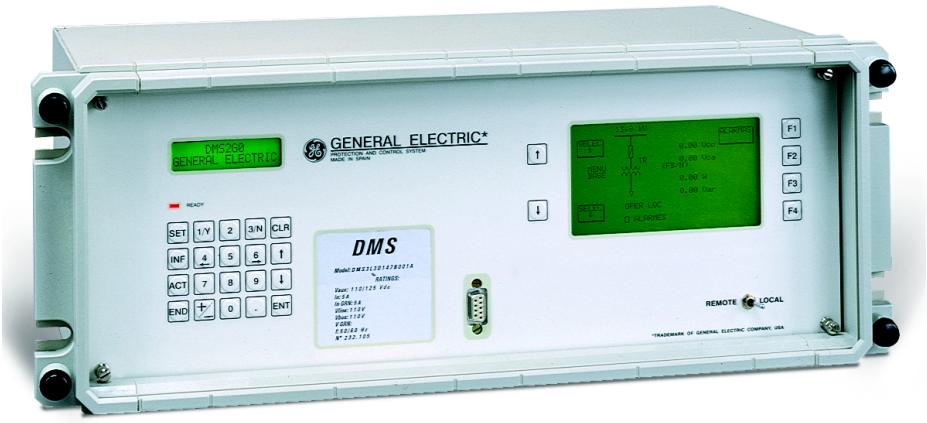
GE Power Management



Integrated Protection & Control System

DDS

Instructions

GEK 106164A

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INTRODUCTION

The DDS protection and control system is a powerful tool for substation's automation. This system includes Level 1 basic field units (protection relays, protection and control units or only control units) and Level 2 substation central control units, composed of computers and software for monitoring and control functions.

The main characteristic of the DDS system is his flexibility and versatility allowing the implementation of many different configurations in hardware as well as in software. This characteristic makes difficult to include and explain clearly in an instruction book all the different configurations that could be present in a particular system.

This instruction manual, together with the instruction books of Level 1 software (GE-LOCAL communication software, GE-INTRO configuration software and GE-OSC oscillography software) is intended to give a general description of the DDS systems' standard functions.
These four instruction books together give a complete description of the DDS system. However, this information should be completed by the specific technical documentation provided to the user with each DDS system.

The first section of this instruction book includes a general description of the system to aid new users in getting a quick knowledge of the system's architecture and capabilities. This chapter by itself is enough to get a general view of the system possibilities.

1. GENERAL DESCRIPTION

The DDS system integrates protection and control functions for distribution and subtransmission substations with the following elements:

- Basic field units or Level 1: Devices that perform protection and control functions, metering, tariffication and local operations or maneuvers.
- Communication link between Level 1 and Level 2.
- Central control of the substation or Level 2: the substation central controller collects the information generated by the basic field units and transmits it to the central dispatching. It performs also the protection and control functions that involve more than one basic field unit, and serves as an interface element with remote control centers.

The following diagram shows the functional architecture described above:

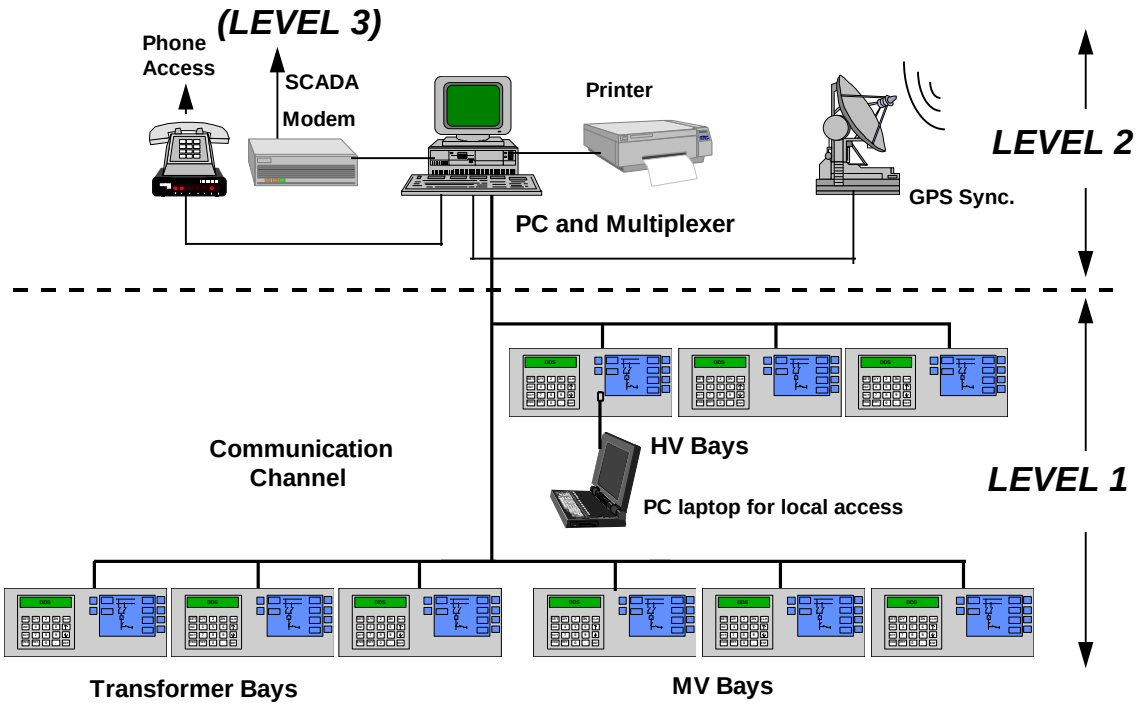


***Figure 1.1**. DDS System Architecture*

Level 1 units can be used independently as protection or/and control devices for feeders, transformers, etc., with no need to integrate them in a system.

The DDS system has the following features:

- Protection functions.
- Setting of protection functions, measurements reading, record of events and oscillography data generated in Level 1 units.
- Open and close operations of switching equipment.
- Real-time acquisition of switching equipment status.
- Realization of sequential control functions (position interlocks).
- Realization of synchronism check functions.
- Load shedding programs.
- Electrical reset of trip and blocking relays.
- Real-time metering data acquisition without the use of transducers.
- Real-time representation of the substation status through the single line diagrams.
- Configuration and display of substation and individual bay's single line diagrams, with indication of the status of different system elements.
- Self-tests, system and hardware status alarms.
- Communication and transference of data and functions to the Level 2 and the SCADA system.

That allows only one DDS system to replace a great number of conventional devices:

- Protection relays.
- Transducers and meters.
- Event recorders.
- Alarm panels.
- Remote units for data acquisition.
- Local and remote mimic panels and related equipment.
- Synchronizing equipment panels and additional related devices.

1.2. Level 1 Modules

1.2.1. General Description

The Level 1 units are the basic elements of the integrated system. These units can be either GE Power Control protection relays compatible with DDS platform (as SMOR_B, DBF, DFF or DTP), or DMS protection and control systems, specifically designed to operate as DDS system distributed field units. These DMS modules include all the required functionality to perform protection, control, measuring and monitoring functions for a substation position or bay (medium or low voltage feeder, transformer, bus bar, coupler, auxiliary services, etc.).

This section will describe only the DMS protection and control modules, bearing in mind that the standard protection devices are well known. Please, refer to other instruction books to get detailed information of GE Power Management protection relays.

In a substation with DMS protection and control modules, each bay or position must include one DMS module, as shown in the following diagram:

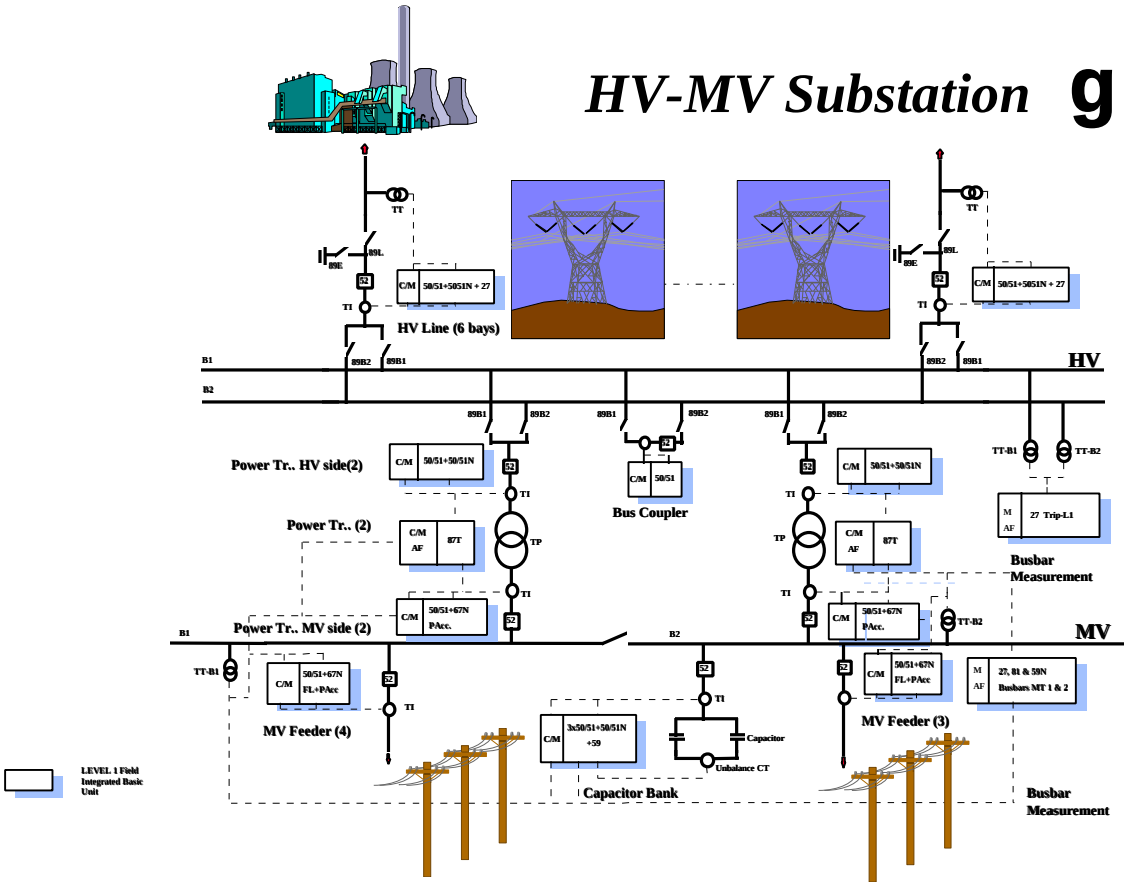


Figure 1.2. *Example of HV/MV substation configuration*

Each DMS module includes several boards for protection and control functions (for analog and digital data acquisition, output boards, etc.). The protection and control boards are controlled by different CPUs.

For each bay, the protection sub-module of the DMS unit receives analog inputs through current and voltage transformers, and the digital signals of the bay through its digital inputs. It performs the protection algorithms and functions included in that unit, and provides the required trip and signaling contacts. The protection functions included in a particular model depend on the application of that unit.

The control sub-module of the DMS unit receives analog inputs for metering and monitoring as well as digital inputs. It performs the programmed control algorithms and provides the required digital outputs to operate switching devices, signaling or

interlocking outputs. The analog inputs of the control module can come through the protection transformers or through separate voltage and current transformers or through transducers.

Besides this main functions, both protection and control sub-modules perform monitoring and record functions. The recorded information can be accessed in local or remote mode through the communication sub-module.

The following diagram shows the connection of a DMS module to a typical bay:

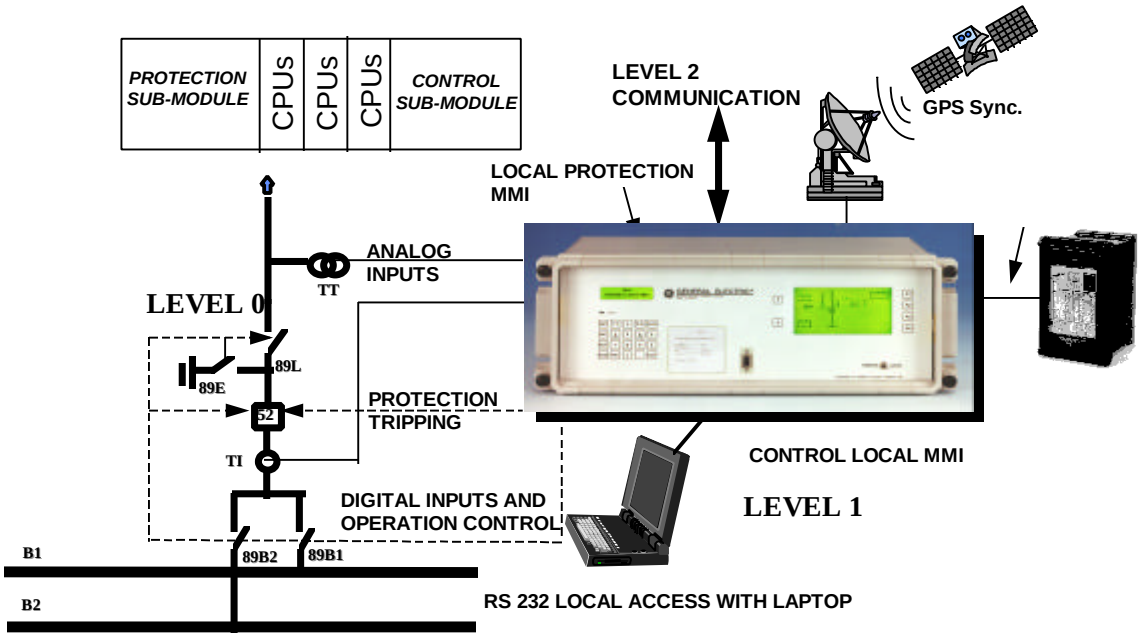


Figure 1.3. *Connection of a DMS module to a typical bay*

1.2.2.- Hardware Description

The Level 1 basic field units are comprised of modular protection and control units in standard 19" racks. There is a common hardware platform for all the DMS units. The different functionality of each module comes from the application software.

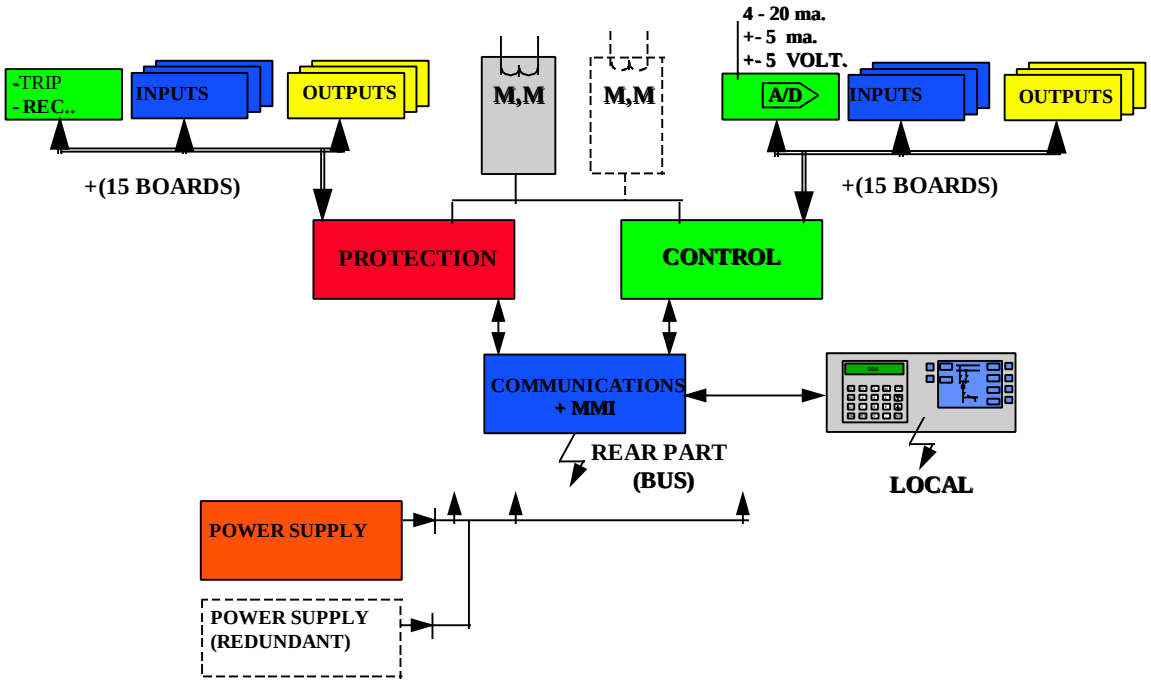


Figure 1.4. *Hardware architecture*

This architecture, as shown above, is modular and is based on the well-known architecture of industrial PLCs. There are several independent hardware modules; each one with a different functionality (data acquisition, outputs, power supply, etc.), connected via a front bus.

The complete DMS unit includes two different sub-modules; one for protection functions and the other for control functions (DMS units with only one of the sub-modules are also available). The hardware boards for both the protection and control sub-modules are identical, but they are controlled by independent CPUs. For each sub-module, the number of boards can be defined up to a maximum given by three different limiting sources: a logic limit given by the addressing capability (a maximum of 15 identical boards in the same sub-module), the outputs and inputs management limitation of the firmware and the physical limitation due to the case size (19" rack).

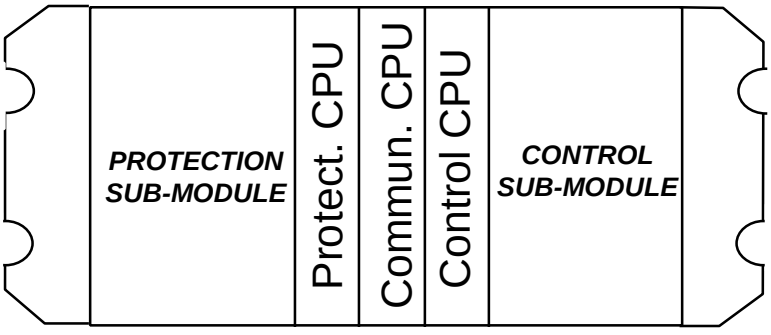


Figure 1.5*. DMS unit sub-modules disposition (front view)*

Each board has all the elements needed to perform its complete functionality, including connectors for front and rear connection. The rear male connector is inserted in the rear female connector of the case that is wired to the external devices of the bay. This connection is draw out type and has short circuit capabilities for current inputs, so that the boards can be easily removed allowing easy maintenance.

The hardware modules available to configure the hardware of the DMS units are the following:

1. **Power Supply**: Including one alarm relay (ready), four tripping duty relays (used as main protection trip and reclose output contacts) and two supervision units for monitoring of trip and/or closing circuits of the breaker.

   These breaker supervision circuits monitor both the battery voltage level and the continuity of the trip and/or closing circuits, applying current through those circuits and checking that it flows properly.

   As an option, a second redundant power supply can be included in the equipment. This redundant power supply has neither contacts nor supervision circuits available. If the redundant power supply is included, both the main and the redundant power supplies are ready to feed the complete unit. However, during normal operation, both are supplying power to the unit, but if one of the power supplies fails, the other provides all the power to the equipment.

2. **Magnetic module**: With a capacity of 8 current and/or voltage analog channels. The standard DMS units include a common magnetic module for protection and control. As an option, and bearing in mind the limitation given by the case size, a second magnetic module can be provided for control functions. This dedicated magnetic module could be connected to external metering transformers and could be used to provide more accurate measurements of the bay.

3. **Standard digital inputs board**: With a capacity of 21 digital inputs grouped in three sets of 7 inputs with the same common terminal. This board is available for protection and control modules.

4. **Analog inputs board**: With a capacity to read mA inputs from measurement converters.

5. **Standard digital outputs board**: With 12 output relays with trip or signaling characteristic n.c. This board is available for protection and control modules.

6. **Digital input/outputs board**: With 7 digital inputs (selectable as one group of 7 inputs with one common terminal or two groups of 3 contacts with separate common terminals) and 8 digital outputs.

7. **Protection CPU board**: Based on 16-bit microprocessor.

8. **Control CPU board**: Based on 16-bit microprocessor.

The CPU boards for protection and control functions use the same hardware configuration. The different functions (protection or control) and application is given by the firmware loaded in the EPROM memories.

9. **Communication CPU board**: Based on 16-bit microprocessor, with future capability to support different communication protocols. The communication is available via RS-232, plastic and glass fiber optics and RS-485.

   All the modules described above are draw out type and are connected via an internal front bus board. This front bus must be removed before removing any other board. The frontal MMI covers all the boards and is connected to the communication CPU board through a flat cable.

10. **MMI module**: This module includes both the protection and control local MMI interfaces. The protection MMI incorporates keyboard (with 20 keys) and alphanumeric LCD display with two rows of 16 characters each. The control MMI incorporates functional keyboard (6 keys) and graphic LCD display.

The fact that protection, control and communication functions are controlled by three independent microprocessors (with 3 different CPU boards) connected via an internal high speed serial communications protocol is provided in this hardware architecture and includes important advantages:

- Improved processing and functional capacity by increasing the global computation ability of the unit.

- More reliability: If one of the functions is lost due to a hardware failure, the rest of the functions can continue working correctly.

- This configuration allows easier modification and upgrading. Any individual module can be easily removed and changed to include technical improvements, allowing longer life of the product with lower costs.

This last advantage is especially important referring to the communication CPU board. In this area, the tendency is to increase the capability of the communication systems (improved speed and horizontal communications "peer to peer"). The modular concept of the DDS communication board allows an easy and low cost future upgrading to include new communication protocols or improved features.

1.2.3.- Available DDS Relays

As noted before, there are two different, but compatible, level 1 equipment types that can be used to perform a DDS integrated system: conventional devices (individual relays compatible with DDS platform) with only protection functions and devices with protection and control or only control functions (DMS units).

1.2.3.1.- DDS Compatible Protection Relays

The following table shows the relay models of GE Power Management compatible with the DDS system:

Table 1.1. *DDS Compatible Protection Relays*

Equipment	Description	Protection Functions
SMOR	Protection system for distribution feeders	3x50/51(67)+50/51N(67N), 46,27, 59, 59NH, 59NL, 81U, 81O, 79
DTP	Transformer differential protection	87T
DBF	Breaker failure protection	50(62) BF
DFF	Frequency protection	8 x 81U or df/dt, 27, 59
MOV	Voltage protection	27/59 for breaker-and-a-half configurations

Please, refer to the instruction books of the individual protections to know their technical characteristics, external connections or metering and monitoring functions.

All these devices are fully compatible with the DDS system and can be used as individual relays. They use the GE-NESIS software of the DDS for configuration and communication.

1.2.3.2.- DMS Protection and Control Modules

Besides the protection devices described above, the DDS system includes the DMS protection and/or control units. There are DMS modules defined for the following main substation applications:

- High Voltage Line Unit.
- High Voltage Bus Bar coupler and metering unit.
- Power Transformer High Voltage Side Unit.
- Power Transformer Unit.
- Power Transformer Low Voltage Side Unit.
- Medium Voltage Line Unit.
- MV Capacitor Bank Unit.
- Medium Voltage Bus Bar coupler and metering unit.
- Auxiliary Services Unit.

For each application listed above, the user can define different models combining protection, control and metering functions, as well as the number of input and output contacts. The table shown in the following section is the model selection guide to define the available models.

This table shows all the possible options; however, all these options are not available as standard models. In order to define them, the section "DDS standard bays" shows the standard models and a reduced model selection table for each main application.

TABLE 1.2. DMS MODEL SELECTION GUIDE

POSITIO	DMS	-	-	-	-	-	-	-	-	-	-	-	A	-	DESCRIPTION
															Functionality:
4		2													Control
		3													Protection and Control
															Application:
5			L												Line (only model 3)
			S												Auxiliary Serv. (only model 2)
															Application Options
6				-											See Table [0]
															Ranges
7					-										Depend on the model
															Communications
8						0									RS232
						1									1mm Plastic F.O.
						2									62.5/125 Glass F.O.
															Protection Inputs and Outputs
9							-								Depend on the model
															Control Inputs and Outputs
10								-							Depend on the model
															Auxiliary Voltage
															Single Power Supply
									A						48 Vdc
11									H						110-250 Vdc.
															Redundant Power Supply (Only Model 3)
									J						48 Vdc.
									M						110-250 Vdc.
															Power Measurement
12, 13, 14										0	0	0			By pulse count
										1	0	0			Direct measurement (1% error in V, I, and 2% in P, Q, Power)
15													A		**Revision Level**
															Language
16														-	Spanish
														I	English

The following table shows the different options for each DMS application:

TABLE 0. APPLICATION OPTIONS FOR DMS MODULES					
	FEEDERS				Auxiliary Services
OPTIONS	**1**	**3**	**4**	**7**	**2**
PROTECTION					
50/51	X	X	X	X	
50/51 N	X	X		X	
50/51 G					
50/51 C					
46	X		X		
67	X	X	X		
67 N	X	X			
67 Ungrounded			X		
21					
27		X		X	
59F				X	
59N					
64					
81		X		X	
Recloser	X	X	X		
CONTROL					
Switchgear	X	X	X	X	X
Interlocks	X	X	X	X	X
25	X				
Capac. Bank					
Tap Changer					
MEASUREMENT					
Phase Current	X	X	X	X	X
Ground Current	X	X	X	X	X
2nd Ground Current					
Transf. Case					
Phase Voltage	X	X	X	X	X
Ground Voltage					
Bus Voltage	X	X			
2^{nd} Bus Voltage					
Negative Sequence	X		X		
Power	X	X	X	X	X
Cos φ	X	X	X	X	X
Frequency	X	X	X	X	
MONITORING					
Circuit Breaker	X	X	X	X	X
Discon. Switch	X	X	X	X	X
Events	X	X	X	X	X
Breaker	X	X	X	X	
Trip Circ.	X	X	X	X	
ANALYSIS					
Logs	X	X	X	X	X
Oscillography	X	X	X	X	

OTHERS					
Multiple Tables	X	X	X	X	X
Cold Load	X	X	X	X	
Time	X	X	X	X	X

The previous table shows the complete list of protection and control functions for each application included in the selected model. For example, for an application option DMS 3L1 (protection and control for distribution feeders), the functions included in that unit are:

- Protection: 3x50/51, 50/51N, 67, 67N, 46, Recloser.

- Control: Switchgear element operation.
Capability to program interlock functions.
Synchronism Check (25).

- Measurements: Ia, Ib, Ic, In, I_2, Vab, Vbc, Vca, Vbus, P, Q, and cos φ.

- Monitoring: Breakers and switches status.
Protection and control events.
Breaker maintenance.
Trip circuit supervision.

- Analysis: Log of events.
Oscillography records.
Multiple setting tables.
Cold load pickup function.
Time synchronization.
Configurable inputs and outputs.

The external connections drawing is different for every DDS module based on the different number of I/O, magnetic and power supply modules selected for both the protection and control sub-modules. A sample DMS module external connection drawing is included as reference.

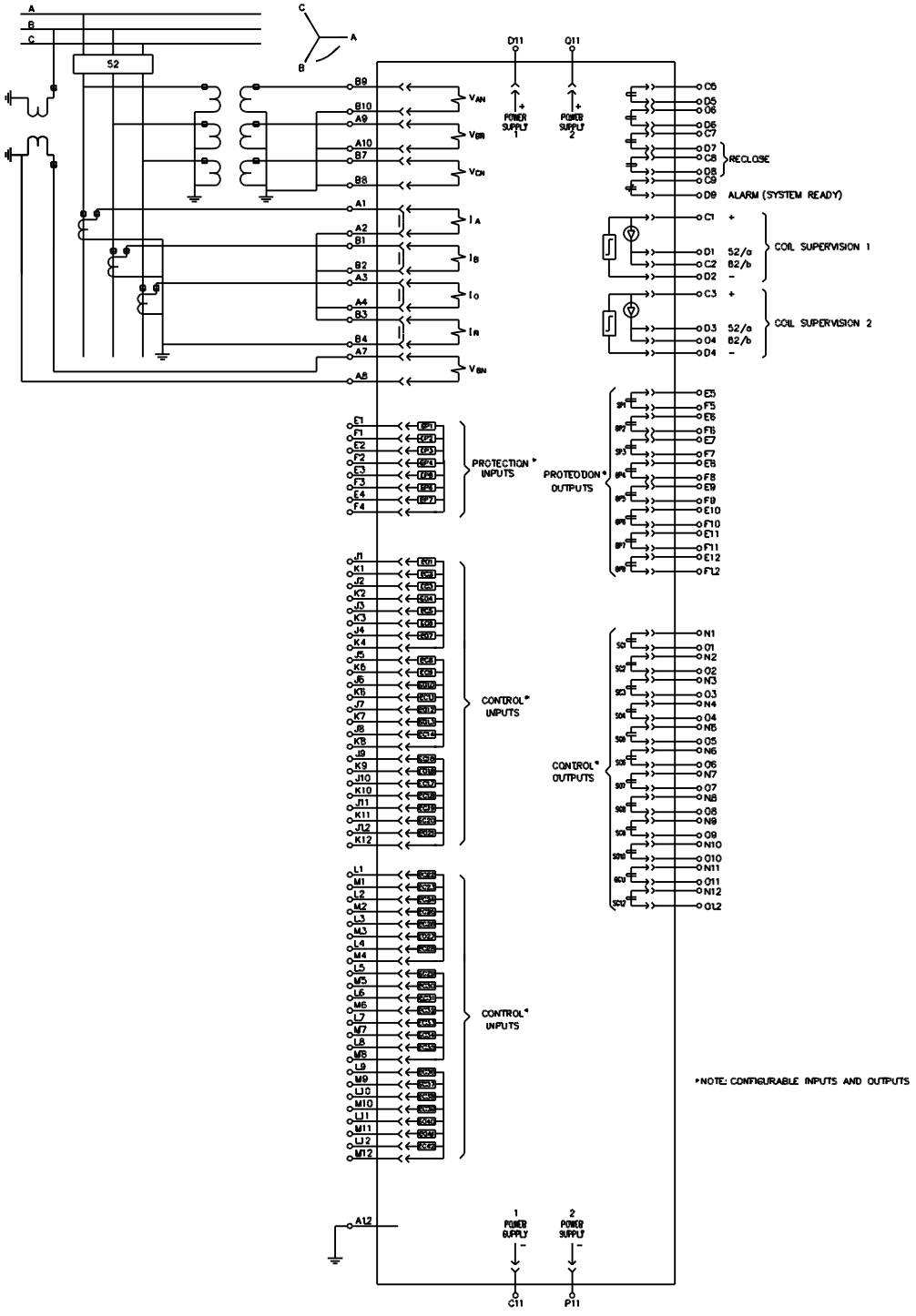


Figure 1.6. Sample External Connection Diagram for a DMS Module

1.3.- Functions Included in the DMS Modules

This section shows a description of the characteristics of the different functions included in the DMS modules. To see what functions are included in one particular DMS unit, please refer to the Model Selection Table.

1.3.1.- Protection Functions

Overcurrent Functions 51, 50, 51N, 50N.

The following overcurrent functions are provided: Time and instantaneous overcurrent for phase (51P, 50P) and ground (51N, 50N) with only one instantaneous level.

The timed overcurrent units can be separately selected to follow *Inverse, Very Inverse or Extremely Inverse* curves or *Definite Time.*

All these inverse time curves are defined by the following equation:

$$t = TD \left| \frac{K}{\left(M^{\alpha} - 1 \right)} \right|$$

where t = time in seconds
TD = Time Dial of the curve (0.05 for the lower curve of the family and 1 for the upper curve)
M = Times the pickup current level set for the overcurrent unit.
K, α = These coefficients identify the selected curve. Their values for the different inverse time curves are shown in the following table:

Table 1.4. Inverse Curve's constants

Curve	Characteristic	K	a
3	Inverse	0.13	0.02
2	Very Inverse	16	1
1	Extremely Inverse	96	2

Directional Functions 67, 67N.

The DMS modules provide the capability to supervise the overcurrent functions with directional units. The directional supervision can be adjusted independently for each of the overcurrent units, so that each unit can become directional if desired.

The phase and ground directional units are both polarized with voltage. For phase directional units, the polarization voltage is the result of the composition of the healthy phase voltages; while the ground directional unit is polarized by zero sequence voltage. The characteristic angle of the directional unit can be independently set for the phase and ground units. The setting range for this angle is from -90º to +90º. To protect against loss of polarization voltage, the system includes adjustable operation logic that allows to select permanent blocking of permission of the directional units if polarization is lost.

Negative Sequence Overcurrent 46

This function can be used in feeders or lines to limit the load unbalance or to detect extreme fault conditions as the breaking of a cable without any contact with ground.

This unit measures the negative sequence component of the line current, which is directly related with the unbalance.

This function also can be used in generator protection systems to avoid rotor heating due to the presence of negative sequence currents.

Voltage Functions 59/27/59N/64

The phase overvoltage (59) and undervoltage (27) functions are three-phase units, that is, the measurement is made in phases A, B and C separately and the unit operates when an overvoltage or undervoltage condition (depending on the unit) is detected in any of the three phases. The setting of both the overvoltage and undervoltage units is referred to phase-phase voltage values, calculated from the phase-to-ground voltages applied to the DMS. The undervoltage unit is supervised by the breaker status, in such a way that the unit cannot be activated when the breaker is opened.

There are two different ground overvoltage units: 59N and 64. For 59N function, the operating voltage is calculated as the sum of the three phase voltages. For 64 function, the operating voltage must be provided through an additional independent voltage input. This function responds only to the fundamental frequency at the neutral since the voltage input is filtered and the harmonics eliminated.

Frequency Functions 81U/81O

The frequency for underfrequency and overfrequency units in the DMS system is always measured over a single phase voltage (phase B).

This function provides one step of under and one step of overfrequency protection, each with an adjustable time delay. The time delay is Definite Time type.

All frequency functions are supervised by an adjustable positive sequence voltage level. This undervoltage cut off level will block the frequency functions while the voltage is under the adjusted level.

1.3.2.- Metering Functions

Up to 32 analog measurements are available in any DMS module. The measurements displayed are fixed for each standard model (see options table in section "DMS MODEL SELECTION GUIDE").

For example, this measurement could be:

- Three phase and ground currents: Ia, Ib, Ic, In.
- Negative sequence current: I2.
- Phase - phase voltages: Vab, Vbc, Vca.
- Active and reactive power: kw and kvar.
- Power factor.
- Frequency.
- etc.

These measurements can be accessed directly on the two line liquid crystal display (LCD) on the front of the equipment, the graphic LCD display (if this option is requested), or via the GE-LOCAL communication software.

The source of the measured values can be different:

1. From current and voltage transformers of the magnetic module: The DMS unit can have only one magnetic module for protection and control modules, or one magnetic module for protection functions and a different one for control and metering functions. This second dedicated module could be connected to external metering transformers in order to get better accuracy in the measurements.

2. A second source of the measured quantities is the analog measurements from external transducers or converters. For that purpose, analog input boards are provided (as an option) in the DMS units. Each analog input board has four independent inputs which range is programmable by means of internal hardware jumpers. The analog available input ranges are: +/-2.5 mA, 0-1mA, 0-5mA, 4-20mA, or +/-10V.

3. Another input source available in the DMS units for metering are the pulse inputs, for pulse counting of energy, etc. For that purpose, some inputs can be configured as pulse inputs to receive signals from external counters with pulse outputs.

Besides the measurements shown above, the DMS modules can include a demand register, as well as current maximeter functions. For the demand register, the maximum and average RMS current is calculated over a selectable period of 15, 30 or

60 minutes corresponding to the last 24, 48 o 96 hours respectively. The current maximeter registers the maximum value for current for periods that are the same as those selected for the demand register.

For example, a demand register with a setting of demand period of 15 minutes would be:

Demand File.
Position: ABCDEF.
03-10-1996 17:57:46

Table 1.5. Demand File

Date	Time	Ia	Ib	Ic	Ia average	Ib average	Ic average
03/10	12:30	0.19	0.21	0.20	0.19	0.21	0.19
03/10	12:45	0.50	0.51	0.49	0.27	0.27	0.26
03/10	13:00	0.49	0.50	0.50	0.30	0.31	0.31
03/10	13:15	0.30	0.31	0.30	0.29	0.29	0.29
03/10	13:30	0.30	0.30	0.30	0.29	0.29	0.28
03/10	13:45	0.30	0.30	0.30	0.29	0.29	0.29
03/10	14:00	0.30	0.31	0.30	0.29	0.29	0.29
0310	14:15	0.30	0.31	0.30	0.29	0.29	0.29
03/10	14:30	0.40	0.40	0.39	0.29	0.29	0.28
03/10	14:45	0.20	0.22	0.20	0.19	0.20	0.19
03/10	15:00	0.20	0.21	0.20	0.18	0.19	0.16
03/10	15:15	0.29	0.30	0.29	0.21	0.21	0.20
03/10	15:30	0.30	0.30	0.30	0.27	0.28	0.27
03/10	15:45	0.21	0.22	0.20	0.19	0.21	0.19
03/10	16:00	0.25	0.26	0.23	0.18	0.19	0.17
03/10	16:15	0.22	0.22	0.21	0.21	0.20	0.20
03/10	16:30	0.22	0.22	0.21	0.20	0.21	0.20
03/10	16:45	0.22	0.22	0.21	0.20	0.20	0.20

1.3.3.- Monitoring Functions

Monitoring of Switching Equipment

DDS units monitor the status of the switching equipment (line breaker, line disconnecting switch, busbar switches, ground switches, etc.) related to the bay. To perform this monitoring function, the user has to configure digital inputs where one or two contacts (type a and b) for each device are wired. When an operation (open or close) is performed over one of the monitored switches, the DMS system monitors the correct opening and closure by means of programmable timers.

