APPLICATION GUIDE

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1. INTRODUCTION

1.1 Protection of Underground and Overhead Lines

The secure and reliable transmission and distribution of power within a network is heavily dependent upon the integrity of underground cables and overhead lines, which link the various sections of the network together. Therefore the associated protection system must also provide both secure and reliable operation.

The most common fault conditions, on underground cables and overhead lines, are short circuit faults. These faults may occur between the phase conductors but will most often involve one or more phase conductor becoming short-circuited to earth.

Faults caused by short circuits require the fastest faulted conductor clearance times but at the same time allowing for suitable co-ordination with other downstream protection devices.

Fault sensitivity is an issue common to all voltage levels. For transmission systems, tower-footing resistance can be high. Also, high resistance faults might be prevalent where lines pass over sandy or rocky terrain. Fast, discriminative faulted conductor clearance is required for these fault conditions.

The effect of fault resistance is more pronounced on lower voltage systems, resulting in potentially lower fault currents, which in turn increases the difficulty in the detection of high resistance faults. In addition, many distribution systems use earthing arrangements designed to limit the passage of earth fault current.

Earthed methods as such as using resistance, Petersen coil or insulated systems make the detection of earth faults arduous. Special protection equipment is often used to overcome these problems.

Nowadays, the supply continuity in the energy distribution is of paramount importance.

On overhead lines most of faults are transient or semi-permanent in nature.

In order to increase system availability multi-shot autoreclose cycles are commonly used in conjunction with instantaneous tripping elements. For permanent faults it is essential that only the faulted section of the network is isolated. High-speed, discriminative fault clearance is therefore a fundamental requirement of any protection scheme on a distribution network.

Power transformers are installed at all system voltage levels and have their own specific requirements with regard to protection. In order to limit the damage incurred by a transformer under fault conditions, fast clearance of the windings with phase to phase and phase to earth faults is a primary requirement.

Damage to electrical plant equipment such as transformers, cables and lines may also be incurred by excessive loading conditions, which leads directly to overheating of the equipment and subsequent degradation of their insulation. To protect against such fault conditions, protective devices require thermal characteristics too.

Uncleared faults, arising either from the failure of the associated protection system or of the switchgear itself, must also be considered. The protection devices concerned should be fitted with logic to deal with breaker failure and relays located upstream must be able to provide adequate back-up protection for such fault conditions.

Other situations may arise on overhead lines, such as broken phase conductors. Traditionally, a series fault has been difficult to detect.

With today's digital technology, it is now possible to design elements, which are responsive to such unbalanced system, conditions and to subsequently issue alarm and trip signals.

On large networks, time co-ordination of the overcurrent and earth fault protection relays can often lead to problematic grading situations or, as is often the case, excessive fault clearance times. Such problems can be overcome by relays operating in blocked overcurrent schemes.

1.2 MiCOM Overcurrent Relays

MiCOM relays are a range of products from AREVA T&D using the latest digital technology. The range includes devices designed for application to a wide range of power system plant equipment such as motors, generators, feeders, overhead lines and cables.

Each relay is designed around a common hardware and software platform in order to achieve a high degree of conformity between products. One product among this range is the overcurrent relay.

MiCOM **P120, P121, P122** and **P123** relays have been designed to provide higher functionality in terms of protections, measuring, automatic operation and order control. They can be applied to industrial and distribution network applications, as well as in high voltage and extremely high voltage protection applications.

They can operate in networks with neutral earthed by impedance, by resonant system such as Petersen coil, in insulated system and in system with neutral earthed.

The protection functions can be used associated with the blocking feature in order to optimise the performance of the protection schemes, thus reducing operating times.

The earth and phase protection functions include instantaneous and time delay information.

The delay time for the first and second stage for phase and earth fault protections can be chosen to be in definite or inverse delay time (IEC, ANSI/IEEE, CO, RI and RECT).

This wide choice of characteristics of triggering times makes it possible to easily integrate these relays to an existing protection scheme, irrespective of other relays already installed on the network.

The protection and additional features of each model are listed in the following table.

Functions	ANSI Code	MiCOM P120	MiCOM P121	MiCOM P122	MiCOM P123
Single-phase overcurrent	50/51 or 50N/51N	X			
Three-phase overcurrent	50/51		X	X	X
Earth fault overcurrent	50N/51N	X	X	X	X
Restrictive Earth fault	64N	X	X	X	X
Thermal overload (True RMS)	49			X	X
Undercurrent	37			X	X
Negative sequence overcurrent	46			X	X
Broken conductor detection				X	X
Cold load pickup				X	X
Instantaneous/start contact		X	X	X	X
Latching output contacts	86	X	X	X	X
Setting groups		1	1	2	2
Circuit breaker failure detection	50BF			X	X
Trip circuit supervision (TCS)				X	X
Switch on to fault (SOTF)					X
CB control Local / Remote					X
Circuit Breaker monitoring and control				X	X
Blocking logic		X	X	X	X
Selective relay scheme logic				X	X
Multi-shot autoreclose	79				X
Clock phase and anti-clock Phase rotation operation				X	X
Measurements (True RMS)		X	X	X	X
Peak and rolling values				X	X
Event records				X	X
Instantaneous records				X	X
Fault records				X	X
Disturbance records				X	X
RS 232 front communication for MiCOM S1 Software				X	X
RS 485 rear communication (Modbus RTU, IEC 60870-5-103, Courier, DNP3.0)		X	X	X	X

2. EARTH AND PHASE CURRENT OVERCURRENT FUNCTIONS

MiCOM P120 range of relays provide definite and independent time delay overcurrent protection.

Each phase current and earth current input has three thresholds.

The first and second thresholds can be set as definite delay time or inverse delay time using the IEC, IEEE/ANSI, CO, RI and RECT curves. Their parameters are shown in the Technical Data chapter of this Technical Guide.

The third threshold can be set as definite delay time only, but can be set to work on the peak of the current measured.

In a similar way, the earth fault elements has three different thresholds, that besides can be set independently of the settings chosen for the phases.

The instantaneous thresholds are represented by the symbol "I>" for the first threshold, "I>>" and "I>>>" for the second and third instantaneous thresholds ("Ie>", "Ie>>" and "Ie>>>" for earth thresholds).

The time delayed thresholds are represented by the symbol "tI>" for the first threshold, "tI>>" and "tI>>>" for the second and third time delay thresholds ("tIe>", "tIe>>" and "tIe>>>" for the time delay earth fault thresholds).

The protection elements trip when the following conditions are realized:

- The phase current exceeds the set overcurrent threshold.
- The time delay has elapsed.
- The blocking logic (if used) is not activated.

The following diagrams show the functionality for each threshold.

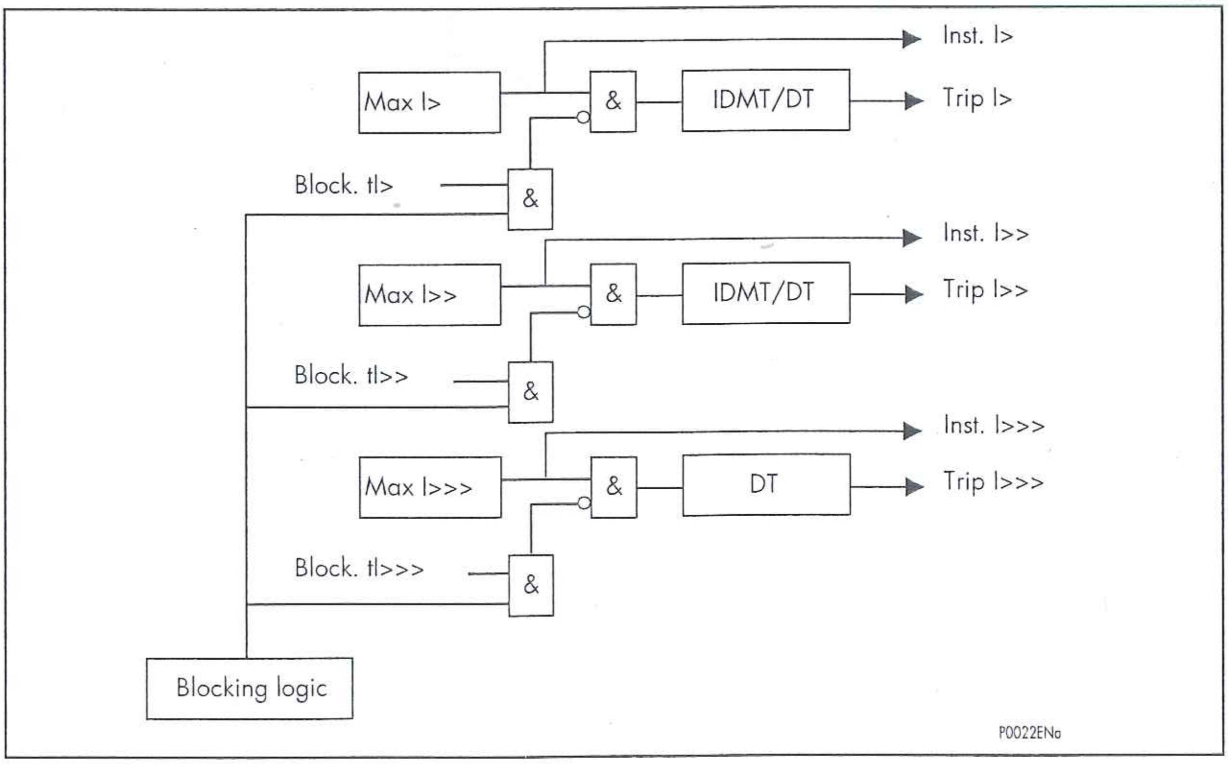


FIGURE 1 : LOGIC OF PHASE THRESHOLDS I>, I>> AND I>>>

With:

Max I> = [IA>] OR [IB>] OR [IC>]

Max I>> = [IA>>] OR [IB>>] OR [IC>>]

Max I>>> = [IA>>>] OR [IB>>>] OR [IC>>>]

The logic associated to the earth fault threshold is identical to the one described above. The different thresholds I> & tI>, I>> & tI>> and I>>> & tI>>> are respectively replaced by thresholds Ie> & tIe>, Ie>> & tIe>> and Ie>>> & te>>>.

Thanks to the «Blocking Logic» function, it is possible to freeze the timer as long as the "Blk Log" signal is active.

As soon as the blocking "Blk Log" signal disappears, if the overcurrent value is still over the set threshold, the time delay resumes its countdown considering the value prior to the activation of the blocking function as its new initial value. This allows a faster clearance of the fault after a reset of the "Blk Log" signal.

2.1 Instantaneous function (50/50N)

For P122 and P123 relays :

In order to ensure fast tripping on highly saturated current signal, it has been decided that I>>> and Ie>>> should operate on a current sample base in addition to the Fast Fourier transformation bases (see User Guide chapter). Both algorithms can operate on a highly saturated current signal. However with a high X/R ratio, it is recommended to use the sample base method.

As soon as a phase (or earth) threshold is running, the instantaneous output associated with this threshold is activated. This output indicates that the protection element has detected a phase (or earth) fault and that the time delay associated with the threshold has started. This time delay can be blocked via the logic input "Blk Log" associated with this threshold. If this blocking input is activated by an output contact of a downstream relay, the logic that will lead to the trip command is then blocked only if the relay that is the closest to the fault can see and therefore eliminate the fault. This principle is known as «Blocking logic» or «Blocking». It is described in more detail in this document.

2.2 DMT thresholds

The three phase (earth) overcurrent thresholds can be selected with a time constant delay. The time to operate is equal to the time delay set, plus the time for the output contact to operate (typically about 20 to 30 ms ; 20ms for a current exceeding or equal to 2 times the threshold) and the time required to detect the overcurrent state (maximum 20ms at 50Hz).

For DMT curves, a reset timer "t Reset" is associated with the first and second thresholds (phase and earth elements).

2.3 IDMT thresholds

2.3.1 Inverse time curves

The first and second phases (earth) overcurrent threshold can be selected with a dependent time characteristic. The time delay is calculated with a mathematical formula.

There are eleven inverse time characteristics available.

The mathematical formula applicable to the first ten curves is :

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

Where:

t = Tripping time

K = Coefficient (see table)

I = Value of measured current

I_s = Value of the programmed threshold (Pick-up value)

α = Coefficient (see table)

L = ANSI/IEEE coefficient (zero for IEC curves)

T = Time multiplier between 0.025 and 1.5

Type of curve	Standard	K factor	α factor	L factor
Short Time Inverse	AREVA	0.05	0.04	0
Standard inverse	IEC	0.14	0.02	0
Very inverse	IEC	13.5	1	0
Extremely inverse	IEC	80	2	0
Long time inverse	ALSTOM	120	1	0
Short Time Inverse	C02	0.02394	0.02	0.01694
Moderately Inverse	ANSI/IEEE	0.0515	0.02	0.114
Long Time Inverse	C08	5.95	2	0.18
Very Inverse	ANSI/IEEE	19.61	2	0.491
Extremely Inverse	ANSI/IEEE	28.2	2	0.1215
Rectifier Protection		45900	5.6	0

The RI curve (electromechanical) is given by the following formula:

$$t = K \times \left(\frac{1}{0.339 - 0.236/(I/Is)} \right)$$

With K that can be adjusted from 0.10 to 10 in steps of 0.05.

This equation is valid for $1.1 \leq (I/Is) \leq 20$.

Although the curves tend towards infinite when the current approaches Is, the minimum guaranteed value of the operating current for all the curves with the inverse time characteristic is 1.1Is (with a tolerance of ± 0,05Is), except rectifier protection curve for which the minimum value is 1.6 Is ±0.05 Is.

2.3.2 Laborelec curves

The first and second earth threshold can be selected with dedicated Laborelec curves.

3 curves are available with the following formula :

$t = aI + b$

where : t = tripping time
a and b = coefficient (see table)
I = Primary residual current (between 1 and 40A)

Type of curve	a	b
LABORELEC 1	– 0.0897	4.0897
LABORELEC 2	– 0.0897	4.5897
LABORELEC 3	– 0.0897	5.0897

In order to be compliant with Laborelec specifications the relay should be used with:

- An earth current range of 0.01 Ion to 8 Ion
- A rated current of 1A
- A core balanced CT with a 20/1ratio.

To use the full range of the curve, the relay must be set to 0.05Ion (secondary residual current).

2.4 Reset timer

The first phase overcurrent threshold [I>/tI>] ([Ie>/tIe>] for the earth) has a reset timer.

The value that is set for this reset timer corresponds to the minimum time during which the current value needs to be lower than 95% of the phase (or earth) threshold before the corresponding phase (or earth) time delay is reset.

NOTE : This rule doesn't apply when the protection triggers. When the protection triggers, the time delay tI> (or tIe>) is immediately reset.

The value of this reset timer depends on the type of timer associated with the first phase (Earth) threshold.

Type of timer associated with the first & second phase (earth) threshold	**Reset Timer**	
	P120, P121	**P122, P123**
DMT (see note below)	0 ms	0 ms to 600 s
LABORELEC *, Rectifier, IDMT IEC or RI	50 ms	Setting range from 40 ms to 100 s
IDMT IEEE or CO	50 ms	Setting range from 40 ms to 100 s or Inverse Time (Choice of 5 IEEE curves)

2.4.1 Reset timer (**P122 & P123** only)

For the first phase and earth overcurrent stages, MiCOM P122 and P123 have a timer hold facility "t Reset", which can be set to a definite time value or to an inverse time characteristic (IEEE/ANSI curves only). This may be useful for some applications, for example when grading with upstream electromechanical overcurrent relays which have inherent reset time delays.

This timer hold facility used to reduce the time to clear a fault is also useful in situations where intermittent faults occur. This may occur for example in a plastic insulated cable. In this case, the fault energy may provocate the cable insulation to melt and reseal, thereby extinguishing the fault. This process repeats itself a couple of times giving a succession of fault current pulses, each one of increasing duration with reducing intervals between the pulses, until the fault becomes permanent.

When the reset time of the overcurrent relay is minimum the relay will be repeatedly reset and not be able to trip until the fault becomes permanent. By using the Timer Hold facility, the relay will integrate the fault current pulses, thereby reducing fault clearance time.

The reset timer "t Reset" for MiCOM P122 & P123 can be found in the following menu :

- If the first phase (earth) threshold is selected with an IDMT IEC or RI curve, the reset timer "t Reset" with DMT characteristic can be set under the menu :
  - Protection /[50/51] Phase OC/t Reset for the phase.
  - Protection /[50N/51N] E/Gnd/t Reset for the earth.
- If the first phase (earth) threshold is selected with an IDMT IEEE or CO curve, the reset timer "t Reset" with a DMTor IDMT characteristic can be set under the menu :
  - Protection /[50/51] Phase OC/Type Tempo Reset for the phase
  - Protection /[50N/51N] E/Gnd/Type Tempo Reset for the earth.

Reset Time "t Reset" with an IDMT characteristic :

The mathematical formula applicable to the five curves is :

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

Where :

t = Reset time

K = Coefficient (see table)

I = Value of the measured current

I_s = Value of the programmed threshold (pick-up value)

α = Coefficient (see table)

T = Reset Time Multiplier (Rtms) between 0.025 and 3.2

Type of curves	Standard	K factor	α factor
Short time inverse	C02	2.261	2
Moderately Inverse	ANSI/IEEE	4.85	2
Long time Inverse	C08	5.95	2
Very inverse	ANSI/IEEE	21.6	2
Extremely inverse	ANSI/IEEE	29.1	2

2.5 Time graded protection

Inverse definite minimum time relays are time graded in such a way that the relay closer to the fault operates faster than the upstream relays. This is referred to as relay co-ordination because if the relay nearest to the fault does not operate, the next relay will trip in a slightly longer time. The time grading steps are typically 400 ms, the operation times becoming progressively longer with each stage.

When difficulty is experienced in arranging the required time grading steps, the use of a blocked overcurrent scheme should be considered (described in a later section).

NOTE : The dynamic range of measurement is typically 1000 times minimum setting.

3. TRANSFORMER INRUSH CURRENTS

Either I>>/Ie>> or I>>>/Ie>>> elements can be used as high-set instantaneous elements. The design is such that they do not respond to the DC transient component of the fault current. The principle of operation allows the current settings to be set down to 35% of the prospective peak inrush current that will be taken by a transformer when it is energised. As a first approximation, the peak inrush is given by the reciprocal of the per unit series reactance of the transformer.

4. BUSBAR PROTECTION ON RADIAL SYSTEMS

The use of non-directional overcurrent relays to protect a busbar is based on the following hypotheses:

- The network is a radial system,
- The incoming and outgoing feeders are clearly defined, the incomers being always considered as suppliers of energy and feeders as loads.

Under these circumstances, the busbar is effectively protected using the interlocking principle (Figure 2).

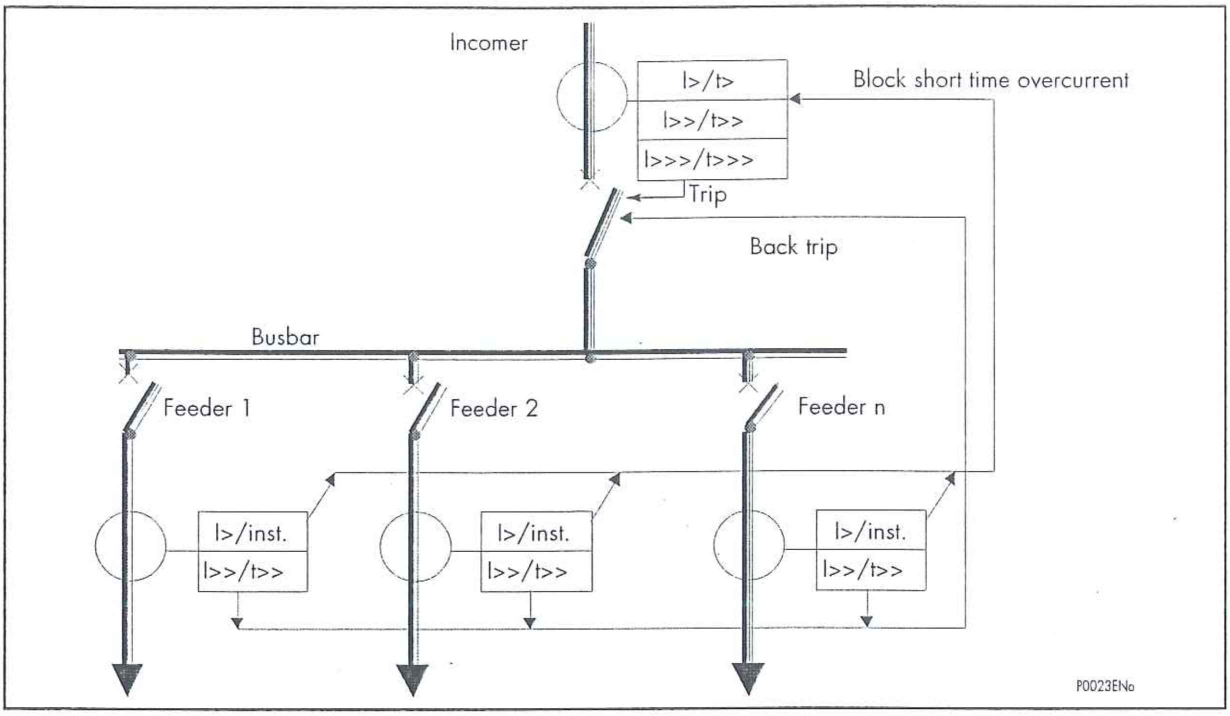


FIGURE 2 : BLOCKED OVERCURRENT FOR BUSBAR PROTECTION

The instantaneous overcurrent signals of the feeders protection are grouped together and wired to the « Blocking logic » logic input of the relay protecting the incomer. The blocking function is programmed to inhibit either the first or first two thresholds. The third I>>> threshold picks up at a high value (>10 In) with a short time delay (<60 ms).

