MSCDN – MP1

Capacitor unbalance protection

Document Release History

This document is issue 2011/10. The list of revisions up to and including this issue is:
Pre release

2011/10	Reference to 60Hz removed
2010/02	Document reformat due to rebrand
28/04/05	R7 Changed all references to CT-X 50 to 87/50-X-1, and changed 87/50-X to 87/50-X-2. Added description of the 87/50-X-X Inhibit DO Delay and use to provide temporary blocking during switching transients.
27/02/03	R6 Default instruments added. Drawings updated
14/02/2003	R5 Minor typos removed
12/02/2003	R4 Ansi diagram added to Introduction
07/02/2003	R3 Type on menu structure corrected
23/01/2003	R2 Software revision now 9
23/10/2002	R1 Revision History Added. C1 and C2 Primary and Secondary Meters removed.

Software Revision History

05/05/2005	2621H80001R9a	

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1 Introduction

The MSCDN-MP1 represents an integration of the protection elements required to provide a single box Main 1 protection unit, these include Overall Differential protection and Capacitor Unbalance protection, and additional Phase Unbalance backup protection. Together with it's sister units MSCDN-MP2A and MP2B, this protection unit offers a complete solution for Main 1 and Main 2 protection of EHV capacitor banks.

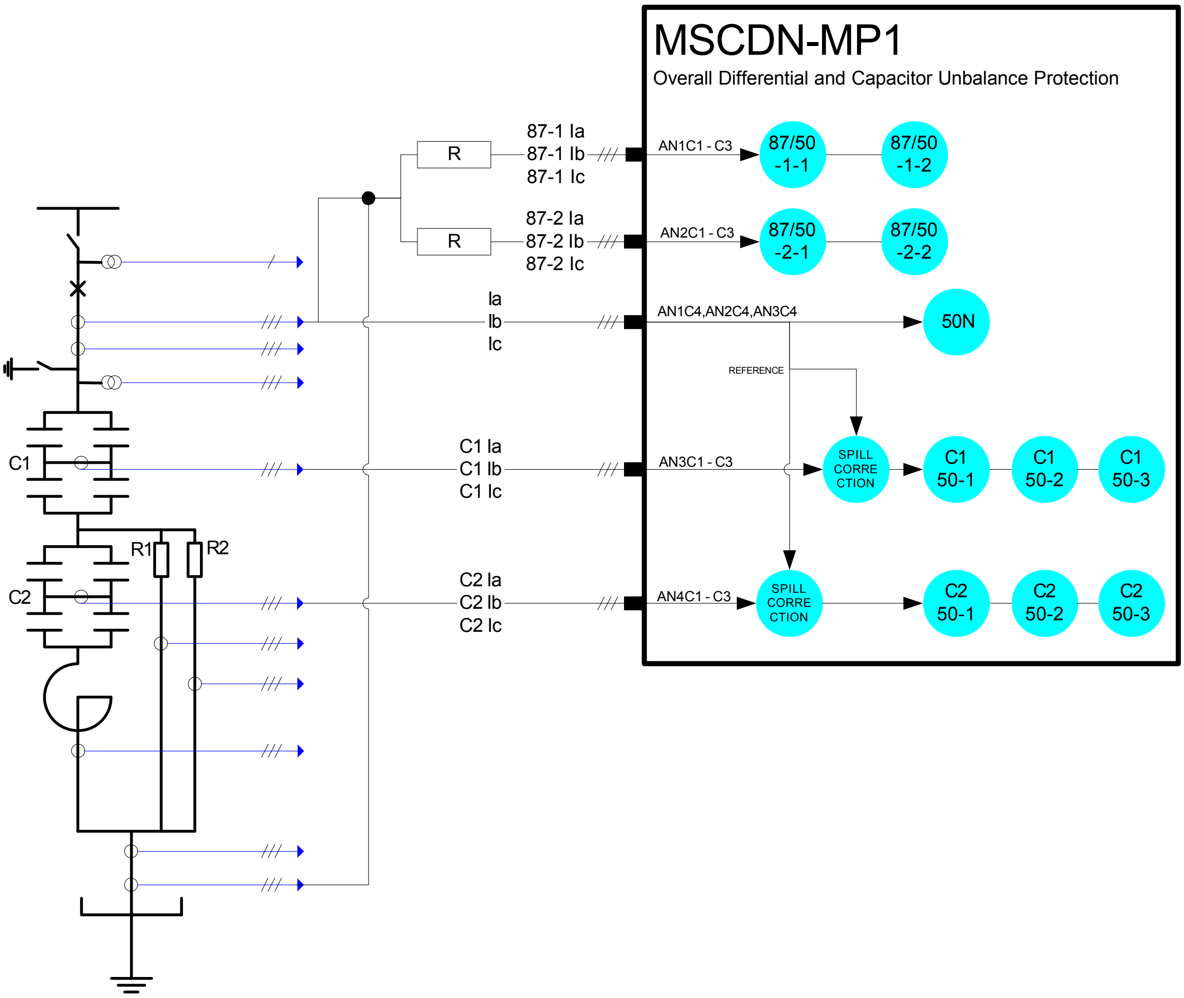

Figure 1 – MSCDN MP1 Capacitor Unbalance Protection

2 Hardware Description

2.1 General

The structure of the relay is based upon the Modular II hardware and software platform illustrated in Figure 3 where the required cards plug in from the front after opening the front fascia. Modules are interconnected by means of ribbon cable. The relay is only supplied in a standard Epsilon case size E16. The Modular II design provides commonality between products and spare parts across a range of protection and control relays including Duobias, Ohmega, Delta, Tau and Iota.

