Protection and control device for HV/MV substation – Multifunctional feeder protection (MFP)

This global standard defines the characteristics of the multifunctional feeder protection (according to IEC 60255 series) and accessories for HV/MV distribution substations a declared fundamental frequency of 50 Hz or 60 Hz.

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INDEX

1 ACRONYMS 10
2 LIST OF COMPONENTS, PRODUCT FAMILY OR SOLUTIONS TO WHICH THE GS APPLIES 12
3 NORMATIVE REFERENCES AND BIBLIOGRAPHY 13
3.1 For all countries 13
3.2 For EU countries 14
3.3 For Colombia 14
4 REPLACED STANDARDS 15
5 APPLICATION FIELDS 16
6 MFP GENERAL REQUIREMENTS 17
6.1 Environmental requirements 17
6.1.1 Enclosure 17
6.1.2 Electrical safety 17
6.1.3 EMC 18
6.1.4 Climatic conditions 19
6.2 Electrical, electronical and data connector characteristics 19
6.2.1 Power supply board (MP connector) 20
6.2.2 Analog Inputs 20
6.2.3 Connection of the Voltage Analog Inputs (MV connectors) 22
6.2.4 Connection of the Current Analog Inputs (MA connectors) 22
6.2.5 Connection of the Embedded Digital Input (MI connector) 22
6.2.6 Connection of the Embedded Digital Output (MO connector) 24
6.2.7 Circuit-breaker control connection (MT connector) 26
6.2.8 Additional Input / Output boards 28
6.3 Layout of the MFP enclosure 28
6.3.1 Labeling 29
6.3.2 Circuit-breaker control buttons 29
6.3.3 Auto-reclosing selector 29
6.3.4 Navigation buttons 29
6.3.5 Display 30
6.3.6 Local LEDs and signals 30
6.4 Reliability requirements 30
6.5 Remote I/O module 31
6.6 Electrical Diagrams 31
7 COMMUNICATION REQUIREMENTS 32
7.1 Interface to the Station Bus (Remote Control LAN) 32
7.2 Interface to the Field Bus 32
7.3 Interface for local connection and configuration 32
7.4 Requirements for the Communication and the File transfer 33
7.5 Time synchronization 33
7.6 IEC 61850 interoperability profile 33
7.7 Remote access for maintenance 34
7.7.1 Data extraction service 34
7.7.2 Data extraction process 34
7.8 On site configurations and programming 34

7.8.1 On site configuration 34
7.8.2 Programmable logic configuration 35

8 SELF-DIAGNOSIS AND CONTROL LOGICS 37
8.1 Self-diagnosis and operation in abnormal conditions 37
8.1.1 Operation of the MFP in case of total block state 38
8.1.2 Operation of the MFP in case of partial block state 38
8.1.3 Local control of the circuit-breaker in case of MFP operates in abnormal conditions 38
8.2 Diagnostic of Voltage Transducers and Current Transducers Supervision (VTS/CTS) 39
8.2.1 Voltage transducers Diagnostic 40
8.2.2 Current transducers Diagnostic 42
8.2.3 Note for 74 VT and 74 CT functions 43
8.3 Bay Diagnostic 43
8.3.1 Circuit bay Diagnostic 43
8.3.2 Wall diagram of the circuit-breaker compartment 46
8.3.3 Check of the recovery voltage when the circuit-breaker is open 46
8.4 MOIM function 46
8.4.1 Protection behavior 46
8.4.2 Setting Parameters 47

9 MEASUREMENT FUNCTIONS 48
9.1 General Overview 48
9.2 Configurable Analog Inputs 48
9.2.1 Current Input C2 48
9.3 Usable CTs and VTs 49
9.4 Conventions of the measurement functions 49
9.5 Characteristic data of the measurement functions 50
9.6 Measurements reports 51

10 ELECTRICAL PROTECTION FUNCTIONS (FdP) 53
10.1 Definition of “Characteristic Times” 53
10.1.1 Start time 53
10.1.2 Operate time 53
10.1.3 Reset time 53
10.1.4 Reset ratio 53
10.1.5 Overshoot time 54
10.1.6 Repetitive error time 54
10.2 Logical representation of a FdP 54
10.3 Trip commands given by the protection functions 55
10.4 Activation Status of the stages in the relevant protection functions 56
10.5 Settings tables 56
10.6 Phase overcurrent protection function IEEE 51 56
10.6.1 Protection Behavior 56
10.6.2 Settings Parameters 57
10.6.3 Accuracy of the measurements 57
10.6.4 Time dependent overcurrent protection IEC 60255 57
10.7 Residual overcurrent current protection function I_E 51N 59
10.7.1 Protection Behavior 59
10.7.2 Setting Parameters 59
10.7.3 Accuracy of the measurements 60

10.8 Residual overcurrent current protection function for TFN, IE 51N, C2 input ... 61
10.8.1 Protection Behavior ... 61
10.8.2 Setting parameters ... 61
10.8.3 Accuracy of the measurements ... 61
10.8.4 Emergency 51N protection function ... 61
10.8.5 Accuracy of the measurements ... 62
10.9 Directional overcurrent protection function IEEE 67 ... 62
10.9.1 Protection behavior ... 63
10.9.2 Setting parameters ... 63
10.9.3 Accuracy of the measurements ... 64
10.10 Negative sequence overcurrent protection function IEEE46 ... 64
10.10.1 Protection behavior ... 65
10.10.2 Setting parameters ... 66
10.10.3 Accuracy of the measurements ... 66
10.11 Unbalance protection function IEEE 46N ... 67
10.11.1 Setting Parameters ... 67
10.11.2 Accuracy of the measurements ... 67
10.12 Directional earth overcurrent protection function IEEE 67N ... 68
10.12.1 Protection behavior ... 69
10.12.2 Setting Parameters ... 69
10.12.3 Accuracy of the measurements ... 70
10.13 Directional overcurrent “Arcing Ground” protection function IEEE 67N ... 71
10.13.1 Protection behavior ... 73
10.14 RLS function ... 73
10.15 Directional earth overcurrent protection function for the detection of evolving faults ... 73
10.15.1 Protection behavior ... 74
10.16 Residual overvoltage protection function IEEE 59N ... 75
10.16.1 Protection behavior ... 75
10.16.2 Setting Parameters ... 75
10.16.3 Accuracy of the measurements ... 76
10.17 Emergency protection function IEEE 59N ... 76
10.17.1 Protection behavior ... 76
10.17.2 Setting Parameters ... 77
10.17.3 Accuracy of the measurements ... 77
10.18 Phase-to-phase overvoltage protection function IEEE 59 ... 77
10.18.1 Protection behavior ... 78
10.18.2 Setting Parameters ... 78
10.18.3 Accuracy of the measurements ... 78
10.19 Phase-to-phase undervoltage protection function IEEE 27 ... 79
10.19.1 Protection behavior ... 79
10.19.2 Setting Parameters ... 79
10.19.3 Accuracy of the measurements ... 79
10.20 Cold Load Pick Up ... 80
10.21 SOTF (Switch-On To Fault) ... 80
10.22 Discrimination of INRUSH currents ... 80
10.22.1 Protection behavior ... 80
10.22.2 Setting Parameters ... 81
10.22.3 Accuracy of the measurements ... 81

10.23 Directional active overpower protection function 32P ... 81
10.23.1 Protection behavior ... 82
10.23.2 Setting Parameters ... 82
10.23.3 Accuracy of the measurements ... 82
10.24 Protection Function of Broken Conductor I2/I1 ... 83
10.25 Protection Function of Breaker Failure ... 83
10.26 Synchro-check protection function IEEE 25 ... 84
10.26.1 Synchronous networks paralleling conditions check (PS) ... 84
10.26.2 Asynchronous networks paralleling conditions check (PA) ... 85
10.27 Overvoltage detection protection function (ES59B) ... 86
10.27.1 Protection behavior ... 86
10.27.2 Setting Parameters ... 86
10.27.3 Accuracy of the measurements ... 87
10.28 DC undervoltage protection function (27) ... 87
10.28.1 Protection behavior ... 87
10.29 Frequency protection function EAC (81) ... 88
10.29.1 EAC blocking stages ... 88
10.29.2 EAC tripping stages ... 90
10.29.3 Frequency and voltage measurements ... 90
10.29.4 EAC Function ... 91

11 FSL function ... 92
11.1 Remote Trip Function ... 94

12 AUTOMATIC RECLOSING FUNCTION (ARF) ... 95
12.1 Operating modes ... 96
12.2 ARF conditioning in the presence of external signals ... 96
12.3 Reclosing cycle reset ... 97
12.4 Autoreclosing coordination practices ... 97

13 DISTURBANCE RECORDING ... 98

14 MFP ADVANCED REQUIREMENTS ... 101
14.1 Hardware requirements ... 101
14.2 Communication requirements ... 101
14.3 Synchronization requirements ... 101
14.4 High impedance fault FdP ... 101
14.5 Parallel Redundancy Interoperability ... 101

15 TESTING AND CERTIFICATIONS ... 102
15.1 Overview Technical Conformity Assessment (TCA) Process ... 102
15.1.1 TCA documents ... 102
15.1.2 Quality ... 102
15.1.3 Safety warnings on Plate ... 102
15.1.4 Tests required to complete the TCA ... 102
15.1.5 Type test list ... 103
15.1.6 Acceptance tests ... 103
15.1.7 Visual inspections ... 104
15.1.8 Type test levels ... 104
15.2 Pilot installation tests ... 105
15.3 Individual tests ... 105

15.4 Certifications and self-certifications 105

16 MISCELLANEOUS 106

16.1 Required documentation 106

16.2 Clarification during procurement process 106

16.3 Procurement management 107

16.4 Receipt of material 107

16.4.1 Reception tests 107

16.4.2 Warranty 108

FIGURES

Figure 1 – Example of application about MI connectors 24

Figure 2 – Example of application about MO connectors 26

Figure 3 – Board for commanding the circuit-breaker 27

Figure 4 – Front view of the MFP 28

Figure 5 – Rear view of the device 29

Figure 6 – PLC programming example 36

Figure 7 – Logical scheme of CB control when MFP is in anomaly status 39

Figure 8 – Logical Scheme VTS-P 40

Figure 9 – Logical scheme: 74VT 41

Figure 10 – Diagram 74 CTS 42

Figure 11 – Logcal Scheme 74 CTS 43

Figure 12 – Trip circuit supervision 44

Figure 13 – Logical scheme resolving and non resolving MOIM Coil 47

Figure 14 – Conventions of the measurements 50

Figure 15 – Behavior of the reset time 53

Figure 16 – Behavior of the Reset ratio 53

Figure 17 – Behavior of Overshoot time 54

Figure 18 – Behavior of repetitive error time 54

Figure 19 – FdP logic 55

Figure 20 – Beahavior of Minimum operate (trip) time 55

Figure 21 – Illustrative example of 3-stages inverse curve 58

Figure 22 – Illustrative example of 3-stages inverse curve 51N 60

Figura 23 – “67Px” setting parameters ranges 63

Figure 24 – Logical scheme: 46 66

Figure 25 – Scheme of principle 46N 67

Figure 26 – Operation characteristic 67N 69

Figure 27 – Tripping sector 67N 70

Figure 28 – Logical control: 67N.S4 72
Figure 29 – Logic control: 67N.S5 74
Figure 30 – Self producer cogeneration automatism 86
Figura 31 – EAC Logic 91
Figure 32 – FSL Operation Logic 93
Figura 33 – FSL Operation Logic 93
Figura 34 – FSL Operation Logic 94
Figura 35 - FSL Operation Logic 94

TABLES

Table 1 – GSTP10X product family and description 12
Table 2 – Standards for the Electrical Safety 17
Table 3 – Standards for the Electromagnetic compatibility (EMC) 18
Table 4 – EMC levels for the Enclosure Port 18
Table 5 – EMC levels for the Grounding Port 18
Table 6 – EMC levels for the Communication Port 18
Table 7 – EMC levels for the In and Out Port of the d.c. supply 18
Table 8 – Climatic conditions 19
Table 9 – Peripheral boards to accommodate in the expansion slots 19
Table 10 – Electrical characteristics of the power supply 20
Table 11 – Electrical characteristics of the power supply 20
Table 12 – Summary of the electrical characteristics of the Analog Inputs 21
Table 13 – Use of the Analog Inputs 21
Table 14 – Connector for the Voltage Analog Inputs 22
Table 15 – Connector for the Voltage Analog Inputs 22
Table 16 – Summary of the electrical characteristics of the Digital Inputs 23
Table 17 – Connector for the Programmable Digital Input (MI connector) 23
Table 18 – Summary of electrical characteristics of the (Command) Digital Output (MO connector) 24
Table 19 – Connector for the Programmable Digital Outputs (MO) 25
Table 20 – Digital Outputs (Command, solid state) 27
Table 21 – Connector for the circuit-breaker command (MT) 28
Table 22 – LEDs assignment 30
Table 23 – Behavior in case of partial block state 38
Table 24 – 60VT-P/T and 60CT-P (measuring transformer supervision) setting 39
Table 25 – List of definitions 42
Table 26 – “MoIM” setting parameters ranges 47

Table 27 – Measurements functions assignable to the Analog Inputs 48
Table 28 – Assignement of the quantity measured by the C2 input 48
Table 29 – Usable VT and CT 49
Table 30 – Accuracy of the measurements 50
Table 31 – Ind. Time 51 stages 56
Table 32 – FdP 51 behavior 56
Table 33 – "51.Sx" setting parameters ranges 57
Table 34 – Accuracy of the intervention times for the overcurrent 57
Table 35 – Configurable inverse curves of the dependent time overcurrent protections 58
Table 36 – Ind. Time 51N stages 59
Table 37 – FdP 51N behavior 59
Table 38 – "51.Nx" setting parameters ranges 59
Table 39 – Accuracy of the intervention times for the residual overcurrent 60
Table 40 – 51N.Sx_a stages 61
Table 41 – 51N.Sx_a behavior 61
Table 42 – 51N.Eme behavior 62
Table 43 – Ind. Time 67 stages 62
Table 44 – FdP 67 behavior 63
Table 45 – "67Px" setting parameters ranges 64
Table 46 – Accuracy of the intervention times for the directional overcurrent 64
Table 47 – Ind. Time 46 stages 65
Table 48 – FdP 46 behavior 65
Table 49 – "46.x" setting parameters ranges 66
Table 50 – Accuracy of the intervention times for the negative sequence overcurrent 46 66
Table 51 – "46N" setting parameters ranges 67
Table 52 – Accuracy of the intervention time for the 46N 68
Table 53 – 67N stages 68
Table 54 – FdP 67N behavior 69
Table 55 – "67Nx" setting parameters ranges 70
Table 56 – Accuracy of the intervention times for the directional earth overcurrent 67N 71
Table 57 – List of definition 72
Table 58 – FdP67N.S4 behavior 73
Table 59 – List of definition 74
Table 60 – Fdp 67N.S5 behavior 75
Table 61 – 59N stages 75
Table 62 – FdP 59N behavior 75
Table 63 –"59N.x" setting parameters ranges 76

Table 64 –Accuracy of the intervention times for the residual overvoltage 59N 76
Table 65 –FdP 59N_eme behavior 77
Table 66 –“59N:EME” setting parameters ranges 77
Table 67 – 59 stages 77
Table 68 – FdP 59 behavior 78
Table 69 – “59” setting parameters ranges 78
Table 70 – Accuracy of the intervention times for the overvoltage 59 78
Table 71 – 27 stages 79
Table 72 – FdP 27 behavior 79
Table 73 –“27” setting paramenters ranges 79
Table 74 –Accuracy of the intervention times for the overvoltage 27 79
Table 75 – “INRUSH” setting parameters ranges 81
Table 76 – Accuracy of the intervention times for the INRUSH blocking function 81
Table 77 – 32P stages 81
Table 78 – FdP 32P behavior 82
Table 79 – “32P” setting parameters ranges 82
Table 80 – Accuracy of the intervention times for the directional overpower 32P_Sx 82
Table 81 – Closing configuration for PS and PA 84
Table 82 – Synchro Check setting parameters ranges (PS) 85
Table 83 – PA algorithm 85
Table 84 – Synchro-Check setting parameters ranges (PA) 85
Table 85 – FdP ES59B behavior 86
Table 86 – “ES59B” setting parameters ranges 87
Table 87 – “DC undervoltage” operating characteristics 87
Table 88 – “Under/overvoltage blocking stages” setting parameters ranges 88
Table 89 – Accuracy of the intervention times for the “Under/overvoltage blocking stages” 88
Table 90 – “β blocking stage” setting parameters ranges 89
Table 91 – Accuracy for the intervention times for the “β blocking stage” 89
Table 92 – “γ blocking stage” setting parameters ranges 89
Table 93 – Accuracy for the intervention times for the “γ blocking stage” 89
Table 94 – “Under/overfrequency stages” setting parameters ranges 90
Table 95 – “Rate of change of frequency stages” setting parameters ranges 90
Table 96 – Auto-reclosing setting parameters ranges 95
Table 97 – ARF conditioning and related operating modes 97
Table 98 – Example of channels assignment 98
Table 99 – Tests Levels 104

1 ACRONYMS

a. **$3I_{OH}$** High Level Residual Current

b. **$3I_{OL}$** Low Level Residual Current

c. **$3V_{OH}$** High Level Residual Voltage

d. **$3V_{OL}$** Low Level Residual Voltage

e. **BSD** Bit Serial Data Protocol

f. **CRC** Reclosing cycle in progress

g. **CT** Current Transformer

h. **DHCP** Dynamic Host Configuration Protocol

i. **E2PROM** Electrically Erasable Programmable Read-Only Memory

j. **EMC** Electromagnetic Compatibility

k. **FdP** Protection functions

l. **FTP** File Transfer Protocol

m. **GOOSE** Generic Object Oriented Substation Event

n. **GS** Enel Global Standard

o. **HIF** High Impedance Fault

p. **HSR** High-availability Seamless Redundancy

q. **I_{4-0} – I_{8-0} – I_{12-0}** Phase Currents

r. **I_E ($3I_o$)** Residual Current

s. **IED** Intelligent Electronic Device

t. **IETF** Internet Engineering Task Force

u. **Ireg** Setting value for current based protection functions

v. **I_{SQL}** Current unbalance of star-connected capacitors

w. **MFP** Multifunctional feeder protection

x. **MMS** Manufacturing Message Specification

y. **MTBF** Mean Operating Time Between Failure

z. **MTTR** Mean Time to Restoration

aa. **NTP** Network Time Protocol

bb. **PLC** Programmable Logic Controller

cc. **Preg** Setting value for electric power based protection functions

dd. **PRP** Parallel Redundancy Protocol

ee. **PS** primary substation, it is a HV/MV substation or other substations having a primary role in the electricity distribution network (for example crtain kind of switching substations)

ff. **PTP** Precision Time Protocol

gg. **RIO** Remote I/O module of multifunctional feeder protection (MFP-RIO)

hh. **RTU** Remote Terminal Unit

ii. **SCADA** Supervisory Control And Data Acquisition

jj. **SFTP** Secure File Transfer Protocol

kk. **SNMP** Simple Network Management Protocol

ll. **SRR** Trip without reclosing

mm. **SSH** Secure SHell

nn. **TATT** time to wait for the opening of the circuit-breaker

oo. **TCA** Technical Conformity Assessment

pp. **TCP** Transmission Control Protocol

qq. **TFN** Neutral Forming Transformer

rr. **THD** Total Harmonic Distortion

ss. **TRMS** True Root Mean Square

tt. **TRR** Interruption / isolation time of the Rapid Reclosing (RR)

uu. **U_E ($3V_o$)** Residual Voltage

vv. **$V_{4\text{-}0}$ – $V_{8\text{-}0}$ – $V_{12\text{-}0}$** Phase Voltages

ww. **V_{SYNC}** Synchronous phase voltage

xx. **VT** Voltage Transformer

yy. **ZSC** Zone Sequence Coordination

2 LIST OF COMPONENTS, PRODUCT FAMILY OR SOLUTIONS TO WHICH THE GS APPLIES

The Multifunctional feeder protection (MFP) described in this GSTP10X series can be classified in several products provided in Table 1.

Table 1 – GSTP10X product family and description

GSTP10X type	Product family code	Description
GSTP101-MFP type R	GSTP10X	Protection and control device for HV/MV substation – Multifunctional feeder protection (MFP) with L = 482,6 mm, W ≤ 310 mm, H = 3U.
GSTP101-MFP type L	GSTP10X	Protection and control device for HV/MV substation – Multifunctional feeder protection (MFP) with L ≤ 482,6 mm, W ≤ 310 mm, H = 4U or 4.3U.
GSTP101-MFP type L-NM	GSTP10X	Protection and control device for HV/MV substation – Multifunctional feeder protection (MFP) with L ≤ 482,6 mm, W ≤ 310 mm, H = 4U or 4.3U and non-modular or alternative modular design.
GSTP101-IP54-TWC enhancement	GSTP10X	IP54 and Thermal Withstand Current enhancement for MFP.
GSTP101-MB enhancement	GSTP10X	Modbus enhancement for MFP with additional boards for digital Inputs/ Outputs MJ and MU.
GSTP101-HIF enhancement	GSTP10X	HIF enhancement for MFP
GSTP101-DNP3 enhancement	GSTP10X	DNP3 enhancement for MFP
GSTP101-IRIGB enhancement	GSTP10X	IRIGB enhancement for MFP
GSTP101-PRI enhancement	GSTP10X	Parallel Redundancy Interoperability for MFP
GSTP102-RIO	GSTP10X	Remote I/O module for MFP
GSTP102-RIO MB enhancement	GSTP10X	Modbus enhancement for MFP-RIO
GSTP102-RIO RJ45 enhancement	GSTP10X	RJ45 port enhancement for MFP-RIO
GSTP102-RIO HW enhancement	GSTP10X	Set of HW enhancements for MFP-RIO
GSTP102-RIO SW enhancement	GSTP10X	Set of SW and configuration enhancements for MFP-RIO.

3 NORMATIVE REFERENCES AND BIBLIOGRAPHY

All the references in this GS are intended in the last revision or amendment.

3.1 For all countries

IEC 60255 series	Measuring relays and protection equipment
IEC 61850 series	Communication protocols for IED at electrical substation
IEC 60297-3-101	Mechanical structures for electronic equipment
IEC 60529	Classification of degrees of protection provided by enclosures for electrical equipment
IEC 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
IEC 61000 series	Electromagnetic compatibility
IEC 60664-1	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
IEC 61810-1	Electromechanical elementary relays - Part 1: General and safety requirements
IEC 62749	Assessment of power quality – characteristics of electricity supplied by public networks
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
IEC 60050-192	International electrotechnical vocabulary – Part 192: Dependability
IEC 60068 series	Environmental testing
IEC 61010-1	Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements
IEC 62439-3	Industrial communication networks - High availability automation networks - Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)
IEEE C37.2	IEEE Standard Electrical Power System Device Function Numbers and Contact Designations
IEEE C37.104	IEEE Guide for Automatic Reclosing of Circuit Breakers for AC Distribution and Transmission Lines
IEEE 802.3u	Physical layer and data link layer's media access control of wired Ethernet
IEEE 802.1q	System of VLAN tagging for Ethernet frames
IEEE 1588	IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
RFC3164	BSD syslog Protocol
RFC 3195	Reliable Delivery for syslog
GSCG002	Technical Conformity Assessment
GSTP10X series	Protection and control device for HV/MV substation – Multifunctional feeder protection (MFP)
GSTP901	Cybersecurity requirements for protection and control devices

3.2 For EU countries

EN 55011	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement
EN 50160	Voltage characteristics of electricity supplied by public distribution systems.
EU directive 2004/108/CEE	EMC directive
EU directive 2006/95/CEE	Low Voltage directive
EU directive 93/68/CEE	CE marking directive

3.3 For Colombia

NTC-2050	Código eléctrico colombiano
RETIE	Reglamento técnico de instalaciones eléctricas

4 REPLACED STANDARDS

Codification	Country	Title
DMI-9-00016	Italy	Requisiti costruttivi e funzionali del Pannello Multifunzione di Protezione e Controllo per Cabina Primaria
SNC002	Iberia	Relé multifunción posiciones MT
PCM001	Brazil Perù Chile Argentina Colombia	Proteccion de sobrecorriente multifuncion
ET189	Brazil	Relé de Freqüência
PCM002	Brazil Perù Chile Argentina Colombia	Protección para Banco de Condensadores MT
ET111d	Perù	Reles de proteción de falla a tierra para redes de distribución con neutro aislado
ET124c	Perù	Equipos de protección y maniobra de media tensión para interior
PCM007	Brazil Perù Chile Argentina Colombia	Proteccion de sobretension homopolar
DWEC19	Argentina	Relevador de frecuencia con derivada
DWEC20	Argentina	Proteccion de sobrecorriente

Differential and distance protections are included in some replaced standards but are not covered by the MFP.

Some Iberia installations may require the persistence of the local standard.

5 APPLICATION FIELDS

This document standardizes the functional, construction and testing requirements of the device used for protection and control purposes in the MV (feeders bays) and in some HV (client's radial delivery line for example) sections of ENEL's HV/MV distribution substation. This device accomplishes to the definition of protection equipment, by according to IEC 60255 series, and IED, by according to IEC 61850 series.

This Multifunctional feeder protection (MFP) is a platform, consisting of an expandable set of boards inside the main enclosure and a set of different firmwares to facilitate easy reconfiguration of the IED functions inside the substation; its I/O functions towards the field devices are readily scalable via remote modules connected to dedicated communication ports or via the LAN in the substation.

The requirements in this specification apply to the nodes of the MV grid and to the Primary Substations (PS), owned by ENEL worldwide, which have the following grounding systems:

a. insulated neutral;

b. neutral earthed through an inductor with in parallel a resistor;

c. neutral earthed through a resistor;

d. neutral earthed through an inductor;

e. neutral directly earthed.

This device may use dedicated remote I/O module (RIO), the RIO is defined in the GSTP102. MFP and RIO mainly use the protocols from the IEC 61850 series to communicate with the RTU, the communication profiles are defined in the GSTP103 and GSTP104.

The multifunctional protection & control device for HV/MV substation is applicable to the following HV/MV substation elements:

f. MV feeder (1 kV < V_n < 36 kV);

g. Power Factor Correction,

h. Earthing Transformer (TFN),

i. Section circuit-breaker (or busbar coupler),

j. Bus transfer coupler

k. Some HV feeders where differential and distance protections are not needed (radial, $V_n \geq 36$ kV),

l. Auxiliary Services.

m. Capacitor Bank

The device will control a three-pole type circuit-breaker.

Security by design is mandatory for any devices developed to be installed in the ENEL premises. The requirements from GSTP901 must be adopted.

6 MFP GENERAL REQUIREMENTS

This chapter present all the mandatory requirements for the MFP hardware.

6.1 Environmental requirements

6.1.1 Enclosure

The MFP enclosure must be compliant with one of the following options:

a. IEC 60297-3-101 compliant to make it suitable for rack-mounting in a standard 19”, with size: L = 482,6 mm, W ≤ 310 mm, H = 3U (MFP type R);

b. IEC 60297-3-101 compliant to make it suitable for rack-mounting in a standard 19”, with size: L ≤ 482,6 mm, W ≤ 310 mm, H = 4U or 4.3U (MFP type L);.

Definitive sizing will be declared during the procurement process (par. 16.2).

The enclosure must be made entirely of galvanized (Zinc coated) and painted steel or of an equivalent material in terms of EMC, mechanical stiffness (metalized plastic is not acceptable) and oxidation protection. It must be supported solely by the fixing screws on the front panel and must have a couple of handles to facilitate the insertion/extraction of the equipment from the front side of the 19” rack.

The following degrees of protection, according to the IEC 60529 will be guaranteed:

c. IP-34 for the enclosure;

d. IP-2x to meet health and safety requirements; therefore, the terminals must be completely covered with protection caps.

Ventilation holes are allowed in the bottom side and in the side vertical walls. A plate holder for the unique identification of the item in the plant must be installed on the front panel. Finally, the terminal boards and connectors on the rear must be protected against physical damages that may be caused during handling and transport (e.g. side protections 30/10 Aluminum or 20/10 galvanized steel).

6.1.2 Electrical safety

The insulation properties must be compliant with the standards on electrical safety referred in Table 2.

On the right hand side of the rear panel there must be a M6 type screw terminal with a double washer made of copper alloy, copper-washed or made of material with equivalent electrical conductivity for the grounding connection.

Table 2 – Standards for the Electrical Safety

IEC 60255-26	Measuring relays and protection equipment - Part 26: Electromagnetic compatibility requirements
IEC 60255-27	Measuring relays and protection equipment - Part 27: Product safety requirements
IEC 60204-1	Safety of machinery - Electrical equipment of machines - Part 1: General requirements
IEC 61000-4-5	Electromagnetic compatibility (EMC) - Part 4-5: Testing and measurement techniques - Surge immunity test
IEC 60529	Degrees of protection provided by enclosures (IP Code)
IEC 60664-1	Insulation coordination for equipment within low-voltage systems - Part 1: Principles, requirements and tests
IEC 61810-1	Electromechanical elementary relays - Part 1: General and safety requirements
IEEE C37.2	IEEE Standard Electrical Power System Device Function Numbers and Contact Designations

6.1.3 EMC

The MFP and the remote modules must comply with all the EMC standards referred in Table 3.

Table 3 – Standards for the Electromagnetic compatibility (EMC)	
IEC 61000-6-4	Electromagnetic compatibility (EMC) - Part 6-4: Generic standards - Emission standard for industrial environments
IEC 61000-6-5	Electromagnetic compatibility (EMC) - Part 6-5: Generic standards - Immunity for equipment used in power station and substation environment
EN 55011	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement

By according to the IEC 61000-4-30 and IEC 62749 and EN 50160, the MFP is called to work also in presence of power quality disturbances affecting also the power supply.

The following tables list the levels of immunity to electromagnetic disturbances, as defined in the relevant standards, the device must comply.