If a fault appears on the network, the relay protecting the associated feeder will immediately (in less than 30 ms) send a blocking order to the relay protecting the incomer. After the fault has been cleared (by opening the circuit breaker), the blocking order is removed and the relay protecting the incomer is unblocked. As the fault current is no longer present, the timer is reinitialised.

If the fault appears on the busbar, the fault current exceeds by far the value of the third threshold (I>>>). As this third threshold is not blocked by the blocking logic of relays protecting the incomers, the trip order is sent in less than 60 ms and the busbar is de-energised.

5. BLOCKING LOGIC FUNCTION (BLOCKED OVERCURRENT PROTECTION)

This type of protection can be applied to radial feeder circuits where there is little or no back feed. For parallel feeders, ring circuits or where there can be a back feed from generators, directional relays should be considered.

The blocking logic function allows the upstream IDMT relay to be blocked by the start output of a downstream relay that has detected the presence of fault current above its threshold. Thus both upstream and downstream relays can have the same current and time settings, and the blocking feature will automatically provide grading. If the breaker fail protection is active, the blocking order on the upstream relay will be removed if the down-stream circuit breaker fails to trip.

Thus for a fault downstream from relay C, the start output from relay C will prevent relay B from operating and the start output of relay B will prevent relay A from operating. Thus all 3 relays could have the same time and current threshold settings and the grading would be obtained by the blocking signal received from a relay closer to the fault. This gives a constant, close time grading, but there will be no back-up protection in the event of pilots being short circuited.

However, in practice it is recommended to set the upstream relay to a value that is 10% higher than the downstream relay setting. This ensures that the downstream relay successfully blocks the upstream relay when required.

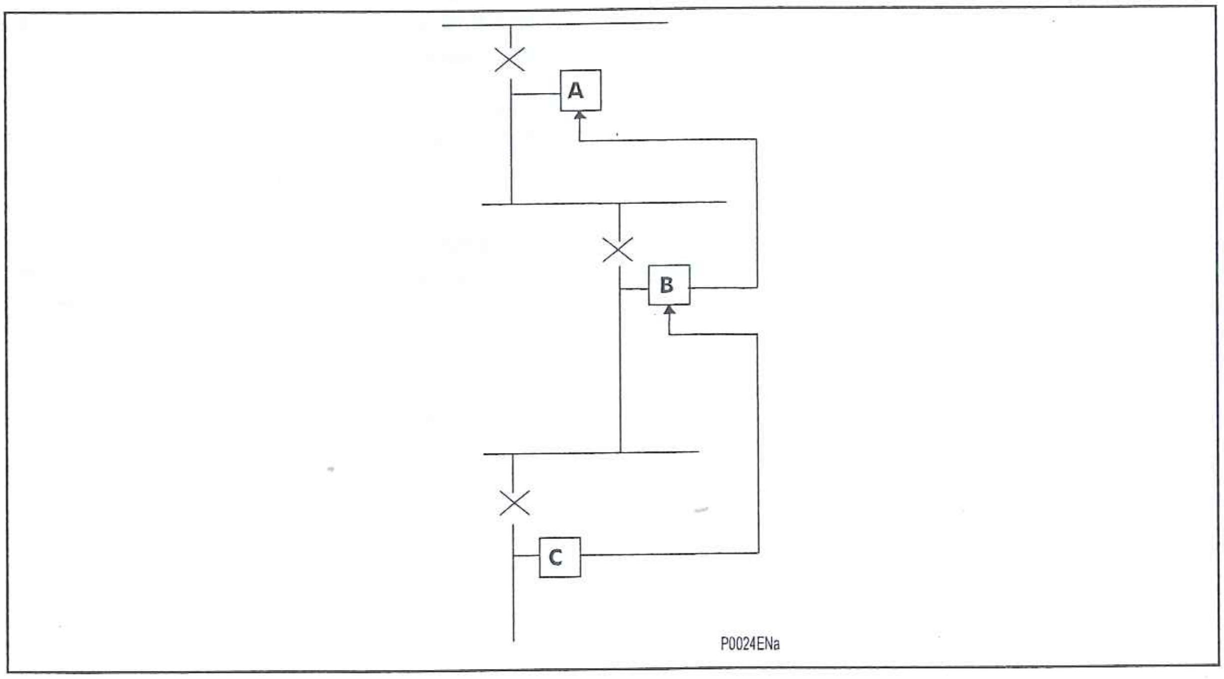


FIGURE 3 : BLOCKING LOGIC

To assign the "Blocking Logic" functions, go under the AUTOMAT CTRL/Blocking Logic menu.

MiCOM P120 & P121 relays have only one blocking logic function.

MiCOM P122 & P123 relays have two blocking functions, which can be used to block the Earth and Phase thresholds.

6. RESTRICTED EARTH FAULT

MiCOM P120, P121, P122 and P123 provide Restricted Earth Fault protection. It should be noted that:

The algorithms implemented in P120 and P121 for the first and second thresholds (I> , I0> and I>>, I0>>) are similar to the ones implemented in the P122 and P123 for the same thresholds. However the algorithm of the third threshold (I>>> and I0>>>) of P120 and P121 is different to the one of P122 and P123.

In fact, the algorithm of the third threshold of the P122 and P123 is based on a current sample base in addition to the Fast Fourier Transformation base. This implementation allows to trip faster on highly saturated current signals. The third threshold of P120 and P121- as it is for the first and second threshold of P120, P121, P122 and P123 products - is based on the Fourier transformation;

This explains the outstanding results obtained by the third threshold of P122 and P123 compared to the other thresholds regarding the high impedance restricted earth fault application. So for :

- P122 and P123 : The user can use all the thresholds for REF application. Note that the results of the third threshold will be greater due to the fact that a sample base algorithm is used.
- P120 and P121 : The user can use all the threshold for REF application. The results of the third threshold will be similar to one of the first and second threshold (since all the thresholds are based on Fast Fourier Transformation).

NOTE: For P122 and P123, the maximum internal fault level for the third threshold (for the 0.002 to 1In range) must not exceed 20In.

6.1 Introduction

The restricted earth fault relay is a high impedance differential scheme which balances zero sequence current flowing in the transformer neutral against zero sequence current flowing in the transformer phase windings. Any unbalance for in-zone fault will result in an increasing voltage on the CT secondary and thus will activate the REF protection.

This scheme is very sensitive and can then protect against low levels of fault current in resistance grounded systems where the earthing impedance and the fault voltage limit the fault current.

In addition, this scheme can be used in a solidly grounded system. It provides a more sensitive protection, even though the overall differential scheme provides a protection for faults over most of the windings.

The high impedance differential technique ensures that the impedance of the circuit is of sufficiently high impedance such that the differential voltage that may occur under external fault conditions is lower than the voltage required to drive setting current through the relay. This ensures stability against external fault conditions and then the relay will operate only for faults occurring inside the protected zone.

6.2 High impedance principle

High impedance schemes are used in a differential configuration where one current transformer is completely saturated and the other CTs are healthy.

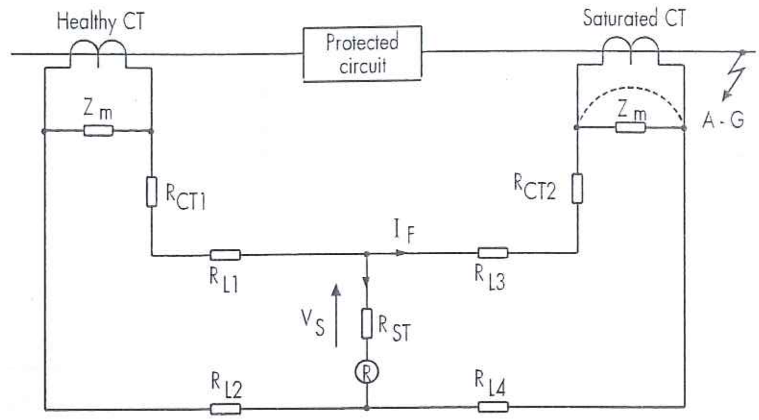


FIGURE 4 : HIGH IMPEDANCE SCHEME PRINCIPLE

The voltage applied across the relay is:

$V_r = I_f (R_{CT} + 2R_L)$

I_f : Maximum secondary external fault current.
R_{CT} : Resistance of the Current transformer secondary winding.
R_L : Resistance of a single wire from the relay to the CT.

A stabilizing resistor R_{ST} can be used in series with the relay circuit in order to improve the stability of the relay under external fault conditions. This resistor will limit the spill current under I_s.

$V_s = I_s (R_{ST})$

I_s : Current relay setting

V_s : Stability Voltage setting

Note that the relay consumption has been taken into account.

The general stability conditions can be obtained when:

$V_s > K.I_f (R_{CT} + 2R_L)$

Where K is the stability factor.

This stability factor is influenced by the ratio V_k/V_s which in turns governs the stability of the REF protection element for through faults .

V_k = The Knee point voltage of the CT.

To obtain a high speed operation for internal faults, the Knee point voltage V_k of the CT must be significantly higher than the stability voltage V_s. A ratio of 4 or 5 would be appropriate.

For MiCOM P121, P122 and P123, we found the following results:

K= 1 for Vk/Vs less or equal to 16 and

K= 1.2 for Vk/Vs > 16.

NOTE: The maximum internal fault level for stage 3 of 0.002 to 1In board must not exceed 20In.

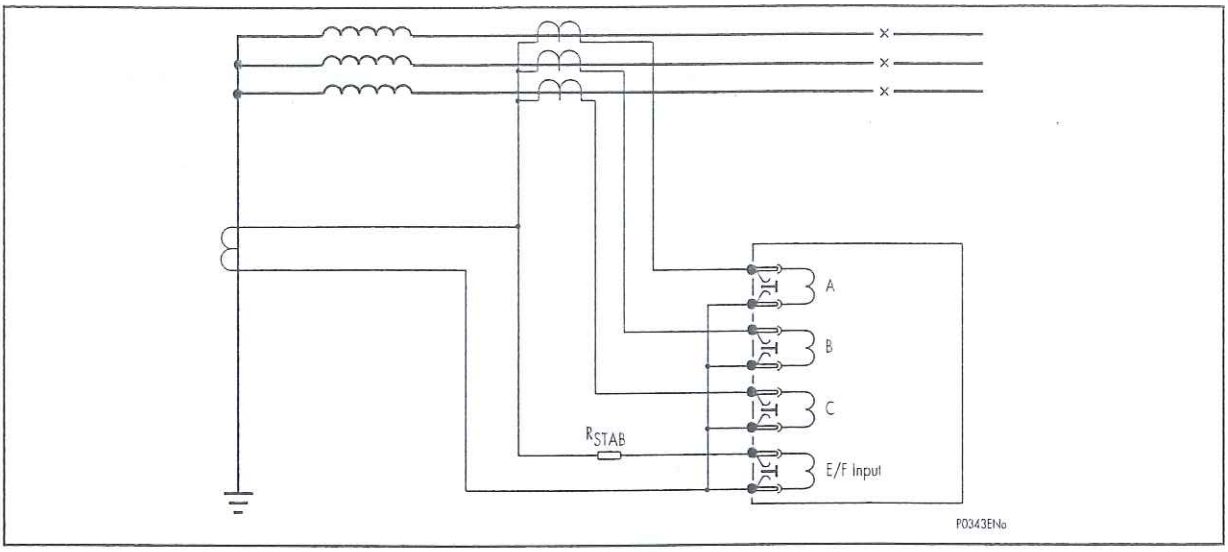


FIGURE 5 : CT CONNECTION DIAGRAM FOR HIGH IMPEDANCE REF APPLICATION

6.3 Setting guide

The characteristics of the relay and the value of K influence the stability of the scheme as explained here above.

The typical setting values shall be chosen to provide a primary operating current less than 30 % of the minimum earth fault level for a resistance earthed system. For a solidly earthed system, the typical setting shall provide an operating current between 10 and 60% of the rated current.

The primary operating current, at the secondary, depends on the following factors:

- Current Transformer ratio
- Relay operating current I_S
- Number of CT in parallel with the relay element (n)
- The inrush current of each CT (I_e) at the stability voltage

$$I_{op} = CT_{Ratio} \cdot (I_s + n.I_e)$$

Current setting should be selected for a high impedance element so that the primary current reaches its nominal current with a given CT, according to the following equation:

$I_s < \{(I_{op} / CT_{Ratio}) - n.I_e\}$

It is also possible to determine the maximum inrush current of the CT to reach a specific primary operating current with a given relay setting.

The setting of the stabilising resistor must be calculated according to the above formula, where the setting depends on the required stability voltage setting V_s and the relay setting I_s

$$\frac{V_s}{I_s} = \frac{k\, I_f (R_{CT} + 2R_l)}{I_s}$$

For MiCOM P12x, I_s is equivalent to $I_e>$, so the above equation becomes:

$$\frac{V_s}{I_e>} = \frac{k\, I_f (R_{CT} + 2R_l)}{I_e>}$$

with

K= 1 for Vk/Vs less or equal to 16 and

K= 1.2 for Vk/Vs > 16.

So

$$R_{ST} = \frac{k\, I_f (R_{CT}+2R_L)}{I_e>}$$

with $Vk \geq 4.Is.R_{ST}$ (A typical value to ensure the high speed operation for an internal fault).

6.3.1 CT requirements for High Impedance Restricted Earth Fault Protection

The High Impedance Restricted Earth Fault element shall remain stable for through faults and operate in less than 40ms for internal faults provided that the following equations are met in determining CT requirements and the value of the associated stabilising resistor:

$$Rs = [k^* (If) * (R_{CT} + 2R_L)] / I_S$$

$$V_K \geq 4 * Is * Rs$$

with

K= 1 for Vk/Vs less or equal to 16 and

K= 1.2 for Vk/Vs > 16.

6.4 Use of METROSIL non linear resistors

Metrosils are used to limit the peak voltage developed by the current transformers under internal fault conditions, to a value below the insulation level of the current transformers, relay and interconnecting leads, which are normally able to withstand 3KV peak.

The following formula should be used to estimate the peak transient voltage that could be induced by an internal fault. This peak voltage depends on:

- CT Knee point (V_K)
- Voltage that would be induced by an internal fault if CT doesn't saturate (V_f)

This prospective voltage itself depends on:

- Maximum internal fault secondary current
- CT ratio
- CT secondary winding resistance
- CT lead resistance to the common point
- Relay lead resistance
- Stability resistor value

$$Vp = 2\sqrt{\{2.V_K (V_f - V_k)\}}$$

$$V_f = I'_f.(R_{ct} + 2R_L + R_{ST})$$

Where

- Vp : peak voltage developed by the CT under internal fault conditions
- V_f : maximum voltage that would be produced if CT saturation did not occur
- V_k : current transformer Knee point voltage
- I'_f : is the maximum internal secondary fault current
- R_{ct} : current transformer secondary winding transformer
- R_L : maximum lead burden from CT to relay
- R_{ST} : Relay stabilising resistor.

When the value given by the formula is greater than 3KV peak, it is necessary to use Metrosils. They are connected across the relay circuit and they allow to shunt the secondary current output of the current transformer from the relay in order to prevent very high secondary voltages.

Metrosils are externally mounted and have annular discs shape.

Their operating characteristics is according to the formula:

$$V = C.I^{0.25}$$

Where

- V : Instantaneous voltage applied to the non-linear resistor (Metrosil)
- C : Constant of the non-linear resistor (Metrosil)
- I : Instantaneous current through the non-linear resistor (Metrosil)

With the sinusoidal voltage applied across the Metrosil, the RMS current would be approximately 0.25 times the peak current. This current value can be calculated as follows:

$$Irms = 0.52\left\{\frac{Vs(rms).\sqrt{2}}{C}\right\}^{4}$$

Where

- Vs(rms) : RMS value of the sinusoidal voltage applied across the Metrosil.

This is due to the fact that the current waveform through the Metrosil is not sinusoidal but appreciably distorted.

For satisfactory application of the non-linear resistor (Metrosil), its characteristics should comply with the following requirements:

- At the relay voltage setting, the non-linear resistor (Metrosil) current should be as low as possible, but no greater than approximately 30mA rms for 1A current transformers and approximately 100mA rms for 5A current transformer.
- At the maximum secondary current, the non-linear resistor (Metrosil) should limit the voltage to 1500V rms or 2120V peak for 0.25 second. At higher relay voltage settings, it is not always possible to limit the fault voltage to 1500V rms, so higher fault voltage may have to be tolerated.

The following tables show the typical types of Metrosil that will be required, depending on relay current rating, REF voltage setting etc.

6.4.1 Metrosil units for relays with 1A CT

The Metrosil units with 1A CTs have been designed to comply with the following restrictions:

– At the relay voltage setting, the Metrosil current should be less than 30mA rms.

– At the maximum secondary internal fault current, the Metrosil unit should limit the voltage to 1500V rms if possible.

The Metrosil units normally recommended to be used with 1Amp CTs are shown in the following table:

Relay Voltage setting	Nominal Characteristics		Recommended Metrosil Type	
	C	β	Single pole Relay	Triple pole relay
Up to 125V rms	450	0.25	600A/S1/S256	600A/S3/1/S802
125 to 300V rms	900	0.25	600A/S1/S1088	600A/S3/1/S1195

NOTE: Single pole Relay Metrosil Units are normally supplied without mounting brackets unless otherwise specified by the customer.

6.4.2 Metrosil units for relays with 5A CT

These Metrosil units have been designed to comply with the following requirements:

– At the relay voltage setting, the Metrosil current should be less than 100mA rms (the actual maximum currents passed by the units shown below their type description)

– At the maximum secondary internal fault current the Metrosil unit should limit the voltage to 1500V rms for 0.25 second. At the higher relay settings, it is not possible to limit the fault voltage to 1500V rms, hence higher voltage have to be tolerated (indicated by * ,** , ***).

The Metrosil units normally recommended for the used with 5 Amps CTs and single pole relays are shown in the following table:

Secondary Internal fault current	Recommended Metrosil Type			
	Relay Voltage Setting			
Amps rms	Up to 200V rms	250V rms	275V rms	300V rms
50A	600A/S1/S1213 C= 540/640 35mA rms	600A/S1/S1214 C= 670/800 40mA rms	600A/S1/S1214 C= 670/800 50mA rms	600A/S1/S1223 C= 740/870* 50mA rms
100A	600A/S2/P/S1217 C= 470/540 35mA rms	600A/S2/P/S1215 C= 570/670 75mA rms	600A/S2/P/S1215 C= 570/670 100mA rms	600A/S2/P/S1196 C= 620/740* 100mA rms
150A	600A/S3/P/S1219 C= 430/500 100mA rms	600A/S3/P/S1220 C= 520/620 100mA rms	600A/S3/P/S1221 C= 570/670** 100mA rms	600A/S3/P/S1222 C= 620/740*** 100mA rms

NOTE: * 2400V peak
** 2200V peak
*** 2600V peak
In some cases, single disc assemblies may be acceptable, contact AREVA T&D for detailed information.
The Metrosil units used with 5 Amps CTs can also be used with triple pole relays and consist of three single pole units mounted on the same central stud but electrically insulated from each other. To order these units please specify "Triple pole Metrosil type", followed by the single pole type reference.