The status of the different devices (up to 7, all of them configurable) can be accessed through the local MMI (graphic LCD) or through the communication program. This

allows the user to display the status of the monitored bay and to realize opening and closure operations of the switches (for more information see control functions in section).

Alarms

The DMS units have alarm monitoring and management functions. The alarms are important states of the system that the user wants to monitor and configure for signaling purposes.

Up to 96 alarms can be configured in one DMS module (32 protection alarms, 48 control alarms and 16 communication alarms). The alarms are defined from the items defined in the protection and control states. It is possible to define logical combinations of several states to define an alarm.

The alarms are displayed in the graphic LCD as soon as they are generated by the system. If desired, the DDS system can be programmed to send the alarms generated in each DMS unit to higher levels: Level 2 (substation) or Level 3 (Central control).

One signaling Alarm can be in one of the following four states:

- The alarm is active and not acknowledged by the operator.
- The alarm is active and acknowledged by the operator.
- The alarm is not active and not acknowledged by the operator.
- The alarm is not active and has been acknowledged by the operator.

To distinguish the different possible status of an alarm, the DDS units show the text of the alarm (that is user configurable) in different ways in the equipment graphic display (please refer to the Alarms Management section later in this instruction book).

Using the Function Keys of the graphic display it is possible to acknowledge only one selected alarm or all the alarms at the same time.

Breaker Health Monitor

To supervise the breaker health, the DMS units of the DDS system calculate and store, for each operation, the cumulative values for the square of the current multiplied by the opening time of the breaker (ΣI^2t) on each of the three phases. If the rated current is not exceeded, as in the case of a manual opening command with no fault current, the relay stores the rated current value instead of the measured value.

The value I^2t is accumulated and stored independently for each phase. These values can be accessed either via local MMI or via GE-LOCAL communications software.

This function has an "Integration Time Selector" setting that can be used to assign a fixed opening time for the breaker (given by the "Integration Time" setting). Otherwise, the DMS equipment itself measures the opening time from the moment the opening

command is given until the moment when the equipment detects that the breaker is opened.

Supervision of trip and closing circuits

As an option, the DMS units can have two complete supervision circuits for the trip and closing coils of the breaker. These supervision inputs monitor both the battery voltage level and the continuity of the trip and/or closing circuits, applying current through those circuits and checking that it flows properly.

The unit independently identifies in the events log and status register both the continuity of each coil ("Coil Continuity Alarm") and the loss of battery voltage ("Coil Voltage Alarm").

The supervision of the open and/or closing circuits is carried out on a permanent basis, regardless of whether the breaker is in the open or closed position, since these circuits are connected both to contact 52/a and 52/b of the breaker, as shown in the following diagram:

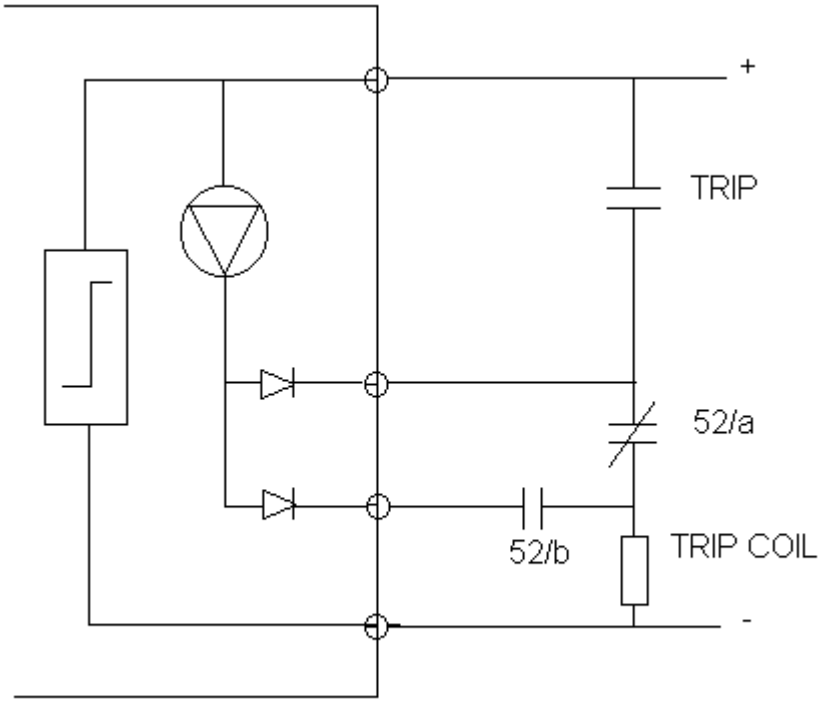


Figure 1.7. *Trip Circuit Supervision*

1.3.4.- Analysis and Record Functions

Event Recorder

The DMS units keep a record of the last 150 events. These events can be generated in the protection sub-module by the trip or pickup actions of the different protection units, self-check or monitoring function alarms, setting changes, etc.

The following information is stored for each recorded event:

- Name (description text) of the event.
- Time and date (1 millisecond accuracy).
- Current and voltages measured at the time that the event has been registered.
- A complete report of the status (digital flags) of the module that has generated the event.

The following diagram shows the format of the recorded events as shown in the GE-LOCAL communication program:

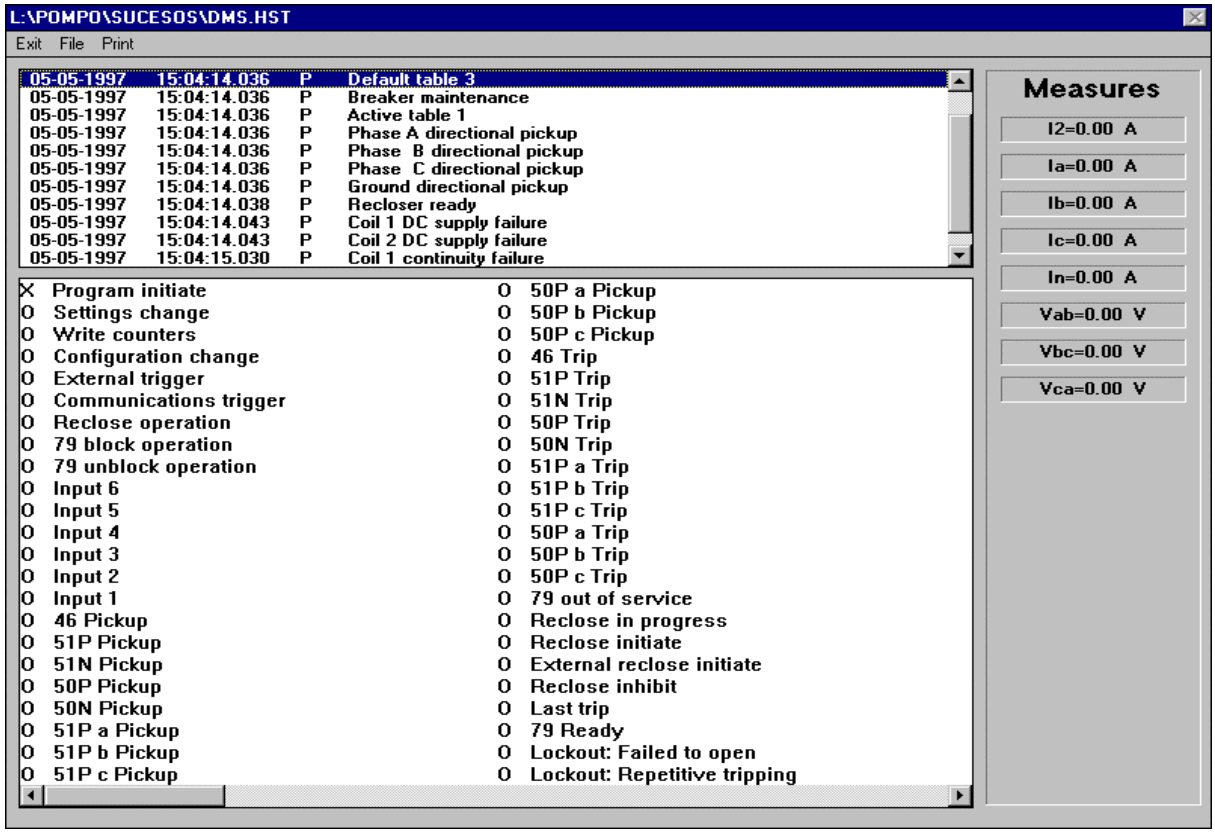


Figure 1.8. *Event List*

These events are stored in non-volatile memory (EEPROM), and are maintained even when dc power supply is removed from the DMS unit.

Oscillography Recorder

The DMS units store up to 4 oscillography records, with a resolution of 16 samples per cycle. Each oscillography record has a maximum capacity of 66 cycles. The number of pre-fault cycles can be selected from 2 to 10 cycles. The information stored in each record depends on the DMS model. As an example, an oscillography record can include the following information:

- 66 cycles with the instantaneous values for voltage and current inputs (I_A, I_B, I_C, I_N, V_{AB}, V_{BC}, $V_{CA,}$ V_{bus}):
    - 2 to 10 pre-fault cycles.
    - Rest of cycles are post-fault cycles.
- Digital information.
    - Pickup and dropout of protection functions.
    - Inputs status.
    - Recloser signals.
- Date and time.
- Causes that triggered the oscillography record.

A configurable mask determines which function operations or trip actions trigger oscillography record. It is also possible to trigger the oscillography by closing a configurable digital input.

The oscillography is stored in capacitor backed dynamic RAM. The oscillography data is maintained at least 24 hours in case of failure of the power supply. The oscillography data is captured and converted in a file using the GE-LOCAL communication program, and can be visualized using the GE-OSC program, with the EXCEL commercial program, or by means of a format conversion program, using the GLOBAL-LAB visualization and mathematical processing software packages.

The following are some examples of oscillography records as shown by GE-OSC program:

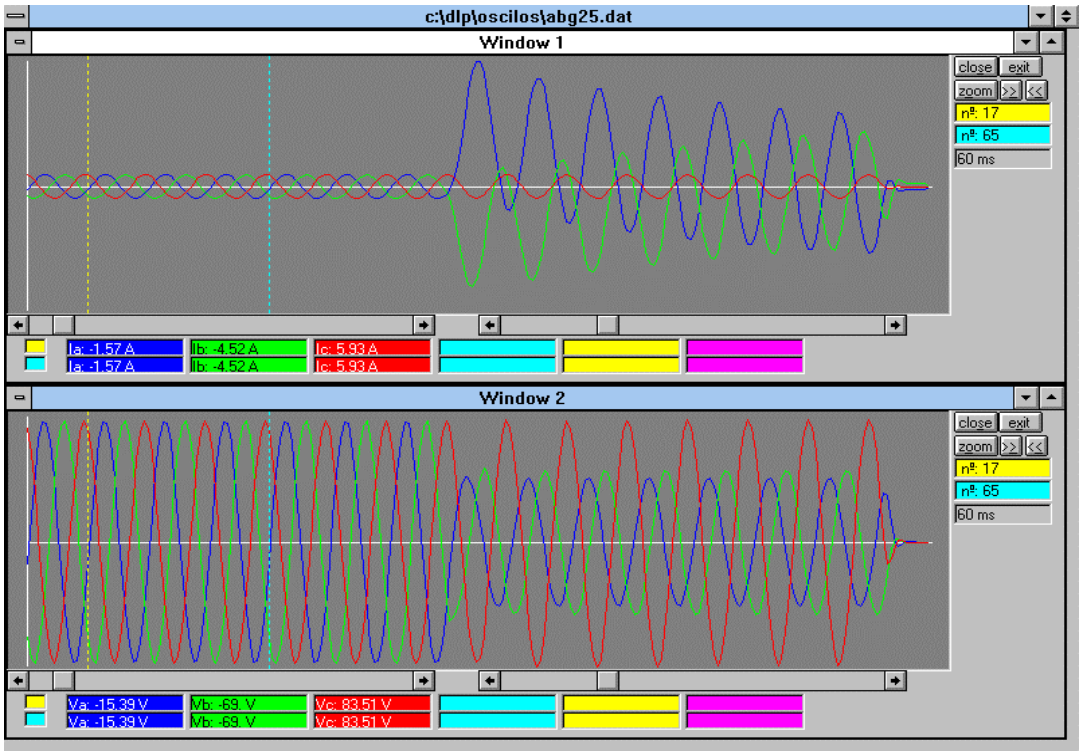


Figure 1.9. *Displaying of analog channels*

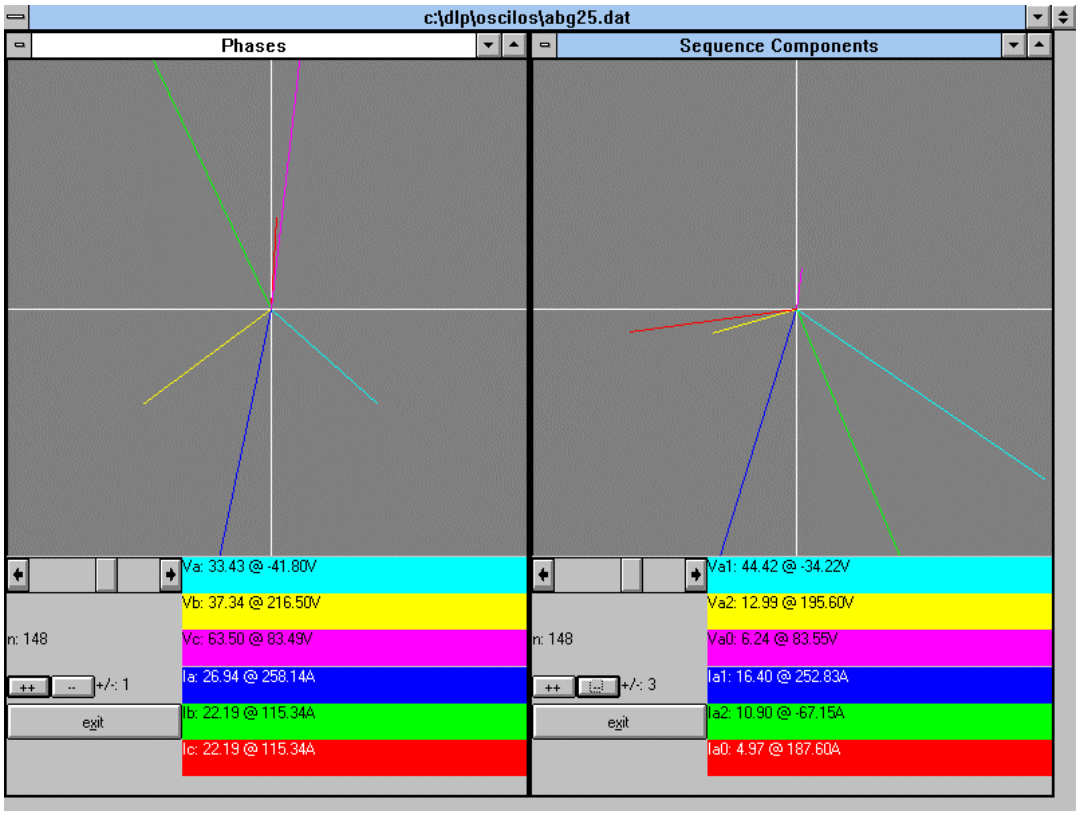


Figure 1.10. *Phasorial fault analysis*

1.3.5. Control Functions

Operations and Interlocks

The control sub-module of the DMS units allows the user to configure (using the GE-INTRO configuration software) and perform up to 16 operations. Two of them are predefined (*Control Blocking* and *Control Unblocking*) and the other 14 are fully configurable. The operation commands are sent to the relay through local communications (graphic display or local keypad), through remote communications or via digital inputs (conventional RTU).

For each operation, the following parameters can be configured:

- **The name that identifies the operation**.

- **The Operation Conditions**, or conditions that must be present in the system before starting the defined operation. The user can program up to 4 operation conditions, selected from 96 states or signals for each operation).

- **The Failure Conditions**: If a condition defined as "Failure Condition" appears during the operation, it is automatically aborted. The user can program up to 3 failure conditions for each operation.

- **Success Condition**: Condition that defines that an operation has been performed successfully. The user can define 1 success condition for each operation.

- **Holding Time:** Which defines the time that the program waits, once the operation command has been given, for any of the operation conditions to become true to start the operation.

- **Dwell Time:** defines the time that the operation output contacts remain activated for that particular operation.

- **Failure Time:** which defines the time the program waits, once the operation has been performed, for the success condition to become true and consider that the operation has been successfully performed.

Each operation generates two signals: a "Device Selection" signal and an "Output" signal. These signals can be assigned to any of the relay output contacts.

The Operation Interlocks are defined through the operation and failure conditions defined above.

Combinational Circuits

Besides the interlocks defined above, which are related to the operations, the user can define "static" type interlocks given by the so-called *combinational circuits*. With these circuits, the user can define actions related to different signals received by the DMS unit, remaining the action active while those signals are as defined.

The DMS has 4 programmable combinational circuits. The user can program each circuit using logical AND, NOT and OR type gates. The input of these gates can be selected from the 64 control states. The combinational circuits 1 and 3 allow defining OR gates where the inputs are up to 4 AND gates. The combinational circuits 2 and 4 allow to define OR gates where the inputs are up to 3 AND gates.

Configuration of inputs and outputs

All the inputs and outputs of DMS units are configurable, excepting the trip and reclose contacts included in the power supply boards. The configuration of the inputs and outputs are performed using the GE-INTRO configuration software, that allows the user to define the following parameters:

- Define the logic inputs the user wants to monitor and/or use as part of the internal programmable logic.
- Define timing functions for logic inputs.
- Define the output contacts to initiate the defined operations.
- Define the physical contacts for the logic outputs, defined from the internal signals and the digital inputs.

The number of inputs and outputs available and their configuration possibilities are different for each DMS equipment (or DDS compatible) depending on the particular characteristics of that equipment. To have a better information in this matter, please refer to the instruction books of the different devices and of the GE-INTRO configuration software.

Besides the digital inputs, the DMS units can have analog inputs, binary inputs and pulse count inputs, that allows the system to perform the following functions:

- Define inputs for analog metering of mA or mV (SCADA), temperature, fault distances coming from other protection devices, and in general, of signals coming from any standard transducer.
- Configure binary inputs: Each input of a set of inputs defines a bit, so that the total set defines a binary number of up to 8 bits. The system allows binary, BCD or Gray codes.

- Define pulse counters, to receive pulse outputs from metering devices for pulse counting of power, energy, etc.

1.4.- User Interface and Communications

1.4.1.- User Local Interface

The local man machine interface in the DMS systems is developed through two keyboard/display sets, one for protection functions and the other for control functions.

Protection local MMI

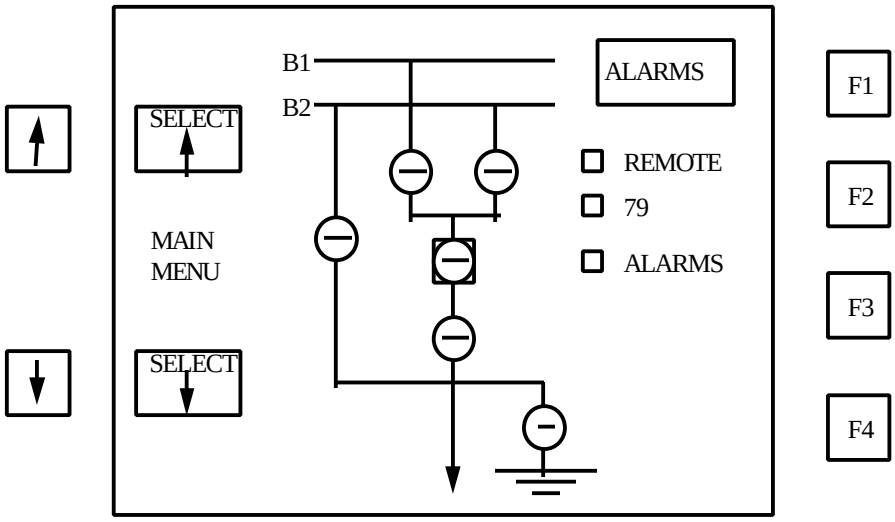
The protection MMI incorporates keyboard (with 20 keys) and alphanumeric LCD display with two rows of 16 characters each, that allows access to all the information available in the protection system, that is:

- Display and change protection and control settings.
- Display of states and measurements.
- Perform operations (only protection operations).
- Access to the Configuration Menu and to the Single Key Menu (the single key menu shows the most important information of the device by pressing only one key).

Control local MMI

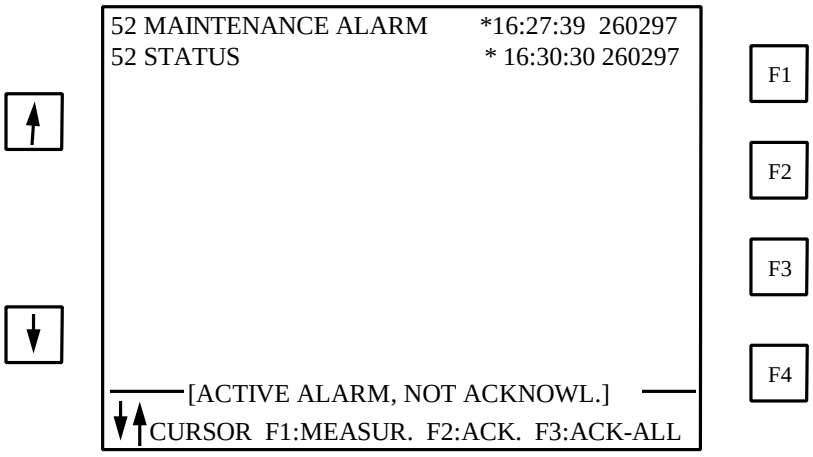
The control MMI incorporates functional keyboard (6 keys) and graphic LCD display. This graphic LCD shows four different screens that can be accessed sequentially.

This screen shows the "mimic" of the bay, that is, a diagram of the bay related to that DMS module showing the status of the breaker, the switches and other devices. This screen can be configured with the GE-INTRO configuration software. The following figure shows an example of this screen:



1. Bay mimic

In this screen, the different switching elements can be selected (with the arrow keys) and the user can perform operations related to those elements. When the user selects an element that can be operated, the display shows the available options that can be selected with the F1 ... F4 keys.

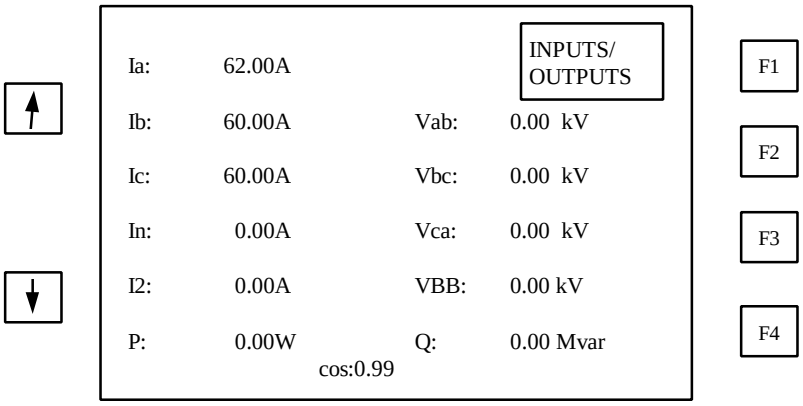


2. Alarms Screen

This screen displays the alarms generated in the system with the following format:

- Identification name of the alarm.
- Time when the alarm was generated.
- Date of the alarm.

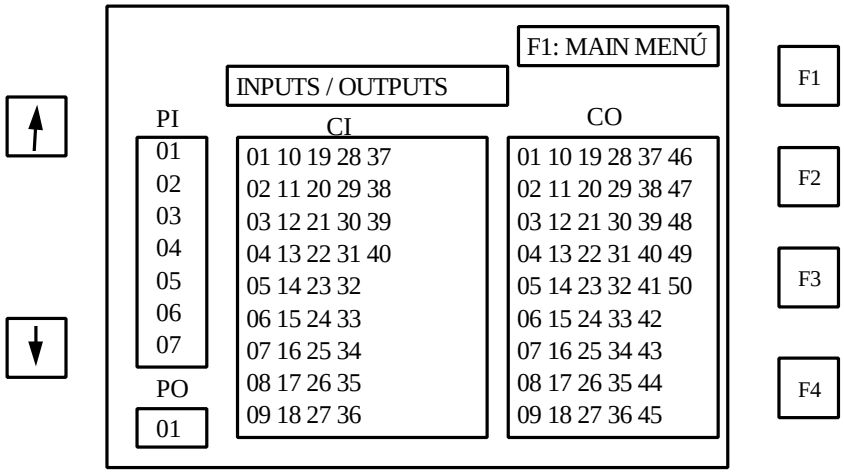
To get more information about the alarms format and management, please refer to section "Monitoring Functions".



3. Screen of Measurements

This screen shows the real time measurements (referred to the primary side) that reads the DMS unit. This screen is different depending on the DMS model selected, and shows the system parameters (currents, voltages, power,...) defined in the application option of the model selection table.

This screen shows the status of all the protection and control inputs and outputs. A dark background means that the input or output is activated. As the number of inputs and outputs is different for different DMS model, this screen will vary depending on the particular model. The following figure shows one example of this screen:



4. Screen of Digital Inputs and Outputs Status

1.4.2.- Remote Communications. Software

Each DMS unit is provided with two communication ports, one RS-232 front port for local communication and a rear port for remote communication (where the Level 2 system is connected). The rear port can be RS-232 or Fiber Optic type. Both ports allow the user to establish communication with the DMS unit using the different programs included in the GE-NESIS software.

The integration of the different Level 1 units is performed through a communication system, that connects these units with higher levels (substation level or level 2). That communication system is point-to-point and uses the GE's MLINK protocol, with a maximum speed of 115 kb. The level 1-level 2 global communication system includes typically the following items:

- A PC for the substations that acts as a MMI of the whole substation.

- A communication concentrator that is connected to all the level 1 units and receives their data, controls the data bases and provides connection with the MMI and the Level 3.

- One or more communication multiplexers that provide point-to-point communication channels for several devices.

The GE-NESIS software includes five different programs each one with a different function:

- **GE-LOCAL**: Level 1 communication software.
- **GE-INTRO**: Level 1 configuration software.

- **GE-OSC**: Oscillography data management and analysis software.
- **GE-POWER**: Level 2 communication software.
- **GE-CONF**. Level 2 configuration software (substation configuration).

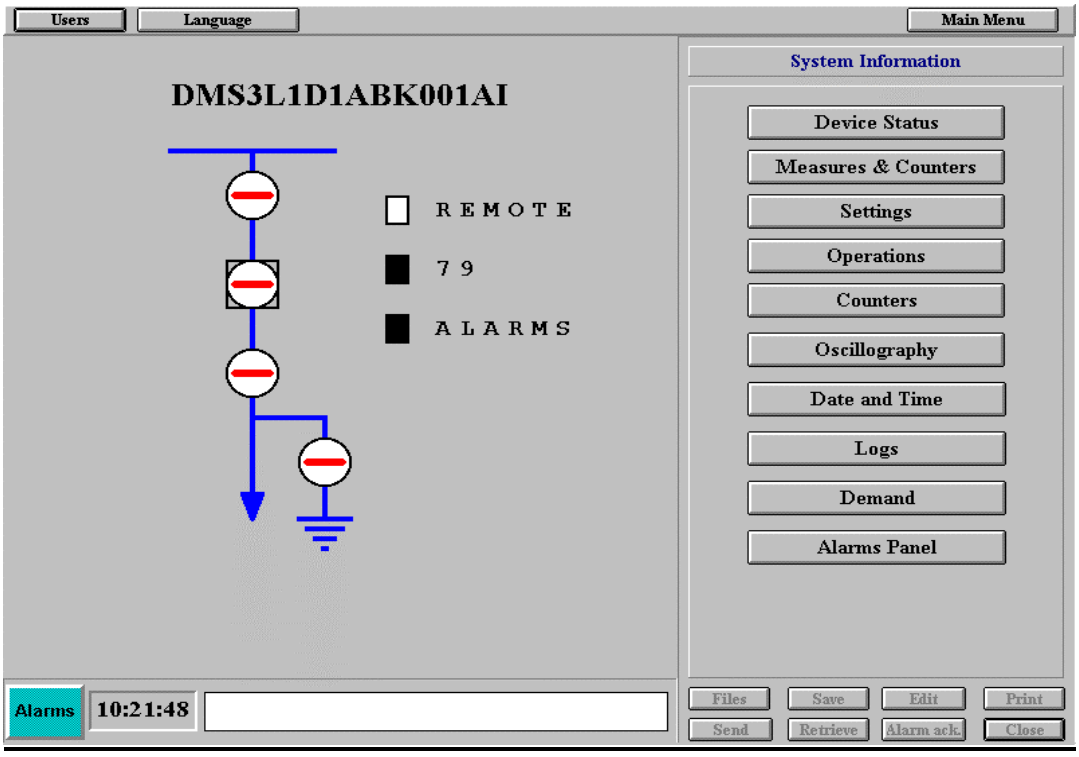
The GE-LOCAL, GE-INTRO and GE-OSC programs constitute the basic communication and configuration software for DMS and DDS compatible devices, allowing the communication with one device at a time, either for level 1 devices integrated in a system or for non integrated devices (operating as individual relays).

In the other hand, GE-POWER and GE-CONF programs provide tools for manage and configure all the DDS system as a unit (substation level).

The functions that can be performed with each program are the following:

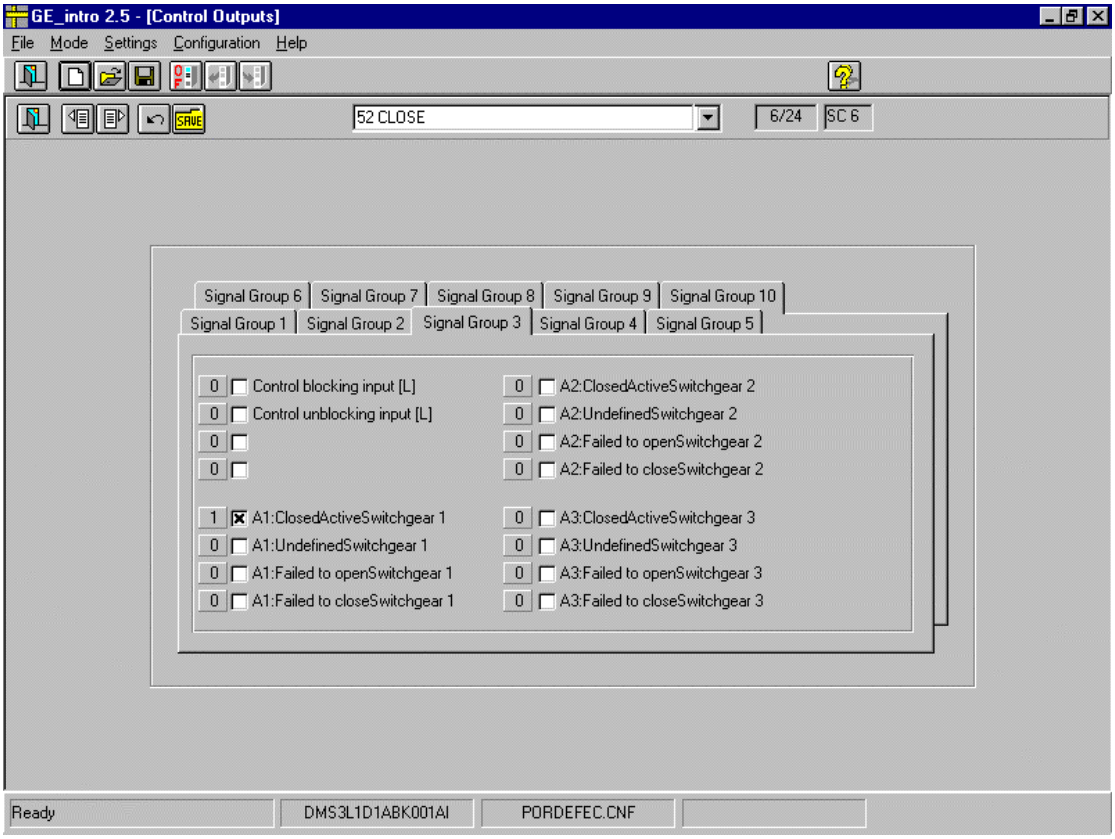
GE-LOCAL:

- Display of Level 1 units status.
- Display and change of settings.
- Display of metering data.
- Perform predefined bay operations or maneuvers.
- Reading, display and reset of counters.
- Display of alarms.
- Upload and display events.
- Upload oscillography records.
- Time synchronization.

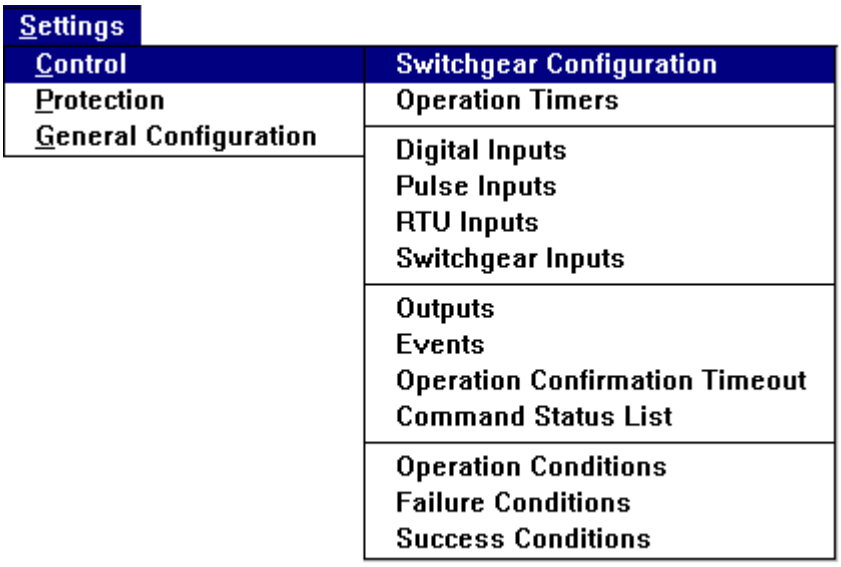


GE-INTRO:

- Configuration of protection inputs and outputs.
- Configuration of control inputs and outputs.
- Configuration of alarms.
- Definition of operations and interlocking conditions.
- Definition and configuration of switching elements.
- Configuration of LED indicators.
- Configuration of the displays shown in the graphic LCD.



Screen of GE-INTRO program.



Control configuration menus of the GE-INTRO program.

GE-OSC:

- Display (in several formats) analog channels.
- Display of digital channels.
- Calculation and display of phasors and symmetrical components.
- Display of fault reports and/or files of settings.
- Analysis tools for different applications: distance, etc.

GE-POWER:

- Display of the single line diagrams of the substation.
- Zoomed display of the single line diagrams of the bay.
- Access to information as:
    - States.
    - Measurements.
    - Alarms.
    - Events.
    - Oscillography.

  for each bay and for the complete substation.
- Perform operations.
- Display and remote change of the setting of each bay.

GE-CONF:

- Configuration of users, access levels and security passwords.
- Configuration of bays (name, type, etc.).
- Configuration of states, measurements, events, etc., that each Level 1 unit must send to Level 2.

- Configuration of data bases, macro-operations and interlocks involving different bays.
- Generation of data bases for the substation.

1.5.- DDS Standard Bays

Finally, in order to simplify the DMS model selection process, we have defined some standard models for each application.

This section shows some of these models, including a short description of their different functions, hardware configuration and a reduced model selection table for that particular standard model.

1.5.1. High, Medium and Low Voltage Feeders, High and Medium Voltage Transformers, Bus bar coupling

Model DMS3L1 - - 4C - X X X A -

- Protection functions: 50/51, 50N/51N, 67/67N, 46, 79, 25
- Monitoring functions: Events, oscillography, alarms, measurements, inputs and outputs status.
- Control functions: Interlocks, Switchgear monitoring and operation.
- Protection Inputs/Outputs (I/O): 6 inputs, 13 outputs
- Control Inputs/Outputs (I/O): 21 inputs, 24 outputs

- ***Hardware configuration:***

Magnetic Module	Power Supply	Mixed I/O Board	Protec. CPU	Comm. CPU	Control CPU		Mixed I/O Board	Mixed I/O Board	Mixed I/O Board	Redund. Power Supply (Option.)

- ***Model selection guide:***

DMS	3	L	1	-	-	4	C	-	X	X	X	A	-	DESCRIPTION
				-										**Current Ranges (see Table 1)**
														Communications
					0									RS232
					1									1mm Plastic F.O.
					2									62,5/125 Glass F.O.
														Single Power Supply
								A						48 Vdc
								H						110-250 Vdc.
														Redundant Power Supply
								J						48 Vdc.
								M						110-250 Vdc.
									-	**-**	**-**			**Configuration**
												A		**Revision Level**
														Language
														Spanish
													I	English

- *Table 1: Current ranges (in Amps):*
-

	C	D	E	H
Phase	1-12	1-12	1-12	0.2-2.4
Ground	0.2-2.4	0.5-6	0.1-1.2	0.1-1.2

1.5.2.- Bus Bar

Model DMS3A20 - 4C - X X X A -

- Protection functions: 27, 59, 59N, 81
- Monitoring functions: Events, oscillography, alarms, measurements, inputs and outputs status.
- Control functions: Interlocks, switchgear monitoring and operation.
- Protection Inputs/Outputs (I/O): 6 inputs, 13 outputs
- Control Inputs/Outputs (I/O): 21 inputs, 24 outputs

- ***Hardware configuration:***

Magnetic Module	Power Supply	Mixed I/O Board	Protec. CPU	Comm. CPU	Control CPU		Mixed I/O Board	Mixed I/O Board	Mixed I/O Board	Redund. Power Supply (Option.)

