Contents

The chapter “Application”

This chapter describes how the general differential protection terminal RED 521 can be used and applied in a power network.

Application of RED 521

1 Introduction

The numerical differential protection terminal RED 521 is designed for the selective, reliable and fast protection of busbars, T-connections, meshed corners, generators, autotransformers, etc. RED 521 can be used for different station switchgear layouts, including single busbar, double busbar, double circuit breaker or one-and-half circuit breaker configurations. The terminal is applicable for the protection of medium voltage (MV), high voltage (HV) and extra high voltage (EHV) installations at a power system frequency of 50Hz or 60Hz. The terminal can detect all types of internal phase-to-phase and phase-to-ground faults in solidly grounded or low impedance grounded power systems, as well as all internal phase-to-phase faults in isolated or high-impedance grounded power systems.

RED 521 has low requirements on the main current transformers (i.e. CTs) and no interposing current transformers are necessary. For all applications, it is possible to include and mix main CTs with 1A and 5A rated secondary current within the same protection zone. Typically, CTs with up to 10:1 ratio difference can be used within the same differential protection zone. Compensation of different main CT ratios is achieved numerically by a parameter setting.

It is a normal practice to have just one set of busbar protection relays per busbar. Nevertheless some utilities do apply two independent busbar protection relays per zone of protection. RED 521 terminal fits both solutions.

RED 521 settings are made directly in primary amperes, thus simplifying the setting procedure and facilitating the protection settings to an optimum.

The RED 521 terminal can be supplied in the following four versions:

1) Three phase terminal with one differential zone and three 3-phase CT inputs

Order No 1MRK 002 001-AA

2) Three phase terminal with one differential zone and six 3-phase CT inputs

Order No 1MRK 002 001-BA

3) One phase terminal with two differential zones and nine 1-phase CT inputs (usually three terminals, one per phase, are required for the complete scheme)

Order No 1MRK 002 003-AA (for one terminal)

4) One phase terminal with two differential zones and eighteen 1-phase CT inputs (usually three terminals, one per phase, are required for the complete scheme)

Order No 1MRK 002 003-BA (for one terminal)

2 Service value reading

The Human Machine Interface (HMI) menu displays information about the:

- measured values from protection functions.
- operation conditions for protected objects in the power system.
- terminal.

Possible types of information are:

- Differential current for each phase and zone of protection
- Through-load current for each phase and zone of protection
- Status of binary output signals from the protection functions
- Status of binary input signals to the protection functions
- Event list
- Internal time

3 Terminal identification

3.1 General

The internal clock is used for time tagging of:

- Events in an event list
- Events transmitted to the SCS substation control system

The internal clock can be synchronized, (see the paragraph 4.4), to achieve higher time tagging correlation accuracy between terminals. Without synchronization, the internal clock is only useful for comparisons among events within the terminal.

The ordering number, serial number, software version and self supervision statues of the hardware modules can be displayed on the local HMI.

3.2 Setting the terminal clock

The internal clock is set from the HMI menu branch:

Settings
Time

Date and time are set by modifying the following parameters:

Table 1: Terminal date and time

Parameter	Setting range	Description
Date	from 1970-Jan-01 to 2037-Dec-31	Date in the format YYYY-MMM-DD
Time	from 00:00:00 to 23:59:59	Time in the format HH:MM:SS

Note: When time synchronization is enabled (i.e. not set to None), time setting from the HMI is not possible. See paragraph 4.4 for more details.

3.3 Displaying terminal status and identification numbers

The terminal identification numbers can be displayed from the HMI menu branch:

TerminalReport
Contents
Product

The following terminal information are displayed:

Table 2: Terminal identification numbers

Parameter	Description
Ver	Version of the terminal
O#	RED 521 terminal ordering number
S#	RED 521 terminal serial number

The terminal hardware modules identification numbers can be displayed from the HMI menu branch:

TerminalReport
Contents
HW-Modules
Slot location and the ordering number for all hardware modules are displayed.

The terminal software modules identification numbers can be displayed from the HMI menu branch:

TerminalReport
Contents
SW-Modules
The version numbers for all terminal internal software modules are displayed.

The terminal self-supervision status can be displayed from the HMI menu branch:

TerminalReport
SelfSuper
The self-supervision status for the terminal and its build-in hardware components are displayed.

4 Time synchronization

4.1 General

The terminal has a built-in real time clock and calender.The calendar starts with year 1970 and lasts till year 2038 and takes all leap years in between into consideration. As with all real time clocks, it has a certain inaccuracy. Thus, in order to have the correct time for time tagging of events etc., it has to be synchronized. The terminal can accept synchronization via the LON serial port or via one binary input. Synchronization via the serial ports will be done with absolute or relative time. Synchronization via a binary input is done with minute pulses.

4.2 Synchronization via the serial ports

4.2.1 Synchronization from SCS

The SCS will broadcast the synchronization signals on the LON bus with absolute time every minute and with relative time every second. In order to get the correct absolute time, the PC for SCS must be synchronized from a world wide source, e.g. from a satellite system or radio clock.

4.3 Synchronization via a binary input

The terminal accepts minute pulses to a dedicated, factory pre-configured binary input called “Time Synch”. These minute pulses can be generated from e.g. station master clock. In case the station master clock is not synchronized from a world wide source, time will be a relative time valid for the substation.

In case the objective of synchronization is to achieve a relative time within the substation and no station master clock with minute pulse output is available, a simple minute pulse generator can be designed and used for synchronization of the terminals.

4.4 Setting the terminal synchronization source

The synchronization source for terminal built-in real time clock are set from the HMI menu branch:

Configuration

Time

Synchronization sources are set by modifying the following parameters:

Table 3: Terminal date and time

Parameter	Setting range	Description
FineTimeSrc	None, LON, BinIn Pos, BinIn Neg, PPH	Fine Time Source
CoarseTimeSrc	None, LON	Coarse Time Source

5 Restricted settings

Setting values of protection parameters within the terminal are important not only for reliable and secure operation of the terminal, but also for the entire power system. Non-permitted and non-coordinated changes, done by unauthorized personnel, can cause severe damages in primary and secondary power circuits. This can influence the security of people working in close vicinity of the primary and secondary apparatuses and those using electric energy in everyday life.

For this reason, the terminal includes a special feature that, when activated, blocks the possibility to change the setting and configuration parameters of the terminal, from the built-in HMI module.

All other functions of the local human-machine communication remain intact. This means that an operator can read all events and other information as well as the setting values for different protection parameters.

The factory pre-configured binary input with name “Block Setting” must be connected to the control DC voltage via a normally closed contact of a control switch, which can be locked by a key. Only when the normally closed contact is open, it will be possible to change the setting and configuration parameters of the terminal via the built-in HMI.

6 Out of service facilities

It might be necessary to take the differential terminal out of service. For that reason, the terminal includes a special feature that, when activated, prevents the operation of the trip output contacts for the selected differential protection zone. All other functions of the terminal remain intact. This means that an operator can read all events and other information as well as the setting values for different protection parameters.

The factory pre-configured binary input with name “Block” is available in the three-phase version of the terminal. When it is energized all trip outputs contacts from the terminal are blocked.

Two factory pre-configured binary inputs with name “Block ZA” and “Block ZB” are available in the one-phase version of the terminal. Therefore it is possible to selectively block the trip output contacts for the required differential protection zone by energizing the respective binary input.

A dedicated binary output contact called “Blocked” is provided in the RED 521 terminal, in order to indicate that the trip output contacts are blocked.

Application of RED 521 Terminal

7 Basic applications for RED 521 terminal

7.1 General

Various basic types of applications for RED 521 terminal are shown and described in this chapter. For these applications usually three phase version of the terminal, with one differential zone and three (or even six) 3-phase CT inputs, is used.

7.2 Meshed corner application and T-connection application

The RED 521 general differential function is suitable for application on mesh-corner arrangements. Mesh corners might have four or even up to six CT inputs and are basically simple single busbar arrangements. A similar application will occur when a T-protection is required for one-and-half breaker or ring busbar arrangements.

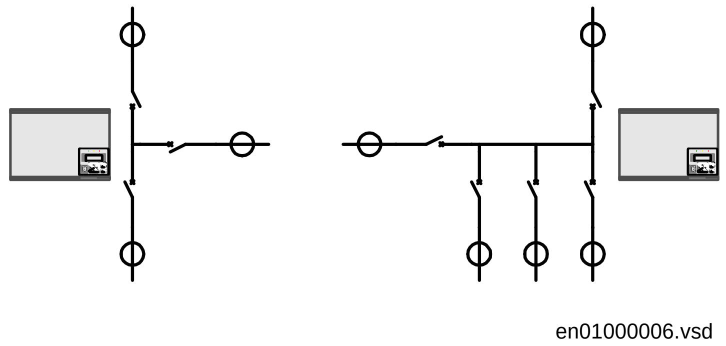

Fig. 1 Example of RED application on T-connection and meshed corner

7.3 Autotransformer and Reactor Applications

The RED 521 general differential function can be applied on autotransformers and reactors as well. It shall be noted that only serial and common windings are protected for autotransformer application (i.e. tertiary delta winding is not protected by this differential arrangement). Currents will be measured in all three phases at terminals and neutral side of the protected object. Second harmonic and fifth harmonic stabilization is not necessary with full differential measurement as in these applications.

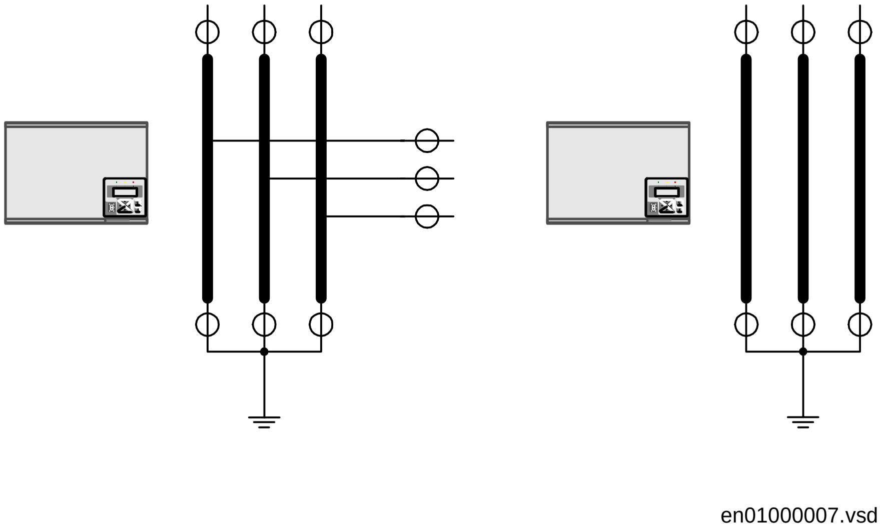

Fig. 2 Example of RED application on autotransformer and reactor

Please note that a common CT in the neutral is not acceptable. Refer to the Fig. 2 for the application principle. The advantage with general differential relay compared with the high impedance differential relay is the flexibility to accept different CT ratios, insensitivity to turns correction in the main CTs and faster operation in case of an internal fault.

7.4 Rotating Machine Application

The RED 521 general differential function is suitable for application on AC rotating machines (i.e. generators or motors). Currents will be measured at machine terminals and neutral side in all three phases.

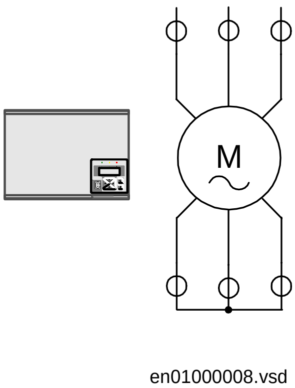

Fig. 3 Example of RED application on rotating machine

The advantage with general differential relay compared with the high impedance differential relay is the flexibility to accept different CT ratios, insensitivity to turns correction in the main CTs and faster operation in case of an internal fault.

7.5 Shunt Capacitor Bank Application

The RED 521 general differential function is suitable for differential protection of shunt capacitor banks. Currents will be measured at object terminal and neutral side in all three phases.

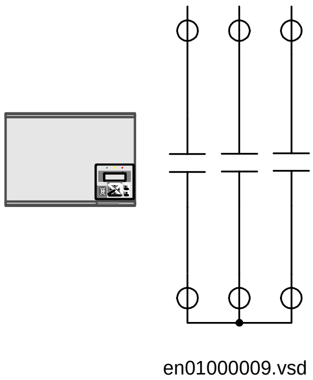

Fig. 4 Example of RED application on shunt capacitor bank

Please note that a common CT in the neutral is not acceptable. The advantage with general differential relay compared with the high impedance differential relay is the flexibility to accept different CT ratios, insensitivity to turns correction in the main CTs and faster operation in case of an internal fault.

8 Busbar Protection Applications for RED 521

8.1 General

A busbar protection is a protection device which protects busbars against short-circuits and earth-faults. In the “childhood” of electricity no separate protection device was used for busbar protection. Remote end line protections were used as main protection for busbar faults.

With the increased short-circuit power in the network separate differential relays for busbar protection have to be installed in order to limit the damage caused by the primary fault currents. In the same time, it is also a must to secure the network stability, as a delayed tripping for busbar faults can also lead to network instability, pole slip of near-by generators and even total system collapse.

8.2 Requirements

For bus zone protection applications, it is extremely important to have good security since an unwanted operation might have severe consequences. The unwanted operation of the bus differential relay will have the similar effect from the operational point of view as simultaneous faults on all power system elements connected to the bus. On the other hand, the relay has to be dependable as well. Failure to operate or even slow operation of the differential relay, in case of an actual internal fault, can have fatal consequences. Human injuries, power system blackout, transient instability or considerable damage to the surrounding substation equipment and the close-by generators are some of the possible outcomes.

Therefore the busbar protection must fulfill the following requirements:

1) Must be absolutely stable during all external faults. External faults are much more common than internal faults. The magnitude of external faults can be equal to the stations maximum short circuit capacity. Heavy CT-saturation due to high DC components and/or remanence at external faults must not lead to maloperation of the busbar differential protection. The security against maloperations must be extremely high due to the heavy impact on the overall network service.

2) Must have as short tripping time as possible in order to minimize the damage, minimize the danger and possible injury to the people which might be working in the station at the moment of internal fault, and secure the network stability.

3) Must be able to detect and securely operate for internal faults even with heavy CT saturation. The protection must also be sensitive enough to operate for minimum fault currents, which sometimes can be lower then the maximum load currents.

4) Must be able to selectively detect faults and trip only the faulty part of the busbar system.

5) Must be secure against maloperation due to auxiliary contact failure, possible human mistakes and faults in the secondary circuits etc.

8.3 Distinctive Features of Busbar Protection Schemes

A busbar protection scheme design, depends very much on the substation arrangement. Complexity of the scheme can drastically vary from station to station. Typical applications problems, for the most common busbar protection schemes, are described in this chapter.

8.4 Busbar Differential Protection

The basic concept for any differential relay is that the sum of all currents, which flow to and from the protection zone, must be equal to zero. If this is not the case, an internal fault has occurred. This is practically a direct use of well known “Kirchhoffs’s first law”. However, busbar differential relays do not measure directly the primary currents in the high voltage conductors, but the secondary currents of magnetic core current transformers, which are installed in all high-voltage bays connected to the busbar.

Therefore, the busbar differential relay is unique in this respect, that usually quite a few CTs, often with very different ratios and classes, are connected to the same differential protection zone. Because the magnetic core current transformers are non-linear measuring devices, under high current conditions in the primary CT circuits the individual secondary CT currents can be drastically different from the original primary currents. This is caused by CT saturation, a phenomenon that is well known to protection engineers. During the time when any of the current transformer connected to the differential relay is saturated, the sum of all CT secondary currents will not be equal to zero and relay will measure false differential current. This phenomenon is especially predominate for busbar differential protection applications, because it has the strong tendency to cause unwanted operation of the differential relay.

Remanence in the magnetic core of a current transformer is an additional factor, which can influence the secondary CT current. It can improve or reduce the capability of the current transformer to properly transfer the primary current to the secondary side. However, the CT remanence is a random parameter and it is not possible in practice to precisely predict it.

Another, and maybe less known, transient phenomenon appears in the CT secondary circuit at the instant when a high primary current is interrupted. It is particularly dominant if the HV circuit breaker chops the primary current before its natural zero crossing. This phenomenon is manifested as an exponentially decaying dc current component in the CT secondary circuit. This secondary dc current has no corresponding primary current in the power system. The phenomenon can be simply explained as a discharge of the magnetic energy stored in the magnetic core of the current transformer during the high primary current condition. Depending on the type and design of the current transformer this discharging current can have a time constant in the order of a hundred milliseconds.

Consequently, all these phenomena have to be considered during the design stage of a busbar differential relay in order to prevent the unwanted operation of the relay during external fault conditions.

The analogue generation of the busbar differential relays (i.e. RADHA, RADSS, REB 103) generally solves all these problems caused by the CT non-linear characteristics by using the galvanic connection between the secondary circuits of all CTs connected to the protected zone. These relays are designed in such a way that the current distribution through the relay differential branch during all transient conditions caused by non-linearity of the CTs will not cause the unwanted operation of the differential relay. In order to obtain the required secondary CT current distribution, the resistive burden in the individual CT secondary circuits must be kept below the pre-calculated value in order to guaranty the stability of the relay.

In new numerical protection relays, all CT and VT inputs are galvanically separated from each other. All analog input quantities are sampled with a constant sampling rate and these discreet values are then transferred to corresponding numerical values (i.e. AD conversion). After these conversions, only the numbers are used in the protection algorithms. Therefore, for the modern numerical differential relays the secondary CT circuit resistance might not be a decisive factor any more.

The important factor for the numerical differential relay is the time available to the relay to make the measurements before the CT saturation, which will enable the relay to take the necessary corrective actions. This practically means that the relay has to be able to make the measurement and the decision during the short period of time, within each power system cycle, when the CTs are not saturated. From the practical experience, obtained from heavy current testing, this time, even under extremely heavy CT saturation, is for practical CTs around two milliseconds. Because of this, it was decided to take this time as the design criterion in RED 521 terminal, for the minimum acceptable time before saturation of a practical magnetic core CT. Thus, the CT requirements for RED 521 terminal are kept to an absolute minimum. See “CT requirements” on page 60. of this manual for more details.

However, if the necessary preventive action has to be taken for every single CT input connected to the differential relay, the relay algorithm would be quite complex. Thus, it was decided to re-use the ABB excellent experience from the analog percentage restrained differential protection relay (i.e. RADSS and REB 103), and use only the following three quantities:

1 incoming current (i.e. sum of all currents which are entering the protection zone)

2 outgoing current (i.e. sum of all currents which are leaving the protection zone)

3 differential current (i.e. sum of all currents connected to the protection zone)

as inputs into the differential algorithm in the numerical relay design.

These three quantities can be easily calculated numerically from the raw sample values (i.e. twenty times within each power system cycle in RED 521) from all analog CT inputs connected to the differential zone. At the same time, they have extremely valuable physical meaning, which clearly describes the condition of the protected zone during all operating conditions.

By using the properties of only these three quantities, a new patented differential algorithm has been formed in RED 521 terminal. This differential algorithm is completely stable for all external faults. All problems caused by the non-linearity of the CTs are solved in an innovative numerical way. In the same time, very fast tripping time, down to 10ms, can be commonly obtained for heavy internal faults.

Please refer to Technical Reference Manual (i.e. Chapter 4) of this manual for more details about the working principles of the Differential Function algorithm, and selected test results from the heavy current tests.

8.5 Switching in current circuits

The so-called CT switching (i.e. zone selection) is required in situation when one particular circuit (i.e. bay) can be connected to different busbars by individual disconnectors. Typical example is a station with double busbars, where any feeder bay can be connected to any of the two buses.

Traditionally has the CT switching been done in CT secondary circuits. However with RED 521 this is not the case. All necessary zone selection (i.e. CT switching) is done in software. Therefore the CT secondary circuits are always intact and without any auxiliary relay contacts.

8.5.1 Zone Selection for RED 521

The RED 521 terminal offers an extremely effective solution for stations where zone selection (i.e. CT switching) is required. This is possible due to the software facility which gives full and easy control over all CT inputs connected to the terminal. The philosophy is to allow every CT input to be individually controlled by a configuration parameter. This parameter called “ZoneSelection/CTx” can be individually configured for every CT input which is available within RED terminal. The parameter can be set to only one of the following three alternatives:

1. Contact Ctrl
2. Fixed to ZA
3. Fixed to ZB (applicable for one phase version only)

If for a particular CT input (i.e. input CTx) setting “Contact Ctrl” is selected, then the CTx input will be only included to the differential zone ZA when a dedicated binary input called “Include CTx ZA” is energized. In the similar way the CTx input will be only included to the differential zone ZB when a dedicated binary input called “Include CTx ZB” is energized. This means that the current connected to the CTx input can be dynamically included/excluded from the differential zones by simply energizing/de-energizing the dedicated binary inputs of the RED terminal.

PLEASE NOTE that the second zone (i.e. ZB) is only available in one-phase version of the RED terminal. See “RED 521 Terminal Diagrams and Descriptions” on page 79. for more details about allocation and terminal numbers for these binary inputs.

If for a particular CT input (i.e. CTx) setting “Fixed to ZA” is selected, then this CT input is always included in the differential zone ZA irrespective of any other condition or status of any other binary input of the RED terminal. This means that the CT current connected to the CTx input will always be included in the differential zone ZA.

If for a particular CT input (i.e. CTx) setting “Fixed to ZB” is selected (**NOTE** that this selection is available only in one-phase terminal), then the CTx input is always included in the differential zone ZB irrespective of any other condition or status of any other binary input of the RED terminal. This means that the CT current connected to the CTx input will be always included in the differential zone ZB.

In applications where zone selection (i.e. CT switching) is required (for example double or multiple busbar stations) all CTs will be permanently connected to analog input module of the RED 521 terminal, as shown in Fig. 5. However, for every feeder bay setting “Contact Ctrl” shall be selected. At the same time the position of the busbar disconnectors must be mirrored by busbar disconnector replica relays, which are usually located within the busbar protection scheme. Each feeder current will be connected to the correct zone when the signal from the busbar disconnector replica relays is connected to the respective binary inputs on the RED 521 terminal for each individual bay.

8.6 Busbar Disconnector Replica

The busbar disconnector replica is used in order to provide the information to the differential terminal which of the measured CT currents shall be included within different differential zones. In order to form the busbar disconnector replica it is necessary to use the auxiliary contacts from each busbar disconnector. In practice, three different solutions are possible depending on the availability of the disconnector auxiliary contacts, type of available equipment within the busbar protection scheme and the available budget.

8.6.1 First solution for busbar disconnector replica

The simplest way to form the busbar disconnector replica is to use only the bistable relays (flip-flop relays). For RED 521 applications it is recommended to use COMBIFLEX bistable relay type RXMD 1 (or even RXMVB 2).

For this solution, it is necessary to use two auxiliary contacts (i.e. a-contact & b-contact) from each busbar disconnector and one bistable relay per each busbar disconnector. However, good timing of two auxiliary contacts is required. The principal drawing for this type of solution for double busbar bay is shown in the following figure:

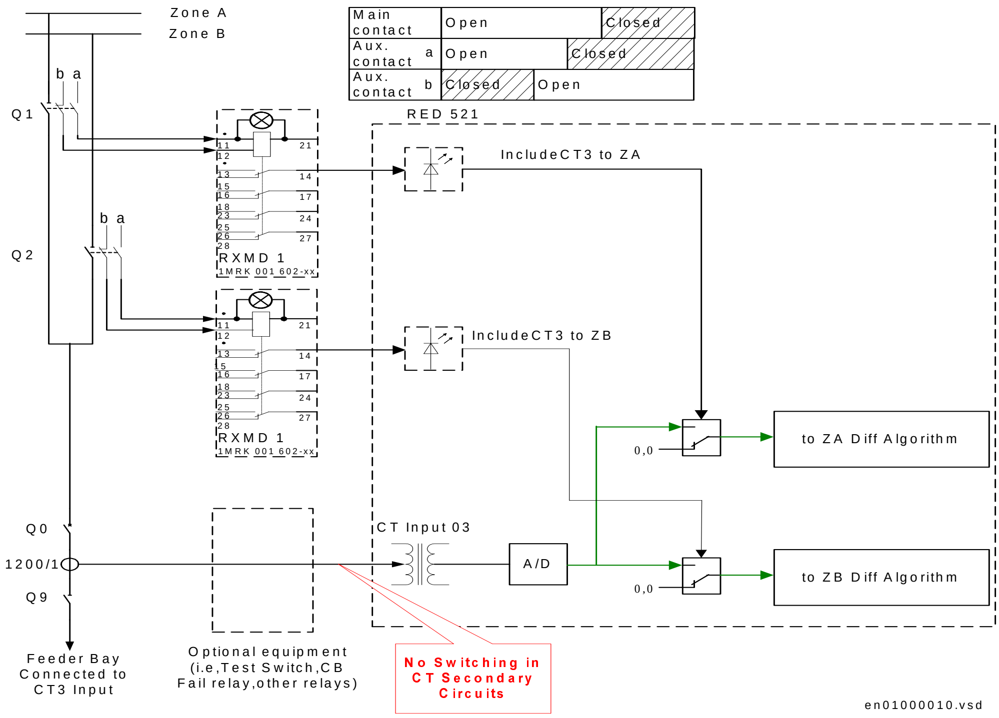

Fig. 5 Example of busbar disconnector replica for RED 521 with a-contact & b-contact from each busbar disconnector, for double busbar station

The main contact, the normally open auxiliary contact (i.e. a-contact) and the normally closed auxiliary contact (i.e. b-contact) of the busbar disconnectors should open and close as shown in the above figure.

When both busbar disconnectors (i.e. Q1 and Q2) are open, the reset coils of bistable relays are energized by normally closed contact (i.e. b-contact) of the disconnectors. The bistable relays are in reset state and consequently binary inputs of the RED 521 terminal are not energized. Thus current from this bay is not included in any of the protection zones. The following sequence of events shall happen when closing command for one of the two disconnectors (for example Q1) is given:

1 primary contacts of the disconnectors start to move

2 normally closed auxiliary contact (i.e. b-contact) immediately opens (i.e. it shall be of the early break type)

3 normally open auxiliary contact (i.e. a-contact) shall close after 50-100ms but **before** the main contacts come to flash-over distance (i.e. it shall be of the early make type)

4 set coil of bistable relay is then energized

5 contacts of the bistable relay change state and energize the binary input “Include CT3 to ZA” of the RED 521 terminal

6 RED 521 terminal includes, by software means, the CT3 current input into zone ZA measurement

7 primary contacts of the disconnector close

8.6.2 Second solution for busbar disconnector replica

For the second solution, it is necessary to use only one normally closed auxiliary contact (i.e. b-contact) from each busbar disconnector. However, one auxiliary relay and one bistable relay per each busbar disconnector is required within the busbar protection scheme. For this application, it is a space saving solution to use the auxiliary relay with two independent operating coils like COMBIFLEX auxiliary relays RXMB 1 or RXMM 1. The principal drawing for this type of solution for double busbar bay is shown in the following figure:

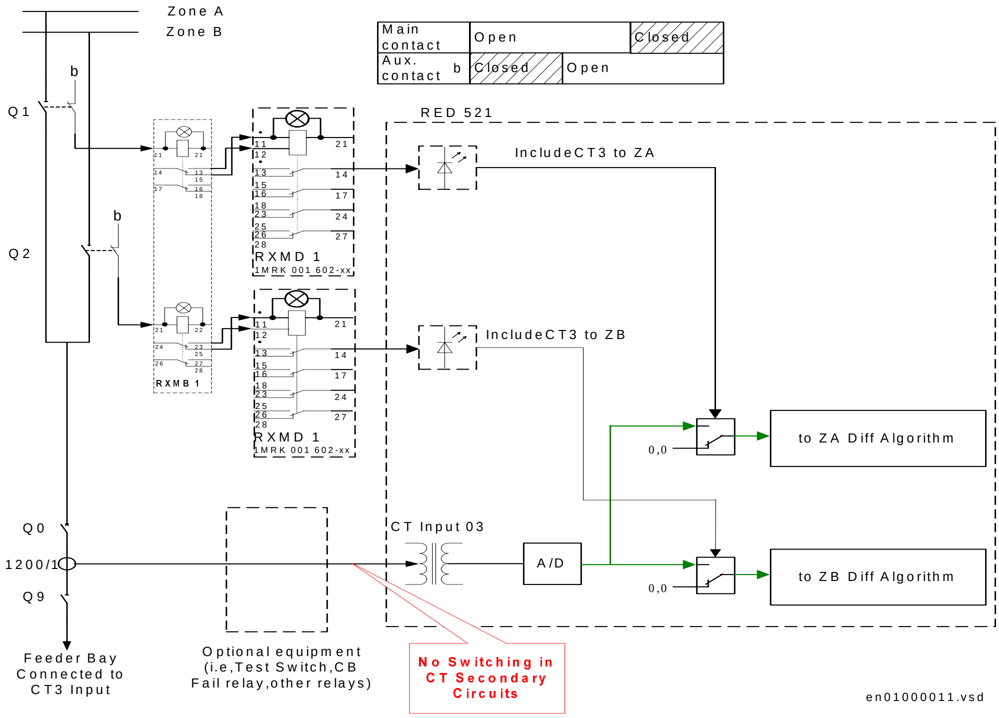

Fig. 6 Example how to form the busbar disconnector replica for RED 521 with only b-contact from each busbar disconnector, for double busbar station

The main contact and the normally closed auxiliary contact (i.e. b-contact) of the busbar disconnectors should open and close as shown in the previous figure.

When both busbar disconnectors (i.e. Q1 and Q2) are open, the coils of both auxiliary relays are energized by normally closed contact (i.e. b-contact) of the disconnectors. The contacts of the auxiliary relays are picked-up and they energize the reset coils of the bistable relays. The bistable relays are in reset state and the binary inputs of the RED 521 terminal are not energized. Thus the current from this bay is not included in any of the protection zones.

The following sequence of events shall happen when closing command for one of the two disconnectors (for example Q1) is given:

1 primary contacts of the disconnectors start to move
2 normally closed auxiliary contact (i.e. b-contact) immediately opens (i.e. it shall be of the early break type)
3 coil of the auxiliary relay is then de-energized and its contacts drop off
4 normally close contact of the auxiliary relay energize the set coil of bistable relay
5 contacts of the bistable relay change state and energize the binary input “Include CT3 to ZA” of the RED 521 terminal
6 RED 521 terminal includes, by software means, the CT3 current input into zone ZA measurement
7 primary contacts of the disconnector close

It shall be noted that the second solution is more fail-safe. If for example the dc supply from the disconnector fails, it will cause the drop-out of the auxiliary relay, which will immediately include the current into the measurement.

8.6.3 Third solution for busbar disconnector replica

Both already described solutions are good and already used and proven in practice for many years within RADSS and REB 103 busbar protection schemes. Nevertheless, the limitations of both solutions is that there is no direct supervision, except of the built-in LED indication within RXMD 1 & RXMB 1 relays, of the status of the busbar disconnector auxiliary contacts. In order to cope with this requirement the third solution is made.

The third solution is similar to the first solution, but the supervision of the disconnectors is added. It is simply achieved by inserting a REC 561 control terminal between the disconnector auxiliary contacts and the bistable relays. Typically only one REC 561 control terminal (very seldom two) is required for complete busbar protection scheme. In this way all required supervision (like disconnector traveling time, status of the auxiliary contacts etc.) can be engineered in the control terminal configuration, and alarmed locally or remotely via communication channels. Principal drawing for this type of solution for double busbar bay is shown in the following figure:

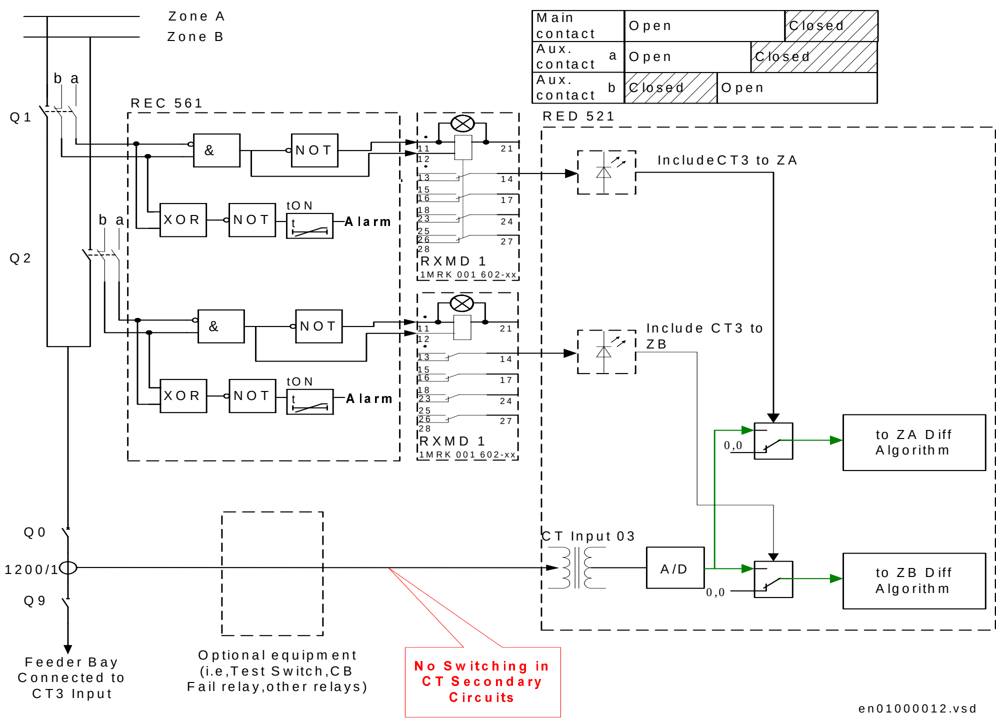

Fig. 7 Example how to form the busbar disconnector replica with supervision by using REC 561 control terminal, for double busbar arrangement

For the third solution, still two auxiliary contacts (i.e. a-contact & b-contact) from each busbar disconnector are required. The main contact, the normally open auxiliary contact (i.e. a-contact) and the normally closed auxiliary contact (i.e. b-contact) of the busbar disconnectors should open and close as shown in the above figure. However, timing between two auxiliary contacts is not critical as for the first solution, because by logic within the REC 561 control terminal the disconnector can be considered closed as soon as the normally closed auxiliary contact (i.e. b-contact) opens.

When both busbar disconnectors (i.e. Q1 and Q2) are open, the reset coils of bistable relays are energized by REC 561. The bistable relays are in reset state and consequently binary inputs of the RED 521 terminal are not energized. Thus current from this bay is not included in any of the protection zones. The following sequence of events shall happen when closing command for one of the two disconnectors (for example Q1) is given:

1 primary contacts of the disconnectors start to move

2 normally closed auxiliary contact (i.e. b-contact) immediately opens (i.e. it shall be of the early break type) and de-energizes the binary input of REC 561

3 internal logic in REC 561 detects the change and immediately de-energizes the reset coil and energies the set coil of the bistable relay. In the same time supervision timer for the disconnector auxiliary contacts status is started

4 contacts of the bistable relay change state and energize the binary input “Include CT3 to ZA” of the RED 521 terminal

5 RED 521 terminal includes, by software means, the CT3 current input into zone ZA measurement

6 normally open auxiliary contact (i.e. a-contact) closes and energizes the binary input of REC 561. The supervision timer for the disconnector auxiliary contacts status is stopped.

7 primary contacts of the disconnector close

All three solutions are possible in practice. Which one of them will be used depends on the client requirements, available equipment and overall scheme cost.

8.7 CT disconnection for Bus Section and Bus Coupler current transformer cores

In practice there are two different solutions for bus section or bus coupler bay layout. First solution is with two sets of main CTs, which are located on both sides of the circuit breaker, as shown in the following figure:

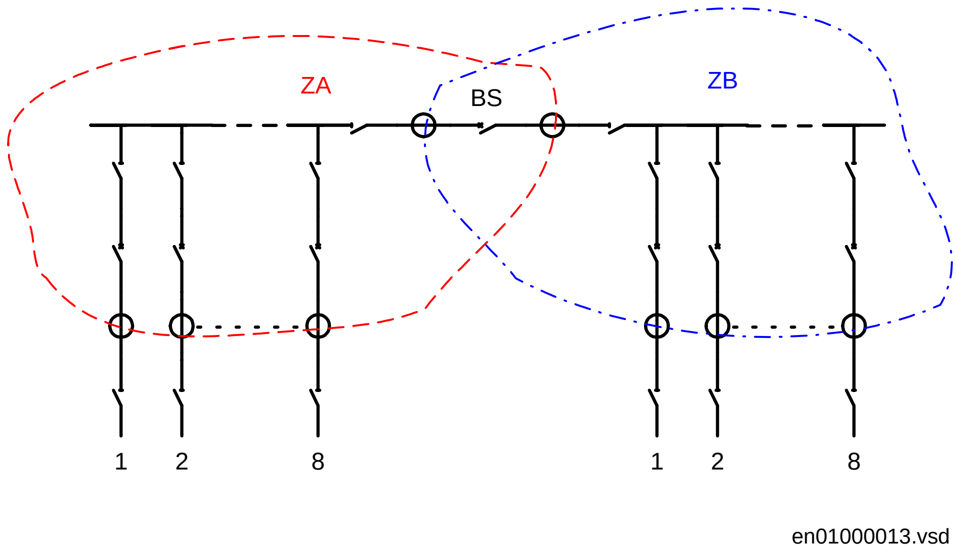

Fig. 8 Example of station with two sets of main CTs in the bus-section bay

This is more expensive, but good solution for busbar protection. Two differential zones overlapping across the bus-section or bus-coupler circuit breaker. No special considerations within busbar protection scheme are then necessary for this type of stations.

Due to the high cost of the HV current transformer often only one current transformer is available in bus-section or bus-coupler bay. This is a solution shown in the Fig. 9.

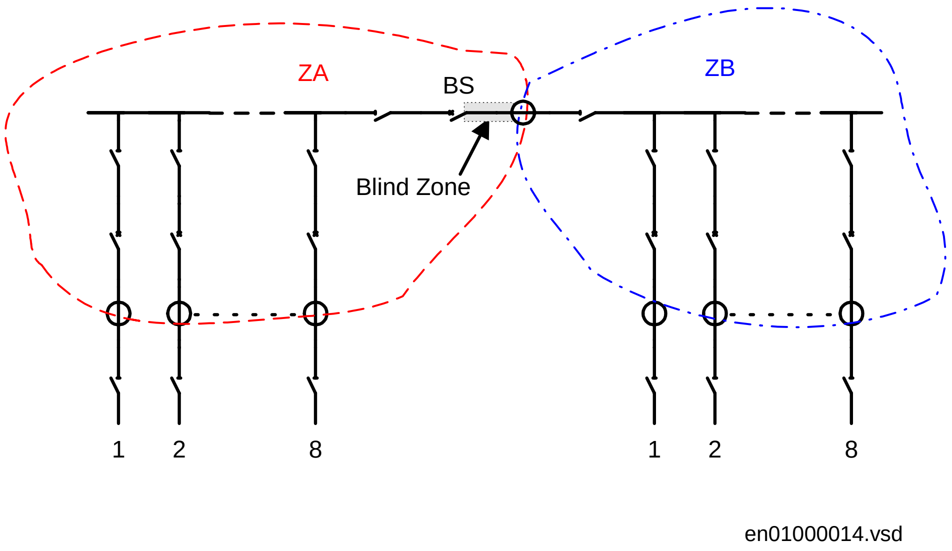

Fig. 9 Example of station with just one main CT in the bus-section bay

For this type of solution just one main CT is located on only one side of the circuit breaker. Thus, there is no zone overlapping across the section/coupler circuit breaker as shown in Fig. 8. Instead, it will exist a blind zone between the current transformer and the circuit breaker in the bus section or bus-coupler bay as shown in Fig. 9. For an internal fault in the blind zone, the differential zone ZA will unnecessarily operate and open the bus section breaker and all other feeder breakers associated with it. Nevertheless the fault will still exists on other busbar section, but is outside the current transformer in the bus section bay and hence outside the zone ZB (i.e. it is external fault for zone ZB). Similar problem will also exist if section/coupler circuit breaker was open before the internal fault in the blind zone. Therefore, the busbar protection scheme does not protect the complete busbar.

In order to improve the busbar protection scheme with this type of station layout, it is often required to disconnect the bus-section or bus-coupler CT from the differential zones as soon as the bus-section or bus-coupler circuit breaker is opened. This arrangement can be easily achieved in the following two ways:

1 Using normally open contact of the section/coupler circuit breaker

2 Using three external relays to obtain the required logic (recommended solution)

For the first solution one normally open auxiliary contact (i.e. a-contact) of the section/coupler circuit breaker is required. However, the timing of this auxiliary contact is very important. Please note that this auxiliary contact initiating CT disconnection shall be a type which closes as soon as the main breaker contacts leave the open position. It shall not be a type which closes when the main breaker contacts reach the closed position. This solution requires good CB maintenance and might experience problems during the life time of the circuit breaker.

For the second solution three external relays are required. However, this solution does not depend on contact timing between the main contacts and auxiliary contact of the breaker. It directly follows the philosophy used for RADSS/REB 103 schemes used for similar applications before. Detailed connection between the bus-coupler CB normally closed auxiliary contact (b-contact), RED 521 and these three external relays are shown in Fig. 10:

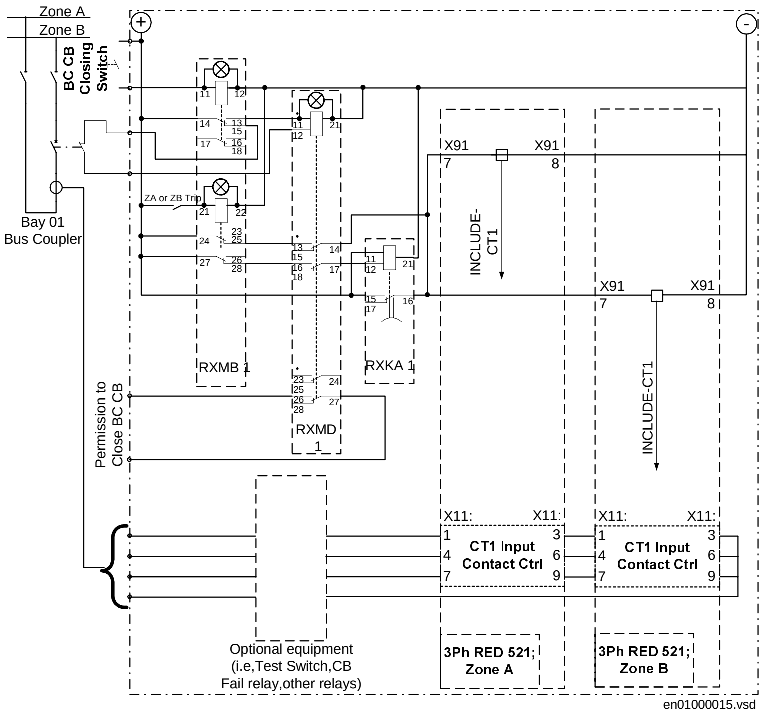

Fig. 10 Detailed connections for Bus-Coupler CT disconnection scheme

The three COMBIFLEX relays required for this scheme are listed in the following table:

Table 4: Relays for bus-section / bus-coupler CT disconnection scheme

COMBIFLEX Relay Type	Ordering No	Comment
RXMB 1	1MRK 000 640-xx	Equipped with two yellow LEDs for indication
RXMD 1	1MRK 001 602-xx	Equipped with one yellow LED for indication

Table 4: Relays for bus-section / bus-coupler CT disconnection scheme

COMBIFLEX Relay Type	Ordering No	Comment
RXKA 1	1MRK 000 424-xx	Used as drop off delay timer with typical setting of 100-150ms

This scheme will disconnect the section/coupler CTs after about 150ms (pre-set time on RXKA 1 timer) from the moment of opening of the section/coupler CB. Nevertheless this time delay is absolutely necessary in order to prevent racing between the opening of the main breaker contact and disconnection of the CT from the differential zones. This scheme will as well disconnect the CT in case of the operation of any of the two differential zones involved. This will secure the delayed (about 150ms) clearing and tripping of the internal fault within the blind zone even in case of section/coupler circuit breaker failure during this fault. This facility will improve the performance of the busbar protection scheme when one CT is located on only one side of the bus-section / bus-coupler circuit breaker.

8.8 Load transfer

In double busbar stations or double busbar with transfer bus stations it is common requirement to use the possibility of load transfer of load current in any feeder bay from one busbar to the other.

The sequence of operation during load transfer is normally as the following:

1- bus coupler bay is closed (i.e. CB and both disconnectors).

2- feeder bay busbar disconnector to the busbar not already in service is then closed. The interlocking system shall allow this only when the bus coupler breaker is already closed. Depending on the thermal capacity of the feeder busbar disconnectors (Q1 and Q2) the opening of the bus coupler circuit breaker is sometimes interlocked while both busbar disconnectors within one of the feeder bays are closed.

3- opening of the feeder bay busbar disconnector originally closed. The load is now transferred from one to other bus.

4- opening of bus coupler CB.

The load transfer has to be taken into consideration for the busbar differential protection scheme, as the two busbar zones are inter-connected together via two disconnectors. The primary current split between the two busbars is not known and the two separate measuring zones cannot be maintained.

In conventional protection systems the solutions have been to, by extensive zone switching relays, disconnect one zone (normally zone ZB) and to connect all feeders to other zone (normally zone ZA). At the same time the current from the bus-coupler bay, which just circulates between two zones, must be disconnected from the measuring differential zone.

Due to the numerical relay design explained in paragraph 8.5.1, the RED 521 can manage the load transfer in an efficient way.

A dedicated binary input called “Load Transfer” is available in RED 521 terminal. When this binary input is energized the load transfer feature inside of the terminal is immediately activated. In this situation the internal terminal measurement is reconnected so that currents from all feeder bays are included in both measuring zones, while the bus coupler bay current is excluded from the both zones. In order to simplify this logic the following is valid regarding the CT inputs in RED 521 terminal:

Table 5: Convention about bus coupler CT inputs in RED 521

Version of RED 521 Terminal	**Dedicated Bus Coupler CT Input(s)**	**Action taken while Load Transfer logic is active**
Three phase terminal with one differential zone (with three or six 3-phase CT inputs)	CT1	CT1 input is unconditionally excluded from the differential zone, all other CT inputs are unconditionally included into the differential zone
One phase terminal with two differential zones (with nine or eighteen 1-phase CT inputs)	CT1 & CT2	CT1 & CT2 inputs are unconditionally excluded from both differential zones, all other CT inputs are simultaneously and unconditionally included into both differential zone (i.e. both differential zones measure exactly the same input data and thus both behave as an overall zone)

Therefore due to the implementation of load transfer feature within RED 521 terminal, care shall be taken that for double busbar stations or double busbar with transfer bus stations:

- input CT1 shall be always used as bus-coupler CT input for three-phase version of the terminal
- inputs CT1 & CT2 shall be always used as bus-coupler CT inputs for one-phase version of the terminal

In addition to the above explanation in the one-phase version of RED 521 an automatic load transfer start feature is available. Any feeder bay, connected to any CT input from CT3 to CT18, will start internal load transfer logic if the following two conditions are met:

1 Configuration parameter for zone selection for this feeder bay is set to “Contact Ctrl”

2 Both dedicated binary inputs for the control of this bay current are simultaneously energized

This feature is provided in the one-phase version of RED 521 terminal in order to simplify the busbar protection scheme engineering for double busbar stations.

A dedicated binary output contact called “Load Transfer” is provided in the RED 521 terminal, in order to indicate that this software feature is activated. It is a common practice to alarm this condition if it remains active for more than five minutes. However, this time delayed alarm has to be arranged by an external delay on pick-up timer (i.e. COMBIFLEX type RXKA 1).

The internal detailed logic for the Load Transfer feature is described in Technical Reference Manual (i.e. Chapter 4) of RED 521 manual.

8.9 Open CT Circuits

When CT-circuits are switched depending on the position of the busbar disconnectors there is a possibility that some of the CT secondary circuits can be open circuited by a mistake. At the same time this can cause unwanted operation of the differential protection scheme.

For this reason, a so-called check zone is often required for a traditional high-impedance busbar protection scheme when switching in CT-circuit is done. The check zone is fixed and has no switching of CTs in any of the outgoing circuits and is not connected to busbar section and busbar coupler bays. The check zone, will detect faults anywhere in the substation but can not distinguish in which part of the station the fault is located. When the check zone detects a fault it gives a release signal to the busbar protection relays in all individual, discriminating zones. The busbar protection discriminating zones will than trip the part of the substation that is faulty. However, this principle creates not only a high cost as separate CT cores are required, but also a need for extra cabling and a separate check zone differential relay.

