
Mean coil current O2	0.0 A	0.0 A	0.0 A
Coil charge O1	0.0 A.ms	0.0 A.ms	0.0 A.ms
Coil charge O2	0.0 A.ms	0.0 A.ms	0.0 A.ms

Coil Current

Mean coil current	0.0 A	0.0 A	0.0 A
Coil charge	0.0 A.ms	0.0 A.ms	0.0 A.ms

Figure 88 – Coil currents and coil charges

Two values are displayed for each pole, for the opening coils being used (open1 or open2) and for the closing coils:

- The “Mean coil current” is the average level of the coil current during the operations
- The “Coil actuation charge” is a measure used to reflect both coil current and actuation time, it is the area under the “coil current /vs/ time” curve and is the integration of the current multiplied by the time (A x ms).

The diagram below shows that the coil actuation charge can be longer (green curve) if the latch is sticking for example and the CB does not start moving as early as on the pink normal curve.
A damage coil will also show a higher current and a longer coil charge.

Figure 89 – Change in coil charge

Please note that in some protection schemes, both the opening 1 and backup opening 2 relays are fired “simultaneously” rather than only if the other one fails to open the breaker. In this case, it is impossible to predict which of the relay will operate which pole of the circuit breaker. The CBW3 system determines which signals it receives first and displays the corresponding current value. So please be aware that we could end up with different poles being triggered by different relays and so displaying a mixture of current values against both open1 and open2.

Data is recorded for the first 300ms (acquisition time) and a “coil current /vs/ time” curve is displayed in the HMI and stored:

HMI: Measurement / Operations charts / opening or closing

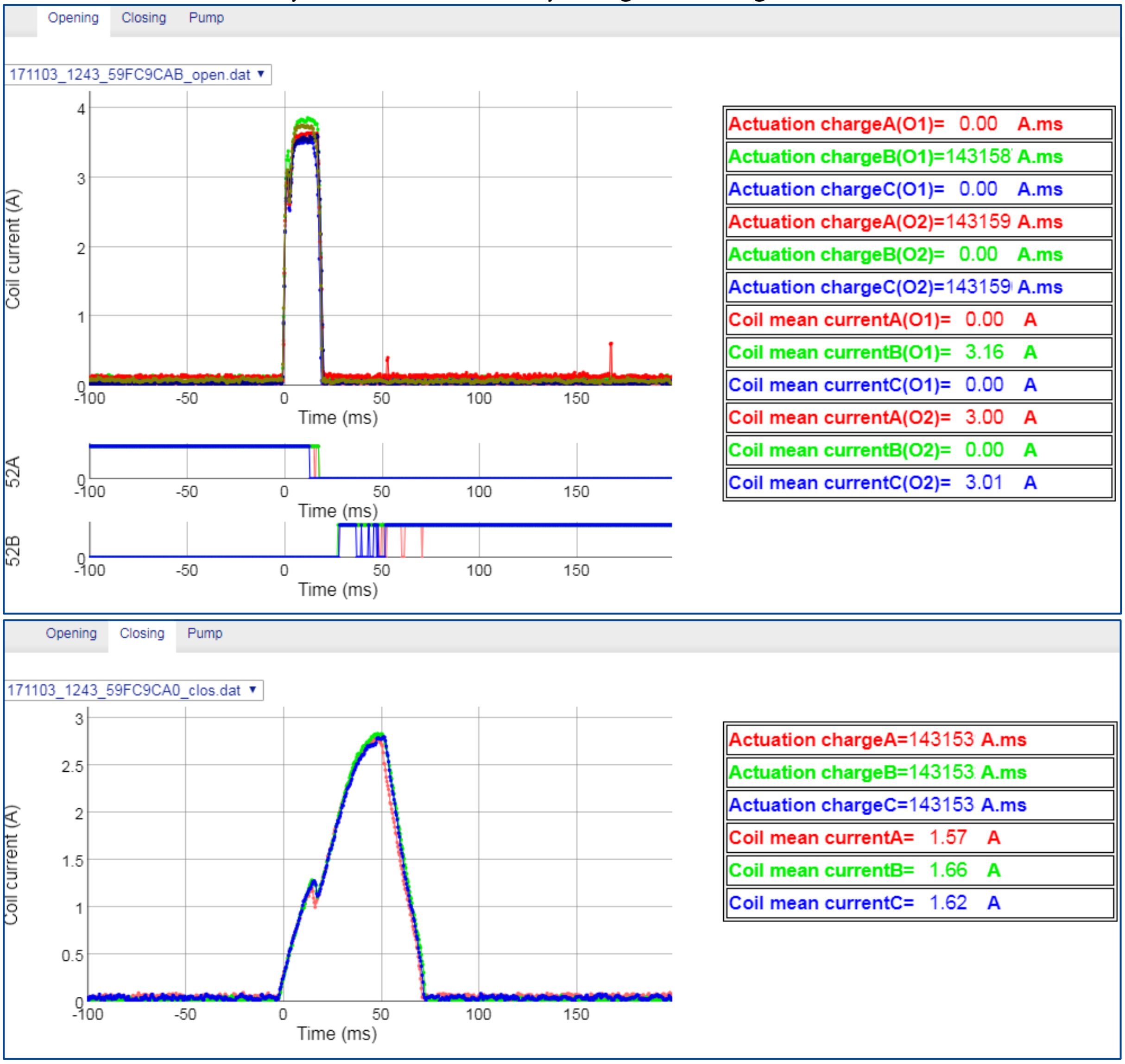


Figure 90 – Graph of coil current during opening or closing operation

The current curves from the last operations are stored so the user can review and compare any previously saved curve using the drop-down menu:

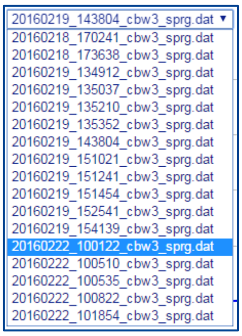


Figure 91 – Drop-down list of previous archives

7.3.2 Coil Current Alarm

An alarm can be set on a maximum threshold for the mean current used to actuate each coil (both during opening and during closing, if the coils are different):

HMI: Settings / Analog channels

	type	low value	high value	min charge O (A.ms)	max charge O (A.ms)	min charge C (A.ms)	max charge C (A.ms)
Coils current (X9)	+/-5V	-2.00	2.00	0.00	0.00	0.00	0.00
Maximum mean open coil current threshold	0.0 A						
Maximum mean close coil current threshold	0.0 A						

Figure 92 – Maximum mean current threshold settings

The resulting alarms are displayed in the HMI:

HMI: Measurements / Alarms

ALARMS RELATED TO OPERATIONS

Maximum mean open coil current 1	OK	OK	OK
Maximum mean close coil current	OK	OK	OK
Maximum mean open coil current 2	Alarm	Alarm	Alarm

Figure 93 – Coil charge alarms

7.3.3 Coil Charge Alarm

Alarms thresholds can be set during setup on:

- Minimum and maximum coil charge when opening
- Minimum and maximum coil charge when closing

HMI: Settings / Analog channels

	type	low value	high value	min charge O (A.ms)	max charge O (A.ms)	min charge C (A.ms)	max charge C (A.ms)
Coils current (X9)	4-20mA	-4.00	4.00	20.00	70.00	60.00	200.00

Figure 94 – Coil charge threshold settings

The resulting alarms are displayed in the HMI:

HMI: Measurements / Alarms

ALARMS RELATED TO OPERATIONS

max coil charge O1	No Error	No Error	No Error
min coil charge O1	No Error	No Error	No Error
max coil charge O2	No Error	No Error	No Error
min coil charge O2	No Error	No Error	No Error
max coil charge cl	No Error	No Error	No Error
min coil charge cl	No Error	No Error	No Error

Figure 95 – Coil charge alarms

7.4 Coil continuity

This is about continuously monitoring the continuity of the open/trip and close coil outside of when an operation is occurring. This is because there is no current flowing through the coil when no operation is taking place and therefore the coil current cannot be measured continuously.

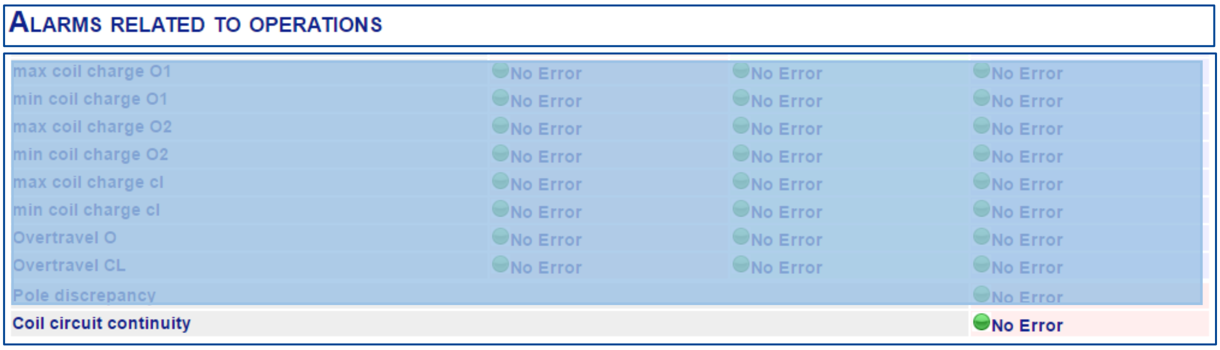
This is a more basic functionality than coil current measurements as it is all or nothing and only detects when the coil has gone open circuit, not when it is deteriorating.

While some modern relays already provide this functionality by continually checking the continuity of the control circuit, including the coil, this is not always the case, especially in older sub-stations with older relays.

With the appropriate sensors installed, the TCW continuity monitoring sensor injects a small current in the control line at either side of each coil, below the level needed to actuate the coil, in order to continually check that the coil is not open circuit.

The sensor has 3 channels and returns a digital true/false signal as to the good state of the coil. If at least one coil goes opens for >10s, then an alarm is raised and is displayed in the HMI:

HMI: Measurements / Alarms



ALARMS RELATED TO OPERATIONS

max coil charge O1	No Error	No Error	No Error
min coil charge O1	No Error	No Error	No Error
max coil charge O2	No Error	No Error	No Error
min coil charge O2	No Error	No Error	No Error
max coil charge cl	No Error	No Error	No Error
min coil charge cl	No Error	No Error	No Error
Overtravel O	No Error	No Error	No Error
Overtravel CL	No Error	No Error	No Error
Pole discrepancy			No Error
Coil circuit continuity			No Error

Figure 96 – HMI - Coil circuit continuity alarm

7.5 Setting Alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

7.5.1 Alarm summary

This table summarises all the alarms that can be set for control circuit monitoring:

<table>
<tr><th rowspan="2">Data obtained from CBW3</th><th colspan="2">Thresholds</th><th colspan="2">Alarms available</th></tr>
<tr><th>Min Alarm</th><th>Max Alarm</th><th>Digital</th><th>Relay</th></tr>
<tr><td>Coil circuit DC voltage source 1</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Coil circuit DC voltage source 2</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Mean coil current - Open 1, per pole</td><td>No</td><td>Yes</td><td>Yes</td><td rowspan="2">Yes</td></tr>
<tr><td>Mean coil current - Open 2, per pole</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Mean coil current - Close, per pole</td><td>No</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Coil actuation charge - Open 1, per pole</td><td>Yes</td><td>Yes</td><td>Yes</td><td rowspan="2">Yes</td></tr>
<tr><td>Coil actuation charge - Open 2, per pole</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Coil actuation charge - Close, per pole</td><td>Yes</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Coil continuity - Open 1, per pole</td><td colspan="2" rowspan="3">Yes</td><td rowspan="3">Yes</td><td rowspan="3">Yes</td></tr>
<tr><td>Coil continuity - Open 2, per pole</td></tr>
<tr><td>Coil continuity - Close, per pole</td></tr>
</table>

Figure 97 – Control circuit monitoring alarms

7.5.2 Threshold values

DC Voltage Supply

This depends on what acceptable level has been set as a policy or what minimum voltage is required by the coils. Normally, low voltage tests are run during the CB FAT and the lowest tested value could be used as the minimum alarm level. High level alarm is much less of a concern and can be effectively de-activated by using a very high threshold like 500V.

If this function is not being monitored and no sensor is present, then the values should be set as such to avoid any erroneous alarm:

HMI: Settings / Analogue channels

	type	low value	high value	DC min	DC max
DC voltage(X2)	0-10V	0.00	300.00	-100.00	500.00

Figure 98 – DC voltage default settings

Mean coil current

Using historical data, we can determine the minimum and maximum values of the mean coil current recorded. We can use them, as shown in the table below, to calculate the max threshold for both opening and closing operation:

	Opening	Closing
Nominal DC Voltage	A	
Coil resistance	C	D
Max mean coil current	(A/C)x((1+p)/100)	(A/D)x((1+p)/100)

Figure 99 – Mean coil current max threshold calculation

Where a percentage "p" margin is added to avoid spurious alarms.

