OPERATING AND INSTRUCTION MANUAL

FOR THE CPR04 RELAY

An economical, digital protection relay for optimized protection of medium and high voltage capacitor- and filter banks featuring:



- Compact draw-out design
- Four software configurable measuring elements
- Operating mode selectable in the menu (Normal Mode; H-Bridge Mode)
- Five configurable output relays
- One self supervision relay
- One frontside RS232 with DB9 connector
- One software selectable RS232 or RS485 serial data port at the backside of the relay
- Firmware upgradeable via serial RS232 frontport
- Time stamping of trip events and modifications to certain status registers

These instructions do not purport to cover all details or variations in equipment, nor to provide for every possible contingency to be met during installation, operation and maintenance. Should further information be required, or should particular issues arise that are not covered sufficiently for the users purpose, the matter should be referred to:

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<u>CAUTION</u> Draws attention to an essential operating procedure, practice or statement, which, if not observed, could result in damage to, or destruction of, equipment.

<u>NOTE</u> Draws attention to an essential operating or maintenance procedure, or statement, that must be observed.

WARNING

This equipment is potentially hazardous in respect of electrical shock or electrical burn.

Only personnel, who are adequately trained and thoroughly familiar with the CPR04 Relay, and these instructions, should install, operate or maintain this equipment.

To minimize the hazard of electrical shock or burn, the user should adhere to approved protection and safety procedures.

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1 INTRODUCTION

This manual contains an overview and specification of the CPR04, as well as detailed installation, setting up, operating, commissioning and maintenance instructions.

As further enhancements are developed, this manual will be expanded and revised to include full details of these options.

The user of this manual should have a prior knowledge of capacitor banks and harmonic filter circuits, power system protection, power system measurements, and power system safety procedures.

Before installing, setting up or operating the CPR04 Relay, the user should study the applicable sections of this manual, taking particular note of *WARNINGS, CAUTIONS* and *NOTES* included for personnel and equipment protection.

Before attempting to trouble-shoot the equipment, the user should thoroughly understand the entire manual.

For trouble-shooting and commissioning the following equipment is required:

- Digital multi-meter with clip-on current tong for measuring 1A or 5A current transformer (CT) secondaries
- A three or alternatively a single phase primary or secondary injection test set.

Due to the nature of the CPR04 Relay, it is not recommended that the user should attempt repairs other than the removal and replacement of the drawout unit, which houses all electrical and electronic parts. Refer to Section 8 for further details.

Faulty CPR04 Relays should be returned to Trench Austria GmbH for testing, and if necessary, for repair or replacement of faulty parts, re-calibration and re-testing.

2 PROTECTIVE FUNCTIONS PROVIDED BY THE CPR04 RELAY

2.1 RELAY CONFIGURED IN NORMAL MODE

2.1.1 Peak repetitive overvoltage protection (Refer to Fig. 13)

The dielectric of a capacitor bank is stressed by the peak repetitive voltage applied to it. According to the standards, a capacitor bank must be able to withstand a *rms* sinusoidal voltage of 110% of its rated voltage at rated frequency for extended periods.

Thus a capacitor can withstand a peak repetitive voltage of $1, 1 \cdot \sqrt{2} \cdot U_N$ for extended periods.

For peak repetitive voltages above this value, an inverse time capacitor temporary overvoltage withstand curve defines the time the capacitor can withstand the peak repetitive voltage before failure (Refer to Fig. 6). This curve has been derived from the relevant ANSI and IEC recommendations.

In service CPR04 determines the peak repetitive voltage by the actual fundamental frequency voltage applied to the capacitor, as well as harmonic voltages (up to the 50th harmonic) superimposed on the fundamental. For each phase, the CPR04 Relay determines the peak repetitive capacitor voltage, *vc*, using advanced digital signal processing techniques, by integrating the measured line current waveform, to give a signal representing the voltage waveform applied to the capacitor bank.

The peak repetitive voltage of this signal, *vc*, is then extracted, and compared to three adjustable thresholds. The alarm threshold *vc*>*al/vcr* with an associated adjustable definite timer, *vc*>*al:xt*; if *vc* exceeds the threshold for the time set the alarm signal, *vc*>*alarm* is output. The second threshold is the so called low-set threshold, *vc*>*/vcr*. For voltages above this threshold, a starter signal, *vc*>*start*, is output, and the ANSI inverse time curve defines the time before the low-set trip signal, *vc*>*trip*, is output. In addition an adjustable high-set threshold, *vc*>*/vcr*, with an associated adjustable definite timer, *vc*>*trip*, is output. In each other trip output, *vc*>*trip*, if the associated threshold is exceeded for the definite time set.

In order to take also care of the so called "memory effect" of capacitors, it is possible to set a timer; vc>reset; which defines the time after which the internal counter for the capacitor overvoltage is cleared after an overvoltage appeared to take care of repetitive short overvoltages.

2.1.2 Thermal overcurrent protection (Refer to Fig. 13)

The connections and current paths within a capacitor bank / harmonic filter circuit are stressed thermally by the heating current, *Irms*, including both the fundamental and harmonic components.

According to the standards, a capacitor bank, and the capacitor units making up the bank, must be rated to withstand continuously a current of 130% of rated current. For currents above this threshold, the resulting temperature rise may cause damage to the capacitor bank and capacitor units.

Similarly, each of the other elements making up the capacitor bank / harmonic filter circuit, including the circuit breaker, feed cable, damping or filter reactors, and filter resistors, also have a continuous current limit, above which excessive temperature rise and damage may occur.

For each phase, the CPR04 Relay protects a capacitor bank / harmonic filter circuit from excessive current stressing, by modeling the thermal response of the circuit to the heating current, *Irms*. Using advanced digital signal processing techniques; *Irms* is continuously calculated from the measured line currents (including up to the 50th harm.). A second order thermal model with an adjustable heating / cooling time constant τ , is then used to continuously calculate the thermal current response, *Ith*, to the heating current, *Irms*.

Ith is continuously compared to the adjustable thresholds, *Ith*> and *Ith*>>, each linked to adjustable

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timers Ith>:xt and Ith>>:xt. When Ith exceeds the threshold, Ith>, a starter signal Ith>start is output. Low-set and high-set trip signals, Ith>trip, and Ith>>trip, are output, if the associated thresholds are exceeded for the definite times set. If the low-set timer Ith>:xt is set to "*Alarm*" then the low-set function acts as pure alarm and only the Ith>start signal without a subsequent Ith>trip signal is output.

The trip times can be evaluated using the following formula:

 $t/tau = -ln (((1/1th>)^2 - 1) / ((1/1th>)^2 - (10/1th>)^2))$

I/Ith> = overload current / thermal trip threshold current
Ip/Ith> = pre-load current / thermal trip threshold current

<u>NOTE</u>

Irms reflects the instantaneous value of the heating current, while *Ith* lags *Irms* depending on τ as set.

2.1.3 Fundamental frequency star point unbalance protection (Refer to Fig. 14)

In a double star connected capacitor bank, the failure of internal capacitor elements, and the subsequent blowing of internal capacitor element fuses or external capacitor unit fuses, is detected by sensitive monitoring of the star point unbalance current flowing between the two star points.

Even though efforts may be taken to balance a double star connected capacitor bank, by optimum selection and positioning of the capacitor units making up the bank, the tolerance in capacitance is such that a "natural" fundamental frequency star point unbalance current flows under normal conditions.

The CPR04 Relay measures the star point unbalance current and calculates the fundamental frequency component, *Iub*. This can then be compensated, in magnitude and phase angle, to zero, to enable further changes, in both magnitude and phase angle, ΔIub , from the initial uncompensated value, to be determined. The magnitude of ΔIub is a measure of the change in capacitance in any leg of a double star capacitor bank arrangement, whereas the phase angle of ΔIub indicates the leg in which the change in capacitance has occurred.

If the natural unbalance has been compensated and the fundamental current in the reference phase (ELEMENT1) drops below 10%, the star point unbalance protection function is suspended, and the compensation vector is ignored.

If the natural unbalance is not compensated and the fundamental current in the reference phase drops below 10%, the star point unbalance protection function is operating just on the amplitude of the measured unbalance current – the phase angle will not be taken into consideration.

The magnitude of (Δ)*Iub* is continuously compared to an adjustable alarm threshold, *Iub_al*, and trip thresholds, *Iub>* and *Iub>>* each with associated adjustable definite timers, *Iub_al:xt*, *Iub>:xt* and *Iub>>:xt*. For (Δ)*Iub* greater than *Iub_al* for the definite time set, an alarm signal, *Iub_alarm*, is output. In addition, a starter signal *Iub>start* as well as low-set and high-set trip signals, *Iub>trip*, and *Iub>>trip*, are output, if the associated thresholds are exceeded for the definite times set.

The advantage of star point unbalance protection is that, unlike line current unbalance, the magnitude and phase angle of (Δ) *Iub* is not influenced by an unbalanced supply voltage. Therefore the sensitivity of star point unbalance current measurement can be much higher than line current unbalance measurement, without spurious tripping caused by unbalanced supply voltages. This sensitivity is often essential for adequate protection of larger capacitor banks with both internal, external and unfused capacitor units.

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In addition, the star point unbalance protection function provided by the CPR04 Relay indicates the leg of the double star bank in which the change in capacitance has occurred. This is particularly convenient for larger capacitor banks with internally fused or unfused capacitor arrangements, to speed up the identification of faulty capacitor units. See also Fig. 10.

2.1.4 Fundamental frequency line current unbalance protection (Refer to Fig. 14)

The monitoring of fundamental frequency line current unbalance provides a means of detecting changes in impedance resulting from failures and faults within the capacitive, inductive and resistive elements of a capacitor bank / harmonic filter circuit. These faults or failures invariably result in an unbalance in the fundamental frequency component of the line currents.

The CPR04 Relay calculates the fundamental frequency line unbalance, *Ilub*, from the fundamental frequency components of the three phase line currents. *Ilub* is continuously compared with two adjustable thresholds, *Ilub*> and *Ilub*>>, each with an associated adjustable definite timer, *Ilub*>:xt and *Ilub*>>:xt. For *Ilub* greater than *Ilub*>, a starter signal, *Ilub*>start, is output. In addition, low-set and high-set trip signals, *Ilub*>trip and *Ilub*>>trip, are output if the associated thresholds are exceeded for the definite times set.

The sensitivity of line current unbalance protection is limited by the effect of supply voltage unbalance on the line currents. Nevertheless, line current unbalance protection is useful as back-up protection to star point unbalance protection, as well as for early detection of filter resistor and reactor faults, and for early detection of capacitor element failures in smaller capacitor banks, in single star or delta connected arrangements, where star point unbalance protection is not provided.

2.1.5 Fundamental frequency earth fault protection (Refer to Fig.14)

The CPR04 Relay calculates the fundamental frequency residual or earth fault current, *Io*, as the magnitude of the vector sum of the three fundamental frequency components of the three phase line currents. *Io* is compared with two adjustable thresholds, *Io*> and *Io*>>, each with an associated adjustable definite timer, *Io*>:*xt* and *Io*>>:*xt*. For *Io* greater than *Io*>, a starter signal, *Io*>*start*, is output. In addition, low-set and high-set trip signals, *Io*>*trip* and *Io*>>*trip*, are output if the associated thresholds are exceeded for the definite times set.

2.1.6 Fundamental frequency overvoltage and overcurrent protection (Refer to Fig. 13)

For each phase, the CPR04 Relay calculates the fundamental frequency component, *II*, of the line current. *II* is continuously compared with two adjustable thresholds, *II*> and *II*>>, each with an associated adjustable definite timer, *II*>:*xt* and *II*>>:*xt*. For *II* greater than *II*>, a starter signal, *II*>*start*, is output. In addition, low-set and high-set trip signals, *II*>*trip* and *II*>>*trip*, are output if the associated thresholds are exceeded for the definite times set.

In the absence of any equipment failures or system faults, the fundamental frequency line currents flowing in a shunt connected capacitor bank / harmonic filter circuit is proportional to the fundamental frequency supply voltage.

The low-set fundamental frequency overcurrent threshold is typically set a little higher than the current that would flow at the maximum system voltage, e.g. at say 107,5% of nominal, with a fairly long definite time setting of, say 300 seconds. This protects the capacitor bank/harmonic filter circuit from an abnormally high supply voltage, in excess of the declared maximum system voltage.

A fundamental frequency line current much higher than that which would normally flow at the maximum system voltage, indicates a catastrophic phase-to-phase, three phase or phase-to-earth fault, or major equipment failure, requiring immediate disconnection of the capacitor bank / harmonic filter circuit. Therefore the high-set fundamental frequency overcurrent threshold is typically set at, say 150% of nominal, with a minimum definite time delay setting (no intentional delay).

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2.1.7 RMS overcurrent protection (Refer to Fig. 13)

For each phase, the CPR04 Relay calculates the RMS current, *Irms*, including both the fundamental and harmonic components, of the line current. *Irms* is continuously compared with two adjustable thresholds, *Irms*> and *Irms*>>, each with an associated adjustable definite timer, *Irms*>:xt and *Irms*>:xt. For *Irms* greater than *Irms*>, a starter signal, *Irms*>start, is output. In addition, low-set and high-set trip signals, *Irms*>trip and *Irms*>trip, are output if the associated thresholds are exceeded for the definite times set.

RMS overcurrent protection can be especially useful for protecting elements within a filter bank which will not be subjected to fundamental current.

2.1.8 Fundamental frequency undercurrent protection (Refer to Fig. 13)

If the mains power supply should fail, while the capacitor bank / harmonic filter circuit breaker is on (Digital input at logic "1" and configured as "Breaker on"), then it is prudent to trip the capacitor bank / filter circuit breaker. After restoration of the mains supply, the bank can then be re-energized under controlled conditions, after the system load has been re-established. In certain cases this can help to avoid over correction and excessive voltage rise, due to load rejection during a mains power dip. For each phase, the CPR04 Relay calculates *II*, the fundamental frequency component of the line current. *II* is continuously compared with an adjustable undercurrent threshold, II<, and associated adjustable definite timer, II<:*xt*. With the capacitor bank / harmonic filter circuit breaker on, if the mains power supply fails, as indicated by a drop in *II* below *II*< for longer than the definite time set, then the undercurrent trip signal, II<*trip*, is output.

2.1.9 Breaker fail protection (Refer to Fig. 13)

Bfail1: The Breaker fail 1 signal is triggered by any of the trip functions and is programmable to be released by the following conditions:

[1] "Ifund<10%In" - a drop in the fundamental currents below 10%

[2] "Dig-Input" - a change of the digital input from "active" to "de-active"

[3] "Ifund OR Input" logical OR combination of [1] and [2]

[4] "Ifund AND Input" logical AND combination of [1] and [2]

For selections which involve the digital input the input function must be set to "Breaker-Bon" or else the release function will be default to "*Ifund*<10%*In*".