Configuration :

Analogue Inputs	Status Inputs	Output Relays	Case	Connections
16	19	21	E16	2621W11001

Each analogue module has up to four inputs; the first three are usually for measuring the CT secondary line currents from each of the three phases A, B and C.

The unit consists of the following modules:

1) Four Analogue Input modules (4 x I per module)

2) One Controller CPU module

3) One Power Supply and Basic I/O module

4) Two Output relay/Status Input Module

5) One Front Fascia

2.2 Analogue Inputs

Four analogue modules are used in the case style E16. Each module consists of up to 4 channels of current.

In order to ensure high accuracy true RMS measurements and accurate phase and slip frequency calculations, the current signals are sampled at a minimum of 8 samples per cycle for 50Hz system frequency. This sampling rate also provides high accuracy and waveform storage records

2.3 Status Inputs

The relay is fitted with 19 status inputs. The user can program the relay to use any status input for any function. A timer is associated with each input and a pickup time setting may be applied to each input. In addition each input may be logically inverted to allow easy integration of the relay within the user scheme. Each input may be mapped to any front Fascia LED and/or to any Output Relay contact. This allows the Relay to act as panel indication for alarms and scheme status without having to use additional external flagging elements. The reference for each input is “Aux I/P X Operated” (where X is the input number), in both the OUTPUT RELAY MENU and the LED MENU. The functional relationship between these features is shown in Figure 2 – Status Input Functionality

2.4 Output Relays

The relay is fitted with 21 output relays, all of which are capable of handling circuit breaker tripping duty. All relays are fully user configurable and can be programmed to operate from any or all of the control functions. There are three relays on the Power Supply/Basic I/O module which have C/O contacts and 2 with N/O contacts. An additional module is fitted with 8 N/O contacts.

In their normal mode of operation output relays remain energised for a minimum of 100msec and a maximum dependent on the energising condition duration. If required, however, outputs can be programmed to operate as latching relays. These latched outputs can be reset by either pressing the TEST/RESET button, or by sending an appropriate communications command.

The operation of the contacts can be simply checked by using the Protection Healthy setting on the Output Relay Menu to energise each relay in turn. Do not forget to reset this setting back to its correct value.

The output relays can be used to operate the trip coils of the circuit breaker directly if the circuit breaker auxiliary contacts are used to break the trip coil current and the contact rating of the relay output contacts is not exceeded for 'make and carry' currents.

With a failed breaker condition the current 'break' may be transferred to the relay output contacts and where this level is above the break rating of the contacts an auxiliary relay with heavy-duty contacts should be utilised.

2.5 Fascia LEDS

In the E16 case there are 32 user programmable LED flag indicators. By opening the front panel it is possible to insert a strip into a slip in pocket, which provides legend information about the meaning of each LED. The legend may be specified when ordering the relay or alternatively the user can create a customized legend. The user can customise which LED is used for which purpose as well as being able to program each LED as being latching or self –resetting.

2.6 Self Monitoring

The relay incorporates a number of self-monitoring features. Each of these features can initiate a controlled reset recovery sequence, which can be used to generate an alarm output. In addition, the Protection Healthy LED will give visual indication.

A watchdog timer continuously monitors the microprocessor. The voltage rails are also continuously supervised and the microprocessor is reset if any of the rails falls outside of their working ranges. Any failure is detected in sufficient time so that the micro can be shut down in a safe and controlled manner.

2.6.1 Protection Healthy/Defective

The normally closed contacts of relay 1 are used to signal protection defective, whilst the normally open contacts are used to signal protection healthy. When the DC supply is not applied to the relay or a problem is detected with the operation of the relay then this relay is de-energised and the normally closed contacts make to provide an external alarm. When the relay has DC supply and it has successfully passed its self-checking procedure then the Protection Healthy contacts are made and the Protection Defective contacts are opened.

3 Protection Functions

3.1 Overall Differential (87/50)

The Overall Differential protection uses the high impedance circulating current principle, a single line diagram of such a scheme is shown in Figure 5 – High Impedance Differential Schematic. The protection consists of two DTL over-current elements 87/50-1-1and 87/50-1-2, both elements have identical setting ranges and are normally configured to provide two stage protection. The protection is duplicated for dependability, with elements 87/50-2-1 and 87/50-2-2 available for this purpose.

Transient stability under through fault conditions is a problem with many forms of differential protection, due to variations in CT magnetising characteristics. When saturation is approached, the current transformer output waveforms become increasingly distorted, with a high percentage of 3^{rd} and other harmonics, the algorithms employed in the Overall Differential protection ensure complete harmonic rejection, thus improving overall protection stability.

In addition the settings for high impedance differential protection are calculated assuming that one CT is completely saturated. Using this worst case condition the voltage, (determined by the value of the stabilising resistor), and current settings for the 87/50 elements can be precisely calculated, with known stability margins. Intermediate conditions where the CT is only partially saturated, increases the stability margin. This approach enables schemes to be engineered with relatively low knee-point voltages.

3.2 Capacitor Unbalance Protection (C1 50 and C2 50)

The relay contains two identical Capacitor Unbalance protection units, which are primarily designed to protect phase segregated capacitor stacks, with a central ‘H’ connection, although application to alternative stack arrangements is possible. Thus providing complete Capacitor Unbalance protection for main and auxiliary capacitor stacks.

