GE Multilin

Power Management
Lentronics

F650
Digital Bay Controller

Instruction manual
GEK-106310

GE Multilin
Avda. Pinoa, 10
48170 Zamudio SPAIN
Tel: +34 94 485 88 00   Fax: +34 94 485 88 45
E-mail: gemultilin.euro@indsys.ge.com

Internet: www.geindustrial.com/multilin

DISCLAIMER

This page contains information that relates to the F650 relay, version 1.0. You will find below a number of information items that appear in the instruction manual GEK-106310 but are not included in the current F650 operations.

The following functions/items are not yet available with the current version of the F650 relay:

Recording: Sequence of events, oscillography and data logger.

Protection: Frequency protection functions (81U and 81O).

Control: IRIG-B synchronization and graphic HMI.

Communications: DNP 3.0 protocol.

The hardware is ready to support this added functions in order to allow easy upgrades of the latest firmware versions that may be downloaded from the GE Multilin website www.geindustrial.com/multilin

1. PRODUCT DESCRIPTION

To help ensure years of trouble free operation, please read through the following chapter for information to help guide you through the initial installation procedures of your new relay.

CAUTION: THE OPERATOR OF THIS INSTRUMENT IS ADVISED THAT IF THE EQUIPMENT IS USED IN A MANNER NOT SPECIFIED IN THIS MANUAL, THE PROTECTION PROVIDED BY THE EQUIPMENT MAY BE IMPAIRED

INSTALLATION MUST BE ACCORDING TO THE NATIONAL ELECTRIC CODE OF THE APPROPRIATE COUNTRY

The F650 is a protection, control, monitoring, metering and registering unit, suitable for many different applications, thanks to its extensive functionality. It is mainly used for feeder protection, as it replaces many other devices, including:

Protections.

Reclosers.

Counters and meters.

Oscillography registers.

Data logger.

Bay control (open/close commands, etc.)

Alarm panel.

Bay mimic.

Event recording

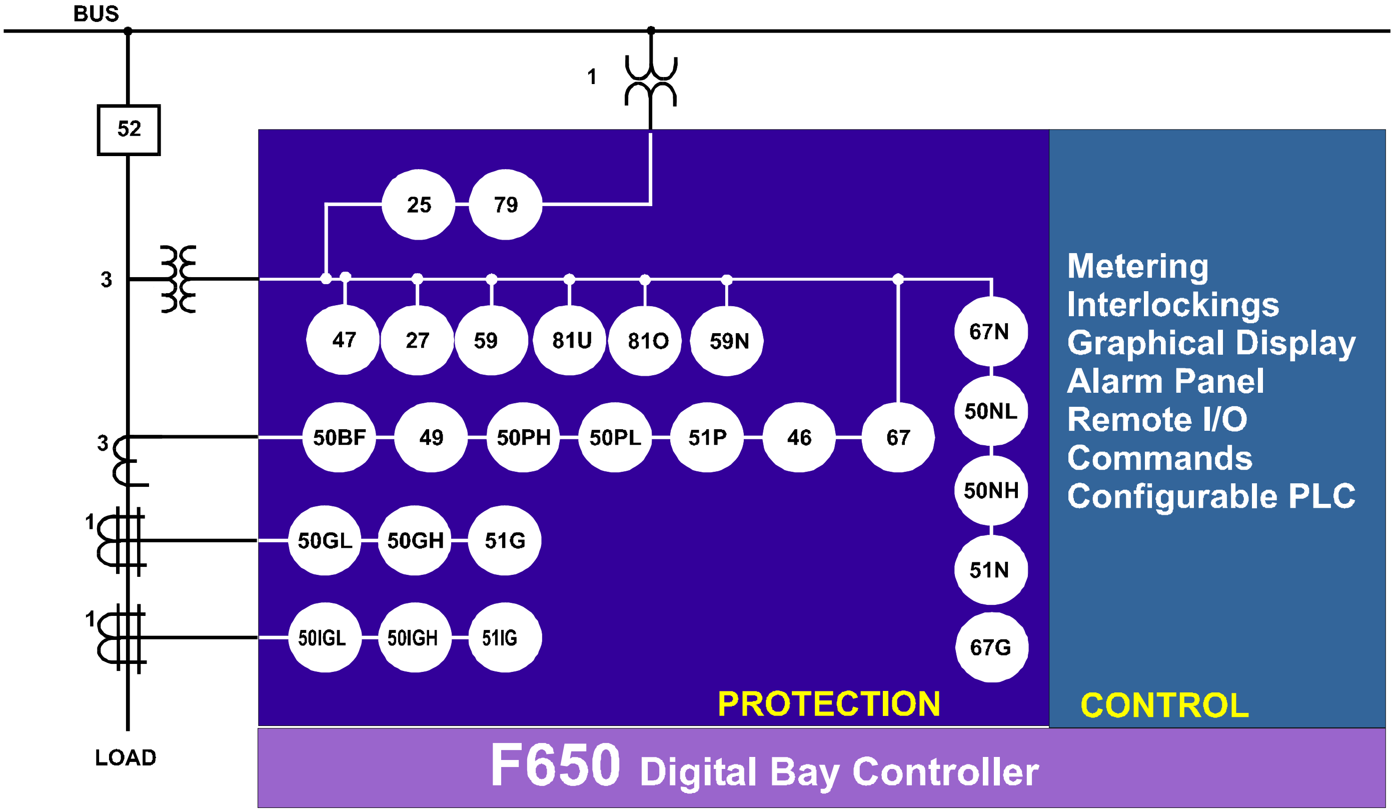


FIGURE 1. FUNCTIONAL BLOCK DIAGRAM

1.1 INSPECTION CHECKLIST

Open the relay packaging and inspect the relay for physical damage.

View the faceplate relay model number and verify that the relay is the correct model ordered.

Ensure that the mounting screws have been included with the relay.

For product information, instruction manual updates, and the latest software updates, please visit the GE Multilin Home Page www.geindustrial.com/multilin.

Note: If there is any physical damage detected on the relay, or any of the contents listed are missing, please contact GE Multilin immediately at:

EUROPE, MIDDLE EAST AND AFRICA:
GE MULTILIN
Avda.Pinoa,10
48170 Zamudio, Vizcaya (SPAIN)
Tel.: (34) 94-485 88 00, Fax: (34) 94-485 88 45

E-mail: gemultilin.euro@indsys.ge.com

AMERICA, ASIA AND AUSTRALIA:
GE MULTILIN
215, Anderson Avenue
L6E 1B3 Markham, ON (CANADA)
Tel.: +1 905 201 6222, Fax: +1 905 201 2098

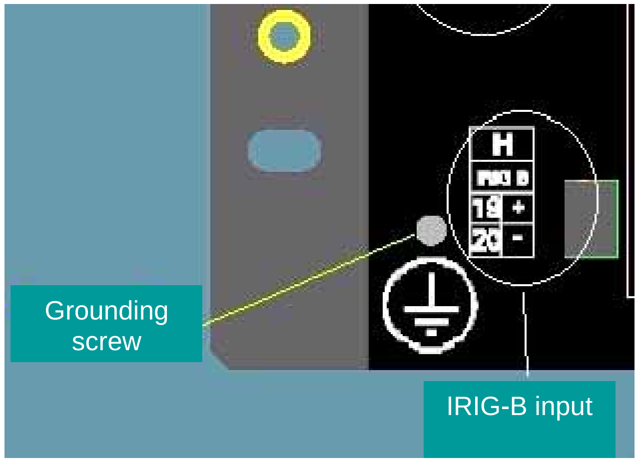
E-mail: info.pm@indsys.ge.com

The information provided herein does not intend to cover all details of variations of the described equipment nor does it take into account the circumstances that may be present in your installation, operating or maintenance activities.

Should you wish to receive additional information, or for any particular problem that cannot be solved by referring to the information contained herein, please contact GENERAL ELECTRIC MULTILIN.

1.2 SAFETY INSTRUCTIONS

The F650 ground screw shown in the following figure must be correctly grounded.



When we want to communicate with the F650 using a computer through the front serial port, please ensure that the computer is grounded.

In the case of using a portable computer, it is recommended not to have it connected to its power supply, as in many cases they are not correctly grounded either due to the power supply itself or to the connector cables used. This way, feeding the unit with its internal battery, the worst case would be an incorrect communication, but we drastically decrease the possibility of producing permanent damage to the computer or the relay.

This is required not only for personal protection, but also for avoiding a voltage difference between the relay serial port and the computer port, that could produce permanent damage to the computer or the relay.

GE Multilin will not be responsible for any damage in the relay or connected equipment whenever this elemental safety rule is not followed.

2. PROTECTION UNITS

2.1 CURRENT ELEMENTS

The F650 incorporates the following overcurrent elements:

Phase time overcurrent (51P)

Phase instantaneous overcurrent (50P)

Phase directional overcurrent (67P)

Neutral time overcurrent (51N)

Neutral instantaneous overcurrent (50N)

Ground time overcurrent (51G)

Ground instantaneous overcurrent (50G)

Ground directional overcurrent (67G)

Directional overcurrent unit for isolated ground systems (67IG)

Negative sequence time overcurrent (46P)

Thermal image (49)

2.1.1. INVERSE TIME CURVES CHARACTERISTICS

Inverse time curves available in time overcurrent units include IEEE (ANSI), IEC, IAC and I^2t. All these curves follow the standards defined for each of them, allowing an efficient coordination with other devices located downstream. A dial or curve setting allows selection of a tripping time X times the set time in the selected curve. Fixing this value to 0 would produce an instantaneous response for any selected curve.

Tripping time calculations are performed on the base of an internal variable called “energy”. This energy represents the system dissipation capability, that is, when 100% of energy is reached, this means that the tripping time associated to the curve for a certain current value has expired.

Therefore, once the current value has exceeded the pickup value, the relay starts increasing the energy variable value. If it reaches 100%, a trip is produced. When the current value falls below 97% of the pickup value, the unit is reset. There are two reset types: Instantaneous and Timed (IEEE) or Lineal.

The instantaneous mode provides that, when the current value falls below the reset level, energy is immediately reset to 0. This mode is used for coordinating with static devices, which behave in a similar way. In the Lineal mode, energy is reduced at a speed associated to the reset times curve (showed in the curve tables), trying to simulate the behaviour of electromechanical relays.

2.1.2. IEEE CURVES (ANSI)

This family of curves follows standard IEEE C37.112-1996 for extremely inverse, very inverse, and inverse classifications. The following formulas define this type of curve:

$$t = dial * \left(\frac{A}{\left(\frac{I}{Itap}\right)^{p} - 1} + B \right)$$

$$T_{RESET} = dial * \left(\frac{t_r}{\left(\frac{I}{Itap}\right)^{2} - 1} \right)$$

where: t = Operation time in seconds

Dial = multiplier setting

I = Input current

Itap = Current pickup value

A, B, p = constants defined by the standard

T_{RESET} = reset time in seconds

t_r = characteristic constant.

Table 2-1: CONSTANTS for IEEE CURVES

Curve	HMI	A	B	p	tr
IEEE Extremely Inverse	IEEE Ext Inv	28.2	0.1217	2.0000	29.1
IEEE Very Inverse	IEEE Very Inv	19.61	0.491	2.0000	21.6
IEEE Inverse	IEEE Mod Inv	0.0515	0.1140	0.0200	4.85

Table 2-2: TRIPPING TIME IN SECONDS FOR IEEE CURVES

Dial	Current (I/Itap)									
	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
IEEE Extremely Inverse										
0.5	11.341	4.761	1.823	1.001	0.648	0.464	0.355	0.285	0.237	0.203
1.0	22.682	9.522	3.647	2.002	1.297	0.927	0.709	0.569	0.474	0.407
2.0	45.363	19.043	7.293	4.003	2.593	1.855	1.418	1.139	0.948	0.813
4.0	90.727	38.087	14.587	8.007	5.187	3.710	2.837	2.277	1.897	1.626
6.0	136.090	57.130	21.880	12.010	7.780	5.564	4.255	3.416	2.845	2.439
8.0	181.454	76.174	29.174	16.014	10.374	7.419	5.674	4.555	3.794	3.252
10.0	226.817	95.217	36.467	20.017	12.967	9.274	7.092	5.693	4.742	4.065
IEEE Very Inverse										
0.5	8.090	3.514	1.471	0.899	0.654	0.526	0.450	0.401	0.368	0.345
1.0	16.179	7.028	2.942	1.798	1.308	1.051	0.900	0.802	0.736	0.689
2.0	32.358	14.055	5.885	3.597	2.616	2.103	1.799	1.605	1.472	1.378
4.0	64.716	28.111	11.769	7.193	5.232	4.205	3.598	3.209	2.945	2.756
6.0	97.074	42.166	17.654	10.790	7.849	6.308	5.397	4.814	4.417	4.134
8.0	129.432	56.221	23.538	14.387	10.465	8.410	7.196	6.418	5.889	5.513
10.0	161.790	70.277	29.423	17.983	13.081	10.513	8.995	8.023	7.361	6.891
IEEE Inverse										
0.5	3.220	1.902	1.216	0.973	0.844	0.763	0.706	0.663	0.630	0.603
1.0	6.439	3.803	2.432	1.946	1.688	1.526	1.412	1.327	1.260	1.207
2.0	12.878	7.606	4.864	3.892	3.377	3.051	2.823	2.653	2.521	2.414
4.0	25.756	15.213	9.729	7.783	6.753	6.102	5.647	5.307	5.041	4.827
6.0	38.634	22.819	14.593	11.675	10.130	9.153	8.470	7.960	7.562	7.241
8.0	51.512	30.426	19.458	15.567	13.507	12.204	11.294	10.614	10.083	9.654
10.0	64.390	38.032	24.322	19.458	16.883	15.255	14.117	13.267	12.604	12.068

2.1.3. IEC CURVES

This family of curves follow standard IEC 255-4 for the classifications of Curve A, B and C. The formulas that define these curves are as follows:

$$t = dial * \left| \frac{K}{\left(\frac{I}{Itap}\right)^{E} - 1} \right| \qquad T_{RESET} = dial * \left| \frac{t_r}{\left(\frac{I}{Itap}\right)^{2} - 1} \right|$$

where: t = Operation time in seconds

Dial = multiplier setting

I = Input current

Itap = Current pickup value

K, E = constants defined by the standard

T_{RESET} = reset time in seconds

t_r = characteristic constant.

Table 2-3: CONSTANTS FOR IEC CURVES

Curve	HMI	K	E	tr
IEC Curve A	IEC Curve A	0.140	0.020	9.7
IEC Curve B	IEC Curve B	13.500	1.000	43.2
IEC Curve C	IEC Curve C	80.000	2.000	58.2

Table 2-4: TRIPPING TIME IN SECONDS FOR IEC CURVES

Dial	**Current (I/Itap)**									
	1.5	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
IEC Curve A										
0.05	0.860	0.501	0.315	0.249	0.214	0.192	0.176	0.165	0.156	0.149
0.10	1.719	1.003	0.630	0.498	0.428	0.384	0.353	0.330	0.312	0.297
0.20	3.439	2.006	1.260	0.996	0.856	0.767	0.706	0.659	0.623	0.594
0.40	6.878	4.012	2.521	1.992	1.712	1.535	1.411	1.319	1.247	1.188
0.60	10.317	6.017	3.781	2.988	2.568	2.302	2.117	1.978	1.870	1.782
0.80	13.755	8.023	5.042	3.984	3.424	3.070	2.822	2.637	2.493	2.376
1.00	17.194	10.029	6.302	4.980	4.280	3.837	3.528	3.297	3.116	2.971
IEC Curve B										
0.05	1.350	0.675	0.338	0.225	0.169	0.135	0.113	0.096	0.084	0.075
0.10	2.700	1.350	0.675	0.450	0.338	0.270	0.225	0.193	0.169	0.150
0.20	5.400	2.700	1.350	0.900	0.675	0.540	0.450	0.386	0.338	0.300
0.40	10.800	5.400	2.700	1.800	1.350	1.080	0.900	0.771	0.675	0.600
0.60	16.200	8.100	4.050	2.700	2.025	1.620	1.350	1.157	1.013	0.900
0.80	21.600	10.800	5.400	3.600	2.700	2.160	1.800	1.543	1.350	1.200
1.00	27.000	13.500	6.750	4.500	3.375	2.700	2.250	1.929	1.688	1.500
IEC Curve C										
0.05	3.200	1.333	0.500	0.267	0.167	0.114	0.083	0.063	0.050	0.040
0.10	6.400	2.667	1.000	0.533	0.333	0.229	0.167	0.127	0.100	0.081
0.20	12.800	5.333	2.000	1.067	0.667	0.457	0.333	0.254	0.200	0.162
0.40	25.600	10.667	4.000	2.133	1.333	0.914	0.667	0.508	0.400	0.323
0.60	38.400	16.000	6.000	3.200	2.000	1.371	1.000	0.762	0.600	0.485
0.80	51.200	21.333	8.000	4.267	2.667	1.829	1.333	1.016	0.800	0.646
1.00	64.000	26.667	10.000	5.333	3.333	2.286	1.667	1.270	1.000	0.808

2.1.4. IAC CURVES

This family of curves follows the time response of IAC electromechanical relays. The following formulas define these curves:

$$t = dial * \left| A + \frac{B}{\frac{I}{Itap} - C} + \frac{D}{\left(\frac{I}{Itap} - C\right)^2} + \frac{E}{\left(\frac{I}{Itap} - C\right)^3} \right| \qquad T_{RESET} = dial * \left| \frac{t_r}{\left(\frac{I}{Itap}\right)^2 - 1} \right|$$

where:

t = Operation time in seconds

Dial = multiplier setting

I = Input current

Itap = Current pickup value

A, B, C, D, E = predefined constants

T_{RESET} = reset time in seconds

t_r = characteristic constant.

Table 2-5: CONSTANTS FOR IAC CURVES

Curve	HMI	A	B	C	D	E	tr
IAC Extremely Inverse	IAC Ext Inv	0.0040	0.6379	0.6200	1.7872	0.2461	6.008
IAC Very Inverse	IAC Very Inv	0.0900	0.7955	0.1000	-1.2885	7.9586	4.678
IAC Inverse	IAC Mod Inv	0.2078	0.8630	0.8000	-0.4180	0.1947	0.990

Table 2-6: TRIPPING TIMES IN SECONDS FOR IAC CURVES

Dial	**Current (I/Itap)**									
	1.5	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
IAC Extremely Inverse										
0.5	1.699	0.749	0.303	0.178	0.123	0.093	0.074	0.062	0.053	0.046
1.0	3.398	1.498	0.606	0.356	0.246	0.186	0.149	0.124	0.106	0.093
2.0	6.796	2.997	1.212	0.711	0.491	0.372	0.298	0.248	0.212	0.185
4.0	13.591	5.993	2.423	1.422	0.983	0.744	0.595	0.495	0.424	0.370
6.0	20.387	8.990	3.635	2.133	1.474	1.115	0.893	0.743	0.636	0.556
8.0	27.183	11.987	4.846	2.844	1.966	1.487	1.191	0.991	0.848	0.741
10.0	33.979	14.983	6.058	3.555	2.457	1.859	1.488	1.239	1.060	0.926
IAC Very Inverse										
0.5	1.451	0.656	0.269	0.172	0.133	0.113	0.101	0.093	0.087	0.083
1.0	2.901	1.312	0.537	0.343	0.266	0.227	0.202	0.186	0.174	0.165
2.0	5.802	2.624	1.075	0.687	0.533	0.453	0.405	0.372	0.349	0.331
4.0	11.605	5.248	2.150	1.374	1.065	0.906	0.810	0.745	0.698	0.662
6.0	17.407	7.872	3.225	2.061	1.598	1.359	1.215	1.117	1.046	0.992
8.0	23.209	10.497	4.299	2.747	2.131	1.813	1.620	1.490	1.395	1.323
10.0	29.012	13.121	5.374	3.434	2.663	2.266	2.025	1.862	1.744	1.654
IAC Inverse										
0.5	0.578	0.375	0.266	0.221	0.196	0.180	0.168	0.160	0.154	0.148
1.0	1.155	0.749	0.532	0.443	0.392	0.360	0.337	0.320	0.307	0.297
2.0	2.310	1.499	1.064	0.885	0.784	0.719	0.674	0.640	0.614	0.594
4.0	4.621	2.997	2.128	1.770	1.569	1.439	1.348	1.280	1.229	1.188
6.0	6.931	4.496	3.192	2.656	2.353	2.158	2.022	1.921	1.843	1.781
8.0	9.242	5.995	4.256	3.541	3.138	2.878	2.695	2.561	2.457	2.375
10.0	11.552	7.494	5.320	4.426	3.922	3.597	3.369	3.201	3.072	2.969

2.1.5. I2T CURVES

The following formulas define this type of curves:

$$t = dial * \left[\frac{100}{\left(\frac{I}{Itap} \right)^{2}} \right] \qquad T_{RESET} = dial * \left[\frac{100}{\left(\frac{I}{Itap} \right)^{-2}} \right]$$

where: t = Operation time in seconds

Dial = multiplier setting

I = Input current

Itap = Current pickup value

T_{RESET} = reset time in seconds

Table 2-7: TRIPPING TIME IN SECONDS FOR I2t CURVES

Dial	Current (I/Itap)									
	1.5	**2.0**	**3.0**	**4.0**	**5.0**	**6.0**	**7.0**	**8.0**	**9.0**	**10.0**
0.01	0.444	0.250	0.111	0.063	0.040	0.028	0.020	0.016	0.012	0.010
0.10	4.444	2.500	1.111	0.625	0.400	0.278	0.204	0.156	0.123	0.100
1.00	44.444	25.000	11.111	6.250	4.000	2.778	2.041	1.563	1.235	1.000
10.00	444.444	250.000	111.111	62.500	40.000	27.778	20.408	15.625	12.346	10.000
100.00	4444.444	2500.000	1111.111	625.000	400.000	277.778	204.082	156.250	123.457	100.000
600.00	26666.667	15000.000	6666.667	3750.000	2400.000	1666.667	1224.490	937.500	740.741	600.000

2.1.6. DEFINITE TIME CURVES

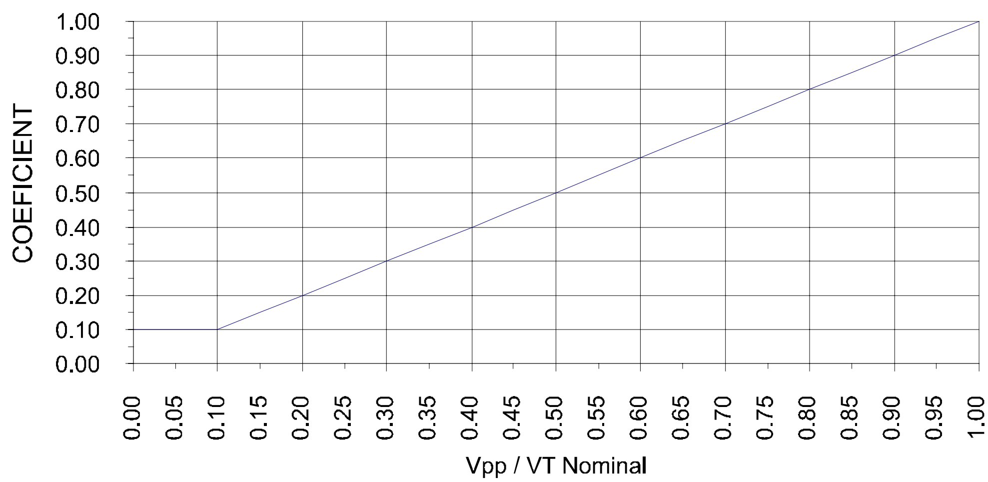
The definite time makes the unit trip when the current value is maintained beyond the pickup value during a longer period than the set value. The Dial setting allows to modify this time frame from instantaneous to 900 seconds in steps of 10 ms.

2.1.7. 51P UNIT

The phase overcurrent element provides a trip in a time period that depends on the applied current and on the set curve. The phase current input quantities may be programmed as fundamental phasor magnitude or total waveform RMS magnitude as required by the application. The unit reset can be selected between Instantaneous or Lineal.

The unit incorporates independent block inputs per phase. When the unit is blocked, the tripping time count is reset to 0, allowing the use of this input as quick reset for the protection unit. The PICKUP setting of the element can be dynamically reduced by a VOLTAGE RESTRAINT feature.

This is accomplished via the multipliers (Mvr) corresponding to the phase-phase voltages of the voltage restraint characteristic curve (see figure below); the pickup level is calculated as 'Mvr' times the 'Pickup' setting.



If the voltage restraint feature is disabled, the pickup level always remains at the setting value.

Table 2-8: 51P UNIT SETTINGS

SETTING	HMI	DEFAULT	RANGE	STEP
Unit permission	FN-51P FUNCTION	Disable	Enable – Disable	N/A
Input	FN-51P INPUT	Phasor	Phasor – RMS	N/A
Pickup	FN-51P PICKUP	1.00	0.02 – 12.00	0.01
Curve	FN-51P CURVE	IEEE Ext Inv	See list of curves	N/A
Dial	FN-51P DIAL	1.00	0.00 – 900.00	0.01
Reset	FN-51P RESET	Inst	Instantaneous – Lineal	N/A
Voltage Restraint	FN-51P VOLT REST	Disable	Enable – Disable	N/A

2.1.8. 50P UNIT

The 50P phase overcurrent unit has a setting range from 0.05 A to 150 A, which can be set as instantaneous or timed, with a timer selectable between 0.00 and 900 seconds. The phase current input quantities may be programmed as Fundamental phasor magnitude or total waveform RMS magnitude as required by the application.. The unit incorporates a reset time selectable between 0 and 900 seconds.

