LBW81 Arc Detection System

Installation
Operation
Programming
and Service
Manual

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1965–2015 50 Jahre MEYLE

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LBW 81 Functionality

The solution for large systems covering up to:
Inputs: 28 optical sensor + 7 current + 1 voltage inputs
Outputs: 5 relay + 8 MOSFET + 4 optical outputs – all freely programmable

Very short tripping time, even <1 ms

- Fast MOSFET-outputs with varistor surge protection
- Fixed cycle time 0,5 ms
- Total Fault Clearing time depends on primary side switching device

Communication

- CP/IP (Ethernet) communication
- Modbus TCP/IP or IEC61850 with Goose commands
- Fast Disturbance Recorder sample time of 2000 Hz (0,5 ms)
- Event log included. It can also be read by a web server

Touch screen colour display with screen saver

- Multi-languages (Unicode) with versatile set of fonts/languages
- Operator-safe ead-only front display
- All necessary information shown automatically
- Simple control logic for the display

Wide range of time and current settings

- Current input: 5 A 1 A and 2 A possible

Fully optical cables and sensors

- Safe technology does not conduct arc plasma (HV) into the relay
- If the arc destroys the optical cable, operation is still guaranteed
- Sensors can be installed into the HV live parts taking into account the adequate creepage distance

Adjustable light sensitivity for each light input (1-50 kLUX)

- Either DIN rail or door mounting
- Removable front panel frame

Power supply 24 - 48VDC (18-72VDC) with PoE or external power supply

- Redundant power supply is possible with PoE

Programming with MS Excel matrix

- Microsoft Excel file => No need for separate configuration programs
- No sp cial training required
- ll features are visible and printable
- Free user programmable names for messages events, alarms etc.

REVISIONS

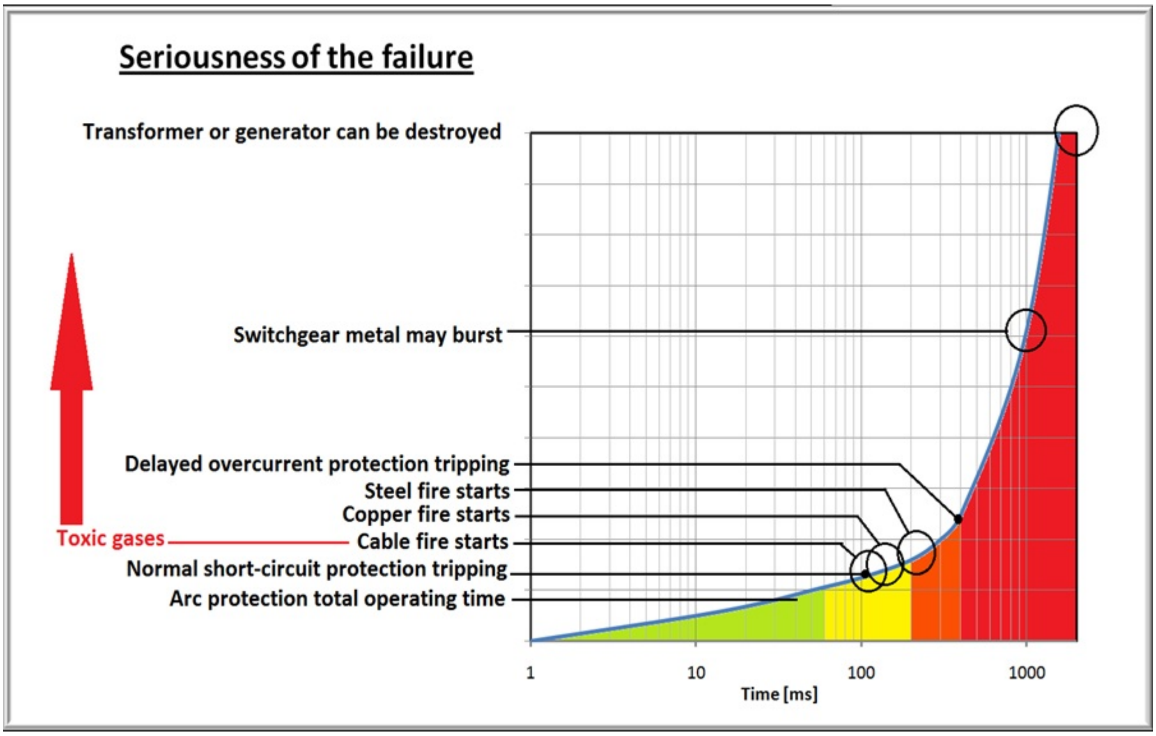
Manuals have been prepared:

Date prepared:	Version:	File name:	Language:
2014-07-01	V1.1	LBW81_manual_11072014.docx	English
2016-01-11	V1.2	LBW81_manual_11012016.docx	English
2016-01-12	V2.1	LBW81_manual_12012016.docx	English
2016-01-27	V2.2	LBW81_manual_27012016.docx English	

CONTENTS

1 GENERAL INFORMATION ON MEYLE LBW81 ARC PROTECTION

The arc protection system protects the operating personnel and minimizes material damage to the switchgear in case of an arc. The arc advances at a speed of 10-300 m/s (depend on current and phase distance), burning any material standing in the way of its path into the short-circuit current. The arc keeps burning as long as it is supplied with power. To be able to put out the arc quickly, an arc protection system based on semi-conducting technology is required. The power of the arc is typically many MW, which means that time is of major importance when trying to minimize the damage to the material. The MEYLE LBW81 Arc Protection System issues the tripping signal in less than 1 ms when tripping conditions are present, which means that the arc protection system can also be used to protect the operating personnel during repairs and installations.



The MEYLE LBW81 arc protection system ensures the personnel's safety and minimizes material damages in case of an arc.

Protection is normally based on the light of the arc and at the same time strongly rising current. When an arc short circuit occurs, LBW81 reacts by sending a tripping signal to the breakers is normally incoming feeder of the switchgear. It is also possible use only light sensors alone to be installed inside the switchgear compartments in order to trip the breaker without requiring a high current at the same time. When using this method, it must be ensured that the service people do not open the switchgear compartment doors during normal operation in order to avoid harmful tripping.

MEYLE has more than two decades of experience in making arc protection systems and thousands of systems have been supplied all around the world.

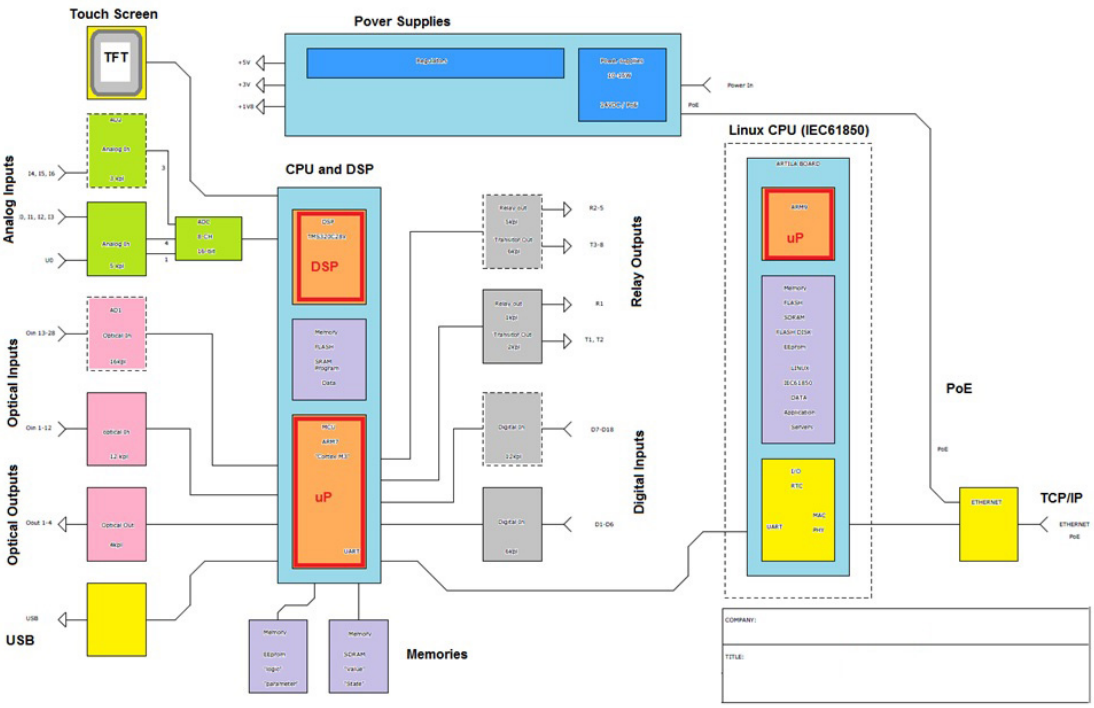
2 MEYLE-LBW81 FEATURES

2.1 LBW81 Relay Features in a Nutshell

- New multi-core CPU with integrated high speed signal processor.
- Full optical light sensors are easy to install and pose no risk of conducting high voltage into the auxiliary compartment and auxiliary circuits.
- All sensor inputs have separately programmable adjustments for light sensitivity.
- A complete set of programmable protective functions, such as overcurrent and earth-fault stages with blocking and SCADA communication.
- Maximum of eight very fast potential-free bidirectional trip relays with surge arresters.
- Four isolated current input channels and one voltage input channel for accurate current and voltage measurement.
- Optionally, three extra current channels for two incoming feed systems.
- Colour multi-language touch LCD display and five programmable multi-colour LEDs on front panel.
- Display shows all messages, alarms, events, measurements etc. without operator activity or training.
- TCP/IP (Ethernet) communication with web server and Modbus TCP/IP or IEC61850 protocol.
- User programming via Excel base file with an interactive matrix. Clever matrix makes it possible to have millions of logical combinations defining the relay action. Programmable user messages for all inputs, outputs and logical functions make it possible for the relay to show almost everything occurring in substation with date and time stamps.
- Four optical outputs make it possible for more LBW81s to be connected in an optical-loop group and transmit signals almost without delay.
- Six or optionally eighteen digital inputs with isolated 24 VDC power supply for switch devices, position indications, alarm indications, relay group application test signals, bus buttons etc.
- Objects for circuit breaker control commands and position indications.
- All input channels are detected by a rapid disturbance recorder with a 2000 Hz sample rate, and a file-and-web-type event log is saved to relay memory. NT relay can be installed in a door or in a DIN-rail.
- Front panel ingress protection is IP65, while at the rear panel it is IP20.

2.2 LBW81 Relay Internal Electronic Features

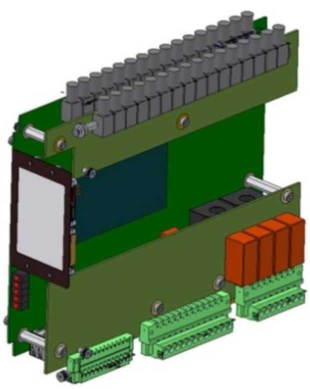
LBW81 basic version has one two core CPUs and a separate independent touchscreen display unit. A fast Digital Signal Processor (DSP) core is used to calculate and analyse analogue signals and the fast logic needed in arc protection. A traditional CPU core used for communication and logic does not require a very fast response time. The IEC 61850 version has an extra communication processor, which is independent and totally reserved for this task.



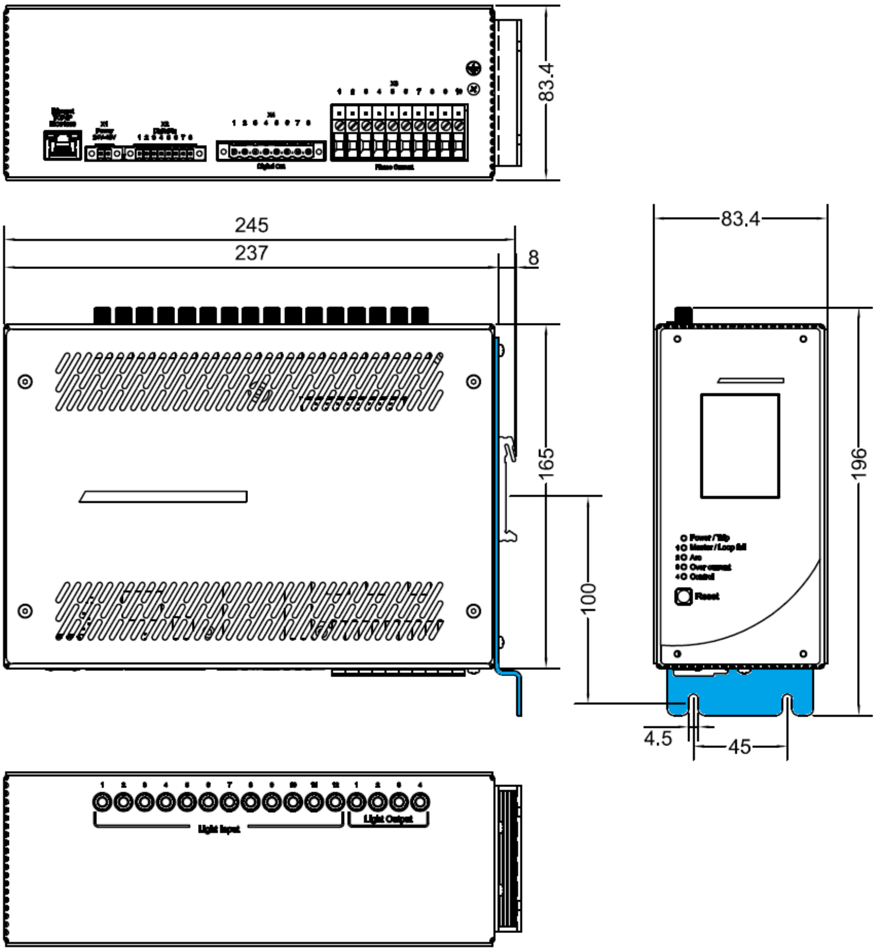
2.3 LBW81 Relay Mechanical Features

The LBW81 basic version has one PCB motherboard, which is mainly made by using surface mounted components.. This board has a maximum of 12 optical sensor inputs, 4 optical outputs, 4 current transformers and one voltage transformer.

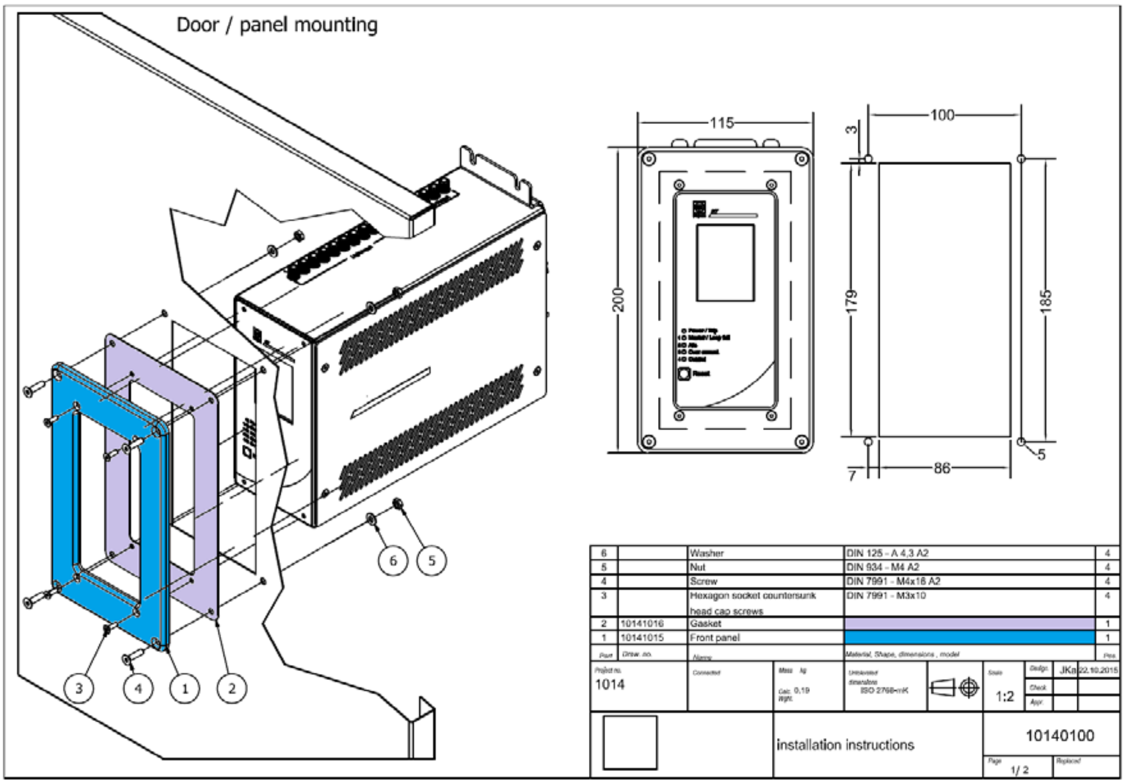
Optionally, extra printed circuit boards can be added to the mother board for increased numbers of optical sensor inputs, traditional and fast relay outputs, digital inputs and analogue inputs.



Case is made of stainless steel and has a DIN-rail on the rear.

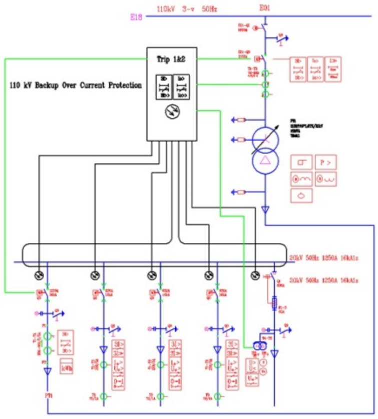


Door mount is made using the external front flange.



2.4 LBW81 Optical Sensors and Fibres

LBW81 has the same sensors (point sensors) and fibres as the previous MEYLE LBW81 relay. Fully optical sensors are safe because they do not conduct high voltages from arcing plasma into the relay and into the other auxiliary circuits. MELYE can offer three different opacities of lenses and the plastic fibre is strong and easy to install. Fully optical lenses can also be installed into the live part if this is necessary in order to comply with regulations concerning creepage distances. All MEYLE LBW81 optical sensor input have separate settings of the sensitivity in the setup matrix and therefore a naked optical loop also goes into many switchgear compartments having radial scattering of the arc light is possible.

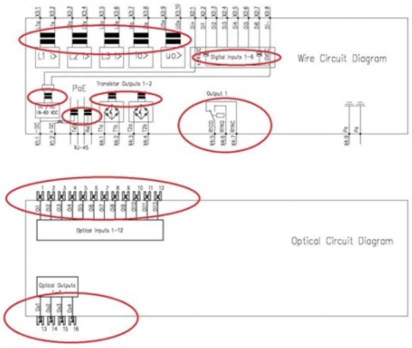


2.5 LBW81 Auxiliary Power System and Isolations

LBW81 relay terminal block power input (X1.1 and X1.2) needs a DC-voltage level of 18-72 VDC. It is possible to supply the relay directly by means of 24 V or 48 V lead acid battery system or to use an external 24 VDC power supply if using substation 110 V or 220 V DC-systems. Power consumption is only a few watts. The relay has two power inputs: the terminal block and the PoE data input, which can also handle the power supplied by a data switch through the data communication lines. If a redundant two-power supply system is needed, it is possible to use both of these at same time by means of the PoE type data switch and external power supply. Note that the PoE data switches usually have a feature where the power is switched off if using the terminal block power inputs (PoE input current is zero).

Digital inputs are insulated from the supply voltage and equipped with an extra internal (24 V 3 W) power supply, which is also isolated. The digital input terminal block has both + and – polarities available on this extra power supply in addition to the digital inputs. Positive polarity is needed when using the internal isolated power supply and negative polarity is needed when using the external power supply, for example, when using the battery supplies at the same time as the relay auxiliary power. All digital inputs have the same negative. Do not use an extra internal 3 W power supply for supplying external user circuits. Use it only for supply voltages going to indication switches and digital inputs.

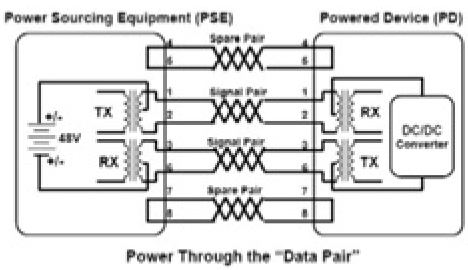
ONLY use industrial power supplies with earthing (ground) connection. Power supply and LBW81 must be connected to ground.



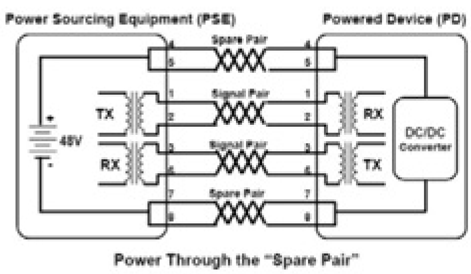
Numerous galvanic isolations ensure that the MEYLE LBW81 withstands high voltages. All inputs and outputs are galvanically isolated from the supply voltage and the TCP/IP communication is also with improved galvanic isolation. **Optical data communication is not normally necessary.**

MEYLE LBW81 can also be supplied by means of the PoE data switch with the help of data cables. PoE is common in industry and many data switches have this feature. Ensure, however, that the data switch chosen is capable supplying LBW81, because they have different power limits.

PoE uses data cable to supply power to the device at the cable end.



Power Through the "Data Pair"



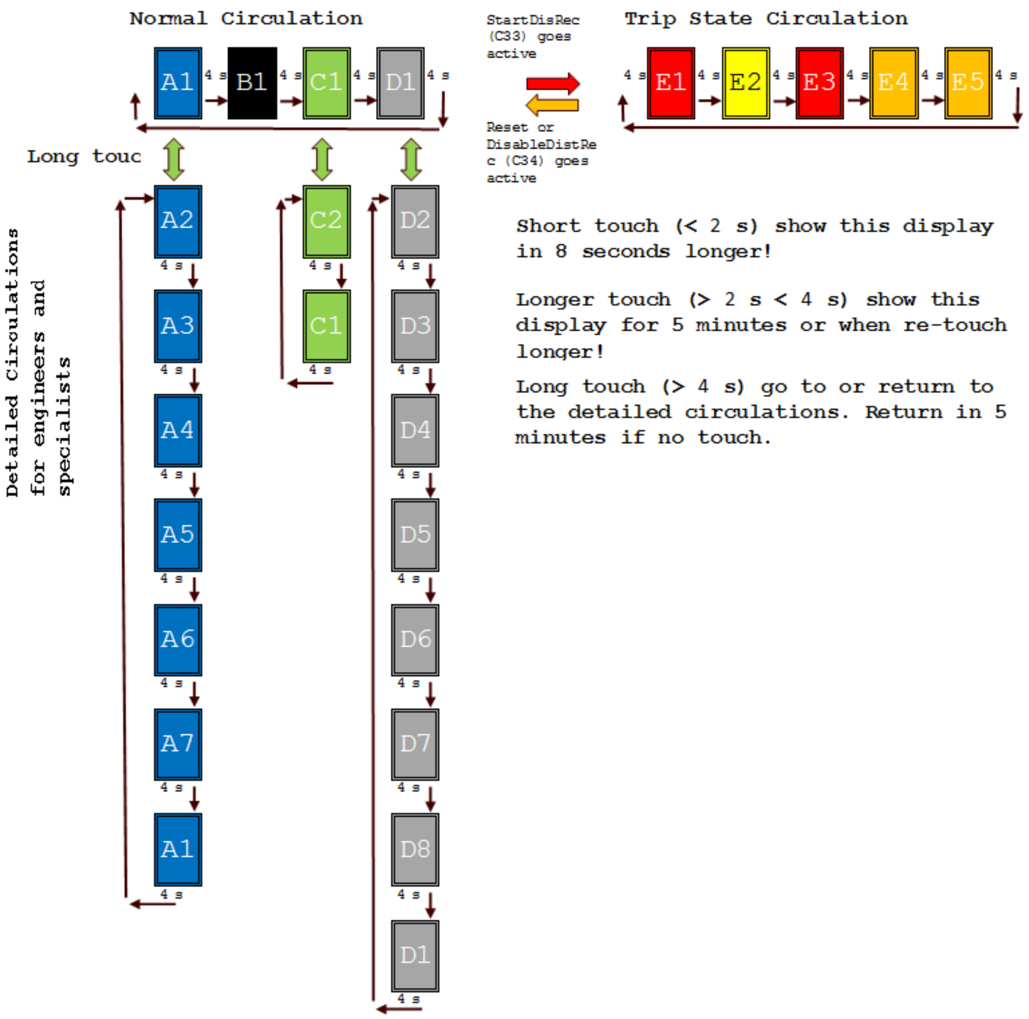
Power Through the "Spare Pair"

3 OPERATING THE SYSTEM

3.1 Touching and Understanding the Displays

In normal operation LBW81 relay display shows after the first waking up touching in circulatory way all information normally needed. The operator does not need to use the menus or touch anything. All the necessary information comes up while waiting for the various screens to appear automatically as it circulates. If more time is needed to read the display information, a short touch (less than 2 seconds) gives 8 seconds of extra time. If you wish to stop the display circulation, a longer touch (2- 4 s) stops it. Normal circulation returns if the display is not touched within 5 minutes. Normal circulation has 4 different types of display. Display A1 is for parameters and names, B1 shows the most important measurements with a larger font and C1 shows more detailed measurements and finally D1 shows the most recent events the system detected.

In the event the system is tripped (disturbance recorder trigging), the display circulation jumps to the Trip State Circulation, which is also very informative and does not need to be touched. Display E1 shows events that occurred leading up to the moment of the trip. E2 shows measurements at the moment the trip occurs and E3 events are shown be before E1 events. Displays E4 and E5 show events just after the tripping without letting the new events coming later overwrite the tripping information immediately following.



You will not change anything by touching the display. Touching the display is absolutely safe!

The trip state circulation returns to Normal Circulation when the relay is RESET or the disturbance recorder is disabled.

If the display is touched for a very long time (>4 s) the circulation jumps to the Detailed Circulation, which shows that pages that are behind the display at the time when touching the screen. Detailed circulation shows all the parameters programmed in Parameter Circulation A, and in Measurements display C, it shows all rows and columns the programming matrix has; furthermore, in Events page D it shows 32 pieces of events before the present time. To exit the Detailed Circulation, use either a very long touch or leave for 5 minutes without touching at all.

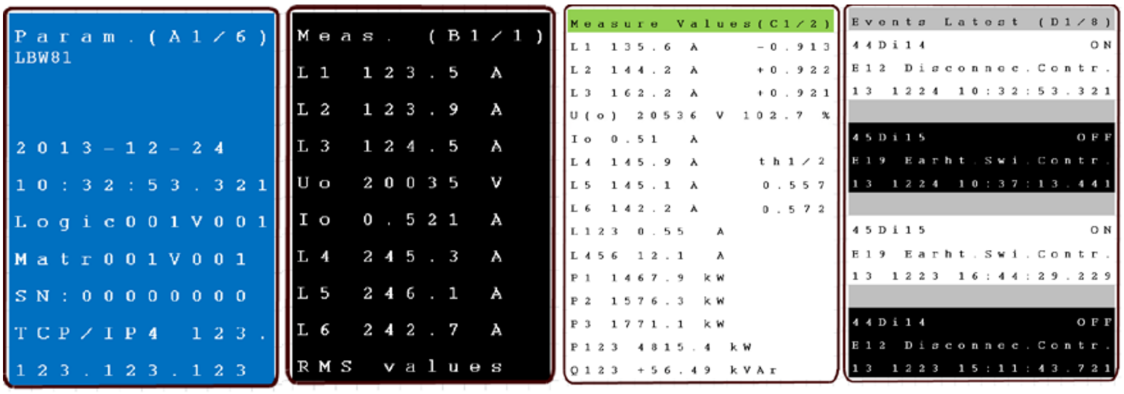
3.2 Display Normal Circulation

Normal circulating of the display shows information needed at the user level. A1 depends on the relay type and programs, but the date, time and TCP/IP address are necessary when establishing the communication and setup connection. In the right corner is the display name with the page number, which also tells you how many detailed screens are in the engineering level.

Display B1 has no displays in the engineering level. Large font and high contrast is good if the relay is installed too high up or far away from the viewer.

Display C1 has one engineering level display and the first sheet shows all measurements. Note that if the relay does not have the A2 option, the current inputs L4, L5 and L6 are however visible.

Display D1 indicates the most recent events and the last is always uppermost on the list. A white background indicates a change to ON (rises to logical 1), while a black indicates a change to OFF (drops to logical 0). A grey bar separates the events. The time stamp has the time on the right and date on the left. The year is indicated using only the two last digits and then the month and date are without punctuation mark. The further down the list you go, the further back in time it takes you. An event is only generated if the matrix line (Excel) has text in the user text column.



Display C1 shows the measurement of the power, which is useful only if the Uo voltage input is connected to a line-to line or line-to-neutral measurement. The Measurements display shows this by having brackets U(o). If the Uo input is for measuring earth fault voltage (for example, using the directional earth fault protection relay function) the power, reactive power and power factors cannot be measured and they are not found on display C1. In this case, display C1 has an angle between Uo and Io stated in degrees. On the right side of the display in rows L4, L5 and L6 is th1/2 and under it two numbers. These are the thermal over-current protection temperature calculations. If the upper number is 1, it means that the machine is connected to L1-3, which is heated up to a maximum, for example, of 90°C, as typical in motors. The number below is for L4-6 currents and loads.

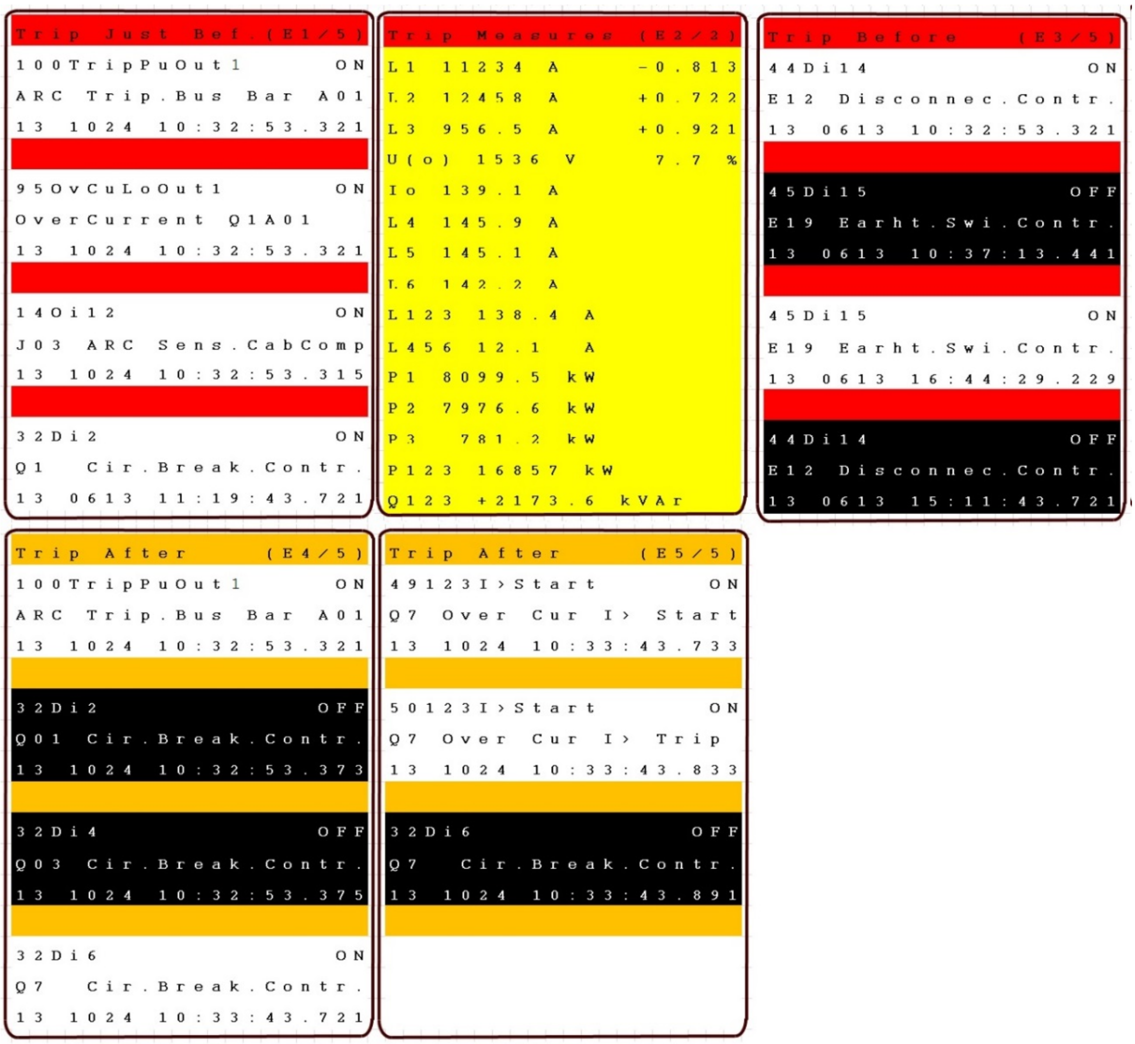
3.3 Display Trip State Circulation

When the relay trips, for example, due to an over-current and light indication at the same time, the display circulation changes to the Trip State Circulation, which is useful for showing information needed in switchgear troubleshooting. This circulation continues until the operator presses the reset button or remote reset. After five minutes without the reset or otherwise being touched, the Trip State Circulation stops at the E1 display and shows the reading at that moment. Note also that the slave units are in loop system with a copper loop detect reset.

If the staff is not familiar with the relay, use a mobile telephone camera to photograph all the screens and save all information before resetting the relay.

Display E1 shows events up to the trip moment and before it. E2 shows measurements at the trip moment, while E3 events are shown before E1. Display E4 and E5 show events just after the tripping without allowing new events occurring later to overwrite them.

Changes to ON are stated in a white background, while changes to OFF are stated in a black background. Red bars are placed between each event.



Display E2 has a yellow background and shows the measurements at the tripping moment and is frozen, which means that later measurements do not change this. The moment when the disturbance recorder is triggered is defined in the matrix by C33. Trip State Circulation continues until the relay RESET button is pressed or the disturbance recorder C34 is disabled by pulse. To save the E2 measurement values, please take a photo or make notes, because after resetting you will only get the values by reading the disturbance recorder, which is saved in relay memory. The same applies to the other E displays, especially if they have lot of events after the tripping moment, because that is when the Normal Circulation Event log D can be occupied by late events.

If two trips have occurred without a reset, the relay between these trips, the Trip State Circulation, shows the first events and measurements. The last trip event, are saved to Event Circulation D and is available only after the resetting, since this log system is always working and the reset does not clear it.

When reading the events, it should be noted that all of the rows of the Excel matrix which have text and change logical state, are visible in displays D and E. Typically, if the trip occurs there is the last trip is connected to the Excel matrix disturbance recorder column and then events are occurred before this, for example over current and the first one is sensor light indication event. It is also possible that the sensor detect a lot of indications, for example, when only one phase is arcing, it generates lot of events are timed two times of the grid frequency (no light when it has zero crossing). In this case, there are lot of optical sensor light indications before and after the signal trigs the disturbance recorder.

3.4 Display Detailed Circulations

The LBW81 display shows the most important measurements and last events automatically without the operator touching anything. When touching the screen for a very long time (> 4 s), you can see more because the Normal Circulation jumps to Detailed Circulation. The moment touching occurs must be the same when page 1 is visible:

- Parameter pages A1-A7
- Measurement pages C1-C2
- Event log pages D1-D8

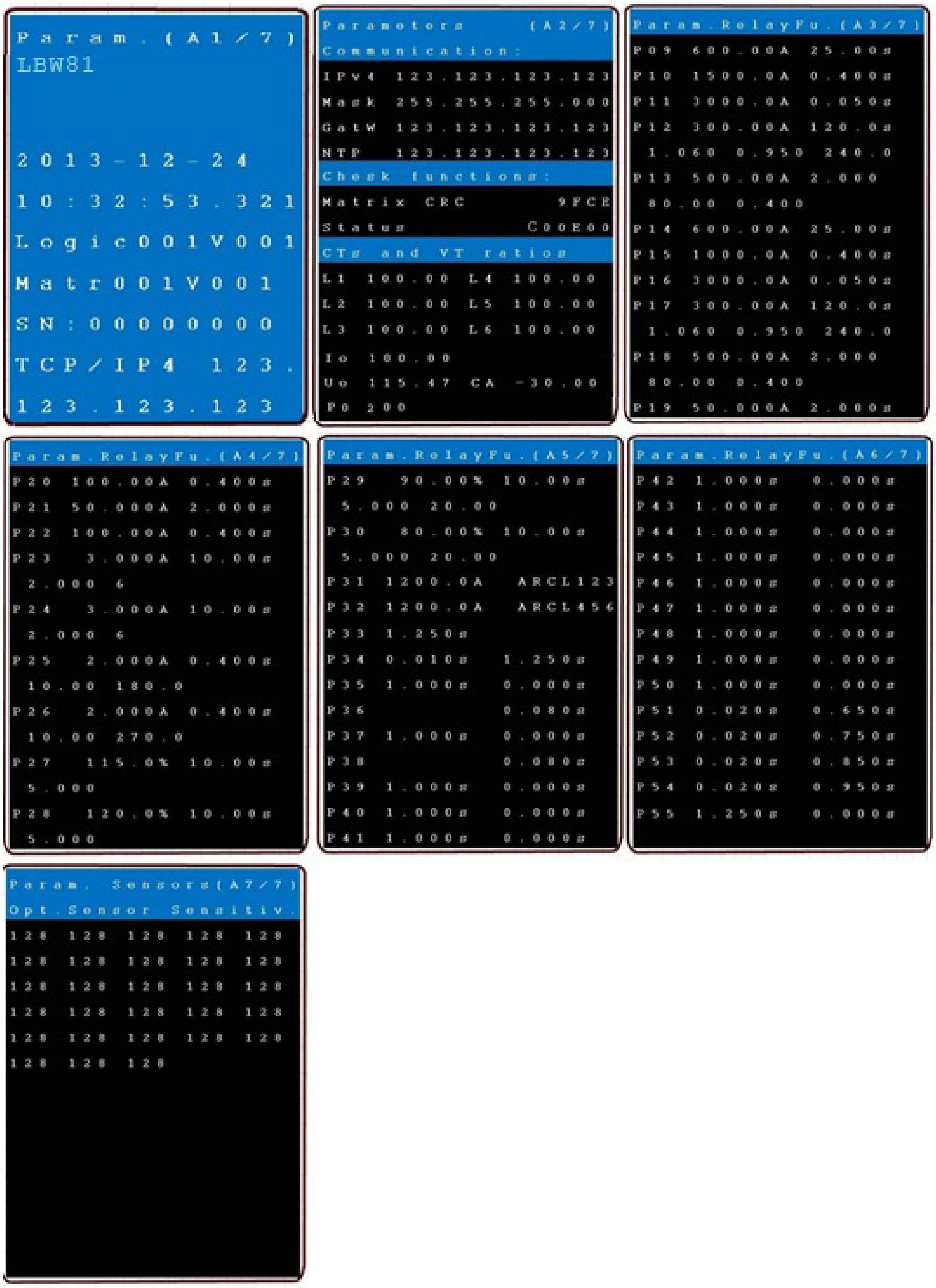
Parameter pages have a blue-coloured top bar tells all parameters are set by using the Excel matrix. Display A1 shows that:

- Relay type as defined by manufacturer
- Date and time
- Logic software name as defined by manufacturer
- Matrix name
- Serial number as defined by manufacturer
- TCP/IP number in use at the moment.