- ***Model selection guide:***

DMS	3	A	2	0	-	4	C	-	X	X	X	A	-	DESCRIPTION
														Communications
					0									RS232
					1									1 mm Plastic F.O.
					2									62,5/125 Glass F.O.
														Single Power Supply
								A						48 Vdc
								H						110-250 Vdc.
														Redundant Power Supply
								J						48 Vdc.
								M						110-250 Vdc.
									-	**-**	**-**			**Configuration**
												A		**Revision Level**
														Language
														Spanish
													I	English

1.53.- Auxiliary and General Services

Model DMS2G00 - 0C - X X X A -

- Protection functions: None
- Monitoring functions: Events, oscillography, alarms, measurements, inputs and outputs status.
- Control functions: Interlocks, switchgear monitoring and operation.
- Control Inputs/Outputs (I/O): 21 inputs, 24 outputs

- ***Hardware configuration:***

	Power Supply			Comm .CPU	Control CPU		Mixed I/O Board	Mixed I/O Board	Mixed I/O Board	Redund. Power Supply (Option.)

- ***Model selection guide:***

DMS	2	G	0	0	-	0	C	-	X	X	X	A	-	DESCRIPTION
														Communications
					0									RS232
					1									1 mm Plastic F.O.
					2									62,5/125 Glass F.O.
														Single Power Supply
								A						48 Vdc
								H						110-250 Vdc.
														Redundant Power Supply
								J						48 Vdc.
								M						110-250 Vdc.
									-	**-**	**-**			**Configuration**
												A		**Revision Level**
														Language
														Spanish
													I	English

2. PROTECTION FUNCTIONS

This section is intended to provide a general description of the protection functions that can be included in the different protection modules of the DDS system.

As noted above, there are several different protection and/or control modules with different applications, functions and setting ranges. This makes it difficult to give a complete description of all of them. So, in this section we have included a description of the characteristics common to the protection functions, as well as an example of available settings (the example corresponds to the SMOR-B protection relay).

2.1. List of Protection Functions

2.1.1 Overcurrent Units

The DDS system can incorporate the following overcurrent units, all of which can be enabled, set and used independently:

2.1.1.1 Phase overcurrent (independent units)

- Time overcurrent: **51PT**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time
- Instantaneous, High Level: **50PH**
- Instantaneous, Low Level: **50PL**

2.1.1.2 Ground overcurrent

- Time overcurrent: **51NT**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time
- Instantaneous, High Level: **50NH**
- Instantaneous, Low Level: **50NL**

2.1.1.3 Ground overcurrent (for application in capacitor banks or in feeders as a second and more sensitive ground unit)

- Time overcurrent: **51G**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time
- Instantaneous: **50G**

2.1.1.4 Negative Sequence Overcurrent (phases)

- Time overcurrent: **46PT**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time

2.1.1.5 Overcurrent for Transformer Tank

- Time overcurrent: **51C**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time
- Instantaneous: **50C**

2.1.1.6 Phase Directional Overcurrent (the directional supervision can be set independently for each one of the phase overcurrent units).

- Time overcurrent: **67PT**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time
- Instantaneous, High Level: **67PH**
- Instantaneous, Low Level: **67PL**

2.1.1.7 Ground Directional Unit (the directional supervision can be set independently for each one of the ground overcurrent units).

For neutral grounded systems:

- Time overcurrent: **67NT**, with the following selectable time characteristics: Inverse Curve, Very Inverse Curve, Extremely Inverse Curve or Definite Time
- Instantaneous, High Level: **67NH**
- Instantaneous, Low Level: **67NL**

For ungrounded systems:

- Time overcurrent: **67NA**, with Definite Time characteristic.

2.1.1.7 Breaker Failure Protection

- Time delayed: **50(62)BF**

2.1.2 Voltage Units

2.1.2.1 Definite Time Phase Voltage

Includes two definite time phase voltage units. Both are three-phase units:

Phase Undervoltage: **27**Æ (3x27)
Phase Overvoltage: **59**Æ (3x59)

2.1.2.2 Definite Time Ground Voltage

Includes two definite time ground voltage units:

Overvoltage, High Level: **59NH**
Overvoltage, Low Level: **59NL**

2.1.2.3 Ground Voltage with Harmonic Filtering

Ground Overvoltage (3V0) 64_{A3rd} (definite time)

2.1.3 Frequency Units

2.1.3.1 Definite Time Frequency Units 81

Can include the following units:

Underfrequency Units: **81U**
Overfrequency Units: **81O**
Frequency Derivative Units: dF/dT

2.1.4 Transformer Differential Unit

Restrained Differential: **87T**
Instantaneous Differential: **87I**

2.2. Characteristics of the Protection Functions

2.2.1 Characteristics of the Time Overcurrent Functions (51)

The timed overcurrent units can be separately selected to follow *Inverse, Very Inverse or Extremely Inverse* curves or *Definite Time.*

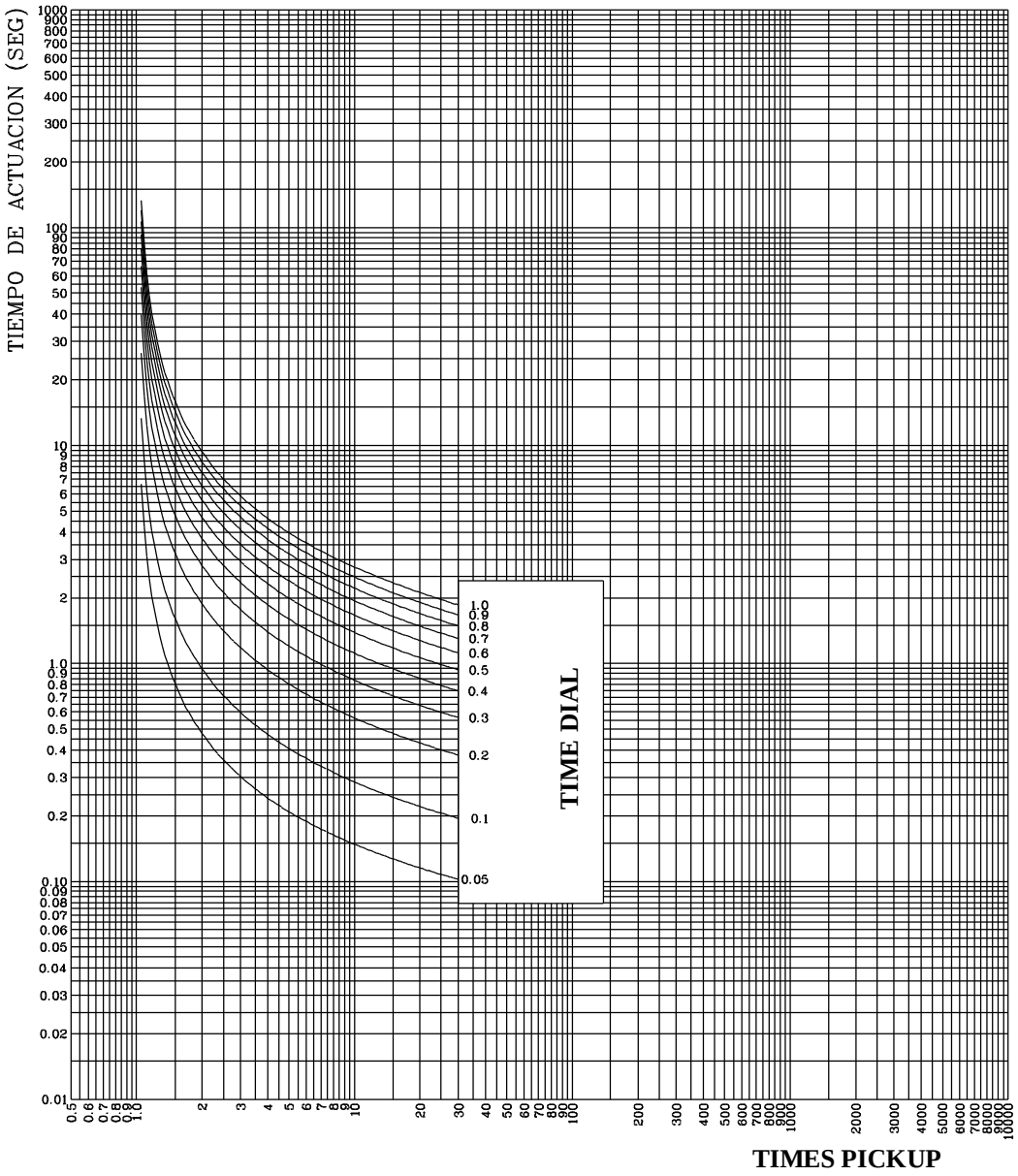
All these inverse time curves are defined by the following equation:

$$t = TD \left| \frac{K}{\left(M^{\alpha} - 1 \right)} \right|$$

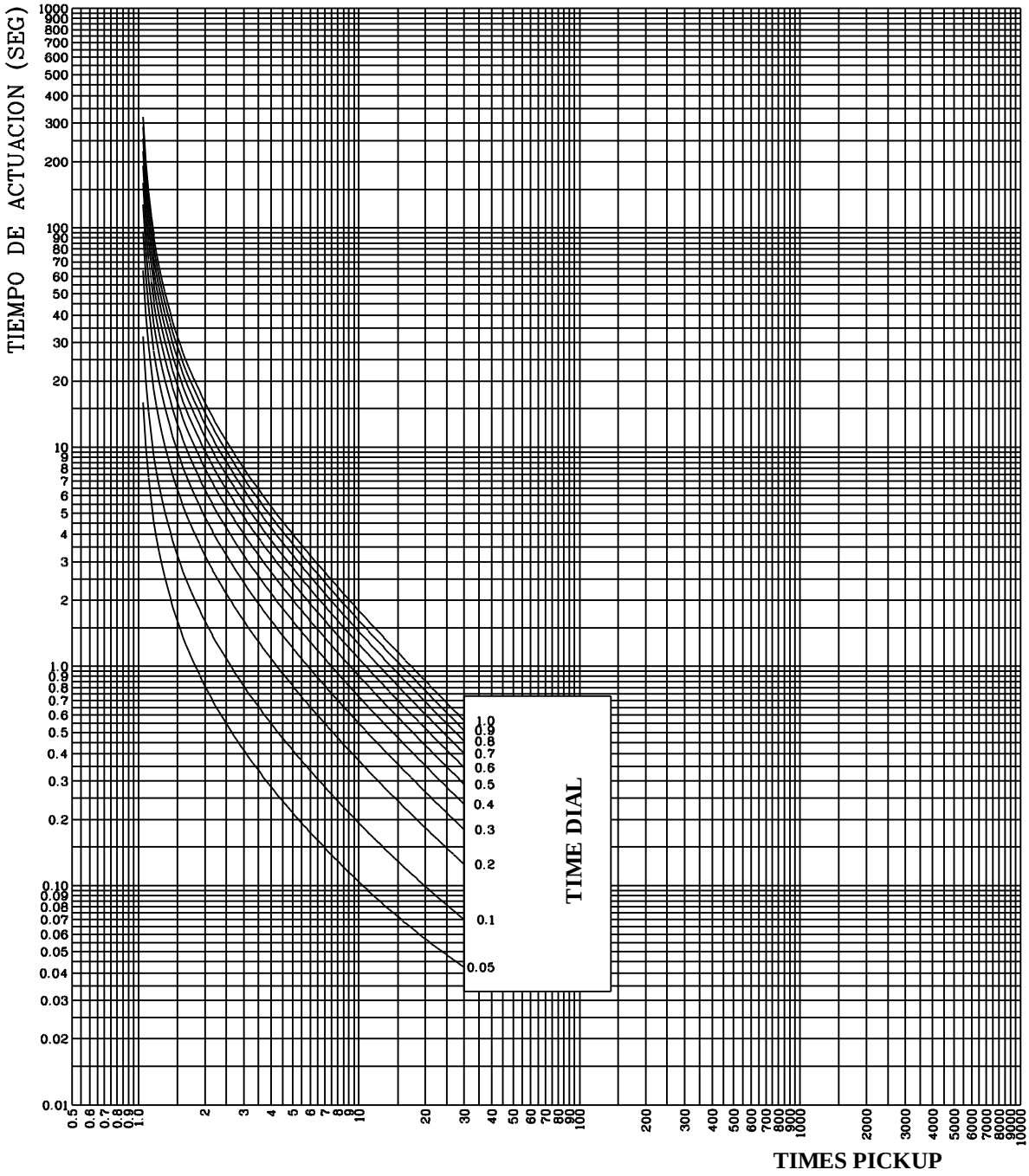
where t = time in seconds
TD = Time Dial of the curve (0.05 for the lower curve of the family and 1 for the upper curve)
M = Times the pickup current level set for the overcurrent unit.
K, α = These coefficients identify the selected curve. Their values for the different inverse time curves are shown in the following table:

Table 2.1. *Inverse Curve's constants*

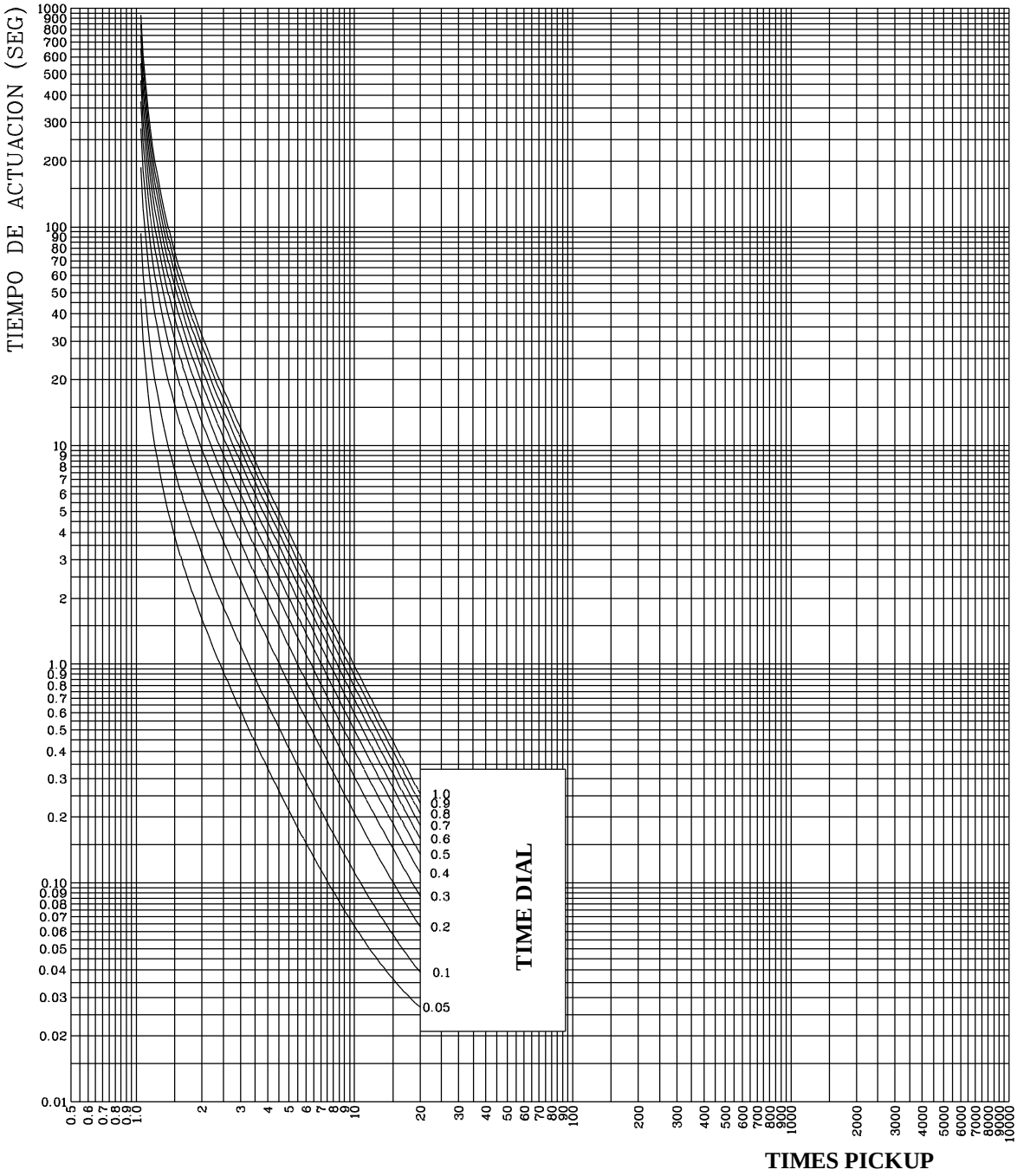
Curve	Characteristic	K	a
3	Inverse	0.13	0.02
2	Very Inverse	16	1
1	Extremely Inverse	96	2



INVERSE characteristic operating curve (226B7414H1).



VERY INVERSE characteristic operating curve (226B7414H2).



EXTREMELY INVERSE characteristic operating curve (226B7414H3).

2.2.2 Directional Functions (67)

The DDS system includes three phase directional units and one ground directional unit. They are completely independent on each other, and they are used to supervise (assuming they are adjusted to do so) the tripping of the phase and ground overcurrent units, according to the direction of the detected fault. This directional supervision does not affect the trip of the negative sequence overcurrent unit.

The DDS system has two settings' groups for the directional supervision:

- For phase to phase overcurrent functions (∅-∅)
- For phase to ground overcurrent functions (∅-G)

The directional supervision operates independently for each pair of phases (∅A-∅B, ∅B-∅C, ∅C-∅A) of the system, although there is only one common setting for all phases.

In the same way, they ground directional supervision setting acts independently depending on the phase involved in the fault.

Once the directional supervision has been set for the phase overcurrent units, each one is polarized by the phase-to-phase voltage of the other two phases (obtained in the relay from the phase-to-ground voltages), while the ground directional unit is polarized by zero sequence voltage.

In both cases, the angle between the polarizing vector and the fault current is called "characteristic angle" and can be independently set for the phase and ground units between -90 and +90º.

2.2.2.1 Grounded Systems

Phase Directional Unit - Characteristic Angle (a)

Figure 2.1. shows the characteristic angle as well as the operating and non-operating half-planes for a phase to phase fault (phase A to phase B).

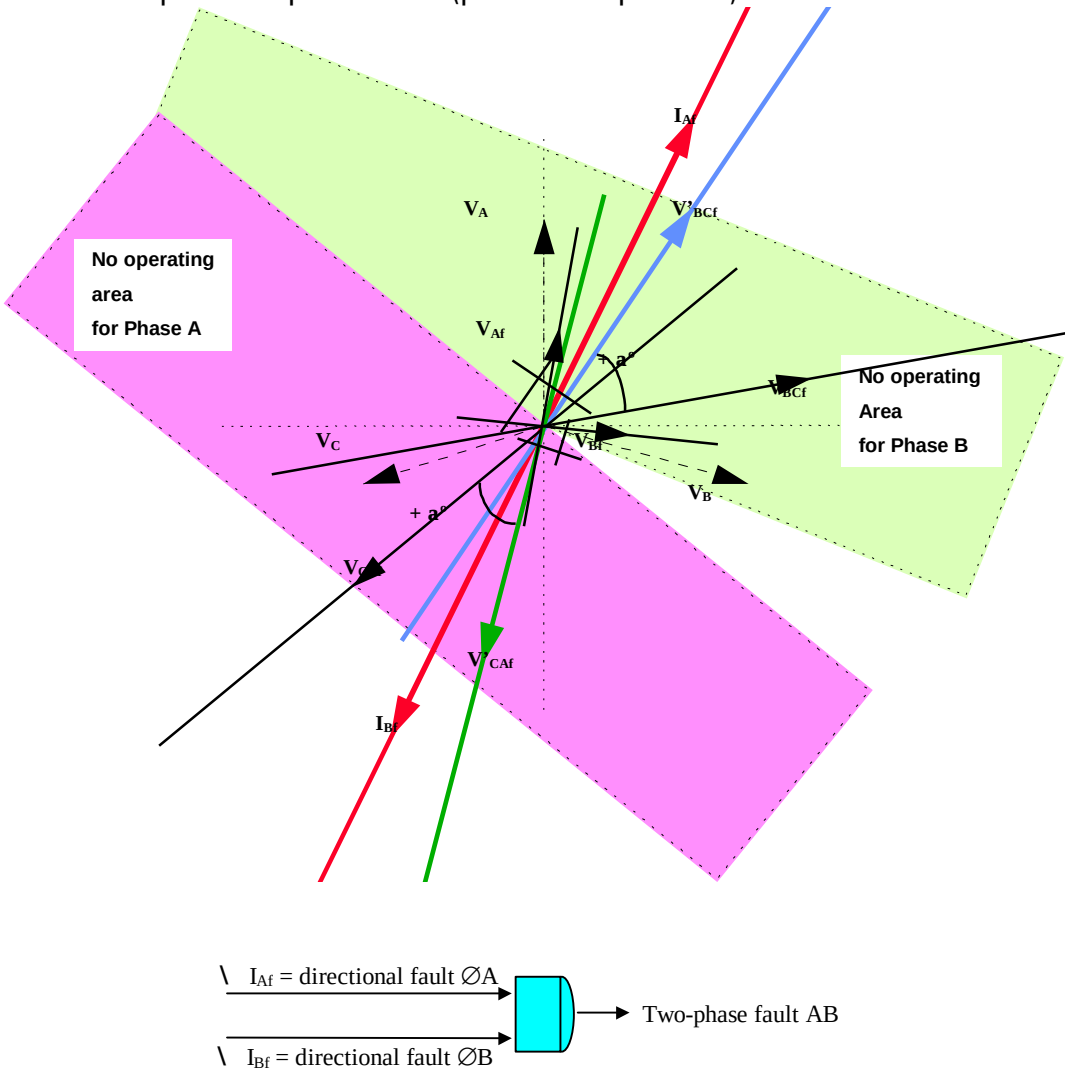


Figure 2.1. *Phase Directional Characteristic*

The characteristic angle ±*a* is the angle that the polarizing voltage must be led to be in phase with the fault current. When this occurs, we have the "maximum torque" or "maximum reach" condition.

As shown in Figure 2.1:

The polarizing voltage for ∅A current is the voltage V'_{BCf}
The polarizing voltage for ∅B current is the voltage V'_{CAf}

The polarizing voltage for ∅C current is the voltage V'_{ABf}

Ground Directional Unit - Characteristic Angle (a)

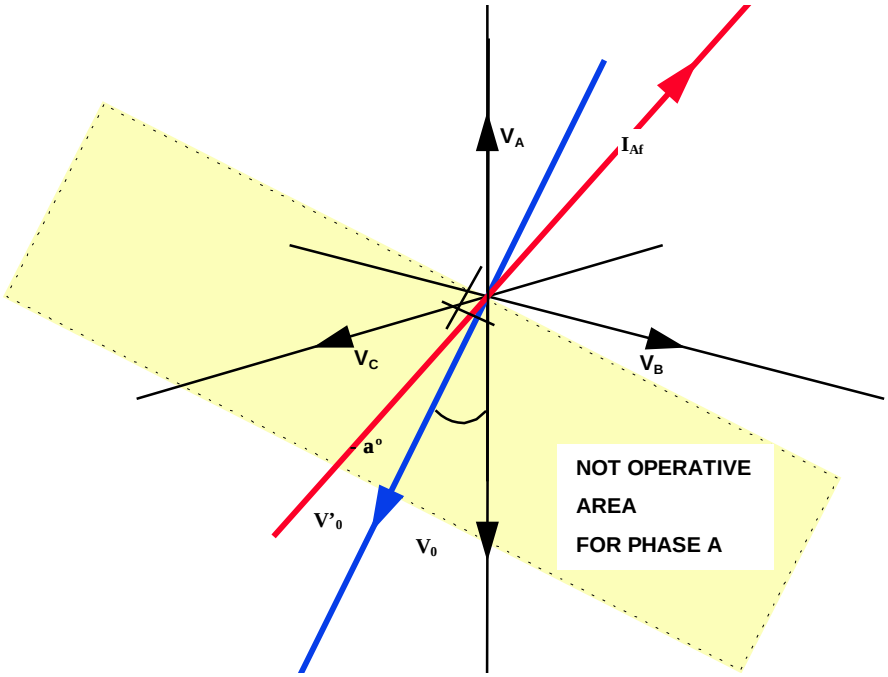


Figure 2.2. *Ground directional characteristic*

Figure 2.2. shows the voltage and current phasors for a phase A to ground fault (∅A-G). In this case, the polarizing voltage is the zero sequence voltage.

The characteristic angle $\pm a$ is now the angle that the used polarizing voltage V'_0 lags the zero sequence voltage V_0 present during the fault. The setting range for this characteristic angle is from -90 to +90º.

The directional unit needs a minimum voltage level to be polarized. This level is set to two volts, that is low enough to provide polarization even in case of three phase faults very close to the relay. However, to protect against loss of polarization voltage the system includes adjustable operation logic that allows to select permanent blocking or permission of the directional units if polarization is lost.

The loss of polarization logic for the phase units follow the OR logic of two conditions:

- The activation of the minimum phase voltage detectors for level set at two volts (2V)
- The activation (if selected) of a digital input from the voltage transformers' MCB breaker.

For the ground units, the only condition is that of the digital input from the voltage transformers' MCB breaker.

2.2.2.2 Ungrounded Systems

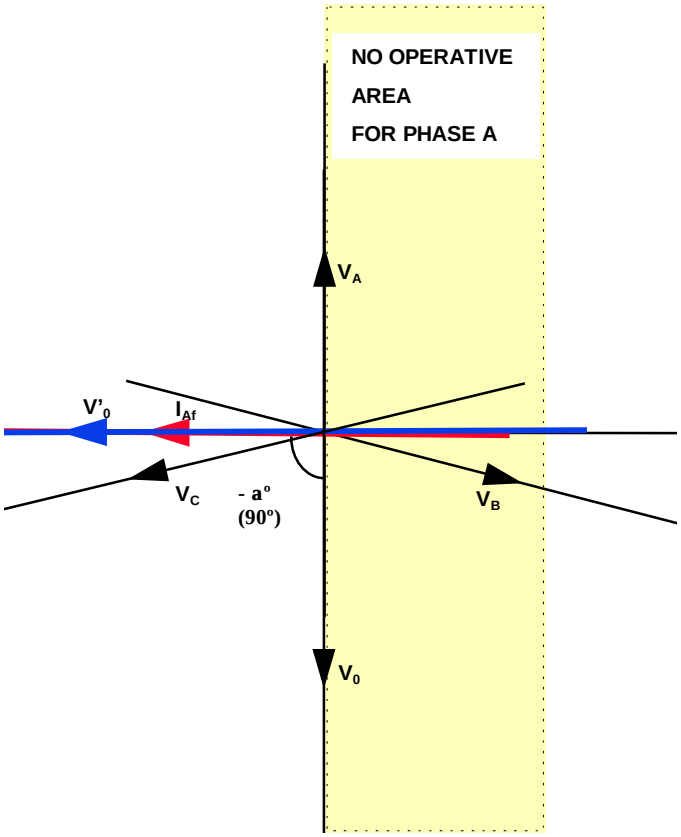


Figure 2.3. *Isolated ground directional characteristic*

Figure 2.3. shows the voltage and current phasors used to define the directionality for phase A to ground faults in ungrounded systems. In this case, the operating magnitude is the capacitive current that result form the contribution of other feeders connected to the same busbar that the faulty feeder. The polarizing voltage is V'_0, that is, the zero sequence voltage V_0 rotated the characteristic angle $-a$, so that it coincides with the capacitive current that the protection sees flowing from the busbar.

2.2.3 Voltage Functions 59/27

The phase overvoltage (59) and undervoltage (27) functions are three-phase units, that is, the measurement is made in phases A, B and C separately and the unit operates when an overvoltage or undervoltage condition (depending on the unit) is detected in any of the three phases. The setting of both the overvoltage and undervoltage units is referred to phase-to-phase voltage values, calculated from the phase-to-ground voltages applied to the system. The undervoltage unit is supervised by the breaker status, in such a way that the unit cannot be activated when the breaker is opened.

There are three different ground overvoltage units: 59NH, 59NL and 64_{A3}. For 59NH and 59NL units, the operating voltage is calculated from phase voltages. For 64_{A3} function, the operating voltage must be provided through an additional independent voltage input. This function responds only to the fundamental frequency at the neutral since the voltage input is filtered and the harmonics eliminated.

2.2.4 Frequency Functions 81U/81O

The frequency for underfrequency and overfrequency units is always measured over a single phase voltage (phase B).

This function provides one step of under and one step of overfrequency protection, each with an adjustable time delay. The time delay is Definite Time type.

An additional frequency unit that operates with the change rate of the frequency is available. This unit measures the frequency derivative over time and operates instantaneously after a selected number of semi-cycles of frequency checking.

All frequency functions are supervised by an adjustable positive sequence voltage level. This undervoltage cut off level will block the frequency functions while the voltage is under the adjusted level.

2.2.5 Transformer Differential Function 87

The transformer differential protection includes two different functions, both differential:

Restrained Differential **87T**
Instantaneous Differential **87I**

The restrained differential unit **87T** includes two restraining characteristics applied over the differential current signal provided from the n transformer windings (maximum 4):

- Percentage restraint: To prevent misoperation because of unbalances between current transformers during external faults. These unbalances can come from CT ratio mismatch, unload tap changers, CT accuracy errors, CT saturation, etc. The percent slope characteristic makes that as the through current in the transformer increases, the level of differential current must increase to operate the unit.

- Harmonic restraint: The harmonic restraint principle allows the relay to distinguish between faults and transformer inrush current. The restraint is proportional to the second and fifth harmonics of the differential current. The ability to select the magnitude of the percent harmonic restraint permits the adaptation of this protection to any type of power transformer.

The typical operating time for 87T unit is 3 cycles for differential currents between 0.3*Itap and 1*Itap. For higher differential current values, the operating time is 1.5 cycles.

The instantaneous differential unit 87I does not include either harmonic restraint or percentage restraint. This unit is intended to prevent misoperation of the restrained differential unit when a current transformer reaches saturation condition. During heavy internal faults, the current transformer can saturate and provide a current with high harmonics' content. This could give larger operating times or inhibition of the restrained unit.

To avoid the trip of the 87I unit during the connection of the power transformer (due to the high inrush current values), this unit must be set above the inrush current value (typically 8 to 10 times the selected tap).

The differential protection includes a sensitivity setting (from 20% to 40% of the selected tap), to accommodate CT errors especially in low through current situation.

2.2.6 Ground Overcurrent 50/51G and Transformer Tank 50/51C Functions

Those units are basically similar to the overcurrent units described above. However, the 50/51G functions includes a second ground unit especially sensitive (with a lower setting range). This function is used in distribution feeders and in the neutral connections of star connected capacitor banks.

The 50/51C unit is used to add the "transformer tank" protection function to power transformer's protection schemes. This function has been used broadly as an alternative to the use of differential protection, especially in low power transformers (< 12 MVA).

2.2.7. Negative Sequence Overcurrent 46T

This function can be used in feeders or lines to limit the load unbalance or to detect extreme fault conditions as the breaking of a cable without any contact with ground.

This unit measures the negative sequence component of the line current, which is directly related with the unbalance.

This function also can be used in generator protection systems to avoid rotor heating due to the presence of negative sequence currents given by unbalanced loads.

2.2.8. Breaker Failure Function 50(62)BF

In addition to the opening and/or closing failure functions included in all the units part of a DDS system, a breaker failure function can be provided. This function includes one step with three-phase pickup and quick reset

2.3. Protection Functions Related with Control

2.3.1. Recloser (79)

The recloser function included in DMS systems is the same for all the modules that include this function and is part of the protection sub-module.

The DDS system recloser allows up to 4 attempts to reclose the line breaker.

For each of these attempts in a given cycle it is possible to program independently the reclose delay, that is, the time that should elapse before the reclosing order is given. In addition, it is possible to set which functions can produce a reclosing, and, after a given reclosing, which functions can trip the breaker again. This makes it possible to implement certain protection arrangements that required special wiring and functions in conventional units. For example, the user could want the first protection trip to be instantaneous and the second to be timed, in order to allow time for the output fuses of a branch of the feeder to blow. This can be easily done by setting adequately the tripping permissions after the first reclosing.

The recloser has a setting called "NUMBER OF TRIPS IN 1 HOUR" (included in the group of breaker settings), which can be set from 1 to 50 trips per hour. This setting prevents damage of the breaker in certain cases, such as a storm for example, in which the protection operation could be tripped and reconnected an excessive number of times. To limit the number of operations, the relay creates a time window of 1 hour in which it registers the number of trips that occur in that period. This window moves continuously so that it always indicates the number of trips that have occurred in the hour up to the present moment. If the number of trips exceeds the setting, the recloser stops working (and enters the lock-out state as shown later in recloser logic diagram).

From now on we will use the term "lock-out" instead of block to distinguish the situations in which blocking occurs due to input or setting (the only ones in which we use the term blocking) from any other type of block.

There is another setting called "RESET TIME" which is the time the unit waits after successful reclosing before returning to reset situation. This is also the time which the recloser waits before returning to the reset state following a manual closure. From now on we will refer to this value as the reset time.

The system allows the possibility of programming a series of conditions which must be fulfilled for the reclosing to occur. These conditions are:

- **Condition 0:** Reclosing always occurs.
- **Condition 1**: While the input "Recloser inhibition" is active there is no reclose. Reclose takes place when this input is deactivated.
- **Condition 2:** Reclosing occurs when there is voltage only on the busbar side.
- **Condition 3:** Reclosing occurs when there is voltage on the busbar, regardless of the presence of voltage on the line.
- **Condition 4:** Reclosing occurs when there is voltage on the line and on the busbar.
- **Condition 5:** Reserved.

***NOTE**: The level of voltage both for the line and for the busbar is 80% of nominal voltage*

If the "HOLD MODE" is set to "YES", the recloser waits for the time set in the "HOLD TIME" setting for the recloser condition selected in the "RECLOSE CONDITIONS" setting to be fulfilled. If this recloser condition is not fulfilled in this time, the recloser goes into "lockout".

If the "HOLD TIME" is set to "NO", the recloser does not take into account the time programmed in the "HOLD TIME" setting.

Recloser logic

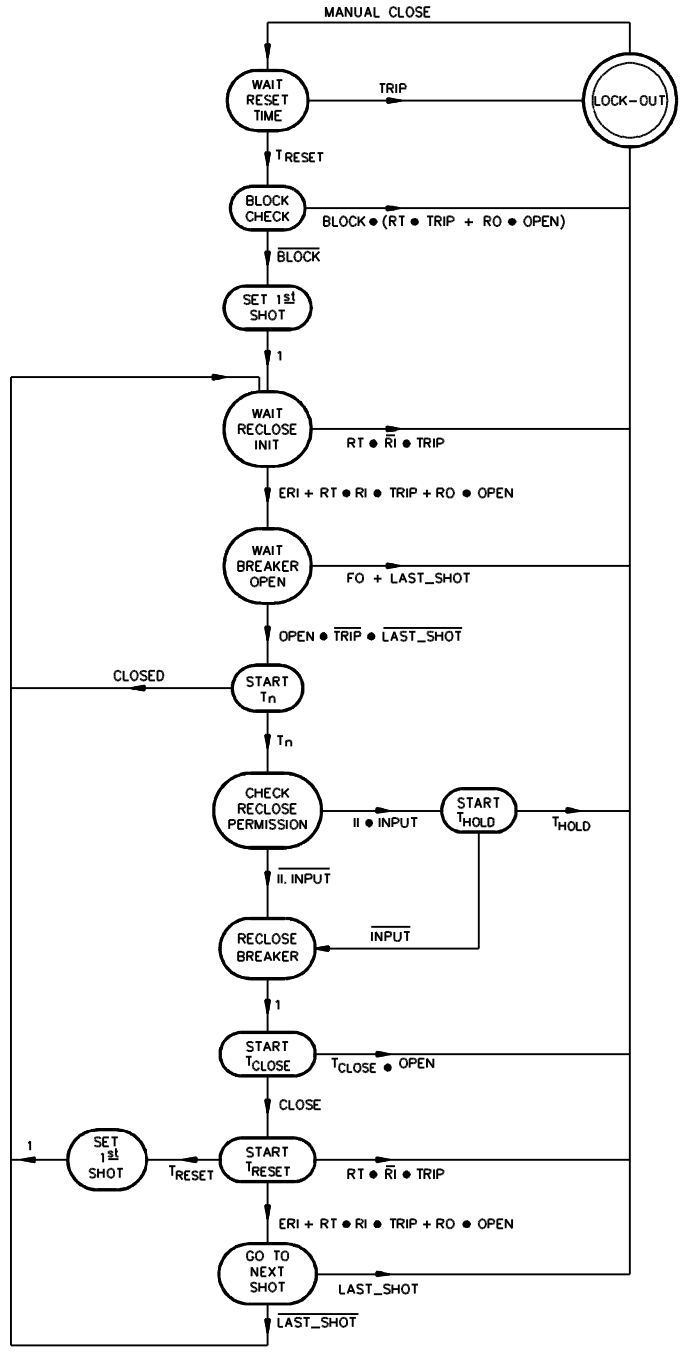
The program flowchart of the recloser, included later in this section, will help to understand the recloser logic. For those who are not familiar with this type of representation the following paragraphs give a summary of how a program flowchart works.

The program flowchart uses circles to represent the state of the recloser. In each circle there is a text with a description of the actions the recloser has to carry out (wait, close, start timer, etc.) or the name of the state ("lock-out", for example).

The double circle shows that the program flowchart starts to operate from this state, which in this case is the "lock-out" state and coincides with the end of the recloser function.