If this function is not being monitored and no sensor is present, then the values should be set as such to avoid any erroneous alarm:

HMI: Settings / Analogue channels

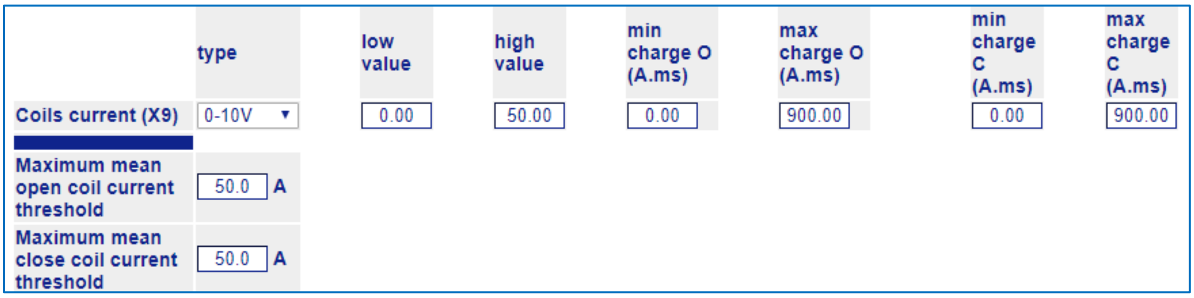


Figure 100 – Coil current and charge default settings

Coil charge

By looking at the historical data, we can determine the minimum and maximum values of the coil currents recorded and the time the coil is energised (which should be roughly equal to the reaction time measured). We can use them, as shown in the table below, to calculate the min and max coil charge for both opening and closing operation:

	Opening		Closing	
	Minimum	Maximum	Minimum	Maximum
Coil current	A	B	C	D
Time	E	F	G	H
Coil charge	(AxE)x((1-p)/100)	(BxF)x((1+p)/100)	(CxG)x((1-p)/100)	(DxH)x((1+p)/100)

Figure 101 – Coil charge alarm threshold calculation

Where a percentage "p" margin is subtracted from the lowest figure or added to the highest figure observed to avoid spurious alarms.

Coil circuit continuity

No thresholds are used as the coils are either “open circuit” or not and the TCW sensor acts as a relay.

If this function is not being monitored and no sensor is present, then ensure that the system is set as such to avoid any erroneous alarm:

HMI: Settings / Operations Monitoring

Figure 102 – Coil continuity default setting

8 STORED ENERGY SYSTEM MONITORING

8.1 General Description

A circuit breaker uses stored energy to open and close the contacts at speed. This stored energy is often supplied by a spring which is rewound/rearmed by an electric motor. But it can also take the form of pneumatic/hydraulic pressure which is built-up by an electric compressor/pump motor. The CBW3 attempts to cover most possibilities, whether there is one motor for all 3 poles or one motor per pole.
The type of energy storage mechanism used by the CB is entered in the settings:

HMI: Settings / Operations monitoring

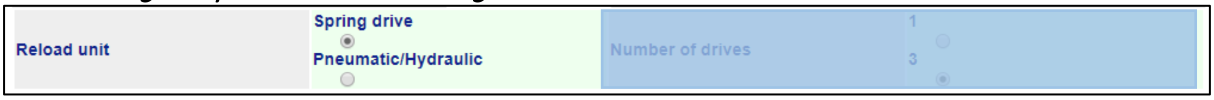


Figure 103 – Type of energy storage system

With spring mechanism, after each closing operation, a contact starts up the rewinding motor for the opening spring. When the spring reaches its fully rewound position, then the same contact is triggered and stops the rewinding motor. In IPO CB, there are 3 separate motors. The springs are rewound quite quickly (measured in seconds).

With a pneumatic/hydraulic mechanism, enough pressure is stored in a tank to enable several operations. The pump motor starts whenever the pressure in the storage tank falls below a certain level. When the required pressure is built up again, then a contact is triggered and stops the pump motor. A single pump and some valves are used to generate the pressure in 3 separate tanks in an IPO CB. The pump motor is usually quite large and takes much longer to restore pressure (measured in minutes).

8.2 Spring Mechanism

8.2.1 Spring rewind time

The spring rewinding motors are usually DC powered. With the motor on/off contacts connected to the system, we can acquire the time at which these contacts are activated and therefore measure the duration of the spring rewinding phase (which is the operating time of the rewinding motor). This is done for the single motor (in a ganged CB) or for the motors at each of the poles (in an IPO CB). The information is displayed in the HMI as part of the closing operation data:

The cumulated motor run time is also stored so that maintenance of the motor(s) can be performed when the prescribed number of run time hours has been reached.

The number of times the motor starts is also recorded, but it is the same as the number of closing operations so is not very significant with a spring drive.

HMI: Measurements / Last closing results

Drive Reload

Drive reload time	0.0 s	0.0 s	0.0 s
Cumulated drive reload time	3.47 min	3.47 min	3.47 min
Number of drive reload	19	19	24
Mean motor current	0.0 A	0.0 A	0.0 A
Max motor current	0.0 A	0.0 A	0.0 A

Figure 104 – Spring rewind data

When installing in a retrofit situation, the initial value for the counters can be entered:

HMI: Settings / Closing

Cumulated Spring rewinding time

Cumulated Spring reload time	0.00 min	Set

Number of Spring reload

Number of Spring reload	0	Set

Figure 105 – Spring motor initial values

8.2.2 Spring rewind time alarms

One can compare the spring rewind times recorded after each closing operation with a minimum and maximum duration threshold. An alarm is triggered if the value recorded falls outside these limits.
Any shortening of the time may indicate a partially broken spring and any lengthening may indicate additional friction or a problem with the motor itself.
An alarm can also be set when for the cumulative spring rewind motor run time:

HMI: Settings / Closing

Operations time

	max t1	min t1		max t2	min t2
Closing reaction time t1	40.0 ms	20.0 ms	Closing operation time t2	85.0 ms	75.0 ms
	min rewind	max rewind		t2-t1 max	t2-t1 min
Spring reload time	3.0 s	8.0 s	Closing travel time t2-t1	60.0 ms	40.0 ms
Max closing reaction time t1 discrepancy	5.0 ms		Max closing operation time t2 discrepancy	5.0 ms	
Max closing travel time t2-t1 discrepancy	5.0 ms		Minimum time since last closing	300.0 ms	
Maximum cumulated drive reload time	0.0 min				

Figure 106 – Spring rewind time thresholds

The alarms can be seen in the HMI:

HMI: Measurements / Alarms

ALARMS RELATED TO OPERATIONS

	Pole A	Pole B	Pole C
Reaction time t1 (open)	No Error	No Error	No Error
Operating time t2 (open)	No Error	No Error	No Error
Number of closing operations	No Error	No Error	No Error
Spring reload time	No Error	No Error	No Error
Close position	No Error	No Error	No Error
Overtravel O	No Error	No Error	No Error
Overtravel CL	No Error	No Error	No Error
Cumulated drive reload time	No Error	No Error	No Error

Figure 107 – Motor run time alarms

8.2.3 Rewind motor current

The CBW3 can measure the current used by the spring rewinding motor (usually a DC motor) in order to notice any change over time, possibly highlighting additional friction in the spring mechanism requiring more torque or a problem with the motor itself.

Both the mean (average) motor current and the maximum motor current (peak inrush current) are recorded and displayed in the HMI:

HMI: Measurements / Last closing results

DRIVE RELOAD

Drive reload time	0.0 s	0.0 s	0.0 s
Cumulated drive reload time	0.00 min	0.00 min	0.00 min
Number of drive reload	0	0	0
Mean motor current	0.0 A	0.0 A	0.0 A
Max motor current	0.0 A	0.0 A	0.0 A

Figure 108 – Spring rewind motor current data

8.2.4 Rewind current alarm

An alarm can be set on the maximum inrush current value of the motor by setting a “Max threshold” value.

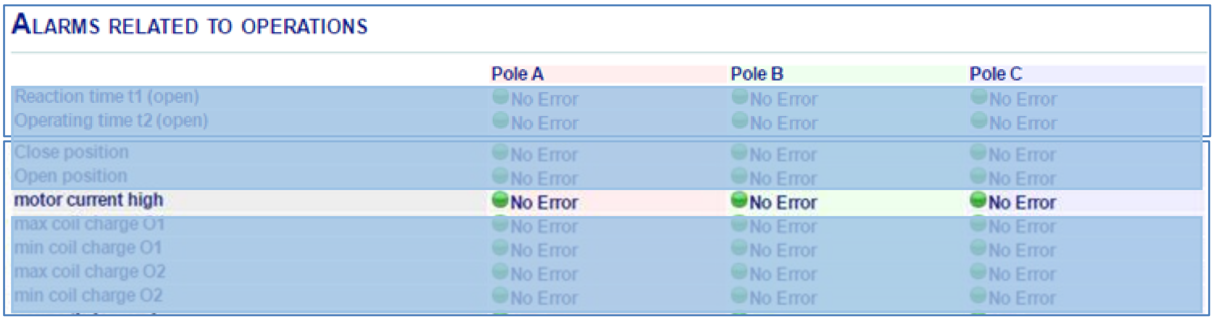
HMI: Settings / Analog channels

	type	low value	high value	max threshold
Motor current (X3)	4-20mA	-5.00	5.00	0.00

Figure 109 – Spring rewind motor current alarm threshold

The alarm is displayed when the threshold has been reached or exceeded:

HMI: Measurement / Alarms



Alarms related to operations

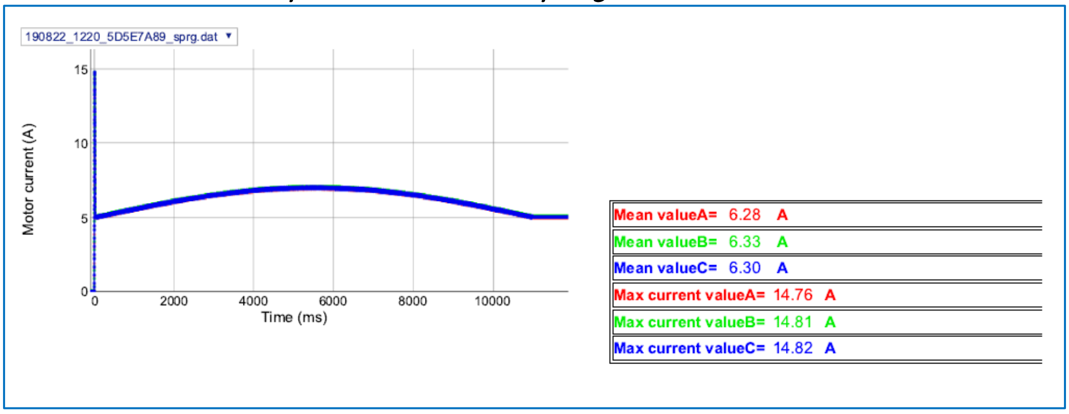
	Pole A	Pole B	Pole C
Reaction time t1 (open)	No Error	No Error	No Error
Operating time t2 (open)	No Error	No Error	No Error
Close position	No Error	No Error	No Error
Open position	No Error	No Error	No Error
motor current high	No Error	No Error	No Error
max coil charge O1	No Error	No Error	No Error
min coil charge O1	No Error	No Error	No Error
max coil charge O2	No Error	No Error	No Error
min coil charge O2	No Error	No Error	No Error

Figure 110 – Spring rewind motor current alarm setting

8.2.5 Spring operations charts

The motor current data is recorded for up to 12 seconds and a curve of current over time is graphed, displayed on the HMI and stored for future comparison:

HMI: Measurement / Operations charts / Spring



Via the HMI, the user is also able to display the previous curves saved in the CBW3:

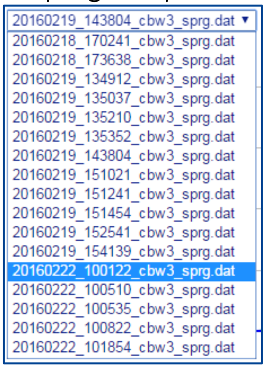


Figure 111 – Drop-down list of previous archives

In addition, the following historical graphs are also available:

- History of mean current value measured
- History of maximum current value measured
- History of spring rewinding time measured
- History of outside ambient temperature when these measurements were made

These graphs enable users to quickly compare the latest value obtained to historical values previously recorded and graphically visualise any change/deviation.