Display A2 shows all the communication parameters that are useful when programming or when connecting the system to SCADA. NTP is Network Time Protocol for clock synchronisation and DHCP is Dynamic Host Configuration Protocol. Both of these can be installed in local network as well, depending on the data switch and substation computer. Check functions are for comparing program changes. CTs and VT ratios are current and voltage transformer ratios, which mean, that the current supplied to a relay must be multiplied by the CT ratio to get the primary current. Relay also shows the primary current in measurement displays. The VT ratio is similar when measuring line-to-line or line- to-neutral voltage. The voltage supply to relay Uo input must be multiplied by the ratio to get the primary voltage. When using a directional earth fault, the Uo input must be reserved for measuring the earth fault voltage, which is normally generated by three voltage transformers having open delta connections. The ratio in this case is 100 % of the earth fault primary voltage (line-to-line voltage / √3) divided by one open delta winding voltage * 3 (system generates in 100 % earth fault).

Displays A3-A6 show all the relay functions settings. The order is the same as in the matrix. The ARC-fault over-current indication parameters are P31 and P32.

A7 shows the optical sensor sensitivities. The order is left to right; Oi1 is first and Oi28 is the last.



3.5 Display Measurement Circulation

The C1 display has two alternatives depending on the Uo connection. Powers and power factors can be measured only if the Uo is connected line-to-line or line-to-neutral. C2 shows the state of all rows and columns at the moment. It is useful when testing the system and likes to see which row or column is activated. The first blue bits are for optical sensors, then the green bits are for digital inputs, and then yellow are the relay function outputs (which show, for example, when the relay starts). Pink bits are for ARC logic rows and red are SCADA rows. Next, the blue are for sensor connection columns and then the green are the switch columns. Orange bits are for output relays and LEDs and yellow for relay functions blocking columns and the last greens for indication columns.

```
Measure Values(C1/2)
L1   135.6  A      -0.913
L2   144.2  A      +0.922
L3   162.2  A      +0.921
U(o)  20536  V  102.7  %
Io   0.51   A
L4   145.9  A      th1/2
L5   145.1  A      0.557
L6   142.2  A      0.572
L123  0.55   A
L456  12.1   A
P1   1467.9  kW
P2   1576.3  kW
P3   1771.1  kW
P123  4815.4  kW
Q123  +56.49  kVAr
```

```
Measure States(C2/2)
00000000000000000000
00000000 00000000000
0000000 000000000000
00000000000000000000
0000000000 000000000
00000000000000000000
00000000000000000000
0000000 000000000000
00000000000000
00000000000000000000
00000000000000
00000000000000000000
00000000000000000000
00000000000000000000
000
```

```
Measure Values(C1/2)
L1   135.6  A
L2   144.2  A
L3   162.2  A
Uo   412.2  V      3.57  %
Io   0.51   A     182.9  D
L4   145.9  A      th1/2
L5   145.1  A      0.557
L6   142.2  A      0.572
L123  0.55   A
L456  12.1   A
```

When using the relay test set and setting the current and voltage, it is very useful to freeze the display C1 by using a longer touch in order to see all times and all measurements.

3.6 Display Events Circulation

The D1 display shows the most recent events. D2-D8 are for showing events that came earlier. Note that one trip or other change of state can cause more events depending on how many matrix rows have text and how the logic is connected. The D displays have grey bars between the each events and in the time stamp the year is indicated on the left with two numbers. Changes to logic ON are with a white background and changes to logic OFF are with black background.

Event Circulation has a total of 8 displays which can show a total of 32 recent events. The new event is shown in display D1 and it automatically overwrites the oldest one as shown in display D8.

When testing the point sensors, it is very useful freeze the display D1 by means of a longer touch. All names of the sensors tested are now visible without having to wait for screen circulation.

3.7 Trip State in Substation

Display E1 shows events up to the trip moment and before it. E2 shows measurements at the trip moment and E3 events before E1 shows. Displays E4 and E5 show events occurring just after the tripping without allowing later events to overwrite them.

After the arc protection tripping, it is always necessary visually check that the indicated switchgear compartment, the cells nearby and the entire switchgear is in good condition before switching the system back on. This is very important because then the reason for the arcing can be discovered. Typical reasons are:

- Dust, water, unknown part or animal nest (ant, insect, mice, rats etc.) in wrong place.
- Broken insulator, for example, ceramic.
- Mistake in the installation, for example, too short a creepage or clearance distance in the cable terminal (cable terminal is made incorrectly).
- Current transformer has open secondary circuit.
- High current in loose connection has too high temperature (loose bolts in the terminal).
- Over-voltage coming outside, for example, lightning starts arcing.
- Fire for miscellaneous reasons.
- Service people opened the door and used a camera or portable lamp (at the same time when the motor or transformer was started with a high inrush current).

Before switching the system on it is necessary to reset the relay by pressing the RESET button on the front panel. In group systems, the RESET button can be external and affects to all relays are member in the same group. Without reset the relay works (generates a new trip) regardless of the LED and display indications and how they are programmed.

The reset button can also be pressed when the system is running, and in some applications this checks that the relay group optical loops are entire. Do not reset the system when there is a high starting (inrush) current present at the same time.

4 DESIGN THE PROTECTION SYSTEM WITH LBW81

4.1 General Matters about Protection

The start time of arc protection systems is about ten times faster than that of the traditional protection relay systems. Faster operation is made possible through the light information with instantaneous values of the high current being enough for trip the circuit breaker without the need of filtering the current transients. If you can ensure that the switchgear compartments are absolutely closed during the operation, then it is possible use light information alone without the need of the relevant current conditions and thus tripping is then even faster.

Typically, the setting of the arc protection current is about 2 - 5 times the normal nominal current. This means that the arc protection indicates sometimes an over-current event is caused when starting the transformers or large motors (normal operations). This is not dangerous as long as the light signal does not occur at the same time. It is important that the arc protection current level is fairly less than what the network impedance calculation enables when all transformers and lines to grid are noted. It is important to calculate the current in phase to ground, the current between two phases and the three-phase short circuit currents. LBW81 has also a voltage input can be used for measuring earth fault voltage. This is useful when you want to detect a non-solidly grounded network switchgear’s internal small current arc fault. In this case, the earth fault voltage with a delay must then activate the arc protection with AND condition of the light sensors, are sat to the sensitive setting.

LBW81 has a very versatile set of normal protection functions can be activated in a setup matrix. This makes possible, that one LBW81 can be worked as an arc protection relay and traditional numeric protection relay. A cost-effective way is, for example, to use LBW81 at the same time the high voltage side backup protection and secondary side arc protection are used. In this case, the current measurement must be taken from the primary side. The versatile set of protective functions makes possible that the LBW81 can be used for protect distribution without automatic reclosing, motors, smaller generators, solar systems, wind turbines, cables and many other industry applications. LBW81 has the following protection function blocks:

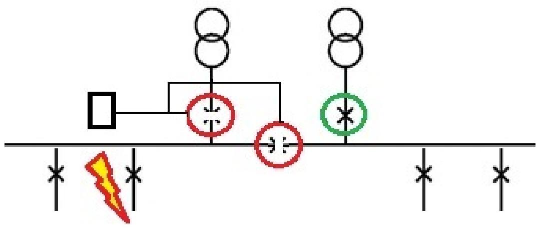
- Three stages of three-phase constant time over current function blocks (123I>; 123I>>; 123I>>>).
- One three-phase thermal overload / current function block (123Ith>; IEC 60255-8).
- One three-phase inverse time over current protection function block (123Ika>; IEC 60255-3).
- Two stages of the three-phase constant time earth fault function blocks (123Io>; 123Io>>).
- Combined block for L1, L2 and L3 phase current transformer, circuit breaker, blown fuse, line cut and tripping circuit supervision (123CT&CB Superv).
- Two stages of a single-phase combined directional and unidirectional sensitive earth fault protection function blocks (Io>; Io>>).
- Two stages of a single-phase constant time over voltage protection function blocks (Uo>; Uo>>).
- Two stages of a single-phase constant time under voltage protection function blocks (Uo<; Uo<<).

If there is an A2 configuration with three extra analogue inputs, then the following functions are available in addition:

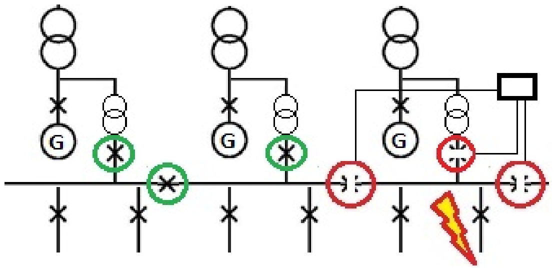
- Three stages of a three-phase constant time over current function blocks (456I>; 456I>>; 456I>>>).
- One three-phase thermal over-load / current function block (456Ith>; IEC 60255-8).
- One three-phase inverse time over current protection function block (456Ika>; IEC 60255-3).
- Two stages of a three-phase constant time earth fault function blocks (456Io>; 456Io>>).
- Combined block for L4, L5 and L6 phase current transformer, circuit breaker, blown fuse band line cut supervision (456CT&CB Superv).

4.2 Design of the Arc Protection System, Cabling and Optical Sensors Placement

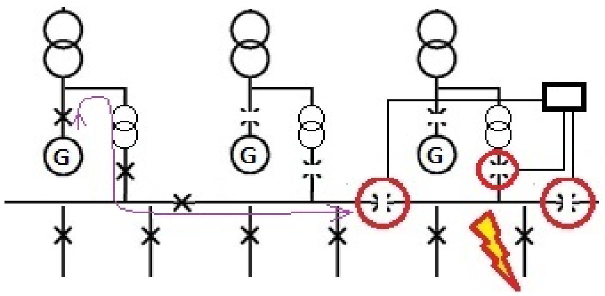
The principle behind arc protection is that the switchgear section has arcing must be switched off as fast as possible. In order to minimise the risk of damage and maximise safety, it is necessary at same time to switch off all breakers supplying power to the arcing section. In order to maximise the electricity available, it is necessary keep voltages in all other sections that do not have arcing.



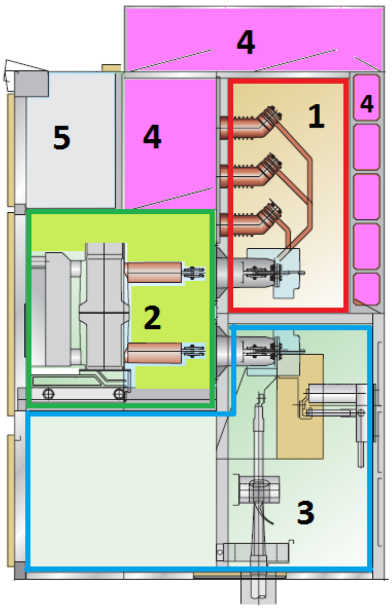
In complicate system, it is very important thing all possible supply directions:

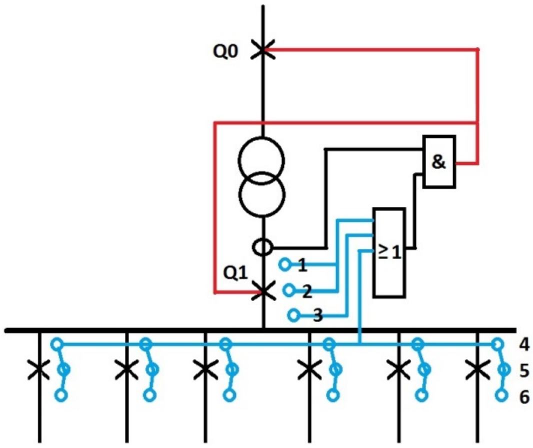


Note that the switchgear section that is arcing does not always have an over- current in same incoming feeder CT:

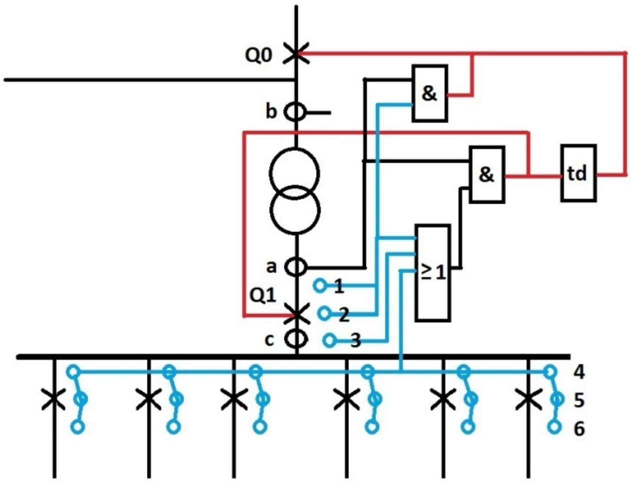


If there is a metal clad switchgear, it needs a sensor in each compartment especially in outgoing feeders. A metal clad switchgear has three separate compartments needing sensors, 1) the bus bar compartment, 2) the circuit breaker compartment and 3) the cable compartment, as arcing is possible in each of these. Other compartments are 4) explosion channels and 5) auxiliary compartment, which do not need sensors. The cable compartment of the incoming feeder is located before the switch and therefore the tripping of breaker Q1 does not break the arcing as detected by sensor 1 or 2. Complete arc protection needs a signal to breaker Q0 to be located before the incoming feeder.

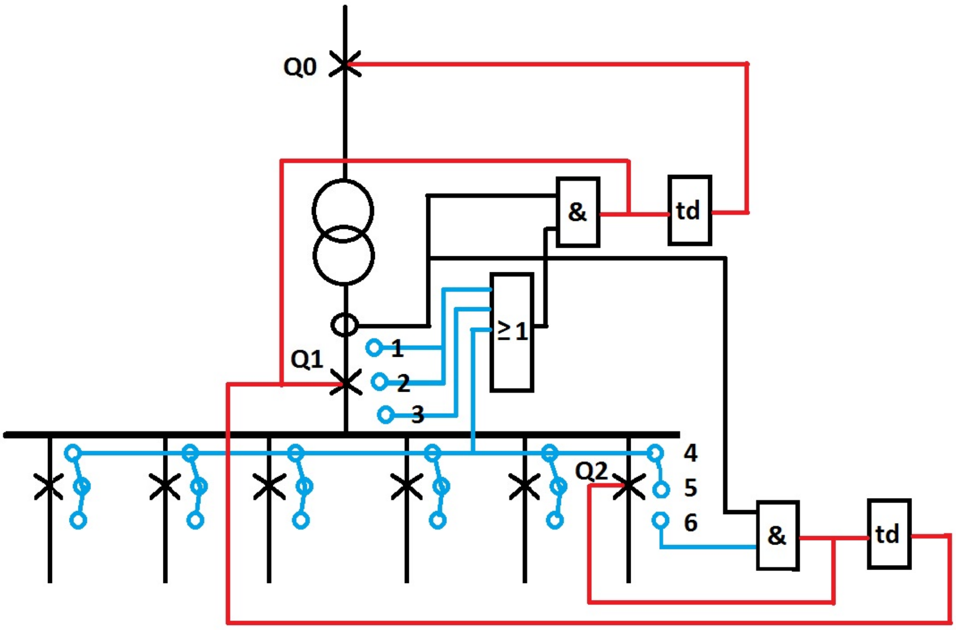




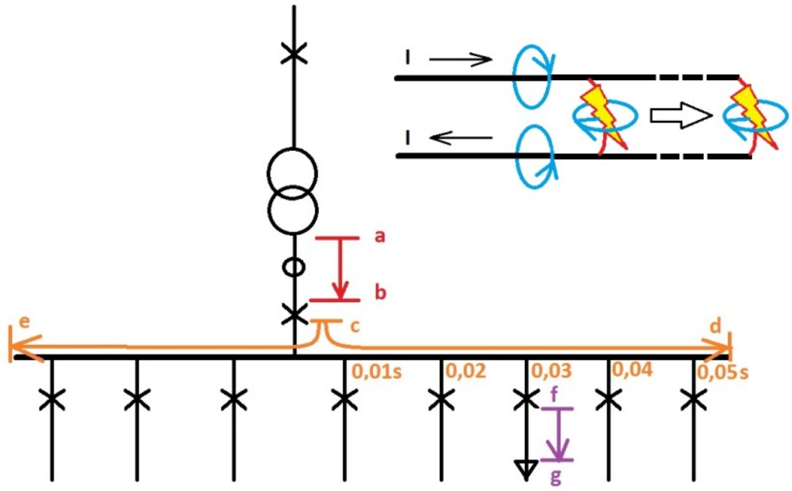
If there are more sections and you wish to maximise the electricity availability, it is clever to have a delay and a direct trip of the high voltage breaker Q0 and a direct trip of the Q1. The normal way is that all sensors 1-6 to trip the incoming feeder breaker Q1 directly and Q0 with a delay (backup tripping), but sensors 1-2 must be tripped directly, as well as Q0. Q1 can switch off the arc detected by sensors 3-6, but they do not affect arcs detected by sensors 1-2. Note also that the protection system does not work if the CT measures a fault current located in point c, but points a or b are both feasible.



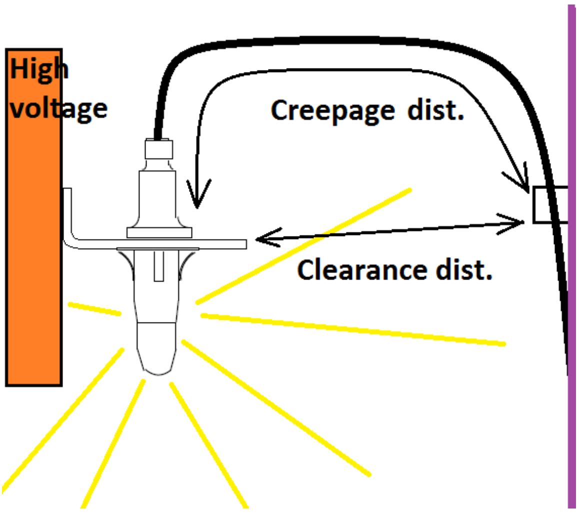
If there is a very important switchgear, it is possible to design the arc protection so that it works in a selective way inside the same switchgear. Selective arc protection minimises the damaged area and circuits must be switched off and by this way it maximises the electric availability. Sensor 6 immediately trips the local outgoing feeder circuit breaker Q2, and after the delay, if arcing still continues, it trips the incoming feeder breaker Q1, above. All outgoing feeders need a similar logic if you want a fully selective system. This is possible by using LBW81 versatile programmability.



The arc moves rapidly, but not very rapidly inside the switchgear and the dynamic magnet field current causes guides it route. Normally, the arc goes in the some tenth of a second to the end of the bus bar and will continue to burn as long as it gets power. It is important to have sensors and light detection in dead ends, where the arc can be stopped. In order to minimize the tripping time, it is also important have light detection at the start of the incoming feed, because having detection at the end alone loses action time. If the arc starts at point a (incoming cable terminal); it stops at point b (circuit breaker is open). If the arc starts at point c (circuit breaker is closed), it stops at point d but, point e is possible (end of the bus bars, two dead ends). If the arc starts at point f (outgoing feeder circuit breaker is closed), it stops at point g (same feeder cable terminal). If the switchgear is 20 m long and the incoming feed is at the end, the arc course time to the other end can take about 0.2 s, which is a very long time in arc protection.

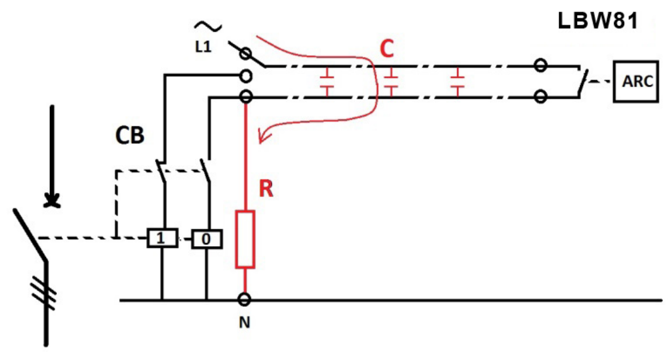


If the switchgear is an open non-enclosed type or if it is located in an unclean environment, it is a good idea to install the sensor so that they look downwards (see picture below). Sometimes, it is necessary to install the sensor very near or close to the high voltage live parts. This is possible if there is enough creepage and clearance distance (see, for example, IEC 60947-1 (≤10 kV) or IEC60076-3 (≥3.6 kV)).

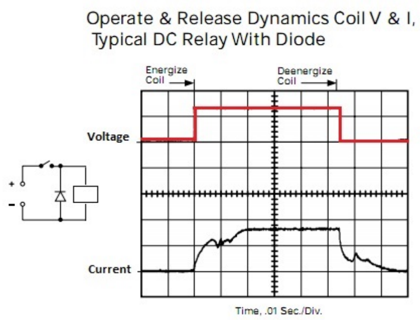


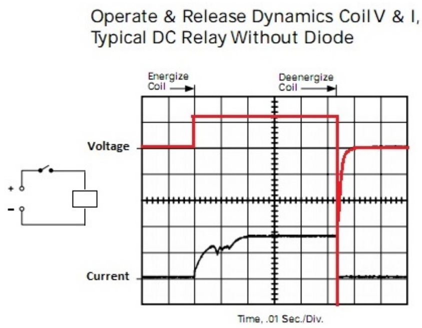
The worst case in arc protection is that it does not work when it should work, but false tripping is also unpleasant. Here are some precautions to ensure a reliable and correct operation:

- Connect LBW81 output relay R1 is activated when power is on, to the substation alarm system. If there are more arc relays, connect the alarm signals that any power failure alarms.
- If there is a circuit breaker with a high tripping coil impedance, use an extra resistor in parallel with the coil in order avoid tripping by auxiliary power voltage transients or capacitive connection by other cables. Do not install the tripping cables close to the high capacitive distortion cables (frequency converter cables). If using AC-voltage in tripping circuits note capacitive current the tripping cables causes, goes over (past) the tripping relay contact. The resistor resistance must be that have about 10 W power when the contact is switched on.



- If there is an external power supply, locate it near the LBW81 or use a well shielded twisted cable connected to the LBW. Do not install this cable close to the other high current and high capacitive distortion cables (frequency converter cables).
- Always use diodes in parallel with the coils (as well as relays) in DC systems for avoid high voltage transients. Connect the diode cathode to + polarity and anode to – polarity.





- LBW81 fast tripping relay (T1...T8) has a surge arrester in parallel with the circuit and it is bidirectional (suitable for AC and DC). Depending on the logic, the tripping signal can be a pulse or continuous type. These relays are capable for switching in a short time many amperes of 220 VDC coils, which traditional relays (R1...R5) cannot switch.
- If a design system has external semiconductor relays which have a very small current in coil circuit, connect an extra resistor in parallel with the semiconductor relay coils (resistor current minimum 20 mA).

4.3 Calculate Optic Cable Light Loss

The optical cable used in the MEYLE-LBW Arc Protection System has been particularly developed to be used in different data transmission applications. The cable is of a single-fibre type and its polyethylene outer layer can endure the most severe operating environment (POF type fibre). The fibre itself is made of plastic, which means that working with it does not require any kind of protection equipment or special tools. The optical cable type is HFBR-EUS.

Light losses in optic components:	
Light loss (extra low loss Plastic Optical Fibre type HFBR-Exx)	0,19 dB / m
Light loss in extension adapter HFBR-4505	min. 0.7 dB, typical 1.5 dB, maxim. 2.8 dB
Light loss in Triplexer	6 dB
Maximum recommend length of HFBR-EUS fibre in ARC-protection sensors	100 m

It is necessary to know roughly the length of the fibre each sensor has, but because the light signal activation level is higher than normal room illuminance, it is normally less than 500 lx; the setting of the separate sensor inputs can normally be same. Note, however, that daylight, portable flashlights and light near the bulb can be lot stronger than the activation level needed. Chapter 6.3 (Set the Optical Sensor Sensitivity) contains a table regarding the sensor sensitivity setting. If needed, calculating some sensor's exact activation level can be done using formula below:

$Ex = En * 10^{\left((s-1)*\frac{0.19}{10}\right)}$ In which Ex is the illuminance level, where the sensor has s metres of fibre and En is the illuminance level when the sensor has 1 m of fibre.

If you want to extend the fibre cable by using HFBR-4505, there will be about 1.5 dB light loss according to the following formula:

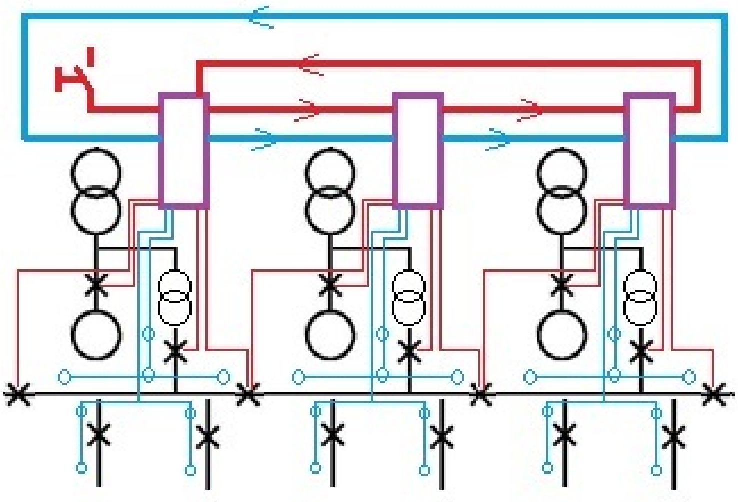
$Ex = En * 10^{\left(\frac{(s1+s2-1)*0.19+1.5}{10}\right)}$ In which (s1+s2) is the total length of the fibres.

4.4 Design System with LBW81 Relays in a Group

LBW81 relays can be worked in a group. Communication takes place via optical outputs and inputs and signal transmission is very fast. Optical signals connected in loop means that the optical fibre goes from relay 1 to relay 2 to N, but then back from relay N to 1. The loop system has internal test when switched on and when pressing the reset button, but it maximises reliability:

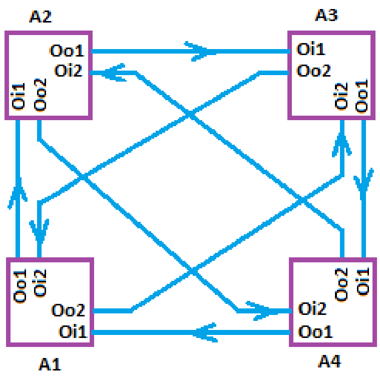
- Connect all LBW81 output relays R1, is activated when power is on, to the substation alarm system.
- Use the same power supply and MCB (fuse) to ensure that all relays start at the same time! If this is not possible, check the internal timers carefully and test the system completely.

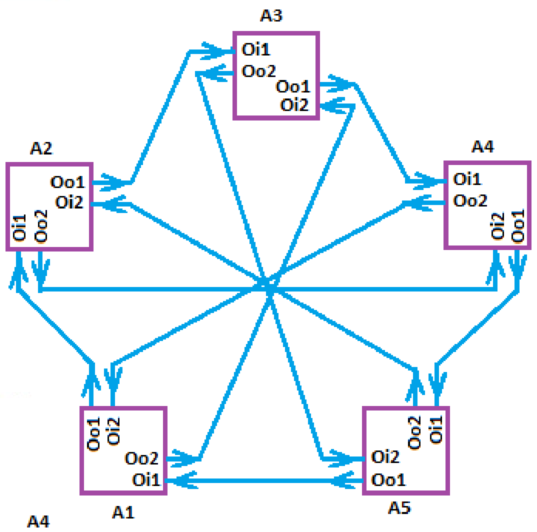
- In order to ensure there is one internal or external RESET button inside the group, the wired signal goes from relay 1 to relay 2 to N and back to 1 (find examples 8.9).
- Do not connect more than 3 relays to a single loop. If there are more current incomings needs current detection, use relays with double analogic current inputs and use redundant loop systems (more below).
- If there are many bus bars and bus couplers, note that typically more relays must trip the same bus coupler (see picture below). Note also that in a substation auxiliary power system, each circuit breaker can be supplier by different MCB (fuse). Do not incorporate galvanically two separate circuits. Use external semiconductor relays if this is necessary to keep circuits separate. Furthermore, all LBW81 output relays (T and R types) are potential free and well isolated.

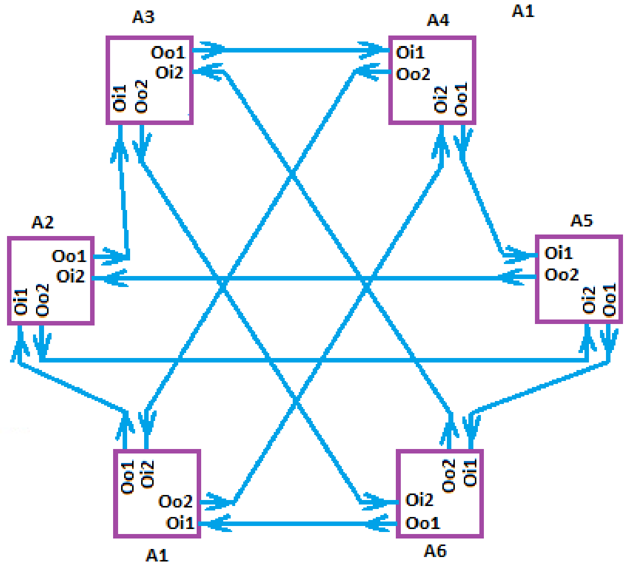


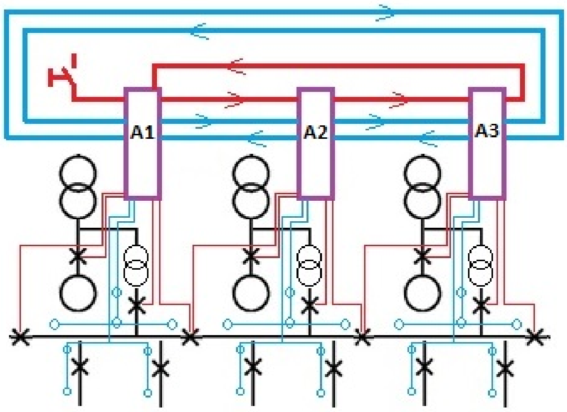
4.5 Redundant Loop Systems

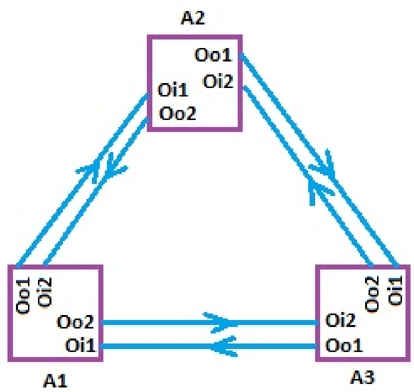
When using LBW relays in group, it is useful to design the system so that it also works when one relay in the loop is without power or damaged. It is possible to define more than one optical input and output for the over current signal loop by using the follow wiring scheme:











When using this kind of system, test it well and check the loop test timing very carefully (matrix parameters P51-P56, find example 8.9).

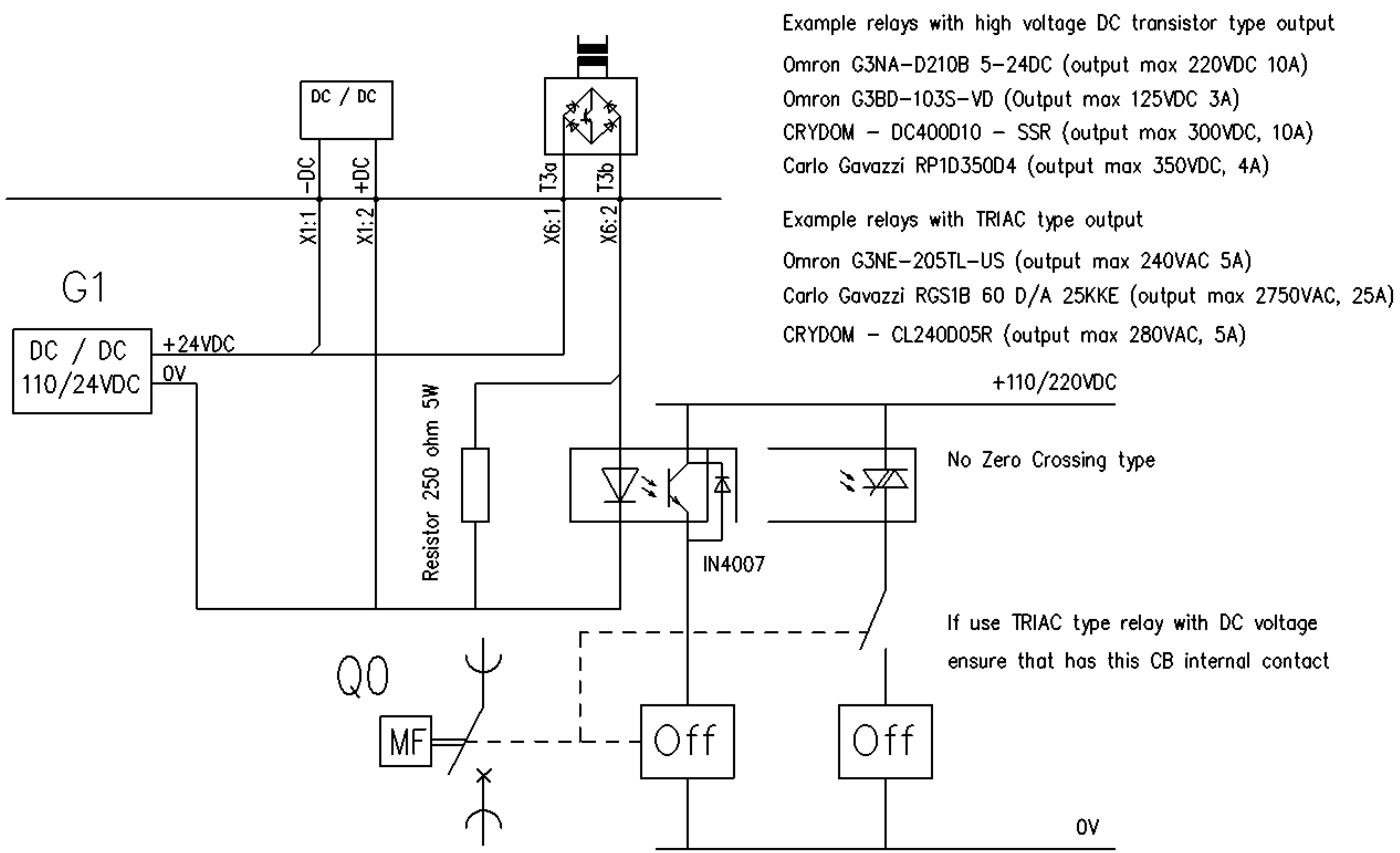
4.6 Adding Extra Semiconductor Relays

In many cases, it is necessary to trip more than one circuit breaker by using only one LBW transistor output. On the other hand, it is very important to keep the different breaker tripping circuits independent of each other. This is possible by using semiconductor relays having only a few µs of internal delay, which means that doesn't affect the tripping time. An alternative solution is, of course, to use circuit breakers having many tripping coils.

Semiconductor relays typically have 5-30 V coil with a few mA of current. In order to improve the transient immunity, it is necessary to place the resistor in parallel. 250 Ω means about 100 mA, and it is absolutely sufficient to remove the capacitive current and for the coil normally to be switched off.

Semiconductor relays have mainly two types of outputs:

- Triac or Thyristor type outputs are normally made only for AC switching, but some types can be also used with DC. The zero-crossing type is the most common and it allows for a switch on the output only if there is AC voltage zero crossing. This type is not suitable for use in arc protection, because it can take about half of cycle (20 ms) before switching on. The random type is suitable for arc protection because it switches on the output immediately when the coil is activated. Triac or thyristor type output conducts current as long as it gets DC voltage and it needs a minimum of about 100 mA current. It is very important to check that the breaker's tripping coil is in serial contact and can switch the coil off automatically when the breaker opens.
- Transistor or Mosfet type outputs are normally suitable only for DC. In AC switching they need an extra rectifier, which is connected as in the LBW transistor output. This type of output is capable switching off DC and therefore it does not need the breaker's internal contact in order to switch the coil off automatically. Note that switching off, especially with 220VDC, is very difficult, which means that it generates a very high voltage of transient if don't use diode. Some semiconductor relays have this diode built-in and it can be connected in parallel with the coil as well.