This unit incorporates a block input for resetting the pickup and trip flags to 0. The outputs are the pickup and trip flags independent for each phase, and general pickup and trip flags for the unit.

Table 2-9: SETTINGS FOR 50P UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Unit permission	FN-50P FUNCTION	Disable	Enable - Disable	N/A
Input	FN-50P INPUT	Phasor	Phasor – RMS	N/A
Pickup	FN-50P PICKUP	30.0	0.05 – 150.0	0.1
Trip time	FN-50P DELAY	0.00	0.00 – 900.00	0.01
Reset time	FN-50P RESET	0.00	0.00 – 900.00	0.01

2.1.9. 67P UNIT

The phase directional element (one for each of phases A, B, and C) determines the direction of flow of the phase current for steady state and fault conditions. The unit outputs (independent per phase) are ACTIVATION and BLOCK. The first one indicates that the power in that phase is flowing in the set direction, while the second one indicates that the unit is blocked because either the BLOCK input is activated, or the polarization voltage is lower than the set block level. These outputs must be used for blocking the overcurrent elements where directional supervision is required.

The direction of current flow is determined by measuring two magnitudes: the operation signal and the polarization magnitude. As operation signal, we use the phase current, and as polarization magnitude, the line-line voltage from the other two phases, rotated counterclockwise for the angle set as torque angle.

If the polarization voltage is lower than the undervoltage setting, it is considered that the direction can not be correctly determined, and the user can choose between blocking the unit or allowing the trip of the overcurrent unit.

Table 2-10: SETTINGS FOR 67P UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Unit permission	FN-67P FUNCTION	Disable	Enable – Disable	N/A
Torque angle	FN-67P MTA	45.00	-90.00 – 90.00	0.01
Direction	FN-67P DIRECTION	FWD	FWD – REV	N/A
Voltage loss logic	POL LOSS LOGIC	Block	Block – Trip	N/A
Undervoltage	POL V LEVEL	40	0 – 260	1

2.1.10. 51N UNIT

Unit 51N is a neutral time delayed overcurrent protection element. This unit uses as input quantity the neutral current, calculated from the phase currents. Trip can be timed by a curve selectable by setting. Reset can be instantaneous or lineal.

Table 2-11: UNIT 51N SETTINGS

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-51N FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-51N PICKUP	1.00	0.02 – 12.00	0.01
Curve	FN-51N CURVE	IEEE Ext Inv	See curve list	N/A
Dial	FN-51N DIAL	1.00	0.00 – 900.00	0.01
Reset	FN-51N RESET	Inst	Instantaneous – Lineal	N/A

2.1.11. 50N UNIT

N50 unit is a neutral instantaneous overcurrent protection element with a setting range from 0.05 A to 150 A, which can also be timed with a delay selectable between 0.00 and 900 seconds. The input magnitude is the neutral current, calculated from the phase currents. The unit has a reset time selectable between 0 and 900 seconds. It incorporates a block input which resets the pickup and trip flags to 0. Outputs are the general pickup and trip flags for the unit.

Table 2-12: SETTINGS FOR 50N UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-50N FUNCTION	Disable	Enable - Disable	N/A
Pickup	FN-50N PICKUP	30.0	0.05 – 150.0	0.1
Trip time	FN-50N DELAY	0.00	0.00 – 900.00	0.01
Reset time	FN-50N RESET	0.00	0.00 – 900.00	0.01

2.1.12. 51G UNIT

51G unit is a ground time delayed overcurrent protection element. The ground current input quantity is measured from the transformers module ground input, and it may be programmed as Fundamental phasor magnitude or total waveform RMS magnitude as required by the application. The unit trip can be time delayed using a selectable curve. And it incorporates a reset time selectable between instantaneous or lineal.

Table 2-13: SETTINGS FOR 51G UNIT

	HMI	DEFAULT	RANGE	STEP
Function permission	FN-51G FUNCTION	Disable	Enable - Disable	N/A
Input	FN-51G INPUT	Phasor	Phasor – RMS	N/A
Pickup	FN-51G PICKUP	1.00	0.02 – 12.00	0.01
Curve	FN-51G CURVE	IEEE Ext Inv	See list of curves	N/A
Dial	FN-51G DIAL	1.00	0.00 – 900.00	0.01
Reset	FN-51G RESET	Inst	Instantaneous – Lineal	N/A

2.1.13. 50G UNIT

50G unit is a ground instantaneous overcurrent protection element, with a setting range from 0.05 A to 150 A, which can also be time delayed, with a delay selectable between 0.00 and 900 seconds. The ground current input quantity is measured from the transformers module ground input, and it may be programmed as Fundamental phasor magnitude or total waveform RMS magnitude as required by the application. The unit incorporates a reset time selectable between 0 and 900 seconds, and a block input that resets the pickup and trip signals to 0. The unit outputs are the general pickup and trip signals of the unit.

Table 2-14: SETTINGS FOR 50G UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-50G FUNCTION	Disable	Enable - Disable	N/A
Input	FN-50G INPUT	Phasor	Phasor – RMS	N/A
Pickup	FN-50G PICKUP	30.0	0.05 – 150.0	0.1
Trip time	FN-50G DELAY	0.00	0.00 – 900.00	0.01
Reset time	FN-50G RESET	0.00	0.00 – 900.00	0.01

2.1.14. 67G UNIT

67G unit is a directional protection element, used for monitoring the ground overcurrent units. The operation magnitude is the ground current measured directly from the corresponding input, while the polarization magnitude is the neutral voltage (3Vo) calculated from the three phase voltages.

The polarization magnitude can also be 3V0 measured at the dedicated voltage input. This input will be available depending on the setting for the use of this input:

If the F650 is set to have synchronism check protection, then this input will be adjusted as busbar voltage and it will not be the 3V0 voltage

If the F650 does not have a synchronism check unit, then this input can be set as 3V0 neutral voltage, and it can be used as polarization magnitude for the 67G unit.

As in the case of a phase directional unit, this element incorporates a voltage loss logic that allows to block or permit the trip by means of a setting

Table 2-15: SETTINGS FOR 67G UNIT

	HMI	DEFAULT	RANGE	STEP
Function permission	FN-67G FUNCTION	Disable	Enable - Disable	N/A
Torque angle	FN-67G MTA	-45.00º	-90.00º – 90.00º	0.01
Direction	FN-67G DIRECTION	FWD	FWD – REV	N/A
Polarization	FN-67G POLARIZATION	V_0	V_0 – I_P – V_0+I_P – V_0*I_P	
Blocking logic	FN-67G BLOCK LOGIC	TRIP	Block – Trip	N/A
Undervoltage	POL V LEVEL	40 V	0 – 260 V	1

2.1.15. 67N UNIT

67N unit is a directional protection element, used for monitoring the ground overcurrent units. The operation magnitude is the neutral current (3I0) calculated from the three phase currents, while the polarization magnitude is the neutral voltage (3Vo) calculated from the three phase voltages.

The polarization magnitude can also be 3V0 measured at the dedicated voltage input, as explained in the section above.

As in the case of a phase directional unit, this element incorporates a voltage loss logic that allows to block or permit the trip by means of a setting

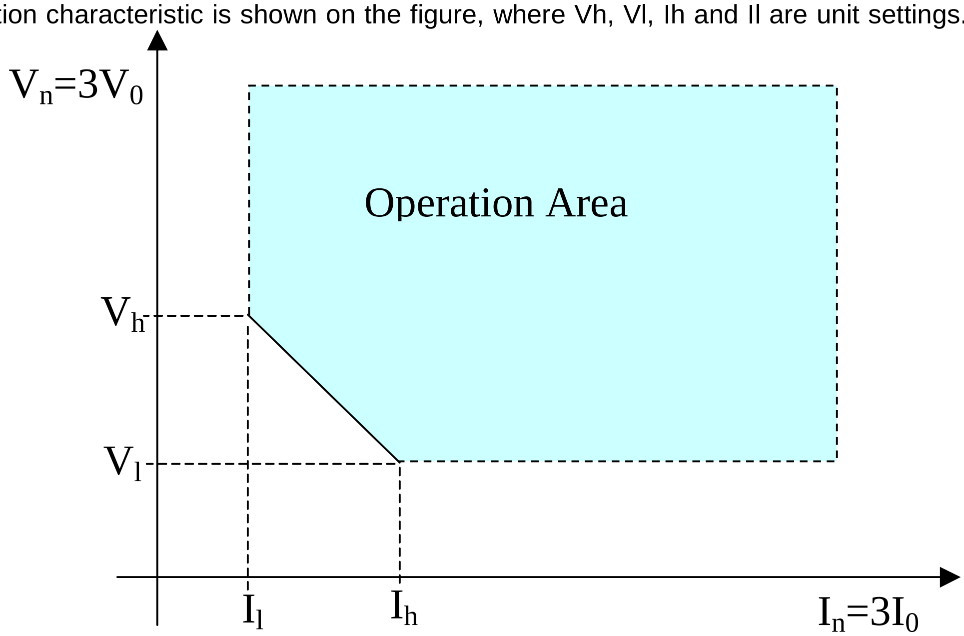
Table 2-16: SETTINGS FOR 67N UNIT

	HMI	DEFAULT	RANGE	STEP
Function permission	FN-67N FUNCTION	Disable	Enable - Disable	N/A
Torque angle	FN-67N MTA	-45.00º	-90.00º – 90.00º	0.01
Direction	FN-67N DIRECTION	FWD	FWD – REV	N/A
Polarization	FN-67N POLARIZATION	V_0	V_0 – I_P – V_0+I_P – V_0*I_P	
Blocking logic	FN-67N BLOCK LOGIC	TRIP	Block – Trip	N/A
Undervoltage	POL V LEVEL	40 V	0 – 260 V	1

2.1.16. 67IG UNIT

67IG unit is a protection element for distribution feeders connected to a busbar which is fed by a power transformer in a delta or wye connection. The operation of this unit is similar to that of ground overcurrent units; the difference is that in the case of 67IG, the 3I0 current is capacitive, and uses very reduced magnitudes (0.5-10 A primary). The continuous polarization magnitude continues to be 3V0.

The operation characteristic is shown on the figure, where Vh, Vl, Ih and Il are unit settings. This unit is also



monitored by a directional unit that uses 3I0 as operation magnitude, and 3V0 as polarization magnitude. Typically, the characteristic angle for the unit is 90º capacitive, but the setting range goes from –90º to +90º.

Table 2-17: SETTINGS FOR 67IG UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function Permission	FN-67IG FUNCTION	Disable	Enable – Disable	N/A
High Voltage	FN-67IG Vh	20	2 – 70	1
Low Voltage	FN-67IG Vl	2	2 – 70	1
High Current	FN-67IG Ih	25	5 – 400 (mA)	1
Low Current	FN-67IG Il	5	5 – 400 (mA)	1
Operation time	FN-67IG DELAY	1.00	0.00 – 900.00	0.01
Direction	FN-67IG DIRECTION	FWD	FWD – REV	N/A
Characteristic angle	FN-67IG MTA	90º	-90º – 90º	1º
Deviation time to instantaneous	FN-67IG INST	0.00	0.00 – 900.00	0.01

2.1.17. 46P UNIT

46P unit is an overcurrent protection element that uses the fundamental phasor of the negative sequence current as input magnitude, calculated from the phase currents. This unit can be used for detecting load unbalance in the system, and for open phase conditions (fallen or broken conductor). The trip time can be selected as an inverse curve (please refer to the list of curves) or instantaneous. The unit reset can also be selected as instantaneous or lineal.

Table 2-18: SETTINGS FOR 46P UNIT

	HMI	DEFAULT	RANGE	STEP
Function permission	FN-46P FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-46P PICKUP	1.00	0.05 – 4.00	0.01
Curve	FN-46P CURVE	IEEE Ext Inv	See list of curves	N/A
Dial	FN-46P DIAL	1.00	0.00 – 900.00	0.01
Reset	FN-46P RESET	Inst	Instantaneous – Lineal	N/A

2.1.18. 49 UNIT

Unit 49 is a protection element that measures the thermal heating generated as a result of the flowing current, and prevents this heating from causing damage to the protected equipment. In order to calculate the thermal image value, the following equation is used:

$$t = \tau * Ln \frac{I'^2}{I'^2 - 1} \Big|$$

Where,

τ is the heating/cooling time constant.

I is the current

When a body is cooled, it does not always follow a time constant similar to the heating time constant; this is why the function has independent settings for heating and cooling constants.

Table 2-19: SETTINGS FOR 49 UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-49 FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-49 PICKUP	1.00	0.02 – 12.00	0.01
Heating constant	FN-49 T HOT	6	3 – 600	1
Cooling constant	FN-49 T COLD	1	1 – 6 (times T HOT)	1
Alarm level	FN-49 ALARM	80%	1 – 100%	1

2.2 VOLTAGE ELEMENTS

The F650 incorporates the following voltage units:

Phase undervoltage (27P)

Phase overvoltage (59P)

Neutral overvoltage (59N)

Negative sequence overvoltage (47P)

2.2.1. 27P UNIT

27P unit is a phase undervoltage protection element that uses as input magnitude the fundamental phasor of phase-to-phase or phase-to-ground voltage, selectable by setting. The unit time delay can be selected between definite time or inverse time. The unit reset is always instantaneous, that is, when the voltage exceeds the dropout value, the unit is reset.

There is an undervoltage setting that allows selection of a voltage level under which the unit will be inhibited. This way, we can distinguish between a fault condition and a Dead-line condition where VTs are located in front of the breaker, and when it is open, the relay loses the voltage values. By setting this level to 0 we make this element operate every time the voltage value is lower than the setting.

This unit generates independent pickup and trip signals per phase, and general pickup and trip signals for the unit. These last signals can be selected, by means of the operation logic setting, to be an OR (any phase signal) or an AND (all phase signals).

Table 2-20: SETTINGS FOR 27P UNIT

	HMI	DEFAULT	RANGE	STEP
Function permission	FN-27P FUNCTION	Disable	Enable – Disable	N/A
Input	FN-27P MODE	Ph-Ph	Ph-Ph – Ph-Gnd	N/A
Pickup	FN-27P PICKUP	10 A	10 – 260 A	1
Curve	FN-27P CURVE	T. def	T. def – Curve	N/A
Operation time	FN-27P DELAY	10.00	0.00 – 900.00	0.01
Undervoltage	FN-27P MIN V	0 V	0 – 260 V	1
Operation logic	FN-27P LOGIC	Any	Any – All	N/A
Supervision by breaker status	FN-27P SUP	Disable	Enable – Disable	

2.2.2. 27X UNIT

This is an auxiliary one-phase undervoltage unit for general use, that uses as input magnitude the voltage measured by the 4th VT. This voltage can be measured from the busbar, the neutral, etc. (this being the reason for its generic name and use).

Table 2-22: SETTINGS FOR 27X UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-27X FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-27X PICKUP	10	10 – 260 V	1
Curve	FN-27X CURVE	Def T.	Def. T. – Curve	N/A
Operation time	FN-27X DELAY	10.00	0 – 900 s	0.01 s

2.2.3. 59P UNIT

59P unit is a phase overvoltage protection element that uses as input magnitudes the phase-to-phase voltages, either measured directly from the voltage inputs in the case of a Delta connection, or calculated from the phase-to-ground voltages in the case of a wye connection. The time delay can be set from instantaneous to 900 seconds. The unit reset can be delayed up to 900 seconds.

As in the case of the undervoltage unit, this unit generates independent pickup and trip signals for each phase. The general signal is selectable by setting to be an OR or an AND of the phase signals.

Table 2-21: SETTINGS FOR 59P UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-59P FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-59P PICKUP	10	10 – 260	1
Operation time	FN-59P DELAY	10.00	0.00 – 900.00	0.01
Reset time	FN-59P RESET	0.00	0.00 – 900.00	0.01
Operation logic	FN-59P LOGIC	Any	Any – All	N/A

2.2.4. 59N UNIT

59N unit is a neutral overvoltage protection element that uses as input magnitude the system neutral voltage (3V0) calculated from the phase voltages, or the voltage value measured by the 4th voltage transformer. It is used for detecting unbalanced system voltage conditions, caused by a ground fault condition, or by the loss of one or two of the voltages. The unit time delay is selectable between 0 and 900 seconds. The unit incorporates a reset with a selectable delay between 0 and 900 seconds.

The selection of the input voltage for this unit, either calculated from the phase voltages or measured from the 4th transformer of the F650, is made by a setting

Table 2-22: SETTINGS FOR 59N UNIT

	HMI	DEFAULT	RANGE	STEP
Function permission	FN-59N FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-59N PICKUP	10V	10 – 260 V	1V
Operation time	FN-59N DELAY	10.00 s	0.00 – 900.00 s	0.01 s
Reset time	FN-59N RESET	0.00 s	0.00 – 900.00 s	0.01 s

If the input is calculated from the phase voltages, the equation for obtaining the input value will be as follows:

$$3V_0 = V_A + V_B + V_C$$

If the input is set as the voltage measured by the 4th voltage transformer, then the metered value will be applied directly to the algorithm. This voltage can be taken through a grounding resistance, a high impedance grounding, a busbar voltage etc.

The setting to select the origin of this voltage is entered in the GENERAL SETTINGS group – AUXILIARY VOLTAGE – Vn or Vx. The first of these refers to a neutral voltage measured by the 4th transformer. The second one (Vx) is the busbar voltage, so if it is chosen, the voltage input for 59N unit will be calculated from the phase voltages.

If phase voltages are taken from voltage transformers connected phase-to-phase, and we choose Vx as auxiliary voltage, then unit 59N will be disabled, as it is not possible to calculate zero sequence components from phase-to-phase magnitudes.

2.2.5. 59X UNIT

This is an auxiliary one-phase overvoltage unit for general use, that uses as input magnitude the voltage measured by the 4th VT. This voltage can be measured from the busbar, the neutral, etc. (this being the reason for its generic name and use).

The time delay for unit 59X can be set from 0 to 900 seconds. The unit has a reset than can be programmed from 0 to 900 seconds.

Table 2-22: SETTINGS FOR 59X UNIT

SETTING	HMI	DEFAULT	RANGE	PASO
Function permission	FN-59X FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-59X PICKUP	10	10 – 260 V	1 V
Operation time	FN-59X DELAY	10.00	0.00 – 900.00 s	0.01 s
Reset time	FN-59X RESET	0.00	0.00 – 900.00 s	0.01 s

2.2.6. 47 UNIT

47P unit is a negative sequence phase overvoltage protection element. It uses as input magnitude the negative sequence component calculated from the phase voltage values. This unit can be used to detect the loss of one or two phases, unsymmetrical voltage conditions, etc.

Table 2-23: SETTINGS FOR 47P UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-47P FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-47P PICKUP	10 V	3 – 150 V	1
Operation time	FN-47P DELAY	10.00	0.00 – 900.00	0.01
Reset time	FN-47P RESET	0.00	0.00 – 900.00	0.01

2.3 FREQUENCY ELEMENTS

2.3.1. 81U UNIT

The 81U unit is an underfrequency protection element. The pickup setting can be selected from 20.00 to 65.00 Hz, allowing its use as load shedding unit. The unit reset time delayed is selectable between 0.00 and 900 seconds, and for the unit to operate it is necessary that the voltage value is over the value set for undervoltage. This way undesired trips are prevented when the signal for metering the frequency doesn't exist or has a very low value.

Table 2-24: SETTINGS FOR 81U UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-81U FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-81U PICKUP	49.50	20.00 – 65.00	0.01
Operation time	FN-81U DELAY	10.00	0.00 – 900.00	0.01
Reset time	FN-81U RESET	0.00	0.00 – 900.00	0.01
Undervoltage	FN-81U MIN V.	10	0 – 260	1

2.3.2. 81O UNIT

The 81O unit is an overfrequency protection element. The pickup setting can be selected from 20.00 to 65.00 Hz, with a time delay selectable between 0 and 900 seconds. The unit reset delay is from 0.00 to 900.00 seconds.

Table 2-25: SETTINGS FOR 81O UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-81O FUNCTION	Disable	Enable – Disable	N/A
Pickup	FN-81O PICKUP	49.50	20.00 – 65.00	0.01
Operation time	FN-81O DELAY	10.00	0.00 – 900.00	0.01
Reset time	FN-81O RESET	0.00	0.00 – 900.00	0.01
Undervoltage	FN-81O MIN V.	10	0 – 260	1

2.4 CONTROL ELEMENTS

The F650 incorporates the following control elements:

Recloser (79)

Breaker failure (50BF)

2.4.1. RECLOSER

The F650 incorporates a three-phase recloser with up to 4 reclosing cycles with independent time delays before reaching the LOCK-OUT state. The recloser includes a reclaim time setting, which is the time during which the recloser will wait after a manual breaker close before switching to a READY state. If during this time the unit detects any abnormal situation, the recloser will switch to LOCK-OUT state.

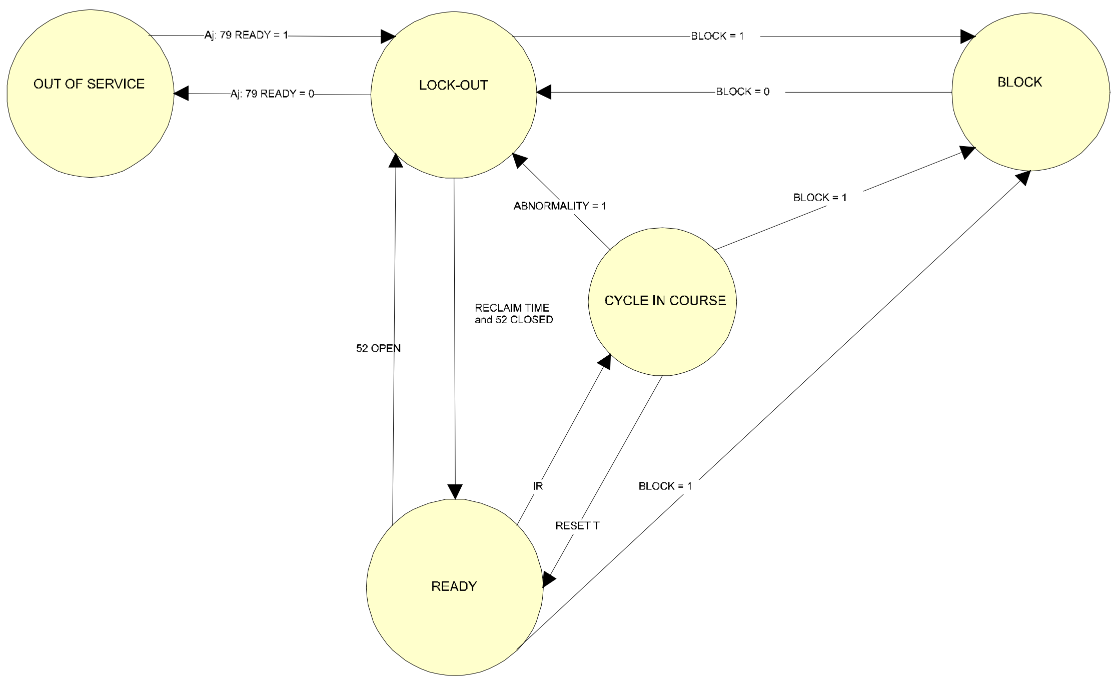
The reset time setting is the time during which the recloser will wait after a breaker close before switching to a READY state. If during this time another reclosing attempt is produced, the recloser will switch to the next reclosing cycle. If the recloser is in the last allowed cycle, it will switch to LOCK-OUT.

Reclosing conditions can be programmed. For this purpose, we must enable the “Reclosing conditions” setting. In this situation, in order for the breaker close command to be issued, the reclosing conditions input must be active in the moment of the closing. A hold time can be programmed, during which the recloser waits for this input to be activated. If this delay expires and the input activation is not produced, it will switch to LOCK-OUT, but if the input is activated, the breaker close command will be issued.

It is possible to block the recloser operation at any time, thanks to the block input. When the unit is unlocked, the recloser switches to LOCK-OUT, and will leave this state with a manual close.

Table 2-26: RECLOSER SETTINGS

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-59P FUNCTION	Disable	Enable – Disable	N/A
Number of shots	NUMBER OF SHOTS	1	1 – 4	1
Dead time shot 1	DEAD TIME SHOT 1	0.00 s	0.00 – 900.00 s	0.01
Dead time shot 2	DEAD TIME SHOT 2	0.00 s	0.00 – 900.00 s	0.01
Dead time shot 3	DEAD TIME SHOT 3	0.00 s	0.00 – 900.00 s	0.01
Dead time shot 4	DEAD TIME SHOT 4	0.00 s	0.00 – 900.00 s	0.01
Reclaim time	RECLAIM TIME	0.00 s	0.00 – 900.00 s	0.01
Reclose conditions	RECLOSE CONDITION	NO PERM	NO PERM – PERM	N/A
Hold time	HOLD TIME	0.00 s	0.00 – 900.00 s	0.01
Reset time	RESET TIME	0.00 s	0.00 – 900.00 s	0.01



52 OPEN : - Open breaker status
IR : - Reclose initiation (Internal or External)
RESET T.: - Represents the "Reset Time" elapsed
RECLAIM T.: - Represents the "Reclaim Time" elapsed
ABNORMALITY: -Any output condition to LOCKOUT from CYCLE IN COURSE. See CYCLE IN COURSE diagram

2.4.2. 50BF UNIT

The breaker failure unit is used to determine when a trip command sent to a breaker has not been executed within a selectable delay. Most commonly it is a failure to open from the tripped breaker. In the event of a breaker failure, the 50BF unit must issue a signal that will trip the rest of breakers connected at that time to the same busbar, and that can provide fault current.