For each unit, expected capacitive spill current for each phase is calculated, based on a proportion of the overall Capacitor Bank current. This expected spill current is then compared with the measured phase spill current and this difference is the operating quantity for the three DTL elements available per unit. Each DTL element is phase segregated, but utilises a common operate setting.

3.2.1 Principle Of Operation

Consider the single phase capacitor stack shown in Figure 6 – Capacitor Unbalance Protection – Phasor Representation of Operating principle, the overall capacitor current is designated the Reference current and therefore for a given capacitor bank configuration, the Spill current across the 'H' Section will be proportional to the Reference and at constant phase angle Ø, this is shown as *(1) - Nominal Condition*.

Should the Reference current increase, due to rise in voltage across the capacitor, then the Spill current will increase, in proportion to the Reference, but this does increase does not indicate a capacitor fault, i.e. *(2) – Normal Condition.*

Measurement of the Reference current and the Spill current at nominal conditions, i.e. rated voltage, allows determination of the Ix Reference, Cy Ix Spill and Cy Ix Angle settings, (where Cy = C1, C2 and Ix Ia, Ib, Ic). These settings allow the Ratio and Angle between Reference and Spill current under healthy conditions to be determined. The Ratio and Angle are then used to calculate the Expected Spill phasor, for any measured Reference current, which is then compared to the measured Spill current, this difference is the Operate Quantity. This is shown as diagram *(3) – Derivation of Operating Quantity*, in this case the Measured Spill current has the same magnitude as the Expected Spill current, but lags the Reference current by angle Φ, however in this case the Operate Quantity is below the pickup level of the C1 50 element.

Diagram (4) – Operate Condition shows phase lag Φ has increased due to a capacitor fault and the Operate Quantity is now above the Operate Setting and the element operates after the given DTL time delay.

A representation of the processing of a single phase calculation is shown in Figure 7 – Capacitor Unbalance Protection - RDL Processing Diagram.

3.3 Phase Unbalance Protection (50N)

The operating quantity for the 50N element, is calculated from the RMS residual of the three phase currents, which is then connected to a DTL overcurrent element.

3.4 Trip Circuit Supervision

Status inputs on the relay can be used to supervise trip circuits while the associated circuit breakers (CB) are either open or closed. Since the status inputs can be programmed to operate output contacts and LED's, alarms can be also generated from this feature.

To use the function set 'Trip Cct Pickup Delay to the required value in the Reylogic Elements Menu and then map the 'Trip Circuit Fail' settings in the Output Relay Menu and LED Menu as required.

See the Applications Guide for more details on the trip circuit supervision scheme.

4 Other Features

4.1 Metering

The metering feature provides real-time data available from the relay fascia in the 'Instruments Mode' or via the communications interface.

The following displays are available:

RMS Capacitor Bank currents (primary, secondary and relay)

RMS Overall Differential currents (secondary and relay)

RMS Capacitor Spill currents (primary, secondary and relay)

RMS Phase Unbalance currents (primary, secondary and relay)

Digital input status

Output relay status

Time and Date

4.2 Data Storage

4.2.1 General

Details of relay operation are recorded in three forms, namely Waveform records, Event records and Fault Data records. All records are time and date stamped with a resolution of one millisecond.

4.2.2 Waveform Records.

The waveform record feature stores analogue and digital information for the current inputs, status inputs and output relays and LED's.

The waveforms are stored with a sampling resolution of at least 8 samples per cycle depending upon relay model. The waveform recorder has the ability to store records for the previous four trip operations of the relay. These are labelled 1-4 with 1 being the most recent record. This however, can be altered using the 'Record Duration' setting, which offers the following selection:

- Four records of one second duration
- Two records of two seconds duration
- One record of five seconds duration

The waveform recorder will be triggered automatically when any protection element operates. It can also be triggered by any of the following means :

Via the 'Trigger Storage" status input signal.

Via the IEC870-5-103 communications interface.

The waveform recorder has a settable pre-fault triggering capability.

4.2.3 Event Records

The event recorder feature allows the time tagging of any change of state (Event) of the relay. As an event occurs the actual event condition is logged as a record along with a time and date stamp to a resolution of 1 millisecond. There is capacity for a maximum of 500 event records that can be stored in the relay and when the event buffer is full any new record will over-write the oldest. The following events are logged:

Change of state of Output Relays.

Change of state of Status Inputs.

Change of Settings and Settings Group

Change of state of any of the control functions of the relay.

4.2.4 Fault Recording

The led flag configuration, date and time of the last five faults are recorded for display via the Fascia LCD.

Note : the real-time clock, waveform records, fault records and event records are all maintained, in the event of loss of auxiliary d.c. supply voltage, by the backup storage capacitor. This capacitor has the ability to maintain the charges on the real-time clock IC and the SRAM memory device for typically 2-3 weeks time duration. This time, however, is influenced by factors such as temperature and the age of the capacitor and could be shorter.

4.3 Time Synchronisation

Time and date can be set either via the relay fascia using appropriate commands in the System Config menu or via an IRIG-B input or via the communications interface

4.3.1 IRIG-B Time Synchronisation

A BNC connector on the relay rear provides an isolated IRIG-B GPS time synchronisation port. The IRIG-B input expects an modulated 3-6 Volt signal and provides time synchronisation to the nearest millisecond.

4.3.2 IEC 60870-5-103 Time Synchronisation

Relays connected individually or in a ring or star configuration can be directly time synchronised using the IEC 60870-5-103 global time synchronisation. This can be from a dedicated substation automation system or from Reydisp Evolution Communications Support Software.