7. RECTIFIER PROTECTION

Rectifiers require a specific inverse time protection curve.

Protecting a rectifier is different from protecting conventional overcurrent applications. In fact, a large number of rectifiers can withstand relatively long periods of overcharge without being damaged. To give an idea, they can generally withstand 150 % of the load for 2 hours and 300 % for 1 minute.

A typical application is shown on the diagram below.

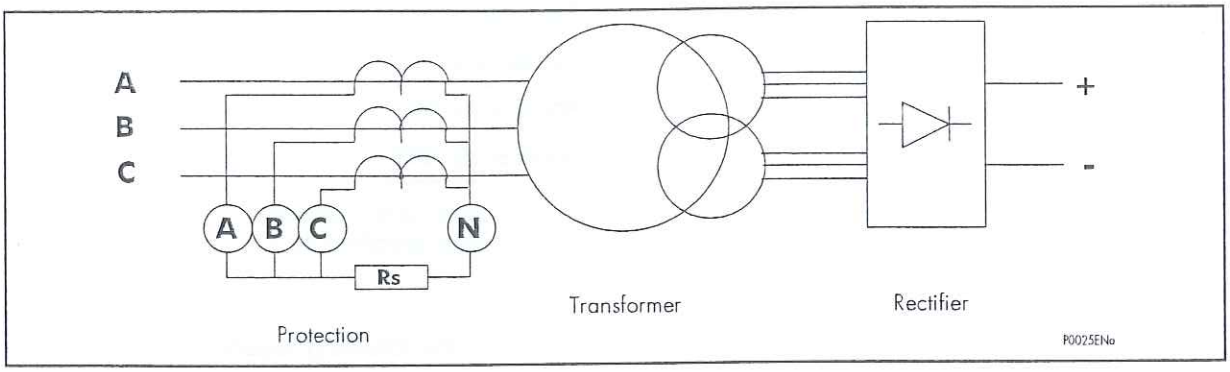


FIGURE 6 : PROTECTION FOR SILICON RECTIFIERS

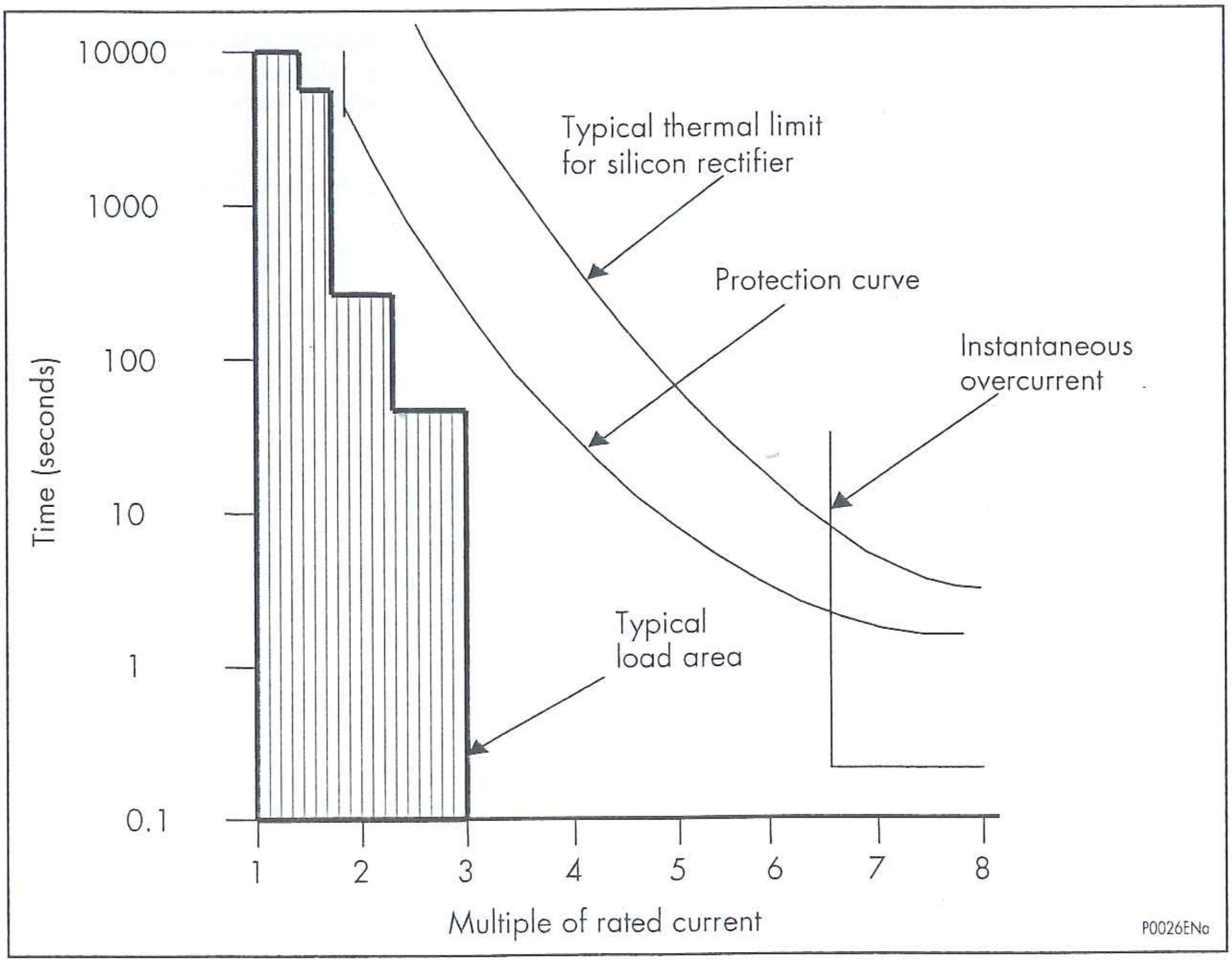


FIGURE 7 : MATCHING CURVE TO LOAD AND THERMAL LIMIT OF RECTIFIER

The current threshold I> should be set to the rated rms value of the current that flows into the transformer when the rectifier is delivering its rated load. The relay will give a start indication when the current exceeds this setting but this is of no consequence because this function is not used in this application. The rectifier curve should be an inverse time curve and should cut-off currents below 1.6 times allowing the rectifier to carry 150% overload for long periods. If this is not acceptable, the I> setting can be adjusted to move the cut-off point relative to the current scale. The operation time can be modified by adjusting the time multiplier setting (TMS) so that the time lies between limiting characteristic of the rectifier and the tolerated load area.

Typical settings for the TMS area :

Light industrial service	TMS = 0.025
Medium duty service	TMS = 0.1
Heavy duty traction	TMS = 0.8

The high set is typically set at 8 times the rated current as this ensures HV AC protection will discriminate with faults covered by the LV protection. However, the high set could be set to 4 or 5 times the rated current if the AC protection is not trustworthy.

Use of the thermal element to provide protection between 70% and 160% of rated current could enhance the protection. It is also common practice to provide restricted earth fault protection for the transformer feeding the rectifier. Refer to the corresponding section dealing with restricted earth fault protection.

8. BACK-UP DIAGRAM USING « TRANSFERRED SELECTIVE TRIPPING »

In this application, the relay protecting the incomer can trip the circuit breaker of the faulty feeder via the watchdog contact of the relay protecting the faulty feeder.

Figure 8 illustrates this example :

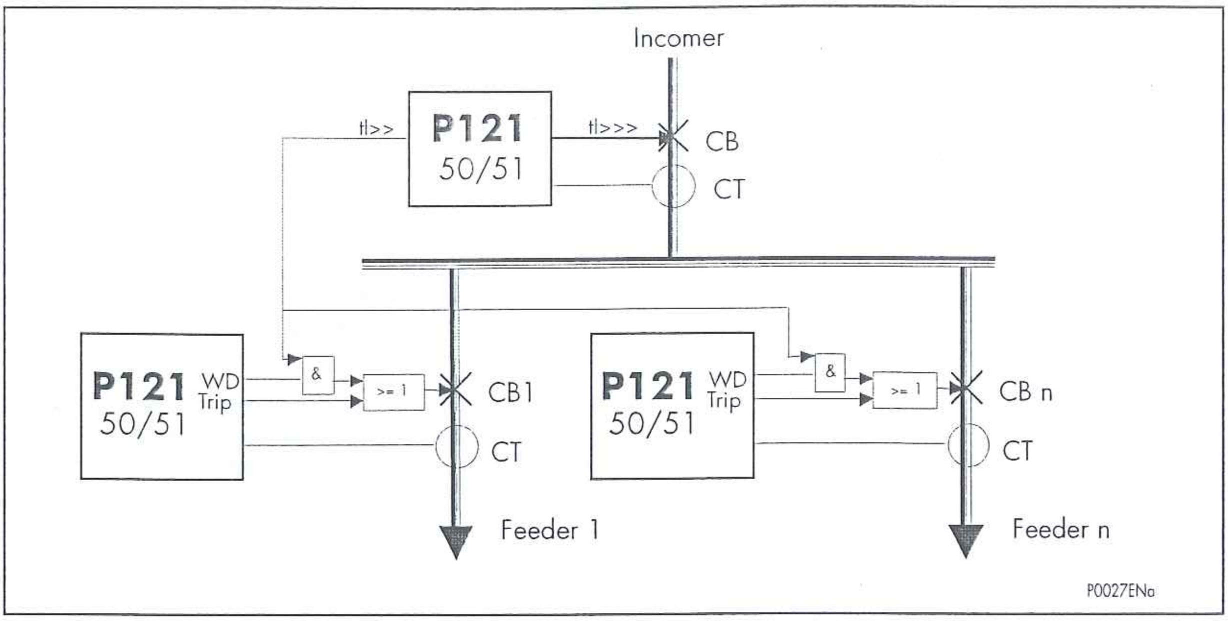


FIGURE 8 : EXAMPLE OF A BACK-UP DIAGRAM USING " TRANSFERRED SELECTIVE TRIP"

Thus, a fault occurring on a feeder can be cleared tripping the circuit breaker of the faulty feeder, even if the relay protecting this feeder failed to operate. Without this function, the fault would normally be cleared by the opening of the circuit breaker of the incomer. This would lead to a total loss of operation on the affected busbar.

The relay protecting the incomer has two time delay output contacts available (among others):

- 3rd threshold: tI>>> time delay at 60ms (active threshold for the high phase faults)
- 2nd threshold: tI>> time delay selectively greater than for the third threshold, i.e. 360ms.

The output contact associated with the 2nd threshold is wired in serie with the watchdog contact of the downstream relays, so that it can activate the trip coil of the circuit breakers of the feeders. Regarding the output contact associated with the 2nd and 3rd threshold, this contact is directly wired to the trip coil of the incomer circuit breaker.

<u>Case n°1 → all relays operate normally :</u>

In this case, watchdog contacts of all the relays are open.

Thus, for a phase fault on the busbar, threshold tI>> or tI>>> of the P121 located on the incomer will clear the fault.

For a phase fault on one of the feeder, the thresholds tI>> and tI>>> of the relay located on the incomer being selectively set to higher values than the ones set for the phase thresholds of downstream relays, the fault shall be cleared selectively by the relay of the faulty feeder (selectivity between the relay of the incomer and relays of the feeders is ensured thanks to intervals of selectivity correctly chosen, or thanks to a suitable blocking diagram).

Case n°2 → the relay supervising one of the feeders is faulty :

In this case, the watchdog contact of this relay is closed.

Thus, for a phase fault on the busbar, thresholds tI>> and tI>>> activate their associated output contact. However, threshold tI>> will clear the fault as this threshold has been set to a lower value than the threshold tI>>>.

For a phase fault on one of the 'healthy' feeders, thresholds tI>> and tI>>> of the relay located on the incomer being selectively set to higher values than the ones set for the phase thresholds of the downstream relays, the fault shall be cleared selectively by the relay of the faulty feeder (selectivity between the relay of the incomer and relays of the feeders is ensured thanks to intervals of selectivity correctly chosen or thanks to a suitable blocking diagram).

For a phase fault on the feeder of the failed relay, the threshold tI>> of the relay located on the incomer operates via the watchdog contact of the faulty relay on the trip coil of the circuit breaker of the faulty feeder. This threshold being selectively set to a value lower than the threshold tI>>> (which operates directly on the coil of the incomer circuit breaker), the fault is therefore selectively cleared.

9. REMOTE PROTECTION STAND-BY DIAGRAM

MiCOM P121, **P122** and **P123** relays can be used as a HV distance back-up protection (Figure 9). Depending on the type of selectivity required, 51/51N function of **P121, P122** and **P123** needs to be set either as time constant or as time dependent. The value of the time delay of I>/Ie> is set to a value that is compatible with thresholds Z2 or Z3 (2nd and 3rd distance protection zone).

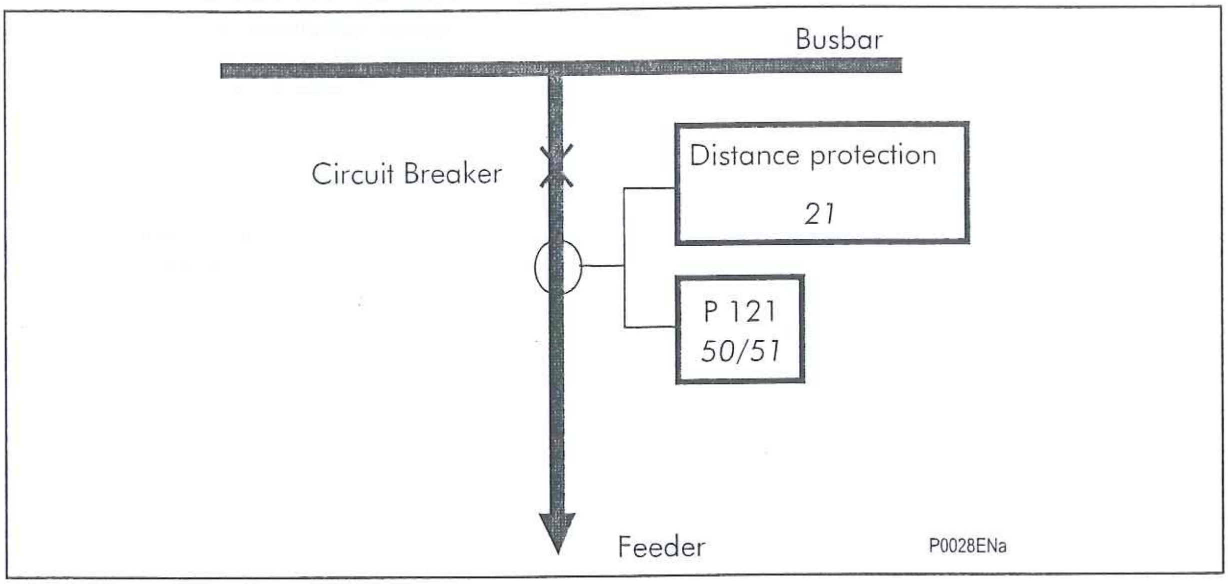


FIGURE 9 : ASSISTANCE OF REMOTE PROTECTION BY A MiCOM P121 PROTECTION

The «Equipment default » contact of the distance protection (case of a numerical protection) can be wired to a **MiCOM P121, P122** and **P123** relays to optimise the time to trip.

10. 1 ½ BREAKER SCHEME

For HV/EHV stations with a 1 ½ circuit breaker scheme (Figure 10), the zone between the two circuit breakers and the switch section needs to be protected with a standard ANSI 50 protection.

The time to trip is an essential criteria to be considered when choosing this protection. **MiCOM P121, P122** or **P123** relays are perfectly suited for this application. The time delay of the first threshold (tI>) is set to a low value (typically 100 ms above the circuit breaker failure time). This will allow the relay to be blocked by the close contact of the associated switch.

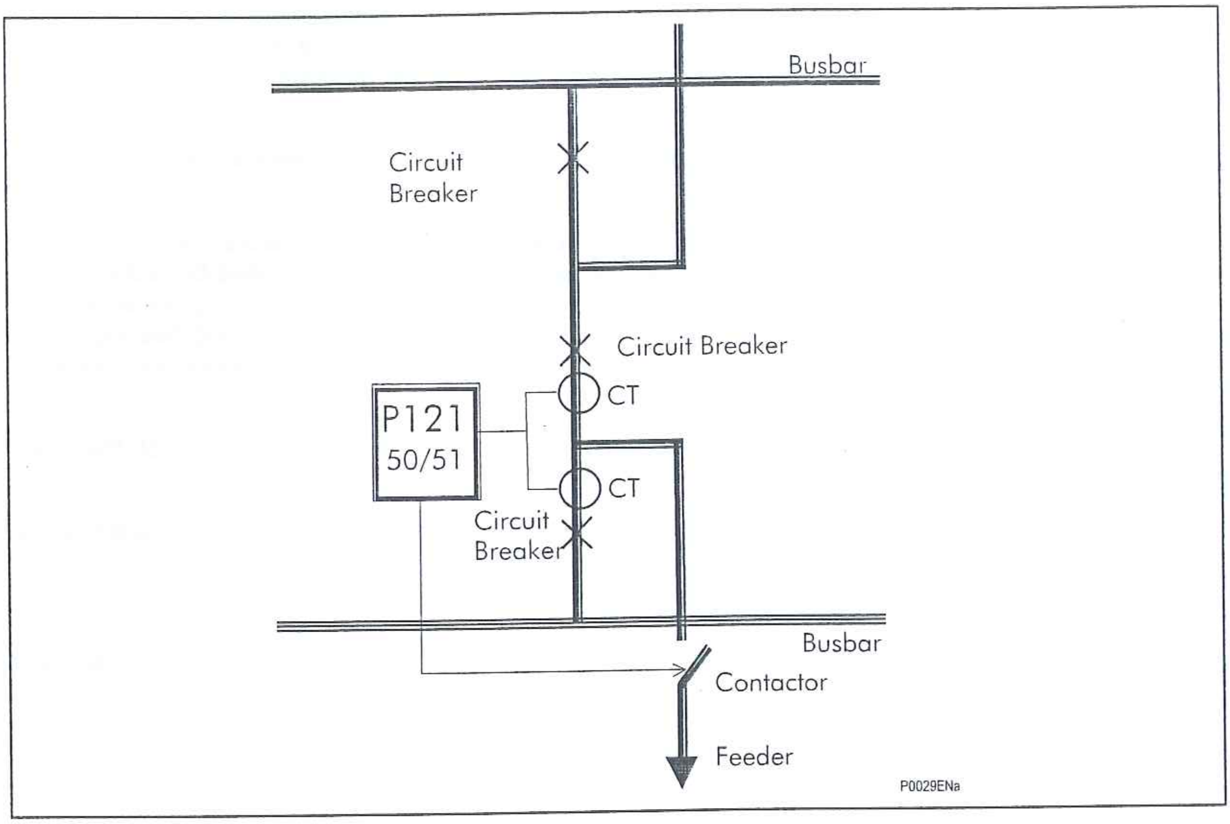


FIGURE 10 : 1 ½ BREAKER SCHEME

11. THERMAL OVERLOAD PROTECTION (P122 & P123 ONLY)

Thermal overload protection can be applied to prevent damages to the equipment of the electrical plant when operating at temperatures that are above the values designed for maximum withstand. A prolonged overloading causes excessive heating, which may result in premature deterioration of the insulation, or in extreme cases, insulation failure.

MiCOM P122 & P123 relays incorporate a current based thermal replica, using load current to reproduce the heating and cooling of the equipment to be protected. The element thermal overload protection can be set with both alarm and trip stages.

The heating within any plant equipment, such as cables or transformers, is of resistive type (I^2R x t). Thus, the quantity of heat generated is directly proportional to the current squared (I^2). The thermal time characteristic used in the relay is based on current squared, integrated over time.

MiCOM P122 & P123 relays automatically use the highest phase current as input information for the thermal model.

Protection equipment is designed to operate continuously at a temperature corresponding to its full load rating, where heat generated is balanced with heat dissipated by radiation etc. Over-temperature conditions therefore occur when currents in excess of rating are allowed to flow for a certain period of time. It can be shown that temperatures during heating follow exponential time constants and a similar exponential decrease of temperature occurs during cooling.

In order to apply this protection element, the thermal time constant (Te) of the plant equipment to be protected is therefore required.

The following sections will show that different plant equipment possesses different thermal characteristics, due to the nature of their construction.

11.1 Time Constant Characteristic

This characteristic is used to protect cables, dry type transformers (e.g. type AN), and capacitor banks.