The breaker failure is detected by comparing the measured current with a selectable level. If the current value is maintained over this level for longer than a selectable time after receiving a breaker failure initiation signal, the unit assumes that the breaker has not been able to open and clear the fault. In the case of the F650, the 50BF unit has three current levels for this comparison, together with three selectable time delays.

The first level is known as "RETRIP". It can be used for issuing a re-trip signal to the same breaker. Sometimes this is a common practice, this means, after the trip signal this re-trip signal is always sent to the breaker approximately 50 milliseconds later.

There are two additional levels, known as Low Level and High Level. These two levels, together with their timers, allow us to create complex protection schemes. Additionally to these two supervision levels, there is a second time step.

The 50BF unit incorporates a without-current trip unit that operates according to the status of the breaker auxiliary contact; this means that if a breaker failure initiation signal is received and the breaker status input does not change to open after a selectable time, a breaker failure signal is produced.

Additionally, an internal arcing unit is included, which detects the arcing produced while the breaker is open.

Table 2-27: SETTINGS FOR 50BF UNIT

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-50BF FUNCTION	Disable	Enable – Disable	N/A
Pickup Supervision	FN-50BF PKP SUP	1.50 A	1.20 – 40.00 A	0.01
High Level pickup	FN-50BF PKP HI	2.00 A	1.20 – 40.00 A	0.01
Low level pickup	FN-50BF PKP LO	2.00	1.20 – 40.00	0.01
Internal arcing time	INT ARC DELAY	10.00 s	0.00 – 900.00 s	0.01
Retrip delay	RETRIP DELAY	10.00 s	0.00 – 900.00 s	0.01
High level delay	FN-50BF HI DELAY	10.00 s	0.00 – 900.00 s	0.01
Low level delay	FN-50BF LO DELAY	10.00 s	0.00 – 900.00 s	0.01
Second stage delay	2^{nd} STAGE	10.00 s	0.00 – 900.00 s	0.01
W/O current unit delay	TRIP W/O I DELAY	10.00 s	0.00 – 900.00 s	0.01

2.4.3. 25 UNIT

The synchronism element is used for monitoring the connection of two parts of the circuit by the close of a breaker. This unit verifies that voltages (V1 and V2) at both sides of the breaker are within the magnitude, angle and frequency limits set by the user. V1 and V2 are voltage values applied to the relay by the voltage sensing transformers; more specifically, V2 corresponds to the busbar voltage and must be entered by the auxiliary input (fourth voltage transformer), and V1 corresponds to the line voltage, and there is a setting in the general settings group where the user can define which of the three phases will be used for comparing V2.

Synchronism check (25) is defined as the comparison of the voltage difference of two circuits with different sources to be either linked through an impedance element (transmission line, feeder, etc.), or connected through parallel circuits of defined impedance (Figure 1). The voltage comparison between both sides of a breaker is performed before closing the breaker, in order to minimize internal damage that could occur due to the voltage difference, both in magnitude and angle. This is extremely important in steam generating plants, where reclosing output lines with angle differences could lead to severe damage to the turbine axis.

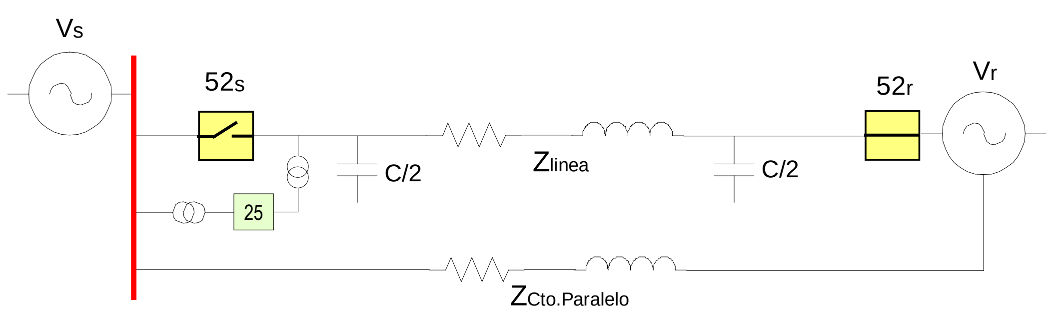


Figure 1

The difference in voltage level and phase angle in a given moment is the result of the existing load between remote sources connected through parallel circuits (load flux), as well as a consequence of the impedance of those elements connecting them (even if there is no load flux in parallel circuits), or because sources to be connected are completely independent and isolated from one another.

In interconnected systems, the angle difference between both ends of an open breaker is usually negligible, as its sources are remotely connected through other elements (equivalent or parallel circuits). However, in isolated circuits as in the case of an independent generator, the difference in angle, voltage levels and relative slip of voltage phasors can be very important. It may happen that the relative slip of voltage values is very low or null so that they will rarely be in phase. Luckily, due to the changing conditions of a power system (connection-disconnection of loads, sources, and new inductive-capacitive elements) the relative slip between phasors is not null and they can be synchronized.

In the first case, even if we must take into consideration the length of the line whose ends (sources) will be connected for determining the angle difference between them, this is not enough to fix the synchronism conditions before closing the breaker. Experience tells us that the window of angle difference between voltage phasors must be fixed to a value of 15º-20º. It is not enough to fix this parameter determined by the propagation equation:

$$AngleDifference\,(^{\circ}) = L * \frac{1}{\upsilon} * f * \omega$$

Where: L = Line length (km)

ν = Light speed (km/s)

f = System rated frequency (Hz)

ω = 360 (degrees/cycle)

as usually we get smaller angle values.

2.4.3.1. SYNCHRONISM FUNCTION IN F650

Voltage Inputs

In order to perform the synchronism check function, the F650 uses only one voltage from each end of the breaker.

Voltage values to be compared must be taken from the same base, that is to say, if the relay has been connected to phase-to-phase voltages for metering and protection algorithms, the voltage value at the other end of the breaker will also need to be phase-to-phase voltage. Additionally, if on one end, three voltages have been connected, the necessary voltage on the other end for Function 25 will only be single-phase voltage. If there is only one voltage (either phase-to-phase or phase-to-ground) at both ends of the breaker, this must be from the same phase in both cases. It is not possible to compare a phase-to-ground voltage on one end with a phase-to-phase voltage on the other end.

By means of a setting, we can choose which voltage to use for Function 25. The correspondence according to the connected voltages is as follows:

	Voltage Correspondence		
Voltage selection for unit 25 of F650	V_{I}	V_{II}	V_{III}
Phase-to-ground voltage connection	V_{a-g}	V_{b-g}	V_{c-g}
Phase-to-phase voltage connection	V_{a-b}	V_{b-c}	V_{c-a}

Application

Even if the application range of F650 is very extensive and the unit can be used in distribution lines at any voltage level, we must take into account that it is a three-pole tripping relay, designed for managing a single breaker. This is why F650 is not suitable for breaker and a half configurations, or ring configurations where a transmission line or feeder has two breakers.

Algorithm

F650 units perform the synchronism check by basically establishing and comparing three parameters:

Module difference of voltage phasors **ΔV** (V)

Phase angle of voltage phasors **$\Delta\varphi$** (º)

Frequency slip between two phasors **S** (Hz)

These parameters are continuously determined and treated once that Unit 25 has been enabled by setting.

If voltage on one side of the breaker is null, the synchronism unit cannot establish the above mentioned parameters, and will not issue a synchronism permission. In these cases, quite usual in breaker maintenance situations or new installations where voltage is not available but we wish to verify the operation of breakers, F650 units incorporate closing permission logics for the following conditions:

Live bus – Dead line (**LBDL**)

Dead bus – Live line (**DBLL**)

Dead bus – Dead line (**DBDL**)

Voltage Difference ΔV

F650 units take information from the continuously sampled RMS voltage values at both sides of the breaker V_1 and V_2, and determines:

If $V_L < (V_1 \text{ and } V_2) < V_H$

If $(V_1 \text{ y } V_2) > V_H$

If $(V_1 \text{ y } V_2) < V_L$

If $V_1 < V_L$ and $(V_L < V_2 < V_H)$

If $V_2 < V_L$ and $(V_L < V_1 < V_H)$

If $V_1 < V_L$ and $V_2 > V_H$

If $V_2 < V_L$ and $V_1 > V_H$

Where: V_L = Minimum acceptable voltage fixed by a setting

V_H = Adequate synchronism voltage fixed by a setting

V_1 = Busbar voltage

V_2 = Line voltage

Only condition (2) will allow to compare both voltage with respect to the setpoint $\mathbf{\Delta V}_{set}$ established by setting.

Conditions (1), (4) and (5) will not be attended for synchronism or Bus-Line logic effects.

The 3rd case will not allow the synchronism function but will allow the DBDL logic if this last is enabled by setting.

Cases (6) and (7) will not allow the synchronism function but will allow the DBLL and LBDL logics, if they are enabled by setting.

If the voltage difference is lower than $\Delta \mathbf{V}_{set}$, unit 25 will proceed to verify the angle difference.

Phase Angle $\Delta\varphi$

In this step, the synchronism function establishes the angle difference between the two voltage phasors that are being measured. If the angle difference is lower than the $\boldsymbol{\Delta\varphi_{set}}$ value, then the unit will proceed to verify the frequency slip **S**.

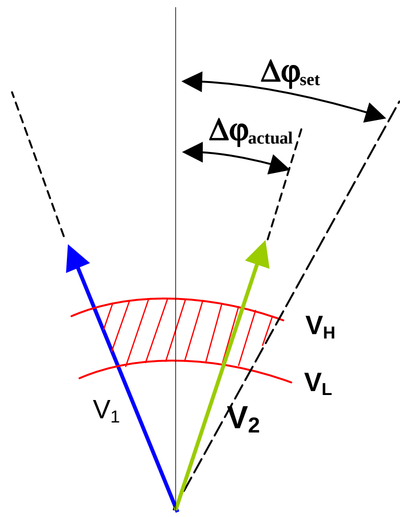


Figure 2

Frequency Slip S

When the algorithm detects that the angle difference is lower than the set value for $\boldsymbol{\Delta\varphi_{set}}$, it starts the calculation of the phasors relative slip. The algorithm learns the slip (mHz) from the sampled information of both phasors, and takes as reference the phasor with the lowest frequency.

If the relative slip Δf is equal to or lower than 0,005 Hz, and taking into account that in the most critical cases the angle cone set is of 10º/2, this phasor would take (10º/360º*0,02s)*(50Hz/0,005Hz) = 5,5 seconds to pass it through, the algorithm will immediately permit synchronism. By doing this, it ensures that when the breaker closes, the angle difference between phasors will be negligible, or at least inside the angle cone, as restrictive as it was set.

If the relative slip is higher than 0,005 Hz, then the algorithm uses the breaker closing time adjusted by setting to establish the permission issue, so that it is run when both phasors are in phase, minimizing the voltage difference in the breaker chamber down to negligible values. The resulting advantage is that after a considerable number of breaker operations, the damage to internal connection elements as well as the chamber isolating element is considerably reduced, enlarging the operative life of the breaker and reducing maintenance operations.

The above mentioned process is shown in Figure 3:

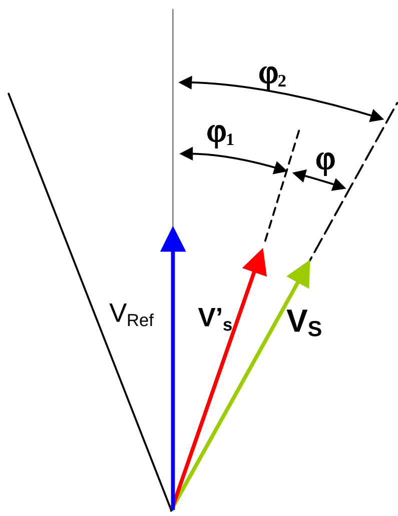


Figure 3

Where:

- **V_{ref}** = Referenced phasor
- **V_s** = Actual voltage phasor
- **V'_s** = Calculated voltage phasor corresponding to the 52 close moment
- **φ** = 360º *TCB *Δf = Calculated angle for phasor V'_s
- **TC**B = Breaker Closing time defined by setting
- **Δf** = Frequency slip (Hz)
- **φ_1** = Angle difference between V'_s and V_p
- **φ_2** = Angle difference between V_p and V_s

And finally, the condition that must be fulfilled for the emission of the closing permission is as follows:

$$\varphi_1 < \varphi \quad and \quad \varphi_2 < \varphi$$

With this, we guarantee that the breaker close happens when the voltage difference between phasors is null.

Table 2-28: SETTINGS FOR 25 UNIT

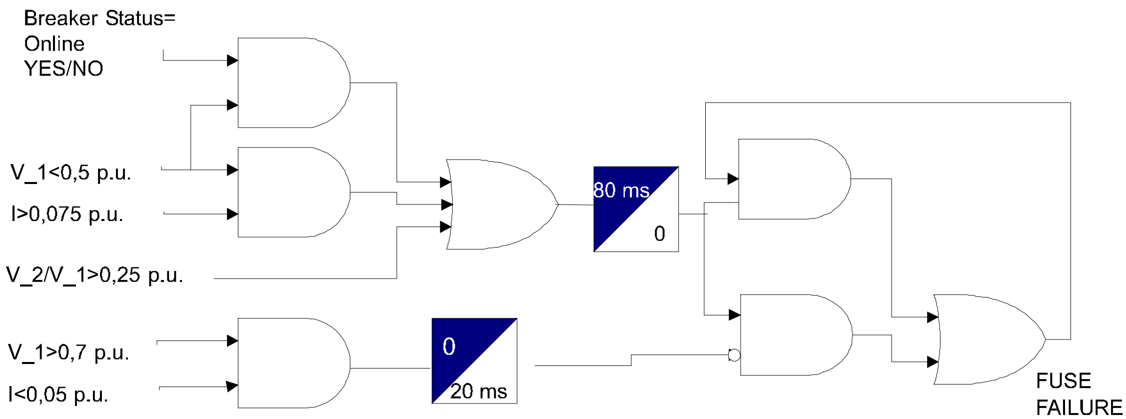
SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	FN-25 FUNCTION	Disable	Enable – Disable	N/A
DEAD BUS level		10	0 – 260	1
LIVE BUS level		50	0 – 260	1
DEAD LINE level		10	0 – 260	1
LIVE LINE level		50	0 – 260	1
Voltage difference		10 V	2 – 100 V	0.01
PHASE angle		10.0º	2.0º – 60.0º	0.5
FREQUENCY Slip		20 mHZ	10 – 500	10
Synchronism delay		0.50 s	0.01 – 600.00 s	0.01
DL-DB		Disable	Enable – Disable	N/A
LL-DB		Disable	Enable – Disable	N/A
DL-LB		Disable	Enable – Disable	N/A

2.4.4. FUSE FAILURE UNIT (VTFF)

The fuse failure detector is used for blocking the voltage-polarized protection elements that might operate incorrectly due to a partial or total loss of the voltage values. This loss can be produced by the fusion of protection fuses in the secondary circuit of voltage transformers.

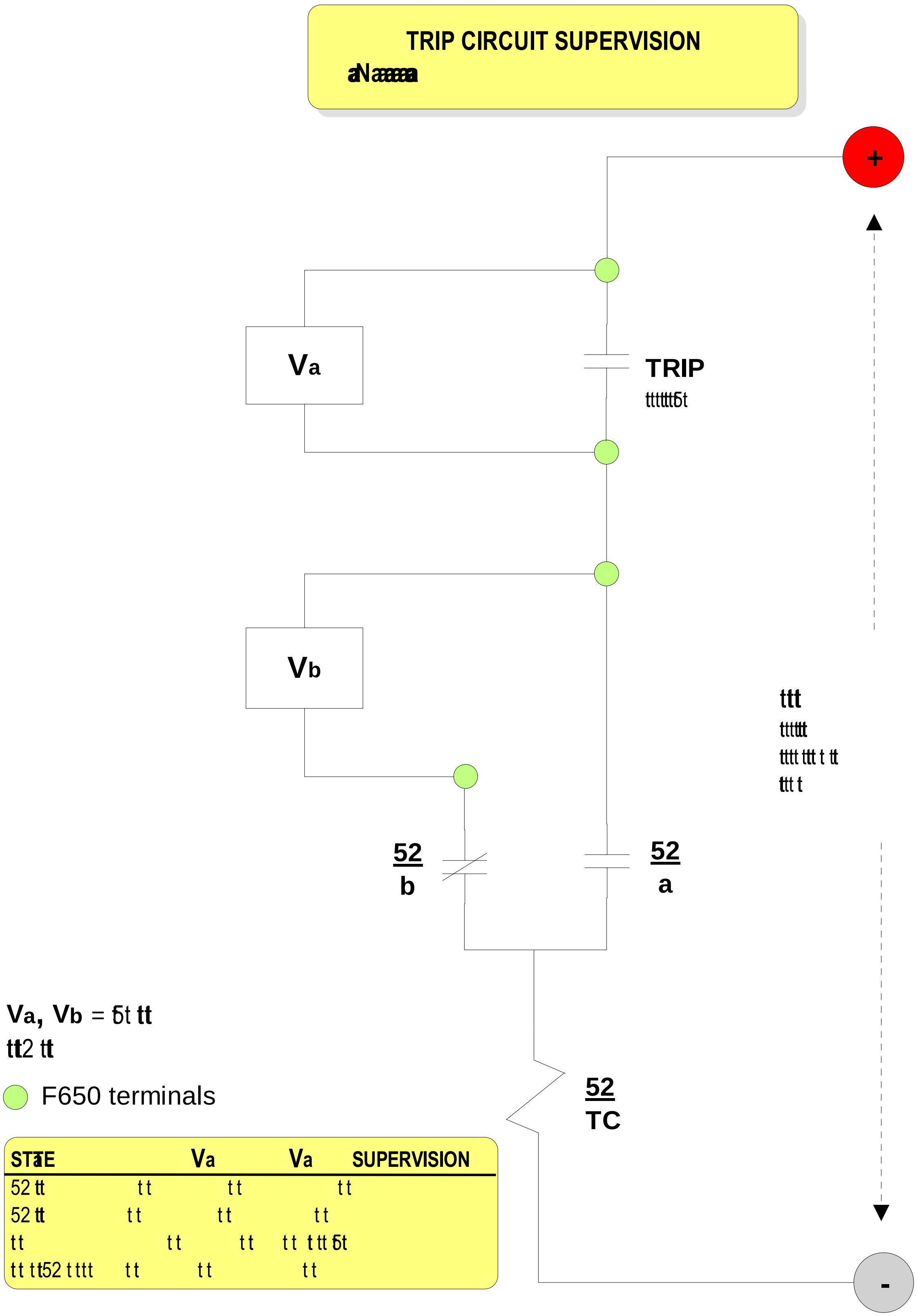
Table 2-29: VTFF SETTINGS

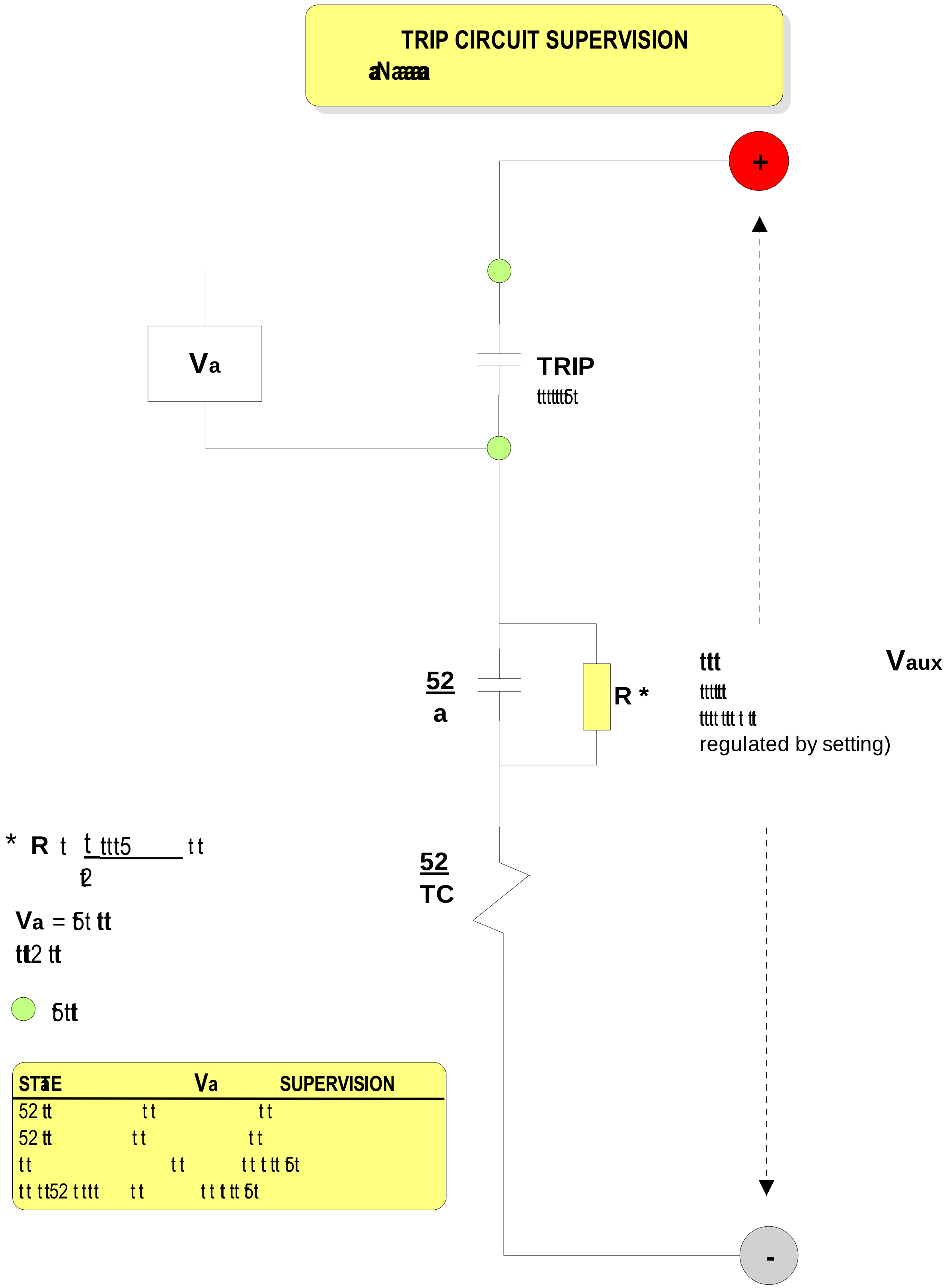
SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	VTFF FUNCTION	Disable	Enable – Disable	N/A



2.4.5. TRIP CIRCUITS MONITORING

The F650 monitors trip circuits as shown on the following figures:





TRIP CIRCUIT SUPERVISION
+
Va
TRIP
52
a
R *
Vaux
regulated by setting)
52
TC
-
* R
Va =
STATE
Va
SUPERVISION

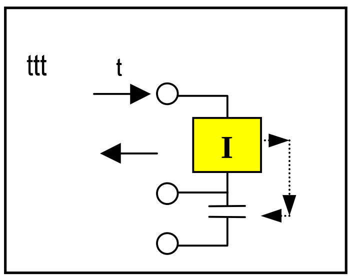
2.4.6. SEALING CIRCUITS

The current sealing circuit is used for verifying the current condition in a circuit during the time that the tripping contact remains closed. If the current in the tripping circuit is maintained over 100 mA, the function is sealed independently of the status of the function that caused the trip.

This current sealing function in tripping circuits is mainly used in applications where auxiliary contacts 52/a (in charge of cutting the current in the tripping circuit) are very slow. This may cause that, once the function that produced the trip is reset, the relay contact will open before the breaker auxiliary 52/a, even if the time delay of the first has expired.

By using this function, we prevent the relay contact from cutting the current (basically inductive and high) from the tripping circuit, which could cause damage to the unit, as these currents exceed the nominal breaking characteristics.

The circuit and the current threshold of the function are as follows:



2.4.7. INPUTS/OUTPUTS

Displayed Elements

This sections applies to all those models including Input/Output board. In this section, we include the Coil Supervision and analog I/O boards, or any other board located on relay terminals F and G.

The power supply alarm contact and the remote I/O boards are not included.

Location

The input/output number, type and location will be determined depending on the relay model and the tables below, as well as the wiring diagram.