Each circle has at least one exit arrow and one input arrow. The exit arrow is called "transition" and has some conditions associated with it. This means that for the recloser to pass from this state to the next one the conditions indicated in the transition must be fulfilled. The logical condition AND is shown by a dot (·), and the logical condition OR is represented by the plus sign (+). The complement or negation is represented by a bar situated above the condition. The transitions which refer to times occur at the end of the time period indicated in the previous state.

The following figure shows the recloser logic flowchart:



TIMES

T_{RESET}	Reset time
T_n	Time of the nth shot
T_{HOLD}	Hold time
T_{CLOSE}	Time of fail to close

VARIABLES

RI	Reclose initiation
FO	Fail to open
OPEN	Breaker opened
CLOSE	Breaker closed

STATES

LOCK-OUT	End of recloser function

SETTINGS

RT	Recloser on breaker trip (internal trip)
RO	Recloser on breaker opened
II	Permission of recloser inhibit input

DIGITAL INPUTS

ERI	External reclose initiation
INPUT	External recloser inhibit

2.3.2. Synchronism Check Function (25)

Although, the synchronism check function (25) is included in the control sub-module, it is described in this section because it is closely related with the reclosing function located in the protection sub-module.

The main applications of the synchronism check function are:

- Connecting a generator to the system.
- Reestablishing the connection between two parts of the system.
- Manual closing of circuit breakers.
- Automatic reclosing of a breaker after a relay trip.

This unit measures bus and line voltages. It checks:

- Voltage difference.
- Frequency slip.
- The phase angle between both voltages.

The unit provides and output to enable to close the circuit when all the values fall within the set limits and remain there for the duration of time selected for the setting. In the event that all the conditions have not been met, after one minute the unit gives off a signal showing a failure of closing conditions.

The synchronism check function (with voltage in line and bus sides) can be controlled by two undervoltage units, which allow the synchronism operation only when both voltages are above the set value.

Additionally, it is equipped with DLDB dead line-dead bus, DLLB dead line-live bus, and LLDB live line-dead bus units, making it possible to select any combination through independent settings.

2.4. Protection Settings

This section describes, as reference, the settings' tables of a typical component of a DDS system: the SMOR-B feeder protection. These tables include the description of the different settings, ranges and corresponding intervals.

2.4.1. Change of Settings

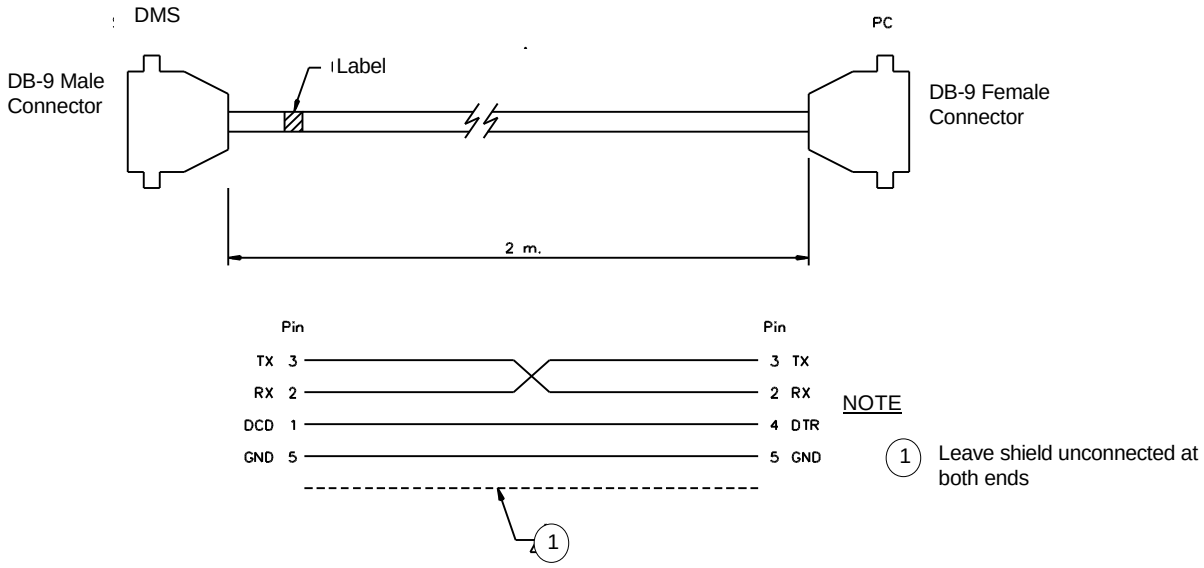
It is possible to see the protection or control settings or to modify them manually, using the keyboard and display, or by means of a computer connected to any of the serial ports. To modify the settings by means of the keyboard, go to section "KEYBOARD AND DISPLAY". To modify the settings by computer, using the GE-LOCAL program, follow these steps:

- Make sure that the available connection cable coincides with the diagram shown in the figure, depending on whether the serial port of your computer is DB9 or DB25.
- Connect the cable between the relay (or modem) and the serial port of your computer.
- Run the GE-LOCAL software. For more details on the installation and use of the GE-LOCAL software see the GE-LOCAL instruction book.
- Make sure that the program's configuration parameters coincide with those of the SMOR unit. More specifically, the parameters on the configuration of the local MMI are the following:

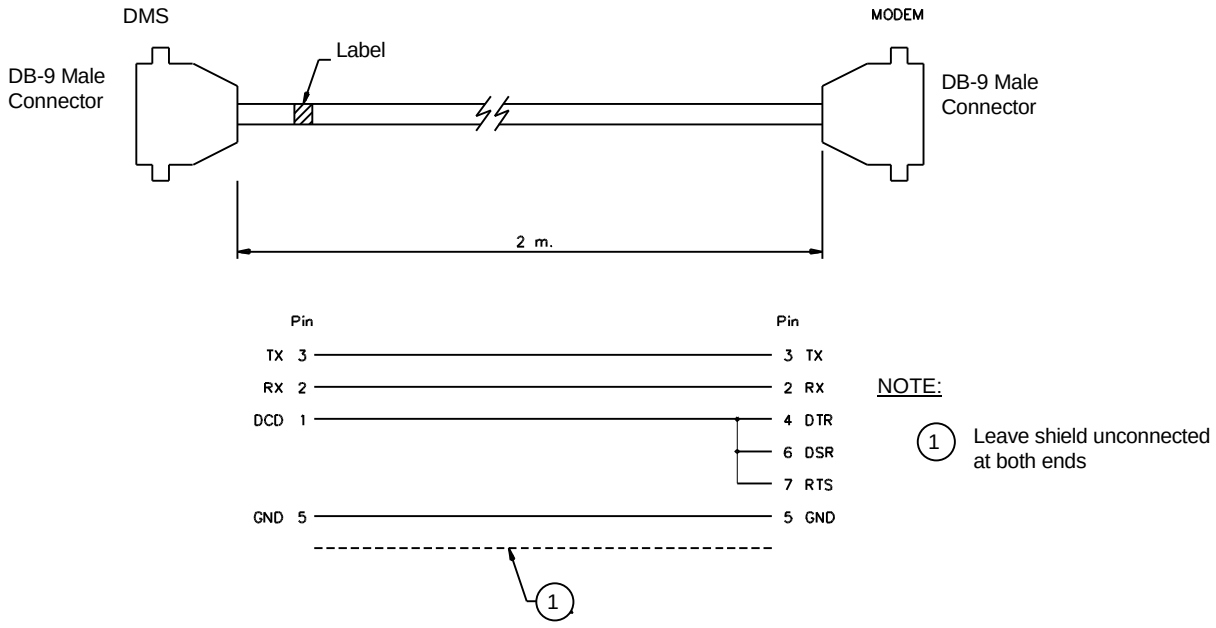
    - COMMUNICATION SPEED (on the relay depending on whether communication is by local or remote port)
    - STOP BIT (on the relay depending on whether communication is by local or remote port)

To modify or view the unit's configuration parameters go to the configuration menu, corresponding to section "KEYBOARD AND DISPLAY".

When connecting to the unit, check that the relay number and password coincide with those which appear on the unit's configuration menu.



RS232 Connection (DMS to PC)



RS232 Connection (DMS to MODEM)

2.4.2. Settings Tables of the SMOR Feeder Protection

The SMOR feeder protection has 3 settings tables stored in non-volatile memory, and these can be selected by settings or configurable inputs. There is also a set of independent settings, common to all the tables. The following categories contain the settings common to the 3 tables:

GENERAL
BREAKER
ACTIVE TABLE
OSCILLOGRAPHY
FUNCTION PERMISSIONS

The remaining categories, shown below, contain the settings which can be selected independently for each of the 3 tables:

- Function 51 PT (Phase Overcurrent)
- Function 51 NT (Ground Overcurrent)
- Function 50 PH (Phase Instantaneous, High Level)
- Function 50 PL (Phase Instantaneous, Low Level)
- Function 50 NH (Ground Instantaneous, High Level)
- Function 50 NL (Ground Instantaneous, Low Level)
- Function 46 PT (Negative Sequence)
- Function 81 (Frequency)

- Function 27/59 (Voltage)
- Directionality
- Recloser

It should be noted that in order to simplify setting the unit and for safety reasons, all settings connected with the configuration of the unit (configurable inputs and outputs, incident configuration and LEDs) have been removed from the keyboard/display and communications software. To carry out these configurations the GE-INTRO configuration software must be run.

The following table shows the settings common to all tables:

TABLE 2.2. Settings common to all tables

Common to all tables	Limits	Default	Interval
General Settings Group			
Relay status	In/out of service	Out of service	NA
Identification	20 ASCII characters	None	NA
Frequency	50 / 60 Hz	60 Hz	NA
Phase PT ratio	1-4000	1	1
Ground PT ratio	1-4000	1	1
Line PT ratio	1-4000	1	1
Bus PT ratio	1-4000	1	1
Demand time	15/30/60 min	60 min	NA
Phase selector	ABC / CBA	ABC	NA
Breaker Setting Group			
Breaker Number	4 ASCII characters	0	NA
Opening failure time	0.05 - 1s	0.5s	0.01s
Closing failure time	0.05 - 5s	1s	0.01s
Accumulative Ampere limit	1 - 999999 k (A^2s)	99999 k (A^2s)	1
I^2t counter operating mode	Fixed / measured	Fixed	NA
Integration time I^2t	0.03 - 0.25s	0.06s	0.01s
Maximum trips in 1 hour	1 - 50	50	1
Active table setting group			
Number of the active settings' table	1 - 3	1	1
Cold start allowed	NO/YES	NO	NA
Time for change to table 3	Reclose time-240s	60s	1s

Common to all tables	Limits	Default	Interval
Time for return from table 3	Safety time-1800s	120s	1s
Oscillography setting group			
Number of pre-fault cycles	2 – 10	2	1
Oscillography Pick-ups per function	Pick-up 51 PT	Enabled	NA
	Pick-up 51 NT	Enabled	NA
	Pick-up 50 PH	Enabled	NA
	Pick-up 50 PL	Enabled	NA
	Pick-up 50 NH	Enabled	NA
	Pick-up 50 NL	Enabled	NA
	Pick-up 46 PT	Enabled	NA
	Pick-up 81 U	Enabled	NA
	Pick-up 81 O	Enabled	NA
	Pick-up 27 P	Enabled	NA
	Pick-up 59 P	Enabled	NA
	Pick-up 59 NH	Enabled	NA
	Pick-up 59 NL	Enabled	NA
	External Input Triggering	Enabled	NA
	CommunicationTriggering.	Enabled	NA
	Trip 51 PT	Enabled	NA
	Trip 51 NT	Enabled	NA
	Trip 50 PH	Enabled	NA
	Trip 50 PL	Enabled	NA
	Trip 50 NH	Enabled	NA
	Trip 50 NL	Enabled	NA
	Trip 46 PT	Enabled	NA
	Trip 81 U	Enabled	NA
	Trip 81 O	Enabled	NA
	Trip 27 P	Enabled	NA
	Trip 59 P	Enabled	NA
	Trip 59 NH	Enabled	NA
	Trip 59 NL	Enabled	NA

Common to all tables	Limits	Default	Interval
Function permission			
Function 51 PT Permission	Not Permitted / / Permitted	Not Permitted	NA
Function 51 NT Permission	Not Permitted / / Permitted	Not Permitted	NA
Function 50 PH Permission	Not Permitted / / Permitted	Not Permitted	NA
Function 50 PL Permission	Not Permitted / / Permitted	Not Permitted	NA
Function 50 NH Permission	Not Permitted /Permitted	Not Permitted	NA
Function 50 NL Permission	Not Permitted / Permitted	Not Permitted	NA
Function 46 PT Permission	Not Permitted / Permitted	Not Permitted	NA
Function 81 U Permission	Not Permitted / Permitted	Not Permitted	NA
Function 81 O Permission	Not Permitted / Permitted	Not Permitted	NA
Function 27 P Permission	Not Permitted / Permitted	Not Permitted	NA
Function 59 P Permission	Not Permitted / Permitted	Not Permitted	NA
Function 59 NH Permission	Not Permitted / Permitted	Not Permitted	NA
Function 59 NL Permission	Not Permitted / Permitted	Not Permitted	NA
Permitted Trips	Mask: NO/YES		
0: Trip 51 PT	Enabled / Disabled	Disabled	NA
1: Trip 51 NT	Enabled / Disabled	Disabled	NA
2: Trip 50 PH	Enabled / Disabled	Disabled	NA
3: Trip 50 PL	Enabled / Disabled	Disabled	NA
4: Trip 50 NH	Enabled / Disabled	Disabled	NA
5: Trip 50 NL	Enabled / Disabled	Disabled	NA
6: Trip 46 PT	Enabled / Disabled	Disabled	NA

Common to all tables	Limits	Default	Interval
7:	Enabled / Disabled	Disabled	NA
8: Trip 81 U	Enabled / Disabled	Disabled	NA
9: Trip 81 O	Enabled / Disabled	Disabled	NA
A: Trip 27 P	Enabled / Disabled	Disabled	NA
B. Trip 59 P	Enabled / Disabled	Disabled	NA
C: Trip 59 NH	Enabled / Disabled	Disabled	NA
D: Trip 59 NL	Enabled / Disabled	Disabled	NA
E:			
F:			

The following table shows the settings that are independent for each table:

TABLE 2.3.. Independent settings for each table

Independent for each table	Limits	Default	Interval
51 PT Settings Group			
51 / 67 P Pick-up level	1.00 – 12.00 A	1.00 A	0.01 A
Curve	Inv / Very Inv /E Inv / Def. Time	3	NA
Time Dial	0.05 – 1.00	1.00	0.01
Definite Time Delay	0.00 – 100	10.00	0.01 s
51 NT Settings Group			
51 / 67 G Pick-up level	0.2 – 2.4 A	0.2 A	0.01 A
Curve	Inv / Very Inv /E Inv / Def. Time	3	NA
Time Dial	0.05 – 1.00	1.00	0.01
Definite Time Delay	0.00 – 100	10.00	0.01 s
50 PH Settings Group			
50 / 67 P Pick-up level	1 – 160 A	2.00 A	0.1 A
Time delay	0.00 – 60 s	0.00 s	0.01 s
50 PL Settings Group			
50 / 67 P Pick-up level	1 – 160 A	2.00 A	0.1 A
Time delay	0.00 – 60 s	0.00 s	0.01 s

Independent for each table	Limits	Default	Interval
50 NH Settings Group			
50 / 67 G Pick-up delay	0.2 – 32 A	1.00 A	0.1 A
Time delay	0.0 – 60 s	0.00s	0.01 s
50 NL Settings Group			
50 / 67 G Pick-up	0.2 – 32 A	1.00 A	0.1 A
Timer	0.0 – 60 s	0.00s	0.01 s
46 PT Settings Group			
46 PT Pick-up level	0.1 – 4 A	0.10 A	0.01 A
Curve	Inv / Very Inv /E Inv / Def. Time	4	NA
Time Dial	0.05 – 1.00	1.00	0.01
Definite Time Delay	0.00 – 100	10.00	0.01 s
81 Settings Group			
81 U Pick-up level	40.00 – 70.00 Hz	40.00 Hz	0.01 Hz
Underfrequency time delay	0.00 – 60.00 s	10 s	0.01 s
81O Pick-up level	40.00 – 70.00 Hz	70.00 Hz	0.01 Hz
Overfrequency time delay	0.00 – 1.00 s	10s	0.01s
Minimum voltage supervision	35 – 110%	40%	1%
Voltage Settings Group			
Undervoltage 27P Pick-up level	10 – 260 V	10V	1 V
Undervoltage activation time	0.03 – 1.00	1.00s	0.01s
Overvoltage 59P Pick-up level	10 – 260 V	260 V	1V
Overvoltage activation time	0.03 – 1.00	1.00s	0.01s
Overvoltage 59 NH Pick-up level	3 – 100 V	100 V	1 V
Time delay	0.03 – 1.00	1.00s	0.01s
Overvoltage 59 NL Pick-up level	3 – 100 V	100 V	1V
Time delay	0.03 – 1.00	1.00 s	0.01 s
Directionality Settings Group			
Direct.. 51 PT permission	Perm. / Not Perm.	NO	NA
Direct.. 51 NT permission	Perm. / Not Perm	NO	NA
Direct.. 50 PH permission	Perm. / Not Perm	NO	NA
Direct. 50 PL permission	Perm. / Not Perm	NO	NA

Independent for each table	Limits	Default	Interval
Direct. 50 NH permission	Perm. / Not Perm	NO	NA
Direct. 50 NL permission	Perm. / Not Perm	NO	NA
Characteristic phase angle	-90º - +90º	45º	1º
Characteristic ground angle	-90º - +90º	-45º	1º
Logic if polarize voltage is lost	Block/ Permiss.	Permission	NA
Recloser Settings Group			
Reclosing permitted	NO/YES	NO	NA
Number of reclosing cycles	1 - 4	1	1
Reset Time	0 - 600 s	10	1 s
Hold mode selection	NO/YES	NO	NA
Hold mode timer	0 - 100s	10	1s
1st reclosing time (RT1)	0.10 - 100s	1s	0.01s
2nd reclosing time (RT2)	0.10 - 100s	1s	0.01s
3rd reclosing time (RT3)	0.10 - 100s	1s	0.01s
4th reclosing time (RT4)	0.10 - 100s	1s	0.01s
Reclosing conditions	0 -5	0	1
	0. No condition		
	1. Check Inhibition Input		
	2. Voltage only on busbar		
	3. Voltage on busbar		
	4. Voltage on both sides		
Functions that Initiate Reclosing	Mask: NO/YES	All YES	
	51 PT	Enabled /Disabled	
	51 NT		
	50 PH		
	50 PL		
	50 NH		
	50 NL		
	46 PT		
	81 U		
	81 O		
	27P		
	27 P		
	59 NH		
	59 NL		

Independent for each table	Limits	Default	Interval
	External input		
Mask trips after 1st reclose	Mask: NO/YES	All YES	NA
	51 PT	Enabled	
	51 NT		
	50 PH		
	50 PL		
	50 NH		
	50 NL		
	46 PT		
	81 U		
	81 O		
	27 P		
	27 P		
	59 NH		
	59 NL		

3. MEASURING, MONITORING AND ANALYSIS FUNCTIONS

3.1. Measuring Functions

DDS system has been designed to deal with up to 32 measured analog signals. These signals are fixed during the development of the specific DDS equipment at our factory, and may vary depending on the type of DDS relay; a voltage relay and an overcurrent relay will handle different type of measurements.

These measurements may be:

- Phase A, B and C currents, Neutral current.
- Negative Sequence Current.
- Phase to phase voltages.
- Active and Reactive Power.
- Power factor.
- Frequency.
- etc.

User can get to these measurements by means of the two lines LCD display or using the graphical display of the relay (if available), or through a communication link, a PC and running the communication software GE_LOCAL.

3.2 Demand. (Load Profile).

DDS relays may include a Demand monitoring function (Load Profile), as well as maximeter function for current and active power (as required). The Demand monitoring function computes the maximum rms current and the average current for each phase during a selectable time period, 15, 30 or 60 minutes. Depending on the period selected, user will have information corresponding to the last 24, 48 or 96 hours respectively. Maximeters will record the maximum value of current and power (as required), using the same period of time set for the Demand monitoring function.

Example of a Current Demand monitoring function set to 15 minutes:

Demand Monitoring File.
Identification: ABCDEF
03-10-1996 17:57:46

Date	Time	Ia	Ib	Ic	Ia average	Ic average	Ic average
03 / 10	12 : 30	0.19	0.21	0.20	0.19	0.21	0.19
03 / 10	12 : 45	0.50	0.51	0.49	0.27	0.27	0.26
03 / 10	13 : 00	0.49	0.50	0.50	0.30	0.31	0.31
03 / 10	13 : 15	0.30	0.31	0.30	0.29	0.29	0.29
03 / 10	13 : 30	0.30	0.30	0.30	0.29	0.29	0.28
03 / 10	13 : 45	0.30	0.30	0.30	0.29	0.29	0.29
03 / 10	14 : 00	0.30	0.31	0.30	0.29	0.29	0.29
03 / 10	14 : 15	0.30	0.31	0.30	0.29	0.29	0.29
03 / 10	14 : 30	0.40	0.40	0.39	0.29	0.29	0.28
03 / 10	14 : 45	0.20	0.22	0.20	0.19	0.20	0.19
03 / 10	15 : 00	0.20	0.21	0.20	0.18	0.19	0.16
03 / 10	15 : 15	0.29	0.30	0.29	0.21	0.21	0.20
03 / 10	15 : 30	0.30	0.30	0.30	0.27	0.28	0.27
03 / 10	15 : 45	0.21	0.22	0.20	0.19	0.21	0.19
03 / 10	16 : 00	0.25	0.26	0.23	0.18	0.19	0.17
03 / 10	16 : 15	0.22	0.22	0.21	0.21	0.20	0.20
03 / 10	16 : 30	0.22	0.22	0.21	0.20	0.21	0.20
03 / 10	16 : 45	0.22	0.22	0.21	0.20	0.20	0.20

3.3. Switchgear Status.

DDS equipment monitors the status of all the switchgear items (circuit breaker, line switch, ground switch, Bus-bar switch, etc.) associated to a particular bay, by using the digital inputs configured by the user. The status of this different switchgear items (up to 7) can be checked by using the graphical LCD display (graphical MMI) in the front plate of the relay, or using a communication link, a PC and the GE_LOCAL communication software. In this way, it is very simple to monitor the status of the whole bay, as well as to perform control actions on any of the switchgear items, as open the circuit breaker, close the ground switch, etc. (if the items are motorized and can be remotely operated).

3.4 Visual Signaling, LEDs.

It is possible to have up to 17 visual signaling (LEDs) in the front panel of some DDS equipment (2 RU height protection relays, like SMOR, DBF, MOV, etc.). One of them is a two-color LED and has a fixed function assigned, this is the equipment alarm (red) or ready status (green). The 16 LEDs left are red color LEDs, and can be configured by the user by means of the GE_INTRO software and a communication link. LEDs can be assigned to light when a selectable combination (16 input AND gate) of the 96 internal events defined by the user gets active or gets deactivated. The 96 events are composed by 48 control events, 32 protection events and 16 communication events). These 96 events are configured also by the user, and each one of them will become active when a selectable combination (16 input OR gate) of internal signals in the status panel of the relay becomes active. (Note: when defining

inputs for the AND or OR gates, the 16 inputs for a particular gate must belong to the same functional group of signals). LEDs also include two additional features. Each LED can be set to blink or not when active, and also it can be set to be a memorized LED. Memorized LEDs will remain ON (blinking or steady, depending on the previous setting) after the relay is switched OFF and ON (memorized LEDs status is stored in an EEPROM memory).

The internal signals available to define the 96 events (which are used to configure LEDs, etc.) are the complete description of the status of the relay, gathering the information of all the different units and functions of the relay (inputs, pick-ups, alarms, etc.). The signals available in the status panel of the relay are grouped into 10 groups of 16 signals each.

The relay also includes a TARGET RESET push button to tests the status of all LEDs (pushing it forces all the LEDs to light). This button is also used to reset the signaling if it is pushed and hold for 1 second.

3.5 Tripping and Closing Circuits Supervision

DDS equipment may include two control circuit supervision (tripping and/or closing circuits) for the tripping and closing coils of the circuit breaker (one input per coil). These supervision inputs monitor both control voltage and tripping and/or closing circuit continuity, monitoring a current injected to these circuits.

The DDS relay will store in the event recorder and in the relay status panel, independently, the circuit continuity for each coil 'Circuit Continuity Alarm – Coil #1', as well as the loss of control voltage 'Control Voltage Alarm – Coil #1'.

Circuit Continuity supervision is performed independently on the open or closed status of the circuit breaker, due the circuit continuity supervision is connected to both 52/a and 52/b auxiliary contacts. The following diagrams show how to connect the relay for a correct tripping and/or closing circuits supervision:

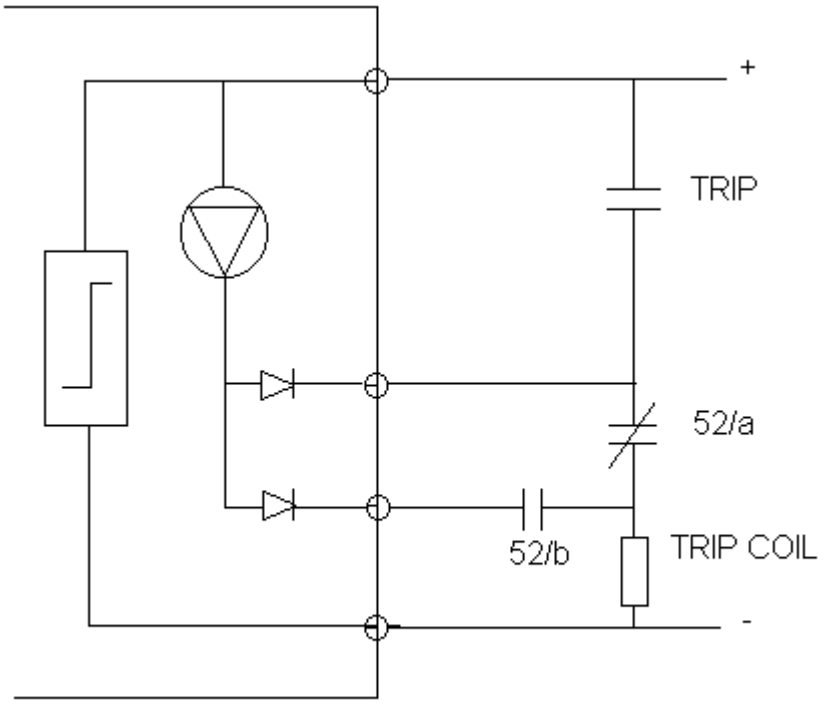


Figure 3.1 *Tripping Coil Supervision.*

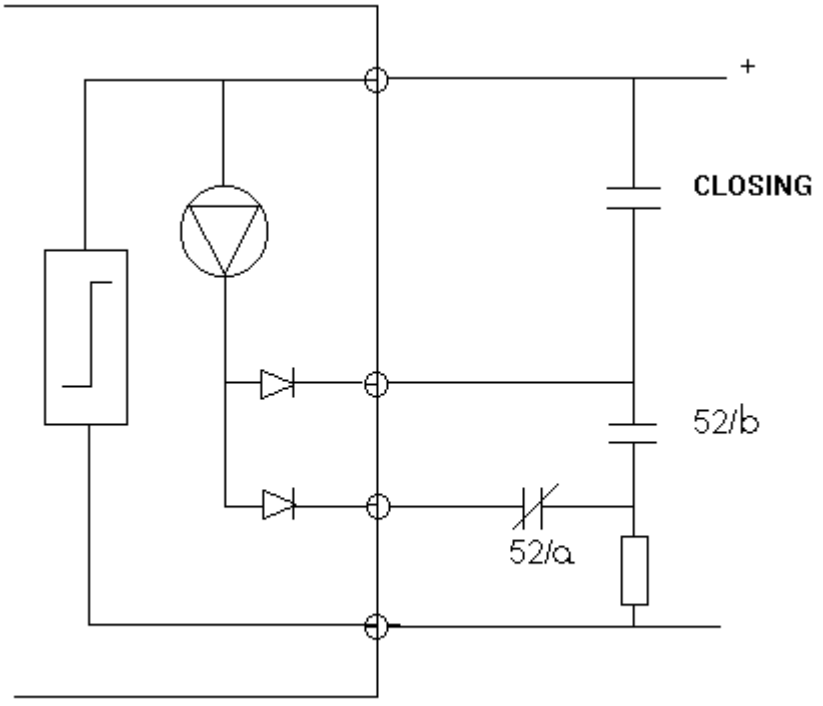


Figure 3.2 *Closing Coil Supervision.*

3.6 Circuit Breaker Aging Monitoring

DDS system can monitor circuit breaker aging, by computing and storing the accumulated I^2t in the opening operations of the breaker. (When current magnitude is lower than nominal current, then nominal current magnitude is used to perform the I^2t value). There are three different counters to compute and accumulate the I^2t magnitude for each phase. Counters can be checked from the local MMI graphical LCD display, as well as from a PC, by means of a communication link and the GE_LOCAL communication software. There is an additional counter to store the number of openings of the circuit breaker.

'Integration Time Selection' setting allows the user to chose from a fixed time value to compute I^2t, time set by the user into 'Integration Time' setting, or let the relay measures the opening time (since opening command is issued until the circuit breaker opens) and then uses it to compute I^2t.

'Maximum Accumulable Amps' setting states the upper limit for the I^2t counter. This setting should be set taking into account the specifications given by the circuit breaker manufacturer. Then the ΣI^2t counter exceeds the limit set, the relay issues an alarm signal.

The propose of this function is to allow a preventive maintenance procedure for the circuit breaker, more accurate than the maintenance procedure based on fixed periods of time, without taking into account the number of openings nor the I^2t magnitude. Once the maintenance operation is done, the I^2t counters can be reset to zero, and get ready to begin a new count.

In order to allow the user to install a new DDS relay with an already existing breaker, with an accumulated I^2t and number of opening operations, counters can be initialized to a specific value, computed by the user or by other means, for the DDS to begin its count from a given value.

3.7 Self-check Functions

DDS system, due to its microprocessor based digital technology, includes self-checking functions, to guaranty the correct performance of the equipment, and its inhibition and alarm indication in case an internal error is detected.

There are start-up self-checking functions and run-time self-checking functions (making use of the microprocessors 'idle time' during system quiescent state). Self-checks are performed on the internal power supply, program memory (ROM), work memory (RAM), oscillographic memory (RAM) and the settings and caliber memory (EEPROM).

Additionally, there is a hardware implemented test for the signaling LEDs. By using the TARGET RESET push button in the front panel of the relay, a test can be

performed (all LEDs should light). Pushing and holding for more than 1 second will produce the resetting of all memorized LEDs.

3.8 Analysis Functions

DDS system includes recording functions, as event recording and oscillographic recording, with a time tagging accuracy of 1 ms. In order to maintain the recorded information as well as the date and time in case the relay is switched off, there is a capacitor back up supply feature. This back up supply is intended for external power supply interruptions no longer than 24 hours.

Protection functions are independent on the other features of the system. There is a dedicated microprocessor to perform protection functions, and its operation is guarantied even in the lose of the communication board or any other part of the system.

3.9 Event Recorder

DDS system keeps a record with the last 150 events detected by the relay. Events are generated by the protection module and have the following structure:

- Event name (descriptive text).
- Date and Time (1 ms resolution.)
- Present currents and voltages.
- Status of the module generating the event.

Example of a PC screen showing the list of events with the additional information stored for each event:

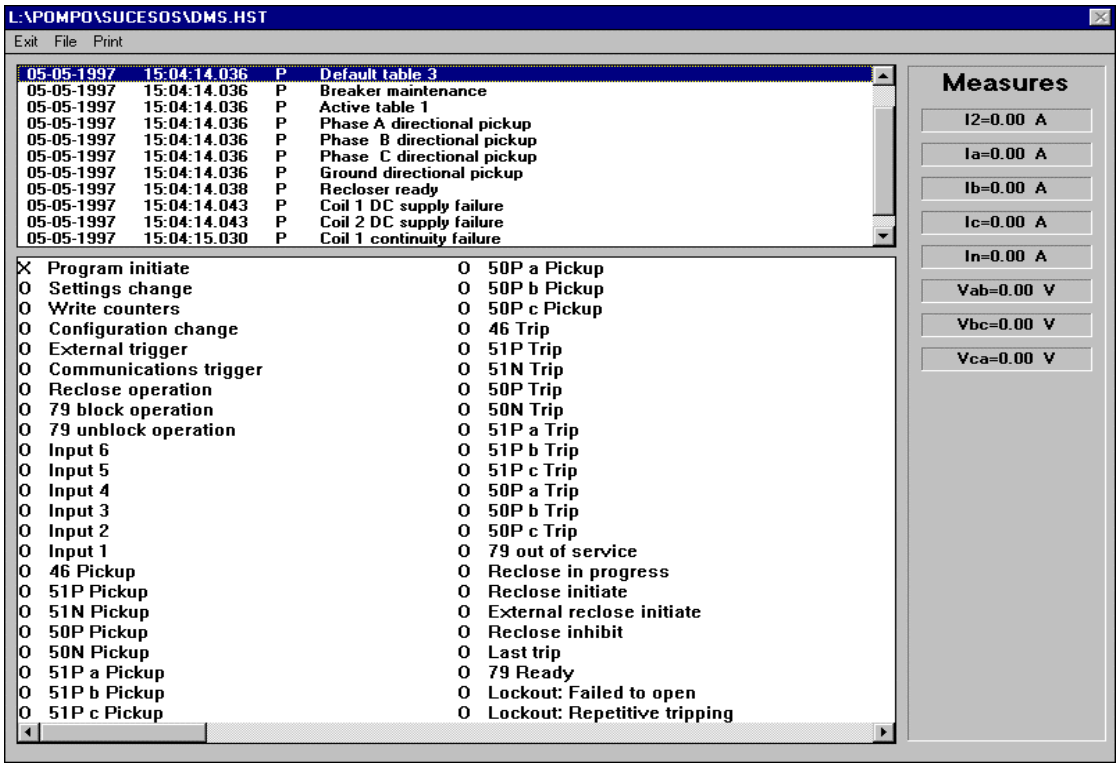


Figure 3.3 *Event register.*

The event register is stored on a EEPROM memory (permanent memory) and it is maintained even if power supply is lost (independently on the duration of the external power supply interruption).

Next follows an example of events that can be generated by a DDS relay, depending on the functions it performs.

Table 3.1 *Event list for DDS relays.*

25		**Synchro-check**
	1	Dead Line - Dead Bus
	2	Live Line - Dead Bus
	3	Dead Line - Live Bus
	4	Live Line - Live Bus
	5	SYNCHRO-CHECK for closing command
	6	SYNCHRO-CHECK for reclosing command
	7	Closing permission
	8	Reclosing permission
	9	Voltage in Phase A
	10	Voltage in Phase B
	11	Voltage in Phase C
	12	Voltage in Bus

	13	Voltage in Bus 1
	14	Voltage in Bus 2
	15	Voltage at both sides of 52-1
	16	Voltage at both sides of 52-0
	17	Voltage at one side of 52-1
	18	Voltage at one side of 52-0
	19	No Voltage in Phase A
	20	No Voltage in Phase B
	21	No Voltage in Phase C
	22	No Voltage in Bus
	23	No Voltage in Bus 1
	24	No Voltage in Bus 2
	25	No Voltage in Line
	26	No Voltage in one side of 52-1
	27	No Voltage in one side of 52-0
27		**Undervoltage**
	1	Bus Undervoltage Pick Up
	2	Bus 1 Undervoltage Pick Up
	3	Bus 2 Undervoltage Pick Up
	10	Weak Infeed Phase A
	11	Weak Infeed Phase B
	12	Weak Infeed Phase C
	16	Phase Undervoltage Pick Up
	17	Single Phase Undervoltage Pick Up
	18	Phase A Undervoltage Pick Up
	19	Phase B Undervoltage Pick Up
	20	Phase C Undervoltage Pick Up
	21	Two Phase Undervoltage Pick Up
	22	Phases AB Undervoltage Pick Up
	23	Phases BC Undervoltage Pick Up
	24	Phases CA Undervoltage Pick Up
	25	Three Phase Undervoltage Pick Up
	26	Neutral Undervoltage Pick Up
	29	Ungrounded Neutral Undervoltage Pick Up
	32	Phase Undervoltage Trip
	33	Single Phase Undervoltage Trip
	34	Phase A Undervoltage Trip
	35	Phase B Undervoltage Trip
	36	Phase C Undervoltage Trip
	37	Two Phase Undervoltage Trip
	38	Phases AB Undervoltage Trip
	39	Phases BC Undervoltage Trip
	40	Phases CA Undervoltage Trip
	41	Three Phase Undervoltage Trip
	42	Neutral Undervoltage Trip
	45	Ungrounded Neutral Undervoltage Trip
	46	Three Phase Undervoltage 52-1 Trip
	47	Three Phase Undervoltage 52-0 Trip

46		**Negative Sequence**
	25	Negative Sequence Pick Up
	41	Negative Sequence Trip
50		**Instantaneous Overcurrent**
	0	Phase Ins. Overcurrent Pick Up (High)
	1	Phase Ins. Overcurrent Pick Up (Low)
	2	Phase Ins. Overcurrent Trip (High)
	3	Phase Ins. Overcurrent Trip (Low)
	16	Phase Ins. Overcurrent Pick Up
	17	Single Phase Ins. Overcurrent Pick Up
	18	Phase A Inst. Overcurrent Pick Up
	19	Phase B Inst. Overcurrent Pick Up
	20	Phase C Inst. Overcurrent Pick Up
	21	Phase to Phase Ins. Overcurrent Pick Up
	22	Phases AB Ins. Overcurrent Pick Up
	23	Phases BC Ins. Overcurrent Pick Up
	24	Phases CA Ins. Overcurrent Pick Up
	25	Three Phase Ins. Overcurrent Pick Up
	26	Neutral Ins. Overcurrent Pick Up
	29	Ungrounded Neutral Ins. Overcurrent Pick Up
	32	Phase Ins. Overcurrent Trip
	33	Single Phase Ins. Overcurrent Trip
	34	Phase A Inst. Overcurrent Trip
	35	Phase B Inst. Overcurrent Trip
	36	Phase C Inst. Overcurrent Trip
	37	Phase to Phase Ins. Overcurrent Trip
	38	Phases AB Ins. Overcurrent Trip
	39	Phases BC Ins. Overcurrent Trip
	40	Phases CA Ins. Overcurrent Trip
	41	Three Phase Ins. Overcurrent Trip
	42	Neutral Ins. Overcurrent Trip
	45	Ungrounded Neutral Ins. Overcurrent Trip
51		**Timed Overcurrent**
	16	Phase Timed Overcurrent Pick Up
	17	Single Phase Timed Overcurrent Pick Up
	18	Phase A Timed Overcurrent Pick Up
	19	Phase B Timed Overcurrent Pick Up
	20	Phase C Timed Overcurrent Pick Up
	21	Phase to Phase Timed Overcurrent Pick Up
	22	Phases AB Timed Overcurrent Pick Up
	23	Phases BC Timed Overcurrent Pick Up
	24	Phases CA Timed Overcurrent Pick Up
	25	Three Phase Timed Overcurrent Pick Up
	26	Neutral Timed Overcurrent Pick Up
	29	Ungrounded Neutral Timed Overcurrent Pick Up
	32	Phase Timed Overcurrent Trip
	33	Single Phase Timed Overcurrent Trip
	34	Phase A Timed Overcurrent Trip

	35	Phase B Timed Overcurrent Trip
	36	Phase C Timed Overcurrent Trip
	37	Phase to Phase Timed Overcurrent Trip
	38	Phases AB Timed Overcurrent Trip
	39	Phases BC Timed Overcurrent Trip
	40	Phases CA Timed Overcurrent Trip
	41	Three Phase Timed Overcurrent Trip
	42	Neutral Timed Overcurrent Trip
	45	Ungrounded Neutral Timed Overcurrent Trip
52		**Circuit Breaker**
	1	Circuit Breaker Closed
	2	Circuit Breaker Status undefined
	3	Circuit Breaker Opening Failure
	4	Circuit Breaker Closing Failure
	5	Circuit Breaker Maintenance
	6	Tripping output ON
	7	Phase A Closed
	8	Phase B Closed
	9	Phase C Closed

Associated with each event, the DDS relay stores all the information available about the status of the module generating he event. See the follow table for an example of the information available for a protection module.