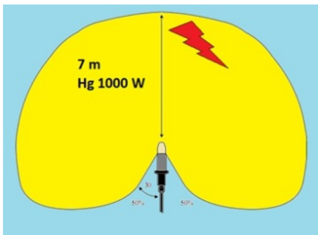

Example relays with high voltage DC transistor type output
Omron G3NA-D210B 5-24DC (output max 220VDC 10A)
Omron G3BD-103S-VD (Output max 125VDC 3A)
CRYDOM - DC400D10 - SSR (output max 300VDC, 10A)
Carlo Gavazzi RP1D350D4 (output max 350VDC, 4A)
Example relays with TRIAC type output
Omron G3NE-205TL-US (output max 240VAC 5A)
Carlo Gavazzi RGS1B 60 D/A 25KKE (output max 2750VAC, 25A)
CRYDOM - CL240D05R (output max 280VAC, 5A)
DC / DC
-DC
+DC
X1:1
X1:2
T3a
T3b
X6:1
X6:2
G1
DC / DC
110/24VDC
+24VDC
0V
Resistor 250 ohm 5W
+110/220VDC
No Zero Crossing type
IN4007
If use TRIAC type relay with DC voltage
ensure that has this CB internal contact
Q0
MF
Off
Off
0V

5 INSTALLATION

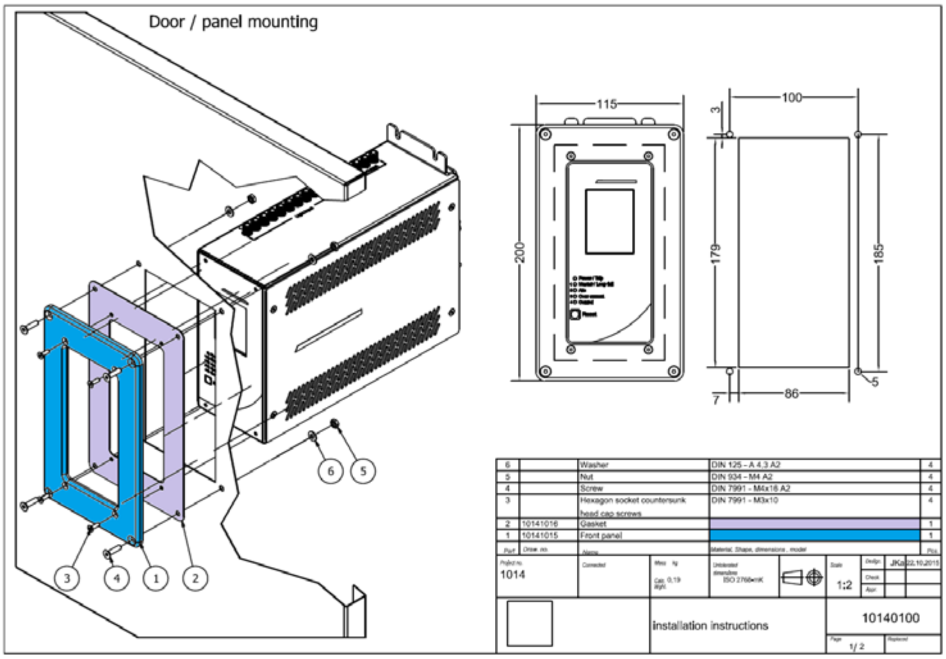
5.1 Installing MEYLE LBW81 on the Door

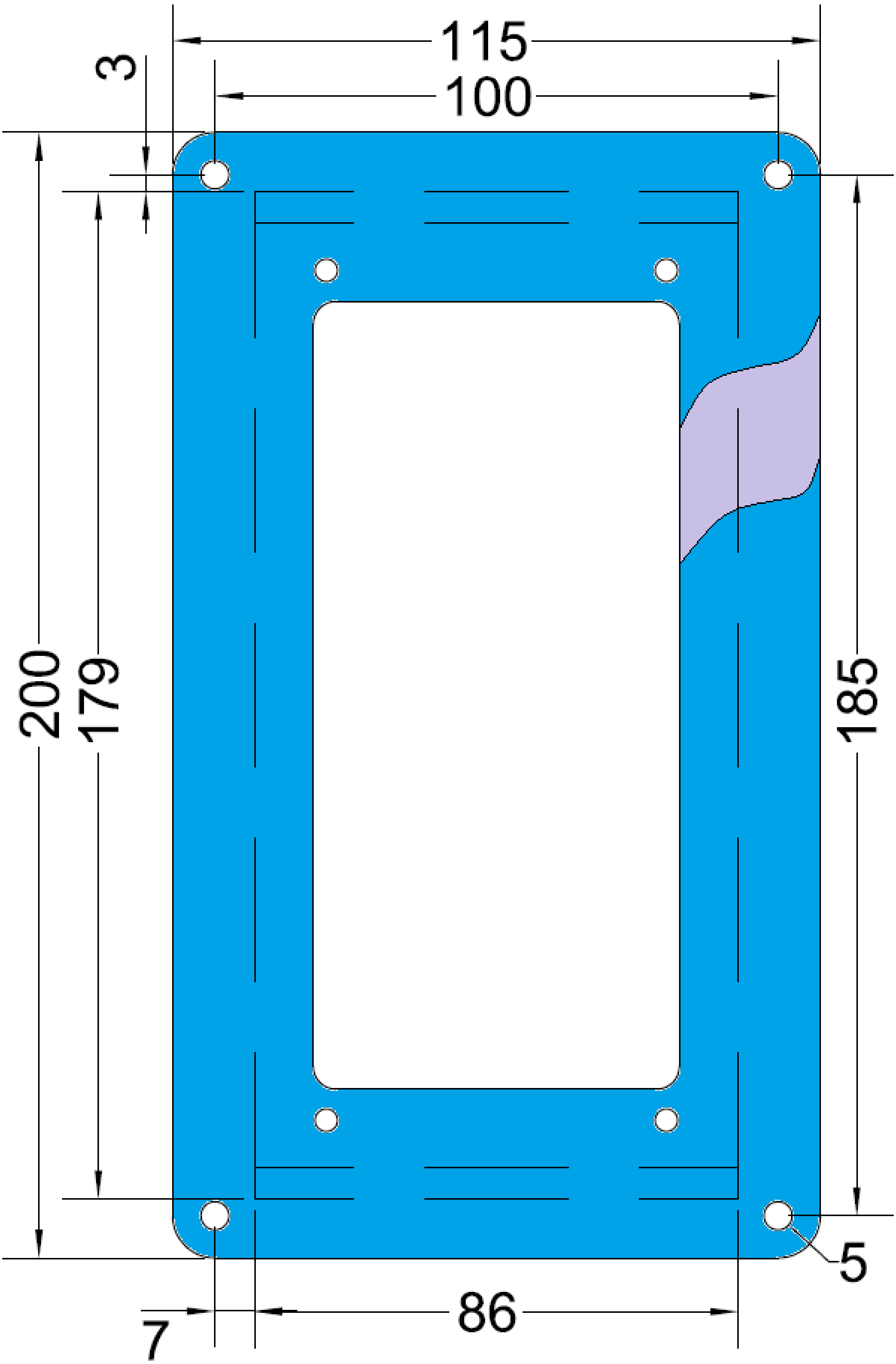
LBW81 is installed on the door so that the front panel of the relay is first mounted on the front side of the door with screws, and then the relay is attached by screws from the rear to the front panel. The door must be made in the shape of a rectangular bore (72 x 170 mm tolerance is -2 mm +0 mm) with four of bolt holes (Φ 5 mm). The picture on the next page shows the dimensions. The blue frame inside the rectangle describes the maximum dimensions of the door boring and of the holes that must be drilled in the door. The purple rectangular shows the position of the gasket relay for sealing the front panel.

- Dimension the door boring carefully, reserve space for the optic sensor cables on the upper side and the wires on the lower side. Dimension the wires and optic fibres so that the door can open and that they reach the relay.
- Make the boring and drill the holes.
- Mount the front panel with the gasket to the door.
- Connect all cables and optic fibres carefully and secure the connections to the relay inside the compartment before mounting the relay to the front panel. If the sensors are set to the very sensitive setting (low lux illuminance), equip these optical inputs with rubber capsules at the relay end in order to prevent diffused light from entering the sensor.



- Mount the relay to the door and to the front panel withy screws via the front side.
- Ensure that the wires and especially the fibres are not subjected to mechanical tension, mechanical compression or too small a bending radius.





LBW81 front panel and door installation dimensions

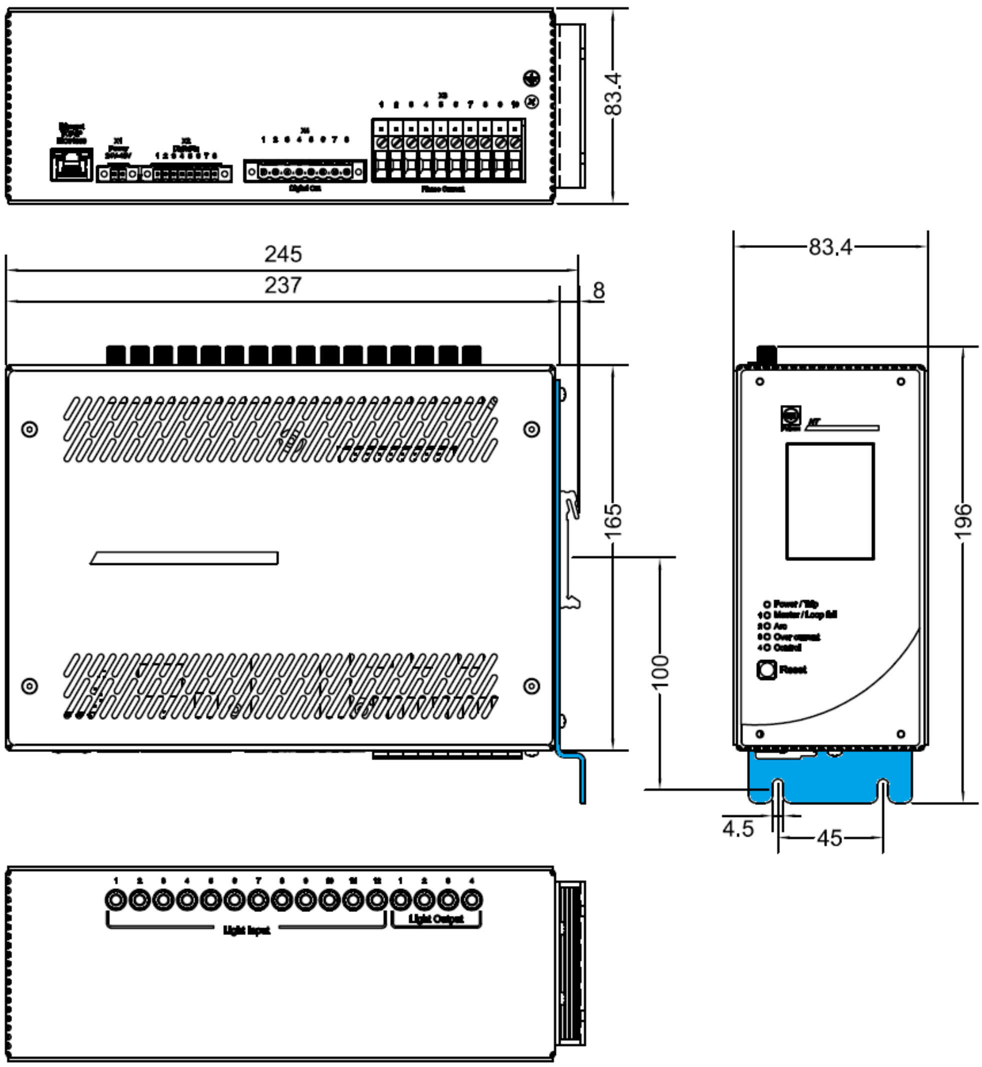
Ensure that the fibres are not subjected to pulling when opening and closing the door. This is very important because the small gap inside the relay sensor connector reduces the sensitivity of the sensor and then it needs more intensity to work. Tighten the sensor input bush rings well and very carefully, and use only your hand when tightening. Always test afterward that the fibre does not come out when pulled a little. Connect the fibres into the door construction before and after the hinges, but let the fibres run from the relay's optical connectors with a natural radius and without any pulling resulting from the installation.

Do not install the auxiliary compartment lamp next to the sensor inputs.

Ensure that the male wire connectors are connected to the relay's female connectors with screws; in particular, the connector has CT circuits which are dangerous when are open.

5.2 Installing MEYLE LBW81 in the DIN-rail

The relay is quite heavy and needs a DIN-rail installation support point outside of the rail. Connect the rail properly and use the support clip (seen in blue in the picture below).



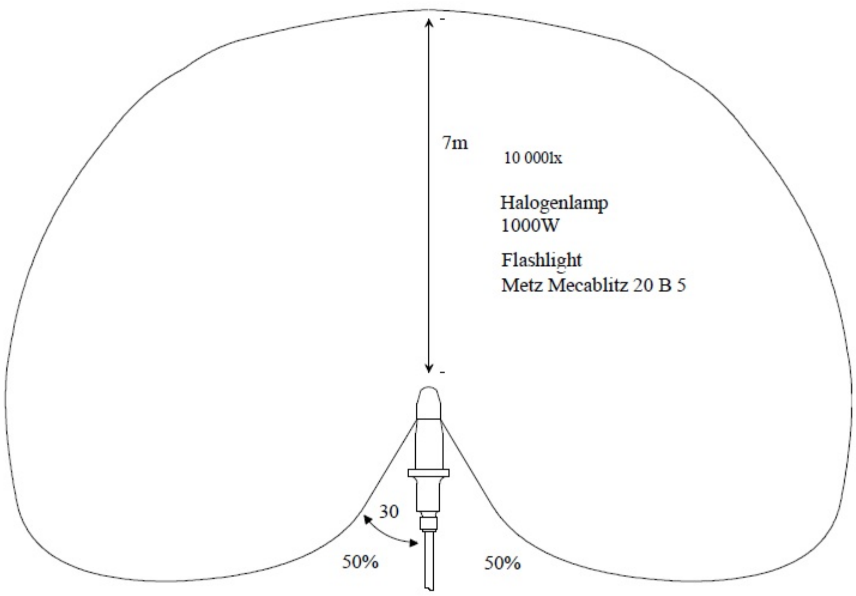
- Connect all cables and optic fibres carefully to the relay before mounting the relay to the switchgear bottom plate. Ensure that the male wire connectors are connected to the relay's female connectors with screws; in particular, the connector has CT circuits which are dangerous when are open.

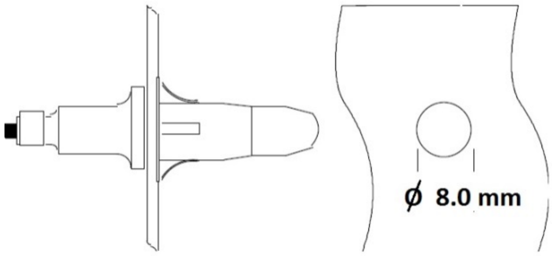
- Place the fibres into the installation duct with a natural radius and without pulling resulting from the installation.
- If the sensors are set to a very sensitive setting (low lux illuminance), equip these optical inputs with rubber capsules at the relay end in order to prevent diffuse light from entering the sensor.
- Tighten the sensor input bush rings well and very carefully, and use only your hand when tightening. Always test afterward that the fibre does not come out when pulled a little.
- Mount the relay to bottom plate with screws. If the DIN-rail height is higher, use a longer screw and nuts or washers, so that the support is good.
- Ensure that the wires and especially the fibre are not subjected to mechanical tension, mechanical compression or too small a bending radius.
- Do not install the auxiliary compartment lamp next to the sensor inputs.

5.3 Installing Optical Sensors

A light sensor is installed into the cell and into the compartment you want to protect. The sensor likely does not need to be directed toward the point where the arc occurred, but shadows must be taken into account. The sensor sees for a distance of about 6-7 m, but only if the space is open, which means there are no capsulated types of switchgear or room. This is the maximum distance between the separate point sensors. Normally, inside the capsulated switchgears the spaces are much smaller and a separate point sensor is needed in each compartment.

See Chapter 4.2 which has useful information about the switchgear compartments and constructions, the behaviour of the arc and information on how to prevent dust accumulation from affecting the sensors.





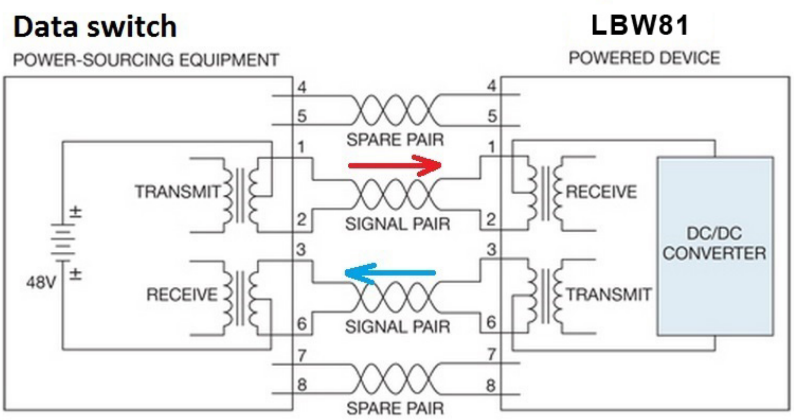
In low voltage switchgears, at least the incoming feeders, bus bar compartments and the largest outgoing feeders must be equipped with sensors.

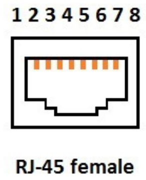
- Normal implementation is that the sensor lens is inside the compartment you want to control, but the fibre inside the auxiliary compartment does not need arc detection.
- In the bus bar compartment, install the sensors so that they see both ends of the bus bars arc is stopped, near the incoming feeder arc probably starts and along the way the arc moves toward the ends of the bus bar (Chapter 4.2).
- If there are devices or constructions that are blocked out the sensor's field of view, install the sensor so that it sees the bus bars, cables or connectors where the arc is stopped.
- Note that in incoming feeder the arc protection system doesn't break the arching is before the breaker trip signal is wired. Use delayed backup trip or trip directly the CB is located before.
- If there is an incoming feed with only one CT, which is after the breaker arc protection trips, the over current detection does not start until the arc is moved over the CT. In order to avoid this delay, use CT which is located before the incoming feeder, for example, at a higher voltage level.

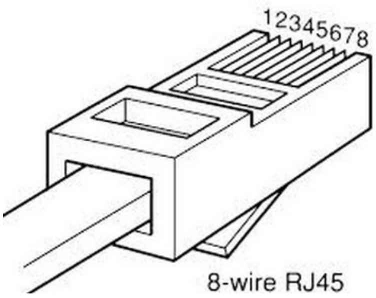
5.7 Installing Communication Cables

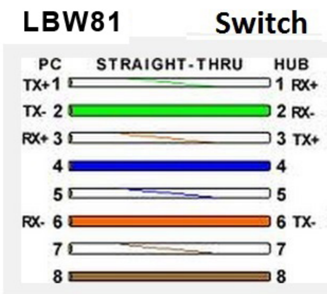
If the data cable is longer than 2 metres, use STP (Shielded Twisted Pair) or FTP (Foiled Twisted Pair) type Cat5 or better cable. Note that the data cable shield must be earthed in one or both ends depending on how high the potential difference is possible between the ends during power system earth fault, short circuit or normal operational state. If the relays and data switch are in same switchgear, and they have good metal and wired grounding, it is better to connect the cable shield in both ends to the relay and data switch ground. If the cables go to separate switchgears and if the system consists lot or relays, it is better to ground only the data switch end. As well, use one grounding at the switch end when the relay is far away from the data switch.

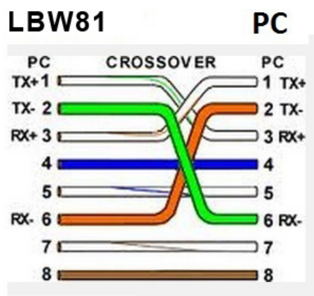
Note that if you connect the relay directly to the PC, the cable between the units must be crossover type.



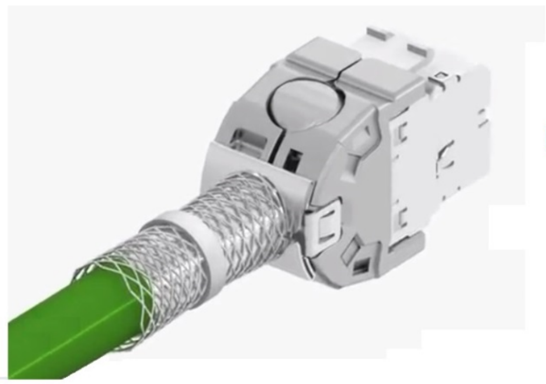


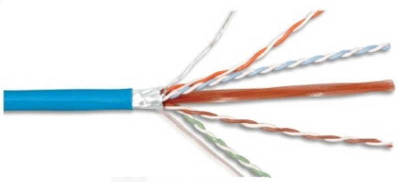






In fixed installation, use cables with twisted pairs and foils or shields and an RJ45 connector having a metal shield connection to relay / switch metal case.





FTP (F/UTP)

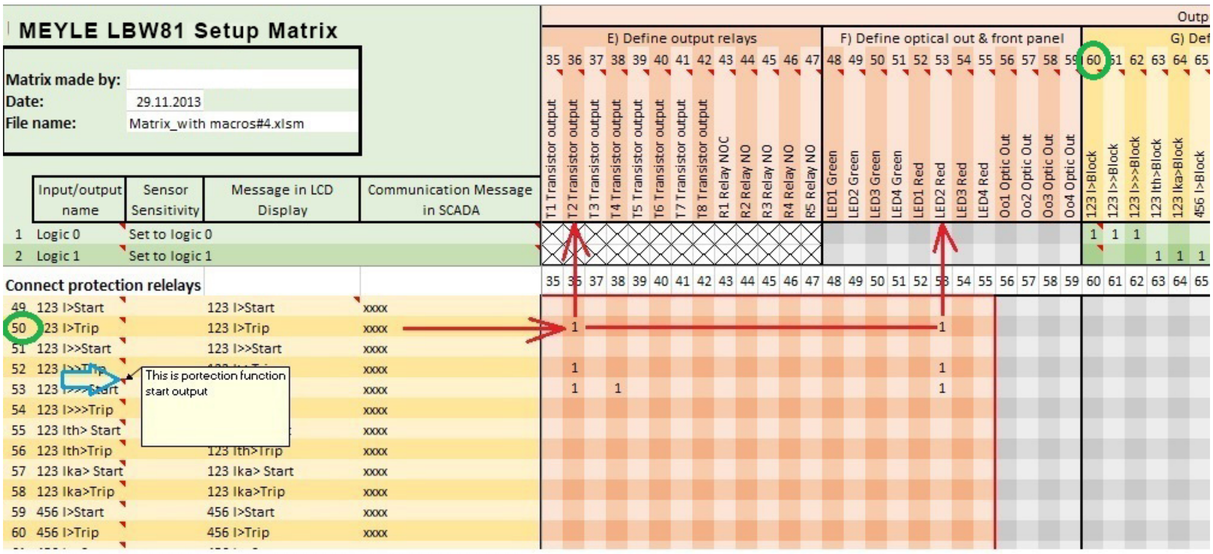
STP (S/FTP)

6 PROGRAMMING LBW81

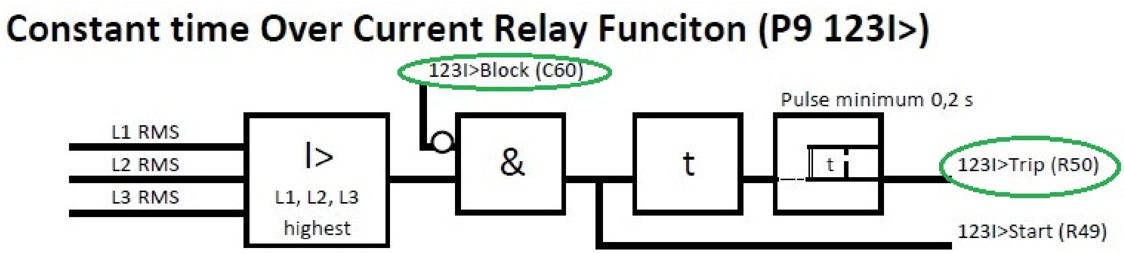
6.1 General Instructions for Programming

LBW81 has very versatile features with regard to programming. The main principle in user level programming is to use and fill the connection matrix made in standard Microsoft Excel. The user program (matrix) of the relay is sent from PC to the relay by pressing the “Send”-button, which is in the Excel sheet. Data are firstly converted by Excel macro into a format the relay can understand and then send by TCP/IP address, which is necessary to give when programming.

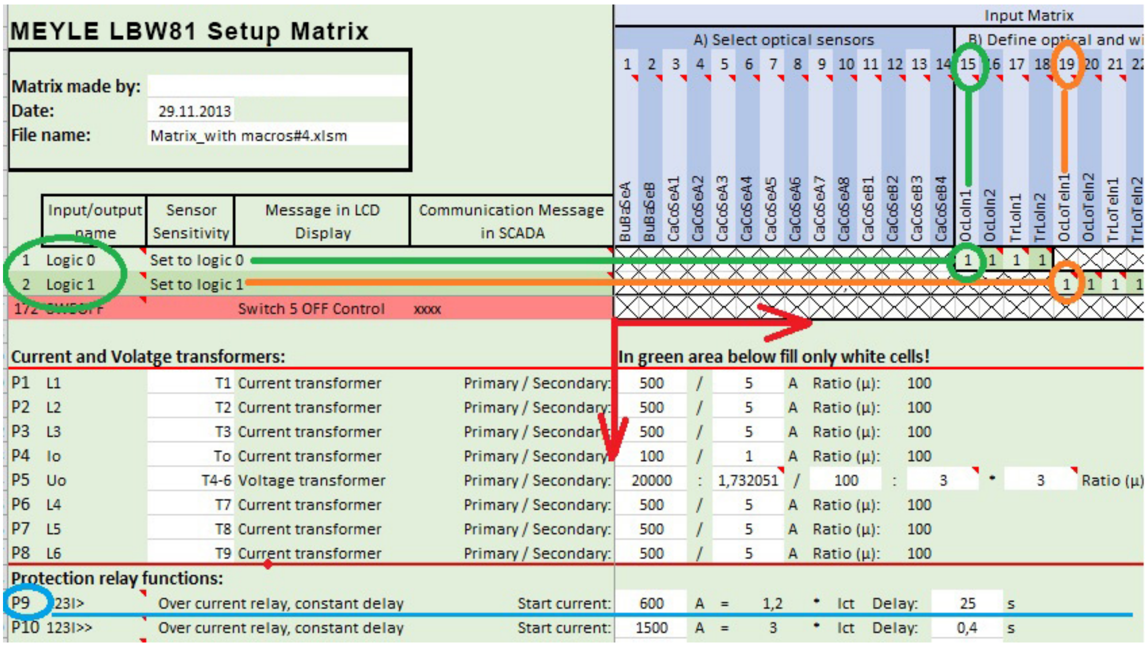
In a matrix, all connections are made by putting the number 1 into each switching point you want to connect. Switching does not affect the other lines, which means that each horizontal row has an OR-gate that keeps signals independent. If one row signal is active and connected by number 1 to some column, it activates the column, for example, the constant time over current relay 123I>Trip activates output relay T2 and LED2 Red at the same time.



Each row and column in the Excel sheet has an identification with a red corner comment, which defines the purpose of this signal (blue arrow). The same Excel file has a Logic sheet, which is described using logical symbols as to how this signal works. Each logic input and output also has a row and column address as in the block diagram (green circles).



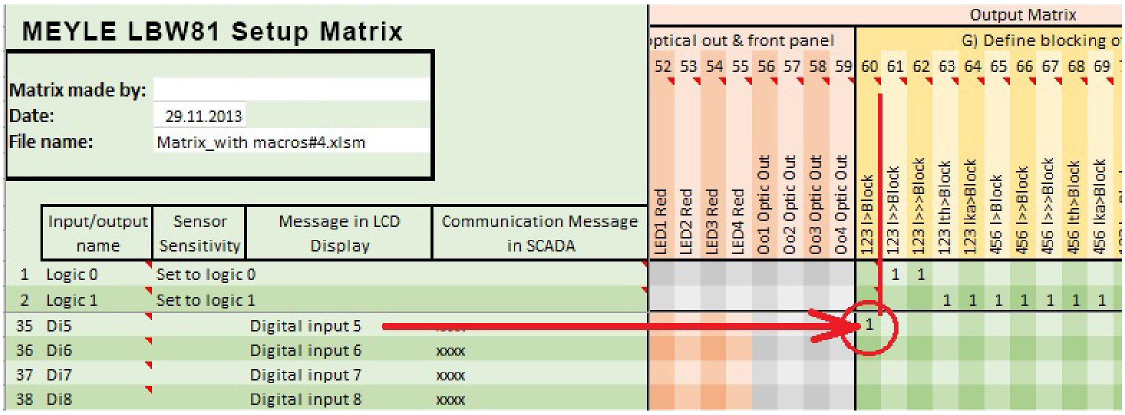
Parameters, all protection relays and block function have, are defined at the end of the Excel matrix. P9 is a row having all the parameters this protection function needs (blue circle and line in picture below).



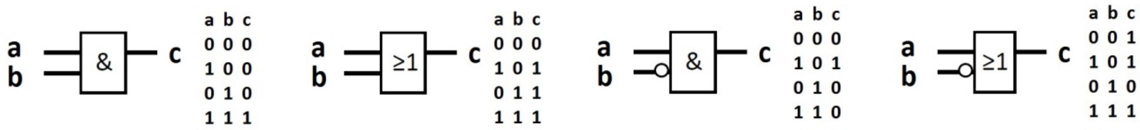
In the matrix the point having red arrows (picture above), is connected in fixed way to the matrix sheet. When using a keyboard arrow buttons, the first rows and columns are always visible. This is useful because row and column comments and numbers are always easy to see.

Rows 1 and 2 are for permanently connecting columns to logical 0 or 1. In the picture above, column 15 (C15) is connected permanently to the logical 0 and column 19 (C19) to logical 1. This is necessary when you want to activate or passive some block or signal input.

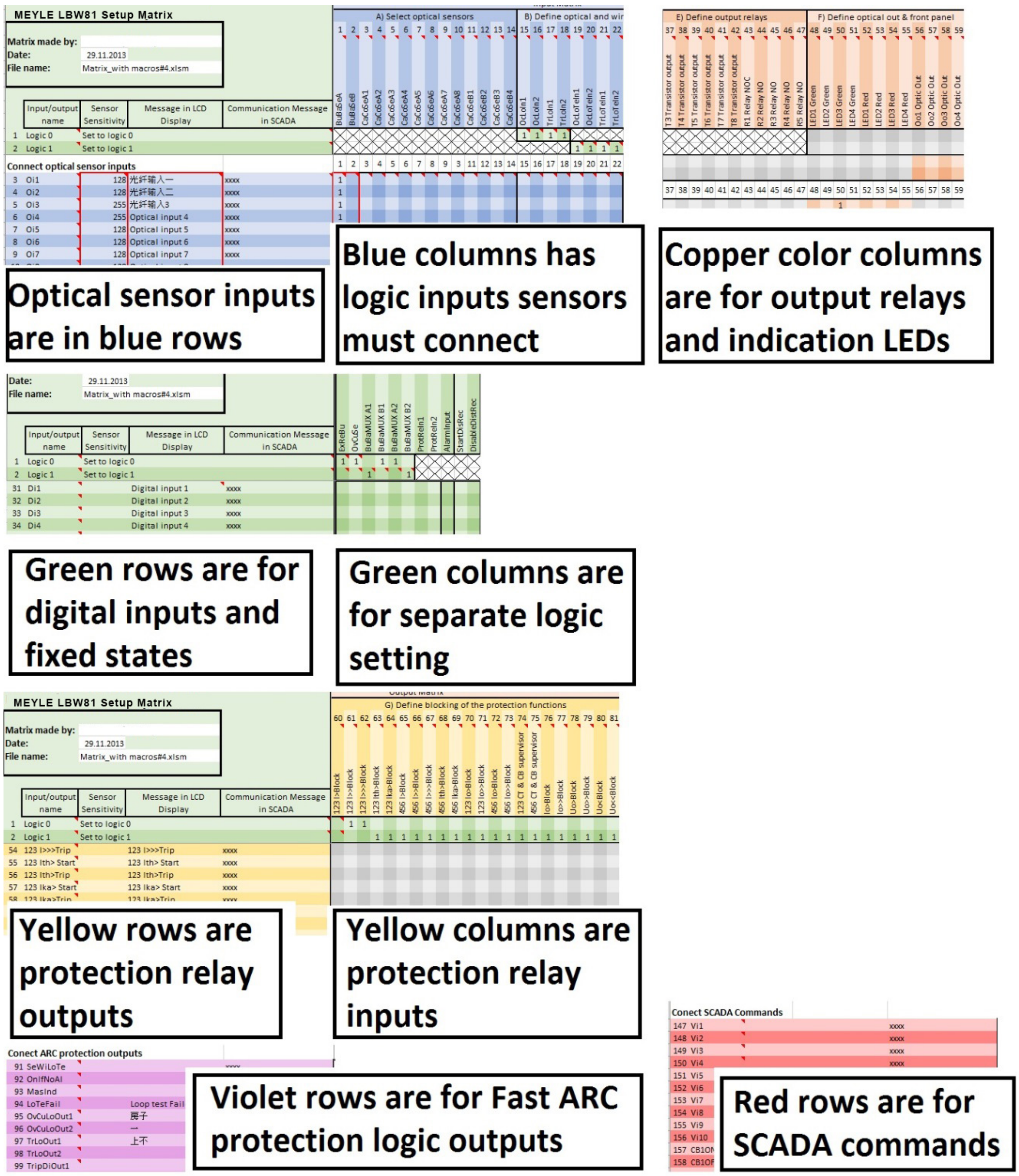
In picture below, the constant time over current relay P9 123I> has a blocking input, C60, which is for making the relay passive when is activated. This input is intended for receive blocking (interlocking) signal and now this is done by using a digital input 5, receives signal, can be generated and sent by other relay in the switchgear’s outgoing feeder. Appropriated block 123I> is in the incoming feeder and the outgoing feeder has an over current. The block signal prevents the operation of this over current relay because the over current relay in the outgoing feeder will trip soon.



Block symbols having a circle means inverse signal operation. Operation Logic of the symbols is defined below.

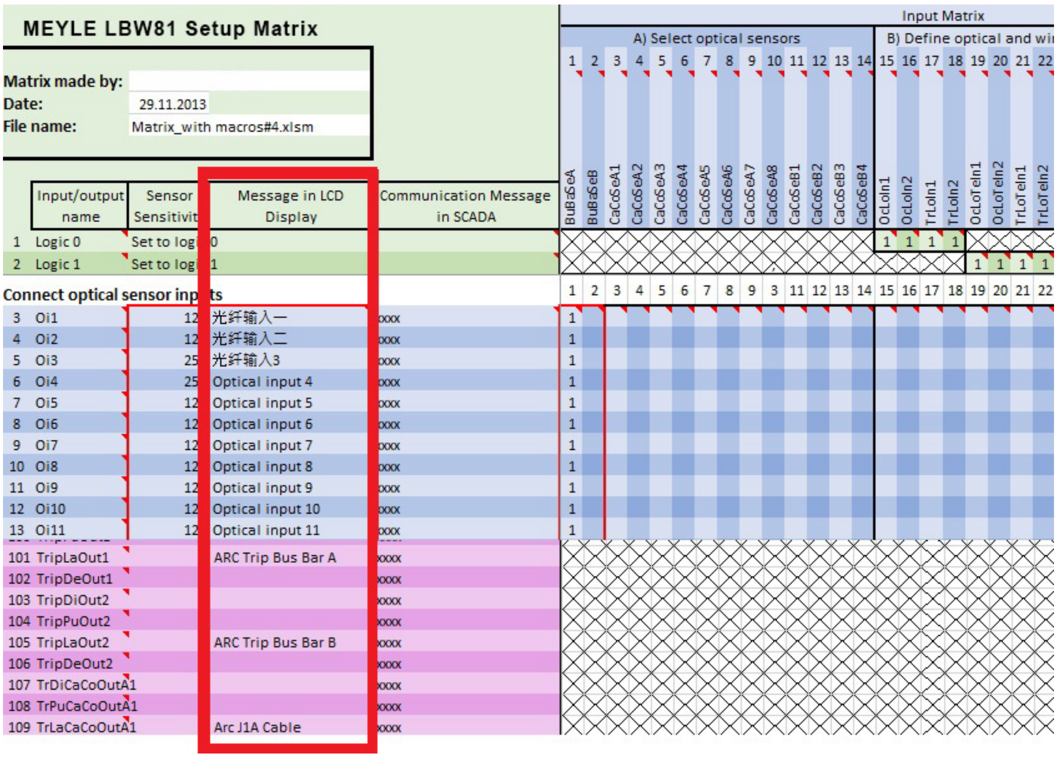


Excel sheet has lot of colours have logical meanings:



6.2 Show User Messages in Front Panel Screen

LBW81 has a colour touch screen display that can show multi-language characters. The Excel matrix has a column (red rectangle) for purposes described; the user messages will be sent to the display if this row goes to an active state or back to passive state. The message is equipped automatically with the date and time stamp and position indication as ON or OFF. If the row changes position but does not have text, the display does not show any message in the screen and in the event log. Do not fill all the rows with text, because, in a fault condition, the same signal can trigger lot of messages by following the logic in the program, and then the general message to the operator is not clear and is hard to understand.



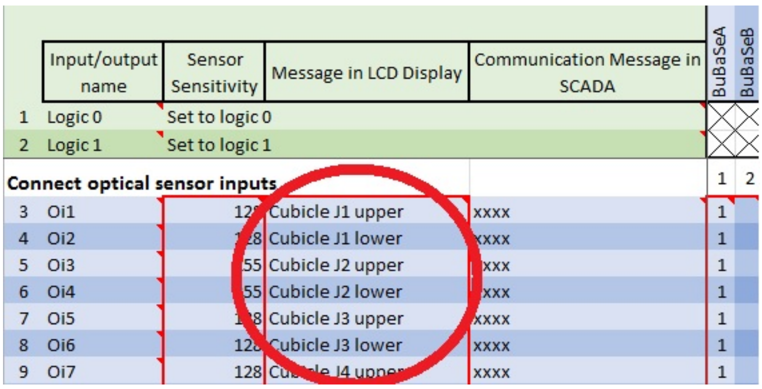
MEYLE LBW81 Setup Matrix

Matrix made by:
Date: 29.11.2013
File name: Matrix_with macros#4.xlsm

Input Matrix — A) Select optical sensors: 1 BuBaSeA, 2 BuBaSeB, 3 CaCoSeA1, 4 CaCoSeA2, 5 CaCoSeA3, 6 CaCoSeA4, 7 CaCoSeA5, 8 CaCoSeA6, 9 CaCoSeA7, 10 CaCoSeA8, 11 CaCoSeB1, 12 CaCoSeB2, 13 CaCoSeB3, 14 CaCoSeB4; B) Define optical and wi…: 15 OcLoIn1, 16 OcLoIn2, 17 TrLoIn1, 18 TrLoIn2, 19 OcLoTeIn1, 20 OcLoTeIn2, 21 TrLoTeIn1, 22 TrLoTeIn2

	Input/output name	Sensor Sensitivit	Message in LCD Display	Communication Message in SCADA	BuBaSeA
1	Logic 0	Set to logi	0		
2	Logic 1	Set to logi	1		
	Connect optical sensor inp		ts		1
3	Oi1	12	光纤输入一	xxx	1
4	Oi2	12	光纤输入二	xxx	1
5	Oi3	25	光纤输入3	xxx	1
6	Oi4	25	Optical input 4	xxx	1
7	Oi5	12	Optical input 5	xxx	1
8	Oi6	12	Optical input 6	xxx	1
9	Oi7	12	Optical input 7	xxx	1
10	Oi8	12	Optical input 8	xxx	1
11	Oi9	12	Optical input 9	xxx	1
12	Oi10	12	Optical input 10	xxx	1
13	Oi11	12	Optical input 11	xxx	1
101	TripLaOut1		ARC Trip Bus Bar A	xxxx	
102	TripDeOut1			xxxx	
103	TripDiOut2			xxxx	
104	TripPuOut2			xxxx	
105	TripLaOut2		ARC Trip Bus Bar B	xxxx	
106	TripDeOut2			xxxx	
107	TrDiCaCoOutA1			xxxx	
108	TrPuCaCoOutA1			xxxx	
109	TrLaCaCoOutA1		Arc J1A Cable	xxxx	

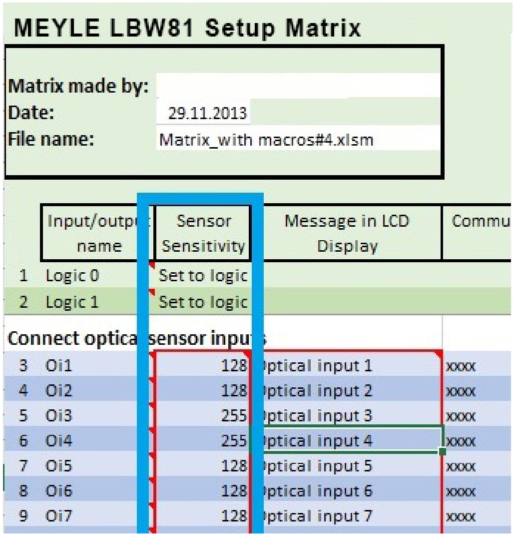
In order to keep the event list clear, do not equip all matrix rows with text when programming. For example, indicate of the CB position needs only text in digital input which is connected to an indication switch NO contact and digital input for CB NC contact should be left without text. It is a good idea to furnish all optical sensor inputs with text.