With the RED 521 terminal, there is no need for an extra check zone due to the following facts:

- the CT switching for RED 521 terminal is made only in software, and CT secondary current circuits do not include any auxiliary contacts, see Fig. 5
- the terminal is always supplied with a special zone and phase selective “Open CT Detection” algorithm, which will instantly block the differential function in case of an open CT secondary circuits caused by accidents or mistakes.

This means that a very cost effective solution can be achieved with RED 521 terminal, producing extra savings during scheme engineering, installation, commissioning, service and maintenance.

The dedicated binary output contacts, one per each phase and zone of protection, are provided in the RED 521 terminal in order to alarm the open CT circuit condition. At the same time the yellow LED on the built-in HMI is lit up. It shall be noted that the “Open CT Circuit” alarm can only be manually reset by one of the three following ways:

1 By pressing “C” button on the built-in HMI

2 By energizing the dedicated binary input called “Reset OCT”

3 By issuing a command via LON communication for the reset of this alarm

For more details about the working principles of the “Open CT Detection” algorithm, please refer to Technical Reference Manual (i.e. Chapter 4) of this manual.

8.10 Tripping circuit arrangement

The tripping outputs on RED 521 are of medium duty type. Normally due to a large number of required trip output contacts, a separate trip relay unit is applied for the tripping of the circuit breakers in all bays. The tripping arrangement can be done in different ways as described below.

8.10.1 Centralized trip relay unit

Tripping is performed by a local trip contact multiplication with an auxiliary trip unit. Separate potential free contacts are provided for each bay and are supplied by the bay auxiliary voltage and will activate the trip coil of each bay circuit breaker at operation.

This tripping setup is suitable when no individual circuit breaker failure relays or lockout of individual bay CB closing coils is required.

A suitable trip unit consists of a combination of RXMS1 /RXMH 2 when heavy duty contacts are required and only RXMS 1 relays when medium duty contacts are sufficient.

8.10.2 Decentralized trip arrangement.

Tripping is performed with one individual auxiliary trip unit for each bay. This individual auxiliary trip unit can be mounted either in the busbar protection cubicle or in the individual bay cubicles. This tripping setup is suitable when individual circuit breaker failure protections and/or CB lock-out relays are required.

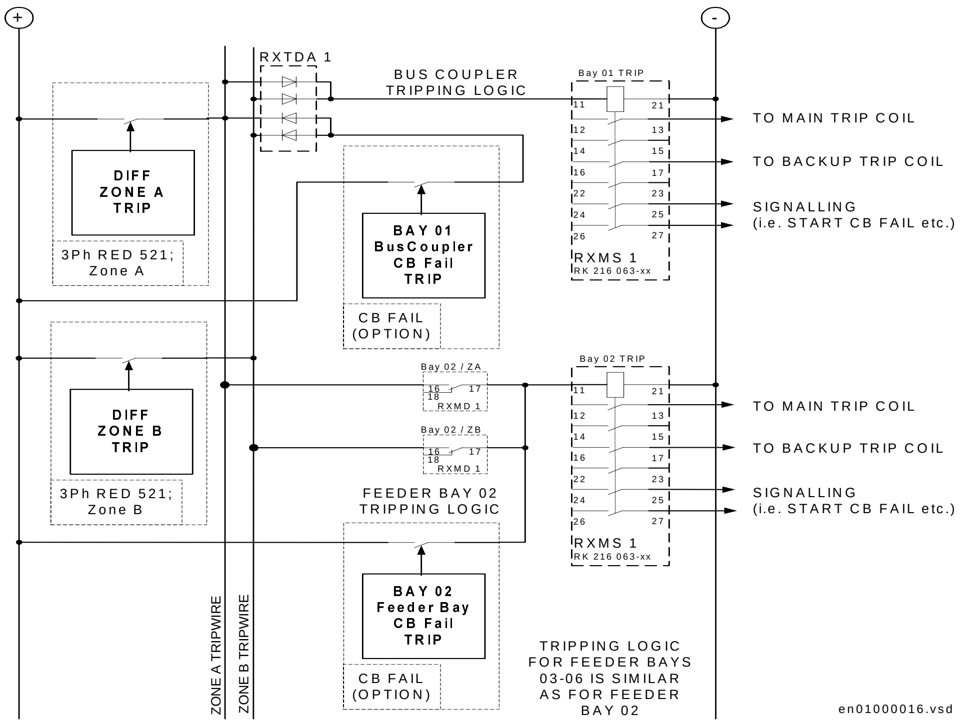

Fig. 11 Example of tripping arrangement for double busbar protection scheme

This solution is especially suitable for the double busbar arrangement which requires the zone selection arrangement (i.e. so called CT switching). The bistable relays used within the busbar disconnectors replica scheme provide the zone selection for busbar protection and correct trip signal distribution (i.e. RXMD 1 contacts on above figure) for busbar and breaker failure protections. This solution simplifies the connection for circuit breaker failure tripping for each bay, because it utilizes the same zone tripping selection system as for the busbar protection. One of the possible tripping arrangement based on this principle for double busbar protection scheme with three-phase version of RED 521 terminal is shown in the Fig. 11.

8.10.3 Lock-out function

It is often required to use lock-out relays for busbar protection.

It is recommended to use lock-out in the closing circuit only where a bay lock-out relay for each bay is activated for the functions where lock-out is required. Lock-out trip relays are available in the COMBIFLEX range (RXMVB2 or RXMVB4 bistable relays for example).

From the application point of view lock-out trip relays might have the following drawbacks:

- The trip contacts will remain closed. If the breaker would fail to open the tripping coil will be burnt and the DC supply short-circuited.

- The trip circuit supervision (TCS) relays will reset and give alarm for a failure in the trip circuit if the alarm is not opened by the lock-out relay or a double trip circuit supervision where the trip circuit is supervised with two TCS relays.

8.10.4 Contact reinforcement with heavy duty relays.

There is often a request for heavy duty trip relays. Normally the circuit breaker trip coils, with a power consumption of 200 to 300 W, are provided with an auxiliary contact opening the trip circuit immediately at breaker tripping. Therefore, no heavy duty breaking capacity is required for the tripping relays.

Nevertheless heavy duty trip relays are still often specified to ensure circuit opening also if the circuit breaker fails due to a mechanical failure or a lack of energy for operation. This can particularly occur during site testing. In this case it is recommended to use COMBIFLEX RXMH 2 or RXMVB 2 heavy duty relays.

8.10.5 Trip circuit supervision for busbar protection

Trip circuit supervision is mostly required to supervise the trip circuit from the individual bay relay panel to the circuit breaker. It can be arranged also for the tripping circuits from the busbar protection.

However, it can be stated that the circuit from a busbar protection trip relay located in the busbar protection panel is not so essential to supervise as busbar faults are very rare compared to faults in bays, specially on overhead power lines. Also it is normally a small risk for faults in the tripping circuit and if there is a fault it affects only one bay and all other bays are thus correctly tripped meaning that the fault current disappears or is limited to a low value.

9 Applications for Different Busbar Arrangements

9.1 General

Busbar differential protection application principles for typical busbar arrangements are shown and described in this chapter.

9.2 Single busbar arrangement

The simplest form of busbar protection is a one-zone protection for single busbar configuration, see Fig. 12. If the main CTs have equal ratio, the Kirchhoffs first law is directly valid and ratio compensation in the bays is not necessary. When different CT ratios exist in the bays compensation is done by setting the CT ratio individually for each bay.

The only requirement for busbar protection is that the protection scheme must have one differential zone. For any internal fault all circuit breakers must be tripped, which will cause loss of supply to all loads connected to the station.

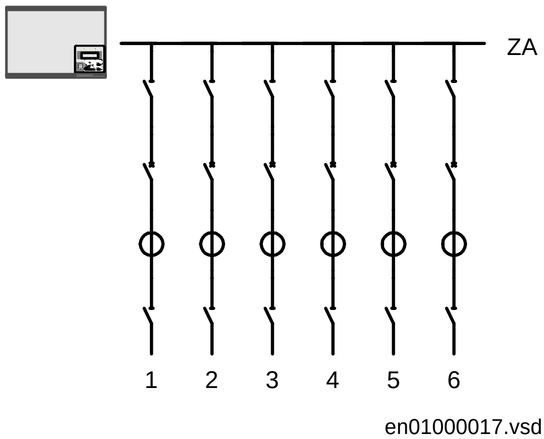

Fig. 12 Example of single busbar section with six feeder bays

With RED 521 this type of busbar arrangement can be very easily protected. The most common setups with RED 521 terminals for this type of station are described in the following table.

Table 6: Typical solutions for single busbar arrangement

Version of RED 521 Terminal	No of feeders per busbar	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤6	1
One phase terminal with two differential zones and nine 1-phase CT inputs	≤9	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤18	3

9.3 Single busbar arrangements with sectionalizer

This arrangement is very similar to the single busbar arrangement. The sectionalizer allows the operator to split the station into two separate buses. However switching of the sectionalizing disconnector have to be done without any load. This means that one of the two busbars has to be de-energized before any opening or closing of the sectionalizer.

For this case the protection scheme must have two differential zones, which can be either split to work independently from each other or switched to one overall differential zone when sectionalizing disconnector is closed. Nevertheless, when sectionalizer is closed, for internal fault on any of the two buses all feeder circuit breakers have to be tripped, which will cause loss of supply to all loads connected to this station.

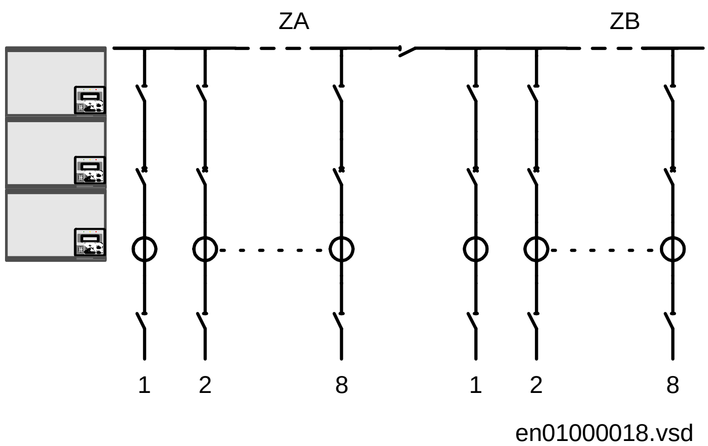

Fig. 13 Example of two single busbar sections with bus-sectionalizing disconnector and eight feeder bays per each busbar section

The most common setups with RED 521 terminals for this type of station are described in the following table.

Table 7: Typical solutions for stations with two single busbar sections with bus-sectionalizing disconnector

Version of RED 521 Terminal	No of feeders per each busbar section	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤3	2
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤8	3

The most simple solution for this type of station is with three single phase terminals. The two differential zones are available and the connecting of the two zones is simply controlled via “Load Transfer” binary input, see paragraph 8.8 for more details. In practice, one auxiliary (bistable) relay is required in order to mirror the position of the sectionalizer and energizes the “Load Transfer” binary input when sectionalizer is closed. At the same time one contact from this auxiliary (bistable) relay must interconnect the two individual bus trip-wires.

Due to implementation of the Load Transfer feature in the single phase version of RED 521 terminal, CT inputs CT1 and CT2 can not be used in this application. This means that 16 CT inputs (i.e. from input CT3 to input CT18) are available for this type of application. In practice this often means eight bays per each busbar section, as shown in Fig. 13. However different number of feeders per each bus section is possible if the total number of feeders in the station is less than or equal to sixteen.

9.4 Single busbar arrangements with bus-section breaker

This arrangement is very similar to the single busbar arrangement. The bus-section breaker allows the operator to split the station into two separate buses under full load.

The requirement for busbar protection scheme is that the scheme must have two independent differential zones, one for each busbar section. In case of an internal fault on one of the two sections, bus-section circuit breaker and all feeder circuit breakers associated with this section have to be tripped, leaving the other busbar section in normal operation.

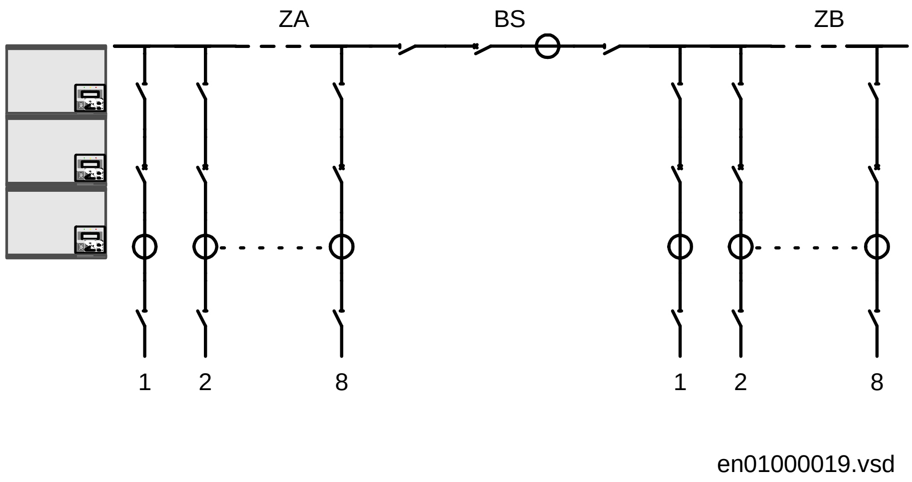

Fig. 14 Example of two single busbar sections with bus-section circuit breaker and eight feeder bays per each busbar section

With RED 521 this type of busbar arrangement can be quite easily protected. The most common setups with RED 521 terminals for this type of station are described in the following table.

Table 8: Typical solutions for single busbar arrangements with bus-section breaker

Version of RED 521 Terminal	No of feeders per each busbar section	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤5	2
One phase terminal with two differential zones and nine 1-phase CT inputs	≤8	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤17	6

For station with just one CT in the bus-section bay, it might be required, depending on the client requirements, to provide the special scheme for disconnection of bus-section CT when the bus-section CB is open. For more information see Fig. 9.

9.5 H-type busbar arrangements

The H-type stations are often used in transmission and sub-transmission networks as a load-centre substations, see Fig. 15. These arrangement are very similar to the single busbar station with sectionalizer or bus-section breaker, but are characterized by very limited number of feeder bays connected to the station (normally only four feeders).

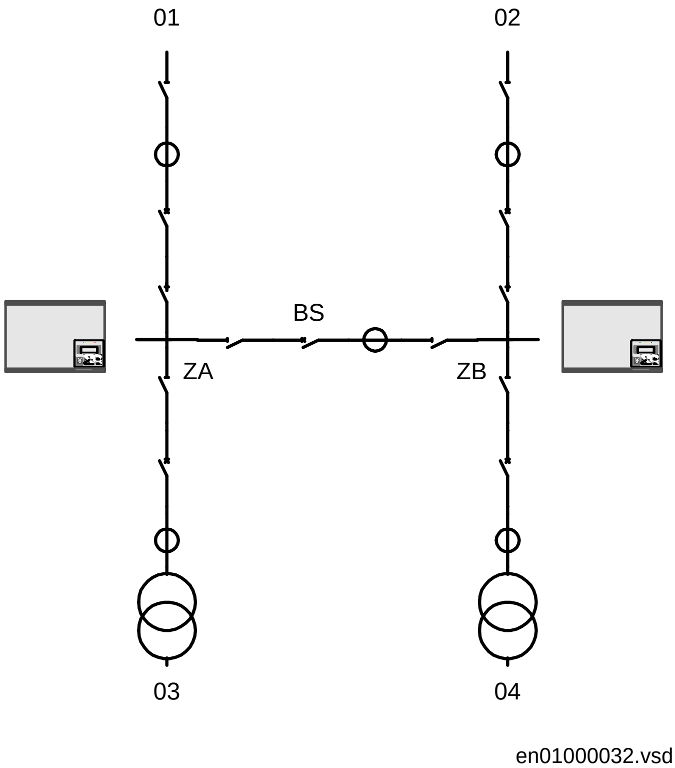

Fig. 15 Example of H-type station

The requirement for the busbar protection scheme for this type of station may differ from utility to utility. It is possible to apply just one overall differential zone, which protects both busbar sections. However, at an internal fault on any of the two buses all feeder circuit breakers have to be tripped, which will cause loss of supply to all loads connected to this station. Some utilities prefer to have two differential zones, one for each bus section. For more details about two-zone solution see the previous two paragraphs.

The most common setups with RED 521 terminals for this type of station are given in the following table.

Table 9: Typical solutions for H-type stations

Version of RED 521 Terminal	No of differential zones/No of feeders per zone	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	1 / ≤6	1
Three phase terminal with one differential zone and three 3-phase CT inputs	2 / ≤2	2
Three phase terminal with one differential zone and six 3-phase CT inputs	2 / ≤5	2

For station with double zone protection and just one set of CTs in the bus-section bay, it might be required, depending on the client requirements, to provide the special scheme for disconnection of bus-section CT when the bus-section CB is open. For more information see Fig. 9.

9.6 Double circuit breaker busbar arrangement

The circuit breaker, disconnectors and instrument transformers are duplicated for every feeder, as shown in Fig. 16.

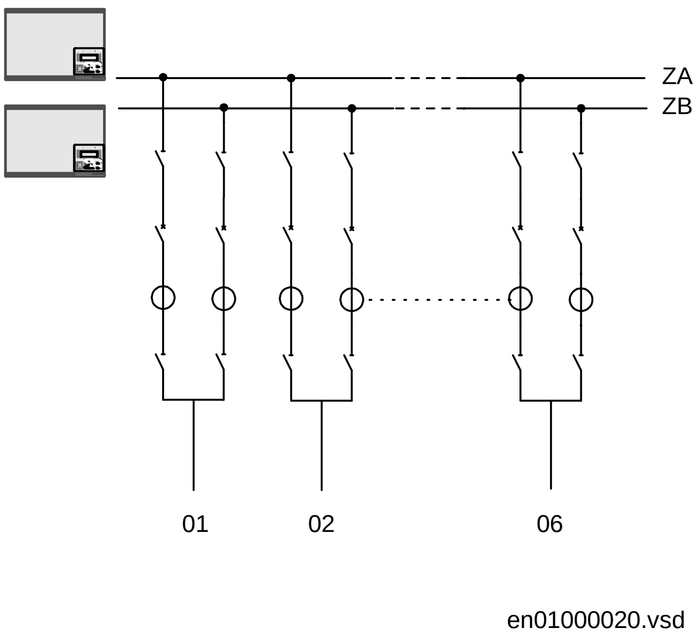

Fig. 16 Example of double breaker station

This is an extremely flexible solution. In normal service all breakers are closed. The requirement for busbar protection scheme is that the scheme must have two independent differential zones, one for each busbar. In case of an internal fault on one of the two buses all circuit breakers associated with the faulty busbar have to be tripped, but supply to any load will not be interrupted. The tripping logic for the circuit breaker failure protection must be carefully arranged.

The most common setups with RED 521 terminals for this type of busbar arrangement are described in the following table.

Table 10: Typical solutions for double circuit breaker busbar arrangement

Version of RED 521 Terminal	No of feeders per station	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤6	2
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤9	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤18	6

9.7 One- and-half circuit breaker busbar arrangement

A fewer number of circuit breakers are needed for the same flexibility as for double circuit breaker busbar arrangement, see Fig. 17.

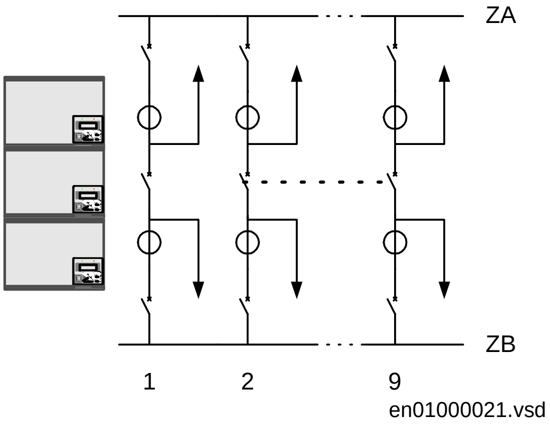

Fig. 17 Example of one-and-half circuit breaker station

All breakers are normally closed. The requirement for the busbar protection scheme is that the scheme must have two independent differential zones, one for each busbar. In case of an internal fault on one of the two buses all circuit breakers associated with the faulty busbar have to be tripped, but the supply to any load will not be interrupted. The breaker failure protection tripping logic also needs carefully arrangement.

With RED 521 this type of busbar arrangement can be very easily protected. The most common setups with RED 521 terminals for this type of station are described in the following table.

Table 11: Typical solutions for one-and-half circuit breaker stations

Version of RED 521 Terminal	No of diameters in the station	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤6	2
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤9	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤18	6

9.8 Double Busbar arrangement

This type of arrangement is shown in Fig. 18.

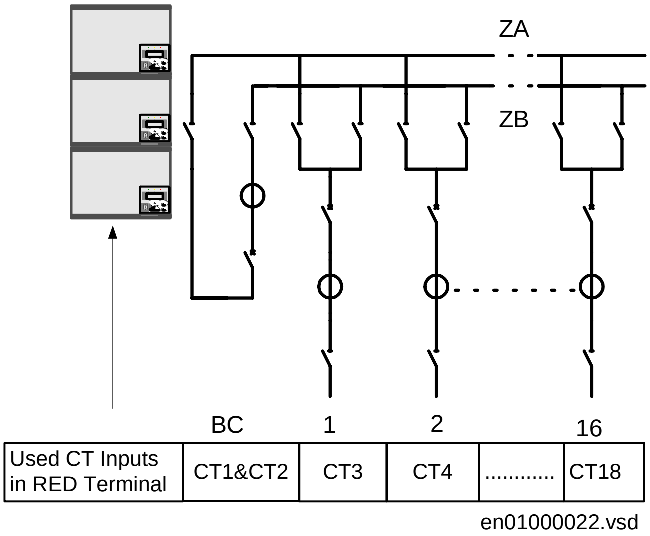

Fig. 18 Example of double busbar station

This type of busbar arrangement is very common. It is often preferred for larger installations. It provides good balance between maintenance work requirements and security of supply. If needed, two busbars can be split during normal service. The requirement for busbar protection scheme is that the scheme must have two independent differential zones, one for each busbar. In case of an internal fault on one of the two buses, buscoupler circuit breaker and all feeder circuit breakers associated with the faulty bus have to be tripped, leaving other busbar still in normal operation. Provision for zone selection, disconnector replica and load transfer have to be included into the scheme design.

With RED 521 this type of busbar arrangement can be protected as described in the following table:

Table 12: Typical solutions for double busbar stations

Version of RED 521 Terminal	No of feeders in the station (excluding bus-coupler bay)	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤5	2
One phase terminal with two differential zones and nine 1-phase CT inputs	≤7	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤16	3

For station with just one CT in the bus-coupler bay, it might be required, depending on the client requirements, to provide the special scheme for disconnection of bus-coupler CT when the bus-coupler CB is open. For more info please refer to Fig. 9.

9.9 Double Busbar arrangement with Transfer Bus

This type of arrangement is shown in Fig. 19.

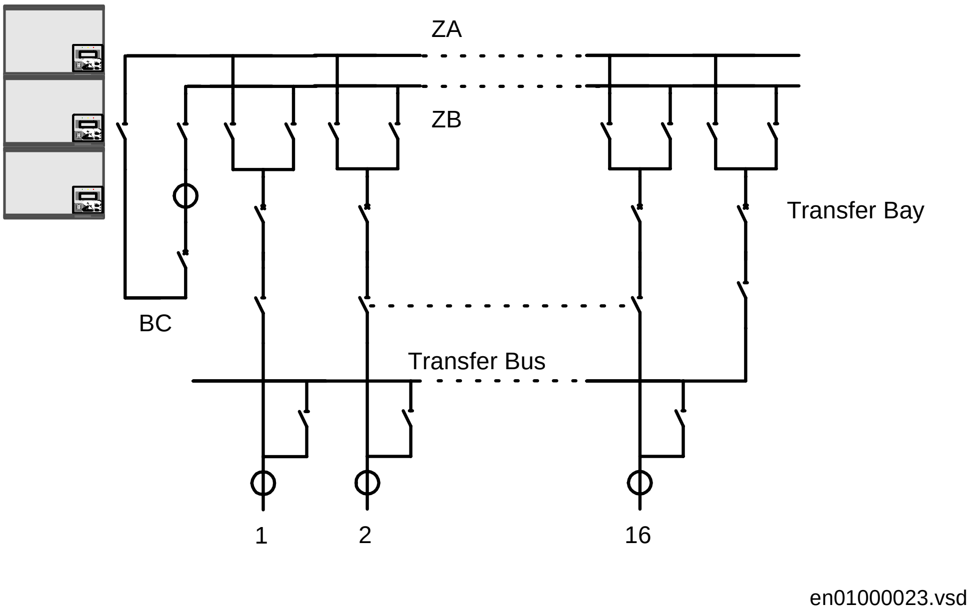

Fig. 19 Example of double busbar arrangement with transfer bus

For this type of arrangement, when CTs are located on the line side of the transfer disconnector, the busbar protection scheme is relatively similar to the double busbar station scheme. The additional thing is that the busbar disconnector replica is more complicated, because it has to take care of the transfer possibility as well. The busbar protection scheme will still have only two independent differential zones. The transfer bus and the transfer bay will be included either in zone ZA or ZB depending on the status of the transfer bay busbar disconnectors. Provision for zone selection, disconnector replica and load transfer have to be included into the scheme design.

With RED 521 this type of station can be protected as described in the following table.

Table 13: Typical solutions for double busbar stations with transfer bus

Version of RED 521 Terminal	No of feeders in the station (excluding bus-coupler & transfer bay)	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	≤5	2

Table 13: Typical solutions for double busbar stations with transfer bus

Version of RED 521 Terminal	No of feeders in the station (excluding bus-coupler & transfer bay)	Number of RED 521 terminals required for the scheme
One phase terminal with two differential zones and nine 1-phase CT inputs	≤7	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤16	3

For station with just one CT in the bus-coupler bay, it might be required, depending on the client requirements, to provide the special scheme for disconnection of bus-coupler CT when the bus-coupler CB is open. For more info please refer to Fig. 9.

9.10 Double Busbar arrangements with two bus-section breakers and two bus-coupler breakers

This type of stations is commonly used for GIS installations. It offers high operational flexibility. For this type of stations, two schemes similar to the double busbar station scheme can be used

.

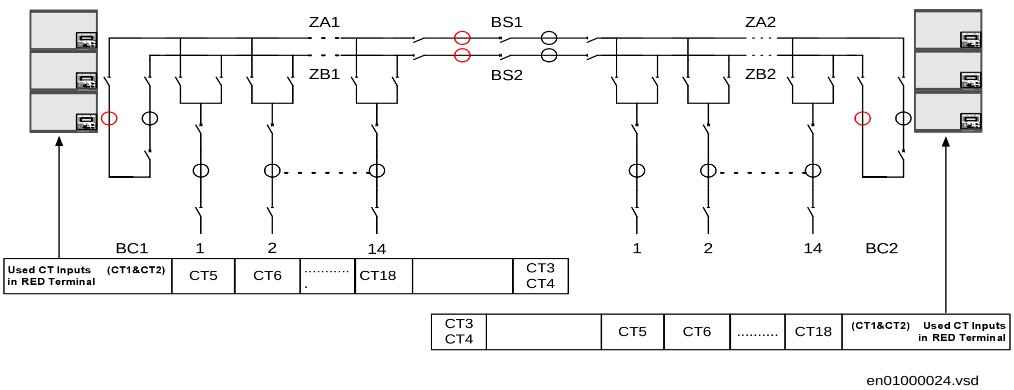

Fig. 20 Example of typical GIS station layout

With RED 521 this type of arrangement can be protected as described in the following table.

Table 14: Possible solutions for a typical GIS stations

Version of RED 521 Terminal	No of feeders on each side of the station (excluding bus-coupler & bus-section bays)	Number of RED 521 terminals required for the scheme
One phase terminal with two differential zones and nine 1-phase CT inputs	≤5	6
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤14	6

Provision for zone selection, disconnector replica and load transfer have to be included into the scheme design.

For station with just one CT in the bus-coupler or bus-section bays, it might be required, depending on the client requirements, to provide the special scheme for disconnection of bus-coupler or bus-section CT when the bus-coupler or bus-section CB is open. For more info please refer to Fig. 9.

9.11 Combined busbar arrangements

There are stations which are practically a combination between two normal types of station arrangements, which are already previously described. Some typical examples will be shown here:

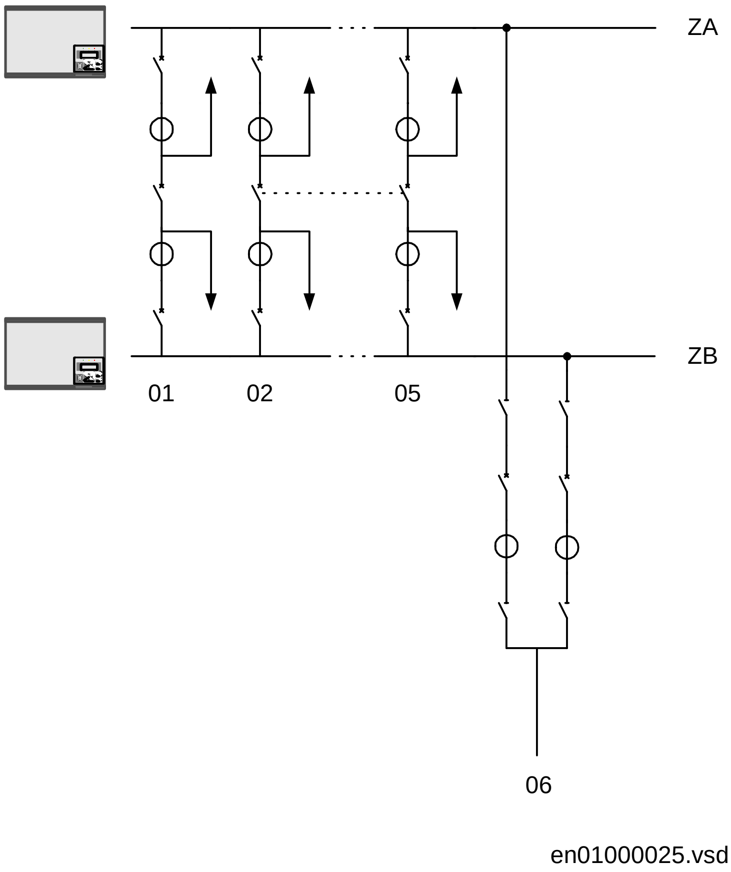

Fig. 21 Combination between one-and-half and double breaker station layouts

This type of stations can be encountered very often in practice. Usually the station is arranged in such a way that double breaker bays can be, at a later stage, transformed into one-and-half breaker setup. For busbar protection this type of station can be protected in the exactly the same way as one-and-half breaker stations described above. The same type of RED 521 terminals can be used, and same limitations regarding the number of diameters apply.

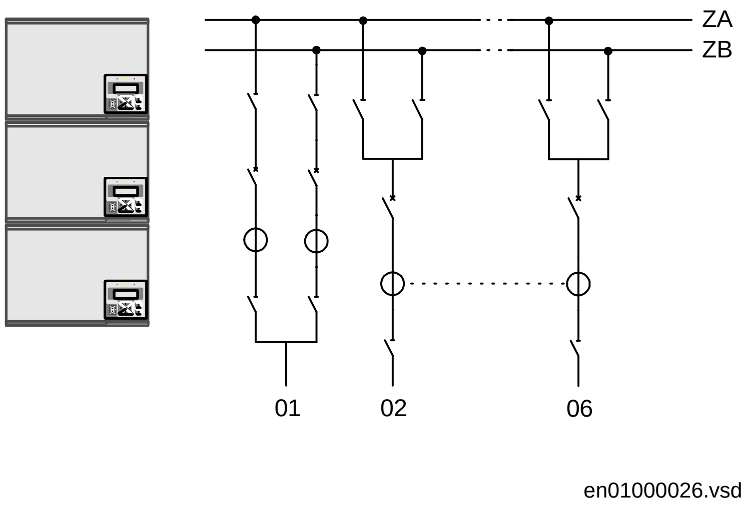

Fig. 22 Combination between double breaker and double busbar station layouts

In this type of arrangement the double breaker bay has in the same time the role of the bus-coupler bay for normal double busbar feeders. Therefore, load transfer, zone selection and disconnector replica facilities have to be provided for all double busbar bays. Because of the implementation of load transfer feature in RED 521, the following should be considered for this type of application:

- input CT1 shall not be used for the three-phase version of the terminal
- inputs CT1 & CT2 shall not be used for the one-phase version of the terminal

Accordingly the following solutions are possible with RED 521 terminals:

Table 15: Typical solutions for combination between double breaker and double busbar station layouts

Version of RED 521 Terminal	No of double breaker feeders / No of double busbar feeders in the station	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	1 / ≤4	2
One phase terminal with two differential zones and nine 1-phase CT inputs	1 / ≤5	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	1 / ≤14	3

Table 15: Typical solutions for combination between double breaker and double busbar station layouts

Version of RED 521 Terminal	No of double breaker feeders / No of double busbar feeders in the station	Number of RED 521 terminals required for the scheme
One phase terminal with two differential zones and eighteen 1-phase CT inputs	2 / ≤12	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	3 / ≤10	3

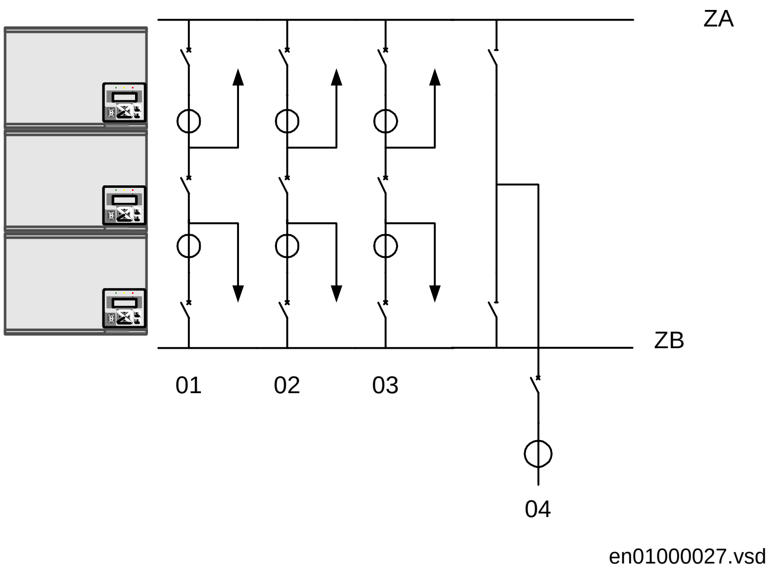

Fig. 23 Combination between one-and-half breaker and double busbar station lay-outs

For this type of busbar arrangement the double busbar bay is usually connected to the reactive power compensation equipment (i.e. shunt reactor or shunt capacitor). The diameters in the one-and-half breaker part of the station have at the same time the role of the bus-coupler bay. Therefore load transfer, zone selection and disconnector replica facilities have to be provided for all double busbar bays.

Because of the implementation of the load transfer feature in RED 521, the following should be considered for this type of application:

- input CT1 shall not be used for the three-phase version of the terminal
- inputs CT1 & CT2 shall not be used for the one-phase version of the terminal

Accordingly, the following solutions are possible with RED 521 terminal:

Table 16: Possible solutions for combination between one-and-half breaker and double busbar station layouts

Version of RED 521 Terminal	No of one-and-half CB diameters / No of double busbar feeders in the station	Number of RED 521 terminals required for the scheme
Three phase terminal with one differential zone and six 3-phase CT inputs	2 / 1	2
One phase terminal with two differential zones and nine 1-phase CT inputs	≤3 / 1	3
One phase terminal with two differential zones and eighteen 1-phase CT inputs	≤7 / ≤2	3

10 Event List

10.1 General

The RED 521 terminal is always supplied with internal time-tagged event list. When using a substation automation system, time-tagged events can be continuously sent from the terminal. These events come directly from the terminal internal event list which is always provided within the terminal.

10.2 Functionality

The time-tagged internal event list is always available from the front HMI or from another location over the LON data communication system. The event list operates on first-in-first-out principle. The last sixteen events are always available. Any change in the status of the following signals will cause a new entry in the terminal event list:

Table 17: Signals logged in the internal event list

Three Phase Version of the Terminal	One Phase Version of the Terminal
1) Trip Phase L1 2) Trip Phase L2 3) Trip Phase L3 4) Open CT Phase L1 5) Open CT Phase L2 6) Open CT Phase L3 7) Load Transfer On 8) Trip Blocked	1) Trip zone ZA 2) Trip zone ZB 3) Open CT zone ZA 4) Open CT zone ZB 5) Load Transfer On 6) Trip Blocked for zone ZA 7) Trip Blocked for zone ZB

A new event is generated at a change of any of the above signals.

The internal clock is used for time tagging of events in the internal event list. It can be synchronized, (see paragraph 4.4), to achieve higher time tagging correlation accuracy between terminals. Without synchronization, the internal clock is only useful for comparisons among events within the terminal.

11 Remote communication (RC)

11.1 General

The remote communication can be used to obtain faster access to the information stored in the terminals and to send information to the terminal.

The remote communication can be used with computerized substation control system (SCS). LON communication is used for SCS

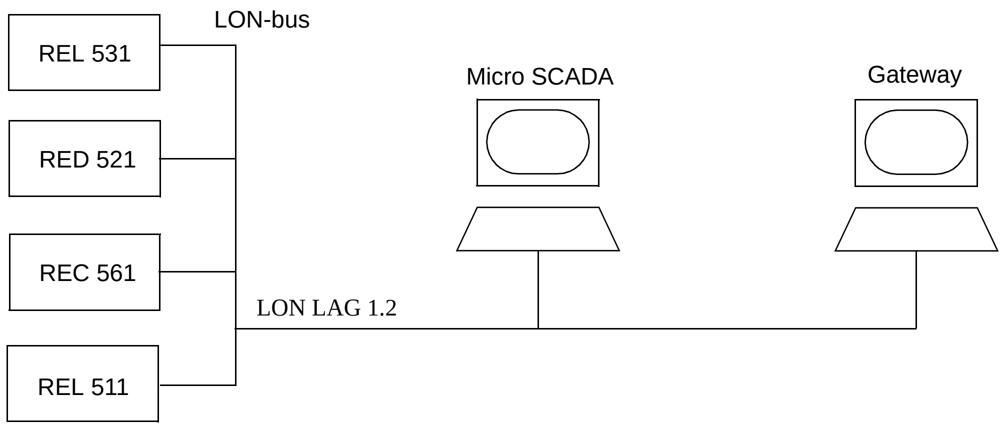

Fig. 24 Example of LON communication structure for SCS

11.2 Functionality

The remote communication use optical fibers for transfer of data within a station.

Remote communication to and from the terminal uses the LON LAG 1.2 protocol.

The LON protocol is specified in the *LON Protocol Specification*. This protocol is designed for communication in control networks and is a peer-to-peer protocol where all the devices connected to the network can communicate with each other directly.

11.3 Settings

The parameters for the LON communication are set with a special tool called LNT, LON Network Tool.

11.4 Configuration

The configuration of the LON communication port within the RED 521 terminal are entered from the HMI menu branch:

Configuration
LON Com

The following is possible to do/see under this HMI menu branch:

- Node Information
- Send Service PinMessage
- Set LON Default values
- Set Session Timers

The chapter “Requirements”

This chapter deals with the requirements for external equipment and functionality that RED 521 demands in order to work as intended.

12 CT requirements

The performance of the RED 521 terminal will depend on the conditions and the quality of the current signals fed to it. The output signal from a CT can be distorted by saturation. However, within the general differential protection function algorithm, special measures are taken to allow a heavy CT saturation with maintained correct operation.

For busbar protection applications it is necessary that the CT requirements are specified in such a way that:

- the protection is absolutely stable for all external faults
- the CT produces a minimum output signal to guarantee operations for all internal faults within the specified sensitivity

The first requirement is always the most demanding for RED 521. To guarantee the stability, the CTs must be able to correctly reproduce the current for a minimum time before the CT will begin to saturate. To fulfil the requirement on a specified time to saturation the CTs must fulfil the requirements of a minimum secondary e.m.f. that is specified below.

There are several different ways to specify CTs. Conventional magnetic core CTs are usually specified and manufactured according to some international or national standards, which specify different protection classes as well. However, generally there are three different groups of current transformers:

- high remanence type CT
- low remanence type CT
- non remanence type CT

The high remanence type CT has no limit for remanent flux. This CT has a magnetic core without any airgap and a remanent flux might remain for almost infinite time. In this type of CTs the remanence flux can be up to 70-80% of the saturation flux. Typical examples for high remanence type CT are class P, TPS, TPX according to IEC, class P, X according to BS and nongapped class C, K according to ANSI/IEEE.

The low remanence type CT has a specified limit for remanent flux. This CT is made with a small airgap to reduce the remanent flux not to exceed 10% of the saturation flux. This small airgap has only very limited influence on the other properties of the CT. Class TPY according to IEC is a low remanence type CT.

The non remanence type CT has practically negligible level of remanent flux. This type of CT has relatively big airgaps in order to reduce the remanent flux to practically zero level. In the same time, these airgaps minimize the influence of the DC-component from the primary fault current. The airgaps will also reduce the measuring accuracy in the non-saturated region of operation. Class TPZ according to IEC is a non remanence type CT.

The rated equivalent limiting secondary e.m.f. E_{al} according to the IEC 60044-6 standard is used to specify the CT requirements for RED 521. The CT can be of high remanence or low remanence type and they can be used together within one zone of protection. Each of them must have an E_{al} that is larger than or equal to the required secondary e.m.f. E_{alreq}. Therefore:

The high remanence CT must fulfil the following requirement:

$$E_{al} \geq E_{alreq} = 0.5 \cdot I_{f\max} \cdot \frac{I_{sn}}{I_{pn}} \cdot (R_{ct} + 2 \cdot R_l + Z_b)$$

The low remanence CT must fulfil the following requirement:

$$E_{al} \geq E_{alreq} = 0.2 \cdot I_{f\max} \cdot \frac{I_{sn}}{I_{pn}} \cdot (R_{ct} + 2 \cdot R_l + Z_b)$$

where

I_{fmax} = The symmetrical RMS value of the maximum primary fault current

on the busbar

I_{sn} = The rated secondary CT current

I_{pn} = The rated primary CT current

R_{ct} = The secondary resistance of the CT

R_l = The resistance of a single secondary wire from the CT to the relay

Z_b = The burden of all relays connected to the CT

The non remanence CT

All CTs within the differential zone must be of the non remanence type, (i.e. TPZ), and they must fulfil the same requirement as for the low remanence CTs.

$$E_{al} \geq E_{alreq} = 0.2 \cdot I_{f\max} \cdot \frac{I_{sn}}{I_{pn}} \cdot (R_{ct} + 2 \cdot R_l + Z_b)$$

12.1 Guidelines for CTs specified according to other standards

All kinds of conventional magnetic core CTs are possible to be used with RED 521 terminal if they fulfill the requirements that correspond to the above specified according to the IEC standard. From the different standards and available data for relaying applications it is possible to approximately calculate a secondary e.m.f. of the CT. It is then possible to compare this to the rated equivalent limiting secondary e.m.f. E_{al} and judge if the CT fulfils the requirements.

A CT according to the British Standard (i.e. BS) will often be specified by the rated knee-point e.m.f. E_{kneeBS}. The value of the E_{kneeBS} is lower than E_{al} according to IEC. So, the CT will fulfil the requirements with an extra margin if the E_{kneeBS} satisfy the E_{al} requirements for the high remanence CT type specified above. It is not possible to give a general relation between the E_{kneeBS} and the E_{al} but normally the E_{kneeBS} is 80 to 85 % of the E_{al} value.

Therefore, the rated equivalent limiting secondary e.m.f. E_{alBS} for a CT specified according to the British Standard can approximately be estimated as follows:

$$E_{alBS} \approx 1.2 \cdot E_{kneeBS}$$

As a conclusion a CT according to the British Standard standard will fulfil the requirements if:

$$E_{alBS} \approx 1.2 \cdot E_{kneeBS} \geq E_{alreq} = 0.5 \cdot I_{f\max} \cdot \frac{I_{sn}}{I_{pn}} \cdot (R_{ct} + 2 \cdot R_l + Z_b)$$

A CT manufactured according to ANSI/IEEE is specified in a little different way, but also in this case it is possible to make an approximate comparison. For example a CT of class C has a specified secondary terminal voltage U_{ANSI}. There is a few standardized value of U_{ANSI} (e.g. for a C400 the U_{ANSI} = 400 V). The rated equivalent limiting secondary e.m.f. E_{alANSI} for a CT specified according to ANSI/IEEE can approximately be estimated as follows:

$$E_{alANSI} = |20 \cdot I_{sn} \cdot R_{ct} + U_{ANSI}| = |20 \cdot I_{sn} \cdot R_{ct} + 20 \cdot I_{sn} \cdot Z_{bANSI}|$$

where

Z_{bANSI} = The impedance (i.e. complex quantity) of the standard ANSI burden for the specific C class

U_{ANSI} = The secondary terminal voltage for the specific C class

Therefore, the CT requirements are fulfilled if:

$$E_{alANSI} \geq E_{alreq} = 0.5 \cdot I_{f\max} \cdot \frac{I_{sn}}{I_{pn}} \cdot (R_{ct} + 2 \cdot R_l + Z_b)$$

Often an ANSI/IEEE CT also has a specified knee-point voltage $U_{kneeANSI}$. This is graphically defined from the excitation curve. The knee-point according to ANSI/IEEE has normally a lower value than the knee-point according to the British Standard. In this case it is a reasonable estimation that the CT will fulfil the requirements if:

$$E_{alANSI} \approx 1.3 \cdot U_{kneeANSI} \geq E_{alreq} = 0.5 \cdot I_{f\max} \cdot \frac{I_{sn}}{I_{pn}} \cdot (R_{ct} + 2 \cdot R_l + Z_b)$$

RED 521 has very low CT requirements, therefore other protection relays may be connected to the same CT core. This feature saves cores and cabling cost for the power utility.

13 Time synchronization

The real time clock in the RED 521 terminal can be synchronized in two different ways:

- via the LON communication link normally from SCS
- via minute pulses to a dedicated, factory pre-configured binary input called “Time Synch”

Since the synchronization via the serial buses is part of SCS and is harmonized with the terminal, the requirements on this synchronization are not dealt with here.

The requirements on the minute pulses are:

- correct voltage according to the rating of the binary input
- the pulse must have a duration of minimum 5 ms and maximum 100 ms
- rise time maximum 1ms
- absolute bounce free pulse

The chapter “Configuration and Settings”

This chapter describes how the terminal can be configured and set.

Introduction

RED 521 terminal is delivered pre-configured from the factory and it does not require any configuration of the binary inputs and outputs at site. Only the configuration of the terminal rated frequency and analogue CT inputs can be made locally, by means of the built-in human-machine interface (HMI).

The parameter settings for the general differential function can be made locally, by means of the built-in human-machine interface (HMI).

The HV/Control software module, included in the MicroSCADA library LIB 520, is intended to be used for accepting the internal events from RED 521 and issuing required commands to the terminal.

Configuration & Settings

14 HV/RED 521

14.1 Product overview

HV/RED 521 is a software module intended for event handling and for issuing of commands to the corresponding RED 521 terminal.

The HV/RED 521 software module is included in the LIB 520 high-voltage process package, which is a part of the Application Software Library within MicroSCADA applications. The HV/RED 521 software consists of three functional parts:

- Read terminal information
- Issue commands to the terminal
- Handling of spontaneous events from the terminal internal event list

The following commands can be issued to RED 521 terminal via the LON bus:

Table 18: Commands to RED 521 terminal via LON bus

Three Phase Version of the Terminal	One Phase Version of the Terminal
1) Reset Trip Indication 2) Reset Open CT condition	1) Reset Trip Indication 2) Reset Open CT condition in zone ZA 3) Reset Open CT condition in zone ZB

The change of any of the following terminal internal binary signals will cause a LON event:

Table 19: Signals logged in the internal event list & send via LON bus

Three Phase Version of the Terminal	One Phase Version of the Terminal
1) Trip Phase L1 2) Trip Phase L2 3) Trip Phase L3 4) Open CT Phase L1 5) Open CT Phase L2 6) Open CT Phase L3 7) Load Transfer On 8) Trip Blocked	1) Trip zone ZA 2) Trip zone ZB 3) Open CT zone ZA 4) Open CT zone ZB 5) Load Transfer On 6) Trip Blocked for zone ZA 7) Trip Blocked for zone ZB

14.2 Operating environment

The software runs on a PC system using operating system Windows/NT 4.0. To run the HV/RED 521 software, also the MicroSCADA packages MicroSYS rev. 8.4.3, Micro-TOOL rev. 8.4.3, LIB 500 rev. 4.0.3 and LIB 510 rev. 4.0.3 (SPA-TOOL) or later must be available.