Bfail2: In addition to the above, if *I1* remains above 10% of rated In, for longer than the adjustable definite time, *Bfail2:xt*, after the breaker switches off (digital input set to "Breaker- Bon" - indicates the breaker open/close status), then this indicates a major failure of the capacitor bank / harmonic filter circuit breaker, and the breaker fail signal, *Bfail2*, is output.

Both signals can be used to trip an upstream breaker.

2.1.10 Capacitor bank re-switching protection (Refer to Fig 14)

When a capacitor bank / harmonic filter circuit breaker switches off for any reason, it should not be reenergized until the capacitor bank has discharged, to prevent severe and stressful voltage and current transients due to the application of mains supply voltage onto a charged capacitor bank.

The CPR04 Relay provides the necessary logic, and a breaker enable output signal, *Bena*, to inhibit the re-energization of the capacitor bank / harmonic filter circuit breaker, for an adjustable definite time, *Bena:xt*, since de-energization.

Bena can be triggered by either "*Ifund*<10%*In*" - a drop in the fundamental currents below 10% or "*Dig-Input*" - a change of the digital input from "active" to "de-active" (digital input senses the status of the breaker).

Also combinations of the two criterias are selectable (*"Ifund AND Input"* respectively *"Ifund OR Input"*). This allows the user to configure the CPR04 as requested by the application.

2.1.11 Event trip

The CPR04 offers the possibility to trip the relay from external via it's digital input. Precondition is that the digital input must be configured as Event trip input. If the digital input changes it's state from inactive to active for the definite time set, *Event:xt*, the output function, *Event_trip*, can be used to operate any of the output relay(s).

2.2 RELAY CONFIGURED IN H-BRIDGE MODE

2.2.1 Fundamental frequency H-BRIDGE unbalance protection (Refer to Fig. 15)

The CPR04 Relay provides fundamental frequency H - BRIDGE MODE capacitor bank unbalance protection to provide sensitive unbalance protection independently for each phase of an H - configured capacitor bank.

If the natural unbalance has been compensated and the fundamental current in the reference phase (ELEMENT1) drops below 10%, the H-Bridge unbalance protection functions are suspended, and the compensation vectors are ignored.

If the natural unbalance is not compensated and the fundamental current in the reference phase drops below 10%, the H-Bridge unbalance protection function is operating just on the amplitude of the measured unbalance current – the phase angle will not be taken into consideration.

The unbalance currents are measured in each phase of an H - configured capacitor bank. Out of these values the fundamental frequency components , *aIub*, *bIub* and *cIub*, are calculated. These can then be compensated in amplitude and phase angle to zero, to enable further changes in both magnitude and phase angle, $\Delta aIub$, $\Delta bIub$ and $\Delta cIub$, from the initial uncompensated value, to be determined. The magnitude of $\Delta aIub$, $\Delta bIub$ and $\Delta cIub$ is a measure for the change in capacitance, while the phase angle indicates the leg in which the change in capacitance has occurred.

The magnitude of $(\Delta)a/b/cIub$; is continuously compared to adjustable alarm thresholds, $a/b/cIub_al$; and the low set trip thresholds, a/b/cIub as well as the high set trip thresholds a/b/cIub>; each of them linked with an associated adjustable definite timer, $a/b/cIub_al:xt$, respectively a/b/cIub>:xt, and a/b/cIub>:xt. For $(\Delta)a/b/cIub$ greater than $a/b/cIub_al$ for the definite time set, an alarm signal, $a/b/cIub_alarm$, is output. In addition, starter signals a/b/cIub>start as well as low-set and high-set trip signals, a/b/cIub>trip, and a/b/cIub>trip, are output, if the associated thresholds are exceeded for the definite times set.

The advantage of H-BRIDGE capacitor bank unbalance protection is that the magnitudes and phase angles of $\Delta aIub$, $\Delta bIub$ and $\Delta cIub$ are not influenced by unbalanced supply voltage conditions. Therefore the sensitivity of H-BRIDGE unbalance current measurement can be much higher than line current unbalance measurement, without spurious tripping caused by unbalanced supply voltages. In addition, this sensitive unbalance protection is now provided independently for each phase of the capacitor bank, thus making it possible to immediately and independently identify the phase and branch in which a change in capacitance has occurred. This is particularly convenient for larger capacitor banks with internally fused or unfused capacitor arrangements, to speed up the identification of faulty capacitor units. See also Fig. 12

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3 CPR04 RELAY HARDWARE DETAILS

3.1 NOMENCLATURE AND IDENTIFICATION OF EXTERNAL COMPONENTS

Refer to Fig. 1 and Fig. 2 for front and rear views of the CPR04 Relay and for identification of external components.

3.2 ENCLOSURE AND DRAW-OUT UNIT

The CPR04 Relay is housed in a draw-out chassis within a fixed case. This housing is particularly suitable for both flush mounting or 19 inch rack mounting. The case is designed for use in tropical climates, and is designed to withstand shock, vibration and the ingress of dust and moisture.

Phosphor bronze earth continuity strips are riveted to the draw-out chassis and make contact with the earthing strips in the fixed case.

In order to remove the draw-out chassis, unscrew by a quarter turn the bottom catch of the removable front cover and remove. Then firmly and slowly pull the draw-out handle on the front fascia plate to remove the draw-out chassis of the CPR04 Relay.

In order to insert the draw-out chassis into the fixed case carefully align the guide rails on the draw-out chassis with the corners of the fixed case. Then firmly and slowly push the handle on the front fascia plate to insert the draw-out chassis into the fixed case. When the chassis is almost fully inserted, an extra resistance will be felt as the moving contacts on the draw-out chassis mate with the contacts of the fixed case. At this point, press the handle very firmly to fully insert the draw-out chassis. Then place the front cover by hooking the top catch over the clip on the fixed case. Align the front cover and refasten the bottom catch by a quarter turn.

<u>CAUTION</u>

The CPR04 Relay incorporates static sensitive devices. However the electronic circuits are well protected by the fixed metal case. Therefore do not withdraw the draw-out chassis unnecessarily. Refer to Section 4.1 for further details on handling of the draw-out chassis when removed from the fixed case.

3.3 TERMINALS

A terminal block, with 28 recessed terminals, is provided on the fixed case. Standard M4 screw terminals (cable lugs with M4 and lug outer diameter \leq 8 mm), or fast-on connectors (4,8 mm width / 0,8 mm thickness), can be used on the terminal block for connections to the protection relay.

Removing the draw-out chassis from the fixed case automatically short circuits the current transformer field terminals, before breaking contact with the draw-out chassis, and ensures that the current transformer circuits are not open circuited during and after removal.

Refer to Fig. 2 and Fig. 4 for details of the terminal layout and terminal connection diagram.

3.4 MEASURING ELEMENTS

Four software configurable (1A/5A) current measuring elements are provided within the CPR04 Relay.

In Normal Mode the Elements 1,2 and 3 are used to measure the line currents while Element 4 is used to measure the star point unbalance current of a double star connected capacitor bank.

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In H-Bridge Mode the Element 1 is used to measure the reference phase current, while Element 2,3 and 4 are used to measure the unbalance currents of the H-configured capacitor bank.

As default, the CPR04 Relay is supplied with each measuring element pre-configured for a 5A nominal rated current (In = 5A). However the user may easily change via the menu or the PC communication program any or all elements to have a 1A nominal rated current, as required by the application.

WARNING

Extremely hazardous high voltages can appear across the CT secondaries if the CT secondary current is open circuited.

<u>CAUTION</u>

Be absolutely sure that the rated currents selected for each element correspond to the CT secondary rated current.

3.5 RELAY OUTPUTS

The CPR04 Relay has a total of six output relays.

The functionality of output relays 1 to 5 is user configurable. The user may program the relay contacts to be latching or non-latching and the output relays to be normally energized or normally de-energized during the power-up healthy condition. In addition, the user may direct any of the binary output signals of the protection functions to output relays 1 to 5.

Output relay 6 is the self-supervision relay for the CPR04 Relay, and its functionality is fixed. The self supervision relay is energized in the power-up, normal condition, and de-energizes on loss of auxiliary power supply, or on failure of the CPR04 Relay internal power supply, microprocessor hardware, software or memory. K6 will only be energized after all start up tests have been passed. In case the self tests show a fault, K6 will be de-energized and stay in this state.

Refer to Appendix 4 for further details.

3.6 CONTACT FORMS

Output relays 1 to 6 each have one changeover (form C) contact. As default, output relays 1 to 6 are supplied with the normally open (relay de-energized) contacts wired to the terminal block. However, the user may easily change any or all of the contacts of output relays 1 to 6 wired to the terminal block to be normally closed, as required by the application.

Refer to Appendix 4 for further details.

3.7 AUXILIARY POWER SUPPLY

A high efficiency, low loss, wide range ac/dc auxiliary power supply is provided within the CPR04 Relay. This allows the CPR04 to cater for auxiliary supply voltages of nominal values between 30 V and 250 V ac/dc.

See Appendix 4 for detailed information regarding the operative ranges as well as for further details. Special care shall be taken to the inrush current of the power supply in order to ensure a proper protection of the power supply. The inrush current can be estimated using the following equations:

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```
\begin{array}{l} DC \mbox{ - Supply : } \hat{l} = U_{DC} \mbox{ / 10} \\ AC \mbox{ - Supply : } \hat{l} = U_{AC} \mbox{ / 20} \end{array}
```

3.8 LED INDICATORS

Three LED indicators are provided on the front panel of the CPR04 Relay:

- Green LED: POWER ON / HEALTHY This signals that the auxiliary power supply is on, and the self supervision relay is energized, indicating that the protection relay is healthy.
- Yellow LED: START Based on the selected setting of "Start LED shows:" in the "Set OTHER functions" menu the following functionality will be achieved:
 - Only trip STARTS: this will cause the Start LED to light up constantly on STARTS which will cause a subsequent trip; ALARMS are ignored
 - Only ALARMS: this will cause the Start LED to flicker (0,5s ON 2s OFF) on ALARMS; STARTS are ignored
 - STARTS + ALARMS: this will cause the Start LED to light up constantly on STARTS which will cause a subsequent trip and flicker (0,5s ON 2s OFF) for ALARMS; if a START and ALARM occur simultaneously the LED will "flicker inverse" (2s ON 0,5s OFF)
 - Always off: this will cause the Start LED to be completely off
- Red LED: TRIP This indicates that a trip condition has occurred that has not yet been reset and
 / or acknowledged.

Refer to Appendix 4 for further details.

3.9 LCD DISPLAY

A two line, 16 character, full alpha-numeric, back-lit, Liquid Crystal Display (LCD) is provided on the front panel of the CPR04 Relay for the following purposes:

- During normal relay operation the display of various measured and calculated parameters, together with the low-set thresholds associated with these parameters.
- After a relay trip condition annunciation of all the fault conditions, including the value of the fault currents and voltages at the instant of trip, the information in which phase the max. / min. value occured and the relay trip time after commencement of the fault condition.
- During relay configuration interactive configuration of the protection relay.
- During testing of the protection relay interactive self-testing of the protection relay.
- In the event of the CPR04 Relay failure annunciation of any protection relay hardware, software
 or memory failures detected during self-testing of the CPR04 Relay, by displaying the relevant
 error codes.

Refer to Appendix 4 and Section 7 for further details.

3.10 KEYPAD

A five-button keypad is provided on the front panel of the CPR04 Relay for the following purposes:

- Interactive configuration of the protection relay
- Acknowledgement and resetting of trip conditions
- Hardware diagnostic testing

The button interface has the following features:

- repeat rates are automatically activated depending on the time the button is pushed continually:
- 5.0 char./s after 0.5 s 6.7 char./s after 2.0 s 14 char./s after 3.5 s 33 char./s after 5.0 s
- after the left and right button is pressed for 5 seconds, the user enters the main menu.
- if the LCD backlight is off, the first button will only switch the LCD backlight on, the function of the button is ignored.

Refer to Appendix 4 and Section 6 for further details.

3.11 DIGITAL INPUT

The CPR04 Relay is provided with an optically isolated, binary (on / off), voltage input channel, to receive an external signal. Any voltage from 30 - 250 V AC/DC can be applied to this input. The characteristic of this input (input active when voltage high or low) can be set in the menu.

Depending on the CPR04 Relay configuration the digital input can be used either as:

- *"Breaker-Bon"* signal from an auxiliary contact on the associated circuit breaker, to signal whether the breaker is open or closed. This signal is used by the undercurrent protection, and can be used by the breaker fail1 protection and Bena function of the CPR04 Relay. In case the relay does not receive the breaker on signal, none of the mentioned functiones will be operative. Refer also to Fig. 13
- *"Remote Reset"* from a normally open reset push button, to acknowledge a trip condition and / or reset any latched trip relays after a fault trip.
- "Event Trip" to trip certain output relays via a signal on the digital input
- "Disabled" if the digital input is not used

Refer to Appendix 4 and Section 6.6.2 for further details.

3.12 TEST FACILITIES

While the CPR04 Relay is in service, it continuously performs various self-testing functions, and if any errors or failures are detected, the corresponding error code(s) will be displayed, and the self-supervision output relay will de-energize, to signal the malfunction. These self-tests include tests of the processors as well as the memory of the device.

In addition, a further set of hardware diagnostic tests may be performed on the CPR04 Relay by the user, to test and check the functionality of the digital input, relay outputs, LCD display and LED's.

Refer to Section 6.8 for further details.

3.13 SERIAL DATA PORT

The CPR04 Relay is provided with two serial data ports which can be used simultanously.

One RS232 at the frontside (DB9 socket) and a second software selectable RS232 or RS485 port at the rear of the relay which is brought out via the rear terminal connector.

Both ports allow communication between a host and the CPR04 Relay, using the CPR04

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communication software or the MODBUS RTU protocol.

Firmware upgrades can only be performed via the frontside RS232 and a special upgrade program.

For communication via the front RS232 port use a 1 to 1 male to female connection cable.

The serial data ports are used for the following purposes:

- Downloading to the CPR04 Relay of a complete set-up, including all hardware settings, threshold settings, timer settings and output relay configuration settings for the CPR04 Relay.
- Uploading from the CPR04 Relay of the set-up currently active within the CPR04 Relay.
- Uploading from the CPR04 Relay of trip history information.
- The uploading from the CPR04 Relay of various instantaneous parameters, measured and calculated by the relay during normal operation.
- Connection of a CPR04 into a SCADA using the MODBUS protocol

3.14 PC BASED SOFTWARE PACKAGE

A Windows 95/98/ME/2000/NT/XP based software package is available for the CPR04 Relay to exploit its communication facilities. This software package enables the user to create, edit, save, open and print any number of the CPR04 Relay set-up files on a PC, and to download or upload a set-up file to or from the CPR04 Relay, either directly or via MODEM. In addition, all the other facilities and functions of the serial data port, as detailed above, can be exploited using this software package.

3.15 MODBUS PROTOCOL

The CPR04 supports the MODBUS RTU protocol for integration of the relay into a SCADA environment. Further information on the implementation can be provided upon request.

4 INSTALLATION

4.1 UNPACKING, STORAGE AND HANDLING

Upon receipt, the CPR04 Relay should be examined to ensure no obvious damage occurred during transit. Care must be taken when unpacking so that none of the parts are damaged.

If the CPR04 Relay is not to be installed immediately upon receipt, it should be stored in a location free of dust and moisture in their original cartons. The allowable storage temperature range is -20°C to +70°C.

The relay uses components that are sensitive to electrostatic discharges. However, the electronic circuits are well protected by the fixed metal case of the CPR04 Relay. Therefore do not withdraw the draw-out chassis unnecessarily.

When handling the draw-out module outside the fixed metal case, care should be taken to avoid contact with the electronic components and electrical connections. If removed from the case for storage and/or transport, the draw-out module should be placed in an anti-static bag.

If it is necessary to withdraw the draw-out module, the following precautions should be taken:

- Before removing the draw-out module, ensure that you are at the same electrostatic potential as the equipment, by touching the fixed metal case.
- Handle the draw-out module by the metal fascia plate, frame or edges of the printed circuit boards. Avoid touching the electronic components, printed circuit board tracks or connectors.
- If the equipment is to be passed to another person, first ensure you are both at the same electrostatic potential, such as, by shaking hands.
- Place the draw-out module on an anti-static surface, or on a conducting surface, which is at the same potential as you.
- Store or transport the draw-out module in an anti-static bag.

Further information on safe working procedures for electronic equipment can be found in the relevant national and international standards.

4.2 MOUNTING

The CPR04 Relay can be mounted anywhere that meets the environmental specifications as detailed in Appendix 3, and in particular it should be mounted indoors, in a clean, dry atmosphere, out of direct sunlight, and free from excessive dust and vibration.

Refer to Fig.3 for details of outline dimensions, cutout details and mounting holes.

CAUTION

Heat producing devices must be located at sufficient distances to ensure that the maximum operating temperature of the CPR04 Relay is not exceeded.

The CPR04 Relay is normally used as a flush mounted or 19 inch rack mounted instrument, for fitting on or within switchgear or relay panels. The relay should be mounted at a convenient height above floor level to facilitate optimum visibility and operator interaction.

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<u>CAUTION</u>

The mounting holes of the fixed metal casing of CPR04 Relay are accessible without removing the front cover and/or the draw-out module. Therefore it is strongly recommended that the draw-out module should remain protected by the fixed metal case during mounting and assembly of a CPR04 Relay into a panel or 19 inch rack.

4.3 WIRING

All current transformer, auxiliary voltage and output relay wiring connects to a terminal block with 28 recessed terminals on the rear of the fixed casing. Standard M4 screw terminals (cable lugs with M4 and lug outer diameter ≤ 8 mm), or fast-on connectors (4,8 mm width / 0,8 mm thickness), can be used on the terminal block for connections to the protection relay.

Refer to Fig. 4 for a terminal and connection diagram showing terminal numbers.

4.3.1 Auxiliary Power Supply

Wire the auxiliary power supply to terminals 5 and 7. The auxiliary power supply terminals can accept ac or dc input voltages and are not polarity sensitive.

<u>CAUTION</u>

Check carefully, before energizing, that the auxiliary voltage is correct, and falls within the range indicated on the CPR04 Relay.

Ensure that the auxiliary supply to the CPR04 Relay is adequately protected by means of fuses or miniature circuit breakers to suit the fault level and wire size used as well as the inrush current. High rupturing capacity fuses (2A) are recommended.

Refer also to the connection diagram of Fig. 4.

4.3.2 Current Transformer Circuits

Connect the current transformer connections for elements 1, 2, 3 and 4 to terminals 21, 22, 23 and 24 as well as 25, 26, 27 and 28, respectively.

Refer also to the connection diagram of Fig. 4.

CAUTION

One side of each CT circuit should be earthed, and multiple earth connections and earth loops should be avoided.

Refer to Appendix 4 for the acceptable current range, the short-time overcurrent, and the VA burden of the measuring elements.

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WARNING

Extremely hazardous voltages can appear across the CT secondaries if the CT secondary current is open circuited. Do not attempt to connect, disconnect, service or insert other devices in the CT secondary current loops without positively switching off the primary circuit, and thus ensuring that the secondary current is zero.

The draw-out module of a CPR04 Relay may be safely withdrawn on-load, because withdrawing the draw-out module automatically short circuits the current transformer terminals, and prevents the possibility of CT open circuits during the process.

4.3.3 Output Relay Circuits

Connect the output relay circuits to the terminals of output relays #1, #2, #3, #4, #5 and #6.

Refer also to the connection diagram of Fig. 4.

CAUTION

Check carefully before applying voltage to the output relay contacts that the loads and voltages to be applied are within the ratings of the relay contacts. Refer to Appendix 3 for the continuous thermal rating, the short time current rating, the making/breaking capacity, the maximum switching voltage and the maximum switching current of the output relays.

Ensure that the voltages applied to the output relay contacts are adequately protected by means of fuses or miniature circuit breakers to suit the fault-level, wire size and contact rating.

4.3.4 Digital Input

If applicable, connect the digital input circuits to terminal numbers 9 and 11.

Refer to the connection diagrams of Fig. 4.

The digital input terminals can accept ac or dc input voltages and are not polarity sensitive.

<u>CAUTION</u>

Check carefully before applying voltage to the digital input terminals that the voltage applied is correct and falls within the range detailed in Appendix 4.

Ensure that the voltage applied to the digital input is adequately protected by means of fuses or miniature circuit breakers to suit the fault level and wire size used. High rupturing capacity fuses (2A) are recommended.

4.3.5 Earth Connection

It is recommended that a 4mm² earth conductor be installed from the CPR04 Relay earth terminal to the panel earth bar. In addition, ensure that the panel is properly earthed in accordance with local regulations.

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WARNING

For personnel safety as well as not to adversely affect the CPR04 Relay by surges, transients and other electrical and electro-magnetic noise, it is essential that the relay is properly earthed as detailed above.

4.4 NOISE ISOLATION

When properly connected and earthed, CPR04 Relays are highly tolerant of electrical and electromagnetic noise. Refer to Appendix 3 for the withstand ability. However, as with other micro-processor based measurement and protection equipment, the CPR04 Relay must be installed, wired and located with some degree of concern for electrical and electromagnetic noise which could cause erratic operation. The relay should be wired, mounted and isolated from sources of potential noise and disturbances in excess of those prescribed in Appendix 3.

In extreme cases this may require that filters or surge suppressors be applied to electromagnetic devices operating in close proximity to the CPR04 Relay.

To avoid possible problems from electrical and electromagnetic noise and disturbances, or if specific problems are experienced in this regard, obtain specialist advice regarding counter measures and solutions.

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5 STEP-BY-STEP INSTRUCTIONS FOR INSTALLING, CONFIGURING, TESTING AND PUTTING INTO SERVICE

5.1 STEP-BY-STEP INSTRUCTIONS

- 1. Unpack the relay, and check for obvious damage.
- If the contact form (normally open or normally closed) of any of output relays #1, #2, #3, #4, #5 or #6 is to be changed from the default settings of normally open to normally closed, withdraw the draw-out module and reconfigure the appropriate contacts.
- 3. Insert the draw-out module back into the fixed casing and affix the front cover of the relay.
- 4. Mount the CPR04 Relay within a cut-out on the switchgear or relay panel, or within an appropriate 19 inch rack.

Ensure that the fixed housing is securely screwed to the panel or 19 inch rack, using the mounting holes on the fixed housing. These are accessible from the front without removing the front cover of the relay.

- 5. Wire the auxiliary power supply to the relay, (Do not apply voltage yet).
- 6. Wire the current transformer circuits to the relay. (Do not apply current to the inputs yet.)
- 7. Wire the appropriate output relay circuits to suit the application. (Do not apply voltage yet.)
- 8. If applicable, wire the digital input circuits. (Do not apply voltage yet.)
- 9. Measure the auxiliary power supply voltage, the voltages for the output relays and the voltage for the digital input. Confirm that these voltages are correct and within the acceptable range in accordance with the CPR04 Relay specifications. Only then apply these voltages to the CPR04 Relay.

Measure the voltages at the terminals of the CPR04 Relay to confirm that the voltages at the relay terminals are correct.