The thermal time characteristic is given by:

$$e^{\left(\frac{-t}{\tau}\right)} = \frac{\left(I^2 - (k \times I_{FLC})^2\right)}{\left(I^2 - I_p^2\right)}$$

Where:

t	=	Time to trip, following application of the overload current, I
τ	=	Heating and cooling time constant of the protected plant equipment
I	=	Largest phase current
I_{FLC}	=	Full load current rating (relay setting 'Thermal Trip')
k	=	1.05 constant, allows continuous operation up to < 1.05 I_{FLC}
I_p	=	Steady state pre-loading current before application of the overload

The time to trip varies depending on the load current carried before application of the overload, i.e. whether the overload was applied from "hot" or "cold".

Curves of the thermal overload time characteristic are presented in the chapter P12x/EN TD/C55 of the Technical Guide.

Mathematical formula applicable to the MiCOM Relays :

The calculation of the Time to Trip is given by :

$$Ttrip = Te \ln\left(\frac{|K^2 - \theta^2|}{|K^2 - \theta trip^2|}\right)$$

With :

Ttrip = Time to trip (in seconds)

Te = Thermal time constant of the protected element (in seconds)

K = Thermal overload equal to Ieq/k Iθ >

Ieq = Equivalent current corresponding to the RMS value of the largest phase current.

Iθ > = Full load current rating given by the national standard or by the supplier.

k = Factor associated to the thermal state formula.

θ^2 = Initial thermal state. If the initial thermal state = 30% then $\theta^2 = 0.3$

$\theta trip^2$ = Trip thermal state. If the trip thermal state is set at 100%, then $\theta\ trip^2 = 1$

The settings of these parameters are available in the menus :

PROTECTION G1/ [49] Therm OL

PROTECTION G2/ [49] Therm OL

The calculation of the thermal state is given by the following formula :

$$\Theta_{\tau+1} = \left(\frac{I_{eq}}{k \times I\Theta >}\right)^2 \left[1 - e^{\left(\frac{-t}{T_e}\right)}\right] + \Theta_\tau e^{\left(\frac{-t}{T_e}\right)}$$

θ being calculated every 20ms.

11.2 Setting Guidelines

The current setting is calculated as:

Thermal Trip (θtrip) = Permissible continuous loading of the plant equipment / CT ratio. Typical time constant values are given in the following tables. The 'Time Constant' parameter is given in minutes.

Paper insulated lead sheathed cables or polyethylene insulated cables are placed above the ground or in conduits. The table shows τ in minutes, for different cable rated voltages and conductor cross-sectional areas:

CSA mm^2	6 -11 kV	22 kV	33 kV	66 kV
25 - 50	10	15	40	-
70 - 120	15	25	40	60
150	25	40	40	60
185	25	40	60	60
240	40	40	60	60
300	40	60	60	90
	Time constant τ (minutes)			

Other plant items:

	Time constant τ (minutes)	Limits
Dry-type transformers	40 60 - 90	Rating < 400 kVA Rating 400 - 800 kVA
Air-core reactors	40	
Capacitor banks	10	
Overhead lines	10	Cross section ≥ 100 mm^2 Cu or 150mm^2 Al
Busbars	60	

An alarm can be raised when reaching a thermal state corresponding to a percentage of the trip threshold. A typical setting might be 'Thermal Trip' = 70% of thermal capacity.

12. COLD LOAD PICK-UP (P122 & P123 ONLY)

The Cold Load Pick-up feature allows selected settings of **MiCOM P122** and **P123** relays to be changed to react to temporary overload conditions that may occur during cold starts.

This condition may happen by switching on large heating loads after a sufficient cooling period, or loads that draw high initial starting currents.

When a feeder is energised, the current levels that flow for a period of time following energising may differ greatly from the normal load levels. Consequently, overcurrent settings that have been applied to give short circuit protection may not be suitable during this period.

The Cold Load Pick-up (CLP) logic included in MiCOM P122 & P123 relays raises the settings of selected stages for a set duration. This allows the protection settings to be set closer to the load profile by automatically increasing them after energising. The CLP logic provides stability, without compromising protection performance during starting. Note that any of the disabled overcurrent stages in the main relay menu will not appear in the Cold Load PU Menu.

The following table shows the relay menu associated to the '*Cold Load Pick-up* ' logic, and the setting ranges and setting by default (out of factory).

MENU TEXT	SETTING RANGE		STEP SIZE
AUTOMAT. CTRL	MIN	MAX	
Cold Load PU	NO	YES	
tI>	NO	YES	
tI>>	NO	YES	
tI>>>	NO	YES	
tI_e>	NO	YES	
tI_e>>	NO	YES	
tI_e>>>	NO	YES	
t Therm	NO	YES	
tI2>	NO	YES	
tI2>>	NO	YES	
level	20 %	500 %	1 %
tCL	100 ms	3 600 s	100 ms

The timer **tCL** in the CLP menu controls the time for which the relevant protections elements in CLP menu (%) are altered following an external input signal (e.g. circuit breaker closure. When the set **tCL** time has elapsed, all relevant settings revert back to their original values or are unblocked.

tCL is initiated thanks to a dedicated logic input signal (refer to **AUTOMAT. CTRL/INPUTS** menu), that is generated by connecting an auxiliary contact from the circuit breaker (52a or 52b) or starting device to the logic relevant inputs of the relay.

The following sections describe applications where the CLP logic may be useful and the settings that need to be applied.

12.1 Air Conditioning/Resistive Heating Loads

Where a feeder is used to supply air conditioning or resistive heating loads there may be a conflict between the "steady state" overcurrent settings and those required following energizing. This is due to the temporary increase in load current that may arise during starting.

With the Cold Load Pick-up function enabled, the affected thresholds are selected to be adjusted for the required time to allow the start condition to subside. A percentage value is selected as the amount by which the selected threshold is increased or decreased.

The time for which the adjusted thresholds are valid is defined by the **tCL** setting. After this time, the settings return to normal.

It may not be necessary to alter the protection settings following a short supply interruption. In this case the CLP function is not activated.

12.2 Motor Feeders

In general, a dedicated motor protection device, such as MiCOM P220, P225 or P241 relays should protect feeders supplying motor loads. However, if no specific protection has been applied (possibly due to economic reasons) then the CLP function in the MiCOM P122 or P123 relay may be used to modify the overcurrent settings accordingly during starting.

Depending upon the magnitude and duration of the motor starting current, it may be sufficient to simply block operation of instantaneous elements or, if the start duration is long, the time delayed protection settings may also need to be raised. Hence, a combination of both blocking and raising of settings of the relevant overcurrent stages may be adopted. The CLP overcurrent settings in this case must be chosen with regard to the motor starting characteristic.

As previously described, the CLP logic includes the option of raising the settings of the first stage of the earth fault protection. This may be useful where instantaneous earth fault protection is required to be applied to the motor. During conditions of motor starting, it is likely that incorrect operation of the earth fault element would occur due to asymmetric CT saturation. This is a result of the high level of starting current causing saturation of one or more of the line CTs feeding the overcurrent and/or earth fault protection. The resultant transient imbalance in the secondary line current quantities is thus detected by the residually connected earth fault element. For this reason, it is normal to either apply a nominal time delay to the element, or to utilise a series stabilising resistor.

The CLP logic may be used to allow reduced operating times or current settings to be applied to the earth fault element under normal running conditions. These settings could then be raised prior to motor starting, via the logic.

12.3 Earth Fault Protection applied to Transformers

Where an earth fault relay is residually connected on the primary side of a delta-star transformer, no time delay is required for co-ordination purposes, due to the presence of the delta winding. However, a nominal time delay or stabilising resistor is recommended, to ensure transient stability during transformer energising.

The CLP logic may be used in a similar manner to that previously described for the motor application.

It should be noted that this method will not provide stability in the event of asymmetric CT saturation which occurs as a result of an unbalanced fault condition. If problems of this nature are encountered, the best solution would still be the use of a stabilising resistor.

13. SWITCH ONTO FAULT / TRIP ON RECLOSE PROTECTION (P123 ONLY)

13.1 General

In some feeder applications, fast tripping may be required if a fault is still present on the feeder after the reclose of the circuit breaker (Close on to fault).

Some faults may not be cleared after a reclose due to the fact that the conditions that led to the fault have not been removed from the feeder after a reclosing cycle or a manual trip, or due to earthing clamps left on after a maintenance visit. In these cases, it may be desirable to clear the fault condition in a quicker time, rather than to wait for the trip delay time DMT or IDMT associated with the involved protection to elapse.

In the case of a CB being manually closed, a switch on to an existing fault may occur. This situation is particularly critical because the overcurrent protection would not clear the fault until the set time delay has elapsed. It is then desirable to clear the fault as fast as possible.

The SOTF acronym means Switch On To Fault.

The TOR acronym means Trip on Recloser.

Activation and setting of the SOTF/TOR function can be done under the AUTOMATIC CTRL/SOTF submenu.

The crossing of I>> and I>>> thresholds initiate the SOTF function.

13.2 SOTF/ TOR description

Three types of signals can activate the SOTF/TOR function:

- a "Control Close" command generated by a digital input labelled "Man. Close"
- a command sent remotely and labelled "Control Close"
- a digital output labelled "AR Close"

The following diagram illustrates this functionality.

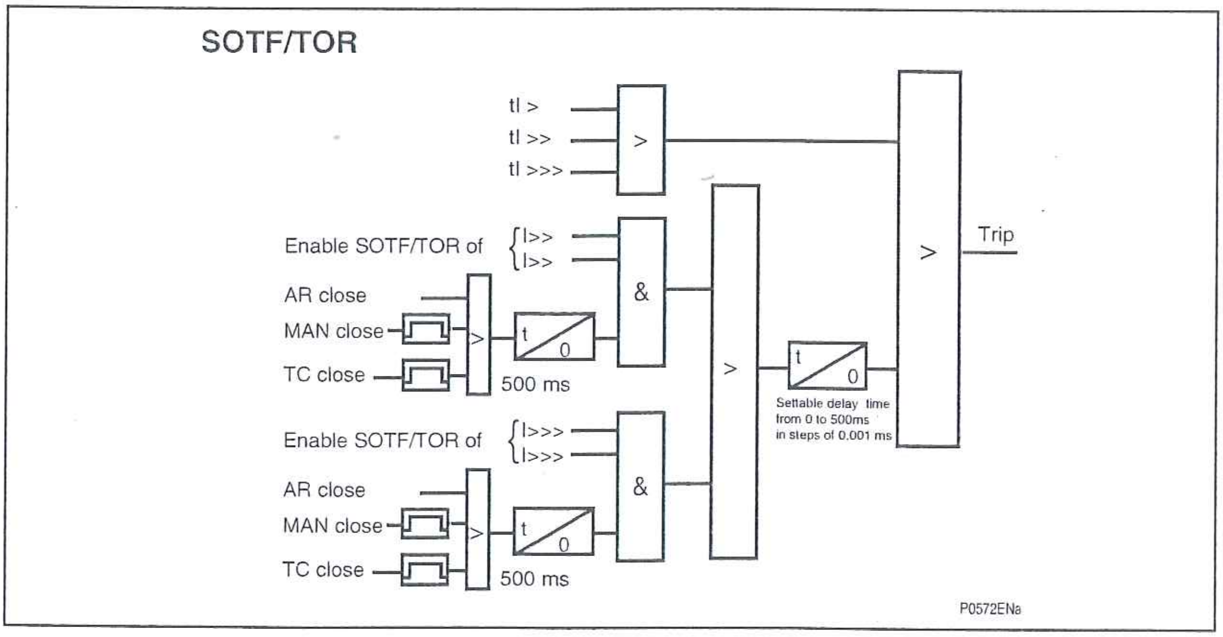


FIGURE 11 : LOGIC DIAGRAM OF THE SOTF

When at least one of these 3 signals have been detected, a fixed timer starts and lasts 500ms.

Once this fixed timer has elapsed and I>> or I>>> thresholds have been crossed, the configurable timer named "t Sotf" starts. This configurable timer is particularly useful in applications where selectivity for fault occurring in stage two or three is requested.

This timer is also useful for cases where serious transient happen, where the three poles of the CB do not close at the same time and in cases where the CB may not instantaneously close.

This "t SOFT" can also be considered a trip delay time that substitutes the trip timer of the threshold that has been crossed so that the time to trip is accelerated.

If a trip due to switch on to fault occurs during the reclaim time of the ARC, the trip will be definitive and the ARC will be locked.

If the I>> and I>>> reset during the settable timer "t Sotf", the SOTF/TOR function is reset.

The user can set the SOTF function under the AUTOMATIC CTRL/TRIP COMMAND submenu and the AUTOMATIC CTRL/Output relays submenu.

14. LOCAL / REMOTE MODE (P123 ONLY)

14.1 General

The goal of this feature is to be able to block commands sent remotely. This is done to prevent any accidents or maloperation during maintenance work performed on site.

A digital input labelled "LOCAL MODE" is assigned to this feature. When this input is energised, remote commands sent through communication networks (like setting parameters, control command, etc.) will not be allowed. Nonetheless, note that even in Local mode the synchronising time signal sent through the communication network is allowed as this signal can't cause operation of the output relays and can't lead to the operation of the circuit breaker.

When the logic input is not energised, writing commands sent remotely will be authorised.

All communication protocols available in the P123 have this feature implemented.

Along with this feature, a differentiation had to be made between a trip issued by the protection elements and a trip issued remotely, as well as between the close command issued remotely and the close command issued by the Auto-reclose function.

Indeed, "Control trip" (named "CTRL TRIP" in the relay menu) and "Control close" (named "CTRL CLOSE" in the relay menu) are named this way to signify that a trip command has been issued remotely.

"Autoreclose close" (named "CB Close" in the relay menu) command is named this way to signify that the close command is issued by the autoreclose function.

"Protection trip" (named "TRIP" in the relay menu) means that the trip command has been issued by the protection elements (time delay threshold crossing).

This is done to identify if the trip order has been issued by a remote command, by the crossing of a time delay threshold or by the activation of the autoreclose function.

Commands sent remotely (CTRL TRIP and CTRL CLOSE) as well as commands sent by the autoreclose function (CB Close) can be set to activate their own dedicated output relay (and not necessarily the same output relay as the protection trip output RL1).

The trip order is issued if the protection trip (named "TRIP" in the relay menu) or a remote control trip (named "CTRL TRIP") is sent (OR gate).

The close order is issued if the Auto-reclose close command (named "CB CLOSE" in the relay menu) or the control close command (named "CTRL CLOSE") is sent (OR gate).

14.2 Setting

In the AUTOMATIC CTRL/TRIP COMMAND menu, TC item uses the "CTRL TRIP" function to open the CB.

In the AUTOMATIC CTRL/Output relays menu, the "CTRL TRIP" and "CTRL CLOSE" functions are assigned to remotely open and close the CB.

The "CB CLOSE" relay is assigned to close the CB by Autoreclose (ARC).

In order to keep the functionality of previous firmware versions, the user will have to assign both "TRIP" and "CTRL TRIP" information to relay RL1, and to assign both "CTRL CLOSE" and "CB CLOSE" information to the same auxiliary relay.

Here is an example of application.

In the following scheme, the user may assign the different signals to different relays: "TRIP" signal may be assigned to the trip relay RL1, the "CTRL TRIP" signal to the auxiliary relay number 2, the "CB CLOSE" signal to the auxiliary relay number 3 and the "CTRL CLOSE" to the auxiliary relay number 4.

When the "Local" input is energised, all remote commands are blocked. When the "Local" input is de-energised, remote control commands can be issued.

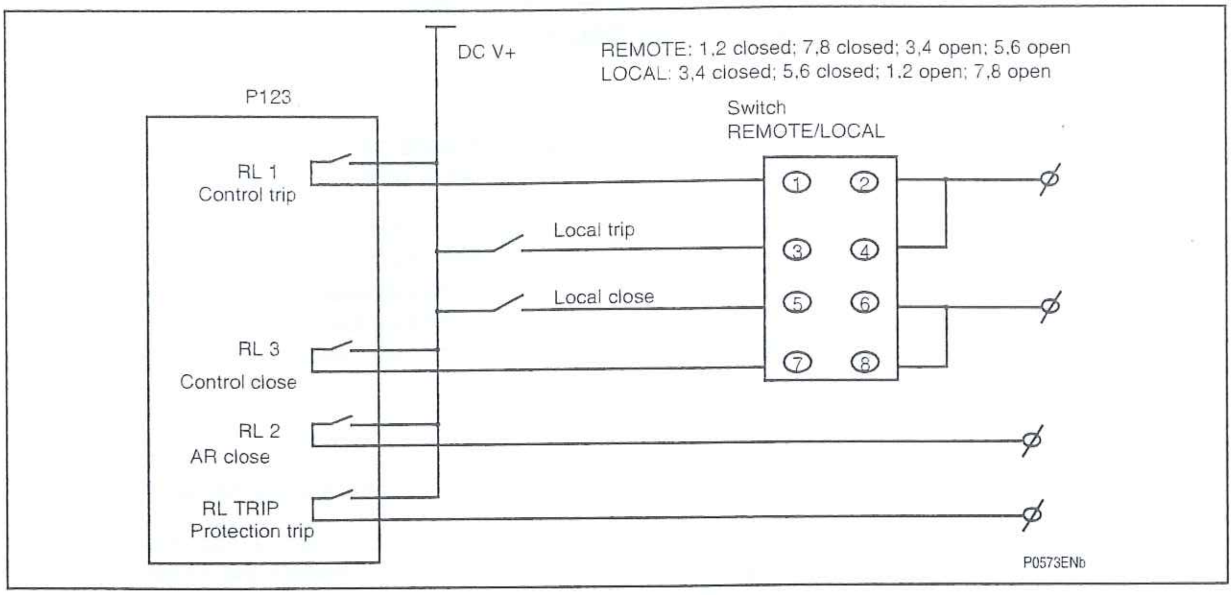


FIGURE 12 : EXAMPLE OF LOCAL/REMOTE APPLICATION

15. AUXILIARY TIMERS (P122 & P123 ONLY)

Four auxiliary timers tAux1, tAux2, tAux3 and tAux4 (P123 only) are available and associated to Aux1, Aux2, Aux3 and Aux4 logic inputs (refer to ***AUTOMAT. CRTL/INPUTS*** menu). When these inputs are energised, the associated timers start and, when the set time has elapsed, the associated output relays close (refer to ***AUTOMAT. CRTL/OUTPUTS*** menu). Time delays can be independently set from 0 ms to 200 s.

NOTE : It is possible to allocate logic inputs of the MiCOM P120 & P121 to the external information Aux1 and Aux2. Therefore, these inputs cannot command output relays. Moreover, the tAux1 and tAux2 timers are fixed and equal to 0. Thus the Aux1 and Aux2 inputs can only be used for indication on the communication network.

16. SETTING GROUP SELECTION (P122 & P123 ONLY)

MiCOM P122 and P123 relays have two setting groups associated to the protection functions named PROTECTION G1 and PROTECTION G2. Only one group is active.

Switching between the groups can be done via:

- the relay front panel interface (CONFIGURATION/GROUP SELECT/ SETTING GROUP 1 or 2),
- a dedicated logic input (AUTOMAT. CTRL/INPUT X/CHANGE SET) where X is the chosen logic input,
- through the communications port (refer to Mapping Database for detailed information).

To avoid any false trip, the change of setting group is only carried out when no protection function is running (except the thermal overload function).

If a setting group change is received during any protection or automation function, it is stored and executed after the last timer has elapsed.

The user can check which one of the active group is active looking under the OP PARAMETERS menu.

The user can also assign the active group to an output relay. Using a normally open contact, this means that:

- an open contact will indicate that the active group is Group 1
- a close contact will indicate that the active group is Group 2

Change of setting group done by a digital input

It is possible to change the setting group via the activation of a digital input (on level).

The user can select an activation of the input on falling edge or low level (idem for rising edge or high level) going under the CONFIGURATION/Group Select/Change Group/Input menu.

Warning: if the digital input that has been assigned to the change of setting group operates on level (low or high), it is not possible to change the setting group via remote communication or front panel.

SWITCH BETWEEN ACTIVE GROUPS :

When powering on the relay, the group selected (Group 1 or Group 2) corresponds to the state of the logic input. This means:

A - With a Logic input configuration = 0

Group 1 = logic Input is not active
Group 2 = logic Input is active

If the programmed logic input is supplied with +V, then the active group will be G1.
If the programmed logic input is not supplied with +V , then the active group will be G2.

B - With a Logic input configuration = 1

Group 1 = logic Input is not active
Group 2 = logic Input is active

If the set logic input is energized with +V, then the active group will be G2.
If the set logic input is not energized with +V, then the active group will be G1.