14.3 HV/RED 521 software module documentation

The HV/RED 521 user's manual mainly consists of the following parts:

Table 20:

Item:	Description:
Instructions	Installation instruction.
Technical description	Describes the general functionality and graphical representation for these functions: • Data groups • Password handling • Event tool
Appendix	Includes a complete file listing, list of process objects and updated files.

See also "Reference publications" on page 89.

15 Human machine interface (HMI)

15.1 General

The built-in human machine interface (HMI) provides local communication between the user and the terminal.

The built-in HMI module is located on the front of the terminal and consists of three LEDs, an LCD display with four lines, each containing 16 characters, six buttons and an optical connector for PC communication.

15.2 Functionality of HMI LED’s

The three HMI LED’s have the following functionality:

Table 21: Functionality of HMI LED’s

	Steady Light	**Flashing Light**
Green LED	Terminal Ready	Terminal NOT Ready
Yellow LED	Open CT Condition Detected	Not used for RED 521
Red LED	TRIP	Not used for RED 521

15.3 HMI Menu Functionality

These main menus for status reading and parameter setting are available:

- **EventList**, gives the information about the last 16 internal events recorded by the terminal.
- **ServiceReport**, displays information about the operating conditions and information available from the terminal.
- **Settings**, is used to set the parameters for the differential function and terminal internal time.
- **Configuration**, is used to tailor the configuration of the terminal regarding e.g. CT inputs, zone selection, rated frequency, time synchronization and LON communication.
- **TerminalReport**, displays self supervision information and terminal identification data.

For more details, see Operators Manual.

16 Configuration of rated frequency for the terminal

The RED 521 terminal is applicable for protection of medium voltage (MV), high voltage (HV) and extra high voltage (EHV) installations at a power system frequency of 50Hz or 60Hz. The rated frequency for the terminal (i.e. 50Hz or 60Hz) can be selected from the built-in HMI.

The value for the rated frequency is set from the HMI menu branch:

Configuration
Frequency

The following parameter shall be set:

Table 22: Rated Frequency Configuration

Parameter Description	Parameter name	Range	Default
Terminal rated frequency	fr	50Hz, 60Hz	50Hz

Note: The RED 521 terminal will automatically restart when the rated frequency for the terminal is changed.

17 Configuration of Current Transformer data

Because all protection algorithms in RED 521 do all calculations in primary system quantities, it is extremely important to properly configure the data about connected current transformers. These data are normally set by the commissioning engineer from the built-in HMI.

The secondary rated current of the CT (i.e. 1A or 5A) is selected by tap connection of wires from the main CT. Each current input into RED 521 terminal has three terminals 1A, 5A and common. See Fig. 25.

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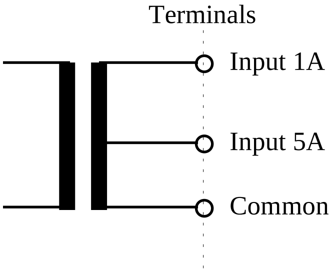


Fig. 25 CT Connections for one current input into RED 521

The primary CT data are entered from the HMI menu branch:

Configuration
AnalogInput

The following parameter shall be set for every current transformer connected to RED 521 terminal:

Table 23: CT Configuration

Parameter Description	Parameter name	Range	Default
Rated CT primary current in A	CT Prim Input x	from -10000 to +10000	0

This parameter defines the primary rated current of the CT. For two set of CTs with ratio 1000/1 and 1000/5 this parameter is set to the same value of 1000 for both CT inputs. Negative values (i.e. -1000) can be used in order to reverse the direction of the CT current by software for the differential function. This might be necessary if two sets of CTs have different location of the star point with respect to the protected bus-bar. It is recommended to set this parameter to zero, for all unused CT inputs.

Typical example of CT configuration is shown in the following figure:

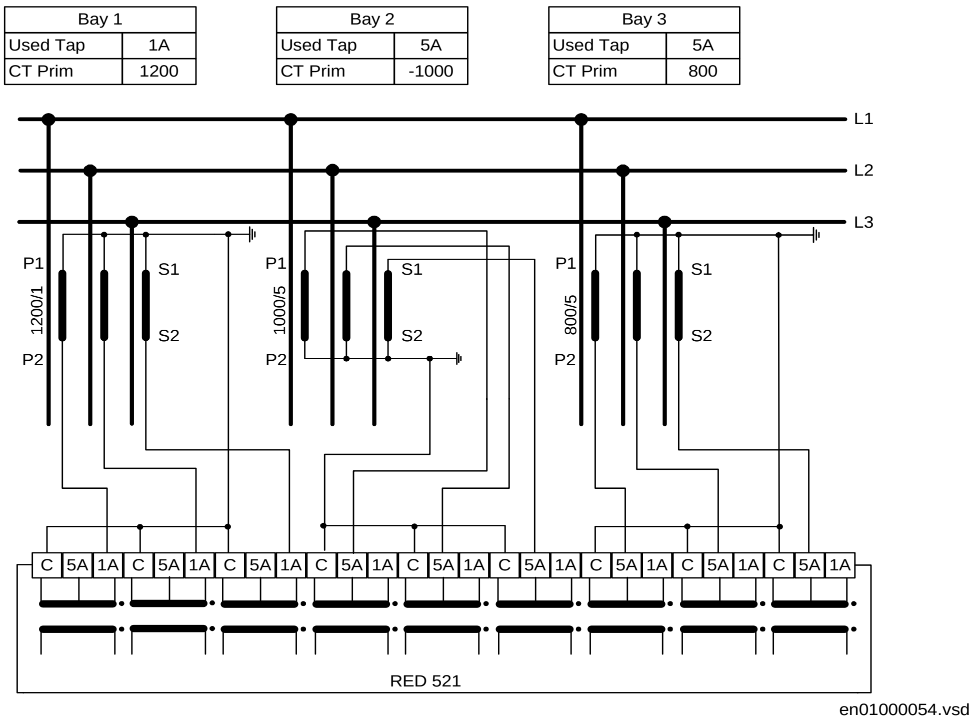


Fig. 26 Example of CT configuration setup for 3-phase version of RED 521 terminal

For main CTs with 2A rated secondary current, it is recommended to connect the secondary wiring to the 1A input and to set the rated primary current to the one half of its true value. For example CT with ratio of 1000/2A can be treated as 500/1A CT.

18 Zone Selection

In order to have properly balanced differential function(s) for all possible type of busbar disconnector switching arrangements, it is extremely important to properly configure the zone selection data for every connected current transformer. These data are prepared by the protection scheme designer and normally set by the commissioning engineer from the built-in HMI.

The zone selection data are entered from the HMI menu branch:

Configuration
    ZoneSelection

The following parameter shall be set for every current transformer connected to RED 521 terminal:

Table 24: Zone Selection Configuration

Parameter Description	Parameter name	Range	Default
Allows differential zones accommodation for different types of busbar arrangements	CT x	Contact Ctrl, Fixed to ZA, Fixed to ZB*	Contact Ctrl

* *only available in one-phase version of the RED 521 terminal*

Due to this configuration parameter, the RED 521 terminal allows an extremely effective application for stations where the zone selection (i.e. CT switching) is required. This is possible due to the software facility to have full and easy control over all CT inputs connected to the terminal. The philosophy is to allow every CT input to be individually controlled by a configuration parameter. This parameter called “ZoneSelection/CTx” can be individually configured for every CT input. The parameter can be set to only one of the following three alternatives:

1. Contact Ctrl
2. Fixed to ZA
3. Fixed to ZB (applicable for one phase version only)

If for a particular CT input (i.e. input CTx) setting “Contact Ctrl” is selected, then the CTx input will be only included to the differential zone ZA when a dedicated binary input called “Include CTx ZA” is energized. In the similar way the CTx input will only be included to the differential zone ZB when a dedicated binary input called “Include CTx ZB” is energized. This means that the current connected to the CTx input can be dynamically included/excluded from the differential zones by simply energizing/de-energizing the dedicated binary inputs of the RED terminal.

PLEASE NOTE that the second zone (i.e. ZB) is only available in one-phase version of the RED terminal. See “RED 521 Terminal Diagrams and Descriptions” on page 79. for more details about allocation and terminal numbers for these binary inputs.

If for a particular CT input (i.e. CTx) setting “Fixed to ZA” is selected, then this CT input is always included in the differential zone ZA irrespective of any other condition or status of any other binary input of the RED terminal. This means that the CT current connected to the CTx input will always be included in the differential zone ZA.

If for a particular CT input (i.e. CTx) setting “Fixed to ZB” is selected (**NOTE** that this selection is available only in one-phase terminal), then the CTx input is always included in the differential zone ZB irrespective of any other condition or status of any other binary input of the RED terminal. This means that the CT current connected to the CTx input will be always included in the differential zone ZB.

In applications where zone selection (i.e. CT switching) is required (for example double or multiple busbar stations) all CTs will be permanently connected to analog input module of the RED 521 terminal, as shown in Fig. 5. However, for every feeder bay setting “Contact Ctrl” shall be selected. At the same time the position of the busbar disconnectors must be mirrored by busbar disconnector replica relays, which are usually located within the busbar protection scheme. Each feeder current will be connected to the correct zone when the signal from the busbar disconnector replica relays is connected to the respective binary inputs on the RED 521 terminal for each individual bay.

See paragraph “Busbar Disconnector Replica” on page 22 for more details.

19 Differential Function Settings

Because the algorithms in RED 521 do all calculations in primary system quantities, the settings for the general differential function are done in primary amperes. These data are calculated by the system engineer and normally set by the commissioning engineer from the built-in HMI.

The settings for the differential function are entered from the HMI menu branch:

Settings
GeneralDiff

The following two parameters shall be entered in primary amperes for the general differential function in RED 521:

Table 25: Differential Function Settings

Parameter Description	Parameter name	Range	Default
Minimum operating level for the differential function	Diff Oper Level	1 - 10000A	1000
Minimum through-load current drop for open CT detection	Open CT Level	1 - 5000A	200

The parameter “Diff Oper Level” defines the minimum operating level for the differential function in primary amperes. Typically, for busbar protection applications, this parameter is set between 50% and 100% of the rated primary current of the biggest CT in the station. Nevertheless for other types of applications, for example generator differential, this value can be set more sensitive, down to 5% of the rated primary current of the main CT.

The parameter “Open CT Level” defines the minimum required through-load current drop which might be recognized by the “Open CT Algorithm” as open CT condition. It can usually be set to detect the open circuit condition for the smallest CT. Typically, this parameter is set between 20% and 80% of the rated primary current of the smallest CT connected to the differential zone.

It shall be noted that only one setting group is available for the RED 521 terminal. For the one phase version of RED 521 terminal, the same setting values for the “Diff Oper Level” and “Open CT Level” parameters are applicable to both differential zones, which are available within the terminal.

The overall tripping criteria for the differential function within RED 521 terminal can be represented with the operating characteristic, as shown in Fig. 27.

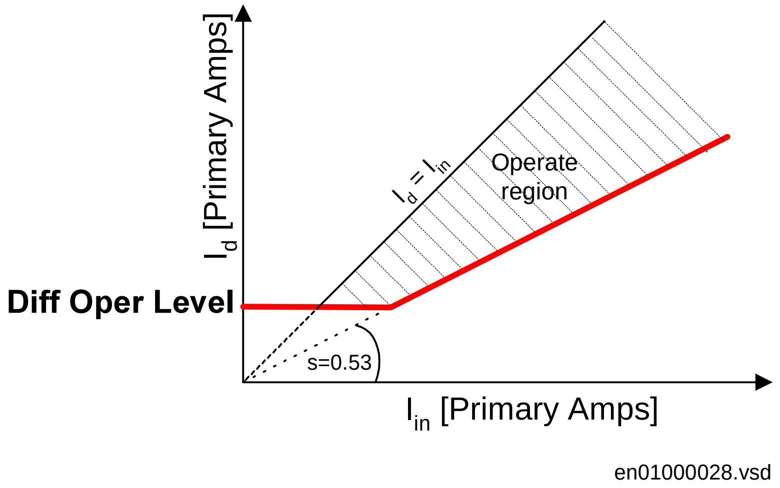


Fig. 27 Overall operating characteristic for the differential function in RED 521

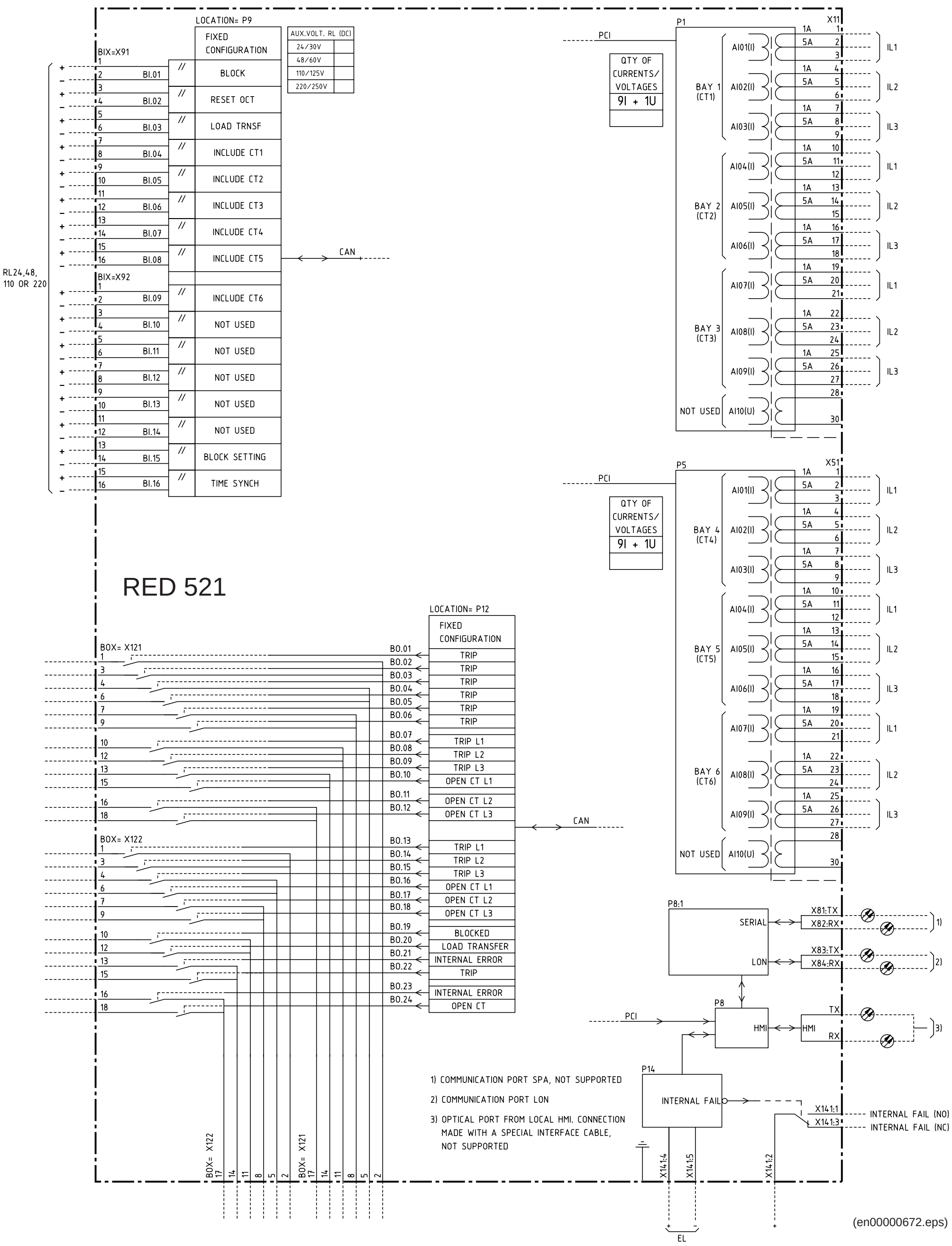
Please note the following:

- on the above figure I_{in} represents the total incoming current to the differential protection zone
- the operating slope for the differential function is fixed to 0.53 in the algorithm and can not be changed by the user

20 RED 521 Terminal Diagrams and Descriptions

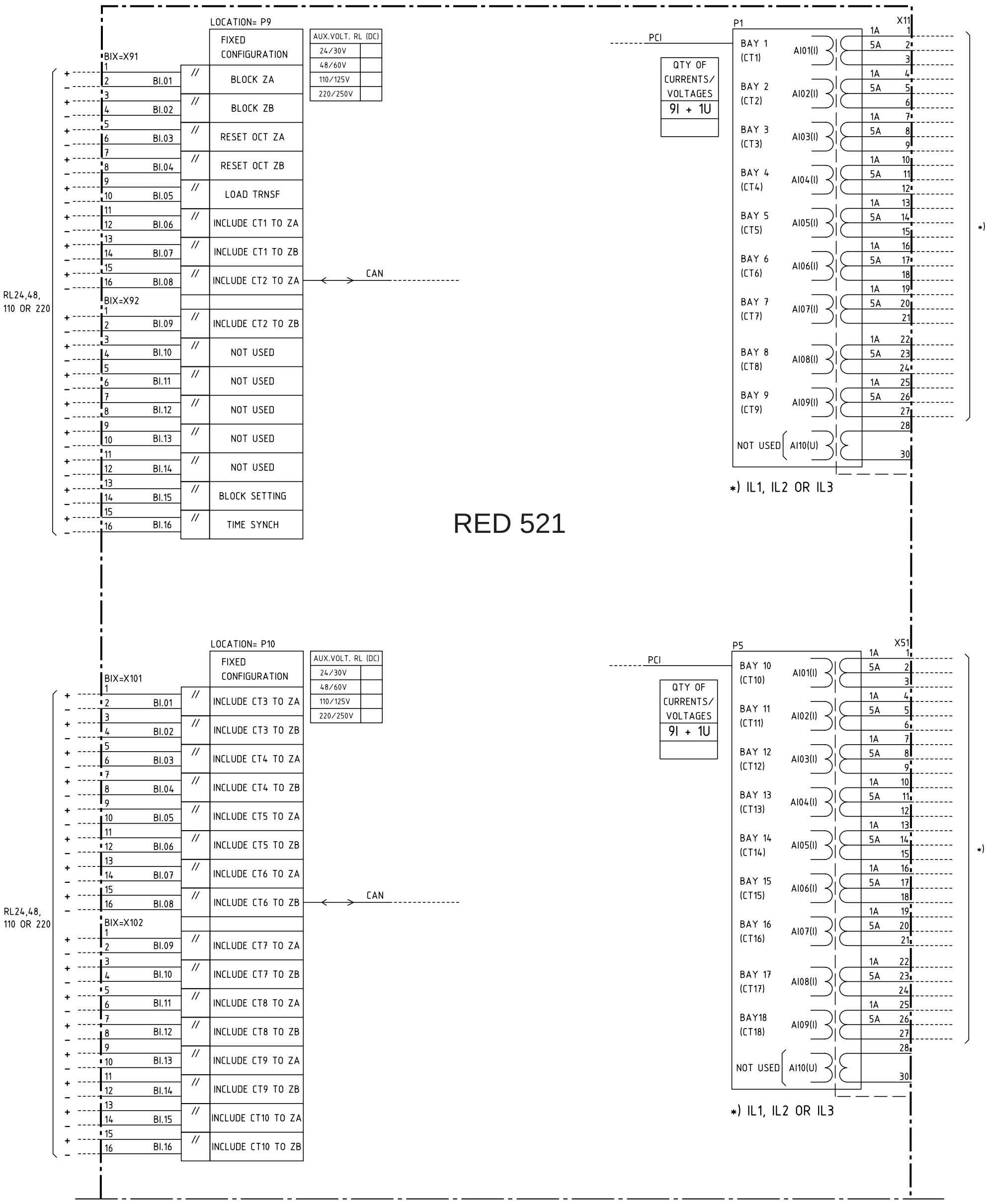
20.1 Terminal Diagrams

Three Phase Terminal



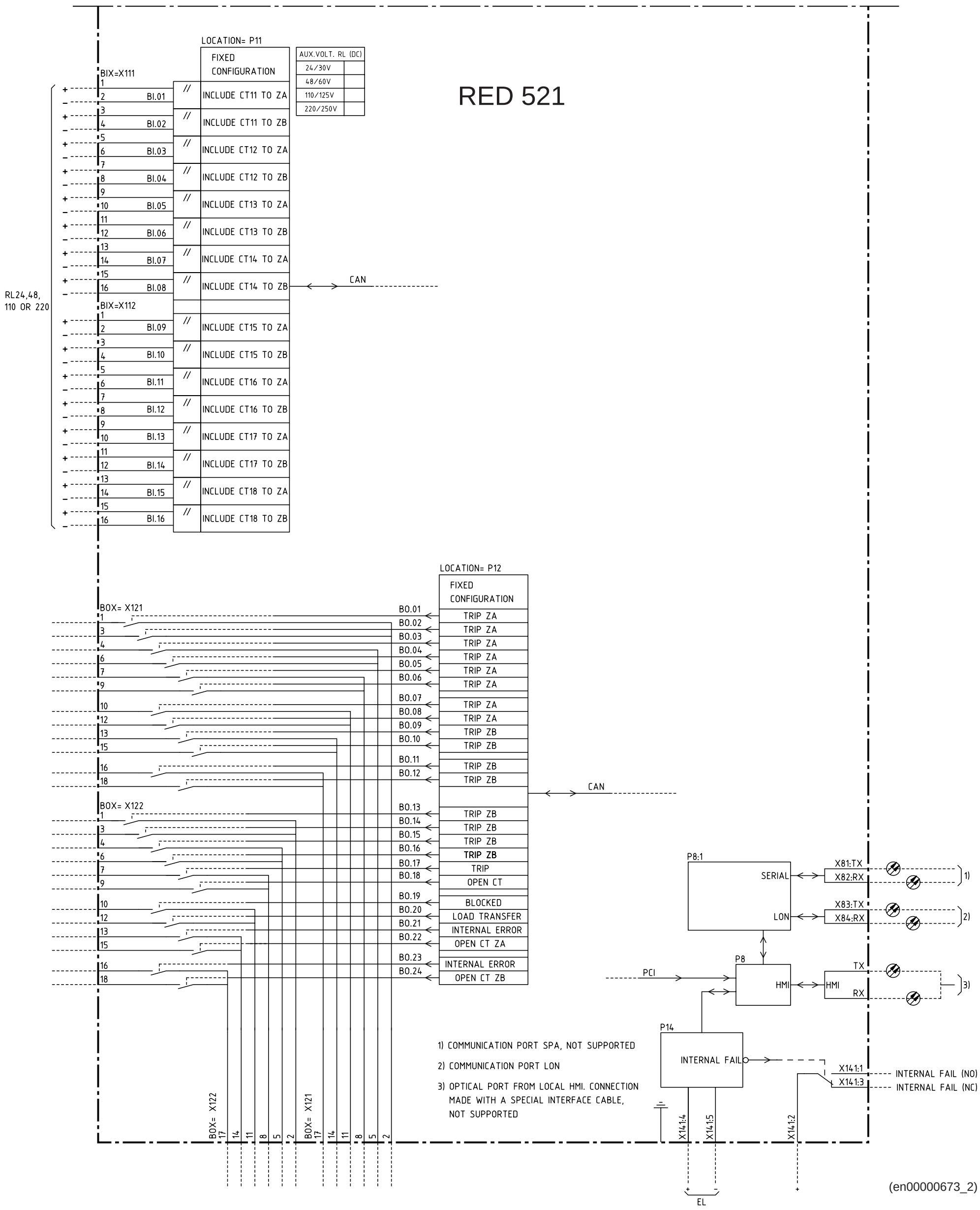
(en00000672.eps)

One Phase Terminal



(en00000673_1)

Please note that the terminal diagram is continuing on the following page.



(en00000673_2)

20.2 Description of Terminal Binary Inputs

Three Phase Terminal

Table 26: Description of Binary Inputs in 3-phase-version of the terminal

Binary Input Location	Name of Binary Input	Action taken when Binary Input is energized
P9 / BI.01	Block	Block TRIP outputs from RED 521 terminal
P9 / BI.02	Reset OCT	Reset of Open CT block condition and its indications
P9 / BI.03	Load Trnsf	Start “Load Transfer” software feature within RED 521 terminal
P9 / BI.04	Include CT1	Include CT1 currents into differential zone if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.05	Include CT2	Include CT2 currents into differential zone if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.06	Include CT3	Include CT3 currents into differential zone if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.07	Include CT4	Include CT4 currents into differential zone if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.08	Include CT5	Include CT5 currents into differential zone if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.09	Include CT6	Include CT6 currents into differential zone if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.10	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.11	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.12	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.13	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.14	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.15	Block Setting	Block any setting and configuration changes from the built-in HMI
P9 / BI.16	Time Synch	Minute pulse for time synchronization

One Phase Terminal

Table 27: Description of Binary Inputs in 1-phase-version of the terminal (1st BIM module)

Binary Input Location	Name of Binary Input	Action taken when Binary Input is energized
P9 / BI.01	Block ZA	Block TRIP outputs for zone ZA from RED 521 terminal
P9 / BI.02	Block ZB	Block TRIP outputs for zone ZB from RED 521 terminal
P9 / BI.03	Reset OCT ZA	Reset of Open CT block condition and its indications for zone ZA
P9 / BI.04	Reset OCT ZB	Reset of Open CT block condition and its indications for zone ZB
P9 / BI.05	Load Trnsf	Start “Load Transfer” software feature within RED 521 terminal
P9 / BI.06	Include CT1 to ZA	Include CT1 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.07	Include CT1 to ZB	Include CT1 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.08	Include CT2 to ZA	Include CT2 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.09	Include CT2 to ZB	Include CT2 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P9 / BI.10	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.11	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.12	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.13	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.14	NOT USED	This binary input is not used in RED 521 terminal
P9 / BI.15	Block Setting	Block any setting and configuration changes from the built-in HMI
P9 / BI.16	Time Synch	Minute pulse for time synchronization

Table 28: Description of Binary Inputs in 1-phase-version of the terminal (2nd BIM module)

Binary Input Location	**Name of Binary Input**	**Action taken when Binary Input is energized**
P10 / BI.01	Include CT3 to ZA	Include CT3 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.02	Include CT3 to ZB	Include CT3 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.03	Include CT4 to ZA	Include CT4 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.04	Include CT4 to ZB	Include CT4 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.05	Include CT5 to ZA	Include CT5 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.06	Include CT5 to ZB	Include CT5 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.07	Include CT6 to ZA	Include CT6 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.08	Include CT6 to ZB	Include CT6 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.09	Include CT7 to ZA	Include CT6 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.10	Include CT7 to ZB	Include CT7 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.11	Include CT8 to ZA	Include CT7 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.12	Include CT8 to ZB	Include CT8 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.13	Include CT9 to ZA	Include CT9 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”

Table 28: Description of Binary Inputs in 1-phase-version of the terminal (2nd BIM module)

Binary Input Location	Name of Binary Input	Action taken when Binary Input is energized
P10 / BI.14	Include CT9 to ZB	Include CT9 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.15	Include CT10 to ZA	Include CT10 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P10 / BI.16	Include CT10 to ZB	Include CT10 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”

Table 29: Description of Binary Inputs in 1-phase-version of the terminal (3rd BIM module)

Binary Input Location	Name of Binary Input	Action taken when Binary Input is energized
P11 / BI.01	Include CT11 to ZA	Include CT11 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.02	Include CT11 to ZB	Include CT11 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.03	Include CT12 to ZA	Include CT12 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.04	Include CT12 to ZB	Include CT12 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.05	Include CT13 to ZA	Include CT13 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.06	Include CT13 to ZB	Include CT13 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.07	Include CT14 to ZA	Include CT14 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.08	Include CT14 to ZB	Include CT14 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”

Table 29: Description of Binary Inputs in 1-phase-version of the terminal (3rd BIM module)

Binary Input Location	Name of Binary Input	Action taken when Binary Input is energized
P11 / BI.09	Include CT15 to ZA	Include CT15 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.10	Include CT15 to ZB	Include CT15 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.11	Include CT16 to ZA	Include CT16 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.12	Include CT16 to ZB	Include CT16 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.13	Include CT17 to ZA	Include CT17 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.14	Include CT17 to ZB	Include CT17 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.15	Include CT18 to ZA	Include CT18 current into differential zone ZA if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”
P11 / BI.16	Include CT18 to ZB	Include CT18 current into differential zone ZB if configuration parameter “Zone Selection” for this CT input is set to “Contact Ctrl”

20.3 Description of Terminal Binary Outputs

Three Phase Terminal

Table 30: Description of Binary Outputs in 3-phase-version of the terminal

Binary Output Location	Name of Binary Output	Description for Binary Outputs
P12 / BO.01	Trip	Terminal general TRIP signal (any phase)
P12 / BO.02	Trip	Terminal general TRIP signal (any phase)
P12 / BO.03	Trip	Terminal general TRIP signal (any phase)
P12 / BO.04	Trip	Terminal general TRIP signal (any phase)
P12 / BO.05	Trip	Terminal general TRIP signal (any phase)
P12 / BO.06	Trip	Terminal general TRIP signal (any phase)
P12 / BO.07	Trip L1	Differential function phase L1 TRIP signal
P12 / BO.08	Trip L2	Differential function phase L2 TRIP signal
P12 / BO.09	Trip L3	Differential function phase L3 TRIP signal
P12 / BO.10	Open CT L1	Open CT condition detected for phase L1
P12 / BO.11	Open CT L2	Open CT condition detected for phase L2
P12 / BO.12	Open CT L3	Open CT condition detected for phase L3
P12 / BO.13	Trip L1	Differential function phase L1 TRIP signal
P12 / BO.14	Trip L2	Differential function phase L2 TRIP signal
P12 / BO.15	Trip L3	Differential function phase L3 TRIP signal
P12 / BO.16	Open CT L1	Open CT condition detected for phase L1
P12 / BO.17	Open CT L2	Open CT condition detected for phase L2
P12 / BO.18	Open CT L3	Open CT condition detected for phase L3
P12 / BO.19	Blocked	Trip Outputs from the RED 521 terminal are blocked
P12 / BO.20	Load Transfer	Software feature “Load Transfer” within RED 521 terminal is active
P12 / BO.21	Internal Error	Error within RED 521 terminal is detected
P12 / BO.22	Trip	Terminal general TRIP signal (any phase)
P12 / BO.23	Internal Error	Error within RED 521 terminal is detected
P12 / BO.24	Open CT	Open CT condition detected (any phase)

One Phase Terminal

Table 31: Description of Binary Outputs in 1-phase-version of the terminal

Binary Output Location	Name of Binary Output	Description for Binary Outputs
P12 / BO.01	Trip ZA	TRIP signal for zone ZA
P12 / BO.02	Trip ZA	TRIP signal for zone ZA
P12 / BO.03	Trip ZA	TRIP signal for zone ZA
P12 / BO.04	Trip ZA	TRIP signal for zone ZA
P12 / BO.05	Trip ZA	TRIP signal for zone ZA
P12 / BO.06	Trip ZA	TRIP signal for zone ZA
P12 / BO.07	Trip ZA	TRIP signal for zone ZA
P12 / BO.08	Trip ZA	TRIP signal for zone ZA
P12 / BO.09	Trip ZB	TRIP signal for zone ZB
P12 / BO.10	Trip ZB	TRIP signal for zone ZB
P12 / BO.11	Trip ZB	TRIP signal for zone ZB
P12 / BO.12	Trip ZB	TRIP signal for zone ZB
P12 / BO.13	Trip ZB	TRIP signal for zone ZB
P12 / BO.14	Trip ZB	TRIP signal for zone ZB
P12 / BO.15	Trip ZB	TRIP signal for zone ZB
P12 / BO.16	Trip ZB	TRIP signal for zone ZB
P12 / BO.17	Trip	Terminal general TRIP signal (any zone)
P12 / BO.18	Open CT	Open CT condition detected (any zone)
P12 / BO.19	Blocked	Trip Outputs from the RED 521 terminal are blocked
P12 / BO.20	Load Transfer	Software feature “Load Transfer” within RED 521 terminal is active
P12 / BO.21	Internal Error	Error within RED 521 terminal is detected
P12 / BO.22	Open CT ZA	Open CT condition detected for zone ZA
P12 / BO.23	Internal Error	Error within RED 521 terminal is detected
P12 / BO.24	Open CT ZB	Open CT condition detected for zone ZB

Reference publications

User’s manual HV/REx 5xx*2.3, 1MRK 511 077-UEN

Technical Overview Brochure RED 521*1.0, 1MRK 505 031-BEN

LON LAG 1.2 protocol specification, EIA-709.1

LNT 505, LON Configuration Tool, 1MRS 151 400

SLDT, LON configuration module REx 500, 1MRK 001 700-A

The chapter “Installation”

This chapter describes how the general differential protection terminal RED 521 can be used and applied in a power network.

1 Introduction

The mechanical and electrical environmental conditions at the site must be within the permissible range according to the data sheets of the terminal. Dusty, damp places, places liable to rapid temperature variations, powerful vibrations and shocks, surge voltages of high amplitude and fast rise time, strong induced magnetic fields or similar extreme conditions should be avoided.

Sufficient space must be available in front of and at rear of the terminal to allow access for maintenance and future modifications.

2 Preparations

2.1 Receiving, unpacking and checking

1 **Remove the protection terminal from the transport case and perform a visual inspection of any possible transport damage.**

Check that all items are included in accordance with the delivery documents. In case of transport damage, appropriate action must be taken against the last carrier and the nearest ABB office or agent should be informed. ABB should be notified immediately if there are any discrepancies in relation to the delivery documents.

2 **Check that the terminal has the correct identity markings on the front.**

The check should confirm that the terminal type, markings and serial number corresponds to what ordered.

2.2 Storage

If the protection terminal is to be stored before installation, this must be done in a dry and dust-free place, preferably in the original transport case.

3 Mechanical installation

The RED 521 protection terminal has a hardware design described in the Technical Overview Brochure, Series RE 500 Mechanical design and mounting accessories, document number 1MRK 514 003-BEN.

It shall be noted that RED 521 terminal is always delivered in full 19” wide, 6U high case (i.e. 6U x 1/1).

Suitable mounting kits for 19" rack mounting, flush mounting, semi-flush mounting and wall mounting can be ordered. The mounting kits contain all parts needed for the mounting, including screws and assembly instructions.

3.1 19" rack installation

3.1.1 Single case installation

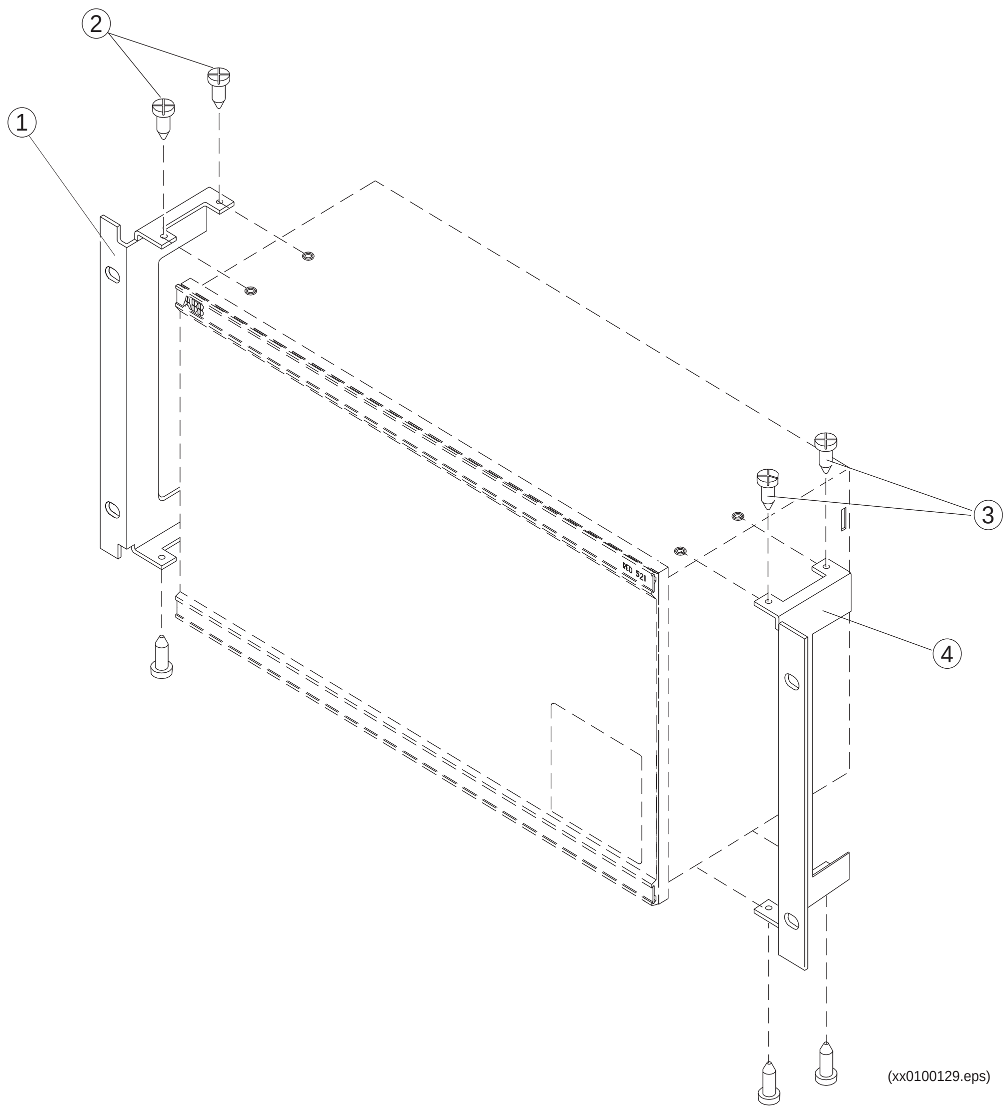


Fig. 1 RED 521 with side plate mounted in 19" rack

The mounting kit, article number 1MRK 000 020-CA for case size 6Ux1/1 consists of:

- two mounting angles for 6U, 19" rack, with four screws (TORX T20), pos (1) and (2)
- assembly instructions.

3.2 Flush mounting

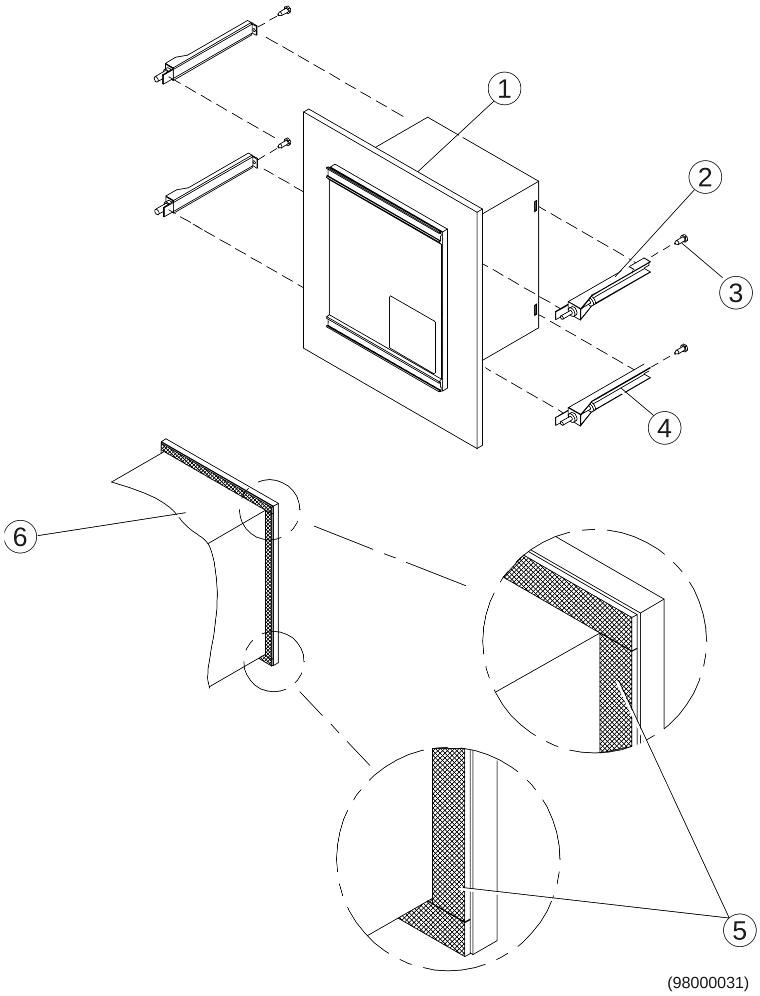


Fig. 2 Flush mounting of REx 5xx terminal

Mounting kit, article number 1MRK 000 020-Y, for flush-mounting of all sizes of case 6U consists of:

- four side holders and a sealing strip, pos (4) and (5)+
- four small (TORX T10), pos (3), and four big screws (TORX T25), not shown
- assembly instructions.

Additional sealing strip for IP54, article number 1MKC 980 001-2, can be ordered separately.

Also see “Case and cut-out dimensions” .

3.2.1 Mounting procedure

1 Cut and affix the sealing strip if IP 54 is required.

2 Put the protection terminal in the cut-out.

3 Fasten the side holders to the back of the protection terminal with the small screws.

4 Fix the protection terminal with the big screws.

3.3 Wall mounting

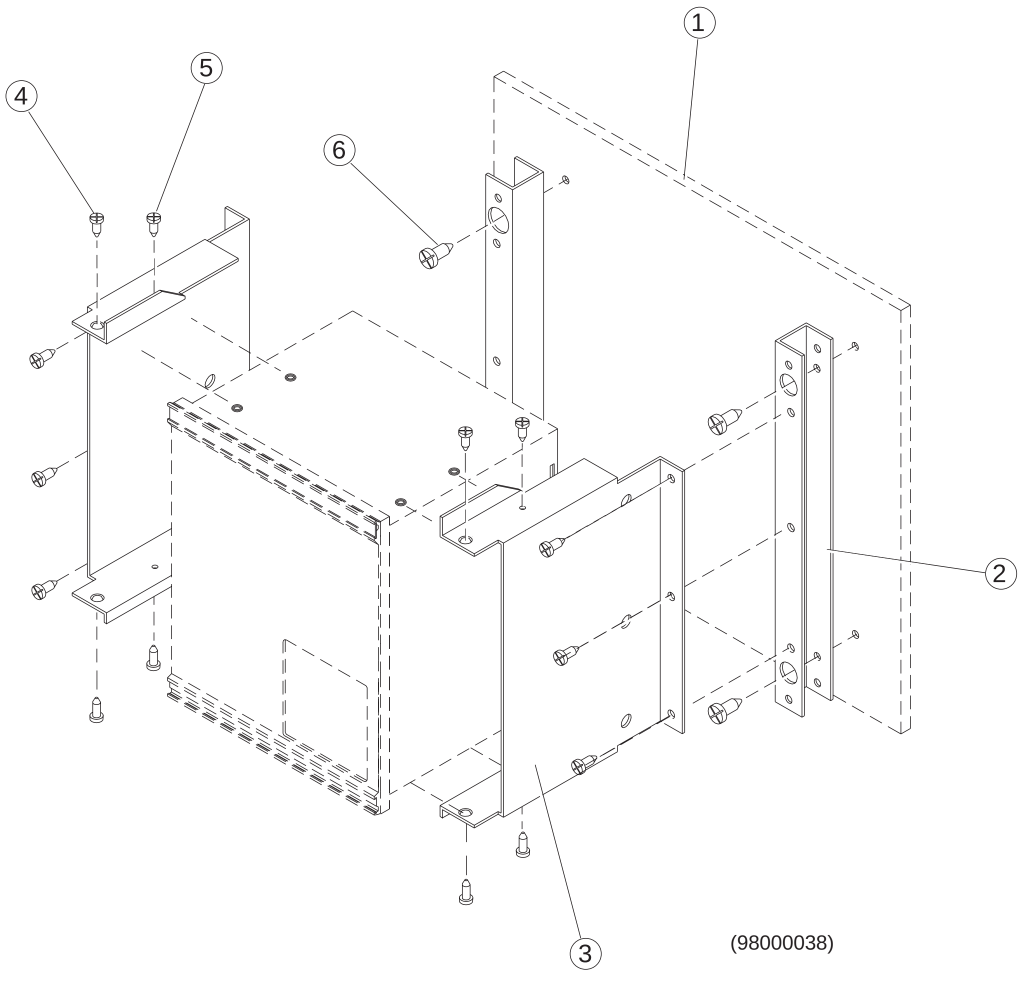
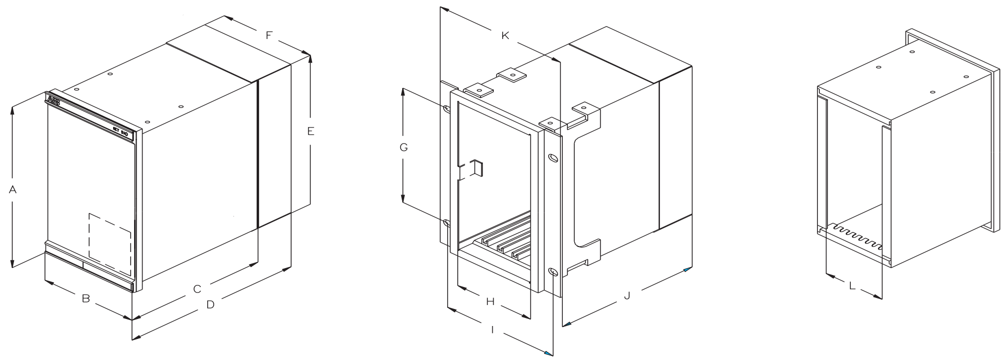


Fig. 3 Wall mounting of REx 5xx terminal

Mounting kit, article number 1MRK 000 020-DA, for wall mounting of all sizes of case 6U consists of:

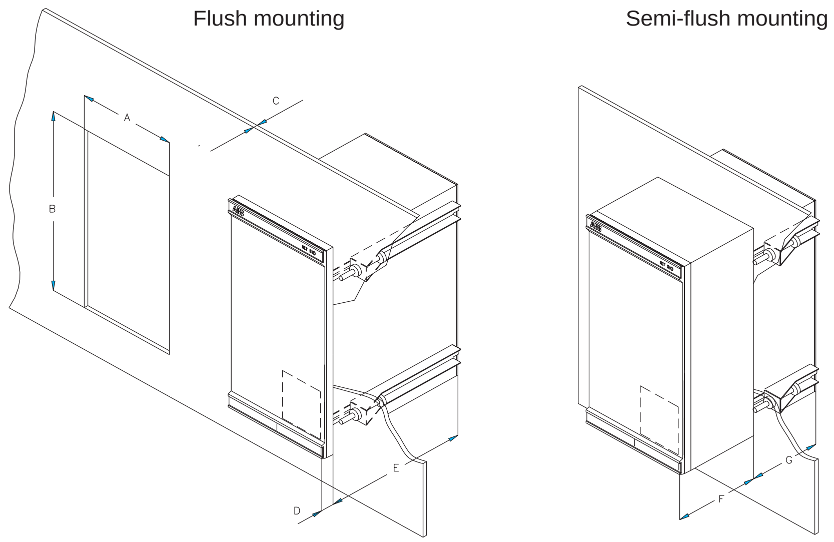
- two mounting angles (side plates), pos (3)
- screws (grip size TORX T20, T25 and T30), pos (4), (5) and (6)
- two mounting bars to be mounted on the wall, pos (2)
- assembly instructions.