Check that with auxiliary power applied, the self-supervision relay #6 is energized and that its contacts are in the correct state.

- 10. Check that the LCD screen of the CPR04 Relay is displaying the normal operation screen display, that the green POWER ON / HEALTHY LED is ON, and that the yellow and red LED's are off.
- 11. Access the main menu. See section 6.3 for details.
- 12. Access the Hardware Setup Menu and configure the relay to suit your application (Normal Mode / H-Bridge Mode \\ 50Hz / 60Hz \\ Element 1-4 rated current selection).
- 13. Configure the parameter settings for the protection elements as well as the OTHER settings to suit the application.
- 14. Save the parameter settings configured.
- 15. From the main menu, access the OUTPUT RELAY SETUP function.
- 16. Configure the functionality of output relays #1, #2, #3, #4, and #5 to suit the application.

- 17. Check that the output relay checksums are correct for the desired output relay configuration
- 18. Save the output relay functionality configured.
- 19. From the main menu, access the DIAGNOSTIC TEST sequence, and execute the diagnostic test. Confirm that all diagnostic tests produce satisfactory results.
- 20. From the main menu, access the SERIAL PORT options, and select the appropriate baud rate and parity (and type of backside port) for the serial ports.
- 21. Save the serial data port settings.
- 22. From the main menu, access the ACCESS AND SET REAL TIME CLOCK and set the actual time and date in the device.
- 23. Revert back to the normal running screen displays.
- 24. Perform primary or secondary injection tests. Confirm that the normal running parameters displayed are correct, and that the protective functions are operational. Perform any other relevant commissioning checks and tests.
- 25. Once any other commissioning tests associated with the complete installation are completed, and the associated circuit breaker is energized, check that the parameters displayed on the normal running screen are sensible and correct.
- 26. Compensate the natural star point unbalance current respectively the individual natural unbalance currents of the H-Bridge.
- 27. Document all the commissioning tests and the CPR04 Relay settings carefully.

CAUTION

Performing any changes to element variable or other settings, changes to output relay configurations, or running the diagnostic test sequence to test the output relays, may cause the associated circuit breaker to trip. This could cause serious system disruption. Therefore the greatest care should be exercised when performing these functions on-line, and the user should have a thorough knowledge of this entire manual as well as the particular application and system.

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6 KEYPAD OPERATIONS

6.1 INTRODUCTION

This section provides details of user keypad operations and the interactive relay screen displays, when executing the various relay functions, including:

- Accessing the normal operation screen displays
- Executing any main menu or sub-menu functions
- Reverting back from the main menu functions to the default normal operation screen display
- Access PARAMETER SETUP menu
- Setting of ELEMENT variables
- Setting of OTHER functions
- Compensating of unbalance currents
- Access OUTPUT RELAY menu
- Run DIAGNOSTIC TEST sequence
- Access STATUS INFORMATION menu
- Browse TRIP HISTORY list
- Access SERIAL PORT options
- Access PASSWORD SETUP menu
- Access HARDWARE SETUP selector
- Access and SET REAL TIME CLOCK

6.2 ACCESSING THE NORMAL OPERATION SCREEN DISPLAYS

After power-up, pressing the \land , \lor , \lt , \succ keys allows the user to access all the normal operation screen displays. Refer also to section 7.1 for further details.

6.3 ACCESSING THE MAIN MENU FUNCTION

During normal relay operation, press the \lt & \succ keys simultaneously for 5 seconds.

Any trip condition must first be cleared before the operator can access the main menu. If a trip occurred while the operator is busy in the setup or any other menu, the trip condition will be logged and on returning from the menu, the trip display will activate.

If the CPR04 Relay password code has not been changed from the default code (000000), then the user will now have access to the main menu, and the first of the main menu functions will be displayed.

However if the user has changed the default password code to any number other than 000000, then at this point the following screen will be displayed:

Type Password	
<u>0</u> 00000	

Pressing the \lt or \succ key moves the cursor to the left or right.

Pressing the \wedge or \vee key increments or decrements the digit at the cursor.

Therefore using the \land , \lor , \checkmark , \succ keys, the correct password code can be entered by the user.

Once the correct password has been entered, press the red ACCEPT key to return to the main menu.

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<u>NOTE</u>

Only the correct password code will allow access to the settable parameters in the sub menu's.

Pressing the \prec or \succ key will scroll through the other main menu functions as shown:

MAIN MENU FUNCTION

KEYPAD OPERATION

	Access PARAMETER SETUP menu	Press ≺ or ≻ ke
	Access OUTPUT RELAY menu	Press ≺ or ≻ ke
	Run DIAGNOSTIC TEST sequence	Press ≺ or ≻ ke
	Access STATUS INFORMATION	Press ≺ or ≻ ke
	Browse TRIP HISTORY list	Press ∢ or ≻ ke
	Access SERIAL PORT options	Press ≺ or ≻ ke
	Access PASSWORD	Press ≺ or ≻ ke
	Access HARDWARE	Press ∢ or ≻ ke
	Access and SET	Press ∢ or ≻ ke
l		

6.4 EXECUTING ANY MAIN MENU OR SUB-MENU FUNCTIONS

After selecting and displaying the desired main or sub-menu function, use the \forall key to access the selected function.

6.5 REVERTING BACK FROM THE MAIN MENU TO THE NORMAL OPERATION SCREEN DISPLAY

When any one of the main menu function screen displays is being shown, the user can revert back to the default normal operation screen display by pressing the \prec and \succ keys simultaneously. If the user does not enter any data or touch any of the buttons for 10 minutes, the relay will automatically return from the menu to the normal mode display.

6.6 ACCESS PARAMETER SETUP MENU (Optional password protection)

From the main menu, select the "Access PARAMETER SETUP menu" using the \lt or \succ keys. Then execute this function by pressing the \lor key.

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The first of the PARAMETER SETUP sub-menu functions will be displayed. Pressing the \prec or \succ key will scroll through the setting menu, which will be displayed as follows:

NORMAL MODE		H-BRIDGE MODE		
Set ELEMENT 1, 2, 3 variables	Set ELEMENTPress < or > key1, 2, 3 variables		Press ≺ or ≻ key	
Set ELEMENT 4 variables	Press ∢ or ≽ key	COMPENSATE for alub	Press ∢ or ≻ key	
Set ELEMENT 5 variables	Press ≺ or ≻ key	COMPENSATE for blub	Press ∢ or ≻ key	
Set OTHER functions	Press ≺ or ≻ key	COMPENSATE for club	Press ≺ or ≻ key	
COMPENSATE for star unbalance	Press ∢ or ≽ key	Set OTHER functions	Press ∢ or ≽ key	
Clear TRIP HISTORY list? No	Press ≺ or ≻ key	Clear TRIP HISTORY list? No	Press ≺ or ≻ key	

To execute any of the above setting menu functions, select the desired sub-menu using the \prec or \succ key, and then execute it using the \forall key.

<u>NOTE</u>

It should be noted that while the CPR04 Relay is in the set-up mode, all the protective functions are still active and thus full protection is still provided, using the previously saved set-up parameters.

6.6.1 Exiting from a setting menu

After accessing any of the parameter set-up functions and making any element setting, other setting or compensation of the unbalance currents, press the red ACCEPT key to revert back to the main menu.

The user will be presented with 3 choices:

- Resume
- Save
- Cancel

Press the \wedge or \vee key to select one of the above.

If **Resume** is selected, then pressing the red ACCEPT key will return the relay to the menu position from where the accept button was pressed, to allow the user to further modify parameters.

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If **Save** is selected, then pressing the red ACCEPT key will save the new settings and return to the main menu.

If **Cancel** is selected, then pressing the red ACCEPT key will abort and return to the main menu without saving the new settings (ie. the new settings will be discarded).

6.6.2 Setting of "ELEMENT" variables

After selecting any of the "Set ELEMENT... variables" functions, press the V key to access the relevant element's variables.

Then press \prec or \succ to scroll through the list of element variables. Once the desired element variable is displayed, press the \land or \checkmark key to increment or decrement the setting value. If the cursor is pressed continually, the variable setting will start to scroll with an increasing number of characters per second. Refer also to section 3.10 for further details

When set as desired press the red accept key to return to the setting menu level again. Proceed as previous until all the element variables have been set as desired.

Refer to Appendix 5 and 6 for a complete list of settable element variables and the relevant setting ranges.

To disable an element variable, scroll the setting value until the mnemonic changes to "N/A" (not available). If a setting variable is disabled by "N/A" then also the associated timer is disabled.

When all the "element" variables have been set as desired, press the red ACCEPT button to revert back to the setting menu level.

6.6.3 Setting of "OTHER" functions

After selecting "Set OTHER functions", press the \forall key to access a list of "OTHER" settings. Depending on the selected operating mode (Normal or H-Bridge) only certain "OTHER functions" will be available. Pressing the \triangleleft or \triangleright key scrolls through these "OTHER" setting variables. When the selected "OTHER" variable is being displayed, press the \land or \forall key to increment or decrement the setting value or scroll through the available setting options.

The "OTHER" setting variables are:

- The functionality of the digital input. This can be either "*Disabled*" if the digital input is not being used, or set as a Breaker on, "*Breaker-Bon*", signal or as a "*Remote-Reset*" or as "*Event Trip*".
- The characteristic of the digital input input active when connected voltage is *high* or *low*
- The Event timer setting, *Event:xt*
- The breaker fail 1 timer setting, *Bfail1:xt* as well as the *Bfail1 release* function; the following release functions are available to stop the *Bfail1* timer: Ifund<10% (fundamental current falls below 10%); Dig-Input (change in status of the digital input); Ifund AND Input (both criteria have to be met), Ifund OR Input (any of the two criteria will release the *Bfail1* function)
- The breaker fail 2 timer setting, *Bfail2:xt*
- The breaker enable timer setting, *Bena:xt* as well as the breaker enable trigger function; the following triggering functions are available: Dig-Input (change in status of the digital input); Ifund<10% (fundamental current falls below 10%), Ifund AND Input (both criteria have to be met), Ifund OR Input (any of the two criteria will trigger the Bena)

- The "Start LED shows:" setting; the following options are available:
 Only trip STARTS: this will cause the Start LED to light up constantly on STARTS which will cause a subsequent trip; ALARMS are ignored
 - Only ALARMS: this will cause the Start LED to flicker (0,5s ON 2s OFF) on ALARMS; STARTS are ignored
 - STARTS + ALARMS: this will cause the Start LED to light up constantly on STARTS which will cause a subsequent trip and flicker (0,5s ON 2s OFF) for ALARMS; if a START and ALARM occur simultaneously the LED will "flicker inverse" (2s ON 0,5s OFF) Always off: this will cause the Start LED to be completely off

When the "OTHER" variables have been set as desired, press the red ACCEPT button to revert back to the setting menu level.

6.6.4 The COMPENSATE functions

Compensation of the natural unbalance current can only be done after the relevant capacitor bank or filter circuit is in service. This is applicable for the star unbalance protection in Normal Mode operation as well as for the H-Bridge unbalance protection in H-Bridge Mode. In the following the relevant sequence is described for the star unbalance protection – however it is equally applicable to the three H-Bridge compensation elements.

After selecting and displaying the COMPENSATE function press the \forall key to execute. At this point the compensation vector is displayed.

When the unbalance current is uncompensated the compensation vector is the null vector as shown below:

% / 0.0°	comp.		vector
70 ∠ 0.0	%	Ζ	0.0°

When the unbalance circuit is compensated the compensation vector is typically shown as:

comp.		vector	
3.4%	\angle	356.9°	

After compensation, the compensation vector has the same magnitude as the initial measured fundamental frequency unbalance current at the instant of compensation, but has the opposite polarity (i.e. is 180° out of phase).

Pressing the > key then displays the calculated unbalance current either in absolute terms, (if uncompensated) or in relative terms, ΔIub , if compensated.

lub	3.4%	Ζ	176.9°	
Compensate? No				

Pressing the ∀ or ∧ key toggles between "No" and "Yes".

When "No" is selected, pressing the red ACCEPT key returns you back to the setting menu level.

If "Yes" is selected, pressing the red ACCEPT key, executes the COMPENSATION function. Immediately after compensation ΔIub will always be the null vector.

However, after compensation any subsequent change in capacitance will cause ΔIub to assume a nonzero magnitude and some phase angle ranging from 0° to 360°. The magnitude of ΔIub is a measure of the change in capacitance in any leg of the capacitor bank arrangement. The phase angle of ΔIub

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indicates the part of the bank in which the change in capacitance has occurred. (Refer to Fig. 10 and 12).

Pressing the \succ key again displays

Uncompensate No

Pressing the \vee or \wedge key toggles between "No" and "Yes".

When "No" is selected, pressing the red ACCEPT key returns you back to the setting menu level.

If "Yes" is selected, pressing the red ACCEPT key, executes the UNCOMPENSATE function and reverts to the previous "Compensate?" display.

6.7 ACCESS OUTPUT RELAY MENU (Optional Password Protection)

From the main menu, select the "Access OUTPUT RELAY menu" using the \prec or \succ key. Then execute this function by pressing the \forall key.

Pressing the \lt or \succ key now scrolls a cursor back or forward through a series of setting options and screens. At each cursor position, the user can select the relevant setting options to be "0" or "1", using the \land or \lor key.

These setting options are used to configure each of the output relays #1 to #5 in terms of:

• whether a software output signal is directed (select "1") or not directed (select "0") to output relays #1 to #5.

Example for relay in Normal Mode:

Relay :	#12345	
l1>>trip	11000	

Example for relay in H-Bridge Mode:

Relay :	#12345	
alubal	11000	

The *II*>>*trip* software output signal is directed to operate relay #1 and #2

The *aIub_al* software output signal is directed to operate relay #1 and #2

• whether output relays #1 to #5 energize (select "1") or de-energize (select "0") to trip.

Example:

Energise	#12345
To trip	11000

Output relay #1 and #2 energize to trip and relays #3 to #5 de-energize to trip

• whether output relays #1 to #5 latch on tripping ("1"), or are self-resetting ("0").

Example :

Latch	#12345
On trip	11000

Output relay #1 and #2 latch on trip, and relays #3 to #5 are self-resetting

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Example:

Relay #2 Checksum 0200002

For each possible configuration of output relay #1, #2, #3, #4, and #5 a unique hexadecimal check sum is calculated by the CPR04 Relay as shown in Appendix 8.

By comparing the check-sums calculated by the CPR04 Relay, with the correct checksums calculated by the user for the desired output relay configuration, the user can confirm that the relay has been configured correctly.

After configuring the output relays and viewing the check-sums press the red ACCEPT key to revert back to the main menu.

6.8 RUN DIAGNOSTIC TEST SEQUENCE

On application of auxiliary supply voltage, and at regular intervals during normal operation, the CPR04 Relay performs a number of diagnostic checks of the:

- EEPROM
- Calibration factors
- EPROM
- RAM
- Processors