2.4.7.1. INPUT/OUTPUT PLACEMENT

SLOT F				SLOT G			
	MIXTA	SUPV		MIXTA	ENTRADAS	SALIDAS	
SCREW	1	2	SCREW	1	3	4	SCREW
1	CC1	COIL 1	1	CC1	CC1		1
2	CC2	52/a	2	CC2	CC2	O1	2
3	CC3	COIL 1	3	CC3	CC3		3
4	CC4	52/b	4	CC4	CC4		4
5	CC5	CC1	5	CC5	CC5	O2	5
6	CC6	CC2	6	CC6	CC6		6
7	CC7	CC3	7	CC7	CC7	O3	7
8	CC8	CC4	8	CC8	CC8		8
9	COMMON 1/8	COMMON 1/4	9	COMMON 1/8	COMMON 1/8	O4	9
10	COMMON 9/16	COMMON 5/8	10	COMMON 9/16	COMMON 9/16		10
11	CC9	CC5	11	CC9	CC9	O5	11
12	CC10	CC6	12	CC10	CC10		12
13	CC11	CC7	13	CC11	CC11	O6	13
14	CC12	CC8	14	CC12	CC12		14
15	CC13	COIL 2	15	CC13	CC13	O7	15
16	CC14	52/a	16	CC14	CC14		16
17	CC15	COIL 2	17	CC15	CC15	O8	17
18	CC16	52/b	18	CC16	CC16		18
19		O1	19		CC17		19
20	O1		20	O1	CC18	O1	20
21		O2	21		CC19		21
22			22		CC20		22
23	O2	O3	23	O2	CC21	O2	23
24			24		CC22		24
25	O3	O4	25	O3	CC23	O3	25
26			26		CC24		26
27	O4	O5	27	O4	COMMON 17/24	O4	27
28			28		COMMON 27/34		28
29	O5	O6	29	O5	CC27	O5	29
30			30		CC28		30
31	O6	I SENS	31	O6	CC29	O6	31
32		O7	32		CC30		32
33	O7		33	O7	CC31	O7	33
34		I SENS	34		CC32		34
35	O8	O8	35	O8	CC33	O8	35
36			36		CC34		36

2.4.8. TIMERS

These elements can be used in the relay logic circuits for introducing time delays. They incorporate a counting input and an output that activates when the counted time reaches a set value. The count is performed in milliseconds and is accessible from the relay states. Additionally, timers incorporate block and reset inputs.

Table 2-30: TIMER SETTINGS

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	TIMER FUNCTION	Disable	Enable – Disable	N/A
Loading delay	PRESET DELAY	10.00	0.00 – 900.00	0.01

2.4.9. COUNTERS

These elements are similar to timers, but they count state transitions received by the counting input.

Table 2-31: COUNTER SETTINGS

SETTING	HMI	DEFAULT	RANGE	STEP
Function permission	CNT FUNCTION	Disable	Enable – Disable	N/A
Loading delay	COUNTER PRESET	10	0 – 900	1

3. TECHNICAL SPECIFICATIONS

TECHNICAL SPECIFICATIONS ARE SUBJECT TO CHANGE WITHOUT NOTICE

3.1 PROTECTION UNITS

Phase and ground units use as operation magnitude the current value received by the unit in current inputs, while the neutral unit uses the calculated current value from the three phase currents.

The isolated ground unit will be used only for those applications where the neutral is completely isolated, and it uses the fifth CT of the unit. This CT has a sensitivity which is 20 times higher than the universal model (connected to 1A or 5A transformers). Therefore, it does not admit such a high permanent overload

3.1.1. PHASE/NEUTRAL AND GROUND OVERCURRENT (51/51N/51G)

Current	Fundamental Phasor (w/o harmonics) or RMS
Rated current	For connection to 1 or 5 A CTs.
Pickup level	0,02 to 12,00 A in steps of 0,01 A
Reset level	97% of the pickup level
Accuracy	±0.5% of the reading ± 10 mA from 0.1 to 10 A ±1.5% of the reading for values higher than 10 A
Operation curves	IEC, IEEE/ANSI, IAC, I^2t, definite time.
Reset time	Instantaneous or time delayed according to IEEE
Timer accuracy	From 1,05 times the pickup, ±3,5% of operation time or 10 ms. (whichever is greater)

3.1.2. PHASE/NEUTRAL AND GROUND OVERCURRENT (50/50N/50G)

Current	Fundamental Phasor (w/o harmonics) or RMS
Rated current	For connection to 1 or 5 A CTs.
Pickup level	0.1 to 160.0 A in steps of 0,1 A
Reset level	97% of the pickup level
Accuracy	±0.5% of the reading ± 10 mA from 0.1 to 10 A ±1.5% of the reading for values higher than 10 A
Overreach	< 2%
Operation time	0,00 to 900,00 s. in steps of 0,01 s.
Reset time	0,00 to 900,00 s. in steps of 0,01 s.
Timer accuracy	From 1,05 times the pickup, ±3% of operation time or 10 ms. (whichever is greater)

3.1.3. PHASE DIRECTIONAL UNITS (67P)

Polarization	Crossed voltage. Phase A: Vbc, Phase B: Vca and Phase C: Vab
Polarizaton voltage	0 to 260 Vac
Characteristic angle	-90º to +90º in steps of 0,01
Angle accuracy	±2º from 0,1 A and 5 Vac
Response time	<25ms at 60Hz and <30ms at 50Hz

3.1.4. NEUTRAL AND GROUND DIRECTIONAL UNIT (67N/67G)

Polarization	Voltage (zero sequence), current, Dual
Polarization voltage	0 to 260 Vac
Characteristic angle	-90º to +90º in steps of 0,01
Angle accuracy	±2º from 0,1 A and 5 Vac
Response time	<25ms at 60Hz and <30ms at 50Hz

3.1.5. ISOLATED GROUND UNIT (67IG)

Current	Fundamental component (without harmonics)
Polarization	Voltage (zero sequence)
Polarization voltage	0 to 260 Vac
Characteristic angle	-90º to +90º in steps of 0,01
Angle accuracy	±2º from 0,1 A and 5 Vac
Response time	<25ms at 60Hz and <30ms at 50Hz
Current accuracy	±3% of the reading; ±1 mA

3.1.6. NEGATIVE SEQUENCE (46)

Current	Fundamental phasor (without harmonics)
Pickup level	0,05 to 4,00 A in steps of 0,01 A
Reset level	97% of the pickup level
Accuracy	±1% of the reading ± 20 mA from 0.1 to 10 A ±3% of the reading for values over 10 A
Operation curves	IEC, IEEE/ANSI, IAC, I^2t, fixed time.
Reset type	Instantaneous or time delayed according to IEEE
Timer accuracy	From 1,05 times the pickup, ±3.5% of operation time or 10 ms. (whichever is greater)

3.2 CONTROL

Recloser: up to 4 programmable shots

Breaker failure

Maximum number of elements to be supervised: 32

Basic interlockings integrated by default

Breaker close with grounded selector switches

Screens:

- Measures
- Bay mimic
- States
- Alarm panel
- Input/Output status

This last screen is very useful when commissioning as it allows to know the status of inputs and outputs as they are in the relay

3.3 CAN BUS

F650 units incorporate a high speed serial CAN bus, for intercommunication between input/output boards and the CPU. The use of a serial bus makes the unit especially resistant and immune to noise and electromagnetic disturbances (EMC) both of low and high frequency. Due to the short distances between modules, a wired bus is used, based on printed circuits.

There is also an optional CAN bus that communicates the CPU board with remote distributed I/O modules; this fact allows to increase the total I/O management capability of F650 for complex applications. This bus is connected using fiber optic, which allows to locate the distributed modules either in the same cabinet or in remote locations up to 1 km far from the main unit.

Speed:	1 Mbps
Media:	Wired for internal modules
	Glass fiber optic, with ST connectors, for external modules (independent bus from the internal)

3.4 MONITORING

3.4.1. OSCILLOGRAPHY

Records:	1 to 16
Samples	Programmable to 8, 16, 32 or 64 samples per cycle
Capacity:	4096 records. From 1.28 up to 10.24 s at 50 Hz.
Trigger:	By pickup or dropout of any element
	By change of state in a digital input
	By command (communications)
	By virtual input (can come from the PLC)
Data:	5 current channels and 4 voltage channels
	Digital inputs
	States
Storage	Permanent in non volatile memory (flash) without battery
Format:	Comtrade standard

3.4.2. EVENTS

Capacity:	1024 scrolling events
Labeling	1 ms using an internal clock of 100 µs
Accuracy:	1 ms (using the IRIG-B synchronization input)
Trigger:	By pickup or dropout of any element
	By change of state in a digital input
	By virtual input (can come from the PLC)
Storage	Permanent in non volatile memory (flash) without battery

3.4.3. DATA LOGGER

Channels:	1 to 16
Parameters	Any analog magnitude
Samples:	1 s; 1, 5, 10, 15, 20, 30, 60 minutes.
Capacity	1024 records

3.5 METERING

Current

Accuracy	±0.5% of the reading ± 10 mA from 0.1 to 10 A
	±1.5% of the reading for values over 10 A

Voltage

Accuracy	±0.5% from 10 to 200 V

Power

Active	±1% of the reading from power factor ±0.8 to 1
Reactive	±1% of the reading from power factor ±0.2 to 0
Apparent	±1% of the reading

Power Factor

Accuracy	0.02

Frequency

Accuracy	±10 mHz at 50 Hz or ±12 mHz at 60 Hz

3.6 CURRENT INPUTS

Phases and ground

Rated current:	Appropriate for 1 or 5 A
Load:	< 0.04 Ohm
Overload:	20 A permanent
	500 A during 1 second

Isolated Ground

Rated current:	1 A
Load:	< 0.5 ohms
Overload:	1 A permanent
	20 A during 1 second

3.7 VOLTAGE INPUTS

VCA inputs do not need varistors, as the shock wave test is applied to 100% of the transformers

Metering range:	From 2 to 200 Vca
Load:	0.025 VA at 120 Vca
Overload:	273 Vca permanent
	300 Vca during 1 minute

3.8 DIGITAL INPUTS

Digital inputs are grouped in two series of 8 inputs with a common per group, as shown in the wiring diagram. These inputs do not have varistors.

Metering range:	Programmable from 20 up to 300 Vdc in 15 stages of 20 V
Load:	< 1 W to maximum voltage. Resistance > 100 kohm
Maximum input rate:	10 impulses/s.

3.9 IRIG-B TIME SYNCHRONIZATION INPUT

Although its use is not compulsory, it is included in all units.

Type:	Demodulated input.
Levels:	2.5 to 6 Vpp with a signal ratio of 3:1
Mode:	TTL
Format:	B B000 B002 and B003
Load:	Input resistance > 100 kohms

3.10 OUTPUTS

The same type of output relay is used both for tripping and for auxiliary outputs, the only difference being the width of the printed circuit board tracks, which allows a higher transient overload for the trip circuits.

A specially robust relay is used for inductive loads, with silver and nickel oxide contact, free from heavy metals (such as cadmium).

Two tripping relays:

Permanent current	16 A
Closing current	60 A during 1 second
Opening current	0.6 A with L/R = 40 ms at 125 Vdc
Operate time	< 8 ms

Six auxiliary relays

Permanent current	16 A
Closing current	45 A during 1 second
Opening current	0.6 A with L/R = 40 ms at 125 Vdc
Operate time	< 8 ms

3.11 POWER SUPPLY

LO (low range)
Range: 24 to 48 Vdc +15% -20%

HI (high range)
Range: 110 to 250 Vdc +15% -20%
110 to 240 Vac +15% -20%

Consumption: 25 VA typical
35 VA maximum with all contacts activated, graphical display lit up and serial port fiber optic communications.

Interruptions: Typical 200 ms, worst case 100 ms, without unit reset.

Display backlight auto power-off mode after 15 minutes without touching any key, in order to ensure long life and minimum consumption.

3.12 COMMUNICATIONS

Front port:

One	COM2
Type	RS232
Baudrate:	1200, 2400, 4800, 9600, 19200, 38400, 57600 y 115200 bauds

Asynchronous rear ports:

Two	COM1, COM2 (COM2 multiplexed with front port)
Type	Depending on model
	RS485
	1 mm plastic F.O.
	Multimode glass F.O. with ST connectors
Baudrate:	1200, 2400, 4800, 9600, 19200, 38400, 57600 and 115200 bauds

Default baudrate: 19200 bauds

Synchronous rear port:

One	COM3	
Type	Model B:	10/100BaseT self-negotiable, included in all models
	Model C:	100Base FX with ST connectors
	Model D:	Double 100BaseFX with ST connectors

***NOTE**: In Models C and D, the 10/100BaseT port is not operative.*

Typical response time to ModBus commands: 10ms

Two witness LEDs for transmission and reception are included

3.13 ENVIRONMENTAL

Operation temperature:	- 10°C to + 60°C
Storage temperature:	- 40°C to + 80°C

Thanks to the use of industrial electronics and specially oversized components, the unit can be used in cabinets without any type of forced ventilation, neither fans nor air conditioning. However, in order to ensure longer life to the unit, we strongly recommend not to install it in specially hot environments and never expose the unit directly to sunlight.

The LCD withstands the following operation temperatures:

-20°C to +70°C

The unit incorporates internal temperature compensation working from 0 to 55ºC without additional adjustments. Outside this range, or if the unit position does not allow to view the display correctly (if the unit is located too high or too low), there is an external regulator for adjusting the contrast, located behind the serial connector cover.

3.14 PACKAGING AND WEIGHT

Net weight: 5 kg

Packaged: 6 kg

Package dimensions: 30x40x50 cm

The packaging incorporates an internal wadding with high density foams, that allow the unit to stand rough transportation conditions. If during the visual inspection, any damage to the unit is detected, please inform GE Multilin immediately, as after 48 hours it will not be possible to claim for damages to the transportation company. In this case, it is recommended, if possible, to shoot a photograph of the unit and mail it to the call center in your area:

EUROPE, MIDDLE EAST AND AFRICA:	AMERICA, ASIA AND AUSTRALIA:
GE MULTILIN **Avda.Pinoa,10** **48170 Zamudio, Vizcaya (SPAIN)** **Tel.: (34) 94-485 88 54, Fax: (34) 94-485 88 38** **E-mail:** gemultilin.euro@indsys.ge.com	**GE MULTILIN** **215, Anderson Avenue** **L6E 1B3 Markham, ON (CANADA)** **Tel.: +1 905 201 6222, Fax: +1 905 201 2098** **E-mail:** info.pm@indsys.ge.com

3.15 TYPE TESTS

Note on the insulation testing:
2000 V at industrial frequency during 1 minute between groups as well as between groups and chassis. This test is not applied to parts connected at low voltage (such as communications terminals, which will be connected to the chassis during tests).

Output contacts incorporate varistors in parallel in order to protect them against overvoltages generated when cutting currents in inductive loads (for example, relay coils or breakers connected to varistors). Therefore, 1000 Vac insulation cannot be applied between ends of an output contact.

Category	Standard	Class	Test
EMC	IEC 1000-4-8 EN61000-4-8	5	Power frequency magnetic field immunity test.
	IEC 1000-4-10 EN61000-4-10	5	Damped oscillatory field immunity test
	IEC 1000-4-3 IEC60255-22-3	3	Radiated, radio-frequency electromagnetic field immunity test
	IEC 1000-4-3	3	Digital radiofrequency electromagnetic field
	IEC 1000-4-2 EN 61000-4-2 IEC60255-22-2	4	Electrostatic discharge immunity test
	IEC 1000-4-16	4	Test for immunity to conducted common mode disturbances in the frequency range 0Hz to 150 kHz immunity test.
	IEC 1000-4-5	4	Surge immunity test
	IEC 1000-4-12 IEC 60255-22-1	3	Noise 1 MHz. Oscillatory waves immunity test.
	IEC 1000-4-4 EC 61000-4-4 IEC60255-22-4	3	Electrical fast transient/burst immunity test
	IEC 1000-4-6 IEC60255-22-6	3	Immunity to conducted disturbances, induced by radio-frequency fields
EMC Emisivity	IEC 60255-25 EN55022	B	Conducted and radiated emissions class B
Safety	IEC / UL		Power supply short-circuitability
Product	IEC60255-5	2 kV	Insulation
	IEC60255-5	6kV .5J	Shock wave
	IEC60255-11; IEC61000-4-29	100 ms	Power supply interruptions
Mechanical	IEC60255-21-1	II	Sinusoidal vibration
	IEC60255-21-2	I	Shocks

F650 has been designed to comply with the highest existing requirements. More specifically, UNIPEDE recommendations for high voltage substations are followed, even if for most applications such high classes are not required.

The relay complies with ANSI C37.90 standards of 1989, and has been designed to comply with international standards.

3.16 ORDERING CODE

The complete model description must be specified when ordering

TABLE 3.1: - ORDERING CODE.

F650	-	-	-	F	-	G	-	-	DESCRIPTION
	B								Basic display (4x20 characters)
	M								Graphic display (240x128 pixels)
									REAR COMMUNICATIONS BOARD 1 (Modbus & DNP)
		F							None
		A							Redundant RS485
		P							Redundant plastic F.O.
		G							Redundant glass F.O.
		X							Redundant RS485 + Distributed I/O CAN
		Y							Redundant plastic F.O. + Distributed I/O CAN
		Z							Redundant glass F.O. + Distributed I/O CAN
									REAR COMMUNICATIONS BOARD 2 (Modbus & DNP)
			B						10/100 Base T
			C						10/100 Base T + 100 Base FX
			D						10/100 Base T + Redundant 100 Base FX
									I/O BOARD 1
					1				16 Inputs + 8 Outputs
					2				8 Inputs + 8 Outputs, 2 for trip coil supervision
									I/O BOARD 2
							0		None
							1		16 Inputs + 8 Outputs
							3		16 Outputs
							4		32 Inputs
									AUXILIARY VOLTAGE
								LO	24-48 Vdc (range 19.2 - 57.6)
								HI	110-250 Vdc (range 88-300) 120-230 Vac (range 88-264)
								LOR	Redundant LO
								HIR	Redundant HI

3.17 APPROVALS

UL certification applied for.

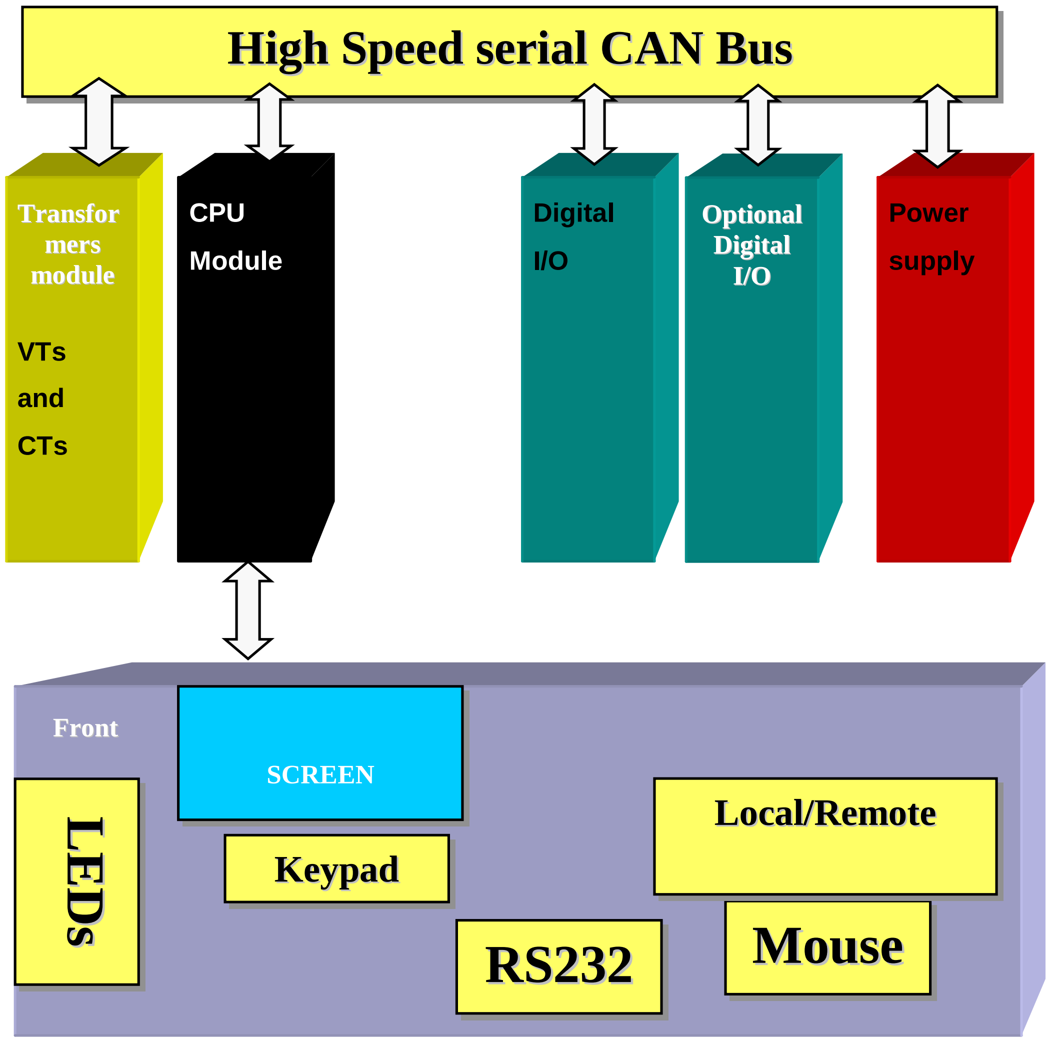
CSA certification applied for.

ISO9001 Registered system.

CE marking: Meets the CE standards relevant for protections.

4. HARDWARE

4.1 DESCRIPTION



F650 units are made of different modules, such as:

Power supply, which can be simple or redundant

Front module with optional alphanumerical display (4 x 20) or graphical (16 x 40 characters). It includes the bus on its rear, which communicates with the rest of modules via a high speed CAN bus.

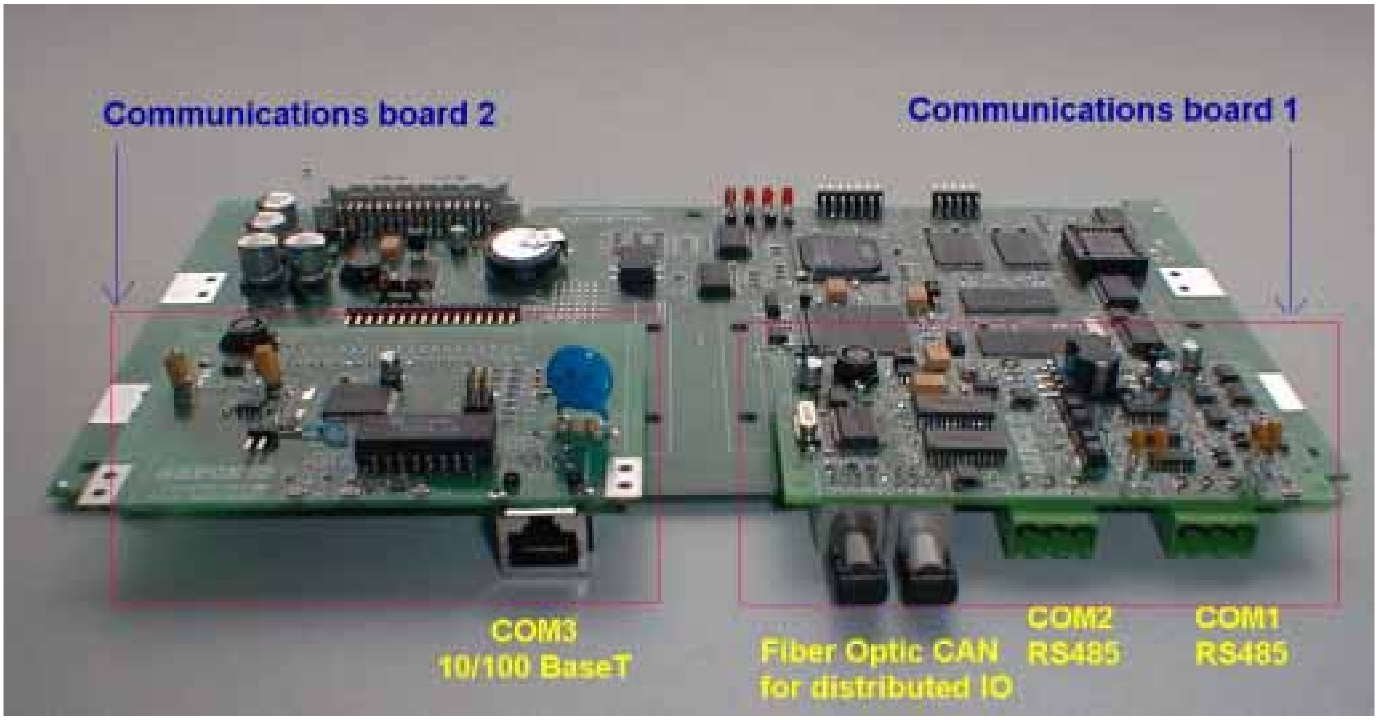
Transformers module with 5 current transformers and 4 voltage transformers

CPU including a powerful DSP for measure processing as well as synchronous an asynchronous communication accessories.

Input/Output module included in basic unit

Optionally, a second I/O module can be added.

The following figure shows how the communications modules are mounted over the CPU by means of nylon tracks. These modules have been designed in accordance with the "plug and play" philosophy, so that units can be easily updated after their purchase, allowing for a simple and economical migration of the application.



4.2 MECHANICAL DESCRIPTION

The model number and electrical characteristics of the unit are indicated on the front plate of the relay case.