4.3.3 Real Time Clock Time Synchronisation

In the absence of IRIG-B and IEC60870 time synchronisation the relay contains a year 2000 compatible real time clock circuit which maintains real time in the absence of DC supply (See Note).

4.4 Communications

Two fibre optic communication ports, COM1 and COM 2b are provided at the rear of the relay, which give superior EMC performance. An isolated RS232 port, COM 2a is provided at the front of the relay for local access using a PC.

Communication is compatible with the IEC870-5-103 FT 1.2 transmission and application standards. For communication with the relay via a PC (personal computer) a user-friendly software package, REYDISP EVOLUTION, is available to allow transfer of the following:

Relay Settings

Waveform Records

Event Records

Fault Data Records

Instrument and meters

Control Functions

Communications operation is described in detail in Section 4 of this manual. For information about all aspects of the communications protocol used in the Modular II range of relays see [2].

4.5 Settings Groups

Depending upon the relay model then up to four alternative setting groups are provided, making it possible to edit one group while the relay protection algorithms operate using another 'active' group. An indication of which group is being viewed is given by the 'Gn' character in the top left of the display. Settings that do not indicate Gn in the top left corner of the LCD are common to all groups.

A change of group can be achieved either locally at the relay fascia or remotely via a communication interface command.

4.6 Password Feature

The programmable password feature enables the user to enter a 4 character alpha code to secure access to the relay settings. The relay is supplied with the password set to 'NOT ACTIVE', which means that the password feature is disabled. The password must be entered twice as a security measure against accident changes. Once a password has been entered then it will be required thereafter to change settings. It can, however, be de-activated by using the password to gain access and by entering the password 'NONE'. Again this must be entered twice to de-activate the security system.

As soon as the user attempts to change a setting the password is requested before any setting alterations are allowed. Once the password has been validated, the user is 'logged on' and any further changes can be made without re-entering the password. If no more changes are made within 1 hour then the user will automatically be 'logged off', re-enabling the password feature.

Note that the password validation screen also displays a numerical code. If the password is lost or forgotten, this code should be communicated to Siemens and the password can be retrieved.

If the code is 1966067850 then 4 spaces have been entered as the password. This is caused by ENTER being pressed three times on the Change Password setting screen. De-activate password using 'NOT ACTIVE' as described above if this was set un-intentionally.

5 User Interface

The user interface is designed to provide a user-friendly method of entering settings and retrieving data from the relay. The relay fascia includes a 20 character by 2 line, backlit, liquid crystal display (LCD), 32 light emitting diodes (LED) and 5 push buttons.

5.1 Liquid Crystal Display

The liquid crystal display is used to present settings, instrumentation and fault data in a textual format on a 2 lines by 20-character interface.

5.2 Back light Control

To conserve power the display backlighting is turned off if no push buttons are pressed for 5 minutes. After an hour the whole display is de-activated. A setting within the “SYSTEM CONFIG MENU” allows the timeout to be adjusted from 1 to 60 minutes and “OFF”, which means the backlight is always on.

5.3 LED Indications

The following indications are provided:

Protection Healthy – Green LED.

This LED is solidly illuminated to indicate that DC volts have been applied to the relay and that the relay is operating correctly. If the internal relay watchdog detects a protection relay unhealthy condition then this LED will continuously flash.

Programmable – Red LED.

An LED MENU is provided to map any relay output or any status input to any LED.

5.4 Keypad

Five pushbuttons are used to control the functions of the relay. They are labelled ⇧, ⇩ and ⇨, **ENTER** and **CANCEL**. Note that the ⇨ button is also labelled **TEST/RESET**.
When the relay front cover is in place only the ⇩ and ⇨ buttons are accessible. This allows only read access to all the menu displays.

5.5 Relay Identifier

The Relay Identifier setting in the SYSTEM CONFIG MENU may be used to place a circuit identifier of upto 16 alphanumeric characters onto the relay fascia e.g. BOLDON SGT1. This information is also returned as part of the System Information command from Reydisp Evolution Communications Support Software.

5.6 Settings Mode

5.6.1 Settings Adjustment

The push-buttons on the fascia are used to display the relay settings, display the operating signals, e.g. currents, on the LCD and to reset the flag indication on the LCDs.

⇩ **READ DOWN / DECREMENT**

In the Settings Display this push-button is used for scrolling down through a list of settings or signals.

In Settings Modification mode it is used for selecting the next value of (or decreasing) the displayed setting or for deselecting a bit position in a particular control setting.

⇧ **READ UP / INCREMENT**

In Settings Display or Signal Displays this push-button is used for scrolling back up through a list of settings or signals.

In Settings Modification mode it is used for selecting the previous value of (or increasing) the displayed setting or for selecting a bit position in a particular control setting.

ENTER

This push-button is used when the cover is removed to select between two modes of operation namely Settings Display or Settings Modification.

When this push-button is pressed and a relay setting is being displayed part of the display will flash to indicate that the setting being displayed can be modified by using the ⇧ **INCREMENT** or ⇩ **DECREMENT** keys on the facia.

When the required value of the setting has been established, it may be entered into the relay and acted upon by pressing the **ENTER** key again.

CANCEL

This push-button is used when the cover is removed to return the relay display to its initial status. It can be used to reject any alterations to the setting being modified provided the **ENTER** key has not been pressed to accept the changes.