Any errors detected will cause the CPR04 Relay to suspend all protective functions, de-energize the self-supervision relay and display an error message as detailed in Appendix 7. In addition, during commissioning, while in normal service, or in the test laboratory, a series of diagnostic tests may be performed by the user.

These tests enable the user to check:

- The serial number
- The software version
- The Relay User Code
- The production Pretest Code
- The LCD screen
- The LED's
- The digital input
- The output relays
- The Control and Display hardware status

All protective functions are fully operational while performing the above series of diagnostic tests, except during the testing of the output relays !

NOTE

Also, testing of the output relays while the CPR04 Relay is in normal service, with the associated circuit breaker energized, may cause the breaker to trip. This is because the output relays sequentially energize for 1 second during the output relay test.

Therefore, before performing the output relay test, the user is given the option to skip this test.

From the main menu, select the "Run DIAGNOSTIC TEST sequence" using the \prec or \succ .

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Then execute this function by pressing the \forall key.

Pressing the \prec or \succ key now scrolls through various diagnostic test screens as follows:

Serial Number XXXXXXXX Press the \geq key

Press the \geq key

Press the \geq key

This screen enables the user to verify that the serial number embedded in the CPR04 Relay corresponds with that engraved on the fascia plate

The first 3 digits indicate the software version number. The next 3 double digit groups refer to changes made, to either the **User Interface**, the **Protection software module**, or the **DSP code**.

Relay User Code XXXXXXXXXX

The Relay User Code is a code which changes with every saving of a setting file. This user code allows Trench to provide a single useable password in case the set password is forgotten. An official written request by fax with this number is required to provide the single usable password.

Pretest Code FLOW: ---PASSED Press the \geq key

This screen shows the results of a series of factory tests prior to dispatch. If the above screen displays anything other than that shown above, this indicates a fault condition, and the CPR04 Relay should be returned at once to Trench Austria.

Press the \geq key

This screen causes every pixel of the LCD display to operate, allowing the user to identify any faulty lines or segments on the LCD screen.

Test:	:	LED's
(Check	c fla	ashing)

Press the ≻ key

This screen enables the user to check that the LED indicators work by checking that they flash during this diagnostic test.

Test: : Input
Input = OFF

Press the ≻ key

This screen enables the user to check that the digital input is functional. When a voltage within the range 30 - 250 V ac/dc is applied to the digital input terminals, the above display should change from OFF to ON.

Test Relays ? No	
CAUTION !!	

Press the \prec , \succ , \bigstar , \forall key

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WARNING

Performing the diagnostic test on the output relays, while the associated circuit breaker is energized may cause the circuit breaker to trip, with consequent system disruption. Therefore the greatest care should be exercised when performing this function under live conditions.

If the user wishes to skip the output relay test, simply press the \prec or \succ key to move back or forward through the other diagnostic tests.

If the user wishes to perform the output relay tests, press the \land or \lor key to toggle the "No" to "Yes", then press the red ACCEPT key.

A screen as shown below will be displayed:

Test Relay #1 No

Press the \lt or \succ key to select the desired relay to test (relays #1 to #5). Then press the \land or \lor key to toggle the "No" to "Yes".

Then press the red ACCEPT key. The selected output relay will then energize for 1 second.

Press the \prec or \succ key to select the next relay to test.

Repeat as above until all the relays have been tested.

Then press the \prec or \succ key until the following screen is displayed:

Return to MENU No

Press the \wedge or \forall key to toggle the "No" to "Yes" and press the red ACCEPT key.

The first screen in the DIAGNOSTIC TEST MENU is now displayed again.

If the user wishes to access the "Control hardware" and "Display hardware" screen, simply press the \triangleleft or \succ key to access the desired position.

Control hardware P:3.00 C:3.00 Press the \geq key

These screens enables the user to check the relay hardware version – this might be necessary to verify that the hardware is suitable for a desired firmware upgrade.

Press the red ACCEPT key again to revert back to the main menu.

6.9 Access STATUS INFORMATION (Optional Password Protection – partially)

This menu allows the user to obtain certain information from the relay like:

- Install information
- Digital input function
- Output relay status

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- Communication port activity
- Setup saved counter
- Protective function trip counters

From the main menu, select the "Access STATUS INFORMATION" using the \prec or \succ keys. Then execute this function by pressing the \forall key.

Pressing the \prec or \succ key now scrolls through various screens as follows:

Install Info. PC and MODBUS pr Press the \geq key

This screen shows the user a text (max. 100 characters / scrolling over the screen) which can be downloaded to the CPR04 Relay using the communication software

Input function			
Status =	Low		

Press the ≻ key

This screen enables the user to check that the digital input is functional taking into consideration the set characteristic for the digital input (active when connected voltage high or low).

Press the \geq key

This screen enables the user to check if any of the output relays is energized.

Front RS232 Tx= OFF Rx= OFF Press the \geq key

The two screens (Front / Rear) enable the user to check if the serial data ports are functional. When data are received or transmitted, the respective part of the communication display should change from OFF to ON.

Setup Saved	
Counter = 00009	

Press the ≻ key

This screen allows user to check how often the setup has been saved on this unit. Additionally by pressing the \land or \forall key the following screen can be accessed:

Save	d: 16:52:18
Tue	23/11/2004

Press the \geq key

The following screens will (depending on the selected operating mode) show the trip and alarm counters for the individual trip / alarm functions together with the time stamp information when the counter has been last cleared.

Relay configured in Normal Mode:

vc>alarm tripped	Press the ≺ or ≻ key to access
Counter = 000012	the next trip counter information

Press the \wedge or \forall key to toggle between the above and the following screen:

Cleared: 14:54:28	
Wed 23/11/2004	

Press the \prec or \succ key to access the next trip counter information

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The 21 screens will show the user, how many trips the unit has performed so far for the respective protection function. These counters can be reset individually if the unit is not password protected, respectively if the password has been entered correctly upon entry into the main menu. In order to reset the individual counters perform the following steps:

Select the desired counter using the \prec or \succ keys. Press the red accept button to select the counter. The display changes as follows:

Vc> tripped Clear NOW ? No

Use the \land or \lor key to toggle the "No" to "Yes" and press the red ACCEPT key to clear the counter. The time stamp information will be updated accordingly. If you selecet "No" and press the red accept key, the relay will revert to the "Access STATUS INFORMATION" menu.

Relay configured in H-Bridge Mode:

alub_al tripped Counter = 000008 Press the \prec or \succ key to access the next trip counter information

Press the \wedge or \forall key to toggle between the above and the following screen:

Clear	ed: 09:25:12	
Tue	22/11/2004	

Press the \prec or \succ key to access the next trip counter information

The 10 screens will show the user, how many trips the unit has performed so far for the respective protection function. Each counters can be reset in the same way as described above for the Normal Mode operation.

6.10 Browse TRIP HISTORY list

When a fault has been cleared and acknowledged after a trip event, a set of post-trip annunciation data is recorded in the TRIP HISTORY list.

The TRIP HISTORY list records the post-trip annunciation data for the last 25 trip events, trip events which happen during a so called trip session are pooled into one trip group with No. 1 being the most recent.

Refer to Section 7.4 for further details.

From the main menu, select: "Browse TRIP HISTORY list" using the \prec or \succ keys. Then execute this function by pressing the \forall key.

Pressing the \wedge or \vee key now scrolls through the TRIP HISTORY entries.

A typical trip history entry in normal mode operation might look as follows:

N01G01	13:57:10
Mon	29/11/2004

This screen shows the date and time of the the 1^{st} trip (N01) of the first trip session (G01)

Press the \prec or \succ key to toggle between the above and the following screen:

lub>trip	5,6%	
<3°	20,01s	

This screen shows that the first trip was a star unbalance low set trip with a trip amplitude of 5,6% and a trip angle of 3° in 20,01s

Press the \prec or \succ key to toggle between the above and the following screen:

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Ref.Phase	5,6%
70%	< 3°

This screen shows that the value of the reference phase during the low set trip (tripped on 5,6% and a trip angle of 3°)

The information shown in the third screen depends on the trip function and provides additional information for better reconstruction of the trip event.

Press the \prec or \succ key to toggle between the above and the following screen:

Relay(s) tripped	
1 - 3	

This screen shows the status of the output relays at time of trip

When all the desired TRIP HISTORY list data have been viewed, press the red ACCEPT key to revert back to the main menu.

If the user wants to clear the complete trip history list, he just needs to enter the Trip History menu using the \forall key and press then the red accept key. The following is displayed:

Trip History	
Clear NOW?	No

Use the \wedge or \forall key to toggle the "No" to "Yes".

Then press the red ACCEPT key to clear the Trip History list.

Press the \prec or \succ key to toggle between the above and the following screen:

Cleare	ed: 09:25:12	
Tue	22/11/2004	

This screen shows the time and date when the trip history list was last cleared

6.11 Access SERIAL PORT options (Optional Password Protection)

From the main menu, select "Access SERIAL PORT options" using the \prec or \succ key. Then execute this function by pressing the \forall key.

Use the ∧ or ∨ key to select the baud rate (2400-115200) of the FRONT port as desired.

Pressing the \geq key then scrolls to the parity setting menu for the FRONT port. Use the \wedge or \forall key to select the desired parity (EVEN/ODD/NONE) for the FRONT port.

Pressing the \geq key then scrolls to the setting menu for the selection of the REAR port type. Use the \wedge or \forall key to select the desired type (RS232/RS485) for the REAR port.

The following two menus contain the baudrate and parity setting for the REAR port and are accessed and set in the same way as described for the FRONT port above.

Pressing the \geq key then scrolls to the MODBUS setting menus. In the following menus you can select the device adress, answer response time, receive dead time and force relay time. To get more detailed information on the MODBUS implementation please contact Trench Austria for further details. Then press the red ACCEPT key to confirm the selected setting.

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6.12 Access PASSWORD SETUP menu

This function is used to change the password code from the initial default password code (000000) on delivery, to a new user selectable password code.

In order to change the password code to a new password code, the user will have to know the existing password code, except when changing from the default password code. From the main menu, select "Access PASSWORD SETUP menu" using the \prec or \succ key. Then execute this function by pressing the \forall key.

The following screen will be displayed:

Old Password <u>0</u>00000

Press the \lt or \succ key to move the cursor, and press the \land or \lor key to increment or decrement the selected digit.

In this way the Old Password code is entered. When the correct Password code is displayed, press the red ACCEPT key to confirm.

The following screen will be displayed:

New Password 000000

In a similar manner to that detailed above, set a New Password code.

When the desired New Password code is displayed, press the red ACCEPT key to accept the New Password code.

If an incorrect password is entered, pressing the red ACCEPT key will revert back to the main menu. The user now has the option to repeat this function.

Please note, that it is also necessary to know the relays password if you want to communicate via the serial port. If a password is set in the relay, it is not possible to download setting values if the password has not been entered correctly in the PC communication program.

NOTE

In case the user looses the password, Trench Austria can provide a single usable password from the User Code which is displayed in the Diagnostic Test Sequence. An official written request has to be sent to Trench Austria to get this special password.

6.13 Access HARDWARE SETUP selector (Optional Password Protection)

This menu allows the user to configure the relay in respect to:

- Set Relay Mode
- Set Frequency
- Set Element 1-4 rated current
- Power up restore functionality

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From the main menu, select the "Access HARDWARE SETUP selector" menu using the \prec or \succ keys. Then execute this function by pressing the \forall key.

Pressing the \prec or \succ key now scrolls through various screens as follows:

Set Relay Mode Normal mode Use the \land or \lor key to change between Normal mode and H-Configuration

Use the \wedge or \vee key to change between

50 Hz and 60 Hz

Press the \succ key to access the following screen:

Set Frequency 50 Hz

Press the \succ key to access the following screen:

Element 1 I(n) 1 Amp Use the \land or \lor key to change between 1 Amp and 5 Amp

Use the \geq key to access the following 3 screens to adjust also Element 2, 3 and 4 rated current. Press then the \geq key to access the following screen:

Power up restore Clear trip state Use the \land or \lor key to change between Clear trip state or Hold trip state

The Power up restore setting allows the user to define the behaviour of the relay when the power is switched off during a trip – Clear trip state will clear the internal trip register, Hold trip state will cause the relay to come up with the same trip messages and hardware status (LED's, output relays,..) as at time of power down.

<u>CAUTION</u>

Never change the relay mode, fundamental frequency or the rated current of the Element 1-4 of the CPR04 Relay while the relay is in service protecting a capacitor bank or filter circuit.

Press the red ACCEPT key to confirm the selected hardware configuration.

6.14 Access and SET Real Time Clock menu

This function is used to set the built in real time clock which is backed up by a goldcap which will supply the clock chip for approx. 2 weeks – after that a re-adjustment of the clock will be necessary.

In order to set the real time clock, the user has two options – either via the serial port using the PC communication programm or directly via this menu point.

From the main menu, select "Access and SET Real Time Clock" using the \prec or \succ key. Then execute this function by pressing the \forall key. The following screen will be displayed:

Set Time	
<u>1</u> 3:40:38	

Press the \lt or \succ key to move the cursor, and press the \land or \lor key to increment or decrement the selected digit.
When the cursor is at the seconds position press the \succ key to access the following screen:

Set Date <u>T</u>hu 25/11/2004

Use the \lt or \succ key to move the cursor, and press the \land or \lor key to increment or decrement the selected digit.

Press the red ACCEPT key to confirm the time and date setting.