The metallic case of the unit is highly resistant to corrosion. It is made of stainless steel (AISI 304), coated with an epoxi layer, and the rest of the metallic pieces are covered with a high quality resistive coating that has successfully passed at least 96 hours in the saline mist chamber (S/N ASTM B-117).

The front of the relay is made of a conductor thermoplastic, auto extinguishable (V0), highly resistive material, which guarantees the unit's immunity to all kinds of EMI/RFI/ESD interferences. As well, an IP51 (IEC 529) protection degree against dust and water through the front and with the relay mounted in the panel.

The modular design of the relay simplifies repair or replacement of its components, without the need to manipulate the wiring. These types of operations will be performed exclusively by qualified personnel and only after removing auxiliary voltage from the unit.

In order to guarantee safety and preventing access to the unit by unauthorised personnel, the front communications port and the operation mode key are protected by a sealable cover.

4.2.1. MOUNTING

The unit is designed for semi-flush mounting. The relay is secured to the panel with the 4 M6 screws provided with the unit this way, the user has access to the front keypad, display and communication port. The wiring is at the rear of the unit. The drilling dimensions are shown on the drilling dimensions diagram (figure 4.3).

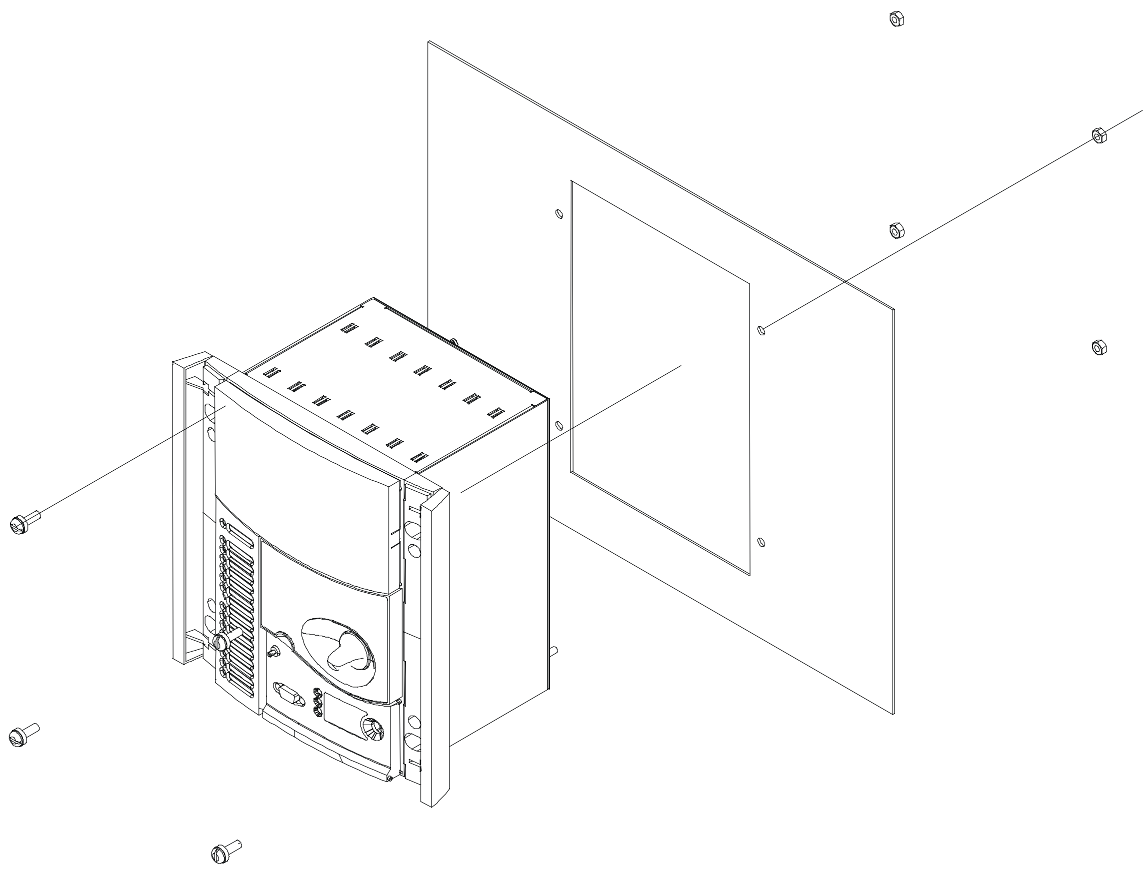


FIGURE 4.2. PANEL MOUNTING

The relay width allows the mounting of two units on a standard 19'' panel, 8 units high.

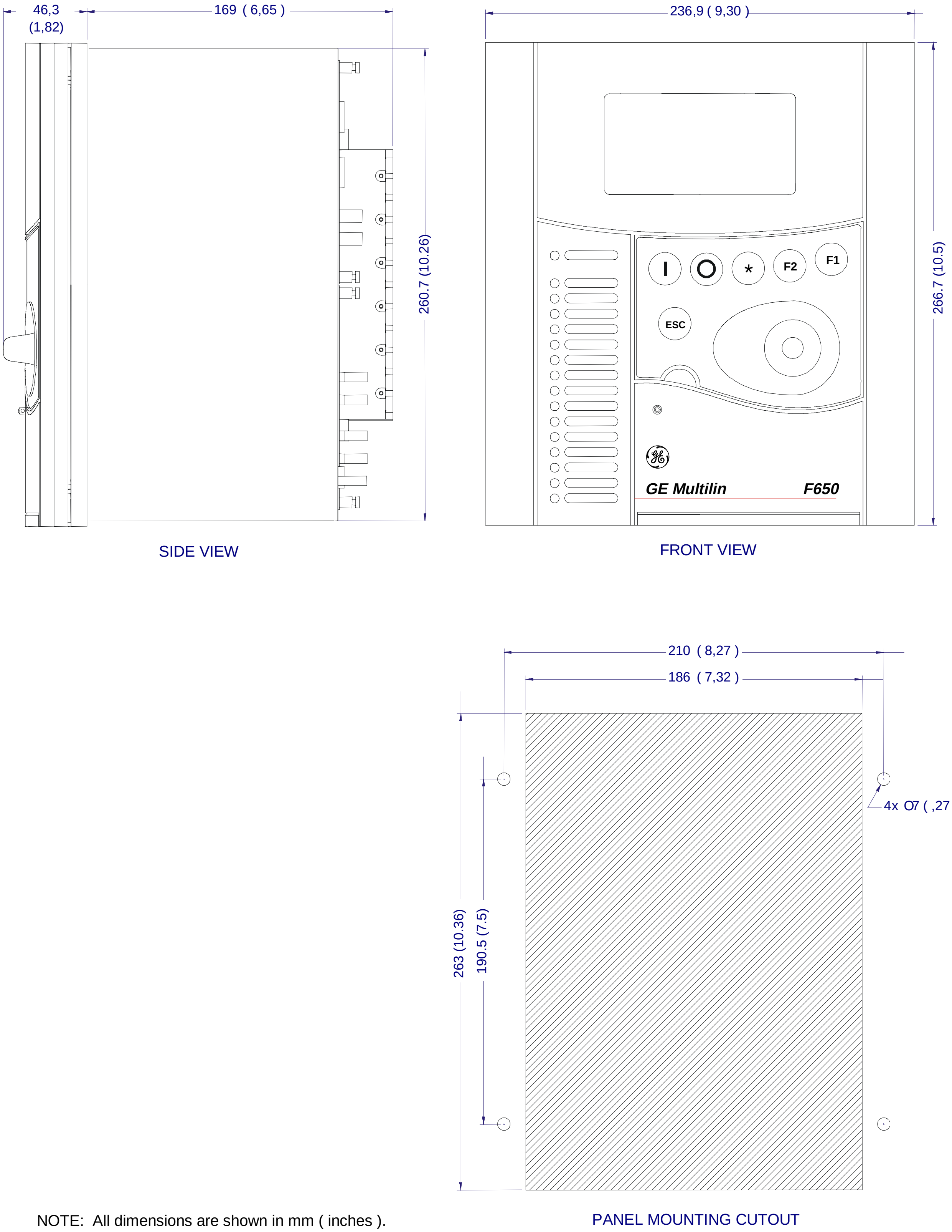


FIGURE 4.3. DRILLING DIMENSIONS DIAGRAM

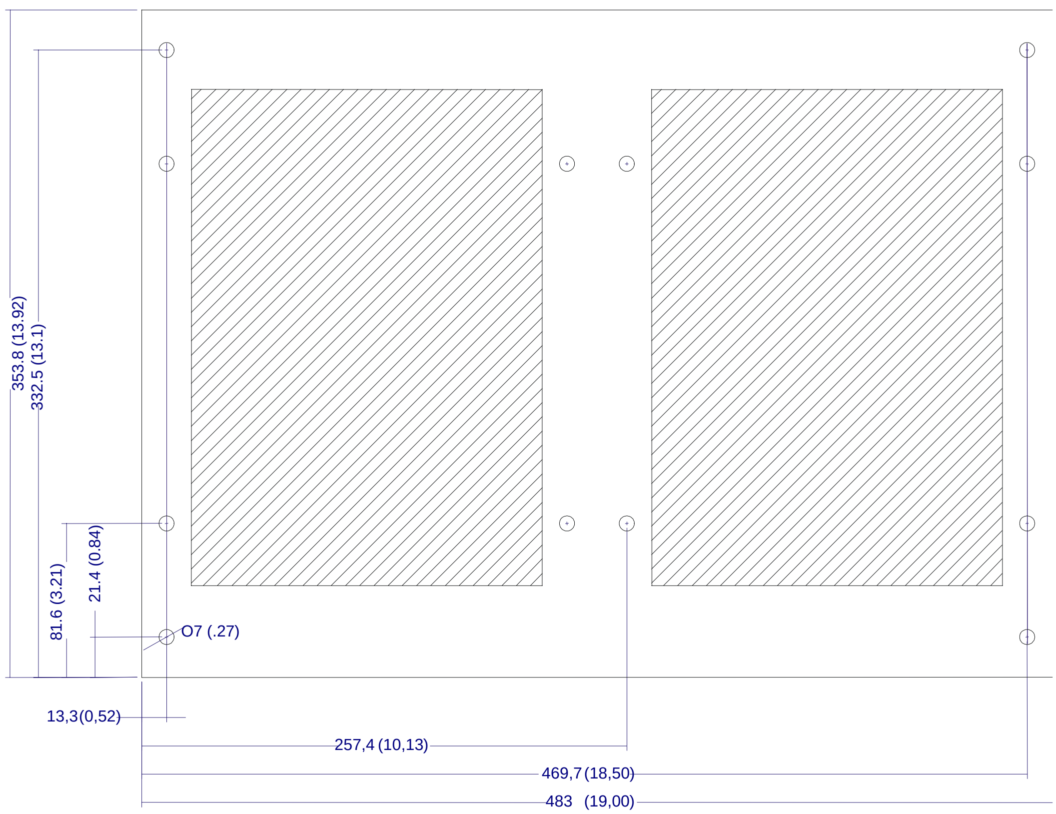


FIGURE 4.4. DIMENSIONS OF THE 19” RACKS 8U HIGH FOR TWO RELAYS

4.2.2. REAR DESCRIPTION

The relay is wired through the terminal blocks located at the rear of the unit. Terminal blocks vary depending on their functionality. The transformer module, which receives the CT secondary currents and the metering voltages, incorporates a very robust terminal board (columns A and B). In this terminal board, current terminals are shorted two-by-two when the transformer module is extracted, so that the CT secondaries never remain open. The maximum recommended cable section for this terminal board, with the appropriate terminal, is 6 mm^2 (AWG 10).

The rest of the terminal blocks (columns F, G, and H), for power supply, inputs/outputs and IRIG-B, incorporate high quality connectors with the capacity to withstand a rated current of 15 A at 300 V. These terminal blocks admit a cable section of up to 4 mm^2 (AWG 12).

The communication boards have a different type of connector depending on the selected media: RS485, glass or plastic fiber optic.

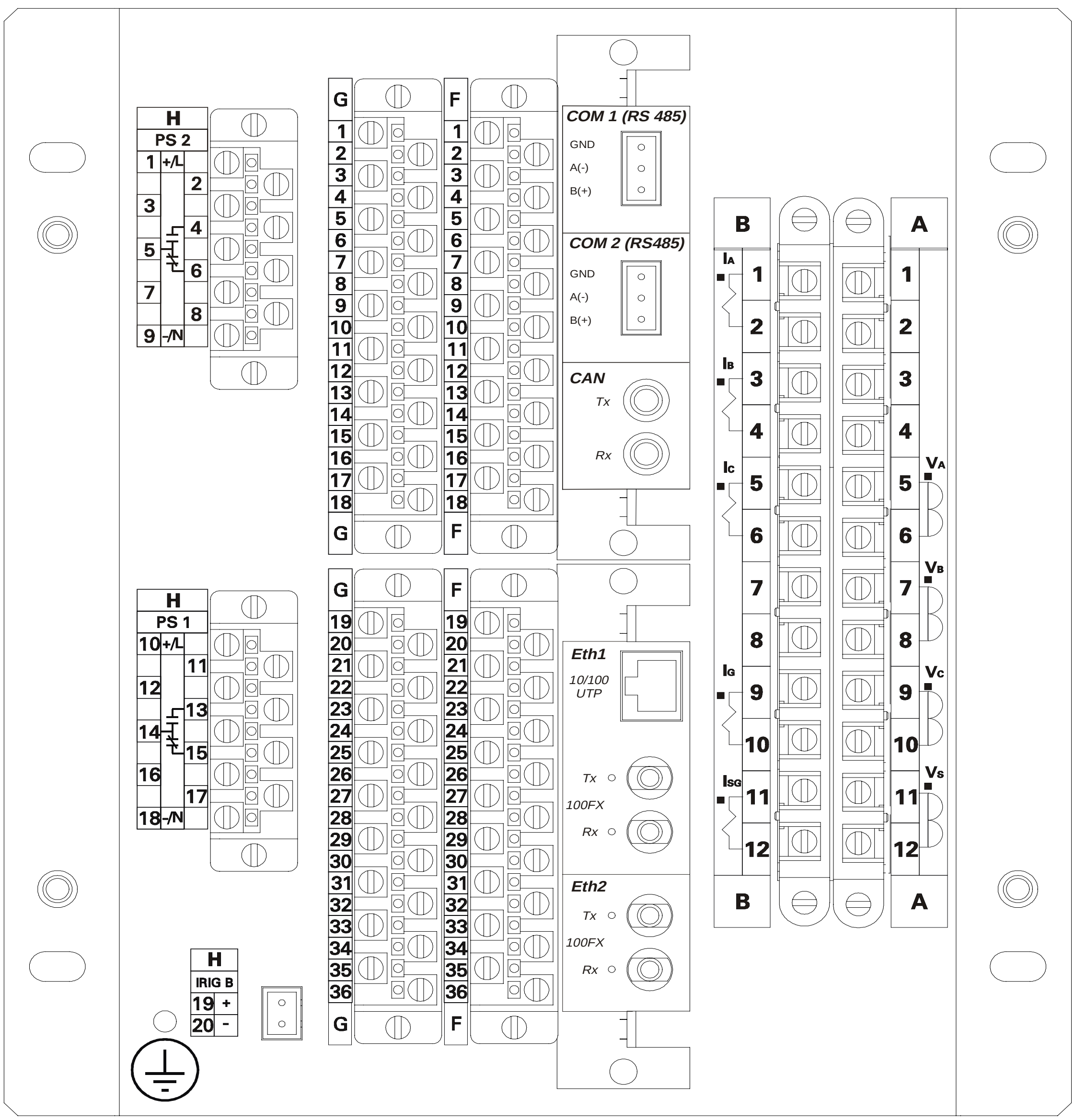


FIGURE 4.5. REAR VIEW OF THE UNIT

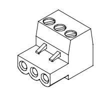
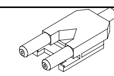
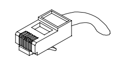
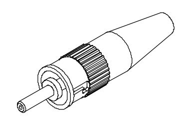
TYPE OF COMMUNICATION	CONNECTOR	
RS485	Plugable, 3 poles.	
IRIG B	Plugable, 2 poles.	
Plastic fiber optic	Versatile Link	
Ethernet 10/100 UTP	RJ45, Class 5.	
Glass fiber optic	ST	
Ethernet 100 FX	ST	
CAN	ST	

FIGURE 4.6 COMMUNICATIONS MEDIA SELECTOR GUIDE

Communication boards are installed at the rear of the unit, the upper port being reserved for the asynchronous communications board and CAN, and the lower port for the ETHERNET board in any of its configurations.

The insertion or extraction of communication boards must be carried out only after interrupting the relay auxiliary voltage, and by skilled personnel.

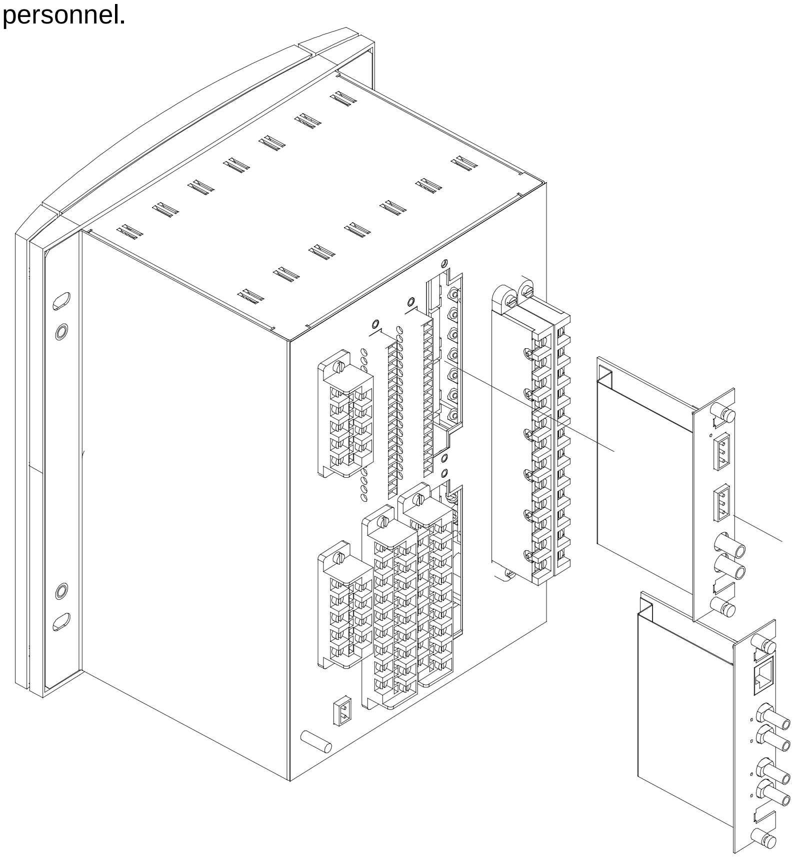


FIGURE 4.7 DETAIL OF INSERTION/EXTRACTION OF COMMUNICATION MODULES

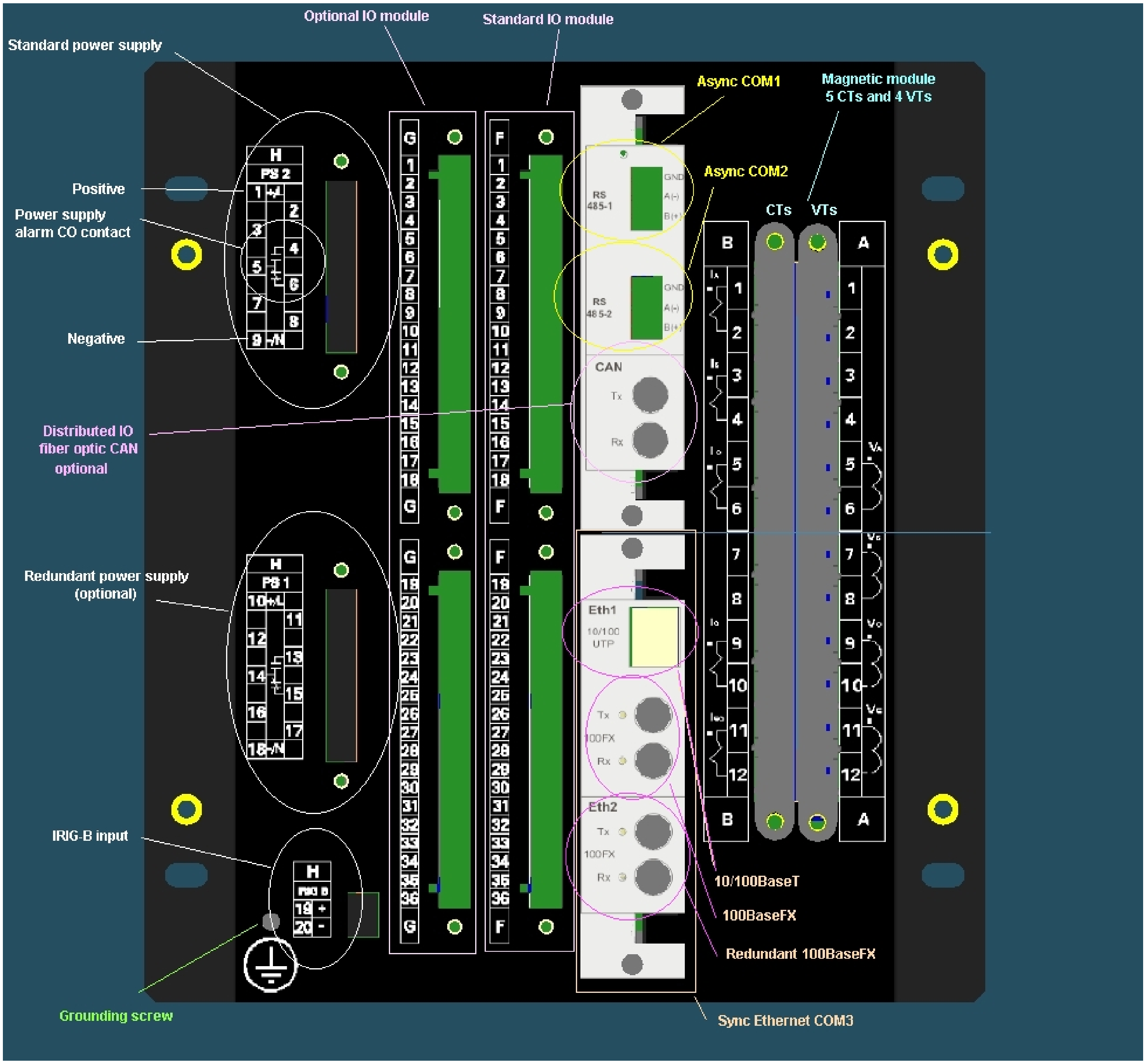
The number of screws and fixtures has been minimized to guarantee an easy maintenance operation, and to protect the application from severe vibrations such as those experienced during long distance transportation.

The transformers module with the VTs and CTs is already connected to a female connector screwed to the case that incorporates shorting bars in the current inputs, so that it can be extracted without the need to short-circuit the currents externally.

A grounded antistatic wristband must be used when manipulating the module in order to avoid electrostatic discharges that may cause damage to the electronic components.

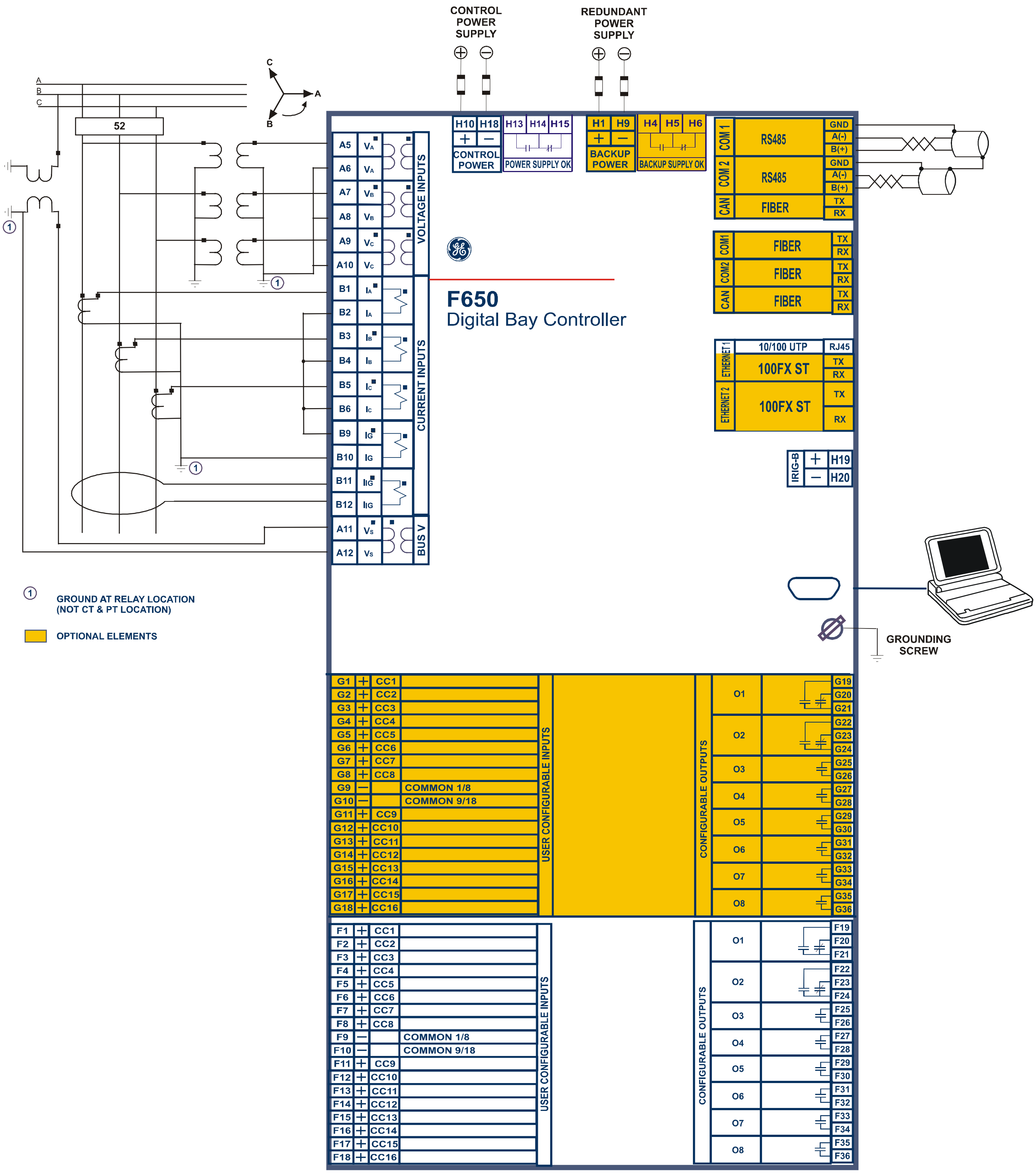
In like manner, when mounting and dismounting the front of the unit, be sure to correctly align the DIN connectors of the rear bus with the DIN connectors of the modules. A slow and careful insertion must be made until the modules are correctly aligned, and then a more firm insertion can be applied, never forcing the modules.