	Input/output name	Sensor Sensitivity	Message in LCD Display	Communication Message in SCADA	BuBaSeA	BuBaSeB
1	Logic 0	Set to logic 0				
2	Logic 1	Set to logic 1				
	Connect optical sensor inputs				1	2
3	Oi1	128	Cubicle J1 upper	xxxx	1	
4	Oi2	128	Cubicle J1 lower	xxxx	1	
5	Oi3	255	Cubicle J2 upper	xxxx	1	
6	Oi4	255	Cubicle J2 lower	xxxx	1	
7	Oi5	128	Cubicle J3 upper	xxxx	1	
8	Oi6	128	Cubicle J3 lower	xxxx	1	
9	Oi7	128	Cubicle J4 upper	xxxx	1	

6.3 Set the Optical Sensor Sensitivity

In each optical sensor input, the LBW81 has an independent programmable setting of the input sensitivity. This is useful, when there are different lengths of fibres and you want to define the exact activation intensity or when there is an optical loop with the naked fibre detecting light coming from the side (radial diffuse light). Illuminances in the table below are measured by halogen light, using a lux-meter beside the sensor and with a normal transparent type of optical lens. The reference is with a one-metre long fibre.



MEYLE LBW81 Setup Matrix

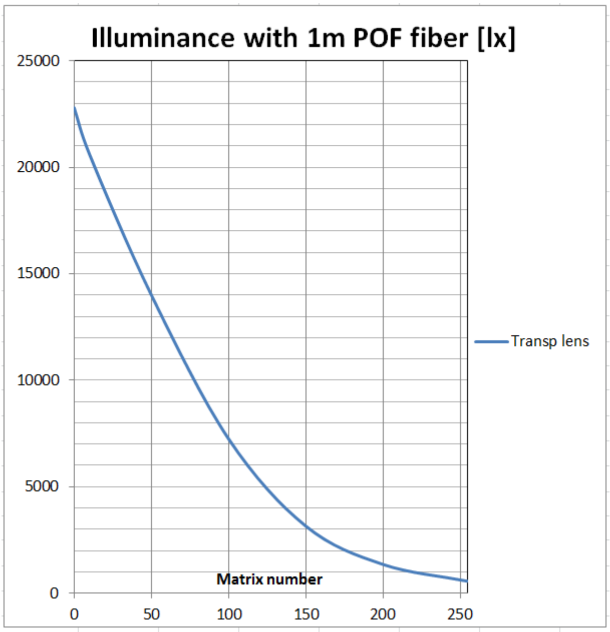
Matrix made by:
Date: 29.11.2013
File name: Matrix_with macros#4.xlsm

	Input/outp name	Sensor Sensitivity	Message in LCD Display	Commu
1	Logic 0	Set to logic		
2	Logic 1	Set to logic		
Connect optica sensor inpu				
3	Oi1	128	ptical input 1	xxxx
4	Oi2	128	ptical input 2	xxxx
5	Oi3	255	ptical input 3	xxxx
6	Oi4	255	ptical input 4	xxxx
7	Oi5	128	ptical input 5	xxxx
8	Oi6	128	ptical input 6	xxxx
9	Oi7	128	ptical input 7	xxxx

Number 0 means: **22,8** klx
Nember 255 means: **0,63** klx
Fiber absorption: POF **0,19** dB/m

Sensor sensitiveness, setting and fiber length

Length of the fiber [m]	2	4	8	16	32	64	128 klx
1	175	139	94	36			
5	183	149	107	52			
10	193	161	121	71	6		
15	203	171	135	88	28		
20	213	182	147	104	49		
25	225	192	159	119	68	2	
30	255	201	170	132	85	24	
40		223	190	157	116	65	0
50			210	178	143	99	42
75				235	196	164	126
100						215	183
123							255



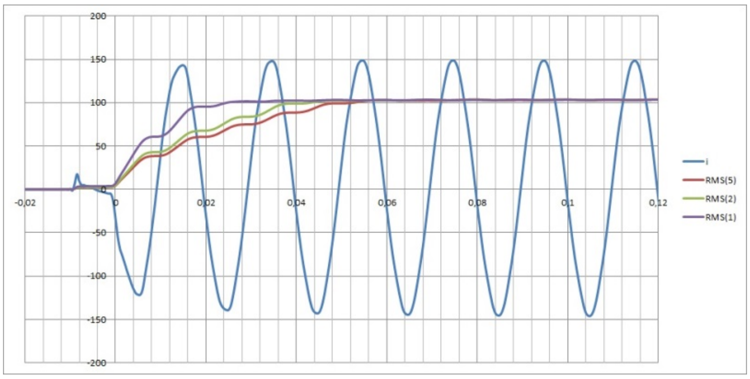
6.4 Setting of the CTs and VTs ratios and RMS value filtering

Parameters P1-P4 and P6-P8 (A2 configuration) are for setting CT ratio. First number is primary and second is secondary nominal current. Next sell calculates ratio means that secondary current supplied to relay must be multiplied by this ratio for get current in primary. The current inputs L123 and in option A2 inputs L456 are dimensioned that they can measure short time maximum RMS 100 A (20*5 A) and input Io that can measure 50 A (10*5 A). Newer set the relay functions tripping parameters to higher level. Note that protection type CT class 5P10 means that error is 5% when primary current is 10 *In and therefore the secondary circuit probably newer reach 20*In level means that the setting must be lower.

Current values are given in matrix parameters and shown in displays are always multiplied by the CT ratio, which means that they are currents in primary.

Parameter P0 is “Number of the samples in RMS calculation”. This defines how many samples are used in RMS value calculation. It is important to note that the shortest time used in one RMS value calculation, is the same as one cycle has. The calculation is a quadratic moving average of the samples and the sample frequency is 2000 Hz means that samples are taken in a 0.5 ms time gap. All protection relay functions use the same RMS calculation, and functions are faster if there are short (one cycle) RMS calculations, but at the same time they are more sensitive to transients and abnormal values which often appears in power switching. If using instantaneous over current protection with less than 0.1 s time, it is important to set the number of the samples, which means P0 to one cycle (50 Hz = 40 and 60 Hz = 33). If needed for the most stable operation, a sample number of 200 is recommended. This is suitable for both 50 and 60 Hz grid frequencies. Note that the RMS calculation affects the tripping time in the magnitude of the over current. This means that the current is twice the relay start current gives always fast operation. This parameter (P0) does not affect the fast arc protection over current indication, which uses instantaneous values.

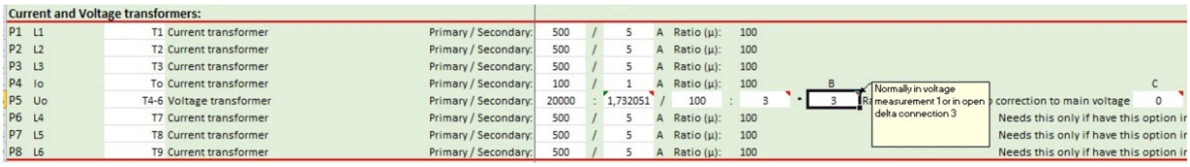
Cycles	1	2	3	4	5	6
Samples in 50 Hz	**40**	**80**	**120**	**160**	**200**	
Samples in 60 Hz	33	67	**100**	133	167	**200**



Parameter P5 is for VT setting. The primary voltage is given by two numbers and the first one is the measuring system’s nominal line to line voltage and the last one is normally in the star connection VT system √3 or in the two-phase line to line system 1.

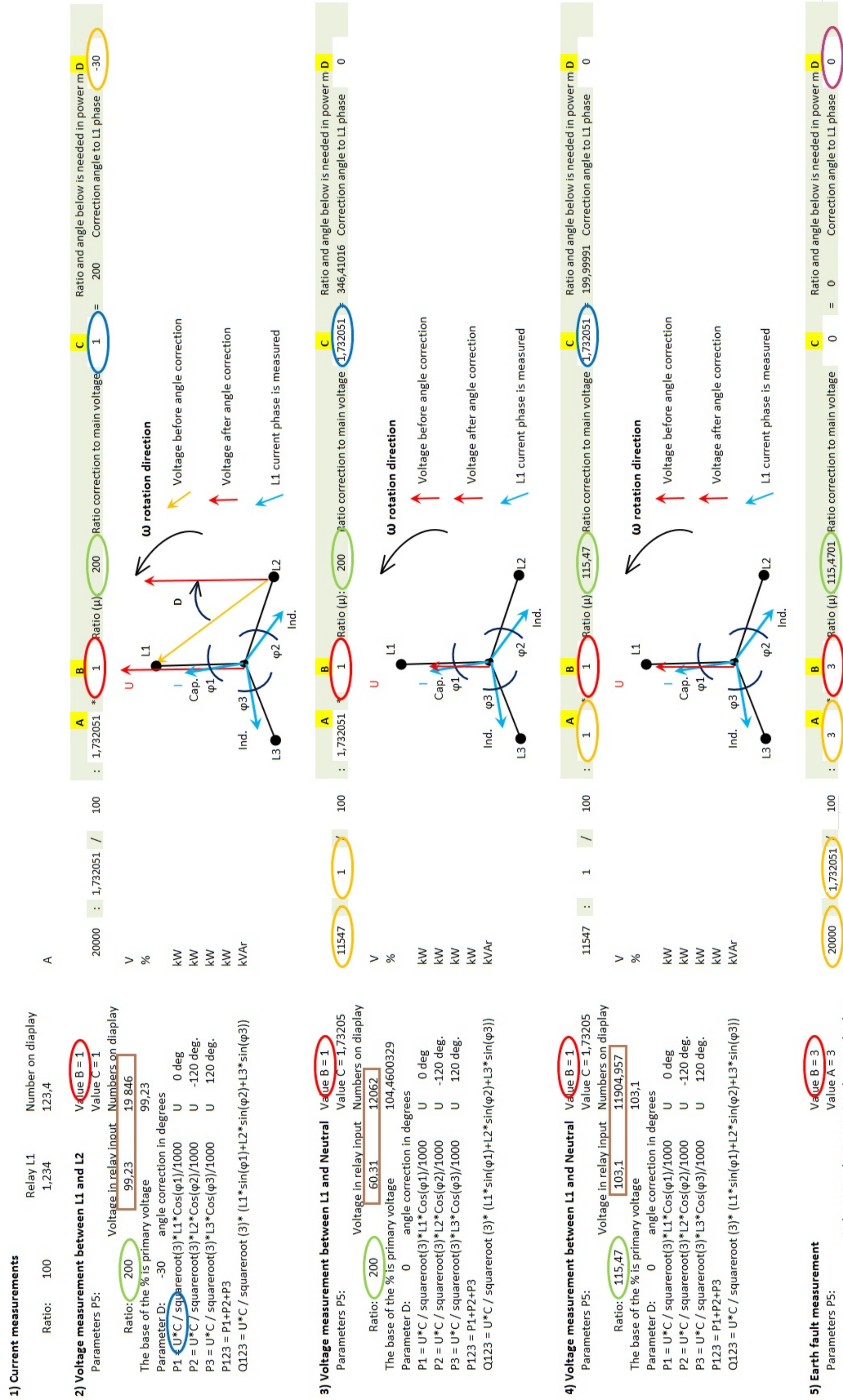
Secondary voltage is defined by three numbers, because VT typically has a residual voltage coil (open delta coil) that creates one earth fault voltage supplied to the relay by using three-phase VTs. Check examples and the picture below to understand the principle.

“Ratio correction to main voltage” is a value-correct power measurement. The relay has only one voltage measurement and therefore the power is calculated by using one line to line or line to neutral voltage. This voltage measurement must be turned to the correct angle that can detect power factors with current inputs L123 (current input L456 cannot be used to measure power). “Correction angle to L1 phase” is phase angle in degrees the voltage must correct that it is in same phase with L1 current when power factor is 1.



Primary voltage	VT-system vector group and connection	Primary setting	Secondary setting	Ratio	Parameter C (blue circle)	Correction angle
10 000	YNyn (a-b)	10000:1.732	100:1.732	100	1	-30
10 000	YNyn (b-c)	10000:1.732	100:1.732	100	1	90
10 000	L1-L2 (a-x)	10000:1	100:1	100	1	-30
400	L1-N	230.94:1	230.94:1	1	1.732	0
Primary voltage	VT-system vector group and connection	Primary setting	Secondary setting	Ratio	Parameter C and correction angle	Parameter B
10 000	YNd11 (da-dx)	10000:1.732	100:3	57.735	0	3

When there is a line to line or line to neutral voltage measurement, parameter B (red circle in picture below) must be 1 and when using an earth fault measurement, the parameter must be 3.

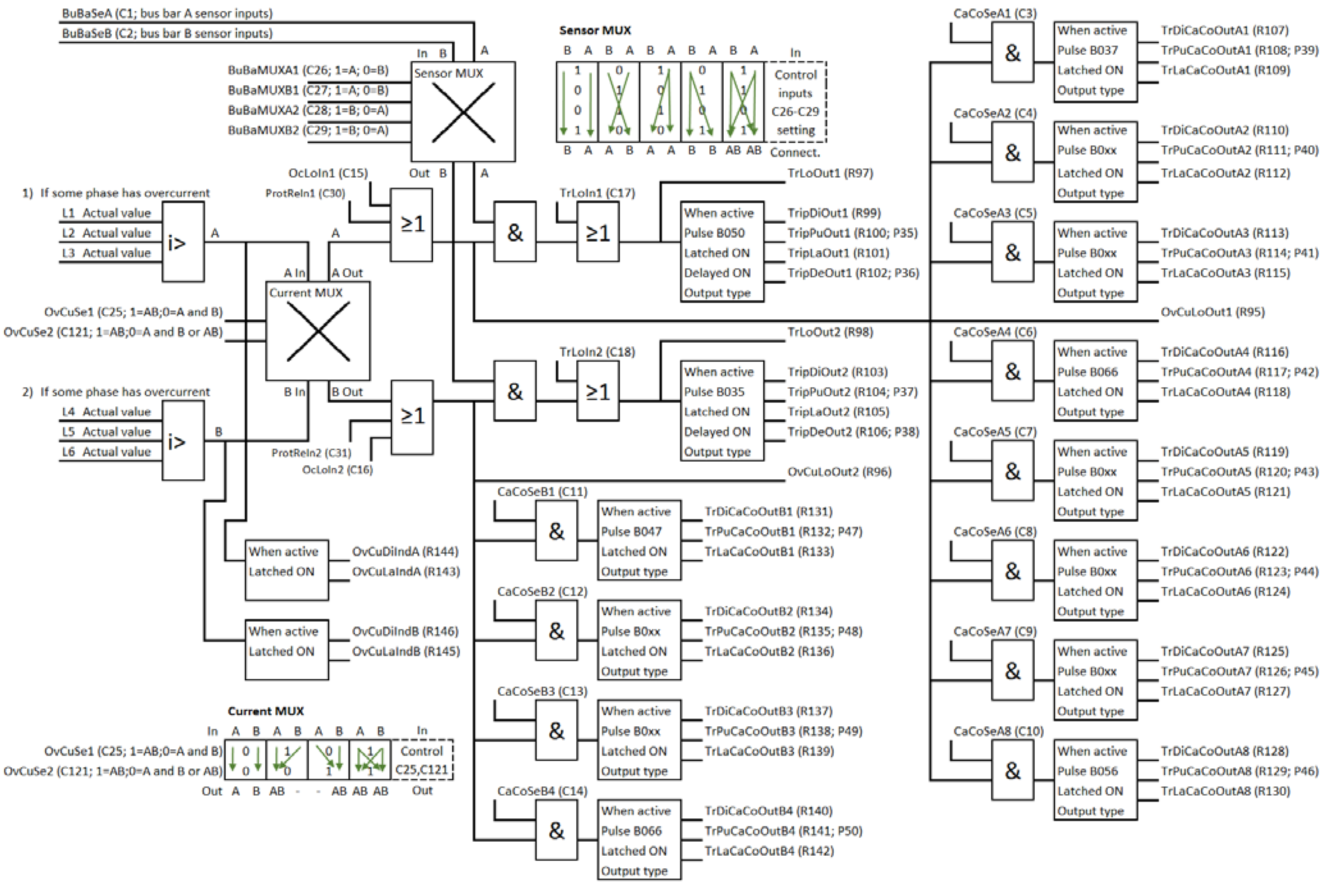


Note circles with colour show how the parameter is affected. A red circle defines how to set the VT-system properly, orange how to set the primary voltage that the % measurement in display C1 and E2 is correct and that the voltage is in the correct angle; green shows the VT ratio and blue shows that the power measurement is correct.

6.5 Programming Fast ARC Protection Logic

LBW81 has very fast arc protection logic which is already equipped with AND gates, working in group features, logic switches, timers and latches. When programming, you must understand the logic, is ready prepared. Note that only LBW81 A2 has analogue current inputs 4, 5 and 6 which are indicated in the diagram below.

Fast ARC protection LOGIC



The Excel file has same drawing in “logic” sheet with higher resolution. Meanings of the signal inputs in Fast ARC protection logic are follows:

- Inputs C1 and C2 are for optical sensors. If there is one bus bar, only C1 needed. C2 is necessary when there is complicated switchgear, which is defined later.
- Inputs C26...C29 are for connecting sensor inputs to over current circuit L1, L2 L3 or L4, L5, L6. Normally these inputs are permanently connected in order to state transfer sensor signals directly from C1 to L123 and from C2 to L456 circuit. The logic of this switch is defined in the right of table. Switch inputs C26...C29 can be connected in matrix to digital inputs if there are disconnectors in the incoming feeder which can connect bus bar A to the current transformers L123 or L456.
- Inputs C15 and C16 are for multi-relay group operations having an optical loop.

- Input OvCuSe C25 connects the current inputs L123 and L456 so that they activate the same way over current line A (OR logic). This is necessary when there are two incoming feeders in same bus bar.
- Inputs C17 and C18 are for multi-relay group operations having an optical loop.
- Outputs R95...R98 are for optical outputs needed in relay group operation.
- Outputs R99…R102 are for trip relays, disturbance recorder starting and front panel LEDs. When sensor line A (C1) has a light indication and switch (C26...C29), connect it to an AND gate receiving the same time over current L123 signal; the output block is activated. Output R99 is of the direct (present) type, which is active only when the system has a light AND over current signal. Output R100 activation is of the pulse type, which is defined in the timer having parameters P35 (which can be delayed and that keep constant time). Output R101 is of the latched type that stays active until pressing the relay reset. Output R102 is activated by a delayed timer P36.
- Outputs R103...R106 works in similar way to R99...R102, but it uses over current signal L456.
- Over current signal A L123 is also connected to 8 systems has an AND gate with an output block. These are for selective arc protection with present tripping in an outgoing feeder circuit breaker when there is arcing in cable compartment is after the circuit breaker (find examples 8.3 & 8.7). Each outgoing feeder system with a sensor input line C3...C10 normally has only one sensor. The output block has similar features to R99...R102, but now delayed tripping must be made by using pulse type timers.
- Over current signal B L456 is connected to 4 outgoing feeder systems. They are similar to what the A L123 has. Sensor inputs are C11…C14 (need these in example 8.7).

Examples in paragraph 8, clarifies the operation more deeply.

6.6 Programming Reset and Loop Test Logic

This paragraph is intended to help in understanding how the system can reset signals and in group operation as to how the loops are working.

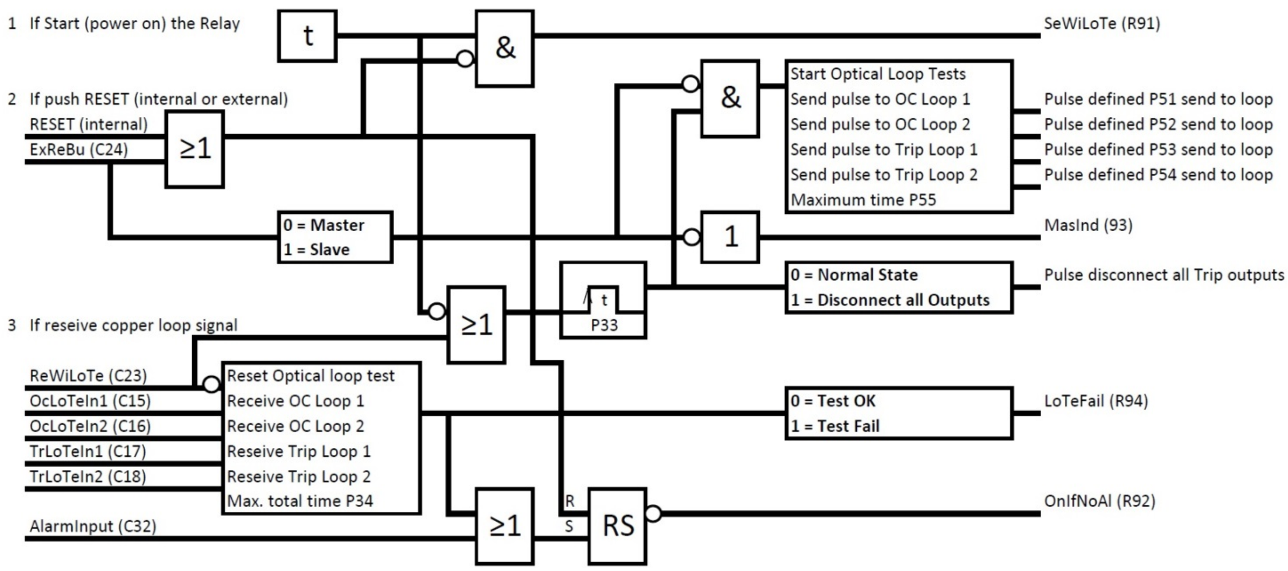
When switch on the relay, all outputs which can make the trip operation, are blocked for a few seconds. During this period, at the same time, the copper wire and all optical loops are tested. The copper wire test is made by sending out an activation signal to relay contact R91, which must be returned back to digital input C23. All relays in group must transfer the same signal from input to output. Optical loops are tested by sending short pulses are defined in parameters P51...P54. The pulse must be transmitted through all relays in the group and loop in a similar way to the wire loop signal. The system can have a maximum four optical loops, which are normally specified as two that are for the over current detection and two for the tripping transmission.

In group operation, one of the relays must nominate a Master and other are Slaves. A Slave is defined by activating input C24, which can also work as a master unit external reset input. Optical loop outputs Oo1-Oo4 are in column C56…C59 and they must connect in the matrix to optical loop outputs seen in the earlier drawing (R95...R98). Test pulses are sent internally to these outputs. Test pulses are reserved by sensor inputs must connect in the matrix to Optical Loop Test block (C15...C18). The test failing signal activates output R94.

Alarm input C32 is for setting the relay in a tripped condition. Normally, all trip relay outputs must connect in the matrix to this input. The tripped state needs to be reset before recovery. In group operation, the reset signal is transmitted from Master to other Slave relays by using the wire loop signal (R91).

Output R92 is tripped state indication for example LEDs in front panel.

Reset and Loop Test LOGIC



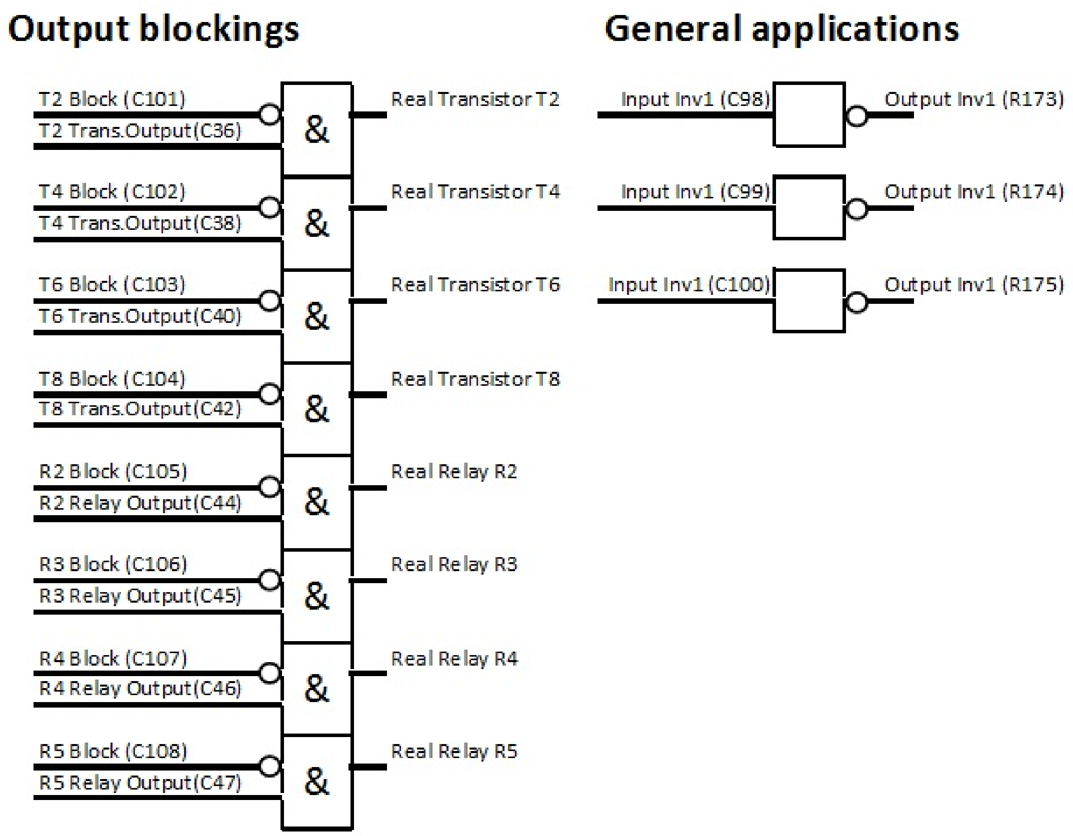
Meaning of the signal Reset and Loop Test Logic:

- Input C24 is for the external reset button in Master unit or Slave setting when continuously 1.
- Input C23 is for the wire loop input and resets the loop test memories.
- Inputs C15...C18 are for connecting the optic loop inputs to sensor inputs. Set to logical 1 if you do not need a loop test.
- Input C32 is for collecting all signals like set the relay to tripped state.
- Output R91 is for connecting the wire loop to some output relay.
- Output R93 is for indicate (by front panel LEDs) master state.
- Output R94 is for indicate loop test fail.
- Output R92 is for indicate tripped state inversely (on when not tripped).

6.7 Programming Output Circuits and Inverse Operation Can be Added to Any Logic

Fast transistor outputs T2, T4, T6 and T8 and relay outputs R2, R3, R4 and R5 are equipped with blocking inputs (C101-C108) in the matrix. These columns are for interlocking circuits and they prevent operation of the outputs. If, for example, you want to prevent control of the motorised disconnector when the breaker in the same circuit is closed, the breaker's NO indication contact goes to the relay digital input, which must be connected to relay output R2 and R3 that are used to control (On and Off) the disconnector by means of SCADA signals. Interlocking for manual buttons in the panel requires an extra breaker indication contact or other relay digital inputs from button with similar effects like SCADA.

In addition, the matrix has three inverters (C98/R173, C99/R174 and C100/R175) can be used in variety of applications. If, for example, there is NO contact instead of NC, it must be connected to digital input; it is possible use NO contact and connects it through the inverter to get NC operation.

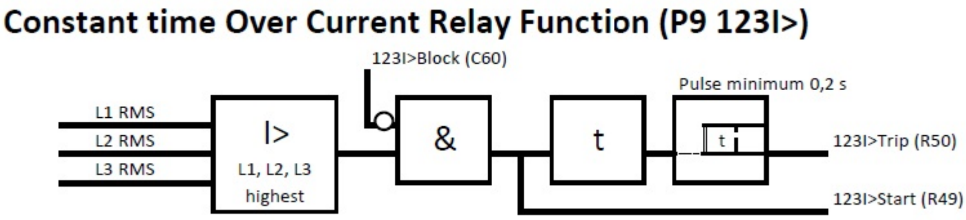


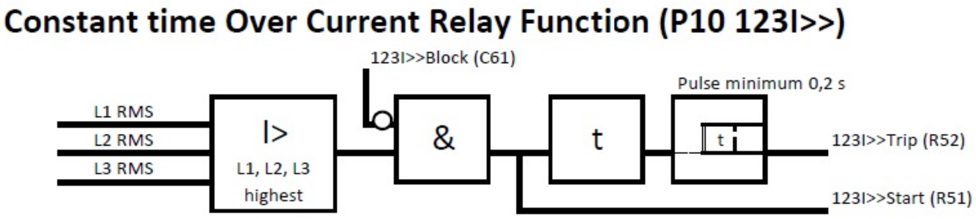
6.8 Programming Protection Relay Functions

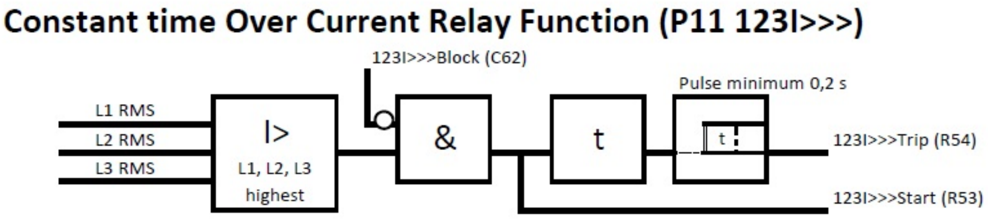
LBW81 has a versatile set of protection functions are useful in minimising the total system cost. Protection functions makes possible that LBW81 can be used for protect distribution without automatic reclosing, motors, transformers, smaller generators, solar systems, wind turbines, cables and many industry applications.

6.9 3-phase Over Current Relays (123I>; 123I>>; 123I>>>; 456I>; 456I>>; 456I>>>).

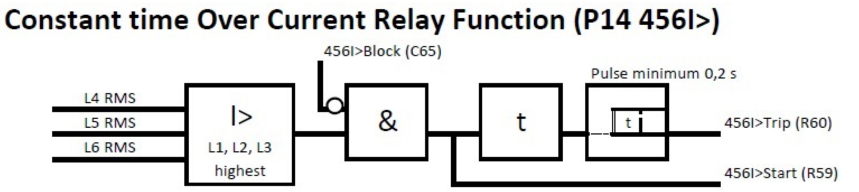
LBW81 has three separate steps of constant time over current relays measuring L123 phases. These relays are available in all LBW81 configurations and can be set by parameters P9-P11 in matrix.

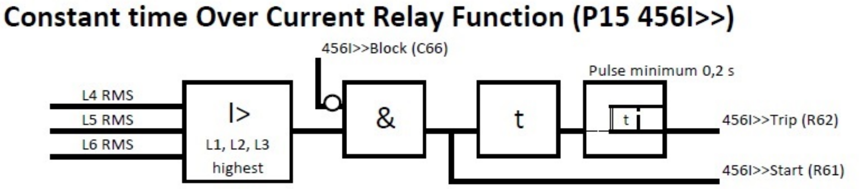


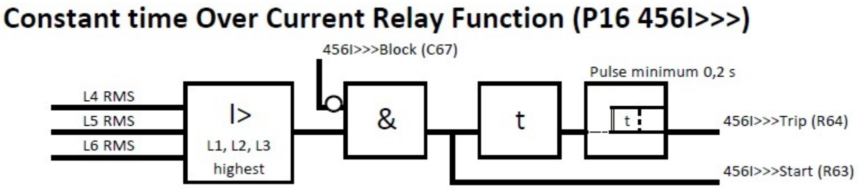




- The relay measures three phases of RMS currents, but chooses only one, is the highest, and compares it with level is set in the parameter (Start current). If blocking input is activated, the relay will not work and will not send events to SCADA. If the current level is higher than what is in the parameter and the blocking input is passive, the relay sets START output active and if same state continuous time is defined in parameters (Delay) the relay sets TRIP signal.
- If the current firstly goes over the tripping level and then decreases that START signal goes passive, the hysteresis is about 5 % smaller than the tripping level is sat in parameters.
- Trip signal is active minimum 0.2 s and stays high level if the over current continuous. Start signal is active only the time relay has over current.
- If these over current relays are needed in your system, set the blocking signal (C60-C62) to logical 0 in row 1 and if not needed, set it to active logical 1 in row 2.
- If there is an external blocking single coming from the outgoing feeder, connect it from the digital (or optic) inputs row to the relay blocking column.



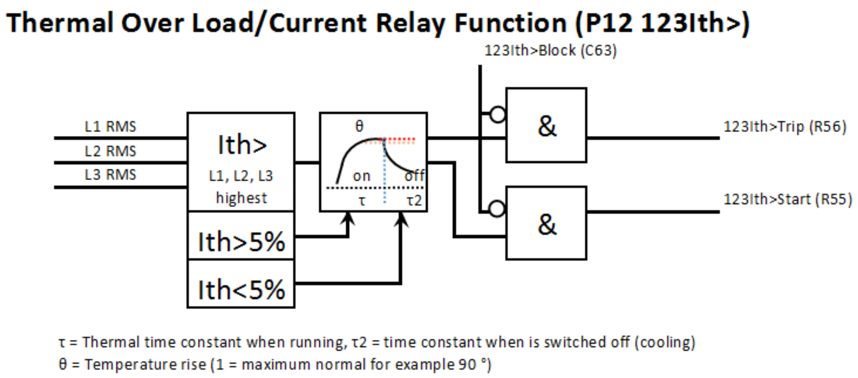


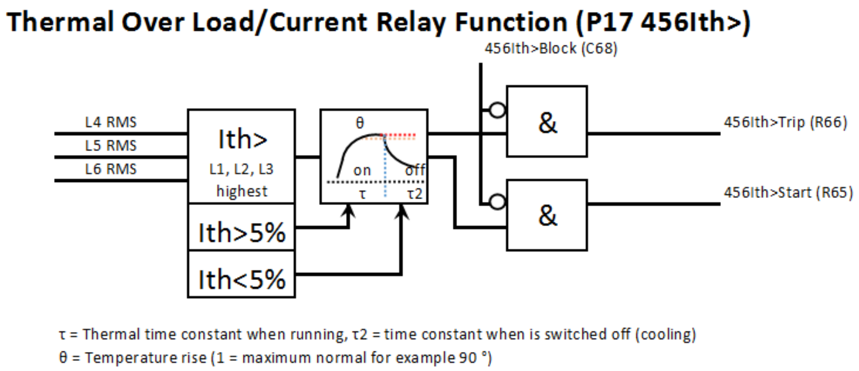


LBW81 with A2 configuration has independent three-phase constant time over current relay functions that are permanently connected to L456 and have parameters P14- P16.

6.10 3-phase Thermal Over Load / Current Relay Functions (123Ith>; 456Ith; IEC 60255-8)

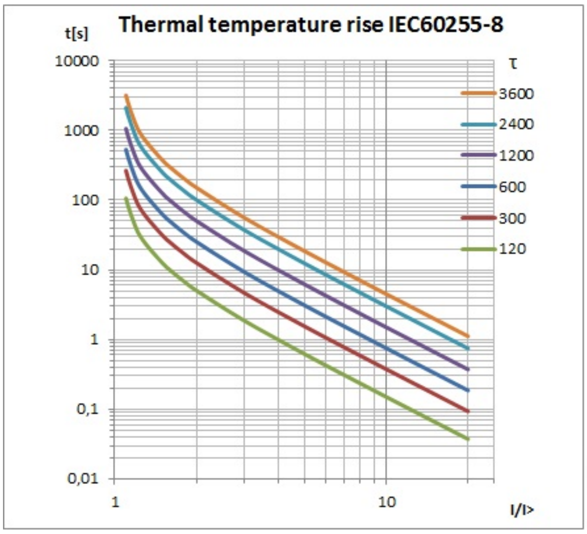
LBW81 has one three-phase thermal over load relay with a temperature integration that is permanently connected to current inputs L123 and the other is connected in A2 with an option of connecting to the current inputs L456.

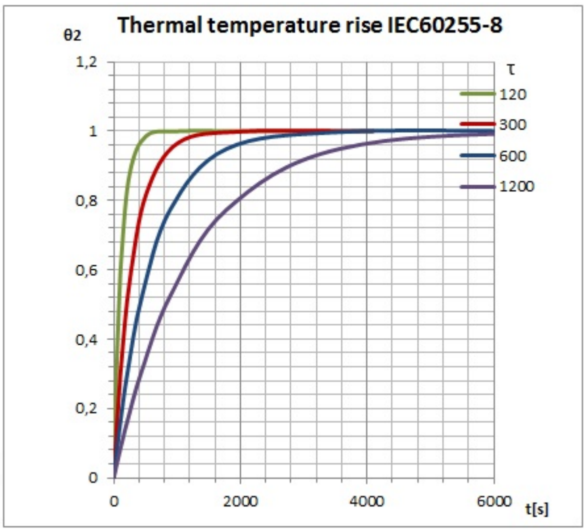




Both relays have separate heating up and cooling constants (τ and τ2), which is useful if there is a motor or generator with a cooling fan that does not cool when the system is switched off. Display C1 (measurements) shows at all times Φ (th1/2 temperature indication), which is number to reach a value of 1 when the load is at nominal maximum temperature. The upper number in current L5 row is a temperature indication of the L123 currents and below is for L456.

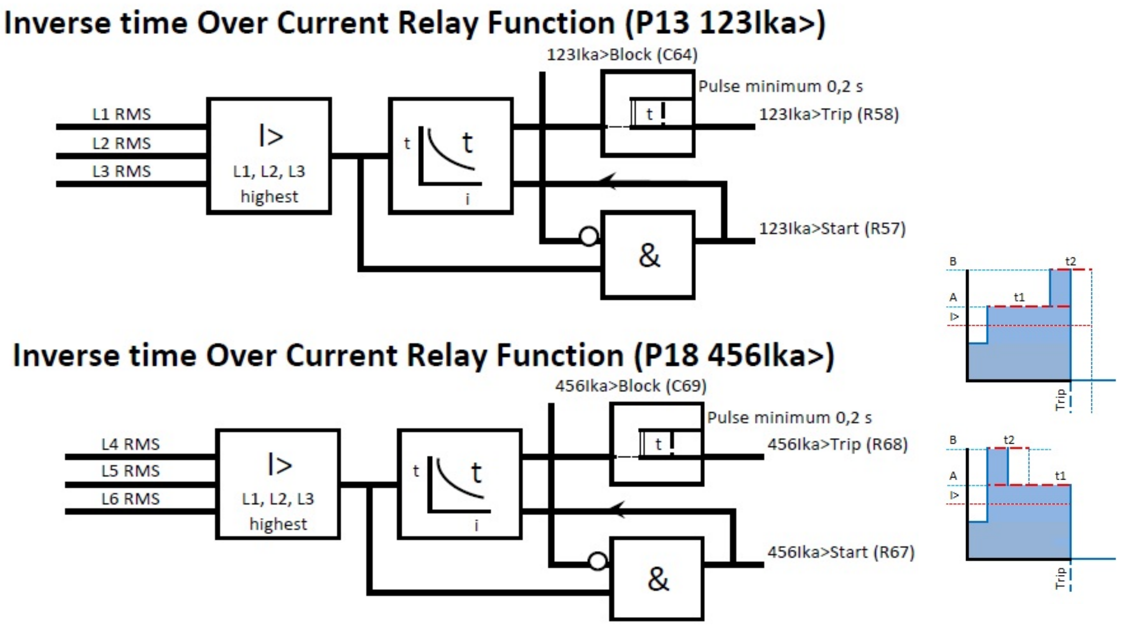
- The relay measures the three-phases highest RMS value at all times and the parameters are P12 for current inputs L123 and P14 for current inputs L456.
- Nominal current In is motor/generator/cable etc. current it thermally endless bears. The next decimal is the same announced the quotient of the CT nominal rate.
- The on-time constant τ is the time when a cold system having a nominal current and running normally heat ups to 63.2 % (1-1/e) of the temperature rise is designed (insulation class F machines for example 105°). If the system runs about 4*τ time, the temperature rise is achieved the designed level and Φ is 1.
- Trip constant k*In defines the tolerance of the nominal current, is normal and too high. Typically, this is 1.06 means that in long run the minimum tripping current is 1.06 * nominal current is set in parameter.
- Start constant works like the Trip constant, but is normally at a lower level. This is in order to alert you that the machine is quite near the tripping temperature rise, or this signal can be used to prevent the starting of too warm a machine.
- Off Time constant τ2 is the time when the warm system, is in the designed temperature rise, cools to the 36.8 % (1/e) level of the designed temperature rise. This is typically longer than the On Time constant τ (for example, the motor having a cooling fan on the main axle). In cable protection, the τ2 and τ are equal.
- Switching from On Time constant τ to Off Time constant τ2 is made automatically depending on the measured current. If the measured current is less than 5% of the nominal current, the time constant is τ2. If the current is higher, then the relay uses time constant τ. A current level of 5% means that the temperature rise is almost zero and therefore the changes can be automatic. Note that the relay calculates temperatures at all times and keeps Φ values valid.
- If use the system in higher (ambient) temperature than are defined in standards, the acceptable temperature rise is smaller and this must be attended to in parameter setting.