Priority

When changing parameters through the front panel, the priority is given to the user that takes local control of the relay when entering a password. Change of setting group done via a remote command is not allowed for as long as the password is active (5mn).

ORIGIN OF THE ORDER	PRIORITY LEVEL
FRONT PANEL	MAXIMUM
LOGIC INPUT	MEDIUM
REMOTE COMMUNICATIONS	MINIMUM

17. MAINTENANCE MODE

This menu allows the user to verify the operation of the protection functions without actually sending any external command (Tripping or signalling).

The selection of the maintenance mode is possible by logic input, control command (rear or front port), or by front panel interface. The end of maintenance mode is done by logic input, by control command or on the front panel interface time out (5 minutes) and by turning off the power supply.

Maintenance Mode	
	YES

When this menu is activated (set to YES), the Alarm led will start to flash and the alarm message "MAINTENANCE MODE" will be displayed. In this case, all the output contacts are blocked, and no command can be issued to these contacts, even if a protection threshold associated to one of these output contacts has been crossed.
(If a protection threshold is crossed, all associated LEDs will be ON, even the TRIP LED, if the threshold is associated to the RL1).

RELAYS	8765W4321
CMD	000000000

This window allows the user to verify the external wiring to the relay output contacts. To do this, the user just has to assign a 1 to any of the output contacts, and this will close the contact and the continuity of the wiring can be verified.

18. SELECTIVE SCHEME LOGIC (P122 & P123 ONLY)

The following figure describes the use of non-cascade protection schemes using the start contacts from downstream relays to block operation of upstream relays.

In the case of Selective Overcurrent Logic (SOL), the start contacts are used to increase the time delays of upstream relays, instead of blocking them. This provides an alternative approach to achieving a non-cascade type of overcurrent scheme. It may be more familiar to some utilities than the blocked overcurrent arrangement.

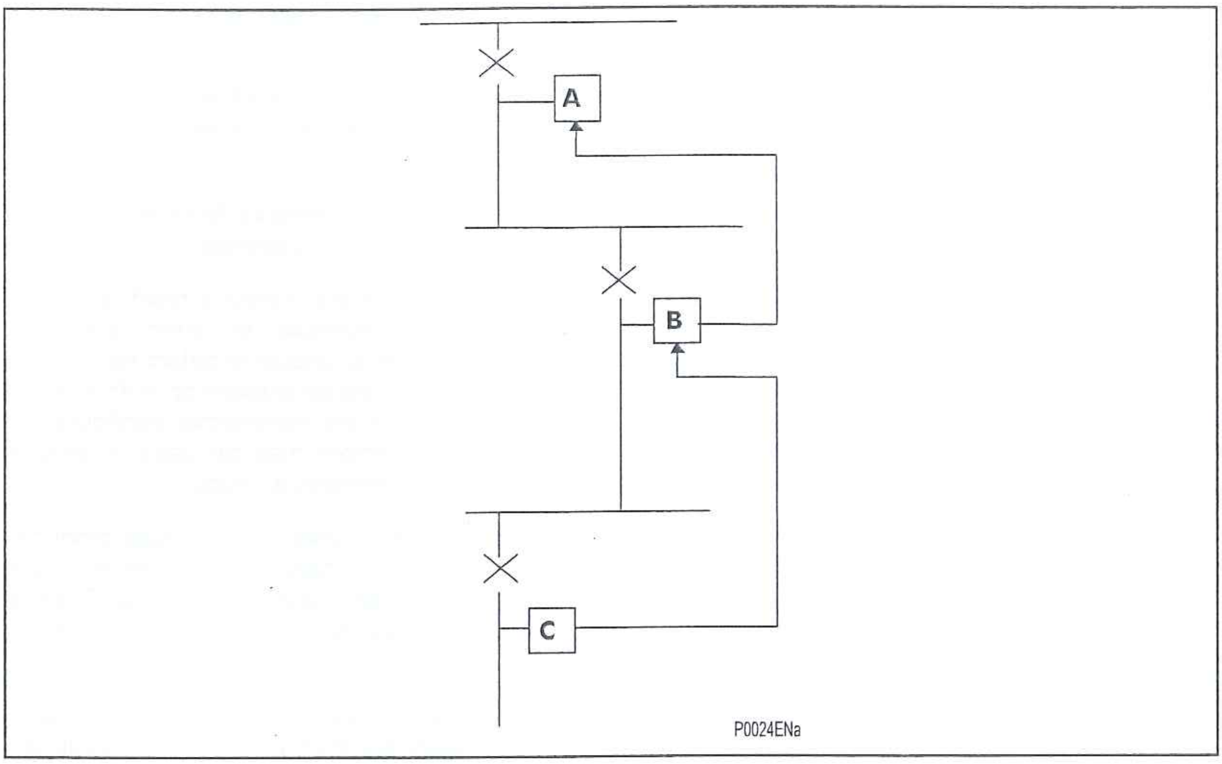


FIGURE 13 : TYPICAL SCHEME LOGIC

The SOL function temporarily increase the time delay settings of the second and third stages of phase overcurrent, derived and measured earth fault and sensitive earth fault protection elements. This logic is initiated by energising the appropriate logic input (Log Sel1 or Log Sel2) as selected in AUTOMAT.CRTL/INPUTS menu.

To allow time for a start contact to initiate a change of setting, the time settings of the second and third stages should include a nominal delay. Guidelines for minimum time settings are identical to those given for blocked overcurrent schemes.

The tSel1 and tSel2 timers can be independently set from 0 to 150 s.

19. NEGATIVE SEQUENCE OVERCURRENT PROTECTION (P122 & P123 ONLY)

In traditional phase overcurrent protection schemes, overcurrent thresholds must be set above maximum load current levels. This limits the sensibility of the relay. Most protection schemes also use an earth fault element using residual current, which improves sensitivity for earth faults. However, it can happen that some faults occur and stay undetected by such schemes.

Any unbalanced fault condition will produce negative sequence current. Thus, a negative phase sequence overcurrent element can detect both phase-to-phase and phase to earth faults.

This section describes how negative phase sequence overcurrent protection may be applied in conjunction with standard overcurrent and earth fault protection in order to solve some problems of application.

- Negative phase sequence overcurrent elements is more sensitive to resistive phase-to-phase faults, whereas phase overcurrent elements may not operate.
- In some applications, an earth fault relay may not be able to detect a residual current because of the configuration of the network. For example, an earth fault relay connected on the delta side of a delta-star transformer is unable to detect earth faults on the star side. However, negative sequence current will be present on both sides of the transformer in any fault condition, independently of the transformer configuration. Therefore, negative phase sequence overcurrent element may be used to provide time-delayed back-up protection for any uncleared asymmetrical faults.
- Where fuses are used to protect motors on rotating machines, a blown fuse produces a large amount of negative sequence current. This is a dangerous condition for the machine because negative phase sequence current generates overheating. Then, a negative phase sequence overcurrent element may be used to back-up motor protection relays.
- It may also be required to trigger an alarm to announce the presence of negative phase sequence currents in the system. Operators are then prompted to investigate the cause of the unbalance.

The negative phase sequence overcurrent elements have a current pick up settings I2> and I2>>, and can be time-delayed using configurable timers tI2> and tI2>>.

19.1 I2> and I2>> Setting Guidelines

I2> and I2>> thresholds can be set under the PROTECTION G1 (2)/[46] Neg Seg 0C menu.

The current pick-up threshold I2> must be set to a value that is higher than the normal negative phase sequence current because of the normal unbalance conditions on the network. This can be done practically during the commissioning, using the MEASUREMENTS menu of the relay to display the negative phase sequence current value. Then, this value has to be increased by 20%.

Where negative phase sequence element is used to clear particular cases of uncleared asymmetric faults, the threshold setting have to be calculated based on a fault analysis of that particular system, due to the complexities involved. However, to ensure that the protection element will operate, the current pick-up value has to be set to approximately 20% below the lowest calculated negative phase sequence fault current for a specific remote fault.

It is essential to set correctly the time delay associated to this function. It should also be noted that this element is used primarily as a back-up protection to other protective devices or to provide an alarm. Therefore, this function is usually set with a long time delay.

Care must be made to ensure that the time delay is set above the operating time of any other protection device (at minimum fault level) present on the system and that may react to unbalanced faults, such as:

- Phase overcurrent elements
- Earth fault elements
- Broken conductor elements
- Negative phase sequence influenced thermal protection elements

tI2> and tI2>> timers associated to I2 threshold can be set under the menu PROTECTION G1(2)/[46] Neg Seg OC.

20. BROKEN CONDUCTOR DETECTION (P122 & P123 ONLY)

Most of the faults that affect a power system occur between one phase and the earth or between two phases and the earth. These faults are shunt faults and are caused by lightning discharges and other overvoltages generating flashovers. They may also arise from birds on overhead lines or mechanical damage on underground cables, etc.

Such faults lead the current to increase appreciably and therefore they can easily be detected in most applications. Open circuit faults are a different type of faults that can happen in electrical networks. These faults can be caused by broken conductors, blown fuses or misoperation of a pole of a circuit-breaker.

Series faults will not lead to an increase in phase current and therefore they can not be easily detected by common overcurrent relays. However, this type of faults produce an unbalance that creates negative phase sequence current, which can be detected.

The use of negative phase sequence overcurrent is then recommended to detect such faulty conditions. However, on lightly loaded lines, the value of the negative sequence current caused by a faulty condition may be very close to, or even inferior, to the full load steady state unbalance generated by CT errors, load unbalance, etc. As a consequence, a negative sequence protection element would not work for low level of loads.

As a solution, MiCOM P122 and P123 have a protection element that measures the ratio between the negative and the positive phase sequence current (I2/I1). Using this ratio instead of the measure of I2 only, the relay will be able to detect a faulty condition independently on the level of load on the network, since the ratio is approximately constant with variations in load current. It is then possible to get a more sensitive setting.

NOTE: the Broken conductor function is inhibited if the current value flowing in each one of the three phases is inferior to 10% of the nominal current.

Setting Guidelines

On single point earthed power systems, there is a low zero sequence current flow and the ratio I2/I1 that flows is close to100%. On multiple earthed power systems, (assuming that the impedances in each sequence network are equals), the ratio I2/I1 will be equal to 50%.

It is possible to calculate the ratio of I2/I1 corresponding to various system impedances, according to the following equations:

$$I_{1F} = \frac{E_g(Z_2+Z_0)}{Z_1Z_2+Z_1Z_0+Z_2Z_0}$$

$$I_{2F} = \frac{-E_gZ_0}{Z_1Z_2+Z_1Z_0+Z_2Z_0}$$

Where :

E_g = System Voltage

Z_0 = Zero sequence impedance

Z_1 = Positive sequence impedance

Z_2 = Negative sequence impedance

Therefore :

$$\frac{I_{2F}}{I_{1F}} = \frac{Z_0}{Z_0+Z_2}$$

As a consequence, for an open circuit in a particular part of the system, I2/I1 can be determined from the ratio between the zero sequence and the negative sequence impedance. It must be noted however, that this ratio may vary depending on the location of the fault. It is therefore desirable to apply a setting that is as sensitive as possible. Practically, the levels of standing negative phase sequence current present on the system guide the choice of this minimum setting. A system study, or the use of measurement data of the relay during commissioning stage are two ways to determine this minimum setting. If the latter method is chosen, it is important to take measurements during maximum load conditions, to be sure that all single phase loads are taken into account.

When sensitive settings are used, it is probable that the element will operate for any unbalance condition occurring on the system (for example, during a single pole autoreclose cycle). Therefore, a long time delay is necessary to ensure co-ordination with other protective devices. It is common to set the time delay to 60 seconds.

The setting range of the Broken Conductor feature is described in the following table:

MENU	DEFAULT SETTING	SETTING RANGE		IN STEPS OF
		MIN	MAX	
AUTOMAT. CTRL				
Brkn Cond.?	NO	NO	YES	
tBC	1	1 s	14 400 s	1 s
RATIO I2/I1	20 %	20 %	100 %	1 %

20.1 Example of Setting

The following information comes from a the relay commissioning report;

$I_{full\ load}$ = 500A

I_2 = 50A

Then:

I_2/I_1 = 50/500 = 0.1

To tolerate some margin and load variations, it is typical to set this value at 200% above this value: Therefore, ***RATIO I2/I1*** = 20%

Set ***tBC*** at 60s to allow short circuits to be cleared by time delayed protections.

21. DESCRIPTION AND SETTING GUIDE OF THE AUTORECLOSE FUNCTION (P123 ONLY)

21.1 Introduction

An analysis of faults on overhead line network has shown that 80-90% are transient in nature.

A transient fault, such as an insulator flashover, is a self clearing 'non-damage' fault. This type of fault can be cleared by the immediate tripping of one or more circuit breakers to isolate the fault, and does not reappear when the line is re-energised. Lightning is the most common cause of transient faults. Other causes are clashing conductors and debris blown by the wind. The remaining 10 - 20% of faults are either non-permanent (arcing fault) or permanent.

A small tree branch falling on the line could cause a non-permanent fault. Here the immediate trip will not clear the fault, and the use of the recloser may be necessary to clear it. Permanent faults could caused by broken conductors, transformer faults, cable faults or machine faults which must be located and repaired before the supply can be restored.

Most of the time, if the faulty line is immediately tripped, and the fault arc has sufficient time to de-ionise, reclose of the circuit breakers will result in the line being successfully re-energised. Autoreclose schemes are used to automatically reclose a switching device once a time delay has elapsed and starting after the CB has opened.

On HV/MV distribution networks, the autoreclose function is used mainly for radial feeders where system stability problems do not generally arise. Using the autoreclose bring the following advantages:

- Minimises time of interruption suffered by the consumer.
- Reduces operating costs. Indeed, less man hours are needed to repair damages caused by the fault and it offers the possibility to have running substations unattended. Thanks to the automatic autorecloser, instantaneous protection can be used, which means shorter time to clear the fault and so helps to minimise damages and to reduce the number of permanent faults.

As 80% of faults in overhead lines are transient, the use of the autorecloser is very advantageous. Automatic autorecloser allow a substation to operate unattended. The number of visits on site to manually reclose a circuit breaker after a fault can then be substantially reduced. This feature constitutes therefore an important advantage for substations supervised remotely.

The autorecloser is of great benefit function gives an important benefit on circuits using time graded protection, in that it allows the use of instantaneous protection to give a high speed first trip. With fast tripping, the duration of the power arc resulting from an overhead line fault is reduced to a minimum, thus lessening the chance of damage to the line, which might otherwise cause a transient fault to develop into a permanent fault.

Using short time delay protection also prevents blowing of fuses and reduces circuit breaker maintenance by eliminating pre-arc heating when clearing transient faults.

The next figure shows an example of 4 autoreclose cycles (maximum numbers of allowed cycles) to the final trip:

tD1, tD2, tD3, tD4 = dead time 1, 2, 3 and 4 timers
tR = Reclaim time
O = CB open
C = CB closed

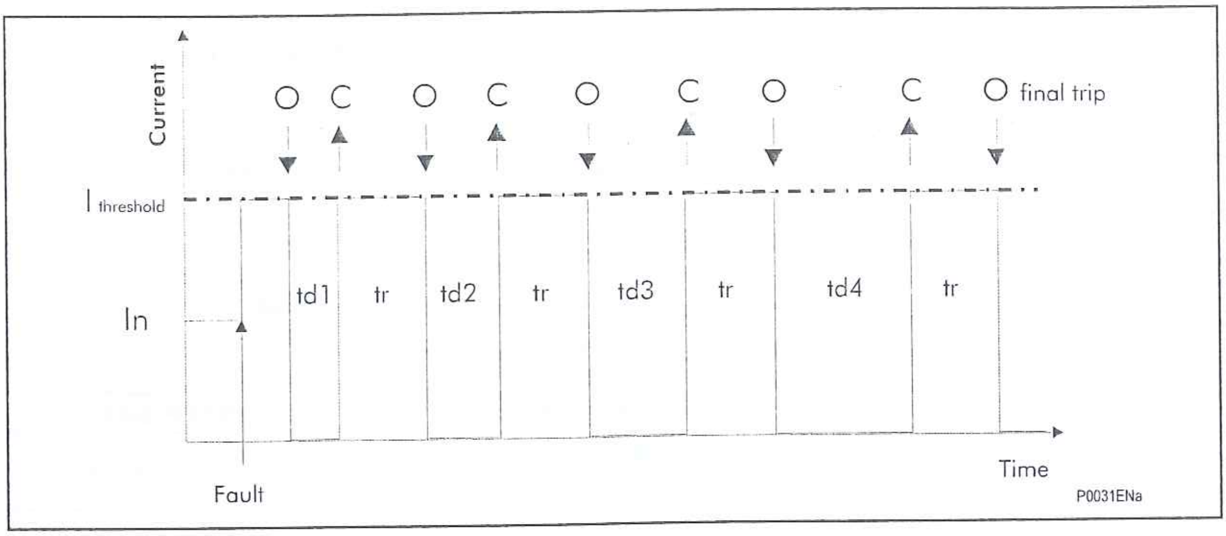


FIGURE 14 : TYPICAL AUTORECLOSE CYCLES

It should be noted that when short time delay protection is used with autoreclose, the scheme is normally arranged to block the instantaneous protection after the first trip. Therefore, if the fault persists after re-closing time graded protection will give discriminative tripping with fuses or other protection devices, resulting in the isolation of the faulted section. However, for certain applications, where the majority of the faults are likely to be transient, it is not uncommon to allow more than one instantaneous trip before the instantaneous protection is blocked.

Some schemes allow a number of re-closings and time graded trips after the first instantaneous trip, which may result in the burning out and clearance of non-permanent faults. Such an approach may also be used to allow fuses to operate in teed feeders where the fault current is low.

When considering feeders which consist partly of overhead lines and partly of underground cables, any decision to apply the autoreclose function would be influenced by all data known on the frequency of transient faults. When a significant proportion of the faults are permanent, the advantages of the autoreclose are small, particularly since re-closing on to a faulty cable is likely to aggravate the damage.

21.2 Description of the function

21.2.1 Autorecloser activation

The autoreclose function of the MiCOM P123 is available only if the following conditions are verified :

- The auxiliary contact of the CB status 52a must be connected to the relay. Refer to the AUTOMAT. CTRL/Inputs menu
- The trip output relay RL1 must not be latched to the earth and/or phase protection function.
  Refer to the AUTOMAT. CTRL/Latch functions menu

NOTE : If the auxiliary supply is lost during an autoreclose cycle, the autoreclose function is totally disabled.

21.2.2 Autoreclose menu

The setting of the Autoreclose function is described in the following table:

The same settings apply for the Menu PROTECTION G2.

MENU TEXT	SETTING RANGE		STEP SIZE
PROTECTION G1	**MIN**	**MAX**	
Autoreclose ?	NO	YES	
Ext CB Fail ?	NO	YES	
Ext CB Fail Time	10 ms	600 s	10 ms
Ext Block ?	NO	YES	
tD1	10 ms	300 000 ms	10 ms
tD2	10 ms	300 000 ms	10 ms
tD3	10 ms	600 000 ms	10 ms
tD4	10 ms	600 000 ms	10 ms
Reclaim Time tR	20 ms	600 000 ms	10 ms
Inhib Time tI	20 ms	600 000 ms	10 ms
Phase Cycles	0	4	1
E/Gnd Cycles	0	4	1
CYCLES tI>	4321 1201		
CYCLES tI>>	4321 1211		
CYCLES tI>>>	4321 1110		
CYCLES tIe>	4321 0111		
CYCLES tIe>>	4321 1121		
CYCLES tIe>>>	4321 1111		
CYCLES tAux1	4321 1112		
CYCLES tAux2	4321 0101		

Example of setting :

CYCLES tI>	4321 1201

4321 are the cycles associated to the trip on tI> pick up
1201 are the actions to be executed after the tI> time delay has elapsed :

0 = no action on autorecloser : definitive trip
1 = trip on tI> pick up, followed by a reclosing cycle
2 = no trip on tI> pick up : and this whatever the setting is in the **AUTOMAT. CRTL/Trip commands/Trip tI>** menu.

In addition to these settings, the user will be able to fully link the autoreclose function to the protection function using the menus **PROTECTION G1/Phase OC** and **PROTECTION/E/Gnd.** Refer to Chapter 3 of the Technical Guide.