HMI: Measurements / Operations charts / Spring

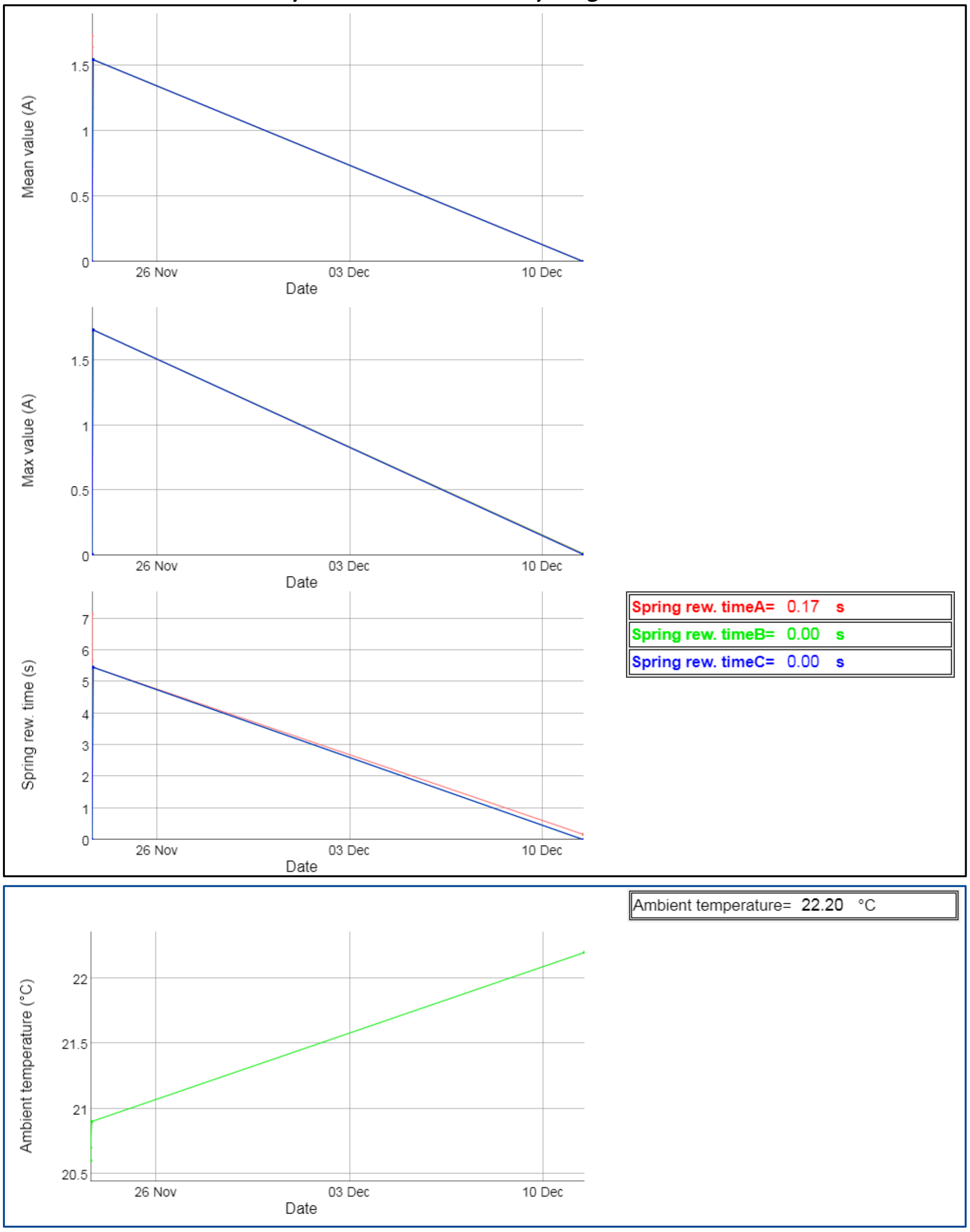


Figure 112 – Operation charts for spring rewind

8.3 Setting Spring Alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

8.3.1 Alarm summary

This table summarises all the alarms that can be set for monitoring the spring energy storage mechanism:

Data obtained from CBW3	Thresholds		Alarms available	
	Min Alarm	Max Alarm	Digital	Relay
Spring rewind time	Yes	Yes	Yes	Yes
Cumulative spring rewind motor time	No	Yes	Yes	Yes
Peak rewind motor inrush current	No	Yes	Yes	Yes

Figure 113 – Spring energy storage mechanism alarms

8.3.2 Alarm thresholds

Spring rewind time

Data is usually available from the User Manual. A possible value could be 25s, but it depends on the CB type.

Cumulative spring rewind motor run time

Data is usually available from the motor's maintenance manual. A possible value could be 12,000 min (200 hr), but it depends on the motor type.

Peak spring rewind motor current

Data is usually available from the motor's maintenance manual. A possible value could be 25A, but it depends on the CB type.

To avoid any alarms set as follows:

	type	low value	high value	max threshold
Motor current (X3)	0-10V	0.00	20.00	100.00

8.4 Pneumatic/hydraulic Pressure

8.4.1 Pump operation time

There is usually only one large AC powered compressor/pump to generate the pneumatic or hydraulic pressure, but the number of motors/pumps can be configured to either 1 or 3 using the drop-down selector:

HMI: Measurement / Settings / Pump

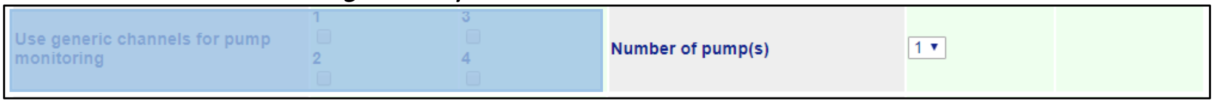


Figure 114 – Number of pumps setup

This compressor motor is controlled by a pressure sensor, but by connecting a relay in parallel to the motor AC supply, we can generate motor on/off signals to acquire the date/time at which these contacts are activated. We can therefore timestamp when the compressor pump operates and measure the duration of its operation.

HMI: Measurements / Pump

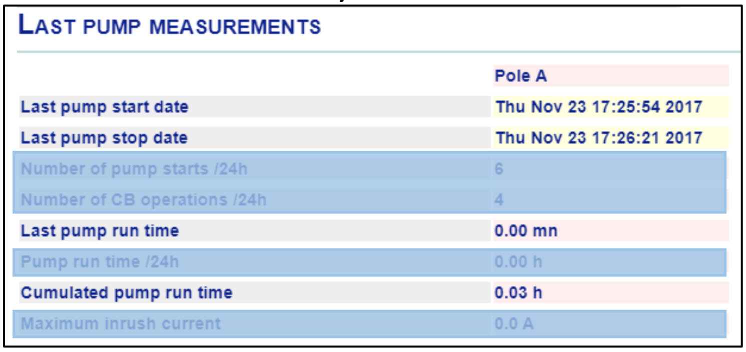


Figure 115 – Pump run time

The pump run time is measured for comparison purposes and to spot if the compressor is needing more time to restore the desired pressure, a possible indication of pump problem. But the results can be affected if the CB is operated at the same time as the compressor is trying to restore pressure.

The cumulated pump run time is also displayed so that maintenance of the pump(s) can be performed when the prescribed number of run time hours has been reached.

Because the pump motor only starts whenever the pressure in the storage tank falls below a certain level and this depends on the number and types of operations previously performed, it is difficult to predict when the pump will operate. What is key is that the pump should not operate if no CB operations were performed, as the only reason for the pressure to drop and require the pump to operate would be a leak in the system.

Therefore, resetting every day at midnight, we also report in the HMI:

- The number of pump operations in the last 24 hours
- The number of CB operations in the last 24 hours
- The total pump run time in the last 24 hours

HMI: Measurements / Pump

Last pump measurements

	Pole A
Last pump start date	Thu Nov 23 17:25:54 2017
Last pump stop date	Thu Nov 23 17:26:21 2017
Number of pump starts /24h	6
Number of CB operations /24h	4
Last pump run time	0.00 mn
Pump run time /24h	0.00 h
Cumulated pump run time	0.03 h
Maximum inrush current	0.0 A

Figure 116 – Pump data in last 24hr

In addition, the following graphs are shown to ease the comparison and graphically detect anomalies:

- History of the number of pump operations in the last 24 hours
- History of the number of CB operations in the last 24 hours
- History of the total pump run time in the last 24 hours

HMI: Measurements / Pump

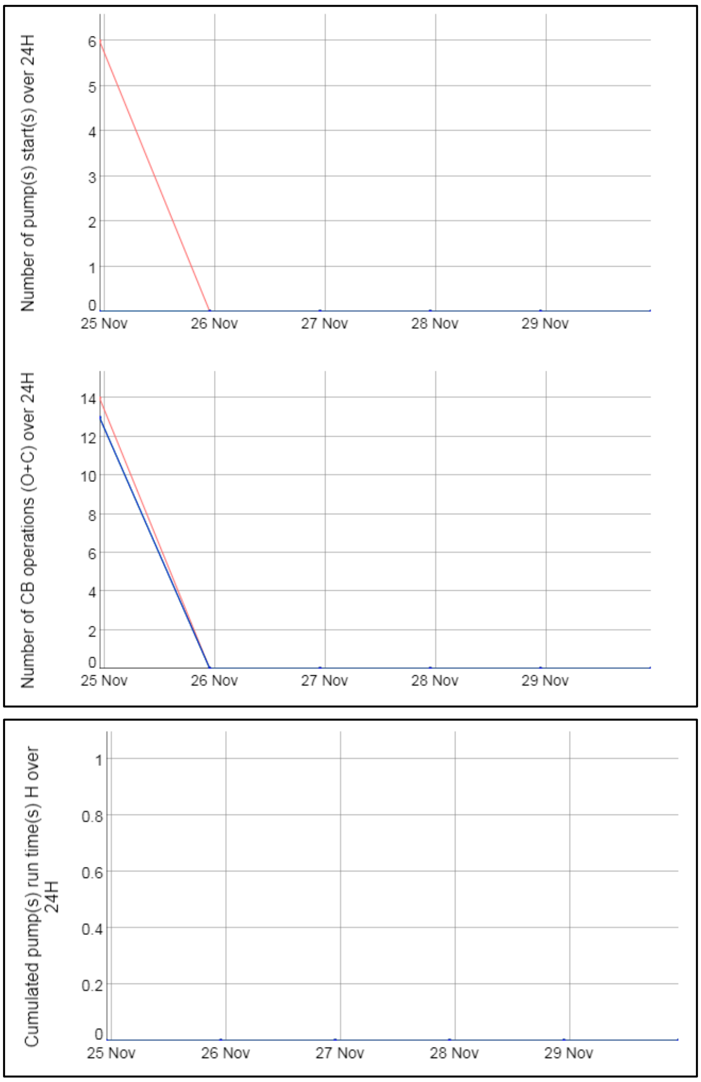


Figure 117 – Historical pump data graphs

8.4.2 Pump operation alarms

One can set threshold alarms on the following daily measurements:

- Maximum number of pump starts in the last 24 hours
- Maximum total pump operation time in the last 24 hours

An alarm can also be set for the cumulative pump motor run time to alert that some form of maintenance is now due.

HMI: Settings / Pump

Max number of pump starts /24h	0	Max pump run time /24h	0.00 h
Max cumulated pump run time	0.00 h	Max inrush current	0.00 A

Figure 118 – Pump operations alarm thresholds

When installing in a retrofit situation, the initial value for the pump/compressor run time can be entered:

HMI: Settings / Pump

SET INITIAL CUMULATED PUMP RUN TIME	
Set cumulated pump run time A	0.00 h

Figure 119 – Pump run time initial value

The various alarms can be seen in the HMI:

HMI: Measurements / Alarms

Number of pump starts /24h	OK
Pump run time /24h	OK
Cumulated pump run time	OK

Figure 120 – Pump operation alarms

8.4.1 Pump motor current

Using a CT, the CBW3 is able to measure the initial inrush current used by the compressor/pump motor(s) in order to notice any changes.