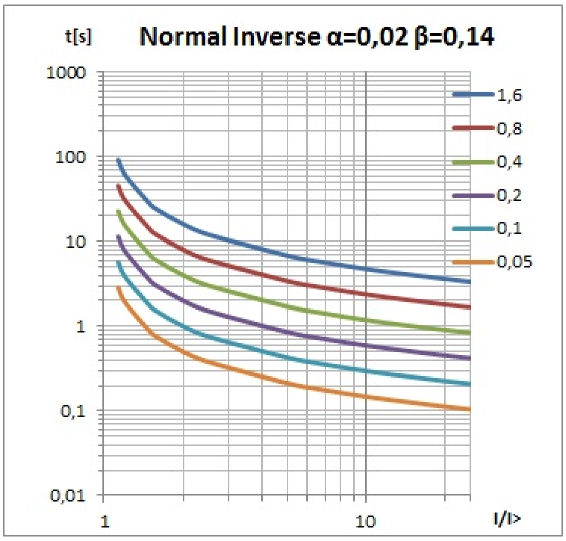


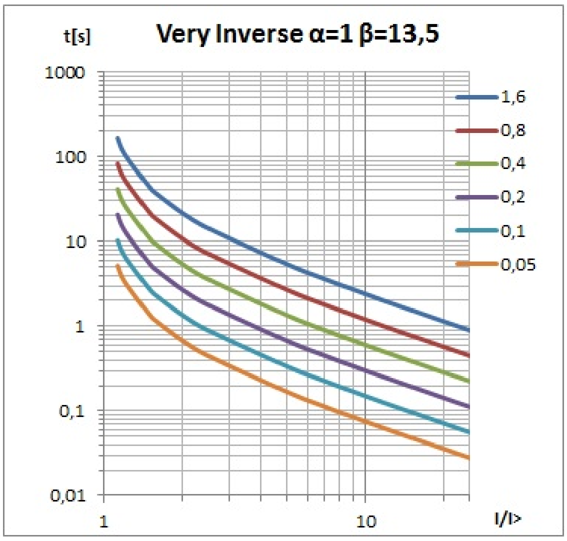
6.11 3-phase Inverse Time Over Current Relay Function (123Ika>; 456Ika>; IEC 60255-3).

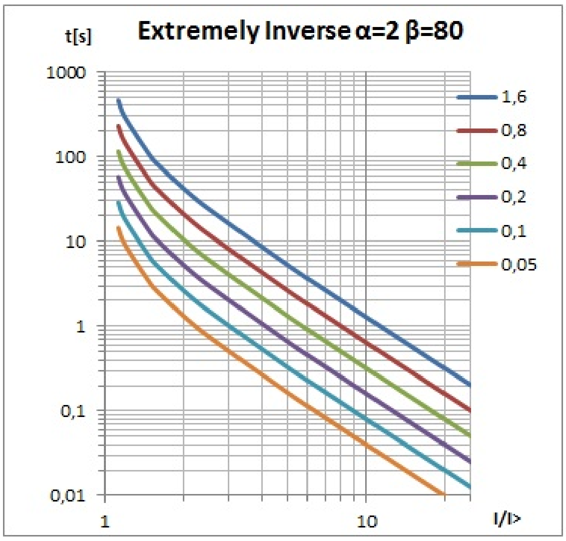
LBW81 has one three-phase inverse time over current relay function, which is permanently connected to current inputs L123 and other is connected in A2 option to the current inputs L456. Both relays have a separate setting of the curve constant s defined in standard IEC60255-3.

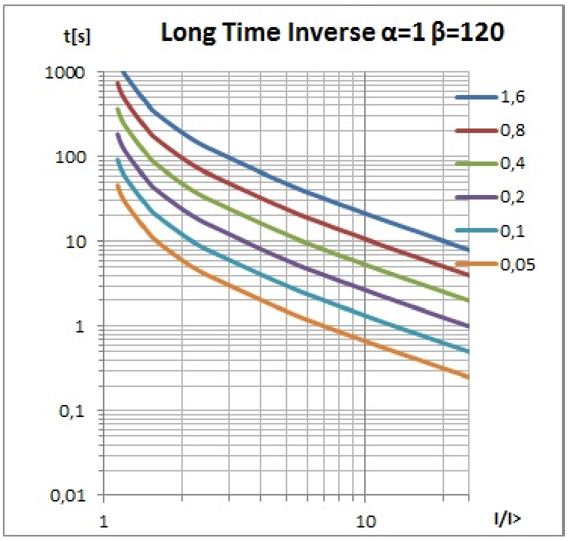


- The relay measures the three phase's highest RMS value and parameters are P13 for current inputs L123, and P15 for current inputs L456.
- The start current is the level of the three-phase highest current where the tripping time definition begins.
- Tripping time is defined by using function $t(s) = \frac{k*\beta}{\left(\frac{I}{I>}\right)^{\alpha}-1}$ Where I is measured current, I> is Start current, α is the inverse time exponent (0.05-4) and β is the time constant (0.1-500 s) and k is time factor (0.05-2).
- If the current rises over the tripping level to value A, has time delay t1, and rises then later to value B, has time delay t2, the final tripping time is the shortest means the rest of t1 or new t2.
- If the current rises over the tripping level to value B, has time delay t2, and then later decreases to value A, has time delay t1, the final tripping time is t1 including current value B elapsed time at begin.
- Standard IEC60255-3 defines four different inverse time over current curves:
  - Normal inverse α = 0.02; β = 0.14
  - Very inverse α = 1; β = 13.5
  - Extremely inverse α = 2; β = 80
  - Long-time inverse α = 1; β = 120


t[s]
Normal Inverse α=0,02 β=0,14
1000
100
10
1
0,1
0,01
1
10
I/I>
1,6
0,8
0,4
0,2
0,1
0,05


t[s]
Very Inverse α=1 β=13,5
1000
100
10
1
0,1
0,01
1
10
I/I>
1,6
0,8
0,4
0,2
0,1
0,05


t[s]
Extremely Inverse α=2 β=80
1000
100
10
1
0,1
0,01
1
10
I/I>
1,6
0,8
0,4
0,2
0,1
0,05

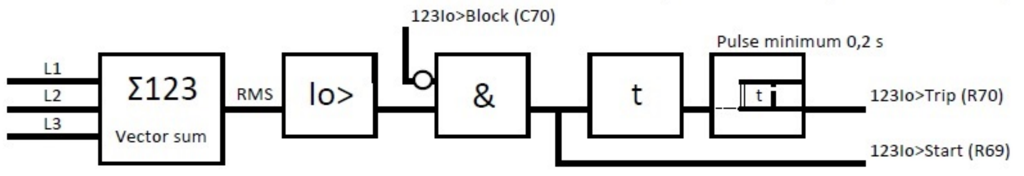

t[s]
Long Time Inverse α=1 β=120
1000
100
10
1
0,1
0,01
1
10
I/I>
1,6
0,8
0,4
0,2
0,1
0,05

6.12 3-phase Constant Time Earth Fault Relay Functions (123Io>; 123Io>>; 456Io>; 456Io>>)

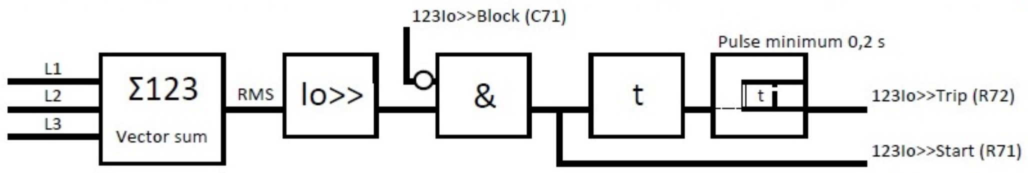
LBW81 has two stages of three phase earth fault relay functions, which are permanently connected to current inputs L123 and other two are connected in the A2 option to the current inputs L456. The first ones have parameters P19 and P20 and the later ones parameters P21 and P22.

These functions are useful, for example, in high voltage (110 kV) backup protection, because this level of grid is typically solidly grounded or grounded at one point and therefore the sum of the phase currents in case of an earth fault is clearly not equal to zero. These relay functions are also useful in all earthed systems having only three phase leads to load or, for example, in generators.

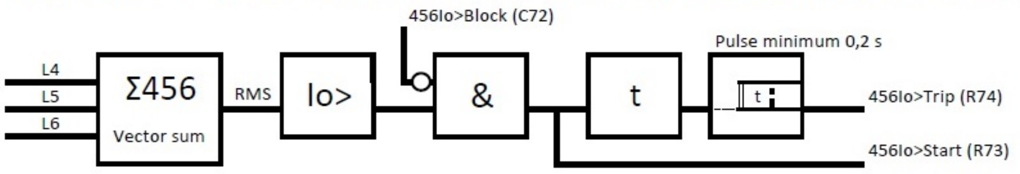
Constant time 3-Phase Earth Fault Current Relay Function (P19 123Io>)



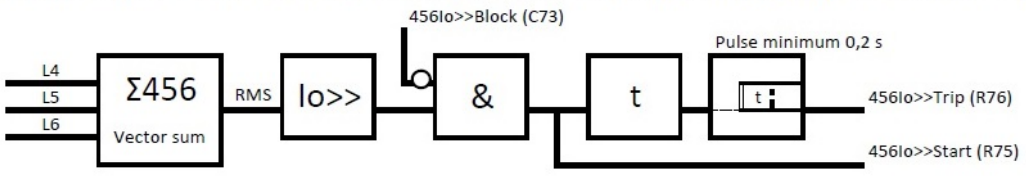
Constant time 3-Phase Earth Fault Current Relay Function (P20 123Io>>)



Constant time 3-Phase Earth Fault Current Relay Function (P21 456Io>)



Constant time 3-Phase Earth Fault Current Relay Function (P22 456Io>>)



- The relay measures the instantaneous value of the three phase currents with high speed and then adds these values by attending to the polarities. The sum is converted to the RMS value of current and is then used in comparison with set point value as defined in the parameter.

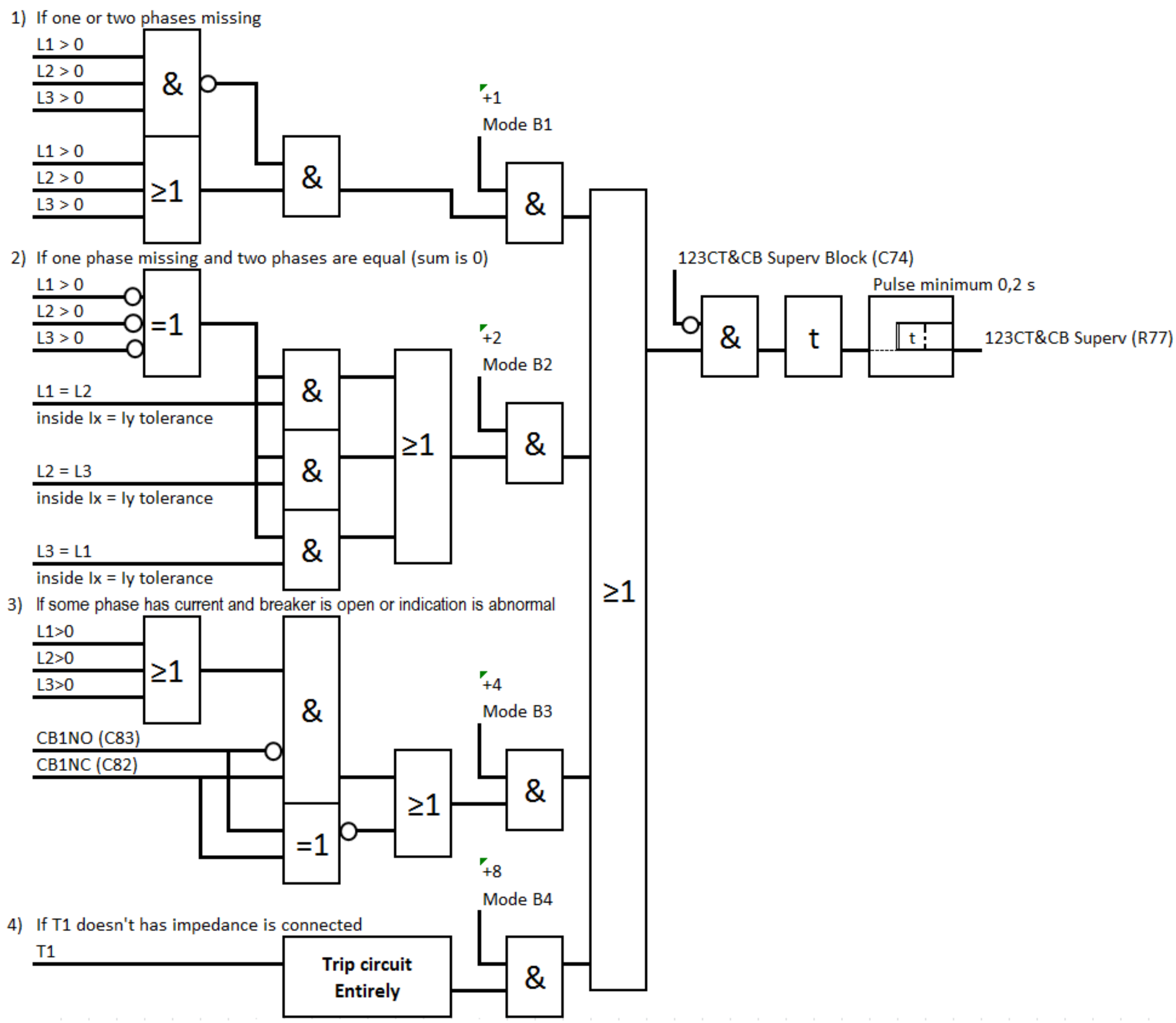
- The relay has 5% of hysteresis, which means that if the current rises over the start level, a return back to the passive state needs 5% decrease under the set point as defined in the parameters.
- The trip signal is active for a minimum of 0.2 s and stays at a high level if the earth fault continues. The start signal is active only at the time the relay has an earth fault.
- This function is also active when the system has an earth fault, but also, when one CT secondary is open.

6.13 Superv. for CT, CB, Fuse, Line and Trip. Circ. Fault (123CT&CB Sup and 456CT&CB Sup)

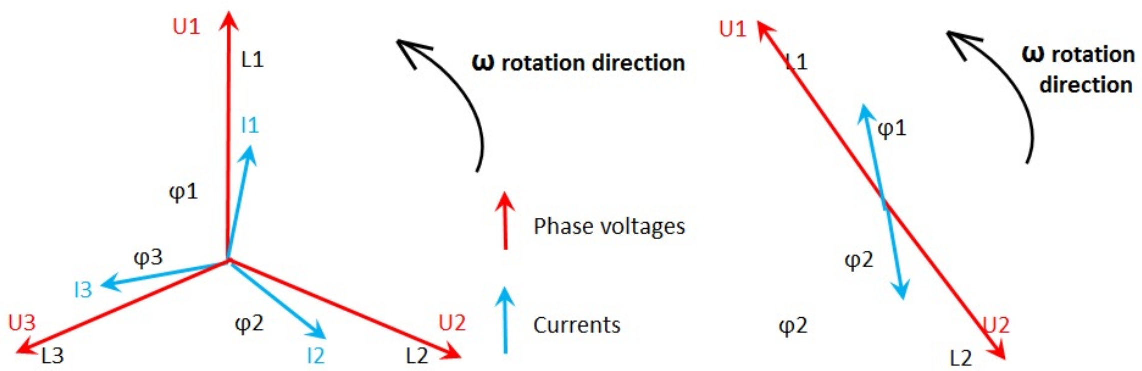
LBW81 has two combined supervision functions with adjustable features for controlling main circuit key components. Features are activated by Mode Byte within the 123CT&CB function 4 bits and in the 456CT&CB function 3 bits.

123CT&CB is permanently connected to L123 phases, CB indication CB1NO (C82) and CB1NC (C83) and output relay T1. Alarm output is R77 can be connected to any columns.

123 CT & CB Circuit Supervisor Relay Function (P23 123CT&CB Superv)



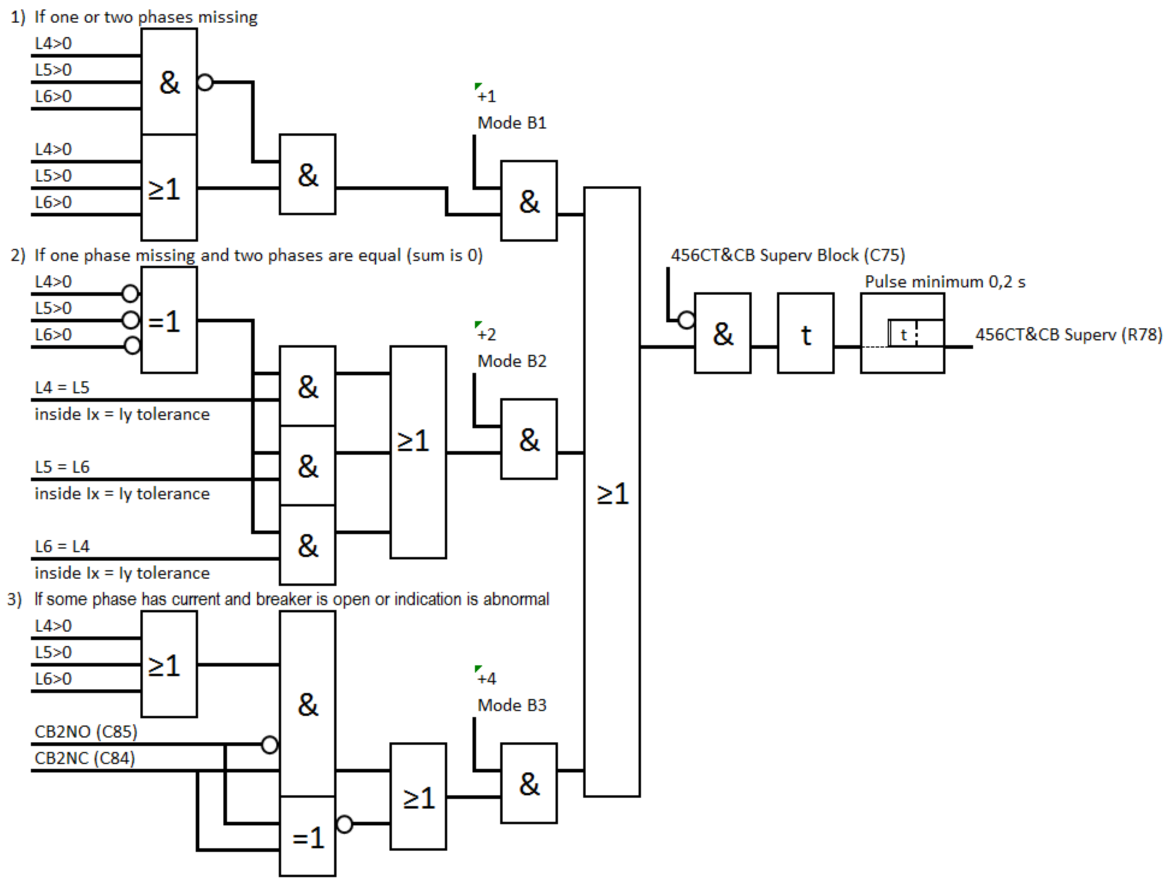
- If the Mode bit 1 is activated, the system measures phase currents and alerts you if one of these is near zero (P23 Imin). This function is useful for alerts, if one fuse in the main circuit is blown or if there is a line cut or if the CT secondary circuit is open.
- If the Mode bit 2 is activated, the system measures, in addition with the first feature, that there are two phases having quite nearly the same current and opposite polarity (P23 Ix=Iy). This alerts you that there is a higher rate of false filtering when one fuse is blown or when there is a line cut or breaker's one phase is missing. Note that this function does not alert you if the CT secondary is open.



- If the Mode bit 3 is activated, the system checks the breaker indications (permanently CB1NO and CB1NC) and L123 phase currents and alarms for an abnormal state (breaker supervision). This alerts you if the breaker has an open indication but the main circuit has current nevertheless. This function also alerts you if the breaker indication stays in an illegal or intermediate position.
- If the Mode bit 4 is activated, the system sends to T1 (permanently this relay output) short low current pulses and measures, that this causes current (trip circuit entirely test). Pulses are very small and fast so that they do not cause a false trip. Note that this low current test pulse can make a fault trip in some type of relay test set, if the input circuit impedance is very high. This can be a reason if get a wrong tripping time.
- Mode byte is for activate functions are defined above. Bit 1 =+1; Bit 2 =+2; Bit 3 =+4 and Bit 4 =+8. Mode 11 for example activates the first two and the last feature.

456CT&CB is permanently connected to L456 phases and CB indication CB2NO (C84) and CB2NC (C85) but do not have trip circuit entirely test. Parameters are P24.

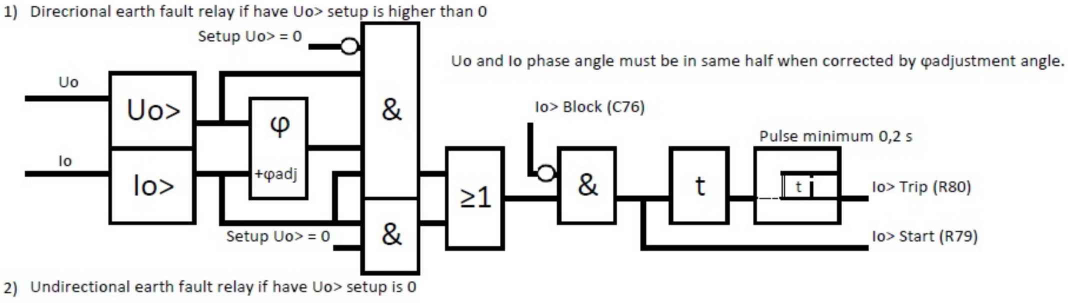
456 CT & CB Circuit Supervisor Relay Function (P24 456CT&CB Superv)



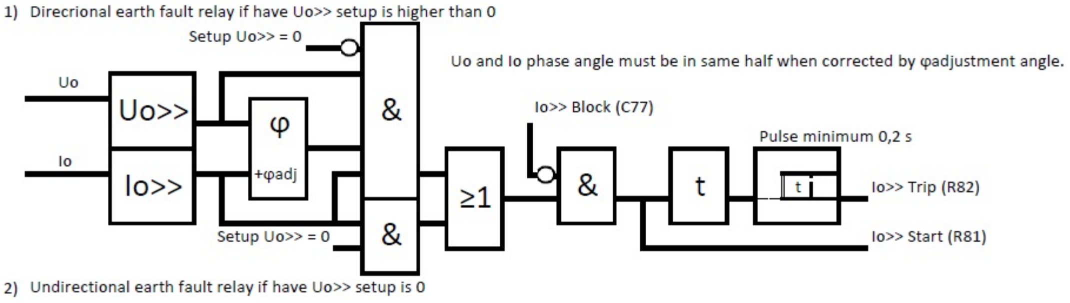
6.14 Single Phase Directional and Undirectional Sensitive Earth Fault function (Io>; Io>>)

LBW81 has two steps of single phase earth fault / residual current functions are useful for directional or unidirectional earth fault protection, but also for controlling compensation systems' star point balance current etc. These relay functions are permanently connected to a single phase current input Io and a voltage input Uo in directional mode. Parameters are P25 and P26.

Directional and Undirectional Sensitive Earth Fault Relay Function (P25 Io>)

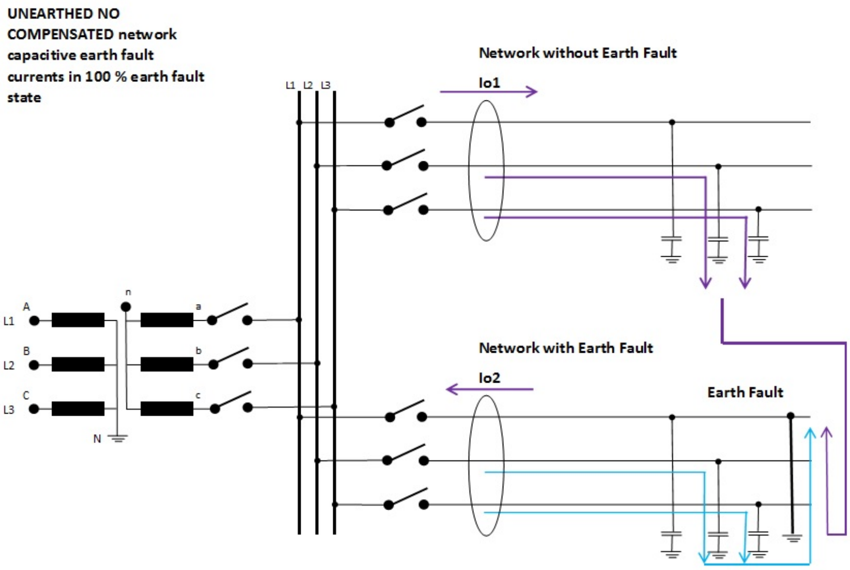


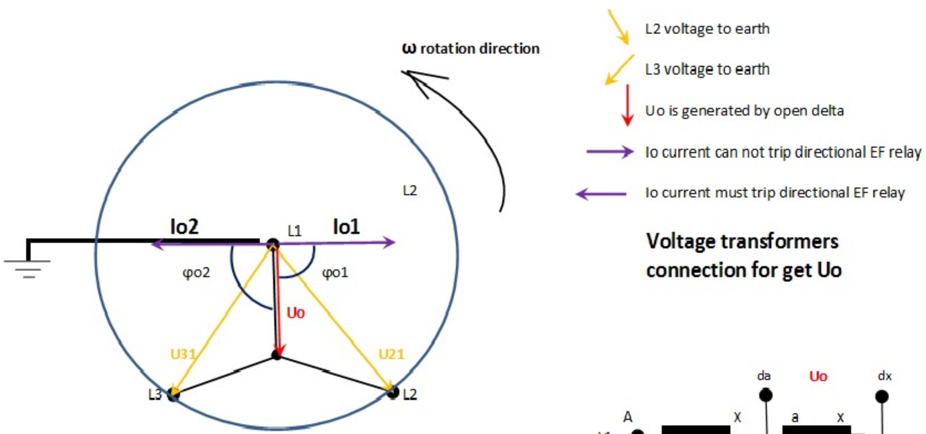
Directional and Undirectional Sensitive Earth Fault Relay Function (P26 Io>>)



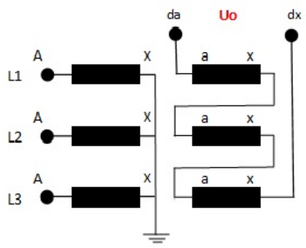
- If the parameter P25 Uo> or P26 Uo>> is 0, the function is then an unidirectional residual current relay, which measures the RMS value of the current by Io input and the Start level setup is found in parameters Io> or Io>>.
- The relay has 5% of hysteresis, which means that if the current rises over the start level, a return back to a passive state needs a 5% decrease under the set point as defined in the parameters.
- In directional mode, the Uo input must be connected to the voltage transformer's residual voltage coil (open delta), but in unidirectional mode, Uo is free and can be used for measuring line voltage with under voltage or over voltage functions.
- In directional mode, Uo must have a setting that is greater than 0. The relay starts when the voltage is greater than Uo> or Uo>> and the current is greater than Io> or Io>>, but in addition the phase angle between the voltage and current must be inside the correct margin. The correct margin is that current which must have a ±90° same phase angle with Uo voltage, which is corrected by means of the Angle Adjustment parameter.
- In directional mode the phase angle between the voltage and current is very important. Normally, if there is an unearthed (non-solidly grounded) grid without earth fault current compensation (Petersen coil), the current, residual current CT generates, is about -90

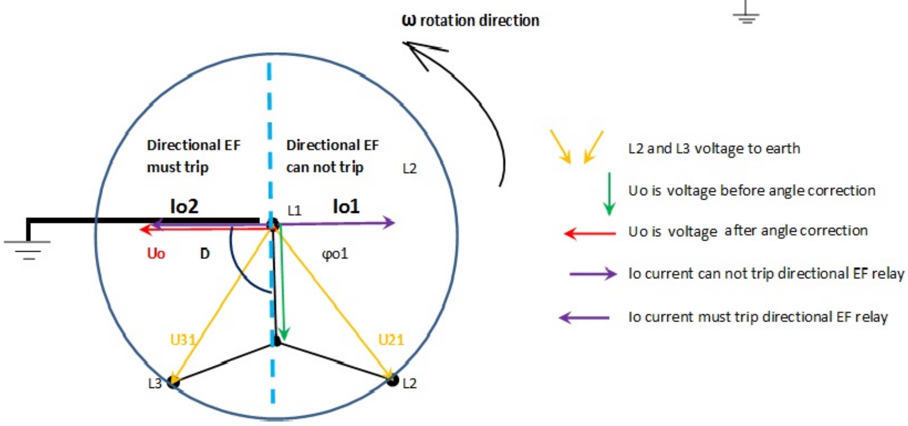
(means 270) degrees behind the voltage which the residual voltage coil generates in the case of an earth fault. With compensation in an unearthed grid, the voltage is quite nearly at the same angle as the earth fault current has and the correction angle is 0. The correction setting is P25 and P26 Adjustment Angle.





Voltage transformers connection for get Uo

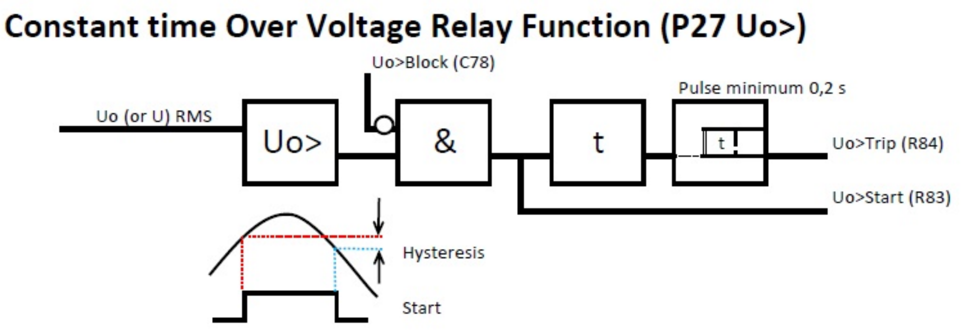


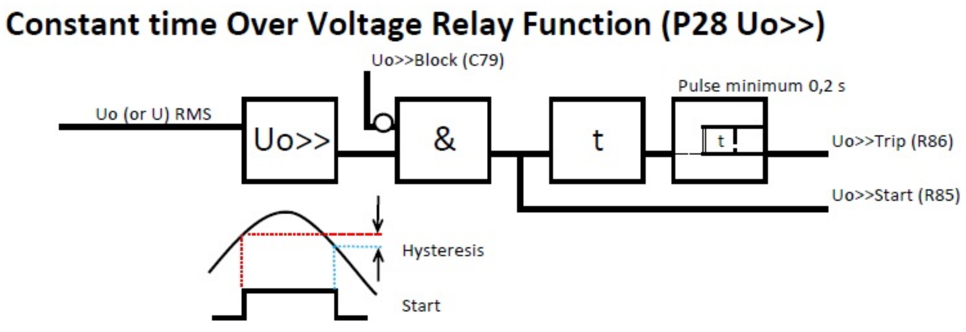


- If there is an earth fault, the current compensation can be switched ON or OFF; it is possible use Io> and Io>> with different a setting of the Adjustment Angle and to activate only one function depending on the compensation setting.
- In undirectional mode, Uo has a 0 setting and the relay works with any Io and Uo phase angle. Functions can then be used for alerts/trips solidly grounded type of grid residual current or for measuring the balance current between two stars connected capacitor banks.
- The trip signal is active for a minimum of 0.2 s and stays at a high level if the earth fault continues. The start signal is active only while the relay has an earth fault.
- In directional mode, this relay function phase angle detection needs a little time. Do not set less than 0.1 s delays. With a small overcurrent, the tripping needs by setting of 0.1 s, for about 0.1 s an extra time (total time 0.2 s). With a higher current, the extra time is about 0.05 s (total time 0.15 s).
- When using directional mode, the VT setting P5 must have parameter B = 3 and the "Correction angle to L1 phase" is in P5 line must be sat to 0.

6.15 Single Phase Constant Time Over Voltage Protection Function (Uo>; Uo>>)

LBW81 has two steps of single phase over voltage relay functions are useful for measuring line-to-line or line-to-neutral voltage, or where residual voltage is generated by VT open delta winding. Even though the function names are Uo, it is also possible use these functions for generating over voltage alerts and trips. Parameters are P27 and P28.



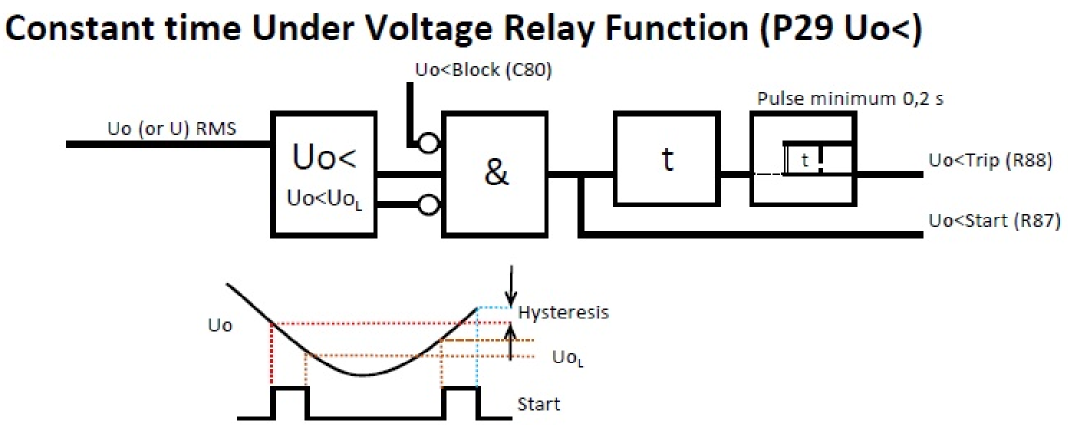


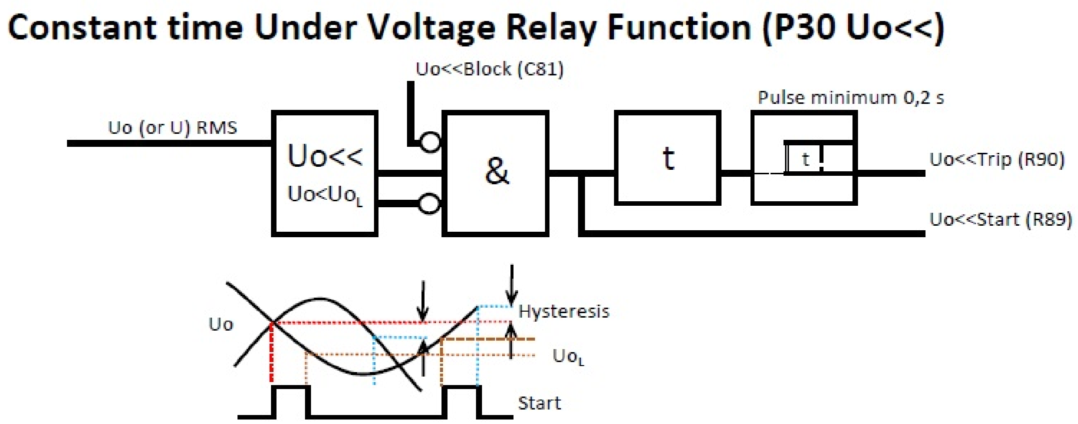
- The relay measures single phase RMS voltage. If blocking input is activated the relay does not work and does not send events to SCADA. If the voltage level is higher than in the parameter and the blocking input is passive, the relay sets the START output as active, and if at the same state is continuous, the time is defined in parameters (Delay) and the relay sets TRIP signal.

- If the voltage firstly goes over the tripping level (start goes active) and then decreases, the recovery level (start goes passive) is a parameter hysteresis amounting to less than parameter Uo> or Uo>>.
- The trip signal is active for a minimum 0.2 s and stays at a high level if the over voltage continues. The start signal is active only while the relay has an over voltage.
- If using and connecting this function to control the line-to-line or line-to-neutral voltage, the directional earth fault functions P25 and P26 cannot be in directional mode.
- This over voltage function is also useful for backup protection of the earth fault or this function can activate arc protection in an unearthed grid with a longer delay set up so that the system can have arcing inside the bus bar compartment with a low arc current between the phase and neutral.

6.16 Single Phase Constant Time Under Voltage Protection Function (Uo<; Uo<<)

LBW81 has two steps of single phase under voltage relay functions are useful for measuring line-to-line or line-to-neutral voltage or controlling auxiliary AC voltage. Even though the function names are Uo, it is also possible use these functions for generating under voltage alerts and trips. Parameters are P29 and P30.