21.2.3 Logic Functions

21.2.3.1 Logic Inputs

The autoreclose function has four inputs that can be assigned to the autoreclose logic. These inputs can be opto-isolated inputs configured for that under the **AUTOMAT. CTRL** menu. External contacts can then be wired to be used as an input and influence the autorecloser scheme. These 4 inputs are described hereafter.

21.2.3.2 External CB fail

Most of circuit breakers are only able to provide only one trip-close-trip cycle. As a consequence, it is necessary to verify if there is enough power to reclose the CB. The state of the CB (healthy or failed) can be checked using an input that has been assigned to the ***"CB FLT"*** function. If on completion of the dead time, the **CB FLT** input indicates that there is not enough energy availableduring the time ***tCFE***, a lockout occur and the CB remains open.

This function is disabled if not assigned under the **PROTECTION G1/Autoreclose** menu (function **CB FLT** set to NO).

21.2.3.3 External starting orders

Two independent and programmable inputs (AUTOMAT.CTRL/INPUTS menu) can be used to initiate the autorecloser function from an external device (such as an existing overcurrent relay). These logic inputs may be used independently and also in parallel with the MiCOM P123 Overcurrent settings.

These external orders can be independently disabled by not assigning the functions in the **PROTECTION G1/Autoreclose/CYCLES tAux1** and **PROTECTION G1/Autoreclose/CYCLES tAux2** menus.

21.2.3.4 External blocking order

The **Block –79** input can be set under the **AUTOMAT.CTRL/INPUTS** menu. This input can block the autoreclose function and cause a lock-out if the autorecloser function is in progress. It can be used when a protection is needed without requiring the use of the autorecloser function.

A typical example is on a transformer feeder, where the autoreclose may be initiated from the feeder protection but need to be blocked from the transformer protection side.

These external orders can be disabled by not assigning the function in the **PROTECTION/Autoreclose/Ext Block** menu.

21.2.3.5 Autoreclose Logic Outputs

The following output signals can be assigned to relay outputs or to LEDs to provide information about the status of the auto Reclose cycle. These outputs are described hereafter.

21.2.3.6 Autoreclose in progress

The "***Autoreclose in progress***" signal is present during the complete reclose cycles from protection initiation to the end of the reclaim time or lockout.

The "***Autoreclose in progress***" information is allocated to a LED in the ***CONFIGURATION/Led/Recloser Run*** menu.

The "***Autoreclose in progress***" information is allocated to the output relays in the ***AUTOMAT.CTRL/Output Relays/79 Run*** menu.

21.2.3.7 Final trip

The "***Final trip***" signal indicates that a complete autoreclose cycle has been completed and that the fault has been cleared. The "***Final trip***" signal can be reset after a manual closing of the CBafter the inhibit time (tl).

This inhibit time (tl) can be set under the menu ***PROTECTION G1/Autoreclose/Inhib Time***.

The "***Final trip***" signal can be assigned to the output relays under the menu ***AUTOMAT.Ctrl/Output Relays/79 Trip***.

The "***Final trip***" signal can be assigned to a LED under the menu ***CONFIGURATION/Led/Recloser Blocked***.

21.2.4 Autoreclose logic description

The autoreclose function provides the ability to automatically control the autorecloser. This function can perform two, three or four shot cycle. The parameters ***Phase Cycles*** numbers and ***E/Gnd Cycles*** numbers are used to enter the number of shots chosen. Dead times for all the shots (reclose attempts) can be independently adjusted.

The number of shots is directly related to the type of faults likely to occur on the system and the voltage level of the system. Generally, on medium voltage networks where the percentage of transient and non-permanent faults is likely to be high, a multi-shot autoreclose device will increase the possibility for the distribution line to be successfully re-energised after the reclosure of the circuit breaker.

The crossing of a protection element (phase or earth) will trigger the autoreclose provided circuit breaker was closed before that. The dead time (***Dead Time tD1***, ***Dead Time tD2***, ***Dead Time tD3***, ***Dead Time tD4***) starts when the CB has tripped (when the 52a input has disappeared).

At the end of the relevant dead time, a CB close signal is sent, provided that certain system conditions are met. For example, the spring that allows the circuit breaker to close should be fully charged. The ***CB FLT*** input provides this information . The CB close signal dropped off as soon as the circuit breaker closes.

The reclaim time (***Reclaim Time***) starts when the CB has closed.

If the circuit breaker does not trip again, the autoreclose function resets at the end of the reclaim time.

If the protection operates during the reclaim time, the relay either advances to the next shot that is programmed in the autoreclose cycle, or, if all the programmed reclose attempts have been accomplished, it locks out.

The total number of reclosures is displayed under the ***MEASUREMENT*** menu. This value can be reset to zero pressing the key "C" (Clear) in the ***MEASUREMENTS/Reclose Stats*** menu.

21.2.5 Autoreclose Inhibit Following Manual Close

The "***Inhib Time tI***" timer can be used to block the autoreclose being initiated after the CB is manually closed onto a fault. The Autoreclose is blocked during the "***Inhib Time tI***" following manual CB Closure.

21.2.6 Recloser lockout

If the protection element operates during the reclaim time, following the final reclose attempt, the relay will lockout and the autoreclose function is disabled until the lockout condition resets.

The lockout condition can reset by a manual closing after the "*Inhib Time tI*".

The Autoreclose can also be locked out using a ***CB FLT*** input. The external information can be generated by the spring of the CB is not charged or suffers a low gas.This CB FLT information can be issued from the "not charged" or "Low gas pressure" indications of CB springs.

Note that Autoreclose can also be locked by :

- The fact that the CB doesn't open after tBf delay (CB Fail)
- An operating time that is above programmed thresholds.

21.2.7 Setting group change lockout

The change of setting groups on MiCOM P122 and P123 is only possible if there are no protection or automation functions running (except the thermal overload function). During the autorecloser cycle, if the relay receives an order to change setting groups, this order is kept in memory, and will only be executed after the timer has elapsed.

21.3 Setting Guidelines

21.3.1 Number Of Shots

There is no perfect rule to define the number of shots for a particular application. For medium voltage systems it is common to use two or three autoreclose shots. However, in some countries, for specific applications, the use of four shots is not uncommon. The advantage of using four shots is that the final dead time can be set for a time long enough to allow thunderstorms to stop before definitive final reclose. This scheme prevents unnecessary lockout caused by consecutive transient faults.

Typically, the first trip, and sometimes the second, are caused by the instantaneous protection. Since 80% of faults are transient, the following trips will be time delayed, and all will have increasing dead times to clear non-permanent faults.

In order to determine the number of shots required, it is important to take into account the following factors.

The first factor is the ability for the circuit breaker to perform several trip-close operations in a short time and, the effect of these operations on the maintenance period.

If the statistics made on a particular system reveal a moderate percentage of non-permanent faults which could be burned out, two or more shots are justified. In addition to this, if fused 'tees' are used and the fault level is low, the timer of the fuses may not discriminate with the main IDMT relay and it would then be useful to have several shots. The use of several shots would then be useful, as this would warm up the fuse to a such extent that it would eventually blow before the main protection operated.

21.3.2 Dead Timer Setting

It is important to take the following factors into consideration when setting the dead timer.

21.3.2.1 Load

Due to the great diversity of load which may exist on a system, it may be very difficult to optimise the dead time. However, it is possible to study each type of load separately and thereby be able to define a typical dead time. Hereafter are presented the most common types of loads.

Synchronous motors tolerate only extremely short interruptions of supply without loss of synchronism. In practice, it is desirable to disconnect the motor from the supply in the event of a fault; the dead time should be sufficient to allow the motor no-volt device to operate. Typically, a minimum dead time of 0.2-0.3 seconds is recommended to allow this device to operate.

Induction motors, on the other hand, can withstand supply interruptions, up to a maximum of 0.5 seconds and re-accelerate successfully. In general dead times of 3-10 seconds are normally satisfactory, but there may be special cases for which additional time is required to allow the reset of manual controls and safety devices.

Loss of supply of lighting circuits, such as street lighting, can lead to important safety problems. A 10 seconds loss of supply may be dangerous for car circulation. Regarding domestic customers, the main consideration is linked to the inconvenience caused.

An important criteria for many power utilities is the number of minutes lost per year to customers which will be reduced on feeders using the autorecloser and will also be affected by the dead time settings used.

21.3.2.2 Circuit Breaker

For high speed autoreclose, the minimum dead time of the power system depends on the minimum time delay imposed by the circuit breaker during a trip and reclose operation.

Since a circuit breaker is a mechanical device, it has an inherent contact separation time. This operating time for a modern circuit breaker is usually within the 50-100ms range, but could be longer with older designs.

After a trip, the mechanism need some time to reset before applying a close pulse. This reset time varies depending on the circuit breaker, but lasts typically 0.1 seconds.

Once the circuit breaker has reset, the breaker can start to close. The period of time between the energisation of the closing mechanism and the making of the contacts is called closing time. Because of the time constant of a solenoid closing mechanism and the inertia of the plunger, a solenoid closing mechanism may take 0.3s. A spring operated breaker, on the other hand, can close in less than 0.2 seconds.

Where high speed reclosing is required, for the majority of medium voltage applications, the circuit breaker mechanism dictates itself the minimum dead time. However, the fault de-ionising time may also have to be considered.

High speed autoreclose may be required to maintain stability on a network that has two or more power sources. For high speed autoreclose, the system disturbance time should be minimised using fast protection, <50 ms, such as distance or feeder differential protection and fast circuit breakers < 100 ms. Fast fault clearance can reduce the time for the fault arc to de-ionise.

To ensure stability between two sources, a dead time of <300 ms is typically required. Considering only the CB, this minimum time corresponds to the reset time of the the mechanism plus the CB closing time. Thus, a solenoid mechanism is not adapted for high speed autoreclose due to the fact that the closing time is generally too long.

21.3.2.3 Fault De-ionising Time

For high speed autoreclose, the time to de-ionise faults may be the factor the most important when considering the dead time. This is the time required for the ionised air to disperse around the fault position so that the insulation level of the air is restored. This time may be around the following value:

De-ionising time = (10.5 + ((system voltage in kV)/34.5)) / frequency

For 66 kV = 0.25 s (50Hz)

For 132 kV = 0.29 s (50 Hz)

21.3.2.4 Protection Reset

It is essential that the protection fully resets during the dead time, so that correct time discrimination is maintained after reclose on to a fault. For high speed autoreclose, instantaneous reset of protection is required.

Typical 11/33kV dead time settings in the UK are as follow:

1st dead time = 5 - 10 seconds

2nd dead time = 30 seconds

3rd dead time = 60 - 100 seconds

4th dead time (uncommon in the UK, however used in South Africa) = 60 - 100 seconds

21.3.3 Reclaim Timer Setting

The following factors influence the choice of the reclaim timer:

- Supply continuity - Large reclaim times can result in unnecessary lockout for transient faults.
- Fault incidence/Past experience - Small reclaim times may be required where there is a high incidence of lightning strikes to prevent unnecessary lockout for transient faults.
- Charging time of the spring - For high speed autoreclose, the reclaim time may be set longer than the spring charging time to ensure that there is sufficient energy in the circuit breaker to perform a trip-close-trip cycle. For delayed autoreclose, this setting is of no need as the dead time can be extended by an extra CB healthy check window time if there is insufficient energy in the CB. If there is insufficient energy after the check window time the relay will lockout.
- Switchgear Maintenance - Excessive operation resulting from short reclaim times can mean shorter maintenance periods. A minimum reclaim time of 5s may be needed to give sufficient time to the CB to recover after a trip and close before it can perform another trip-close-trip cycle.

The reclaim time must be long enough to allow any time delayed protection leading to autoreclose to operate. Failure to do so can cause the autoreclose scheme to reset too soon and the reactivation of the instantaneous protection.

If that were the case, a permanent fault would look like some transient faults, caused by continuous autorecloses. Applying a protection against excessive fault frequency lockout is an additional precaution that can solve this problem.

It is possible to obtain short reclaim times by blocking the reclaim time from the protection start signals. If short reclaim times are to be used, then the switchgear rating may dictate the minimum reclaim time. The advantage of a short reclaim time is that there are less lockouts of the CB, and therefore the number of maintenance visits periods would be reduced.

Sensitive earth fault protection is used to detect high resistance earth faults. The time delay of such protections is usually a long time delay, typically about 10-15s. If autoreclose is generated by the SEF protection, this timer must be taken into account when deciding the value of the reclaim time, if the reclaim time is not blocked by an SEF protection start signal. Sensitive earth faults, caused by a broken overhead conductor in contact with dry ground or a wood fence are rarely transient faults and may be dangerous to people.

It is therefore common practice to block the autoreclose using the sensitive earth fault protection and lockout the circuit breaker.

Where motor-wound spring closed circuit breakers are used, the reclaim time must be at least as long as the spring winding time for high speed autoreclose to ensure that the breaker can perform a trip-close-trip cycle.

A typical 11/33kV reclaim time is 3-10 seconds, this prevents unnecessary lockout during thunderstorms. However, times up to 60-180 seconds maybe used.

22. CIRCUIT BREAKER STATE MONITORING

An operator at a remote location requires a reliable indication of the state of the switchgear. Without an indication that each circuit breaker is either open or closed, the operator has insufficient information to decide on switching operations. The MiCOM P120/P121/P122/P123 relays incorporate a circuit breaker state monitoring, giving an indication of the position of the circuit breaker.

This indication is available either on the relay front panel (P122 - P123 only) or via the communication network.

The positions of the CB can be selected under the ***AUTOMAT.CTRL/Inputs*** and ***CONFIGURATION/Led*** menu.

Further, the MiCOM P122 and P123 relays are able to inform the operator that the CB has not opened following a remote trip command (refer section "CB FAIL protection").

23. CIRCUIT BREAKER CONDITION MONITORING (P122 & P123 ONLY)

Periodic maintenance of circuit breakers is necessary to ensure that the trip circuit and that the mechanism operates correctly, and also that the interrupting capability has not been compromised due to previous fault interruptions. Generally, such maintenance is based on a fixed time interval, or a fixed number of fault current interruptions. These methods of monitoring circuit breaker condition give a rough indication only and can lead to excessive maintenance.

The relays record various statistics related to each circuit breaker trip operation, allowing a more accurate assessment of the circuit breaker condition. These monitoring features are discussed in the following section.

23.1 Circuit Breaker Condition Monitoring Features

For each circuit breaker trip operation the relay records statistics as shown in the following table taken from the relay menu. The ***RECORDS/CB Monitoring*** menu cells shown are counter values only.

This information is for reading only.

MENU TEXT	
CB Monitoring	
CB Opening Time	Display the CB opening time (Note 1)
CB Closing Time	Display the CB closing time (Note 2)
CB Operations	Display the number of opening commands executed by the CB
ΣAmps(n) IA	Display the summation of the Amps (or square Amps) interrupted by the CB phase A
Σ Amps(n) IB	Display the summation of the Amps (or square Amps) interrupted by the CB phase B
Σ Amps(n) IC	Display the summation of the Amps (or square Amps) interrupted by the CB phase C

NOTE 1: the CB opening time is measured between the trip command (Trip output relay) and the change of position of O/O (52a).

NOTE 2: the CB closing time is measured between the closing command (output auxiliary relay) and the change of position of O/O (52a).

The above counters in the CB condition monitoring function may be reset to zero, for example, following a maintenance inspection and overhaul.The following table, detailing the options available for the CB condition monitoring, is taken from the relay menu. It includes the setup of the current broken facility and those features which can be set to raise an alarm or CB lockout.

All the settings are available in the ***AUTOMAT.CTRL/CB supervision*** menu.

MENU TEXT	SETTING RANGE		STEP SIZE
	MIN	MAX	
CB Supervision			
CB Open S'vision	No	Yes	
CB Open Time	50 ms	1 000 ms	50 ms
CB Close S'vision	No	Yes	
CB Close Time	50 ms	1 000 ms	50 ms
CB Open Alarm ?	No	Yes	
CB Open NB	0	50 000	1
ΣAmps (n) ?	No	Yes	
ΣAmps (n)	0	4 000 E6	1 E6
n	1	2	1
t Open Pulse	100 ms	5 000 ms	100 ms
t Close Pulse	100 ms	5 000 ms	100 ms

The circuit breaker condition monitoring counters will be updated every time the relay issues a trip command. In cases where the breaker is tripped by an external protection device it is also possible to update the CB condition monitoring. This is achieved by allocating one of the logic inputs or via the communication to accept a trigger from an external device.

23.2 Setting guidelines

23.2.1 Setting the ΣI^n Thresholds

Where overhead lines are prone to frequent faults and are protected by oil circuit breakers (OCB's), oil changes account for a large proportion of the life cycle cost of the switchgear. Generally, oil changes are performed at a fixed interval of circuit breaker fault operations. However, this may result in premature maintenance where fault currents tend to be low, and hence oil degradation is slower than expected.

The ΣI^n counter monitors the cumulative severity of the duty placed on the interrupter allowing a more accurate assessment of the circuit breaker condition to be made.

For OCB's, the dielectric withstand of the oil generally decreases as a function of ΣI^2t. This is where 'I' is the fault current broken, and 't' is the arcing time within the interrupter tank (not the interrupting time). As the arcing time cannot be determined accurately, the relay would normally be set to monitor the sum of the broken current squared, by setting ***n*** = 2.

For other types of circuit breaker, especially those operating on higher voltage systems, practical evidence suggests that the value of ***n*** = 2 may be inappropriate. In such applications ***n'*** may be set to 1.

An alarm in this instance may be indicative of the need for gas/vacuum interrupter HV pressure testing, for example.

It is imperative that any maintenance programme must be fully compliant with the switchgear manufacturer's instructions.

23.2.2 Setting the Number of Operations Thresholds

Every operation of a circuit breaker results in some degree of wear for its components. Thus, routine maintenance, such as oiling of mechanisms, may be based upon the number of operations. Suitable setting of the maintenance threshold will allow an alarm to be raised, indicating when preventative maintenance is due.

Should maintenance not be carried out, the relay can be set to lockout the autoreclose function on reaching a operations threshold. This prevents further reclosure when the circuit breaker has not been maintained to the standard demanded by the switchgear manufacturer's maintenance instructions.

Certain circuit breakers, such as oil circuit breakers (OCB's) can only perform a certain number of fault interruptions before requiring maintenance attention. This is because each fault interruption causes carbonising of the oil, degrading its dielectric properties.

23.2.3 Setting the Operating Time Thresholds

Slow CB operation is also indicative of the need for mechanism maintenance. Therefore, alarm is provided and is settable in the range of 100 ms to 5 s. This time is set in relation to the specified interrupting time of the circuit breaker.

24. UNDERCURRENT PROTECTION FUNCTION (P122 & P123 ONLY)

MiCOM P122 & P123 relays include 2 undercurrent elements. One is dedicated for the CB fail detection (see CB failure protection section).

The other one can be used to provide additional protective functions to prevent damage/further damage to the power system. This function allows typical applications such as loss of load.

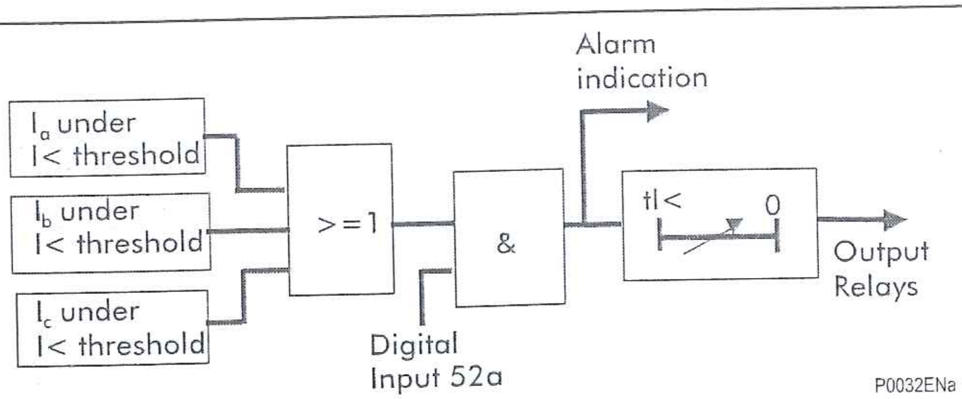


FIGURE 15 : UNDERCURRENT PROTECTION LOGIC

The undercurrent protection function is available only if the auxiliary contact of the CB status is connected to the relay. A logic input should be energised via the 52a contact of the CB.

In this way a logic input (1 to 5 for P123, 1 to 3 for P122) is allocated to the 52a function. See the ***AUTOMAT. CTRL/ Inputs x*** menu.