Table 4 – EMC levels for the Enclosure Port		
Power frequency magnetic field	IEC 61000-4-8	Test Level 5
Damped oscillatory magnetic field	IEC 61000-4-10	Test Level 5
Radiated, radio-frequency, electromagnetic field (including digital radio telephones)	IEC 61000-4-3	Test Level 3 (up to 2 GHz)
Electrostatic discharges	IEC 61000-4-2	Test Level 4

Table 5 – EMC levels for the Grounding Port		
Electrical fast transient/burst	IEC 61000-4-4	Test Level 4
Conducted disturbances, induced by radio-frequency fields	IEC 61000-4-6	Test Level 3

Table 6 – EMC levels for the Communication Port		
Power frequency voltage	IEC 61000-4-16	Test Level 4
Conducted disturbances in the frequency range 0 Hz to 150 kHz	IEC 61000-4-16	Test Level 3
Voltage surges 1.2/50ms – Current surges 8/20ms	IEC 61000-4-5	Test Level 3
Damped oscillatory waves	IEC 61000-4-18	Test Level 3
Ring wave	IEC 61000-4-12	Test Level 3
Electrical fast transient/burst	IEC 61000-4-4	Test Level 4
Conducted disturbances, induced by radio-frequency fields	IEC 61000-4-6	Test Level 3

Table 7 – EMC levels for the In and Out Port of the d.c. supply		
Power frequency voltage	IEC 61000-4-16	Test Level 4
Conducted disturbances in the frequency range 0 Hz to 150 kHz	IEC 61000-4-16	Test Level 3
Voltage surges 1.2/50ms – Current surges 8/20ms	IEC 61000-4-5	Test Level 4
non-repetitive damped oscillatory transients	IEC 61000-4-12	Test Level 3
Electrical fast transient/burst	IEC 61000-4-4	Test Level 4
Conducted disturbances, induced by radio-frequency fields	IEC 61000-4-6	Test Level 3
Voltage dips	IEC 61000-4-29	50% for 0,1 s
Short interruptions	IEC 61000-4-29	100% for 0,05 s
Voltage variations	IEC 61000-4-29	Un + 20% - 40%
Ripple on d.c. input power port	IEC 61000-4-17	10%

6.1.4 Climatic conditions

The Table 8 provides applicable MFP operating conditions. Exact conditions depend on installation site, during the procurement process (par. 16.2), the information about the operating conditions will be shared.

Table 8 – Climatic conditions

Operating temperature (average)	20°±3°C
Operating temperature (limits)	-10°C ÷ 70°C
Storage temperature	-20°C ÷ 70°C
Relative humidity	≤ 95 %
Atmospheric pressure	860 kPa ÷ 1060 kPa

Besides, at the maximum operating temperature, the hottest MFP component must reach a temperature below or equal to 10°C with respect to its maximum permissible temperature. At the minimum operating temperature, the internal temperature of the device (air) must be higher or equal to 10°C than the test temperature.

6.2 Electrical, electronical and data connector characteristics

All the connectors with poles > 1 should have fixed screws. The HW platform must be based on a modular design to guarantee flexibility and scalability. Non modular design or different modular approaches may be allowed during the procurement process (par. 16.2) only for MFP type L (par. 6.1.1).

The chassis (including the front panel, the display screen and the buttons), the power supply and the main-board are the basic/common components of the MFP that will be shared by all the modules in the equipment.

The main-board (MB) must be provided with expansion slots to accommodate the peripheral boards (Table 9).

In order to have contacts switching time less than 10 μs, MOSFET or MOSFET hybrid switching technologies must be adopted.

Table 9 – Peripheral boards to accommodate in the expansion slots

Board code	Board description	Order
MA	Analog Inputs, 4 currents	1
MV	Analog Inputs, 4 voltages	2
MT	Circuit-breaker Control	3
MI	Digital Inputs	4
MO	Digital Outputs	5
MP	Power supply	6
MJ	Predisposition for additional Digital Inputs	7
MU	Predisposition for additional Digital Outputs	8
MM	Mainboard with CPU and communication Interface: a. 2 x Ethernet 100 BASE FX (LC connector) for the Process BUS; b. Ethernet 100 Base FX (LC connector) for the Station BUS; c. Ethernet 100 Base TX (RJ45), connector on the front panel. These 4 Ethernet ports must be independently addressable at the MAC level (each one must have its own dedicated MAC Address), they must be directly controlled by the CPU, the use of Copper-to-Fiber converters, Serial/Ethernet converters, XPort, etc. and any other adapter is not acceptable. The Ethernet optical ports on the rear must be labelled (Process or Station Bus).	9

The Supplier may propose another position/sequence/order of the peripheral boards in the device.

6.2.1 Power supply board (MP connector)

The connector for the power supply must be 3 poles, pitch 5.08, with common polarization; as a part of the MT (Table 9).

The power supply unit of the device must comply with the requirements in the Table 10.

Table 10 – Electrical characteristics of the power supply

Auxiliary Voltage (Vaux)	110V (+30%, -60%) - 125V (+30%,-30%) - 220V (+10%,-60%) d.c. Auxiliary Power depends from installation site, during the procurement process (par. 16.2), the information about the operating conditions will be shared.
Ripple rate for DC power supply	10%
Temperature at maximum load	Max ϑ = Envir. temp. + 25 K
residual ripple at maximum deliverable current	10%
Insensitivity to micro-interruptions	Vaux 0V per 100 ms
Overload 1 s	2 Vn
Maximum MFP consumption	25 W
Starting current	<10A 10ms
Environmental temperature	Table 8
Cooling	Natural ventilation

The maximum consumption refers to the entire device in a test configuration including all the HW fully functional, backlit display switched-on and the Digital Outputs closed.

A self-diagnosis function must be provided in order to continuously check the general efficiency of the power supply and any anomaly or failure detection must be signaled by switching off the "power supply OK" LED on the front panel and sending an alarm to the RTU of the Primary Substation.

The anomaly or failure state of the power supply must automatically activate the 27X relay of the circuit-breaker Control board.

Further, the front panel must have light signals (i.e. green led) for:

a. input voltage presence (Vaux);

b. correct operation of the power supply (power supply OK).

The power supply must be protected against the inadvertent power supply polarity inversion.

The power supply for the device will be connected to the auxiliary power subsystem of the Primary Substation using the MP connector specified in Table 11.

Table 11 – Electrical characteristics of the power supply

Signal	CLAMPS	Function	Voltage
PS	01	Ground	
PS	02	+ Power Supply Aux	+Vaux
PS	03	- Power Supply Aux	-Vaux

6.2.2 Analog Inputs

The analog signals acquisition boards must have 4 inputs for the voltages and 4 inputs for the currents with the following rated characteristics:

a. Voltage Inputs (Vn): 100/ √3 – 120 V a.c. (selectable value);

b. Current Inputs (In): 1 A – 5 A (selectable value through software or hardware);

c. Sampling: 128 samples/cycle.

Each input must be user configurable via software without 3rd party (manufacturer's) interventions and without having to recalibrate the relative Analog Input.

The MFP must be configurable for use in both 50 and 60 Hz networks. The sampling must be synchronized with the mains frequency in order to ensure a constant number of samples per cycle. Sampling frequency may be reduced for the protection functions only (excluding disturbance recording) but any modifications implemented by the manufacturer must be approved in advance by ENEL.

The terminals for both the Current and Voltage Inputs and their polarities must be clearly identified on the device.

According to these parameters, the Analog Inputs can be overloaded within the limits described in Table 12 without any damage.

Table 12 – Summary of the electrical characteristics of the Analog Inputs

Current	In	1A or 5A
	Input impedance	<0,05Ω
	Consumption	<0,05VA (CT 1A) <0,25VA (CT 5A)
	Thermal Withstand	4 In (5 In for the C4 Input)
	Overload 1s	50 In 800 A peak for a half-wave (10 ms) for In = 5 A 160 A peak for a half-wave (10 ms) for In = 1 A
Voltage	Vn	100 – 115 V a.c. (selectable value)
	Input impedance	>50kΩ
	Consumption	<0,2 VA (VT 100V)
	Thermal Withstand	1,3 Vn
	Overload 10 s	2 Vn
Rated frequency		50 Hz (60 Hz configurable via SW)
Magnetic induction		0÷1.5 mT all directions

The Table 13 specifies the eight Analog Inputs with their associated measurement functions as configured in the running FW.

Table 13 – Use of the Analog Inputs

Protective function			MV feeder, Aux. Serv.	Power Factor Correction	Earting Transformer (TFN)	Section circuit-breaker	Bus transfer	HV delivery line to the customer
FIRMWARE			FW900 LMT	FW900 CAP	FW900 TFN	FW900 K	FW900 TSL	FW900 ATU
Signal		Clamp	Measurement Functions					
Analog Voltage Input	V1	MV1 - MV4	V_{4-0}	V_{4-0}	V_{4-0}	V_{4-0}	V_{4-0}	V_{4-0}
	V2	MV2 - MV4	V_{8-0}	V_{8-0}	V_{8-0}	V_{8-0}	V_{8-0}	V_{8-0}

	V3	MV3 - MV4	V_{12-0}	V_{12-0}	V_{12-0}	V_{12-0}	V_{12-0}	V_{12-0}
	V4	MV5 - MV6	V_0/V_{SYNC}	-	-	-	V_{RIF}	V_0
Analog Current Input	C1	MA1 - MA2	I_4	I_4	I_4	I_4	I_4	I_4
	C2	MA3 - MA4	I_8	I_{SQL}	$3I_0$ (51N)	I_8	I_8	I_8
	C3	MA5 - MA6	I_{12}	I_{12}	I_{12}	I_{12}	I_{12}	I_{12}
	C4	MA7 - MA8	$3I_0$	$3I_0$	$3I_0$	$3I_0$	$3I_0$	$3I_0$

6.2.3 Connection of the Voltage Analog Inputs (MV connectors)

The connector for the Voltage Analog Inputs must be 6 poles, pitch 5.08; as a part of the MV (Table 9). Additional details are in Table 14.

Table 14 – Connector for the Voltage Analog Inputs

Input	Clamp	Measure
V1	MV1	V_{4-0}
V2	MV2	V_{8-0}
V3	MV3	V_{12-0}
common	MV4	Neutral MT
V4	MV5	$3V_0$
V4	MV6	$3V_0$ (ground)

6.2.4 Connection of the Current Analog Inputs (MA connectors)

The connector for the Current Analog Inputs must be 8 poles, pitch 7.62 and section 6 mm^2; as a part of the MA (Table 9). Additional details are in Table 15.

Table 15 – Connector for the Voltage Analog Inputs

Input	Clamp	Measure
C1	MA1 (IN)	I4
	MA2 (OUT)	I4
C2	MA3 (IN)	I8, ISQL, 3Io (51N)
	MA4 (OUT)	I8, ISQL, 3Io (51N)
C3	MA5 (IN)	I12
	MA6 (OUT)	I12
C4	MA7 (IN)	3Io
	MA8 (OUT)	3Io

The current signals must be acquired by means of a system that electrically decouples (e.g. using toroidal CTs) the inputs from the rest of the circuits.

6.2.5 Connection of the Embedded Digital Input (MI connector)

The connector for the Programmable Digital Inputs must be 7 poles, pitch 5.08, with common polarization; as a part of the MI (Table 9).

The sampling of digital signals must allow the processing of the digital signals as well as the corresponding output on the disturbance-recording file with 1 ms resolution. While typically a change in the status of the Digital Inputs is detected on the rising edge of the signal, it must be possible via programmable functions to detect the variation also on the falling edge of the signal.

The default parameters that must be set in the MFP are in Table 16.

Table 16 – Summary of the electrical characteristics of the Digital Inputs	
Vaux	ref to Par.6.2.1
Voltage Level HI	≥ 0,75 Vaux
Voltage Level LO	≤ 0,6 Vaux
Input Resistance to Vn	12 kΩ ÷ 40 kΩ
Power Consumption	≤ 3,6 W

The Table 17 shows the default configuration of the pin-outs of the MI connector for the Digital Inputs, where “Prog.” means that the associated function is programmable.

Table 17 – Connector for the Programmable Digital Input (MI connector)							
Protective function		MV feeder, Aux. Serv.	Power Factor Correction	Earting Transformer (TFN)	Section circuit-breaker	Bus transfer	HV delivery line to the customer
FIRMWARE		FW900 LMT	FW900 CAP	FW900 TFN	FW900 K	FW900 TSL	FW900 ATU
Signal	Clamp	Associated function					
Dig In 1	MI 1	Prog.	Prog.	Prog.	Prog.	Prog.	Prog.
Dig In 2	MI 2	Prog.	Prog.	Prog.	Prog.	Prog.	Prog.
Dig In 3	MI 3	+TC	+TC	+TC	+TC	+TC	+TC
Dig In 4	MI 4	Prog.	Prog.	Prog.	Prog.	Prog.	Prog.
Dig In 5	MI 5	Prog.	Prog.	Prog.	Prog.	Prog.	Prog.
Dig In 6	MI 6	Prog.	Prog.	Prog.	Prog.	Prog.	Prog.
Common	MI 7	-Vaux	-Vaux	-Vaux	-Vaux	-Vaux	-Vaux

These pin-outs are mapped into the connection diagram shown in the following example of application (Figure 1).

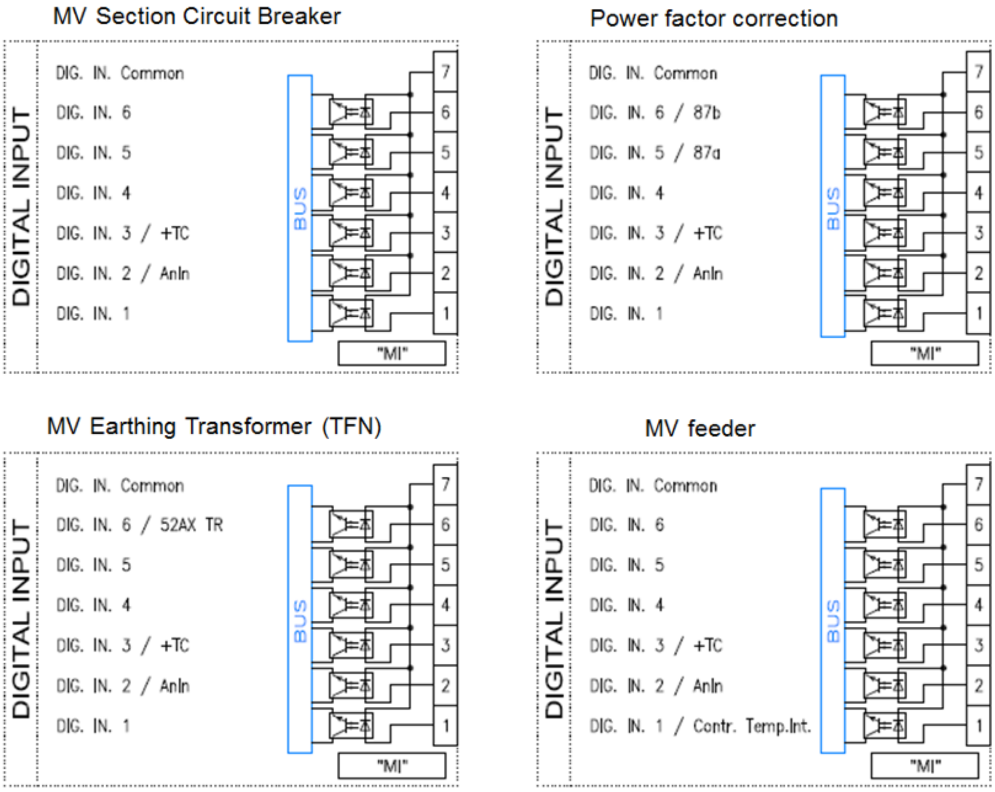

Figure 1 – Example of application about MI connectors

6.2.6 Connection of the Embedded Digital Output (MO connector)

The connector for the Programmable Digital Outputs must be 12 poles, pitch 5.08, with common polarization; as a part of the MO (Table 9).

These digital outputs are needed to send commands to other devices. The MFP sends commands to other devices or through the MO connectors or through the Remote I/O modules (Chapter 7).

The relays driving the Digital Outputs must comply with the IEC 61810-1, and must have the electrical characteristics shown in Table 18.

Table 18 – Summary of electrical characteristics of the (Command) Digital Output (MO connector)	
DC supply voltage	Vaux
Permanent current	5 A
Current breaking capacity L/R=40ms	0,5 A
Number of electric maneuvers	100000
Number of mechanical maneuvers	1000000
Minimum command duration	100 ms (setting)
Maximum command dropout	150 ms (setting)

The digital outputs must be dry contacts (not wetted by a voltage source).

The pin-outs of the MO connector and the functions of the Digital Outputs are in Table 19.

Table 19 – Connector for the Programmable Digital Outputs (MO)

Protective function		MV feeder, Aux. Serv.	Power Factor Correction	Earting Transformer (TFN)	Section circuit breaker	Bus transfer	HV delivery line to the customer
Signal	Clamp	Associated function					
Dig Out 1	MO 1	Com. Dig. Out 1	Com. Dig. Out 1	+SNI	Com. Dig. Out 1	Com. Dig. Out 1	Com. Dig. Out 1
Dig Out 1	MO 2	Dig. Out 1 Programmable	Dig. Out 1 Programmable	SNI	Dig. Out 1 Programmable	Dig. Out 1 Programmable	Dig. Out 1 Programmable
Dig Out 2	MO 3	Com. Dig. Out 2	Com. Dig. Out 2	+SNC	Com. Dig. Out 2	Com. Dig. Out 2	Com. Dig. Out 2
Dig Out 2	MO 4	Dig. Out 2 Programmable	Dig. Out 2 Programmable	SNC	Dig. Out 2 Programmable	Dig. Out 2 Programmable	Dig. Out 2 Programmable
Dig Out 3	MO 5	Com. Dig. Out 3	Com. Dig. Out 3	+ RP CX	Com. Dig. Out 3	Com. Dig. Out 3	Com. Dig. Out 3
Dig Out 3	MO 6	Dig. Out 3 Programmable	Dig. Out 3 Programmable	RP CX	Dig. Out 3 Programmable	Dig. Out 3 Programmable	Dig. Out 3 Programmable
Dig Out 4	MO 7	Com. Dig. Out 4	Com. Dig. Out 4	+RP AX	Com. Dig. Out 4	Com. Dig. Out 4	Com. Dig. Out 4
Dig Out 4	MO 8	Dig. Out 4 Programmable	Dig. Out 4 Programmable	RP AX	Dig. Out 4 Programmable	Dig. Out 4 Programmable	Dig. Out 4 Programmable
Dig Out 5	MO 9	Com. Dig. Out 5	Com. Dig. Out 5	Com. Dig. Out 5	Com. Dig. Out 5	Com. Dig. Out 5	Com. Dig. Out 5
Dig Out 5	MO 10	Dig. Out 5 Programmable	Dig. Out 5 Programmable	Dig. Out 5 Programmable	Dig. Out 5 Programmable	Dig. Out 5 Programmable	Dig. Out 5 Programmable
Dig Out 6	MO 11	+ LOCAL ALARM	+ LOCAL ALARM	+ LOCAL ALARM	+ LOCAL ALARM	+ LOCAL ALARM	+ LOCAL ALARM
Dig Out 6	MO 12	LOCAL ALARM	LOCAL ALARM	LOCAL ALARM	LOCAL ALARM	LOCAL ALARM	LOCAL ALARM

These pin-outs are mapped into the connection diagram shown in the following example of application (Figure 2).

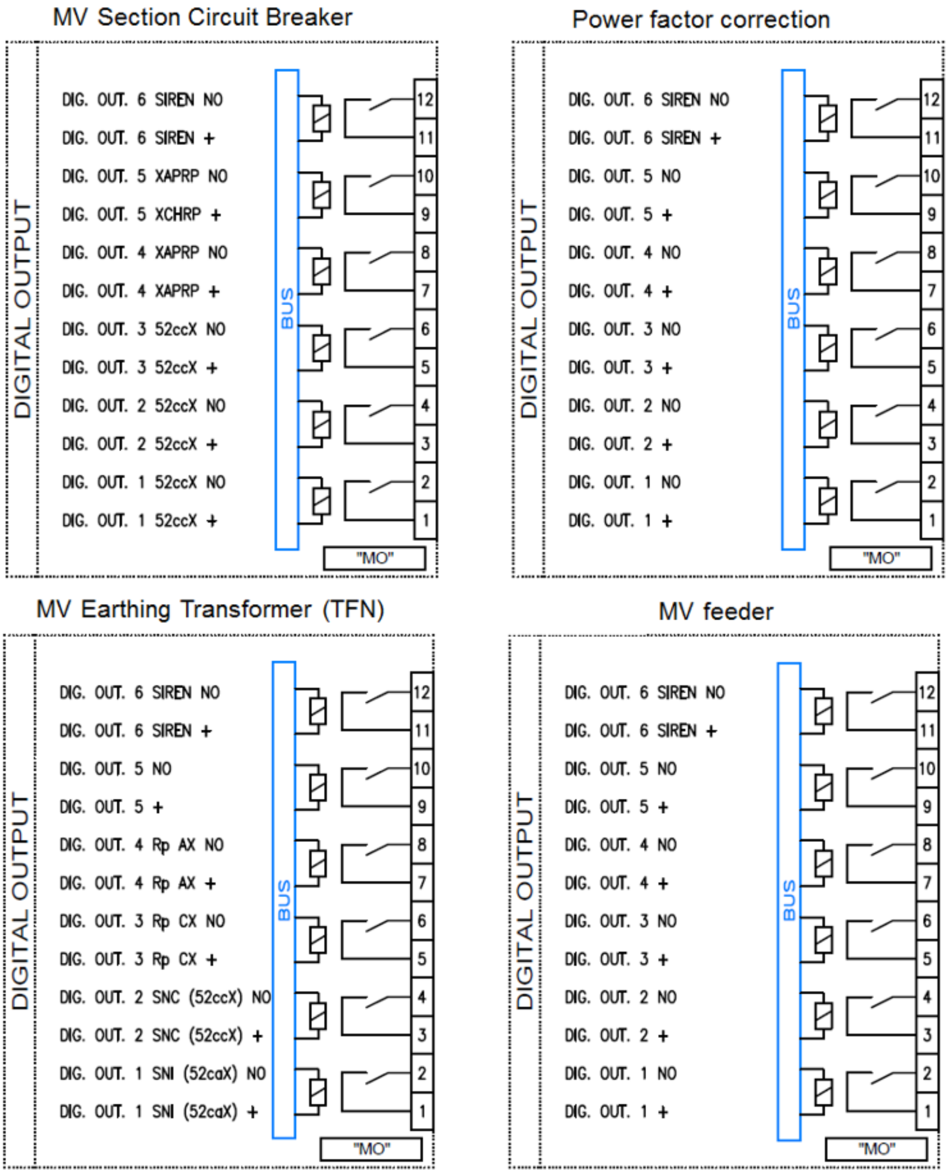

Figure 2 – Example of application about MO connectors

6.2.7 Circuit-breaker control connection (MT connector)

The connector for the circuit-breaker command must be 14 poles, pitch 5.08, with common polarization; as a part of the MT (Table 9).

The device must provide Active-High Digital Inputs at the rated power supply and Outputs must be equipped with control relays.

The device must have a board called (MV) Circuit-breaker control. The board has the purpose of transducing the positions of the MV or HV circuit-breaker controlled by the device and sending the Open and Close commands, both coming from remote and those given by the local buttons and by the automatic commands. The Inputs that transduce the positions must be driven by the rated voltage and must recognize the high state when the value of 0,75Vaux d.c. is exceeded and the low state when the voltage goes below 0,6Vaux d.c. and have a rated bias voltage resistance between Max. 40 kΩ and min. 12 kΩ.

The relays are used to transduce the

a. manual opening and protection commands for the MV or HV circuit-breaker;

b. manual closing and auto-reclosing commands for the MV or HV circuit-breaker.

The relays must be supplied by the +V pole on the MT connector.

The electrical characteristics, pin-outs and functions of the connector of the Digital Inputs are specified in par. 6.2.5.

The embedded output, reported on the connector with board code **MT** (Table 9), command the circuit-breaker. The four outputs (opening commands, 2° opening circuit, closing and 27 – power supply) must be realized by solid-state or hybrid technology.

Table 20 – Digital Outputs (Command, solid state)	
DC supply voltage	Vaux
Permanent current	10 A
Current breaking capacity L/R=40ms	4 A
Minimum command duration	100 ms (setting)
Maximum command dropout	150 ms (setting)

The solid state (Command) Outputs must have the same insulation level as for traditional (Command) relays between the contacts and the actuation coil, that means that the driving stage of the solid state Command must be galvanically separated from the power supply of the device.

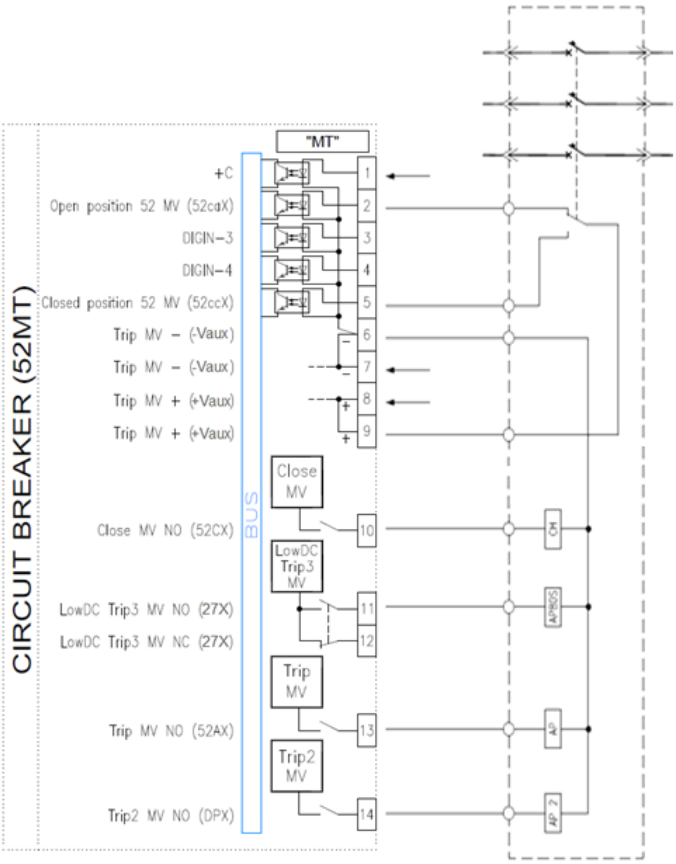

Figure 3 – Board for commanding the circuit-breaker

The pin-outs of the MT connector for the circuit-breaker command are specified below:

Table 21 – Connector for the circuit-breaker command (MT)

Signal	Clamp	Description	Common Polarization Voltage
Dig-IN	1	+ Local Commands	
Dig-IN	2	52MT- caX	
Dig-IN	3	Available	
Dig-IN	4	Available	
Dig-IN	5	52MT- ccX	
PS	6	- Vaux	
PS	7	- Vaux	
PS	8	+ Vaux	
PS	9	+ Vaux	
Dig-OUT	10	52MT- CX	
Dig-OUT	11	52MT- AX 3rd circuit NO in case of voltage absence (27X)	
Dig-OUT	12	52MT- AX 3rd circuit NC in case of voltage absence (27X)	
Dig-OUT	13	52MT- AX Opening 1st circuit	
Dig-OUT	14	52MT- AX Opening 2nd circuit	

6.2.8 Additional Input / Output boards

The device must be ready to support two additional boards, one with Inputs and the other with Outputs, to allow for future applications and functions based on PLC programming (e.g. the diagnostic functions described in 8.3).

The electrical characteristics of the Digital Inputs are specified in 6.2.5.

The control Outputs of this board are specified in 6.2.6.

6.3 Layout of the MFP enclosure

The front and rear views of the MFP are shown in the following figures, Figure 4 and Figure 5; these figures are only examples and represent a minimal expected equipment of the device.

The manufacturer may offer alternative solutions that ENEL will evaluate.

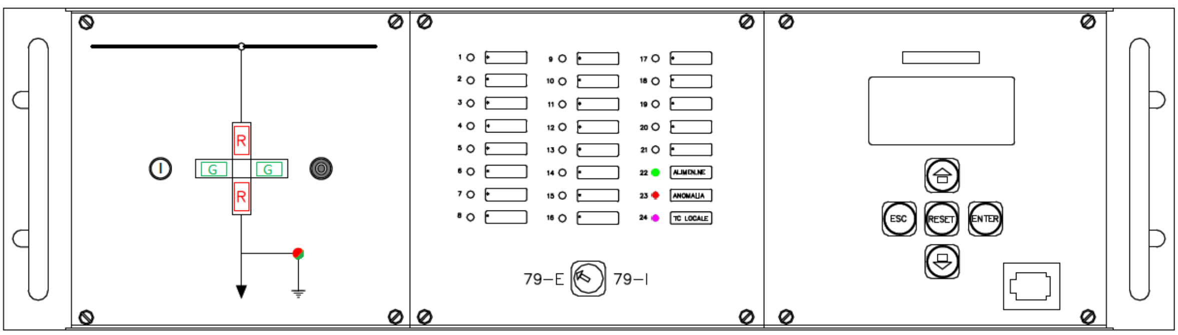

Figure 4 – Front view of the MFP

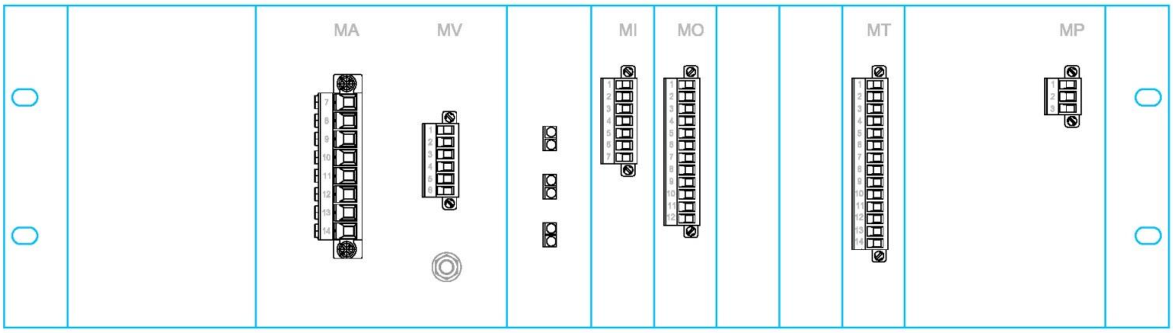

Figure 5 – Rear view of the device

The front panel of the device must contain:

a. Light Indicators (LEDs);
b. Display screen;
c. Push-buttons and / or keyboard;
d. Communication port (RJ45 type).

6.3.1 Labeling

The following information must appear on the device in a permanent and non-erasable engraving:

a. Protection functions;
b. Voltage and current rated values;
c. Brand, model and serial number;
d. Power supply voltage.

6.3.2 Circuit-breaker control buttons

The circuit-breaker operating buttons must meet the requirements of mechanical strength IK03 by according to IEC 62262. They must not be of a touch-sensitive type in order to prevent the unintentional activation of the device with the following characteristics:

a. Closing button: White button with black imprinted “I”,
b. Opening button: Black button with white imprinted “O”.

6.3.3 Auto-reclosing selector

A rotary selector switch must be provided for the Inclusion/Exclusion of the 79 function, auto-reclosing of the circuit-breaker, in case a Primary Substation is locally controlled; the selector must be compliant with IK03 mechanical strength rating, according to IEC 62262. The “79” function selector must be protected with a removable protection cover.

6.3.4 Navigation buttons

The device must be equipped with navigation-selection buttons or rotary selector / confirmation, which allow the operator full access to the MFP functions. The local setting/configuration of the MFP must only be possible via a software application running on a PC connected to the device.

They must be compliant with IK01 mechanical strength rating that precludes solutions based on capsule or touch-screen technologies.