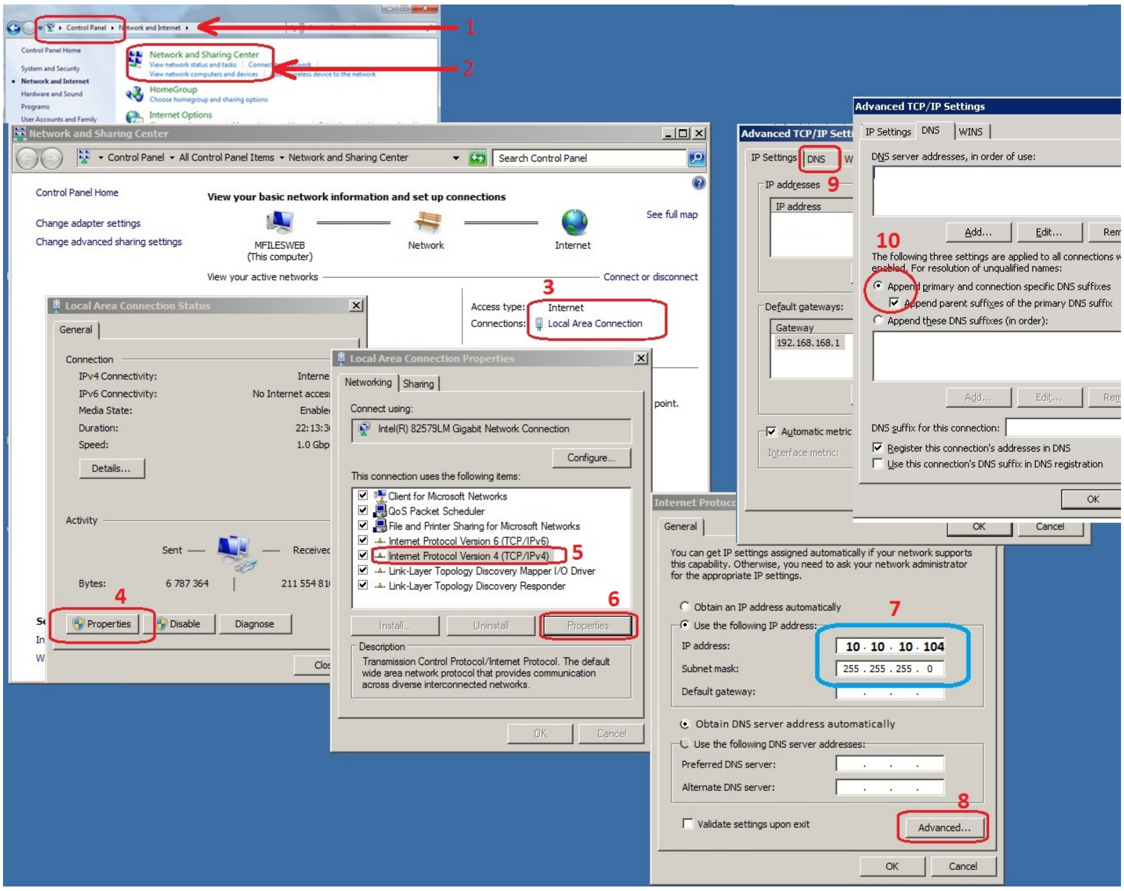
- The relay measures single phase RMS voltage. If blocking input is activated, the relay does not work and does not send events to SCADA. If the voltage level is less than in the parameter and blocking input is passive, the relay sets the START output to active, and if the same state is continuous, the time is defined in parameters (Delay) and the relay sets TRIP signal.
- If the voltage firstly goes under the tripping level (start goes active) and then rises, the recovery level (start goes passive) is parameter of the hysteresis amount is higher than parameter Uo< or Uo<<.
- If the voltage decreases under the parameter UoL level, the relay returns to a passive state (start goes passive). This is useful when you want to filter out the normal "system is switched off" cases. Set UoL level to 0, if do not need this feature (relay is then always active when there is an under voltage).
- Trip signal is active for a minimum of 0.2 s and stays at a high level if the under voltage is continuous. The start signal is active only while the relay has an under voltage.
- If using and connecting this function to control line-to-line or line-to-neutral voltage, the directional earth fault functions P25 and P26 cannot be in directional mode.
- This under voltage function is useful for backup protection of line-to-line voltage or to control auxiliary AC voltage.

6.17 Create Communication Connection to Relay

Before the configuration matrix can be saved to the relay memory, the communication connection must be created. The relay has a fixed TCP/IP address visible in screen A1. Firstly, the configuration must be sent to this address. The matrix can have new TCP/IP address, which is valid after succeeding in sending and new booting. If connecting the relay directly to the PC, the communication cable must be a crossover type, which means that TX (3 & 6) and Rx (1 & 2) are changed order in the wire. If there is a data switch, the relay is connected with the cable wire order is direct. The communication is created by opening the computer control panel and following steps 1-10. Note the TCP/IP number must be defined for PC in step 7 and cannot be the same is in relay display A1. If the relay TCP/IP is, for example, 10.10.10.103 the PC TCP/IP address can be, for example, 10.10.10.104 (change only the last 8-bit number). Note that each device must have a different TCP/IP number is in the same subnet, which means that only the last number changes. After this, the operator can open a web browser (Internet Explorer) and call address 10.10.10.103, is relays address or send matrix to the relay (to same address) by Excel button.

If the relays are already installed in the substation with a data switch, the configuration PC must be connected to some data switch free terminal and the PC TCP/IP address must be defined for joining it to the network. The address defined in the PC control panel must be unique, but close to others on the same sub net addresses, which means that the network net mask does not discriminate. If the relays are powered on the display, A1 shows the TCP/IP address they use.

Do not connect the relays to a public network giving free right everybody to use, because relay web browsing and programming is done without passwords and protection. If communication by public access network is nevertheless necessary, do so with skilled people who are knowledgeable about fire walls and protection.



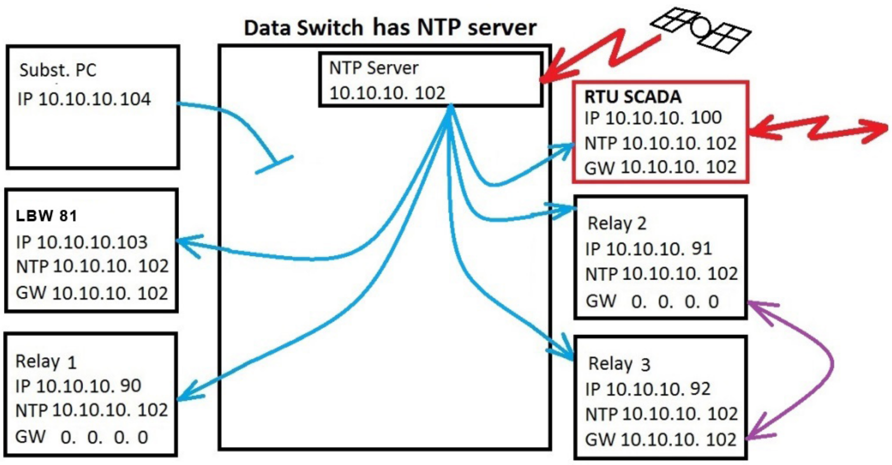
Note that the computer can normally have only one local area TCP/IPv4 connection, which means that the connection to public networks, for example, to the internet, must be done by using another system.

6.18 Synchronise the Relay's Clock

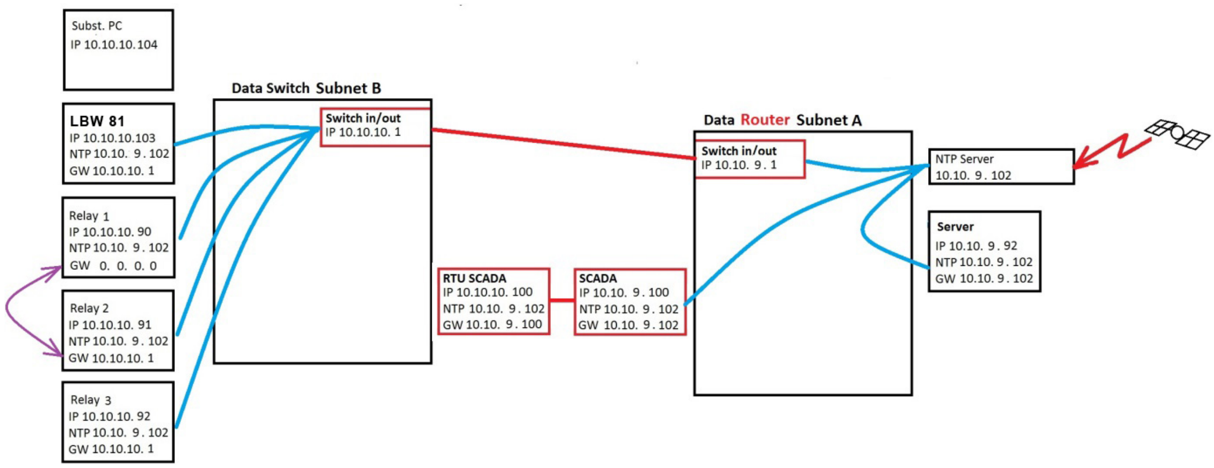
LBW81 has a powerful event log and disturbance recorder with exact time and internal real time clock with battery which keeps the time and date of the power cuts (zero serial relays do not have a real time clock). The relay's system clock is possible synchronize to the network, and the SCADA clock must be ran in same time.

LBW81 can be synchronised in two ways: 1) by using an NTP server or 2) by SCADA command in Modbus or IEC61850.

- NTP server (Network Time Protocol) is a common accurate clock in the local area network to which all relays have access. Some profession class data switches have their own NTP server which can be synchronised by satellite, GPS etc. The picture below is an example of when the data switch has an NTP server in the same subnet:



- If the NTP server is in another subnet or in a public network, the system is as follows:



- If using the SCADA system to synchronise the relay clock by Modbus commands, the relay has Read/Write type Holding registers 126 (High Word) and 127 (Low Word) keeping epoch time (Unix time). The time setting has no effect if the NTP is enabled (Holding register 128). When setting this register to the exact time, the decimal seconds start at 0.00, which means that by this method, all relays must be synchronised just after the new second changes and the error is then the setting lapse in data network.

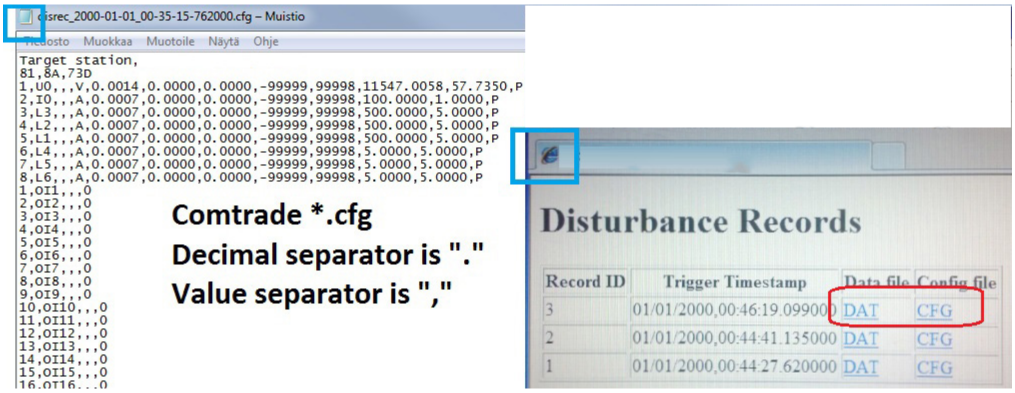
6.19 Disturbance Recorder

LBW81 has a very high performance disturbance recorder which stores all analogue and digital channels (optical sensors, digital inputs, SCADA virtual inputs, optical outputs, transistor outputs and relay outputs) and having a fast 2000 Hz sample frequency. When starting the recorder, it stores all these 2 seconds before and 2 seconds after the start time. The disturbance recorder format is standard COMTRADE (Common format for Transient Data Exchange for power systems) and can be read by many programs. Comtrade-format has two files, configuration file *.cfg defines start time, all variables and ratios and data file *.dat consists of measured data. Both files are ASCII-files, which means that they can be opened even by Excel or Notepad. Analogue channels are stored in an instantaneous value-like oscilloscope and therefore the measures can easily be converted by calculations to the RMS-value or harmonic Fourier series.

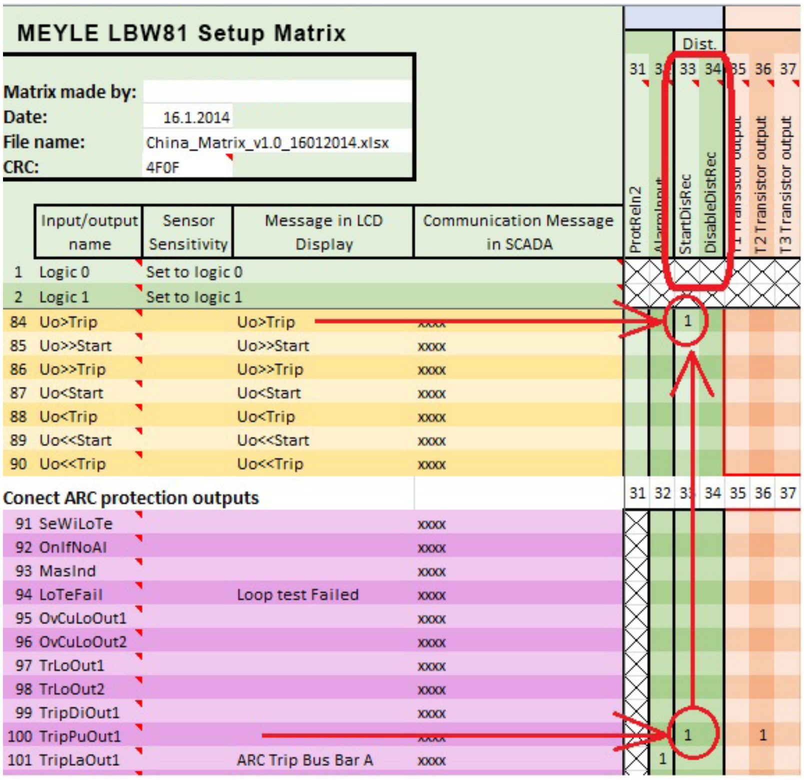
The disturbance recorder is triggered by programming matrix column 33 StartDisRec. If there is a lot of tripping, the recording is the first, because the recorder needs reset before it starts again. The relay memory can store 10 recordings (Modbus version) and are named by date. Resetting is done by activating a pulse in matrix column 34 DisableDistRec or by relays front panel or remote reset. When starts the disturbance recorder, the relay display changes at the same time to show the Trip State Circulation E, which shows visually all analogue measurements and events before and after trigging. If the relay memory has too many recordings, the first one is deleted automatically. It is also possible to trigger and reset the recorder by means of virtual input that can be controlled by SCADA. Normally, the disturbance recorder is started by activating in matrix all trip type of rows needed in later analyses. Normally, they are the same signals that trip transistor outputs, and by tripping coil, the system circuit breakers are tripped. Resetting can be automated for example when some breaker changes position in digital inputs.

The disturbance recorder memory in the relay is large and is therefore without battery backup, which means that you must read the recorder before switching off the relay's auxiliary power.

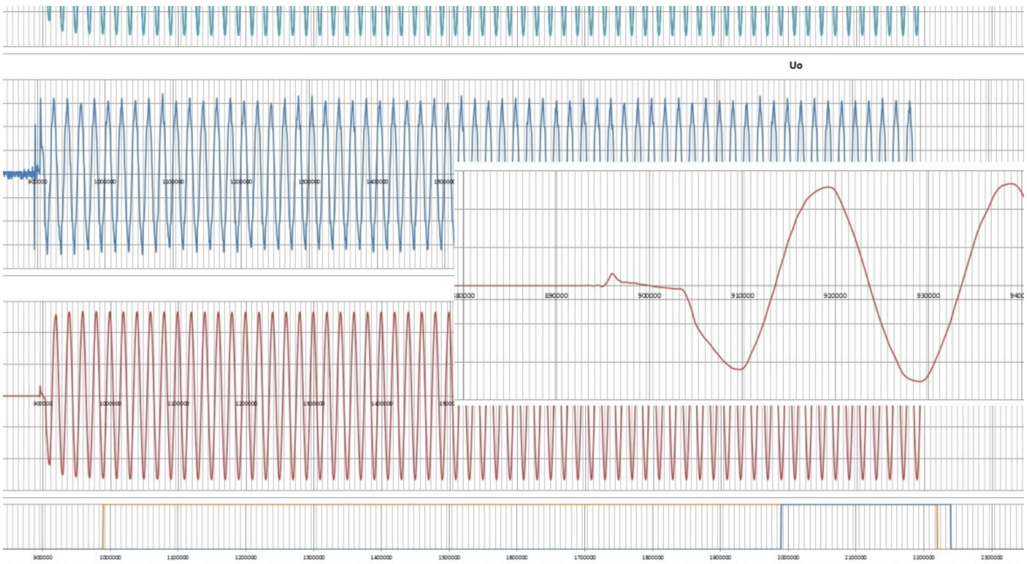
The disturbance recorder is read by internet web browser for example, MS Windows Internet Explorer. The relay has a web server that communicates with the user and downloading the files from relay to user computer is very easy. The web browser needs the URL (web address), which is the relay's TCP/IP address and is always visible in relay display A1.



Because LBW81 has a very high performance disturbance recorder, it is possible use it when you want to analyse all phenomena that appear in power lines when switching, starting, synchronising, when there is an earth fault etc.



Example on how to trigger the disturbance recorder by means of ARC-protection trip signal TripPuOut1 and Uo>>Trip relay function.



The Comtrade-format is easy to import to Excel and to get similar waves like on an oscilloscope. Each cycle has 40 samples in a 50 Hz grid, which means that short transients can also be detected.

The Comtrade-format disturbance recorder files can be examined by many free programs, but most of the relay manufacturers are programmed the viewers, that they shows only the manufacturers own recording. One free program is TOP, made by PQ Soft.

http://www.pqsoft.com/

6.20 Event Log

LBW81 has an event log that keeps in memory the 2000 last events. The list can be read by web browser, just like the disturbance recorder. The file format is ASCII and the extension is *.txt. It is easy to open in Notepad or by any other word-processing program. Log messages are likewise shown in display D and E. It is important to nominate the rows where there are user messages (chapter 5.8) so that everything necessary but nothing unnecessary goes into the log. If you do not have user messages in some matrix row, for example, digital input, the change of this input does not go to the log, but if there is a message, then it does go into the log.

Normally, LBW81 active displays circulation (D1) and shows the four last events without being touched and with the long touch in detailer displays D1-D8 quite many events more, so separate reading of the event log is not typically necessary. In the event of a trip, the display circulation E shows the event before and after tripping, as well as the RMS values of the analogue channels.

Events are also listed directly in a relay web sheet by using web browser, which means that they do not always need to download the file to computer.

10	2000-01-01	00:00:05.443	098TrLoOut2	Trip Loop Out 2	OFF
9	2000-01-01	00:00:05.424	098TrLoOut2	Trip Loop Out 2	ON
8	2000-01-01	00:00:05.344	097TrLoOut1	Trip Loop Out 1	OFF
7	2000-01-01	00:00:05.325	097TrLoOut1	Trip Loop Out 1	ON
6	2000-01-01	00:00:05.244	096OvCuLoOut2	Loop Out 2	OFF
5	2000-01-01	00:00:05.225	096OvCuLoOut2	Loop Out 2	ON
4	2000-01-01	00:00:05.144	095OvCuLoOut1	Loop Out 1	OFF
3	2000-01-01	00:00:05.125	095OvCuLoOut1	Loop Out 1	ON

When there are more than 2000 events, the first events are deleted. The event log memory in the relay is large and is therefore without battery backup, which means that you need to read log before switching off the relay's auxiliary power.

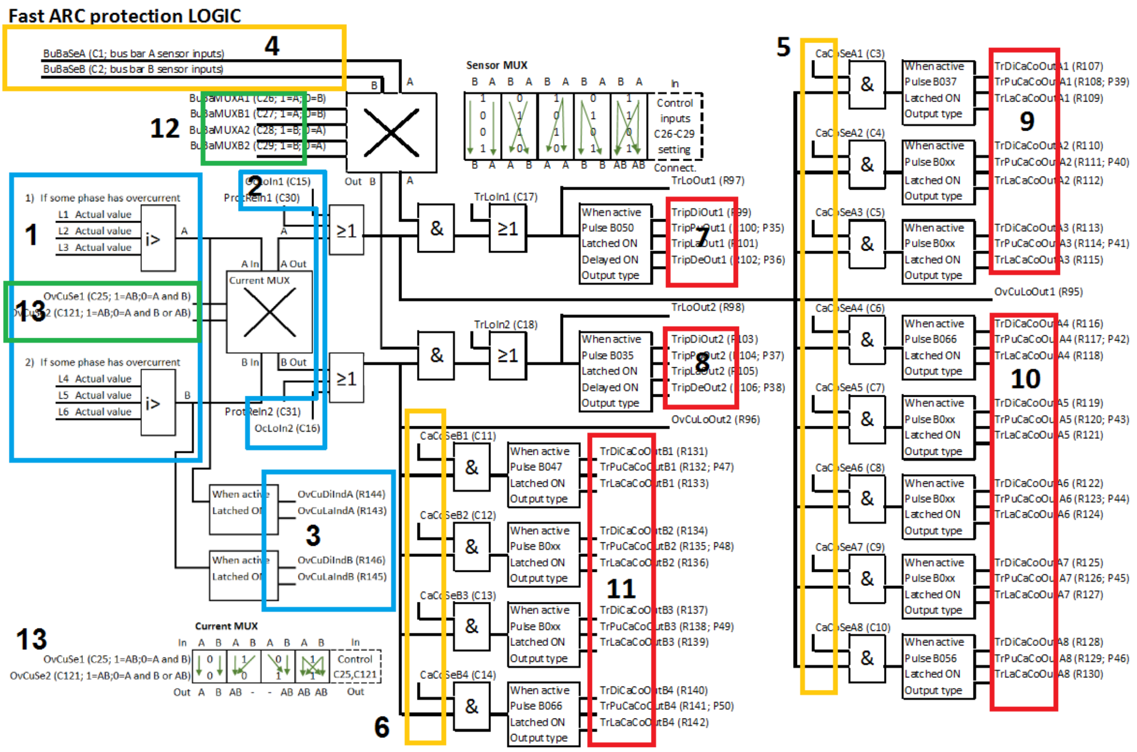
7 TESTING (COMMISSIONING AND UPKEEPING)

7.1 Testing Optical Point Sensors and Trips

When the ARC protection system is installed, it is important test all sensors by using real light, for example, by using a camera with a flash or a portable lamp. If there are any uncertainties in light detection, check that the fibres are well installed (into the sensor connector) and that the installation and fibres looks good. Change the sensor sensitivity, if seems that the light detection is not reliable. Do the same if the sensor seems too sensitive and that room light or normal operation may trip the system. Normally, light illuminance tolerance is quite large and separate settings for each sensor, is not necessary. Also check when testing that the message in the relay display event log (D or E) is correctly customised or designed as defined. It is also important to test that the light detection with over current causes a final circuit breaker trip. Test the trip signals to all breakers. Note that the system can have many protection areas, which means that the program's principle must be understood.

Ensure before starting the test that the optical cables are well installed with permissible radius and that the system installations are final. Also check that the system works well when switching the auxiliary power ON and OFF. Check, that the mains system switching ON after the arc trip, is blocked enough well and that the operator understands this. It is necessary visually check the switchgear, especially the tripped compartments, before switch it ON again. Check that the CT ratios are correct and that the circuits are closed.

It is possible to simulate the arc protection over current state by using the relay's free digital input or temporary setting over current line to a logical one in matrix (row 2 sets the input, which is activated to logical one). OcLoIn1 (c15) and OcLoIn2 (c16) are for receiving over current information in loop system and ProtReIn1 (c30) and ProtReIn2 (c31) are for simulate over current state or when like remove the over current condition in logic.



If supplying current to analogue inputs (1), the over current start can be found in outputs (3, rows) which can be connected to transistors (columns) if you want to measure times when testing.

- Inputs (2, column) can be used to simulate over current when connecting to digital inputs.
- Sensors are located in a bus bar or incoming protection area, and are normally connected in area (4, columns).
- Sensors are in outgoing feeders after the breakers in area (5 or 6, columns).
- Transistor output trips the breakers in areas (7, 8, 9 and 10, rows).
- Areas (12 and 13, column) are for changing the bus bar the over current or sensor affects.
- Display C2 is useful for understand the fast arc protection logic signals when testing (chapter 6.4).

When testing the point sensors, it is very useful to freeze the display D1 by using a longer touch. All names of the sensors tested are now visible without waiting screen circulation.

Use display C2 to discover the states of the relay internal logic.

7.2 Testing Optical Naked Loop

- Do the test after the power cables are installed.
- Test the Naked fibre by removing the connector in hindmost compartment (chapter 5.5 G in picture) and introducing light in a radial direction inside the fibre. Remember to block the end of the fibre with a finger because light goes very easily in an axial direction inside the fibre. Ensure that the relay input sensor is connected to the first (A) compartment to detect the light. If anything is uncertain in light detection, check that the fibres are well installed, and if needed, change the sensitivity of the sensor.
- Do the same test when the connector in compartment A is opened and light is detected by relay input connected to compartment G.
- Test all compartments by introducing light and check that fibre is well installed.

7.3 Testing Relay Group

If there are many relays connected to group by using optical loops and wired signals, test the system on the whole so that all relays are programmed and installed.

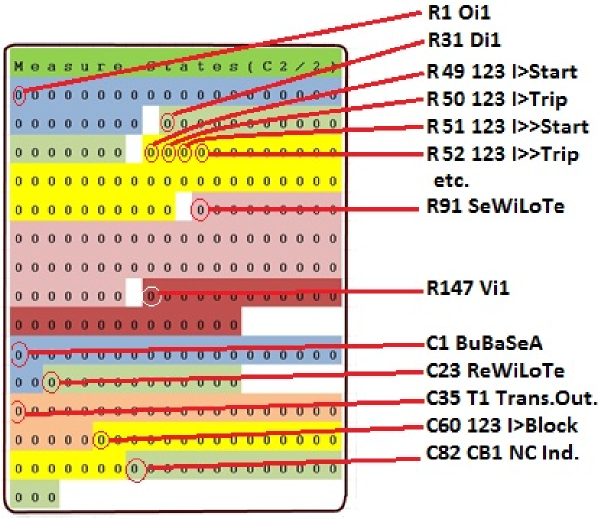
- Check that the system works well when switching the auxiliary power ON and OFF, especially if there is more power supplied. Check that the system works properly when one power source is missing.
- Test the reset buttons and signals.
- Check that all optical loops transmit signals correctly between all units.
- Check that the bus coupler breakers are connected and that correct relays can be tripped (typically, the same bus coupler is tripped by two relays).
- Using a lamp, check that the protection areas are correct and that all sensors and naked loops are working. Check that the CT rates are correct and circuits closed.

- Check SCADA messages to the control room and that it found all relays by substation computer web browser.
- Check that the switching of the mains power back after the arc tripping is enough well blocked and that the operator understands the requirement visually check the inside of the tripped compartment (before switching on).

7.4 Testing Protection Relay Functions

LBW81 has a lot of protection relay functions that can be used in normal protection and backup protection. Tests can be done by means of a normal relay test set.

- Check that CT and VT rates are correct.
- Check that the phase rotation and correction angles in matrix are correct (needed in directional earth fault protection and power measurement).
- Display C2 shows all protection relay function start and trip signals, which is useful when you want to measure the start ON and OFF current/voltage levels. This display shows almost all the states the relay has including digital inputs, sensors, transistor relays, etc.



Note that different relay versions have a different number of states are shown on display C2.

- Note that blocking signals (R60-81) must be set to logical zero to activate the relay function.
- Note that the relay's transistor outputs (T1-T8) have a rectifier inside with a 2 volt threshold. Some relay test sets use only 5 V internal signals, which means that they must use external voltage to trip the relay test set clock.
- If use T1 output in trip signal and P23 123CB&CT supervisor function Mode bit 4 are activated, check that the entire test pulse does not affect the relay test set clock.
- If a fast or well filtered stabile tripping signal is needed, note parameter P1 "Number of the Samples in RMS Calculation" (chapter 5.10).
- If you want to set the over current protection relay that it just bears the transformer's inrush current, first set the over current delay longer and then do a practical test by starting the transformer. Set the relay's disturbance recorder that it is triggered by an over current start signal. Note anyhow the alternation depending on the starting time and the direction of the transformer's remanence. The same trick can be used when you want to define the motor starting current or generator currents when synchronising to grid.

7.5 Testing SCADA Messages

LBW81 has two SCADA protocols versions, Modbus TCP (Server) and IEC61850 (Server). Both SCADA protocols can be used for:

- generating analogue channel measurements (*e.g.*, currents and voltage)
- generating events from tripping signals (*e.g.*, arc protection or protection relay functions)
- generating indication signals (*e.g.*, circuit breaker position)
- receiving and executing control commands (*e.g.,* closing circuit breaker).

It is a useful list which tests the signals used when starting up the relay and system. LBW81 Modbus and IEC61850 have separate documents.

7.6 Testing Auxiliary Power Fails

It is important always to test when starting up the system how it behaves when switching the auxiliary power OFF and ON. Especially if there are more power supplies, this is very important. If the system is well designed the control room gets alarm if the relay does not get auxiliary power (use relay R1 NO contact).

Tripping relays and transistors outputs are normally connected to breaker tripping coils and the circuits are separate in each switchgear cubicle. Check that this has been done correctly and that when one system is being switched off, it does not block or supply the other ones. Also test the auxiliary power earth fault alarming and that the systems are separate if there are two systems.

8 APPLICATION EXAMPLES

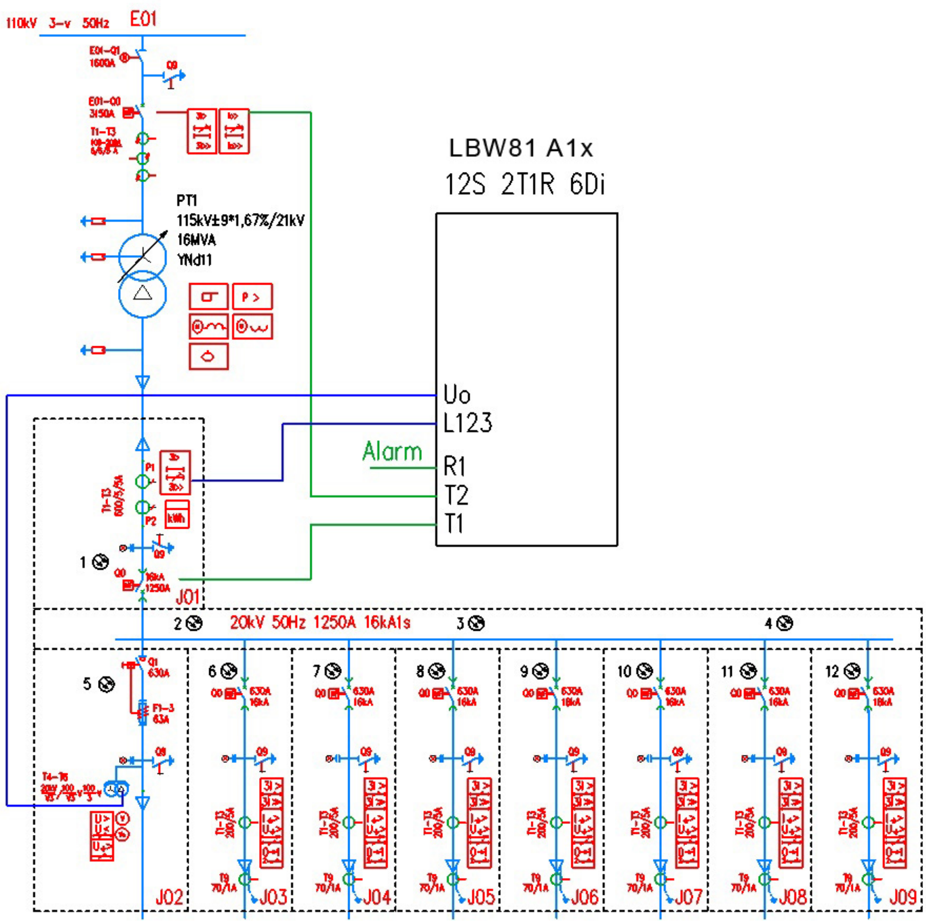
8.1 Single Bus Bar, Single Incoming Feeder, Earth Fault Condition in Extra

This is the simplest example in which there is only one incoming feeder and all outgoing feeders are in same protection area. A high voltage circuit breaker E01-Q1 is tripped at the same time as the medium voltage breaker Q0 in J01 compartment.

The tripping signal is generated when there is the same time over current set by parameter P31 in one or more incoming phases and an arc indication in one or more optical point sensors.

- This example has one specialty, which is the earth fault voltage measurement for detecting arcs between the one phase and earth inside the bus bar or feeder compartments. If the network is unearthed, the electric arc current goes to earth, which is very small depending on the line capacitance and transformer neutral system (Petersen coil). Earth fault voltage is generated by a VT open delta connection. In addition to the high level of current normally used in arc protection systems, now an over voltage relay function, P27 or P28, is also used to activate point sensors in detecting light and in causing a trip. It is possible to use, for example, the P27 function Start (R83 is fast but may have a switching time error activation) or Trip signal (R84 has a delay) to activate light sensors C15.
- LBW81 has a separate light sensitivity setting in each optical input and therefore sensors 2-4 inside the bus bar compartment in particular, can be set to be more sensitive.

The system logic now functions so that where there is an over current or earth fault, a trip occurs if there is the same time light indication.

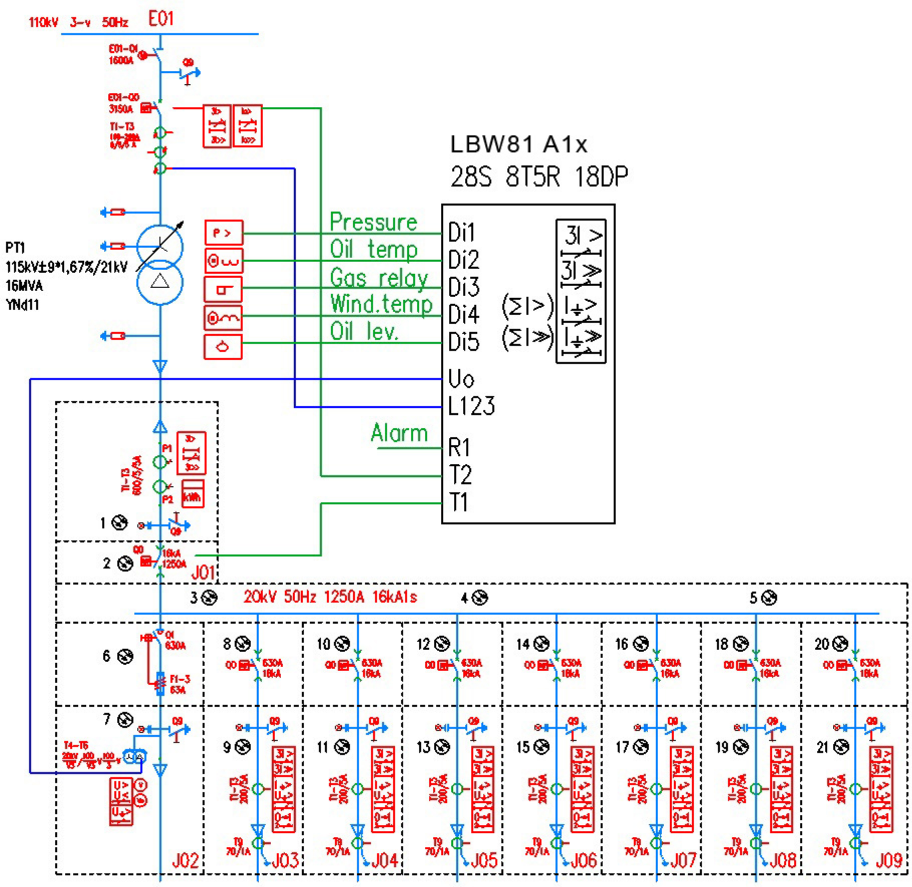


Cubicle type of switchgear

8.2 Single Bus Bar, Single Incoming Feeder, Use Protection Features

This example is similar to the first one, but now the current measurement is in the main transformer primary high voltage side and Uo is now used for measuring line voltage. Current detection and arc protection logic works similarly in the secondary side, but when starting the main transformer, there is an inrushing current which activates the arc protection over current condition for a short time. Normally, this only means that as the transformer is starting, all arc sensors inside the switchgear are sensitive for a short time. This example has special features:

- The LBW81 voltage measurement input Uo is used to measure line voltage and therefore the relay display shows powers and power factors (note ratio!).
- Because the relay now knows the high voltage current, it can be used for high voltage side over current (P9, P10, P11) and earth fault protection (P19 and P20) or backup protection. Note that the relay functions, P19 and P20, which can be used for earth fault protection in 110 kV grids, is normally earthed at one or more points. Functions P19 and P20 are measured as the sum of the phase currents.
- LBW81 has digital inputs which can be used for get information to SCADA. In order to improve transient durability, it is useful to use an extra isolation relay with a 110/220VDC voltage between the main transformer and relay or else use at least an internal 3 W 24VDC isolated power supply with a shielded cable (relay end earthed isolated 24VDC system as floating).
- By using all 18 inputs, it is possible to cover almost all the most important devices inside the substation and to get the local log list on display.