A graph of the first 12 seconds of the “pump motor current /vs/ time” curve is displayed in the HMI. It is used to visualise the peak inrush current at startup:

HMI: Measurement / Operations charts / Pump

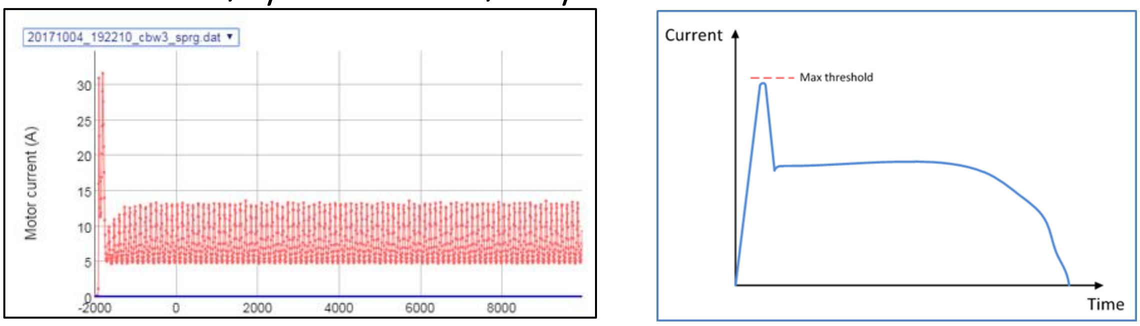


Figure 121 – Pump motor current

The curves are stored and previous curves can be retrieved and displayed via the HMI:

20160219_143804_cbw3_sprg.dat ▼
20160218_170241_cbw3_sprg.dat
20160218_173638_cbw3_sprg.dat
20160219_134912_cbw3_sprg.dat
20160219_135037_cbw3_sprg.dat
20160219_135210_cbw3_sprg.dat
20160219_135352_cbw3_sprg.dat
20160219_143804_cbw3_sprg.dat
20160219_151021_cbw3_sprg.dat
20160219_151241_cbw3_sprg.dat
20160219_151454_cbw3_sprg.dat
20160219_152541_cbw3_sprg.dat
20160219_154139_cbw3_sprg.dat
20160222_100122_cbw3_sprg.dat
20160222_100510_cbw3_sprg.dat
20160222_100535_cbw3_sprg.dat
20160222_100822_cbw3_sprg.dat
20160222_101854_cbw3_sprg.dat

Figure 122 – Drop-down list of previous archives

The maximum pump motor current (peak inrush current) is displayed in the HMI:

HMI: Measurements / Pump

LAST PUMP MEASUREMENTS

	Pole A
Last pump start date	Sun Jan 0 00:00:00 1900
Last pump stop date	Sun Jan 0 00:00:00 1900
Number of pump starts /24h	0
Number of CB operations /24h	0
Last pump run time	0.00 mn
Pump run time /24h	0.00 h
Cumulated pump run time	0.00 h
Maximum inrush current	**0.0 A**

Figure 123 – Maximum inrush current

8.4.2 Pump motor current alarm

An alarm can be set on the maximum inrush current value of the pump motor by setting the "Max threshold" value.

HMI: Settings / Analog channels

	type	low value	high value	max threshold
Motor current (X3)	4-20mA ▼	-5.00	5.00	0.00

Figure 124 – Pump motor inrush current maximum threshold setting

The alarm is displayed when the threshold has been reached:

HMI: Measurement / Alarms

ALARMS RELATED TO OPERATIONS

	Pole A	Pole B	Pole C
Reaction time t1 (open)	No Error	No Error	No Error
Operating time t2 (open)	No Error	No Error	No Error
Close position	No Error	No Error	No Error
Open position	No Error	No Error	No Error
motor current high	No Error	No Error	No Error
max coil charge O1	No Error	No Error	No Error
min coil charge O1	No Error	No Error	No Error
max coil charge O2	No Error	No Error	No Error
min coil charge O2	No Error	No Error	No Error

Figure 125 – Pump motor inrush current alarm

8.4.3 Related additional sensors

Additional information specific to pneumatic/hydraulic stored energy systems are often requested, for example:

- AC supply voltage to the pump
- Pressure in pneumatic/hydraulic storage tank

This information can be monitored using sensors connected to the generic analogue channel inputs. Values can be displayed in the HMI and alarms can be set. Please refer to section 11 for more details.

The interesting feature is that the additional sensors relating to the pump operation can be grouped on the pump HMI page for ease of viewing. This is done by selecting which of the generic channels (1 to 4) are relevant to display in the pump page:

HMI: Measurement / Settings / Pump

Use generic channels for pump monitoring	1 ☐ 2 ☑	3 ☑ 4 ☐	Number of pump(s)	1

Figure 126 – Display of generic channels

As an example, if we connect the sensors that give us the above-mentioned information to generic channels 2 and 3 and we select these 2 channels to be displayed as part of the pump data, then we would see the following information in the HMI:

HMI: Measurements / Pump

Last pump measurements

	Pole A
Last pump start date	Sun Jan 0 00:00:00 1900
Last pump stop date	Sun Jan 0 00:00:00 1900
Number of pump starts /24h	0
Number of CB operations /24h	0
Last pump run time	0.00 mn
Pump run time /24h	0.00 h
Cumulated pump run time	0.00 h
Maximum inrush current	0.0 A

Additional channels

AC supply voltage	0.0 V
Pneumatic tank pressure	0.0 psig

Figure 127 – Generic channel display

The description and the units associated with the generic channels are configurable. See Section 11 for more details.

These selected generic values can also be stored in the “pump” COMTRADE file. See Section 11 for more details.

Note that when generic channels are selected to appear in the “Measurements/pump” page of the HMI, they no longer appear in the “Measurements/Sensors” page of the HMI.

8.5 Setting Pump Alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

8.5.1 Alarm summary

This table summarises all the alarms that can be set for monitoring the hydraulic/pneumatic energy storage mechanism:

Data obtained from CBW3	Thresholds		Alarms available	
	Min Alarm	Max Alarm	Digital	Relay
Number of pump starts /24h	No	Yes	Yes	Yes
Pump run time /24h	No	Yes	Yes	Yes
Cumulative pump run time	No	Yes	Yes	Yes
Pump motor inrush current	No	Yes	Yes	Yes

Figure 128 – Pump based energy storage mechanism alarms

8.5.2 Alarm thresholds

Number of pump starts /24h

In some instances, an engineered leak ensures that the pump starts every couple of days, so this should be considered. Depending on how often the breaker is supposed to operate, more than 2 or 3 pump starts per day should be flagged.

Pump run time /24h

Depending on how long the pump cycle takes (typically 15-20minutes), the pump run time should not exceed 60 minutes per day.

Cumulative pump motor run time

Data is usually available from the motor's maintenance manual. A possible value could be 12,000 min (200 hr), but it depends on the motor type.

Peak pump motor inrush current

Data is usually available from the motor's maintenance manual. A possible value could be 50A, but it depends on the motor type.

To avoid any alarms set as follows:

	type	low value	high value	max threshold
Motor current (X3)	0-10V	0.00	20.00	100.00

9 CB OPERATION GRAPHS

9.1 HMI Graphs

9.1.1 Operation Graphs

We have already seen that you can view various operation graphs in the web HMI:

9.1.1.1 Opening Operation Graphs

HMI: Measurements / Operations charts / Opening

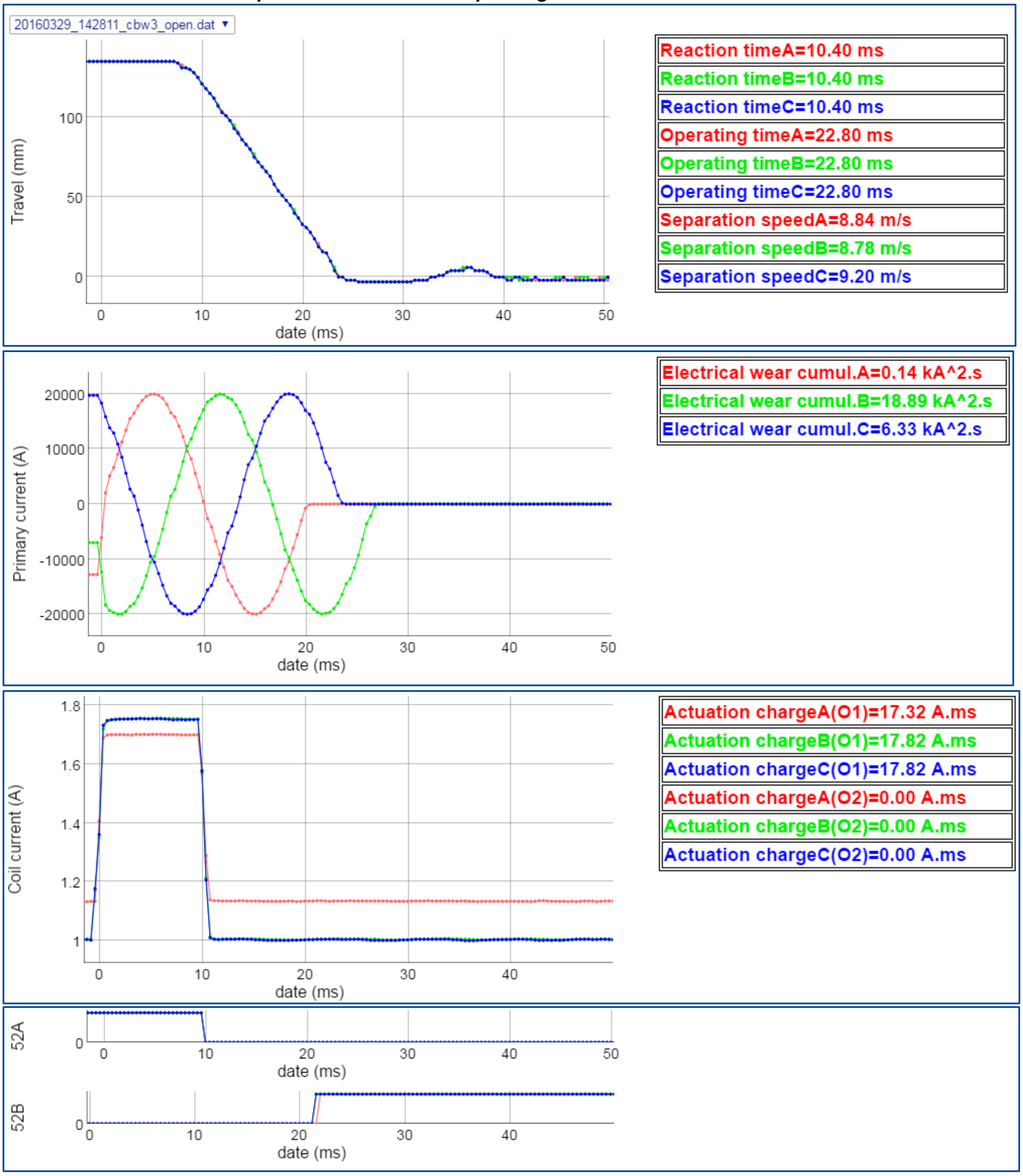


Figure 129 – Operation graphs for opening

9.1.1.2 Closing Operation Graphs

HMI: Measurements / Operations charts / Closing

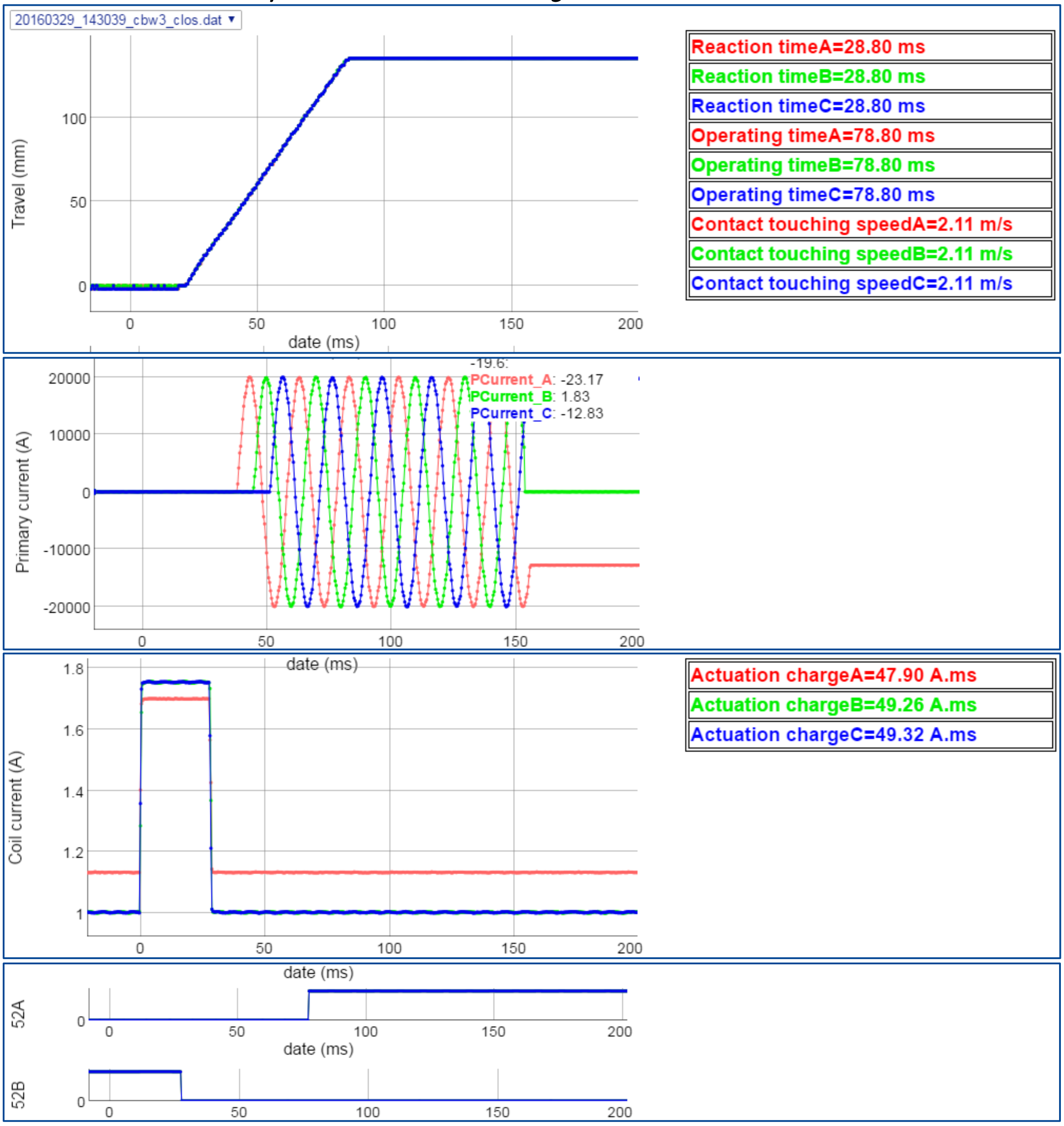


Figure 130 – Operation charts for closing

Note that the content will depend on the presence of the related sensors.