An alarm is given when :

– at least one of the 3 phase current is detected under the threshold I<

– and the CB is closed.

When the alarm condition is present and lasts longer than the set time tI<, one or more output relay can be energised.

See the ***AUTOMAT. CTRL/trip commands/Trip tI<*** menu to assign tI< to the trip output relay RL1.

See the ***AUTOMAT. CTRL/Output Relays/ tI<*** menu to assign tI< to the auxiliary output relay RL2 to RL8 (to RL6 for P122).

I< threshold can be set under the ***PROTECTION G1(2)/Undercurrent/ I<*** menu from 2% to 100% of the rated current In.

tI< time can be set under the ***PROTECTION G1(2)/Undercurrent/ tI<*** menu from 0 to 150s.

25. CIRCUIT BREAKER FAILURE PROTECTION : CBF (P122 & P123 ONLY)

When a fault is detected, one or more main protection elements will issue a trip order to the associated circuit breaker(s). To isolate the fault, and prevent (heavier) damage on the power system it is essential that the circuit breaker operates correctly.

On power systems, a fault that is not clear quickly enough threatens the stability of the system. It is therefore common practice to install circuit breaker failure protection, which monitors that the circuit breaker has opened within a reasonable period of time. If the fault current has not been eliminated after the set time delay, the breaker failure protection (CBF) will send a signal.

The CBF protection can be used to back-trip upstream circuit breakers to ensure that the fault is correctly isolated. The CBF protection can also eliminate all blocking orders associated to logic selectivity.

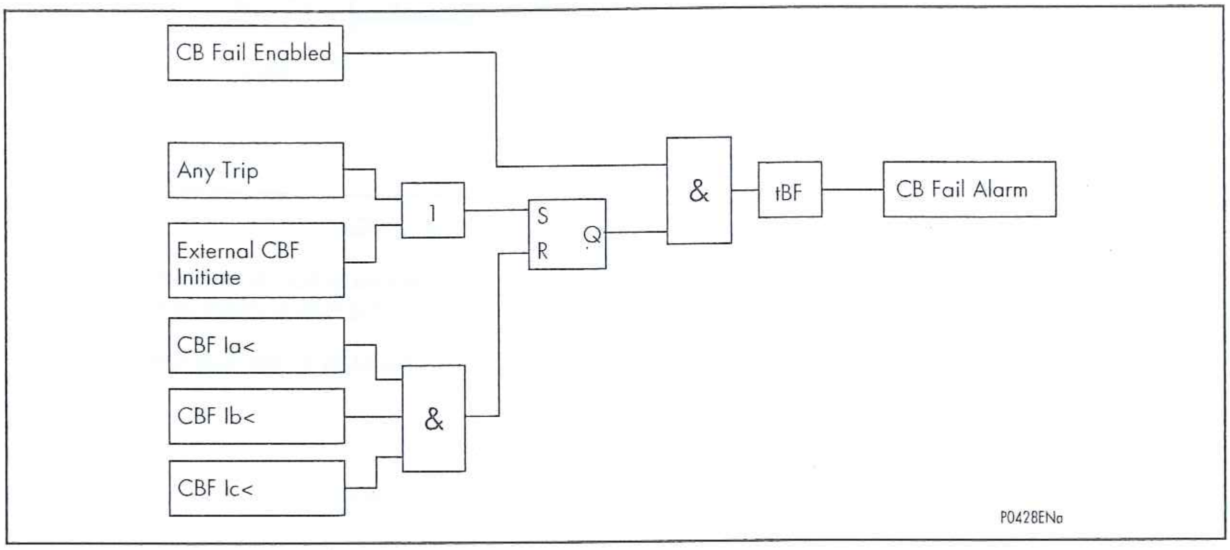


FIGURE 16 : CB FAIL PRINCIPLE

25.1 Circuit Breaker Failure Protection mechanism

Hereafter is described how the CB failure protection available in MiCOM P122 & P123 relays works.

The t BF timer is initiated when a trip order is given to the output relay **RL1**. Note that the trip order can be issued either by a protection element, or by a logic input. Then the relay monitors the current signal of each phase and compares each phase current signal with the bandzone made by the undercurrent I< threshold. This threshold value can be set under the AUTOMAT. CTRL/CB FAIL menu.

Once the t BF timer has been initiated, the relay detects the first time that the current goes out of the I< bandzone. When the relay detects this transition, it initiates an other timer. This timer is of fixed duration and equivalent to 20 samples.

The relay sampling rate being 32 samples by cycle, this timer is of 12,5 ms duration for system at 50 Hz and 10,4 ms for a system at 60 Hz. During this period of time, the relay is checking if the current goes out the I< bandzone again. In case that the current is not eliminated, the current signal should again go out the I< bandzone, and this after half a cycle, i-e 16 samples (10ms at 50Hz).

Each time the relay detects that the current goes out the I< bandzone, the relay re-initiates again the timer (of a 20 samples). In this 20 samples time window, the relay checks that the current signal going out the I< bandzone is in opposite way than the first one.

- If there is no current signal going out in opposite way compared to the first one, the relay considers that there is an opened CB pole condition. The « CB pole open » internal signal is initiated.

- If there is a current signal going out in opposite way compared to the first one, the relay considers that the pole of the CB is not yet open. The « CB pole closed » internal signal is maintained.

Once the t BF time delay has elapsed, the relay checks the internal state of each pole of the circuit breaker. If one or several internal poles are not opened, the relay then declares that the CB has failed. The "CB FAIL" message is displayed.

Note that it is possible to initiate the CB fail detection function by a digital input without having any trip order being given by the relay. In this case, the tBF timer starts its countdown when receiving this digital input signal. If the CB is not opened (by an another protection relay) once the tBF has elapsed, the relay declares that the CB has failed.

The user can associate the digital input to the "CB Fail detection" under the AUTOMAT. CTRL/Inputs menu.

Figure 17 hereafter shows the start of the CB Fail detection after a trip order was sent:

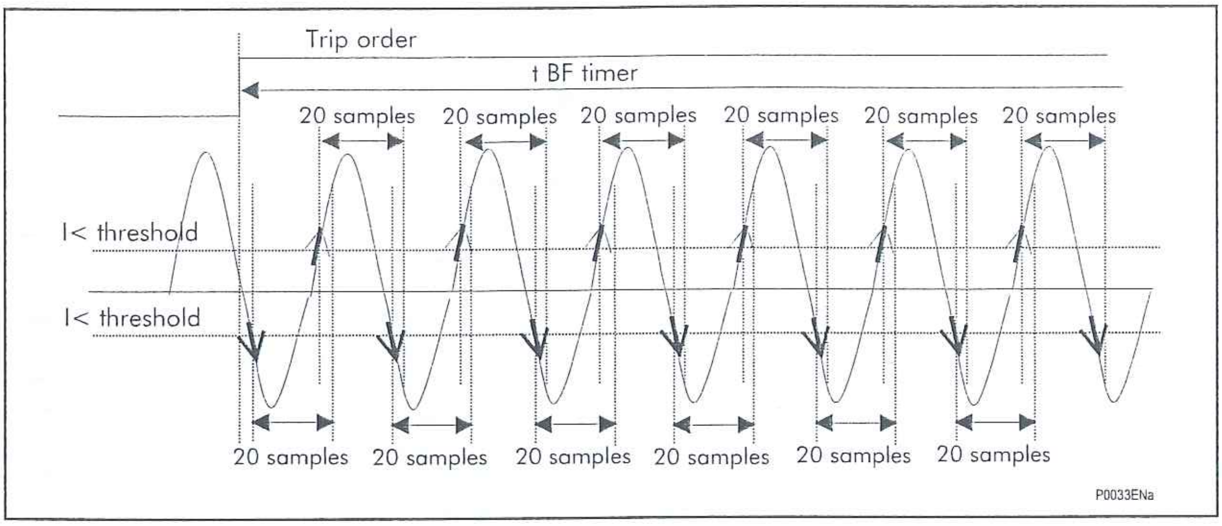


FIGURE 17 : CB FAIL DETECTION PRINCIPLE

Figure 18 hereafter shows the normal opening of the CB before tBF has elapsed. In this case, no CB fail alarm is given.

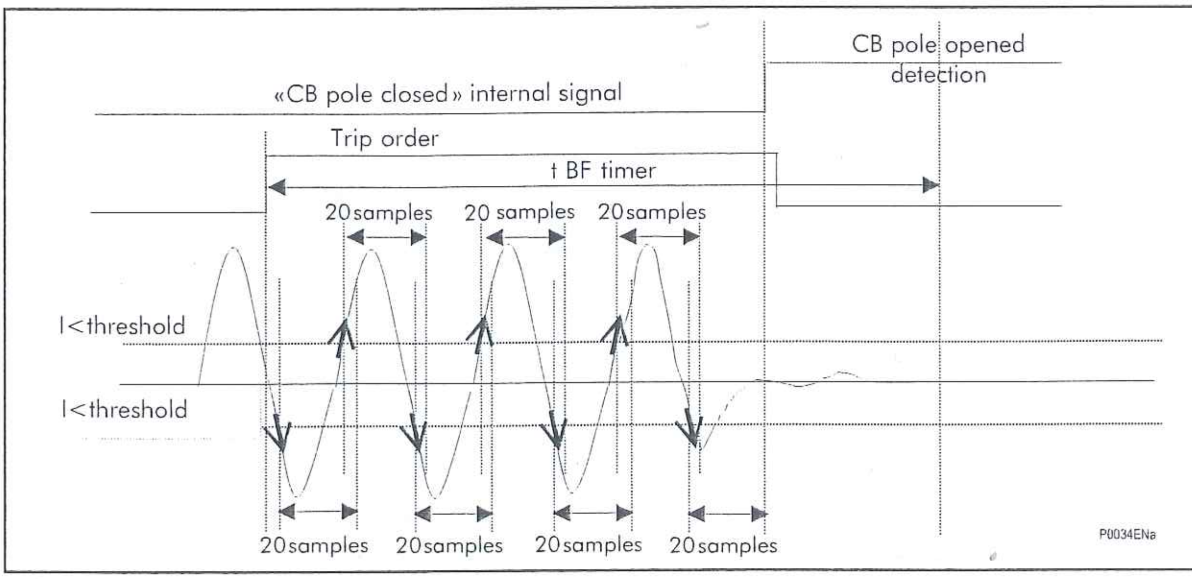


FIGURE 18 : CB OPEN BEFORE tBF EXPIRED

Figure 19 hereafter shows a CB failure condition. After the t BF timer elapses, the relay doesn't detect the opening of the CB pole. Therefore, a CB FAIL signal is given.

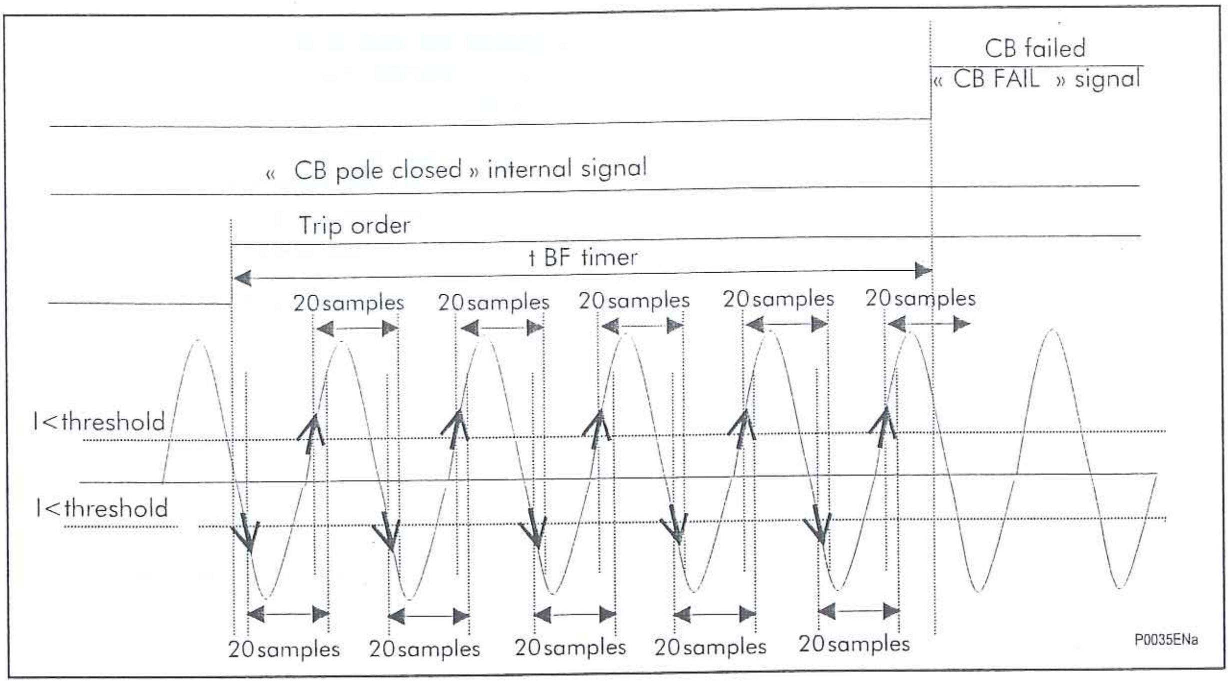


FIGURE 19 : CB NOT YET OPEN BEFORE tBF EXPIRED

Figure 20 hereafter shows an other case of normal CB operation. Once the fault is cleared, the phase current signal takes time to decrease due to the de-magnetisation of the phase CT. It is a typical case for TPY class CTs which are built with air gap in their magnetic core. Before the drop off of the t BF timer, the relay has detected an opening of the CB pole, thus no CB failure signal is given as it is required. A basic Breaker Failure element based on an simple undercurrent element would detect a false CB failure condition as the current signal value is outside the I< bandzone at the t BF timer drop off.

NOTE : Both « CB pole closed » and « CB pole opened » internal signals mentioned in the above diagrams are derived from the Circuit Breaker Failure function algorithm. They are not affected by the status of the relay opto-inputs wired to the 52a and 52b CB auxiliary contacts.

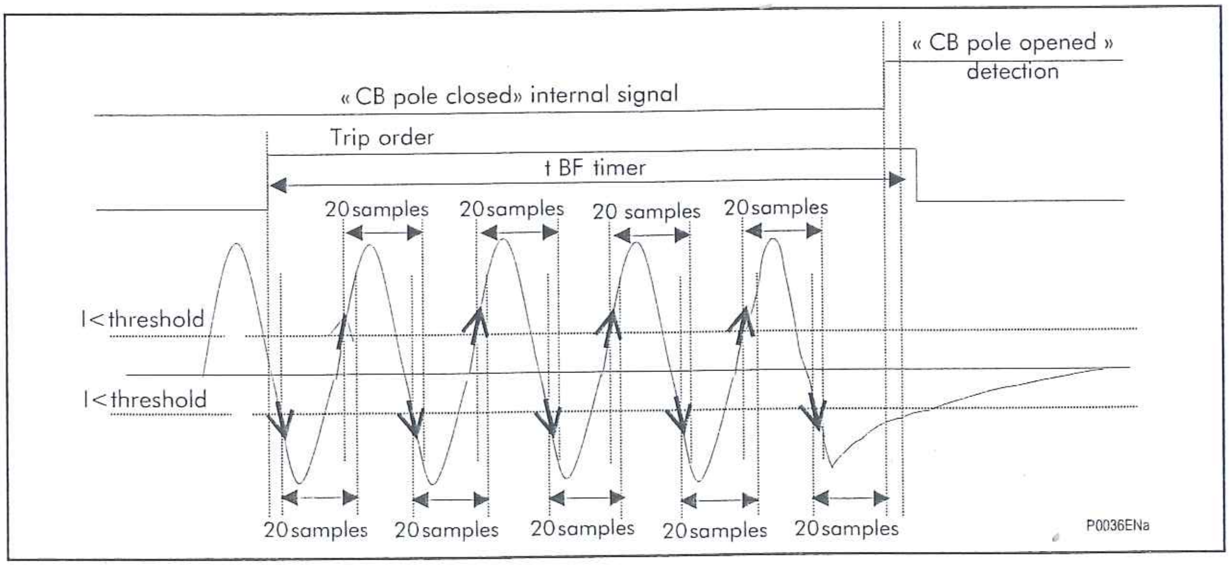


FIGURE 20 : DE-ENERGIZATION OF THE CT PHASE

The selection in the relay menu is grouped as follows:

MENU TEXT	SETTING RANGE		STEP SIZE
	MIN	MAX	
CB Fail ?	No	Yes	
tBF	0.03 s	10 s	10 ms
I<	0.02 In	In	0.01 In

25.2 Typical settings

25.2.1 Breaker Fail Timer Settings

A typical timer setting used with a 2 ½ cycle circuit breaker is around 150 ms.

25.2.2 Breaker Fail Undercurrent Settings

The phase undercurrent settings (I<) must be set to a value that is under the load current, to ensure that I< operation indicates that the circuit breaker pole is open. A typical setting for overhead line or cable circuits is 20% In, with 5% In common for generator circuit breaker CBF.

NOTE: The reset time of P122 and P123 is around 15 ms.

26. TRIP CIRCUIT SUPERVISION (P122 & P123 ONLY)

The trip circuit extends beyond the relay enclosure and passes through more components, such as fuse, wires, relay contacts, auxiliary switch contact and so on.

These complications, coupled with the importance of the circuit, have directed attention to its supervision.

The simplest arrangement for trip circuit supervision contains a healthy trip lamp in series with a resistance placed in parallel with a trip output relay contacts of the protection device.

26.1 Trip Circuit Supervision mechanism

The Trip Circuit Supervision function included in the **MiCOM P122** and **P123** relays is described below:

A logic input is programmed to the **AUTOMAT. CTRL/CB Supervision/TC Supervision** function. The logic input is associated to the label **Trip Circ** within the **AUTOMAT. CTRL/Inputs** menu. Then, this logic input is wired in the trip circuit according to one of the typical application diagrams shown in the following example.

When the function TC Supervision is set to "Yes" under the **CB Supervision** sub-menu, the relay checks continuously on trip circuit continuity whatever the CB status is CB opened or CB closed. The function **TC Supervision** is enabled when the trip logic output (**RL1**) is not energised. The function **TC Supervision** is not enabled when the trip logic output (**RL1**) is energised.

A **52 Fail** (trip circuit failure) signal is generated if the logic input detects no voltage signal during a time longer than the settable timer **tSUP**. See Chapter P12y/EN FT (User Guide) and Chapter P12y/EN TD (Technical Data) for the settings.

As this function is disabled when the trip logic output (**RL1**) is energised, this function is suitable for use with the enabled relay latching logic.

The tSUP timer can be set according to the following table :

MENU TEXT	SETTING RANGE		STEP SIZE
	MIN	MAX	
TC Supervision ?	Yes	No	
tSUP	100ms	10s	50ms

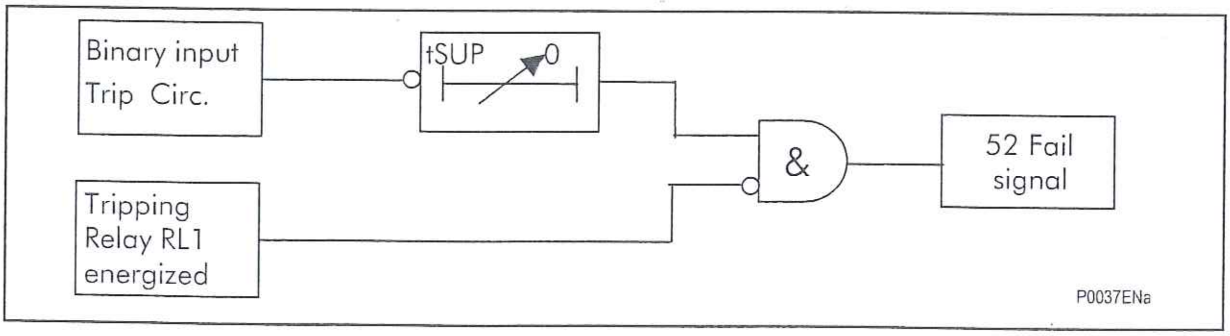


FIGURE 21 : TRIP CIRCUIT SUPERVISION PRINCIPLE DIAGRAM

Three examples of application are given below.

NOTE : It is considered that the CB is fitted out with its own safety device.

Example 1

In this example only the 52a auxiliary contact is available, the MiCOM relay monitors the trip coil whatever the CB status is (CB open or CB closed).