6.3.5 Display

The device must be provided with a graphic LCD display with a resolution that, at minimum, is capable of simultaneously displaying the three-phase currents, the active and reactive power, the phase-to-phase voltage and the state of the auto-reclosing. An Energy Saving function with configurable parameters must be provided. Further, the display must be capable of being back-lit in the event that the + C signal on the C1 connector is activated.

The expected service life of the display must be at least 10^5 h.

6.3.6 Local LEDs and signals

The relay must have a LED, preferably green, to indicate the presence of the auxiliary voltage supply. This indicator must be located on the front panel of the device and marked as “V_{aux}”.

On the front panel of the MFP must be there, at least, 16 LEDs for signaling the local alarms. The alarm functions associated to the LED and their colors (at least three colors) must be user configurable via the PC-based SW application for the configuration of the MFP.

The reset of the LEDs must be manual and operable on the front panel of the MFP. The LEDs assignment is shown in Table 22:

Table 22 – LEDs assignment

N.	Description
1	Tripping of the 51/50 protections
2	Tripping of the 51N/50N protections
3	Tripping of the 67N protections
4	Tripping of the 46 protections
5	Tripping of the 59N protection
6	Tripping of the 46N (61N) protection
7	Tripping of the 27 protection
8	Tripping of the 59N protection
9	Locked Auto–reclosing
10	Reconnection command (79)
11	Missing Closing Conditions (25)
12	Voltage Anomaly
13	Tripping Circuit Fault
14	Opened Circuit-breaker
15	External Tripping Command
16	Cogeneration automation in service

6.4 Reliability requirements

By according to the terms and definitions from IEC 60050-192, the MFP useful life (or lifetime), is the time interval, from first use until user requirements are no longer met, due to economics of operation and maintenance, or obsolescence. In this context, “first use” excludes testing activities prior to hand-over of the item to the end-user.

The useful life must exclude the early life failure period (infant mortality period); the Supplier must perform all necessary tasks to eliminate the “child mortality” of the devices before the delivery and these activities must be fully described in the documentation, which must accompany the device. Accordingly, the Supplier must certify that the equipment, when delivered, has commenced its constant failure rate period.

The Supplier must declare the failure rate of the device to ensure that it is consistent with the project specifications (the underlying calculation method will be reported in the documentation) and must not exceed 0,3% per year failure and the 4.5% cumulative failure in the lifetime, when the device is installed and operating the required environmental conditions.

The “constant fault-rate” period means the “lifetime” of the device and must be greater than 15 years, with the exception of batteries, displays and Flash E2PROM, for which “life cycle” must not be less than 8 years.

For the purpose of failure analysis, a possible restoration (reparation or maintenance) must not affect the error rate during “lifetime”.

A failure is defined as the loss of operation of the device that requires its removal from the substation or the change of the SW existing to eliminate the defect.

For the purpose of the analysis of the device’s reliability during its lifetime, the “pertaining faults” exclude improper use or a wrong operation; accordingly, the Supplier must define in detail the usage conditions and the correct operation of the equipment.

The MFP must be designed for an expected mean operating time between failures (MTBF) longer than 30 years.

The MFP must be designed for an expected mean time to restoration (MTTR) smaller than 3 h.

6.5 Remote I/O module

The Remote I/O module (RIO) is a slave IED of the MFP that monitors the operating status and the defects of both, the switching device and any controlled equipment and notifies them to the MFP.

The quantities of RIO to be supplied with each MFP will depend on the engineering project of the installation.

The RIO must be compliant with the GSTP102.

6.6 Electrical Diagrams

For the electrical diagrams, please refer to GSTX101 Electrical Diagrams for Protection and control device for HV / MV substation – Multifunctional Feeder Protection MFP.

7 COMMUNICATION REQUIREMENTS

In case of advanced RTU (IEC 61850 Client) the ENEL standard system configuration of the Primary Substation, requires that the communication among IEDs and between IEDs and RTU will take place on the Station Bus, according to the IEC 61850 series, through the IED physical interface described in this chapter.

As stated before, the MFP accomplishes to the definition of IED, by according to IEC 61850 series, so it uses protocols defined in the IEC 61850 series to communicate with the RTU. The communication profile is defined in the GSTP103.

The MFP↔RIOs communication is point-to-point through the optical ports of the interface as described in Par. 7.3. However, it should be possible to establish dedicated switches to allow this communication through implementation of a Process Bus LAN by means of dedicated switches.

The MFP must be able to manage up to 3 RIO modules, due the limitation of the MODBUS.

Nevertheless, if the protocol of communication between the MFP and the RIOs is IEC 61850 instead of MODBUS then the number of the RIO modules managed by the MFP could be up to 8 (if there are available IP addresses in the LAN).

7.1 Interface to the Station Bus (Remote Control LAN)

The hardware interface of the MFP to the Station BUS, according to the IEC 61850 series, must be the Ethernet 100 BASE-FX (by according to IEEE802.3u and IEEE802.1q) with an LC type optical port.

7.2 Interface to the Field Bus

Regardless of the type of connection between the MFP and the RIOs or the chosen communication protocol (MODBUS or IEC 61850), the maximum time between the acquisition of a status from a module and the execution of a command (closed state of a command relay) to another module must be less than 15ms.

The 1000 BASE-FX network card must be consistent with IEEE802.3u and IEEE802.1q and be equipped with two LC type optical ports allows the MFP to communicate with two RIO.

The MFP (Client) and the Remote I/O modules (Servers) can communicate either via the MODBUS TCP/IP protocol suite or with the protocols specified in the IEC 61850 series.

The interoperability between MFP and RIOs, even among different manufacturers, is mandatory; for that reason, any amendment to the above mentioned protocols or standard will be not accepted.

7.3 Interface for local connection and configuration

The MFP must have an Ethernet 100 BASE-TX with an RJ45 connector on the front panel to facilitate the local configuration, including all the FW updates of the boards. The local maintenance interface is Ethernet native so serial/Ethernet adapters/ converters are not allowed.

The software application must be compatible with the operating system homologated in ENEL at the procurement time (par. 16.2).

During the lifetime of the MFP supply contract the functional tests must be mandatorily repeated in case the manufacturer makes any firmware or software modification.

Once the settings of an MFP have been configured, they must be retained, without any alteration, in long-term memory storage even in the absence of auxiliary power supply.

Web based solution (web server integrated in the MFP) are preferable solution for local connection and configuration; nevertheless Enel will evaluate proprietary software (installable or portable) based solution.

7.4 Requirements for the Communication and the File transfer

The MFP must natively support both Internet Protocol IPV4 and IPV6; all the application communications must be compliant with the IEC 61850 series.

The MFP must have, at the same time but on different Ethernet interfaces:

a. A static IP address (192.168.1.1) for local connection, not associated with any gateway;

b. An additional IP address that can be configured as static

Therefore, before the activation of the MFP, the operator (with the local configuration SW) has to configure the following fields:

c. MFP IP address, if static,

d. Subnet mask,

e. Default gateway.

The following services must be available:

f. WEB server,

g. NTP client,

h. SSH server,

i. SNMP server,

j. SFTP server.

The CID file transfer will be implemented according to the File Transfer service specified in the IEC 61850 series. The configuration server must be able to configure the list of IED subscribed within each IED (maximum 100 per IED). Each IED, according to its CID (received from the central configuration server, independent to the MFP manufacturer), must be able to subscribe the messages from max 100 IEDs.

7.5 Time synchronization

The time synchronization of the MFP must be done via NTP with one PSS: the MFP is the Client and the RTU in the Substation is the Server.

In case of losing NTP Server synchronization, the drift of the MFP internal clock, must not exceed 50 ppm.

If the synchronization signal is missing for a time greater than a user configurable threshold (1 to 240 h), the alarm message "Absence of remote time synchronization" must be displayed on the MFP and notified to the RTU.

7.6 IEC 61850 interoperability profile

The IEC 61850 interoperability profile must be compliant with the GSTP103.

The MFP must be able to receive the standard CID file via the IEC 61850 file transfer service and via SFTP. It must be possible to activate the configuration with an IEC 61850 command from the Central configurator.

The CID file will be used to:

a. Update the MFP Communication and Data Modelling configuration;

b. Configure/set the parameters of the functions, in particular the protections; a dedicated flag in the Web page and in the configuration software will enable this feature.

The CID file can be downloaded from the MFP via IEC 61850 file transfer and via SFTP.

The CID file will have a name defined by the ENEL operator, which must be maintained unchanged if downloaded from the MFP. The CID file does not have a default name and must be accepted by the receiving MFP.

If the handling of the CID file requires to restart the device, the MFP's protection functions must be available within 30s and the communication server within 1 minute of initiating the restart sequence.

The performance of the protection functions, the publication/subscription of the GOOSEs, the emission of the Reports must not be influenced by the number (up to its maximum) of the subscribed BLIND GOOSEs.

In the event that one MFP's Client is either disconnected or shutdown, the reports enabled by that Client must be set to a disabled and un-reserved status. A normal Client restart cycle is about 20s, which means that the MFP must recognize the disconnection of a client in less than 15s. This will allow the Client to re-enable the relevant reports after re-establishing a Client/Server communication session.

7.7 Remote access for maintenance

Remote access to the following data files:

a. Disturbances files/oscillography, COMTRADE format mandatory,

b. Fault records,

c. Event records,

d. Protection parameters (at least the ones related to the functions modelled in the IEC 61850 profile of the MFP).

The MFP must use the MMS service (file transfer) in a client/server MMS-based communication (by according to IEC 61850 series); this access should not depend to any proprietary SW provided by the manufacturer of the MFP (see also the exception in par. 7.3).

7.7.1 Data extraction service

The manufacturer must identify:

a. Storage path,

b. File name, identifying the name received in the file transfer service,

c. Storage deep and name assignment.

7.7.2 Data extraction process

The manufacturer must identify the trigger wich allow the extraction of data by means on an indication in the data model identifying both the attribute and the process of activation / deactivation. In the case of not having trigger, data extraction would be cyclic (at a user configurable frequency).

Additionally, the manufacturer must deliver a read-only-level license of the software application so that an external application (developed by others) could retrieve the information mentioned above from the MFP.

7.8 On site configurations and programming

7.8.1 On site configuration

The MFP must implement a Web Server that supports generic Web browsing to display and configure the calibration thresholds related to the FdP. In particular, the following capabilities are minimal requirements and must not be regarded as either limits or targets:

a. MFP general data, including the labelling assigned by the user,

b. identification of the firmware version,

c. continuous monitoring of all the measurement functions on a 1s refresh cycle,

d. monitoring of the status of Inputs and Outputs,

e. MFP diagnostic results (overall device and specific elements),

f. calibration values of the protection stages (thresholds and timers),

g. total and partial counters,

h. information related to the internal disturbance recording (number of records, active triggers, internal memory status).

The MFP must support programming of specific logics using discrete and mathematical logical variables (volatile and non-volatile), timers and counters. It must have the following minimum quantities:

i. Volatile variable: 30

j. Non-volatile variable: 30

k. Timer: 30

l. Mathematical variable: 10

Must support the following operations:

m. "AND" gate

n. "OR" gate

o. "NOT" gate

p. "XOR" gate

q. Comparator

r. Rising edge sensibility

s. Falling edge sensibility

t. Flip Flop SR

The complete set of operations (configuration of programmable logics, status and forcing of the physical I/O and Goose/MMS, internal states, etc.) must be possible using ad-hoc software developed by the manufacturer.

The software must be unlocked licensed freeware (without any SW and/or HW keys) that limits the number of installations or the overall functionality. The software must be compatible with the operating system homologated in ENEL in the moment of the adjudication.

The MFP will be fully working during the upload & configuration of a new profiles (including calibration and configuration). The MFP will activate the new profile only at the end of the upload and configuration procedure, following the usual integrity and congruity checks of the new profile.

If using ad-hoc SW, it must be possible to configure the MFP either off-line (disconnected from the IED) or on-line, and via the same interface. The off-line configuration/setting must produce a file to be uploaded to the MFP at a later time either via local or remote connection to the device.

The remote configuration file transfer will be performed using the relevant services of the IEC 61850 series. Further details about this feature will be provided by ENEL during the prototyping phase.

The MFP must be able to store measurements, status and diagnostics data in text format files.

7.8.2 Programmable logic configuration

The SW for the configuration/setting of the MFP provided by the manufacturer or a separate third party software product that meets the requirements stated, must be able to program of logic based either on pre-set or user-customizable logic blocks. A graphical programming interface similar to the example shown in the Figure 6 below is required.

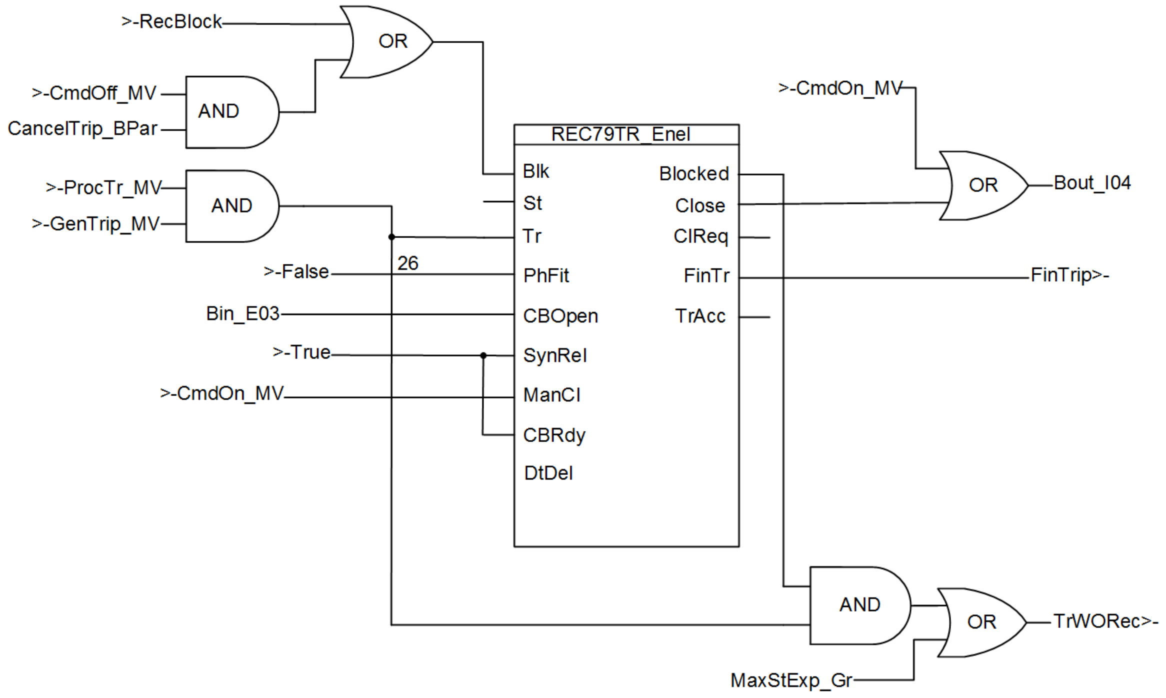

Figure 6 – PLC programming example

8 SELF-DIAGNOSIS AND CONTROL LOGICS

These features refer to all the functions implemented in the MFP either through dedicated hardware control circuitry or by SW tasks.

8.1 Self-diagnosis and operation in abnormal conditions

The internal self-diagnosis functions of the MFP must continuously monitor the efficiency of its hardware, software and communication functionalities, in particular:

a. Integrity of the data contained in the various memory banks, as well as the correct execution of the firmware and communication protocols,

b. General control of the RIO (Par. 6.5) performances (hardware and communication),

c. Integrity checks of the auxiliary power circuits (internal Power Supply).

The self-diagnosis described above must be performed by means of a watchdog-like control which must not affect the performances of the protection functions. The manufacturer must report the diagnostic checks made to ensure the availability of the measurement, protection, control and automation functions.

The self-diagnosis function must also include an:

d. Integrity check of the internal circuits for current (amperometric) measurements,

e. Integrity check of the internal circuits for voltage (voltmetric) measurements.

The detection of an abnormal condition must be identified by issuing the “AnPa – General state of the MFP” signal, which must persist until the cause is rectified.

The “AnPa” signal must also be issued during the whole start-up phase of the device and always after a self-reset operation (if provided), and the alarm must cease only when the MFP is fully operational. The “AnPa” signal must be mapped, via configuration, to one of the Digital Outputs of the MO connector.

All abnormal conditions must be clearly shown on the front panel display of the MFP (excluding the total block of the device). The event recorded, to ensure that it is searchable in the internal events database, must be shown:

f. Locally on the display or via an appropriate PC based application;

g. Remotely with an MMI populated though the IEC 61850 data exchanges.

The MFP internal database must store 2000 events in a circular buffer (minimum 48 hours with loss of power supply). Any event can be recorded in the MFP and:

h. can be assigned to a digital channel of the disturbance recording;

i. can be assigned to a digital output;

j. can be sent to the RTU.

The MFP must:

k. Display the AnPa “xxx” message on the display of the front panel; xxx is an error code (string) that uniquely identify the type of anomaly,

l. Report (according to IEC 61850) the “AnPa” signal to the RTU of the substation,

m. Store in its internal Log the “AnPa” xxx" event with the Time stamp using the format “YYYY:MM:DD:hh:mm:ss,000”.

All anomalous (both partial and total) states of the device must be saved in a special Log text file, stored in non-volatile memory to allow a detailed analysis of the causes of software and hardware anomalies.

The file must be downloadable either through the configuration SW or through “emergency procedures” in case of irreversible machine failure.

The log files must be transmitted via LAN/network, using the BSD syslog protocol as defined by IETF RFC3164 and RFC3195.

8.1.1 Operation of the MFP in case of total block state

In the presence of anomalies “a”; “b”; “c”; “d” and “e” (Par. 8.1); and in the start-up phase the MFP must:

a. Switch-on the “AnPa” LED,

b. Display the “AnPa” message on the display screen on the front panel,

c. Report (IEC 61850) the “AnPa” signal to the RTU in the Primary Substation,

d. Store in the internal Log the “AnPa” event including the timestamp using the “YYYY:MM:DD:hh:mm:ss,000” format.

8.1.2 Operation of the MFP in case of partial block state

The Table 23 below shows the behavior of the device in the presence of anomalies par. 8.1.d or par. 8.1.e, highlighting which protection functions must be blocked and which are activated to handle an emergency.

Table 23 – Behavior in case of partial block state

Type of anomaly	Blocked protection functions	Protection functions activated in case of emergency
Par. 8.1.d	67 and 67N	59Vo emergency
Par. 8.1.e	67 and 67N	Active stages 51Sx; 51Nx

The MFP must:

a. Switch-on of the “AnPa” LED,

b. Display the “AnPa” message on the display screen on the front panel,

c. Report (IEC 61850) the “AnPa” signal to the RTU in the Primary Substation,

d. Store in the internal Log the “AnPa” event including the timestamp using the format “YYYY:MM:DD:hh:mm:ss,000”.

8.1.3 Local control of the circuit-breaker in case of MFP operates in abnormal conditions

A dedicated electrical circuitry, supervised by a watchdog task, must substitute the CPU of the MFP when it is not able to handle the commands, issued by the buttons on the front panel, to open/close the circuit-breaker.

Where, the CPU is not able to handle the commands means:

a. Partial or total block of the CPU in the MFP,

b. MFP unavailable due to power supply failure.

When the substation is in Local Control, in case of a serious MFP anomaly status, the above mentioned electrical circuit must polarize with the +Vaux the opening and closing buttons on the front panel, allowing (directly or via an additional relay) the sending of the commands to the circuit-breaker.

The logical scheme of this operation is shown in Figure 7.

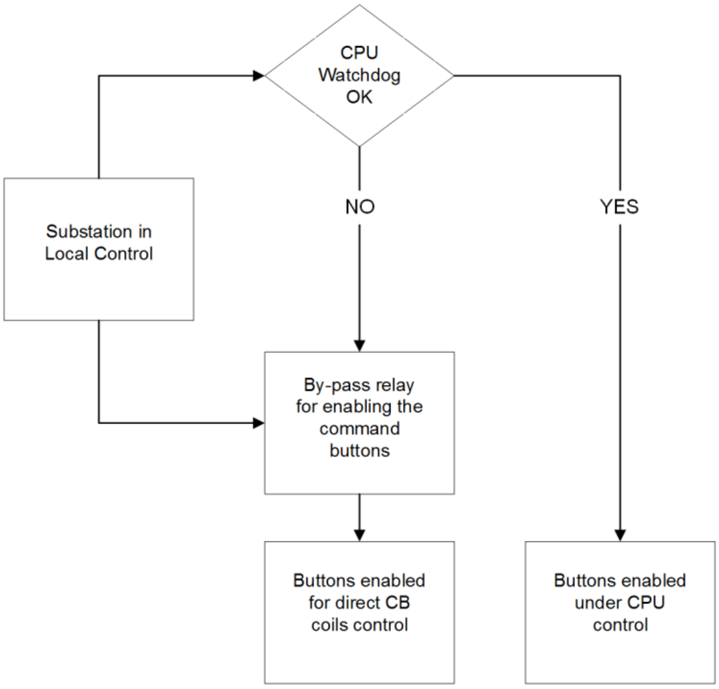

Figure 7 – Logical scheme of CB control when MFP is in anomaly status

8.2 Diagnostic of Voltage Transducers and Current Transducers Supervision (VTS/CTS)

The following functions must be capable to be activated/deactivated.

The MFP must identify the partial (VTS-P) or total (VTS-T) fault in the three-phase voltage measurement chain (VT, cabling) as well as the partial loss (CTS) of the three-phase current measurement (CT, cabling).

The occurrence of any of the above anomalies must be handled locally in the MFP and reported via IEC 61850 to the RTU as follows:

a. Message “VTS phase x” (if partial) or “AnPa VTS” if total on the local display,

b. Report (IEC 61850) the “VTS” alarm to the RTU,

c. Store in the internal Log the “VTS” condition with its timestamp in the format “YYYY:MM:DD:hh:mm:ss,000”.

Following an example of implementation of the functions described above. Any solution proposed by the supplier is subject to acceptance by ENEL.

Table 24 – 60VT-P/T and 60CT-P (measuring transformer supervision) setting

(IEEE Code)	Function/Stage Acronym	Active Function	Range	Default
-	VTS-P	Partial loss of voltage transduction	Enabled/Disabled	Ena
-	VTS-T	Total loss of voltage transduction	Enabled/Disabled	Ena
-	CTS	Partial loss of current transduction	Enabled/Disabled	Ena
-	$V_{(VTS)}$	Positive Sequence Phase Voltage (VTS)	Table 30 ID “F”	-
47	$47_{(VTS)}$	Negative Sequence maximum Phase Voltage (VTS)	0,05÷1,2Vns Table 30 ID “H”	-
51	$51_{(CTS)}$	Positive Sequence Phase Current I(CTS)	0,02In÷30In Table 30	-

46	$46_{(CTS)}$	Negative Sequence Phase Current I_{si} (CTS)	0,02÷30In Table 30	-
59	$59Ue_{(VTS)}$	Residual overvoltage for 60 VTS-P(VTS)	0,001÷1,2Vns	-
27	$27Ue_{(VTS)}$	Residual undervoltage for VTS-T	0÷0,5Vns	-
-	T10	Timer T10	0÷600s Table 30ID "S"	-
-	$\varphi_{Ia,Ib}$; $\varphi_{Ib,Ic}$; $\varphi_{Ic,Ia}$	Max. phase angle shift on the healthy phases, that is 120° ± $\varphi_{Ia,Ib}$	1÷15 degrees	-
-	T11	Timer T11	0÷300s Table 30 ID "S"	-
27	$27Uf_{(MT)}$	MT busbar minimum voltage	0÷1 Vns	-
ES59B		Detection of voltage in line	0÷1 Vns	-

8.2.1 Voltage transducers Diagnostic

8.2.1.1. Partial loss VTS-P

Figure 8 shows an example of a logical scheme for the detection of the partial loss of the voltage transduction chain.

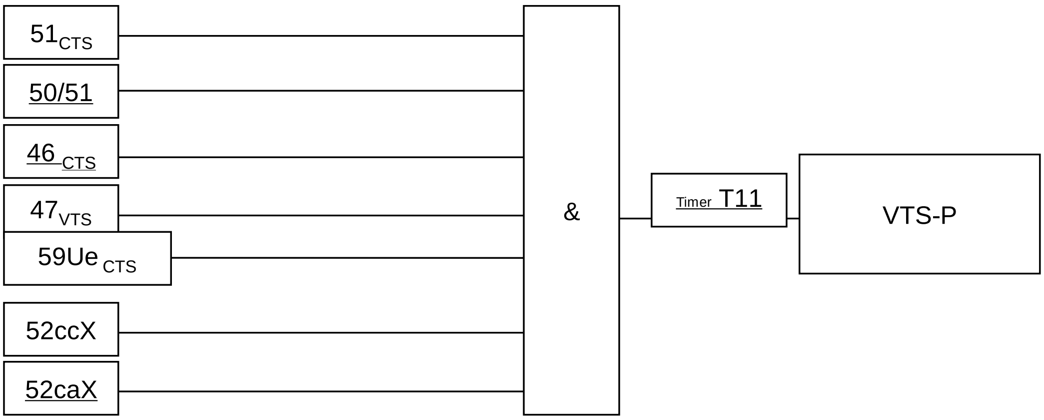

Figure 8 – Logical Scheme VTS-P

8.2.1.2. Total loss VTS-T

Figure 9 shows an example of a logical scheme for the detection of the total loss of the voltage transduction chain and Table 25 contains the related list of definitions.

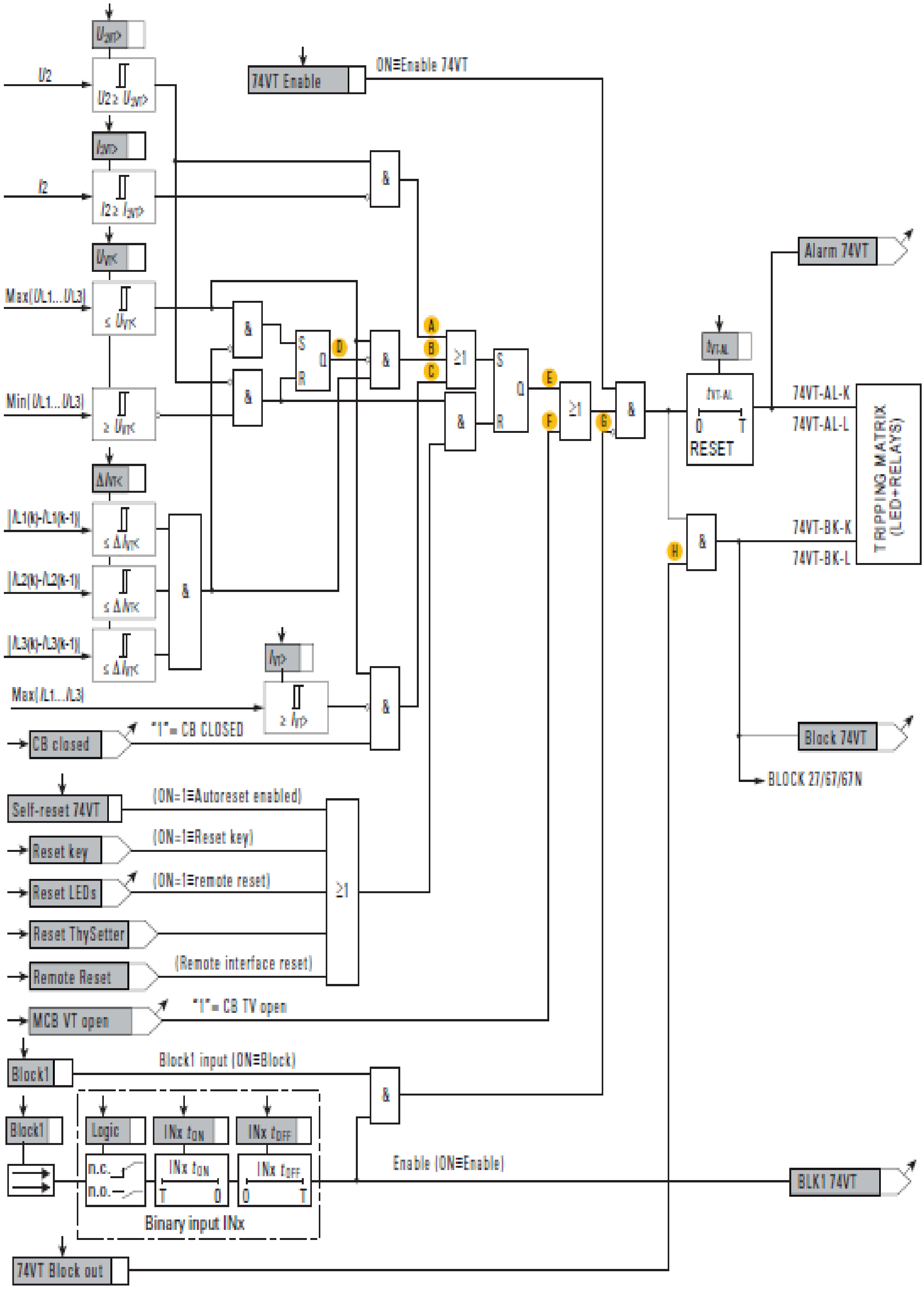

Figure 9 – Logical scheme: 74VT

Table 25 – List of definitions	
A	Activates the 74VT function when one or two phase voltages are lost in the absence of negative sequence current (to discriminate from asymmetric short circuits).
B	Activates the 74VT function when all three phase voltages are lost and the generator is in service.
C	Activates the 74VT function in the event of absence of all three phase voltages during the energization of the line (VT not connected), under the condition that none of the three currents exceeds $I_{VT>}$. To prevent the activation of the 74VT when closing in the event of a poly-phase short-circuit, the value of $I_{VT>}$ must be preset lower than I_{CC} (but higher than the maximum current during the energization of the feeder). In any case the circuit-switch must be closed, otherwise the 74 VT function is activated when the device is stopped.
D	Inhibits the 74VT function in the event of poly-phase short-circuits, setting the flip-flop when at least one phase current undergoes a pulse change. The 74VT function is automatically enabled when all three phase voltages raise above the threshold and the negative sequence voltage falls below the threshold.
E	The 74VT function is maintained active when at least one of the conditions A, B, C is fulfilled. The 74VT function can be manually reset, provided that the automatic reset condition in D is satisfied, or automatically if user-configured.
F	The opening of the magneto thermal circuit-breaker protecting the secondary circuit of the TV can activate the 74VT function.
G	A blocking command applied to a digital input can inhibit the activation of the 74VT function.
H	The activation of the 74VT function is always signaled. If user-configured, also the voltage protections can be blocked.

8.2.1.3. Emergency mode with VT failures

When the VTS-P or VTS anomaly occurs, the protection functions 67, 67N, 59, 59Ue, must be inhibited and the overcurrent emergency 51N, described in Par. 10.8.4, must be activated automatically if enabled by configuring the relevant settings.