⇨ **TEST / RETEST**

This push-button is used to reset the fault indication on the LEDs on the fascia It also acts as a lamp test button because when pressed all of the LEDs will momentarily light up to indicate their correct operation.

The ⇩ **READ DOWN** and ⇧ **READ UP** push-buttons may then be used to scroll through the various signals.

5.6.2 Settings And Displays

The display menu structure is shown in Figure 8. This diagram shows the three main modes of display, which are the Settings Mode, Instruments Mode and the Fault Data Mode.

When the relay is first energised the user is presented with the following message,

SETTINGS DEFAULTED PRESS ENTER

Which shows that the relay has been set with the standard factory default settings. If this message is displayed ENTER must be pressed to acknowledge this initial condition, the display will then indicate the relay software variant. e.g.

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Pressing the ⇨ **TEST / RETEST** key on this display initiates an LED test. Pressing ⇩ **READ DOWN** at this display allows access to the three display modes, which are accessed in turn by pressing the ⇨ **TEST / RETEST** key.

The Settings Mode contains 15 setting sub-menu's. These hold all of the programmable settings of the relay in separate logical groups. The sub menus are accessed by pressing the key. This enters the sub menu and presents a list of all the settings within that sub menu. Pressing ⇩ **READ DOWN** scrolls through the settings until after the last setting in the group the next sub menu is presented. Access to this group is via the same method as before. If a particular sub menu is not required to be viewed then pressing ⇩ **READ DOWN** will skip past that particular menu and present the next one in the list. Note that all screens can be viewed even if the password is not known. The password only protects against unauthorised changes to settings.

While viewing an editable screen pressing the **ENTER** key allows the user to change the displayed data. A flashing character(s) will indicate the editable field. Pressing the ⇧ **INCREMENT** or ⇩ **DECREMENT** scrolls through the available setting values or, pressing ⇨ **TEST / RETEST** moves right through the edit fields. Note that all settings can be incremented or decremented using the ⇧ **INCREMENT** or ⇩ **DECREMENT** keys and they all wraparound so that to go from a setting minimum value to the maximum value it is quicker to press the ⇩ **DECREMENT** key, rather than scroll through every setting. Also, to facilitate quicker setting changes an acceleration feature is available which if ⇧ **INCREMENT** or ⇩ **DECREMENT** are depressed and held, then the rate of scrolling through the setting values increases.

If **ESCAPE/CANCEL** is pressed during a setting change operation the original setting value is restored and the display is returned to the normal view mode.

If changes are made to the setting value then pressing **ENTER** disables the flashing character mode and displays the new setting value. This is immediately stored in non-volatile memory.

The next sections give a description of each setting in the relay. The actual setting ranges and default values can be found in the Relay Settings section of this manual.

5.7 Instruments Mode

In INSTRUMENT MODE metering points can be displayed to aid with commissioning, the following meters are available

Instrument	Description
[CAP BANK METERS]	Start of Capacitor Bank current meters
Prim'y Currents	Capacitor Bank Primary current meters
Sec'y Currents	Capacitor Bank Secondary current meters
[DIFF METERS]	Start of Overall Differential current meters
Diff1 Sec'y Currents	Differential 1 Secondary currents
Diff1 Currents	Differential 1 currents
Diff2 Sec'y Currents	Differential 2 Secondary currents
Diff2 Currents	Differential 2 currents
[UNBALANCE METERS]	Start of Capacitor Unbalance current meters
Reference Currents	Capacitor Unbalance Reference currents
C1 Ia Spill	C1 Ia Spill current
C1 Ib Spill	C1 Ib Spill current
C1 Ic Spill	C1 Ic Spill current
C1 Operate Currents	C1 Operate currents
Instrument	**Description**
C2 Ia Spill	C2 Ia Spill current
C2 Ib Spill	C2 Ib Spill current
C2 Ic Spill	C2 Ic Spill current
C2 Operate Currents	C2 Operate currents
[PH UNBAL METERS]	Start of Phase Unbalance current meters
Residual Prim'y Current	Residual Primary current
Residual Sec'y Current	Residual Secondary current
Residual Current	Residual current
[MISC METERS]	Start of miscellaneous meters
Status Inputs 1-16	Displays the state of DC status inputs 1 to 16
Status Inputs 17-19	Displays the state of DC status inputs 17 to 19
Output Relays 1-16	Displays the state of output relays 1 to 16
Output Relays 17-21	Displays the state of output relays 1 to 21
Time & Date	Time and Date

Note that meters not designated as primary or secondary values are usually displayed as multiples of nominal

i.e. x In, 1 Amp or 5 Amp.

5.7.1 Hidden Instruments

At the “INSTRUMENTS MODE” title screen, pressing ENTER and DOWN simultaneously reveals some additional metering for calibration purposes. The reference channels as well as DC offsets may be displayed along with the RMS values in raw ADC counts. The relationship between current and ADC counts is 1 x In = 600 counts.

5.8 Fault Data Mode

In “FAULT DATA MODE”, the time and date of relay operations are recorded together with a record of the LED flag states.

5.9 Default Instruments Screens

The menu presentation of the various instruments allows the user to view a single screen at a time. However, for in service use, it is desirable that a small number of high interest, user selectable screens are presented automatically by default without user intervention. The instrument screens of interest to the user e.g. those required to be presented to a visiting engineer for record purposes can be selected by the user by pressing ENTER when viewing the required screen. On pressing ENTER a **‘D’** symbol will appear at the top right of that screen. The ‘**D’** indicates that a screen is a ‘default screen’. To de-select a default screen, simply press ENTER while on that particular screen and the **‘D’** symbol will be cleared.