9.1.1.3 Spring Rewind Graphs

HMI: Measurements / Operations charts / Spring

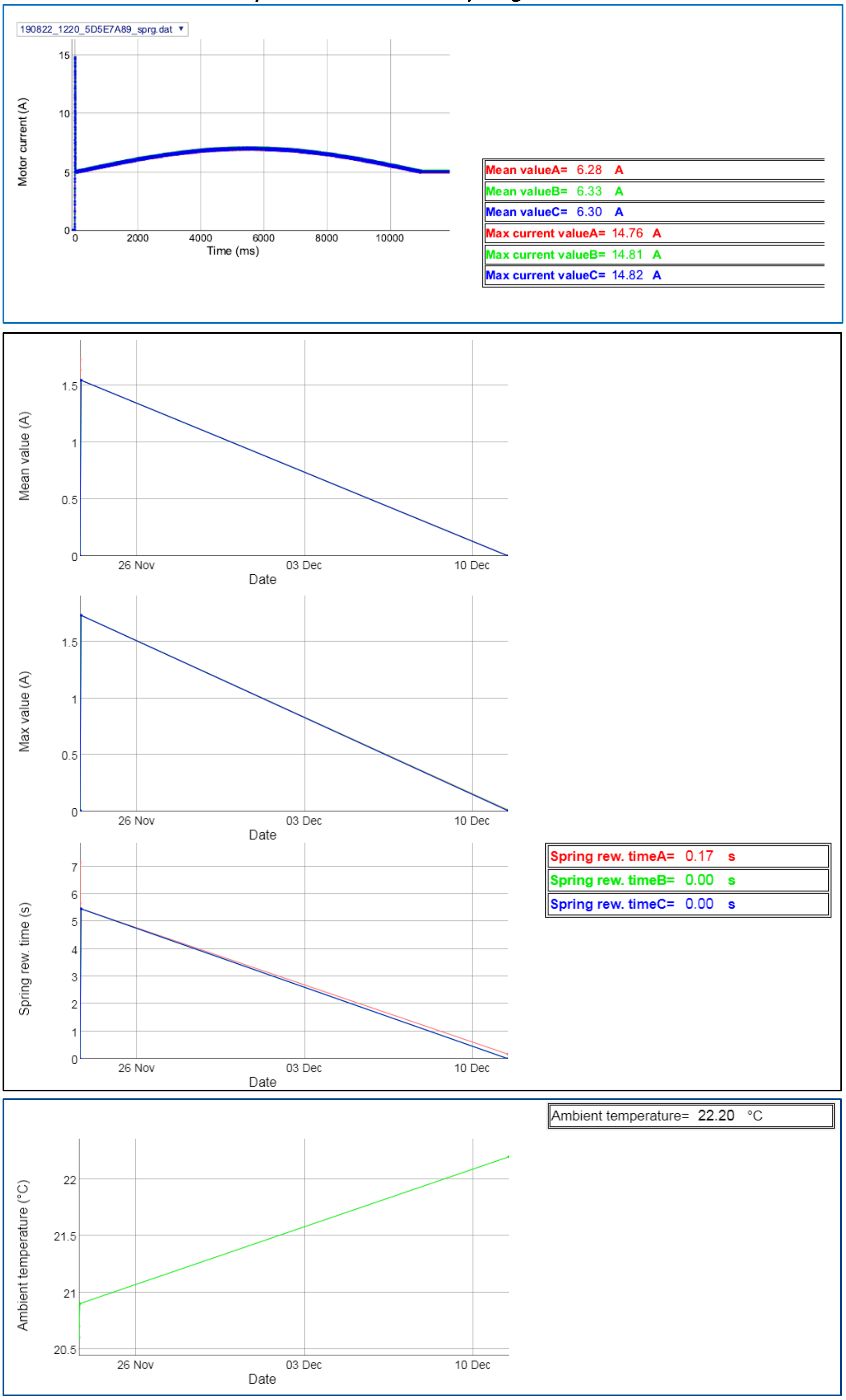
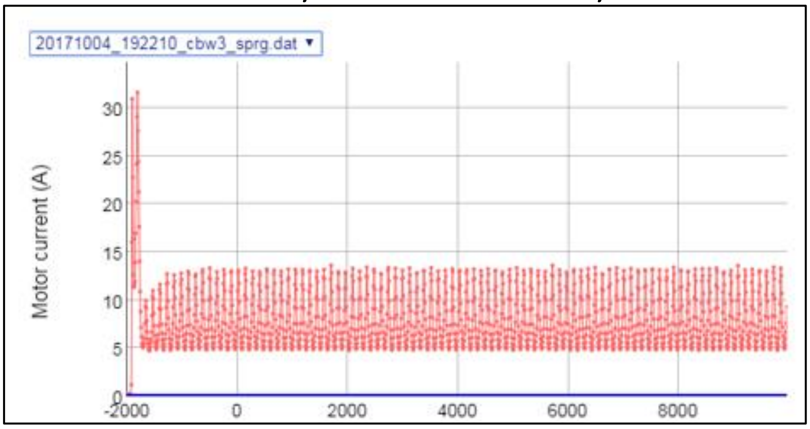


Figure 131 – Operation charts for spring rewind

9.1.1.4 Pump Motor Graphs

HMI: Measurements / Operations charts / Pump



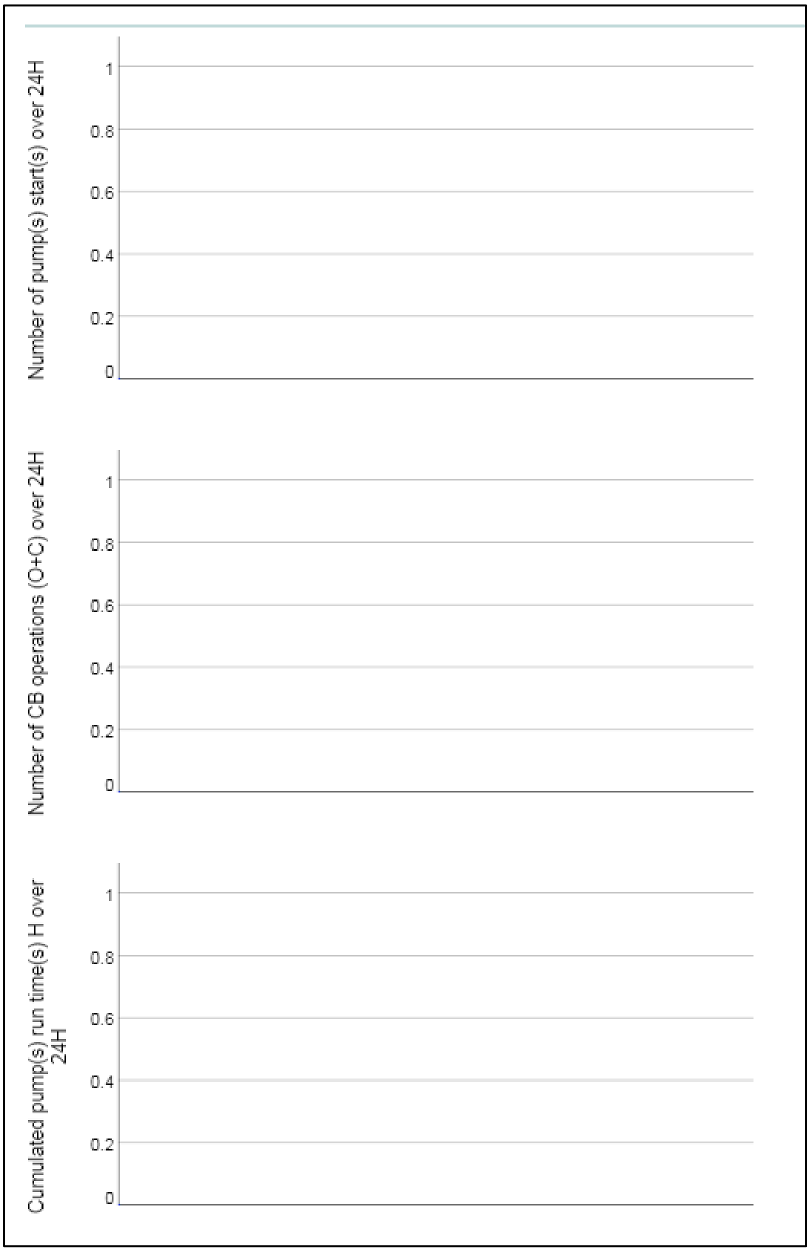


Figure 132 – Operation charts for pump motor

9.1.2 Graph history

The graphs associated with the last operations are stored and the user is able to review and compare any previously saved graph by selecting the date/time in the drop-down menu:

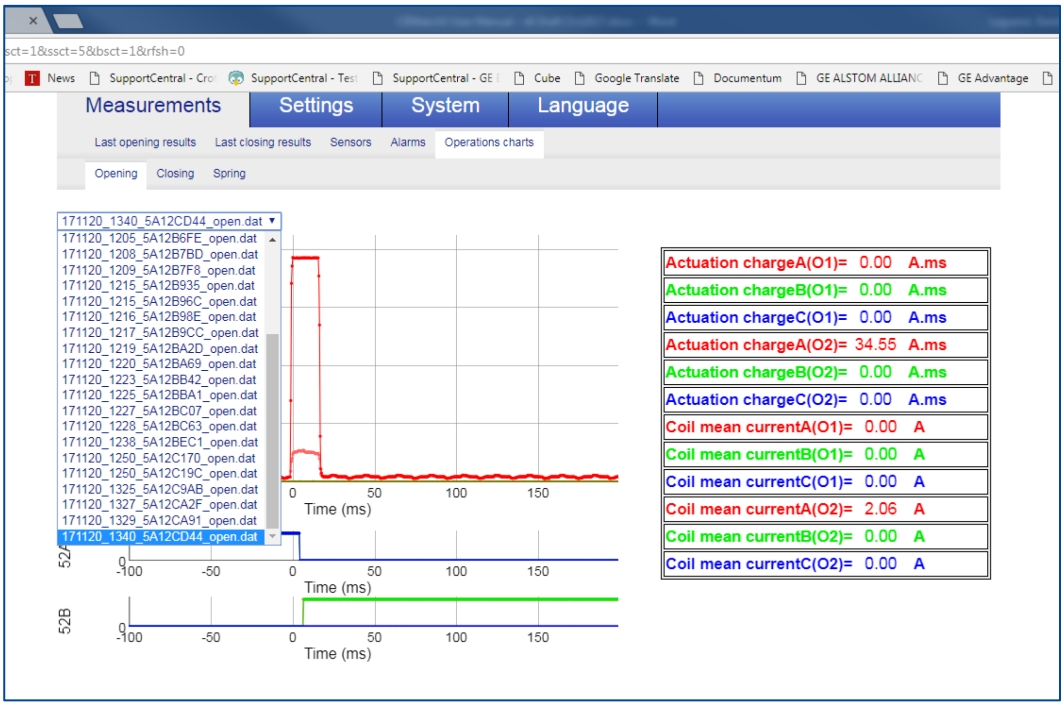


Figure 133 – Drop-down list of previous archives

A total of 50 graphs is stored in memory, over all operation types and the oldest is replaced by the most recent when the buffer memory is full.