3.4 Case and cut-out dimensions



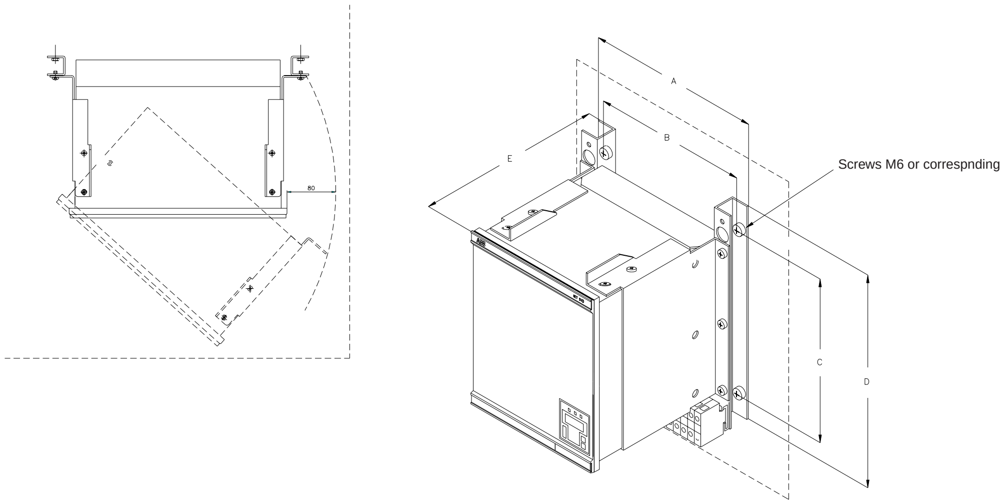
Case size	A	B	C	D	E	F	G	H	I	J	K	L
6U x 1/2		223,7				205,7		203,7	–		–	189,7
6U x 3/4	265,9	336	204,1	245,1	255,8	318	190,5	316	–	227,6	–	302
⇒ 6U x 1/1		448,3				430,3		426,3	465,1 *)		482,6	414,3

*) equal to 19" (mm)



Case size	Cut-out dimensions	
	A ±1	B ±1
6U x 1/2	210,1	
6U x 3/4	322,4	259,3
⇒ 6U x 1/1	434,7	

(mm)



(98000047)

	Case size	A	B	C	D	E
	6U x 1/2	292	267,1	272,8	390	247
	6U x 3/4	404,3	379,4			
⇒	6U x 1/1	516	491,1			

(mm)

4 Electrical installation

The wiring from the cubicle terminals to the terminals on the rear side of the unit must be made in accordance with the established guidelines for this type of equipment. The wires for binary inputs and outputs and the auxiliary supply should be laid separated from the current transformer cables between the cubicle terminals and the protection terminal.

The external connections to the terminals of RED 521 shall be made in accordance with the valid terminal diagram (section of the section five of RED 521 manual). The cables from the current transformers should be identified with regards to phases and connected to the proper terminals.

4.1 Connectors for CT circuits

Connectors X11 and X51 for current transformer circuits are so called “feed-through terminal blocks” and are designed for conductors with cross sectional area up to 4 mm^2.

4.2 Signal connectors

Signal wires are connected to female screw compression connector, which is then plugged into the corresponding circuit board male connectors, located at the rear of the unit.

At installation, all wiring to the female connector should be done before plugged into the male part and fixed to the case by screws. The conductors can be of rigid type (solid, stranded) or of flexible type

The female connectors can be used with conductors with a cross section area of 0.2-2.0 mm^2. If more than one conductor is used in the same screw terminal, the allowed cross section area is 0.2-1 mm^2.

If two conductors, each with area 1,5 mm^2 shall be applied to the same socket, a ferrule must be used. This ferrule, ABB article number 1MKC 840 003-4 or Phoenix type AI-TWIN 2. 1,5 - 8 BK, is applied with crimping pliers type ZA3 from Phoenix. No soldering is needed.

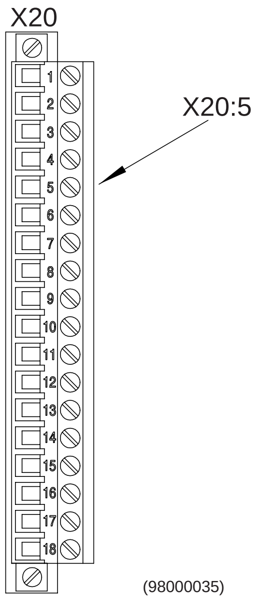


Fig. 4   Signal connector

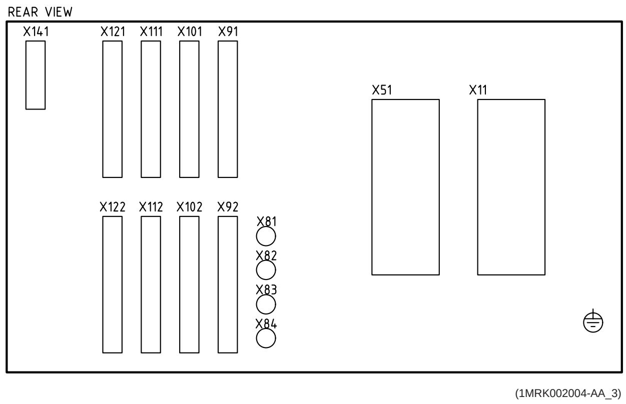


Fig. 5   Rear side of RED 521 with maximum number of connectors.

The number of connectors depends on the type of RED 521. Connectors which are not included are replaced with a blanking plate.

Table 1: Connectors and associated printed board assemblies for three-phase RED 521 terminal

Connector	Location of PBA	Type of PBA (printed board assembly)
X11	P1	Analogue input module 1 (CT1 to CT3)
X51	P5	Analogue input module 2 (CT4 to CT6) *
X81-X84	P8	Optical communication module
X91/X92	P9	Binary input module (general inputs and zone selection inputs for CT1 to CT6)
X101/X102	P10	Empty (Not Used)
X111/X112	P11	Empty (Not Used)
X121/X122	P12	Binary output module (trip outputs, open CT outputs etc.)
X141	P14	DC/DC converter module

* only supplied for 6-bay version

Table 2: Connectors and associated printed board assemblies for one-phase RED 521 terminal

Connector	Location of PBA	Type of PBA (printed board assembly)
X11	P1	Analogue input module 1 (CT1 to CT9)
X51	P5	Analogue input module 2 (CT10 to CT18) *
X81-X84	P8	Optical communication module
X91/X92	P9	Binary input module (general inputs and zone selection inputs for CT1 & CT2)
X101/X102	P10	Binary input module (zone selection inputs for CT3 to CT10)
X111/X112	P11	Binary input module * (zone selection inputs for CT11 to CT18)
X121/X122	P12	Binary output module (ZA & ZB trip outputs, open CT outputs etc.)
X141	P14	DC/DC converter module

* only supplied for 18-bay version

For more detailed information please see the terminal diagrams, section of the section five of RED 521 manual.

4.3 Safety and EMC earthing

To fulfill safety regulations and to get full EMC protection, a separate flexible earthing wire must be connected the shortest possible route from the earthing screw at the rear of the terminal case to the nearest earthing point in the cubicle. The cubicle must be properly connected to the station earthing system.

4.4 Protection terminals with COMBITEST test switch

When RED 521 terminal is ordered together with a COMBITEST test switch, the following type of test switch will be delivered (one per each analog input module):

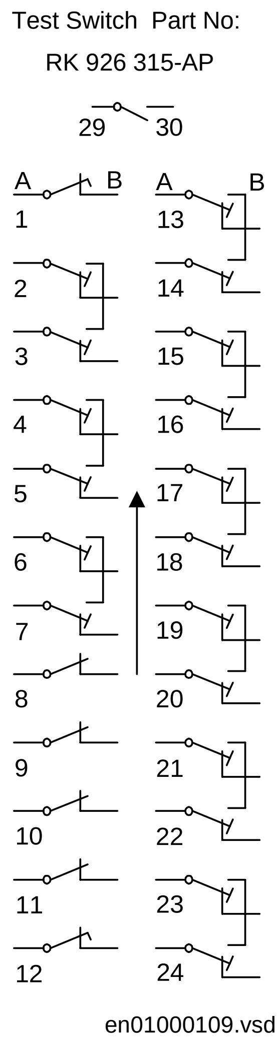


Fig. 6 Type of COMBITEST RTXP 24 test switch which is delivered together with RED 521 terminal

However it shall be noted that the test switches will be delivered as stand-alone items in separate RHGS 6 cases with window door.

COMBIFLEX wires are used to interconnect the test switch and the connection terminals on the rear side of the RED 521 terminal. The wires have 20 A sockets on the end which is connected to the test switch. See the COMBIFLEX Connection and installation components Buyer’s Guide (ABB Document No 1MRK 513 003-BEN).

With this type of test switch the typical connection of one CT input circuit (i.e. for example current input CT3) for one-phase version of the RED 521 terminal can be arranged as shown in Fig. 7:

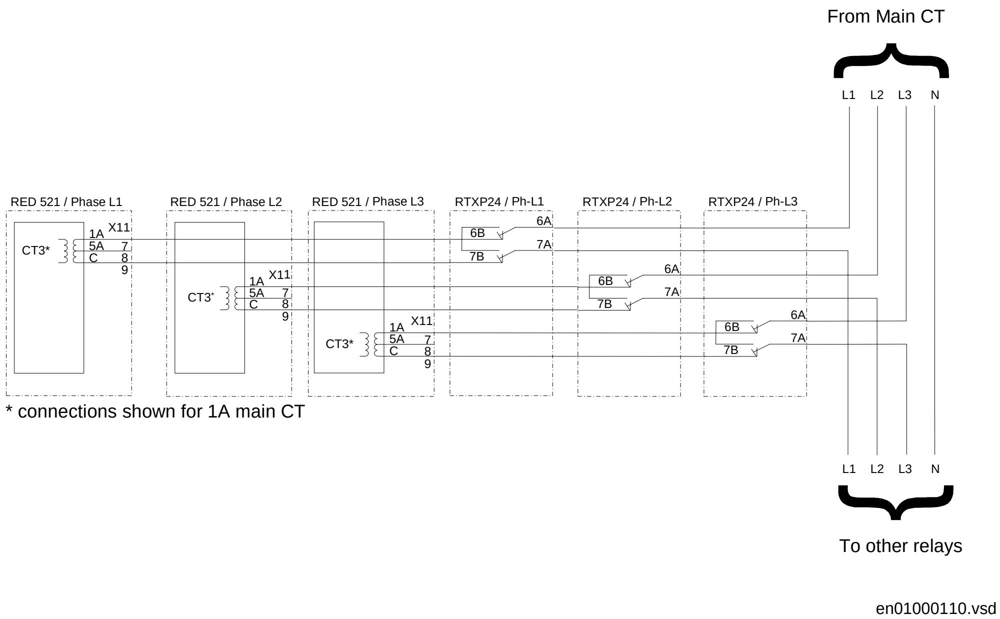


Fig. 7 Typical connection for CT3 input when COMBITEST RTXP 24 test switch is delivered together with one-phase RED 521 terminal

In the similar manner the three-phase version of the RED 521 terminal can be connected.

It should be noted that four test switch contacts are available to be used for tripping and signaling purposes. One possible solution how to arrange them for 9-bays, one-phase version of RED 521 terminal is shown in Fig. 8.

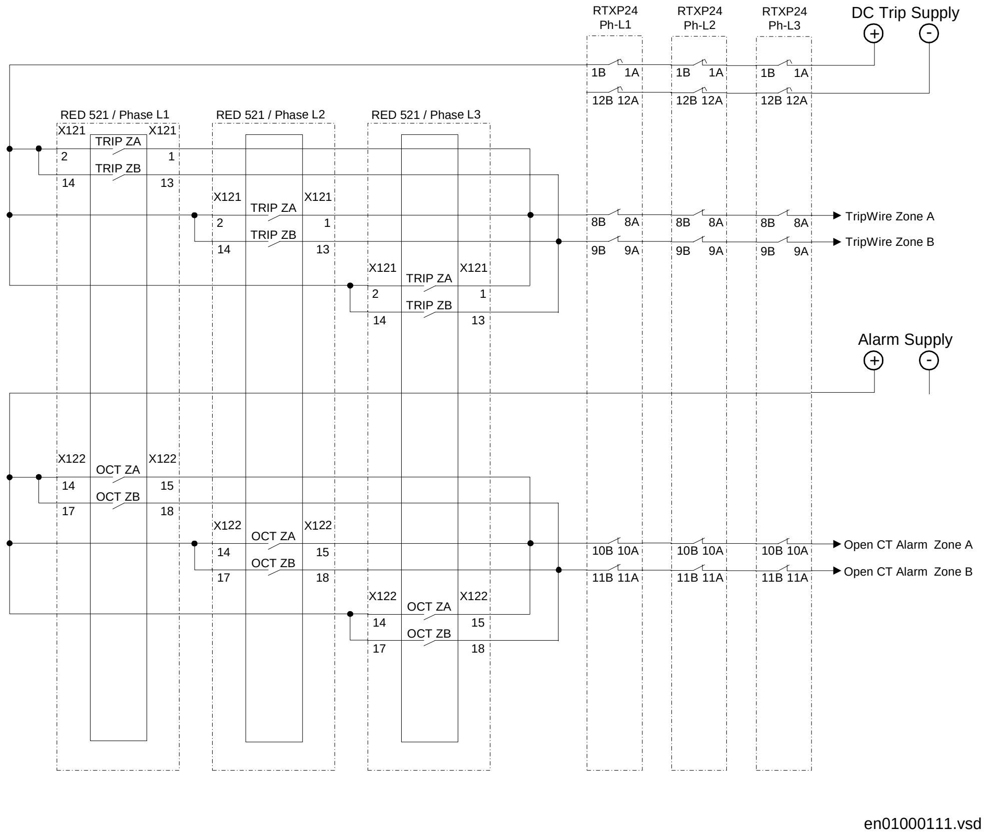


Fig. 8 Possible arrangement for tripping and alarm signals when COMBITEST RTXP 24 test switches are delivered together with 9-bays, one-phase version of RED 521 terminals

The DC trip supply can be used as auxiliary voltage for the supply to the internal RED 521 DC/DC converters.

5 Optical fiber installation

The terminal can, if ordered accordingly, be equipped with optical LON communication. In such case optical ports are provided on the rear side of the case for connection of the optical fibres. Optical ports X83 and X84 are used for the LON bus communication.

Either plastic or glass fibers can be used. Plastic fibers use a snap-in connector, glas fibers a bayonet connector. Connectors are color coded in order to avoid faulty connections. Blue or dark grey fiber connector always goes to blue or dark grey chassie connector, and is used for receiving data. Black or grey fiber connector always goes to black or grey chassie connector, and is used for transmitting data. Depending on the fiber type used, plastic or glass, the blue/black (plastic) or dark grey/grey (glass) connector colors are used.

Fiber optical cables are sensitive to handling. The most important to have in mind when handling optical fibers is that they must not be bent too sharply. The minimum curvature radius is:

- 15 cm for plastic fibres.
- 25 cm for glass fibres.

When connecting or disconnecting the optical fibres, be certain not to apply any force to the fiber itself. Always hold the contact in a firmly grip, without twisting, pulling or bending the optical fibre.

If the optical fiber is too long and cable straps have to be used, the cable strap must not be applied too hard. There should always be some space between the optical fiber and the cable strap.

The chapter “Commissioning“

This chapter instructs the user how to perform the commissioning work.The commissioning work includes general testing of associated equipment, entering the configuration and setting values into the terminal, secondary injection testing and primary injection test.

6 Introduction

A number of checks must be carried out before the protection terminal is taken into service.

Secondary testing of RED 521 is made to verify that the general differential protection function operates in accordance with the relay setting plan.

Checking of external circuits and associated equipment, such as CT’s, circuit-breakers and signalling equipment is part of the commissioning work.

The commissioning work must also be properly documented for future reference.

7 Preparations

Before the commissioning work is started up, check that all necessary test equipment and documentation are available at site. Necessary documentation for commissioning includes:

- operators manual for RED 521. See “Reference publications” on page 126.
- valid circuit diagrams.
- protection setting list and sheets for test protocols.

For secondary testing of RED 521, a test set with three-phase or single-phase current outputs and time measuring function should be available. The magnitude and phase angle of the output currents should be variable.

8 General testing

8.1 Check of CT circuits

The CTs must be connected in accordance with the circuit diagram provided with the terminal, both with regards to phases and polarity in order to achieve current balance during normal service. The following tests shall be done on every primary CT connected to the RED 521 terminal:

- primary injection test to verify the current ratio of the CT and the correct wiring up to the protection terminal
- polarity check to prove that the predicted direction of secondary current flow is correct for a given direction of primary current flow. This is essential test for proper operation of the differential function.
- CT secondary loop resistance measurement in order to confirm that the current transformer secondary loop dc resistance is within specification and that there are no high resistance joints in the CT winding or wiring.
- CT excitation test in order to confirm that the current transformer is of the correct accuracy rating and that there are no shorted turns in the current transformer windings. Manufacturer's design curves should be available for the current transformer in order to compare the actual results.

Note!

Both primary and secondary side must be disconnected from line and terminal when plotting the excitation characteristics.

- check the earthing of the individual CT secondary circuits to verify that each three-phase set of main CTs is properly connected to the station earth and only at one electrical point.

Note!

If the CT secondary circuit earth connection is removed without the current transformer primary being de-energized, dangerous voltages may result in the secondary CT circuits.

8.2 Check of auxiliary voltage circuits

Check that the auxiliary voltage supplied to the DC/DC converter is in accordance with the data for the terminal and that the voltage has correct polarity.

8.3 Check of binary input circuits

Check the connections to the binary inputs so that both input levels and polarity are in accordance with terminal specifications.

8.4 Check of binary output circuits

Check the connections to the binary outputs so that both output loads and polarity are in accordance with terminal specifications.

8.5 Check of trip circuits and circuit breakers

The trip circuits are tested as part of the secondary/primary injection test.

9 Generating setting and configuration values

RED 521 terminal is delivered pre-configured from the factory and it does not require any configuration of the binary inputs and outputs at site. Only the configuration of the terminal rated frequency and analogue CT inputs can be made locally, by means of the built-in human-machine interface (HMI).

The parameter settings for the general differential function can be made locally, by means of the built-in human-machine interface (HMI).

The setting and configuration access on the built-in HMI can be blocked by lockable switch. When this is requested, the factory pre-configured binary input with name “Block Setting” must be connected to the control DC voltage via a normally closed contact of a control switch, which can be locked by a key. Only when the normally closed contact is open, it will be possible to change the setting and configuration parameters of the terminal via the built-in HMI.

10 Secondary injection testing

10.1 General

Secondary injection testing is a normal part of the commissioning. The operating value of all protection functions, the output to the proper trip and alarm contacts and the operation of binary input signals is checked and documented for future reference.

The connection of the test set to RED 521 is greatly simplified if the RTXP 24 test switch is included. When the test handle RTXH 24 is inserted in the test switch, preparations for testing are automatically carried out in the proper sequence, i.e. blocking of the tripping circuits, short-circuiting of the current circuits on the transformer side, opening of current transformer circuits and making relay terminals accessible from the terminals on the test plug handle.

If RED 521 is not provided with a test switch, the terminal has to be tested in the proper way from external circuit terminals. Make sure that the instrument transformers are isolated from the circuits connected to the test set. The secondary phase terminals of the current transformers must be short-circuited to neutral before the circuit is opened if any current can flow on the primary side.

The testing requires a good understanding of the protection functionality of the RED 521 terminal. A testing instruction is given for each type of protection function. Note that RED 521 is designed for a maximum continuous current of four times rated value.

10.2 Operation of the General Differential Protection from CTx input

The typical connection between the 3-Ph current test set and RED 521 terminals is shown in Fig. 9:

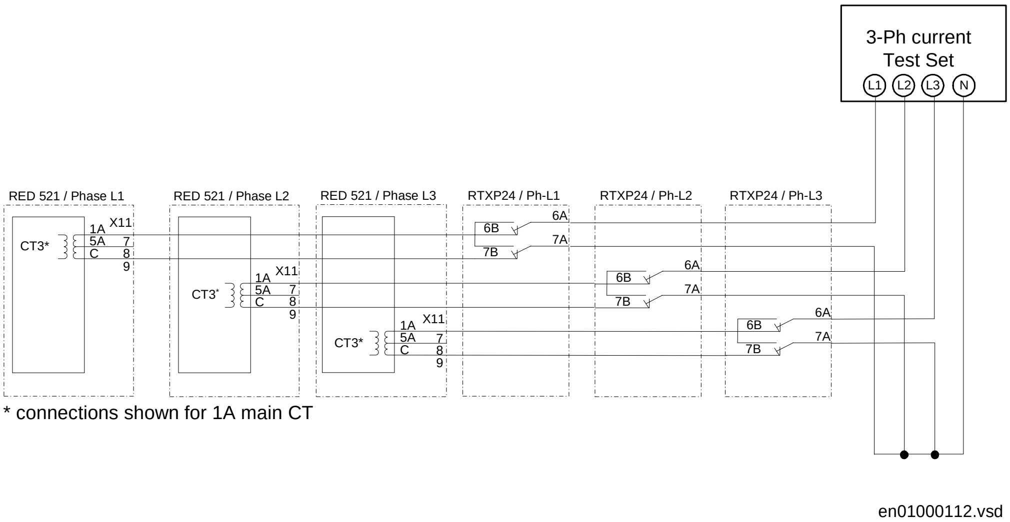


Fig. 9 Typical test connection for CT3 current input when COMBITEST RTXP 24 test switch is delivered together with one-phase RED 521 terminal

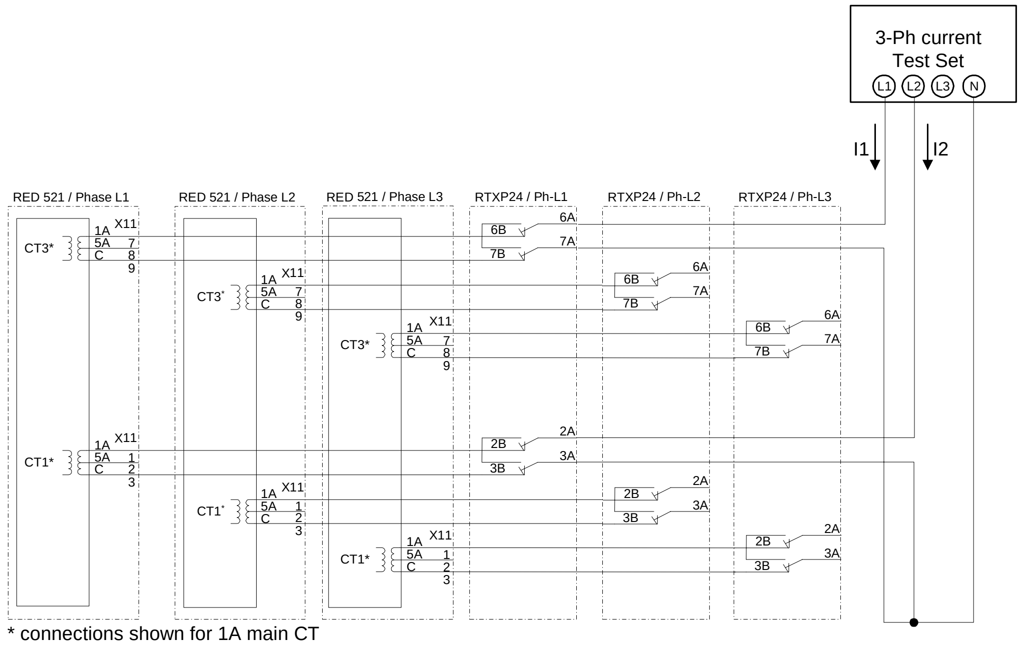
Testing will be explained from one general current input CTx (i.e. x=1, 2,..., Nmax; where Nmax is equal to the maximum number of available CT inputs). Follow the following test instructions for all used current inputs in RED 521 terminal.

1. **Connect the test set for injection of 3-phase current (or if not available 1-phase current) to the current terminals of CTx input of RED 521 terminal.**
2. **Check and write down the value for the configuration parameter “CT Prim Input x” which should correspond to the rated primary CT current of the main CT connected to CTx current input.**
3. **Check the value for the configuration parameter ZoneSelection/CTx. If this value is “Fixed to ZA” or “Fixed to ZB” proceed with next point. If this value is “Contact Ctrl” energize the binary input “Include CTx to ZA” in order to include the current from this current input into ZA measurement.**
4. **Increase the current in phase L1 until the correct differential function (i.e. either ZA or ZB) operates and note the incoming and differential currents at the moment of operation.**
5. **Check that trip and alarm contacts operate according to the scheme wiring.**
6. **Check that trip information is stored in the Event List**
7. **Switch-off the current**
8. **Check that trip reset information is stored in the Event List**
9. **Check in the same way the function by injecting current in phases L2 and L3.**
10. **Inject a symmetrical 3-phase current and note the operate value (possible with 3-phase test set only).**
11. **Connect the timer and set the current to five times the set value for “Diff Oper Level” parameter.**
12. **Switch on the current and note the operate time.**
13. **If the value for the configuration parameter ZoneSelection/CTx is “Contact Ctrl” de-energize the binary input “Include CTx to ZA” and now energies the binary input “Include CTx to ZB” in order to include the current from this current input into ZB measurement.**
14. **Repeat the steps from 4 to 12 for zone ZB**
15. **If the value for the configuration parameter ZoneSelection/CTx is “Contact Ctrl” energize now both binary inputs “Include CTx to ZA” and “Include CTx to ZB” in order to include the current from this current input into both measuring zone simultaneously.**
16. **Make sure that the dedicated binary output “Load Transfer” has operated (i.e. it is closed)**
17. **Repeat the steps from 4 to 12. Note that now both zones shall operate during these tests.**
18. **Check in the same way that the differential function properly operates for all used and connected CT inputs.**

Information on how to use the event menu is found in the RED 521 operator’s manual. See “Reference publications” on page 126.

10.3 Stability of the General Differential Protection

For stability test one current input shall always be used as a reference input. The reference current input then shall be tested for stability against all other current inputs in RED 521 terminal. It is recommended to use current input CT1 as the reference current input. The typical connection between the 3-Ph current test set and RED 521 terminals for this type of tests is shown in Fig. 10:



* connections shown for 1A main CT

en01000113.vsd

Fig. 10 Typical test connection for CT3 current input phase L1 when COMBITEST RTXP 24 test switch is delivered together with one-phase RED 521 terminal

The connections are shown for phase L1 only. Similar connection shall be used for testing phase L2 & L3 also.

Testing will be explained for one general current input CTx (i.e. x=2, 3,...,Nmax; where Nmax is equal to the maximum number of available CT inputs).

Follow the following test instructions to perform this type of test:

1. **Connect the currents I1 and I2 from the 3-ph test set test set to the current terminals of CT1 & CTx inputs of RED 521 terminal as shown in Fig. 10.**
2. **Make sure that current measurement from CT1 and CTx inputs are included into the same differential zone (see previous test instruction for more details)**
3. **Set the current I2 (i.e. current connected to reference current input CT1) to the nominal value of 1A (or to 5A if CT1 is connected to a main CT with 5A secondary rating) at zero degree.**
4. **Set the current I1 (i.e. connected to current input CTx) to the value calculated by the following formula:**

   I1= IXr*(CT Prim Input1/CT Prim Inputx)

   where

   IXr is rated secondary current of the current input CTx (i.e. normally 1A or 5A)

   CT Prim Input1 is the rated primary CT current of the main CT connected to CT1 current input

   CT Prim Inputx is the rated primary CT current of the main CT connected to CTx current input

5. **Set the phase angle of current I1 to 180 degrees if both current inputs (i.e. CT1 and CTx) has the same sign for entered configuration parameters CT Prim Input1 & CT Prim Input3 (i.e. both positive or both negative). Otherwise set the phase angle of current I1 to zero degree.**
6. **Inject these two currents into RED 521. Differential function shall be stable. Write down the service values for incoming and differential currents for phase L1. Differential current should be very small.**
7. **Switch off the currents.**
8. **Repeat the same test procedure for phases L2 and L3.**

10.4 Operation of fast open CT detection algorithm

For open CT test two current input shall always be used. The typical connection between the 3-Ph current test set and RED 521 terminals for this type of tests is shown in Fig. 10.

The connections are shown for phase L1 only. Similar connection shall be used for testing phase L2 & L3 also.

Follow the following test instructions to perform this type of test:

1. **Connect the currents I1 and I2 from the 3-ph test set test set to the current terminals of CT1 & CT3 inputs of RED 521 terminal as shown in Fig. 10.**
2. **Make sure that current measurement from CT1 and CT3 inputs are included into the same differential zone (see previous test instructions for more details).**
3. **Set the current I2 (i.e. current connected to input CT1) to the nominal value of 1A (or to 5A if CT1 is connected to a main CT with 5A secondary rating) at zero degree.**
4. **Set the current I1 (i.e. connected to current input CT3) to the value calculated by the following formula:**

   $$I1 = I3r*(CT\ Prim\ Input1/CT\ Prim\ Input3)$$

   where

   I3r is rated secondary current of the current input CT3 (i.e. normally 1A or 5A)

   CT Prim Input1 is the rated primary CT current of the main CT connected to CT1 current input

   CT Prim Input3 is the rated primary CT current of the main CT connected to CT3 current input

5 Check that the value of the product I1*CT Prim Input3 is bigger that the value of the product 1.1*Open CT Level (this is just a check to see that enough current will be disconnected later during testing in order for open CT algorithm to operate).

6 Set the phase angle of current I1 to 180 degrees if both current inputs (i.e. CT1 and CT3) has the same sign for entered configuration parameters CT Prim Input1 & CT Prim Input3 (i.e. both positive or both negative). Otherwise set the phase angle of current I1 to 0 degree.

7 Inject these two currents into RED 521 for approximately 5s. Differential function shall be stable. Write down the service values for incoming and differential currents for phase L1. Differential current should be very small.

8 Then switch off the current I2 only (i.e. set its magnitude back to 0A).

9 Open CT condition shall be detected by the terminal and yellow LED shall lit-up. The differential function will be blocked.

10 Check that open CT alarm contacts operate according to the scheme wiring.

11 Check that open CT information is stored in the Event List.

12 Switch-off the currents.

13 Reset the open CT blocking by pressing C button on built-in HMI.

14 Check that open CT reset information is stored in the Event List.

15 Repeat the same test procedure for phases L2 and L3.

10.5 Operation of slow open CT detection algorithm

For open CT test two current input shall be always used. The typical connection between the 3-Ph current test set and RED 521 terminals for this type of tests is shown in Fig. 10.

The connections are shown for phase L1 only. Similar connection shall be used for testing phase L2 & L3 also.

Follow the following test instructions to perform this type of test:

1. **Connect the currents I1 and I2 from the 3-ph test set to the current terminals of CT1 & CT3 inputs of RED 521 terminal as shown in Fig. 10.**
2. **Make sure that current measurement from CT1 and CT3 inputs are included into the same differential zone (see previous test instructions for more details).**
3. **Set the current I2 (i.e. current connected to current input CT1) to the nominal value of 1A (or to 5A if CT1 is connected to a main CT with 5A secondary rating) at zero degree.**
4. **Set the current I1 (i.e. connected to current input CT3) to the value calculated by the following formula:**

   I1= 0.85*I3r*(CT Prim Input1/CT Prim Input3)

   where

   I3r is rated secondary current of the current input CT3 (i.e. normally 1A or 5A)

   CT Prim Input1 is the rated primary CT current of the main CT connected to CT1 current input

   CT Prim Input3 is the rated primary CT current of the main CT connected to CT3 current input

5 **Check that the value of the product 0.15*I1*CT Prim Input1 is bigger that the pre-set value of Open_CT_Level. If it is not increase current into CT1 input until this condition is satisfied and change current into input CT3 accordingly.**

6 **Set the phase angle of current I1 to 180 degrees if both current inputs (i.e. CT1 and CT3) has the same sign for entered configuration parameters CT Prim Input1 & CT Prim Input3 (i.e. both positive or both negative). Otherwise set the phase angle of current I1 to 0 degree.**

7 **Inject these two currents into RED 521. Differential function shall be stable. Write down the service values for incoming and differential currents for phase L1. Differential current should be approximately 15% of the incoming current.**

8 **After 1000 power system cycles (i.e. 20s for 50Hz or 16.7s for 60Hz system) open CT condition shall be detected by the terminal and yellow LED shall lit-up. The differential function will be blocked.**

9 **Check that open CT alarm contacts operate according to the scheme wiring.**

10 **Check that open CT information is stored in the Event List.**

11 **Switch-off the currents.**

12 **Reset the open CT blocking by pressing C button on built-in HMI.**

13 **Check that open CT reset information is stored in the Event List.**

14 **Repeat the same test procedure for phases L2 and L3.**

10.6 Communication via the rear ports

10.6.0.1 LON communication

LON communication is normally used by SCS. The communication link is optical fiber within the substation.

The test can only be carried out when the whole communication system is installed. Thus, the test is a system test and is not dealt with here.

10.7 Check of the trip circuits

Check that the circuit breakers associated with the RED 521 protection scheme operate when the tripping relays are activated. The trip relays are conveniently activated by secondary injection to activate a suitable protection function.

11 Primary injection testing

Whenever it becomes necessary to work on primary equipment, it is essential that all the necessary switching, locking, earthing and safety procedures are observed and obeyed in a rigid and formalized manner. Operating and testing procedures should be strictly followed in order to avoid exposure to the substation equipment that has not been properly de-energized.

A test with primary current through the protected zone is usually a final check that the current circuits are correctly connected to the RED 521 protection scheme. It is important to have an appropriate source, which is able to inject sufficient current in the primary circuit in order to distinguish between noise and real injected current. Therefore it is recommended that the injection current should be at least 10% of rated CT primary current.

11.1 Operation of the General Differential Protection

The primary injection tests of a RED 521 differential terminal consist of applying a suitable current source across the primary winding of the CT connected to the current input CTx of RED 521 terminal. The testing is normally done in one phase at the time. If the primary current is bigger than the set value of the Diff_Oper_Level parameter, the RED 521 terminal shall issue the trip command as well. The primary current injection test should be repeated for every CT until all current circuits in all phases are checked. The typical connection for the primary current test set for this type of tests is shown in Fig. 11:

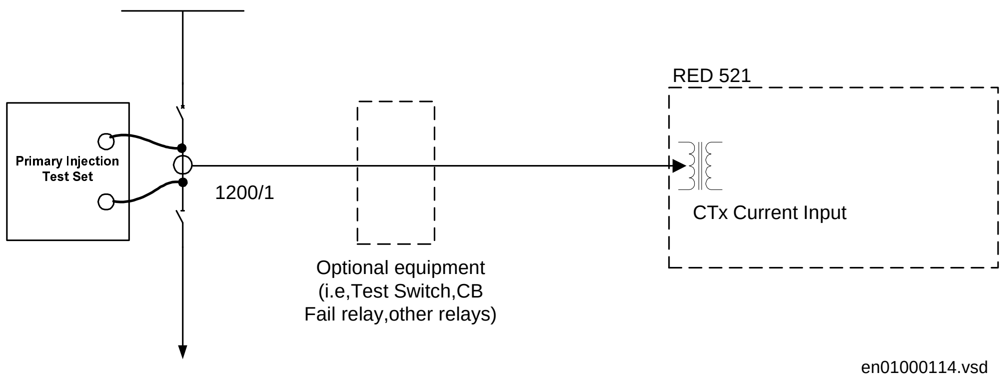


Fig. 11 Typical test connection for primary injection which should prove the operation of the RED 521 terminal

Testing will be explained from one general current input CTx (i.e. x=1, 2,..., Nmax; where Nmax is equal to the maximum number of available CT inputs).

Follow the following test instructions for all used current inputs in RED 521 terminal.

1. **Connect the test set for injection primary current to the main CT connected to the current terminals of CTx input of RED 521 terminal as shown in Fig. 11.**
2. **Make sure that current measurement from CTx input are included in one of the differential zones (i.e. ZA or ZB).**
3. **Inject the primary current in phase L1 and note the incoming and differential currents on the terminal HMI display. The values of the incoming and the differential currents shall correspond to the injected primary current.**
4. **Check that the current is present only in the phase being tested.**
5. **If injected current is high enough check that trip contacts operate according to the scheme wiring.**
6. **Check that trip information is stored in the Event List.**
7. **Switch-off the current.**
8. **Check that trip reset information is stored in the Event List.**
9. **Check in the same way the function by injecting current in phases L2 and L3.**

Information on how to use the event menu is found in the RED 521 operator’s manual. See “Reference publications” on page 126.

It is recommended that at least once each primary CB is tripped directly from the RED 521 protection scheme during these tests. That shall prove the trip circuit connection between the RED 521 protection scheme and the CB.

11.2 Stability of the General Differential Protection

For stability test one current circuit shall always be used as a reference input. The reference current circuit then shall be tested for stability against all other current circuit connected to RED 521 protection scheme on a one-by-one basis. It is recommended to use current circuit connected to the CT1 current input as the reference current circuit. The typical connection for the primary current test set for this type of tests is shown in Fig. 12:

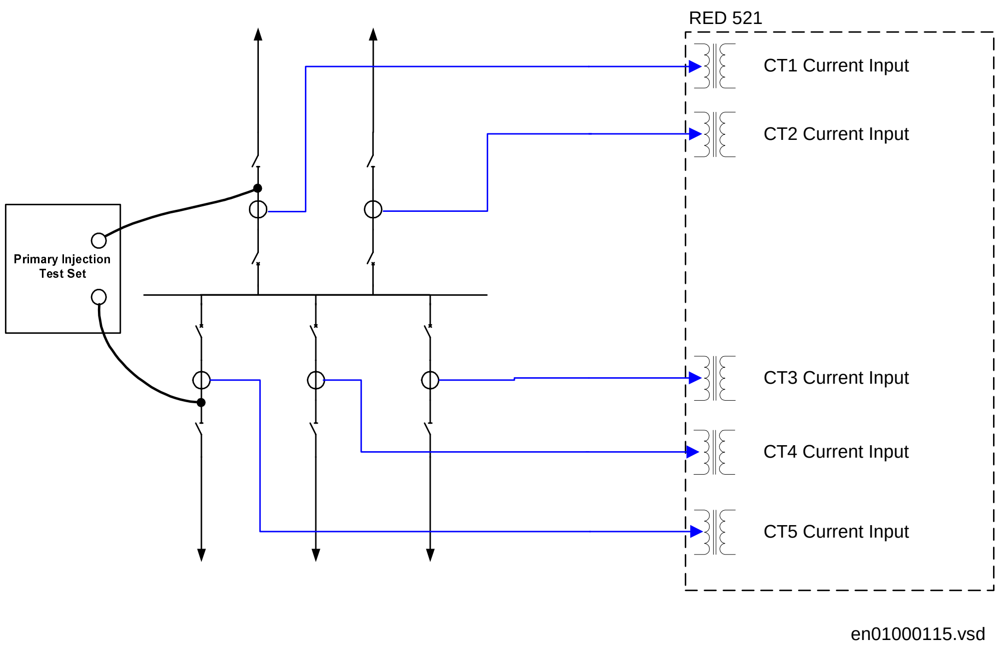


Fig. 12 Typical test connection for primary injection which should prove the stability of the main CT connected to current input CT5 of RED 521 terminal

For this type of primary injection tests a suitable current source should be applied across the primary windings of two CTs connected in series as shown in Fig. 12. The testing is normally done in one phase at the time. The currents in the secondary winding of these CTs are then opposite in phase. The differential current displayed by the RED 521 terminal should be negligible while the incoming current displayed by the RED 521 terminal should be equal to the value of the injected primary current. Therefore the RED 521 terminal must not issue the trip command during these tests. If it trips or the differential current has a high value it usually means that some problem do exist within the wiring of the CT circuits connected to current input CTx (i.e. a differential current equal to twice the injection current probably indicates wrong polarity of the main CT connected to the CTx current input). This problem must be found and fixed before the RED 521 protection scheme is put in service.

Follow the following test instructions to perform this type of test:

1 **Connect the test set for primary current injection to the main CTs as shown in Fig. 12.**
2 **Make sure that current measurement from CT1 & CTx inputs are included in the same differential zones (i.e. either ZA or ZB).**
3 **Inject the primary current in phase L1 and note the incoming and differential currents on the terminal HMI display. The value of the incoming current for phase L1 shall correspond to the injected primary current. The value of the differential current for phase L1 shall be negligible.**
4 **Check that the current is present only in the phase being tested.**
5 **Switch-off the current.**
6 **Check in the same way the function by injecting current in phases L2 and L3.**

11.3 Proper operation of the busbar isolator replica scheme

The busbar disconnector replica is used in order to provide the information to the RED 521differential terminals which of the measured CT currents shall be included within different differential zones. In order to form the busbar disconnector replica it is necessary to use the auxiliary contacts from each busbar disconnector. For more information please refer to the Application Manual for RED 521 terminal. See “Reference publications” on page 126.

Proper operation of this scheme have to be checked during commissioning, by manual operation of the primary busbar disconnectors and verification that the associated mirror relay(s) properly operate and energies the corresponding binary inputs of relevant RED 521 terminals. If necessary proper timing of the disconnector auxiliary contacts have to be checked as well.

After all these test are conducted the RED 521 protection scheme can be put in service.

Reference publications

Technical Overview Brochure, Series RE 500 Mechanical design and mounting accessories, 1MRK 514 003-BEN

Technical Overview Brochure, COMBIFLEX Connection and installation components, 1MRK 513 003-BEN

LNT 505, LON Configuration Tool, 1MRS 151 400

SLDT, LON configuration module REx 500, 1MRK 001 700-A

The chapter “How to use the human machine interface”

This chapter instructs the user how to use the human machine interface (HMI).

1 Introduction

The built-in human machine interface (HMI) provides local communication between the user and the terminal.

This chapter describes the basic principles of local human-machine communication (HMC).

See the section “Human Machine interface - tree structure” for a detailed description of the tree structure.

2 Human machine interface module

The HMI module consists of three light emitting diodes (LEDs), a liquid crystal display (LCD), six membrane push buttons and one optical connector.

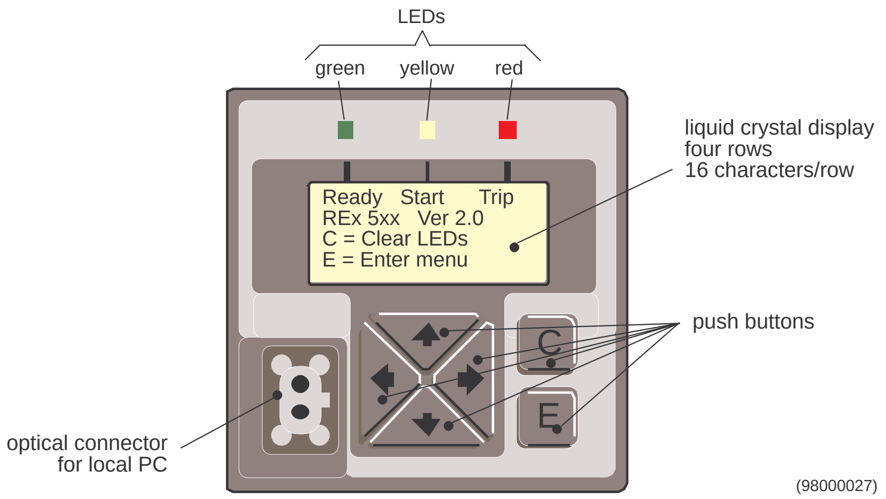


Fig. 1 Built-in human-machine interface module.

2.1 LEDs

Three LEDs provide primary information on the status of a terminal. Each LED has a special function and provides terminal status information when the LED is lit, flashing or off.

The three HMI LED's have the following functionality:

Table 1: Functionality of HMI LED's

	Steady Light	Flashing Light
Green LED	Terminal Ready	Terminal NOT Ready
Yellow LED	Open CT Condition Detected	Not used for RED 521
Red LED	TRIP	Not used for RED 521

2.2 LCD display

The liquid crystal display (LCD) provides detailed information about the terminal. Normally it is off. Select any button to turn on the display and study the type of terminal with its version, together with instructions on how to continue local communication with the terminal.

The display shuts down after exiting the menu tree or if no button is selected for more than about 45 minutes.

2.3 Push buttons

The number of buttons used on the HMI module are reduced to a minimum in order to make the communication as simple as possible for the user. The buttons normally have more than one function, depending on where they are used in the dialogue.

All buttons have one common function when the display is in idle mode (dark, non active). By selecting any of them the display will be activated.

The C button has three main functions:

- Cancels the operation when used together with the dialogue windows.
- Provides an Exit operation in a menu tree. This means that each selection of the C button within the menu tree results in stopping the current function or leaving the menu branch and moving one step higher in the menu tree.
- Clears LEDs when in an upper menu level.

The E button mainly provides an Enter function. It activates, for example, the selected menu tree branch, confirm settings, and different actions.

The left and right arrow buttons have two functions, to:

- Position the cursor in a horizontal direction, for instance, to move between the digits in a number during the setting procedures for real values.
- Move between the data windows within the same menu branch.

The up and down arrow buttons have three functions, to:

- Move among different menus within the menu and the dialogue windows.
- Scroll the menu tree when it contains more branches than shown on the display.
- Change the parameter values in the data windows during the setting procedure.

2.4 Optical connector for local PC

In this version of RED 521 terminal, the SPA communication protocol for the optical connector to local PC is not supported. Therefore the local PC can not be used for communication with the RED 521 terminal.

3 Unattended HMI

When the terminal is in normal operation and no one has attended the HMI for more than 45 minutes, the green LED remains active. The yellow and red LEDs are off and no text is shown on the display. The display is dark, with no light behind.

The display will turn-on its status when one of the buttons is pressed. The LEDs will turn-on when Open CT or Trip mode is set.

3.1 Open CT mode

When the terminal has detected an open CT condition since the latest reset of the indications, the HMI LEDs look like this:

Green LED	Lit
Yellow LED	Lit
Red LED	Off

3.2 Trip mode

When the terminal has issued the trip command since the latest reset of the indications, the HMI LEDs look like this:

Green LED	Lit
Yellow LED	Off
Red LED	Lit

4 Menu window

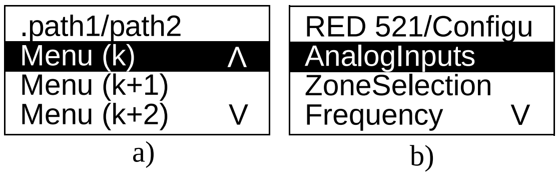


Fig. 2 Menu window, general configuration (2a) and typical example (2b)

For row one:

- A dot always appears at the beginning of the row when the selected menu window does not represent the main menu.
- path1 displays the name of the superior menu.
- path2 displays the name of the active menu window.

For rows two, three, and four:

- Menus k, k + 1 and k + 2 appear in the three bottom rows.
- When the cursor highlights one of the rows, it indicates the path that you can activate by selecting the E button.

The up arrow appears in row 2 when more menus are available before the k menu. The down arrow appears in the bottom row when more menus are available after the k+2 menu. To change the active path within the menu tree (scrolling the menu) select the up or down arrow button.

To change the menu window into a new menu window or into a data window select the E button. In same case the paths in the first row change in such a way that the old path2 now becomes a path1 and the previous menu line with the cursor then changes into path2.

Fig. 2b shows a menu window that appears during the configuration procedure on the terminal. The configuration of analog inputs will become possible by selecting the E button, since this submenu appears marked as an active path by a cursor. The down arrow informs the user about the additional menus that are available for a configuration.

5 Dialog window

The dialog windows instruct the operator how to perform the actions defined by the text in the third and fourth rows. The first and second rows usually display a headline that provides more information to the user about the proposed action or the terminal.

RED 521 has five different dialogue windows:

- Start window (Starting the dialogue)
- Command without selection (Confirming a command)
- Command with selection (Selecting a command)
- Command with cancellation (Cancelling a command)
- Command with selection and cancellation (Selecting and cancelling a command)

The five dialogue windows are described in the following sections.

5.1 Starting the dialogue

Fig. 3a and Fig. 3b show two typical dialogue windows to start communication with the terminal. Select the:

- C button to clear the LEDs (if required), or
- E button to enter the menu tree

The text (Ready, OCT, Trip) in row one of the window in Fig. 3a describes the function of the LEDs that are at the top of the display when the LEDs are active.

```
Ready  OCT   Trip
RED 521 VER 1.0
C=Clear LEDs
E=Enter menu
```
a)

```
Ready
RED 521 VER 1.0
C=Quit
E=Enter menu
```
b)

Fig. 3 Start dialogue windows, typical examples

5.2 Confirming a command

Fig. 4 shows a typical example of a dialogue window for command without selection. The instructions in the first two rows describe possible actions. YES and NO with the flashing cursor on one of them appear in the bottom row. You can move the cursor from one to another possibility by selecting the right or left arrows. The user must, after taking the decision, confirm the same one by selecting the E button.

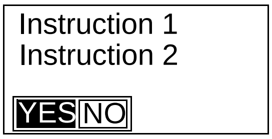


Fig. 4 Dialogue window for command with confirmation

1. **Position the cursor on YES and select the E button to confirm the instructions (commands) in rows one and two.**
2. **Position the cursor on NO and select the E button to exit the dialogue window without saving changes that were made during communication within the menu tree. Or select C with the same result.**

5.3 Selecting a command

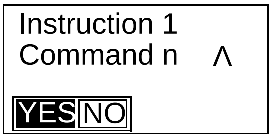


Fig. 5 Dialogue window for command with selection

Use the up or down buttons to position the cursor on a command. Select YES to execute the command. Select NO to cancel and exit the dialogue window.