Time & Date	**D**
01/01/1980 01:31:39	

If no keys have been pressed for a pre-determined time the relay will jump to the default instrument display regardless of where the menu has been left by the user. It will then scroll through each of the selected default instruments and remain on each for approximately 5 seconds. The Default Screens Timer that sets the time to elapse before the relay goes into the default instruments mode is found in the SYSTEM CONFIG MENU.

6 Diagrams

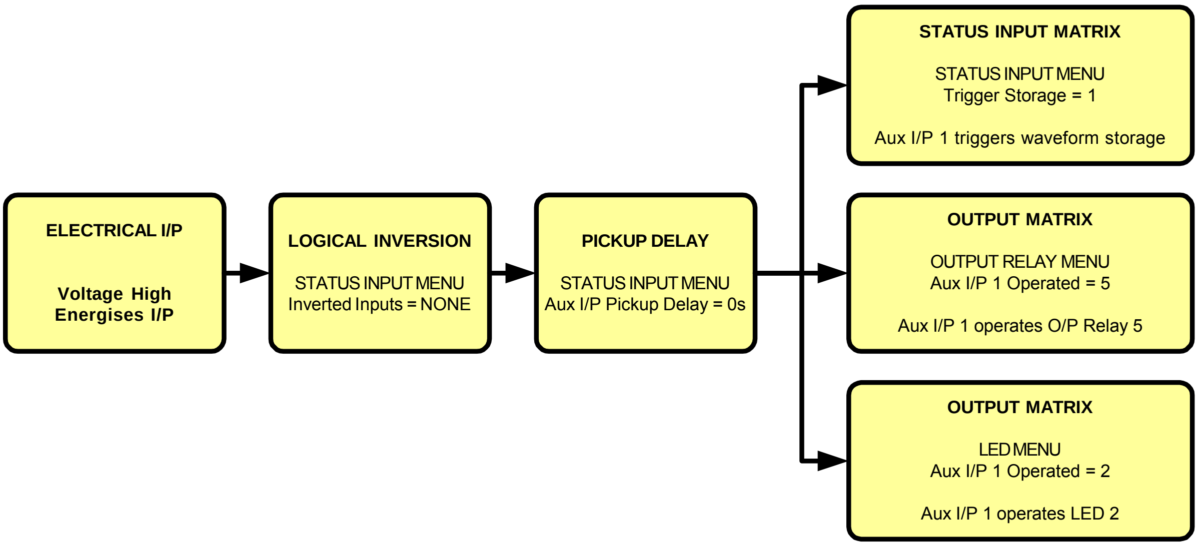

Figure 2 – Status Input Functionality

Figure 3 – MSCDN-MP1 in E16 case with front panel open

Figure 4 – MSCDN-MP1 Rear View

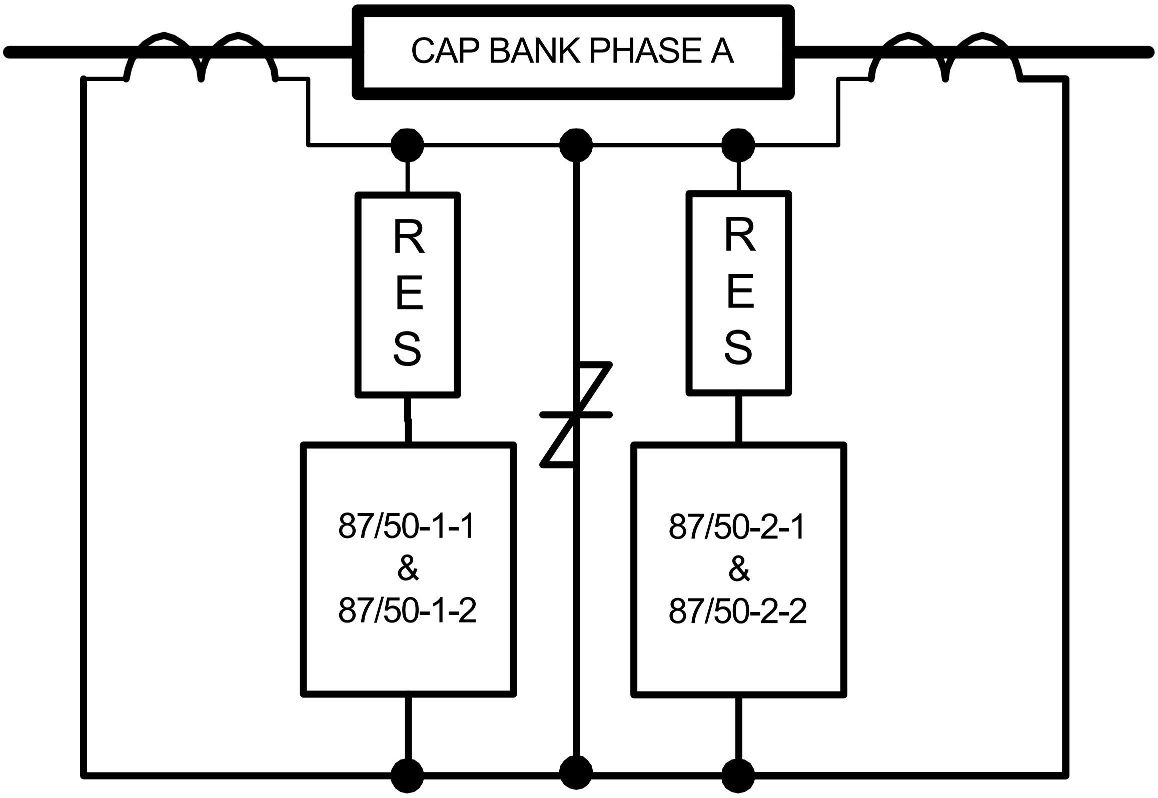

Figure 5 – High Impedance Differential Schematic

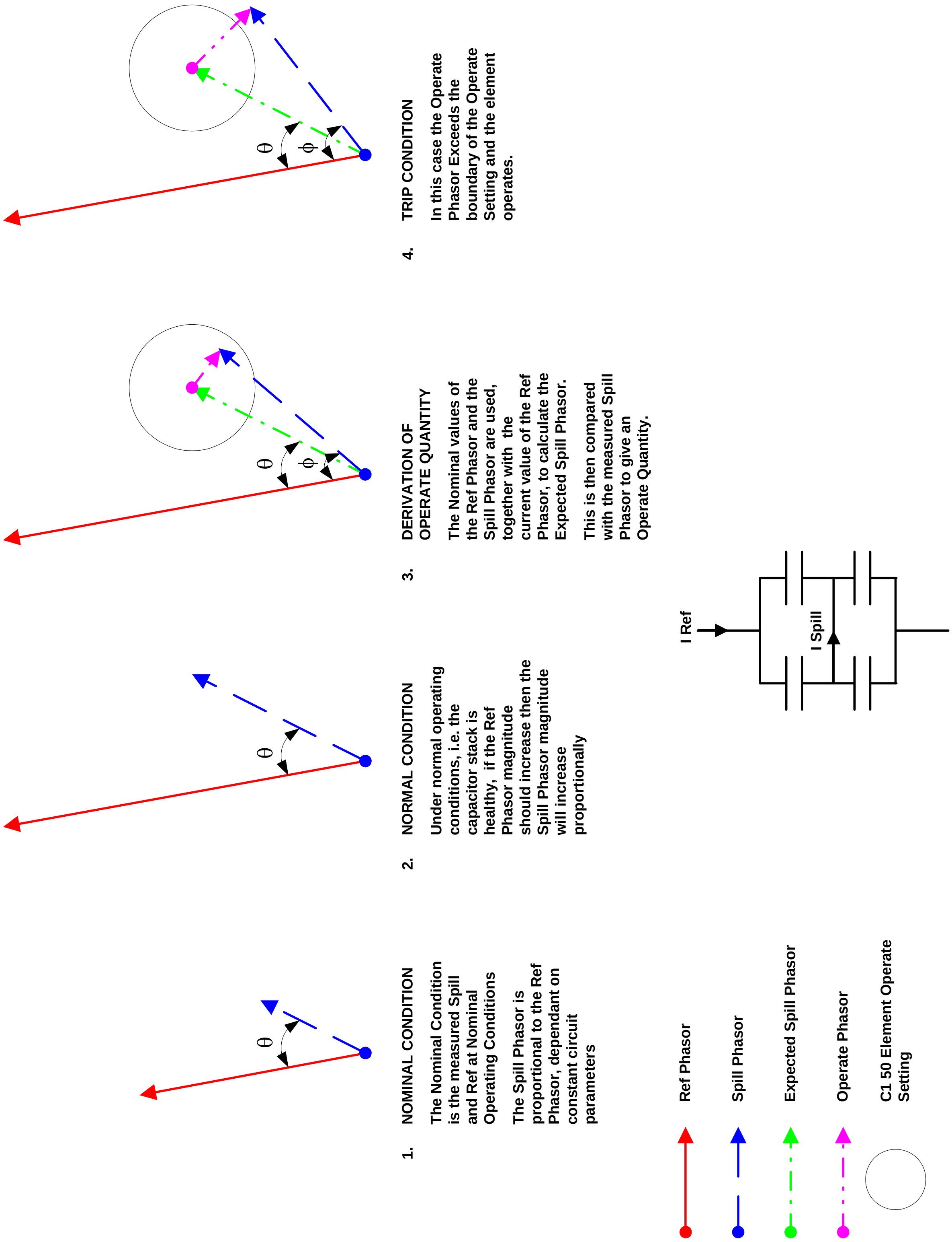

Figure 6 – Capacitor Unbalance Protection – Phasor Representation of Operating principle