9.1.3 Graph scaling

The scale on the graphs can be changed by selecting an area on the graph with the mouse as shown below. The scaling will automatically expand:

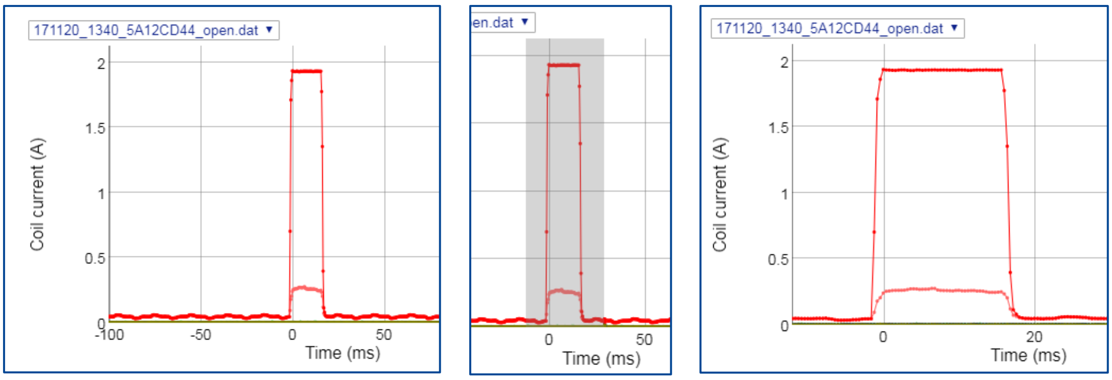


Figure 134 – Scaling graphs

To return to the original scaling, position the cursor on one of the points on the graph. (red point is highlighted and value is displayed), then double click on the mouse.

9.2 COMTRADE Graphs

9.2.1 Downloading COMTRADE Files

Most of the data recorded during each circuit breaker operation is available to download in the COMTRADE file format (also used by relays).

This can be done by going to the "System/Downloads" area of the HMI:

HMI: System / Downloads

COMTRADE

171123_1550_5A16E01C_open.cfg	171123_1557_5A16E1C8_open.cfg	171123_1558_5A16E22B_open.cfg	171123_1600_5A16E288_open.cfg
171123_1603_5A16E358_clos.cfg	171123_1604_5A16E37F_pump.cfg	171123_1621_5A16E781_pump.cfg	171123_1629_5A16E968_sprg.cfg
171123_1631_5A16E9B9_sprg.cfg	171123_1633_5A16EA39_clos.cfg	171123_1633_5A16EA39_sprg.cfg	171123_1637_5A16EB1C_clos.cfg
171123_1642_5A16EC50_open.cfg	171123_1642_5A16EC79_open.cfg	171123_1643_5A16ECA5_open.cfg	171123_1716_5A16F461_open.cfg
171123_1718_5A16F4D3_open.cfg	171123_1719_5A16F511_open.cfg	171123_1721_5A16F597_clos.cfg	171123_1721_5A16F5A6_pump.cfg
171123_1723_5A16F61D_pump.cfg	171123_1725_5A16F665_pump.cfg	171123_1725_5A16F692_pump.cfg	171123_1727_5A16F6FA_sprg.cfg
171206_1524_5A27FD89_clos.cfg	171206_1704_5A281509_clos.cfg	171211_1225_5A2E6B34_clos.cfg	171211_1226_5A2E6B68_clos.cfg
171211_1257_5A2E72A2_clos.cfg	171211_1300_5A2E7346_clos.cfg	171211_1301_5A2E7382_sprg.cfg	171211_1304_5A2E7439_open.cfg
171212_1237_5A2FBF7D_open.cfg	171212_1242_5A2FC091_open.cfg	171212_1252_5A2FC2FA_open.cfg	171212_1300_5A2FC4F9_open.cfg

171123_1550_5A16E01C_open.dat	171123_1557_5A16E1C8_open.dat	171123_1558_5A16E22B_open.dat	171123_1600_5A16E288_open.dat
171123_1603_5A16E358_clos.dat	171123_1604_5A16E37F_pump.dat	171123_1621_5A16E781_pump.dat	171123_1629_5A16E968_sprg.dat
171123_1631_5A16E9B9_sprg.dat	171123_1633_5A16EA39_clos.dat	171123_1633_5A16EA39_sprg.dat	171123_1637_5A16EB1C_clos.dat
171123_1642_5A16EC50_open.dat	171123_1642_5A16EC79_open.dat	171123_1643_5A16ECA5_open.dat	171123_1716_5A16F461_open.dat
171123_1718_5A16F4D3_open.dat	171123_1719_5A16F511_open.dat	171123_1721_5A16F597_clos.dat	171123_1721_5A16F5A6_pump.dat
171123_1723_5A16F61D_pump.dat	171123_1725_5A16F665_pump.dat	171123_1725_5A16F692_pump.dat	171123_1727_5A16F6FA_sprg.dat
171206_1524_5A27FD89_clos.dat	171206_1704_5A281509_clos.dat	171211_1225_5A2E6B34_clos.dat	171211_1226_5A2E6B68_clos.dat
171211_1257_5A2E72A2_clos.dat	171211_1300_5A2E7346_clos.dat	171211_1301_5A2E7382_sprg.dat	171211_1304_5A2E7439_open.dat
171212_1237_5A2FBF7D_open.dat	171212_1242_5A2FC091_open.dat	171212_1252_5A2FC2FA_open.dat	171212_1300_5A2FC4F9_open.dat

Figure 135 – COMTRADE files

Each COMTRADE file is in fact made up of two files: one with extension ".cfg" and one with extension ".dat".

There are 4 different types of files:
- "open" for opening operation data
- "clos" for closing operation data
- "sprg" for spring rewind data
- "pump" for pump operation data

Each file shows the date at which the operation occurred and the data was recorded.

9.2.2 Visualising COMTRADE Files

To visualise the file content, you will need to:
- Download both the corresponding files (.cfg and ,dat) into the same location
- Use a COMTRADE file reader software (for example: WaveWind)
- Point the reader to the location where the 2 files have been stored
- You will then be able to see the data and the graphs:

The example below shows the content of an opening operation file where all 6 coils (open 1 and open 2) have fired to open the CB:

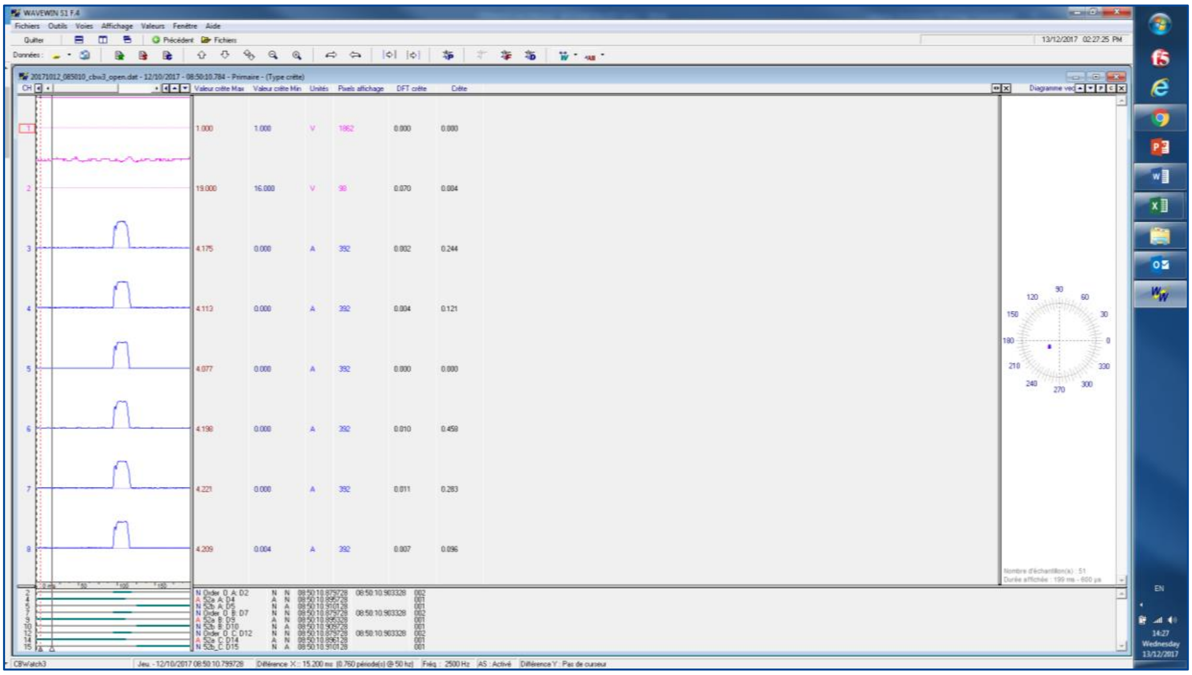


Figure 136 – Visualising a COMTRADE file

10 HEATER MONITORING

10.1 General Description

Using the RTD8 module, the CBW3 can accommodate up to 8x PT100 temperature sensors. The number of sensors must be declared during setup.

The first channel is always reserved for the outside ambient temperature, but the other 7 channels can be assigned to measure any temperature. Cabinet temperatures is very common (to ensure that the heater is working) but measuring tank heater operation is another common use. So 1x outside ambient, 3x Drive cabinets, 1x control cabinet and 3x tank heaters could be a possible use of the 8 sensors.

By default, the temperatures are displayed in degrees centigrade, but degrees Fahrenheit can be selected to display in instead.

HMI: Settings / Aux. temperatures

AUXILIARY TEMPERATURES

Number of PT100 gauges	8
Use °F unit	Yes ☐

Figure 137 – Number of PT100 sensors

Each temperature sensor can be given a name to make it easier to identify what temperature is being measured:

HMI: Settings / Aux. temperatures

	Min	Max	delta negative	delta positive	Name
Temperature 1	-55 °C	85 °C	0 °C	0 °C	Outside Ambient Temp
Temperature 2	-55 °C	85 °C	-99 °C	100 °C	Control Cabinet Temp
Temperature 3	-55 °C	85 °C	-99 °C	100 °C	Drive Cabinet Pole A Temp
Temperature 4	-55 °C	85 °C	-99 °C	100 °C	Drive Cabinet Pole B Temp
Temperature 5	-55 °C	85 °C	-99 °C	100 °C	Drive Cabinet Pole C temp
Temperature 6	-55 °C	85 °C	-99 °C	100 °C	CBWatch3 Cabinet
Temperature 7	-55 °C	85 °C	-99 °C	100 °C	
Temperature 8	-55 °C	85 °C	-99 °C	100 °C	

Figure 138 – Naming of PT100 sensors

This assigned name is displayed in the HMI together with two values per sensor:
- The actual measured temperature
- The positive/negative delta to ambient temperature (measured temp – ambient temp)

HMI: Measurements / Sensors

TEMPERATURE SENSORS

Ambient temperature	26.2 °C		
Control Cabinet Temp	35.7 °C	Delta to ambient temperature	9.5 °C
Drive Cabinet Pole A Temp	-100.0 °C	Delta to ambient temperature	-100.0 °C
Drive Cabinet Pole B Temp	-100.0 °C	Delta to ambient temperature	-100.0 °C
Drive Cabinet Pole C temp	-100.0 °C	Delta to ambient temperature	-100.0 °C
CBWatch3 Cabinet	-100.0 °C	Delta to ambient temperature	-100.0 °C

Figure 139 – Display of PT100 sensors

10.2 Ambient temperature

The outside ambient temperature is usually measured using a PT100 temperature sensor connected as the first input of the RTD8 module (which is always reserved for it).

If the RTD8 module is not present in the configuration but SF6 gas sensors are present, then because they are usually mounted away from direct sunlight an underneath the breaker, the temperature sensor built into the gas sensor is used as the ambient temperature reference. If there are 3x gas sensors, then the average of the 3 measurements is used.