8.2.2 Current transducers Diagnostic

8.2.2.1. Partial loss CTS

In Figure 10 and Figure 11 is shown a possible logical scheme for the detection of the partial loss of the current transduction chain.

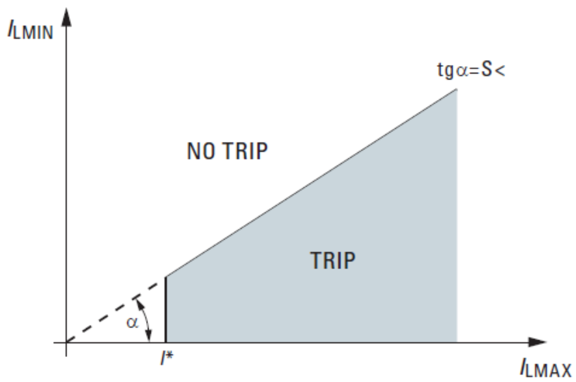

Figure 10 – Diagram 74 CTS

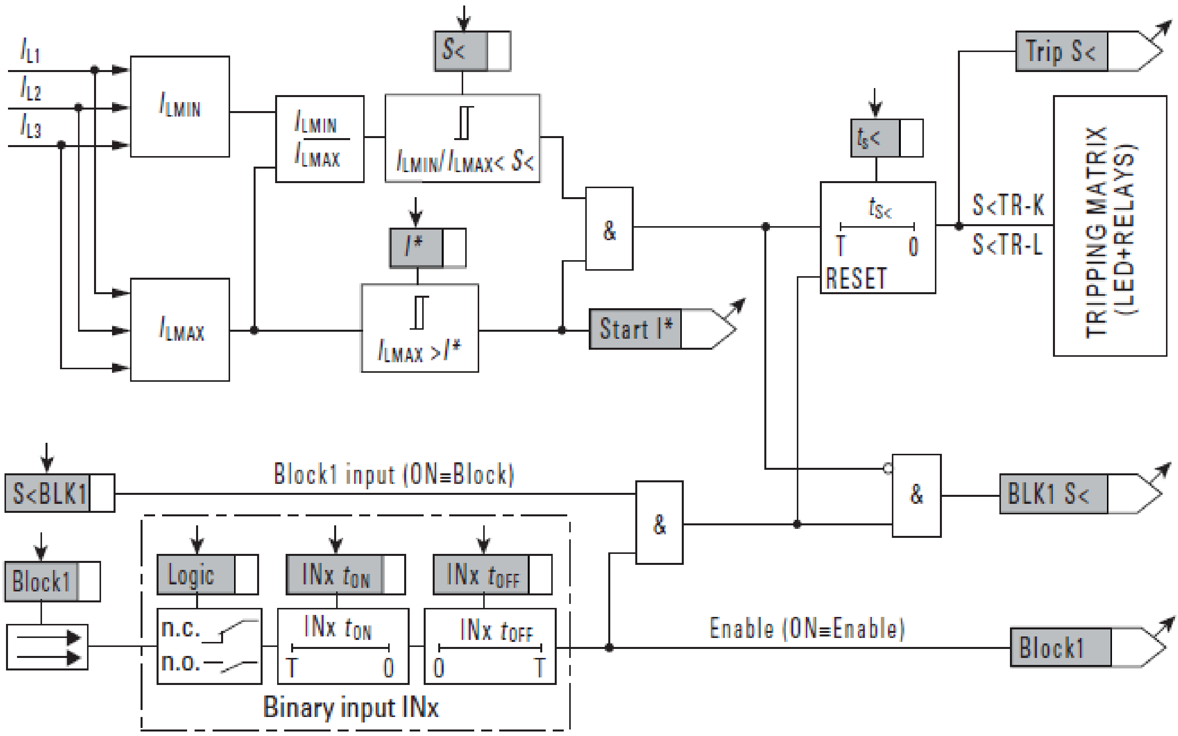

Figure 11 – Logcal Scheme 74 CTS

8.2.2.2. Emergency mode with CT failure

When the CTS anomaly occurs, the protection functions 32P, 46, 51N, 67N must be inhibited and the emergency 59Ue protection, described in Par. 10.17, must be activated if enabled by configuring the relevant settings.

The occurrence of the CTS anomaly must be handled locally in the MFP, with the detail of the phase(s) involved in the failure, and reported via IEC 61850 to the RTU as follows:

a. Message "CTS" on the local display,

b. Report (as per IEC 61850) the "CTS" alarm to the RTU,

c. Store in the internal Log the "CTS" condition with its timestamp in the format "YYYY:MM:DD:hh:mm:ss,000".

8.2.3 Note for 74 VT and 74 CT functions

The manufacturer may present solutions that may vary from the ones described above in Figure 9,Table 25, Figure 10 and Figure 11; they will be subject to approval by ENEL.

8.3 Bay Diagnostic

The following functions must be capable to be activated/deactivated.

8.3.1 Circuit bay Diagnostic

8.3.1.1. Supervision of the circuit-breaker control 74TC

The MFP must implement the 74TC diagnostic functionality, which involves constant monitoring of the following:

a. Electrical continuity of the control circuits,

b. Presence of auxiliary power supply to the control circuits,

c. congruence of the circuit-breaker positions.

Any interruption or incongruence must be promptly displayed on the display of the MFP and sent via IEC 61850 to the RTU in the Primary Substation.

Figure 12 below shows an example implementation:

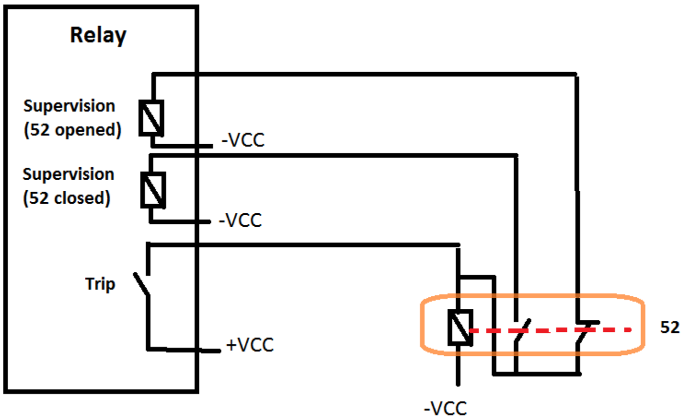

Figure 12 – Trip circuit supervision

Other solutions will be subject to approval by ENEL.

8.3.1.2. Circuit-breaker mechanical monitoring – operating times

The MFP must have two configurable thresholds associated with the maximum permitted opening and closing times of the circuit-breaker.

The operation timing starts from the instant the opening or closing command is issued and the reaching of the opposite state, both for automatic maneuvers and manual controls.

If the limits set in the thresholds are exceeded, the MFP must emit the related alarm on the display and report (by IEC 61850) the "Circuit-breaker failure T1" to the RTU in the Primary Substation.

The thresholds setting will be in the range 0÷200ms with a default value setting of 120ms.

8.3.1.3. Recording of the currents of the CB control coils with an optional board

A record in COMTRADE format must be kept of the driving currents of the circuit-breaker control coils (opening and closing) and a minimum of 10 records of each command must be stored in a circular buffer.

The record starts as soon as a command is issued and lasts until the circuit-breaker reaches the opposite state. There must be a fixed pre-trigger of 10 ms and a timeout of 300 ms that stops recording in case of missed (or incomplete) operation.

This function will use a 2 kHz sampling rate, 12-bit resolution and a measuring range 0-10 A.

8.3.1.4. Mechanical monitoring and cyclical movement of the circuit-breaker

The MFP must be provided with a function (which can be enabled/disabled from MMI, in configuration and through IEC 61850) which performs the cyclical movement of the circuit-breaker. This functionality is conditioned by the fact that:

a. the circuit-breaker is closed,

b. the line is in-service,

c. the protection functions aren't started

d. the auto-reclosing cycle is not in progress

The cyclical movement is characterized by an Opening-Closing cycle to be performed according to planned days, times, frequency and Opened status duration. The default values provide for the cyclical movement at 1:00 a.m. on the first Sunday of the month, repeated every 28 days, i.e. the fourth Sunday following the start of the cycle. The function must be delayed by 60 minutes if there is a start (not followed by a trip) of a protection function (Chapter 10).

On the other hand, if the trip of a protection or a (local/remote) manual operation occurs, the cyclical movement function must be postponed to the next scheduled day. If the movements, whether voluntary or due to FdP take place, for example, on Thursday the 4th, the following cyclical movement must be carried out at 1.00 a.m. on Sunday the 28th.

8.3.1.5. Totalizers of maneuvers and of interrupted energy

The MFP must have three totalizers for counting the circuit-breaker operations and the interrupted energy:

a. Counting of mechanical maneuvers without loads (independently, opening and closing),

b. Counting of maneuvers with loads (independently, opening and closing),

c. Interrupted energy per phase (in each opening),

d. Sum of the interrupted energy per phase (cumulative calculation),

$$\sum_{i=1}^{p} I_i^2 t_i \leq K$$

e. Opening time (ms)

f. Closing time (ms)

g. Fault elimination time, from detection to elimination (ms)

All this information can be retrieved via communication profile and can be seen in the device display and via software.

There must be two thresholds that are user configurable via the configuration application for each FW developed for the MFP. The thresholds are:

h. Maximum number of operations with load interruption,

i. Maximum limit of energy that can be interrupted by the circuit-breaker.

When one or both thresholds are exceeded, the MFP must generate the relevant alarm locally shown on the display with the cause of the anomaly and simultaneously report to the RTU in the Primary Substation the message "circuit-breaker anomaly".

8.3.1.6. Other anomalies of the circuit-breaker

The potential occurrence of the following faults in the circuit-breaker must be monitored:

a. Discharged springs X33,
b. Trip of the automatic switch for the power supply of the springs recharging motors 6L,
c. SF6 Low pressure (Par 12.2 for more information about the management of the SF6 low pressure alarm/trip),
d. automatic trip of the switch of the anti-condensation resistance,
e. closing block BLC.

The acquisition of digital signals coming from the circuit-breaker compartment, is carried out by means of the Remote I/O Module installed in the compartment.

In case of alarm, it must be locally displayed and reported to the RTU in the Primary Substation the message “circuit-breaker anomaly”.

8.3.2 Wall diagram of the circuit-breaker compartment

The display of the MFP must show a graphical representation of the status of the circuit-breaker compartment, which must include:

a. opened or closed position of the breaker,
b. connected or disconnected breaker,
c. current state of the compartment’s grounding switch.
d. Other switches in the bay

The states at points b. and c. are acquired via the Digital Inputs of the Remote Module in the circuit-breaker compartment.

All the statuses in a., b. and c. must be reported to the RTU in the Primary Substation too.

8.3.3 Check of the recovery voltage when the circuit-breaker is open

This functionality can be enabled via software.

The presence of voltage downstream of the opened circuit-breaker is acquired via a Digital Input of the Remote Module placed in the circuit-breaker compartment. Alternatively, this functionality can be implemented by detecting the presence of voltage downstream of the MV circuit-breaker from the Analog Input V4 when it has the functionality of VSync (Par.9.2).

The possible presence of voltage on the MV feeder downstream of the opened circuit-breaker must be displayed locally on the screen with the warning message "Live line with opened circuit-breaker" and reported (tele-signal "circuit-breaker anomaly") to the RTU in the Primary Substation.

8.4 MOIM function

The device must provide a system monitoring function that is able to diagnose if a 67N fault was cleared by the Petersen Coil or by the operation of a 67N tripping the controlled circuit-breaker.

8.4.1 Protection behavior

The logical scheme of the MOIM function is shown in Figure 13.

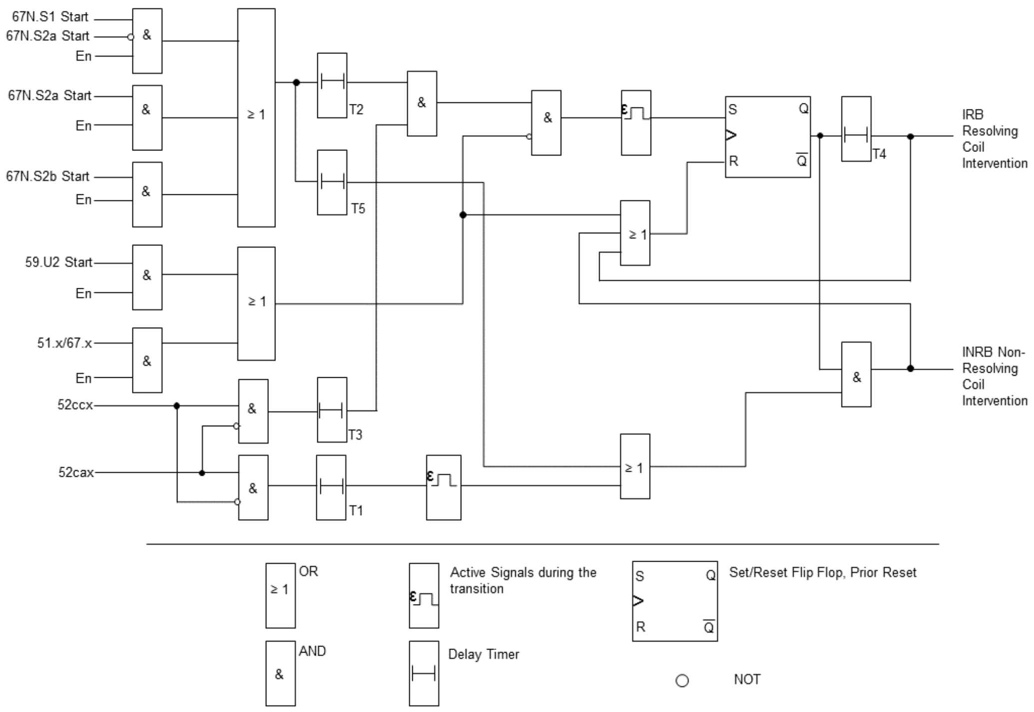

Figure 13 – Logical scheme resolving and non resolving MOIM Coil

8.4.2 Setting Parameters

The stages must be settable according to the ranges indicated in Table 26 below:

Table 26 – "MoIM" setting parameters ranges

Parameter	Range	Step
T1	0 ÷ 0,1s	0,01s
T2	0 ÷ 0,1s	0,01s
T3	0 ÷ 200	0,01s up to 9,990s 0,1 up to 200s
T4	0 ÷ 10 s	0,01s
T5	0 ÷ 10 s	0,01s
59.U2	0,0 4 ÷ 1,5 E_n	0,001

9 MEASUREMENT FUNCTIONS

9.1 General Overview

The MFP must have eight Analog Inputs for the measurement of voltages and currents; the electrical characteristics of the Analog Inputs are defined in 6.2.2. Please refer to Table 30 for the accuracy of the measurements.

The accuracy of the current measurements must not be affected by the selected type of secondary circuit (1A; 5A). The current inputs must allow the connection with CT and/or CT for residual current with 5A or 1A secondary current; the selection of the secondary circuit type of the CT must be independent for each of the four Analog Inputs and configurable via software only, without opening the enclosure, as occurs when carried out via internal bridge or jumper.

Table 27 – Measurements functions assignable to the Analog Inputs

Input type	ID	Clamps	MEASUREMENT FUNCTIONS
Voltage Analog Input	V1	MV1 - MV4	V_{4-0}
	V2	MV2 - MV4	V_{8-0}
	V3	MV3 - MV4	V_{12-0}
	V4	MV5 - MV6	V_o/V_{Sync}
Current Analog Input	C1	MA1 - MA2	I4
	C2	MA3 - MA4	I8; I_{SQL}; I_E (51N), according to the firmware running on the MFP
	C3	MA5 - MA6	I12
	C4	MA7 - MA8	3Io

9.2 Configurable Analog Inputs

9.2.1 Current Input C2

Depending on the selected FW, in Table 28 are specified the quantities measured by the C2 Input.

Table 28 – Assignement of the quantity measured by the C2 input

Bay type	Quantity measured via C2
MV feeder, Aux. Serv.	a) ; b)
Power Factor Correction	c)
Earting Transformer (TFN)	d)
Section circuit-breaker	a)
Bus transfer	a)
HV delivery line to the customer	b)

Where:

a) No measurement,

b) I8,

c) I_{SQL}, unbalance current to be used to protect the power factor correction bank,

d) IE (51N), second residual current.

The second residual current, used in the TFN, provides that the current signal is taken from the CT (typically 300/5) downstream of the Petersen coil only for the diagnostic/statistical monitoring functions (resolving/non-resolving intervention of Petersen coil) and for the protection function referred to in Par. 10.8.

9.3 Usable CTs and VTs

Table 29 below defines transformation ratio range of the measuring reducers that can be connected and configured in the MFP.

Table 29 – Usable VT and CT

General Parameters		Selectable reducers	Secondary rated value	Default	Primary value	Default
If n	Rated phase current of the CT	2/3 CT (5P30, 5P20)	1A/5A	5A	1 A ÷ 5000A	300A
I_{SQL} n	Rated unbalance capacitors star current of the CT	(5P30, 5P20)	1A/5A	5A	1A÷ 30A	5A
Ie n	Primary rated residual current of the CT	(5P30, 5P20)	1A/5A	1A	1A÷ 1000A	100A
Un Vn	Rated phase-to-phase voltage Rated phase voltage Vnp=Unp/√3V		100V 110V 115V 100/√3V 110/√3V 115/√3V		1kV÷30kV for MV level applications 30kV÷150kV for HV level applications	20kV
Ue n	Rated residual voltage	1 VT or reconstructed	100V 110V 115V			
V_{SYNC}	Synchronous voltage		100V 110V 115V		1kV÷30kV	20kV

9.4 Conventions of the measurement functions

Through the Analog Inputs, the MFP must be able to measure the electrical quantities in Table 12; the voltage and current TRMS measurements are referred to the 50Hz/60Hz fundamental component.

The conventional positive direction of the current, consequently of the Active Power, is established in the transformation direction HV/MV towards the MV/LV distribution with incoming currents in the terminals MAA7; MAA9; MAA11 (**Table 27**).

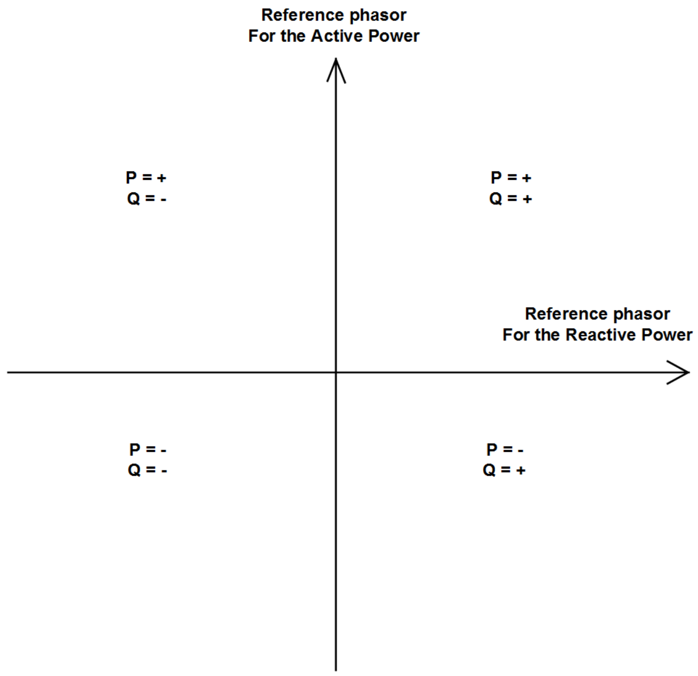

Figure 14 – Conventions of the measurements

The power measurements must be made using the Aron insertion for the measurement of the Active Power and the Barbagelata insertion for the measurement of Reactive Power (using I_4 and I_{12} currents).

9.5 Characteristic data of the measurement functions

The following shows the characteristic data requested in the various measurement functions.

Table 30 – Accuracy of the measurements

ID	Measurement	Acronym	Range	Resolution	Thresholds	Step	Error limit	Error limit variation
				CURRENT MEASUREMENTS				
A	Phase current	If	0,02÷30 In	0,005 In	0,05÷25 In	0,05 In	≤ 1%	≤0.5%
B	Current unbalance of star-connected capacitors	I_{SQL}	0,02÷30 In	0,005 In	0,02÷25 In	0,05 In	≤ 1%	≤0.5%
C	Residual current	I_E ($3I_0$)	0,001÷30 In	0,001 In	0,001÷25 In	0,001 In	≤1%	≤0.5%
D	Negative-sequence phase current	I_{SI}	0,02÷30 In	0,005 In	0,05÷25 In	0,05 In	≤1%	≤0.5%
				VOLTAGE MEASUREMENTS				
E	Phase –to-phase voltage	U_{12};U_{23}; U_{31}	0,04÷1,5Un	0,01 Vn	0,04÷1,5Vn	0,01 Un	≤1%	≤0.5%
F	Phase voltage	V_1;V_2;V_3 (V_{4-0};V_{8-0};V_{12-0})	0,04÷1,5Vn	0,01 Vn	0,04÷1,5Vn	0,001 Vn	≤1%	≤0.5%
G	Residual voltage	U_E ($3V_0$) $V_1+V_2+V_3$	0,04÷1,5 U_E n	0,01 Vn	0,04÷1 U_E n	0,01 U_E n	≤3%	≤0.5% ≤1.5%
H	Negative-sequence phase voltage	V_{SI}	0,05÷1,2Vn	0,01 Vn	0,05÷1,2Vn	0,01 Vn	≤1%	≤0.5%
I	Synchronous voltage (phase)	V_{SYNC}	0,8÷1,2Vn	0,01 Vn	0,8÷1,2Vn	0,01 Vn	≤1%	≤0.5%
				FREQUENCY MESUREMENTS				

L	Frequency	f	47,5÷51,5 Hz 57,5÷61,5 Hz	0,01 Hz			±0,01 Hz	≤1%
POWER MEASUREMENTS								
M	Active Power (total and phase)	PF;PT	-25÷25MW	0,1 MW			≤%	≤0.5%
N	Reactive Power (total and phase)	QF;QT	-25÷25MVAR	0,1 MVAR			≤1%	≤0.5%
O	Apparent Power (total and phase)	SF;ST	-25÷25MVA	0,1 MVA			≤1%	≤0.5%
P	Power factor		-1 ÷ +1	0,01			±0,01	≤1%
Q	Phase difference angle φ1;φ2;φ3 (between V and I)		0°÷359°	1°	0°÷359°		≤0,5°	≤0.5%
R	Phase difference angle φ0 (between 3Vo and 3Io)		0°÷359°	1°	0°÷359°		≤0,5°	≤0.5%
TIME MEASUREMENTS								
S	Time measurements and Timers		0÷1000 s	0,001s (0÷1s) 0,01s (1÷10s) 0,1s (10÷100s) 1s (100÷1000s)	0÷1000 s	0,001s(0÷1s) 0,01s(1÷10s) 0,1s (10÷100s) 1s (100÷1000s)		
HARMONIC CONTENT MEASUREMENTS								
T	Harmonic content V	THD_V	2°-25°					
U	Harmonic content A	THD_I	2°-25°					

The Error limit, shown in the Table 30 refers to the entire measuring of the measured electrical quantity.

The Error limit (ID “C”) is ≤1% ± 2mA for current secondary values up to 20mA.

The Error limit (ID “G”) is ≤3% ± 50mV for measurements up to 1% of the rated value.

For the values of range of Frequency (ID “L”), the rated working frequency is set during the MFP configuration.

For more information regarding the precision of the time measurements and the related error limit variation (ID “S”), please refer to the paragraphs describing the protection functions.

9.6 Measurements reports

The following electrical quantities must be shown on the display in the home page and periodically reported (as per IEC 61850) to the RTU of the Primary Substation:

a. Phase-to-phase voltage, primary values (kV),

b. Line currents I_4, I_8 (direct or recalculated) and I_{12}, primary values (A)

c. Residual current ($3I_o$)

d. Total P and Total Q, primary values (kW, kVAr); measurements with sign according to the convention in Figure 14,

e. THDv and THDi.

The measurements of the electrical quantities must be periodically reported to the RTU (as per IEC 61850) with the following frequencies:

f. 10 s for "instantaneous" values,

g. 600 s for “average” values, to be logged.

The MFP must calculate the RMS value of the electrical quantities directly measured at a sampling period of 200 ms. The samples must be discarded in case of a fault. The measurements are automatically resumed when the normal operating conditions of the MFP are restored.

Therefore, the measurements, must be

h. averaged over a time base Tm, typically 10s and transmitted to the RTU with a periodic report for “instantaneous” measurements,

i. averaged over an initial time base of 60 s [M1]; [M1] must be averaged again over 10 minutes and transmitted to the RTU with a periodic report for “average” measurements.

The IEC 61850 profile of the MFP as implemented in the ICD file (included in the GSTP103), distinguishes between the instantaneous and mediated measurements.

The “average” measurements will also be logged in a dedicated circular buffer file (at least two days of recording) that can be accessed locally.

10 ELECTRICAL PROTECTION FUNCTIONS (FdP)

10.1 Definition of "Characteristic Times"

10.1.1 Start time

Time period between the variation (application, removal or modification under specified conditions) of the input quantity (ies) bringing the MFP into an operating state in progress and the state change of the Start output (start relay).

10.1.2 Operate time

Time period between the variation (application, removal or modification under specified conditions) of the input quantity (ies) bringing the MFP into an operating state in progress and the state change of the Operate/Trip output (Trip relay).

10.1.3 Reset time

Time required by the relay to restore, under specified conditions, after an intervention so that its next intervention time doesn't deviate more than a specified percentage by the previously measured time.

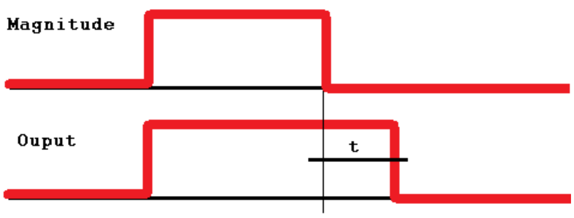

Figure 15 – Behavior of the reset time

10.1.4 Reset ratio

The relay operates when the measured quantity has reached and exceeded a pre-set value and releases when the measured quantity reaches a so called Reset value, which depends on the physical characteristics of the relay. The ratio between the Reset value and the Trip value is called Reset ratio.

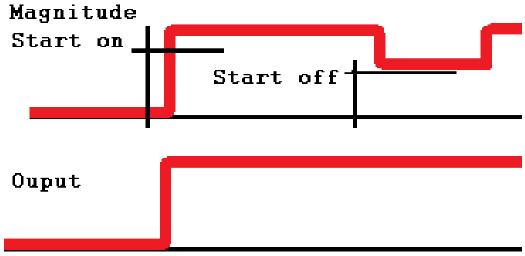

Figure 16 – Behavior of the Reset ratio

10.1.5 Overshoot time

The Overshoot time corresponds to the difference between the relay intervention time, for a specified value of the input quantity, and the maximum duration of a value reduction, below the operating level, of the input quantity, potentially insufficient to trigger the relay.

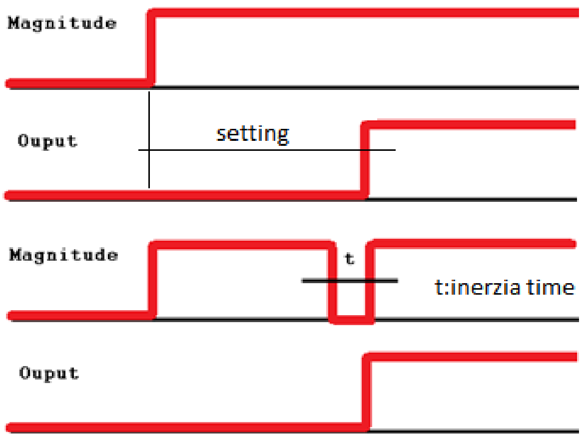

Figure 17 – Behavior of Overshoot time

10.1.6 Repetitive error time

Ten different measurements will be made in identical test conditions. The difference between the maximum and minimum measurements will define the width of the zone of dispersion (Ad).

Repetitive error time requirement:

a. For instantaneous functions: Ad<6ms

b. For delayed functions: Ad<12ms

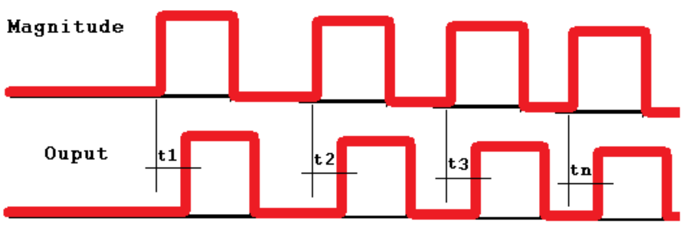

Figure 18 – Behavior of repetitive error time

10.2 Logical representation of a FdP

Figure 19 shows the logical scheme of a protection function (FdP). For functions not used in the FSL the back-up timer and the FSL enable logic mustn't be considered.

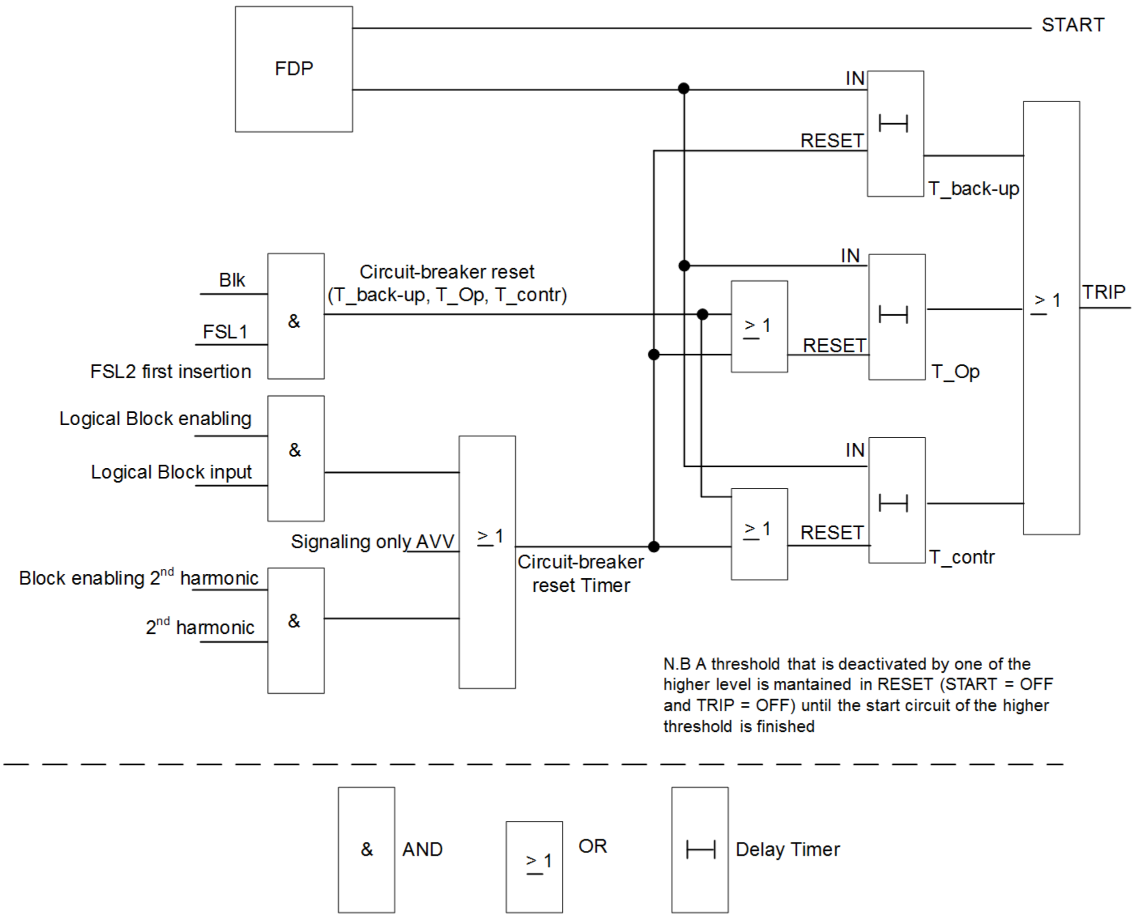

Figure 19 – FdP logic

10.3 Trip commands given by the protection functions

The trip command given by the individual protection functions must have a user configurable minimum duration (typically 150 ms) and must stay active until the protection releases or the faulty/tripping conditions are removed.