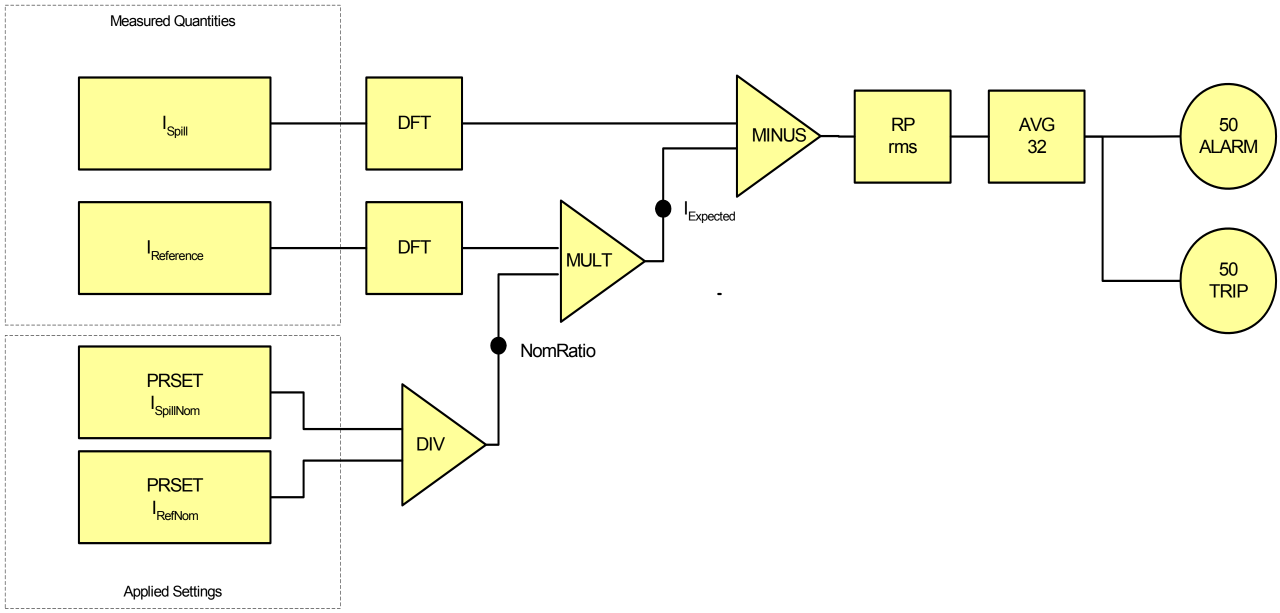

Figure 7 – Capacitor Unbalance Protection - RDL Processing Diagram

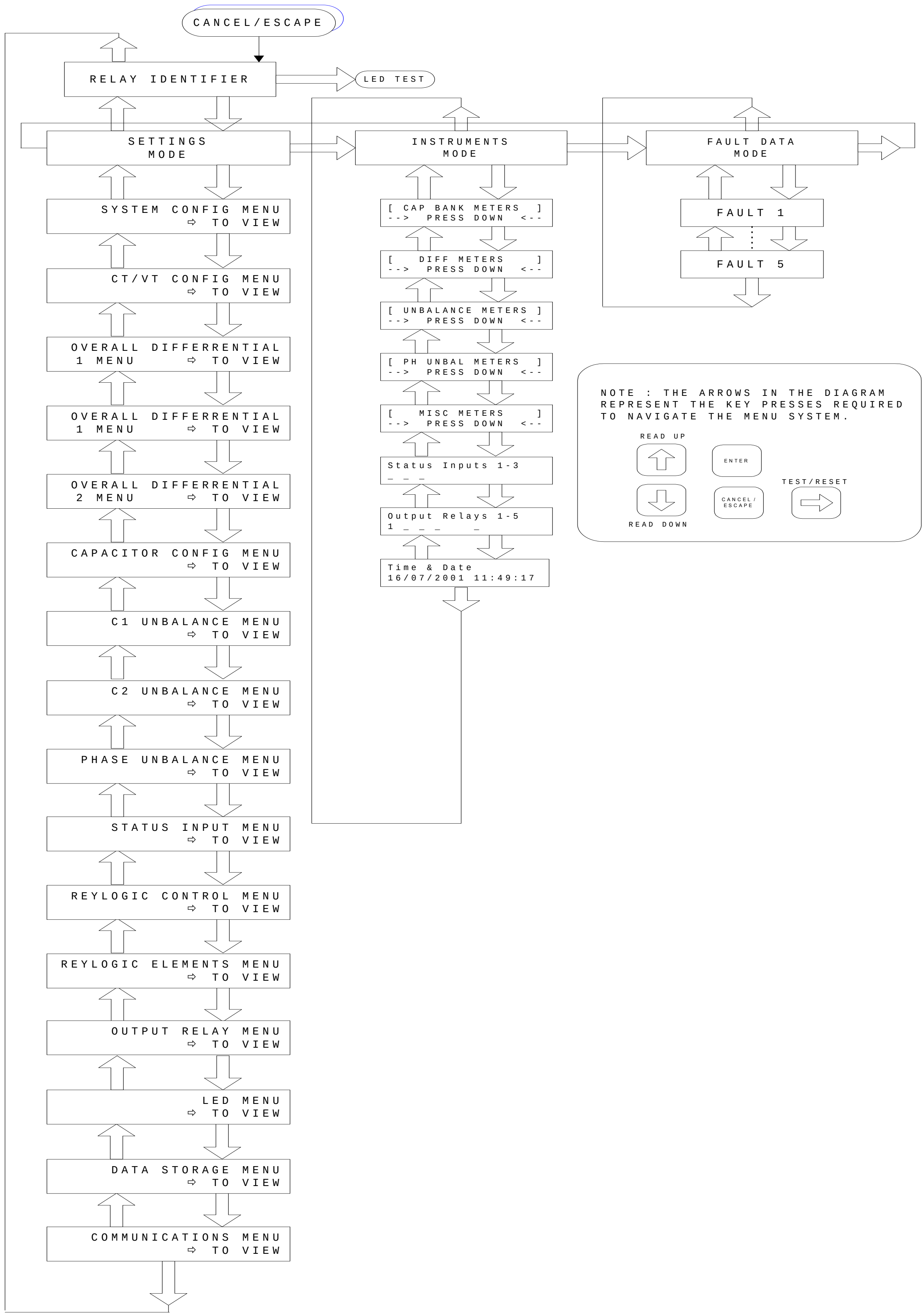

Figure 8 – MSCDN-MP1 Menu Structure