5.4 Cancelling a command

Fig. 6 shows a typical dialogue window for command with cancellation. Use the right or left arrows to move to YES, NO or CANCEL. Then select E to confirm your selection. If you select CANCEL confirmed with E, you return to the window that was shown on the display before the dialogue window appeared.

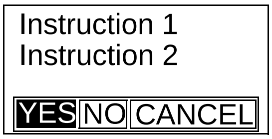


Fig. 6 Dialogue window for command with cancellation

5.5 Selecting and cancelling a command

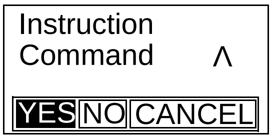


Fig. 7 Dialogue window for a command with selection and cancelling

Here you can select the command in row two, which is indicated by the up or down arrow at the end of the row.

Use the right or left arrows to position the cursor on YES, NO or CANCEL. Select YES to execute the command. Select NO or CANCEL to cancel and exit the dialogue window.

The chapter "How to perform specific operations"

This chapter instructs the user how to perform specific operations, e.g. how to read service values, internal events, disturbance reports and terminal status.

6 How to set internal terminal time

Use the setting menu to set the internal time for a complete terminal, as shown in the Fig. 8.

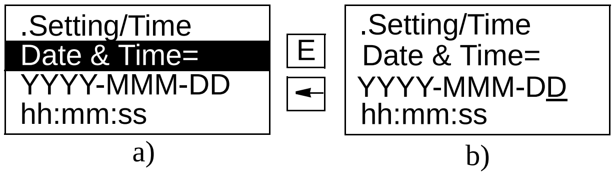


Fig. 8 Setting internal time within a terminal

After you select the E button, the data window changes from Fig. 8a to Fig. 8b. Note that the cursor is always positioned under the seconds value when you begin. Select the left arrow to move to the date value.

Real time in a terminal uses these values:

- *YYYY*, year
- *MMM*, first three letters of the month’s name
- *DD*, day in the month
- *hh*, hour
- *mm*, minutes
- *ss*, seconds

Apply the rules for setting a string when you set the month value. All other values are real values.

7 How to read service values

7.1 General

The Human Machine Interface (HMI) menu displays information about the:

- measured values from protection functions.
- operation conditions for protected objects in the power system.
- terminal.

Possible types of information are:

- Differential current for each phase and zone of protection
- Through-load current for each phase and zone of protection
- Status of binary output signals from the protection functions
- Status of binary input signals to the protection functions
- Event list
- Internal time

7.2 Information subgroups

7.2.1 Differential current and through-load current for each phase and zone of protection

HMI branch:

Service Report
  Measurands

The terminal displays the values of differential current (i.e. Id) and through-load current (i.e. Iin) per phase and zone of protection.

7.2.2 Binary input signals to the protection functions

HMI branch:

Service Report
  Inputs

The current status (i.e. 0 or 1) of the binary input signals together with the signal name are displayed.

7.2.3 Binary output signals from the protection functions

HMI branch:

Service Report
  Outputs

The current status (i.e. 0 or 1) of the binary output signals together with the signal name are displayed.

7.2.4 Event List

HMI branch:

EventList
  Events

The last 16 time-tagged internal events are available.

7.2.5 Internal time

HMI branch:

Settings
  Time

The internal terminal date and time can be checked under this submenu. The data comprises information on the date and on the time with an accuracy of 1 second.

The chapter "Human machine interface"

This chapter describes the tree structure of the human machine interface. Each menu is displayed with its submenus.

8 Introduction

This chapter describes the structure of the human machine interface (HMI).

The following pattern is used:

1. The table header displays the actual path of the information shown in the cells. The information in the header is displayed in an cell with a grey-scale-fill.

   Example:

RED521	RED521/Service	.Service/Measura

Is equal to:

RED521
  ServiceReport
    Measurands

2. The path to the end-nodes appear in **bold**.
3. Data nodes (parameters) appear in *italic*.

   Example:

.Configu/AnalogI
CT Prim Inp 1
CT Prim Inp 2

4. Dialogues and references to other documents are located in thicker frames.
5. In the following sections HMI tree structure is shown for one-phase terminal. However the HMI menu tree for the three-phase version of the terminal is very similar to the one shown on these pages.

9 Display for Event List menu

RED521	RED521/EventLi	.EventLi/Events
EventList	**Events**	*Event 1*
ServiceReport	ClearEvents	*Event 2*
Settings		*Event 3*
Configuration		*Event 4*
TerminalReport		*Event 5*
		Event 6
		Event 7
		Event 8
		Event 9
		Event 10
		Event 11
		Event 12
		Event 13
		Event 14
		Event 15
		Event 16

“Clear Events”
with confirmation

10 Display for Service report menu

RED521	RED521/Service	.Service/Measura
EventList	**Measurands**	*Id ZA*
ServiceReport	Inputs	*Iin ZA*
Settings	Outputs	*Id ZB*
Configuration		*Iin ZB*
TerminalReport		

.Service/Inputs	.Service/Outputs
Block ZA	*Blocked*
Block ZB	*Trip*
Reset OCT ZA	*Trip ZA*
Reset OCT ZB	*Trip ZB*
Load Transfer	*Open CT*
Incl CT1 to ZA	*Open CT ZA*

Continuation from the previous page

Incl CT1 to ZB	*Open CT ZB*
Incl CT2 to ZA	*Load Transfer*
Incl CT2 to ZB	
Incl CT3 to ZA	
Incl CT3 to ZB	
Incl CT4 to ZA	
Incl CT4 to ZB	
Incl CT5 to ZA	
Incl CT5 to ZB	
Incl CT6 to ZA	
Incl CT6 to ZB	
Incl CT7 to ZA	
Incl CT7 to ZB	
Incl CT8 to ZA	
Incl CT8 to ZB	
Incl CT9 to ZA	
Incl CT9 to ZB	
Incl CT10 to ZA	
Incl CT10 to ZB	
Incl CT11 to ZA	
Incl CT11 to ZB	
Incl CT12 to ZA	
Incl CT12 to ZB	
Incl CT13 to ZA	
Incl CT13 to ZB	
Incl CT14 to ZA	
Incl CT14 to ZB	
Incl CT15 to ZA	
Incl CT15 to ZB	
Incl CT16 to ZA	
Incl CT16 to ZB	
Incl CT17 to ZA	
Incl CT17 to ZB	
Incl CT18 to ZA	
Incl CT18 to ZB	
Block Setting	

11 Display for Setting menu

RED521	RED521/Setting	.Setting/General
EventList	**GeneralDiff**	*Diff Oper Level*
ServiceReport	Time	*Open CT Level*
Settings		
Configuration		
TerminalReport		

.Setting/Time
Date & Time

12 Display for Configuration menu

RED521	RED521/Configu	.Configu/AnalogI
EventList	**AnalogInput**	*CT Prim Inp 1*
ServiceReport	ZoneSelection	*CT Prim Inp 2*
Settings	Frequency	*CT Prim Inp 3*
Configuration	Time	*CT Prim Inp 4*
TerminalReport	LON Com	*CT Prim Inp 5*
		CT Prim Inp 6
		CT Prim Inp 7
		CT Prim Inp 8
		CT Prim Inp 9
		CT Prim Inp 10
		CT Prim Inp 11
		CT Prim Inp 12
		CT Prim Inp 13
		CT Prim Inp 14
		CT Prim Inp 15
		CT Prim Inp 16
		CT Prim Inp 17
		CT Prim Inp 18

.Configu/ZoneSel
CT1
CT2
CT3
CT4
CT5
CT6
CT7
CT8
CT9
CT10
CT11
CT12
CT13
CT14
CT15
CT16
CT17
CT18

.Configu/Frequen
fr=50Hz

.Configu/Time	.Time/Fine
FineTimeSrc	*TimeSyncSource*
CoarseTimeSrc	

.Time/Coarse
CoarseTimeSourc

LON Com	.Configu/LON Com	.LON Com/NodeInf
	Node Information	*AdressInfo*
	ServicePinMsg	*NeuronID*
	LONDefault	*Location*
	SessionTimers	**LON Com/Session**
		SessionTmo
	“Send SrvPinMsg” with confirmation	*RetryTmo*
		IdleAckCycle
		BusyAckCycle
	“Set LONDefault” with confirmation	*ErrNackCycle*

13 Display for Terminal Report menu

RED 521	RED 521/TermRep	.TermRep/SelfSup
EventList	**SelfSuperv**	*Module=RED521*
ServiceReport	Contents	*Pos=*
Settings		*OK*
Configuration		*Module=RTC*
TerminalReport		*Pos=*
		OK
		Module=TimSync
		Pos=
		OK
		Module=AIM1
		Pos=p1
		OK
		Module=AIM2
		Pos=p5
		OK
		Module=BIM1
		Pos=p9
		OK
		Module=BIM2
		Pos=p10
		OK
		Module=BIM3
		Pos=p11
		OK
		Module=BOM1
		Pos=p12
		OK
		Module=CanIo
		Pos=CBM
		OK

.TermRep/Content	.Content/Product
Product	*RED 521 Ver 1.0*
SW-Modules	*O# (order No)*
HW-Modules	*S# (serial No)*

.Content/SW-Mod
RED523 Version
BASE500 Version
VX_SBS Version
AIMSW Version

.Content/HW-Mod
AIM at p1 Part No
AIM at p5 Part No
NUM at p8 Part No
SLM at p8 Part No
BIM at p9 Part No
BIM at p10 Part No
BIM at p11 Part No
BOM at p12 Part No

The chapter “Functional description”

This chapter describes the functionality of the protection terminal RED 521. The descriptions deals with how the functions are designed and how they operate. For hardware descriptions refer to the chapter “Design descriptions”.

RED 521 terminal functionality

1 Analog input data

In order to get correct measurement results as well as correct protection functionality, the analog input channels must be configured. Because all protection algorithms in RED 521 are utilizing the primary system quantities it is extremely important to properly set the data about connected current transformers. These data are calculated by the system engineer and normally set by the commissioner from the built-in HMI or from SMS.

1.1 Configuration for analog CT inputs

The secondary rated current of the CT (i.e. 1A or 5A) is selected by tap connection of wires from the main CT. Each current input into RED 521 terminal has three terminals 1A, 5A and common. See Fig. 1.

.

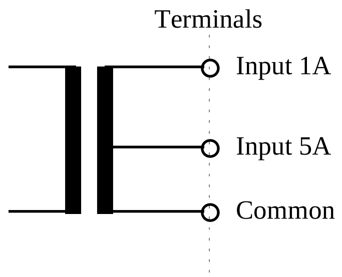


Fig. 1 CT Connections for one current input into RED 521

The primary CT data are entered from the HMI menu branch:

Configuration
AnalogInput

The following parameter shall be set for every current transformer connected to RED 521 terminal:

Table 1: CT Configuration

Parameter Description	Parameter name	Range	Default
Rated CT primary current in A	CT Prim Input x	from -10000 to +10000	0

This parameter defines the primary rated current of the CT. For two set of CTs with ratio 1000/1 and 1000/5 this parameter is set to the same value of 1000 for both CT inputs. Negative values (i.e. -1000) can be used in order to reverse the direction of the CT current by software for the differential function. This might be necessary if two sets of CTs have different location of the star point with respect to the protected busbar. It is recommended to set this parameter to zero, for all unused CT inputs.

Typical example of CT configuration is shown in the Fig. 2:

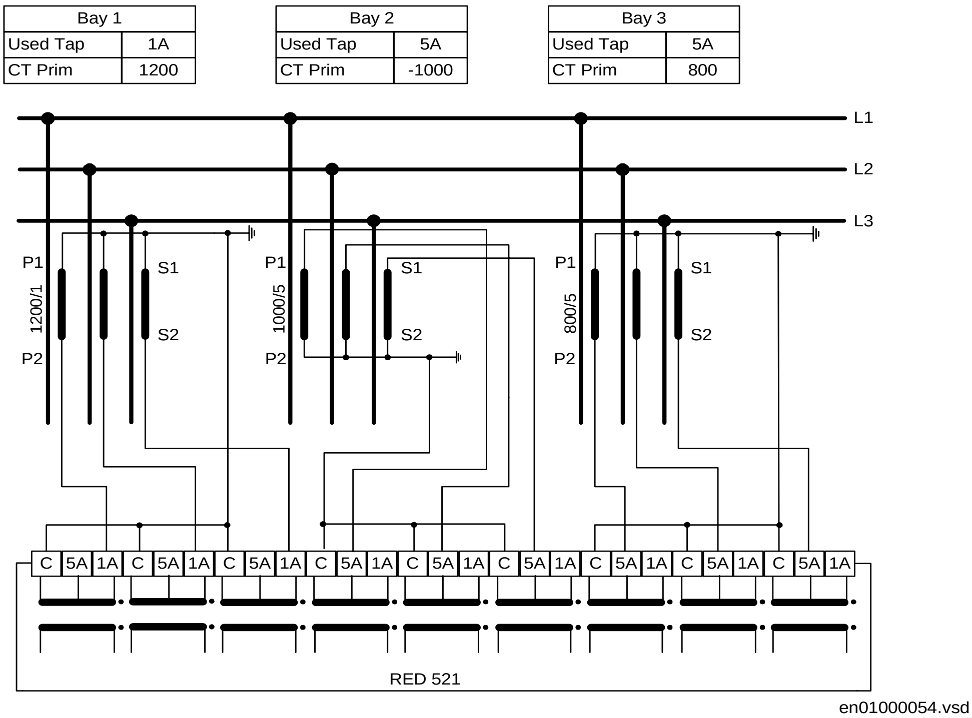


Fig. 2 Example of CT configuration setup for 3-phase version of RED 521 terminal

For main CTs with 2A rated secondary current, it is recommended to connect the secondary wiring to the 1A input and to set the rated primary current to the one half of its true value. For example CT with ratio of 1000/2A can be treated as 500/1A CT.

2 Time synchronization

2.1 System overview

The terminal has a built-in real time clock (RTC) with a resolution of one millisecond. The terminal is also provided with a calendar. The starting date and time is 1970-01-01 00:00:00. The last date and time is 2037-12-31 23:59:59. The clock and calendar is battery- backed to provide safe operation also during supply failure.

The terminal can be synchronized via the serial port and via a binary input.

On the serial bus (i.e. LON bus) two types of synchronization messages are sent.

- Coarse message is sent every minute and comprises complete date and time, i.e. year, month, day, hours, minutes, seconds and milliseconds
- Fine message is sent every second and comprises only seconds and milliseconds.

Synchronization via a binary input is intended for minute pulses from e.g. a station master clock. Both positive and negative edge on the signal can be accepted.This signal is considered as a fine signal.

2.2 Design

The time synchronization algorithm sets the internal time to a minimal error by adjusting the clock rate in small steps using one or two external synchronization sources. This way the clock will maintain a long-time rate accuracy better than 2 ppm.

The clock error is the difference between the actual time of the clock, and the time the clock is intended to have. The clock accuracy shows how much the error increases, that is, how much the clock gains or loses time.

The design allows for sporadic loss of synchronization sources and bad time messages. Normally it takes up to 20 minutes after power on to reach full accuracy, for instance when using course LON synchronization and fine minute-pulse, ±1 ms clock error.

2.3 Configuration

The following configuration alternatives for time synchronization are available in the RED 521 terminal:

FineTimeSrc:

- None
- LON
- BinIn_Pos
- BinIn_Neg

- PPH (only for PPH type of RED 521 terminal

CoarseTimeSrc:

- None
- LON

Table 2: Time source configuration alternatives

	FineTimeSrc	Coarse-TimeSrc	Description
1.	None	None	No external time sync, time is set from terminal HMI.
2.	LON	LON	Time sychronization from LON. Coarse time from LON.
3.	BinIn_Pos	None	Time sychronization from Binary Minute pulse, positive edge. No coarse time.
4.	BinIn_Neg	None	Time sychronization from Binary Minute pulse, negative edge. No coarse time.
5.	BinIn_Pos	LON	Time sychronization from Binary Minute pulse, positive edge. Coarse time from LON.
6.	BinIn_Neg	LON	Time sychronization from Binary Minute pulse, negative edge. Coarse time from LON.
7.	LON	None	Time sychronization from LON. No coarse time.
8.	None	LON	No time synchronization. Coarse time from LON.

If no external time is available (alt.1), the system time will be taken from the battery-backed RTC at start-up. After that the terminal time can be set from the built in HMI.

If no coarse time is available (alt. 3, 4 & 7) and fine time exists, the RTC time is used as terminal time at start-up. Then the fine time is used for synchronization.

If no fine time is available (alt. 8) and coarse time exists, the coarse time is used for synchronization of the system time as long as it does not deviate more than 0,5 seconds from the terminal time. If the deviation is larger than 0.5 seconds the terminal time will be set to the value of the coarse time message.

If both fine and coarse time exists (alt. 2, 5 & 6), the first coarse time message will set the terminal time. After that the fine time is used for synchronization. If coarse time deviates more than 10 seconds from the terminal time, the terminal time will be set to the value of the coarse time message.

In order to achieve ±1ms relative time synchronization accuracy between the terminals it is recommended to use alternative 5 or 6 from the previous table.

The synchronization source for terminal built-in real time clock are set from the HMI menu branch:

Configuration
Time

2.4 Setting date and time

If no external time is available (alternative 1 in Table 2:) the internal time can be set on the built-in HMI display at:

Settings
Time

The time is set with year, date and time.

The maximum time that can be set is 2037-Dec-31 23:59:59. When the internal clock has overflowed, this will be handled so that the protection functions of the terminal will not be disturbed.

The minimum time that can be set is 1970-Jan-01 00:00:00

2.5 Error signals

Two error signals are available for time errors:

- TIME-RTCERR internal RTC errors
- TIME-SYNCERR time synchronization error

TIME-SYNCERR will be set to *WARNING* during terminal startup, and will be set to *OK* when the calculated error of the clock is less than 10 ms.

Both signals are normally in state *OK* and will change to *WARNING* when an error occurs.

2.5.1 TIME-SYNCERR

If no external time synchronization is available, i.e. both FineTimeSrc and CoarseTimeSrc is set to *none*, TIME-SYNCERR is always *OK*.

If external time synchronization is available, TIME-SYNCERR will change from WARNING to OK at start or restart of each configured source. This means that time synchronization is up and running. It should however be noted, that TIME-SYNCERR = OK does not indicate that the system time has been synchronized to the required accuracy.

The status of these error signals is shown on the HMI at:

TerminalReport
SelfSuperv

2.5.1.1 Causes for error signals

TIME-SYNCERR:

- Malfunctioning or missing binary IO module.
- Malfunctioning AIM, TIM or CIM module.
- The calculated error of the internal time is larger than 10 ms.
- Error in synchronization signals according to the following section.

2.5.1.2 Check of synchronization signals

Binary minute pulses are checked with reference to frequency. Period time (a) should be 60 seconds. Deviations larger than ±50 ms will cause TIME-SYNCERR.

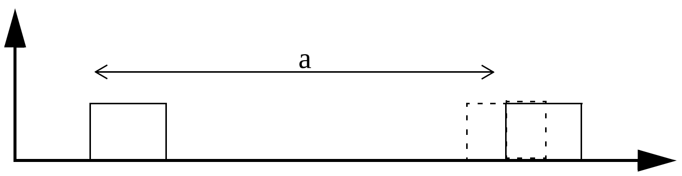


Fig. 3 Binary minute pulses

Loss of minute pulse signals will cause an internal timer to generate TIME_SYNCERR after 2 minutes.

LON time are checked according to the following:

1 Time messages from LON should have a period time of 1 second for fine synchronization messages. Loss of LON synchronization signals will cause an internal timer to generate TIME_SYNCERR after 2 minutes.

2 In a synchronized node, a discrepancy between message time and terminal time of more than 10 seconds will cause TIME_SYNCERR.

2.5.2 TIME-RTCERR

Activation of this signal can have two causes:

1 Failure in reading the RTC time at start-up.

2 Overflow of the internal clock. This will happen in the year 2038.

3 Restricted settings

Setting values of protection parameters within the terminal are important not only for reliable and secure operation of the terminal, but also for the entire power system. Non-permitted and non-coordinated changes, done by unauthorized personnel, can cause severe damages in primary and secondary power circuits. This can influence the security of people working in close vicinity of the primary and secondary apparatuses and the consumers.

For this reason, the terminal includes a special feature that, when activated, blocks the possibility to change the setting and configuration parameters of the terminal, from the built-in HMI module.

All other functions of the local human-machine communication remain intact. This means that an operator can read all events and other information as well as the setting values for different protection parameters.

The factory pre-configured binary input with name “Block Setting” must be connected to the control DC voltage via a normally closed contact of a control switch, which can be locked by a key. Only when the normally closed contact is open, it will be possible to change the setting and configuration parameters of the terminal via the built-in HMI.

RED 521 functionality

4 Zone Selection

4.1 Summary

The zone selection enables the user to provide the information to the general differential function about which of the connected CT currents shall be included/excluded to/from the calculations in the differential zone.

4.2 Description of zone selection logic for three-phase terminal

In order to have properly balanced differential function for the station busbar disconnector switching arrangements, it is important to properly configure the zone selection data for every connected current transformer. Due to this configuration parameter, the RED 521 terminal allows an effective application for stations where the zone selection (i.e. CT switching) is required. This is possible due to the software facility to have full and easy control over all CT inputs connected to the terminal. The philosophy is to allow every CT input to be individually controlled by a configuration parameter. This parameter called “ZoneSelection/CTx” can be individually configured for every CT input. The parameter can be set to only one of the following two alternatives:

1 Contact Ctrl

2 Fixed to Zone

If for a particular CT input (i.e. input CTx) setting “Contact Ctrl” is selected, then the CTx input will be only included to the differential zone when a dedicated binary input called “Include CTx” is energized. This means that the current connected to the CTx input can be dynamically included/excluded from the differential zone by simply energizing/de-energizing the dedicated binary input of the RED 521 terminal.

If for a particular CT input (i.e. CTx) setting “Fixed to Zone” is selected, then this CT input is always included in the differential zone ZA irrespective of any other condition or status of any other binary input of the RED 521 terminal. This means that the CT current connected to the CTx input will always be included in the differential zone.

In addition to this configuration facilities a dedicated binary input called “Load Transfer” is available as well. “Load transfer” means transfer of load current in any feeder bay from one busbar to an other busbar. When this binary input is energized the load transfer feature inside of the terminal is immediately activated. In this situation the internal terminal measurement is reconnected so that input CT1, which is connected to the CT´s in the bus-coupler bay, is unconditionally excluded from the differential zone, while all other CT inputs (i.e. CT2 - CT6) are unconditionally included into the differential zone.

The overall internal logic for zone selection built-in the three-phase version of RED 521 terminal is shown in Fig. 4:

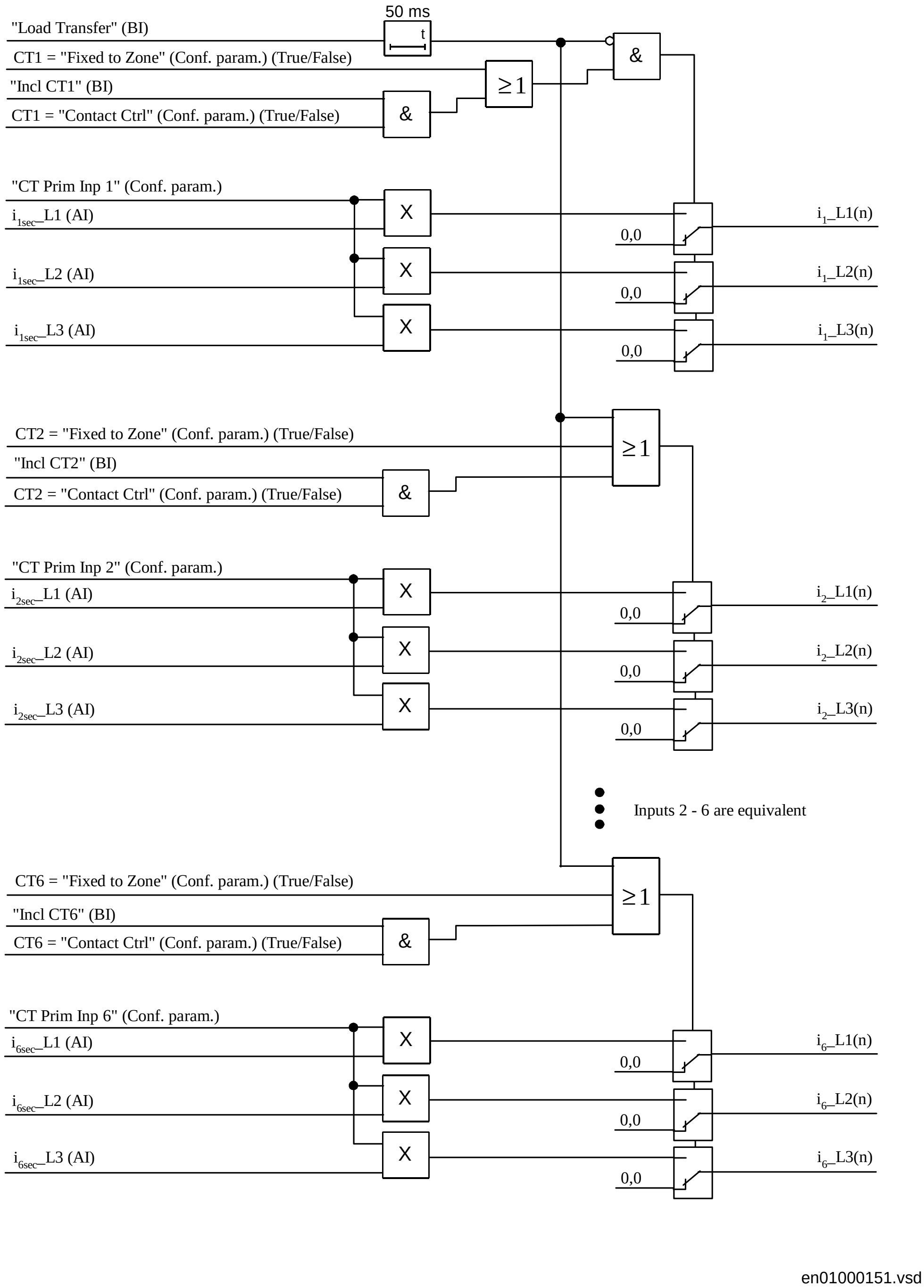


Fig. 4 Internal zone selection in three-phase version of RED 521 terminal

When any of the CT inputs is excluded from the differential zone, then the zero value is delivered to the differential algorithm instead of the measured current value.

4.3 Description of zone selection logic for one-phase terminal

In order to have properly balanced differential functions for the station busbar disconnector switching arrangements, it is important to properly configure the zone selection data for every connected current transformer. Due to this configuration parameter, the RED 521 terminal allows an effective application for stations where the zone selection (i.e. CT switching) is required. This is possible due to the software facility to have full and easy control over all CT inputs connected to the terminal. The philosophy is to allow every CT input to be individually controlled by a configuration parameter. This parameter called “ZoneSelection/CTx” can be individually configured for every CT input. The parameter can be set to only one of the following three alternatives:

1. Contact Ctrl
2. Fixed to ZA
3. Fixed to ZB

If for a particular CT input (i.e. input CTx) setting “Contact Ctrl” is selected, then the CTx input will be only included to the differential zone ZA when a dedicated binary input called “Include CTx ZA” is energized. In the similar way the CTx input will only be included to the differential zone ZB when a dedicated binary input called “Include CTx ZB” is energized. This means that the current connected to the CTx input can be dynamically included/excluded from the two differential zones by simply energizing/de-energizing the dedicated binary inputs of the RED 521 terminal.

If for a particular CT input (i.e. CTx) setting “Fixed to ZA” is selected, then this CT input is always included in the differential zone ZA irrespective of any other condition or status of any other binary input of the RED 521 terminal. This means that the CT current connected to the CTx input will always be included in the differential zone ZA.

If for a particular CT input (i.e. CTx) setting “Fixed to ZB” is selected then this CT input is always included in the differential zone ZB irrespective of any other condition or status of any other binary input of the RED 521 terminal. This means that the CT current connected to the CTx input will be always included in the differential zone ZB.

However, in addition to these configuration facilities a special software feature called “Load Transfer” is as well available. This feature can be activated manually via binary input or automatically as shown in Fig. 5:

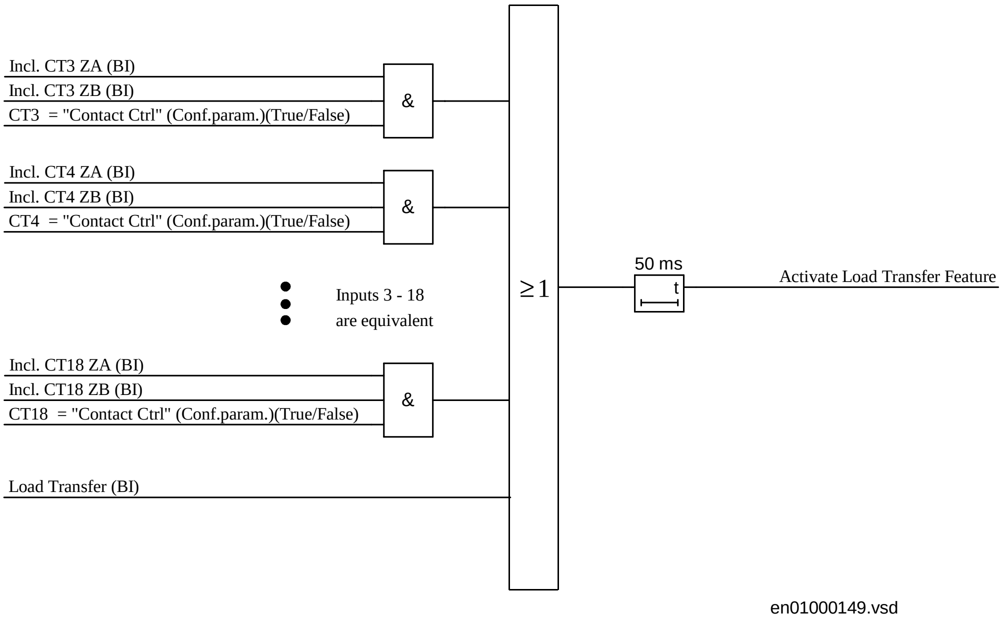


Fig. 5 Internal load transfer activation in one-phase version of RED 521 terminal

When this feature is activated the internal terminal measurement is reconnected so that inputs CT1 & CT2, which are connected to the CT´s in the bus-coupler bay, are unconditionally excluded from both differential zones, while all other CT inputs (i.e. CT3 - CT18) are simultaneously and unconditionally included into both differential zone (i.e. both differential zones measure exactly the same input data).

The overall internal logic for zone selection built-in the one-phase version of RED 521 terminal is shown in Fig. 6:

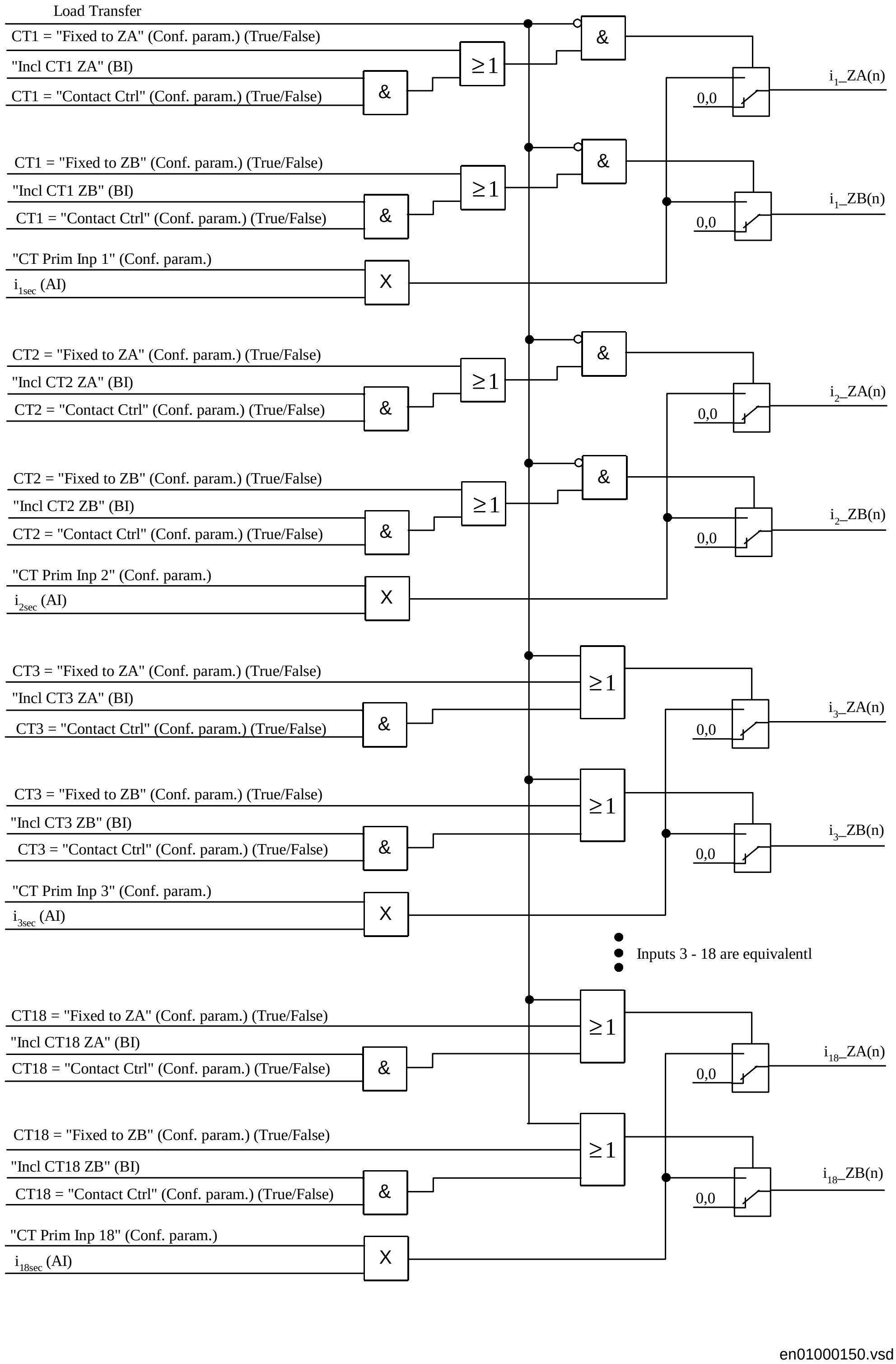


Fig. 6 Internal zone selection in one-phase version of RED 521 terminal

When any of the CT inputs is excluded from the differential zone, then the zero value is delivered to the differential algorithm instead of the measured current value.

5 Calculation of differential quantities

5.1 Summary of function

After zone selection logic, the calculation of relevant quantities from the CT input values are performed. Then these calculated values are passed to the general differential function and open CT algorithm for further processing.

5.2 Description of calculation

The calculations are completely phase-segregated therefore they will be explained for one phase only. Calculations for other two phases are done in exactly the same way.

The pre-requests for correct calculations are:

- Sampling of all analogue current inputs have to be done simultaneously
- Current samples have to be in primary amps
- All currents connected to the zone have to be measured with same reference direction (i.e. all towards the zone or all from the zone)

List of used symbols and abbreviations in this document:

i_j = instantaneous current value (i.e. latest sample value) for bay j

N = total number of bays connected to the protection zone

M = number of bays with positive value of the latest current sample (M<N)

i_d = instantaneous differential current (calculated from raw samples)

i_{in} = instantaneous incoming current into the zone of protection (calculated from raw samples)

i_{out} = instantaneous outgoing current from the zone of protection (calculated from raw samples)

Id = RMS value of the differential current

Iin = RMS value of the incoming current

Iout = RMS value of the outgoing current

First the instantaneous differential current is calculated as absolute value of the sum of all currents connected to the protection zone:

$$i_d = \left| \sum_{j=1}^{N} i_j \right|$$

Then only the sum of all latest current samples with positive value is made:

$$SP = \sum_{j=1}^{M} i_j$$

as well as the absolute value of the sum of all latest negative current samples:

$$SN = \left| \sum_{j=M+1}^{N} i_j \right|$$

Now the instantaneous incoming and outgoing currents are calculated as follows:

$$i_{in} = max\{SP, SN\}$$

$$i_{out} = min\{SP, SN\}$$

All these quantities are calculated for every set of samples (i.e. 20 times in one power system cycle in RED 521). It should be noted that all three quantities (i.e. i_{in}, i_{out} & i_d) will be of a “DC” nature in time (i.e. these quantities can only be positive). This means that the instantaneous incoming current during normal load condition looks like as the output of the full wave rectifier. It shall be noted that i_{in} is always bigger than or equal to i_{out}.

The Fig. 7 shows the comparison between above calculated quantities and REB 103 (or RADSS) design:

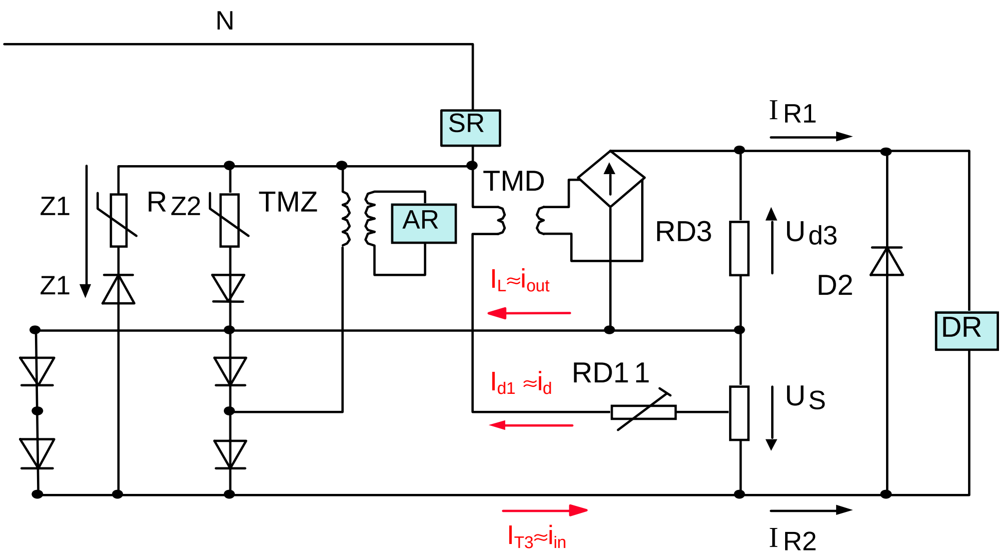


Fig. 7 Comparison between i_{in}, i_{out} & i_d quantities inside RED 521 terminal and REB 103 (or RADSS) analogue design

This practically means that any differential protection zone in RED 521 terminal can be represented as shown in Fig. 8, regardless the number of the connected feeders.

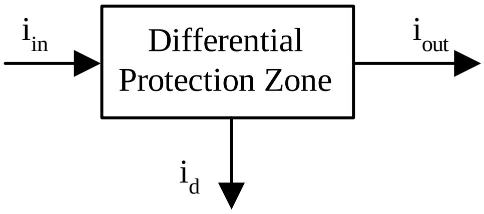


Fig. 8 Differential zone representation inside RED 521 terminal

The instantaneous quantities are constantly changing in time, therefore it was decided to additionally use RMS values of the incoming, outgoing and differential currents (i.e. Iin, Iout & Id respectively) as well. These quantities are calculated over last power system cycle (i.e. 20ms long, moving window for 50Hz system). The only requirement for this type of calculation is that the last twenty samples of the instantaneous quantity must be stored in the terminal internal memory. The calculated values of Iin & Id are available as service values on the built-in HMI.

When all six values (i.e. i_{in}, i_{out}, i_d, Iin, Iout & Id) are calculated, they are passed further to the general differential protection function & open CT algorithm for further processing.

6 General differential protection function

6.1 Summary of application

The general differential protection function in RED 521 terminal is designed for the selective, reliable and fast protection of busbars, T-connections, meshed corners, generators, autotransformers, etc. The function is applicable for the protection of medium voltage (MV), high voltage (HV) and extra high voltage (EHV) installations at a power system frequency of 50Hz or 60Hz. It can detect all types of internal phase-to-phase and phase-to-ground faults in solidly grounded or low impedance grounded power systems, as well as all internal phase-to-phase faults in isolated or high-impedance grounded power systems.

6.2 Input quantities

The six input quantities into the general differential function are:

- i_d = instantaneous differential current
- i_{in} = instantaneous incoming current into the zone of protection
- i_{out} = instantaneous outgoing current from the zone of protection
- Id = RMS value of the differential current
- Iin = RMS value of the incoming current
- Iout = RMS value of the outgoing current

See “Description of calculation” on page 169. for more information about them.

It shall be noted that the general differential function does not know the number of connected CT inputs into the RED 521 terminal.

The function is completely phase-segregated. Therefore it will be explained for one phase only.

6.3 CT saturation

Differential relays do not measure directly the primary currents in the high voltage conductors, but the secondary currents of magnetic core current transformers, which are installed in all high-voltage bays. Because the current transformer is a non-linear measuring device, under high current conditions in the primary CT circuit the secondary CT current can be drastically different from the original primary current. This is caused by CT saturation, a phenomenon that is well known to protection engineers. This phenomenon is especially relevant for bus differential protection applications, because it has the tendency to cause unwanted operation of the differential relay.

Another difficulty is the large number of main CTs (i.e. up to 18 for RED 521) which can be connected to the differential relay. If the CT saturation have to be checked and preventive measures taken for every HV CT connected to the protection zone on one-by-one basis, the differential relay algorithm would be slow and quite complex. Therefore in RED 521 design only the properties of incoming, outgoing and differential currents are used in order to cope with CT saturation of any main CT connected to RED 521 terminal as shown in Fig. 9.

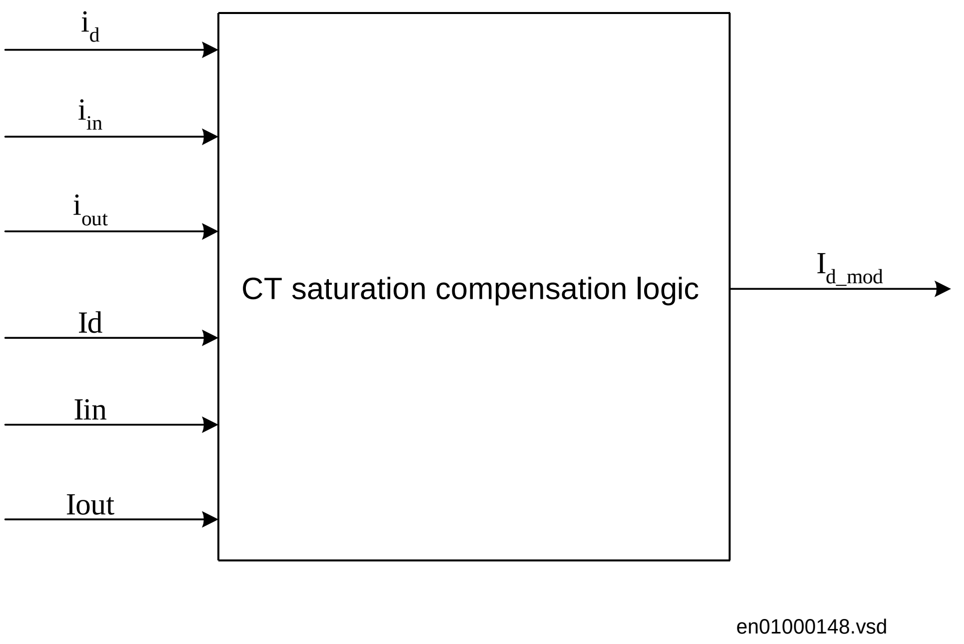


Fig. 9   CT saturation compensation logic inside RED 521 terminal

This CT saturation compensation logic effectively suppress the false differential current by looking into properties of the six input quantities. Output of the logic is modified RMS value of the differential current I_{d_mod} which has quite small value during external faults followed by CT saturation or full Id value in case of an internal fault.

This logic incorporate a memory feature as well in order to cope with full CT remanence in the faulty overhead line bay in case of a high speed autoreclosing onto permanent fault.

By this approach a new, patent pending differential algorithm has been formed which is completely stable for all external faults and operates very fast in case of an internal fault. All problems caused by the non-linearity of the CTs are solved in an innovative numerical way on the basic principles described above.

6.4 Tripping criteria

In order to provide reliable but fast differential protection, a multiple tripping criteria is implemented in general differential protection function.

The main tripping criterias can be listed as follows:

- Minimum differential current level (Id > Diff Oper Level)
- RMS tripping criteria (I_{d_mod} > 0.53 * Iin)
- Instantaneous tripping criteria based only on properties of i_{in}, i_{out} and i_d
- No pick-up of the “Block” binary input
- No operation of open CT algorithm

These tripping conditions are then arranged in an AND gate in order to provide final trip signal to the binary output contacts of the terminal.

For the testing purposes, the overall tripping criteria for the general differential function within RED 521 terminal can be represented with an operating characteristic, as shown in Fig. 10.

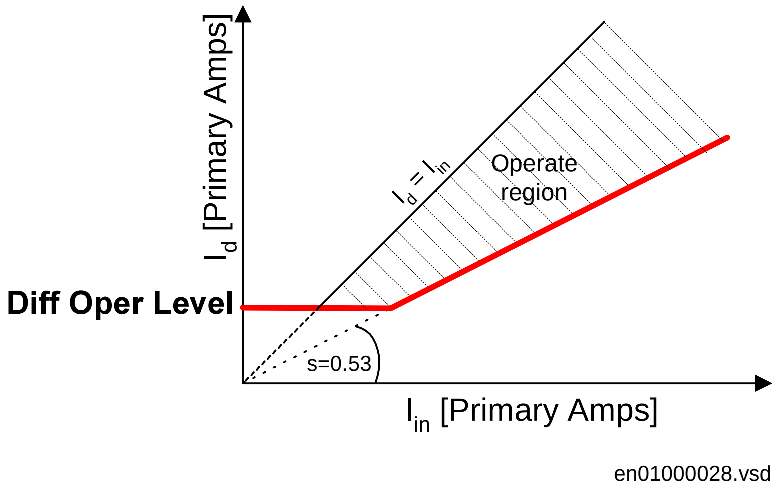


Fig. 10 Overall operating characteristic for the differential function in RED 521

Please note the following:

- in Fig. 10 I_{in} represents the RMS value of the incoming current to the differential protection zone
- in Fig. 10 I_d represents the RMS value of the differential current of the differential protection zone
- the operating slope for the differential function is fixed to 0.53 in the algorithm and can not be changed by the user

6.5 Setting parameter and ranges

Table 3: Differential function setting

Parameter Description	Parameter name	Range	Default
Minimum operating level for the differential function	Diff Oper Level	1 - 10000A	1000A

6.6 Service report values

Table 4: Service report values from the differential function

Parameter:	Description:
Id	RMS value of the differential current[a]
Iin	RMS value of the incoming current into differential zone[a]

a. This value is available for each phase and zone of protection

7 Open CT detection algorithm

7.1 Summary of function

Quite a number of main CTs can be connected to one bus differential relay. When a CT-circuit is open circuited by a mistake the differential relay might maloperate and disconnect all circuits connected to the protected busbar. This might have serious consequences for the power utility. Due to this reason a special algorithm is implemented inside of RED 521 terminal in order to prevent maloperation of the general differential protection function in case of an open CT circuit condition.

7.2 Input quantities

The three input quantities into the open CT detection algorithm are:

- Id = RMS value of the differential current
- Iin = RMS value of the incoming current
- Iout = RMS value of the outgoing current

See “Description of calculation” on page 169. for additional information.

It shall be noted that the open CT detection algorithm does not know the number of connected CT inputs into the RED 521 terminal.

The open CT detection algorithm is completely phase-segregated. Therefore it will be explained for one phase only.

7.3 Fast operating logic

Fast operating open CT detection logic will instantly detect the moment when an healthy CT secondary circuit carrying the load current is accidently opened (i.e. current interrupted to the differential relay). The logic is based on the perception that the total through-load current is the same before and after that CT is open circuited.

In order to prevent false operation of this logic in case of a fault or disturbance in the power system, the total through-load current must not have big changes three seconds before the open CT condition is detected.

When one CT secondary circuit is open circuited during normal through-load condition one measuring point is lost and therefore the following should hold true:

- values of Iin and Iout were equal one cycle before
- value of Iin remains constant (i.e. unchanged)
- value of Iout drops for more than pre-set value of “Open CT Level”
- value of Id rises for more than pre-set value of “Open CT Level”
- value of the sum Iout + Id is equal to value of Iin one cycle before

When all above conditions are simultaneously detected open CT condition is declared, the trip output of the affected phase is blocked and alarm output is set.