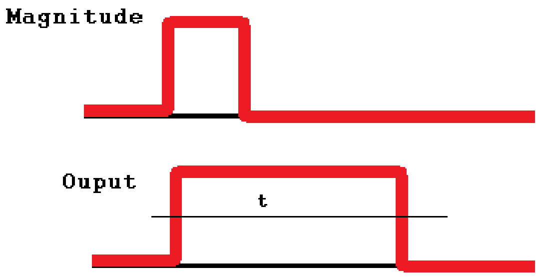

Figure 20 – Beahavior of Minimum operate (trip) time

10.4 Activation Status of the stages in the relevant protection functions

All stages in the respective protection functions must be individually settable (typical parameters are standard trip threshold and delay time, accelerated trip delay time).

It must also be possible to activate a triple operating mode, for each stage, as follows:

a. Disabled/Excluded

b. Start only (storage on the internal log and reporting to the RTU)

c. Start/Operate(Trip) (storage on the internal log and reporting to the RTU)

d. Further information can be found in the sections specific to individual FdPs.

10.5 Settings tables

The MFP must have 4 setting tables/profiles. The switch from one to another will be done by activating/deactivating two Digital Inputs or triggered by a GOOSE/MMS message or a MODBUS command (if the extended requirements, ref. to Par. 14.2, is present).

10.6 Phase overcurrent protection function IEEE 51

The phase overcurrent protection function 51 must be executed in three-wire mode (three-phase), except in cases where a different assignment of C2 input (Par.9.2.1) is provided.

In case I_E current is assigned to C2 input, I_8 current will be calculated indirectly by I_4, I_{12}, $-I_E$.

Four independent-time overcurrent stages with dual time calibrations must be provided. When configured, it should also be possible revert to dependent-time (selectable curves in Table 35) as required by the IEC 60255 standard.

The independent-time functions must have two calibration banks for intentional delay times, as shown in Table 31.

Table 31 – Ind. Time 51 stages

Standard Stages	Accelerated Stages
51.S1	51.S1_c
51.S2	51.S2_c
51.S3	51.S3_c
51.S4	51.S4_c

10.6.1 Protection Behavior

The measurement function of the phase overcurrent I_f (Table 30, ID “A”) must seamlessly compare the related phasors with the corresponding calibration parameters (Table 33) set for each overcurrent stage.

When a phasor is in the intervention sector, the following internal logical states occur

Table 32 – FdP 51 behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	51.Ax_Fy	Yes	Yes	Yes
Operate/Trip	51.Sx_Fy	Yes	Yes	Yes

The “51.Sx_Fy” event is stored in the internal Log, including the timestamp in “YYYY:MM:DD:hh:mm:ss,iii” format.

The protection functions in this technical specification are named according to the following convention: the letter “x” replaces the start/operate threshold number and the letter “y” indicates the phase affected by the fault.

Operate/trip, showed in the table above, occurs when the user-configurable delay timers, for each threshold of each FdP, expires.

If the measurement function of the phase overcurrent detects that the phasor left the tripping sector of one of the overcurrent stages, before the expiry of the tripping time, the protection must release.

10.6.2 Settings Parameters

The stages must be settable according to the ranges shown in Table 33 and according to the operating modes described in Par. 10.4.

Table 33 – “51.Sx” setting parameters ranges

Stage/Timers			Operating mode	Start Current Value		Operate/Tripping Time	
Stage	Std.	Accelerated		Range	Step	Range	Step
51.S1	T51.S1	T51.S1_c	Independent-Time / Dependent-Time (available Curve Types in Table 35)	0,05÷25In (Table 30, ID “A”)	0,005In (Table 30, ID “A”)	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s
51.S2	T51.S2	T51.S2_c					
51.S3	T51.S3	T51.S3_c					
51.S4	T51.S4	T51.S4_c					

10.6.3 Accuracy of the measurements

Measurements accuracy meets the following requirements:

a. Error and Error limit variation in the measurement of the module: Table 30, ID “A”

b. Error and Error limit variation in the measurement of the times: Table 34

Table 34 – Accuracy of the intervention times for the overcurrent

Description	Range	Time	Error limit	Error limit variation
Start time	I = (0,05÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	I = (0,05÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	(I=10xIreg)	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.6.4 Time dependent overcurrent protection IEC 60255

The Operating Curve Type of all the 51 stages must be settable according to one of the following types:

Table 35 – Configurable inverse curves of the dependent time overcurrent protections	
Type	Description
NIT (Normal Inverse)	$t = \frac{0,14}{(I/I_p)^{0,02} - 1} \cdot T_p$
VIT (Very Inverse)	$t = \frac{13.5}{(I/I_p) - 1} \cdot T_p$
EIT (Extremely Inverse)	$t = \frac{80}{(I/I_p)^2 - 1} \cdot T_p$
LIT (Long Time Inverse)	$t = \frac{120}{(I/I_p) - 1} \cdot T_p$

Where

I = fault current	
I_p = set start current	Setting; Table 30, ID "A", for range, resolution, accuracy of the measure and error limit variation
t = Operate/Tripping Time	Setting
T_p = Time Dial Multiplier	Setting: range 0,05 to 9,99; step 0,01

An illustrative example of 3-stages inverse curve is shown in Figure 21.

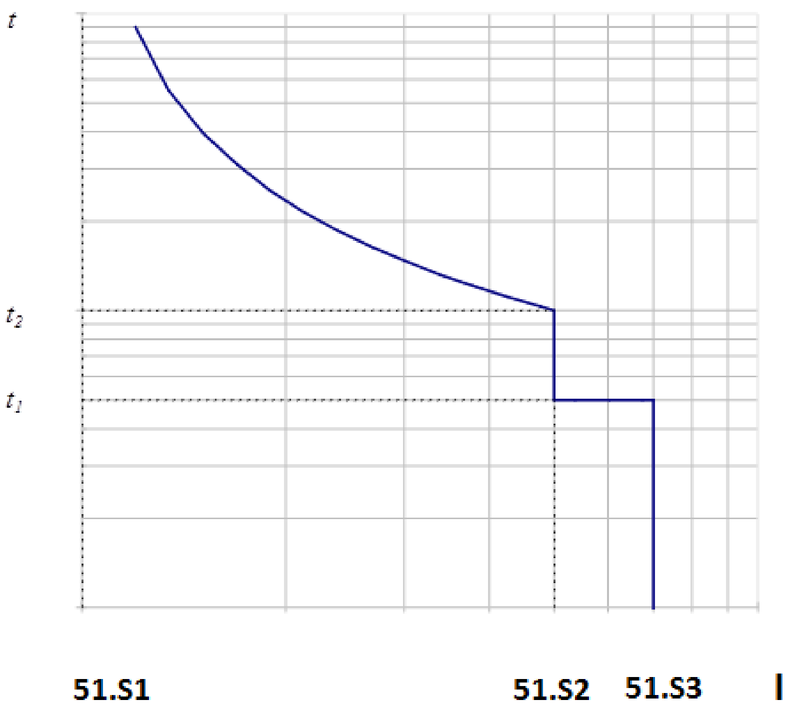

Figure 21 – Illustrative example of 3-stages inverse curve

10.7 Residual overcurrent current protection function I_E 51N

Five independent-time residual overcurrent stages 51N with double time calibration must be provided. When configured, it should also be possible revert to dependent-time (selectable curves in Table 35) as required by the IEC 60255 standard.

Table 36 – Ind. Time 51N stages	
Standard Stages	Short-time Stages
51N.S1	51N.S1_c
51N.S2	5N1.S2_c
51N.S3	51N.S3_c
51N.S4	51N.S4_c
51N.S5	51N.S5_c

Each stage must be independently selectable to use $3I_0$ current measurement (C2 Analog Input) or a calculated $3I_0$ current.

10.7.1 Protection Behavior

The measurement function of the residual overcurrent $\mathbf{I_E}$ (Table 30, ID “C”) must seamlessly compare the related phasors with the corresponding calibration parameters (Table 38) set for each overcurrent stage.

When a phasor is in the intervention sector, the following internal logical states occur:

Table 37 – FdP 51N behavior				
FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	51N.Ax	Yes	Yes/No	Yes/No
Operate/Trip	51N.Sx	Yes	Yes/No	Yes/No

If the measurement function of the phase overcurrent detects that the phasor left the tripping sector of one of the overcurrent stages, before the expiry of the tripping time, the protection must release. A blocking command applied to a digital input, or generated by a logic, can inhibit the activation of each stage of this function, independently.

10.7.2 Setting Parameters

The stages must be settable according to the ranges indicated in Table 38 and according to the operating modes in Par. 10.4.

Table 38 – “51.Nx” setting parameters ranges								
Stage/Timers			Operating mode	Start Current Value		Operate/Tripping Time	
Stage	Std.	Accelerated		Range	Step	Range	Step
51N.S1	T51N.S1	T51N.S1_c	Independent-Time / Dependent-Time (available Curve Types in Table 35)	0,05÷25In (Table 30, ID “C”)	0,005In (Table 30, ID “C”)	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s
51N.S2	T51N.S2	T51N.S2_c					
51N.S3	T51N.S3	T51N.S3_c					
51N.S4	T51N.S4	T51N.S4_c					
51N.S5	T51N.S5	T51N.S5_c					

10.7.3 Accuracy of the measurements

Measurements accuracy must meet the following requirements:

a. Residual current measurement accuracy: Table 30, ID "C",

b. Error and Error limit variation in the measurement of the times: Table 39.

Table 39 – Accuracy of the intervention times for the residual overcurrent

Description	Range	Time	Error limit	Error limit variation
Start time	I = (0,05÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	I = (0,05÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	(I=10xIreg)	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

An illustrative example of 3-stages inverse curve is shown in Figure 22.

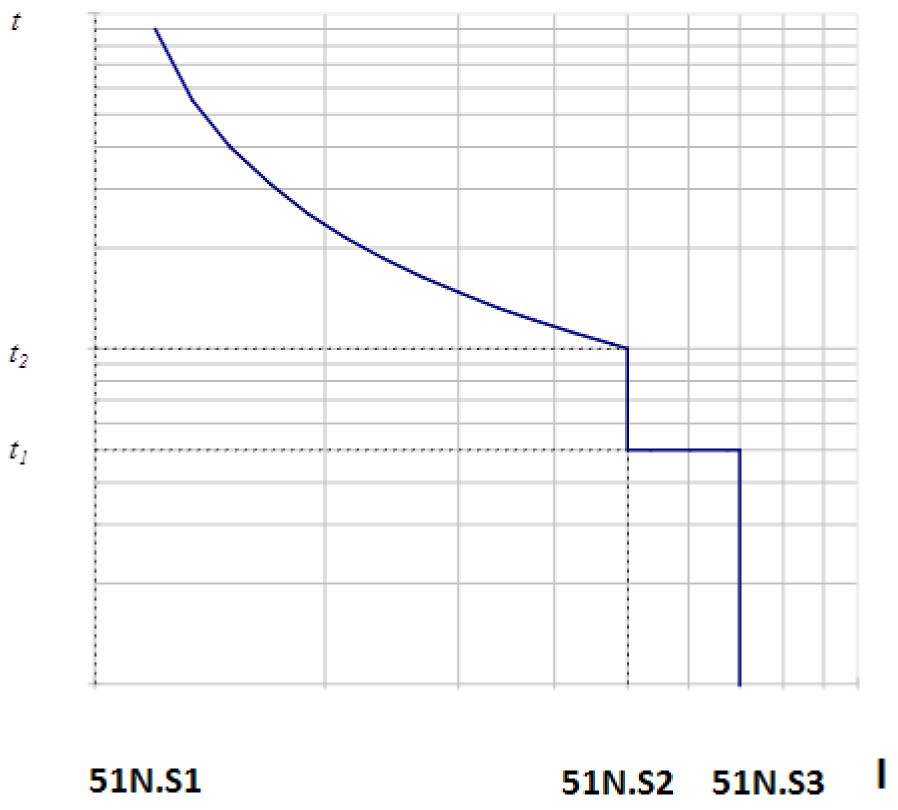

Figure 22 – Illustrative example of 3-stages inverse curve 51N

10.8 Residual overcurrent current protection function for TFN, IE 51N, C2 input

The configuration of the MFP designated to protect a TFN bay requires that the C2 input is used to measure the residual current $\mathbf{I_E}$ (51N) on the CT (300/5) downstream of the Petersen coil (9.2.1, option d).

In this operating mode enables two additional 51N independent-time stages. When configured, it should be possible to revert to dependent-time (selectable curves in Table 35) as required by the IEC 60255 standard.

Table 40 – 51N.Sx_a stages	
Standard Stages	Accelerated Stages
51N.S1_a	Back-up 67
51N.S2_a	Start only

10.8.1 Protection Behavior

The behavior of the protection is the same as defined in the previous Par.10.7. with the following variations:

Table 41 – 51N.Sx_a behavior				
FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	51N.Ax_a	Yes	Yes/No	Yes/No
Operate/Trip	51N.Sx_a	Yes	Yes/No	Yes/No

10.8.2 Setting parameters

The stages must be settable according to the ranges indicated in Table 38 and according to the operating modes in Par. 10.4.

10.8.3 Accuracy of the measurements

The same requirements apply as defined in Par. 10.7.

10.8.4 Emergency 51N protection function

The MFP, user-configured via SW application, must automatically provide protection functions that ensure a minimum level of electric protection to the controlled bay when the internal or external anomalies, dealt with in Par.8.1 and following, occur.

This function will be inhibited while there is no loss of voltage, partial or total.

In the event of a failure in the embedded voltage inputs board or in the event of a failure in the voltage transduction chain, the independent-time emergency 51N protection function must activate automatically. When configured, it should also be possible to revert to dependent-time (selectable curves in Table 35) according to IEC 60255 standard.

It must be possible to configure the MFP to autonomously deactivate all the protection functions that use voltage measurements:

a. 67,

b. 67N, 67N for intermittent arcs and evolving faults,

c. 32P,

d. 25,

e. 59,

f. 59N,

g. ES59B (line voltage absence)

10.8.4.1. Protection Behavior

The behavior of the protection is the same as defined in the previous Par.10.7. with the following variations:

Table 42 – 51N.Eme behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	51N.E.A	Yes	Yes/No	Yes/No
Operate/Trip	51N.E.S	Yes	Yes/No	Yes/No

10.8.4.2. Setting parameters

The stages must be settable according to the ranges indicated in Table 38 and according to the operating modes in Par. 10.4.

a. Voltage threshold and accuracy: Table 30, ID “C”,

b. Operate/Tripping Time (T51N.E.S): Table 30, ID “S”,

c. Operate/Tripping Time accuracy: Table 39

10.8.5 Accuracy of the measurements

The same requirements apply as defined in Par. 10.7.

10.9 Directional overcurrent protection function IEEE 67

The directional overcurrent protection 67 must be executed in three-wire mode (three-phase), except in cases where a different assignment of C2 input (Par. 9.2.1) is provided. In this case the measurement of the I8 current will be calculated indirectly by I_4, I_{12}, $-I_E$. The protection function must, however, guarantee the selectivity even in case of failures where reference voltage becomes close to zero using the voltage memory function.

The minimum voltage value to polarize is 2 V (phase-to-phase). The supplier must propose a solution to add different polarization methods of the 67 function.

Four directional independent-time residual overcurrent stages with double time calibration must be provided. When configured, it should also be possible to revert to dependent-time (selectable curves in Table 35) according to IEC 60255 standard.

Table 43 – Ind. Time 67 stages

Standard Stages	Accelerated Stages
67.S1	67.S1_c
67.S2	67.S2_c
67.S3	67.S3_c
67.S4	67.S4_c

10.9.1 Protection behavior

The measurement function of the phase overcurrent (Table 30, ID "A") must seamlessly compare the related phasors with the corresponding calibration parameters (Table 45) set for each overcurrent stage.

When a phasor is in the intervention sector, the following internal logical states occur:

Table 44 – FdP 67 behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	67.Ax.Fy	Yes	Yes/No	Yes/No
Operate/Trip	67.Ax.Fy	Yes	Yes/No	Yes/No

If the measurement function of the phase overcurrent detects that the phasor left the tripping sector of one of the overcurrent stages, before the expiry of the tripping time, the protection must release.

10.9.2 Setting parameters

The stages must be settable according to the ranges indicated in Table 45 and according to the operating modes in Par. 10.4.

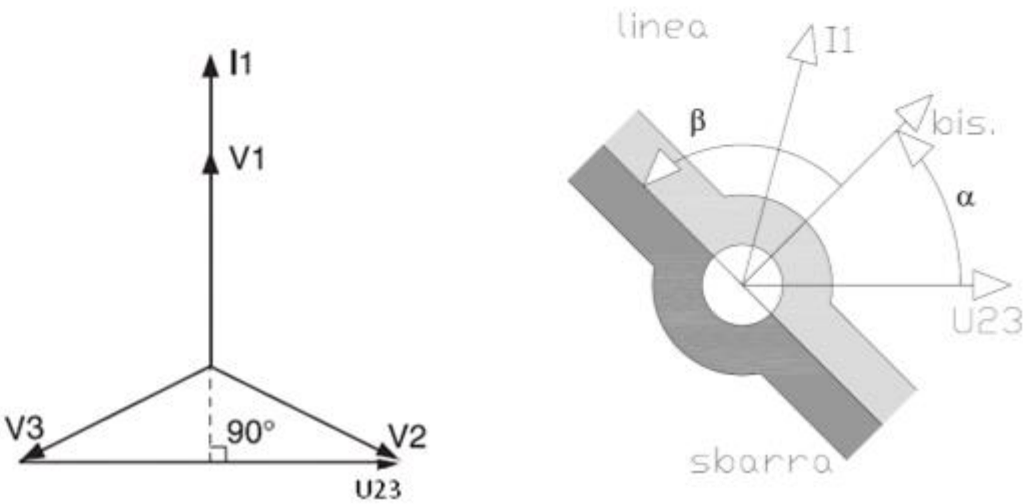

Figura 23 – "67Px" setting parameters ranges

Table 45 – "67Px" setting parameters ranges										
Stage/Timers			Operating mode	Start Current Value		Operate/Tripping Time		Operate/Tripping Sector		
Stage	Std.	Accelerated		Range	Step	Range	Step	bisector α (fig23)	half-width β (fig.23)
67.S1	T67.S1	T67.S1_c	Independent-Time / Dependent-Time (available Curve Types in Table 35)	0,05÷25In (Table 30, ID "A")	0,005In (Table 30, ID "A")	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s	0°÷360° Step 1º	1°÷180° Step 1º
67.S2	T67.S2/	T67.S1_c							
67.S2	T67.S2/	T67.S1_c							
67.S4	T67.S4	---							

10.9.3 Accuracy of the measurements

For measurements accuracy, refer to the following prescriptions:

a. Error and Error limit variation in the measurement of the module: Table 30, ID "A"

b. Error and Error limit variation in the measurement of the phase angle: Table 30, ID "S",

c. Error and Error limit variation in the measurement of the times: Table 46

Table 46 – Accuracy of the intervention times for the directional overcurrent				
Description	Range	Time	Error limit	Error limit variation
Start time	I = (0,05÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	I = (0,05÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	(I=10xIreg)	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.10 Negative sequence overcurrent protection function IEEE46

The negative sequence overcurrent protection function IEEE 46 must be executed in three-wire mode (three-phase), for the assignment of C2 input Par.9.2.1. The thresholds must be both dependent time and independent time mutually exclusive.

Two independent-time overcurrent stages with double time calibration must be provided. When configured, it should also be possible to revert to dependent-time (selectable curves in Table 35) according to IEC 60255 standard

Table 47 – Ind. Time 46 stages		
Standard Stages	Accelerated Stages	
46.S1	46.S1_c	Independent time
46.S4	---	Reverse time IEC60255, selectable from **Table** 33

10.10.1 Protection behavior

The IEEE 46 protection function, using the reverse current measurement function (Table 30, ID “D”) must be able to detect:

a. The two-phase faults at the ends of a relevant length line

b. Imbalances in powered loads

c. Inversion or breaking of the line conductors

The measurement function of the negative sequence overcurrent protection function IEEE 46 (Table 30, ID “D”) must seamlessly compare the related phasors with the corresponding calibration parameters (Table 49) set for both 46 stage. It must be provide two directional residual overcurrent thresholds, both time dependent and time independent, mutually exclusive, according to IEC 60255.

When a phasor is in the intervention sector, the following internal logical states occur:

Table 48 – FdP 46 behavior				
FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	46.Ax	Yes	Yes/No	Yes/No
Operate/Trip	46.Sx	Yes	Yes/No	Yes/No

If the measurement function of the phase overcurrent detects that the phasor left the tripping sector of one of the overcurrent stages, before the expiry of the tripping time, the protection must release.

10.10.1.1. Extension of protection function 46

This function can be configured to trip the circuit-breaker or just to send an alarm (without tripping the circuit-breaker). Due to a possible malfunction when loads are low, it must be possible to activate the following logic to avoid incorrect operations:

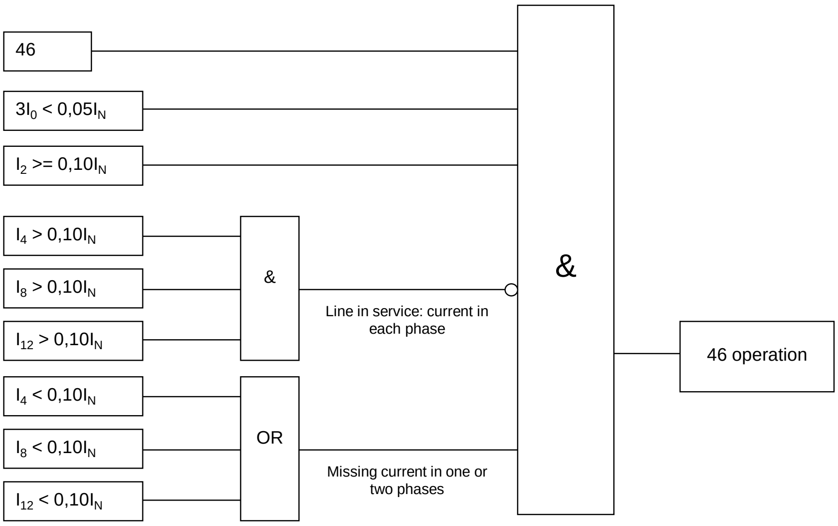

Figure 24 – Logical scheme: 46

Every level used in this logic can be set by the user. Other solutions will be subject to approval by ENEL.

10.10.2 Setting parameters

The stages must be settable according to the ranges of Table 49 and according to the operating modes in Par. 10.4.

Table 49 – "46.x" setting parameters ranges

Stage/Timers			Operating mode	Start Current Value		Operate/Tripping Time	
Stage	Std.	Accelerated		Range	Step	Range	Step
46.S1	T46.S1	T46.S1_c	Independent-Time / Dependent-Time (available Curve Types in Table 35)	0,1÷5In (TAB.30, ID "D")	0,01In (TAB.30, ID "D")	0,1÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s
46.S4	T46.S4	---					

10.10.3 Accuracy of the measurements

For measurements accuracy, refer to the following prescriptions:

a. Error and Error limit variation in the measurement of the module: Table 30,ID "D",

b. Error and Error limit variation in the measurement of the times: Table 50

Table 50 – Accuracy of the intervention times for the negative sequence overcurrent 46

Description	Range	Time	Error limit	Error limit variation
Start time	I = (0,1÷5) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	I = (0,1÷5) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%

Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	(I=10xIreg)	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.11 Unbalance protection function IEEE 46N

The unbalance protection function 46N must detect the unbalance between two banks of capacitors by measuring the current flowing between the star-points. Figure 25 shows a scheme of principle.

An independent-time overcurrent stage with double time calibration must be provided. When configured, it should also be possible to revert to dependent-time (selectable curves in Table 35) according to IEC 60255 standard.

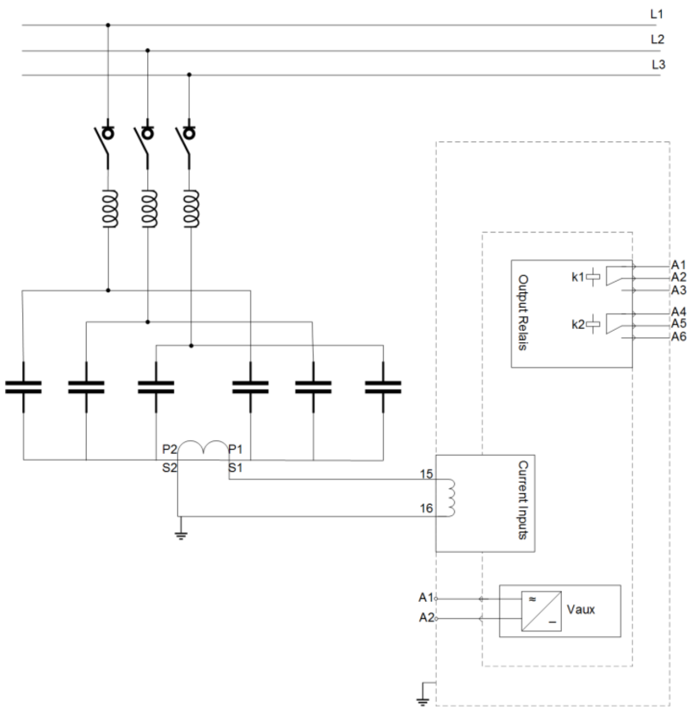

Figure 25 – Scheme of principle 46N

10.11.1 Setting Parameters

The stage must be settable according to the ranges of Table 51 below:

Table 51 – "46N" setting parameters ranges							
Stage/Timers			Operating mode	Start Current Value		Operate/Tripping Time	
Stage	Std.	Accelerated		Range	Step	Range	Step
46N.S1	T46N.S1	T46N.S1Tc	Independent-Time	0,01÷2In (Table 30, ID "D")	0,01In (Table 30, ID "D")	0,01÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s

10.11.2 Accuracy of the measurements

For measurements accuracy, refer to the following prescriptions:

a. Error and Error limit variation in the measurement of the module: Table 30, ID “D”,

b. Error and Error limit variation in the measurement of the times: Table 52,

Table 52 – Accuracy of the intervention time for the 46N

Description	Range	Time	Error limit	Error limit variation
Start time	I = (0,005÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	I = (0,005÷25) x Ireg	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	(I=10xIreg)	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.12 Directional earth overcurrent protection function IEEE 67N

The 67N directional earth overcurrent protection function operates without HW/SW modifications or settings when switching from one network type to another.

The minimum voltage value to polarize is 0,5 V ($3V_0$). The relay must allow to set the polarization voltage value, and this can be taken from a measured V_0. The supplier must propose a solution to add the polarization of the 67N function through negative sequence components.

Table 53 lists the 7 stages that must be provided. The independent-time ones must be able, when configured, to revert to dependent-time (selectable curves in Table 35) according to IEC 60255 standard.

Table 53 – 67N stages

Standard Stages	Accelerated Stages	
67N.S1	67N.S1_c	independent-time
67N.S2a	67N.S2a_c	independent-time
67N.S2b	67N.S2b_c	independent-time
67N.S3	67N.S3_c	independent-time
67N.Sb	-	Start only
67N.S6	67N.S6_c	Curve
67N.S7	67N.S7_c	independent-time

Stages 67N.S1, 67N.S2a, 67N.S2b, 67N.S3, independently, must be selectable to use $3I_0$ current measurement (C2 Analog Input) or $3I_0$ calculated current.

Stages 67N.S6 and 67N.S7 will use $3I_0$ current measurement (C2 Analog Input).

The capability to build an operation characteristic as shown in Figure 26

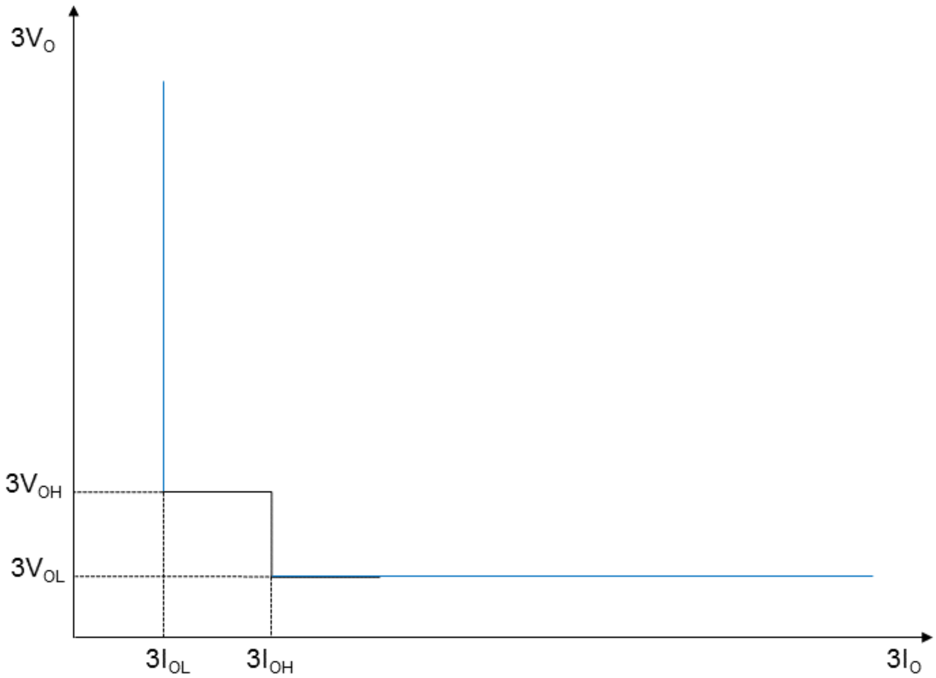

Figure 26 – Operation characteristic 67N

10.12.1 Protection behavior

The measurement functions of the overcurrent (Table 30, ID "C") must seamlessly compare the U_E, I_E phasors and the φ_o phase with the corresponding calibration parameters in Table 55.