4.3 REAR TERMINALS LOCATION



4.4 WIRING

4.4.1. EXTERNAL CONNECTIONS



5. PLC EDITOR

5.1 INTRODUCTION

PLC Editor is a tool developed for providing the F650 with a determined configuration creating different logic functions.

The logical configuration is performed using graphical functions based on the IEC 61131-3 standard.

This standard defines five basic ways of programming :

- Sequential Function Chart (SFC).
- Instruction List (IL).
- Structured Text (ST).
- Ladder Diagram (LD).
- Function Block Diagram (FBD).

Out of these five methods, FBD has been chosen because it allows for graphical configurations that are more comprehensive. This method provides the possibility of grouping several basic functions inside a single function (hereon called libraries), achieving higher modularity and clarity in the design.

For the development of the configuration, this tool provides not only the unit data such as protection states, measures, digital inputs, etc., but also logic operations or functions that enable us to operate with these data. Among these operations, we can find purely digital operations, such as AND, OR, XOR, NOT gates, and analog operations, such as higher than, and equal to comparators, etc.

The result of these operations will be one of the data sources in the configuration of outputs, operations, events, LEDs and HMI objects in the relay.

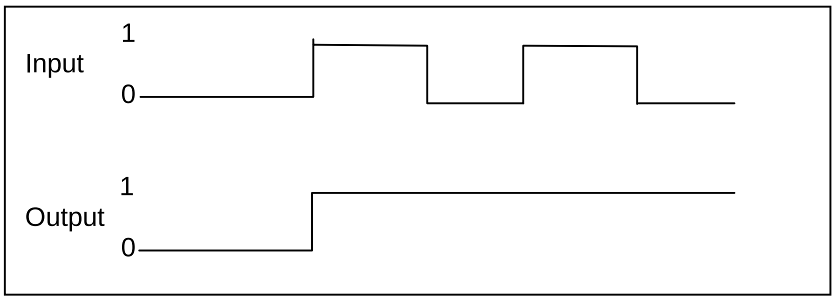
5.2 OPERATION

5.2.1. DESCRIPTION

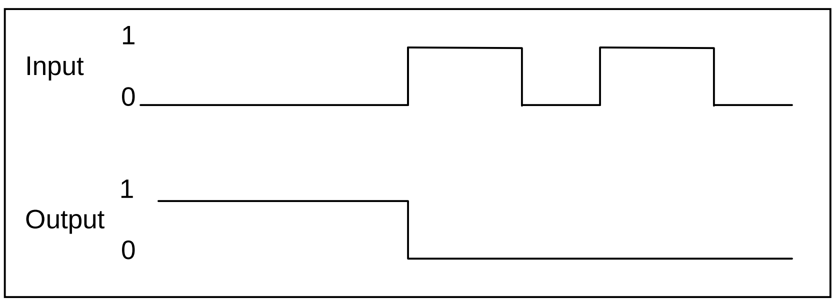
As already mentioned in the introduction, this tool uses FBD mode of IEC 61131-3 standard. For this purpose we have defined a series of basic operations with illustrations below.

The basic operations available in the Editor are as follows:

AND of two digital inputs.
OR of two digital inputs.
XOR of two digital inputs.
NAND of two digital inputs.
NOT of a digital input.
SET.

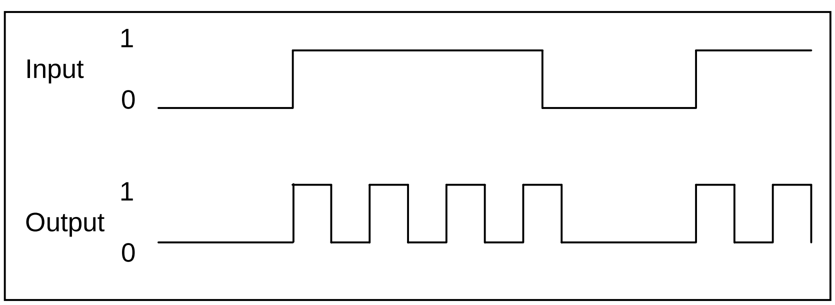


RESET.

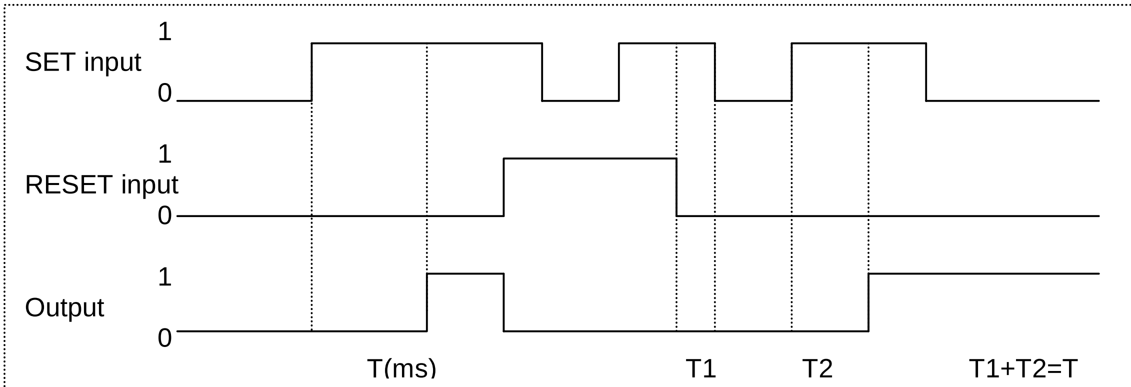


ONS.

The width of the output pulse will be the same as that of the PLC cycle



TIMER with selectable time, one SET input and one RESET input



Analog comparison "higher than".

Analog comparison "equal to".

Multiplication of two analog inputs.

Division of two analog inputs.

Addition of two analog inputs.

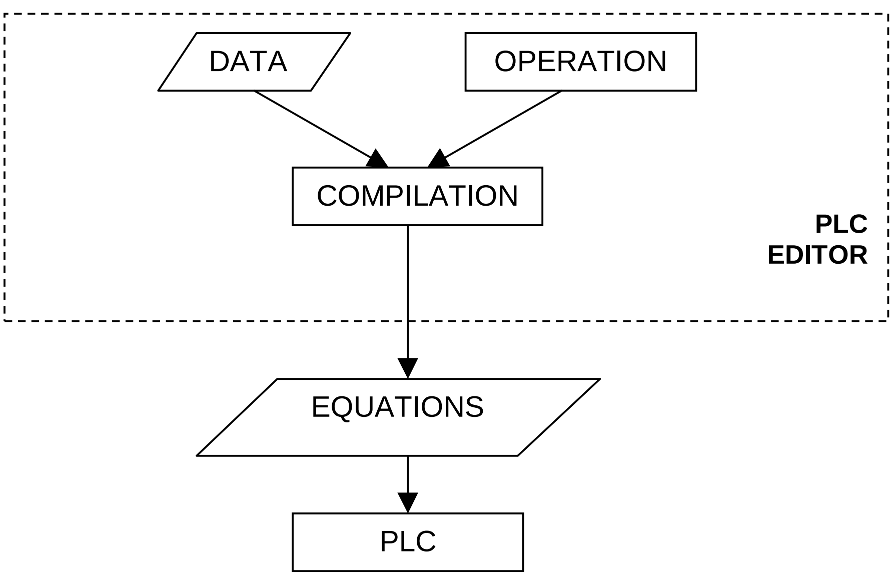
Integration of analog input in each PLC cycle will add the input value to the output variable

AND of two analog inputs (byte type), so that a mask can be applied to one byte leaving the result in a digital output

Analog and digital internal variables

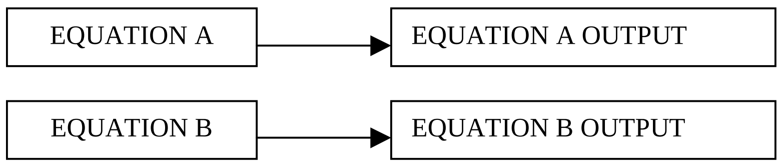
The F650 configuration will be made using these basic operations and more complex operations developed inside libraries.

The PLC acting as the engine of the F650 must read and interpret this graphical configuration. For this purpose there will be a compilation of this configuration, creating a series of equations that will form the logical configuration of the unit.

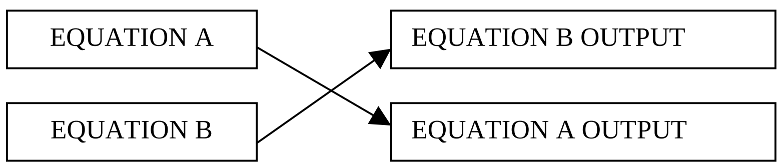


A single equation will be composed of one or more inputs, one or more operations, and one output. The order of equations is determined by the relative position of their outputs.

For example:



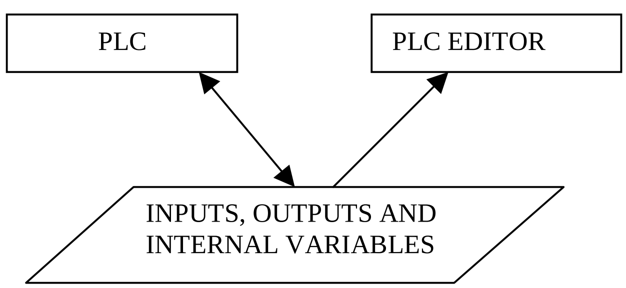
In this case, equation A is the first to be executed.



However, in the second case, the first equation to be executed would be B, as its output is before the Equation A output.

The debugging of automatisms is carried out together with the simulator program (PLC version). The PLC is in charge of executing equations, reading and writing inputs, outputs and internal variables.

The editor reads the values in inputs, outputs and internal variables, colouring the graphic depending on the values read.



5.2.2. OPERATION MODES

The PLC Editor has two operation modes, DESIGN and MAINTENANCE

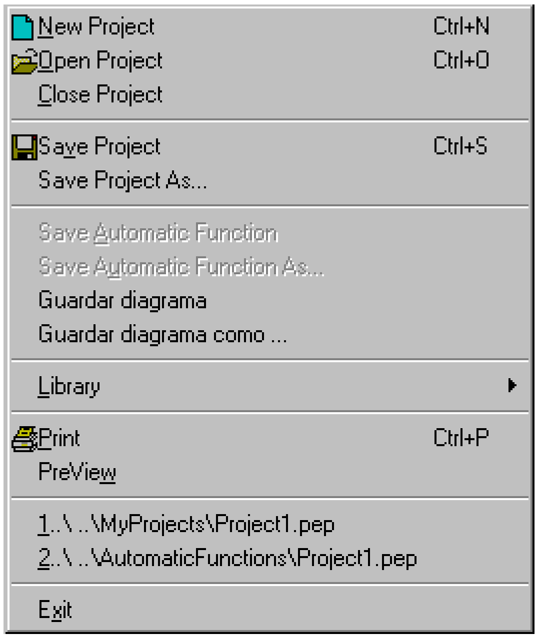
In the DESIGN **mode, the user has the option of entering new graphical elements in automatic functions, creating new libraries, modifying the properties of the objects, cutting, pasting, etc. Everything the user needs to configure the logic is included. A debugging application is also included to be used with the PLC simulator.**

In the MAINTENANCE **mode, it is not possible to modify the logic configuration. The user can only open the configuration and trigger the data maintenance, so that the behaviour of the different logic operations is displayed. Either the F650 or the PLC simulator can be used as a data source.**

5.3 MAIN MENU

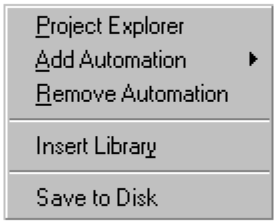
When entering the PLC Editor the user will find a main menu at the top of the with six submenus: File, Project, Edit, Run, View, Language, Window and Help

5.3.1. FILE



New Project:	allows to create a new project that will include the files of the logic configuration
Open Project:	opens an existing project.
Close Project:	closes the currently open project.
Save Project:	saves the open project.
Save Automatic Function:	saves the file of the active project.
Library:	gives access to the libraries' sub-menus, where we can create new, open and save libraries.
Print:	prints the active configuration file.
Preview:	preview of the document before printing.

5.3.2. PROJECT



Project Explorer**:** **displays a window where we see a tree structure with the files contained in the project.**

Add Automation**:** **here we can add new files to the project so that the unit configuration is separated in several files.**

Remove Automation: removes the active file from the project.

Insert library: Inserts a library in the active automatic function.

Save to Disk: compresses all the project files into a single file.

5.3.3. EDIT

Undo: undoes the last modification in the active function.

Redo: remakes the last modification.

Cut: cuts one or more logic operations.

Copy: copies one or more logic operations.

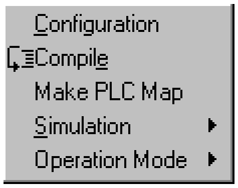
Paste: pastes one or more logic operations.

Find: looks for a logic operation in the project.

Copy as Bitmap: copies the active automatic function to the clipboard in bitmap format.

View Clipboard: launches the clipboard viewer application.

5.3.4. RUN



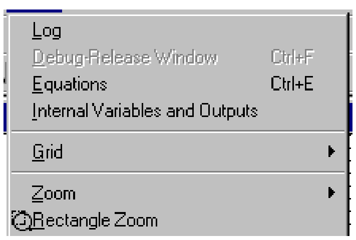
Configuration: **configuration of the simulation colors, the path where the PLC simulator is located, and the timer for the analog operations.**

Compile: **compiles the configuration functions to generate the equations that will be interpreted by the PLC.**

Simulation: **runs the PLC simulator to debug automatic functions.**

Operation Mode: **allows to switch from Maintenance mode to Design mode and vice versa.**

5.3.5. VIEW



Log: displays, in one screen, the states name and time stamp of the digital states configured in the PLC logic.

Debug-Release window: displays the values for the different project inputs, outputs, and variables.

Equations: displays the equations resulting from the compilation.

Internal variables and outputs: displays the different characteristics for internal variables and outputs of automatic functions.

Grid: shows or hides the form grid where the configuration functions are developed. It also aligns the different objects to the grid.

5.4 CONFIGURATION GENERATION.

5.4.1. CREATE A NEW PROJECT

Clicking on the "File – New Project" menu option, the program will request the database where we want to create the automatism. Once selected, we can start the programming.

An automatism can be formed by one or more equations.

5.4.2. CREATE EQUATION

A single equation can be formed by one or more inputs, one or more operations, and one output.

The order of equations is determined by the relative position of their respective outputs, this order being downward.

If we want to link the output of an equation with the input of another equation, we must use an internal variable. Leaving the result of the first equation in an internal variable allows us to use this internal variable as an input for the second equation.

5.4.3. ADD AN INPUT TO AN AUTOMATISM

Using the mouse click on the button that represents the inputs in the toolbar at the top of the screen.

As input, we can select states, unit measures, internal variables, all those data read by the unit.

5.4.4. ADD AN OUTPUT TO AN AUTOMATISM

Using the mouse click on the button that represents the outputs in the toolbar at the top of the screen.

As output, we can select any data that can be written by the unit.

5.4.5. ADD A DIGITAL OPERATION

Press on any of the digital operations in the toolbar at the top of the screen, and then click on the window background.

5.4.6. ADD A LIBRARY

Click on the "LIB" button and select the corresponding file.

5.4.7. ADD AN ANALOG OPERATION

Click on any analog operation from the toolbar.

5.4.8. LINK INPUTS, OUTPUTS AND OPERATIONS

The user can link the different graphic objects clicking on an object output and dragging to the input of another graphic object.

The different graphic objects are divided by digital objects and analog objects.

There is a series of restrictions when performing connections:

It is not possible to link digital objects to analog objects;

It is not possible to auto-link an object; the output of a certain object cannot be linked to its input;

There can only be one input per object input;

The output of both the EQU and GT functions cannot be directly linked to a digital operation, and therefore should be linked by means of an internal auxiliary digital variable;

The outputs of the MUL, DIV, SUM, and INT functions must be an analog variable, because the PLC can only handle one analog operation for a single equation; therefore, the outputs of analog operations cannot be inputs of new analog operations in the same equation; and;

RESET and SET outputs must be internal variables or outputs.

We must take into account that as the timer is a digital operation that operates as an analog, there must only be a single internal variable or digital input in the timer input.

5.5 GENERATION OF LIBRARIES

Libraries can contain a set of operations grouped in a single graphic object being formed by inputs, outputs and operations.

Inside the libraries, it is not possible to insert unit input and output objects. We will use library inputs and outputs to create the library object.

Internal variables inside the libraries will be assigned randomly when compiling.

These libraries are saved in the LIB folder in order to be used in further projects

5.6 EXAMPLE OF APPLICATION

In this section we will describe step by step a simple application, where we will create a logic such that while keeping activated one input, several outputs will be activated and deactivated in a time window. Outputs will remain activated for 200 ms and deactivated for 5 ms.

The application will be started in DESIGN mode, and we will select NEW PROJECT from the menu. After loading the data, we will have a screen where we will be able to create logic configurations and a toolbar at the top, containing different graphic objects.

As input to the automatism, we will have a digital input, so we will click on the tool bar for inputs .

We will then see a form where we must select one of the inputs. This input will be the SET input for the output activation timer, so we will click on the button to insert the timer.

The timer has three inputs: SET, RESET and timing input. As output to the timer, we will insert a Boolean variable belonging to the group of outputs that will be renamed as “Output-Activation”. This variable will be the input to the timer SET for deactivation of outputs. In order to configure the timer time delay, we must enter an analog constant with the value of time in milliseconds.

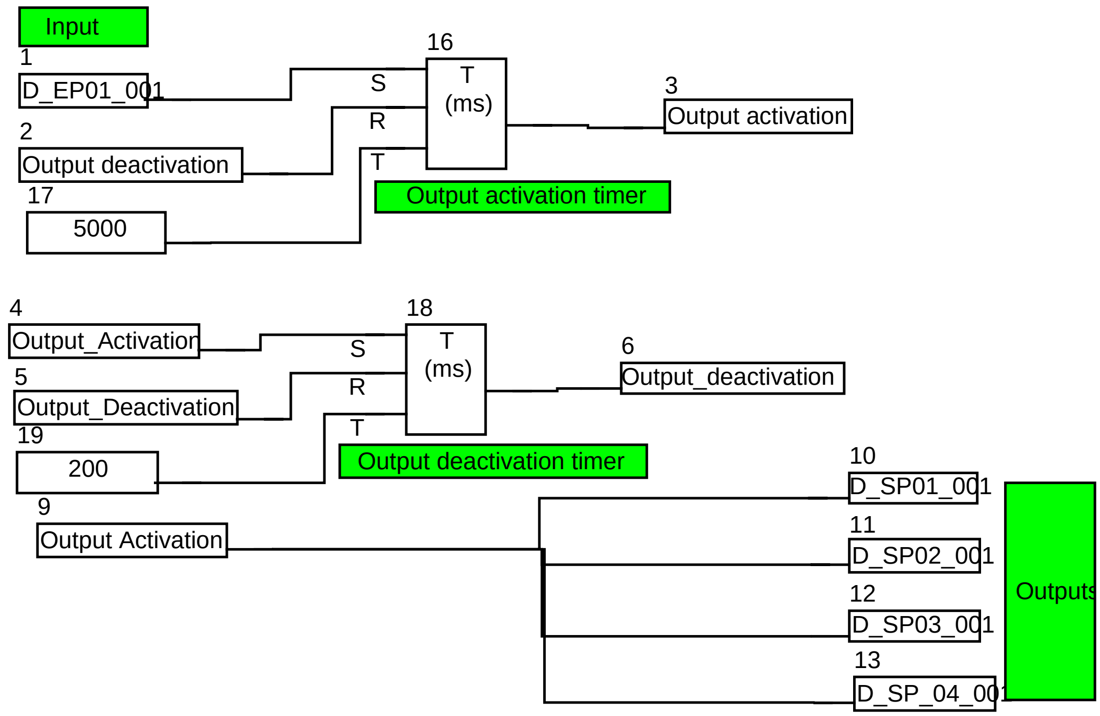
The output deactivation timer will have as SET input the Boolean variable “Output-Activation”, as RESET input the Boolean variable “Output-Deactivation”, as time delay 200 ms, and as output a Boolean output variable for Output deactivation.

We will select several unit outputs and link them to the “Output-Activation” variable.

Therefore, outputs will be activated if the “Output-Activation” variable switches to 1. Once the output is active, it will be deactivated after 200 ms, and will remain deactivated for 5 seconds. This process will be repeated while the digital input is active.

If we wish to simulate this configuration and see the logic behaviour, we must click on the button.

The logic will be compiled and the simulator will be started automatically. In the configuration menu, we can select the simulation color. Active objects will turn to one color and deactivated objects to a different color, so that we know every time how the logic function evolves. Another screen will be displayed with the instantaneous value of each variable included in the logic.


Input
1
D_EP01_001
2
Output deactivation
17
5000
16
S
R
T
T
(ms)
Output activation timer
3
Output activation
4
Output_Activation
5
Output_Deactivation
19
200
18
S
R
T
T
(ms)
Output deactivation timer
6
Output_deactivation
9
Output Activation
10
D_SP01_001
11
D_SP02_001
12
D_SP03_001
13
D_SP_04_001
Outputs

6. HUMAN INTERFACES

6.1 F650PC SOFTWARE INTERFACE

6.1.1. OVERVIEW

F650PC software offers easy access to the unit values and settings by using a personal computer. It eases configuration, monitoring, maintenance and unit diagnosis both if the relay is individually connected or integrated in a local or wide area network.

This software package, provided with the relay, can run on any computer using Windows 95, 98 or NT. Its most recent version can be downloaded from the GE Multilin web site.

For communication with the relay, a serial port is required, or as an alternative, an Ethernet port.

The F650PC allows the user to work in two different modes, off-line and on-line.

Working off-line, the user can prepare in the office a file with the settings for a further download to the relay in the field, making easier the parameterization of units. For working off-line, the user needs the database of the unit to be emulated, which can be obtained from the GE Multilin website by entering the relay model and firmware version.

Working on-line, we can communicate directly with the relay. In this case, the first communication allows us to update the relay database with the information provided by the unit.

Using F650PC, the user can:

- View and modify settings.
- Load and save setting files from and to the computer disk.
- Read measurements, states, and inputs, both physical and virtual
- Program inputs, outputs and LEDs.
- Program advanced protection and control logic schemes using PLC Editor.
- Program the screens that will be shown on the graphic display GUI Editor.
- Access on-line help menus.

For viewing the oscillography records, we need to use a different software, such as GE-OSC, or else move the files to URPC software.

The unit firmware download and update process is not included in version 1.00 of the software. Therefore, specific instructions will need to be requested to GE Multilin.

The following sections describe the options available in F650PC, as well as how to start communicating with the relay.

This software package uses only ModBus protocol, and it is designed to communicate with a single relay at a time. GE offers different communication software packages, such as GE-POWER, which can be used to communicate simultaneously with several relays.