7 DISPLAY ANNUNCIATION AND SCREEN NAVIGATION

7.1 THE LCD SCREEN DISPLAYS DURING NORMAL OPERATION

After auxiliary power-up, and during normal operation, the LCD screen displays show the instantaneous values of various measured and calculated parameters of the CPR04 Relay.

Upon delivery, the default LCD screen display for the relay in normal mode operation is the Element 1,2 and 3 peak repetitive capacitor voltage, *vc* screen, while for the H-Configuration mode the summary screen showing the a-, b- and c-phase unbalance currents is the default display.

The other LCD screen displays during normal operation may be accessed by pressing the $\land, \forall, \prec, \succ$ keys. This will scroll through the various other normal operation screen displays enabling the user to view the instantaneous values of the various measured and calculated parameters of the CPR04 Relay as well as the the low set threshold.

If, after accessing any normal operation screen display, the \land , \lor , \lt , \triangleright keys have not been pressed for a period of about 1 minute, the back lightning will switch off and the relay will return to the default display. In order to define any other screen display as default display, just press the red accept key while that desired screen display is selected. The relay will show a short message "New DEFAULT DISPLAY saved".

The display features small indicators for each of the protective function thresholds (alarm: $_{al}$; low: [>]; high: _{>>}; undercurrent: _<). This allows the user to see from the display which protective functions are set. Furthermore if the function is active the associated indicator starts to blink.

If the relay is not measuring a signal or if the signal is below the suppression level the display will only show --% or $--^{\circ}$.

7.1.1 Screen displays for Normal mode

With the relay being configured in normal mode a number of various normal operation screens are available:

The following displays can be viewed:	Keypad operation
Element 1, 2 and 3 peak repetitive capacitor voltage, vc	A or V
Element 1, 2 and 3 fundamental frequency line currents, II	A or V
Element 1, 2 and 3 thermal response currents, Ith	A or V
Element 1, 2 and 3 rms currents, Irms	A or V
Star point unbalance current and phase angle, <i>Iub</i> (or ΔIub)	∧ or ∀
Earth fault current, Io	A or V
Line unbalance current, <i>Ilub</i>	A or V
Reference phase current	🔺 or 🏹
Time and date	∧ or ∨

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The Reference phase is the fundamental component of the Element 1. If the Reference phase current falls below 10%, then this has an impact on the way the star point unbalance protection function operates – see section 2.1.3 for details.

A typical screen display will look as follows:

or in case of star point unbalance:



A second set of screen displays allows the user to view the actual measured / calculated parameter together with the associated low-set threshold. In case of protective functions which operate with values from Element 1,2 and 3, the display shows the actual maximum of the three Elements. There is also a screen, showing if the Bfail1, Bfail2 and Bena have been set and one screen showing the function of the digital input – this screen changes its text based on the function selected for the digital input as follows: *Disabled* = Digital Input (OFF or ON); *Breaker-Bon* = Breaker Position (Open or Close); *Remote Reset* = Trip Reset State (No trip reset or Trip reset); *Event trip* = Free Text (Inactive text or Active text) – the three text messages can be downloaded using the PC communication program.

Keypad operation:

The following displays can be viewed:

≺ or ≻
< or ≽
< or >
< or ≽
< or ≽
< or >
< or ≽
< or ≽
t < or >
í

A typical screen display can look as follows:

The above screen shows that the low set and high set trip thresholds have been set, and that the maximum of the capacitor voltage in the three elements is 103%. If the value would exceed the low set threshold (110%) the low set trip indicator ($^{>}$) would start to blink, while if the value would exceed the high set threshold, both indicators ($^{>}$ and $_{>>}$) would blink.

7.1.2 Screen displays for H-Configuration

With the relay being configured in H-Configuration a number of various normal operation screens are available:

The following displays can be viewed:	Keypad operation:
a-phase unbalance current and phase angle, <i>aIub</i> (or <i>AaIub</i>)	∧ or ∀
b-phase unbalance current and phase angle, <i>bIub</i> (or <i>AbIub</i>)	∧ or ∀
c-phase unbalance current and phase angle, $cIub$ (or $\Delta cIub$)	∧ or ∀
Time and date	∧ or ∀
a & b & c-phase unbalance current, <i>alub / blub / club</i>	∧ or ∀

The Reference phase is the fundamental component of the Element 1. If the Reference phase current falls below 10%, then this has an impact on the way the H-Bridge unbalance protection function operates – see section 2.2.1 for details.

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A typical screen display can look as follows:



A second set of screen displays allows the user to view the actual measured / calculated parameter together with the associated low-set threshold.

The following displays can be viewed:

aIub	&	aIub>/In threshold setting
bIub	&	bIub>/In threshold setting
cIub	&	cIub>/In threshold setting
Event text / Tr	ip reset state	
		_

Reference phase current Element 1

A typical screen display will look as follows:

▫◗▰▮		

or in case of compensated unbalance:



Keypad operation: < or > < or > < or ≽ < or ≽

< or >

The above screen shows that the natural unbalance in the a-phase has been compensated and the alarm as well as the low set and high set trip thresholds have been set, and that the actual unbalance current in the a-phase is 1%. If the value would exceed the alarm threshold for the time set, the alarm indicator will start to blink; if the unbalance current exceeds the low set threshold (10%) - the low set trip indicator ([>]) would also start to blink, while if the value would exceed the high set threshold, all three indicators ($_{al}$ and $^{>}$ and $_{>>}$) would blink.

7.2 THE LCD SCREEN DISPLAY DURING FAULT / OVERLOAD CONDITION

During a fault / overload condition the normal operation screens simply display the various measured and/or calculated parameters. In addition the small indicators ($_{al}$ or $^{>}$ or $_{>>}$) on the display start to blink, to signal the active function.

7.3 THE LCD POST-TRIP FAULT ANNUNCIATION and TRIP HISTORY SCREEN DISPLAYS

POST-TRIP FAULT ANNUNCIATION SCREEN DISPLAYS

The set of post trip annunciation data for each trip event indicates which software trip signals were output during the trip event. The magnitude of parameter causing the corresponding software trip signal is recorded at the instant of output, as well as the time taken from the moment the relevant trip threshold was exceeded, until the software signal was output. In case of protective functions which operate with values from Element 1,2 and 3, the post trip display also shows the Element number in which the maximum or minimum of the parameter occurred as well as the element(s) which have been above the threshold at the instant of trip. In addition, in the case of the star-point unbalance trip signals or if the unit is in H-Bridge operation, the relevant phase angle of the unbalance current is recorded, to indicate in which part of the capacitor bank the capacitor failure has occurred (Refer to Fig. 10 and 12).

After a trip event, the first-up of the post-trip fault annunciation screens of the event is displayed on the LCD screen.

Under normal circumstances, after a trip condition, an operator would investigate the trip condition, inspect the relevant CPR04 Relay, note and record the post trip annunciation screen display, and then acknowledge (i.e. reset) the relay post trip fault annunciation, by pressing the red ACCEPT key. At this

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point, the other trip conditions that may have occurred after the first-up trip condition, will be displayed. Again the user can acknowledge (i.e. reset) this indication, by pressing the red ACCEPT key.

After all the post trip fault annunciation screens have been acknowledged, then the normal operation screen is displayed again. At this time the relay will write the trip information into the trip history list.

After investigating and rectifying the fault condition, the operator would normally only then re-energize the tripped circuit breaker, after which the normal operation screen would be displayed.

If, however, the tripped circuit breaker is re-energized before the post trip fault annunciation screens have been acknowledged, then the post trip annunciation screens will continue to be displayed until they are acknowledged, as previously detailed, after which the normal operation screen, will be displayed.

If a further fault condition were to occur, causing the circuit breaker to trip again, before the previous post trip fault annunciation screens have been acknowledged, then the previous fault trip annunciation data is replaced with the latest fault trip annunciation data.

<u>NOTE</u>

It is only possible to acknowledge a trip once the fault has been cleared – the yellow LED must be OFF, otherwise you will only be able to scroll through the post trip data – only exception is the lth trip function, were it is possible to acknowledge a trip as soon as the Irms has fallen below the Ith> or Ith>> threshold – the yellow LED and the trip output will stay active until the Ith has fallen below the Ith> or Ith>> threshold level.

TRIP HISTORY LIST

When the fault has been cleared after a trip event, a set of post-trip annunciation data is recorded in the TRIP HISTORY list.

The TRIP HISTORY list records data for a maximum of 25 trip events, with No. 1 being the most recent. The complete TRIP HISTORY LIST can be accessed with the Relay in normal operation (Refer to Section 6.10).

The TRIP HISTORY list is saved in the Flash memory and is therefore also available after loss of power supply.

TYPICAL POST-TRIP FAULT ANNUNCIATION AND TRIP HISTORY DISPLAYS



8 TROUBLE SHOOTING

Before attempting to trouble-shoot the equipment, the user should thoroughly understand this entire manual, and should have a prior knowledge of power system protection, power system measurements, and power system safety procedures. The user should study carefully the applicable sections of this manual, taking particular note of *WARNINGS, CAUTIONS* and *NOTES* included for personnel and equipment protection.

For trouble-shooting and commissioning, the following equipment is required:

- Digital multimeter with clip-on current tong for measuring 1A or 5A current transformer secondaries.
- A three or single phase primary or secondary injection test set to enable injection of the CT nominal rated secondary currents into the CPR04 Relay measuring elements.

Due to the nature of the CPR04 Relay, it is not recommended that the user should attempt repairs other than the removal and replacement of the draw-out unit which houses all electrical and electronic parts.

If erroneous, inconsistent or nonsensical data is displayed on the CPR04 Relay, or if erratic faulty operation is experienced by the user, check the various parameters set in the relay and veryfiy that the relay is set up correctly.

If the user has performed all the above checks, and is satisfied that no external or setting-up problems exist which are causing the problems experienced, then return the CPR04 to Trench Austria GmbH together with a fault report, documenting the details of the problem experienced, the CPR04 Relay fascia plate - , configuration & set-up as well as installation details.

The user may elect to withdraw the draw-out unit from the fixed case and send this to *Trench Austria GmbH* for checking, repair, testing and calibration. In this case special attention should be paid to the handling requirements, as detailed in Section 4.

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APPENDIX 1: NOMENCLATURE AND DEFINITIONS FOR NORMAL MODE OPERATION

SYMBOL	DEFINITION
1/2/3/4/5	Element 1 / 2 / 3 / 4 / 5
Icr	Capacitor rated current.
In	Current transformer nominal primary current.
Icr/In	Capacitor rated current per unit of current transformer nominal primary current.
VC	Calculated capacitor peak repetitive voltage.
vcr	Capacitor rated peak repetitive voltage.
vc>al	Capacitor peak repetitive alarm withstand threshold.
vc>	Capacitor peak repetitive withstand ability threshold.
vc>>	Capacitor peak repetitive highset overvoltage threshold
vc>al:xt	Timer setting for the capacitor peak repetitive alarm withstand ability threshold.
vc >>:xt	Timer setting for the capacitor highset overvoltage threshold
vc>reset	Timer setting for the overvoltage vc>/vcr reset-timer
vc>alarm	Software signal indicating that the definite timer associated with $vc>al$ has timed out
vc>start	Software signal indicating that vc has exceeded vc>, and that the associated timer is timing
vc>trip	Software signal indicating that the inverse timer associated with vc has timed out
vc>>trip	Software signal indicating that the definite timer associated with $vc>>$ has timed out
Irms	The calculated <i>rms</i> heating current
τ	Heating / cooling time constant
Ith	Calculated thermal current response to the <i>Irms</i>
Ith>	Low set thermal response overcurrent threshold
Ith>>	High set thermal response overcurrent threshold
Ith>:xt	Timer setting for the low set / high set thermal response overcurrent threshold
Ith>>:xt	
<i>Ith>start</i>	Software signal indicating that <i>Ith</i> has exceeded <i>Ith</i> >
Ith>trip	Software signal indicating that <i>Ith</i> has exceeded <i>Ith</i> > for the time <i>Ith</i> >:xt set
Ith>>trip	Software signal indicating that <i>Ith</i> has exceeded <i>Ith</i> >> for the time <i>Ith</i> >>:xt set
Irms> / Irms>>	Low set / high set rms overcurrent threshold
Irms>:xt	Timer setting for the low set / high set rms overcurrent threshold
Irms>>:xt	Cofficient indication that I has available I as and that the approxisted times is
Irms>start	software signal indicating that <i>Irms</i> has exceeded <i>Irms</i> , and that the associated timer is
Irmestrin	Software signal indicating that the associated timer with <i>Irms</i> has timed out
Irms> trip	Software signal indicating that the associated timer with <i>Irms</i> has timed out
11 11	Calculated fundamental frequency current
11>/11>>	Low set / high set fundamental frequency overcurrent threshold
II > rt	Timer setting for the low set / high set fundamental frequency overcurrent threshold
l >> rt	
11 > start	Software signal indicating that <i>I</i> / has exceeded <i>I</i> />, and that the associated timer is timing
11>trip	Software signal indicating that the associated timer with <i>II</i> > has timed out
11>> trip	Software signal indicating that the associated timer with <i>II</i> >> has timed out
Iub	Calculated uncompensated fundamental frequency star point unbalance current
Iub al	Star point unbalance alarm threshold
Iub al:xt	Timer setting for the star point unbalance alarm threshold
Iub alarm	Software signal indicating that the associated timer with <i>Iub</i> al has timed out
Iub>	Low set star point unbalance overcurrent threshold
Iub>:xt	Timer setting associated with the low set star point unbalance overcurrent threshold
Iub>>	High set star point unbalance overcurrent threshold
Iub>>:xt	Timer setting associated with the high set star point unbalance overcurrent threshold
<i>Iub>start</i>	Software signal indicating that (Δ)Iub has exceeded Iub>, and that the associated timer is
	timing
<i>Iub>trip</i>	Software signal indicating that the associated timer with <i>Iub</i> > has timed out
<i>Iub>>trip</i>	Software signal indicating that the associated timer with <i>Iub>></i> has timed out
ΔIub	Compensated fundamental frequency rms star point unbalance current, i.e. the change in
	fundamental frequency rms current from compensated fundamental frequency rms current from
	the instant of compensation

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Ilub	Calculated fundamental frequency line unbalance current
Ilub>	Low set fundamental frequency line unbalance current threshold
llub > xt	Timer setting associated with the low set fundamental frequency line unbalance current
1000 000	threshold
Ilub>>	The high set fundamental frequency line unbalance current threshold
Ilub>>:xt	Timer setting associated with the high set fundamental frequency line unbalance current
	threshold
<i>Ilub>start</i>	Software signal indicating that <i>Ilub</i> has exceeded <i>Ilub</i> >, and that the associated timer is timing