When the threshold values of the U_E, I_E phasors are exceeded simultaneously, in addition to the entrance of the I_E phasor in the intervention sector, the state of the protection evolves to the following internal logical states:

Table 54 – FdP 67N behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	67N.Ax	Yes	Yes/No	Yes/No
Operate/Trip	67N.Sx	Yes	Yes/No	Yes/No

If the measurement functions detect that the U_E, I_E phasors fall below the threshold levels and/or the I_E phasor (change of φo) left the tripping sector of one of the directional earth overcurrent stages before the expiry of the tripping time, the protection must release.

It is required that the IEEE67N protection function can take part to the "blocking TPS" logical selectivity; this blocking signal is received subscribing a GOOSE published by the same protection function of an MFP downstream in the same feeder (Par.10.2).

A blocking command applied to a digital input, or generated by a logic, can inhibit the activation of each stage of this function, independently.

10.12.2 Setting Parameters

The stages must be settable according to the ranges of Table 55 and according to the operating modes in Par.10.4.

Table 55 – "67Nx" setting parameters ranges

Stage/Timers			Operating mode	Start Current Value		Start Voltage Value		Operate/Tripping Time		Operate/Tripping Sector	
Stage	Std.	Accelerated		Range	Step	Range	Step	Range	Step	bisector α (fig.27)	half-width β (fig.27)
67N.S1	T67N.S1	T67N.S1_c	Independent-Time / Dependent-Time (available Curve Types in Table 35)	0,005÷25In (Table 30 ID "C")	0,005 In (Table 30 ID "C")	0,001÷1 UEn (Table 30 ID "G")	0,001 (Table 30 ID "G")	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s	0°÷360° Step 1º	1°÷180° Step 1º
67N.S2a	T67N.S2a	T67N.S2a_c									
67N.S2b	T67N.S2b	T67N.S2b_c									
67N.S3	T67N.S3	T67N.S3_c									
67N.Sb	T67N.Sb	---									
67N.S6	T67N.S6	T67N.S4_c									
67N.S7	T67N.S7	T67N.S7_c									

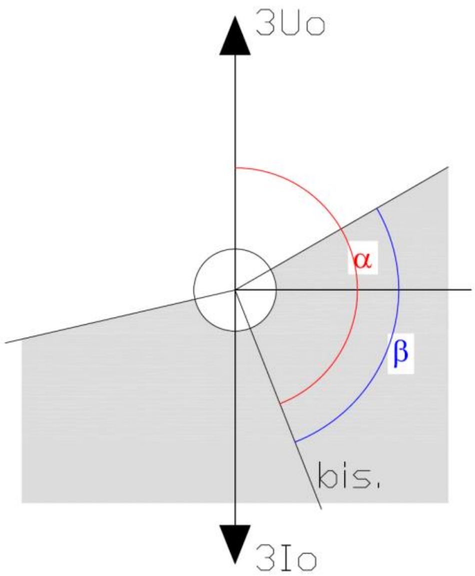

Figure 27 – Tripping sector 67N

10.12.3 Accuracy of the measurements

The accuracy of each single measurement (magnitude, phase angle, start and tripping times) for the protection functions that simultaneously compare and measure several phasors is checked in consecutive phases.

In each phase changes are made to a single phasor (or phase angle between the phasors) keeping the others in a sector of secure intervention equal to 120% of the set value.

For measurements accuracy, refer to the following prescriptions:

a. Error and Error limit variation in the measurement of the I_E module: Table 30 ID "C",

b. Error and Error limit variation in the measurement of the U_E module: Table 30 ID "G",

c. Error and Error limit variation in the measurement of the phase angle U_E ^ I_E: Table 30 ID "R",

d. Error and Error limit variation in the measurement of the times: Table 56

Table 56 – Accuracy of the intervention times for the directional earth overcurrent 67N

Description	Fixed phasor (in sector of secure intervention)	Modified phasor	Range variation	Error limit	Error limit variation
Start time	U_E φo (U_E^ I_E)	I_E	I_E reg. = (0,1÷25) x I_E n I_E reg. = (0,005÷0,1) x In	≤ 40 ms ± 5 ms ≤ 60 ms ± 5 ms	1,5%±5ms 1,5%±5ms
	I_E; φo	U_E	Vo reg.=(0,01÷1) x Von	≤ 40 ms ± 5 ms	1,5%±5ms
	U_E; I_E	φo	±2° (on the limit of the intervention sector)	≤ 40 ms ± 5 ms	1,5%±5ms
Operate/Tripping time without intentional delay time	U_E; φo	I_E	I_E reg. = (0,1÷25) x I_E n I_E reg. = (0,005÷0,1) x In	≤ 40 ms ± 5 ms ≤ 60 ms ± 5 ms	1,5%±5ms 1,5%±5ms
	I_E; φo	U_E	Vo reg.=(0,01÷1) x Von	≤ 40 ms ± 5 ms	1,5%±5ms
	U_E; I_E	φo	±2° (on the limit of the intervention sector)	≤ 40 ms ± 5 ms	1,5%±5ms
Reset time	U_E; φo	I_E		≤ 50 ms ± 5ms	1,5%
	I_E; φo	U_E			
	U_E; I_E	φo			
Reset ratio	U_E; φo	I_E		≥0,90 e ≤ 0,95	1,5%
	I_E; φo	U_E			
	U_E; I_E	φo			
Overshoot time	U_E; φo	I_E	(I=10xIreg)	≤ 40 ms ± 5ms	1,5%±5ms

10.13 Directional overcurrent "Arcing Ground" protection function IEEE 67N

The directional overcurrent "Arcing Ground" protection function IEEE 67N.S4 must detect, in the operating conditions of the network described in Par. 10.12, the type of earth fault known in the electrical literature as "arcing ground".

The detection process is comprised of a logic check of:

a. The starting of the IEEE 67N (Par. 10.12) protection function,

b. The starting of a specific 59U_E stage,

c. or, alternatively,

d. Upon receiving via IEC 61850 GOOSE the starting for residual overvoltage of the protection that fulfills this function.

The RLS (Healthy Line Detection) function of the this FdP is meant to identify the presence of a earth fault by means of an algorithm that takes into account, in the first milliseconds of failure the opposite sign of the IE current measurement samples with respect to the 3Vo in the faulty line and/or a function that detects the energy levels (this functionality must be validated by ENEL).

The logic control that implements the stage 67N.S4 is shown in Figure 28

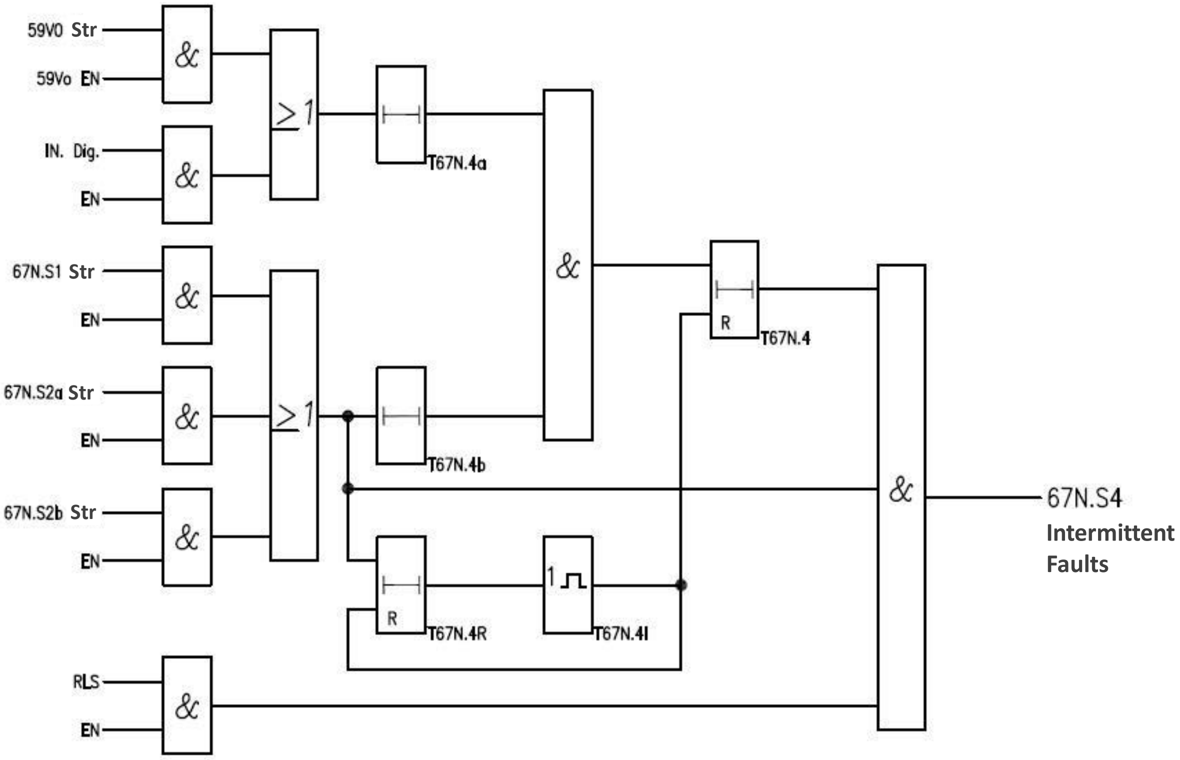

Figure 28 – Logical control: 67N.S4

The logic scheme shown in the above figure, must be implemented using the configuration software of the MFP. It must provide a graphical interface with programmable logic functions that allows the modification of the logic control elements and the related attributes.

Table 57 – List of definition	
T67N.4a	Reset Delay time Str 59Vo
T67N.4b	Reset Delay time Str 67N.Sx
T67N.4	Str time 67N.S4
T67N.4R	Max. fault time before Str 67N.S4 inhibition
T67N.4I	Inhibition-hold time 67N.S4
59Vo ext:	Start signal for residual overvoltage generated by the HV/MV Transformer integrated-protection, sent to the MV feeder (LMT) protections via IEC 61850 GOOSE. It is required to Enable/Disable the signal during the configuration of the stage 67N.S4 via MFP SW interface
U_E	Residual overvoltage stage that can be set according to the range of Table 30 ID “G”and intended solely for the detection of intermittent arcs and evolving faults
67N.S1 Str	Start logic state of the directional earth overcurrent 67N.S1; the 67N.S1avv (Str) must be Enabled/Disabled by the calibration SW of the MFP
67N.S2a Str	Start logic state of the directional earth overcurrent 67N.S2a; the 67N.S1avv (Str) must be Enabled/Disabled by the calibration SW of the MFP
67N.S2b Str	Start logic state of the directional earth overcurrent 67N.S2b; the 67N.S1avv (Str) must be Enabled/Disabled by the calibration SW of the MFP
67N.S4	Stage for the detection of intermittent arcs that can be Enabled/Disabled by the configuration software
RSL	Healthy Line Detection algorithm
EN	Function Enabling
T67N.4a,	Timers that can be set according to the range of Table 30 ID “S”

T67N.4b, T67N.4R, T67N.4I, T67N.4	

10.13.1 Protection behavior

The final outcome of the logic in Figure 28 is the transition of the logical state of "67N.S4" as shown in the Table 58 below:

Table 58 – FdP67N.S4 behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Operate/Trip	67N.S4	Yes	Yes/No	Yes/No

10.14 RLS function

The RLS function identify a fault line from healthy line analysing the electrical quantities in time domain (3Vo and 3Io) during the first instant of fault.

ENEL will provide additional information during the development phase.

10.15 Directional earth overcurrent protection function for the detection of evolving faults

The 67N.S5 directional earth overcurrent protection function for the detection of evolving faults, must detect the type of intermittent fault that originates on different feeders in the sequence they occur and in the operating conditions of the network according to Par. 10.9.

The detection is based on the logic check of:

a. The starting of the FdP IEEE 67N (Par. 10.9)

b. The starting of a specific threshold 59 UE (common to FdP 10.13)

or, alternatively,

c. Upon receiving via IEC 61850 GOOSE the starting of the residual overvoltage protection.

The RLS (Healthy Line Detection) function of the FdP serves to identify the presence of a earth fault by means of an algorithm that takes into account, in the first milliseconds of failure, the opposite sign of the IE current measurement samples with respect to the 3Vo of the faulted line and/or a function that detects the energy (this functionality must be validated by ENEL).

The logic control that implements the stage 67N.S5 is shown in Figure 29

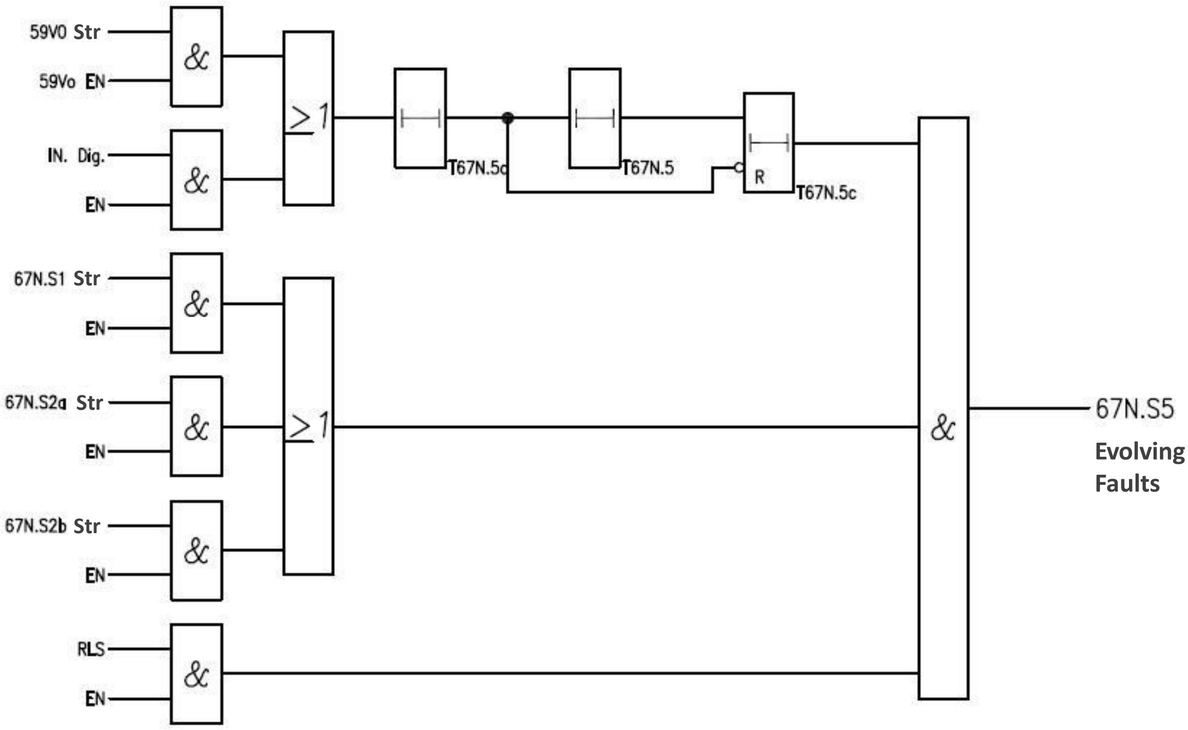

Figure 29 – Logic control: 67N.S5

The logic scheme shown in the above figure, must be implemented using the configuration software of the MFP. It must provide a graphical interface with programmable logic functions that allows the modification of the logic control elements and the related attributes.

Table 59 – List of definition	
59Vo ext:	Start signal for residual overvoltage generated by the HV/MV Transformer integrated-protection, sent to the MV feeder (LMT) protections via IEC 61850 GOOSE. The use of the signal must be inserted / disconnected in the configuration section of the threshold 67N.S4 of the MFP interface software
59 Vo Str	Residual overvoltage stage that can be set according to the range of Table 30, ID “G”, and intended solely for the detection of intermittent arcs and evolving faults
67N.S1 Str	Start logic state of the directional earth overcurrent 67N.S1; the 67N.S1avv (Str) must be Enabled/Disabled by the calibration SW of the MFP
67N.S2a_avv	Start logic state of the directional earth overcurrent 67N.S2a; the 67N.S1avv (Str) must be Enabled/Disabled by the calibration SW of the MFP
67N.S2b_avv	Start logic state of the directional earth overcurrent 67N.S2b; the 67N.S1avv (Str) must be Enabled/Disabled by the calibration SW of the MFP
67N.S5	Stage for the detection of evolving faults that can be Enabled/Disabled by the configuration software
RSL	Healthy Line Detection algorithm
T67N.5a, T67N.5, T67N.5c	Timers that can be set according to the range of Table 30, ID “S”

10.15.1 Protection behavior

The final outcome of the logic in Figure 29 is the transition of the logical state of “67N.S5” as shown in the Table 60 below:

Table 60 – Fdp 67N.S5 behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Operate/Trip	67N.S5	Yes	Yes/No	Yes/No

10.16 Residual overvoltage protection function IEEE 59N

The 59N residual overvoltage protection function correctly operates without HW/SW modifications or settings when switching from one network type to another.

Two independent and dependent time stages, according to Table 61 must be provided.

Table 61 – 59N stages

Standard Stages	Note
59N.S1	
59N.S2	

10.16.1 Protection behavior

The measurement functions of the residual overvoltage (Table 30, ID “G”) must seamlessly compare the U_E phasor with the corresponding calibration parameters in Table 63 set for each 59N.x stage.

When the threshold values of the U_E phasor are exceeded, the state of the protection evolves to the following internal logical states:

Table 62 – FdP 59N behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	59N.Ax	Yes	Yes/No	Yes/No
Operate/Trip	59N.Sx	Yes	Yes/No	Yes/No

If the measurement functions detect that the U_E phasor falls below the threshold levels before the expiry of the tripping time, the protection must release.

10.16.2 Setting Parameters

The stages must be settable with the ranges indicated in Table 63 and according to the operating modes in Par. 10.4

Table 63 –"59N.x" setting parameters ranges

Stage/Timers		Start Voltage Value		Operate/Tripping Time	
Stage	Std.	Range	Step	Range	Step
59N.S1	T59N.S1	0,001÷1 U_{En} (*) (Table 30, ID "G")	0,001 (Table 30, ID "G")	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s
59N.S2	T59N.S2				

(*) $U_{EN} = \sqrt{3}U_N$

10.16.3 Accuracy of the measurements

The accuracy of the measurements of the:

a. Magnitude must be according to Table 30, ID "G"

b. Start and Op/Trip times must comply with the requirements in the Table 64 below:

Table 64 –Accuracy of the intervention times for the residual overvoltage 59N

Description	Range	Time	Error limit	Error limit variation
Start time	U = (0,005÷2) x U_{EN}	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	U = (0,005÷2) x U_{EN}	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time		≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.17 Emergency protection function IEEE 59N

The MFP, user-configured via SW application, must automatically provide protection functions that ensure a minimum level of electric protection to the controlled bay when the internal or external anomalies, dealt with in Par. 8.1 and following, occur.

The function must be both dependent and independent time.

10.17.1 Protection behavior

In the event of a failure in the embedded current inputs board or in the event of a failure in the current transduction chain, the independent-time emergency 59N protection function must be activated.

If enabled via SW, the MFP must autonomously deactivate all the protection functions that use current measurements:

a. 51, only the faulty phase, in case of partial loss (Par. 8.2),

b. 51N,

c. 67,

d. 67N, 67N for intermittent arcs and evolving faults,

e. 32P.

The measurement functions of the residual overvoltage (Table 30, ID "G") must seamlessly compare the UE phasor with the corresponding calibration parameters in Table 63 set for each 59N.x stage.

The exceeding of the threshold values of the UE phasor generates the following internal logical states:

Table 65 –FdP 59N_eme behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	59N.E.Ax	Yes	Yes/No	Yes/No
Operate/Trip	59N.E.Sx	Yes	Yes/No	Yes/No

If the measurement functions detect that the U_E phasor falls below the threshold levels of the overvoltage stages before the expiry of the tripping time, the protection must release.

10.17.2 Setting Parameters

The stage must be settable with the ranges indicated in Table 66 and according to the operating modes in Par. 10.4

a. Voltage threshold and accuracy: Table 30, ID "G"

b. Operate/Tripping Time: Table 30, ID "S"

Table 66 –"59N:EME" setting parameters ranges

Stage/Timers		Start Voltage Value		Operate/Tripping Time	
Stage	Std.	Range	Step	Range	Step
59N.E	T59N.E	0,001÷1 U_{En} (Table 30, ID "G")	0,001 (Table 30, ID "G")	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s

10.17.3 Accuracy of the measurements

The accuracy of the measurements of the:

a. Magnitude must be according to, Table 30, ID "G",

b. Error and Error limit variation in the measurement of the times must comply with the requirements in the Table 64.

10.18 Phase-to-phase overvoltage protection function IEEE 59

The overvoltage protection function 59 must be in OR or AND configuration to measure three phase voltages or phase to phase voltage. Two independent/dependent time overvoltage stages must be provided.

Table 67 – 59 stages

Standard Stages	Note
59.S1	-
59.S2	-

10.18.1 Protection behavior

The measurement function of the phase-to-phase overvoltage (Table 30, ID “G”), must seamlessly compare the U phasors with the corresponding calibration parameters (Table 69) set for each overcurrent stage.

When the threshold values of a U_{XX} phasor are exceeded, the state of the protection evolves to the following internal logical states:

Table 68 – FdP 59 behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	59.Ax	Yes	Yes/No	Yes/No
Operate/Trip	59.Sx	Yes	Yes/No	Yes/No

If the measurement function detects that all the U_{XX} phasor (AND logic) falls below the threshold levels before the expiry of the tripping time, the protection must release.

10.18.2 Setting Parameters

The stages must be settable according to the ranges indicated in Table 69 and according to the operating modes in Par. 10.4

Table 69 – “59” setting parameters ranges

Stage/Timers		Start Voltage Value		Operate/Tripping Time	
Stage	Std.	Range	Step	Range	Step
59.X	T59.X	0,8÷1,5 Un (Table 30, ID “E”)	0,001 (Table 30, ID “E”)	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s

10.18.3 Accuracy of the measurements

The accuracy of the measurement of the:

a. Magnitude must be according to Table 30, ID “G”,

b. Start and Op/Trip times must comply with the requirements in the Table 70 below:

Table 70 – Accuracy of the intervention times for the overvoltage 59

Description	Range	Time	Error limit	Error limit variation
Start time	U = (0,8÷1,5) x Un	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	U = (0,8÷1,5) x Un Un	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time		≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.19 Phase-to-phase undervoltage protection function IEEE 27

The phase-to-phase undervoltage protection function 27 must be configurable in OR or AND configuration to measure three phase voltages or phase to phase voltage. Two independent and dependent time overcurrent stages must be provided.

Table 71 – 27 stages

Standard Stages	Note
27.S1	
27.S2	

10.19.1 Protection behavior

The measurement functions of the residual overvoltage (Table 30, ID “G”) must seamlessly compare the voltage (U_{xx}) phasors with the corresponding calibration parameters in Table 73 set for each 27.Sx stage.

When the threshold values of the U_{XX} phasor are exceeded, the state of the protection evolves to the following internal logical states:

Table 72 – FdP 27 behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	27.Ax	Yes	Yes/No	Yes/No
Operate/Trip	27.Sx	Yes	Yes/No	Yes/No

If the measurement function detects that all the U_{XX} phasor (AND logic) falls below the threshold levels, before the expiry of the tripping time, the protection must release.

10.19.2 Setting Parameters

The stages must be settable according to the ranges indicated in Table 73 and according to the operating modes in Par. 10.4

Table 73 –“27” setting paramenters ranges

Stage/Timers		Start Voltage Value		Operate/Tripping Time	
Stage	Std.	Range	Step	Range	Step
27.X	T27.X	0,01÷1,1 Un	0,001	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s

10.19.3 Accuracy of the measurements

The accuracy of the measurement of the:

a. magnitude must be according to Table 30, ID “G”,

b. Start and Op/Trip times must comply with the requirements in the Table 74 below:

Table 74 –Accuracy of the intervention times for the overvoltage 27

Description	Range	Time	Error limit	Error limit variation

Start time	U = (0,01÷1,1) x Un	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	U = (0,01÷1,1) x Un	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time		≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.20 Cold Load Pick Up

Every FdP must be according to the Cold Load Pick Up (CLP) function. The CLP has following characteristics:

a. The CLP function must be Enabled/Disabled inside the FdP

b. The CLP function is activated when the circuit-breaker switch from open to close

c. It must be possible closing or changing the intervention value of the protection for a settable duration time

d. When the function is blocked, it maintains the delay time at 0s and continues to return the start-up stage of the FdP.

The Cold Load Pickup function must have two different operation mode. The first one, the pickup value of the 51 function must be equal a user defined parameter during a configurable time. The second mode, the 51 function must follow a specific curve during a configurable time. The kind of curve could be time defined or inverse time (IEC and ANSI Curves as specified in par. 10.6).

10.21 SOTF (Switch-On To Fault)

The function must enable the protections with the contract time setting on the transition from absence of voltage-to-voltage presence. The function is able to work with the breaker position (from off to on), in case the position has not voltage transformers on the line side. It is selectable to use this function with each stage of the protection functions 51, 51N, 67 and 67N.

This function must consider the discrimination of inrush currents as specified in 10.22.

10.22 Discrimination of INRUSH currents

In order to avoid unwanted operations of the protections due to the energization of the transformers installed along the feeder, a dedicated harmonic restraint FdP must prevent the 51, 51N, 67 and 67N stages from starting when the 2nd harmonic current overcomes a predetermined fraction of the fundamental component.

10.22.1 Protection behavior

The blocking function must be configurable to inhibit independently each of the stages 51, 51N, 67 and 67N for the overflow of the harmonic component both of a single phase or two of three phases.

Through the FFT, the function must compare the value of the 2nd harmonic with the threshold value. If the measured value is higher than the threshold value, the function must inhibit the stages 51.Sx, 51N.Sx, 67.Sx.Fy and 67N.Sx from tripping, for the pre-set time, and for as long as no current phase exceeds an adjustable threshold.

If the preset time is exceeded and the starting of 51.Ax.Fy, 51N.Ax.Fy, 67.Ax.Fy or 67N.Ax are not released, despite the 2nd harmonic is still exceeding the relevant threshold, the MFP must resume the normal protection logic 51, 51N, 67 or 67N and send the trip command towards the controlled circuit-breaker.

If during the inrush blocking, the pick-up of the function that has started, is released, the associated timing for the trigger will be reset, waiting for a new start of the corresponding function. If the 2nd harmonic level condition is released with the preset time window, the trip occurs according to the operation characteristic of the function that is started once the time window expired, without additional delay.

10.22.2 Setting Parameters

The blocking function must be settable according to the ranges indicated in the Table 75 below:

Table 75 – "INRUSH" setting parameters ranges

Start Current Value (FFT I_{50Hz})		Operate/Tripping Time	
Range	Step	Range	Step
10÷50% Default. 25% Maximum current for inrush recognition: 0,20÷20 I_N (step 0,02 I_N)	1%	0,05÷10 s 10÷100 s (default 0,45s)	0,01 s 0,1 s

10.22.3 Accuracy of the measurements

The accuracy of the measurement of the INRUSH blocking function must comply with the requirements in the Table 76 below:

Table 76 – Accuracy of the intervention times for the INRUSH blocking function

Description	Range	Time	Error limit	Error limit variation
Start time	I = (0,1÷2) x In	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	I = (0,1÷2) x In	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%
Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	(I=10xIreg)	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.23 Directional active overpower protection function 32P

This function is mainly used when the MFP protects a bay exclusively dedicated to a self-producer customer.

Two independent-time overpower stages must be provided with the possibility of insertion with the 2 and 3 Wattmeters methods, depending on the type of configuration of the C2 input (Par. 9.2.1).

Table 77 – 32P stages

Standard Stages	Note
32P.S1	independent-time

32P.S2	independent-time

The threshold 32 P must be automatically deactivated if P≤5%Q in order to guarantee sensitivity and stability to the protection function, in the event of a short circuit.

10.23.1 Protection behavior

The measurement functions of the overpower (Table 30, ID “M”, “N”, “O”) must constantly monitor the flow of active power passing through the node controlled by the MFP.

When the threshold values are exceeded, the state of the protection evolves to the following logical states:

Table 78 – FdP 32P behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Start	32P.Ax	Yes	Yes/No	Yes/No
Operate/Trip	32P.Sx	Yes	Yes/No	Yes/No

If the measurement functions detect that the Active Power value falls below the threshold levels before the expiry of the tripping time, the protection must release.

10.23.2 Setting Parameters

The stages must be settable according to the ranges indicated in Table 79 and according to the operating modes in Par.10.4. Moreover, it must be possible to select the direction of the power flow considering that the default setting is according to the convection in Par.9.4.

Table 79 – “32P” setting parameters ranges

Stage/Timers		Start/Tripping settings 32P					Operate/Tripping Time	
Stage	Std.	Active State	Direction	Pn	Range	Step	Range	Step
32P_S 1	T32P_S 1	Ena/Dis	Positiva / Negativa	0,1÷25 MW step 0,1MW	80%÷120% Pn Default. 100%	1%	Table 30, ID “S” (default 900s)	Table 30, ID “S”
32P_S 2	T32P_S 2	Ena/Dis						

10.23.3 Accuracy of the measurements

The accuracy of the measurement of the:

a. magnitude must be according to Table 30, ID “M”, “N”, “O”,

b. Start and Op/Trip times must comply with the requirements in the Table 80 below:

Table 80 – Accuracy of the intervention times for the directional overpower 32P_Sx

Description	Range	Time	Error limit	Error limit variation
Start time	80%÷120% Pn	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Operate/Tripping time without intentional delay time	80%÷120% Pn	≤ 1.5 cycles	± 0.25 cycles	1,5%± 0.25 cycles
Reset time		≤ 1.5 cycles	± 0.25 cycles	1,5%

Reset ratio		≥0,90 e ≤ 0,95 x Ireg		1,5%
Overshoot time	S=10xPreg	≤ 2 cycles	± 0.25 cycles	1,5%± 0.25 cycles

10.24 Protection Function of Broken Conductor I2/I1

The broken conductor (phase interruption) function is based on exceeding of the ratio between the negative sequence current and direct sequence current.