Provided there is a source, the information is continuously displayed in the HMI:

HMI: Measurements / Sensors

TEMPERATURE SENSORS

Ambiant temperature	22.13 °C

Figure 140 – Ambient temperature

The outside ambient temperature is also always recorded and stored for each operation:

HMI: Measurements/Last opening and closing results

LAST OPENING MEASUREMENTS

	Pole A	Pole B	Pole C
Record Date	Thu Nov 9 16:41:52 2017		
Opening operations counter	633	633	633
52A contact switching time	15.2 ms	14.0 ms	15.2 ms
Opening reaction time (t1)	15.2 ms	14.0 ms	15.2 ms
52B contact switching time	26.8 ms	26.8 ms	28.0 ms
Opening operation time (t2)	26.8 ms	26.8 ms	28.0 ms
Opening travel time (t2-t1)	11.6 ms	12.8 ms	12.8 ms
Contacts separation time	16.7 ms	15.5 ms	16.7 ms
Contact separation speed	12.9 m/s	11.7 m/s	11.7 m/s
Overtravel	0.0 mm	0.0 mm	0.0 mm
Coil circuit voltage 1	1.00 V		
Ambient temperature	0.0 °F		

LAST CLOSING MEASUREMENTS

	Pole A	Pole B	Pole C
Record Date	Thu Nov 9 16:25:01 2017		
Closing operations counter	632	632	632
52B contact switching time	56.8 ms	56.8 ms	57.2 ms
Closing reaction time (t1)	56.8 ms	56.8 ms	57.2 ms
52A contact switching time	94.4 ms	99.6 ms	100.4 ms
Closing operation time (t2)	94.4 ms	99.6 ms	100.4 ms
Closing travel time (t2-t1)	37.6 ms	42.8 ms	43.2 ms
Contact touching speed	4.0 m/s	3.5 m/s	3.5 m/s
Overtravel	0.0 mm	0.0 mm	0.0 mm
Coil circuit voltage 2	1.00 V		
Ambient temperature	0.0 °F		

Figure 141 – Last operation temperature measurements

10.3 Heater temperature

10.3.1 Winter heating monitoring

When CB must operate in harsh winter conditions, making sure that the various drive cabinets and control cabinets are adequately heated and maintained at the proper temperature becomes key.

In the old days, heaters were permanently on and older monitoring systems relied on monitoring the heater current to verify that the heating resistance was not open circuit and that the heater was working. Nowadays, manufacturers are becoming more environment-friendly and heaters are thermostatically controlled. This means that they are not always on and measuring heater current no longer works or the logic becomes quite complicated to avoid creating false alarms when the heater is simply off).

Instead of using an indirect measurement (heater current), the CBW3 prefers to monitor the end result of keeping the correct cabinet temperature.

We are therefore interested in setting a minimum and maximum threshold for the temperature in the cabinet. An alarm will be raised if:

- Measured value > Maximum threshold
- Measured value < Minimum threshold

HMI: Settings / Aux. temperatures

	Min	Max	delta negative	delta positive	Name
Temperature 1	-45 °C	45 °C	0 °C	0 °C	Outside Ambient Temp
Temperature 2	-20 °C	70 °C	-99 °C	100 °C	Control Cabinet Temp
Temperature 3	-20 °C	70 °C	-99 °C	100 °C	Drive Cabinet Pole A Temp
Temperature 4	-20 °C	70 °C	-99 °C	100 °C	Drive Cabinet Pole B Temp
Temperature 5	-20 °C	70 °C	-99 °C	100 °C	Drive Cabinet Pole C temp

Figure 142 – Thresholds for measured temperatures

10.3.2 Condensation prevention monitoring

In some countries with high humidity, compensation is the key issue and users are trying to avoid condensation forming inside the cabinet on the electronics/electrical. The heaters are there to ensure that the cabinet is always hotter than the outside ambient temperature.

We are therefore interested in setting a minimum and maximum threshold for the temperature in the cabinet. An alarm will be raised if:

- Measured value (inside) – Outside Ambient temp > Delta positive value
- Measured value (inside) – Outside Ambient temp < Delta negative value

HMI: Settings / Aux. temperatures

	Min		Max		delta negative		delta positive		Name
Temperature 1	-45	°C	45	°C	0 °C		0 °C		Outside Ambient Temp
Temperature 2	-20	°C	70	°C	-10	°C	100	°C	Control Cabinet Temp
Temperature 3	-20	°C	70	°C	-10	°C	100	°C	Drive Cabinet Pole A Temp
Temperature 4	-20	°C	70	°C	-10	°C	100	°C	Drive Cabinet Pole B Temp
Temperature 5	-20	°C	70	°C	-10	°C	100	°C	Drive Cabinet Pole C temp

Figure 143 – Thresholds for relative delta temperatures

Depending on the thresholds set (absolute and/or relative) for each temperature measured, any alarm raised is displayed in the HMI:

HMI: Measurement / Alarms

Outside Ambient Temp	OK
Control Cabinet Temp	OK
Drive Cabinet Pole A Temp	OK
Drive Cabinet Pole B Temp	OK
Drive Cabinet Pole C temp	OK

Figure 144 – Temperature alarms

10.4 Setting temperature alarms

Notice: It is the customer's responsibility to decide whether to set alarms or not and to decide what thresholds to set alarms at, as this will depend on the customer's operational priorities and risk philosophy. However, here are some guidelines that may prove helpful in deciding what threshold values to use:

10.4.1 Alarm summary

This table summarises all the alarms that can be set for monitoring the hydraulic/pneumatic energy storage mechanism:

<table>
<tr><th rowspan="2"><u>Data obtained from CBW3</u></th><th colspan="2"><u>Thresholds</u></th><th colspan="2"><u>Alarms available</u></th></tr>
<tr><th><u>Min Alarm</u></th><th><u>Max Alarm</u></th><th><u>Digital</u></th><th><u>Relay</u></th></tr>
<tr><td>Outside ambient temperature</td><td>Yes</td><td>Yes</td><td>Yes</td><td rowspan="6">Yes</td></tr>
<tr><td>Absolute temperature 1</td><td>Yes</td><td>Yes</td><td rowspan="2">Yes</td></tr>
<tr><td>Delta 1 to outside ambient temperature</td><td>Yes</td><td>Yes</td></tr>
<tr><td>:</td><td></td><td></td><td></td></tr>
<tr><td>Absolute temperature 7</td><td>Yes</td><td>Yes</td><td rowspan="2">Yes</td></tr>
<tr><td>Delta 7 to outside ambient temperature</td><td>Yes</td><td>Yes</td></tr>
</table>

Figure 145 – Spring energy storage mechanism alarms

10.4.2 Alarm thresholds

<u>Ambient temperature</u>

Warning alarms could be set if the outside ambient temperature falls very low (-45ºC) or very high (+45ºC) so that any appropriate actions (e.g. heating blankets on the CB) can be taken in these extreme conditions.

Absolute cabinet temperature

Alarms should be set to check that the heaters are working correctly. Depending on the heater control settings, a minimum threshold could be set around -20ºC to warn that the heater is not maintaining the temperature above what is needed for the electronics.

A maximum temperature threshold could be set at 70ºC to warn of any serious overheating issue within the cabinet.

If no alarm is required, a very low minimum threshold (-100ºC) and a very high maximum threshold (100ºC) should be set to ensure that no alarm is ever triggered.

Relative cabinet temperature

To avoid condensation, it is usually accepted that the inside of a cabinet should not be much colder than the outside temperature. A delta negative of -10ºC could be set to warn that the heater is letting the difference in temperature exceed 10ºC, or, in other words, warn that the internal temperature is more than 10ºC below the outside ambient temperature.

The delta positive value is not very useful since we have absolute thresholds. It should be set to a high number to avoid triggering an alarm (100ºC)

11 GENERIC ANALOGUE CHANNEL MONITORING

11.1 General Description

Depending on the configuration, there may be up to 4 spare generic analogue channels that can be assigned to connect other sensors in order to measure and monitor other values on the circuit breaker.

The CBW3 can accept sensors with a wide range of outputs:
- Voltage outputs: 0-10V, +/-10V, 0-5V, +/-5V,
- Current outputs: 0-20mA, +/-20mA, 4-20mA,

Typical use for these spare analogue channels would be:
- AC voltage monitoring
- Pneumatic pressure
- Barometric pressure
- …….

11.2 Configuration

The name of the value being measured by each channel can be configured by the user to reflect the value monitored. The units of the value being measured can also be configured by the user. This is done through the HMI:

The user can also specify in which COMTRADE file the data recorded will be added to:
Open, Close, Spring, Pump
or even Open-Close, Open-Close–Spring rewind, etc…

HMI: Settings / Analog channels

	type	low value	high value	min threshold	max threshold	unit	name	record
Generic channels (X4)	0-10V	0.00	250.00	210.00	225.00	V	AC Volta	None
Generic channels (X4)	None	0.00	0.00	0.00	0.00		GEN 2	None
Generic channels (X4)	None	0.00	0.00	0.00	0.00		GEN 3	None
Generic channels (X4)	None	0.00	0.00	0.00	0.00		GEN 4	None

Figure 146 – Spare analogue channels configuration

Both the name and the units are then displayed in the HMI whenever the data is being viewed, making for painless complete integration.

See below output shown for the example above:

HMI: Measurements / Sensors

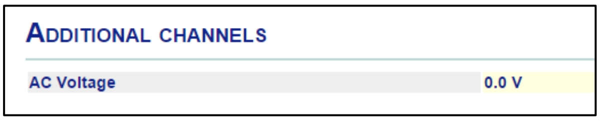


Figure 147 – Spare analogue channels display

11.3 Alarms

Both minimum and maximum thresholds can be set on these generic channel values in order to trigger an alarm:

HMI: Settings / Analog channels

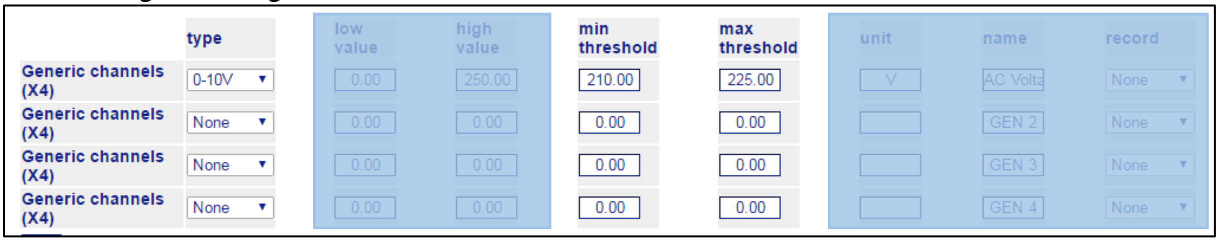


Figure 148 – Spare analogue channels alarm thresholds

Any alarm triggered can be seen in the HMI:

HMI: Measurements / Alarms

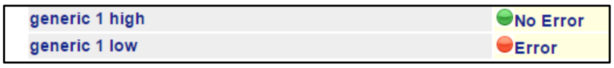


Figure 149 – Spare analogue channels alarms

Alarm summary:

<u>**Data obtained from CBW3**</u>	<u>**Min Alarm**</u>	<u>**Max Alarm**</u>
Any analogue sensor (voltage or current output) - #1	Yes	Yes
Any analogue sensor (voltage or current output) - #2	Yes	Yes
Any analogue sensor (voltage or current output) - #3	Yes	Yes
Any analogue sensor (voltage or current output) - #4	Yes	Yes

12 DRY CONTACT RELAY ALARMS

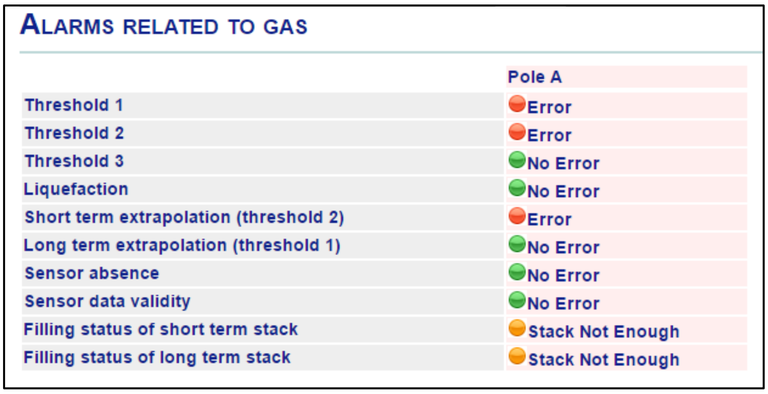
12.1 General Description

As seen throughout this manual, alarms can be set on a long list of parameters. These alarms are available in three different ways:

- Through the HMI using colour coded notifications flags

  Alarms will appear in red and warnings in yellow, otherwise all will be green:

HMI: Measurements / Alarms



ALARMS RELATED TO GAS

	Pole A
Threshold 1	Error
Threshold 2	Error
Threshold 3	No Error
Liquefaction	No Error
Short term extrapolation (threshold 2)	Error
Long term extrapolation (threshold 1)	No Error
Sensor absence	No Error
Sensor data validity	No Error
Filling status of short term stack	Stack Not Enough
Filling status of long term stack	Stack Not Enough

Figure 150 – Alarm colour coding

- Through the digital interface to the CBW3, depending on the protocol used, with alarm status fields

- Though their assignment to available dry contact relays

We will cover this last method here. Even though modern digital protocols are most often used, it is available for connection to older SCADA systems.