It shall be noted that this logic can only detect an instant of time when an already connected CT with the secondary load current is open circuited. This logic will not detect for example the situation when a new bay is connected to the differential zone, but its CT secondary circuits are short circuited or open circuited.

7.4 Slow operating logic

Slow operating open CT detection logic will detect most abnormalities in the CT secondary circuits or in the Zone Selection logic, but with the delay of one thousand power system cycles (i.e. 20s for 50Hz system or 16.67s for 60Hz system). The logic is based on the perception that the values of Iin and Iout shall be equal during normal through-load situation.

In order to prevent false operation of this logic in case of a low level noise signals the differential current of the protected zone must be bigger than pre-set value of “Open CT Level” before the open CT condition can be detected.

This logic will operate when:

- there was not any big through-load current change during last five seconds
- value of Iin is much bigger than value of Iout (0.9*Iin > Iout)

When these conditions are fulfilled for more than one thousand power system cycles the open CT condition is declared, the trip output of the affected phase is blocked and alarm output is set.

For small stations (i.e. with just few main CTs connected to RED 521 terminal) it might be necessary to set the minimum operational level for the differential current (i.e. setting parameter “Diff Oper Level”) to the value equal to or bigger than the rated primary current of the biggest CT connected to the terminal. This shall be done in order to avoid racing between trip command and slow operating open CT logic.

7.5 Setting parameters and ranges

Table 5: Open CT detection algorithm setting

Parameter Description	Parameter name	Range	Default
Minimum through-load current drop for open CT detection	Open CT Level	1 - 5000A	200A

Monitoring functionality

8 Event List

8.1 Summary of application

The RED 521 terminal is always supplied with internal time-tagged event list. When using a substation automation system, time-tagged events can be continuously sent from the terminal. These events come directly from the terminal internal event list which is always provided within the terminal.

8.2 Functionality

The time-tagged internal event list is always available from the front HMI or from another location over the LON data communication system. The event list operates on first-in-first-out principle. The last sixteen events are always available. Any change in the status of the following signals will cause a new entry in the terminal event list:

Table 6: Signals logged in the internal event list

Three Phase Version of the Terminal	One Phase Version of the Terminal
1) Trip Phase L1 2) Trip Phase L2 3) Trip Phase L3 4) Open CT Phase L1 5) Open CT Phase L2 6) Open CT Phase L3 7) Load Transfer 8) Trip Blocked	1) Trip zone ZA 2) Trip zone ZB 3) Open CT zone ZA 4) Open CT zone ZB 5) Load Transfer 6) Trip Blocked for zone ZA 7) Trip Blocked for zone ZB

A new event is generated at a change of any of the above signals.

The internal clock is used for time tagging of events in the internal event list. It can be synchronized, (See “Time synchronization” on page 159.), to achieve higher time tagging correlation accuracy between terminals. Without synchronization, the internal clock is only useful for comparisons among events within the terminal.

9 Remote communication (RC)

9.1 Summary of application

9.2 General

The remote communication can be used to obtain faster access to the information stored in the terminals and to send information to the terminal.

The remote communication can be used with computerized substation control system (SCS). LON communication is used for SCS

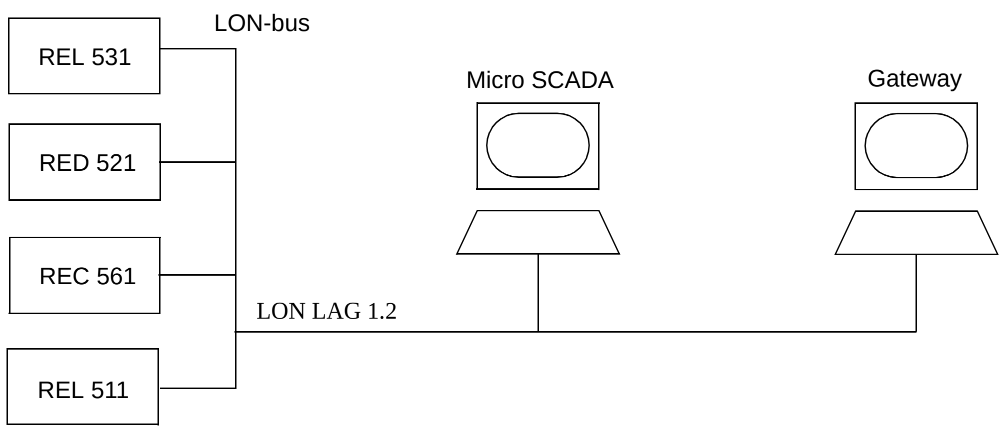


Fig. 11 Example of LON communication structure for SCS

9.3 Functionality

The remote communication use optical fibers for transfer of data within a station.

Remote communication to and from the terminal uses the LON LAG 1.2 protocol.

The LON protocol is specified in the *LON Protocol Specification*. This protocol is designed for communication in control networks and is a peer-to-peer protocol where all the devices connected to the network can communicate with each other directly.

9.4 Settings

The parameters for the LON communication are set with a special tool called LNT, LON Network Tool.

9.5 Configuration

The configuration of the LON communication port within the RED 521 terminal are entered from the HMI menu branch:

Configuration
LON Com

The following is possible to do/see under this HMI menu branch:

- Node Information
- Send Service PinMessage
- Set LON Default values
- Set Session Timers

9.5.1 LON communication

The hardware needed for applying LON communication depends on the application, but one very central unit is the LON Star Coupler and optical fibres connecting the star coupler to the terminals.

The LNT, LON Network Tool is used to set the communication parameters. This is a software tool, that is applied as one node on the LON bus.In order to communicate via LON, the terminals need to know which node addresses the other connected terminals have and which network variable selectors should be used. This is organized by the LNT. The node address is transferred to the LNT via the built-in HMI or the LNT can scan the communication network for new nodes.

The speed of the communication is set to default 1,25 Mbits/s. This can be changed by the LNT. If the communication stops, caused by setting of illegal communication parameters or by other disturbance, the parameters can be re-set to default values on the built-in HMI.

9.6 Setting parameters and ranges

9.6.1 LON communication

There are a number of session timers which can be set via the built-in HMI.These settings are only for advanced users and should only be changed after recommendation from ABB Automation Products AB.

Table 7: Session timers

Parameter	Default value	Description
SessionTmo	20s	Time-out value for the session
RetryTmo	2000 ms	Triggers a retransmission of the message if the message or ACK/NACK is missing when time is out.
IdleAckCycle	5s	Periocity for cyclic idle channel alive transmissions and retransmission of ACK when lost.
BusyAckCycle	300ms	ACK delay time upon received message. Sender can bypass the delay by flagging a message for immediate ACK.
ErrNackCycle	500ms	Periocity value for cyclic NACK transmission during network congestion

The chapter “Design description”.

This chapter describes the protection terminal hardware design and each module.

HW-description RED 521

10 Hardware design

The RED 521 follows the 6U Eurocard industry mechanical standard with a passive backplane and a number of slots. The backplane supports two kinds of modules, standard CompactPCI modules and specific ABB Automation Products AB modules based on the CAN bus.

All modules are designed for low power dissipation (no fans), EMC safety (both immunity and emission) and good environmental resistance. That gives high reliability and safe system also under disturbed and rugged conditions.

10.1 Hardware architecture

RED 521 consists of a number of different modules. These modules communicate through the PCI bus or the CAN bus. The PCI bus is used for modules which need extra high transfer rate. Modules with low and medium data rate use the CAN bus.

The local HMI unit communicates directly with the NUM module through two serial channels.

10.2 Hardware modules

The basic configuration of the RED 521 consist of the following modules:

- CBM, Combined Backplane Module. The backplane has 8 slots for CompactPCI modules and 4 slots for specific ABB Automation Products AB modules. One slot is designed for the power supply module.
- AIM, Analog Input Module. CompactPCI module with 10 high performance analogue input channels. The module consists of transformers, analogue to digital converters and a signal processor. Main functions in the software are:
  - time stamping of all values
  - filtering and calibration adjustments of analog inputs
  - self supervision

- NUM, Numerical Module. Main CPU module based on a high performance. Fits into the specific system slot in the backplane. The module may carry a mezzanine card, according to the PMC (PCI Mezzanine Card) standard, see SLM module. The software system is running under a real time operating system. Main functions in the software are:
  - administration of the CompactPCI bus
  - administration of the CAN bus
  - supervision of all modules included in the rack
  - control error handling
  - control the I/O system
  - handle local HMI
  - handle remote HMI (communication via LON bus)
  - RED521 function execution
- PSM, power supply module. DC/DC converter that support the electronics with +/-12V, +5V and +3,3V. The module can provide up to 50W. Supervision of all voltages are implemented. The module includes one relay output for the “Internal Fail” signal.
- HMI, human machine interface. Local HMI panel located at the front of the RED 521 terminal.
- SLM, Serial channel and LON channel Module. A mezzanine card for the NUM module, follows the PMC standard. Communication module with two optical interfaces.
- BIM, Binary input module. CAN based module with 16 optical isolated binary inputs. Main functions in the software are:
  - time stamping of all events
  - filtering of binary inputs
  - possibility to have any input as time synchronizing input using galvanic minute-pulse
  - self supervision
- BOM, Binary output module. CAN based module with 24 relay outputs. 24 single-output relays or 12 freely contacts for “select before execute” output relays. Main functions in the software are:
  - time stamping of all event
  - self supervision

11 Technical data

Table 8: Electromagnetic compatibility (EMC), immunity tests

Test	Type test values	Reference standards
1 MHz burst disturbance	2,5 kV	IEC 60255-22-1, Class III
Electrostatic discharge Direct application Indirect application	 8 kV, air discharge 6 kV, contact discharge 6 kV, contact discharge	 IEC 60255-22-2, Class III IEC 61000-4-2, Class III
Fast transient disturbance	4 kV	IEC 60255-22-4, Class IV
Surge immunity test	1-2 kV, 1,2/50 µs, high energy	IEC 61000-4-5, Class III
Power frequency magnetic field test	1000 A/m, 3 sec.	IEC 61000-4-8, Class V
Radiated electromagnetic field disturbance	10 V/m, (25-1000) MHz	IEC 61000-4-3, level 3
Radiated electromagnetic field disturbance	35 V/m, (25-1000) MHz	IEEE/ANSI C37.90.2
Radiated electromagnetic field disturbance, GSM	10 V/m, 900 MHz	ENV 50204
Conducted electromagnetic field disturbance	10 V, (0,15-80) MHz	IEC 61000-4-6, level 3

Table 9: Electromagnetic compatibility (EMC), emission tests

Test	Type test values	Reference standards
Electromagnetic emission, radiated	Class A	EN 55011
Electromagnetic emission, conducted	Class A	EN 50081-2

Table 10: Insulation tests

Test	Type test values	Reference standards
Dielectric test	2,0 kV ac, 1 min	IEC 60255-5
Impulse voltage test	5 kV, 1,2/50 µs, 0,5 J	IEC 60255-5
Insulation resistance	>100 MΩ at 500 V DC	IEC 60255-5

Table 11: CE-mark

Test	Reference standards
Immunity	EN 50082-2
Emissivity	EN 50081-2
Low voltage directive	EN 50178

Table 12: Mechanical tests

Test	Type test values	Reference standards
Vibration	Class I	IEC 60255-21-1
Shock and bump	Class I	IEC 60255-21-2
Seismic	Class I	IEC 60255-21-3

Table 13: Connection system

Connector type	Rated voltage	Maximum square area
CT and VT connectors	250 V AC	4 mm^2
Other electrical connectors	250 V AC	2,5 mm^2 2×1 mm^2
Fiber connectors	Glass: Bayonet ST Plastic: Snap in Simplex Latching	

Table 14: Additional general data

Weight approx.	18 kg
Dimensions width height depth	 448mm (1/1 of 19” rack) 267 mm 245 mm
Storage temperature	-40 °C to +70 °C
Operating temperature	-5° C to +55° C

12 Block diagram

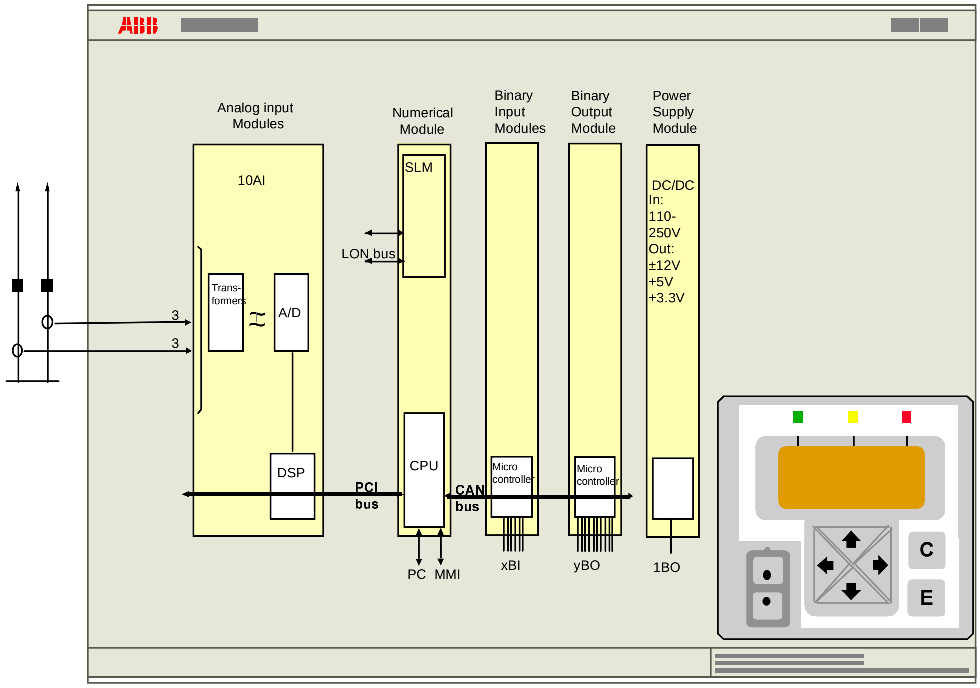


Fig. 12 Internal hardware structure of the RED 521 platform

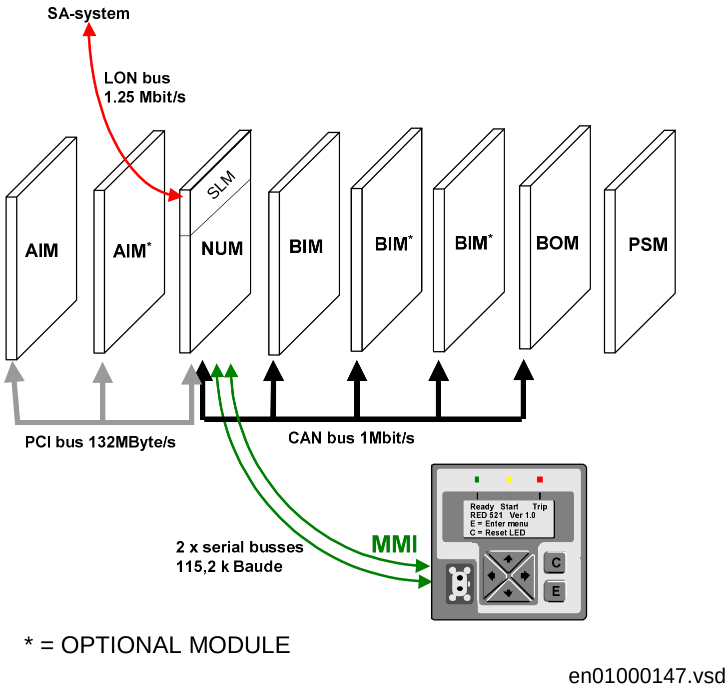


Fig. 13 Internal and external communications busses in RED 521

13 Terminal diagrams

For detailed information please see the terminal diagrams, part of the section five of RED 521 manual.

HW-modules

14 Numerical module (NUM)

14.1 Hardware design

The NUM, NUmerical Module is a high performance, compact-PCI CPU module. It uses the 6U-format on the board and takes one slot in height.

For communication with high speed modules ex. analog input modules and high speed serial interfaces the NUM is equipped with a CompactPCI bus. The NUM is the compact PCI system card i.e. it controls busmastering, clock-distribution and receives interrupts.

NUM is equipped with a PMC slot (32-bit IEEE P1386.1 compliant) in which as an option a daughter-card may be mounted e.g. an SLM for SPA and LON.

To reduce bus loading of the compactPCI bus in the backplane the NUM has one internal PCI bus for internal recourses and the PMC slot and external PCI accesses through the backplane are buffered in a PCI/PCI bridge.

The application code and configuration data is stored in flash memory using a flash file system. During power up the application code is moved to and then executed from the DRAM. The code is stored in the flash memory because its nonvolatile and executed in DRAM because of the DRAMs higher performance.

The NUM is equipped with a real time clock and complies with the year 2000 transition. It uses a battery for power backup of the real time clock and this has to be changed on regular bases e.g. 5 years. This is only necessary when no time synchronization is used.

All the communication not possible with a standard CPU-module is added on the CEM.

No fans are used on this standard module since the power dissipation is low.

14.2 Technical specifications

The NUM conforms to the CompactPCI Specification revision 2.0.

Take care when using PMC modules as to how much current they require, especially from the +5V supply

14.3 Block diagram

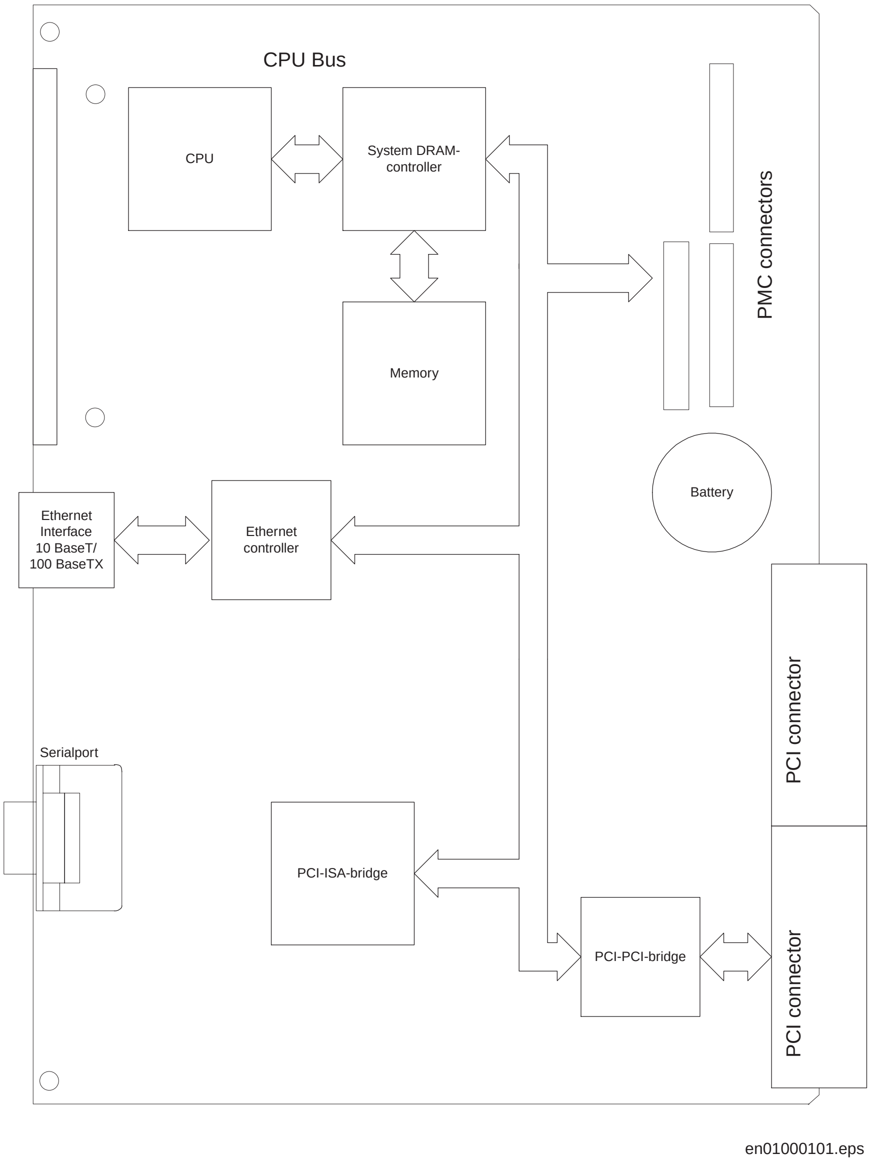


Fig. 14 NUmerical Module block diagram (actual placement of components differ)

15 Compact backplane module (CBM)

15.1 Hardware design

CBM is a backplane that has 8 CompactPCI connectors and 4 connectors for RCAN based ABB boards. One of the CompactPCI connectors have a special use since it hosts the CEM and is therefore mounted on the opposite side of the backplane. For the compact PCI slots a 220pin 2mm Hard Metric connector is used. The RCAN based ABB boards uses a 3 row, 96 pin standard Euro-connector. There is a need for some signals to be present in both connector types. For this purpose some of the User defined part of the CompactPCI connector is used. There are no user pins use on the system-slot (for the CPU-module).

The CompactPCI specification gives the possibility for a 3.3V OR 5V signaling in the backplane. The CBM backplane and connected modules are 5V PCI-compatible.

Some pins on the CompactPCI connector is connected to the RCAN bus, to be able to communicate with RCAN based modules.

For identification in production and field upgrades the CBM is equipped with two Id chips with the contents of a factory programmed unique serial number and during production it is programmed with article number, hardware version and final test date. One Id contains backplane data and the other contains product data.

For the power supply there is a 3 row, 96 pin, Euro-connector.

For power degradation early warning there is a signal, AC Fail.

If a modules self-test discovers an error it informs other modules through the Internal Fail signal.

15.2 Technical specifications

Table 15: Mounted connectors

Function	Connector identifier
CompactPCI	X1-8 (where X2 is mounted on the opposite side for CEM)
RCAN based	X9-12
Power supply	X14
MMI connector	X30

Table 16: The buses in the backplane are connected to the following connectors.

Bus	Connectors
CompactPCI	X1-8 (X8 according to v2.1 where no user pins are used, rest is according to v1.0 of the CompactPCI-standard)
RCAN	X1-7,9-12,14
MMI display and keyboard interface	X1-7,9-12
MMI optical communi-cation interface	X1-7,9-12

Table 17: Special signals

Signal	Description	Connector
PRST	System reset	X1-7,9-12,14
AC_FAIL_N	Power supply degradation early warning	X1-7,9-12,14
INTERNAL_FAIL_N	Module failure broadcast signal	X1-7,9-12,14
PPS, MPPS, CMPPS	Timesyncronisation	X1-7,9-12,14
SYS_ID	Electronic ID	X1-7,9-12,14

Impedance matching: Every signal is impedance matched to 65 Ohm +/-10%, calculated for a bare PCB.

15.3 Block diagram

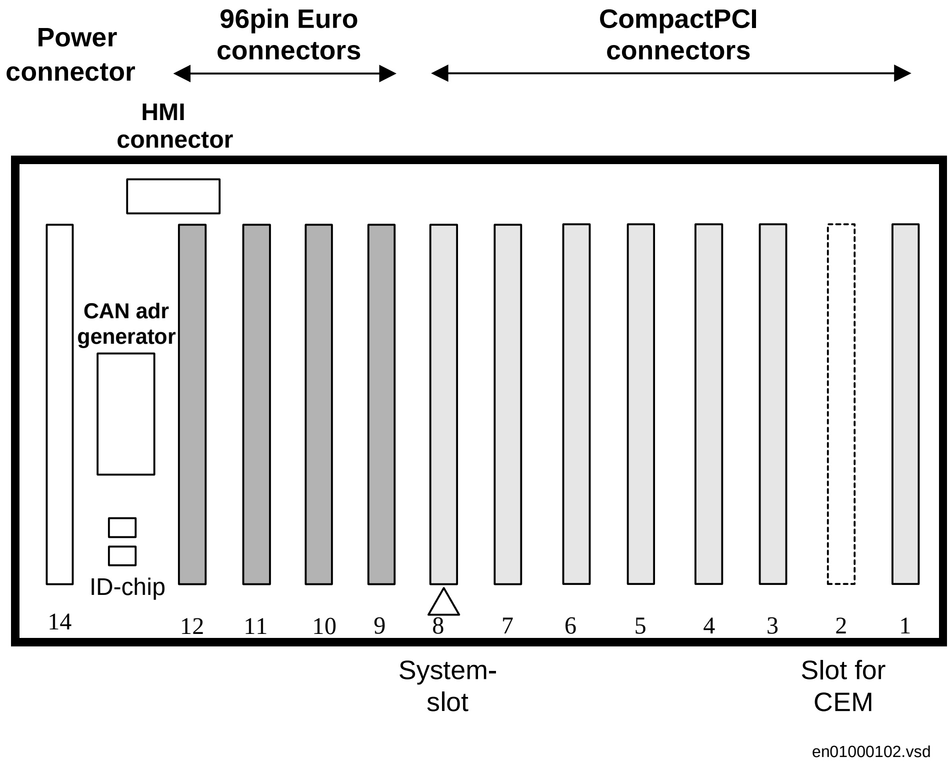


Fig. 15 Connectors on the 3/4 backplane as seen from the connector side

16 Combination Extension backplane Module (CEM)

16.1 Hardware design

CEM is an addition to the CBM and is mounted on the CompactPCI-connector X2 placed on the opposite side of the CBM. For the compact PCI slot a 220pin 2mm Hard Metric connector is used. All communication between the RCAN based ABB boards are handled inside the CEM.

There are also two asynchronous serial ports. One for the HMI-display and keyboard and one for the HMI optical interface.

For identification in production and field upgrades the CEM is equipped with two ID chips with the contents of a factory programmed unique serial number and during production it is programmed with article number, hardware version and final test date. One ID contains CEM data and the other contains the data about the standard CPU-module, NUM. It also handles the common ID-signal SYS_ID in the same way.

The CEM also handles the power degradation early warning signal, AC Fail, and present this as an interrupt to the CPU-module.

If a modules self-test discovers an error it informs other modules through the Internal Fail signal. Since there is no direct connection to the CPU-module the CEM also handles this signal.

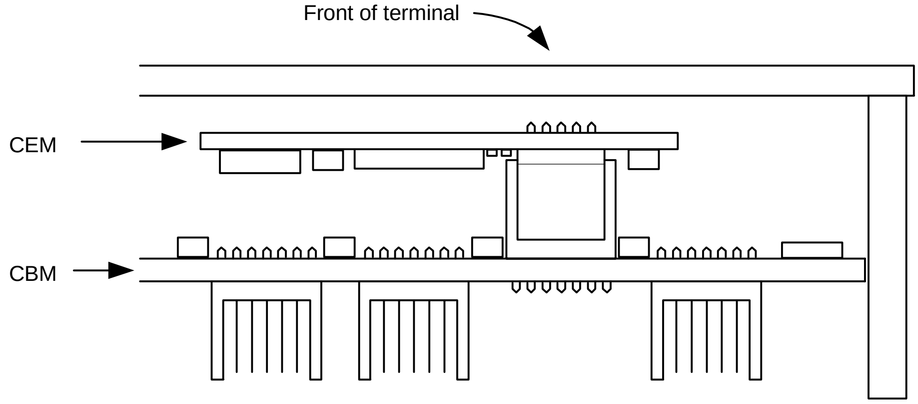


Fig. 16 CBM and CEM seen from the top of the terminal

16.2 Technical specifications

CEM uses the CompactPCI specification revision 1.0 where user pins are available.

Table 16.1: Resources

Function	Description
Serial I/O	HMI display and keyboard interface
Serial I/O	HMI optical communication interface
RCAN interface	Communication with all RCAN based modules on the backplane, CBM.
ID chips	Handling of the three ID-signals.

Table 16.2: Special signals

Signal	Description
PRST	System reset
AC_FAIL_N	Power supply degradation early warning

Table 16.2: Special signals

Signal	Description
INTERNAL_FAIL_N	Module failure broadcast signal
SYS_ID	Electronic ID
RCAN_ID	Rack information ID. Slot numbers

16.3 Block diagram

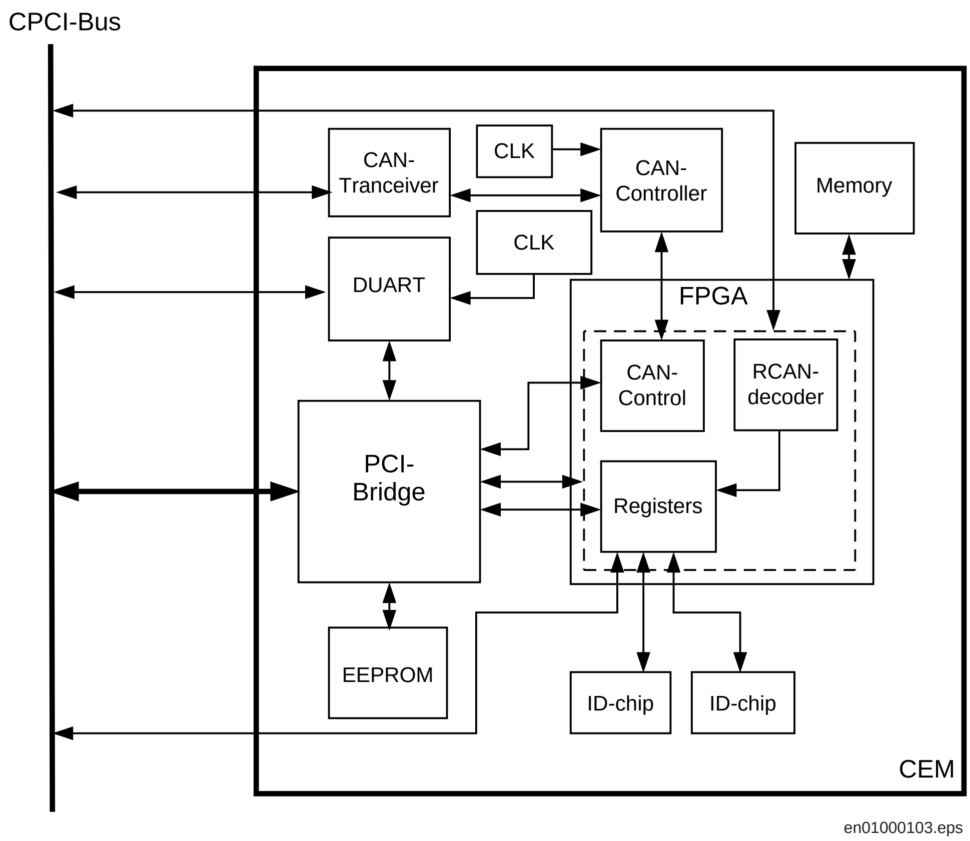


Fig. 17 CEM block diagram

17 Power Supply Module (PSM)

17.1 Hardware design

There are two different types of power supply modules. The power supply module contains a built-in, self-regulated DC/DC converter that provides full isolation between the terminal and the external battery system.

The PSM, converts an input voltage range from 110 to 250 V, including a ±20% tolerance on the EL voltage.

The output voltages are +3.3, +5, +12 and -12 Volt and the module can provide 50W.

17.2 Block diagram

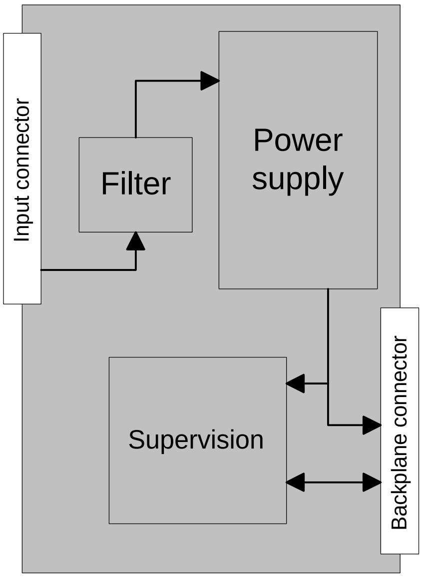


Fig. 18 Block diagram for the PSM.

18 Analogue input module (AIM)

18.1 Hardware design

The analogue input module (AIM) consists of two connectors for the external connections and two printed board assemblies; transformer board and A/D board.

Current and voltage input transformers are mounted on the transformer board. The transformers form an insulating barrier between the external wiring and the A/D-conversion board, and adapt the values of the measuring quantities to the input circuits of the A/D-conversion board. Maximum ten transformers can be mounted on the transformer board. The design is made for mounting of a current transformer alternatively a voltage transformer in all of the transformer places.

The other printed board assembly is the A/D-conversion board. Over a contact socket strip on the transformer board and a contact pin strip on the A/D board the signals from the transformers are transmitted to input channels of the A/D board. This board is mainly filtering and converting analogue to digital signals. The transmission of data between the A/D board of the analogue input module and the numerical module is done on a backplane board with a CompactPCI bus. The A/D board has ten measuring channels. The channels are equipped with components for current measuring alternatively voltage measuring.

The printed circuit board assemblies and the external connectors are attached with screws to a common mounting plate. The primary windings of the transformers are connected to the external connectors with cables.

Variants of the analogue input module are provided with components for time-synchronization. The time-synchronization components are located on the A/D board. An external synchronization pulse from a synchronization device will be used to get the same time everywhere in the system when the modules are distributed.

18.2 Technical specifications

18.2.1 Transformer board

Toroidal type of transformers are used as current input transformers and EI 38 type of transformers are used as voltage input transformers. The current transformers have windings for both 1A and 5A rated current. The voltage transformers are covering a rated range from 57,7V to 120V. The process interface of the external connector has screw terminals for maximum one conductor with the area $4mm^2$ alternatively two conductors with the area $2,5\ mm^2$.

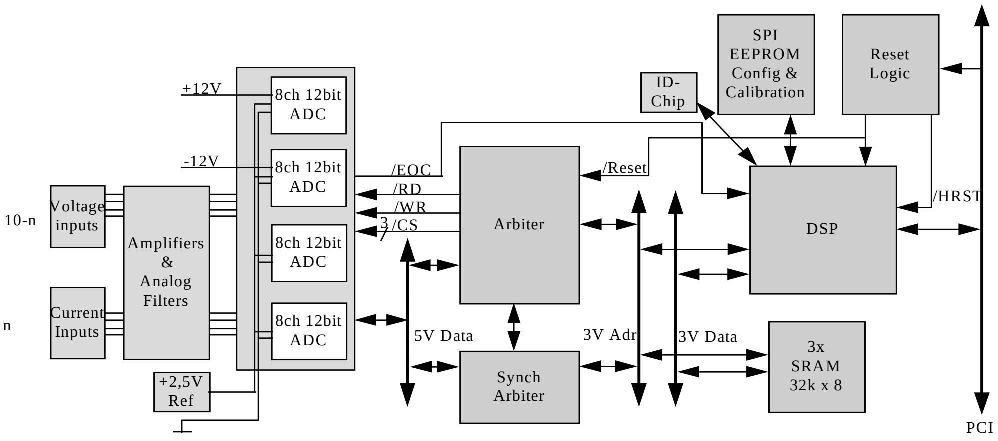
18.2.2 A/D-conversion board

The signals from the transformer board are amplified and filtered with a bandwidth of 10kHz on two ranges for each channel and converted with a resolution of 12 bits. The results, from the conversion on the two ranges, are combined into a single 24bit word and filtered in two cascaded decimation filters programmed into a digital signal processor (DSP).

The numerical filters are of finite impulse response type, giving a linear phase response and appropriate anti aliasing.

High accuracy is obtained by a calibration process and internal supervision of all vital functions is implemented.

18.3 Block diagram for the A/D-conversion board



19 Binary input module (BIM)

19.1 Hardware design

In RED521 the BIM module can be located in positions P9, P10 & P11 depending on the version of the terminal. The voltage level of the input modules is selectable at order RL48, 110, or 220 (48/60 V ±20%, 110/125 V ±20% or 220/250 V ±20%). The Binary input module are also available in an RL 24 version (24/30 V ±20%).The Binary input module contains 16 optical isolated binary inputs.

Fig. 19 shows the operating characteristics of the binary inputs of the three voltage levels.

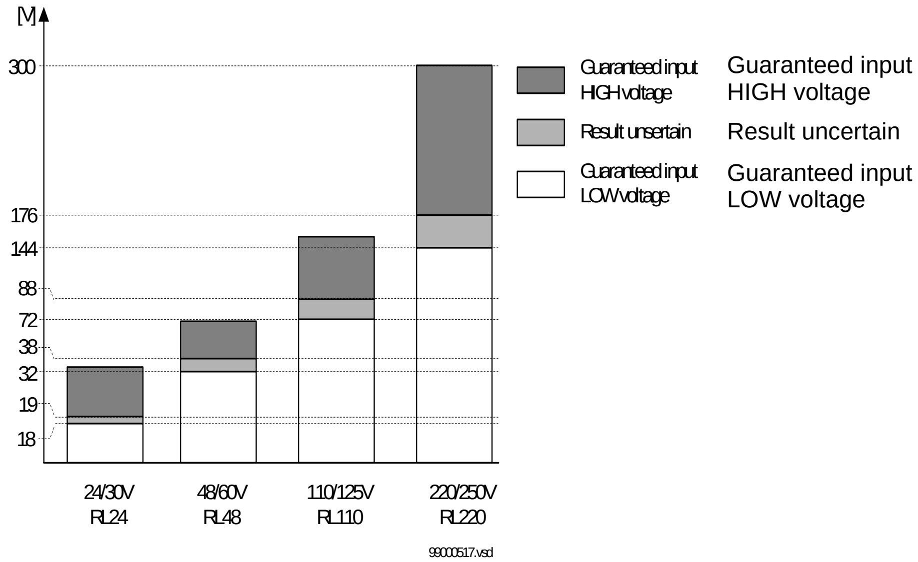


Fig. 19 Voltage dependence for the binary inputs

This module communicates with the NUmerical Module via the CAN-bus on the backplane.

The design of all binary inputs enables the burn off of the oxide of the relay contact connected to the input, despite the low, steady-state power consumption, which is shown in Fig. 20.

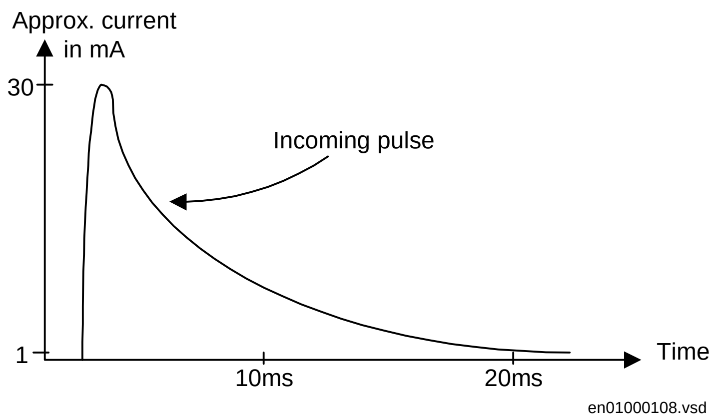


Fig. 20 Current through the relay contact

19.2 Technical specifications

Table 18: Energizing quantities, rated values and limits

Quantity	Rated value	Nominal range
Binary input module		
dc voltage RL	RL24 = (24/30)V RL48 = (48/60)V RL110 = (110/125)V RL220 = (220/250)V	± 20 % ± 20 % ± 20 % ± 20 %
power consumption		
each input-board	≤ 0,5 W	
RL24 = (24/30)V	max. 0,05 W/input	
RL48 = (48/60)V	max. 0,1 W/input	
RL110 = (110/125)V	max. 0,2 W/input	
RL220 = (220/250)V	max. 0,4 W/input	

19.3 Block diagram

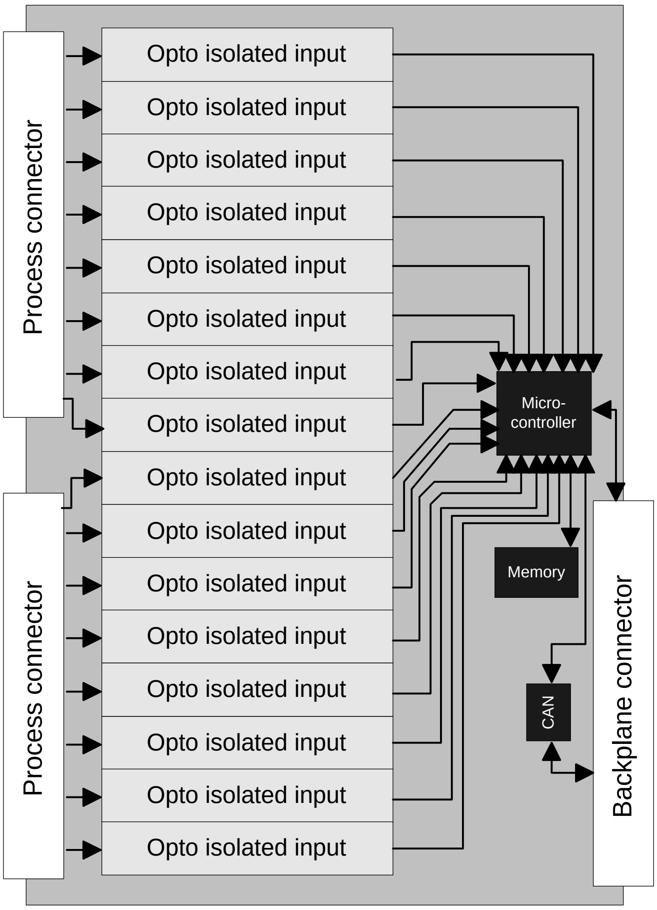


Fig. 21 Block diagram of the Binary input

20 Binary output module (BOM)

20.1 Hardware design

In RED521 the BOM module is located in position P12. The Binary output module has 24 single-output relays. They are grouped together in twelve groups of two as can be seen in the block diagram below. All the output relays have contacts with a high switching capacity (Trip and signal relays)

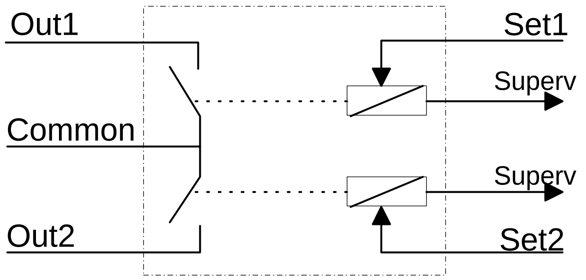


Fig. 22 One of twelve binary output groups

20.2 Technical data

Quantity:	Rated value:	Nominal range:
Binary output module power consumption each output-board each output relay	 ≤ 1,0 W ≤ 0,25 W	

20.3 Block diagram

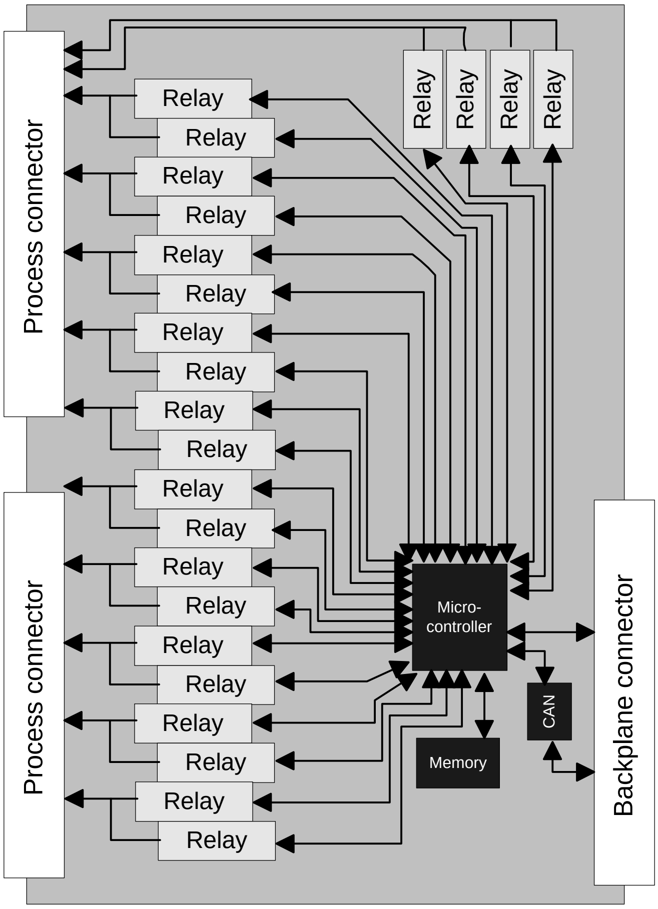


Fig. 23 Block diagram of the Binary Output Module

Referenced publications

No applicable publications available.

Summation Principle of RED 521

This chapter describes how the summation type bus differential protection scheme with RED 521 can be used and applied in a power network.

Summation Principle of RED 521

1 Introduction

A simplified bus differential protection for phase and ground faults can be obtained by using a single, one-phase RED 521 terminal with external auxiliary summation current transformers. By using this approach, more cost effective bus differential protection can be obtained. Such a solution makes it feasible to apply bus differential protection even to medium voltage substations.

The principal differences between full, phase-segregated bus differential protection scheme and summation type bus differential protection scheme with RED 521 are shown in Figure 1.

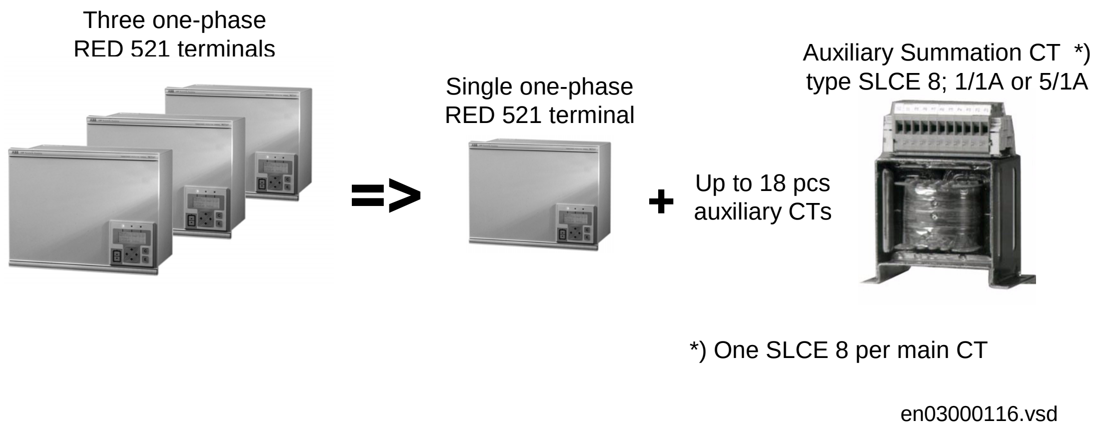


Figure 1 Difference between phase segregated & summation type differential protection

In the full, phase-segregated design three, one-phase RED 521 terminals (i.e. one per phase) are used. However for the summation type only single, one-phase RED 521 terminal plus one auxiliary summation CT per each main CT is required. These auxiliary summation CTs convert each main CT 3-phase currents to a single-phase output current, which are all measured by one RED 521 terminal. The differential calculation is then made on a single-phase basis. By doing so, this more cost effective bus differential protection can be applied. Due to this characteristic, this summation type of bus differential protection with RED 521 can be applied for all types of stations arrangements as shown section “Application of RED 521 Terminal” in the RED 521 User’s Manual, for three, one-phase terminals.

As an example, the necessary equipment for the summation type, busbar differential protection for a single busbar station with up to eighteen bays, is shown in Figure 2.