FIGURE 6.1. MAIN SCREEN OF F650PC

6.1.2. SYSTEM REQUIREMENTS

The minimum hardware requirements for installing and running the PLC Editor are:

- PENTIUM processor
- 32 M RAM
- 3 ½ disk drive
- CD-ROM drive
- RS-232C serial port

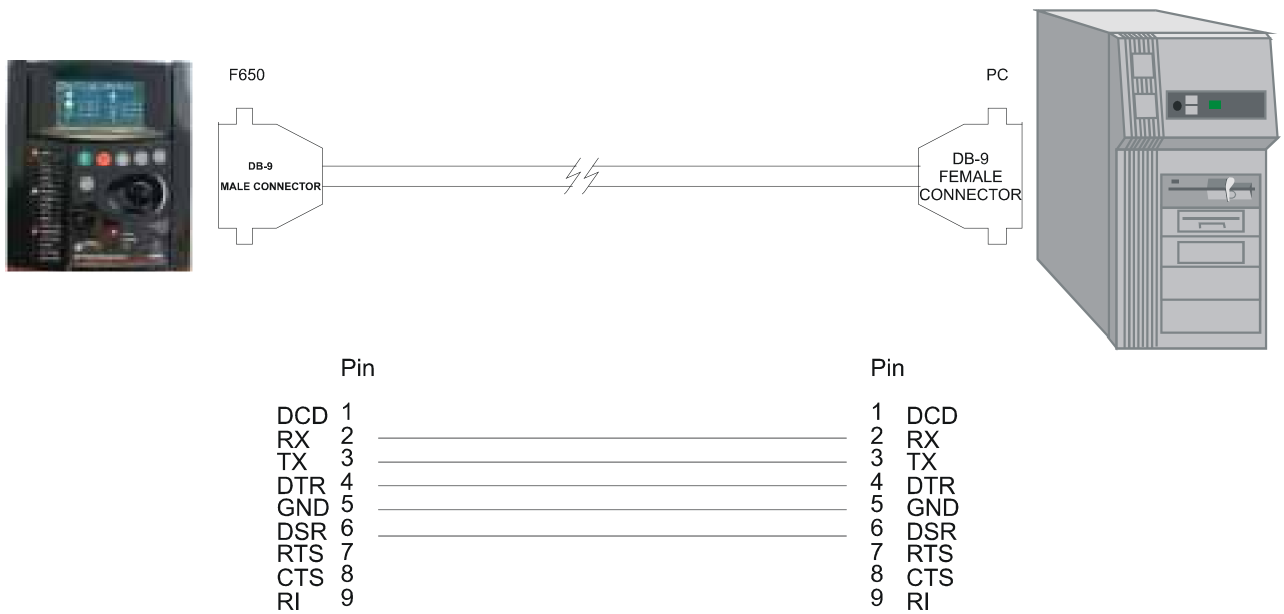
6.1.3. INSTALLATION

The PLC Editor can be installed using the installation disks. Run the setup.exe file on Disk 1 or the CD.

6.1.4. CONNECTING WITH THE UNIT

The F650PC software can communicate to the relay via the faceplate RS232 port, or the rear panel RS485. To communicate with the relay via the faceplate RS232 port, a standard "straight through" serial cable is used. The DB9 male end is connected to the relay and the DB9 or DB25 female end is connected to the PC COM1 or COM2 port as described in the figure below.

To communicate with the relay rear RS485 port from a computer RS232 port, an RS232/RS485 converter box is needed. We recommend to use the F485 converter, manufactured by GE. This converter box is connected to the computer using a "straight through" serial cable. A shielded twisted pair (20, 22 or 24 AWG according to the American standards; 0.25, 0.34 or 0.5 mm^2 according to the European standards) cable is used to connect the converter box to the relay rear communications terminals. The converter box (-, +, GND) terminals are connected to the relay (SDA, SDB, GND) terminals respectively. For long communications cables (longer than 1 km), the RS485 circuit must be terminated in a RC network (i.e. 120 ohm, 1 nF) as shown on figure 6.3.



RELAY - PC CONNECTION WIRE FOR RS-232 FRONT PORT

FIGURE 6.2. RELAY- PC CONNECTION FOR RS232 FRONT PORT

For the connection with the front port, we will use a direct cable.

Connection to the Ethernet port will be carried out using a crossed cable. If this connection is performed through a hub or switch, we will use direct Ethernet cable.

In addition to the RS232 port on the faceplate, the relay provides the user with an additional RS485 communication port. RS485 data transmission and reception are accomplished over a single twisted pair with transmit and receive data alternating over the same two wires. Through the use of these port, continuous monitoring and control from a remote computer, SCADA system or PLC is possible.

To minimise errors from noise, the use of shielded twisted pair wire is recommended. For a correct operation, polarity must be respected, although if it is not so, there is no danger to damage the unit. For instance, the relays must be connected with all RS485 SDA terminals connected together, and all SDB terminals connected together. This may result confusing sometimes, as the RS485 standard refers only to terminals named “A” and “B”, although many devices use terminals named “+” and “-“. As a general rule, terminals “A” should be connected to terminals “-“, and terminals “B” to “+”. There are exceptions to this rule, such as ALPS and DDS family relays. The GND terminal should be connected to the common wire inside the shield, when provided. Otherwise, it should be connected to the shield. To avoid loop currents, the shield should be grounded at one point only. Each relay should also be daisy chained to the next one in the link. A maximum of 32 relays can be connected in this manner without exceeding driver capability. For larger systems, additional serial channels must be added. It is also possible to use commercially available repeaters to increase the number of relays on a single channel to more than 32. Do not use other connection configuration different than the recommended.

Lightning strikes and ground surge currents can cause large momentary voltage differences between remote ends of the communication link. For this reason, surge protection devices are internally provided. To ensure maximum reliability, all equipment should have similar transient protection devices installed.

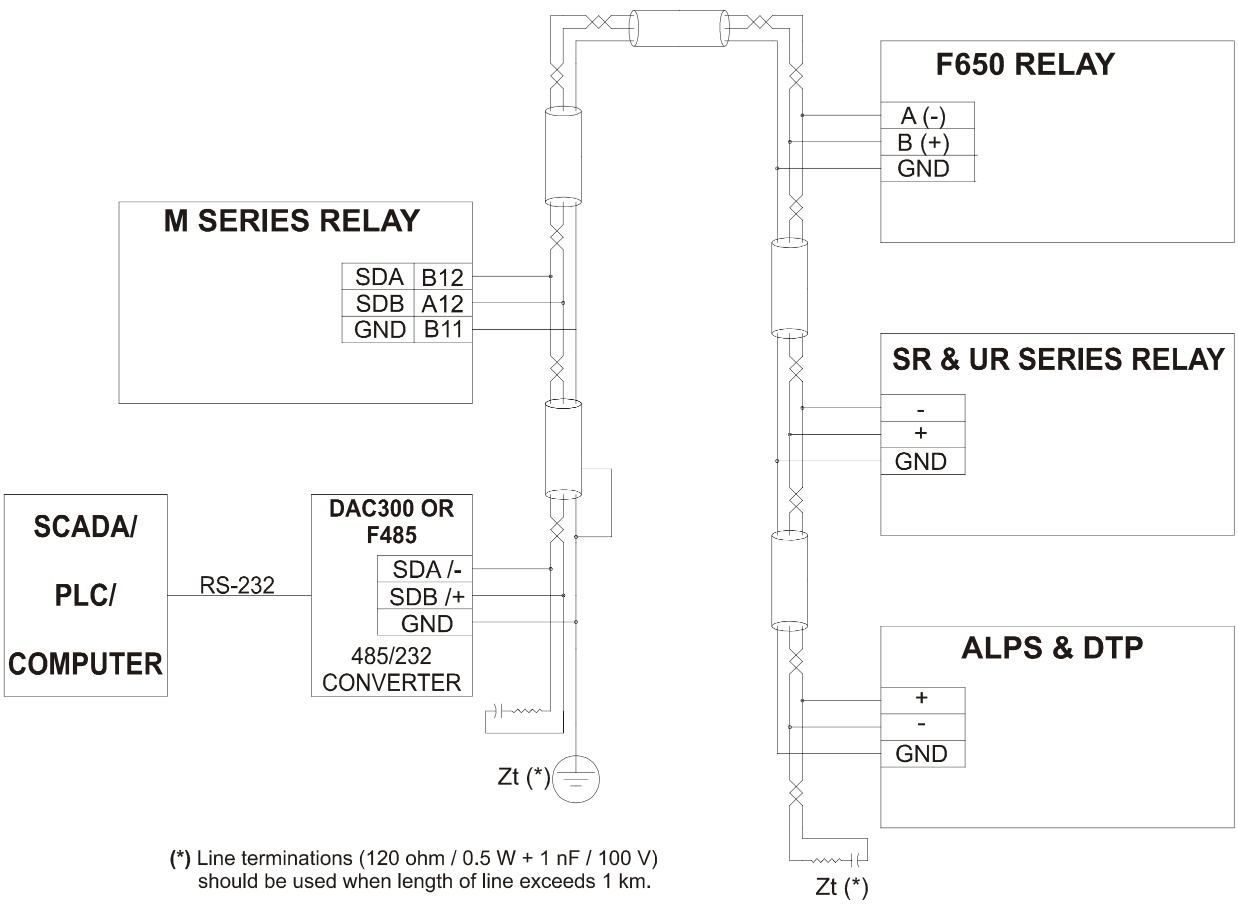


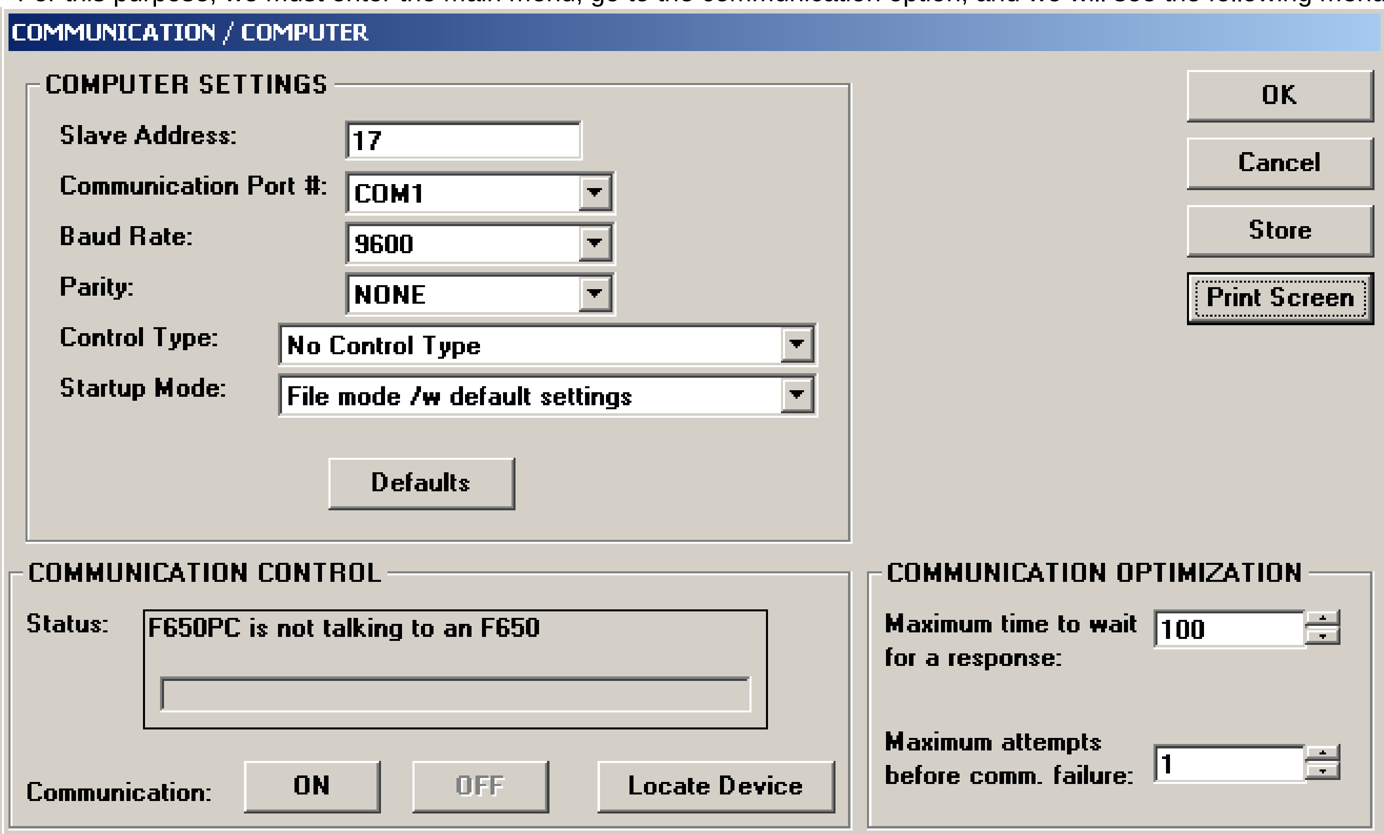
FIGURE 6.3. RS485 CONNECTION FOR F650 UNITS

6.1.5. STARTING COMMUNICATION

Before the physical connection to the relay, we must remember the safety instructions detailed in section 1.2. This section explains that we need to connect the relay ground terminal and the communicating computer to a good grounding. Otherwise, communication may not be viable, or even, in the worst case, the relay and/or the computer could result damaged.

For working on-line, we must previously ensure that all the relay communication parameters (e.g. baudrate, address) match the parameters in the computer.

For this purpose, we must enter the main menu, go to the communication option, and we will see the following menu:

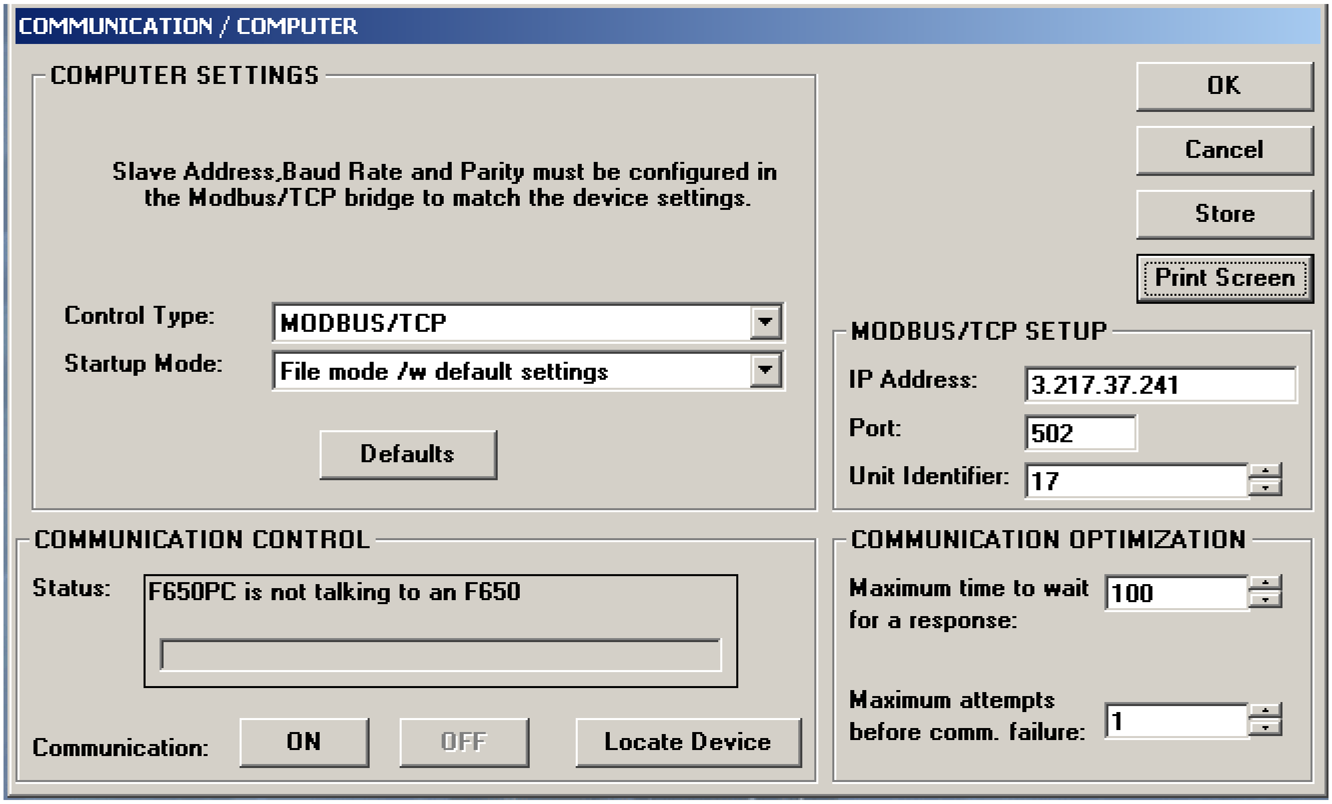


This screen shows the communication parameters on the top left window: ModBus Address, Communication Port, Baudrate, parity, whether there is or not control, and Startup mode.

Available control modes are:

No Control Type, for use with serial ports COM1 or COM2, RS485, or plastic or glass fiber optic.

MODBUS/TCP, for communication through the Ethernet port. In this case, the top right window will show the typical parameters to be programmed; IP address, port address and unit identifier.



The bottom left window displays a message that will let us know whether the software is communicating or not with the relay. In the example above, communication has not been established yet.

The parameters shown on the bottom right window can improve communication, although it is recommended to leave the default values indicated by the F650PC.

In this communication menu we will find soon a sub-menu called “Firmware Update”, that will enable the user to easily update the F650 unit software. There will be no need for special passwords if the update is for a more recent version of the same model.

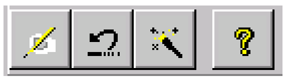
Thanks to the use of a double flashROM memory, one fixed with the BOOT program, and a second one with the application program (OS+PROTECTION), a high reliability is guaranteed when updating the unit firmware, as even if the case of a communication breakdown during the downloading process, we can retry the download for an unlimited number of times.

6.1.6. SETTINGS

The Settings menu shows three submenus:

S1 Settings
S2 Configuration
S3 Logic

The first one shows all the possible settings of the F650 unit. In this menu, we can view and modify the settings of any of the integrated functions. The icons describe the possible operations:



|-- Save   Saves the actual values
|--------------------------------- Restore   Restores the previous values
|---------------------------- Default   Sets the default settings
|----------------- About   Provides contextual help

The configuration menu includes several submenus to program the different items:

1. Inputs	For programming inputs
2. Outputs	Outputs
3. LEDs	LED indicators
4. Operations	Operations (e.g., breaker opening and closing)
5. Events	Events
6. HMI	Graphical configuration of the GUI editor screen

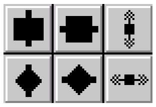
6.1.6.1. GUI EDITOR

The GUI Editor opens a programming menu for the graphical display. In this menu we can program up to 3 independent graphic screens without limitation in the number of elements to be represented, except for the physical limitation of 16x40 characters.

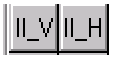
The following screen is displayed when entering the GUI (Graphic User Interface) Editor:

This tool allows the user to program the desired screen to be shown on the graphic display, using a simple icon menu that can be dragged and dropped. There is a maximum of 3 programmable screens.

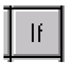
On the left column we can see the elements to be used for programming the screen. Their meaning is detailed on the right.



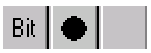
These symbols correspond to a breaker (square) and selector switch (rhombus), in vertical and horizontal positions. The symbol on the right represents an unpluggable breaker.



Symbols reserved for future uses.

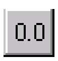


This button represents a text that is function of the state of a variable (switch case like). This feature allows, for example, to associate significant texts for the user to the different possible states of a recloser 1, 2, 3, and 4, such as STAND-BY, RECLOSING, WAITING, LOCKOUT)



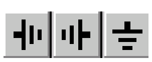
Bit   Represents the state of a bit from an internal variable, 1 or 0.

O   Performs the same function in a graphical mode. This way, it works as a virtual LED. When showing a black circle, it means that the signal is active (logic level 1), and if the circle is blank, the signal is inactive (logic level 0)



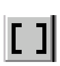
Used for displaying floating point numbers, such as a current value (123.5 A). The number of decimals can be selected, in order to facilitate the reading of analog values (current, voltage, power, power factor, etc.)

This symbol means that operations can be performed on the element, that becomes an active element on the one-line diagram. The operation will be associated to several properties that will facilitate the configuration. It can be associated for example to controllable breakers. If we wish to view a breaker that cannot be controlled, we will not place this icon on it.

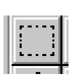


Ground symbols in different positions.

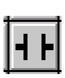
These symbols are used for representing transformers.



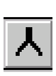
Symbols reserved for future uses (related to special operations)



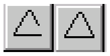
Symbols reserved for future uses (related to switchgear)



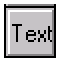
Symbol for capacitor banks.



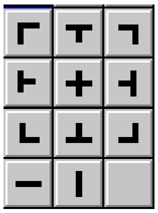
Symbol for wye connection.



Symbol for open delta and delta connection.



Display of a fix text chain that can contain up to 7 ASCII characters



The logic allows to set the relay logic configuration using a sophisticated and complete program based on standard IEC1131-3, with block diagrams, which is described more in detail in the PLC EDITOR section.

6.1.7. OPERATIONS

This menu shows a list of all the available operations in the F650, as follows:

Reset relay.	For resetting the unit variables.
Open breaker.	This is a SBO (Select Before Operate) operation, that requires confirmation.
Close breaker.	This operation will also require confirmation.
Block recloser.	For putting the recloser out of service, for maintenance and safety purposes.
Unblock recloser.	For putting the recloser back in service.
Delete records.	Can delete events or data records (log files).
Thermal Image Reset.	
Time synchronization.	Sends the computer date and time to the relays through the corresponding communication channel.

6.1.8. ACTUAL VALUES

Allows the user to view measurements, internal states, digital inputs and virtual inputs.

6.1.9. VIEW TRACES

This option displays two windows showing emitted and received ModBus messages, for easy tracking of communication messages.

6.1.10. HELP

This menu has three options:

Instruction manual, that displays the complete version of the F650 instruction manual.

Help, that provides contextual help.

About, provides the installed version of F650PC.

6.2 LOCAL HMI

F650 units are available with two different options for the front display. The first option is an alphanumerical display of 4 lines with 20 characters each, and the second option is a graphical display.

6.2.1. FRONT PRESS BUTTONS

I	This button is used for closing the user programmable switchgear
O	This button is used for opening the user programmable switchgear
*	User programmable
F1	User programmable
F2	User programmable
	Rotary Knob Used for selecting menus, submenus, settings, and confirmation
ESC	(ESC) Escape key

This figure shows the detail of the front communication port and local/remote button access cover sealing system. The sealing system is similar to the one used in energy meters, using wire and plumb seal.

High quality plastic designs have been used to withstand extreme environmental conditions, both mechanical and electrical, sun radiation, humidity, etc. in order to guarantee a long life for the unit.

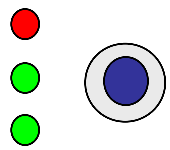
6.2.2. COMMAND PUSH BUTTON

The unit incorporates a command pushbutton located at the bottom right side of the faceplate. This button has three options: local, remote and off. The local option allows users to manipulate the relay front the local HMI. The remote option allows the user to manage the unit only via communications. The third option (off) blocks all the relay outputs. Each position is identified with a LED indicator, as follows:

LOCAL command (red)

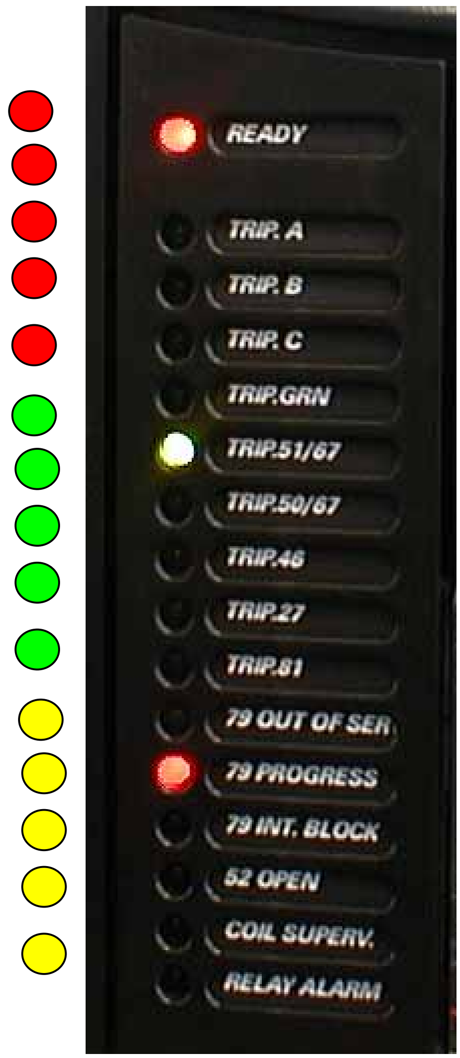
REMOTE command (green)

OFF (green)



6.2.3. FRONT LED INDICATORS

The relay incorporates 16 LED indicators, out of which one is fixed for showing that the relay is in service (READY) and the other 15 are user programmable using PLC logic.
Programmable LEDs are divided into groups of 5 LEDs, each of the groups having a different colour, as shown below:



15 LEDS PROGRAMABLE USING PLC LOGIC

6.2.4. ROTARY KNOB

Starting from the standby screen, when we press once, we enter the main menu. This main menu can also be accessed rotating the commuter to the left or the right, or pressing the ESC key.