The main features are:

a. The function must be Enabled/Disabled.

b. The function must have an overcurrent threshold; from which the I2/I1 is activated.

c. The function must have discrimination currents thresholds (one for I2 and one for I1); under this, the function is inhibited.

d. If the I2 / I1 exceeds the set threshold, it must be able to activate a relay or a virtual output or both to send its status.

e. A time defined setting with a range 0 to 60 seconds and step 0,1 seconds;

f. A positive sequence voltage threshold that will avoid the operation for phase-to-phase short-circuits, with range 0 to 0.9 Vn and step 0.01.

g. A zero sequence voltage threshold that will avoid the operation for phase-to-ground short-circuits, with range 0.1 to 1.3 Vn and step 0.01.

It must be possible to activate and deactivate the Broker Conductor protection function either through the configuration and local control software, or through the commands (as per IEC 61850) generated by the RTU in the Primary substation. Following the execution of such a command, the MFP must report the status back to the RTU and display it on the screen of the MFP.

10.25 Protection Function of Breaker Failure

The breaker failure function consist of two overcurrent directionless function, one for poly-phase faults and other for single-phase faults. The function is used to signal the opening failure of the circuit breaker.

The main features are:

a. The function must be Enabled/Disabled,

b. It must be associable with an OR matrix to the protection functions to be monitored,

c. The function is activated at the trigger command of the associated protections in the matrix,

d. If the protection functions activated do not fall within the set time, a relay or a virtual output associable via SW must be command.

e. The main parameter for open failure detection must be configurable.

The Breaker Failure function operation must report to the RTU, record in internal logging and disturbance recording. The IEC 61850 point must be available to send a GOOSE message and open the upstream breaker.

It must be possible to activate and deactivate the Breaker Failure protection function either through the configuration and local control software, or through the commands (as per IEC 61850) generated by the RTU in the Primary substation. Following the execution of such a command, the MFP must report the current status back to the RTU and display it on the screen of the MFP.

10.26 Synchro-check protection function IEEE 25

The Synchro-check protection function is designed to allow the interconnection in safe conditions of two grids, each one in the presence of electrical generation.

It must be possible to activate and deactivate the Synchro-Check protection function either through the configuration and local control software, or through the commands (as per IEC 61850) generated by the RTU in the Primary substation. Following the execution of such a command, the MFP must report the current status back to the RTU and display it on the screen of the MFP.

This protection compares the upstream and downstream voltages of the controlled circuit-breaker. In particular, the measured phase voltage V_{RIF} downstream of the circuit-breaker must be compared with the corresponding measured phase voltage upstream of the circuit-breaker.

This function works within an acceptable voltage range (minimum and maximum voltage thresholds):

a. Upper limit threshold: 0,5 ÷ 1,5 Vn , step 10%

b. Lower limit threshold: 0,2 ÷ 1,5 Vn , step 10%

In the configuration section of the Synchro-Check protection function it must be possible to select which of the phase voltages V_{4-0}, V_{8-0}, V_{12-0} (Table 30, ID “F”) must be compared with V_{RIF}.

The Synchro-check protection function must satisfy all the requisites that allow the interconnection (or paralleling) between:

a. Synchronous networks: Parallel control function for Synchronous networks (PS).

b. Asynchronous networks: Parallel control function for Asynchronous networks (PA).

The Synchro-check protection for synchronous (PS) and asynchronous (PA) networks must also be capable of configuring to ensure the independent operation of both manual and automatic closing of the circuit-breaker, in particular in case of a slow reclosing event.

Table 81 – Closing configuration for PS and PA

Parallel control function	Manual closing	Automatic Slow closing
Synchronous networks (PS)	YES/NO	YES/NO
Asynchronous networks (PA)	YES/NO	YES/NO

In absence of the paralleling conditions, the Synchro-check protection, whether enabled or not, must not generate either a Manual or Automatic closing command.

10.26.1 Synchronous networks paralleling conditions check (PS)

This function allows the interconnection of networks that are in sync or with a reduced Slip, that is defined as the percentage difference between the frequency of the VRIF voltage and the one of the reference voltage.

The condition of very low slip is defined as follows:

EQUATION 1

Slip: $|S_{PS}| < S_{SYNC}$

When evaluating the slip, by means of a suitable filtering algorithm, the normal oscillation due to the non-prevalent generation, that could therefore prevent the recognition of the synchronism condition must be considered.

When the synchronization conditions are met (EQUATION 1) a time window T_{SYNC} must be opened during which the following conditions must be checked:

EQUATION 2

Difference between the modules: $|V_{4\text{-}0}; V_{8\text{-}0}; V_{12\text{-}0}| - |V_{RIF}| < \Delta V_{PS}$

EQUATION 3

Difference between the phase angles: $|(V_{4\text{-}0}; V_{8\text{-}0}; V_{12\text{-}0}) \wedge V_{RIF}| < \Delta\varphi$

Table 82 – Synchro Check setting parameters ranges (PS)		
Parameter	Range	Step
Slip S_{SYNC} [%fn]	0÷0,2	0,05
Difference between the modules of the voltages ΔV_{PS} [% Vn]	1÷40	1
Difference between the phase angles of the voltages: $\Delta\varphi$ [°]	0÷60	1
Synchronization conditions control time T_{SYNC} [s]	0÷600	1

10.26.2 Asynchronous networks paralleling conditions check (PA)

This function allows the interconnection of networks that are out of sync or networks in which a certain level of Slip persists over time. The conditions that must be considered before issuing the closing command, both on automatic slow closing and on manual control, are shown in the Table 83 below:

Table 83 – PA algorithm		
EQUATION 4	Voltage phase angles difference decreasing	$\varphi = (V_{4\text{-}0}; V_{8\text{-}0}; V_{12\text{-}0}) \wedge V_{RIF}$ $\delta\varphi/\delta t<0$
EQUATION 5	Asynchronous Slip less than threshold	$S_{PA} < S_{ASYNC}$
EQUATION 6	Difference between the modules	$\lvert V_{4\text{-}0}; V_{8\text{-}0}; V_{12\text{-}0}\rvert - \lvert V_{RIF}\rvert < \Delta V_{PA}$
EQUATION 7	Positive rate of change of the Slip between the reference voltages	$\delta S_{PA} / \delta t > 0$
	Voltages Slip less than threshold	$\delta S_{PA} / \delta t < \delta S_{ASYNC} / \delta t$
	Limit of Slip Positive rate of change	$\delta S_{ASYNC} / \delta t = 0{,}01*(0{,}5*Ta)$

When the conditions in Table 83 are met, the device must determine the lead time (Ta) for issuing the closing command, taking into account both the degree of Slip and the real closing time of the circuit-breaker (derived from the mechanical monitoring function of the circuit-breaker, Par.8.2.2.1).

This is to ensure that the closing of the circuit-breaker poles occurs when the voltages of the MV busbar and of the live line (line with presence of generation) are almost in phase.

Table 84 – Synchro-Check setting parameters ranges (PA)		
Parameter	Range	Step
Slip S_{ASYNC} [%fn]	0÷0,2	0,05

Difference between the modules of the voltages ΔV_{PA} [% Vn]	1÷40	1
Lead time (Ta) [ms]	0÷200	1

10.27 Overvoltage detection protection function (ES59B)

The overvoltage detection/supervision function ES59B is used for lines with connected co-generation plants.

10.27.1 Protection behavior

This function can be Enabled and Disabled via SW configuration and inhibited by a Digital Input. The MFP will assume that the protection is in service if the Digital Input is activated, and out of service when the Digital Input is deactivated.

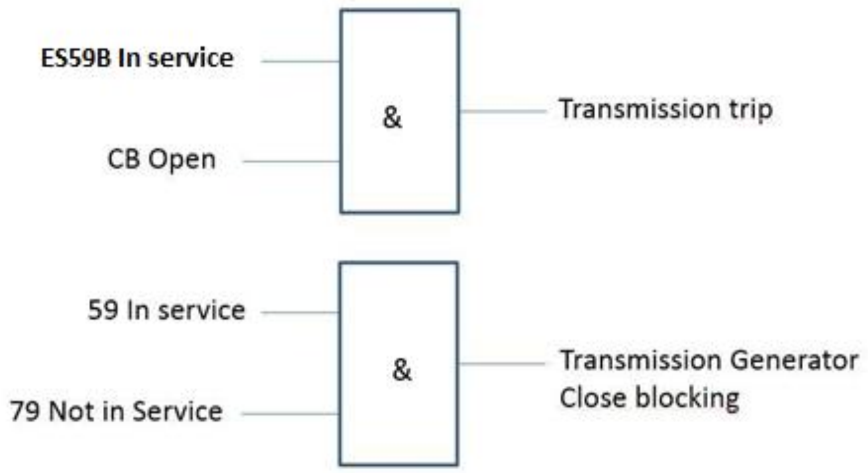

Figure 30 – Self producer cogeneration automatism

The ES59B protection performs also the following functions:

a. Supervision of the line voltage to determine the operation of the self-producer user, when the breaker is opened,

b. Block all attempts at closing the circuit-breaker according to the voltage presence on the line,

c. Block all attempts at closing of the circuit-breaker due to the fall of the magneto-thermal voltages,

d. Emission of the trip signal to the external communications equipment. When the circuit-breaker is disconnected and ES59B is in service this Digital Output will be activated;

e. Emission of the tele-blocking signal to the external communications equipment. When the auto-reclosing automatism is out of service and ES59B is in service this Digital Output will be activated.

Table 85 – FdP ES59B behavior

FdP logical state	Displayed message	IEC 61850 Report to the RTU	Internal Logging	Disturbance recording
Operate/Trip	ES59B.Sx	Yes	Yes/No	Yes/No

10.27.2 Setting Parameters

The stages must be settable according to the ranges indicated in Table 86 and according to the operating modes in Par. 10.4.

Table 86 – "ES59B" setting parameters ranges					
Stage/Timers		Start Voltage Value		Operate/Tripping Time	
Stage	Std.	Range	Step	Range	Step
59.X	T59.X	0,00÷1 Un (Table 30, ID "E")	0,01 (Table 30, ID "E")	0,05÷10 s 10÷100 s 100÷1000 s	0,01 s 0,1 s 1 s

10.27.3 Accuracy of the measurements

The accuracy of the measurement of the

a. magnitude must be according Table 30, ID "F",

b. Start and Op/Trip times must comply with the requirements in the Table 70.

10.28 DC undervoltage protection function (27)

The DC undervoltage protection function of the Primary Substation must be executed in three-wire mode (three-phase); it must have a single opening Digital Output. One stage (with tripping capability) must be provided. This function can be selectable ON / OFF.

10.28.1 Protection behavior

When the settable delay time of the stage has expired, the logical trip signal 27X must be issued. When the voltage value returns above the threshold values, the protection must release. The opening command is triggered by opening the MT-12 contact terminal board, which is normally closed when the device is in normal operation, and normally opened when the device is off.

This function can be configurable as either Enabled/Disabled via configuration.

The operating characteristics of the function must be according to the ranges indicated in the Table 87 below:

Table 87 – "DC undervoltage" operating characteristics		
Parameter	Range	Step
Rated Voltage Vndc	Vaux	
Tripping Voltage	0.6÷1. Vndc	0,1 V
Threshold Errors		
Error limit	≤1%	
Error limit variation	≤0,5%	
Tripping Delay time (fixed)	0.÷10 s	0,01 s
Time Errors		
Error limit	≤3%± 20ms	
Error limit variation	≤3%	
Reset time	50÷100ms	
Reset ratio	1,02÷1,05	
Overshoot time	≤35ms	
Absorption	≤1,5W	

10.29 Frequency protection function EAC (81)

The frequency measurement must be performed on the three phase voltages monitored by the device. This function can be selectable to ON/OFF.

10.29.1 EAC blocking stages

The function must be equipped with blocking stages to guarantee the reliability of the measurements and the correct behavior of the protections. The blocking stages are able to inhibit the operations based on the frequency measurement.

10.29.1.1. Undervoltage and overvoltage blocking stages

The three (V4, V8, V12) voltages must be monitored to support the operation of the device; if one falls below or rises above the preset minimum and maximum voltage thresholds respectively, the operation of all the tripping stages will be inhibited. This blocking stage must have two timers:

a. Stage activation delay,

b. Stage reset delay.

Table 88 – "Under/overvoltage blocking stages" setting parameters ranges

		Blocking settings		Blocking Time	
Stage	Active State	Range	Step	Range	Step
27	Ena/Dis	0 ÷ 1.4 Vn	0,05 Vn	0 ÷ 60 s	0,05 s
59	Ena/Dis	0 ÷ 1.4 Vn	0,05 Vn	0 ÷ 60 s	0,05 s

Table 89 – Accuracy of the intervention times for the "Under/overvoltage blocking stages"

Stage	Measurement Accuracy	Minimum intervention Time	Time measurement error
27	0,01 Vn	±50 ms	±50 ms
59	0,01 Vn	±50 ms	±50 ms

10.29.1.2. Maximum unbalance β blocking stage

It is required to implement stages based on the maximum difference between the magnitude of the single monitored voltages and their average value in order to preclude the operation of the MFP in case of unbalanced voltages.

The unbalance stage must have a reset delay time. This stage inhibits the operation of all tripping stages when the β ratio goes above a set value which value is so calculated as follows:

$\mu = (V4+V8+V12) / 3$

$$\beta = \frac{\max[\,abs(V4-\mu); abs(V8-\mu); abs(V12-\mu)]}{\mu}$$

Table 90 – "β blocking stage" setting parameters ranges

		Blocking settings		Blocking Time	
Stage	Active State	Range	Step	Range	Step
β	Ena/Dis	0,05 ÷ 1	0,05	0 ÷ 60 s	0,05 s

Table 91 – Accuracy for the intervention times for the "β blocking stage"

Stage	Measurement Accuracy	Minimum intervention Time	Time measurement error
β	0,01 Vn	±50 ms	±50 ms

10.29.1.3. Max frequency difference γ blocking stage

This stage inhibits the operation of all the tripping stages when the maximum difference between the recorded frequencies of the monitored signals exceeds the preset γ value. The Max frequency difference blocking threshold must have a reset delay time.

γ = max ((frequency V_4 – frequency V_8); (frequency V_8 – frequency V_{12}); (frequency V_{12} – frequency V_4))

Table 92 – "γ blocking stage" setting parameters ranges

		Blocking settings		Blocking Time	
Stage	Active State	Range	Step	Range	Step
γ	Ena/Dis	10 ÷ 100 mHz	0,10 mHz	0 ÷ 60 s	0,05 s

Table 93 – Accuracy for the intervention times for the "γ blocking stage"

Stage	Measurement Accuracy	Minimum intervention Time	Time measurement error
γ	10 mHz	≤100 ms (4 cycles)	±50 ms

10.29.1.4. Maximum variation allowed between consecutive periods Maxdt blocking stage

The Maxdt blocking stage uses the following mechanism to inhibit the frequency measurements:

a. When Δt is greater than a value pre-set via the configuration SW (range 100÷7000 μs) it detects a perturbation on the phase and blocks the frequency (tripping) stages and the rate of change of frequency (tripping) stages,

b. EAC continue to measures the cycles and compare the last one with the second-last; only when Δt falls below the pre-set value configurable SW, the perturbation on the phase is over and the frequency measurement must be re-established,

c. to restart and pass the frequency and the rate of change of frequency measurements to the (tripping) stages, it must properly fill the memories of the moving average (e.g. if N is the number of the cycles of the average calculation, then the frequency will be available after N cycles and the rate of change of frequency after N+N).

10.29.2 EAC tripping stages

The EAC will implement underfrequency, overfrequency and rate of change of frequency protection functions. These can be simultaneously/selectively enabled and can send the trip command towards the controlled circuit-breaker. The setting parameters ranges are specified in the Table 94 and Table 95, where the operating time are measured in a sliding temporal window of 5 cycles.

Table 94 – "Under/overfrequency stages" setting parameters ranges

stages settings			Operation Time		
Active State	Range	Step	Range	Step	cycles
Ena/Dis	0.9fn ÷ 1.1fn Hz	0,0002fn Hz	0 ÷ 3000 cycles	0,5 cycles	5 cycles

Table 95 – "Rate of change of frequency stages" setting parameters ranges

stages settings			Operation Time		
Active State	Range	Step	Range	Step	cycles
Ena/Dis	±(0,01÷ 10) Hz/s	0,1 Hz/s	0 ÷ 3000 cycles	0,5 cycles	5 cycles

Rated change of frequency function, will work within a frequency band selectable by the user (inside 45 - 65 Hz operating range).

10.29.3 Frequency and voltage measurements

The frequency and voltage measurements must refer to the fundamental component and to the RMS value. Suitable filtering systems must ensure the measured values are unaffected by any electromagnetic disturbances.

The frequency and rate of change of frequency measurements must be carried out with the required accuracy in the 45 - 65 Hz operating range, for voltage values 0.3 times greater than the rated one.

The voltage measurements must be carried out with the required accuracy in the 45 - 65 Hz operating range, for values from 0 to 1.4 times greater than the rated one. In the case of signals with a THD<10% the frequency measurements must be adjusted.

The frequency stages must be immune to the most common transients on the HV grid and ENEL will provide the related digital recordings (transformers energization, lines reclosing, short-circuits).

Note that the MFP must base the frequency measurement by measuring the time between two zero crossings of a period and summing the N measured intervals, with N = number of periods to be integrated.

It is necessary that the number of samples used per period be sufficiently dense to approximate the curve between two consecutive samples by a straight-line segment. This means that the errors inserted in the time measurement between the zero-crossing and the sample position must be compensated by means of linear interpolation.

The manufacturer must clearly indicate the methodology and the calculation algorithm implemented in the MFP (including also algorithms based on moving averages, sampling frequency, number of processed samples and the filtering systems) for making the following measurements:

a. Frequency,

b. Rate of change of the frequency,

c. Voltage,

d. Rate of change of the voltage.

10.29.4 EAC Function

The EAC function is made up of two protection stages based on EQUATION 8 below and must be activated upon detecting the sign of active power.

The operation of the stages will be communicated according to the IEC 61850 series and must be associated with Vout virtual outputs.

EQUATION 8

$$81\_S_x = (((f_{x1} and \frac{df}{dt}) and (ON/OFF)) or (f_{x2} and (ON/OFF)) and seg\{\overline{P}\})$$

ENEL will provide the details for the implementation of the EAC FdP during the development phase.

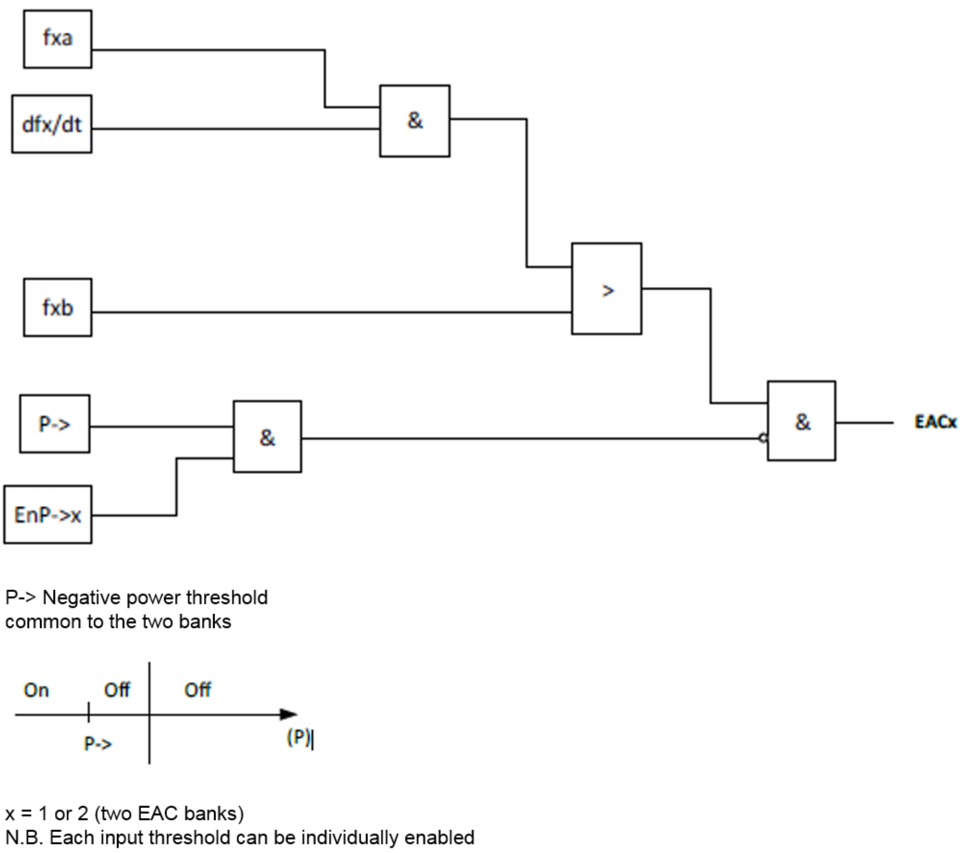

Figura 31 – EAC Logic

11 FSL FUNCTION

With the implementation of the IEC 61850 protocol it is expected that the IEDs, by exploiting the real-time communication capability, can exchange block signals (goose) called Blind. These signals temporarily inhibit the opening orders that are given by the FDPs and therefore allow the exclusive selection of the line affected by a fault, or, in the event of short circuits at the MV line terminals, avoiding cases of simultaneous shutter release of the MT line protection and transformer line.

Blind signals are conveyed in multicast in the Primary Bus LAN and in the VLAN where the secondary cabin IED (RGDM) take place through the IEC 61850 protocol (Goose). The FSL functionality must be selectable in local configuration or activated by an appropriate IEC 61850 message.

The logical selectivity is based on the comparison of the information content of the BLIND message, requested by the IEDs following the detection of the fault condition. This information content is the topological code (TAG), calculated by the telecontrol system, and written in the IED by the TPT2020 client. In order to be able to compare the topological codes, the system sends the identifier defined ADRLEVBN that defines the composition of the TAG code by the number of bits via the TPT2020. The information, related to the logical selectivity (TAG, ADRLEVBN, etc ..), once written by the client, must be kept in the memory of the IED until a new writing, even if the IED is restarted.

The comparison algorithm that the IED must implement and the format of the “TAG” are described in the specification:

“TAG assignment and comparison algorithms for the FSL automation and the teledistacco.doc”.

Details related to the IEC61850 profile are contained in the technical specification of the IEC61850 profile of the MFP. The IED must be able to process at least 30 BLIND messages sent at the same time of failure. That is, a configuration involving at least 30 IEDs installed along the medium voltage line.

The following are some cases of use of the FSL functionality.

Figure 32 shows the use case that the fault appears along the MT line and an electrically upstream IED sends a BLIND message. In this condition the BLIND message is ignored, because it is sent by an electrically upstream IED. So the FdP ends its intentional delay time Top_fdp and sends the trip command to the MV switch.

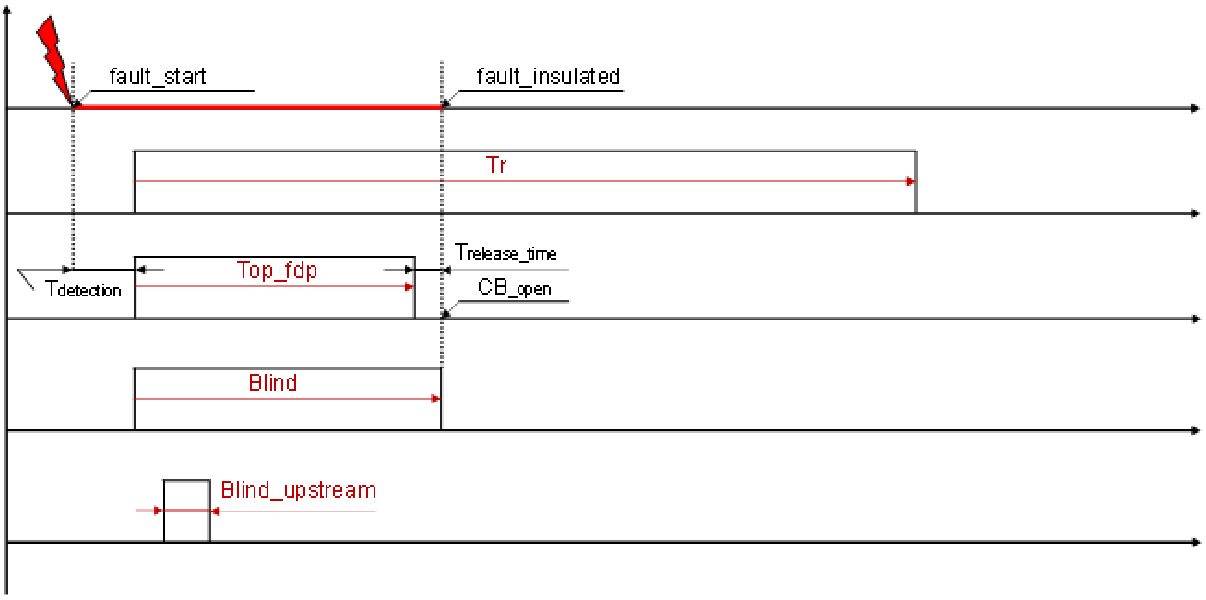

Figure 32 – FSL Operation Logic

Figura 33 shows the case that the fault appears along the MT line and a placed IED electrically downstream sends a BLIND message. In this condition the BLIND message is ignored, since it is received after the time for sending the trip command to the MV circuit-breaker.

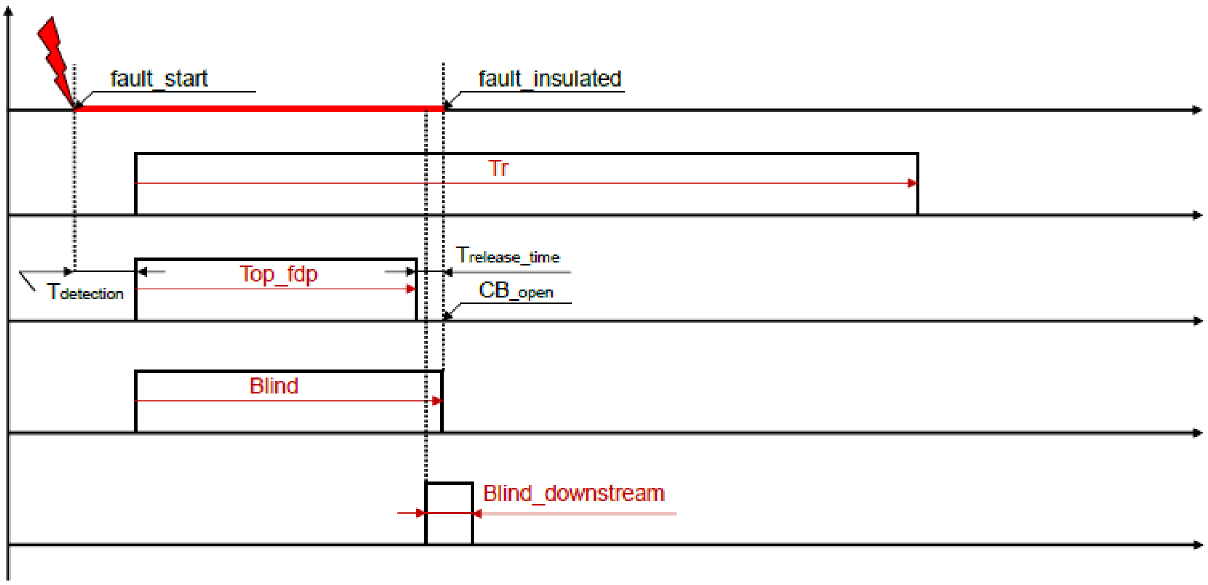

Figura 33 – FSL Operation Logic

Figura 34 shows the case that the fault appears along the MT line and an electrically downstream IED sends a BLIND message. In this condition, the message of BLIND is taken over as sent by an IED placed electrically downstream. In this condition the FdP is kept in the reset state (Top_fdp = 0) until the valid BLIND reception condition is confirmed. If, as shown, the BLIND condition sent by the downstream IED falls back, the timer Top_fdp is restarted proceeding up to the trip condition in which the trip command is sent to the MV switch.

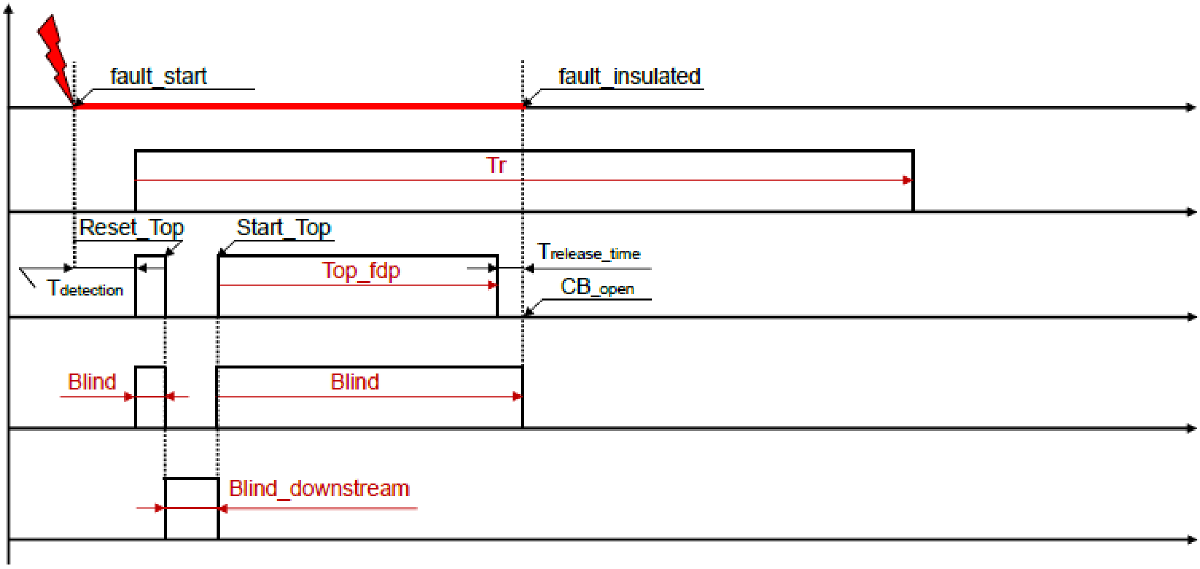

Figura 34 – FSL Operation Logic

Figura 35 shows the case that the fault appears along the MT line and an electrically downstream IED sends a BLIND message several times. In this condition the message of BLIND is taken over as sent by an IED placed electrically downstream. In this condition the FdP is kept in the reset state (Top_fdp = 0) until the valid BLIND reception condition is confirmed. If, as shown, the BLIND condition sent by the IED leads to exceed the Tr backup timer, the IED proceeds to the trip condition and sends the trip command to the MV switch.