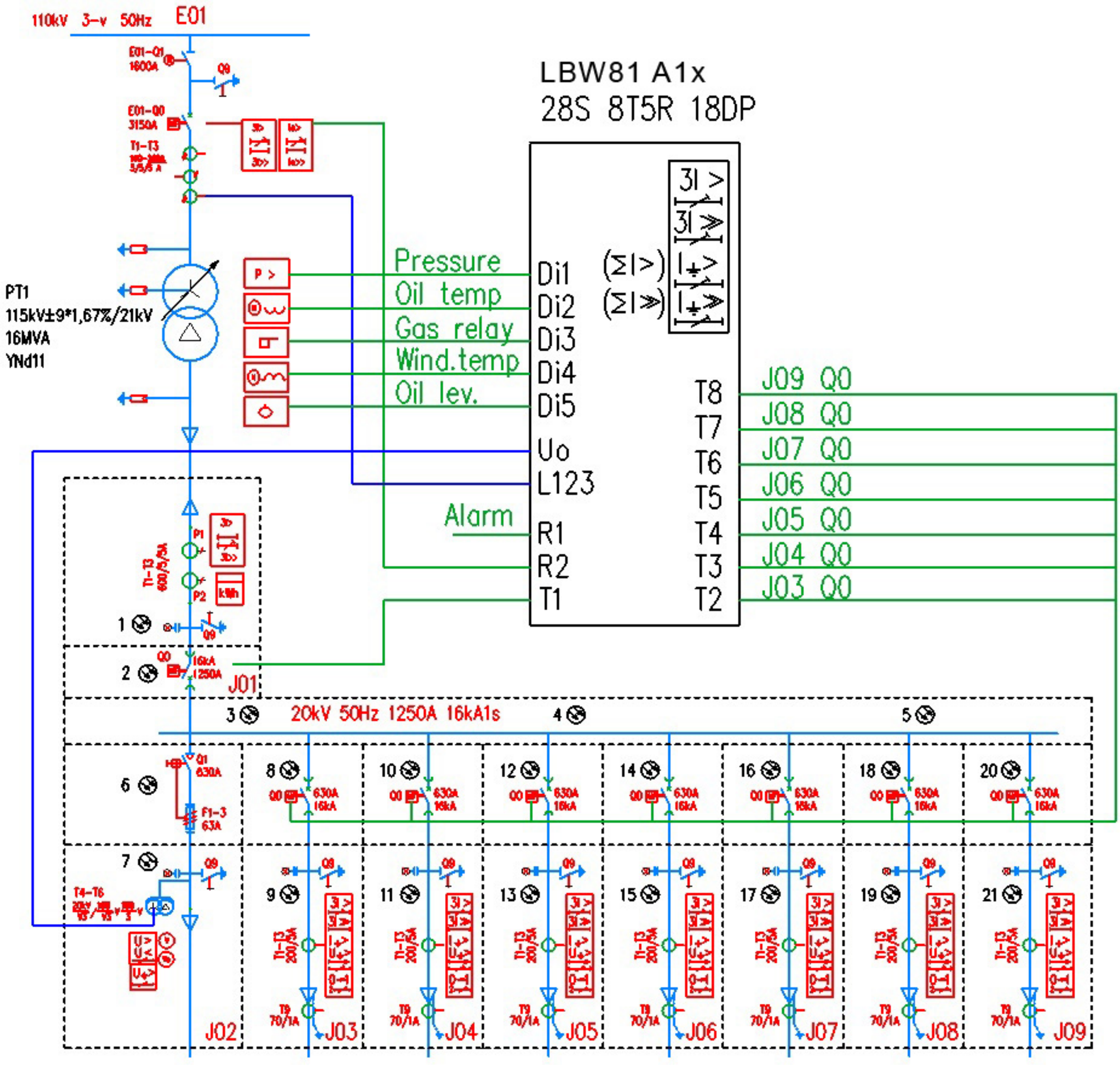


Metal Clad type of switchgear

8.3 Single Bus Bar and Incoming, User-protection Features, Arc Protection is Selective

This example is similar to the earlier (8.2), but now the outgoing feeders have a separate arc protection area in the switchgear cable compartments. This maximises the usability and in the event of arc tripping, only the faulty compartment is switched off. This example has special features:

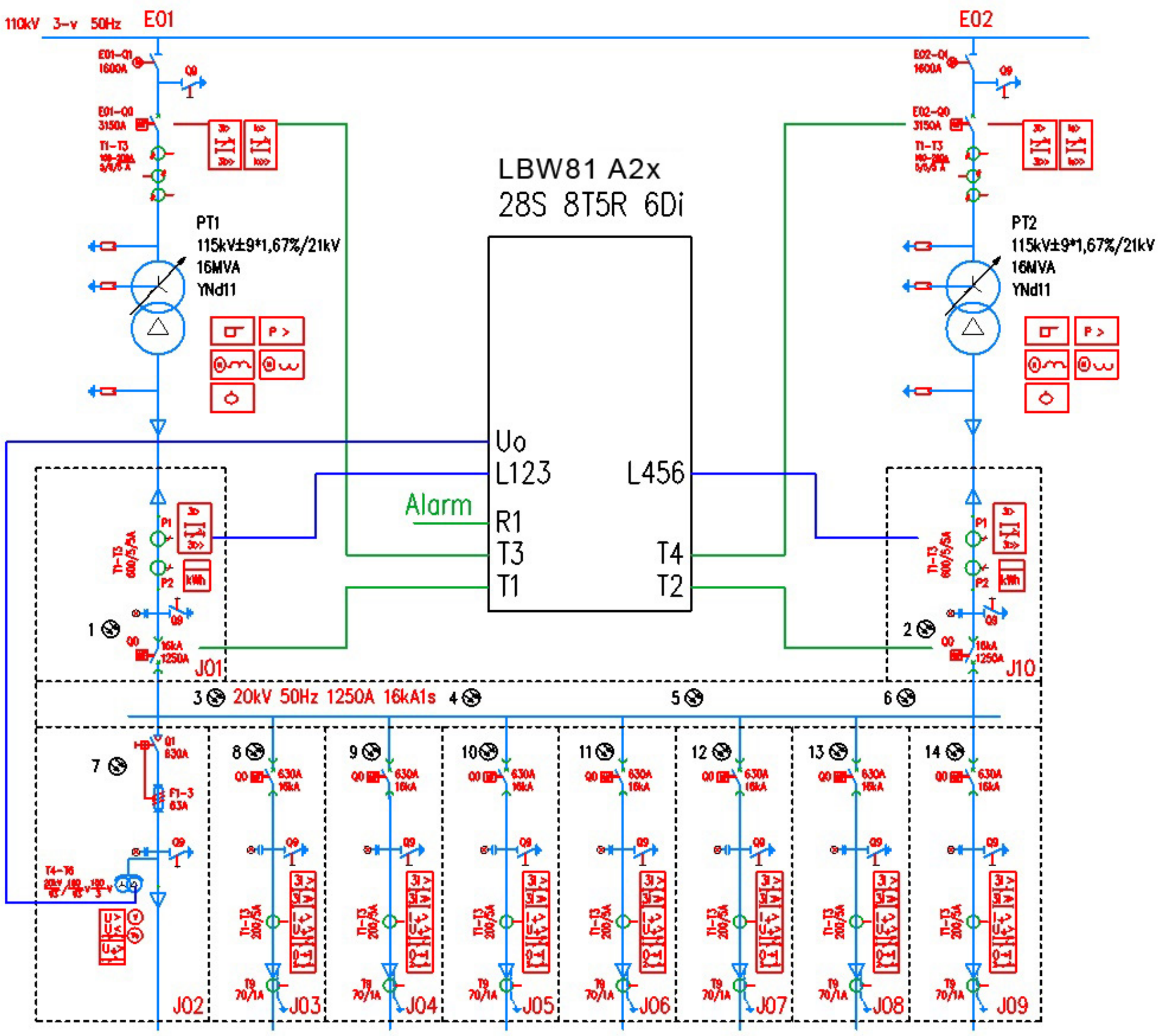
- The optical point sensors 9, 11, 13, 15, 17, 19 and 21 in the metal clad switchgear cable compartment are after the feeder's circuit breaker, which can be used for switching off the arc in this limited area. Incoming feeders (Q0 in J01 and Q0 in E01) are tripped only if the arcing continuous even though the local breaker opens. Other sensors are tripped directly without delay the incoming feeders Q0.



Metal Clad type of switchgear

8.4 Single Bus Bar, Double Incoming Feeders, Low Current Phase to Ground Arc Detecting

This example is the simplest double incoming type of substation. The over current is detected at both inlets, and in the extra earth fault voltage detection by VT, there is an open delta winding. This system has only one protection area because it does not have a bus coupler. Point sensors 3, 4, 5 and 6 can be set to be more sensitive for detecting unearthed network small arc current between the one phase and earth. The relay must be equipped with an A2 option, which means three extra current measurements. All incoming feeders in E1, E2, J01 and J10 are tripped at same time, but they need a separate LBW tripping relay because the probably have separate tripping circuits.

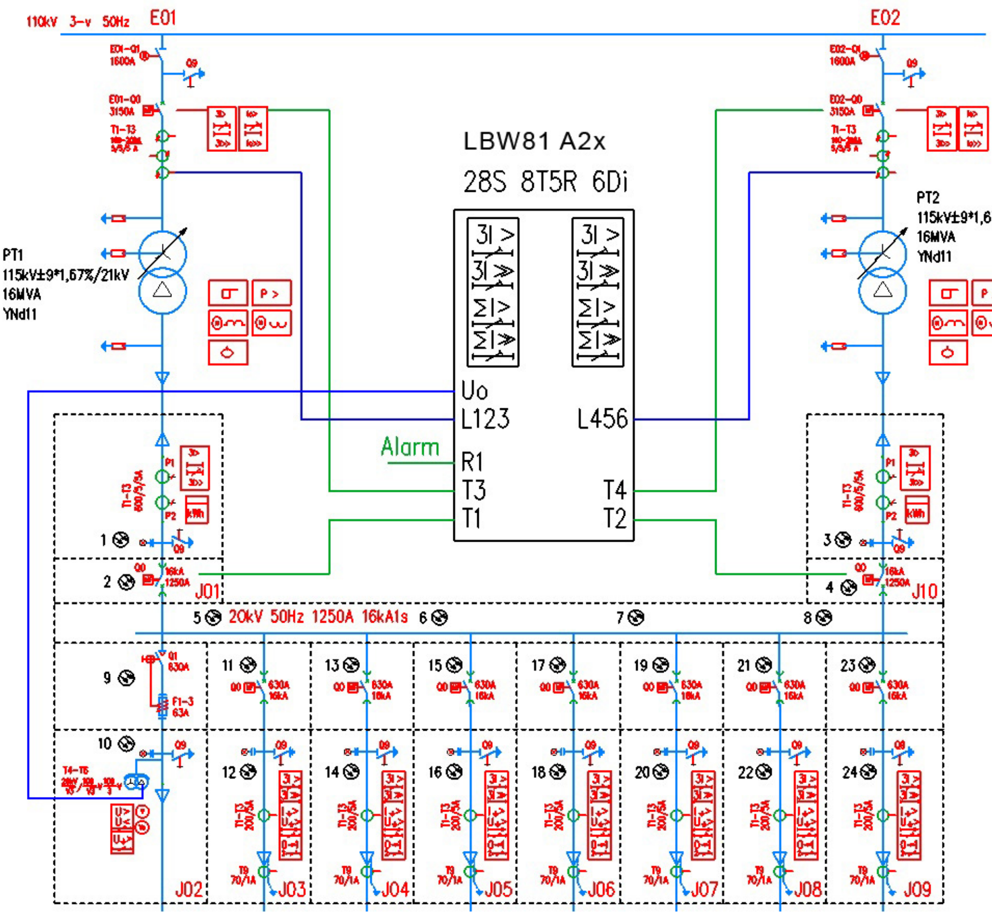


Cubicle type of switchgear

8.5 Single Bus Bar, Double Incoming Feeder, Use Protection Features

This example is similar to 8.4, but now the current measurements are in the main transformer's primary high voltage side. Current detection and arc protection logic works similarly to the way it works in the in secondary side, but when starting the main transformer there, is an inrushing current that activates the arc protection over current condition for a short period. Normally, this only means that while the transformer is starting, all arc sensors inside the switchgear are sensitive for the short time. In the event of arc tripping, all incoming feeders are tripped, but in the case of an over current or earth fault first, only the breaker before and after the main transformer (transformer fault), are tripped. This example has special features:

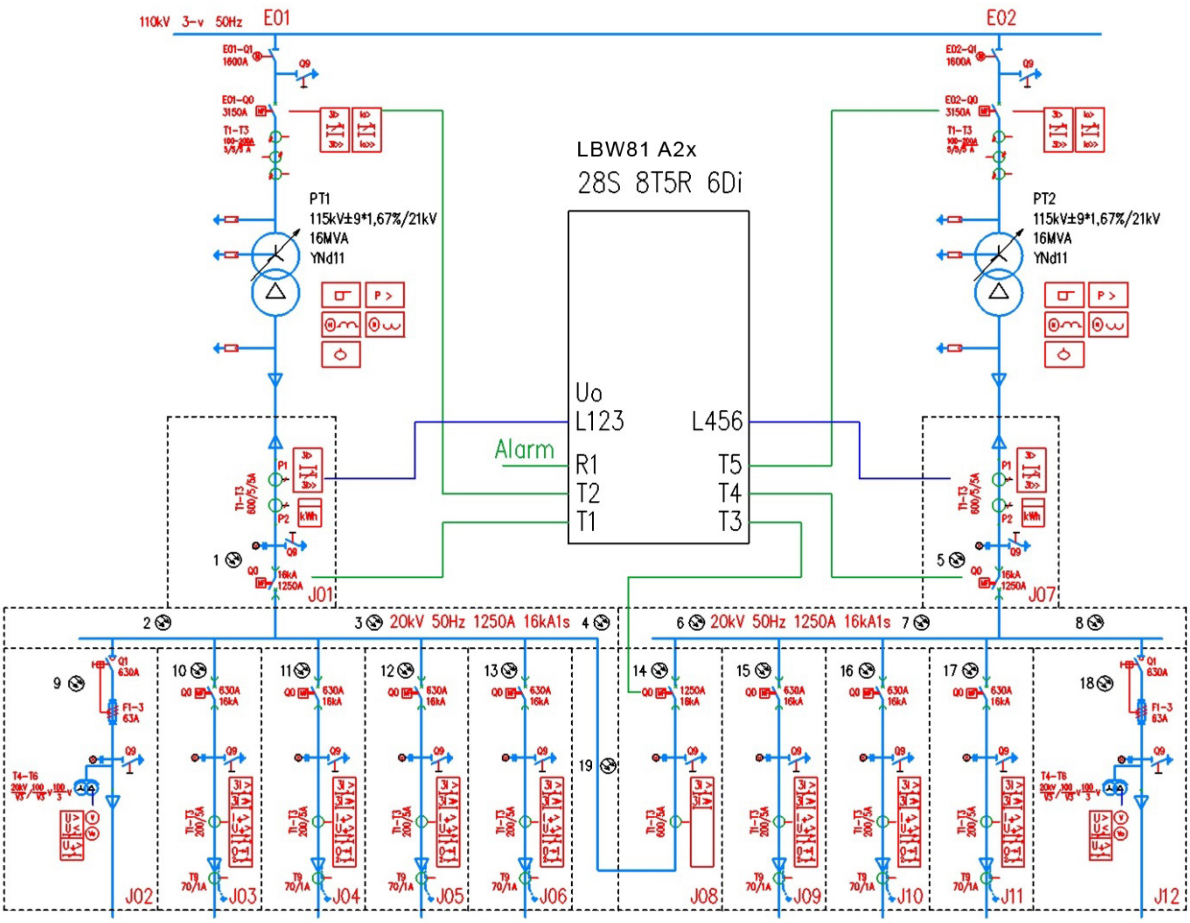
- The Uo measurement can be used to detect small arc currents by means of earth fault voltages with or without a delay in a manner is similar to that in single incoming feeder systems.
- LBW81 A2 has separate protection relay functions for L123 and L456 current channels, which can be used for high voltage side over current and earth fault protection or backup protection. Protection functions P14-P18 are used for current channels L456 over current protection and P21 and P22. Earth fault protection in 110 kV grids is normally earthed at one or more points.
- When there is a fault inside the main transformer, *e.g.,* PT2, the over current protection trips breakers Q0 in E02 and Q0 in J10, but if PT1 is in normal operation, the switchgear maintains the voltage.



Metal Clad type of switchgear

8.6 Two Bus Bars with a Bus Coupler (H-type), Two Incoming, Two Arc Protection Areas

This example is a double incoming feeder with a bus coupler and double bus bars. Now, over currents are detected in both incomings feeders, but because this system has two arc protection areas, only one bus bar has the same time arc detection switched off. This improves usability. Because power can be also supplied through the bus coupler, it must be always switched off. The system can also work so that only one transformer is switched on and the power goes through the bus coupler to other bus bar having the dead transformer. Traditional protection functions like over current and earth fault are also available if needed.

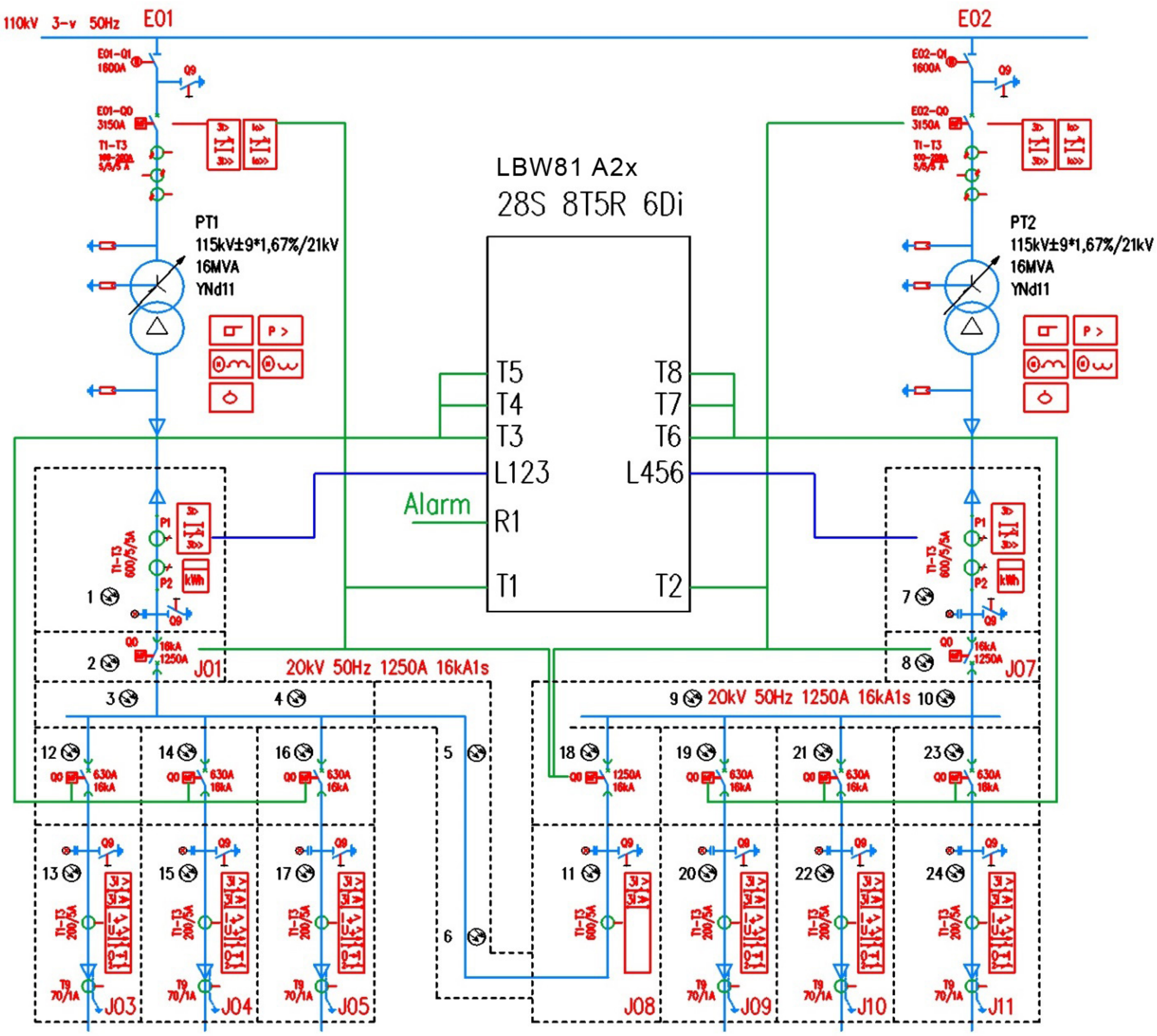


Cubicle type of switchgear

8.7 Two Bus Bars with Bus Coupler, Two Incoming, Many Arc Protection Areas

This example is a metal clad type of switchgear with double incoming feeders and with bus coupler and double bus bars. The over currents are detected in normal way by both incomings feeders, but because the system has separate cable compartments in each outgoing feeders, the usability is improved by using six local arc protection areas, which only trips the local outgoing feeder breaker. For example, point sensor 17 only trips breaker Q0 in J05, but if arcing continues longer, it breaks the incoming Q0 in J01 and the bus coupler Q0 in J08. This example has special features:

- To minimise the need for fast-tripping relays (T1-T8), there are many tripping coils connected to same tripping circuit. It is very important to understand that the breaker tripping coils must be separate, which means that the traditional protection relays use different coils or that the system is designed to use semiconductor relays to separate the tripping circuits. As well, the bus coupler breaker must be equipped with separate coils or separation relays. More information about the semiconductor relays can be found in in paragraph 4.6.

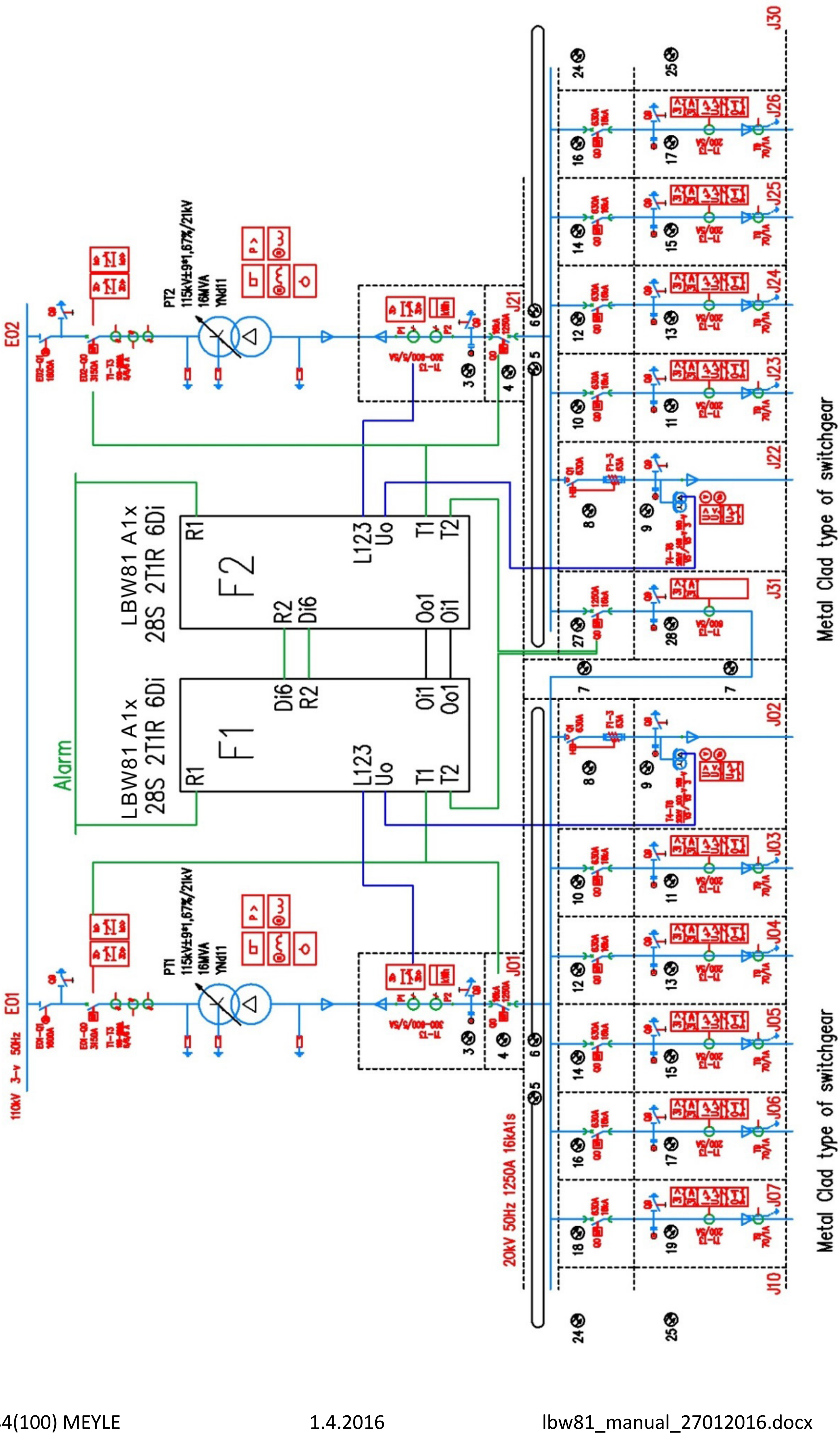


Cubicle type of switchgear

8.8 Two Bus Bars with Bus Coupler, Two Incoming Large System with two LBW81s

This example has two LBW81 relays that are worked in group. This is necessary, because now the switchgears have too many compartments needing optical point sensors. Over current Information between the units is transferred by optical loop and is connected to Oo1 and Oi1 in both relays. The system also has a copper loop connected to R2 and Di1. This loop is for power failure detection and to start the loop test done when pressing the reset button. Relay F1 is the master and F2 the slave. This means that the reset pressed in relay F1 also affects relay F2. If more optical sensors are needed in the switchgears, more relays can be connected in a similar way to same loops to work in a team. This example has special features:

- Bus bars now have a naked optical loop. This is one possibility for reducing the number of the optical inputs, but the installation is not as simple as that with point sensors (5.5).
- Note that it is necessary for there to be a separation in the circuits which are connected to T1 and T2 (HV and bus coupler). Of course, this is in place of using 81 version 8T5R, which has more trip relays.
- Now, because there are two relays with Uo inputs, earth fault voltage detection is enabled.

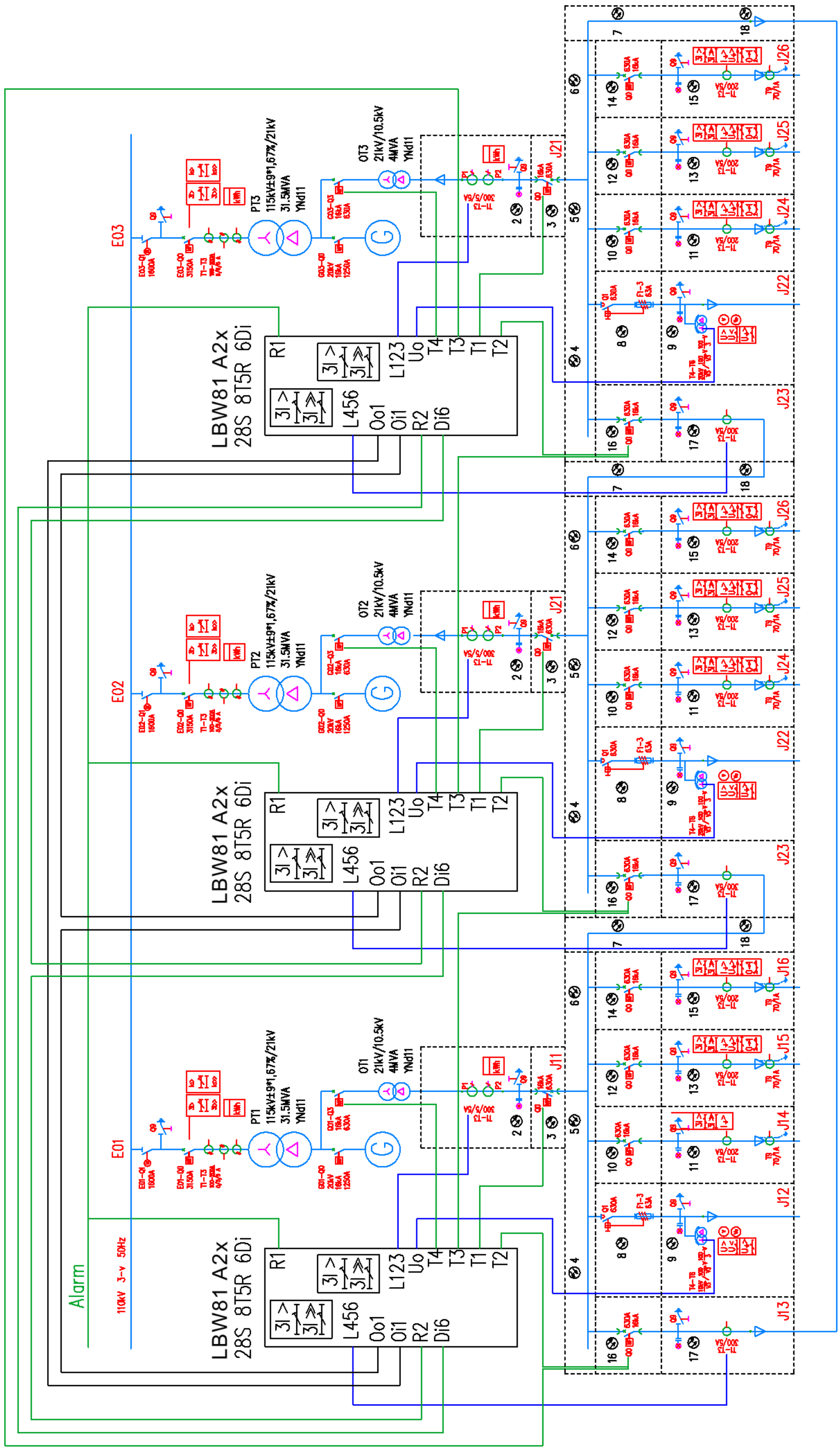


E01
E02
110kV 3~ 50Hz
PT1
PT2
115kV±9*1,67%/21kV
16MVA
YNd11
LBW81 A1x
28S 2T1R 6Di
F1
F2
R1
R2
Di6
L123
Uo
T1
T2
Oi1
Oo1
Alarm
J01
J02
J03
J04
J05
J06
J07
J10
J21
J22
J23
J24
J25
J26
J30
J31
20kV 50Hz 1250A 16kA1s
Metal Clad type of switchgear
Metal Clad type of switchgear

8.9 Power Plant Application, Many of Bus Bars and Incomings with Bus Couplers, Group

This example has three or more relays working in a group. This type of switchgear topology is common in power plants and on many larger ships. If there are three relays, the loop can be single, which means that it only needs Oi1 and Oo1 for create loop. If there are more relays, it is recommended that redundant loops also be used when one relay is switched off (find paragraph 4.5). Note parameters P51-P56 in the matrix defining loop tests and how the loops behave when activated. Carefully, test all trips and over current cases and reset and relay power off cases before putting them to use. This example has special features:

- Because the switchgears are connected in triangle (bus coupler in both ends) and the relay don't know the breakers positions, the fast arc fault tripping is always made that all three breakers must be tripped off immediately. This is generally advisable in arc protection and no harm is done if an open breaker receives another off command.
- In this example, LBW81 has an A2 option, which means that each relay controls two- three phase CTs. Now, the over current protection in bus couplers and the incoming feeder are made only by using LBW. This is very cost effective and simple. In over current protection, the bus couplers must be tripped faster than the incoming feeders because then the unbroken switchgears can survive without a cut in electricity. This means that the system firstly check, do the switchgear works when it is independent and only the incoming is connected.
- In arc protection over current detection (and over current protection), the CT in bus coupler circuit is not mandatory. This means that the same system can be protected quite well by using LBW relays without an A2 option. All optical sensors are always better activated, when one of the whole system incoming feeders (or bus couplers) have over current and then immediately trip the incoming feeder and both bus couplers in the switchgear detects the light. In over current protection, the simpler LBW relay only has three over current stages, which means that it uses one of the bus couplers with the shortest time.
- Note that Uo, is connected in each switchgear to the VT's open delta, which can be used to detect the switchgear bus bar's internal arc to ground. In the matrix, the Uo> start or delayed trip activates over current loops between the relays like the arc protection over the current, and then all the optical sensors in all relays are now ready to detect light. The sensors inside the switchgear bus bar compartment must be set to be more sensitive in order to detect smaller non-grounded network earth fault arcing.



LBW81 A2x
28S 8T5R 6Di
Alarm
110kV 3~ 50Hz
E01
E02
E03

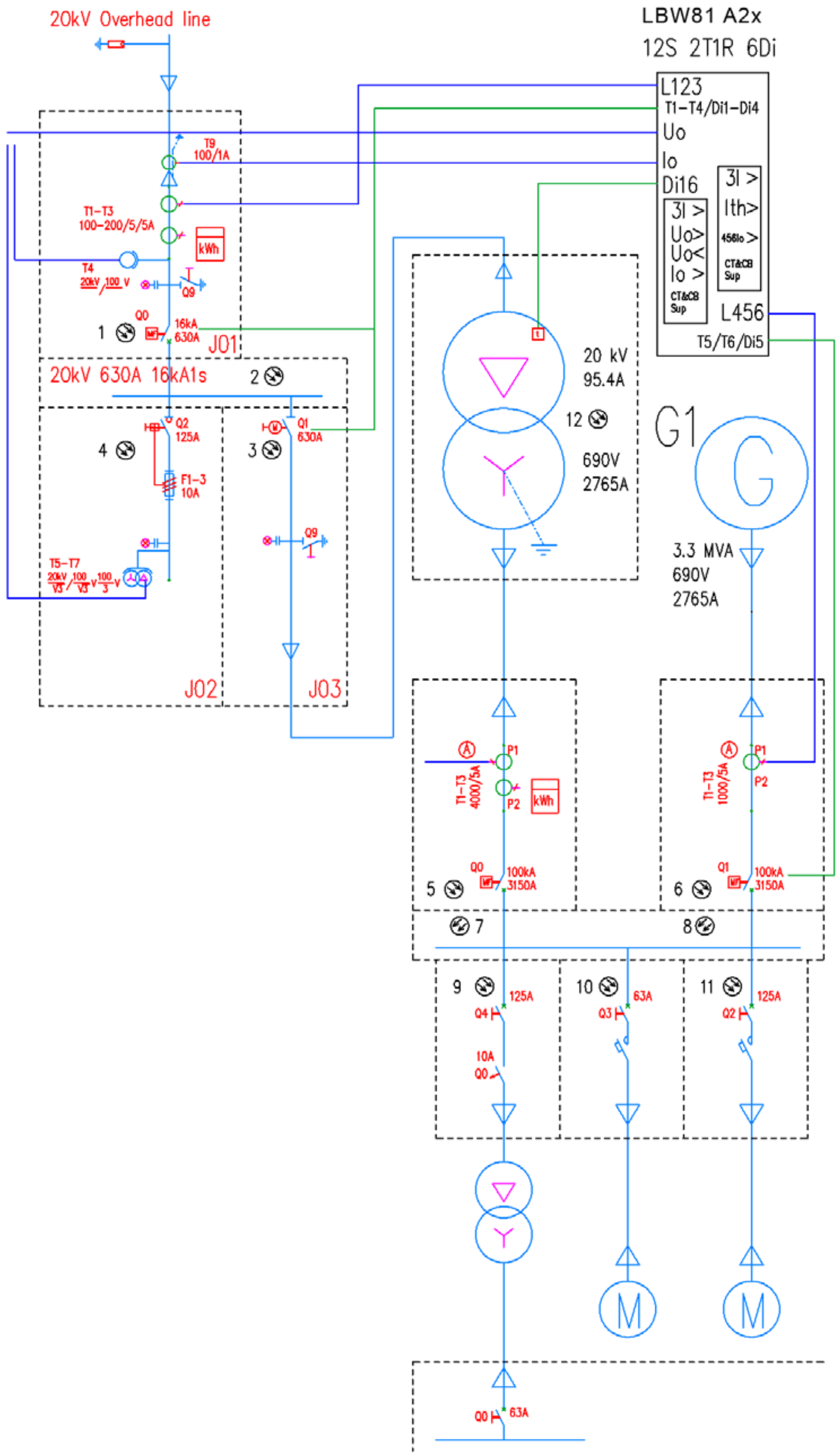
8.10 Small Wind or Hydro Power Plant, Total Protection, Cost Effective

This example can be a small hydro plant with one turbine or separate wind turbine or solar energy system is connected to medium voltage network. Protection is obtained by a very cost effective method, which means that it only needs one LBW81 relay instead of separate protection relays. This is possible without sacrificing performance, because LBW81 has good protection features that are enough for this kind of system. The arc protection is, in this example, very holistic because small power plants normally operate far away without human control. Note follow details:

- LBW81 is capable of totally controlling the switchgears, which means that the breakers' ON and OFF controls, events and position indications can be received and transmitted to remote SCADA. Output T1 is used to open the MV-breaker and T2 to close it. T3 and T4 are used to open and close the MV disconnector by SCADA, which is now necessary because the utility likes to ensure safe isolation during overhead line work (the power plan is absolutely disconnected). T5 and T6 are used for controlling the generator breaker.
- Indications are generated by using digital inputs. Di6 is for alarms, for example, for transformer overheating. Di1 and Di2 are used to indicate MV breaker Q0 position, Di3 and Di4 for MV disconnector Q1 position and Di5 generator breaker position. Because the generator breaker has only one input, it is copied by using a matrix inverter in order to get two bits of information which can be sent to the control room in a way similar to the other switching devices.
- The MV system uses L123 protection functions and the tripping signal goes to Q0. The system can have a normal over current protection and, in addition, a sensitive directed earth fault protection Io>, which means that the system trips if have earth fault between the incoming feeder and power plant block transformer (need for example if the cable is long). Earth fault current must be higher than 1A (20 kV earth fault current means 10 mA relay current) is measured by cable CT T9 ratio 100/1A. Directed earth fault protection function needs the Uo, is generated by VTs T5-T7, to have an open delta winding. The CT and CB supervisor protection functions can be also used to detect one phase loss, lost connection or wrong breaker indication (normally this function alone is alerted).
- If utility or safety demands required that the power plant must be automatically disconnected by a visible contact gap in longer electric cut, it is possible to realise this by using Uo> and Uo< protection functions and VT T4 is in the MV incoming feeder. If, for example, there is more than a half-hour interruption in electricity to the MV network, the Uo< function must open the disconnector Q1 (and breaker Q0). The same applies when the electricity comes back to the MV network, as the system connection can be delayed and that, for example, needs 6 minutes before closing disconnector Q1 and breaker Q0. This solution needs a battery powered auxiliary voltage and Uo> and Uo< need Uo input which now cannot be used for the directed earth fault protection and VTs T5-T7 open delta. Note that the power plant needs in any case its own automation care for network synchronisation and fast disconnection and to prevent the system operation in island (grid tie system), which is normally parameters inside the solar or wind turbine converter.
- Generator protection is achieved by using L456 protection functions. It normally has over current protection and there can be many steps and in addition earth fault protection 456Io> if needed, because the LV side (690V) is solidly earthed in this case. This function

trips if the sum of the current is not zero, which means the generator has an earth fault. Function CT & CB supervisors are used to detect the missing phase caused by a loose contact or CT or breaker fault. This function also detects any generator winding short circuit, which indicates an unbalanced current.

- Note that the optical point sensor 12 is now used as a transformer smoke detector.