12.2 Available alarm relays

Two dry contact alarm relays, K1 and K2, are provided as standard on the base ProWatch module.

The K2 output is used to provide the state of the CBW3. It is the result of the system's own self-checking function. It can inform the maintenance service and/or supervision system of an internal malfunction with the CBW3 system.

The K1 output is user programmable and can be set against one or many of the alarm parameters available. For example, in the context of gas supervision, it is possible to assign the output to one of the gas level thresholds.

An additional 16 different alarm relays are available with the DO16 optional module. Each one can be triggered by one or several alarms which were set and specified by the user.

12.3 Alarm assignment to each relay

Virtually all alarms can be assigned to one of the 16 relays or to K1 by filling the associated matrix for these alarms in the set-up. The alarms available have already been defined in each of the relevant previous sections.

This example shows the matrix for the gas alarms shown in the example in Figure 150 above.

HMI: Settings / Alarms / Gas

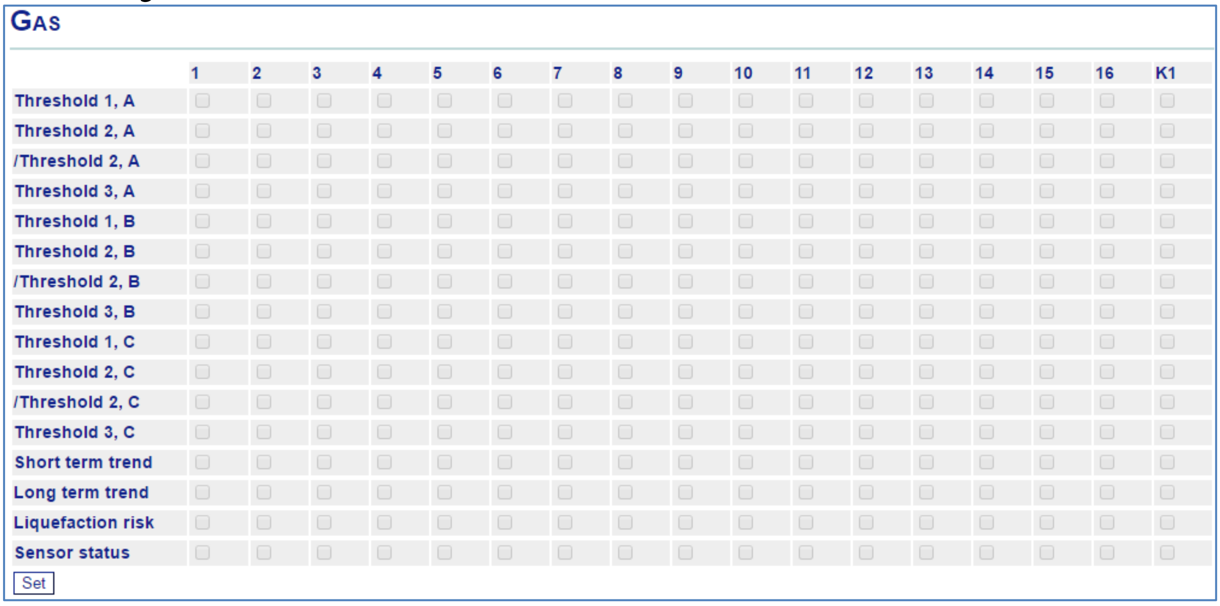


Figure 151 – Gas alarm assignments

Each monitoring function has its own alarms that can be assigned in a similar manner to one of the 16 relays or K1 by selecting them in the appropriate table in the alarm setup section.

Each function has its own section:

HMI: Settings / Alarms

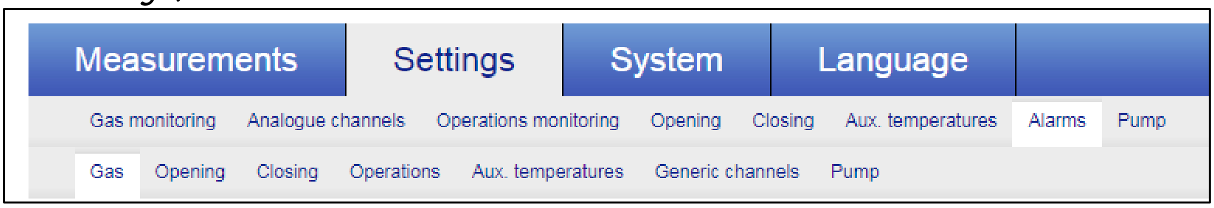


Figure 152 – Alarm sections for each monitoring function

12.1 Clearing alarms

Some alarms depend on the status of a continuous measurement and auto clear themselves when the status changes. Other alarms are based on an operation and will stay active based on the value recorded during the last operation. They can however be cleared manually by:

- Selecting the “Clear alarms” relay assignment
- Pressing the “Set” button

There are two alarm clearing buttons:

- One for all the gas related alarms

HMI: Settings / Alarms / Gas

Figure 153 – Clearing gas related alarms

- One for all the operations related alarms

HMI: Settings / Alarms / Operations

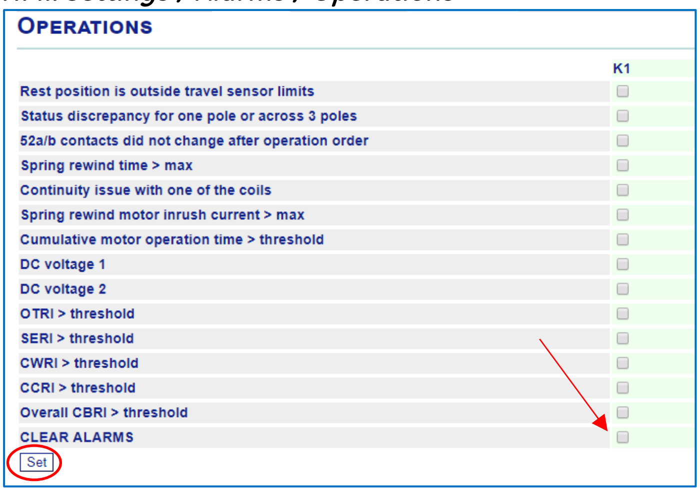


Figure 154 – Clearing operations related alarms

13 DIGITAL COMMUNICATION

13.1 Protocols

Depending on the configuration of your system, one or several digital communication protocols may be available from:

- Modbus
- DNP3
- IEC 61850 Ed2

The protocols enabled in the configuration are displayed with a tick in:

HMI: System / Network

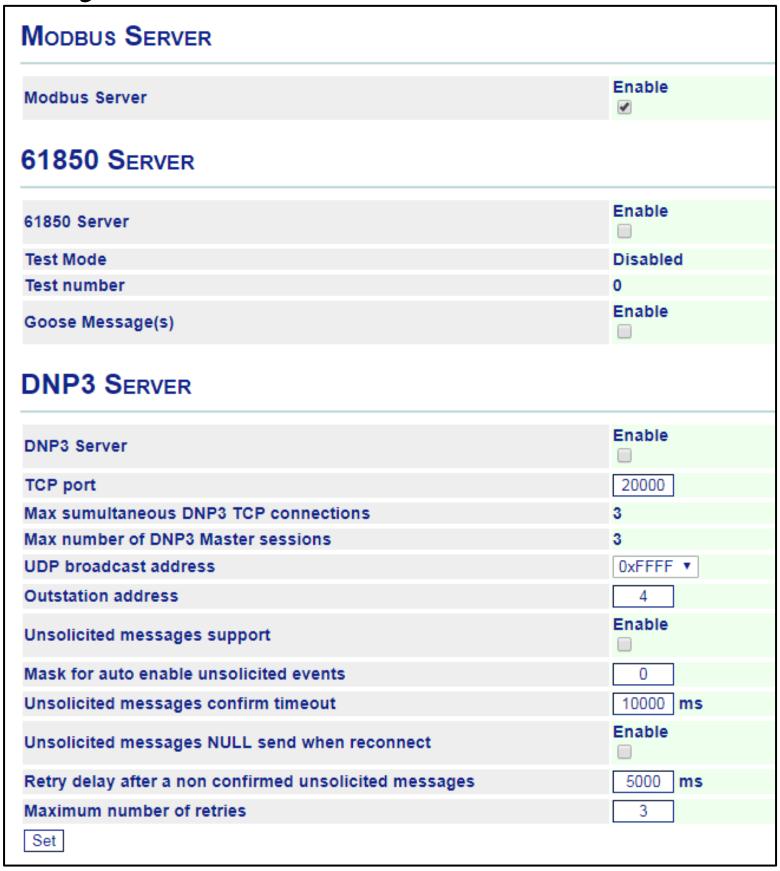


Figure 155 – Protocols available

Please refer to the specific documentation of that protocol for further information.

14 REMOTE ASSISTANCE

14.1 Assistance File

In certain circumstances, you may be asked to generate, download and send to GE data about the configuration of your system so we can help you understand and remotely fix any issue encountered. The "Assistance file" can be accesses as follows:

Login as "Specialist" and go to:

HMI: System / Downloads

Figure 156 – Generating the remote assistance file

At the bottom of the page, you will find the button to "generate" the assistance file. Press it and wait about 20 seconds for the file to appear underneath:

HMI: System / Downloads

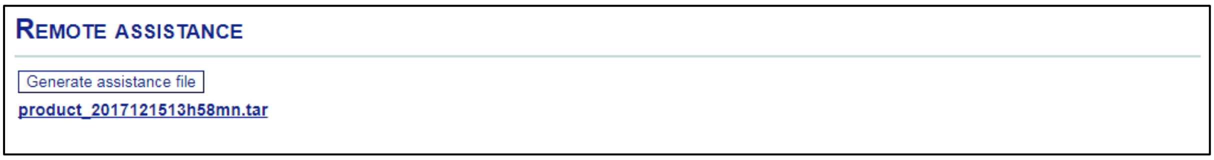


Figure 157 – Remote assistance file

The ".tar" file is time and date stamped and can be downloaded by double clicking on it. This is the file you need to send to GE if you are asked for the "Assistance file".

14.2 Product/System Files

If we have to make some changes, we will then send you back a modified "Product.a2c" or "Settings.a2c" file or both:

In order to upload them into your system, again login as "Specialist" and go to:

HMI: System / Uploads

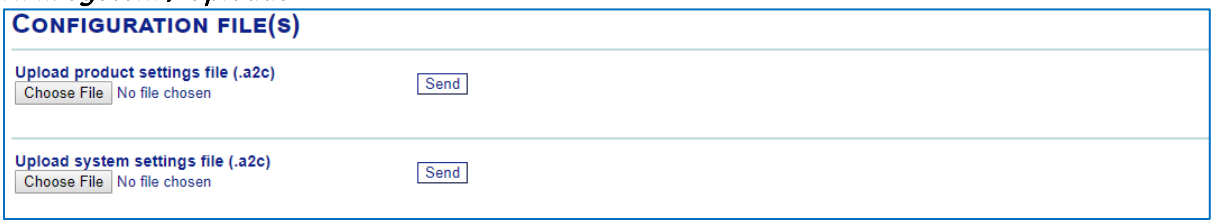


Figure 158 – uploading a product or system file

Choose the file by browsing to the location on your laptop

Upload the file by pressing the “Send” button

Repeat for the other file if required

15 TECHNICAL SPECIFICATION

15.1 Measurements

15.1.1 Continuous measurements

Feature		Value
Refresh frequency		Approx. every 1 second
Gas measurements	Pressure accuracy	±8mBar (0.05% FS)
	Temperature Precision	±2˚C
Analogue measurements	Accuracy	0.1% of measuring range
	A/D conversion	16 bit
Time	Accuracy	1 second
Data storage	Short Term gas data	last 3,000 values @ 1 per minute
	Long Term gas data	last 500 values @ 1 per day

15.1.2 Operations measurement

Feature		Value
Time horizon	Operation	0.3 seconds
	Motor current	12 seconds
Refresh frequency		every 400 micro seconds
Analogue measurements	Accuracy	0.1% of measuring range
	A/D conversion	16 bit
Time	Accuracy	+/- 1 milli second
Temperature	Accuracy	+/- 0.1 deg C (PT100 3-wire)
Data storage	Operation data	last 50 operations
	Pump data	Last 5 pump starts per pump

15.1.3 Processor

Feature	Value
CPU frequency	100 MHz
Memory	512Mbit SDRAM + 256Mbit Flash
Battery	No battery used
Date/time	Saved by super capacitor for ~10days

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