<i>Ilub>trip</i>	Software signal indicating that the associated timer with <i>Ilub</i> > has timed out
<i>Ilub>>trip</i>	Software signal indicating that the associated timer with <i>Ilub>></i> has timed out
Іо	Calculated fundamental frequency earth fault current
Io>	Low set fundamental frequency earth fault current threshold
Io>:xt	Timer setting associated with the low set fundamental frequency earth fault current threshold
Io>>	High set fundamental frequency earth fault current threshold
Io>>:xt	Timer setting associated with the high set fundamental frequency earth fault current threshold
<i>Io>start</i>	Software signal indicating that <i>Io</i> has exceeded <i>Io</i> >, and that the associated timer is timing
<i>Io>trip</i>	Software signal indicating that the associated timer with <i>Io</i> > has timed out
Io>>trip	Software signal indicating that the associated timer with <i>Io</i> >> has timed out
<i>I1</i> <	Fundamental frequency undercurrent threshold
Il<:xt	Timer setting associated with the fundamental frequency undercurrent threshold
11 <trip< th=""><th>Software signal indicating that II has dropped below $II <$ for the time set while the digital input</th></trip<>	Software signal indicating that II has dropped below $II <$ for the time set while the digital input
	sensing the status of the circuit breaker (Breaker-Bon) was at logic "1"
Bon	Input signal indicating that the circuit breaker of the capacitor bank / harmonic filter circuit is on
Event:xt	Timer setting associated with the <i>Event trip</i>
Event_trip	Software signal indicating that the digital input (Event input) has changed from logic "0" to "1"
DC 11	and the associated definite timer <i>Event:xt</i> has timed out
Bfail1:xt	I limer setting associated with the <i>Bfail1</i> logic
Bfail1 release	Selection of the function which stops the <i>Bfail1</i> timer; ifund<10%in; Dig-input (logic "1" to "0");
Dfail1	Figure and indicating that when a trip accurred, the <i>Rfaill valages</i> function has not been
Бјан	fulfilled within the <i>Bfaillist</i> time, indicating a failure of the circuit breaker to open
Rfail?.rt	Timer setting associated with the $Bfail2$ logic
Bfail?	Software signal indicating that the fundamental frequency current remained above the
Djuliz	undercurrent threshold for the <i>Bfail2</i> :xt time, while the digital input (Breaker-Bon) signalled a
	switching off (logic "1" to " 0 ") - indicating the failure of the circuit breaker to interrupt the
	capacitor bank / harmonic filter circuit current.
Bena trigger	Selection of the function which triggers the <i>Bena</i> logic; Ifund<10%In; Dig-Input (logic "1" to "0");
	Ifund AND Input; Ifund OR Input
Bena:xt	Timer setting associated with the Bena logic
Bena	Software signal that can be used to inhibit the re-energizing of the banks circuit breaker for a
	definite time after the <i>Bena trigger</i> signal has has become active. <i>Bena</i> output signal (Breaker
	inhibit) is normally at logic "0" (low) and goes to logic "1" (high) when the bank is switched off,
	and reverts to logic "0" (low) the definite time <i>Bena:xt</i> thereafter.
Trip session	A trip session starts from the first active trip condition until the last trip condition has been
	cleared. The visible observation of this session is defined by the time when the trip LED lights
	up to the time when the alarm LED goes off. During this time the up and down cursors may be
	used to scroll between the different trip messages. The red ACCEPT key may be used to
	acknowledge trips for which the cause of the trip has fallen below the trip threshold. In case of
	threshold however the trip output function will only be reset once. It has follow the Ith
	trin threshold

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APPENDIX 2: NOMENCLATURE AND DEFINITIONS FOR H-CONFIGURATION OPERATION

SYMBOL	DEFINITION
1:	Element 1
2:	Element 2
3:	Element 3
4:	Element 4
In	Current transformer nominal primary current.
a/b/cIub	Calculated uncompensated fundamental frequency a/b/c-phase unbalance current
a/b/cIub_al/In	a/b/c -phase unbalance alarm threshold per unit of current transformer nominal primary current
a/b/cIub_al:xt	Timer setting for the a/b/c -phase unbalance alarm threshold
a/b/cIub_alarm	Software signal indicating that the associated timer with <i>a/b/cIub_al</i> has timed out
a/b/cIub>/In	Low set a/b/c -phase unbalance overcurrent threshold per unit of current transformer nominal
	primary current
a/b/cIub>:xt	Timer setting associated with the low set a/b/c -phase unbalance overcurrent threshold
a/b/cIub>>/In	High set a/b/c -phase unbalance overcurrent threshold per unit of current transformer nominal
	primary current
a/b/cIub>>:xt	Timer setting associated with the high set a/b/c -phase unbalance overcurrent threshold
a/b/cIub>start	Software signal indicating that $(\Delta)a/b/cIub$ has exceeded $a/b/cIub>$, and that the associated
	timer is timing
a/b/cIub>trip	Software signal indicating that the associated timer with <i>a/b/cIub></i> has timed out
a/b/cIub>>trip	Software signal indicating that the associated timer with <i>a/b/cIub>></i> has timed out
∆a/b/cIub	Compensated fundamental frequency rms a/b/c -phase unbalance current, i.e. the change in
	fundamental frequency rms current from compensated fundamental frequency rms current from
	the instant of compensation

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APPENDIX 3: GENERAL CHARACTERISTICS

Applicable standard	IEC 60255 and EN 50263
Operating temperature	-10 to +55 °C to IEC 60068-2-2
Storage temperature range	-20 to +70 °C to IEC 60068-2-2
Humidity	4 days, 95% RH, with temperature cycled between +25°C and + 45°C, to IEC 60068-2-3
Enclosure degree of protection	IP50 to IEC 60529
Shock and bump	Shock: 15g, 3 pulses per direction, per axis. (total 18 times). Bump : 10g, 1000 pulses per direction, per axis (total 6000 times). To IEC 60255-21-2
Vibration	9,8ms ⁻² (1g) constant frequency from 10 to 150 Hz per axis. To IEC 60255-21-1
Power frequency voltage withstand	2 kV rms 50 Hz for 1 minute, from all terminals to case (earth), and between terminals of independent circuits. 1,5 kV rms across open contacts of output relays. To IEC 60255-5
Impulse voltage withstand	5 kV peak, 1,2/50 μs waveshape, 0,5 J energy content, 10 shots in each polarity, between all terminals and case (earth), and between terminals of independent circuits. To IEC 60255-5
Insulation resistance	50 M Ω minimum at 500 V dc, to IEC 60255-5
Immunity to high frequency disturbances (1MHz burst disturbance test)	2,5 kV peak between independent circuits, and to case (earth).1 kV peak across terminals of the same circuit.To IEC 60255-22-1
Immunity to electrostatic discharges (Electrostatic discharge test)	8 kV discharge in air 6 kV point contact discharge To IEC 60255-22-2 and EN 50263
Immunity to fast transient bursts (Fast transient burst test)	4kV supply lines / 2kV input & output lines / 1kV communication lines To IEC 60255-22-4 and EN 50263
Immunity to high frequency electromagnetic fields	10 V / m, 100% PM, at 900 MHz 10 V, 80% AM, from 150 kHz to 80 MHz as well as 10 V / m, 80% AM, from 80 MHz to 1000 MHz, to EN 50263
Immunity to surge voltages	2kV peak common / 1kV peak differential To EN 61000-4-5 and EN 50263
Immunity to voltage interruptions	230 VAC – 100% interruption – 200ms 110 VDC – 100% interruption – 50ms To EN61000-4-11
Harmonics and flicker of main current	To EN 61000-3-2
Conducted emissions	To EN 50263, from 150 kHz to 30 MHz.
Radiated emissions	To EN 50263, from 30 MHz to 1000 MHz.
Nett Mass	3 kg
Overall dimensions	103(w) x 177(h) x 248(d)

WARNING

The power supply inputs of the CPR04 are protected by MOV's. Therefore it is not possible to perform the power frequency and the impulse voltage withstand test on these terminals on the commercial unit without causing damage !

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APPENDIX 4: TECHNICAL SPECIFICATIONS

Measuring elements	Quantity	4		
C C	Nominal rated current, In	1A or 5A selectable in the software		
	Continuous current	15A		
	Short time current	300A for 1s		
	Burden	<40mΩ		
	Accuracy of measurement	+/- 2% of nominal rated current		
Auxiliary power supply	Nominal rated voltage, Vx	30 – 250V ac/dc		
	Operative range AC / DC	40 - 250V AC / 30 - 300\	/ DC	
	Burden with dc supply	<14W with all relays and b	back-light ON	
	Burden with ac supply	<24VA with all relays and	back-light ON	
Output relays	Quantity	Alarm/trip relays: 5		
		Self-supervision relay: 1		
	Contact form (per relay)	1 - changeover contact (f	orm C), user configurable	
		as N/O or N/C		
	Load	Resistive load:	Inductive load:	
		$(\cos\phi = 1)$	$(\cos\phi = 0.4 \text{ L/R} = 7 \text{ ms})$	
K1	Rated load	5A at 250 VAC:	3,5A at 250 VAC:	
		1A at 220 VDC	0,8A at 220 VDC	
		3A at 110 VDC	2A at 110 VDC	
		5A at 48 VDC	4A at 48 VDC	
	Max. operating voltage	380VAC,	250 VDC	
K2, K3, K4, K5, K6	Rated load	5A at 250 VAC:	3,5A at 250 VAC:	
		5A at 30 VDC	2,5A at 30 VDC	
	Rated carry current	5	A	
	Max. operating voltage	380VAC,	125 VDC	
	Min. permissible load	100mA a	at 5 VDC	
Digital input channel	Quantity	1		
	Function	Breaker on; Remote reset	;; Event trip	
	Isolation	Optically isolated		
	Туре	30 – 250V ac/dc voltage in	nput	
Pushbuttons	Function	\succ , \prec , \wedge , \forall , and ACCEPT	(red)	
	Туре	Miniature spring loaded m	anual pushbuttons	
Display	Туре	Back-lit Liquid Crystal Dis	play (LCD), with full	
		alpha-numeric character s	set	
	Screen Size	16 character x 2 line		
	Character height	4mm		
Indicators	Туре	Light Emitting Diodes (LE	Ds)	
	Function	Green : POWER ON / H	IEALTHY	
		Yellow : START (ALARM)		
		Red : TRIP		
Serial data port	Quantity	2		
	Isolation	Optically isolated		
	Frontport type	RS232 via DB9 socket		
	Rearport type	RS232 or RS485 – selectable in the software		
	Baudrate (kBd)	2.4 up to 115.2 for each port seperatly selectable		
Real Time Clock	Functionality	Date; Weekday; HH:MM:SS		
	Accuracy	+/- 30 s per month		
	Backup	Supercap (>14 days without power)		

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APPENDIX 5: SETTABLE PARAMETERS AND SETTING RANGES NORMAL MODE OPERATION

PARAMETER	SETTING RANGE	RESOLUTION	PRESET VALUE
Icr/In	0,25 to 1,50	0,01	1.00
vc>al/vcr	0.80 to 1.50 // N/A	0.01	N/A
vc>al:xt	0,1 to 3600 s	0,1 s	0,1 s
vc>/vcr	0.80 to 1.50 // N/A	0,01	N/A
vc>>/vcr	0,80 to 10,0 // N/A	0,01	N/A
vc>>:xt	0,03 to 10,0 s	0,01 s	0,03 s
vc>reset:xt	1 s to 3600 s	1 s	1 s
Ith>/In	0,25 to 1,50 // N/A	0,01	N/A
Ith>:xt	0 to 600 s // Alarm	0,01 s	0,0 s
Ith>>/In	0,25 to 1,50 // N/A	0,01	N/A
Ith>>:xt	0 to 60 s	0,01 s	0,0 s
au	0,5 to 7200 s	0,1 s	0,5 s
I1>/In	0,25 to 1,50 // N/A	0,01	N/A
II>:xt	0,1 to 1200 s	0,1 s	0,1 s
11>>/In	0,2 to 10,0 // N/A	0,1	N/A
<i>I1>>:xt</i>	0,05 to 10,0 s	0,01 s	0,05 s
I1 <td>0,05 to 1,00 // N/A</td> <td>0,01</td> <td>N/A</td>	0,05 to 1,00 // N/A	0,01	N/A
II<:xt	0,1 to 10,0 s	0,1 s	0,1 s
Irms>/In	0,25 to 1,50 // N/A	0,01	N/A
Irms>:xt	0,1 to 1200 s	0,1 s	0,1 s
Irms>>/In	0,2 to 10,0 // N/A	0,1	N/A
Irms>>:xt	0,03 to 10,0 s	0,01 s	0,03 s
Iub_al/In	0,01 to 2,00 // N/A	0,01	N/A
Iub_al:xt	0,1 to 600 s	0,1 s	0,1 s
Iub>/In	0,01 to 2,00 // N/A	0,01	N/A
Iub>:xt	0,1 s to 14400 s	0,1 s	0,1 s
Iub>>/In	0,01 to 2,00 // N/A	0,01	N/A
Iub>>:xt	0,05 to 60 s	0,01 s	0,05 s
Io>/In	0,05 to 1,00 // N/A	0,01	N/A
Io>:xt	0,1 to 60 s	0,01 s	0,1 s
Io>>/In	0,05 to 10,0 // N/A	0,01	N/A
Io>>:xt	0,05 to 10,0 s	0,01 s	0,05 s
Ilub>/In	0,01 to 1,00 // N/A	0,01	N/A
Ilub>:xt	0,1 to 60 s	0,1 s	0,1 s
Ilub>>/In	0,01 to 1,00 // N/A	0,01	N/A
Ilub>>:xt	0,05 to 10,0 s	0,01 s	0,05 s
Function of	Breaker-Bon // Remote Reset		Disabled
Digital Input	Event Trip // Disabled		
Event:xt	0,03 to 600 s	0,01 s	0,03 s
Bfail1:xt	0,05 to 2,0 s // N/A	0,01 s	N/A
Bfail1 released:	lfund<10%In // Dig-Input		lfund<10%In
	Ifund AND Input // Ifund OR Input		
Bfail2:xt	0,05 to 2,0 s // N/A	0,01 s	N/A
Bena:xt	1 to 1200 s // N/A	1 S	N/A
Bena trigger by:	Ifund<10%In // Dig-Input Ifund AND Input // Ifund OR Input		Itund<10%In
Start LED shows:	Only trip STARTS // Only ALARMS		STARTS + ALARMS
	STARTS + ALARMS // Always off		

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PARAMETER	SETTING RANGE	RESOLUTION	PRESET VALUES
aIub_al/In	0,01 to 2,00	0,01	N/A
T 1 1 .	N/A	0.4 -	0.1 -
alub_al:xt	0,1 to 600 s	0,1 \$	0,1 S
alub>/In	0,01 to 2,00	0,01	N/A
	N/A	.	
alub>:xt	0,1 s to 14400 s	0,1 s	0,1 s
aIub>>/In	0,01 to 2,00 N/A	0,01	N/A
aIub>>:xt	0,05 to 60 s	0,1 s	0,05 s
bIub_al/In	0,01 to 2,00 N/A	0,01	0,01
bIub al:xt	0,1 to 600 s	0,1 s	0,1 s
bIub>/In	0,01 to 2,00 N/A	0,01	0,01
bIub>:xt	0.1 s to 14400 s	0.1 s	0.1 s
bIub>>/In	0,01 to 2,00 N/A	0,01	0,01
bIub>>:xt	0.05 to 60 s	0.1 s	0.05 s
cIub_al/In	0,01 to 2,00 N/A	0,01	N/A
cIub al:xt	0,1 to 600 s	0,1 s	0,1 s
cIub>/In	0,01 to 2,00 N/A	0,01	N/A
cIub>:xt	0,1 s to 14400 s	0,1 s	0,1 s
cIub>>/In	0,01 to 2,00 N/A	0,01	N/A
cIub>>:xt	0,05 to 60 s	0,1 s	0,05 s
Function of	Remote Reset // Event Trip		Disabled
Digital Input	Disabled		
Event:xt	0,03 to 600 s	0,01 s	0,03 s
Start LED shows:	Only trip STARTS // Only ALARMS STARTS + ALARMS // Always off		STARTS + ALARMS

APPENDIX 7: DIAGNOSTIC ERRORS

On application of auxiliary supply voltage to a CPR04 Relay, and at regular intervals during normal operation, the relay performs a number of self-test diagnostic functions. Any errors detected will cause the CPR04 Relay to suspend all protective functions, de-energize the self-supervision relay and display an error message as follows:

ONLINE DIAGNOSTICS:

CPR04 DISPLAY MESSAGE

ERROR DESCRIPTION

EPROM error	EPROM checksum test failed
EEPROM error	Serial EEPROM checksum incorrect for the following section
+ Calibration	 calibration factor checksum test failed
+ Set-up	 parameter checksum test failed
+ Relay Set-up	- relay setup checksum test failed
+ Trip History	 trip history checksum test failed
+ CT ratio	- CT ratio checksum test failed
RAM error	RAM failure
DSP stopped	DSP failed a watchdog test

APPENDIX 8: CALCULATION OF CHECKSUMS FOR OUTPUT RELAYS 1 TO 5

A number of software output functions can be set for each relay. For each set function a binary 'one' must be entered, for each function not routed to the relay 'zero' is to set.

This represents a so called binary code. Very often however the so called hexadecimal code (hex code) is used. In this case four binary digits are combined to one hex digit (starting from the left side). The four digits represent the values 8,4, 2 and 1.

Example: 1010 = 1 * 8 + 0 * 4 + 1 * 2 + 0 * 1 = 10 = A

The result can get values between 0 and 15. As the hex digit must be a one only digit, the characters A...F are used instead of the numbers 10...15. (valid hexadecimal numbers: 1...9, A...F)

A) Relay in Normal Mode Operation



FUNCTIONS BINARY CODE

B) Relay in H-Configuration Operation



FUNCTIONS BINARY CODE

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APPENDIX 9: INJECTION TESTING

The CPR04 Relay is a complex device with many sophisticated protective functions. It is beyond the scope of this manual to fully detail how to comprehensively injection test the CPR04 Relay. However the following points should be noted.

Ideally to properly test the CPR04 Relay, one would require a 3 phase secondary injection test set with the ability to inject not only mains frequency currents, but also complex 3 phase waveforms with harmonic currents superimposed on the fundamental currents. In this way one can properly test and confirm the peak repetitive overvoltage protective functions, the *rms* thermal overcurrent protective functions, the *rms* thermal overcurrent protective functions including the star unbalance or H-Bridge unbalance, line unbalance, earth fault, fundamental frequency over and under current, breaker fail and breaker enable timer.

Often the user will only have access to a single phase current injection test set. In this case the user should preferably test each element separately, one protective function at a time, with all other protective functions disabled.

A) Relay configured in Normal Mode:

If testing several protective functions and/or elements simultaneously, the following must be kept in mind:

The earth fault current *Io* is derived mathematically as the vector summation of the phase currents of elements 1, 2 and 3. Therefore the earth fault protective function should be tested by injecting 1/3 of the desired earth fault current into elements 1, 2 and 3 connected in series. This will generally avoid the other protective functions, including the line unbalance current protective function, from operating before the earth fault protective function.