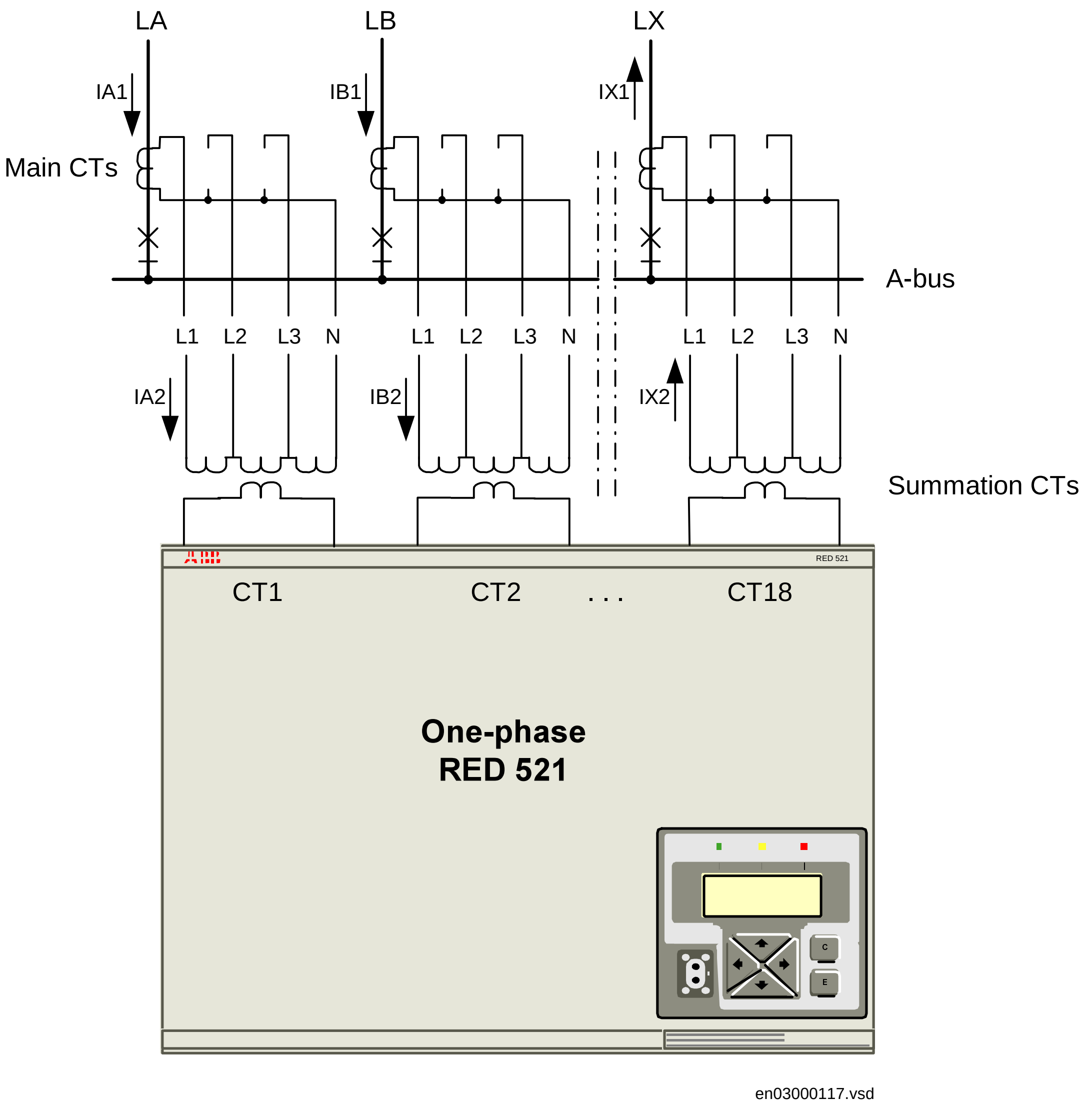


Figure 2   Principle CT connections for the complete station

This summation type bus differential protection still has the same main CT requirements as outlined in section “Application of RED 521 Terminal”, in the User’s Manual for the phase segregated RED 521 terminal. Some of these are:

- main CT ratio differences can be tolerated up to 10:1 (e.g. 3000/5A CT can be balanced against CT's as low as 300/5)
- different main CT ratios are compensated numerically by a parameter setting
- main CT shall not saturate quicker than 2ms (please refer to chapter “Application of RED 521 Terminal” in the RED 521 manual for detailed CT requirements regarding main CT knee-point voltage)

However, due to the summation principle this type of busbar protection scheme has the following limitations:

- Only one measuring circuit is utilized for all fault types (i.e. no redundancy for multi-phase faults)
- Primary fault sensitivity varies depending on the type of fault and involved phase(s), see Table 2
- The load currents in the healthy phases might produce the stabilizing current when an internal, single phase to ground fault occurs. However this is in general no problem for solidly earthed systems with high earth-fault currents
- No indication of faulty phase(s) in case of an internal fault
- Not possible to fully utilize Open CT detection feature built-in in RED 521 terminal

2 Auxiliary Summation CTs for RED 521

Auxiliary Summation Current Transformer (i.e. ASCT in further text) of the type SLCE 8 is used with the summation principle of RED 521. The principle drawing of one such ASCT is shown in Figure 3.

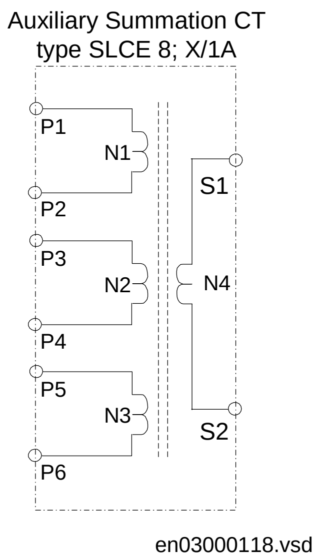


Figure 3   Principle ASCT drawing

The ASCT has three primary windings and one secondary winding. In further text, turn numbers of these windings will be marked with N1, N2, N3 & N4, respectively (see Figure 3 for more information).

There are only two types of ASCT for RED 521:

1 ASCT type with ratio 1/1A, for balanced 3-Ph current input, shall be used with all main current transformers with 1A rated secondary current (i.e. 2000/1A)

2 ASCT type with ratio 5/1A, for balanced 3-Ph current input, shall be used with all main current transformers with 5A rated secondary current (i.e. 3000/5A)

Please note the following:

- main CT rated primary current is not important for ASCT selection
- possible main CT ratio differences will be compensated by a parameter setting in RED 521 terminal
- rated secondary current of ASCT is 1A for both types. That means that secondary ASCT winding should be always connected to 1A tap on RED 521 terminal, irrespective of the rated secondary current of the main CT

All of these features simplify the ordering of the ASCTs. Practically, in order to purchase ASCTs, the only required information is the main CT rated secondary current (i.e. 1A or 5A).

Table 1 summarizes the ASCT data:

Table 1: Auxiliary summation CT data

	N1	N2	N3	N4	Ukp [V]	Burden [VA]
ASCT SLCE 8; 1/1A	52	52	104	90	33	1.0
ASCT SLCE 8; 5/1A	12	12	24	104	38	1.0

Where:

- N1, N2, N3 & N4 are ASCT windings turn numbers (see Figure 3)
- Ukp is knee point voltage, at 1.6T, of the secondary winding with N4 turns
- Burden is the total 3Ph load of ASCT imposed to the main CT

Please note that due to ASCT design, the ASCTs for summated bus differential protection, must always be mounted as close as possible to the RED 521 terminal (i.e. in the same protection cubicle).

3 Possible ASCT connections for RED 521

It is possible to connect the ASCTs for summated bus differential protection with RED 521:

- at the end of the main CT circuit (e.g. beyond the other protective relays - see Figure 4)
- in series with other secondary equipment when some other relay must be located at the end of the main CT circuit (see Figure 5)

End connection is the preferred arrangement as it gives greater sensitivity for summation type bus differential protection (see Table 2 for more information).

However, it should be noted that these two connection types must not be mixed. This means that within one busbar installation all auxiliary summation CTs have to be either end-connected or series-connected.

Typical end-connection with ASCT is shown in Figure 4.

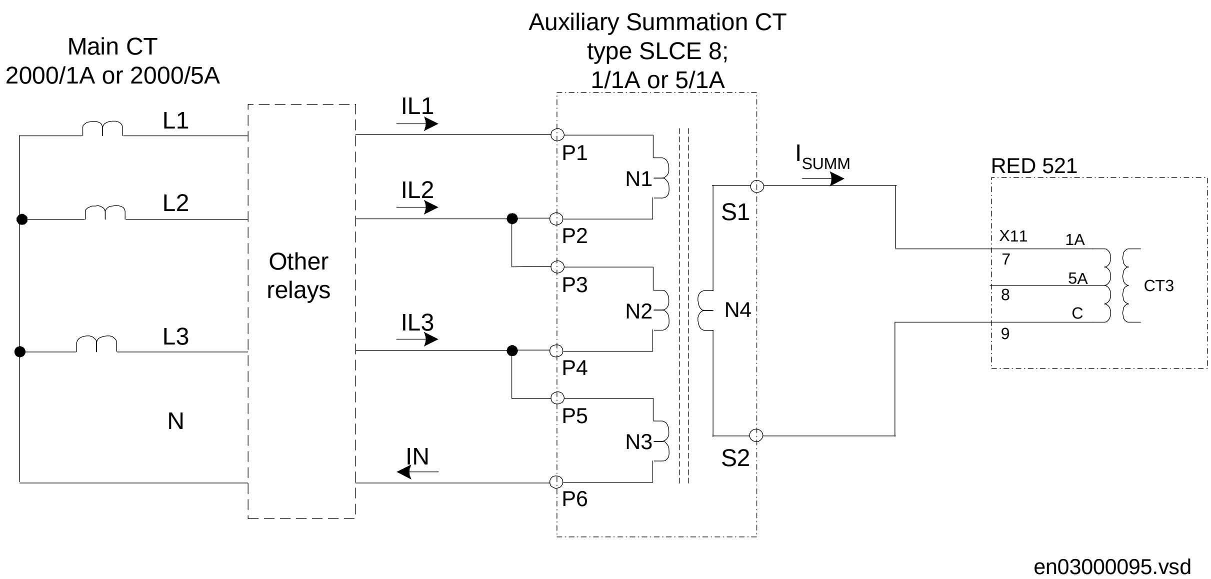


Figure 4 End-connection with ASCT connected to CT3 input of RED 521 terminal

It is important to notice that even in the case of 5A main CTs, secondary current of the summation CTs shall be connected to 1A input of RED 521 (see Figure 4). The reason for this is that the rated secondary current of ASCT is always 1A irrespective of the rated secondary current of the main CT.

Please refer to Annex 1 for detailed ASCT current calculations for end-connection.

Typical series-connection with ASCT is shown in Figure 5.

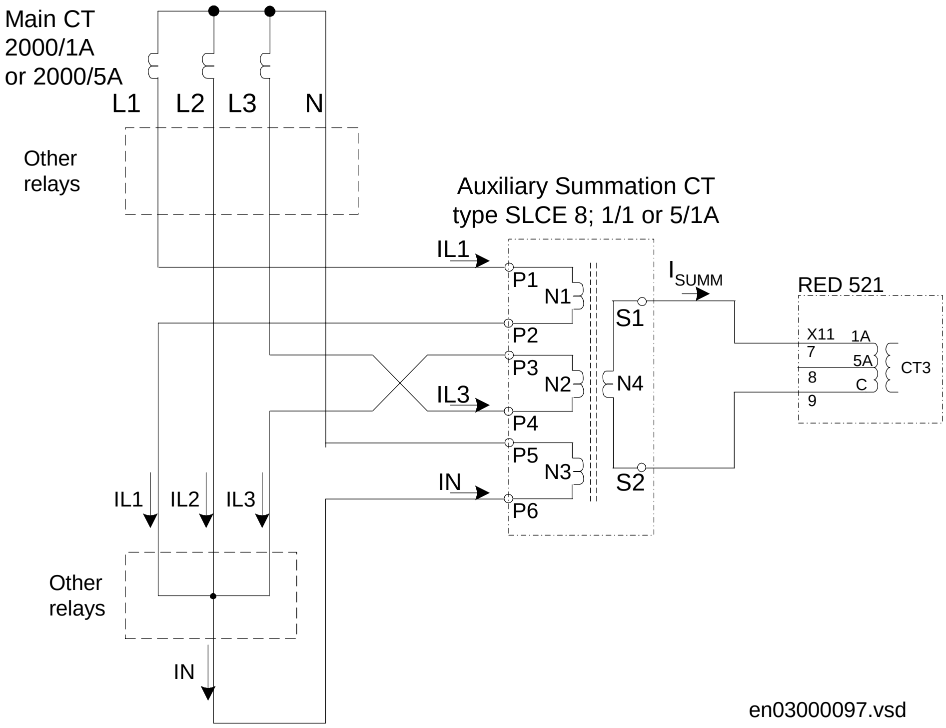


Figure 5   Series-connection with ASCT connected to CT3 input of RED 521 terminal

Please refer to Annex 2 for detailed ASCT current calculation for series-connection.

4 Main CT ratio mismatch correction

As stated before only two types of ASCTs for RED 521 are available. The first type shall be used for main CTs with 1A rated secondary current. The second type shall be used for main CTs with 5A rated secondary current. Different main CT ratios still will be corrected by a configuration parameter setting, which should be entered in the RED 521 front HMI. The rated primary current of the main CT shall be entered in the front HMI. This procedure is exactly the same as for the phase segregated RED 521 differential protection. Please refer to section “Configuration & Settings” in the RED 521 manual for detailed setting description.

5 Primary Pick-up Levels for Summation type differential protection with RED 521

In the RED 521 differential terminal, the minimal differential operating current level is entered directly in primary amperes. However, as stated previously, in case of the summated differential protection the primary fault sensitivity varies depending on the type of fault and involved phase(s). The entered value, for the minimal differential operating current level, will exactly correspond to the RED 521 pickup value in the event of a 3-phase internal fault. For all other fault types this value must be multiplied by a coefficient shown in the Table 2 in order to calculate the actual primary pickup value.

Table 2: Pickup coefficients for Summated Differential Protection with RED 521

Type of fault	L1-Gnd	L2-Gnd	L3-Gnd	L1-L2	L2-L3	L3-L1	L1L2L3
ASCT end connected	0.434	0.578	0.867	1.732	1.732	0.867	1.0
ASCT series connected	1.732	0.867	0.578	1.732	1.732	0.867	1.0

Please note that the above coefficients are only relevant for ideal internal faults (i.e. load currents do not exist in the healthy phases).

Example #1:
The minimal differential operating current level in RED 521 terminal is set to 1250A. All ASCTs are series connected. What is the theoretical primary pickup value in case of L3-Gnd fault?

Answer #1:
According to Table 2, pickup coefficient for this type of ASCT connection and this type of fault is 0.578. Therefore:

$$I_{\text{Pickup}}(L3-Gnd) = 0.578 \cdot 1250 = 722.5\text{A}$$

Equation 1

This means that if 722.5 primary amperes is injected only in phase L3 of any of the connected main CTs, RED 521 shall display the differential current of 1250A (primary) and should be on the point of the pickup (i.e. trip).

6 Ordering

For the summated bus differential protection the following equipment shall be ordered:

1 Single piece of one-phase bus differential terminal RED 521. Depending on the number of required main CTs which shall be connected either 9-bay or 18-bay version shall be ordered.

2 Auxiliary summation current transformers. They are ordered as a set of three SLCE 8, ASCTs mounted on a 2U high, 19” wide plate. All three ASCTs have 1/1A or 5/1A ratio (see Figure 6 for more information). Please note that it is not possible to order just one SLCE 8, ASCT as stand alone unit.

3 Tripping relays, disconnector replica relays etc. shall be ordered as for the phase segregated bus differential protection in accordance with specific busbar arrangement.

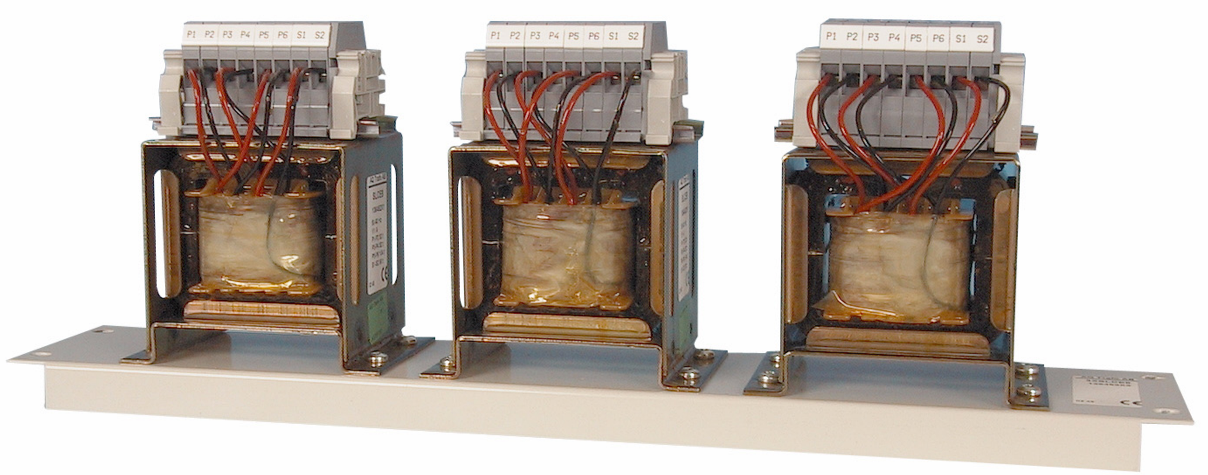


Figure 6 Three SLCE 8, ASCTs mounted on a 2U high, 19” wide plate

Annex 1 SLCE 8/ASCT characteristics for end-connection

Typical ASCT end-connection is shown in Figure 4. For this ASCT connection type, the ampere-turn balance equation has the following form:

$$\mathrm{N4} \cdot I_{\mathrm{SUMM}} = \mathrm{N1} \cdot \mathrm{IL1} + \mathrm{N2} \cdot (\mathrm{IL1} + \mathrm{IL2}) + \mathrm{N3} \cdot (\mathrm{IL1} + \mathrm{IL2} + \mathrm{IL3})$$

Equation 2

The relationships between number of turns for this SLCE 8, ASCT for RED 521, is shown by the following three equations:

$$\mathrm{N1} = \mathrm{N2} = \mathrm{N};$$

Equation 3

$$\mathrm{N3} = 2 \cdot N$$

Equation 4

$$\mathrm{N4} = k \cdot \sqrt{3} \cdot N$$

Equation 5

where k is a constant, which depends on the type of ASCT (i.e. k=1, for 1/1A ASCT or k=5 for 5/1A ASCT).

The well-known relationship, between positive, negative and zero sequence current components and individual phase current quantities is shown in the following equation:

$$\begin{bmatrix} \mathrm{IL1} \\ \mathrm{IL2} \\ \mathrm{IL3} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ a^2 & a & 1 \\ a & a^2 & 1 \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \\ I_0 \end{bmatrix}$$

Equation 6

where a is complex constant (i.e. a=-0.5+j0.866).

By including Equation 3, Equation 4, Equation 5 and Equation 6 into the Equation 2 the following equation for the end-connected, ASCT secondary current (i.e. summated current) can be derived:

$$I_{\text{SUMM}} = \frac{1}{k} \cdot (I_1 \cdot e^{-j30°} + I_2 \cdot e^{j30°} + 3 \cdot \sqrt{3} \cdot I_0)$$

Equation 7

From Equation 7 it is obvious that for the ASCT rated ratios (i.e. 1/1A and 5/1A) are declared for balanced three phase current system, when only positive sequence current component exist. For any unbalanced condition (i.e. external or internal fault), both negative and zero sequence current components will give their own contribution to the summated current.

Annex 2 SLCE 8/ASCT characteristics for series-connection

Typical ASCT series-connection is shown in Figure 5. For this ASCT connection type, the ampere-turn balance equation has the following form:

$$\mathrm{N4} \cdot I_{\mathrm{SUMM}} = \mathrm{N1} \cdot \mathrm{IL1} - \mathrm{N2} \cdot \mathrm{IL3} - \mathrm{N3} \cdot (\mathrm{IL1} + \mathrm{IL2} + \mathrm{IL3})$$

Equation 8

The relationships between number of turns for this SLCE 8 ASCT for RED 521, is shown in the following three equations:

$$\mathrm{N1} = \mathrm{N2} = \mathrm{N};$$

Equation 9

$$\mathrm{N3} = 2 \cdot N$$

Equation 10

$$\mathrm{N4} = k \cdot \sqrt{3} \cdot N$$

Equation 11

where k is a constant, which depends on the type of ASCT (i.e. k=1, for 1/1A ASCT or k=5 for 5/1A ASCT).

The well-known relationship, between positive, negative and zero sequence current components and individual phase current quantities is shown in the following equation:

$$\begin{bmatrix} \mathrm{IL1} \\ \mathrm{IL2} \\ \mathrm{IL3} \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ a^2 & a & 1 \\ a & a^2 & 1 \end{bmatrix} \cdot \begin{bmatrix} I_1 \\ I_2 \\ I_0 \end{bmatrix}$$

Equation 12

where a is complex constant (i.e. a=-0.5+j0.866).

By including Equation 9, Equation 10, Equation 11 and Equation 12 into the equation Equation 8 the following equation for the series-connected, ASCT secondary current (i.e. summated current) can be derived:

$$I_{\mathrm{SUMM}} = \frac{1}{k} \cdot (I_1 \cdot e^{-\mathrm{j}30°} + I_2 \cdot e^{\mathrm{j}30°} + 2 \cdot \sqrt{3} \cdot I_0)$$

Equation 13

From Equation 13 it is obvious that for the ASCT rated ratios (i.e. 1/1A and 5/1A) are declared for balanced three phase current system, when only positive sequence current component exist. For any unbalanced condition (i.e. external or internal fault), both negative and zero sequence current components will give their own contribution to the summated current.

The chapter “Terminal Diagrams”

This chapter includes Terminal diagrams for one-phase and three-phase

Three-phase diagrams	**1MRK 002 002-AA**
One-phase diagrams	**1MRK 002 004-AA**

Decision table for sheets included depending on chosen options

Selected Option (X) 3 Ph,3 Bays,1 Zone	Selected Option (X) 3 Ph,6 Bays,1 Zone	Position	Type of terminal RED 521 *1.0 1/1x19"	Sheets from 1MRK 002002-AA
Basic	Basic	P1	Analogue Input Module 9I+1U (AIM)	6
-	Basic	P5	Analogue Input Module 9I+1U (AIM)	7
Basic	Basic	P8	Numerical Module (NUM)	4,5
Basic	Basic	P9	Binary Input 16 Module (BIM)	8
Basic	Basic	P12	Binary Out Module (BOM)	9,10
Basic	Basic	P14	Power Supply Module (PSM)	4,5
Basic	Basic		Human Machine Interface (HMI-LCD)	4,5
		P8:1	Serial and LON Module (SLM)	4,5
		101	Test switch RTXP 24 (rack 2)	3
		113	Test switch RTXP 24 (rack 2)	3
		501	DC-switch (rack 2)	3

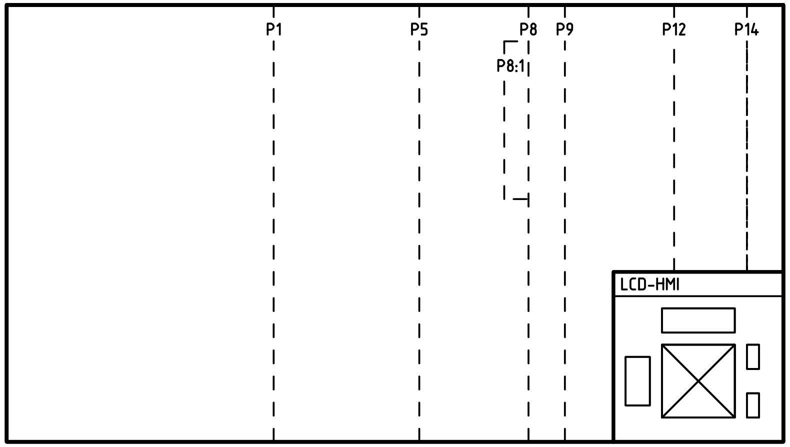
Customer drw no	Prep. ATCF/ SA/DP Rydh Agneta 2003-04-01	Terminal Diagram		Conf. sh/ No of sh 2
	Appr. ATCF/ SA/DP Jonsson Patrik 2003-04-02	General differential terminal		
Based on	Resp. dept ATCF/ SA/DP			
	ABB Automation Technology Products	Documentnumber 1MRK002002-AA	Lang. en	Rev. B	Sheet 1

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

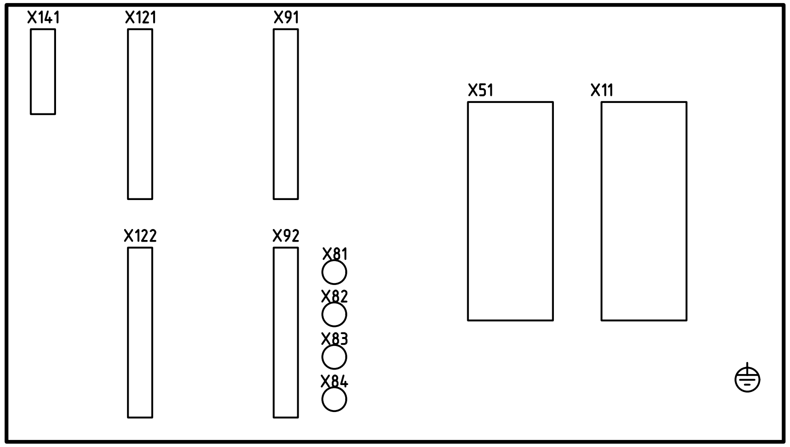
19" (482,6 mm)

FRONT VIEW



6U (266,7 mm)

REAR VIEW



ANALOGUE INPUT MODULE			
LOCATION	CURRENTS/VOLTAGES	RATED FREQUENCY,fr	RATED CURRENTS, Ir
P1	9I+1U	50Hz / 60Hz	1A OR 5A
P5	9I+1U		

LON MODULE	
LON R/T GLASS	LON R/T PLASTIC

LOCATION	BINARY IN 16 MODULE			
	AUXILIARY VOLTAGE (DC)			
	RL24	RL48	RL110	RL220
	24/30V	48/60V	110/125V	220/250V
P9				

LOCATION	POWER SUPPLY MODULE	
	AUXILIARY VOLTAGE EL (DC)	
	24-60V	90-250V
P14		

DESIGNATION CORRESPONDING TO CASING		
MODULE	FRONT	REAR
AIM	P1	X11
AIM	P5	X51
NUM	P8	-
SLM	P8:1	X81-84
BIM	P9	X91,92
BOM	P12	X121,122
PSM	P14	X141

Customer drw no

Based on

Prep. ATCF/ SA/DP Rydh Agneta 2003-04-01

Appr. ATCF/ SA/DP Jonsson Patrik 2003-04-02

Resp. dept ATCF/ SA/DP

ABB Automation Technology Products

Terminal Diagram

General differential terminal

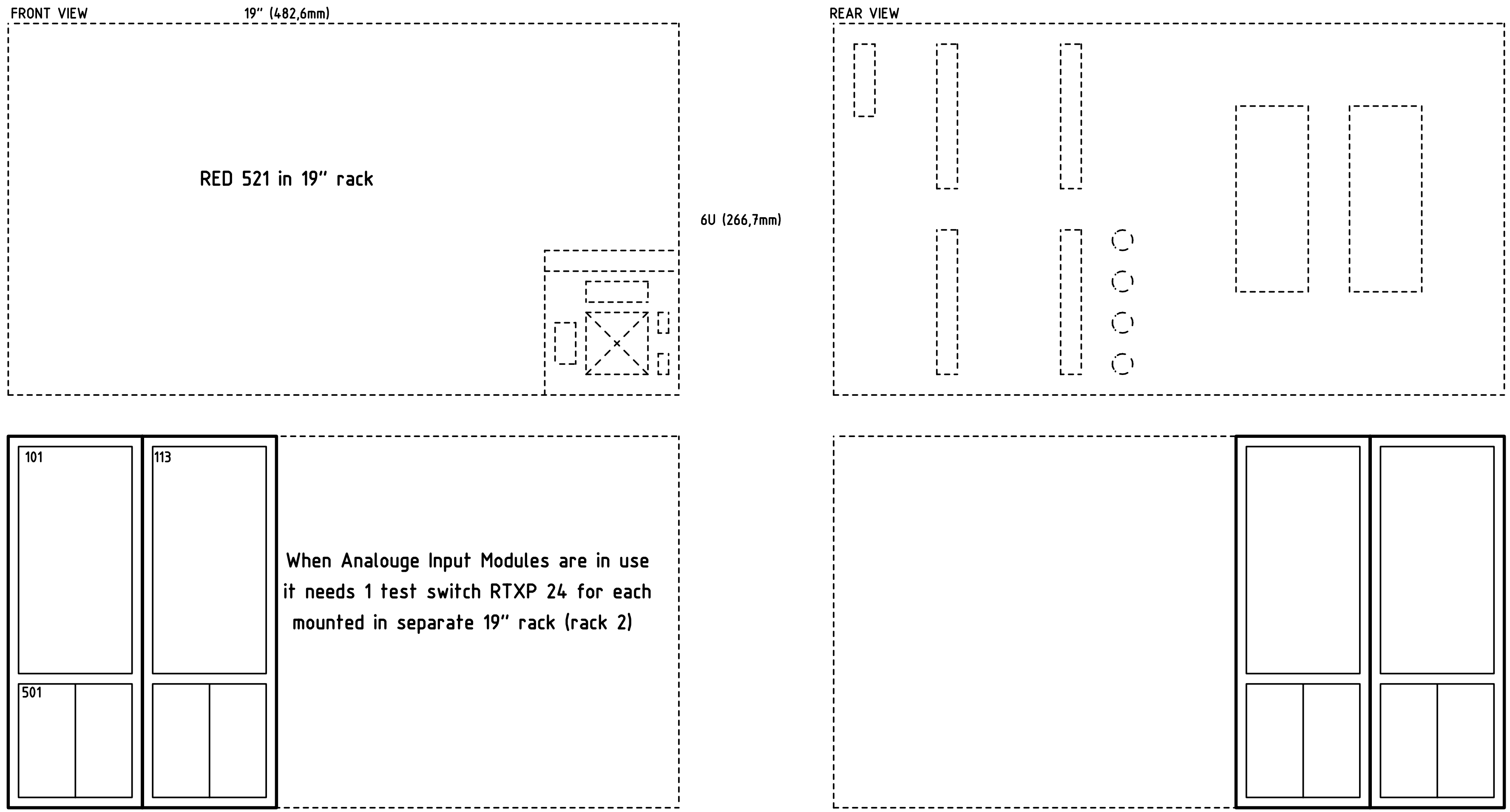
Documentnumber 1MRK002002-AA

Lang. en | Rev. B | Cont. sh/ No of sh 3 | Sheet 2

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



INCLUDED	LOCATION	DESCRIPTION
	101	TEST SWITCH RTXP 24
	113	TEST SWITCH RTXP 24
	501	DC-SWITCH

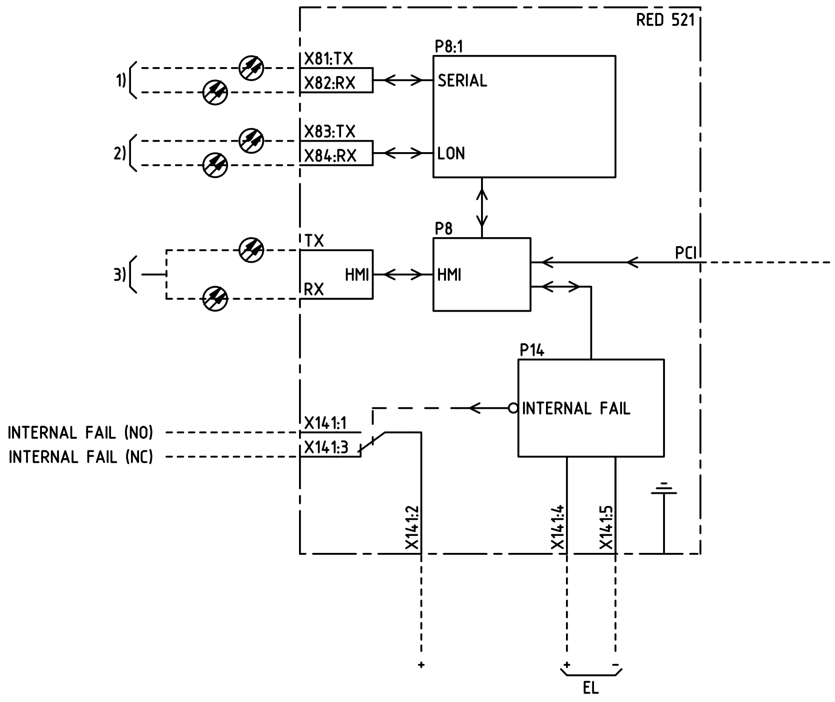
Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB ABB Automation Technology Products			Documentnumber 1MRK002002-AA

Lang.	Rev.	Sheet	Cont. sh/ No of sh
en	B	3	4

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



1) COMMUNICATION PORT SPA, NOT SUPPORTED

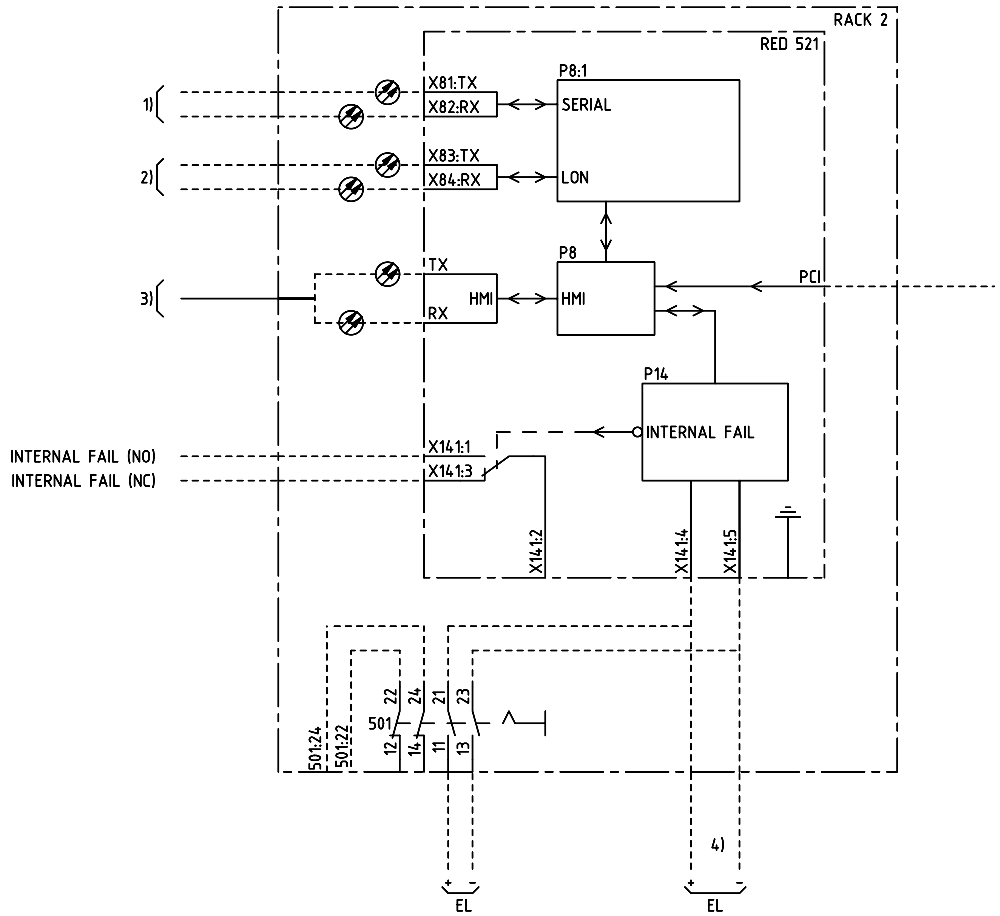
2) COMMUNICATION PORT LON

3) OPTICAL PORT FROM LOCAL HMI. CONNECTION MADE
WITH A SPECIAL INTERFACE CABLE, NOT SUPPORTED

Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram	Cont. sh/ No of sh 5
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal	
	Resp. dept ATCF/ SA/DP				
Based on	ABB Automation Technology Products			Documentnumber 1MRK002002-AA	Lang. en / Rev. B / Sheet 4

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01



1) COMMUNICATION PORT SPA, NOT SUPPORTED

2) COMMUNICATION PORT LON

3) OPTICAL PORT FROM LOCAL HMI. CONNECTION MADE
WITH A SPECIAL INTERFACE CABLE, NOT SUPPORTED

4) NOT CONNECTED WHEN DC-SWITCH
501 IS INCLUDED.

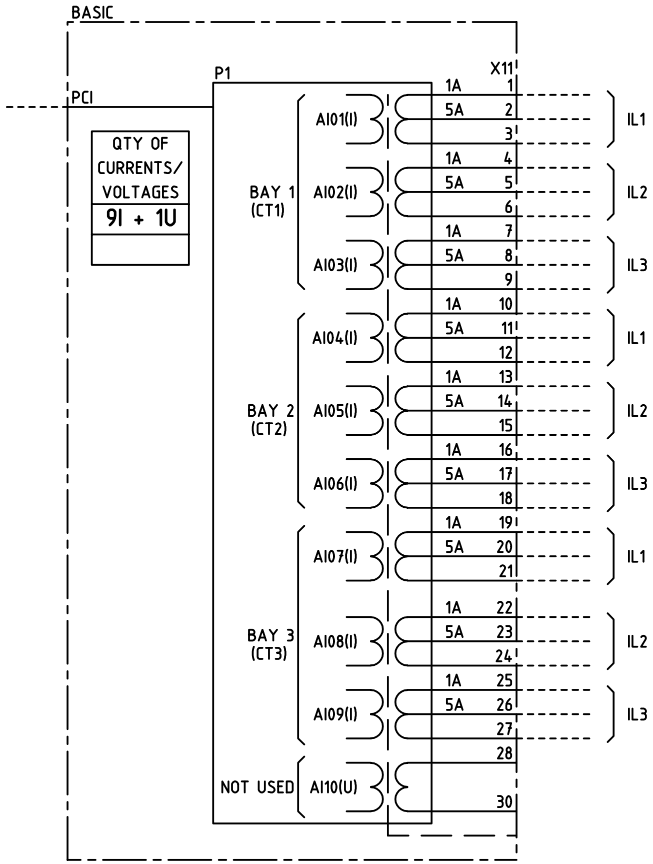
Customer drw no	Prep.	ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr.	ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept	ATCF/ SA/DP			
Based on	ABB Automation Technology Products				

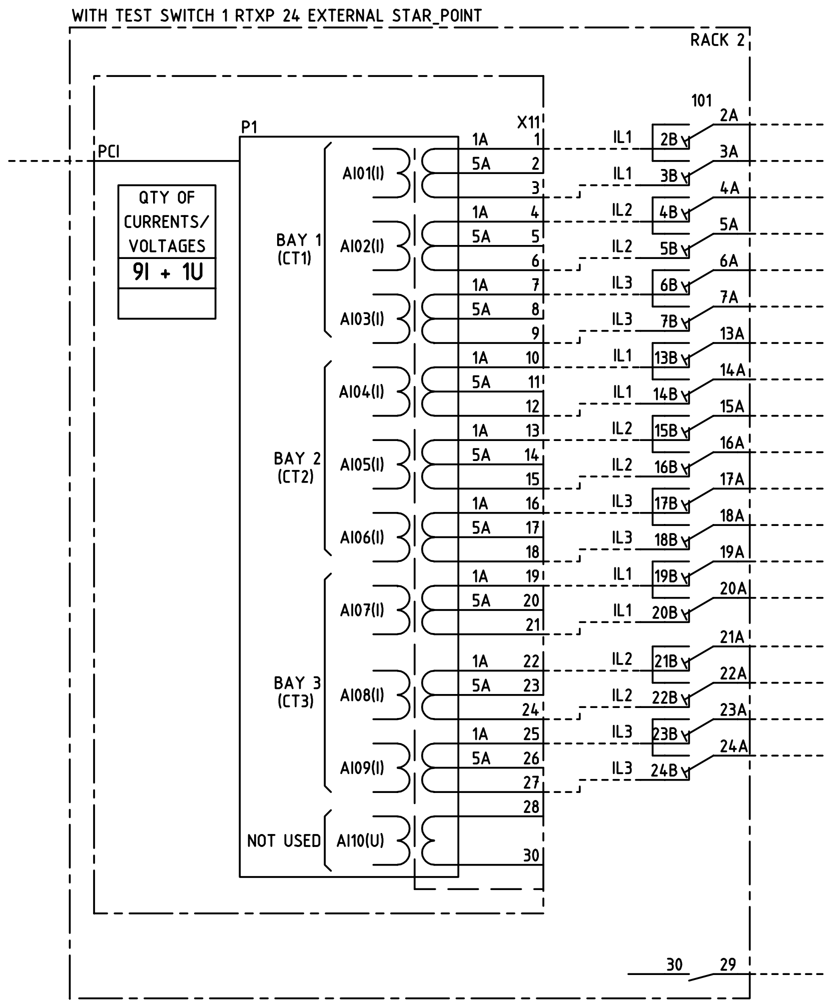
Documentnumber	Lang.	Rev.	Sheet	Cont. sh/ No of sh
1MRK002002-AA	en	B	5	6

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved





NOTE! TEST SWITCH CONNECTION IS SHOWN FOR 1A

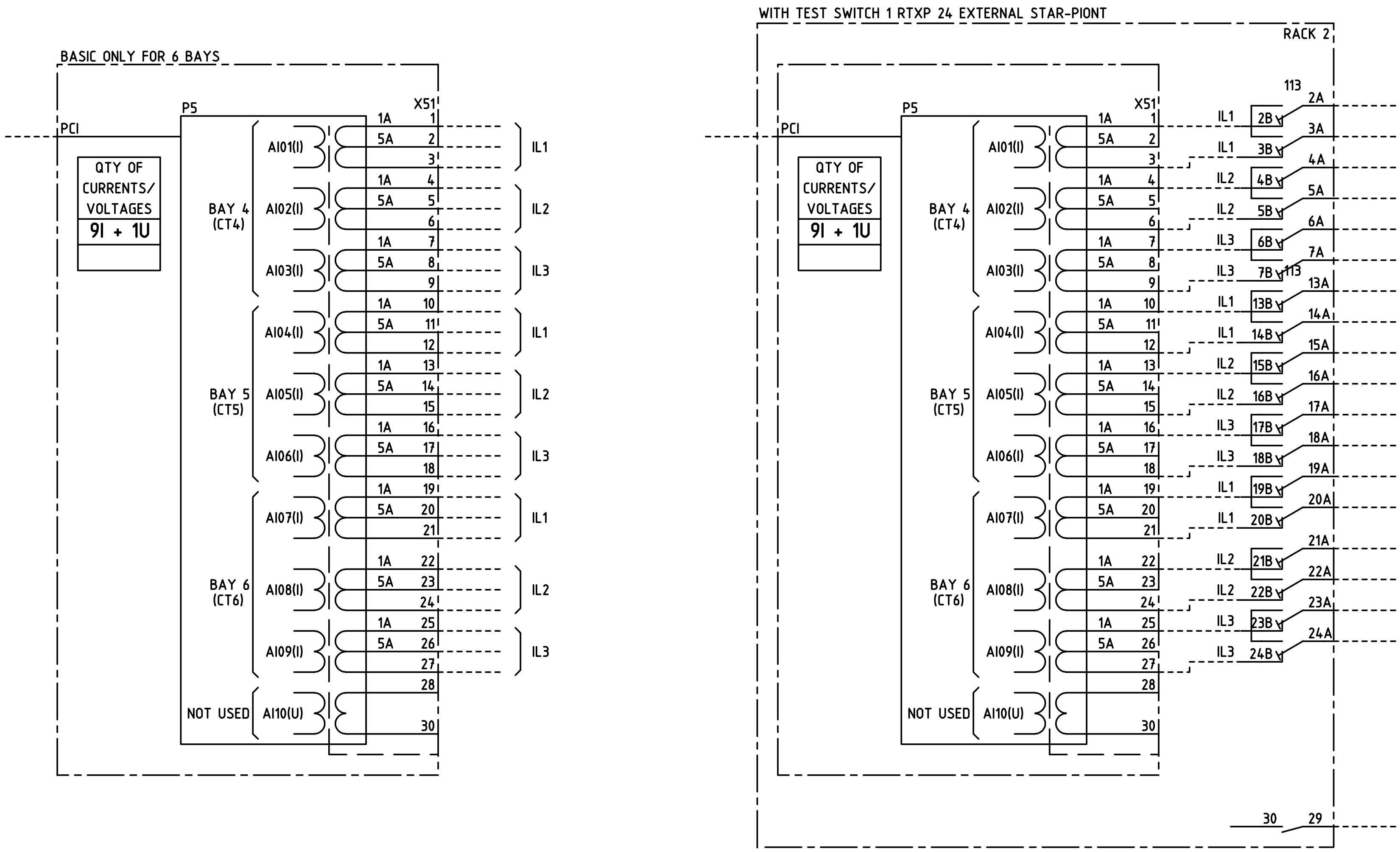
Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002002-AA

Lang.: en | Rev.: B | Sheet: 6 | Conf. sh/ No of sh: 7

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



NOTE! TEST SWITCH CONNECTION IS SHOWN FOR 1A

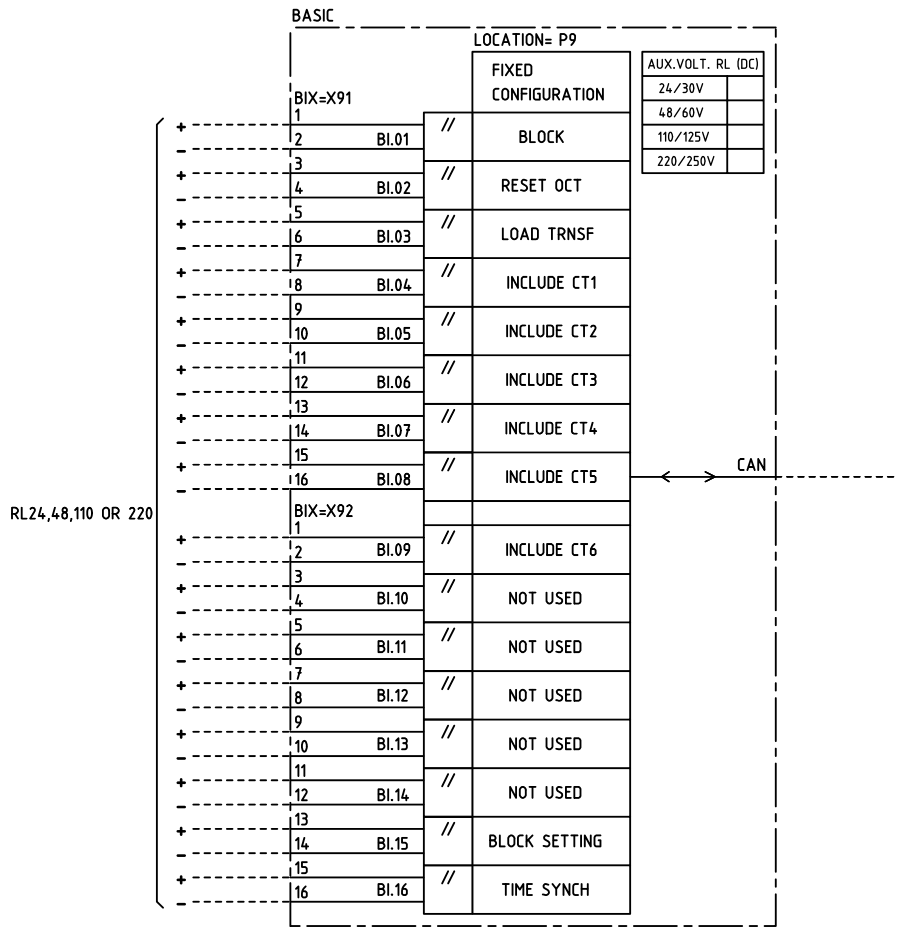
Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002002-AA