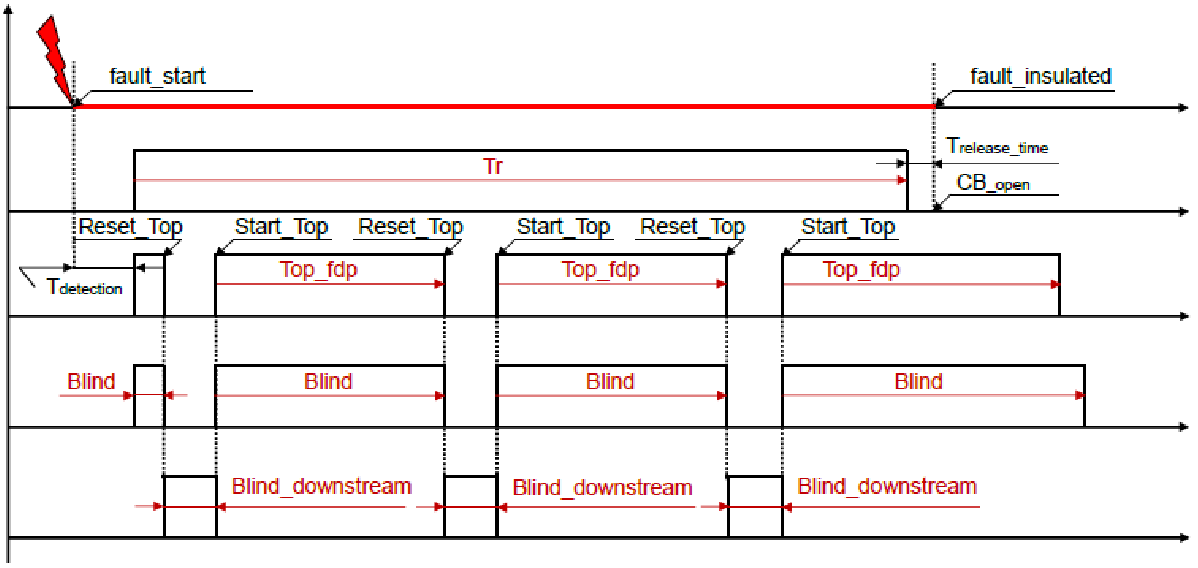

Figura 35 - FSL Operation Logic

11.1 Remote Trip Function

Associated with the FSL function, it is necessary to set up a function for opening the circuit-breakers downstream of the line circuit-breaker. ENEL will provide the details to implementation of the function Remote Trip during the development phase.

12 AUTOMATIC RECLOSING FUNCTION (ARF)

The MFP must be equipped with the automation that performs the reclosing of the controlled circuit breaker which has been tripped by the FdPs.

The ARF is required to select a proper reclosing sequence according to the kind of FdP that operated; the independent and simultaneous configurability of two reclosing banks is required for each of which it will be possible to choose the sequence of insulation cycles and the reclosing FdPs associated with each bank.

Each bank must have up to five programmable isolation cycles, listed in Table 96, moreover, the ARF could be submitted (RR excluded) to the synchronization control in (Par.10.26).

The reclosing sequence, programmable via SW, must allow the activation/deactivation of the following options:

a. (E) closing Excluded – no reclosing attempts must be performed;

b. (RR) Fast Closing – at the end of one short interruption time a Closing is performed;

c. (RR + RL) Fast Closing + Slow Closing - following a RR and at the end of a longer interruption time a Closing is performed;

d. (RR + RL + RMx) - following a (RR + RL) sequence, up to three additional interruption/closing cycles, called “Memorized Closings” RM1, RM2; RM3 can also be performed.

Table 96 – Auto-reclosing setting parameters ranges

Reclosing Type		Interruption/isolation Timer	Setting ranges	Range and Errors	Default value
RR	Fast Closing	Trr	200 ms ÷ 2s Step 50 ms	Table 30 ID “S”	0,4
RL	Slow Closing	TRL	200 ms ÷ 200s Step 50 ms	Table 30 ID “S”	30
RM1	1st Memorized Closing	TN1 (the Interruption Time of the RMx matches with the Neutralization Time TN1)		Table 30 ID “S”	120
RM2	2nd Memorized Closing				
RM3	3rd Memorized Closing				
T	Recovery time		2 ms ÷ 300 s Step 50 ms		
TD_{CM}	(after manual closing)		2 ms ÷ 200 s Step 50 ms		

It is requested to Include / Exclude the reclosing function:

e. By a switch placed on the front panel (acts on both reclosing banks),

f. Via SW configuration SW (acts on both reclosing banks),

g. Via IEC 61850 commands (acts on both reclosing banks).

The reclosing is:

h. Included when all the elements in e., f., and g. are included (logical AND condition),

i. Excluded when at least one e., f., and g. is excluded (logical OR condition).

The status of reclosing included/excluded must be maintained in case of shutdown and subsequent restart of the device.

12.1 Operating modes

An FdP, at the expiration of the delay time triggered by its starting (TATT), trips the controlled circuit-breaker and the ARF triggers the TI (IED profile according to IEC 61850) counter. If during the TATT there is a fault type evolution and a subsequent change or further starting of a different stage of the same FdP, or even of a different FdP, the TATT must be adapted (reduced) to the new time settings of the starting stage.

In the event that the FdP releases within the TI expiration, the TRR (interruption/isolation Time of the RR) timer will start, otherwise the Automatic reclosings will not be performed and the MFP will report (as per IEC 61850) the SSR (trip without reclosing) signal to the RTU.

When the TRR expires, the ARF issues the closing order to the circuit-breaker, displays the CRC (reclosing cycle in progress) information on the MFP screen, issues a report to the RTU and starts the TDR and TN counters.

If during the TD_R, or later, but during the TN with the Slow Closing inactive (point b. in Par.12), a FdP commands a trip, the ARF will report locally and to the RTU the status of FR (Failed Reclosing).

Otherwise, if via SW configuration is requested the execution of the closing programs at points c. or d. () the start of a FdP beyond the TD_R, but during the TN, will restart the TATT; when TATT expires a new tripping order will be issued, the TI will be restarted (and the above mentioned checks on the FdP releases), started the TRL time which expiry will cause the execution of the Slow Closing.

Following the Slow Closing, the TDL will be started and the TN will be restarted. If no further re-closing are programmed (point c.in Par.12), in the event of a fault within the TN, a further opening command will be issued while the ARF will report locally and to the RTU the status of FR.

If one or more Memorized Closings are programmed (point d. Par.12), in the event of a fault beyond the TD_L, (remaining the controls on the release of the FdP startings with a further TI) at the expiration of the TN the ARF will issue the first Memorized Closing and start TD_M and TN timers.

According to the SW configuration, the ARF can issue up to three Memorized Closings repeating, for each one, the controls initiated with the TI, the TD_M and the closing command when the TN expires. In case of a further tripping over the third Memorized Closing, the ARF will report locally and to the RTU the status of FR.

The ARF must inhibit the closing if, following a manual closing, a fault occurs inside a control time window defined by the TD_{CM} parameter.

A manual closing will trigger the TN, for the faults check while TN is active and the TD_{CM} has expired, the ARF will perform the first closing after the TRL expiration and then, according to the settings, the subsequent ones.

A (settable) recovery time is needed to consider the auto-reclosing cycle as finished. After this time expires, a trip will activate again a complete auto-reclosing cycle.

After a manual closing, the automatic reclosing function will be inhibited for a selectable time. After this time expires, the automatic reclosing function will be ready to operate in case there’s no other blocking condition.

12.2 ARF conditioning in the presence of external signals

The configuration SW must allow different operating modes of the ARF, listed in Table 97, which may be affected by events such as Digital Input, IEC 61850 messages (GOOSE, MMS), MODBUS messages or by internal MFP such as, e.g., a FdP trip.

The combination of the conditioning event and the operating mode of the ARF must be configurable in the programmable logic section.

Table 97 – ARF conditioning and related operating modes

Operating Mode	ARF operations
No event	No further action.
Circuit-breaker automatic opening	The ARF must disable the closing until the disappearance of the event/state.
Automatic commands locking	The ARF mustn't issue automatic commands until the disappearance of the event/state causing the locking.
Conditioned automatic opening and ARF locking	The ARF: doesn't control the opening of the circuit-breaker due to the intervention of specific FdPs (programmable, typically 51 and 67.S3), trips the circuit-breaker due to the intervention of specific FdPs (programmable, typically 67.S1; 67S2), doesn't activate its logics and interrupts or cancels the cycle, if already started.
ARF locking	After a trip command from a FdP, the ARF is locked.

12.3 Reclosing cycle reset

The ARF must abort the reclosing cycle if the controlled circuit breaker is opened and a local or remote manual opening command is issued. If an external close command is received during a reclosing cycle (manual or by remote control), the cycle will be completely aborted, starting the TDCM timer, as it is a manual closing.

12.4 Autoreclosing coordination practices

By according to IEEE C37.104, the following autoreclosing coordination practices must be included:

a. Sequence coordination described at par. 5.3.4 of IEEE C37.104, this practice is also called ZSC (Zone Sequence Coordination);

b. Autoreclose blocking described at par. 5.3.6.j of IEEE C37.104, this practice is also called 79SK (Skip Shot).

13 DISTURBANCE RECORDING

The MFP must have a Disturbance Recording function that allows the storage of fault-related events in a circular memory of, at least, 1000s.

The PC-software must be able to display the trends of the measurements over time (indicated in Table 30), the status of the embedded and remote Digital I/O and the internal states of functions and logic inputs/outputs. An example of channels assignment is shown Table 98.

The MFP, must have:

a. at least, 100 digital channels

b. the order of allocation / visualization of the channels will be configurable by the user;

c. the text associated with the digital channel must be intelligible; it is desirable that it can be configurable by the user.

The sampling frequency of the analog and digital quantities as defined in Par. 6.2.2 and 6.2.5 allows the processing of signals up to 2.5 kHz by applying an anti-aliasing filter; a resolution of 1ms is required for the logic channels.

The recording must last until the last triggering signal releases plus configurable (via SW) post-trigger and pre-trigger times. The recording must never exceed the maximum time configured via software.

The total time of the recording is equal to the sum of the:

d. Pre-fault recording (duration configurable via software [0 ÷ 2000 ms]),

e. Recording of the disturbance event (duration configurable via software [0 ÷ 70 s]),

f. Post-trigger recording (duration configurable via software [0 ÷ 2000 ms]).

In any case the recording must last until the last configured trigger has released, which must happen inside the maximum limits set in the configuration.

Records storage: minimum 48 hours with loss of power supply.

All the starts/trips of the FdPs must be configurable as trigger events. The ability to sync the recording with both wired and via IEC 61850 Digital Inputs will it is also be required. It must be possible to start manual recordings from the MFP's display and keypad via s GOOSE message.

The data related to the individual events must be convertible in COMTRADE format according to the IEC 60255-24 standard and downloadable to a PC for offline analysis. The COMTRADE file transfer must be via FTP or IEC 61850, locally or remotely

Table 98 – Example of channels assignment

SIGNAL	Position in the Substation						Signal N.
	MV radial feeder	Section circuit-breaker	Measurement	Auxiliary Services	Capacitor banks	HV delivery line to the customer	
52 State	X	X		X	X	X	1
52 State	X	X		X	X	X	2
89 Busbar 1 State	X	X		X	X	X	3
89 Busbar 1 State	X	X		X	X	X	4
89 Busbar 2 State	X	X		X		X	5
89 Busbar 2 State	X	X		X		X	6

89 Grounding State	X	X		X	X	X	7
89 Grounding State	X	X		X	X	X	8
89 Grounding 2 State	X	X		X		X	9
89 Grounding 2 State	X	X		X		X	10
Busbar grounding disconnector – Closed					X		11
Busbar grounding disconnector – Open					X		12
Auto-reclosing state	X					X	13
Cogenerator state	X						14
Without command	X				X	X	15
Local Command	X				X	X	16
Special Settings	X					X	17
Discharged Springs	X				X	X	18
Anti-Pumping Actuation	X				X	X	19
Do Not Open	X				X	X	20
Do Not Close	X				X	X	21
Missing Busbar 1 (B1) or Capacitor Bank 1 (BAT1)	X				X	X	22
Missing Busbar 2 (B2) or Capacitor Bank 2 (BAT2)	X				X	X	23
Exceeded Cut Amps	X				X	X	24
Thermal Magnetic DC motor protection breaker - F1 – Open	X				X	X	25
Thermal Magnetic motor disconnector - F2 – Open	X				X	X	26
Thermal Magnetic (Cogenerator) capacitor - external command F3E – Open	X				X		27
Thermal Magnetic phase Voltages - F4 – Open	X		X		X	X	28
Thermal Magnetic phase Voltages – zero-sequence voltage F460 – Open	X					X	29
DC Supervision Failure - S13	X		X	X	X	X	30
Busbar 1 disconnector operation failure - intermediate-state filter 2 sec	X	X		X	X	X	31
Busbar 2 disconnector operation failure - intermediate-state filter 2 sec	X	X		X		X	32
(Disturbance) Recording Activated	X		X	X	X	X	33
Instantaneous Phases Start (protection)	X			X	X	X	34
Inverse Time Phase Start (protection)	X			X	X	X	35
Instantaneous Zero-Sequence Start (protection)	X			X	X	X	36
Zero sequence Time Zero-Sequence Start (protection)	X			X	X	X	37
Directional Zero-Sequence - Isolated Neutral Start (protection)	X			X	X	X	38
Sensitive Neutral Start (protection)	X					X	39
Zero-Sequence Alarm – Resistive Earth	X					X	40
Phase Currents Unbalance	X					X	41
Self-Locked Auto–reclosing	X					X	42
Auto–reclosing Cycle In Progress	X					X	43
Auto–reclosing End of Cycle	X					X	44
Auto–reclosing Command	X					X	45
Instantaneous Phases Tripping	X			X	X	X	46
Directional Phases Tripping				X	X	X	47
Inverse Time Phases Tripping	X			X	X	X	48
Instantaneous Zero-Sequence Tripping	X			X	X	X	49
Inverse Time Zero-Sequence Phases Tripping	X			X	X	X	50
Sensitive Neutral Tripping	X						51
Directional Neutral Tripping	X					X	52
Final Tripping (LockOut)	X					X	53
External Trip	X			X	X	X	54
Co-generation Direct Trip command	X						55
Co-generation Remote Block command	X						56
Directional Residual Protection Inhibited	X					X	57
Directional Phase Protection Inhibited						X	58
Switching Condition Failure – Live Line (Voltage Presence)	X						59

CTR Closing Block	X						60
Busbar 1 Low Pressure	X	X	X	X	X	X	61
Busbar 2 Low Pressure	X			X		X	62
Circuit-Breaker Low Pressure	X	X		X	X	X	63
Sensitive Neutral Tripping Permission	X					X	64
Busbar 1 disconnector operation failure - intermediate-state filter 10 sec	X	X	X	X	X	X	65
Busbar 2 disconnector operation failure - intermediate-state filter 10 sec	X			X		X	66
Zero-sequence Thermal Magnetic Closed – F40 and F60	X		X			X	67
Missing (disconnector) DC recharge of failure				X			68
Auxiliary Service Transformer - Overload Alarm				X			69
Auxiliary Service Transformer - Overload Trip				X			70
Fuse Fusing (Opening)				X			71
Current unbalance between neutral points in the capacitor banks - Trip					X		72
Phase Overvoltage Trip					X		73
Phase Undervoltage Trip					X		74
Protection closing block					X		75
Non-connectable					X		76
Phase Overvoltage Start (protection)					X		77
Phase Undervoltage Start (protection)					X		78
Unbalance between neutral points – Start					X		79
Zero Sequence Overvoltage – Alarm			X				80
Zero Sequence Overvoltage – Trip			X				81
Directional Sensitive Neutral – Start	X					X	82
Directional Sensitive Neutral – Trip	X					X	83
Sensitive Neutral – Alarm	X					X	84
Directional Sensitive Neutral – Alarm	X					X	85
Busbar 1 Truck State	X	X		X	X	X	86
Busbar 1 Truck State	X	X		X	X	X	87
Busbar 2 Truck State	X	X		X		X	88
Busbar 2 Truck State	X	X		X		X	89
89 Bypass State	X	X		X	X	X	90
89 Bypass State	X	X		X	X	X	91
Breaker failure Trip							92
Broken conductor Trip							93
Under/Over frequency Trip							94
VTS/CTS supervision							95

14 MFP ADVANCED REQUIREMENTS

The requirements from this chapter must be respected just if expressly requested during the procurement process (par. 16.2).

14.1 Hardware requirements

With reference to par. 6.1.1 clause d, the degrees of protection for the enclosure must be improved to IP 54.

With reference to Table 12 , the current thermal withstand must be improved to 100 In.

14.2 Communication requirements

Inbuilt MODBUS TCP/RTU server must be implemented for enabling straightforward integration into existent SCADA/RTU solutions.

The DNP3 communication profile must be implemented for enabling straightforward integration into existent SCADA/RTU solutions.

14.3 Synchronization requirements

The time synchronization of the MFP must be done also via IRIG B.

14.4 High impedance fault FdP

An additional FdP to detect high impedance fault (HIF) in distribution networks is requested. The proposed approach can successfully distinguish the HIFs from normal operations in power system such as harmonic load switching, capacitors switching, and transformer energization.

In recent years various methods have been presented in order to detect the HIFs. Considering the deviation in different harmonics of current waveform as the main parameter for HIFs detection, several methods based on magnitude, phase angle and also the energy content of even, odd and in-between harmonics are proposed. Wavelet transform is also used as a method to analyze the current waveform in time-frequency domain through which the HIFs can be detected.

So the proposed HIF FdP must be supported by scientific and experimental data, the results must show high accuracy of the proposed method in the detection task.

The final acceptance of the approach is entrusted to ENEL, that can require any additional certificate, self-certificate or testing.

Other GS may add further requirements.

14.5 Parallel Redundancy Interoperability

Parallel Redundancy Protocol (PRP) or High-availability Seamless Redundancy (HSR), both with Precision Time Protocol (PTP) must be adopted to provide seamless recovery in case of single failure of an inter-bridge link or bridge in the network, which are based on the same scheme: parallel transmission of duplicated information. The reference standards are IEEE 1588, IEC 62439-3, IEC 61850-9-1, IEC 61850-9-2 and IEC 61850-9-3.

Because of this requirement, all the Ethernet port (LC or RJ45) that are used for interoperability must be doubled.

Other GS may add further requirements.

15 TESTING AND CERTIFICATIONS

All the requirements from this chapter must be respected. ENEL has the right to ask for a prototype for any kind of verification testing. These tests must be performed in the provider factory or third party laboratories (by according to ENEL or relevant standards provision), with no cost participation by ENEL.

The MFP will be subjected to an ENEL Technical Conformity Assessment (TCA) process, by according to GSCG002, that is intended to verify if the supplied device meets regulatory standards and specifications.

15.1 Overview Technical Conformity Assessment (TCA) Process

The information of this paragraph are only indicative and may change by according with ENEL TCA management; final TCA organization will be discussed during the TCA kick off meeting.

15.1.1 TCA documents

The ENEL technical organization unit in charge of the Technical Conformity Assessment of the MFP will supervise the technical documentation and the execution of the tests required to receive the "Statement of Conformity", according to GSCG002 prescriptions.

All the technical documentation required during that process shall be in English or in the local language of ENEL technical organization unit in charge of the TCA.

The TCA documents that shall be delivered include:

a. Type A documentation (Not confidential documents used for product manufacturing and management from which it is possible to verify the product conformity to all technical specification requirements, directly or indirectly).

b. Type B documentation (Confidential documents used for product manufacturing and management where all product project details are described, in order to uniquely identify the product object of the TCA). This type of documentation must be delivered **only to the ENEL technical organization unit in charge of the TCA**

c. TCA dossier (Set of final documents delivered by the Supplier for the TCA)

d. The supplier shall provide the TCA Dossier on digital support.

15.1.2 Quality

During the TCA, the supplier shall provide the technical documentation listed in ENEL Quality Specification for Electronic Assemblies.

15.1.3 Safety warnings on Plate

The safety warnings required in the plate of the MFP and its components must be written in the local language of the device destination Countries.

15.1.4 Tests required to complete the TCA

This process consists of the following tests cases:

a. static accuracy/precision tests,

b. real-world tests cases (in COMTRADE format, supplied by ENEL)

c. approximately 300 laboratory tests cases.

The manufacturer must have a valid and product specific homologation before he may supply devices to ENEL. In compliance with this technical specification, the manufacturer must satisfactorily pass, within a maximum period of 6 months after contract award, all the tests described in the following sections.

Once these tests have been successfully completed, an approved manufacturer's MFP will be subject to ad-hoc reception tests.

In addition, ENEL reserves the right to request the repetition of the type tests at any time to ensure that the devices continue to meet the standards achieved by the initial testing and certification programs at the time the contact was awarded.

Type tests will be carried out in Official Laboratories or Laboratories recognized by ENEL, or in the workshops of the manufacturer. ENEL reserves the right to attend any or all of these tests and must be kept informed of the manufacturer's testing programs, schedules and result.

The manufacturer will bear the cost for type tests and for pilot installation tests.

15.1.5 Type test list

a. Visual examination and control of geometric characteristics,
b. Verification of all functions,
c. Insulation tests,
d. Electromagnetic compatibility tests,
e. Mechanical compatibility tests,
f. Climate compatibility tests,
g. Overload test of current circuits and voltage circuits,
h. Determination of the accuracy class of the measurement relays,
i. Measure of the Reset ratio,
j. Measure of the Start, Operate, Reset time (repetitive error),
k. Measurement of consumption,
l. Functional tests with different values of influence quantities,
m. Influence of asymmetric and harmonic component on short circuits,
n. Influence of frequency on measurements and operation,
o. Testing of the auxiliary control relays (making and breaking capacity) and signaling,
p. Power supply interruptions,
q. Influence of auxiliary voltage value,
r. Final verification of the MFP operation.

The supplier must retain all the documentation proving the successful results of the type tests and all data must be made available to ENEL in real time.

At ENEL's discretion these tests may be completely or partially repeated during the lifetime of the contract as continuing evidence of type conformity.

15.1.6 Acceptance tests

The acceptance tests are those indicated in Par. 15.1.5. clause a, b, c, j and r.

The acceptance tests must be carried out using specifically designed and automated test equipment (SCA). Each device must be accompanied by a report stating that all SCA tests have been concluded successfully.

15.1.7 Visual inspections

It is mandatory to verify the absence of visible manufacturing defects, the highest build-quality and precision of manufacture, the compliance of the enclosure dimensions with those indicated in the present specification, as well as the required degree of IP protection.

15.1.8 Type test levels

The test level for each requested environmental compatibility test and the relevant standard, where applicable, is shown in. Table 99.

Regardless of the verified function (protection, measurement, data communication, etc.), the criteria for acceptance for all the tests listed below is "Normal performance within the specification limits, A+B" (ref. IEC 60255-26:2014, Tab. 23).

Table 99 – Tests Levels

Type	Description		Test Level/Note	Standard
Insulation and EMC	Impulse withstand voltage		Overvoltage category IV	IEC 60664-1
	Dielectric strength		Test Voltage = 2 kV for the circuits in a.c.	IEC 60255-27
	Insulation resistance		≥100 MΩ a 500 V d.c.	IEC 60255-27
	Electrostatic discharges		Contact discharge level 3 Air discharge level 3	IEC 61000-4-2 IEC 60255-26
	Ring wave		Test level 3	IEC 61000-4-12
	Damped oscillatory wave		Test level 3	IEC 61000-4-18 IEC 60255-26
	Electrical fast transient/burst		Test level 4	IEC 61000-4-4 IEC 60255-26
	Voltage surges 1.2/50ms – Current surges 8/20ms		Test level 3	IEC 61000-4-5 IEC 61000-4-5/A1
	Power frequency Magnetic field		Test level 5	IEC 61000-4-8
	Damped oscillatory magnetic field		Test level 5	IEC 61000-4-10
	Radiated, radio-frequency, electromagnetic field		Test level 3	IEC 61000-4-3 IEC 60255-26
	Radiated, radio-frequency, electromagnetic field from digital radio telephones		Test level 3	
	Short interruptions on d.c. input power port		level 0% t = 0,05 s	IEC 61000-4-29
	Voltage dips on d.c. input power port		level 50% t = 0,1 s	
	Voltage variations on d.c. input power port		Un ± 20%; t = 10 s	
	Power frequency voltage		Test level 3	IEC 61000-4-16 IEC 60255-26
	Conducted disturbances in the frequency range 0 Hz to 150 kHz		Test level 3	
	Conducted disturbances, induced by radio-frequency fields		Test level 3	IEC 61000-4-6 IEC 60255-26
Environment	Non powered equipment	Dry heat	(+70 ± 2)°C; duration 16 hour	IEC 60068-2-2
		Damp heat	(40±2)°C; (93±3)% RH; duration 4 days	IEC 60068-2-78

		Cold	(-25 ± 3)°C; duration 16 hour	IEC 60068-2-1
		Change of temperature	TA = -25°C; TB =70°C; duration 3 hour + 3 hour	IEC 60068-2-14
	Powered equipment	Dry heat	(+70 ± 2)°C; duration 16 h	IEC 60068-2-2
		Damp heat	(40±2)°C; (93±3)% RH; duration 4 days	IEC 60068-2-78
		Cold	(-25 ± 3)°C; duration 16 hour	IEC 60068-2-1
		Change of temperature	TA = -25°C; TB =70°C; duration 3 hour + 3 hour	IEC 60068-2-14
Mechanical	Vibration immunity		Inf. limit 10 Hz Sup.limit 500 Hz Acceleration 10 m/s^2 Displacement amplitude 0,075 mm	IEC 60068-2-6
	Broadband random Vibrations			IEC 60068-2-64

15.2 Pilot installation tests

In a substation chosen by ENEL will be installed one MFP granted by the manufacturer in order to evaluate its behavior and stability in a real environment.

The manufacturer will configure the device and will collaborate in the commissioning with all the necessary modifications to enable all the required functionalities and completely integrate the MFP in the substation.

15.3 Individual tests

These tests will consist of the visual checking of:

a. Terminal blocks for the power supply, Digital Inputs and Outputs, Current and Voltage Inputs, communication ports/channels, etc.. For these tests it will be necessary to provide:
    a) Photo(s) of the front panel of the device,
    b) Photo(s) of the rear of the device.

b. Identification label with the characteristics of the device (including complete model and firmware version).

The device will also be powered on to verify (via its keyboard/display) that the information about its identifying characteristics match those registered in the homologation process.

15.4 Certifications and self-certifications

About the compliance of all the requirements/standards recalled in this GS, a certificate or selfcertificate must be provided.

Regional laws or standards may requires additional certifications or self-certifications.

Certifications and self-certifications must be made according to the relevant standards or laws (including the template format).

16 MISCELLANEOUS

This chapter include further requirements, recommendations and additional information.

16.1 Required documentation

The following documents (in pdf format) must be provided:

a. MFP data sheet with snapshots;
b. installation, operation and maintenance manuals, with instructions on the installation and interfacing procedures;
c. Protocol Implementation Conformance Statement (PICS)
d. Protocol Implementation extra Information for Testing (PIXIT)
e. Tissues Conformance Statement (TICS)
f. Model Implementation Conformance Statement (MICS)
g. administrator’s manual, for proper integration of MFP into communication and IT networks (this document should describe any network service the MFP is supplying);
h. list of pre-installation checks to ensure that the components have been delivered correctly;
i. quick installation and set-up guide;
j. installation and one-wire diagrams (also in DWG/DXF formats);
k. all software need to MFP operation;
l. parts list;
m. required but not included parts list;
n. recommended Tool List;
o. electrical schematics;
p. mechanical drawings;
q. spare parts list;
r. maintenance procedures;
s. troubleshooting guide;
t. component specification literature.

This documents must be made according to IEC 61010-1 and they must be approved by ENEL.

A copy of these documentation must be accessible by the MFP HMI.

16.2 Clarification during procurement process

By summarizing, during the procurement process the following clarification will be provided to the supplier:

a. Choice about enclosure (par. 6.1.1);
b. Installation site information (par. 6.1.4);
c. Non modular design acceptance (par. 6.2);
d. Auxiliary Power Supply (par. 6.2.1);
e. Information about operating system homologated in ENEL (par. 7.3);
f. Advanced requirement to include (chap. 14);

g. Language for embedded sw and documentations;

h. Details about unique serial identifier, serial code and other labeling.

16.3 Procurement management

The information of this paragraph are only indicative and may change by according with ENEL procurement management; final procurement approach will be issued by entrusted ENEL units.

Within 30 days of receiving the present specification, the manufacturer must send the following documentation, in English, along with the technical proposal:

a. Dimensions and weight of the MFP,

b. General description of functions, operational characteristics, functional schema, wiring diagrams, power consumption requirements, errors limit, etc. The description must also include the algorithms used for the treating and filtering signals and the number of samples per cycle,

c. Photos or detailed drawings of the MFP
   - side view
   - rear view
   - LEDS
   - MP connector
   - MV connector
   - MA connector
   - MI connector
   - MO connector
   - Communication ports

d. Lists of references,

e. Exceptions to this specification,

f. Instructions for the installation, adjustment and commissioning of the MFP,

g. Examples of adjustment and configuration,

h. Instructions for checking and maintenance.

If the manufacturer fails to provide any or all of the above information within 30 days of receipt of this specification, he will be disqualified as supplier, for ENEL, of the product standardized in this Technical Specification.

16.4 Receipt of material

The information of this paragraph are only indicative and may change by according with ENEL product management; final procurement approach will be issued by entrusted ENEL units.

16.4.1 Reception tests

Part of the process of accepting delivery of a manufacturer's devices will include the proof of having successfully passed previously performed acceptance tests (Par 15.1.6).

Then, the reception tests will be carried out in Official Laboratories or Laboratories accredited by ENEL, or in the workshops of the manufacturer. ENEL reserves the right to attend any or all of these tests and must be kept informed of the manufacturer's testing programs, schedules and results. If the assistance of an ENEL representative is not available, the provisional reception procedure will be conducted when tests protocols are received.

The reception will be deemed as completed once the reception tests have been carried out and the material has been delivered with the associated tests protocols. The tests are the ones mentioned in Par. 15.3 and will be performed before any order is delivered; the associated testing protocols will be presented to ENEL for approval. The results obtained in these individual tests must be indicated in a report; every device must be accompanied by this report.

In the event the documentation has undergone modifications with reference to the actual devices delivered, the manufacturer must provide the updated documentation before the reception procedure will be deemed to have been completed.

16.4.2 Warranty

The manufacturer will commit to providing a guarantee of the IEDs for a minimum period of 24 months, which will commence immediately following a successful reception; final procurement approach will be issued by entrusted ENEL units.

The guarantee will be legally binding for any device/component failures and/or defects that occur within the guarantee period: accordingly, the devices and/or components will be replaced. Further, the manufacturer will undertake to continue, free of charge, the software and firmware development and provide the updates to ENEL for the lifetime of the devices.

If during the contract term the manufacturer fails to address in a prompt and timely manner any functional anomalies or defects in the device behavior or manufacture (hardware or firmware), ENEL reserves the right to block the necessary positions on the contract, staged payments and/or alter the payment schedules as necessary until the anomalies have been resolved to the complete satisfaction of ENEL.