In order to test the line unbalance current function, inject a low magnitude single phase current into elements 1 and 2 (or elements 2 and 3) connected in series but with opposite polarities. This will avoid the earth fault protective function from operating.

In order to test the overcurrent, undercurrent and thermal current, protective functions of elements 1, 2 and 3, disable the earth fault protective function and inject a single phase current into elements 1, 2 and 3 connected in series. This will avoid both the earth fault and the line unbalance current protective functions from operating. Alternatively disable both the earth fault and the line unbalance current protection functions. This will enable elements 1, 2 and 3 to be tested individually, without all 3 elements connected in series.

Without the ability to inject harmonic currents superimposed onto the fundamental current, the peak repetitive overvoltage protective function of element 1, 2 and 3 can be easily tested by disabling all other protective functions, and injecting a sinusoidal current into element 1, 2 or 3. It is suggested that *Icr/In* = 1 and vc>/vcr = 1,1 should be set. In this case, when a sinusoidal current equal to In is injected (1A or 5A *rms*) then the calculated peak repetitive voltage vc/vcr should be 1p.u. The vc>*starter* should operate for injected currents above 1,1In. Trip times for currents above the threshold (1,1In) may be checked against the inverse time curve of Fig. 6.

B) Relay configured in H-Bridge Mode:

If the unbalance protection is tested using a single phase injection test set and the injected current is below 10% this will mean that the relay has to be tested in the uncompensated operation. As the reference current is below 10% the protection functions will only operate based on the amplitude values – the phase angle will be ignored and also not displayed.

33kV / 50Hz

X

20A / 1A

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630A

500A / 5A

20,6mH 400A_{rss}

37,19 MVAr at 45kV

APPENDIX 10: SETTING EXAMPLE

20 Mvar harmonic filter with a double star capacitor bank

System Earthing Switch Line CT's Cable Filter Filter reactors	$33 \text{ kV} \pm 5\%$, 3 Solidly earthe 630 A SF6 cir 500 / 5 A $185 \text{ mm}^2 \text{ XLI}$ Output at 33 I Inductance: 2	3 phase, s ed rcuit brea PE kV 50 Hz: 20,6 mH p	50 Hz, 20 kA fault le ker :20 Mvar (lead) per phase	evel
Rated Currents	11 385A 12 30A 13 90A 14 25A <i>Irms</i>	$ \frac{15}{17} \\ \frac{111}{113} \\ \sqrt{\sum_{n=1}^{13} (I_{n})^{13}} $	30 A 20 A 10 A 5 A $\overline{n}^{2} = 400 \text{ A}$	
Capacitor bank	Double star configuration Rated output: 37,193 Mvar Rated voltage and frequency: 45 kV, 50 Hz Rated current lcr = 37,193 $\cdot 10^{6}/(\sqrt{3} \cdot 45000)$			
Unbalance CT	Star point unbalance alarm current: $4 \text{ A} - 3 \text{ s}$ Star point unbalance low set trip current: $8 \text{ A} - 10 \text{ min}$ Star point unbalance high set trip current: $12 \text{ A} - 1 \text{ s}$ 20 / 1 A			

SETTINGS:

	Elem	ent 1,2,3 variables			Elei	ment 4 variables	
Icr/In	=	477/500=0,95	(1)	Iub al/In	=	4/20 = 0,2	(23)
vc>al/vcr	=	1,08	(2)	Iub ⁻ al:xt	=	3 s	(24)
vc>al:xt	=	30 s	(3)	Iub>/In	=	8/20 = 0,4	(25)
vc>/vcr	=	1,1	(4)	Iub>:xt	=	600 s	(26)
vc>>/vcr	=	3,0	(5)	Iub>>/In	=	12/20 = 0,6	(27)
vc >>:xt	=	0,03 s	(6)	Iub>>:xt	=	1 s	(28)
vc>reset:xt	=	30 s	(7)		Elei	ment 5 variables	
Ith>/In	=	395/500 = 0,79	(8)	Io>/In	=	0,2·350/500 = 0,14	(29)
Ith>:xt	=	Alarm	(9)	Io>:xt	=	0,1 s	(30)
Ith>>/In	=	410/500 = 0,82	(10)	Io>>/In	=	N/A	(31)
Ith>>:xt	=	0 s	(11)	Io>>:xt	=	0 s	(32)
τ	=	1200 s	(12)	Ilub>/In	=	0,05·350/500 = 0,04	(33)
11>/In	=	1,075·350/500 = 0,81	(13)	Ilub>:xt	=	2 s	(34)
11>:xt	=	600 s	(14)	Ilub>>/In	=	0,1.350/500 = 0,07	(35)
11>>/In	=	1,5·350/500 = 1,05	(15)	Ilub>>:xt	=	0,2 s	(36)
11>>:xt	=	0 s	(16)		O	ther variables	
Irms>/In	=	1,2·400/500 = 0,96	(17)	Bfail1:xt	=	0,2 s	(35)
Irms>:xt	=	30 s	(18)	Bfail1 released	=	lfund<10%In	(37)
Irms>>/In	=	1,5·400/500 = 1,20	(19)	Bfail2:xt	=	0,1 s	(38)
Irms>>:xt	=	0,03 s	(20)	Bena:xt	=	600 s	(39)
				Function for	=	Breaker On – Bon	(40)
				Digital Input			
Il <td>=</td> <td>0,2·350/500 = 0,14</td> <td>(21)</td> <td>Bena trigger by</td> <td>=</td> <td>Dig-Input</td> <td>(41)</td>	=	0,2·350/500 = 0,14	(21)	Bena trigger by	=	Dig-Input	(41)
II <:xt	=	0,2 s	(22)	Start LED shows	=	STARTS + ALARMS	(42)

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NOTES ON SETTINGS:

- (1) Capacitor rated current in p.u. of line CT primary current.
- (2) In this example the alarm threshold is chosen with 108% of the capacitor voltage
- (3) The associated timer is set to 20s to avoid alarm messages due to short time overvoltages
- (4) Capacitors made to IEC can withstand 110% of rated voltage for extended periods of time.
- (5) With reference to Fig.6, it can be seen that for *vc/vcr* greater than 3,0 the peak repetitive overvoltage withstand curve is undefined and therefore for capacitor overvoltages above this value it is considered necessary to trip with a definite time delay.
- (6) The time delay should be set as low as possible, preferably with no intentional delay.
- (7) Refer to Fig.16 to see the effect of vc>reset:xt.
- (8) The low set thermal trip threshold is set in this case slightly below the continous current rating, as it is assumed that the total current includes some safety magins.
- (9) The associated timer is set to "Alarm" which means that only the Ith>start signal will be generated in case of an overload and no subsequent trip signal Ith>trip is output.
- (10) The high set thermal overcurrent threshold is set slightly above the max. continuous rms current rating of the reactor. If this is exceeded the bank must be disconnected.
- (11) The associated definite time delay is set to 0 (no intentional delay).
- (12) Refer to Appendix 11 for some guidance of the heating/cooling time constant of air-core filter reactors. The time constant is the time taken for the reactors to reach 63% of their final temperature, for a step change in current from 0 to 100%. (i.e. the first order time constant of the device.)
- (13) For a system having a maximum system voltage of 105% of nominal, a low set fundamental frequency overvoltage/overcurrent limit of 107,5% is considered appropriate. Above this value the associated definite timer will start timing out.
- (14) A value of 600s for this definite timer is considered appropriate to allow any automatic tapchangers to operate in the case of extended fundamental frequency system overvoltages (which in time causes fundamental frequency overcurrents in the capacitor/filter circuit).
- (15) A fundamental frequency overcurrent above 150% of nominal would indicate a catastrophic failure of some kind requiring immediate tripping.
- (16) Therefore the associated definite time delay is set to 0,05s (no intentional delay).
- (17) For a rms current of 20% above nominal value the associated definite timer will start timing out.
- (18) A value of 30s for this definite timer is considered appropriate.
- (19) A rms overcurrent of 150% of nominal would indicate a catastrophic failure or excessive harmonic currents requiring immediate tripping.
- (20) Therefore the associated definite time delay is set to 0,03s (no intentional delay).
- (21) Any undercurrent threshold significantly below nominal current is appropriate.
- (22) The undercurrent definite timer is set as 0,2s or any appropriate low value to avoid spurious trip outs.

- (23) The star point unbalance alarm level is to be provided by the capacitor unit and bank designer / manufacturer as it is determined by the specific capacitor unit and capacitor bank design.
- (24) The definite timer associated with the above should be set to a reasonable value to avoid spurious alarms due to inrush or other short time operating conditions.
- (25) The star point unbalance low set trip current is to be provided by the capacitor unit and bank designer/manufacturer.
- (26) The definite timer associated with the above is set as 600 s as informed by the capacitor unit / bank manufacturer.
- (27) The star point unbalance high set trip current is to be provided by the capacitor unit and bank designer / manufacturer.
- (28) The definite timer associated with the above is set as 1 s as informed by the capacitor unit / bank manufacturer. Also this timer should not be set less than 1s due to the response time of the calculation of the phase angle of the unbalance current, if the phase angle of this unbalance current is of interest to the user after a trip out.
- (29) The fundamental frequency earth fault threshold is set to any suitably low value below the expected earth fault current (as limited by the system and earth fault zero sequence impedance.
- (30) The definite time delay is set to 0,1 (no intentional delay).
- (31) As the low set earth fault definite time delay is set to 0,1 the high-set threshold is disabled.
- (32) Because the high-set threshold is disabled, the timer setting is irrelevant.
- (33) The low-set line unbalance current threshold should be set as low as possible whilst avoiding spurious trip outs due to normal system line voltage unbalance. A line unbalance current of 5% of nominal capacitor current is considered suitable.
- (34) The definite timer associated with the above is set at 2s to avoid trip out on short term unbalance disturbances.
- (35) The high-set line unbalance current threshold is set as 10% of nominal capacitor current.
- (36) The definite time associated with the above is set as 0,2s
- (37) The breaker fail timer is set as 0,2s for *Bfail1* and 0,1s for *Bfail2* or any appropriate low value to avoid spurious breaker fail signal output.
- (38) The Bfail1 release function is selected to be a drop in the fundamental current below 10% In
- (39) The breaker enable timer is set to enable breaker re-energization 600s (10min) after deenergization to allow the capacitor to discharge before switching on again.
- (40) Setting the digital input to Breaker-Bon allows the breaker enable re-switching timer and the undercurrent protection function to be used.
- (41) This parameter is set to Dig-Input so that the Bena function is triggered by the digital input.
- (42) The START LED is configured to show STARTS and ALARMS

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APPENDIX 11: CALCULATION OF THE REACTOR HEATING AND COOLING TIME CONSTANT (7)

The correct heating and cooling time constant of a damping or filter reactor should normally be obtained from the reactor manufacturer.

The formula below is considered accurate for reactor coils manufactured by Trench Austria GmbH, but may give default results in the absence of any other information.

τ = C1 * m / A

Where:

C1 Constant of convection and radiation and heat capacity

C1=100 for single layer coils C1 = 76 for multi layer coils

m Mass of winding (Aluminium and insulation)

A Surface for convection and radiation

[kg] [m²]

For single - layer coil : A = (D1 + D2) * Hw * Π

For double – layer coil : A =
$$\left(\frac{Dl+D2}{2}\right) * \Pi * Hw * 2,5$$

For n – layer coil : A = $\left(\frac{Dl+D2}{2}\right) * \Pi * Hw * n$

D1	Inner diameter	[m]
D2	Outer diameter	[m]
	VAC: all a la all all all all all all all a	F





APPENDIX 12: MENU NAVIGATION CHART – MAIN MENU LEVEL



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APPENDIX 13: MENU NAVIGATION CHART PARAMETER SETUP MENU – NORMAL MODE



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APPENDIX 14: MENU NAVIGATION CHART PARAMETER SETUP MENU – H-CONFIGURATION



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FIGURE 1: FRONT VIEW AND IDENTIFICATION OF EXTERNAL COMPONENTS



LEGEND

- MOUNTING HOLES FOR FIXED CASING 1:
- 2: BOTTOM LOCK FOR FRONT COVER
- 3: DRAW OUT HANDLE
- LIQUID CRISTAL DISPLAY (LCD) 4:
- 5: "START" LED (YELLOW) "POWER ON / HEALTHY" LED (GREEN)
- 6: 7: "TRIP" LED (RED)
- 8:
- EXTERNAL "ACCEPT" PUSHBUTTON INTERNAL "ACCEPT" KEY (RED) <u>9</u>.
- INTERNAL KEYPAD 10:
- 11: FASCIA PLATE
- TOP CATCH FOR FRONT COVER 12:
- REMOVABLE TRANSPARENT FRONT PROTECTIVE COVER 13:
- 14: SERIAL DATA PORT RS232

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FIGURE 2: REAR VIEW AND IDENTIFICATION OF EXTERNAL COMPONENTS



LEGEND

- EARTH TERMINAL 1:
- 2: EARTH STRAP
- TERMINAL NUMBERS 3:
- FAST-ON TERMINAL CONNECTORS 4:
- 5: SCREW TERMINALS 6: TERMINAL BLOCK
- 7: BLANKING PLATE

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FIGURE 3: DIMENSIONS AND CUTOUT DETAILS



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FIGURE 4: TERMINAL AND CONNECTION DIAGRAM



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FIGURE 5: OUTPUT RELAY CONTACT FORM CONFIGURATION DIAGRAM

	ENERGIZE	TO TRIP = 1	ENERGIZE TO TRIP = 0		
	N/O	N/C	N/O	N/C	
Power supply OFF	OPEN	CLOSED	OPEN	CLOSED	
Power supply ON & normal operation	OPEN	CLOSED	CLOSED	OPEN	
Power supply ON & trip output	CLOSED	OPEN	OPEN	CLOSED	



INSTRUCTIONS

- 1: WITHDRAW THE DRAW OUT CHASSIS
- 2: IDENTIFY THE PC BOARD SHOWN IN THIS DRAWING
- 3: IDENTIFY THE NORMALLY OPEN (NO) AND NORMALLY CLOSED (NC) LINK TERMINALS FOR EACH CHANGE OVER CONTACT OUTPUT RELAY 1-6 (K1 K6 ON THE PC-BOARD)
- 4: REMOVE THE LINK CONNECTOR ON THE NO LINK TERMINAL AND REPOSITION IT ONTO THE NC LINK TERMINAL FOR EACH OF THE OUTPUT RELAY CONTACTS REQUIRING RECONFIGURATION FROM NORMALLY OPEN TO NORMALLY CLOSED

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FIGURE 7: THERMAL TRIP TIME CURVE FOR VARIOUS LOADING CONDITIONS



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FIGURE 8: APPLICATION EXAMPLES



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FIGURE 9: TYPICAL WIRING DIAGRAM FOR A DOUBLE STAR CAPACITOR / FILTER BANK



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FIGURE 10: ELEMENT FAILURE IN A DOUBLE STAR CONNECTED CAPACITOR BANK



A) Element failure on internally or externally fused capacitor units

With respect to the phase angle of Ia

If $\theta \approx 0^{\circ}$	this indicates element failure in	capacitor a ₂
If $\theta \approx 60^\circ$	this indicates element failure in	capacitor c ₁
If $\theta \approx 120^{\circ}$	this indicates element failure in	capacitor b ₂
If $\theta \approx 180^\circ$	this indicates element failure in	capacitor a ₁
If $\theta \approx 240^\circ$	this indicates element failure in	capacitor c ₂
If $\theta \approx 300^\circ$	this indicates element failure in	capacitor b ₁

B) Element failure on unfused capacitor units

With respect to the phase angle of I_a

If $\theta \approx 0^{\circ}$	this indicates element failure in	capacitor a ₁
If $\theta \approx 60^\circ$	this indicates element failure in	capacitor c ₂
If $\theta \approx 120^{\circ}$	this indicates element failure in	capacitor b ₁
If $\theta \approx 180^\circ$	this indicates element failure in	capacitor a ₂
If $\theta \approx 240^\circ$	this indicates element failure in	capacitor c1
If $\theta \approx 300^\circ$	this indicates element failure in	capacitor b ₂

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FIGURE 11: TYPICAL WIRING DIAGRAM FOR A H-BRIDGE CAPACITOR / FILTER BANK



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FIGURE 12: ELEMENT FAILURE IN A H-BRIDGE CONNECTED CAPACITOR BANK





A) Element failure on internally or externally fused capacitor units

With respect to the phase angle of Ia

If $\theta \approx 0^{\circ}$	this indicates element failure in	capacitor a ₂ or a ₃
If $\theta \approx 180^\circ$	this indicates element failure in	capacitor a ₁ or a ₄
If $\phi \approx 120^{\circ}$	this indicates element failure in	capacitor b ₂ or b ₃
If $\phi \approx 300^\circ$	this indicates element failure in	capacitor b ₁ or b ₄
If $\beta \approx 240^{\circ}$	this indicates element failure in	capacitor c ₂ or c ₃
If $\beta \approx 60^{\circ}$	this indicates element failure in	capacitor c1 or c4

B) Element failure on unfused capacitor units

With respect to the phase angle of Ia

$a_1 \text{ or } a_4$
$a_2 \text{ or } a_3$
$b_1 \text{ or } b_4$
$b_2 \text{ or } b_3$
$C_1 \text{ or } C_4$
$c_2 \text{ or } c_3$

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FIGURE 13: LOGIC DIAGRAM FOR ELEMENTS 1,2 AND 3 – NORMAL MODE OPERATION



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FIGURE 14: LOGIC DIAGRAM FOR ELEMENT 4 AND 5 – NORMAL MODE OPERATION



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FIGURE 15: LOGIC DIAGRAM FOR ELEMENT 2,3 AND 4 – H-CONFIGURATION OPERATION


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FIGURE 16: EFFECT OF PEAK REPETITIVE OVER VOLTAGE RESET TIMER, vc>reset:xt, DURING INTERMITTANT PEAK REPETITIVE OVER VOLTAGES



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FIGURE 17: CONFIGURATION OF OUTPUT RELAYS 1 TO 5