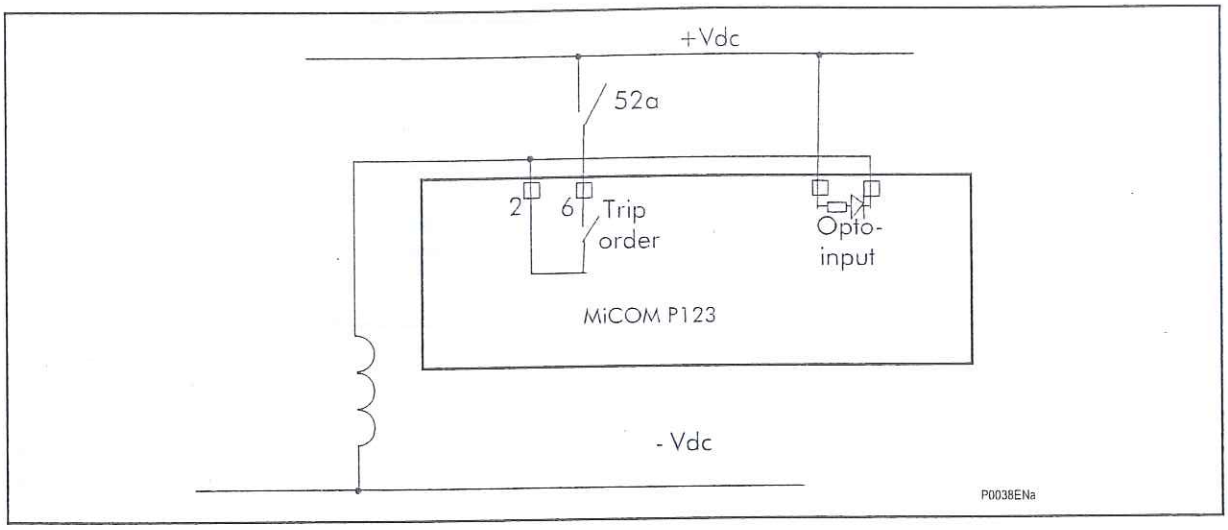


FIGURE 22 : TRIP COIL MONITORING

Example 2

In this example both 52a and 52b auxiliary contacts are available; the MiCOM P122 and P123 relays monitor the complete trip circuit when the CB is closed and a part of the trip circuit when the CB is open.

In this case it is necessary to insert a resistor R1 in series with 52b, if either the output (**RL1**) trip is latched or it stays involuntarily closed, or a long time trip pulse is programmed.

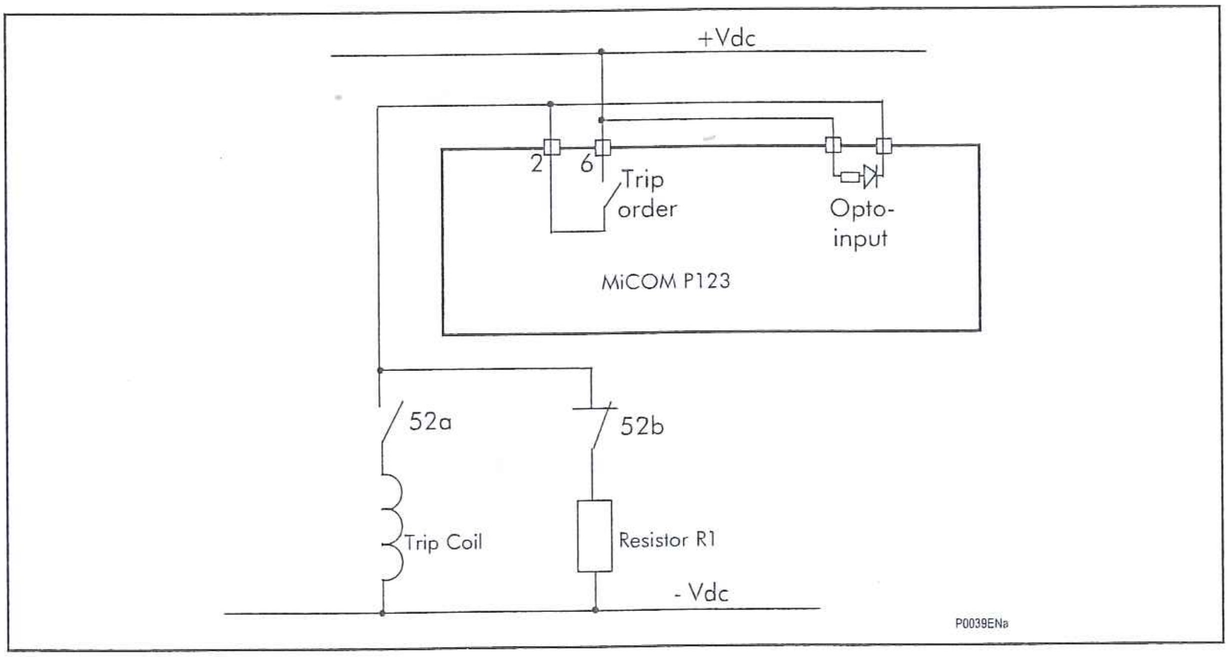


FIGURE 23 : TRIP COIL AND AUXILIARY CONTACTS MONITORING

Example 3

In this example both 52a and 52b auxiliary contacts are available, the MiCOM P122 and P123 relays monitor the complete trip circuit whatever the CB status (CB open or CB closed).

In this case it is necessary to insert a R1, if either the output (**RL1**) trip is latched, or it stays involuntarily closed, or a long time trip pulse is programmed.

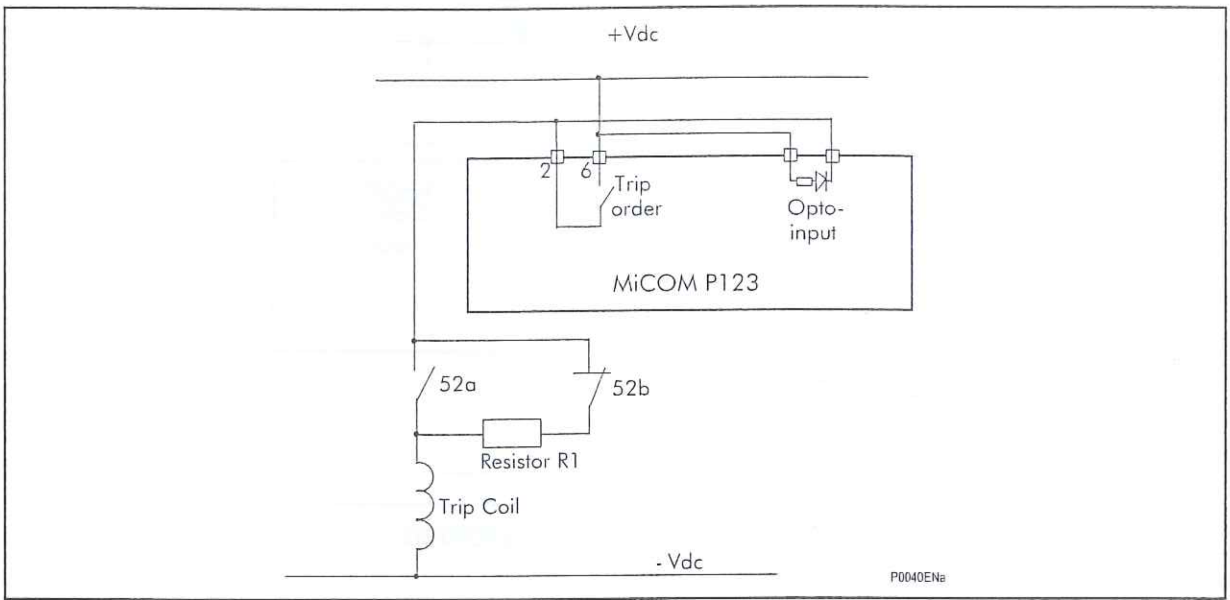


FIGURE 24 : TRIP COIL AND AUXILIARY CONTACTS MONITORING WHATEVER THE POSITION OF THE CB

EXTERNAL RESISTOR R1 CALCULATION

The calculation of the R1 resistor value will take into account that a minimum current is flowing through the logic input. This minimum current value is a function of the relay auxiliary voltage range (Ua).

1 - Case of example No 2 :

The R1 resistor maximum value (in Ohm) is defined by the following formula:

$$R1 < \frac{0{,}8 \times U_a - U_{min}}{I_{min}} [\text{Ohm}]$$

Where:

Ua = auxiliary voltage value (in this case a DC voltage; range is given on label under the top hinged cover. See table below).

Umin = internal minimum voltage value needed for the opto logic input to operate.

Imin = minimum current value needed for the opto logic input to operate.

Relay auxiliary voltage range (Ua)		
24-60 VDC	48-150 VDC	130-250 VDC/110-250 VAC
R1 < (0,8 x Ua – 15)/0.0035	R1 < (0,8 x Ua – 25)/0.0035	R1 < (0,8 x Ua – 38)/0.0022

The R1 resistor withstand value (in Watt) is defined below:

$$P_{R1} > 2 \times \frac{(1{,}2 \times U_a)^2}{R1} [\text{W}]$$

2 - Case of example No 3 :

The R1 resistor maximum value (in Ohm) is defined by the following formula:

$$R1 < \frac{0.8 \times U_a - U_{min}}{I_{min}} - R_{Coil}[Ohm]$$

Where:

Ua = auxiliary voltage value (in this case a DC voltage; range is given on label under the top hinged cover. See table below).

Umin = internal minimum voltage value needed for the opto logic input to operate.

Imin = minimum current value needed for the opto logic input to operate.

R_{coil} = Trip coil resistance value.

Relay auxiliary voltage range (Ua)		
24 – 60 VDC	48 – 150 VDC	130 – 250 VDC/110-250 VAC
R1 < (0,8 x Ua – 15)/0.0035–R_{coil}	R1 < (0,8 x Ua – 25)/0,0035–R_{coil}	R1 < (0,8 x Ua – 38)/0,0022–R_{coil}

The R1 resistor withstand value (in Watt) is defined below:

$$P_{R1} > 2 \times \frac{(1{,}2 \times U_a)^2}{(R1 + R_{Coil})} [W]$$

NOTES:

- The presence of auxiliary relays, such as an anti-pumping system for instance, in the trip circuit must be taken into account for the R1 resistance values specification.
- We consider that the maximum variations of the auxiliary voltage value is ±20%.

27. EVENT RECORDS (P122 & P123 ONLY)

The relay records and time tags up to 75 events and stores them in a non-volatile (battery backed up) memory. This allows the system operator to analyse the sequence of events that occurred within the relay after a particular power system condition, or switching sequence, etc. When the available space is exhausted, the new fault automatically overwrites the oldest fault.

The real time clock within the relay times tag each event, with a resolution of 1ms.

The user can view event records either via the front panel interface, via the EIA (RS) 232 port, or remotely, via the rear EIA (RS) 485 port.

28. FAULT RECORDS (P122 & P123 ONLY)

Each time any of the programmed thresholds are crossed, a fault record is created and stored in memory. The fault record tags up to 5 faults and stores them in a non-volatile (battery backed up) memory. This allows the system operator to identify and analyse network failures. When the available memory space is exhausted, the new fault automatically overwrites the oldest fault.

The user can view actual fault record under the ***RECORD/Fault Record*** menu, where he can select to display up to 5 stored records. These records are fault flags, fault measurements, etc. Also note that the time stamp displayed in the fault record itself will be more accurate than the corresponding time stamp given in the event record. This is due to the fact that events are logged some time after the actual fault record happens.

The user can view event records either via the front panel interface, via the EIA (RS) 232 port, or remotely, via the rear EIA (RS) 485 port.

29. INSTANTANEOUS RECORDER (P122 & P123 ONLY)

Each time any of programmed thresholds are crossed, an instantaneous record is created and displayed under the RECORDS/Instantaneous menu. The last five starting information with the duration of the information are available.

The following information is displayed under the RECORDS/Fault Record menu: number of faults, hour, date, origin (crossing of I>, I>>, I>>> or Ie>, Ie>> or Ie>>> thresholds), duration of the instantaneous, and if the crossing of the threshold lead to a trip or not.

30. DISTURBANCE RECORDER (P122 & P123 ONLY)

The integral disturbance recorder has a memory space specifically dedicated for storage of disturbance records. Up to 5 disturbance records of 3 seconds duration each can be stored. When the available memory space is exhausted, the new record automatically overwrites the oldest record.

The recorder stores actual samples that are taken at a rate of 32 samples per cycle.

Each disturbance record consists of analogue and digital channels. (Note that the relevant CT ratios for the analogue channels are also extracted to enable scaling to primary quantities). The ***RECORD/DISTURB RECORD*** menu is shown below :

MENU TEXT	SETTING RANGE		STEP SIZE
	MIN	MAX	
Disturb Record			
Pre-Time	100 ms	3000 ms	100 ms
Post-Time	100 ms	3000 ms	100 ms
Disturb Rec Trig	On Instantaneous	On Trip	

The total disturbance recording time is 3.0 s (pre-trigger plus post-trigger). For example, default settings show that if the pre-time time is set to 100 ms and the post -time to 2.5 s, than the total disturbance recording time will be 2.6 s.

31. ROLLING AND PEAK VALUE DEMANDS (P122 & P123 ONLY)

MiCOM P122 and P123 relays can store the 3 phases rolling average and maximum subperiod values. The description and principle of calculation are presented hereafter.

31.1 Rolling demand

Calculation of the rolling demand value for IA, Ib and IC currents is done the following way:

- Calculation of the average of the RMS values on a "Rolling Sub Period" period.

The width of the period "Rolling Sub Period" can be set under the "RECORDS/Rolling Demand/Sub Period" menu.

Setting range : from 1 to 60 minutes.

- Storage of these values in a sliding window.

Calculation of the average of these average values (sliding window values) on the number of "Num of Sub Periods" periods.

The number of Sub Period "Num of Sub Periods" can be set under the "RECORDS/Rolling Demand/Num of Sub Per" menu.

Setting range : from 1 to 24.

- Display of the first result under the MEASUREMENTS menu only after the storage of "Num of Sub Periods" periods. The 3 phases Rolling average value are displayed :

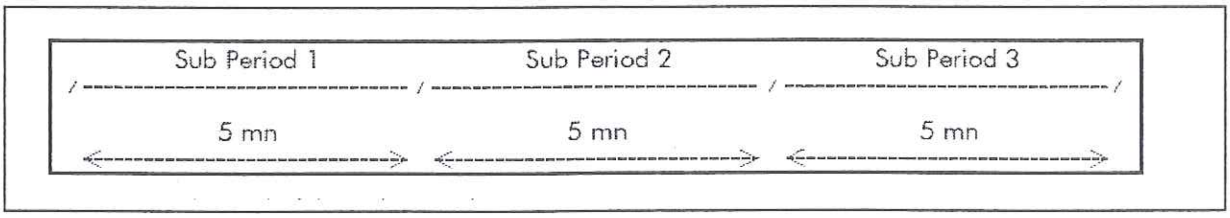
Rolling Average IA RMS
Rolling Average IB RMS
Rolling Average IC RMS

The calculation is reset either via the front operator interface (Key c) without entering a password, or by a remote command.

NOTE : In case of loss of power supply the rolling demand are not stored. A modification of the settings (either "Rolling Sub Period" or "Num of Sub Periods" parameter) reset the calculation.

Example :

Sub Period = 5 mn
Num of Sub Period = 2



At the end of the Sub Period 2 :
Rolling average value = (average value 1 + average value 2)/2

At the end of the Sub Period 3 :
New Rolling average value = (average value 2 + average value 3)/2

31.2 Peak value demand

The principle of calculation of the Peak value demand for IA, IB and IC currents is the following :

For every "Rolling Sub Period", a new average value is compared with the previous value calculated at the previous "Rolling Sub Period". If this new value is greater than the previous value already stored, then this new value is stored instead of the previous one.
In the other way, if this new value is lower than the previous value already stored, then the previous value is stored.
This way the average peak vale will be refreshed each Sub Period;

There is no dedicated setting for this calculation. The setting of the Sub Period in the RECORDS menu is used.

The 3 phase Peak value demand are displayed in the MEASUREMENTS menu :

MAX SUBPERIOD IA RMS
MAX SUBPERIOD IB RMS
MAX SUBPERIOD IC RMS

- The calculation is reset either by pushing key ⓒ without using a password, or by remote command.

  NOTE : In case of loss of power supply, Peak average values are stored. A modification of the "Rolling Sub Period" parameter reset the calculation.

32. CT REQUIREMENTS

Hereafter are presented the CT requirements for MiCOM P12x Overcurrent. Current transformer requirements are based on a potential maximum fault current that is 50 times the relay rated current (In) and on the setting of the instantaneous at 25 times rated current (In). The current transformer requirements are designed to provide operation of all protection elements.

When the criteria for a specific application are higher than the criteria described above, or when the actual lead resistance exceeds the limiting value recommended, it may be desirable to increase the CT requirements according to the following formula.

Nominal Rating	Nominal Output	Accuracy Class	Accuracy Limit Factor	Limiting lead resistance
1A	2.5VA	10P	20	1.3 ohms
5A	7.5VA	10P	20	0.11 ohms

32.1 Definite time / IDMT overcurrent & earth fault protection

Time-delayed Phase overcurrent elements :

$$V_K \geq I_{cp}/2 * (R_{CT} + R_L + R_{rp})$$

Time-delayed Earth Fault overcurrent elements :

$$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

32.2 Instantaneous overcurrent & earth fault protection

CT requirements for instantaneous phase overcurrent elements :

$$V_K \geq I_{sp}/2 * (R_{CT} + R_L + R_{rp})$$

CT requirements for instantaneous earth fault overcurrent elements :

$$V_K \geq I_{sn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

32.3 Definite time / IDMT sensitive earth fault (SEF) protection

Time delay SEF protection :

$$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

SEF Protection - as fed from a core-balance CT :

The type of current transformers that are required are core balance type and with metering class accuracy and with a limiting secondary voltage that follows the following formula:

Time Delayed element:

$$V_K \geq I_{cn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

Instantaneous element:

$$V_K \geq I_{fn}/2 * (R_{CT} + 2R_L + R_{rp} + R_{rn})$$

In addition, note that phase error of the applied core balance current transformer should be less than 90 minutes at 10% of rated current and less than 150 minutes at 1% of rated current.

Abbreviations used in the previous formula are explained below:

Where :

VK = Required CT knee-point voltage (volts),
Ifn = Maximum prospective secondary earth fault current (amps),
Ifp = Maximum prospective secondary phase fault current (amps),
Icn = Maximum prospective secondary earth fault current or 31 times I> setting (whichever is lower) (amps),
Icp = Maximum prospective secondary phase fault current or 31 times I> setting (whichever is lower) (amps),
Isn = Stage 2 & 3 Earth Fault setting (amps),
Isp = Stage 2 and 3 setting (amps),
RCT = Resistance of current transformer secondary winding (ohms)
RL = Resistance of a single lead from relay to current transformer (ohms),
Rrp = Impedance of relay phase current input at 30In (ohms),
Rrn = Impedance of the relay neutral current input at 30In (ohms).

32.4 Low impedance restricted earth fault (REF) protection

$V_K \geq 24 * In * (R_{CT} + 2R_L)$ for $X/R < 40$ and if $< 15In$

$V_K \geq 48 * In * (R_{CT} + 2R_L)$ for $X/R < 40$, $15In < If < 40In$ and $40 < X/R < 120$, $If < 15In$

Where :

V_K = Required CT knee point voltage (volts),
I_n = Rated secondary current (amps),
R_{CT} = Resistance of current transformer secondary winding (ohms)
R_L = Resistance of a single lead from relay to current transformer (ohms),
If = Maximum through fault current level (amps).

32.5 High Impedance Restricted Earth Fault Protection

The High Impedance Restricted Earth Fault element shall remain stable for through faults and shall operate in less than 40ms for internal faults provided that following equations are met when determining CT requirements and the value of the associated stabilising resistor:

$$Rs = [K * (If) * (R_{CT} + 2R_L)] / I_S$$

$$V_K \geq 4 * Is * Rs$$

K = 1 for Vk/Vs less or equal to 16
K = 1.2 for Vk/Vs greater than 16

Where :

V_K = Required CT knee-point voltage (volts),
Rs = Value of Stabilising resistor (ohms),
If = Maximum through fault current level (amps).
V_K = CT knee point voltage (volts),
I_S = Current setting of REF element (amps),
R_{CT} = Resistance of current transformer secondary winding (ohms),
R_L = Resistance of a single lead from relay to current transformer (ohms).

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