***Table 3.2**. Example of protection status*

0.0 Program Initialization
0.1 Change of Settings
0.2 Counters modification
0.3 Configuration Change
0.4 External Trigger
0.5 Communication Trigger
1.0 Reclose Command
1.1 Block Recloser Command
1.2 Unblock Recloser Command
3.0 Input #7, etc.
3.1 Input #6
3.2 Input #5
3.3 Input #4
3.4 Input #3
3.5 Input #2
3.6 Input #1
4.0 46 Function Pick Up
4.1 51P Function Pick Up
4.2 51N Function Pick Up
4.3 50P Function Pick Up
4.4 50N Function Pick Up
5.0 51P A Function Pick Up
5.1 51P B Function Pick Up

5.2 51P C Function Pick Up
5.4 50P A Function Pick Up
5.5 50P B Function Pick Up
5.6 50P C Function Pick Up
6.0 46 Function Trip
6.1 51P Function Trip
6.2 51N Function Trip
6.3 50P Function Trip
6.4 50N Function Trip
7.0 51P A Function Trip
7.1 51P B Function Trip
7.2 51P C Function Trip
7.4 50P A Function Trip
7.5 50P B Function Trip
7.6 50P C Function Trip

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3.10 Alarms Treatment

DDS relays include Alarm generation and treatment functions. Alarms are relevant system operating conditions or status, as defined by the user, which are desired to be specially indicated or signaled by the DDS system.

It can be defined up to 32 different Alarms. To define an Alarm, the user may use all the information available in the status panel of the protection module and the status of the control module of the DDS system. 16 inputs OR gates may be used to define alarms.

Alarms will be shown at the graphical MMI display in the front panel of the relay, as soon as they are generated, tagged with date and time information. Alarms will also be transferred through the communication link to the Level 2 (Local Protection & Control Room) and Level 3 (Remote P&C Office, if available).

There are four different status for a given alarm:

- Active alarm and not acknowledged by the operator.
- Active alarm and acknowledged by the operator.
- Non active alarm and not acknowledged by the operator.
- Non active alarm and already acknowledged by the operator.

DDS system will present alarms in different formats depending on their status. The text message associated to an alarm, which will be also defined by the user, will appear in the graphical MMI in the front panel of the relay in one of the following formats: (also see the MMI chapter of this instruction book for a detailed description.)

- Active and not acknowledged: Dark Background, Blinking Text, with a star character.
- Active and acknowledged: Normal Steady Text, with a star character.

- Non active and not acknowledged: Dark Background, Steady Text, with a star character.
- Non active and acknowledged: Text disappears from LCD display.

This is:

- Dark background means NOT ACKNOWLEDGED.
- Star character means ACTIVE ALARM.

By using the keys around the graphical display, user may acknowledge a particular alarm (or all of them with a single key).

3.11 Signaling

DDS system includes a different type of signaling function, which also generates date and time tagged signals.

In this case, signals are not shown in the local graphical MMI in the front panel of the relay, but they are transferred by a communication link to Level 2 and 3 (if exists), and can be send to a local printer as they are generated. These signals do not need the treatment alarms need (acknowledging, etc.)

3.12. Oscillography Recorder

DDS relays keep four oscillography records, associated to the last four faults, or oscillography triggers, with 16 samples per cycle resolution. Each oscillography record has a fixed length of 66 cycles, with a configurable prefault, from 2 to 10 cycles. The exact content of an oscillography record depends on the DDS relay model (if the relay has current inputs or not, etc.). In general, it will content the following information:

- 66 cycles of all analog inputs, voltages and currents (IA, IB, IC, IN, VAB, VBC, VCA, VBUS, etc.), with 2 to 10 prefault cycles.

- Digital flags information, containing information as Protection functions Pick Ups, Trips, Drop Out, Activation of Inputs, Outputs, Recloser digital signals, etc.

- Date and Time.

- Causes that generated the oscillography record.

It can be configured the causes that can trigger the oscillography function, which functions or internal trips. Oscillography may also be triggered by an external input, and also by a command through the communication link.

Oscillography records are stored in RAM memory with a capacitor back up. This information will not be lost if the external power supply is lost for less than 24 hours. The oscillography records are taken from the relay using the GE_LOCAL communication software, and stored into a file in the COMTRADE (IEEE C37.111-1991) standard format. These files can be visualized by the GE_OSC analysis software, or commercially available software like EXCEL, etc. importing the oscillography '.DAT' ASCII file.

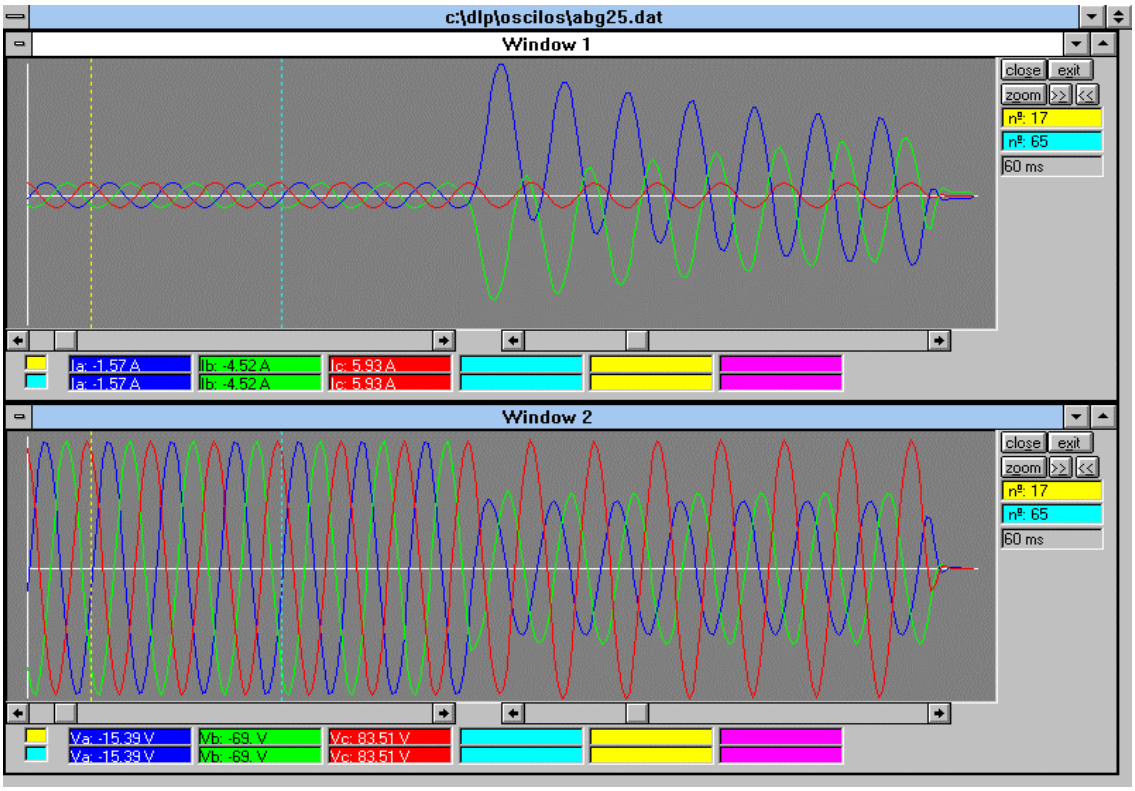


Figure 3.4 *GE_OSC analysis software*

GE_OSC has been designed to work with COMTRADE (IEEE C37.111-1991) Standard files, and allows the user to:

- Visualize analog channels recorded by the relay.
- Zoom in and out into these analog channels.
- Visualize digital channels recorded by the relay.
- Zoom in and out into these digital channels.
- Customize the presentations by template definition.
- Perform Phasor analysis, sample by sample, computing phase phasors and symmetrical components phasors.
- Access to advanced fault analysis tools designed by GE Power Management.

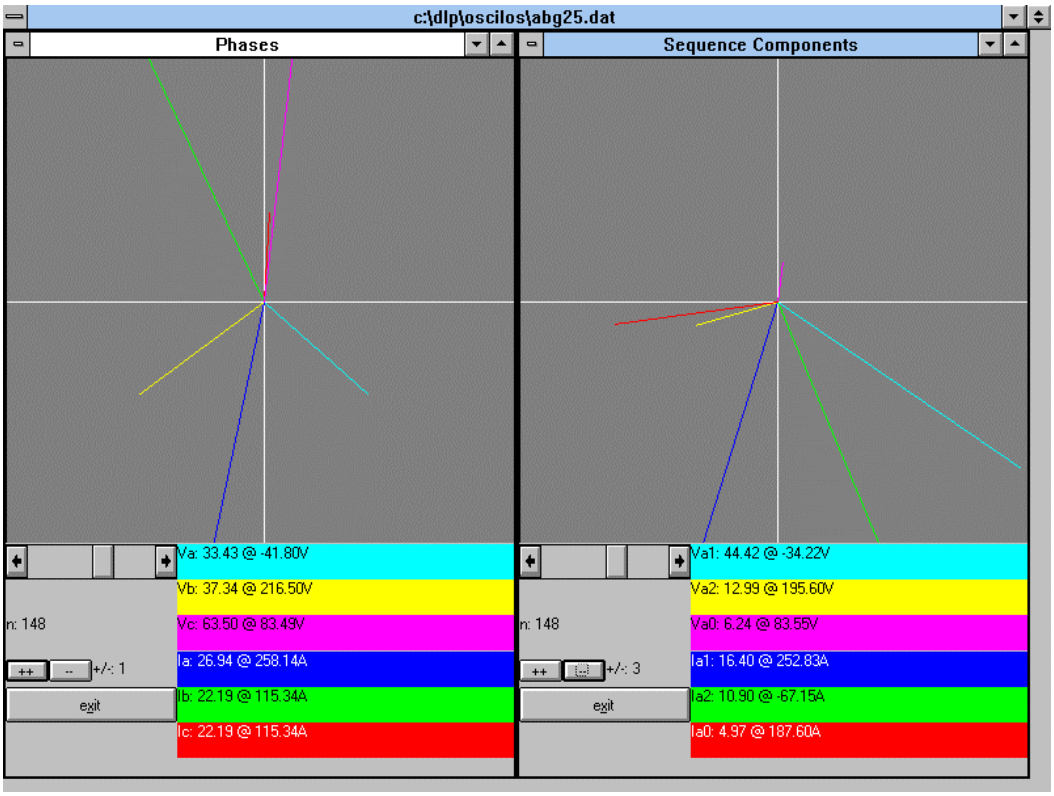


Figure 3.5 *Phasor analysis*

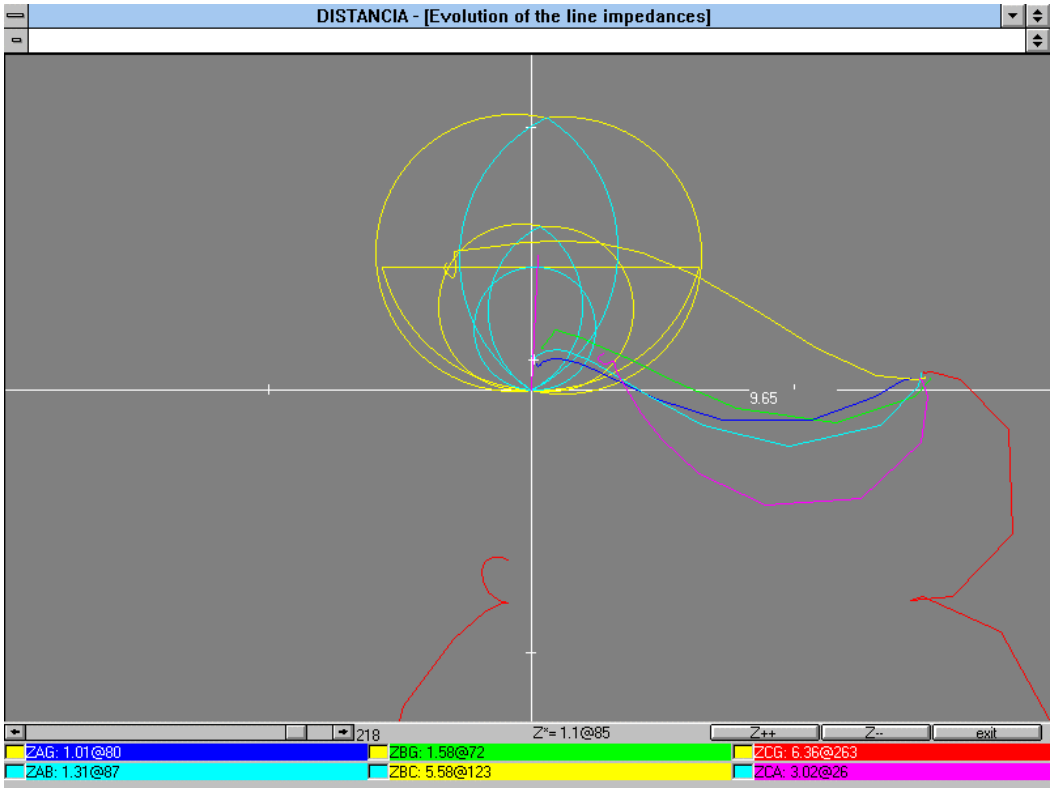


Figure 3.6 *Distance analysis tool.*

For further information refer to GE_OSC instruction book.

The COMTRADE format used for the DDS oscillography records is the IEEE Standard Common Format for Transient Data Exchange for Power Systems, IEEE C37.111-1991. This standard defines three different files for a given transient record:

1. Data File:

('.DAT' extension). This files contain all the analog values, sample by sample for each channel. This values must be integer numbers and the structure is the following:

n, tt, A1, A2, A3, ..., D1, D2, D3, ..., Dm

where:

n = sample number.
tt = time corresponding to the sample, in microseconds.
A1 .. Ak = Integer number corresponding to the value of the sample, for each channel, from 1 to k analog channels.
D1 .. Dm = 1 or 0 digits, indicating the value of each digital channel, from 1 to m digital channels.

2. Configuration channel:

('.CFG' extension) This file contain the description of the data file contain, with this structure:

Identif., number
TT, nnA, nnD
nn, id, p, cccccc, uu, a, b, skew, min, max

nn, id, p, cccccc, uu, a, b, skew, min, max
nn, id, m

nn, id, m
freq.
nrates
sssss1, endsample1
sssss2, endsample2

sssss2, endsample2
mm/dd/yy, hh:mm:ss.ssssss
mm/dd/yy, hh:mm:ss.ssssss
Data file type

where :

Identif.:	Identification, Text.
number:	Identification, number.
TT:	Number of channels in data file.
nnA:	Number of analog channels in data file.
nnD:	Number of digital channels in data file.
nn:	Channel number.
id:	Channel identifier.
p:	Phase identifier.
cccccc:	Circuit/component being monitored.
uu:	Units (kV, MVA, etc.)
a:	Real number for the following equation:
b:	Real number for the following equation. Actual value recorded = a x integer number in data file + b
skew:	Real number to take into account the time difference between different channels in the same sample number.
min:	Integer number, minimum value of the corresponding channel.
max:	Integer number, maximum value of the corresponding channel.
m:	Normal status of each channel (for digital channel only).
freq.:	System frequency (50/60)
nrates:	Number of different sampling rates used in data file.
sssss1:	Sampling rate #1.
endsample1:	Last sample number taken at sample rate sssss1.
sssss2:	Sampling rate a #2.
endsample2:	Last sample number taken at sample rate sssss2.
etc.	
sssssn:	Sampling rate #n.
endsamplen:	Last sample number taken at sample rate sssssn.
mm:	Month
dd:	Day
yy:	Year
mm:	Minutes.
ss.ssssss:	Seconds.
Data File type:	ASCII or BINARY

3. Header File:

('.HDR' extension). This is a free format text file which contain additional information on the oscillography record. DDS system uses this file to store all the settings the relay was using at the moment the oscillography recorder war triggered. This is done in order to help analyze the performance of the protection functions of the DDS.

4. CONTROL FUNCTIONS IN DDS SYSTEM

4.1. Introduction

DDS integrated system includes in the same equipment Protection functions (see corresponding chapter in this instruction book) and Control functions, which will be described in this chapter.

The Control Module in DDS system comprises the following functions:

4.1.1. Switchgear Control Functions

This set of functions allows the user to:

- Define the existing switchgear items into a particular bay, which will be operated by the DDS relay.
- Configure (Design) the graphical display in the local MMI, in the front panel of the relay, by using the items of the DDS data base (circuit breaker, line switch, ground switch, etc.)
- Monitor the status of the switchgear defined, by means of the local graphical display in the front panel of the relay, or by using a communication link, a PC and the GE_LOCAL communication software.
- Perform control actions (open - close) on the HV switchgear items (circuit breaker, line and ground switches, etc.) locally, using the graphical display, or remotely, with a communication link and a PC.
- Perform control actions (open - close) on the HV switchgear items (circuit breaker, line and ground switches, etc.) by using external contacts of the DDS relay (inputs), using pulses from a conventional RTU.
- Monitor operations performed on the HV switchgear items, to generate closing and opening failure alarms, independently on the way the control action was done (locally, remotely)
- Define the interlockings per switchgear item and per control action, which allow or not the performance of a closing or opening control action.
- Define failure conditions per switchgear item and per control action, which cancel an operation.
- Define success conditions, per switchgear and per control action, to determine when a control action has been successfully performed.

4.1.2. External Equipment Control.

- Monitor the status of external equipment, like external reclosers, external synchro-check etc.
- Perform control actions on these equipment, like get an external recloser in service, or out of service, rise or lower taps in an OLTC on a Power Transformer, with similar interlockings, failure conditions and success conditions definition.

4.1.3. Input and Output Configuration

- Define output contacts associated to each control action (open circuit breaker, close circuit breaker, open line switch, close line switch, etc.)
- Define output contacts associated to each output signal defined in the internal logic, using 16 inputs OR gates and all the internal information available in the status panel of the DDS relay.
- Define input contacts which are wanted to be used to define the internal logic.
- Define timers (if wanted) for the digital inputs.

4.1.4. Event Generation and Treatment

- Generation and treatment of two different user defined events: Alarms and Signaling. (see sections 3.11 and 3.12)
- Define Alarms:
    - Alarm Text description.
    - when it has to be generated (using 16 inputs OR gates and all the information available in the status panel of the control and protection DDS modules.)
- Manage generated alarms, differing among four different alarm status:
    - Active alarm and acknowledged by the operator.
    - Active alarm and not acknowledged by the operator
    - Non active alarm and not acknowledged by the operator.
    - Non active alarm and acknowledge by the operator
- Define Signaling (same procedure as in alarms definition.)

4.1.5. Analog, Binary and Pulse inputs.

- Define analog inputs (mA or mV), to measure temperatures, fault distances from other protection equipment, and in general, analog signals coming from any standard converter.

- Configure binary inputs. The defined group of digital inputs will conform a 8 bits binary number for the DDS system to use as information for the internal logic.
- Define pulse inputs, for power metering, etc.

4.1.6. Miscellaneous Control Functions.

- On Load Tap Changer for Power Transformers (OLTC).
- Synchro-check function.
- Voltage functions (Live or Dead) for line and bus bar side.
- Measuring of present values of phase currents, negative sequence current, zero sequence current, voltages, power factor, active power, reactive power, etc.
- Define logic circuits. There are 4 circuits available: the output of two of them is the output of an OR gate of 3 AND gates (64 inputs AND gates). The output of the other two is the output of an OR gate of 4 AND gates (64 inputs AND gates).

The above mentioned functions are configured by using a PC software and a communication link. GE_INTRO is the PC software designed to configure DDS relays. It is a Windows based program, and belong to the software package called GE_NESIS (GE_LOCAL, GE_INTRO and GE_OSC). Refer to the specific instruction book for a more detailed description of each program.

The configuration procedure using GE_INTRO is described in the following sections. For more details please refer to the GE_INTRO software instruction book.

4.2 Configuration Procedure.

DDS Control configuration will be divided into 11 sections:

4.2.1 HV Switchgear Configuration.

Up to 7 HV switchgear items can be defined in to the DDS system (circuit breaker, line switch, ground switch, bus-bar A switch, bus-bar B switch, by-pass switch, etc.). Into this section, the user defines which HV switchgear items will be associated to a specific DDS relay (bay items) and also the opening and closing times. The opening and closing times are the time 52/a and 52/b auxiliary contacts are allowed to be both in the same status (open or close, transient situation before the HV item finally opens or closes) before issuing a 'Opening Failure Alarm' or 'Closing Failure Alarm'.

It is possible to use only one auxiliary contact instead of two (52/a and 52/b). In this case, the mentioned alarm will not be issued.

The following example shows a bay configuration, with 4 HV switchgear items and 1 external equipment:

- Circuit breaker (52).
- Ground switch (89E).
- Line switch (89L).
- Bus-bar switch (89B).
- External recloser (79 EXT).

Switchgear item	Opening Time	Closing Time
52	1000 ms	1000 ms
89E	30000 ms	30000 ms
89L	30000 ms	30000 ms
89B	30000 ms	30000 ms
79 EXT	40 ms	40 ms

79 EXT input will define the status of the external recloser, In Service or Out of Service.

4.2.2 Control Actions Configuration: Operation Time, Dwell Time and Failure Time.

The control module of the DDS can perform up to 16 control actions, 2 of them are fixed (Block and Unblock Control Module), and 14 can be configured. Control commands may come from local communications (local keyboard and display), from remote communications, or from pulse inputs (conventional RTU).

For each control action, the user must configure:

- Control action identification (Text).
- Operation conditions (interlockings): to allow a control action to be performed (Up to 4 different conditions).
- Failure conditions: to cancel a control action already started (Up to 3 different conditions).
- Success condition: to determine when an operation has be finished successfully.
- Operation Timer: Time the DDS system is waiting to detect that at least one of the operation condition is accomplished, and the operation can be started.
- Dwell Timer: Time the output contact is closed to issue a control command.
- Failure Timer: Time the DDS system is waiting to detect that the success condition is accomplished, and the command has been successfully performed.

For each control action, two signals are generated: a HV switchgear selection signal, and an Output signal. These signals can be assigned to the external contacts preferred by the user. The selection signal gets active when the control action is confirmed, and it keeps active until the control action finishes successfully or the Failure Timer times out. The Output signal gets active when at least one of the

operation condition is accomplished and keeps active during the time defined as dwell time.

In this section, the user will define the control actions he wants to perform on each HV switchgear item (previously defined), with their associated timers. Using the previous example, Line bay, with single bus-bar and an external recloser, the configuration could be:

Command Identifier	Operation Time	Dwell Time	Failure Time
Control Block	**0**	**40**	**40**
Control Unblock	**0**	**40**	**40**
Open 52	100	100	200
Close 52	100	100	200
Open 89E	100	200	30000
Close 89E	100	200	30000
Open 89L	100	200	30000
Close 89L	100	200	30000
Open 89B	100	200	30000
Close 89B	100	200	30000
79 EXT IN	100	1000	2000
79 EXT OUT			

4.2.3 Digital Inputs Assignment.

User can define up to 42 digital inputs. There are four different groups of digital inputs: Switchgear status inputs (up to 16 inputs), Configurable Digital Inputs (up to 32 inputs), RTU inputs (up to 16 inputs), Pulse inputs (up to 4 inputs). User can define how many inputs of each type are needed for his application. Total number of inputs cannot exceeds 42.

- **Switchgear Status Inputs**: The propose of these inputs is to let the DDS relay know the status of the HV switchgear items and external equipment (-a and -b auxiliary contacts per HV switchgear item). These are level activated inputs (input must remain ON to define the status of the item). GE_INTRO will automatically prompt for external -a and -b contacts configuration for the user to define.
- **Configurable Digital Inputs**: These are generic inputs, which meaning and use must be defined by the user. These inputs, external contacts, are internally assigned to digital signals, which will be available anytime at the Control Status panel, for the user to define alarms, event, outputs, etc. User has to define an identification text for each input. As has been mentioned previously, these inputs, and all the internal signals are mapped into the control status panel, and user can use all this information to define alarms, events, outputs, etc. using 16 inputs OR gates. They can also be used to define the interlockings, failure conditions, success conditions, etc. Eight of these signals (the first 8) can be timed, between 0 and 60000 ms, this means that the relay will not consider the activation of the input until his associated timer has timed out. These inputs are also level activated inputs.

- **Pulse inputs**: Used to read pulses coming from external energy meters.
- **RTU inputs**: These are assigned to external contacts when control commands coming from a conventional RTU need to be used. RTU inputs are pulse inputs.

Following with the previous example, the Switchgear Inputs could be as indicated in the next page:

Switchgear input	Control Input
Control Block	-
Control Unblock	-
52-A	CI - 9
52-B	CI - 8
89E-A	CI - 19
89E-B	CI - 20
89L-A	CI - 17
89L-B	CI - 18
89B-A	CI - 15
89B-B	CI - 16
79 EXT-A	CI - 36

Note: *CI is the generic denomination for Control Input. The external contacts associated to each CI are defined in the elementary diagram of each particular DDS relay.*

The list of switchgear inputs depends on the HV switchgear items defined in the previous section, cause GE_INTRO prompts automatically for two CI (-a and -b auxiliary contacts) for each HV switchgear item defined.

Configurable Digital Inputs could be:

Configurable Digital Inputs	Control Input	Temporization in ms
P.T. Secondary Protection Trip	CI - 1	0
52 Control Voltage Failure	CI - 2	0
89 Control Voltage Failure	CI - 3	0
Key Reception	CI - 4	0
Key Transmission	CI - 5	0
Carrier Failure	CI - 6	0
Oscillography in progress	CI - 7	0
52 Springs Failure	CI - 27	30000
External Synchro-check Permission	CI - 10	-
52 Single pole Trip	CI - 11	-
Control Voltage Failure	CI - 12	-
Line Differential Protection Trip	CI - 13	-

SF6 Blocking Signal	CI - 14	-
98 U2 Closed	CI - 21	-
Distance Protection Trip	CI - 22	-
Distance Protection Pick Up	CI - 23	-
Out of Step Blocking	CI - 24	-
No Closing Conditions	CI - 25	-
Main Recloser Blocked	CI - 26	-
SF6 Alarm	CI - 28	-

RTU Inputs could be:

RTU Input	Control Input
52 Opening Command	CI - 29
52 Closing Command	CI - 30

***Note**: Same Control Input (and associated external contacts) could be used in different inputs definition. For example, 52/a and 52/b auxiliary contacts can be defined as HV Switchgear Status Inputs, to let DDS monitor and control the circuit breaker, and also can be defined as Configurable Digital Inputs, to be used in the internal logic defined later on by the user, to generate alarms, close outputs, etc.*

4.2.4 Outputs Configuration.

The control Module of a DDS system can handle up to 24 user configurable outputs.

To define the outputs, user can use 16 inputs OR gates, and NOTs over all the information contained in the Control Status panel. The Control Status panel is divided into 10 groups with 16 control signals each. In the definition of the internal logic, using OR gates, all the signals going into the same OR gate must belong to the same Control group.

The Control Status panel is comprised of 160 control signals, which contain all the information related to the Control Module. Among other signals, user will find the status of every HV switchgear defined in section 4.2.1, the selection and output signals for each control action (open / close) defined in section 4.2.2, the configurable digital inputs defined in section 4.2.3, etc.

An example of a Control Status Panel, could be: (depending on the DDS model)

Control Signals Group #1

1. Program Initializing
2. Settings Change
3. Counters modification
4. New Events Recorded
5. New Signaling
6. Undefined
7. Undefined
8. Local / Remote
9. Time synchronization
10. Parallel EEPROM Alarm
11. Serial EEPROM Alarm
12. Default Caliber Alarm
13. Default General Settings Alarm
14. Default Command tables Alarm
15. Undefined
16. Power Supply Alarm

Control Signals Group #2

17. Control Blocked
18. Control Ready
19. Control Operating
20. Control, reclosing in progress
21. Control, Undervoltage
22. Control, Underfrequency
23. Undefined
24. Undefined
25. Waiting Operation Conditions
26. No Operation Conditions
27. Waiting Confirmation Comm.
28. Control Timer
29. Waiting Dwell Time
30. Waiting for success conditions.
31. Operation Completed
32. Operation not Completed

Control Signals Group #3

33. Control Block Input
34. Control Unblock Input
35. Undefined
36. Undefined
37. 52 Closed
38. 52 Status Error
39. 52 Opening Failure
40. 52 Closing Failure
41. 89E Closed
42. 89E Status Error
43. 89E Opening Failure
44. 89E Closing Failure
45. 89L Closed
46. 89L Status Error
47. 89L Opening Failure
48. 89L Closing Failure

Control Signals Group #4

49. 89B Closed
50. 89B Status Error
51. 89B Opening Failure
52. 89B Closing Failure
53. Undefined
54. Undefined
55. Undefined
56. Undefined
57. Undefined
58. Undefined
59. Undefined
60. Undefined
61. Undefined
62. Undefined
63. Undefined
64. Undefined

Control Signals Group #5

65.89B-A
66.89B-B
67.89L-A
68.89L-B
69.89E-A
70.89E-B
71.Digital Input 7
72.Digital Input 8
73.52-A
74.52-B
75.Digital Input 11
76.Open 52
77.Close 52
78.Unblock Control
79.Block Control
80.Digital Input 16

Control Signals Group #6

81.Control Voltage Failure
82.Signaling Voltage Failure
83.SF6 Alarm
84.SF6 Block Signal
85.52 Springs Failure
86.No Closing Conditions
87.PT Secondary Protection Trip
88.Digital Input 24
89.Digital Input 25
90.Digital Input 26
91.Digital Input 27
92.Digital Input 28
93.Digital Input 29
94.Digital Input 30
95.Digital Input 31
96.Digital Input 32

Control Signals Group #7

97.Operation Condition -1
98.Failure Condition -1
99.Operation Condition -2
100.Failure Condition -2
101.Open 52 Selection Signal
102.Open 52 Output Signal
103.Close 52 Selection Signal
104.Close 52 Output Signal
105.Open 89E Selection Signal
106.Open 89E Output Signal
107.Close 89E Selection Signal
108.Close 89E Output Signal
109.Open 89L Selection Signal
110.Open 98T Output Signal
111.Close 89E Selection Signal
112.Close 89E Output Signal

Control Signals Group #8

113.Open 89B Selection Signal
114.Open 89B Output Signal
115.Close 89B Selection Signal
116.Close 89B Output Signal
117.Undefined
118.Undefined
119.Undefined
120.Undefined
121.Undefined
122.Undefined
123.Undefined
124.Undefined
125.Undefined
126.Undefined
127.Undefined
128.Undefined

Control Signals Group #9

129.Va < 50% VN
130.Vb < 50% VN
131.Vc < 50% VN
132.VbB < 50% VN
133.Va > 70% VN
134.Vb > 70% VN
135.Vc > 70% VN
136.VbB > 70% VN
137.Dead Line and Bus
138.Live Line - Dead Bus
139.Dead Line - Live Bus
140.Live Line and Bus
141.Undefined
142.Synchro-check
143.Undefined
144.Permission to close

Control Signals Group #10

145.Control Block Command
146.Control Unblock Command
147.Open 52
148.Close 52
149.Open 89E
150.Close 89E
151.Open 89L
152.Close 89L
153.Open 89B
154.Close 89B
155.Order 11
156.Order 12
157.Order 13
158.Order 14
159.Order 15
160.Order 16

An example of control outputs could be:

Control Output Identification Text	Control Output
Open 89-T	CO - 1
Close 89-T	CO - 2
Bus Bas Switch Selection	CO - 3
Line Switch Selection	CO - 4
Ground Switch Selection	CO - 5
Local Mode	CO - 6
Key Reception	CO - 7
Key Transmission	CO - 8
Oscillography record in progress	CO - 9
Remote Control	CO - 10
External Recloser in service	CO - 11
External Recloser out of service	CO - 12
52 Open	CO - 13
52 Closed	CO - 14
89-B Open	CO - 15
89-B Closed	CO - 16
89-L Open	CO - 17
89-L Closed	CO - 18
89-E Open	CO - 19
89-E Closed	CO - 20
Manual Close Command	CO - 21
Pole Disagreement Trip	CO - 22
SF6 Block	CO - 23
79 Out of Service Command	CO - 24
Critical Alarm	CO - 25
Control Voltage Alarm	CO - 26
Distance Protection Trip	CO - 27
Distance Protection Pick Up	CO - 28
Out of Step Blocking	CO - 29
Main Recloser Blocked	CO - 30
Single Pole 52 Trip	CO - 31
PT Secondary Protection Trip	CO - 32
52 Springs Failure	CO - 33
SF6 Alarm	CO - 34
SF6 Block	CO - 35
Pole Disagreement Trip	CO - 36
52 Control Voltage Failure	CO - 37
89 Control Voltage Failure	CO - 38
Carrier Error	CO - 39
52 Open Command	CO - 40
52 Open Command	CO - 41
52 Open Command	CO - 42
52 Close Command	CO - 43
89-B Open Command	CO - 44
89-B Close Command	CO - 45
89-L Open Command	CO - 46

89-L Close Command	CO - 47

Note: *CO means Control Output, the external contact numbers should be found in the elementary diagram of the specific DDS relay model.*

4.2.5 Events Configuration.

48 different Events can be defined by the user into the Control Module of the DDS system.

16 inputs OR gates can be used during the configuration of these events. The input signals to these OR gates must be selected from the Control Status Panel, and all the inputs to one OR gate must belong to the same Control Signal Group. The activation of any one of those inputs will produce an output in the OR gate, and will generate an event. To deactivate the OR gate and the event, all of the inputs to the OR gate must be low.

User can assign a 32-character string (Identification Text) o each event.

Each event contains the following information:

- Identification Text.
- Alarm acknowledge mark (star character).
- Status of the signal generating the event (active or deactive)
- Date and time.

An example of events could be:

Event
52 Closed
52 Status Error
52 Opening Failure
52 Closing Failure
89-E Closed
89-E Status Error
89-E Opening Failure
89-E Closing Failure
89-L Closed
89-L Status Error
89-L Opening Failure
89-L Closing Failure
89-B Closed
89-B Status Error
89-B Opening Failure
89-B Closing Failure
Key Reception

Key Transmission
Oscillography record in progress
External Recloser in service
Pole Disagreement Trip
SF6 Block
Control Voltage Failure
Distance Protection Trip
Distance Protection Pick Up
Out of Step Protection Block
No Closing Conditions
Main Recloser Blocked
Single pole 52 Trip
PT Secondary Protection Trip
52 Springs Failure
SF6 Alarm
SF6 Block
52 Control Voltage Failure
89 Control Voltage Failure
Carrier Error
Synchro-check Permission.

4.2.6 Confirmation Timer.

To perform a control action with a DDS relay requires two actions: select the control action desired and confirm it must be done. When a control action is selected, DDS relay check the interlockings defined for that particular action, and if at least one of the Operation Condition is accomplished, then it waits for the operator to Confirm he still wants to perform the control action. If the operator confirmation do not received before the Confirmation Timer times out, the DDS control module cancel the operation.