Lang.	Rev.	Conf. sh/ No of sh	Sheet
en	B	8	7

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved

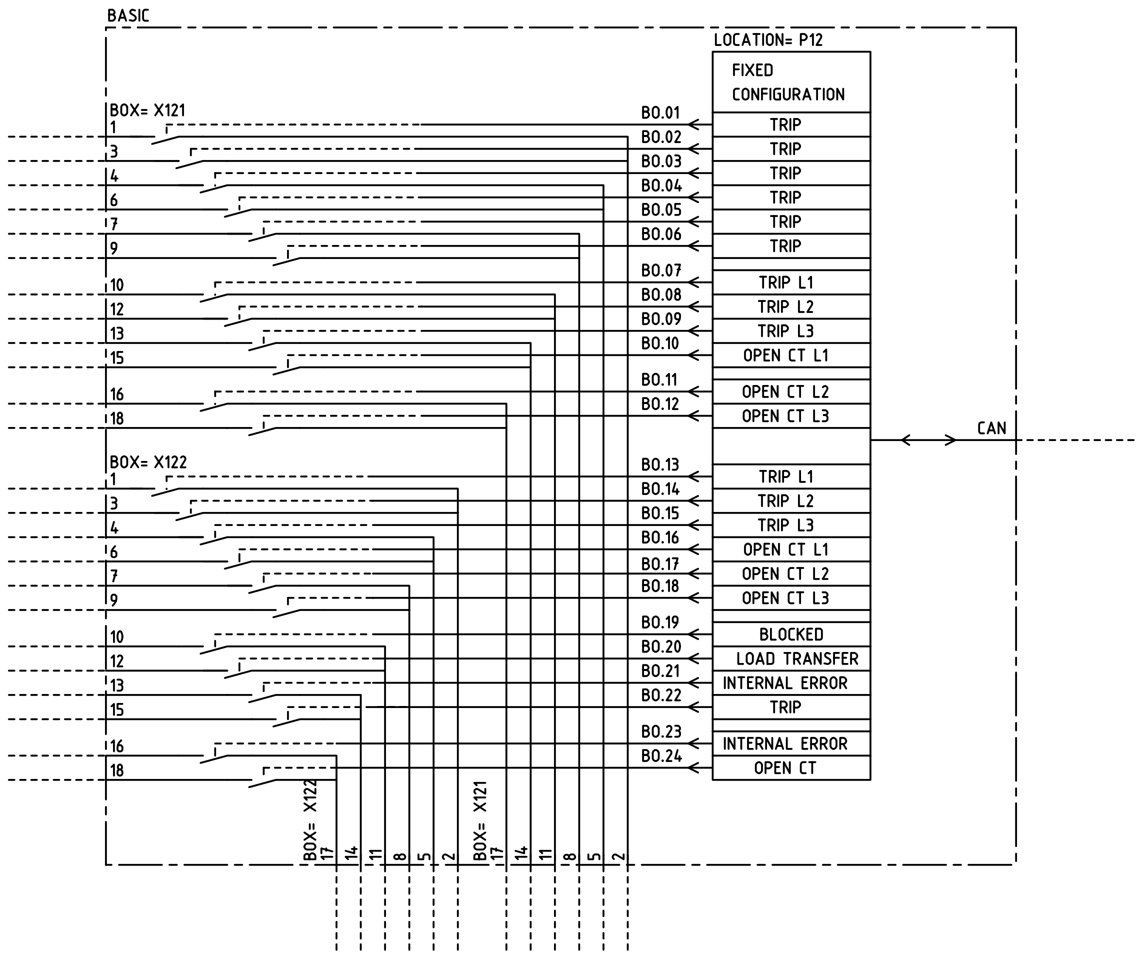


Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram	Cont. sh/ No of sh 9
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal	
	Resp. dept ATCF/ SA/DP				
Based on	ABB Automation Technology Products			Documentnumber 1MRK002002-AA	Lang. en / Rev. B / Sheet 8

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



Customer drw no	Prep.	ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram			Cont. sh/ No of sh 10
	Appr.	ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal			
	Resp. dept	ATCF/ SA/DP						
Based on	ABB	ABB Automation Technology Products			Documentnumber 1MRK002002-AA	Lang. en	Rev. B	Sheet 9

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

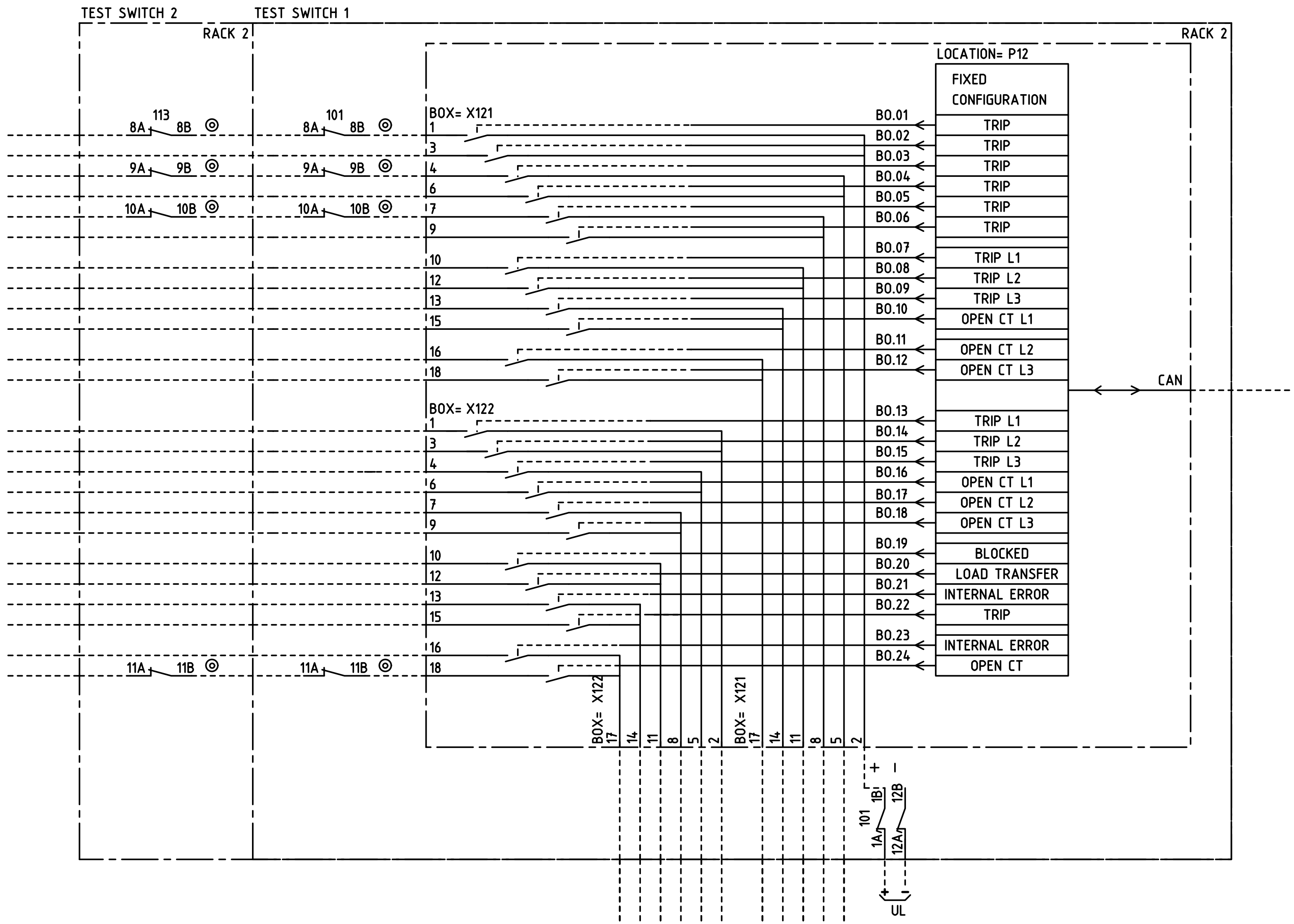
Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved

BINARY OUT MODULE WITH TEST SWITCH RTXP 24

EXAMPLE OF CONNECTION OF RTXP 24 (TEST SWITCH)

ATTENTION: TERMINAL IS NOT DELIVERED WITH THESE CONNECTIONS



Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002002-AA

Lang.	Rev.	Sheet	Cont. sh/ No of sh
en	B	10	

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

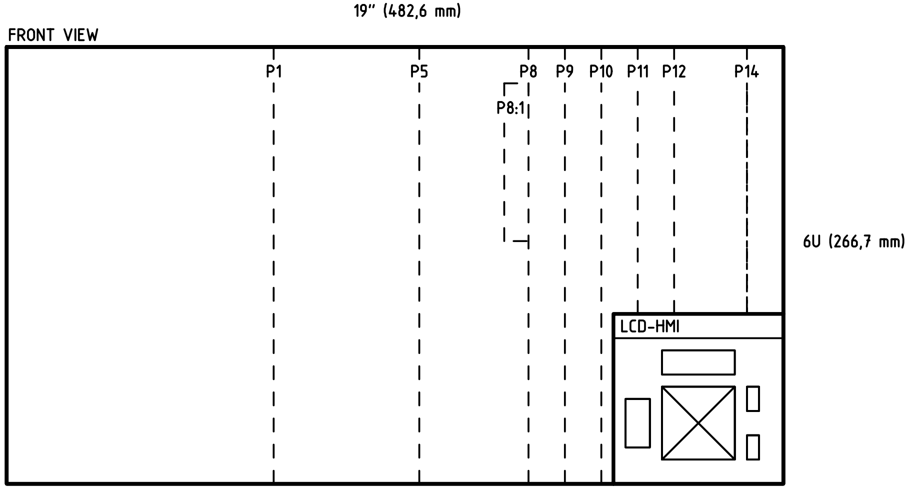
Project or order number:
Version label: 1.3
Modify date: 2003-04-01

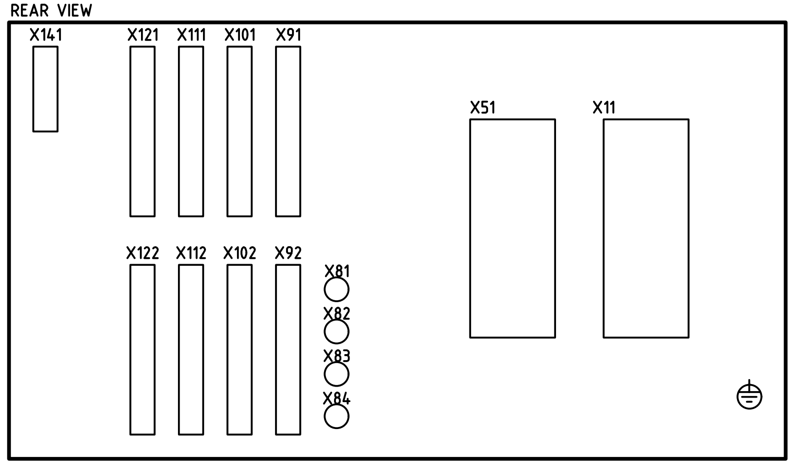
Documentstatus: Approved

Decision table for sheets included depending on chosen options

Selected Option (X) 1 Ph,9 Bays,2 Zones	Selected Option (X) 1 Ph,18 Bays,2 Zones	Position	Type of terminal RED 521 *1.0 1/1x19"	Sheets from 1MRK 002004-AA
Basic	Basic	P1	Analogue Input Module 9I+1U (AIM)	6
-	Basic	P5	Analogue Input Module 9I+1U (AIM)	7
Basic	Basic	P8	Numerical Module (NUM)	4,5
Basic	Basic	P9	Binary Input 16 Module (BIM)	8
Basic	Basic	P10	Binary Input 16 Module (BIM)	9
-	Basic	P11	Binary Input 16 Module (BIM)	10
Basic	Basic	P12	Binary Out Module (BOM)	11,12
Basic	Basic	P14	Power Supply Module (PSM)	4,5
Basic	Basic		Human Machine Interface (HMI-LCD)	4,5
		P8:1	Serial and LON Module (SLM)	4,5
		101	Test switch RTXP 24 (rack 2)	3
		113	Test switch RTXP 24 (rack 2)	3
		501	DC-switch (rack 2)	3

Customer drw no
Based on
Prep. ATCF/ SA/DP Rydh Agneta 2003-04-01
Appr. ATCF/ SA/DP Jonsson Patrik 2003-04-02
Resp. dept ATCF/ SA/DP
ABB Automation Technology Products
Terminal Diagram
General differential terminal
Documentnumber 1MRK002004-AA
Lang. en
Rev. B
Cont. sh/ No of sh 2
Sheet 1
Product family: 891157
Product type designation: RED 521
Product information: 7451K-7
Project or order number:
Version label: 1.3
Modify date: 2003-04-01
Documentstatus: Approved





ANALOGUE INPUT MODULE			
LOCATION	CURRENTS/VOLTAGES	RATED FREQUENCY,fr	RATED CURRENT, Ir
P1	9I+1U	50Hz / 60Hz	1A OR 5A
P5	9I+1U		

LON MODULE	
LON R/T GLASS	LON R/T PLASTIC

LOCATION	BINARY IN 16 MODULE			
	AUXILIARY VOLTAGE (DC)			
	RL24	RL48	RL110	RL220
	24/30V	48/60V	110/125V	220/250V
P9				
P10				
P11				

LOCATION	POWER SUPPLY MODULE	
	AUXILIARY VOLTAGE EL (DC)	
	24-60V	90-250V
P14		

DESIGNATION CORRESPONDING TO CASING		
MODULE	FRONT	REAR
AIM	P1	X11
AIM	P5	X51
NUM	P8	-
SLM	P8:1	X81-84
BIM	P9	X91,92
BIM	P10	X101,102
BIM	P11	X111,112
BOM	P12	X121,122
PSM	P14	X141

Customer drw no

Based on

Prep. ATCF/ SA/DP Rydh Agneta 2003-04-01
Appr. ATCF/ SA/DP Jonsson Patrik 2003-04-02
Resp. dept ATCF/ SA/DP

ABB Automation Technology Products

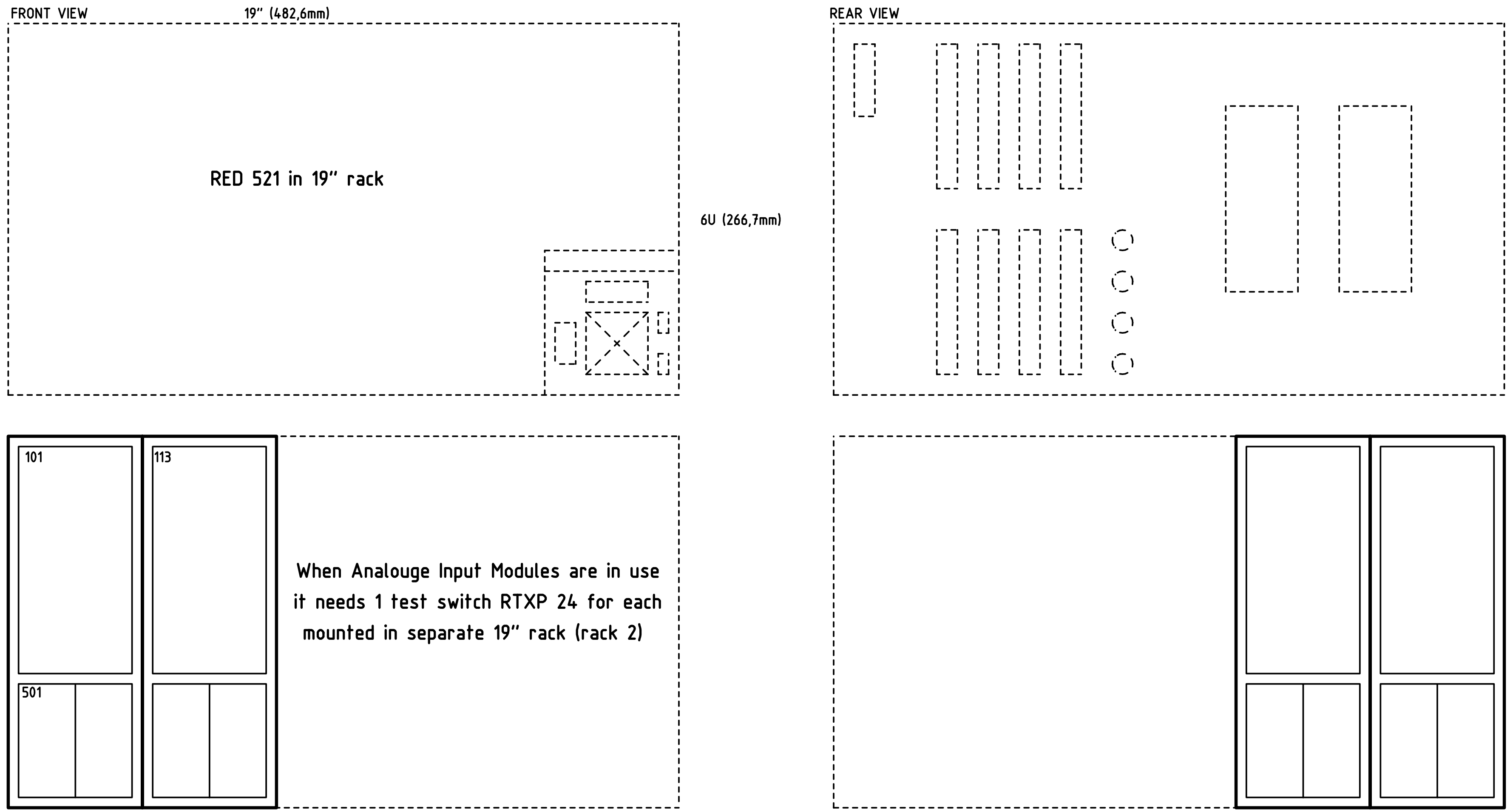
Terminal Diagram
General differential terminal

Documentnumber 1MRK002004-AA
Lang. en
Rev. B
Conf. sh/ No of sh 3
Sheet 2

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



INCLUDED	LOCATION	DESCRIPTION
	101	TEST SWITCH RTXP 24
	113	TEST SWITCH RTXP 24
	501	DC-SWITCH

Customer drw no	Prep.	ATCF/ SA/DP	Rydh Agneta	2003-04-01
	Appr.	ATCF/ SA/DP	Jonsson Patrik	2003-04-02
Based on	Resp. dept	ATCF/ SA/DP		

Terminal Diagram
General differential terminal

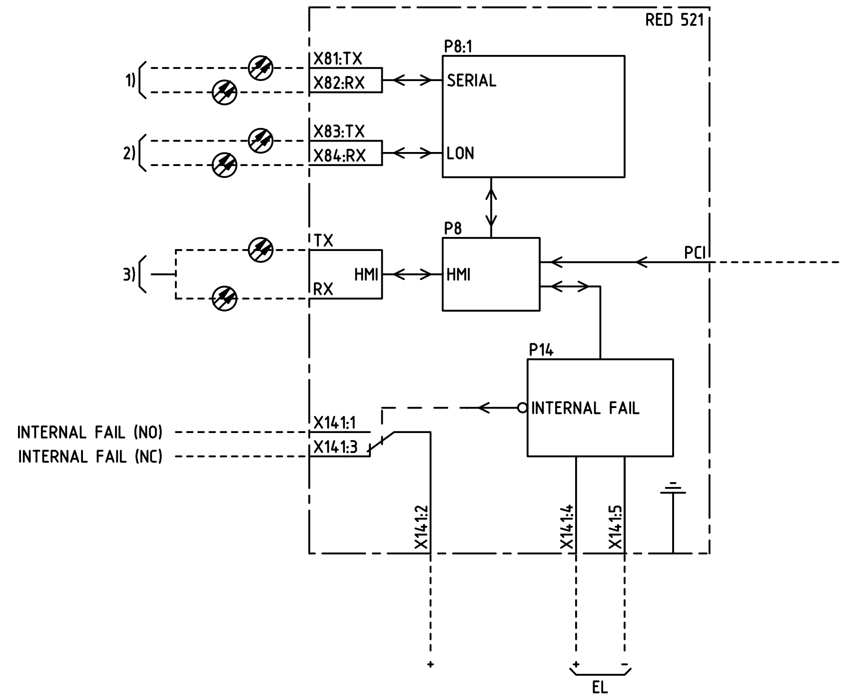
ABB Automation Technology Products

Documentnumber: 1MRK002004-AA | Lang.: en | Rev.: B | Sheet: 3 | Cont. sh/ No of sh: 4

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



1) COMMUNICATION PORT SPA, NOT SUPPORTED

2) COMMUNICATION PORT LON

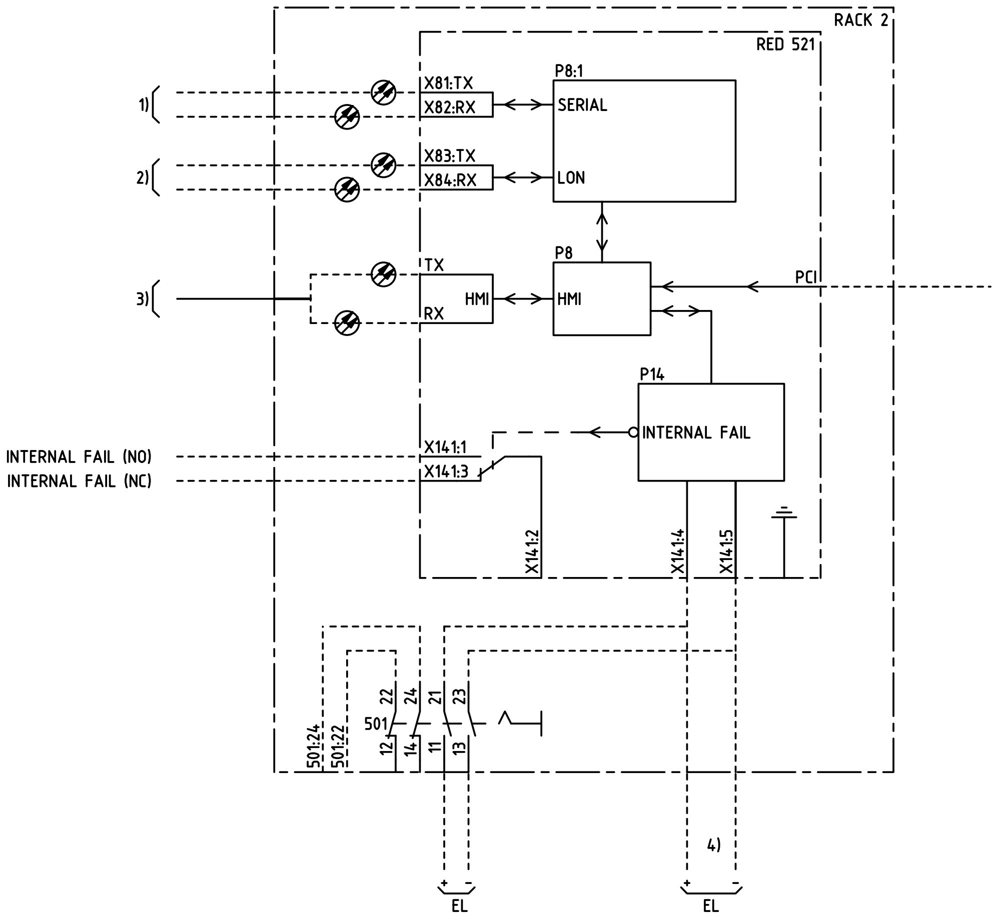
3) OPTICAL PORT FROM LOCAL HMI. CONNECTION MADE WITH A SPECIAL INTERFACE CABLE, NOT SUPPORTED

Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			Cont. sh/ No of sh: 5
Based on	ABB Automation Technology Products			Documentnumber: 1MRK002004-AA; Lang.: en; Rev.: B; Sheet: 4

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



1) COMMUNICATION PORT SPA, NOT SUPPORTED

2) COMMUNICATION PORT LON

3) OPTICAL PORT FROM LOCAL HMI. CONNECTION MADE WITH A SPECIAL INTERFACE CABLE, NOT SUPPORTED

4) NOT CONNECTED WHEN DC-SWITCH 501 IS INCLUDED.

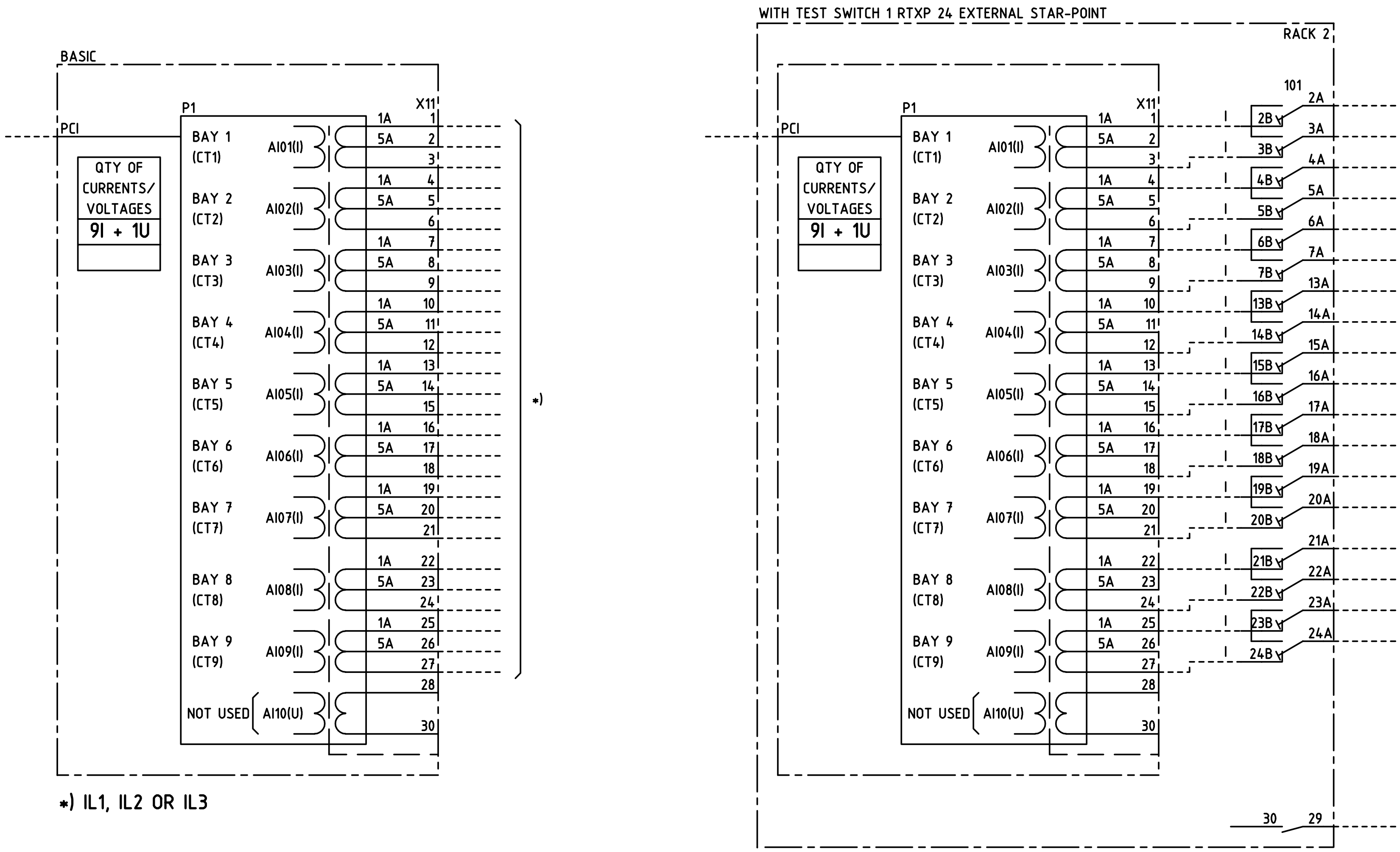
Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA

Lang.	Rev.	Sheet	Cont. sh/ No of sh
en	B	5	6

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



*) IL1, IL2 OR IL3

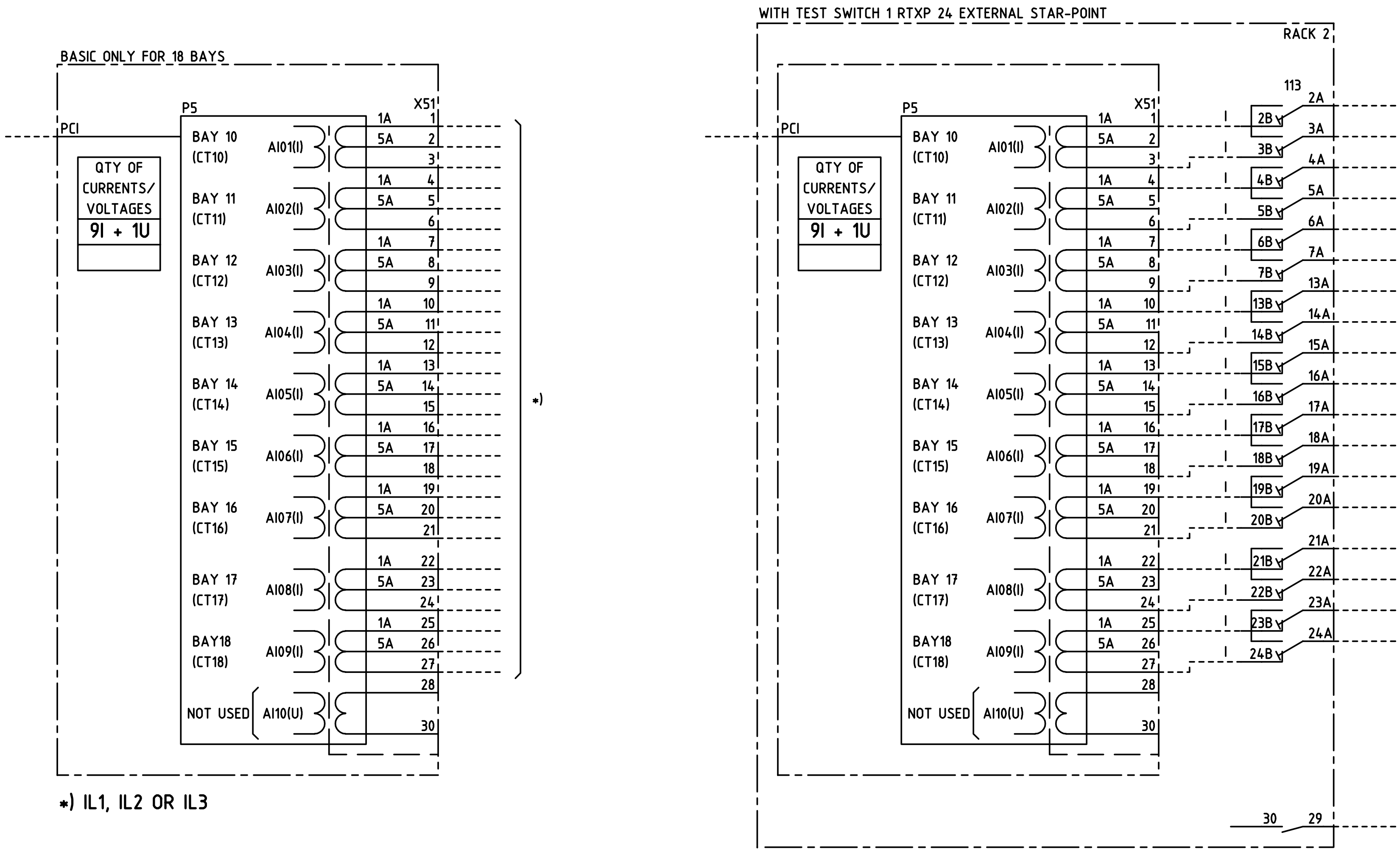
NOTE! TEST SWITCH CONNECTION IS SHOWN FOR 1A.

Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			Conf. sh/ No of sh 7
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA; Lang. en; Rev. B; Sheet 6

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



NOTE! TEST SWITCH CONNECTION IS SHOWN FOR 1A.

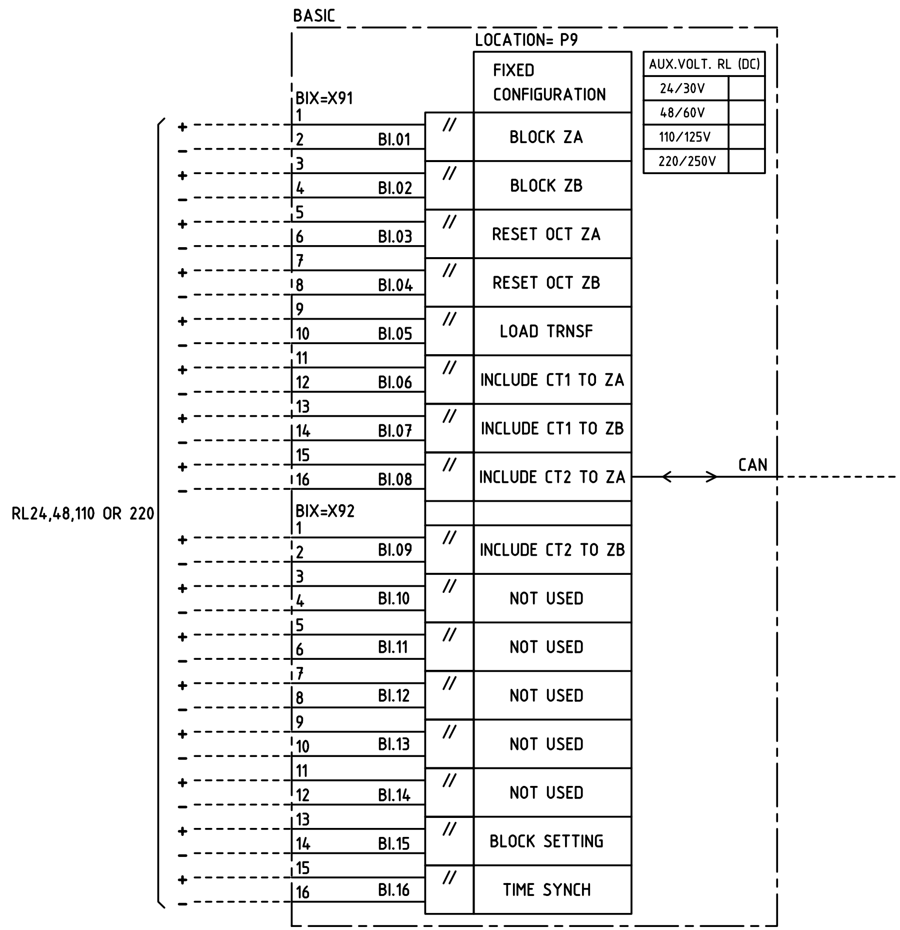
Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA

Lang. en | Rev. B | Conf. sh/ No of sh 8 | Sheet 7

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



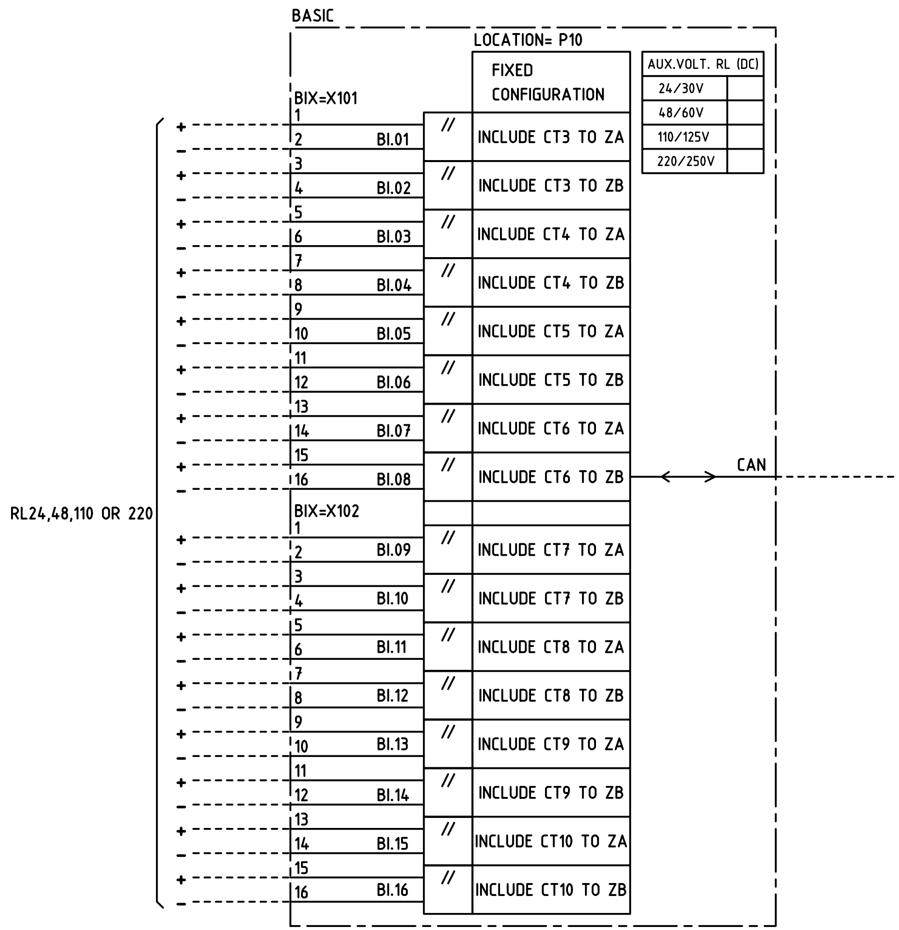
Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA

Lang.	Rev.	Sheet	Conf. sh/ No of sh
en	B	8	9

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



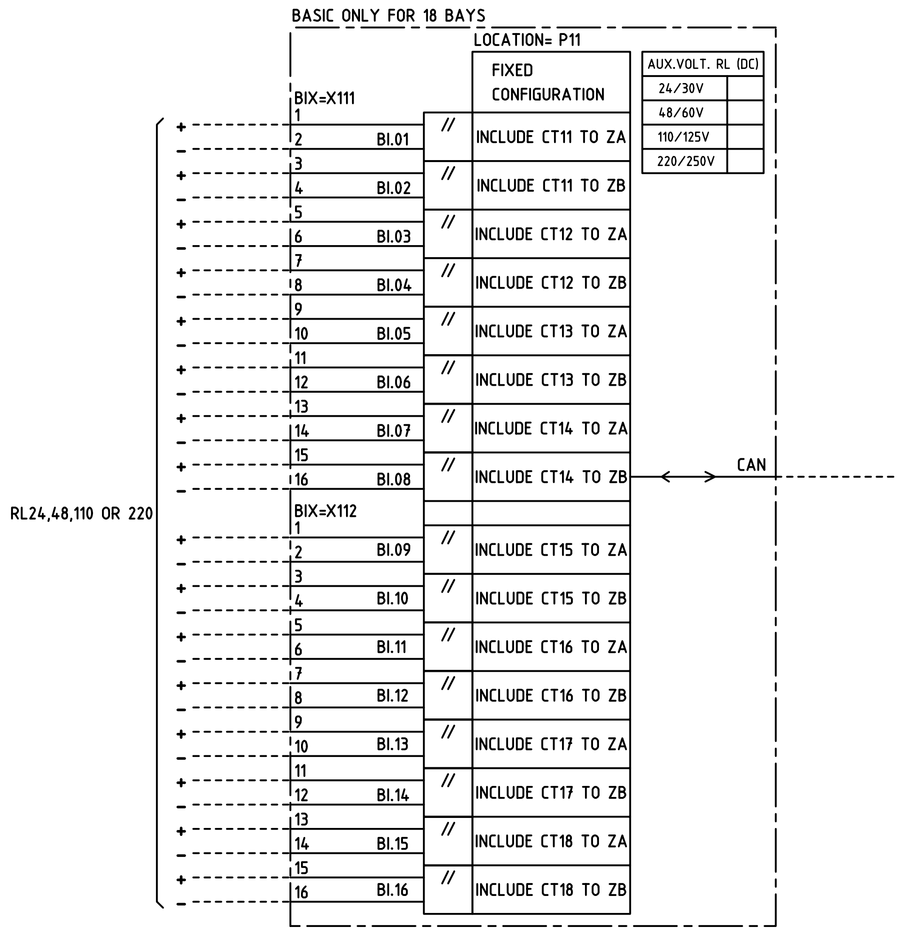
Customer drw no	Prep.	ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr.	ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept	ATCF/ SA/DP			
Based on	ABB Automation Technology Products				

Documentnumber	Lang.	Rev.	Sheet	Cont. sh/ No of sh
1MRK002004-AA	en	B	9	10

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved

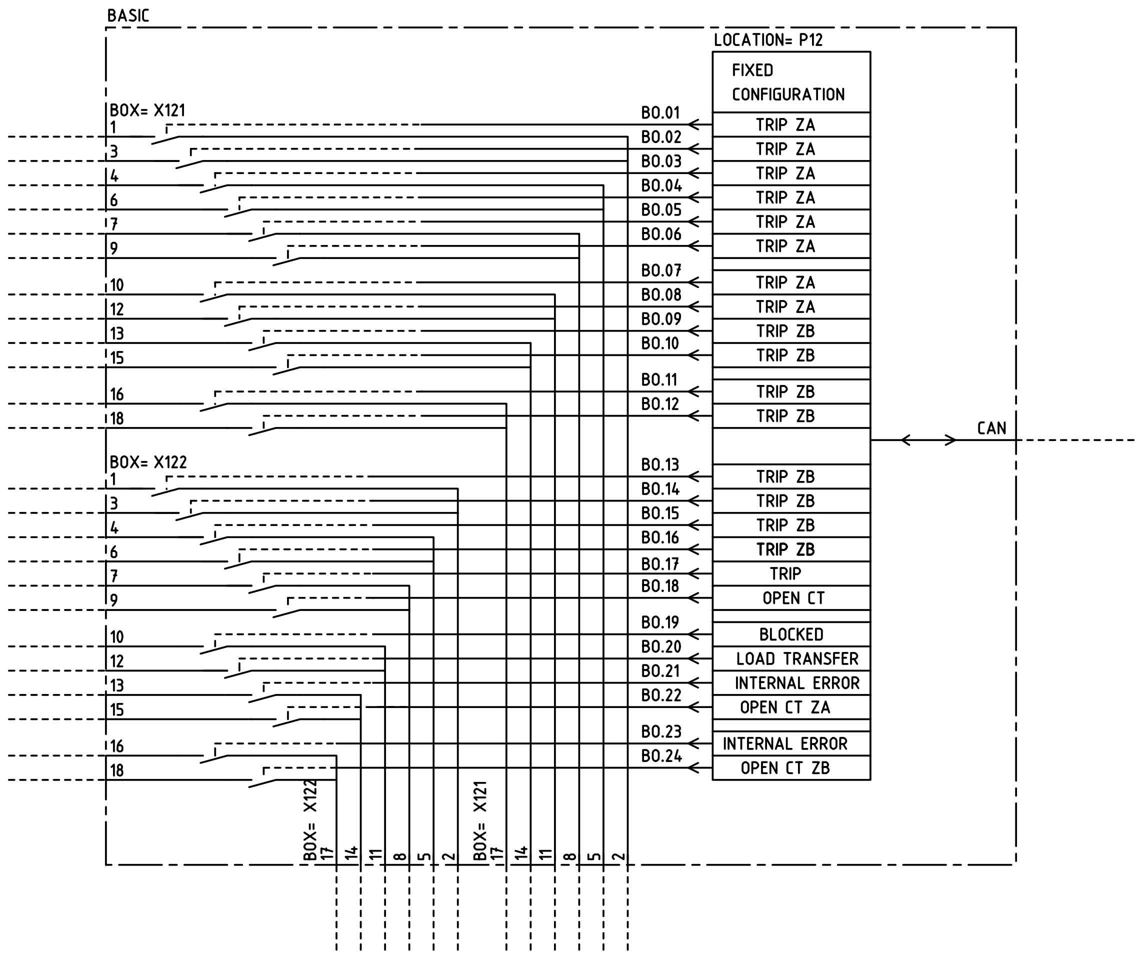


Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			Cont. sh/ No of sh 11
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA; Lang. en; Rev. B; Sheet 10

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved



Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal
	Resp. dept ATCF/ SA/DP			
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA

Lang. en | Rev. B | Conf. sh/ No of sh 12 | Sheet 11

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

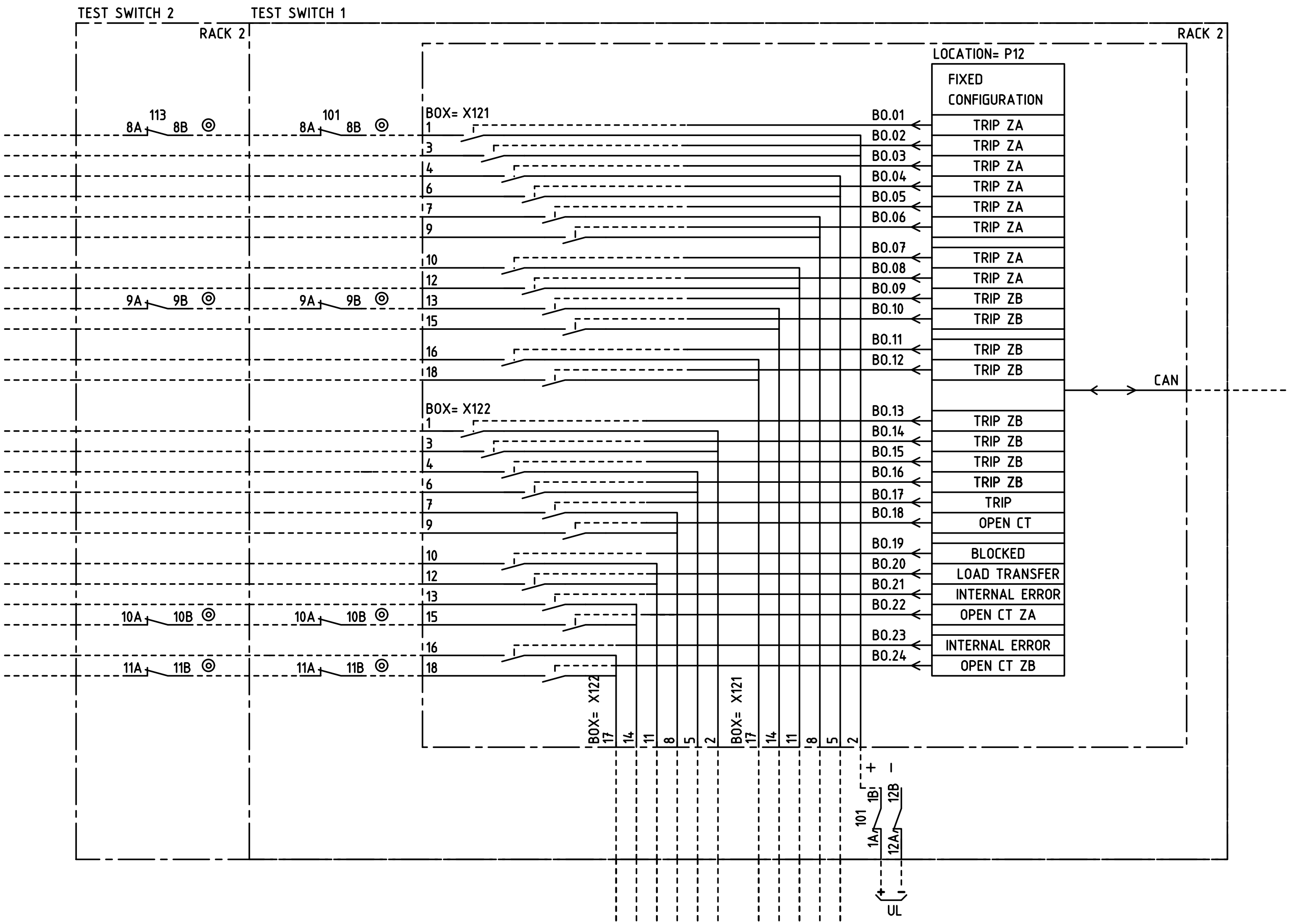
Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved

BINARY OUT MODULE WITH TEST SWITCH RTXP 24

EXAMPLE OF CONNECTION OF RTXP 24 (TEST SWITCH)

ATTENTION: TERMINAL IS NOT DELIVERED WITH THESE CONNECTIONS



Customer drw no	Prep. ATCF/ SA/DP	Rydh Agneta	2003-04-01	Terminal Diagram		Conf. sh/ No of sh
	Appr. ATCF/ SA/DP	Jonsson Patrik	2003-04-02	General differential terminal		
	Resp. dept ATCF/ SA/DP					
Based on	ABB Automation Technology Products			Documentnumber 1MRK002004-AA	Lang. en	Rev. B / Sheet 12

Product family: 891157
Product type designation: RED 521
Product information: 7451K-7

Project or order number:
Version label: 1.3
Modify date: 2003-04-01

Documentstatus: Approved

Customer feedback report

Product:

ABB Automation Technology Products AB would appreciate your comments on this product. Please grade the following questions by selecting one alternative per category. Your answer will enables us to improve our products.

How do you grade the quality of the product?

	Excellent				Poor
Total impression	☐	☐	☐	☐	☐
Useability	☐	☐	☐	☐	☐
Functionality	☐	☐	☐	☐	☐
Human-man interface	☐	☐	☐	☐	☐

Comments: ______________________________

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How do you grade the quality of the documentation?

	Excellent				Poor
Total impression	☐	☐	☐	☐	☐
Layout	☐	☐	☐	☐	☐
Illustrations	☐	☐	☐	☐	☐
Readability	☐	☐	☐	☐	☐
Easy to find	☐	☐	☐	☐	☐
Content structure	☐	☐	☐	☐	☐

Comments: ______________________________

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Customer feedback report

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Please send this report to:

ABB Automation Technology Products AB
Substation Automation
ATCE/SA, Support Line
SE-721 59 Västerås
Sweden

By facsimile:

Send to + 46 (0) 21 14 69 18