9 TECHNICAL SPECIFICATION

9.1 LBW81 Types and Ordering Codes

LBW81 option alternatives are as follow:

		Inputs				Outputs		
ARC	Multifunction	Optical	Analogue		Digital	MOSFET	Relay	Optical
			Current	Voltage				
IEC61850 - protocol								
LBW81-11	LBW81-31	12	4	1	6	2	1	4
LBW81-12	LBW81-32	28	4	1	6	2	1	4
LBW81-13	LBW81-33	28	7	1	6	8	5	4
LBW81-14	LBW81-34	28	4	1	18	8	5	4
ModBus TCP/IP - protocol								
LBW81-21	LBW81-41	12	4	1	6	2	1	4
LBW81-22	LBW81-42	28	4	1	6	2	1	4
LBW81-23	LBW81-43	28	7	1	6	8	5	4
LBW81-24	LBW81-44	28	4	1	18	8	5	4
LBW51		6	1				1	
LBW21		4					1	

LBW81 Arc Protection Relay (ARC): Standard relay features - LBW81-1x / LBW81-2x

3I> &	51/AFD	Arc Protection, Light or Light and Current (Voltage also possible) L1-L6 and/or U0
U0>, U0>>	59N	1-phase Overvoltage protection

LBW81 Arc Protection Relay with Multifunctional Protection Relay features (Multifunction (MF)) - LBW81-3x / LBW81-4x

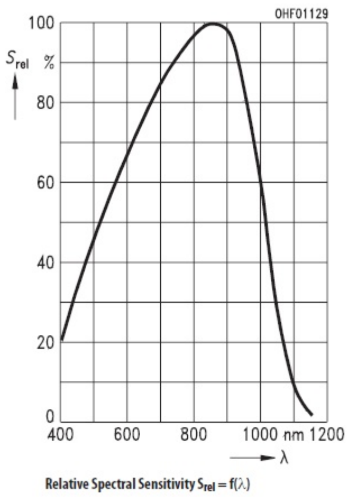
3I> &	51/AFD	Arc Protection, Light or Light and Current (Voltage also possible) L1-L6 and/or U0		
3I>, 3I>>, 3I>>>	50	3-phase Overcurrent relays, with constant-time	L1, L2, L3	
3I>, 3I>>, 3I>>>	50	3-phase Overcurrent relays, with constant-time	L4, L5, L6	(Only LBW81-33, -43)
3Ith	49	3-phase Thermal Overload / Current	L1, L2, L3	
3Ith	49	3-phase Thermal Overload / Current	L4, L5, L6	(Only LBW81-33, -43)
3Ika>	51	3-phase Overcurrent relay with inverse-time (IEC60255-3)	L1, L2, L3	
3Ika>	51	3-phase Overcurrent relay with inverse-time (IEC60255-3)	L4, L5, L6	(Only LBW81-33, -43)
3I0>, 3I0>>	50N	3-phase Earth-fault relay with constant time	L1, L2, L3	
3I0>, 3I0>>	50N	3-phase Earth-fault relay with constant time	L4, L5, L6	(Only LBW81-33, -43)
I0φ>, I0φ >>	67N	Directional and Undirectional Sensitive Earth Fault function		
U0>, U0>>	59N	1-phase Overvoltage protection		
U0<, U0<<	27	1-phase Undervoltage protection		

9.2 LBW81 Nominal and Limit Values

Analogue inputs:

Current inputs L1, L2, L3, L4, L5 and L6	• Rated current 5 A RMS • Measuring range 100 A RMS • Thermal withstand 20 A continuously • Thermal withstand 100 A 10 s • Thermal withstand 500 A 1 s • Burden < 0.2 VA
Current input Io	• Rated current 5 A RMS • Measuring range 50 A RMS • Thermal withstand 20 A continuously • Thermal withstand 100 A 10 s • Thermal withstand 500 A 1 s • Burden < 0.2 VA
Voltage input Uo	• Rated voltage 100 V • Measuring range 250 V • Thermal withstand 250 V continuously • Burden < 0.5 VA

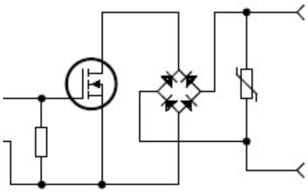
Optical inputs:

Optic sensor inputs (POF type) 	• Sensitivity setting 0.6 – 23 klx (with 1 m POF fibre and MEYLE transparent lens) • Fibre diameter 1 mm POF type • Each input has separate sensitivity setting • Maximum Wavelength λSmax typ. 850 nm • Photosensitivity Spectral Range (S = 10% Smax) λ min. 400 nm max. 1100 nm

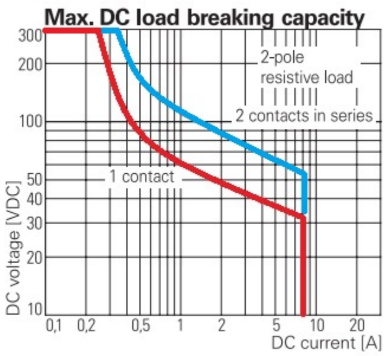
Optical output:

Optic output (POF type)	• Peak wavelength λPeak 660 nm • Fibre diameter 1 mm POF type • Output power coupled into plastic fibre ΦIN 16 … 80 µW • Pulse power ΦIN 160 … 800 µW (possible use in special case)

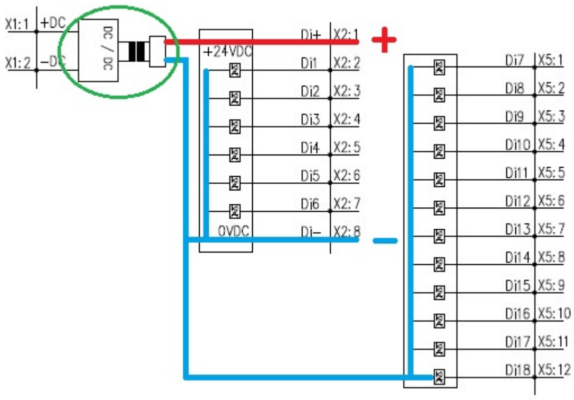
Transistor Outputs:

T1-T8 	• Maximum continuous current 4 A • Maximum pulse current 10 A 1 s • Maximum voltage 250 VAC and DC • Surge arrester energy 60 J • Note that the diode's barrier voltage is about 2 V • Each output is isolated and mutually separate 2500 VAC 1 min

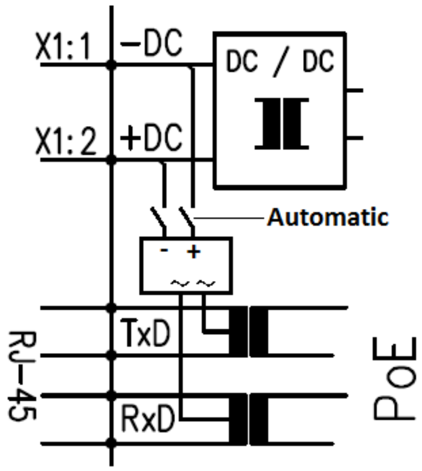
Relay outputs:

R1 (NOC-type) 	• Maximum continuous current 10 A • Maximum voltage 240 VAC and DC by following the red curve in the graph on the left • Endurance 8 A, 250 VAC, NO contact, 70°C, EN61810-1 $100x10^3$ cycles • Mechanical endurance > 30 x 10^6 cycles
R2-R5 (NO-type)	• Maximum continuous current 8 A • Maximum voltage 400 VAC and DC by following the blue curve

Digital inputs:

6 or 18 pieces of separate digital inputs with common minus polarity and extra internal power supply 	• Nominal input voltage 24 V • Maximum continuous input voltage 40 V • Input current 5.2 mA with 24 V means low impedance and enough current for most of the auxiliary and indication contact types • Rises to logical 1 state when ≤ 13 V • Drops to logical 0 state when ≥ 11 V • Isolation 2500 VAC 1 min • Common negative polarity (X2:8) • Equipped with internal 24 VDC 3 W output power supply (green circle), can only be used for digital inputs (X2:1 has + polarity)

Relay Auxiliary Power Input:

	• Voltage minimum 18 V • Voltage maximum 72 V • Power normally 3 W, maximum 11 W • 81 A2M 28S 8T5R 6D **p**ower when all relays and LEDs are activated 7 W • Can be supplied by POE type data switch or through terminal block (X1:1 -; X1:2 +) • Redundant two-power supply system is possible by using PoE while an external power supply is connected to the foremost terminal block. • LBW81 power and communication inputs, just like the digital inputs and sensors, are well isolated and therefore the optical data fibre communication is normally not necessary!

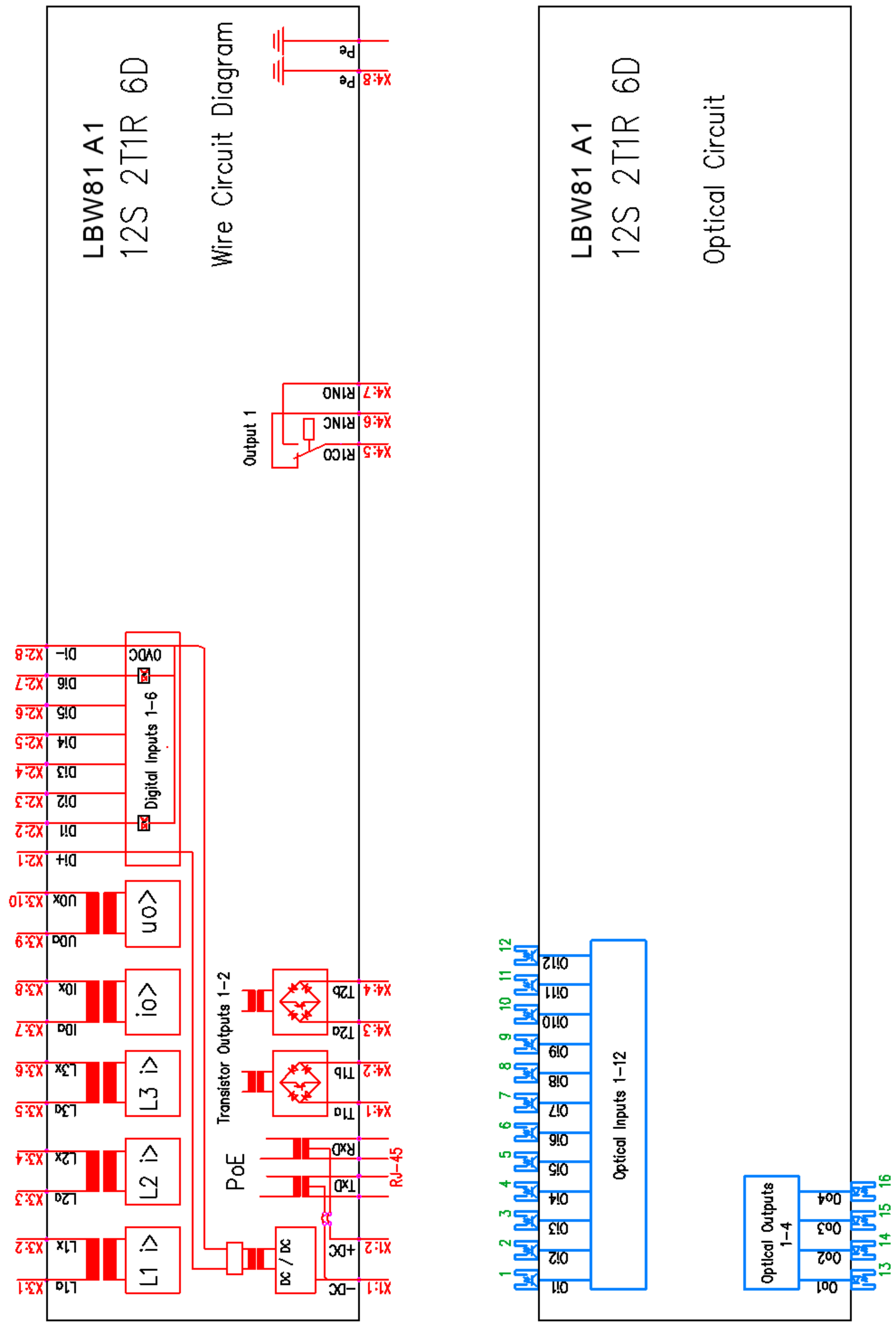
Communication:

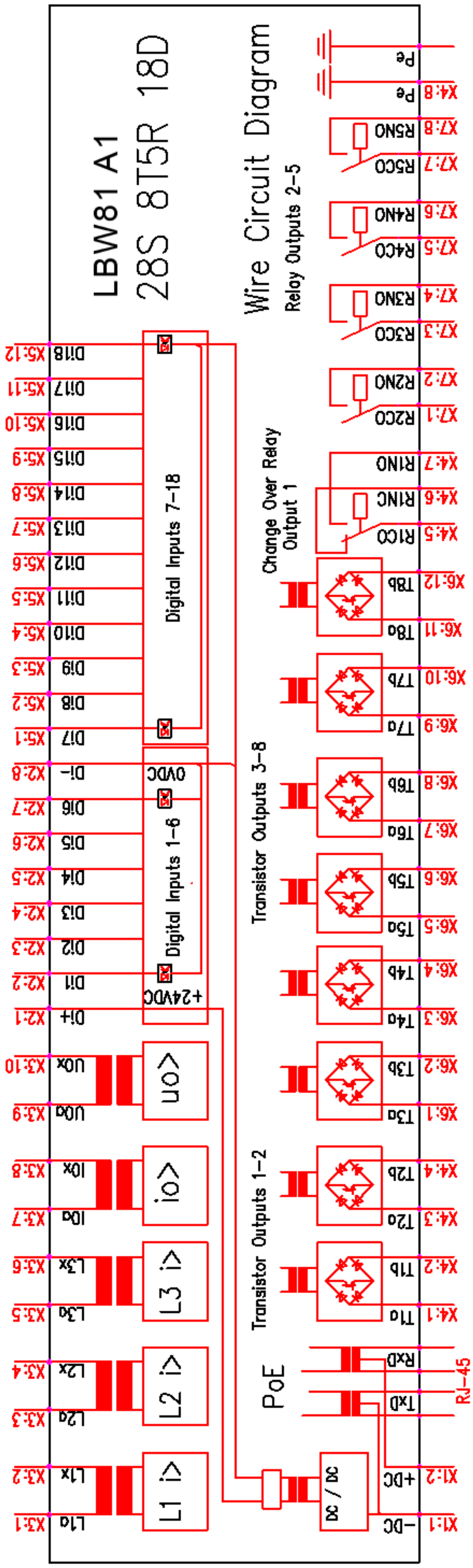
Read event log (IP address of course changes): http://10.10.10.103/cgi-bin/eventfile.cgi Read disturbance recorder configuration file: http://10.10.10.103/cgi-bin/getCfg.cgi?n=1 Read disturbance recorder data file: http://10.10.10.103/cgi-bin/getDat.cgi?n=1	• RJ45 connector for 10/100BASE-T Ethernet with Power Over Ethernet (PoE) features • For cables longer than 2 metres, use STP (Shielded Twisted Pair) or FTP (Foiled Twisted Pair) type Cat5 • Fixed IP addresses can be set in the configuration • Support Network Time Protocol (NTP) in the relay's internal clock synchronisation • Web server (Hypertext Transfer Protocol HTTP) for the manufacturers setup and for reading the disturbance recorder and event log • Modbus TCP (server) or IEC 61850 (server) protocol for SCADA communication • Insulation level 4 kV AC 1 min is improved and this means that optical data fibre communication is normally not necessary

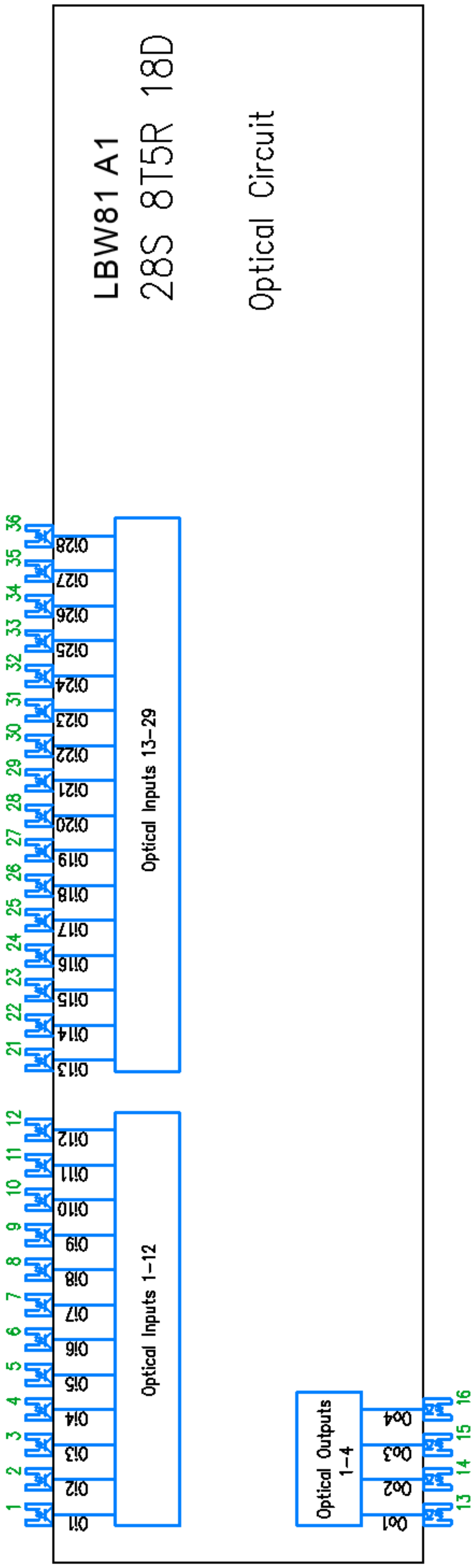
9.3 LBW81 Standards

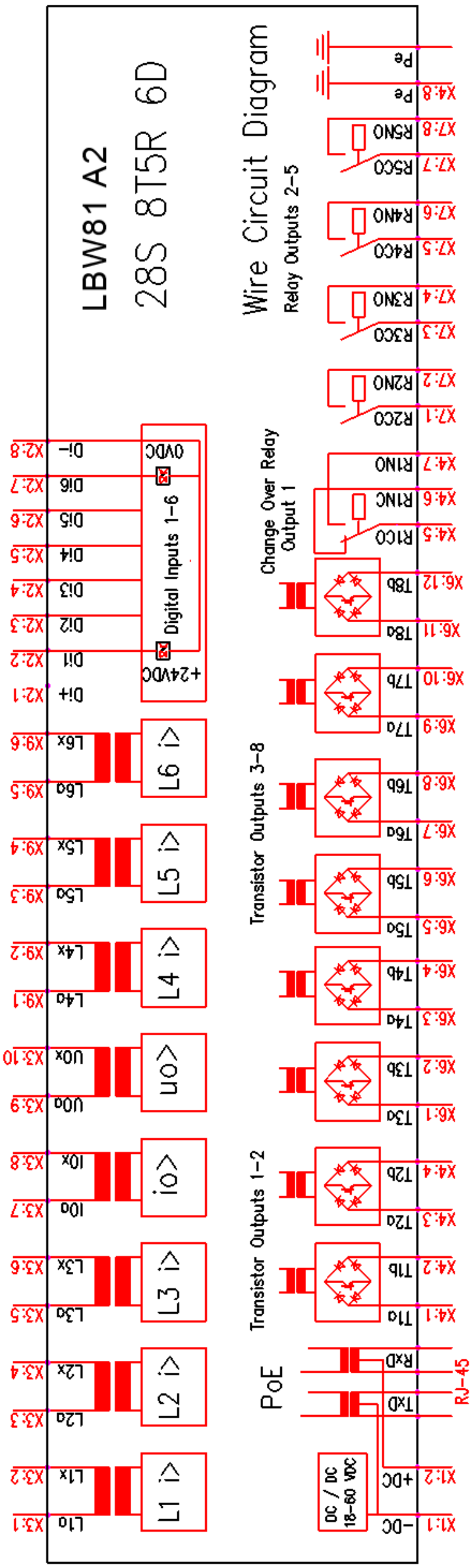
EMC Emission	• Emission connected IEC61000-6-4 (class A) • Emission Emitted IEC61000-6-4 (class A)
EMC Immunity	• ESD Static IEC61000-4-2 (class 4, contact 8 kV, Air 15 kV) • RF Radiated IEC61000-4-3 (class 3, 10 V/m) **Power 24VDC input & I/O inputs:** • Surge IEC61000-4-3 (class 4, 4 kV L-Gnd, 4 kV L-L) • EFT Transient IEC61000-4-4 (class 4, 4 kV) • Conducted RF IEC61000-4-6 (10 Vrms) **Data input:** • Surge IEC61000-4-3 (class 4, 4 kV L-Gnd) • EFT Transient IEC61000-4-4 (class 4, 4 kV) • Conducted RF IEC61000-4-6 (10 Vrms)
EMC Dielectric test	• Withstand Insulation IEC 60255-5 (2 kV 1 min) • Impulse IEC 60255-5
Protection functions	• Over current IEC60255-3 • Thermal Over Load IEC60255-8 • Function requirement IEC60255-151
LV Switchgear and control gear standard	• IEC 60947-1
Generic Power and Substations standard	• IEC 61000-6-5
Generic Industry standard	• IEC 61000-6-2
Measuring relays and protection standard	• IEC 50263

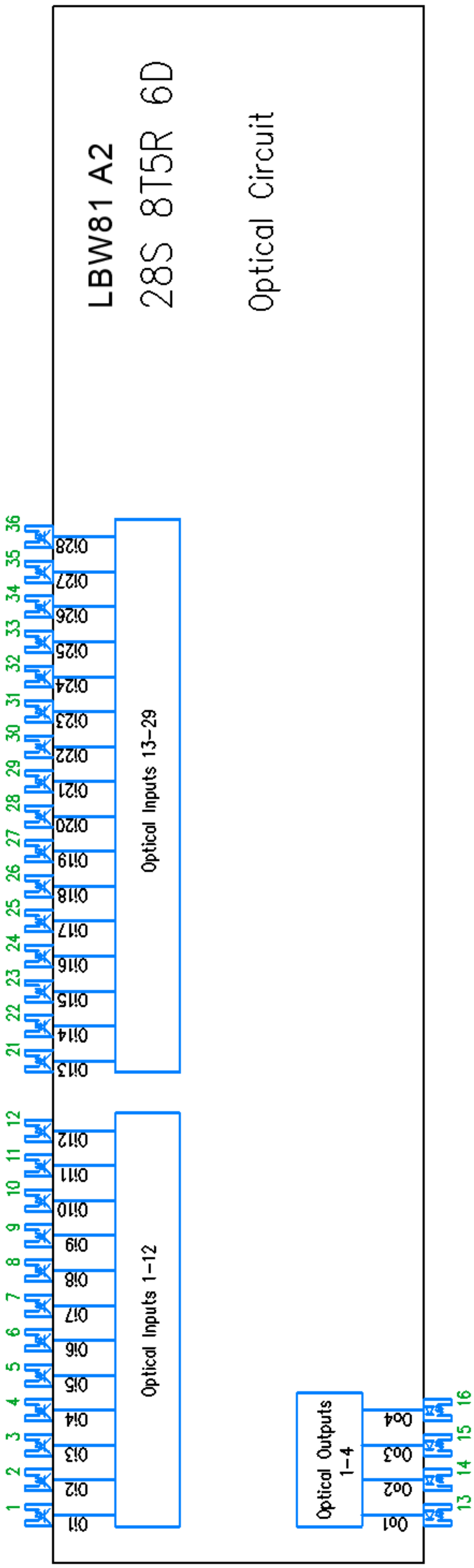
9.4 LBW81 Connections Drawings




LBW81 A1
28S 8T5R 18D
Wire Circuit Diagram
Relay Outputs 2–5
Change Over Relay Output 1
Digital Inputs 7–18
Digital Inputs 1–6
Transistor Outputs 3–8
Transistor Outputs 1–2
PoE
RJ-45

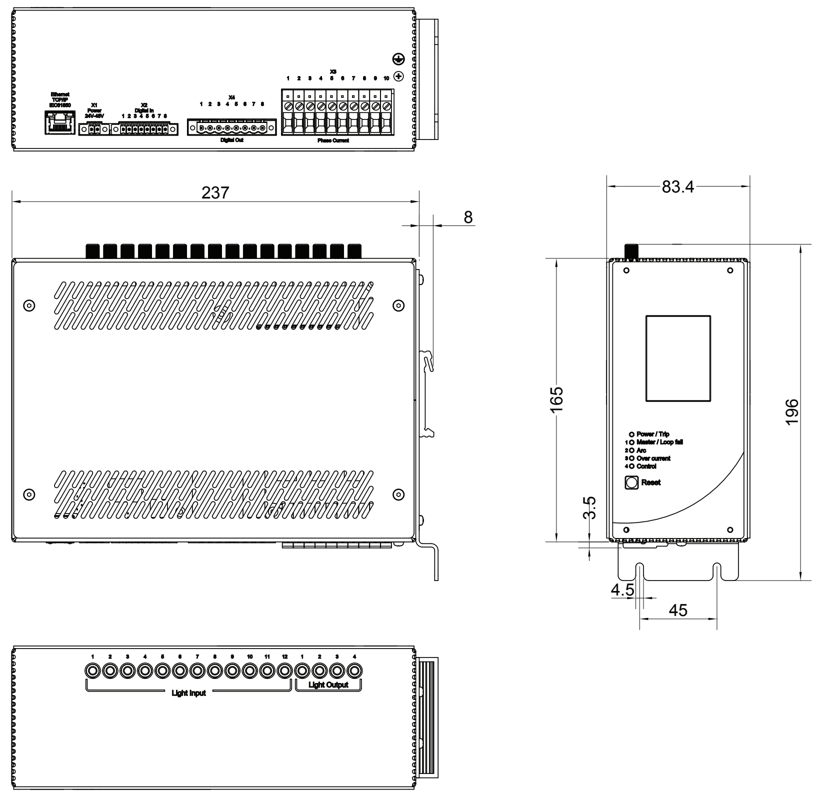

LBW81 A1
28S 8T5R 18D
Optical Circuit
Optical Inputs 13–29
Optical Inputs 1–12
Optical Outputs 1–4


LBW81 A2
28S 8T5R 6D
Wire Circuit Diagram
Relay Outputs 2–5
Change Over Relay Output 1
Digital Inputs 1–6
Transistor Outputs 3–8
Transistor Outputs 1–2
PoE
RJ-45
DC / DC 18–60 VDC
+24VDC
0VDC

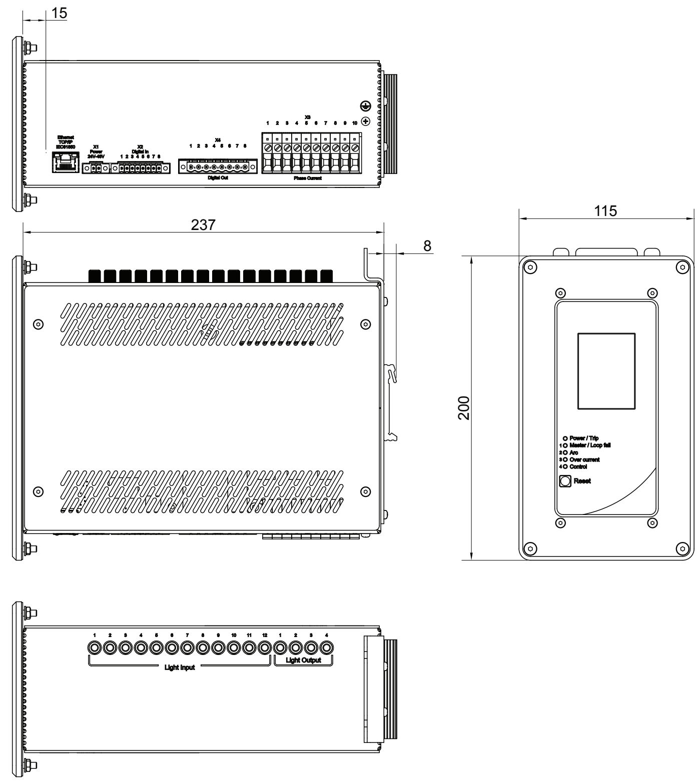

LBW81 A2
28S 8T5R 6D
Optical Circuit
Optical Inputs 13–29
Optical Inputs 1–12
Optical Outputs 1–4

Dimensions

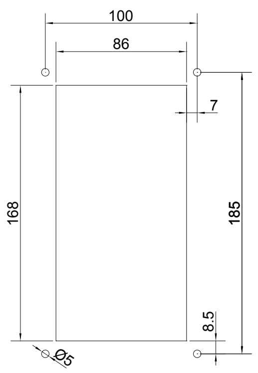
DIN-rail mounting



Door mounting with optional frame LBW81-AC1



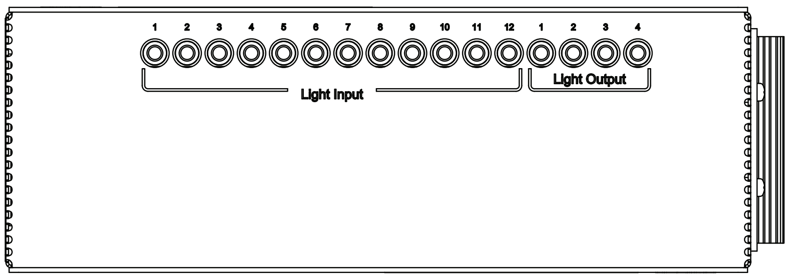
Perforation of door



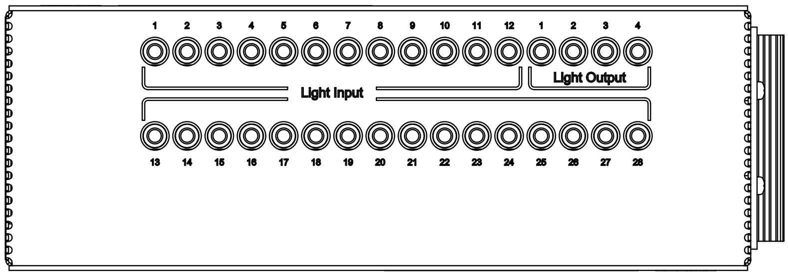
Connections

Top

LBW81-x1

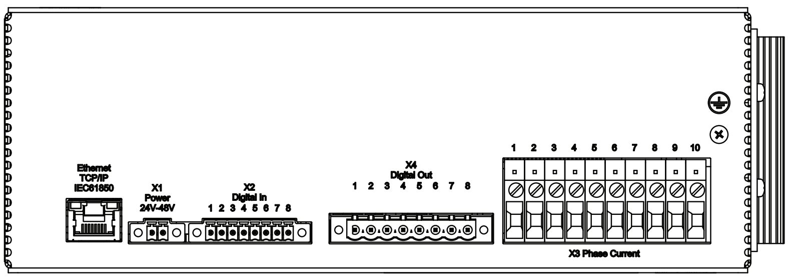


LBW81-x2, LBW81-x3, LBW81-x4

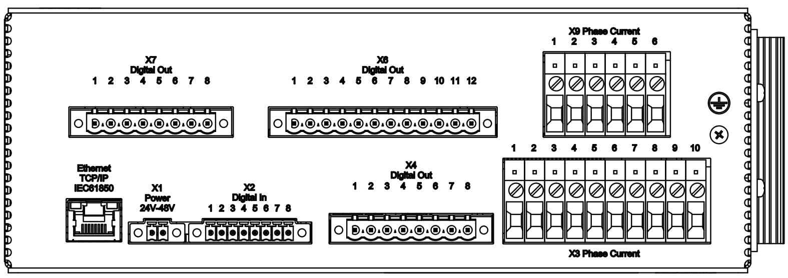


Bottom

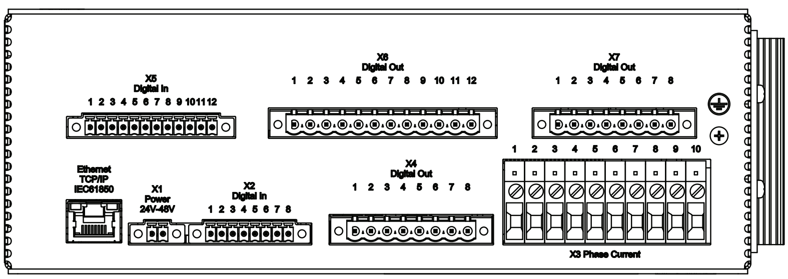
LBW81-x1, LBW81-x2



LBW81-x3

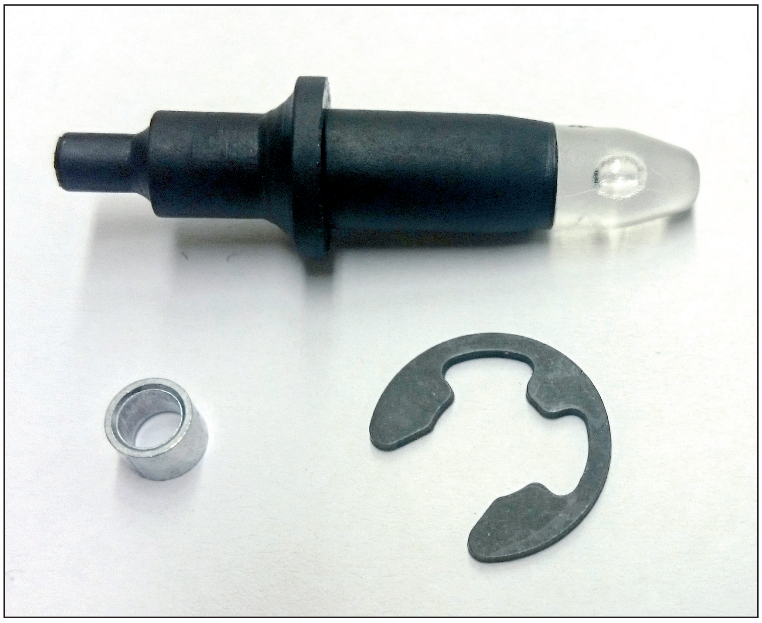


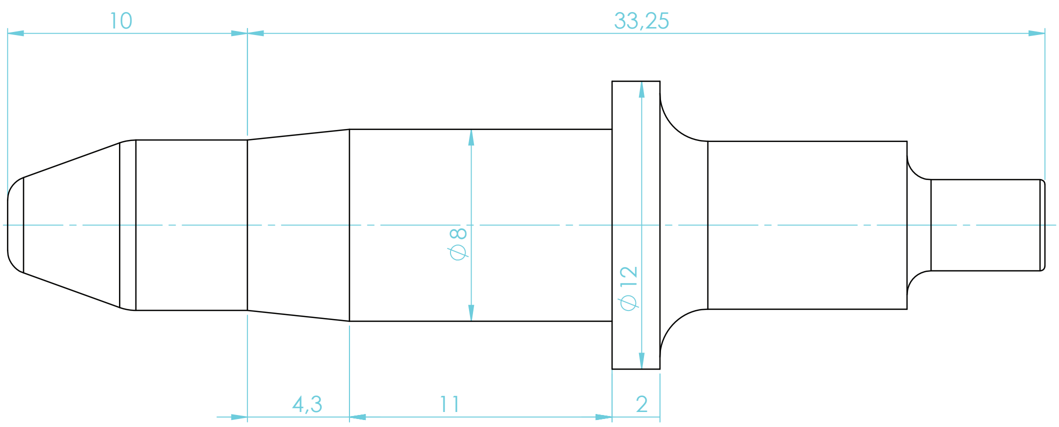
LBW81-x4



Accesories for LBW81 systems:

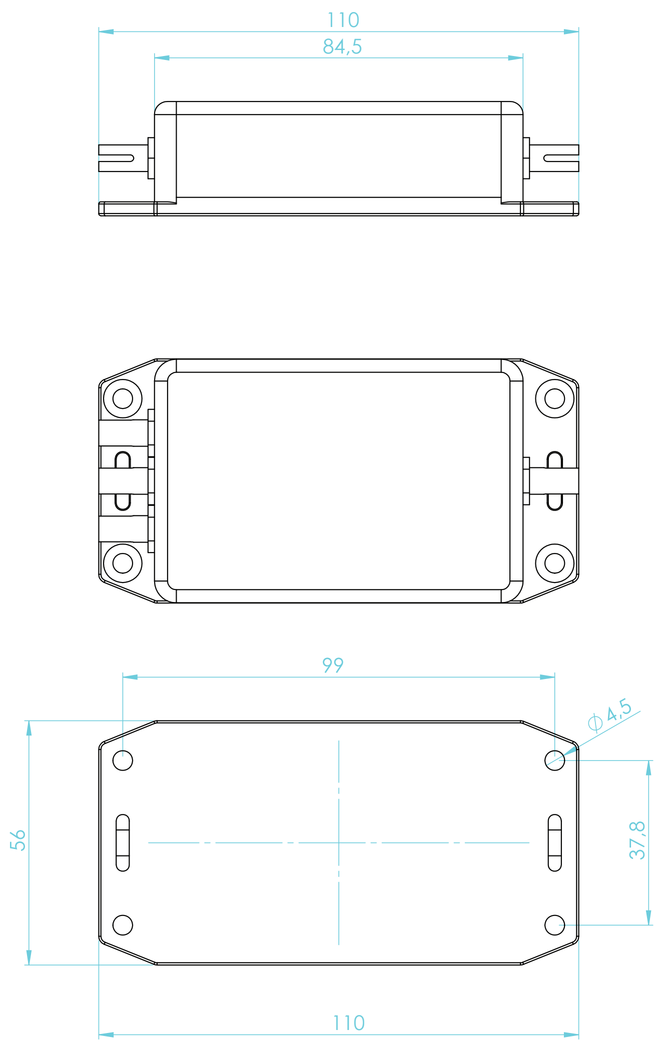
LBW81-AC1	**Frame for door installation**
LBW81-AC124	**Power supply unit** **Output: 24VDC 1,3A 30W** **Input AC: 100 - 240V (-15%/+10%)** **Input DC: 110 - 300V (-20%/+25%)**
LBW81-AC605 **+ cable length**	**Light sensor bright + fibre optic cable**





LBW81-AC651 TRIPLEXER

Makes it possible to connect up to three (3) light sensors to one (1) light input of LBW81



9.5 Troubleshooting

Relay starts but the display is not normal	• Switch OFF and wait more than 10 seconds, and then switch ON again.
Relay does not start with PoE supply	• PoE-switch goes to a short circuit state, which means that it cannot be supplied enough current to relay. • Check that the data cable is correctly wired and properly installed in both ends.
Tripping without reason and without event on display	• Does the tripping circuit have transients that the surge arrester inside the relay conducts? • Is the tripping coil impedance too high? • Is the capacitance in tripping cable so high that leakage current trips the coil? • Read chapter 4.2 • Check the transistor output with multimeter to see that it does not conduct all the time (note 2 volts diode barrier) • Does the matrix have a user message in the row which should be tripped in order to get the message to display?
Relay test set gives shorter and changing times measured by T1 output	• Do you have the P23 123CT&CB supervision function Mode bit 4 activated? If so, turn it off. • The tripping circuit entirety test affects only T1 output and causes a short test pulse and is a few mA; this may trip the relay test set clock.
Relay test set does not detect output T1-T8 tripping signals	• Measure the internal voltage relay test set used for detecting the tripping contract position. • If the voltage is very low, for example 5 VDC, use external power, for example, 24 VDC. • Transistor outputs have internal rectifiers with about 2 V threshold voltage which means that the very low voltage is not enough.
Optical sensor on event appears without reason	• Is it possible that the sun or room lighting triggers the signal via sensor? Adjust the sensor sensitivity, or if this does not help, install the sensor in another place or change the non-transparent lens to the sensor. • If it looks like the event occurs when opening the auxiliary compartment, check the auxiliary lamp position and sensor

	setting and tighten the sensor input bush rings, or if this does not help, put a rubber capsule on the relay sensor input.
Optical sensor looks too insensitive	• Check that the fibre ends are prepared well. • Check that the fibre is at the rear of the sensor input. • Check that the sensor input works when illuminated directly by the hand lamp. • Check that the fibre is not bruised or too long.
Relay does not trip when testing	• What kind of events are on the display? • If there is no optical event, check the fibres that are well prepared and that are well inside the sensor input and that the input works directly by hand lamp. • If there is not over current event, check the current measurement and that the current goes through the relay. Check the CT ratios and ratios in matrix. • If there is a normal tripping signal on the display, check that the tripping circuit is connected, that is has enough voltage and that the coil works. Note that some relay test set has only 5 VDC in test circuit, which means that it needs a higher test voltage. • Check that the green/orange connectors are well installed into the relay.
Power measurement does not work properly	• Check the correction angle in matrix P5 that defines the correct vector group. • Check the power measurement ratio P5 parameter C. • Check the phase rotation and connections. • Check the CT and VT ratios in matrix.
Directional earth fault does not work properly	• Check that the correction angle in VT setting P5 that 0 • Check that the adjustment angles in matrix P25 and P26 are proper. • Check the phase rotation and connections • Check the CT and VT ratios and ratios in the matrix.
Need very fast operation of the protection relay function, but now the tripping signal is delayed too much	• Set P0 • The normal minimum of the P0 is 40 in a 50 Hz and 33 in a 60 Hz grid (full cycle calculation). • Read chapter 6.4. • If you want it even faster, it is possible to measure only half of the cycle (20 or 17),

	but then DC components, for example transformers have, cause that the measurement is not stabile during this time.
Measurements (for example currents) are too unsettled and there are too many over current starts events	• Check P0. The setting of 200 is the most stable and is suitable for 50 Hz and 60 Hz grids. • Read chapter 6.4.