As an example, this timer can be set to 60 s.

4.2.7. Command Status Configuration.

As it has already been mentioned, configuration may be defined by several methods in the DDS system in order to allow a control action to be done (interlockings, Operation Conditions), cancel a control action already started (Failure Conditions) and determine if a control action has been finished successfully (Success Conditions).

To define the Operation Conditions, Failure Conditions and Success Conditions, the user can take all the information from the Command Status panel. This Command Status panel is a subset taken from the Control Status Panel. User must select which control signals from the Control Status Panel are important and needed to define the Operation Conditions, Failure Conditions and Success Conditions, and create in this

way the Command Status Panel. This may include up to 64 signals from the Control Status Panel. User can also use 32 predefined signals from a panel call External Status panel (because it contains signals from other modules (Protection and Communication) not from the Control Module. To define the Command Status Panel, user can also use 16 inputs OR gates with signals from the Control Status panel. All signals going to the same OR gate must belong to the same control signal group.

An example of the Command Status Panel could be:

Command Status Signal
52 Closed
52 Status Error
52 Opening Failure
52 Closing Failure
89E Closed
89E Status Error
89E Opening Failure
89E Closing Failure
89L Closed
89L Status Error
89L Opening Failure
89L Closing Failure
89B Closed
89B Status Error
89B Opening Failure
89B Closing Failure
Default Interlockings.
Phase A – Undervoltage
Phase B – Undervoltage
Phase C – Undervoltage
Live Line – Live Bus
52 Springs Failure
98 U2 Closed
79 EXT. in service
79 EXT. in service Command
79 EXT. out of service Command
52 Open Command
Remote Control
Logic Circuit number 1
Logic Circuit number 2

Using the selected signals from the Control Status Panel to create the Command Status Panel, and with the prefixed signals from the External Status Panel, user will now define the Operation Conditions, Failure Conditions and Success Conditions.

4.2.8 Operation Conditions (Interlockings)

Up to 4 different Operation Conditions can be defined for each control action (open / close circuit breakers, etc.). The four operation conditions are ORed together to determine if a control action can be performed or not. At least one of the four conditions defined must be accomplished for the control action to be performed.

Each Operation Condition is defined using ANDs and NOTs of up to 96 signals, coming from the External Status (32 signals) and from the Command Status Panel (64 signals). To define the Operation Conditions the user can take all the information from the Command Status panel. This Command Status panel is a subset taken from the Control Status Panel. User must select which control signals from the Control Status Panel are important and needed to define the Operation Conditions, Failure Conditions and Success Conditions, and create in this way the Command Status Panel. This may include up to 64 signals from the Control Status Panel. User can also use 32 predefined signals from a panel call External Status panel (because it contains signals from other modules (Protection and Communication) not from the Control Module.

As an example, lets assume the following Operation Condition to close the circuit breaker.

- The circuit breaker must be open.
- Protection module must be on.
- The ground switch must be open.

This can be defined using AND gates in the following way:

52 Open **AND** Protection in service **AND** 89E Open

Note: An AND gate must have all its inputs ON to have its output ON.

If in the Control Status Panel the user do not have the signal '52 Open', but the signal '52 Closed', the previous operation condition can be rewritten in the following way:

NOT(52 Closed) **AND** Protection in service **AND** **NOT**(89E Closed)

Because NOT CLOSED equals OPEN. This example explains the use of AND and NOTs to define an Operation Condition.

Example of Operation Condition Definition:

CONTROL ACTION = OPEN CIRCUIT BREAKER

1st Operation Condition to Open 52

52 Closed	ON
52 Status Error	OFF
52 Closing Failure	OFF

2nd Operation Condition to Open 52
3rd Operation Condition to Open 52
4th Operation Condition to Open 52

Lets assume that the Circuit Breaker Closing Command could be issued if the circuit breaker is open, and there is no 52 Status Error, (no disagreement between the information given by the 52/a contact and the 52/b contact), and the Protection Module must be in service and with its outputs enabled, and either the 89L is open or the 89B is open or the 89E is open. The configuration could be as follows:

CONTROL ACTION = CLOSE CIRCUIT BREAKER

1st Operation Condition to Close 52

52 Closed	OFF
52 Status Error	OFF
52 Opening Failure	OFF
89L Closed	OFF
89L Status Error	OFF
Protection Outputs Disabled	OFF
Protection Out of Service	OFF

2nd Operation Condition to Close 52

52 Closed	OFF
52 Status Error	OFF
52 Opening Failure	OFF
89E Closed	OFF
89E Status Error	OFF
Protection Outputs Disabled	OFF
Protection Out of Service	OFF

3rd Operation Condition to Close 52

52 Closed	OFF
52 Status Error	OFF
52 Opening Failure	OFF
89B Closed	OFF
89B Status Error	OFF
Protection Outputs Disabled	OFF
Protection Out of Service	OFF

4th Operation Condition to Close 52

The previous conditions can be shown in a logic circuit representation as follows:

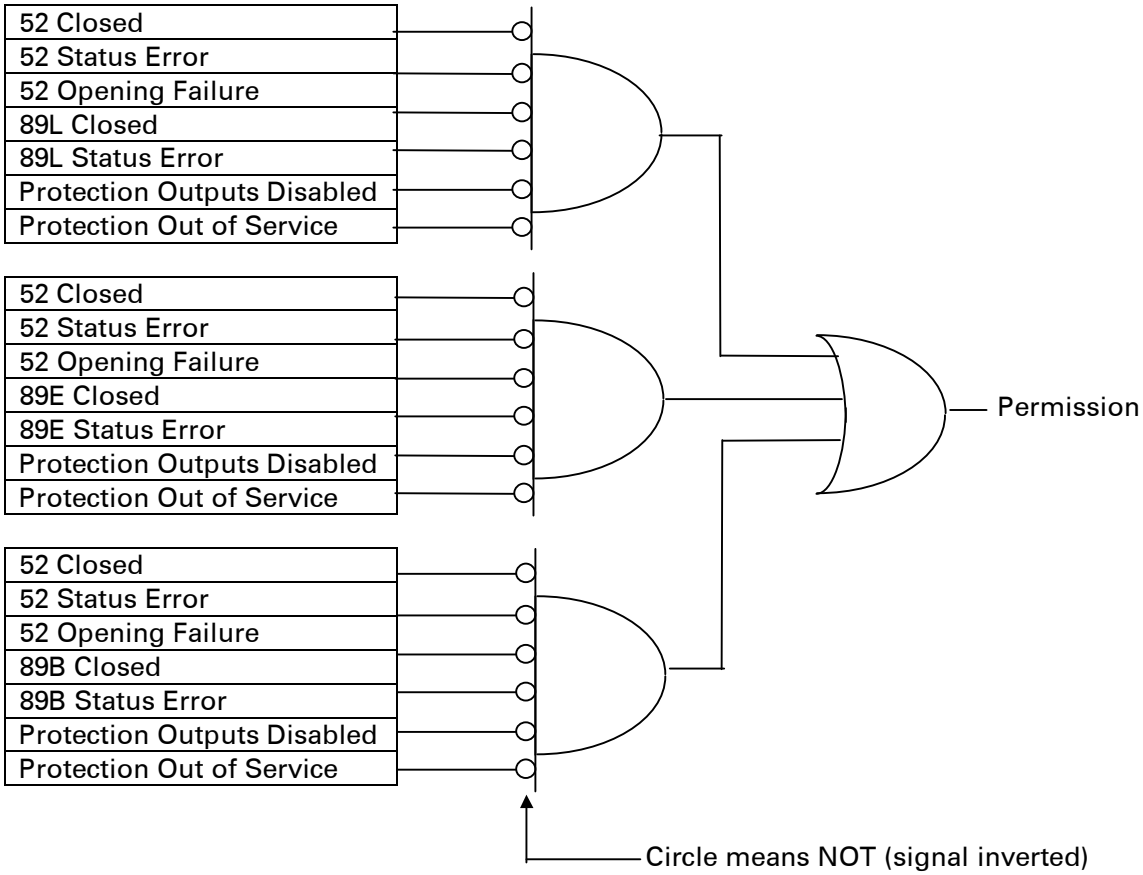


Figure 4.1. *Operation Diagram*

CONTROL ACTION = OPEN GROUND SWITCH:

1st Operation Condition to Open 89E

89E Closed	ON
89E Status Error	OFF
89E Closing Failure	OFF
Logic Circuit number 3	ON

2nd Operation Condition to Open 89E
3rd Operation Condition to Open 89E
4th Operation Condition to Open 89E

CONTROL ACTION = CLOSE GROUND SWITCH

1st Operation Condition to Close 89E

89E Closed	OFF
89E Status Error	OFF
89E Opening Failure	OFF
89L Closed	OFF

89L Status Error	OFF
Phase A – Undervoltage	ON
Phase B – Undervoltage	ON
Phase C – Undervoltage	ON
98 U2 Closed	ON

2nd Operation Condition to Close 89E
3rd Operation Condition to Close 89E
4th Operation Condition to Close 89E
ETC.

4.2.9 Failure Conditions Configuration.

Up to 3 Failure conditions can be configured in a DDS relay. These conditions are internally ORed together, so if any of them is accomplished, the corresponding control action already started will be canceled.

Each Failure Condition is defined using ANDs and NOTs of up to 96 signals, coming from the External Status (32 signals) and from the Command Status Panel (64 signals). To define the Failure Conditions the user can take all the information from the Command Status panel. This Command Status panel is a subset taken from the Control Status Panel. User must select which control signals from the Control Status Panel are important and needed to define the Operation Conditions, Failure Conditions and Success Conditions, and create in this way the Command Status Panel. This may include up to 64 signals from the Control Status Panel. User can also use 32 predefined signals from a panel call External Status panel (because it contains signals from other modules (Protection and Communication) not from the Control Module.

As an example, the failure conditions could be as follows:

1st Failure Condition to Open 52

52 Opening Failure	ON

2nd Failure Condition to Open 52
3rd Failure Condition to Open 52

1st Failure Condition to Close 52

52 Closing Failure	ON

2nd Failure Condition to Close 52
3rd Failure Condition to Close 52

1st Failure Condition to Open 89E

52 Opening Failure	ON

2nd Failure Condition to Open 89E
2nd Failure Condition to Open 89E

1st Failure Condition to Close 89E

89E Closing Failure	ON

2nd Failure Condition to Close 89E

3rd Failure Condition to Close 89E

1st Failure Condition to Open 89L

89L Opening Failure	ON

2nd Failure Condition to Open 89L
3rd Failure Condition to Open 89L

1st Failure Condition to Close 89L

89L Closing Failure	ON

2nd Failure Condition to Close 89L
3rd Failure Condition to Close 89L
ETC.

4.2.10 Success Conditions Configuration.

Each control action has a success condition to be defined by the user. If this condition is accomplished before the Failure timer times out, the operation will be considered a successful operation.

The Success Condition is defined using ANDs and NOTs of up to 96 signals, coming from the External Status (32 signals) and from the Command Status Panel (64 signals). To define the Success Condition the user can take all the information from the Command Status panel. This Command Status panel is a subset taken from the Control Status Panel. User must select which control signals from the Control Status Panel are important and needed to define the Operation Conditions, Failure Conditions and Success Conditions, and create in this way the Command Status Panel. This may include up to 64 signals from the Control Status Panel. User can also use 32 predefined signals from a panel call External Status panel (because it contains signals from other modules (Protection and Communication) not from the Control Module.

As an example, the Success Condition could be as follows:

Success Condition to Open 52

52 Closed	OFF
52 Status Error	OFF
52 Opening Failure	OFF

Success Condition to Close 52

52 Closed	ON
52 Status Error	OFF
52 Closing Failure	OFF

Success Condition to Open 89E

89E Closed	OFF
89E Status Error	OFF
89E Opening Failure	OFF

Success Condition to Close 89E

89E Closed	ON

89E Status Error	OFF
89E Closing Failure	OFF

Success Condition to Open 89L

89L Closed	OFF
89L Status Error	OFF
89L Opening Failure	OFF

Success Condition to Close 89L

89L Closed	ON
89L Status Error	OFF
89L Closing Failure	OFF

ETC.

4.2.11 Graphical Display Configuration.

It is possible for the user to configure the graphical display of the local MMI, in the front panel of the relay. User can configure the configuration of the switchgear monitoring screen and the measures screen of the LCD graphical display of the DDS relay.

GE_INTRO, the configuration software for DDS relays, includes the capability for drawing the one-line drawing of the bay, using several items from a item data base (circuit breaker, ground switch, line section, bus-bar section, etc.) and then, download the screen design to the DDS relay through a serial communication link.

The measures screen can also be redesign and customize by the user at any time, using again the GE_INTRO software.

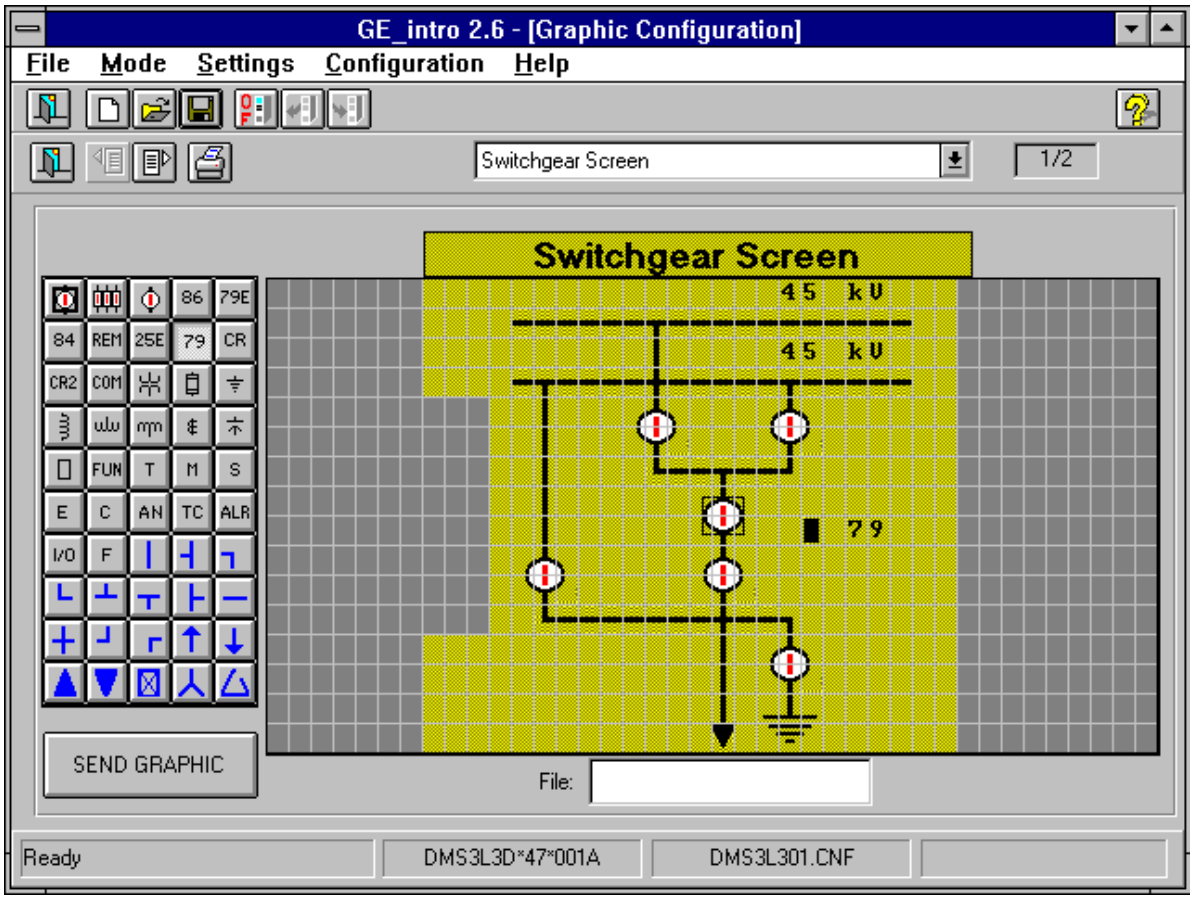


Figure 4.2 *Graphic configuration (switchgear).*

For further information please refer to the GE_INTRO instruction manual, GEK-105569A.

4.3 Logic Diagrams

The logic diagrams corresponding to the control module of DDS relays are included in this section. These diagrams correspond to:

- Control Status Sequence.
- Control actions (Open / Close) Manager.
- Switchgear Items Status Monitor.
- Control Status Assignment.

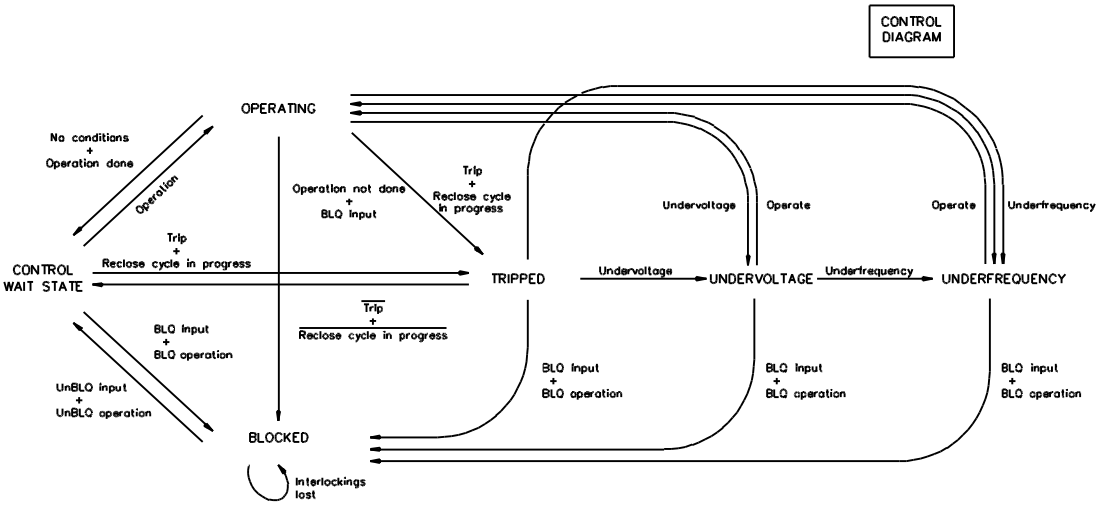


Figure 4.3 *Control Status Sequence.*

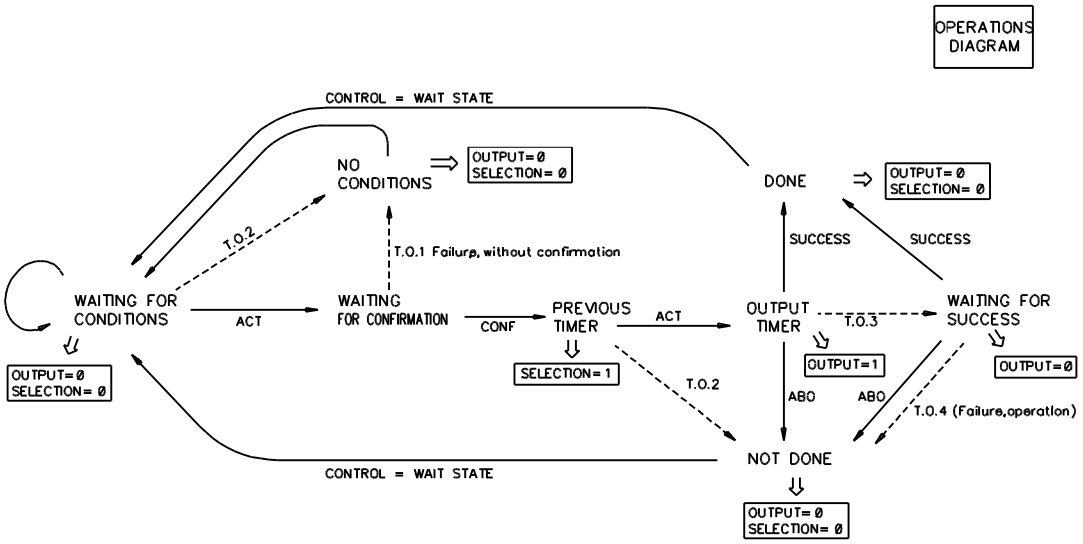


Figure 4.4 *Control actions (Open / Close) Manager.*

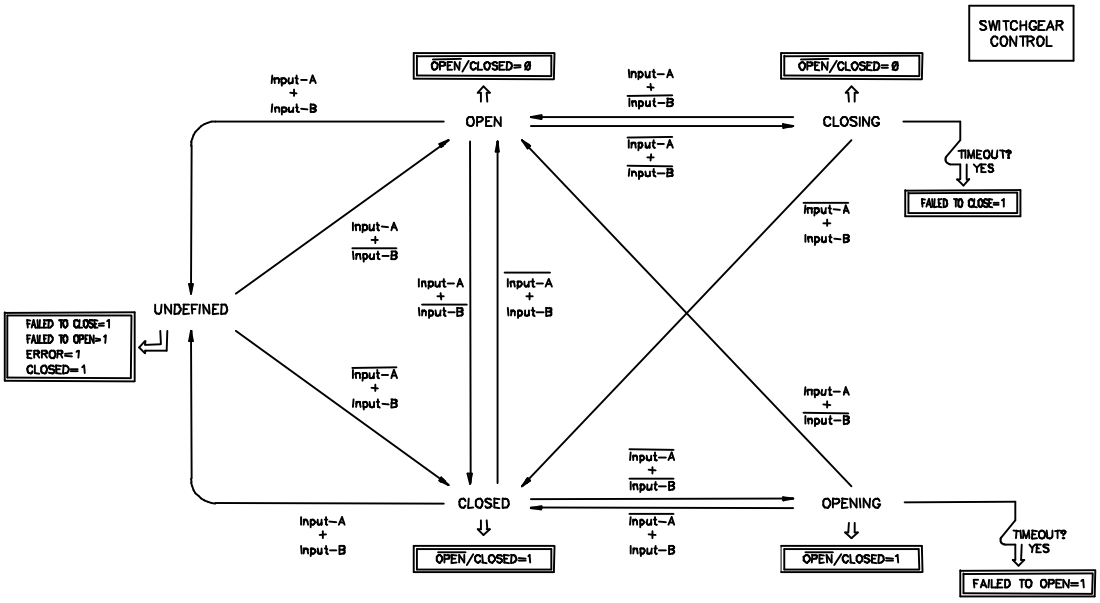


Figure 4.5 *Switchgear Items Status Monitor.*

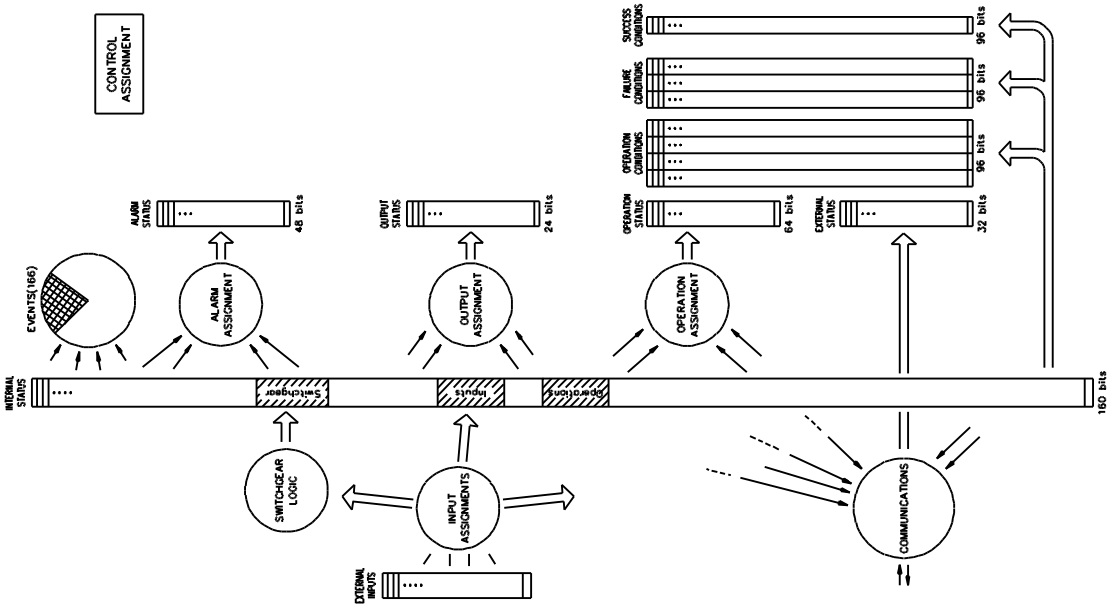


Figure 4.6 *Control Status Assignment.*

5. HARDWARE DESCRIPTION

WARNING

The DDS system incorporates electronic components that might be affected by electrostatic discharge currents flowing through certain components terminals. The main source of electrostatic discharges is human body, especially under low humidity conditions, with carpet floors or isolating shoes. If such conditions are present special care should be taken while manipulating DDS's modules and boards. Operators, before even touching any component, must make sure that their bodies are not charged by either touching a grounded surface or by using an antistatic grounded wrist bracelet.

The DDS system architecture is of modular type, allowing to form, from a series of standard modules, protection and/or control racks, characterized by the software used in each concrete case (The level 1 modules are named DMS). This flexibility of the system allows each of the racks to adopt different configurations according to the functions included and the desired application.

The following hardware description is general, and includes those relevant aspects that are common to the different protection and/or control equipments included in the DDS system.

5.1. Mechanical Construction

5.1.1. Box Construction

The DMS modules are assembly in box of an standard 19" rack four units high, manufactured in stainless steel and painted with gray epoxy resin. It is composed of a backbone structure, that includes the strips where all the modules and boards are connected, plus a rear plate with all the female connectors.

All the boxes have a surge ground connection terminal, essential not only in terms of safety but also on behavior against electromagnetic interference.

All the modules (described in a generic form in section 5.2) are of draw-out type, enabling easy maintenance and repair of the equipment.

The DMS also incorporates a plastic antitampering front cover. This cover keeps the relay sealed and provides a high protection against dust and water (IP51 index

according to IEC 529). The use of a push-button allows access to the main functions without the need of removing the cover.

The front and rear views of a typical DMS equipment are shown on figures 5.1. and 5.2.

5.1.2. Electrical Connections.

All the DMS electrical connections (voltage inputs and digital I/Os) are done through drawout terminal boards of 12 terminal blocks each located at the rear of the device.

The current signals connectors are automatic short-circuitable type, with capacity of bearing overloads of up to 100 times the nominal current during 1 second.

Additionally to those terminal blocks, the DMS includes two communication ports. One front DB-9 port for local connection and another located on the rear nameplate, used for remote connection to the PC.

This second port may be used for point-to-point connection with a central computer in the substation by means of a multiplexer.

This second communication port may be, depending on the selected option, a RS232 with a DB-9 connector, a fiber optics (glass or plastic) connector or finally an RS-485.

In the rear plate are also included the terminal blocks for the time synchronization through a demodulated IRIG-B input.

5.1.3. Internal Construction.

The internal architecture of the most general DMS modules, including protection and control functions, includes the following 4 units high drawout modules:

- Power Supply module.
- Magnetic Module (CT and VT analog inputs)
- Protection CPU board
- Communications CPU board.
- Control CPU board
- Digital inputs board.
- Digital outputs board.
- Digital inputs/outputs mixed board.
- Analog inputs board (coming from measurement transducers).

Each of these modules has a DIN type front connector for the connection to the internal communication bus. Also, in the case of having connections to the outside (Inputs, Outputs and power supply modules), the male part of the terminal block is incorporated. The female portion of the connector is located in the rear plate of the

box. All these boards are inserted in the box perpendicularly to the rear plate, as described in section 5.2.

Besides all these modules there are some other boards mounted in parallel to the front of the box. These boards are:

- Internal bus board.

This is a PCB board that makes the connection between the digital inputs and the power supply through their front DIN connectors.

- Front display board.

It is a PCB that includes the two LCD displays of the DMS protection and control equipments, the alphanumeric display for the protection management, and the graphic display for control management and visualization of events and measures, as well as its associated electronics, including the controls of brightness and contrast of the displays. Additionally, the board includes the front communications connector, the switch for local/remote operation selection of the control position and the bicolor LED indicator of the equipment state.

The front module is mechanically and solidly connected to the keypad board, the electrical connection is done through a flexible flat cable of 12 pins.

The subgroup formed by these two front boards (see figure 5.3) is connected to the rest of the relay through another flexible flat cable of 40 pins, connected itself to the front of the communications CPU.

- Front keypad board

It is a printed board which is solidly joined to the front board of the display, as mentioned before, and supports the keypad for the protection operation (20 keys alpha-numeric and functional keypad that acts on the alpha-numeric display) The board also includes a transparent window for the display and for the control board in which the unit identification (model number and serial number) and its more relevant technical characteristics are included.

The group formed by both front boards is mechanically and electrically joined to the box by means of 4 screws placed at upper and lower part of the front. To get the access to the internal electronic modules of the relay the next steps must be followed (once the relay has been disconnected):

1. Remove the plastic cover.
2. Slack the fixed frontal screws till they are untied and only fixed by their fastening sleeve.
3. Let the front part fall softly till the flat cable, that is connected to the communications board, is accessible, and unfasten the extreme connected to this board.

4. Remove the frontal module.
5. Take out the internal bus board which fixes the different modules themselves.

If this process is followed, every relay module can be accessed in order to be taken out, maintained or replaced. In order to assembly the relay again, the procedure is the contrary, that is to say:

1. Make sure that every vertical drawout module has been correctly inserted.
2. Assembly the internal bus board which joins the different modules themselves by pressing from left to right every connector in order to be sure of their right insertion.
3. Connect the flat cable that connects the frontal module with the communications board.
4. Place the frontal module at its position and screw it on the box.
5. Cover again the relay with its protective cover.

5.1 4.- Identification.

The identification label of the model is placed at the right of the alpha-numeric keypad. This label includes the model number, serial number and the most important nominal values (including nominal voltage and current, and DC power supply nominal voltage).

Terminal blocks placed at the rear cover are identified by black color serigraphy on the cover (see figure 5.2.). Each of the terminals blocks are identified by a letter placed at the upper border of the cover close to the connector. This connector identification is assigned to the different connectors, beginning by A which corresponds to the connector placed on the right extreme (looking at the relay from the back).

In the terminals blocks, each of the 12 terminals of each block is identified from the top to the bottom by a number between 1 and 12 that is serigraphied on the cover close to each connector at the input side of the connection cables. The connector terminals for synchronization are identified by "IRIG-B" serigraphy and the terminals polarity is indicated by "+" and "-".

For relays with fiber optics communications (plastic or crystal), transmission and reception connectors terminals are identified by TX and RX serigraphy respectively.

5.2 .- Boards

As indicated in the hardware general description, the DMS equipments have been designed taking as a basic criterion the creation and use of hardware boards common to the different functions. Customization to a required function is carried out using the protection/control software in the EPROM memories of the protection, control and communications CPU modules.

A series of hardware modules has been defined for this purpose, which can be used in any of the equipments, depending on the required application, with the only limitation of the 19" rack capacity to contain modules.

All the DMS protection and control modules include two sub-modules (one for protection and one for control), separated by the whole of the three CPU boards. Different box configurations are available, and can be identified by the number of rails (slots) available for inputs, outputs or mixed boards in the protection sub-module.

The three configurations available are characterized by:

- P0: Not available space for boards in the protection sub-module.
- P1: Available Space for only one board in the protection sub-module.
- P2: Available Space for two boards in the protection sub-module.

The most common architecture is P1, including the following typical distribution of modules (from left to right, watching from the front side of the equipment):

- Magnetic Module (analog inputs)
- Power supply module.
- Mixed protection inputs/outputs modules.
- Protection CPU
- Communications CPU
- Control CPU
- Analog Inputs
- Control Inputs
- Mixed control inputs/outputs (first module)
- Mixed control inputs/outputs (second module)
- Mixed control inputs/outputs (third module)
- Redundant Power supply module.

The hardware modularity provides advantages in several aspects:

- Greater reliability and experience accumulated in the hardware, because of this being common to all the equipments.
- Decrease of the number of different spare parts.
- Easy training for equipment maintenance and commissioning.

An additional aspect to emphasize is the separation of protection, communications and control functions in different CPU boards, each of them with its own dedicated 16 bit microprocessor.

This involves the following advantages:

- Higher processing capacity than architectures with a single microprocessor to support the protection and control functionality.
- The modification or improvement of one of the components does not involve modification of the whole assembly.

- Greater reliability. A failure in the communications or control hardware does not affect the protection functionality.

5.2.1.- Magnetic Module.

Magnetic module takes voltage signals of the substation conventional transformers, and with these signals performs the following:

- It gives galvanic isolation to external signals by means of relay internal transformers.

- It makes suitable the external signals to the adequate voltage levels for the internal circuitry.

This module condition up to 8 analog signals, these being voltage or current signals. For this purpose, three types of internal transformers are available:

- Current transformers, for connection with external current transformers of secondary nominal current of 1 or 5 A.

- Voltage transformers, for connection with external voltage transformers of secondary nominal values of 110 V (phase-to-phase connection) or 110/√3 V (phase-to-ground connection).

- Ring CT´s for residual current signals or nominal values lower than 1 A.

As these are protection transformers, where the dynamic range of the analog inputs is fundamental to avoid saturation, high range transformers are always used.

Anti-noise filters are another element of the module. As the magnetic module is connected to external switchgear signals, it can be affected by electromagnetic disturbance. In order to avoid their effect, anti-noise filters have been included in the transformers' primary (capacitors connected to chassis), as well as in the secondary (ferrites), so as to prevent disturbance from entering the equipment. These protection elements act as well as a barrier, preventing possible disturbances generated in the protection equipment to come out of this and affect the external equipment.

The last element included in the magnetic module consists of load resistors that convert the current signals in voltages, in the current signals case, and of resistive attenuators in the voltage signals case.

5.2.2.- Protection CPU Processing Board.

This module is the main part of the equipment with reference to protection functions. The main functions are:

- Sampling of analog signals coming from magnetic module.

- Protection algorithm evaluation.
- Protection logic and auxiliary functions.
- Monitoring functions, events register, oscillography register, etc.
- Equipment self-check.
- Protection data communication to the communications CPU.

CPU module nucleus is a 16 bits microprocessor together with its auxiliary associated circuitry.

5.2.3.- CPU Communications Board.

Communications CPU module nucleus is very similar to the protection CPU module, and it also consists of a 16 bits microprocessor together with the auxiliary electronic.

The main function of the communications CPU module is to maintain and control the communications in the following channels:

- Internal communication with the protection and control CPU modules.
- Local mode communication with a PC by the front communications port.
- Remote mode communication by rear communication port.
- Man-machine interface by means of keypads and displays.

5.2.4.- Control CPU Board

This board is, at the hardware level, exactly the same as the protection CPU board, being differentiated only in the software contained in its EPROM memories.

The main functions carried out by the control board are the following:

- Control Measurement
- Monitoring and signaling of switchgear states
- Operations and interlocking of the switchgear equipment at the position level.

5.2.5.- Digital Inputs Board.

The design of the DMS has been done for assuring the maximum capacity of inputs by board, maintaining at the same time the maximum reliability against electromagnetic disturbance. For this purpose, the standard board of inputs, identical for protection and control applications, includes 21 digital inputs divided into 3 groups of 7 inputs each one, with a common for each group of inputs.

Each of the board inputs has a resistive attenuate which adequates the external voltage battery levels (48 V, 125 V, ...) to the needs of the optocoupler that gives

galvanic isolation to each input. As the majority of these inputs come from elements that are connected to the substation equipment, together with the resistive attenuate one passive filter is provided in order to get better behavior against electromagnetic perturbations.

Input modules (as well as the output ones), provide one selectable of 4 bits address, which allows to include up to 16 modules of each kind in the same DMS protection and control equipment.

5.2.6.- Digital Outputs Board

Each of the DMS output boards includes 12 heavy duty relays, 16 Amperes nominal continuous capacity and 4000 VA breaking capacity or signaling, of continuos nominal capacity of 8 Amp. Each of these relays has an only contact (NO). The contact of each relay can be set separately as normally close or normally open by jumpers (fixed by welding) placed on the board.

In every configuration the contacts are non potential contacts, without common elements and all of them have varistors between their terminals in order to protect them against overvoltages generated by the coils they are connected to. This provides a high immunity against electrical interferences.

5.2.7.- Mixed Digital Inputs/outputs Boards

It includes the characteristics of the two previously mentioned boards. Each board includes 7 digital inputs, selectable by an internal jumper as an only group of 7 inputs with one common point or as two groups of 3 inputs with independent common points, and 8 digital outputs.

5.2.8.- Analog Inputs Board (measurement transducers)

Each board includes 4 analog inputs, each one being able to be selected independently for the different defined range (+ /- 2.5mA, 0-1 mA, 0-5 mA, 4-20 mA ó + /- 10V).

5.2.9.- Power Supply.

The Power Supply module includes the following functions:

- Generation of the necessary voltages for the operation of the DMS modules circuitry, in this case 8V (subsequently regular to 5 V) for the logic, and 24 V for the tripping activation.

- Four relays, with the same characteristics as the ones included in the outputs board (2 relays for tripping functions and 2 relays for reclosing).

- An auxiliary relay for equipment alarm.

- Supervision Circuits for two trip and/or closing coils including voltage and current consumption supervision.

As regards the power supply board we should emphasize that:

- One passive filter is included in the power supply input in order to avoid any possible electromagnetic disturbances. A current limiter is also included in order to protect the power supply against unintentional groundings.

- The tripping relays are stronger (in capacity and in control operations life) than the normal ones used for similar protection equipment. Besides this, as the output contacts type can be configured, a high versatility is provided.

- The output circuits for feeding other boards are conditioned so that they can have several boards connected, being possible to switch the service from one board to another one in case of failure, increasing the reliability of the equipment.

5.3.- Reception, Handling & Storage

DDS modules are supplied to the customer in a special package, which adequately protects it during transportation, as long as this is performed in normal conditions. Immediately after receiving the equipment, the customer should check whether it shows any signs of transportation damage. If it is apparent that the equipment has been damaged by inappropriate handling, it must be immediately advised in writing to the carrier, and the damage must be reported to the manufacturer

For unpacking the relay, normal care should be taken in order not to lose the screws, documents and other auxiliary elements also supplied in the box.

If it is not intended to install the relay immediately, it is recommended to store it in its original package, and keep it in a dry, dust free and metal particles free place.

5.4.- Installation

DMS units must be mounted in vertical surface which allows access to the front and rear sides of the equipment. It is not necessary to have access to the lateral surfaces of the equipment mounted. Dimensions and panel drilling for boxes of a 19" rack 4 units high in shown in Figure 5-4.

5.5.- External Connections

The external connections for different DDS modules are different, as they offer the possibility to include a variable combination of modules according to the required application.

Figure 6-5 shows the external connections for a standard DMS line protection module including protection and control functions, with duplicate outputs modules for control and redundant power supply.

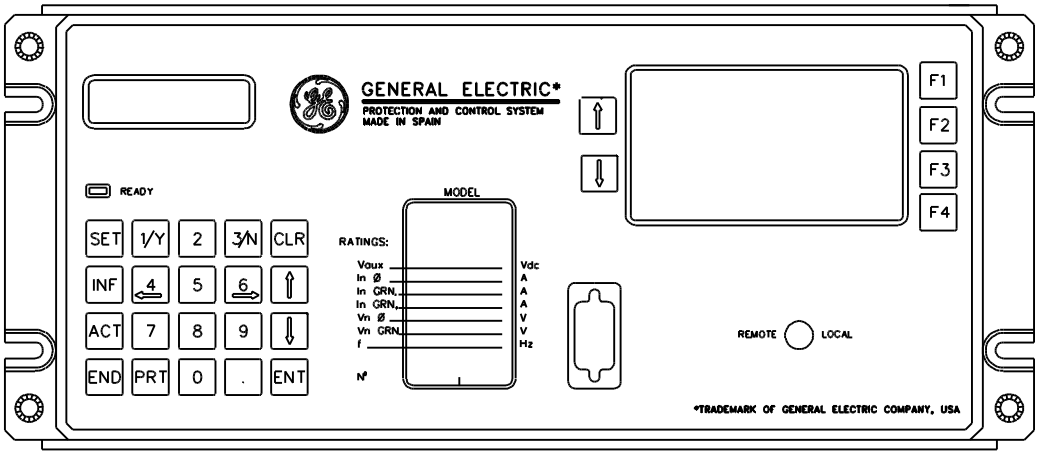


Figure 5-1 *Front View of DMS equipment (226B3356 Fig 2)*

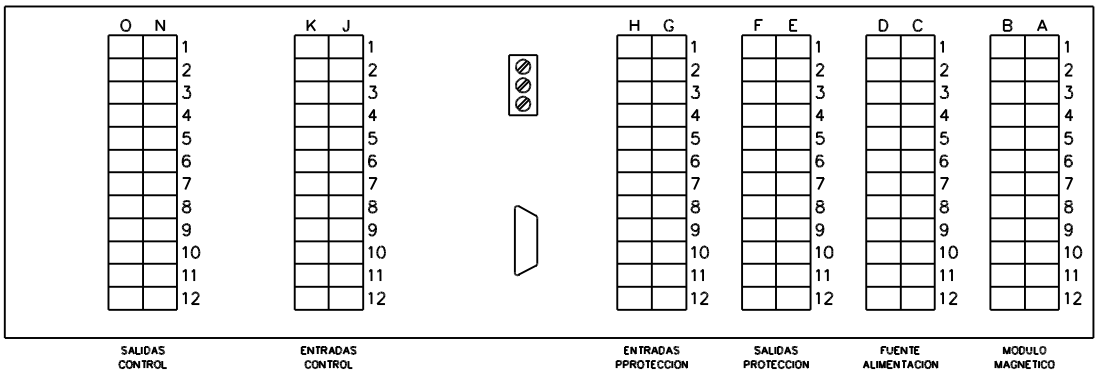


Figure 5-2 *Rear View of DMS equipment (189C4096 Fig 6)*

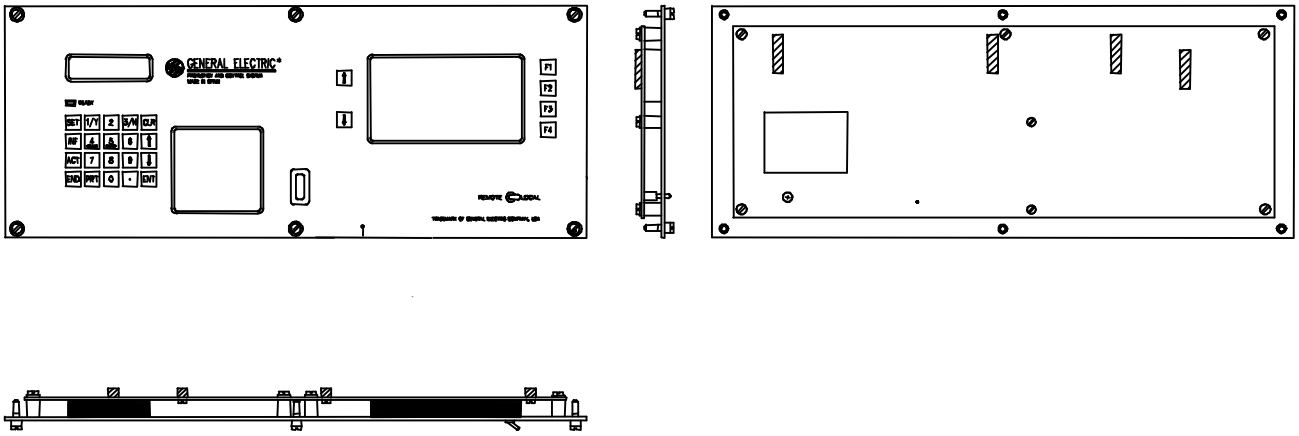


***Figure 5-3**. Frontal assembly (226B3351 Fig 1)*

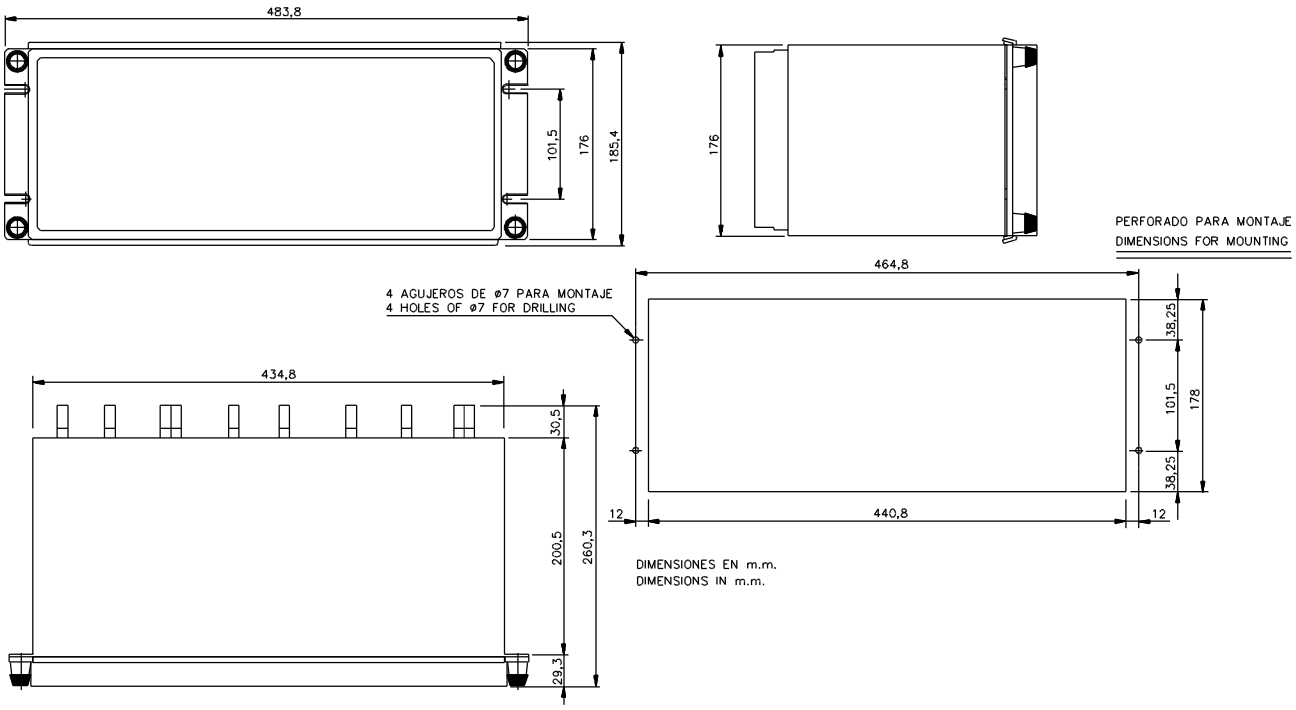


***Figure 5-4** Dimensions and drilling (226B6086 Fig 3)*

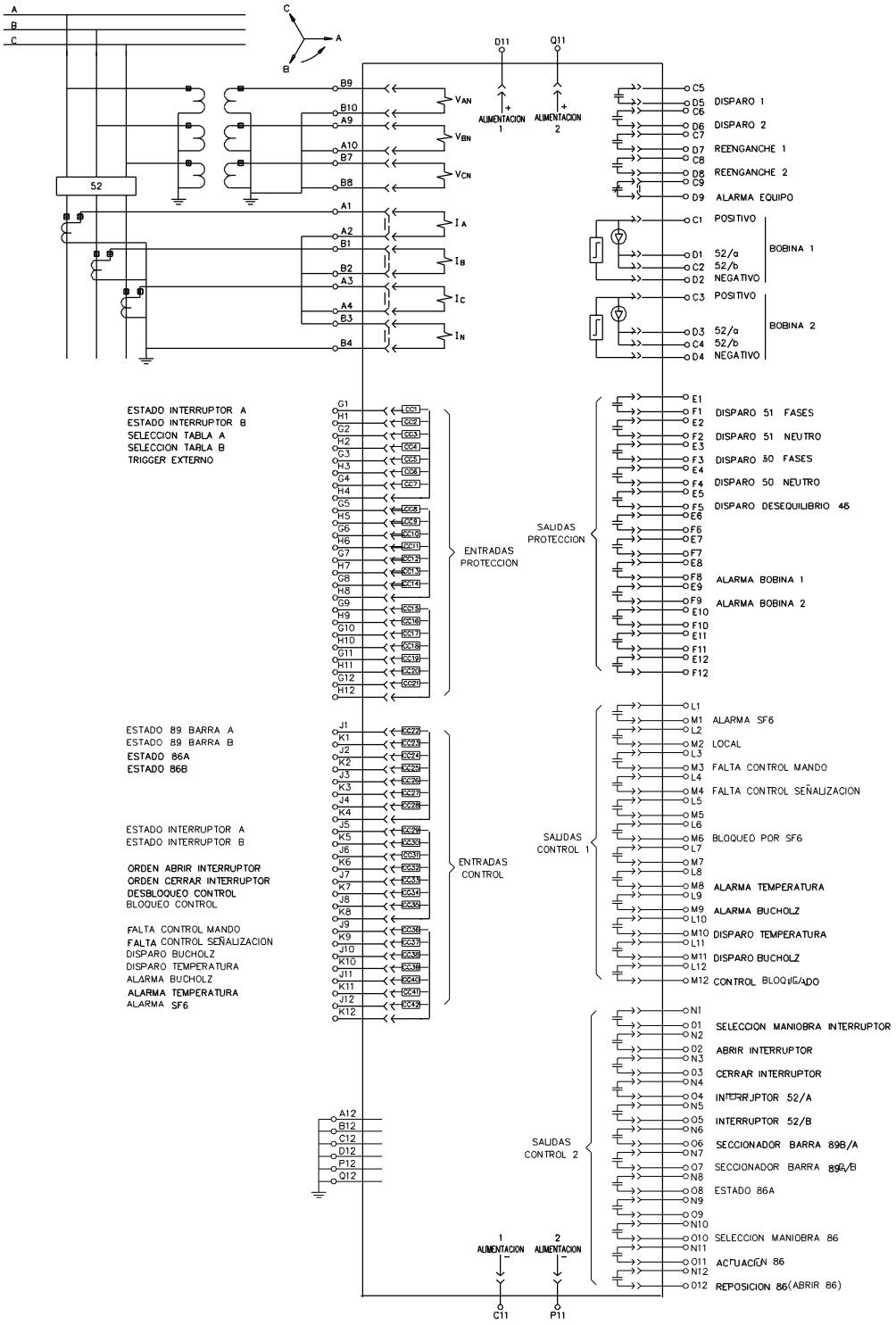


Figure 5-5 *Generic external Connections (189C4096 Fig 1)*

6. TECHNICAL CHARACTERISTICS OF LEVEL 1 UNITS

a..- Mechanical and environmental

Mechanical packing in a 19" 4 units high stainless steel box.

Terminal boards composed by draw-out, short-circuitable terminals of 12 boards.

Dimensions: 484 mm x 179 mm x 230 mm

Weight: 15 kg.

Protection level IP41, according to IEC 529

Temperature: storage -40 to +65C operation -20 to +55C

Ambient humidity: up to 95% without condensing.

b.- Electrical

Frequency: 50/60 Hz.

Nominal Current: 1 or 5 A.

Thermal capacity: Permanent: 4xIn
During 3 s: 50xIn
During 1s: 100xIn

Nominal Voltage: 63V (phase - ground), 110 V (phase - phase)

Thermal capacity: Permanent: 2.5xVn
During 1 min: 3.5xVn

Auxiliary voltage: 48 VDC or 110-250 VDC

Admissible operation range of the auxiliary voltage: 20%

Burdens:

Current circuits:
1 VA at In = 5 A
0.2 VA at In = 1 A

Voltage Circuits:
0.2 VA at Vn = 63 V

6.1. Electromagnetic Compatibility Standards

The DDS system Level 1 (DMS modules) units comply with the following standards, including the GE standard for insulation and electromagnetic compatibility and the standard required by the EU directive 89/336 for the CE marking, according to the harmonized European standard:

Test	**Standard**	**Class.**
Insulation	IEC 255-5	2 kV 50/60 Hz 1 minute
Impulse 1.2/50 ms	IEC 255-5	5 kV, 0.5 J
Interference 1 Mhz	IEC 255-22-1	2.5 kV common, 1 kV differential
Electrostatic discharge	IEC 255-22-2 EN 61000-4-2	Class IV: 8 kV contact, 15 kV air
Fast Transient	IEC 255-22-4 EN 61000-4-4	Class IV: 4 kV
Magnetic fields	EN 61000-4-8	30 TA/m
Radiated Emisivity	EN 50081-2	Class A
Immunity RF radiated 80%	EN 50082-2 (Items 1.1 &1.2)	10 V/m 26-1000 Mhz 1 kHz AM 10 V/m 900 Mhz 200 Hz PM 50%
Immunity RF conducted	EN 50082-2 (Items 2.1, 3.1, 4.1 & 6.1)	10 V 0.15-80 Mhz 1 kHz AM 80%

The units comply as well with the following ANSI standards:

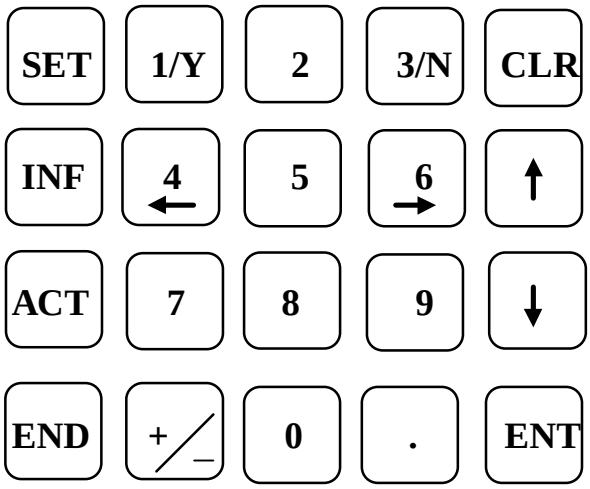
C37.90 (Standard for relays and relay systems)

C37.90.1 (Surge withstand capability)

C37.90.2 (Withstand capability to radiated interference)

7. KEYBOARD AND DISPLAY

Each DMS module has a 20 key keyboard and a 32-character liquid crystal display, which are distributed in two rows of 16 characters each. The layout of the keyboard can be seen in the following picture:



The keypad program uses menus to provide access to the different functions of the relay. These are divided into five big groups, each of them is accessed by means of a different key. These groups are the following:

Information: It gives data about the relay status. To access this menu press the **INF** key.

Control Operations: It allows synchronizing the date and time of the relay and to do communications trigger. To access this menu press the **ACT** key.

Settings: It allows to view and modify all the settings of the relay. To access this menu press the **SET** key.

Configuration Menu: It allows to access to the configuration of the relay, allowing the modification of communication baud rates, passwords, etc. To access this menu press **"7169"** (GE in ASCII code). In order to be able to access this menu, the relay must be in the main screen.

Single Key Menu: The DMS modules allows a simplified operating mode by pressing the **ENT** key. It is not necessary to remove the front cover to access to this mode.

In standby mode, each DMS module shows the following message:

- In the first line, the five first indicative letters of the DMS model, which allow to know its functionality. (e.g. DMS3L1: rack DMS of protection and control, for application in line type L1).

- In the second line: GENERAL ELECTRIC.

For the example, the message in the screen is:

DMS3L1
GENERAL ELECTRIC

Here one of the last five groups must be selected. In order to select other group, you must return to this screen and press the corresponding key.

Once you are in a group, another one can not be selected without leaving first and going back to the standby screen. You can move inside a group by pressing **ENT, CLR**, ↑, ↓, ← y → keys. Their meanings are as follows:

ENT: To accept the option that appears on the screen at that moment. It is equivalent to go down one level in the tree menu.

CLR: To leave the option that appears on the screen at that moment. It is equivalent to go up one level in the tree menu.

↑/↓: Change the option. It is equivalent to a horizontal movement inside a menu. When the desired option appears on the screen, select it by pressing the **ENT** key.

←/→: Show the different possibilities of a particular setting. When the desired option appears on the screen, select it by pressing the **ENT** key.

7.1 Tree Menus.

The DMS modules have different menus organized in levels. Level 0 is the standby screen. To access to level 1, a group key must be pressed (SET, INF, etc.). To move along a level é/ê keys must be pressed. To go down to levels 2 and 3 **ENT** key must be pressed. To go up along the menu tree, **CLR** key must be pressed.

Level 1, depending on the selected group, provides the following information:

***TABLE 12**. Menu MMI. Description*

Group	Level 1	Description
SET	• SHOW PROTECTION SETTINGS	• Show Protection settings
	• CHANGE PROTECTION SETTINGS	• Change protection settings
	• SHOW CONTROL SETTINGS	• Show control settings
	• CHANGE CONTROL SETTINGS	• Change control settings
	• CHANGE PROTECTION COUNTERS.	• Change protection counters
INF	• STATUS	• Show the DMS status
ACT	• DATE & HOUR	• Set the date and hour.
	• TRIGGER BY COMMUNICATION	• Start oscillography by communication
	• RESET CURRENT MAXIMETER.	• Reset the current maximeter
ENT	• Ia	• Show the phase A current in primary values.
	• Vab	• Shoe the phase AB voltage in primary values.
	• P	• Show the active Power in MW
	• Q	• Show the reactive Power in MW
	• In	• Show the neutral current in primary vales.
	• I2	• Show the negative sequence current in primary values.
	• VBB	• Show the phase-phase (VBB) voltage in primary value.
	• COS PHI	• Show the cos phi.
	• FREQUENCY	• Show the frequency in Hz
	• I MAXIMETER	• Show the current maximeter.
	• COUNTER I2t A	• Show the accumulated current in the phase A.
	• COUNTER I2t B	• Show the accumulated current in the phase B.
	• COUNTER I2t C	• Show the accumulated current in the phase C.
	• No OPENINGS	• Show the number of openings.

Group	Level 1	Description
	• PROTECTION STATUS	• Show the protection status (in service/out of service)
	• PICKUP 46	• Pickup 46
	• PICKUP 51F	• Pickup 51F
SET	• PICKUP 51N	• Pickup 51N
	• PICKUP 50 F	• Pickup 50 F
	• PICKUP 50N	• Pickup 50 N
	• ACTIVE SETTINGS	• Show the active settings table
	• 52 STATUS	• Show the circuit breaker status
	• 67 A	• Show the status (enable/blocking) of the phase A directional unit.
	• 67 B	• Show the status (enable/blocking) of the phase B
	• 67 C	• Show the status (enable/blocking) of the phase C directional unit.
	• DATE & HOUR	• Show the date & hour
Confi-guration unit **7169**	• BAUD REMOTE	• Baud for remote communication
	• STOP BITS	• Stop Bits in remote communication
	• BAUD LOCAL	• Baud for local communication
	• STOP BITS LOCAL	• Stop Bits for local communication
	• LOCAL SETTING	• Local settings enabled
	• REMOTE SET	• Remote settings enabled
	• LOCAL COMMAND	• Local commands enabled
	• REMOTE COMMAND	• Remote commands enabled
	• UNIT NUMBER	• Show the DMS number.
	• PASSWORD	• Password modification enabled
	• t TIMEOUT	• Timeout for communication

7.2 Settings Group.

This group allows viewing and modifying DMS settings. It can be accessed by pressing the **SET** key when the DMS is in standby mode. The following message will be displayed:

VIEW
PROTECCION SETTINGS

Pushing the keys ↑ ↓ the following message will be displayed:

CHANGE
PROTECCION SETTINGS

DMS settings menu tree is represented in the following table. It is important to remember that in order to go down along the tree **ENT** key must be pressed, and that to go up the tree the **CLR** key should be pressed instead.

NOTE: The table shows a particular case, the DMS3L1 model; this means that those SETTINGS that depend on the functions present in the module, according to its functionality, will vary for different models (Permission x function, oscillography mask).

***TABLE 13**. Menu MMI. Ranges and Settings*

Level 1	Level 2	Level 3	Valid Range
• **SHOW PROTECTION SETTINGS** • **CHANGE PROTECTION SETTINGS**	• **GENERAL SETTINGS**	• DMS STATUS	• In service Out of service
		• NAME OF FEEDER	• Alphanumeric chain of 20 characters
		• FREQUENCY	• 50 Hz 60 Hz
		• NOMINAL V PH-G	•
		• PHASE CT RATIO	• 1 - 4.000 in 1 step
		• NEUTRAL CT RATIO	• 1 - 4.000 in 1 step
		• LINE PT RATIO	• 1 - 4.000 in 1 step
		• BUSBAR PT RATIO	• 1 - 4.000 in 1 step
		• TIME DEMAND	• 15-30-60 min

Level 1	Level 2	Level 3	Valid Range
	• **SETTINGS CIRCUIT BREAKER**	• NUMBER OF OPENINGS	• Alphanumeric chain of 20 characters
		• t FAIL TO OPEN	• 0.05-1 in 0.01 step
		• t FAIL TO CLOSE	• 0.05-1 in 0.01 step
		• LIMIT KI2t	• 1-999.999 K(A2s) in 1 step.
		• KI2t OPERATING MODE	• Through measurement-fixed
		• t INTEGRATION KI2t	• 0.03 - 0.25 s in 0.01 step.
		• MAX. NUMBER OF TRIPPINGS IN 1 hour	• 1 - 50 in 1 step
	• **ACTIVE SETTINGS**	• ACTIVE SETTINGS	• 1-3
		• COLD LOAD PICKUP	• Enabled - Disabled
		• t TO SECOND ACTIVE SETTINGS CHANGE	• 0 - 240 s in 1s step.
		• t TO FIRST ACTIVE SETTINGS RESET	• 0 - 1800 s in 1s step.
SHOW PROTECTION SETTINGS **CHANGE PROTECTION SETTINGS**	**OSCILLOGRAPHY MASK**	• PICKUP 46	• Enabled - Disabled
		• PICKUP 51/67 F	• Enabled - Disabled
		• PICKUP 51/67 N	• Enabled - Disabled
		• PICKUP 50/67 F	• Enabled - Disabled
		• PICKUP 50/67 N	• Enabled - Disabled
	FUNCTION X PERMISSION	• FUNCTION 46	• Permitted - Non permitted
		• FUNCTION 51/67 F	• Permitted - Non permitted
		• FUNCTION 51/67 N	• Permitted - Non permitted
		• FUNCTION 50/67 F	• Permitted - Non permitted
		• FUNCTION 50/67 N	• Permitted - Non permitted
		• TRIP 46PT	• Enabled - Disabled
		• TRIP 51/67 F	• Enabled - Disabled
		• TRIP 51/67 N	• Enabled - Disabled

Level 1	Level 2	Level 3	Valid Range
		• TRIP 50/67 F • TRIP 50/67 N	• Enabled – Disabled • Enabled – Disabled
SHOW PROTECTION SETTINGS **CHANGE PROTECTION SETTINGS**	• **FUNCTION 46 T1**	• PICKUP 46 • CURVE • DIAL SETTINGS • t TIME DEFINITE	• 0.1 – 1.2 A in 0.01 step. • Inverse – very inverse.- extremely. inverse. – t definite • 0.05 – 1.00 s in 0.01. • 0.00 – 60.00 s in 0.01 step.
	• **FUNCTION 51/67 T1**	• PICKUP 51/67 F • CURVE • DIAL SETTINGS • t TIME DEFINITE	• 1 – 12 A in 0.01 step. • Inverse – very inverse.- extremely. Inverse. – t definite • 0.05 – 1.00 s in 0.01 step. • 0.00 – 60.00 s in 0.01 step.
• **SHOW PROTECTIO N SETTINGS** • **CHANGE PROTECTION SETTINGS**	**FUNCTION 51/67N T1**	• PICKUP 51/67 F • CURVE • DIAL SETTINGS • t TIME DEFINITE	• 0.5- 6.0 A in 0.01 step. • Inverse – very inverse.- extremely. inverse. – t definite • 0.05 – 1.00 s in 0.01 step. • 0.00 – 60.00 s in 0.01 step.
	• **FUNCTION 50/67 F**	• SETTINGS 50/67 T1 • TIMER	• 1.00–160.00 A in 0.01 step. • 0.00 – 2.00 s in 0.01 step.
	• **FUNCTION 50/67 N**	• PICKUP 51/67P T1 • TIMER	• 0.5 a 80.0 A in 0.01 step. • 0.00 – 2.00 s in 0.01 step.

Level 1	Level 2	Level 3	Valid Range
	• **DIRECTIONAL SETTINGS**	• 51F DIRECTIONAL	• Permitted - Non permitted
		• 51N DIRECTIONAL	• Permitted - Non permitted
		• 50 F DIRECTIONAL	• Permitted - Non permitted
		• 50 N DIRECTIONAL	• Permitted - Non permitted
		• ANGLE PHASE	• -90º - +90º in 1º step
		• ANGLE NEUTRAL	• -90º - +90º in 1º step
		• LOST OF LOGIC	• Permitted - Blocked
• **SHOW CONTROL SETTINGS**	• **GENERAL SETTINGS**	• CONTROL	• In service - Out of service
		• FREQUENCY	• 50 Hz 60 Hz
		• RATIO CT PHASE	• 1 - 3.000 in 1 step
		• RATIO CT NEUTRO	• 1 - 3.000 in 1 step
		• RATIO PT LINE SIDE	• 1 - 2.000 in 1 step
		• RATIO PT NEUTRAL SIDE	• 1 - 2.000 in 1 step
		• PHASE WIRED	• 1 to 3
		• BYPASS INTERLOCK	• In service - Out of service
	• **SINC. CLOSING**	• DIFF. MODULE	• 1- 30 V in steps of 1
		• DIFF. ANGLE	• 1 a 45º in steps of
		• DIFF. FREQUENCY	• 0.01 a 2.00 Hz in steps of 0.01
		• TIMER CLOSING	• 0.10 a 20.00 s. in steps of 0.01
		• LL-LB	• Permitted - Non permitted
		• LL-DB	• Permitted - Non permitted
		• DL-LB	• Permitted - Non permitted
		• SINCHRO CHECK	• Permitted - Non permitted
• **CHANGE PROTECTION COUNTER**	• **COUNTER I2t A**		
	• **COUNTER I2t B**		
	• **COUNTER I2t C**		
	• **No OPENINGS**		

Each DMS has a common group of settings for all the tables an another specific for each settings table. In the previous table we have only shown the settings related to table 1.

- General settings
- Circuit breaker
- Active table
- Oscillography mask

The rest of settings groups are applicable to each table independently, different groups being available for each table, e.g. function 46 T1,T2,T3, SETTINGS of the negative sequence function for each of the possible tables.

The procedure for changing any setting is as follows:

1. Press the SET key
2. Select the CHANGE SETTINGS. option
3. Select the desired setting in the menu.
4. Insert the value to be modified (or to select the desired one in the available list of SETTINGS with ← →).
5. Press the **ENT** key. If any other setting is to be modified, inside the same group, third and fifth steps must be repeated.
6. Press **END** key.
7. The DMS will ask for confirmation of the change showing in the screen the following message:

CONFIRM
Y/N

8. To confirm the change, press the **1/Y** key. (otherwise press **3/N** key).
9. The DMS will show then the following message:

SETTINGS CHANGE
EXECUTED

10. Press the **CLR** repeatedly to return to the standby mode.

If during the settings modification any range limit is exceeded, the relay will not accept the change and the following message will be displayed:

SETTINGS
OUT OF RANGE

Some settings do not require to enter a value through the keypad. They are just a selection of an option among several possibilities. In this case the options can be visualized using the ← → keys.

Example: Configure the TIME OF DEMAND in 15 min.

In order to make this change of settings we will start from the standby screen giving the following steps:

***TABLE 14**. Procedure to change settings*

Key	Screen	Comments
	DMS3L1 **GENERAL ELECTRIC**	Standby screen.
SET	**SHOW PROTECTION SETTINGS**	Level 1 settings
–	**CHANGE PROTECTION SETTINGS**	Move in the level 1
ENT	**GENERAL SETTINGS**	Level 2 settings
ENT	**RELAY STATUS** **IN SERVICE ----------**	Level 3 settings. The message IN SERVICE shown on the screen is the factory configuration for the relay status. On the left side is the assigned value and on the right side the new value.
↓	**RATIO CT PHASE** **-------**	We move in the level 3 setting.
↓	**TIME DEMAND** **60 ----------**	Search the setting wanted.
←	**TIME DEMAND** **60 30_**	We move in the level 3 setting
←	**TIME DEMAND** **60 15_**	We found the setting.
ENT	**TIME DEMAND** **60 15**	We accept the 15 value
CLR	**GENERAL SETTINGS**	Go to the level 2
CLR	**SHOW PROTECTION SETTINGS**	Go to the level 1
CLR	**(*) DMS3L1** **GENERAL ELECTRIC**	This is the status previous to the standby screen. In this status the remote settings change is not possible.
CLR	**DMS3L1** **GENERAL ELECTRIC**	Standby status.

7.3 Information Group.

This group provides information related to the DMS internal status. To access to this group press the **INF** key from the main menu. The information group includes the following sub-groups:

- Status.

As in the settings group, to access this sub-group, you must press the **INF** key. After this action, we are in the level 1 of the menu. Once the sub-group is selected (in this case the only existing group) push the **ENT** key to see its contents, (going down to level 3). In this level, we can see the contents using the ↑ / ↓ keys. The exit of the information group is carried out pressing repeatedly the CLR key until the standby screen appears.

Status.

The DMS allows visualizing the status of various internal DMS values. We go the status menu and press **ENT** key. Pressing the ↑ key we can move inside the status menu, obtaining the information of the following table:

TABLE 15. Information about the relay status

Screen	Possible values
MODEL **DMS3L1D1BEK001A**	According to the model
DATABASE	According to the model
PROTECTION VERSION	According to the model
CONTROL VERSION	According to the model
COMM. VERSION	According to the model
Ia	
Ib	

Screen	Possible values
Ic	
Vab	
Vbc	
VAC	
Vn	
P	
Q	
COS PHI	
In	
I2	
VBB	
MAXIMETER INT	
COUNTER I2t A	
COUNTER I2t B	
COUNTER I2t C	
No OPENINGS	
PICKUP 46	YES - NO
PICKUP 51F	YES - NO
PICKUP 51N	YES - NO
PICKUP 50F	YES - NO
PROTECTION STATUS	IN SERVICE - OUT OF SERVICE
MODE	
ACTIVE GROUP	1: GROUP 1 2: GROUP 2 3: GROUP 3
STATUS 52	OPEN - CLOSE
DIRECTIONAL A	PERMITTED - BLOCKED
DIRECTIONAL B	PERMITTED - BLOCKED
DIRECTIONAL C	PERMITTED - BLOCKED
DIRECTIONAL N	PERMITTED - BLOCKED
LOCAL CONNECTION	IN SERVICE - OUT OF SERVICE
DATE AND TIME	
E2PROM COMM.	
COMMUNICATION SETTINGS	USER - DEFAULT
PROTECTION LINK	YES - NO
CONTROL LINK	
EVENTS LEVEL 2	
DATE AND TIME	SHOW DATE AND TIME

7.4 Control Operations Group.

This group allows to operate the circuit breaker from the keyboard, as well as to block, unblock the recloser and set the equipment time. To access this group, press the **ACT** key when the relay is in standby mode. When entering the operations menu, the first element of the menu appears and the following message is displayed:

ENTER DATE/TIME

This indicates that the first element of the Operations menu is entering the date and time into the relay. Pressing the ↑ / ↓ keys the rest of elements of the Operations menu will appear. When the desired operation appears on the screen, press **ENT** key to select it.

In order to avoid not desired operations, the program will ask for confirmation of all of them. To confirm an operation, press the **1/Y** key and then **ENT**. To abort the operation, press **3/N** and then **ENT**. Pressing **CLR** when confirmation is requested, is equivalent to **3/N** and **ENT**, aborting the operation.

If the order is confirmed, the result of the operation will appear on the screen. Pressing **ENT** or **CLR** indistinctly the message is accepted and the screen returns to the operations menu.

As an example, this would be the procedure to open the circuit breaker starting from the operations menu:

ENTER DATE/HOUR	**ENT** →	**CONF (YES/N)**	**1/Y** →	**CARRIED OUT**

If the circuit breaker had not been opened, the result shown for the operation would have been "NOT CARRIED OUT"

The possible operations in the DMS are:

- Enter date/hour
- Communication Trigger
- Replacing int. maximeter

7.5 Single Key Operations.

The DMS allows a simplified way of operation, by using the **ENT** key. This mode allows to access different information about the DMS with no need to remove the external plastic cover. The operation consists of pressing repeatedly the **ENT** key. To access this mode we must start from the standby screen. The available information in this model of operation is shown in the following table, in its order of presentation.

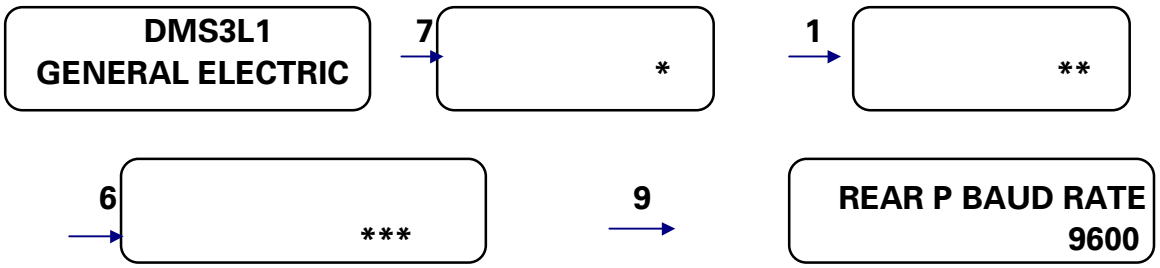
Magnitude
• Ia
• Vab
• P
• Q
• COS PHI
• In
• I2
• VBB
• MAXIMETER INT
• COUNTER I2t A
• COUNTER I2t B
• COUNTER I2t C
• No OPENINGS
• PICKUP 46
• PICKUP 51F
• PICKUP 51N
• PICKUP 50 F
• PICKUP 50 N
• PROTECTION STATUS
• ACTIVE GROUP
• STATUS 52
• DIRECTION A
• DIRECTION B
• DIRECTION C
• DIRECTION N
• DATE AND TIME

7.6 Configuration Menu.

The DMS relay includes a configuration unit that can be accessed exclusively through the keypad. It is used to select how the relay will interact with the external environment.

The configuration unit is entered from the standby screen by entering a four digit numerical code. If the code is correct you will enter into the configuration menu, if not the relay will return to the standby screen.

The code is common to all DMS. It is not meant to be a password, but a simple measure of security to avoid accidental manipulation of the configuration. The code is **7169** , which was selected because it is the corresponding ASCII code for the initials GE. This is the way to access the configuration unit from the standby screen:



The value and meaning of the settings are as follows: (It is important to mention that to move in this group, é/ê keys must be pressed).

- **REAR PORT BAUD RATE**: It is the baud rate that DMS relay uses to communicate with the remote end. The possible values for setting are between 1200 and 19,200 baud.

- **REAR PORT STOP BITS**: It is the number of bits added to each byte transmitted across the serial line. It is treated as a logical binary setting with the logical keys **1/Y** for 1, and **3/N** for 2.

- **FRONT PORT BAUD RATE**: It is the baud rate that DMS relay uses to communicate with the local end. The possible values for setting are between 1,200 and 19,200 baud.

- **FRONT PORT STOP BITS**: They are the number of bits added to each byte transmitted across the serial line. It is treated as a logical binary setting with the logical keys **1/Y** for 1, and **3/N** for.

- **LOCAL SETTINGS**: Setting which enables/disables the settings change via local communication.

- **REMOTE SETTINGS**: Setting which enables/disables the settings change via remote communication.

- **LOCAL CONTROL**: Setting which enables/disables local mode control operations (computer directly connected).

- **REMOTE CONTROL**: Setting which enables/disables remote control operations (e.g. via modem).

- **UNIT NUMBER**: Each DMS is identified by a unit number which serves to identify the messages directed to it when there are several devices connected to the same communication network. This number may be between 1 and 255, both included.

- **PASSWORD**: The relay provides a password in order to prevent unauthorized personnel from communicating remotely with the relay through the use of GE_LOCAL communications software (which allows settings modifications or control operations). The password may only be viewed through the relay display and it consists of a number between 0 and 99999. The introduced password through GE_LOCAL must be identical to the relay password in order to permit the connection with it.

- **TIMEOUT t:** Maximum synchronization time in order not to produce "clock not set" alarm event

8. ACCEPTANCE TESTS

In this section we will explain the different tests that allow verification of the complete functionality of a protection and/or control DMS equipment. For a given DMS equipment, only those tests corresponding to the functions included in it should be carried out, according to the table of application variables in the models selection guide.

The test instructions that follow correspond to the complete testing of a DMS3L3 model.

8.1. Visual Inspection

- Unpack the relay and make sure that there are no broken parts and that there are no signs that the relay has been damaged during transportation

- Make sure that all the screws are well tightened and the terminal blocks are not damaged.

- Make sure that the device type indicated on the front plate matches with the order data.

8.2. Insulation Test

During the testing, the A12 terminal should be to connected to ground for security reasons. It must be verified that connection to ground exists in the terminal C12.

- Apply gradually 2500 volts between all the terminals of a group, connected among themselves, and the box, during a second.

8.3. Power Supply

Apply nominal voltage (maximum and minimum) to the relay. For each of this voltages, check that the ALARM relay is open when it is powered and close when it is not powered.

Configure as trips all the configurable contacts and produce an trip.

When the relay is tripped, measure its DC power consumption and check that it communicates correctly.

The test will be carried out on the following models:

"A" and "J" Models:
Maximum Voltage: 57.6
Limit minimum Voltage: 38.4

"B" and "K" Models:
Maximum Voltage: 150
Limit minimum Voltage: 88

"C" and "L" Models:
Maximum Voltage: 300
Limit minimum Voltage: 176

8.4. Communications

- Verifying that the 2 communication PORT of the DMS, allow communication with the relay.

- The communication parameters that will be adjusted to the PC as well as to the DMS are:

  Number of relay = 1
  Baud remote = 9600
  Baud local = 9600
  Bits stop remote = 1
  Bits stop local = 1

- Communicate with the relay through both ports using the GE-LOCAL software.

- Repeat the test for different speeds.

8.5. Measurements

- Set the relay as follows:

Disabled Voltage =	35%
CT Ratio phases =	1000
CT Ratio ground =	1000
PT Ratio phases line =	1000
PT Ratio phases busbar =	1000
Frequency =	50 Hz

***NOTE**: ALL THE ANGLES THAT ARE INDICATED IN THIS TEST INSTRUCCION ARE LAGGING ANGLES.*

VOLTAGES

- Enter the following voltage values to the DMS using the corresponding inputs (see the external connections diagram of the equipment in test):

Magnitude	Phase	1	2	3	4	5	6
Vab (V)	0º	0	1	10	50	100	200
Vbc (V)	120º	0	1	10	50	100	200
VAC (V)	240º	0	1	10	50	100	200
VBB(V)	0º	0	1	10	50	100	200

- Verify that the DMS , measures Vab, Vbc, VAC, VBB with maximum error of 3%.

- Repeat tests for 60 Hz (changing to 60 Hz the frequency setting in the general group).

PHASE CURRENTS

- Enter the following current values to the relay:

***NOTE**: THE VALUES ARE GIVEN IN TIMES THE MINIMUM VALUE OF EACH SETTING RANGE (WITH A MAXIMUM OF 20 A).*

Magnitude	Phase	1	2	3	4	5	6
Ia (v. takes)	45º	0	20	10	5	1	0.5
Ib (v. takes)	165º	0	20	10	5	1	0.5
Ic (v. takes)	285º	0	20	10	5	1	0.5

- Repeat tests for 60 Hz.

GROUND CURRENT

- Enter the following current values to the equipment:

***NOTE**: THE VALUES ARE GIVEN IN TIMES THE MINIMUM VALUE OF EACH SETTING RANGE (WITH A MAXIMUM OF 20 A).*

Magnitude	Phase	1	2	3	4	5	6
In (v. takes)	0º	0	20	10	5	1	0.5

- Repeat test for 60 Hz.

ACTIVE MEASUREMENT OF ACTIVE AND REACTIVE POWER, AND COS jj

- With the following values, verify that the power measurement coincides with the one indicated. The maximum admissible error is a 5% for P, a 6% for Q and a 3% for cos φ.

Apply the following Current and Voltage values:

VA = 50V, 0º	VB = 50V, 120º	VC = 50V, 240º
IA = 5 v, 45º	IB = 5 v, 165º	IC = 5 v, 285º

	Nominal Value	Admissible range
P:	530* min. (MW)	504 to 556 * takes min (MW)
Q: (Mvar)	+530* min (Mvar)	+ 498 to + 561 * takes min (Mvar)
Cos φ:	0.707	0.666 to 0.728

FREQUENCY MEASUREMENT

- Apply 100 V, 50 Hz for phase B.

- Verify that the frequency measured by the equipment, is between 49.97 and 50.03 Hz.

MEASURING TEST FOR THE PROTECTION UNIT

FOR CONSIDERING FINISHED THE MEASURING TEST, FUNCTIONAL TESTS OF THE PROTECTION UNITS SHOULD BE CARRIED OUT IN ORDER TO ASSURE CORRECT MEASUREMENTS.

8.5. Digital Inputs

- This test should be carried out to values corresponding to +20% and -20% of the auxiliary voltage.

- Apply voltage to an input and check that the equipment detects its activation.
  (This can be done by associating one output relay with one input. Each time an input is activated the output relay will be operated too. Other way would be to associate one front LED to the activation of an input. This configuration can be done by means of GE_INTRO software).

- Repeat the test with the rest of protection and control Inputs.

8.7. Outputs

8.7.1. Tripping Outputs Checking. (Non Configurable)

- Enable all the protection functions
- Enable the trips
- Produce a trip condition (through any of the previously enabled functions).
- Make sure that the trip contacts are closed while the trip condition exists and that they are opened when this condition disappears.

8.7.2. Closing Outputs Checking. (Non Configurable)

- Enable all the protection functions.
- Enable the trips.
- Produce a closing condition.
- Make sure that the closing contacts are closed while the closing condition exists and that they are opened when this condition disappears.

8.7.3. Alarm Output Checking.

- Without applying auxiliary power supply, make sure that the alarm output contact is closed.
- Apply the auxiliary power supply voltage and make sure that there are no alarm conditions. For instance: protection out of service or all protection functions disabled. In such case, make sure that the alarm contact is opened..

8.7.4. Configurable Outputs Checking.

Make one of the configurable contacts close in one of the following ways:

- Configuring the outputs as protection unit pickups and producing one trip condition.
- Conditioning the output activation to an input activation.

Make sure that all the configurable relays close when the closing condition happens and open when this condition disappears.

***NOTE 1**: If the equipment does not include trip and closing contacts, points 1 and 2 will not be tested.*

***NOTE 2**: If the equipment does not include a protection CPU, the outputs will be closed conditioned to the inputs performance.*

8.8. Coils Supervision

8.8.1. Power Supply Alarm Checking.

COIL 1

- Apply 100 VDC to the voltage supervision input of coil 1. The positive is applied to terminal "C1" and the negative to terminal "D2".
- Verify that the internal state of "ALARM COIL 1 POWER SUPPLY " is not activated.
- Eliminate the voltage applied to the above mentioned input.
- Verify that the previous alarm is active.

COIL 2

- Repeat the previous test for coil 2. The positive is applied to terminal "C3" and the negative to terminal "D4".

8.8.2. Coil Continuity Alarm Checking.

- Set the equipment with the following values:

  Maximum opening time = 0.5 s
  Maximum closing time = 1.0 s

COIL 1

- Connect the terminal boards D1, C2 and D2 (common).
- Apply 100 VDC to the voltage supervision input of coil 1. The positive must be applied to terminal "C1" and the negative to terminal "D2".
- The "alarm of continuity of the coil 1" must not be activated
- Eliminate the connection between terminal boards D1 and D2
- Produce the previous alarm.
- Eliminate the connection among the terminal boards C2 and D2
- After 1 s, the previous alarm will be activated.

COIL 2

- Repeat the previous test for coil 2. The positive voltage is applied to terminal "C3" and the negative to terminal "D4". The terminal boards corresponding to the terminal boards D1, C2 and D2 will be D3, C4 and D4 respectively.

IRIG-B

- Connect the output of an IRIG-B equipment with decoded output to the input of the IRIG-B equipment (respect polarity).

- Verify that the hour measured by both equipments is the same.

8.9. Protection Functions

8.9.1. Phase Overcurrent Units (50/51P)

Instantaneous Phase Overcurrent Unit (50P)

- Set the equipment, so that it trips for 50P:

Settings:

50P pickup value =	2 times the minimum setting
Timer =	0

- Configure any of the outputs so that it is activated only by function 50P.

- Apply 0.9 times the pickup current and verify that the equipment does not trip.

- Rise the current gradually and verify that the equipment, acts between 1 and 1.1 times the set current. The equipment, should trip in a time between 10 and 50 ms. All the tripping contacts of the equipment must be activated, as well as the contact configured like 50P.

- Apply 4 times the pickup current. The equipment, should trip instantaneously in a time between 10 and 40 ms.

- Carry out the test for the phases A, B and C.

Phase Inverse Time Overcurrent (51P)

The 4 curves will be tested (Inverse, Very inverse, Extremely inverse and definite time), with 3 points per curve (one of not trip and two of trip). This gives us a total of 12 points for each protection function. The tests will be carried out on different phases. Each point will be tested with a different setting and dial in order to test the whole range of the equipment.

For making sure that the equipment trips, it will be verified that all the tripping relays are activated as well as a contact configured like 51P.

- Set the equipment, so that it trips for 51P.

- Configure any of the outputs so that it is activated only by function 51P.

Inverse Curve

- Enter the following settings into the equipment:
- Curve: INVERSE;
- Dial: 1;
- 51P pickup Value = 1 time the minimum tap.

- The test is carried out for phase A.

- Apply 0.9 times the pickup current and check that the equipment does not trip.

- Apply 1.5 times the pickup current. The equipment, should trip in 16 sec. (Admissible range of time among 14.90 and 17.30 sec.)

- Apply 5 times the pickup current. The equipment, should trip in 4 sec. (Admissible range of time among 3.93 and 4.08 sec.)

Very Inverse Curve

- Introduce the following settings to the equipment:
  Curve: VERY INVERSE;
  Dial: 0.5
  Pickup Value 51P = 2 times the minimum setting

- The test is carried out for phase B.

- Apply 0.9 times the pickup current and the equipment should not trip.

- Apply 1.5 times the pickup current. The equipment should trip in 16.03 sec. (Admissible range of time among 14.71 and 17.61 sec.)

- Apply 5 times the pickup current. The equipment, should trip in 2.03 sec. (Admissible range of time among 1.96 and 2.11 sec.)

Extremely Inverse Curve

- Enter the following SETTINGS to the equipment,:
  Curve: EXTREMELY INVERSE
  Dial: 0.05
  Pickup Value 51P = 4 times the minimum setting

- The test is carried out for phase C.

- Apply 0.9 times the pickup current. The equipment should not trip.

- Apply 1.5 times the pickup current. The equipment should trip in 3.87 sec. (Admissible range of time among 3.49 and 4.33 sec.)

- Apply 5 times the pickup current. The equipment should trip in 0.20 sec. (Admissible range of time among 0.16 and 0.24 sec.)

Definite Time

- Enter the following settings to the equipment:

  Curve: DEFINITE TIME;
  Definite time: 1.0
  Pickup Value 51P = 5 times the minimum setting

- The test is carried out for phase A.

- Apply 0.9 times the pickup current. The equipment should not trip.

- Apply 1.1 times the pickup current. The equipment should trip in a time among 0.97 and 1.03 sec.

- Apply 4 times the pickup current. The equipment should trip in a time among 0.97 and 1.03 sec.

8.9.2. Ground Overcurrent Units (50/51N)

Instantaneous Ground Overcurrent Unit (50N)

- Set the equipment, so that it trips for 50N:

SETTINGS :
  50N pickup Value = 2 times the minimum setting value
  Timer = 0

- Configure any of the outputs so that it is activated only by function 50N.

- Apply 0.9 times the pickup current and verify that the equipment does not trip.

- Rise the current gradually and verify that the equipment acts between 1 and 1.1 times the setting current. The equipment should trip in a time between 10 and 50 ms. All the tripping contacts of the equipment should operate, as well as the contact configured like 50N.

- Apply 4 times the pickup current. The equipment should trip in a time between 10 and 40 ms.

- Carry out the test for phases A, B and C.

Ground Inverse Time Overcurrent Unit (51N)

The 4 curves will be tested (Inverse, Very inverse, Extremely inverse and definite time), with 3 points per curve (one of not trip and two of trip). This gives us a total of 12 points. Each point will be tested with a different setting and dial in order to test the whole range of the equipment.

For making sure that the equipment trips, verify that all the trip relays are activated, as well as the contact configured like 51N.

- Set the relay, so that it trips for 51N.

- Configure any of the outputs so that it is activated only by function 51N.

Inverse Curve

- Enter the following SETTINGS to the relay:
  Curve: INVERSE;
  Dial: 1;
  51N pickup Value = 1 time the minimum setting

- Apply 0.9 times the pickup current. The equipment should not trip.

- Apply 1.5 times the pickup current. The DMS should trip in 16 sec. (Admissible range of time between 14.90 and 17.30 sec.)

- Apply 5 times the pickup current. The DMS should trip in 4 sec. (Admissible range of time among 3.93 and 4.08 sec.)

Very Inverse Curve

- Enter the following settings to the DMS,:

  Curve: VERY INVERSE;
  Dial: 0.5;
  Pickup Value 51N = 2 times the minimum setting

- Apply 0.9 times the pickup current. The DMS should not trip.

- Apply 1.5 times the pickup current. The DMS should trip in 16.03 sec. (Admissible range of time between 14.71 and 17.61 sec.)

- Apply 5 times the pickup current. The DMS should trip in 2.03 sec. (Admissible range of time between 1.96 and 2.11 sec.)

Extremely Inverse Curve

- Enter the following SETTINGS to the DMS,:
  Curve: EXTREMELY INVERSE;
  Dial: 0.05;
  Pickup Value 51N = 4 times the minimum setting

- Apply 0.9 times the pickup current. The DMS should not trip.

- Apply 1.5 times the pickup current. The DMS should trip in 3.87 sec. (Admissible range of time between 3.49 and 4.33 sec.)

- Apply 5 times the pickup current. The DMS should trip in 0.20 sec. (Admissible range of time between 0.16 and 0.24 sec.)

Definite Time

- Enter the following SETTINGS to the DMS,:

  Curve: DEFINITE TIME;
  Definite time: 1.0;
  Pickup Value 51N = 5 times the minimum setting

- Apply 0.9 times the pickup current and the DMS should not trip.

- Apply 1.1 times the pickup current. The DMS should trip in a time between 0.97 and 1.03 sec.

- Apply 4 times the pickup current. The DMS should trip in a time between 0.97 and 1.03 sec.

8.9.3. Phase Directional Unit (67)

In order to prove the directionality of the relay, instantaneous trips will be produced.

4 Points will be tested:

1. One situated clearly in the non-tripping area.
2. One situated clearly in the tripping area.
3. Another non-tripping, located at 5º of the upper limit of the non-tripping area.
4. Another non-tripping, situated to 5º of the lower limit of the non-tripping area.

The test will be repeated for the 3 phases.

- Set the DMS as follows:
  Pickup value unit 50P: 5 times the minimum setting.
  Timer unit 50P: 0 sec.

Directional permission 50P: YES;
Phase characteristic angle: 45º;
Loss of directional: PERMISSION;

- Configure one of the outputs so that it is only activated by function 50P.

Directional Phase A Testing

- Apply 4 times the pickup current, with 0º, through phase A. The positive will be applied to terminal A1 and the negative to terminal A2.

- Apply 60 V, with 0º, through phase C. Apply the positive to terminal B7 and the negative to terminal B8.

- Verify that the relay does not trip.

- Reduce gradually the voltage down to 1.5 V and verify that the DMS continues without tripping.

- Reduce voltage to 0.8 V and verify that the DMS trips.

- Repeat the test but applying 60 V, with 180ϕ through phase C.

- Verify that the DMS trips.

- Repeat the test, but applying 60 V, with 320ϕ, through phase C.

- Verify that the DMS does not trip.

- Repeat the test applying 60 V, with 130ϕ, through phase C.

- Verify that the DMS does not trip.

Directional Phase B Testing

- Apply 4 times the pickup current, with 0º, through phase B. Apply the positive to terminal B1 and the negative to terminal B2.

- Apply 60 V, with 0º, through phase A. Apply the positive to terminal B9 and the negative to terminal B10.

- Verify that the DMS does not trip.

- Reduce gradually the voltage down to 1.5 V and verify that the DMS continues without tripping.

- Reduce the voltage to 0.8 V and verify that the DMS trips.

- Repeat the test but applying 60 V, with 180º, through phase A.

- Verify that the DMS trips.

- Repeat the test but applying 60 V, with 320º, through phase A.

- Verify that the DMS does not trip.

- Repeat the test but applying 60 V, with 130º, through phase A.

- Verify that the DMS does not trip.

Directional Phase C Testing

- Apply 4 times the pickup current, with 0º, through phase C. Apply the positive to terminal A3 and the negative to terminal A4.

- Apply 60 V, with 0º, by the phase B. Apply the positive to terminal A9 and the negative to terminal A10.

- Verify that the DMS does not trip.

- Reduce slowly the voltage until 1.5 V and verify that the DMS continues without tripping.

- Reduce the voltage to 0.8 V and verify that the DMS trips.

- Repeat the test but applying 60 V, with 180º, through phase B.

- Verify that the DMS trips

- Repeat the test but applying 60 V, with 320º, through phase B.

- Verify that the DMS does not trip

- Repeat the test but applying 60 V, with 130º, through phase B.

- Verify that the DMS does not trip

8.9.4. Ground Directional Unit (67N)

To test the directional unit of the DMS, instantaneous trips will be produced.

4 Points will be tested:

1. One situated clearly in the non-tripping area.
2. One situated clearly in the tripping area.

3. Another situated to 5º of the upper limit of the non-tripping area
4. Another situated to 5º of the lower limit of the non-tripping area.

Set the relay as follows:

Pickup value unit 50N:	5 times the minimum setting.
Timer unit 50N:	0 sec.
Directional Permission 50N:	YES;
Phase characteristic angle:	-45º;
Directional Loss:	PERMISSION;

- Configure one of the outputs so that it is activated only by function 50N.

- Apply 4 times the pickup current, with 0º, through the neutral. Apply the positive to terminal B3 and the negative to terminal B4.

- Apply 60 V, with 0º, through phase B. Apply the positive to terminal A9 and the negative to terminal A10.

- Verify that the DMS does not trip.

- Reduce slowly the voltage to 1.5 V and verify that the DMS continues without tripping.

- Reduce the voltage to 0.8 V and verify that the DMS trips.

- Repeat the test but applying 60 V, with 180º, through phase B.

- Verify that the DMS trips

- Repeat the test but applying 60 V, with 230º, through phase B.

- Verify that the DMS does not trip.

- Repeat the test but applying 60 V, with 40º, through phase B.

- Verify that the DMS does not trip.

8.9.5. Minimum Voltage Unit (27)

- Set the DMS so that it trips for minimum voltage (27).

- Configure one of the outputs so that it is only activated by function 27.

- The test is carried out applying voltage to phases A, B and C successively. To those phases that are not being tested, a voltage should be applied over the tripping level, so that they do not act.

- In order to make sure that the relay trips, we will verify that all the trip relays are activated, as well as the contact configured as 27.

- Enter the following SETTINGS to the relay:
  -Pickup Value of the unit 27: 20 V
  -Timer activation undervoltage: 0.20 s

- Apply 21.5 V and verify that the DMS does not trip. Reduce the voltage gradually and verify that the DMS trips for a voltage of 20 V (with an admissible error of 5%).

- Verify that the time is between 0.18 and 0.22 s.

- Repeat the same test for the following settings:
  - Pickup Value of the unit 27: 110 V
  - Timer activation undervoltage: 4.0 s

- Apply 116 V and verify that the DMS does not trip. Reduce the voltage gradually and verify that the DMS trips for a voltage of 110 V (with an admissible error of 5%).

- Verify that the activation time is between 3.9 and 4.1 s.

8.9.6. Underfrequency Unit (81U)

- Set the relay as follows:

  Pickup Value of the underfrequency unit. (81U): 47.5 Hz
  Underfrequency timer: 2 sec.
  Minimum voltage supervision: 35%
  Frequency: 50 Hz

- Configure one of the outputs so that it is only activated by function 81U.

- Apply 100 VAC through phase B, varying the frequency from 46 Hz to 54 Hz, in steps of 1 Hz.

- Measure the activation time, which should be in the range of time between 1.9 and 2.1 s, with a frequency of 46 Hz and 47 Hz. With the rest of frequencies the relay should not trip.

- Apply 18 VAC through phase B with a frequency of 46 Hz. The DMS should not trip.

8.7. Overfrequency Unit (81O)

- Set the DMS as follows:

Pickup Value of the maximum frequency unit. (81O) :	52.5 Hz
Underfrequency timer:	2 seg
Supervision by minimum voltage:	35%
Frequency:	50 Hz

- Configure one of the outputs so that it is only activated by function 81O.

- Apply 100 VAC through phase B, varying the frequency from 46 Hz to 54 Hz, in steps of 1 Hz.

- Measure the operating time, that should be between 1.9 to 2.1 s, for a frequency of 46 Hz and 47 Hz. For other frequencies the DMS should not trip.

- Apply 18 VAC through phase B with a frequency of 46 Hz. The DMS should not trip.

8.8. Recloser (79)

SETTINGS:

- Enter the following SETTINGS:

Input 2:	"Reclosing cycle start " (P)
Input 3:	" Inhibit recloser" (P)
Input 4:	"Block recloser" (P)

Output 1:	Function:	"Global lockout"
Output 2:	Function:	"Cycle under way"
Output 3:	Function:	"Recloser in standby"

Recloser settings:

Recloser:	Enabled
Time of security:	10 sec.
Nº of reclosings:	4

Time 1st reclosing:	2.1 sec.
Time 2nd reclosing:	4.1 sec.
Time 3rd reclosing:	6.1 sec.
Time 4th reclosing:	8.1 sec.
Standby mode:	Enabled
Permission after a reclosing:	50P
Dwell time:	15 sec.

Tripping settings:

Set the relay so that it trips for 50P
Pickup Value 50P unit: 1 time the minimum setting
Timer of 50P: 0 sec.

1.- Reclosing Cycle

- After setting the DMS, close the circuit breaker and wait for 10 sec. After this time the recloser is prepared to initiate the reclosing cycle.

- Produce a 50P trip and verify that the DMS recloses in 2.1 sec.

- Produce a 50P trip and verify that the DMS recloses in 4.1 sec.

- Produce a 50P trip and verify that the DMS recloses in 6.1 sec.

- Produce a 50P trip and verify that the DMS recloses in 8.1 sec.

- Produce a 50P trip and verify that the recloser turns to LOCKOUT.

- Check the correct operation of the programmed outputs.

2.- Recloser Lockout

- Activate input 4 (recloser lockout).

- Verify that the recloser is in LOCKOUT, checking the "lockout" output.

- Close the circuit breaker and wait for 10 sec. After this time the recloser is prepared to initiate the reclosing cycle.

- Produce a trip and verify that the recloser continues in LOCKOUT, checking the "lockout" output.

3.- Reclosing Inhibition Check

- Close the circuit breaker and wait for 10 sec. After this time the recloser is prepared to initiate the reclosing cycle.

- Produce a trip and wait for the 1st reclosing.

- Activate input 3 (reclosing inhibition) and produce a 50P pickup.

- After 12 sec., disable input 3 and verify that the relay recloses in that moment.

- Activate input 3 (reclosing inhibition) and produce a 50P pickup.

- After 18 sec. disable input 3 and verify that the relay does not reclose. The recloser should be in LOCKOUT.

4.- Reclosing Start

- Close the circuit breaker and wait for 10 sec. After this time the recloser is prepared to initiate the reclosing cycle.

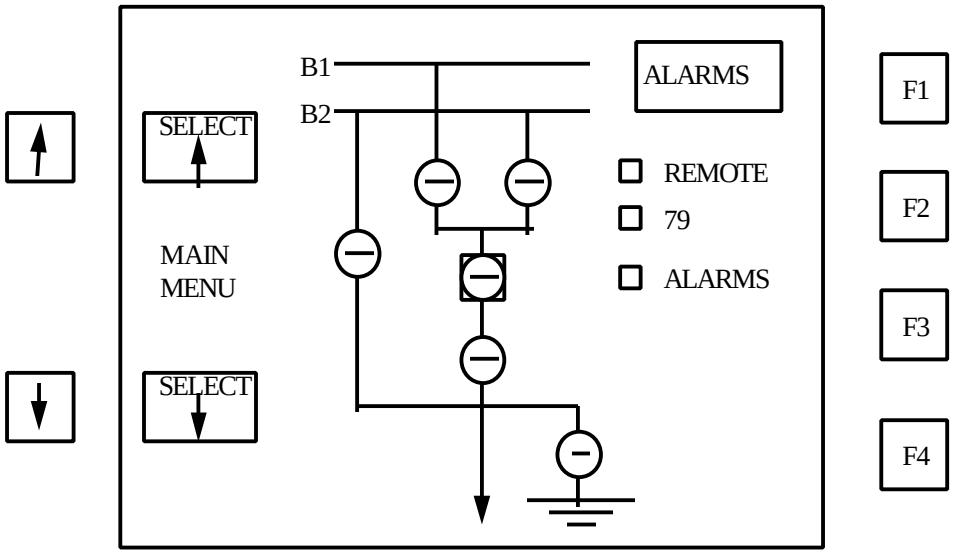
- Produce a trip and wait for the first reclosing.

- Activate input 1 (Reclosing start) and verify that after 4 sec. (corresponding to the 2nd reclosing) the DMS recloses again.

9. MIMIC OF THE POSITION

The DMS modules including protection and control functions, incorporate at the right side of the module a graphic display of 112 x 62 mm. Here it is shown a mimic of the position associated to this DMS module (circuit breakers, switch selectors and their status)

The standby mode screen is as follows:



The keyboard for accessing the different screens and acting with the existing elements on a screen is situated at the left and right sides of the graphic display as follows:

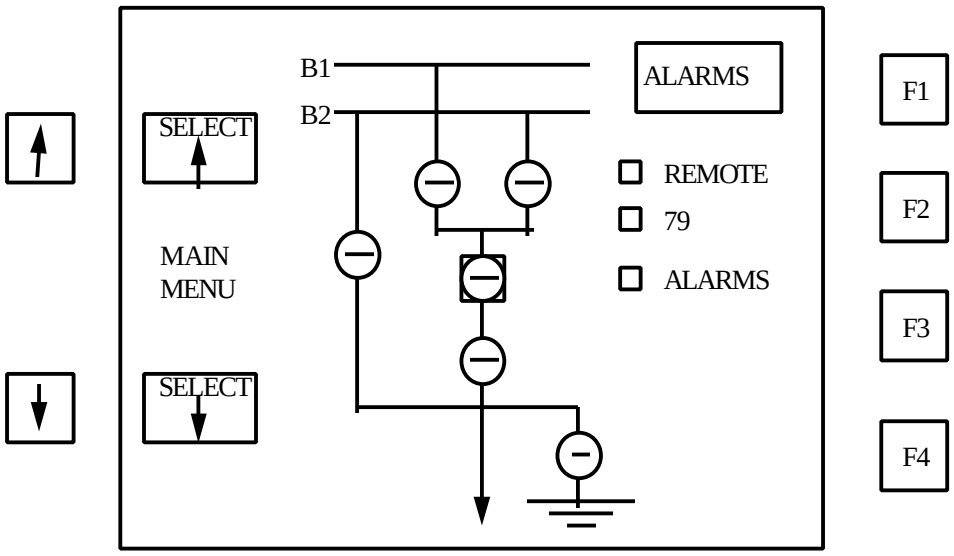
- On the left side there are two keys with arrows, upward and downward. These keys are used to select the different elements in the screen.

- On the right there are several function keys F1, F2, F3, F4. Depending on the screen and on the operation we are performing, we will see on the display beside each function key, the operation it allows to perform. (e.g. In the above shown display, we find an "ALARMS" legend next to F1 key, which means that pressing this key we will move to the Alarms screen).

If after 15 minutes none of these keys is pressed, the display will be turned off automatically in order to avoid unnecessary consumption. When a key is pressed, it turns on again.

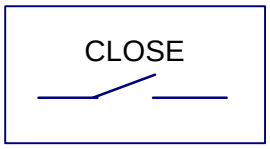
9.1. Main Screen

Here we will see the first screen or main screen that appears on the graphic display. This screen represents the mimic of the position.

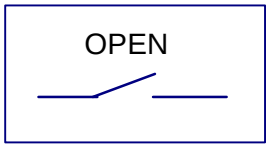


In the standby mode, none of the elements that can perform an operation is selected. We can move through them using the arrows, and they will turn darker as we select them (circuit breakers, switches, recloser).

When an item is selected, it will turn dark, and the user will be able to see the available operations on the display, next to the function keys.



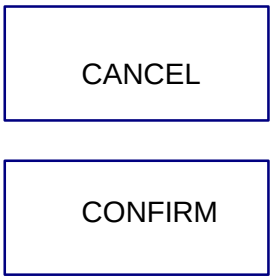
F4



F3

F4

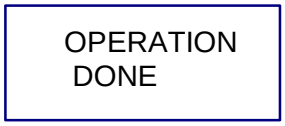
When pressing an operation key, the DMS will ask for confirmation, as follows:



If the operation is not performed, or the module does not receive confirmation from the switchgear, the following message will appear on the screen:

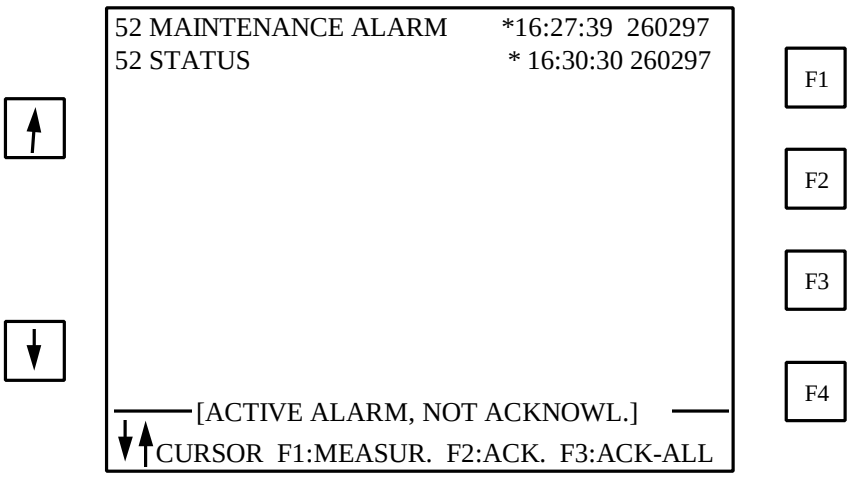
Besides in the main screen, in the place in which will appear "to cancel", appears "menu select", being presented the next screen:

In the case that the maneuver be executed correctly, the message that appears is:



9.2. Alarms Screen

If we go from the main screen to the alarms screen pressing F1 key, as indicated on the main screen, the following picture will appear:



Here we can see a list of the alarms that have been produced in the substation. The maximum number of alarms is 12. Alarms are represented as follows:

- Alarm label, that is to say, associated text.
- Time when the alarm was produced.
- Alarm date.

When an alarm is produced, we will see on the screen the previous data with a dark blinking shadow. This blinking means that the alarm has not been "acknowledged". For "recognizing" the alarm you must press F2 key, as indicated on the bottom of the screen. Once the alarm is acknowledged, the blinking shadow disappears, but the alarm will remain on the screen until the reason for its generation disappears.

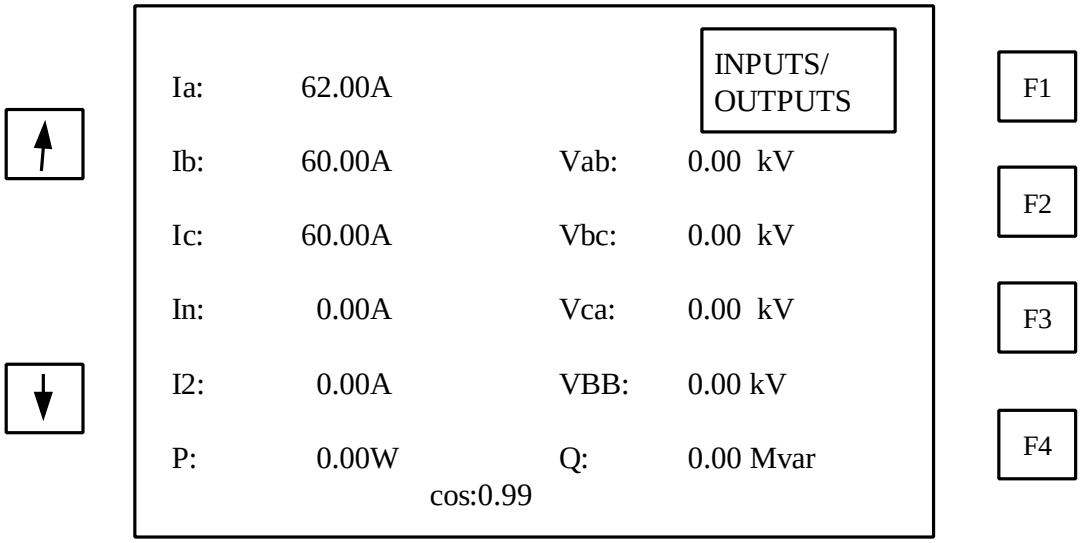
Now we can understand the text appearing at the bottom of the screen: "ACTIVE ALARM, NOT ACKNOWLEDGED". When the alarm is acknowledged, the text changes to "ACTIVE ALARM".

The help text at the bottom of the screen shows the different actions to be carried out in that screen:

- The arrows are used to go from one alarm to another.
- Pressing F1 key, you will go to the measures screen.
- Pressing F2, the selected alarm is acknowledged. (When an alarm is selected, it changes color).
- Pressing F3, all the alarms are acknowledged automatically.

9.3. Measures Screen

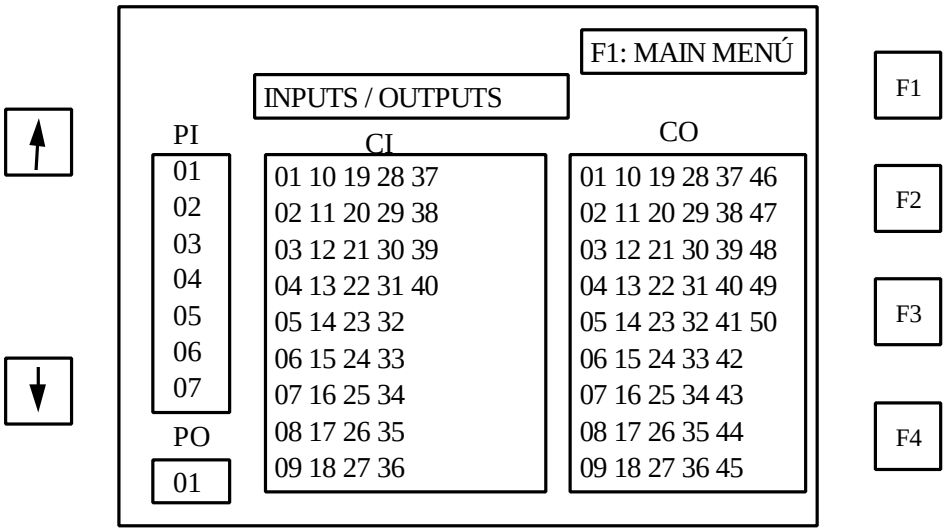
If we go from the alarms screen to the measures screen, the following screen will appear:



The presented values are those on the primary side. This screen will change according to the chosen DMS rack. E.g. the auxiliary services rack does not have any measure.

9.4. Inputs and Outputs Screen

Pressing F1 key, we will go from the measures screen to the Inputs and Outputs screen. Here we can find the different inputs and outputs, which will appear separated by protection and control. The number of inputs/outputs is different depending on the DMS rack. The screen will be similar to the following:



Active inputs/outputs will appear with a dark shadow.