6.2.5. 4X20 DISPLAY

When the relay auxiliary voltage is connected, it will show the following display

F650
GENERAL ELECTRIC
F650MABF1G0HI
V1.0

6.2.6. MAIN MENU

The main menu shows the following options:

Measures and Counters
States
Virtual states (remote inputs and outputs via Ethernet)
Display Settings
Modify Settings
Operations (32)
Time synchronization
Events

6.2.6.1. MEASURES AND COUNTERS

This menu is selected by pressing the rotating commuter. The first measure of signals and counters will be displayed (by rotating the commuter). The shown values are fixed for the metered analog variables, as well as programmed variables using PLC logic.

6.2.6.2. STATES

When selecting this menu, we will see the state of the different bits representing a series of internal relay variables, such as pickups, trips, communication states, inputs, outputs, etc. The displayed value for each of them can be 1 or 0, depending on whether it is active or not.

If we press the ESC key from any state screen, we will return to the main menu. If we press again on the States menu, the system will return to the state that was being displayed before pressing the ESC key, this means, the position is memorized.

6.2.6.3. VIRTUAL STATES

When selecting this menu, we will see (as in the previous **States** menu), the state of all the remote programmed variables. In other words, this screen displays sequentially, by rotating the commuter, the state of all those horizontal remote signals (remote inputs and outputs), configured using the PLC logic. The displayed value for each of them can be 1 or 0, depending on whether it is active or not.

If we press the ESC key from any state screen, we will return to the main menu. If we press again on the **Virtual States** menu, the system will return to the state that was being displayed before pressing the ESC key, this means, the position is memorized.

6.2.6.4. DISPLAY SETTINGS

This submenu allows only to display the settings of the protection functions included in the relay. By selecting this submenu from the main menu, the unit will display the protection units as follows:

Current Functions:

phase overcurrent
neutral overcurrent
ground overcurrent
isolated ground
Negative sequence overcurrent I_2

Voltage Functions

phase overvoltage
phase undervoltage
neutral overvoltage
negative sequence overvoltage
auxiliary overvoltage
auxiliary undervoltage

Advanced Settings

recloser settings
Synchronizer
Breaker failure
Fuse failure
Protection timers
Protection counters
Overfrequency
Underfrequency

If we place the cursor over a function, we can access its settings. They will be display sequentially as we rotate the commuter. The displayed settings can only be viewed, but not modified.

6.2.6.5. MODIFY SETTINGS

This submenu allows the user to modify the protection settings. By selecting this submenu from the main menu, the unit will display the protection units as follows:

Current Functions:

phase overcurrent
neutral overcurrent
ground overcurrent
isolated ground
Negative sequence overcurrent I_2

Voltage Functions

phase overvoltage
phase undervoltage
neutral overvoltage
negative sequence overvoltage
auxiliary overvoltage
auxiliary undervoltage

Advanced Settings

recloser settings
Synchronizer
Breaker failure
Fuse failure
Protection timers
Protection counters
Overfrequency
Underfrequency

If we place the cursor over a function, we can access its settings. They will be displayed sequentially as we rotate the commuter. By pressing again the commuter over a setting, we will be able to modify it by rotating the knob.

6.2.6.6. OPERATIONS

Operations are commands programmed using the PLC logic, and executed using the front pushbuttons.

Using the PLC, the user can program up to 32 operations, labelled with a text. This way, when we select an operation from the front of the F650, its description will be displayed to the user.

6.2.6.7. TIME SYNCHRONIZATION

If we select this submenu, the following format will be displayed:

Year /Month/Day/Hour/Minute/Second
0 0 / 0 0 / 0 0 / 0 0 / 0 0 / 0 0

The cursor is placed over the first Year digit. Its value can be modified by rotating the knob. When the first digit has been modified, we press again on the commuter, and the cursor will move to the next digit. This process is repeated for all the digits.

6.2.6.8. EVENTS

When this submenu is selected, the F650 displays the stored events sequentially (by rotating the knob).

Events are states stored in the relay, to which a text has been added using the PLC programmable logic. With each displayed event, the relay shows the programmed text, the date and time of the event, and the phase current measure when the event was generated.

6.2.7. HUMAN MACHINE INTERFACE (HMI) – GRAPHICAL DISPLAY

In F650 models including a graphical display instead of the 4x20 display, when starting the relay the display will light up. If a one-line diagram has been previously programmed, the user will be able to place the cursor over each switchgear element by rotating the knob, and then the programmed operations for each element can be commanded.

At the bottom of this screen we will find an option for returning to the main menu. Using the knob we will access the main menu screen, which will be displayed with the same dimensions as in the alphanumerical display, and centered on the graphical display.

This main menu is the same as the one described for the 4x20 display, and its whole functionality is identical. Therefore, we will only describe in this section the operation of the different screens shown on the graphical display.

Figure 1 shows the screen that will be displayed when selecting the Main Menu.

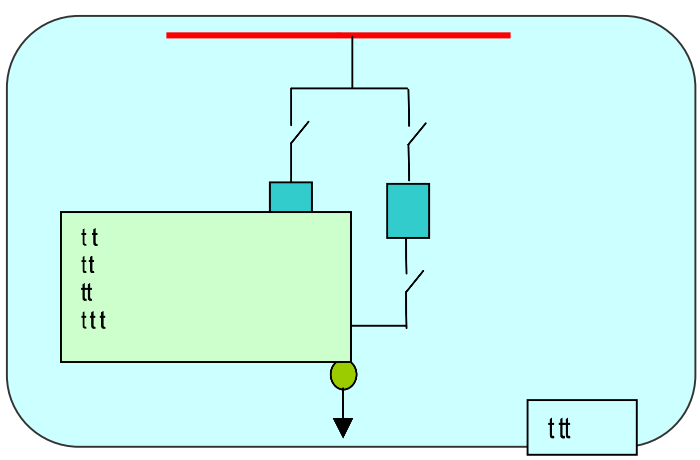
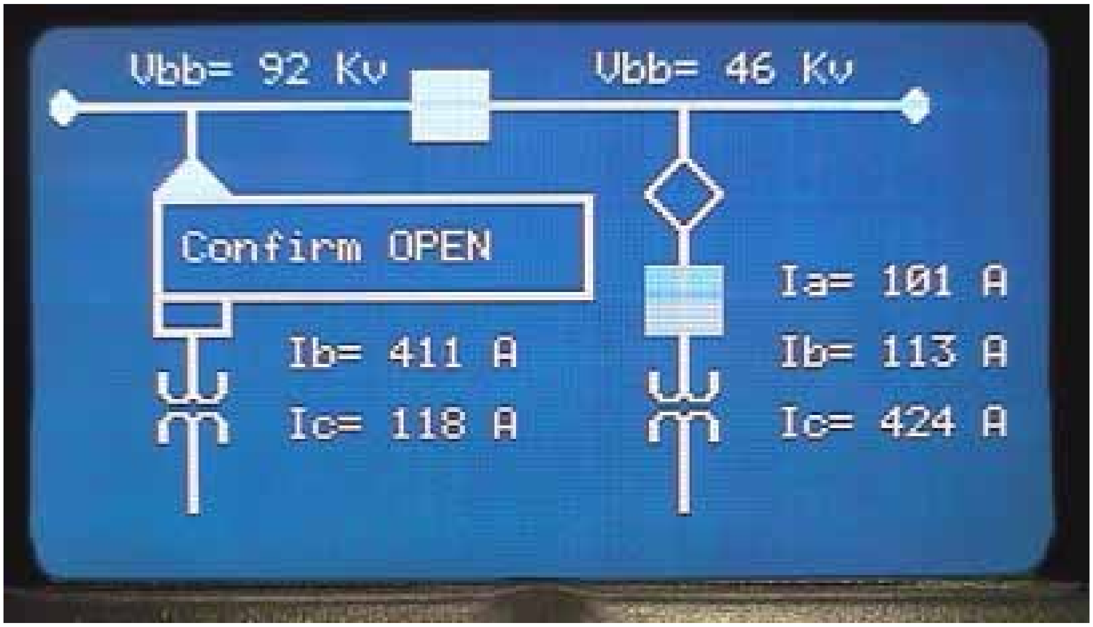


Figure 1

6.2.8. SWITCHGEAR COMMAND

Once the different switchgear elements have been programmed using the PLC, we will be able to command operations on them using the graphical display. By rotating the knob, we can move through the different elements, and select one by pressing the knob when the cursor is located on it. By doing this, the available operation will be displayed, and confirmation must be given by pressing again the knob.



7. MODBUS MAP FOR F650

7.1 ACCESS TO F650 INFORMATION

This section describes the steps to follow in order to read and write information on the F650.

The protocol used will be standard MODBUS/RTU, one of the different protocols supported by the F650.

A generic database has been created with all possible objects that can be included in an F650, whatever its type or configuration may be. This database is used for describing completely each of these objects. The description includes the type of data, length, position in the memory, version, etc. In addition, the database will group objects in sub-groups, such as states and setting groups.

Each object has a **UNIQUE** memory position for the whole family. Only after having read a relay's particular objects, will it be possible to create its map. This map is only valid for a single unit and a single memory version. Although the memory positions will remain fixed, there might be objects that are on one version and not on another.

The steps to create the memory map of an F650 unit are as follows:

Reading the particular identifiers of the relay: **One unit will have only one subset of all the identifiers defined in the generic object database. These identifiers are saved in a text file that allows the user to emulate the relay when a real unit is not available or connected.**

Searching the identifiers on the database**: With the list of identifiers, we access the object database and this way the customized map for the unit is described.**

All this allows the user to perform integration tasks in the unit without the unit itself, working with the corresponding software in emulation mode for more convenience and simplicity. As there might be several models and versions for the same family of units, the valid memory map for a determined unit will be obtained, depending on its version, directly from the software supplied with the relay.

7.2 F650 MODBUS

7.2.1. INTRODUCTION

The F650 type relays communicate with other computerized equipment such as programmable logic controllers, personal computers, or plant master computers, using the **Modbus ® RTU Protocol**. Following are some general notes:

- The units always act as slave devices, meaning, they never initiate communications; they only listen and respond to requests issued by a master computer.
- For Modbus® , a subset of the Remote Terminal Unit (RTU) format of the protocol is supported which allows extensive monitoring, programming, and control functions using read and write register commands.

Implemented functions will be:

Reading function 3 (or 4)

Writing function 16

7.2.2. PHYSICAL LAYER

The Modbus ® RTU protocol is hardware-independent so that the physical layer can be any of a variety of standard hardware configurations including RS232, RS485, fiber optics, Ethernet, etc.

The relay unit includes a faceplate (front panel) RS232 port and two rear terminal communications ports, which may be configured as RS485 or fiber optic; a 10/100 BaseT port; and in some models, two 100BaseFX ports. Data flow is half duplex in all configurations.

Each data byte is transmitted in an asynchronous format consisting of 1 start bit, 8 data bits, 1 stop bit, and possibly 1 parity bit. This produces a 10 or 11 bit data frame.

The baud rate and parity are independently programmable for each communications port. Baud rates of 1200, 2400, 4800, 9600, 19200, 38400, 57600, or 115200 bps are available. Even, odd, and no parity are available.

The master device in any system must know the address of the slave device with which it is to communicate. The unit will not act on a request from a master if the address in the request does not match the relay's slave address (unless the address is 0 or the broadcast address, in which case the relay will act but will not send any kind of response).

7.2.3. DATA LINK LAYER

Communications takes place in packets which are groups of asynchronously framed byte data. The master transmits a packet to the slave and the slave responds with a packet (with the exception of broadcast messages). The end of a packet is marked by 'dead-time' on the communications line. The duration of this dead-time will depend on the baudrate.

The following table describes general format for both transmit and receive packets.

For exact details on packet formatting, refer to subsequent sections describing each function code.

MODBUS PACKET FORMAT

SLAVE ADDRESS	1 byte	Each slave device on a communications bus must have a unique address to prevent bus contention. All of the relay's ports have the same address which is programmable from 1 to 254. A master transmit packet with a slave address of 0 indicates a broadcast command. All slaves on the communication link will take action based on the packet, but none will respond to the master. Broadcast mode is only recognized when associated with writing functions. For any other function code, a packet with broadcast mode slave address 0 will be ignored.
FUNCTION CODE	1 byte	This is one of the supported functions codes of the unit which tells the slave what action to perform. In our case, the supported codes will be 3, 4 for reading and 16 for writing. An exception response from the slave is indicated by setting the high order bit of the function code in the response packet. For example, an exception for function 3 will be indicated with a 13 as the function code and an exception for function 16 or 0x10 in hexadecimal, will be indicated with a 0x90.
DATA	N bytes	This will be a variable number of bytes depending on the function code. This may include actual values, settings, addresses or exception codes sent by the slave to the master.
CRC	2 bytes	This is a two byte error checking code. The RTU version of Modbus ® includes a 16 bit cyclic redundancy check (CRC-16) with every packet which is an industry standard method used for error detection. If a Modbus ® slave device receives a packet in which an error is indicated by the CRC, the slave device will not act upon or respond to the packet thus preventing any erroneous operations. The CRC ordering is LSB-MSB.
DEAD TIME	3.5 bytes transmission time	A packet is terminated when no data is received for a period of 3.5 byte transmission times (about 15 ms at 2400 bps, 2 ms at 19200 bps, and 300 µs at 115200 bps).

7.2.4. FUNCTION CODES

<table>
<tr><th colspan="2">CODE</th><th rowspan="2">MODBUS DEFINITION</th><th rowspan="2">F650 DEFINITION</th><th rowspan="2">MODBUS DEFINITION</th></tr>
<tr><th>HEX</th><th>DEC</th></tr>
<tr><td>03</td><td>3</td><td>Read Holding Registers</td><td>Read actual values or settings</td><td rowspan="2">This function code allows the master to read one or more consecutive data registers (actual values or settings) from a relay. Data registers are always 16 bit (two byte) values transmitted with high order byte first. The maximum number of registers that can be read in a single packet is 125 (250 bytes).</td></tr>
<tr><td>04</td><td>4</td><td>Read Input Registers</td><td>Read actual values or settings</td></tr>
<tr><td rowspan="2">10</td><td rowspan="2">16</td><td rowspan="2">Preset Multiple Registers</td><td>Store multiple settings</td><td>This function code allows the master to modify the contents of one or more consecutive setting registers in a relay. Setting registers are 16-bit (two byte) values transmitted high order byte first. The maximum number of setting registers that can be stored in a single packet is 60.

Slave address: 0x01
Function code: 0x10
Setting address: 0x0080
# of registers to write: 0x0001
# of bytes to write: 0x02
Setting data to write: 0x00xx
CRC</td></tr>
<tr><td>Command execution</td><td>This function can also be used for executing commands in the relay. Commands are writings of an operation code in the command address of the F650. All operations are written in the same address. The operation code will be written in MOTOROLA format, that is to say, MSB-LSB.

Slave address: 0x01
Function code: 0x10
Command address: 0x0080
# of registers to write: 0x0001
# of bytes to write: 0x02
Operation code data: 0xMMMM
CRC

Section 4 lists the operation codes for F650 units</td></tr>
</table>

7.2.5. EXCEPTIONS AND ERROR RESPONSES

Programming or operation errors happen because of illegal data in a packet, or hardware or software problems in the slave device, etc. These errors result in an exception response from the slave. The slave detecting one of these errors sends a response packet to the master with the high order bit of the function code set to 1. Besides, an error code is included for indicating the reason for the exception. For example:

Slave address:	**0x01**
Function code:	**0x90**
Error code:	**0x01**
CRC	

Error codes defined by MODBUS protocol are as follows:

01	ILLEGAL FUNCTION	The slave device does not allow the user to perform any function with the function code received in this message.
02	ILLEGAL DATA ADDRESS	The master device is trying to perform an operation in the wrong address
03	ILLEGAL DATA VALUE	The slave device has detected an invalid value sent by the master.
04	ILLEGAL RESPONSE LENGTH	Indicates that a response to the message required by the master device would exceed the maximum length specified by the function code.
05	ACKNOWLEDGE	Generic acknowledgement.
06	SLAVE DEVICE BUSY	The slave device is busy and it cannot perform the requested operation
07	NEGATIVE ACKNOWLEDGE	Negative generic acknowledgement.

7.3 DATA TYPES

TYPE	LENGTH	DESCRIPTION
F1	1	Boolean type data. As it is one bit, in order to evaluate it we need a memory address and a bit. Example: *Value 0x1A41-0001101001000001b* *Bit 15 0* *Bit 14 0* *Bit 13 0* *Bit 12 1* *Bit 11 1* *Bit 10 0* *Bit 09 1* *Bit 08 0* *Bit 07 0* *Bit 06 1* *Bit 05 0* *Bit 04 0* *Bit 03 0* *Bit 02 0* *Bit 01 0* *Bit 00 1*
F2	2	Integer with 4 bytes sign. It must be scaled multiplying by 1000 the value to be sent, or dividing by 1000 the received value. For example, if 34509 value is received, the converted value will be 34.509, and for writing value 334, we will need to send 334000. This method avoids the loss of accuracy involved in the use of double or float. *Example: 12312 0x00003018.* *Real Value = 12312/1000=12,312*
F3	2	Number in floating point “Float” of 4 Bytes *Example: 1240.556 0x449B11CB*
F4	1	Integer with 2 bytes sign. *Example: 123 0x007B*
F5	2	Integer with 4 bytes sign. *Example: 12312 0x00003018*

TYPE	LENGTH	DESCRIPTION
F6	4	Number in floating point “Float” of 8 Bytes *Example: 123.324 0x405ED4BC6A7EF9DB*
F7	1	Character without sign. As it must go in a record, that is, in two bytes, the character will go in the lower part. *Example: ‘β’ x00E1*
F8	1	Character with sign. As it must go in a record, that is, in two bytes, the character will go in the lower part. *Example: ‘A’ x0041*
F9	16	String. Fix length character chain (32 bytes). The end of the String will be marked with a ‘\0’. Example: “ABC” 0x41x42x43x00....
F10	1	Unsigned integer of 16 bits. Each of the values that can be held by this integer will have a correspondence in the database auxiliary table. In this table we can find the corresponding string that must be shown for each value. The memory will only receive an integer value Example: 0, 1 Corresponds to “CLOSED”, “OPEN”
F11	3	Milliseconds from 00:00:00.000 of 1/1/2000.

7.4 MEMORY MAP

The memory map is composed of several blocks. Each block has its own address and a determined size.

ADDRESS	SIZE	INFORMATION
0xE000	16W	10W Commercial model
		1W Data structure version
		5W Free
0xE010	8W	Serial number
0xE018	2W	Version (Date-Subpart-Year-Month)
0xE01A	2W	Free
0xE01C	1W	Reading data initiation address (INPUT REGISTERS)
0xE01D	1W	Reading data size
0xE01E	1W	Writing data initiation address (HOLDING REGISTERS)
0xE01F	1W	Writing data size
0xE020	1W	Address of the memory area where the PLC configuration is stored
0xE021	1W	Size of the above area
0xE022	1W	Address of the memory area where the relay display configuration is stored
0xE023	1W	Size of the above area
0xE024	1W	Address of the area where the event texts are stored
0xE025	1W	Size of the above area
0xE026	1W	Number of records that fit each event text
0xE054	1W	Number of objects in the relay
0xE055	xW	Indexes of objects in the relay. Each index is an integer number without sign of two bytes

8. DNP 3.0 PROTOCOL FOR F650

8.1 DNP 3 PROTOCOL SETTINGS

F650 units enable the user to program certain parameters related to DNP3 protocol. These parameters are called DNP3 protocol settings and can be modified from the front panel or from the Level 2 software.

Setting No	Setting Name	Default value	Range
1	DNP PORT	NONE	NONE, COM1, COM2, NETWORK
2	DNP ADDRESS	255	0 to 65534, step 1
3	DNP NETWORK CLIENT 1 ADDRESS	0.0.0.0	0.0.0.0 to 255.255.255.255
4	DNP NETWORK CLIENT 2 ADDRESS	0.0.0.0	0.0.0.0 to 255.255.255.255
5	DNP NETWORK CLIENT 3 ADDRESS	0.0.0.0	0.0.0.0 to 255.255.255.255
6	DNP NETWORK CLIENT 4 ADDRESS	0.0.0.0	0.0.0.0 to 255.255.255.255
7	DNP NETWORK CLIENT 5 ADDRESS	0.0.0.0	0.0.0.0 to 255.255.255.255
8	DNP TCP/UDP PORT NUMBER	20000	1 to 65535, step 1
9	DNP UNSOL RESPONSE FUNCTION	DISABLED	DISABLED, ENABLED
10	DNP UNSOL RESPONSE TIMEOUT	5 s	0 to 60 sec, step 1
11	DNP UNSOL MAX RETRIES	10	1 to 255, step 1
12	DNP UNSOL RESPONSE DEST ADDRESS	1	0 to 65519, step 1
13	DNP SCALE 1 FACTOR	1	0.01, 0.1, 1, 10, 100, 1000
14	DNP SCALE 2 FACTOR	1	0.01, 0.1, 1, 10, 100, 1000
15	DNP SCALE 3 FACTOR	1	0.01, 0.1, 1, 10, 100, 1000
16	DNP SCALE 4 FACTOR	1	0.01, 0.1, 1, 10, 100, 1000
17	DNP SCALE 5 FACTOR	1	0.01, 0.1, 1, 10, 100, 1000
18	DNP DEFAULT DEADBAND 1	30000	0 to 65535, step 1
19	DNP DEFAULT DEADBAND 2	30000	0 to 65535, step 1
20	DNP DEFAULT DEADBAND 3	30000	0 to 65535, step 1
21	DNP DEFAULT DEADBAND 4	30000	0 to 65535, step 1
22	DNP DEFAULT DEADBAND 5	30000	0 to 65535, step 1
23	DNP MESSAGE FRAGMENT SIZE	240	30 to 2048, step 1

1. **DNP PORT**: The F650 supports the Distributed Network Protocol (DNP) version 3.0. The F650 can be used as a DNP slave device connected to a single DNP master (usually either an RTU or a SCADA master station). Since the F650 maintains one set of DNP data change buffers and connection information, only one DNP master should actively communicate with the F650 at one time. The DNP PORT setting is used to select the communications port assigned to the DNP protocol. DNP can be assigned to a single port only. When this setting is set to NETWORK, the DNP protocol can be used over either TCP/IP or UDP/IP.

2. **DNP ADDRESS**: This setting is the DNP slave address. This number identifies de F650 on a DNP communications link. Each DNP slave should be assigned a unique address.

3. **DNP NETWORK CLIENT x ADDRESS**: These settings can force the F650 to respond to a maximum of 5 specific DNP masters. The front panel menu includes the DNP NETWORK CLIENT ADDRESSES option. This option allows to enter the lowest level menu for defining each address separately.

8. **DNP TCP/UDP PORT NUMBER**: TCP/UDP port number for the case of DNP3 communication being performed through the Ethernet.

9. **DNP UNSOL RESPONSE FUNCTION: ENABLED**, if unsolicited responses are allowed, and DISABLED otherwise.

10. **DNP UNSOL RESPONSE TIMEOUT**: sets the time the F650 waits for a DNP master to confirm an unsolicited response.

11. **DNP UNSOL MAX RETRIES**: This setting determines the number of times the F650 will retransmit an unsolicited response without receiving a confirmation from the master. Once this limit has been exceeded, the unsolicited response will continue to be sent at a different frequency.

12. **DNP UNSOL RESPONSE DEST ADDRESS**: This setting is DNP address to which all unsolicited responses are sent.

13. **DNP SCALE x FACTOR**: These settings are numbers used to scale Analog Input point values. Each setting represents the scale factor for all Analog Input points of that type. These settings are useful when Analog Input values must be adjusted to fit within certain ranges in DNP masters. Note that a scale factor of 0.1 is equivalent to a multiplier of 10 (i.e. the value will be 10 times larger).

14. **DNP DEFAULT DEADBAND x**: These settings are the values used by the F650 to determine when to trigger unsolicited responses containing Analog Input data. Each setting represents the default deadband value for all Analog Input points of that type. Note that these settings are the default values of the deadbands. DNP object 34 points can be used to change deadband values, from the default, for each individual DNP Analog Input point. Whenever power is removed and re-applied to the F650, the default deadbands will be in effect.

23. **DNP MESSAGE FRAGMENT SIZE**: This setting determines the size, in bytes, at which message fragmentation occurs. Large fragment sizes allow for more efficient throughput; smaller fragment sizes cause more application layer confirmations to be necessary which can provide for more robust data transfer over noisy communication channels.

8.2 DNP V3.00 DEVICE PROFILE DOCUMENT

8.2.1.1. DNP V3.00 DEVICE PROFILE DOCUMENT

The following table provides a "Device Profile Document" in the standard format defined in the DNP 3.0 Subset Definitions Document.

<table>
<tr><td colspan="2">(Also see the IMPLEMENTATION TABLE in the following section)</td></tr>
<tr><td colspan="2">Vendor Name: General Electric Multilin</td></tr>
<tr><td colspan="2">Device Name: F650 Relay</td></tr>
<tr><td>Highest DNP Level Supported:
For Requests: Level 2
For Responses: Level 2</td><td>Device Function:
☐ Master
Slave</td></tr>
<tr><td colspan="2">Notable objects, functions, and/or qualifiers supported in addition to the Highest DNP Levels Supported (the complete list is described in the attached table):
Binary Inputs (Object 1)
Binary Inputs Changes (Object 2)
Binary Outputs (Object 10)
Binary Counters (Object 20)
Frozen Counters (Object 21)
Counter Change Event (Object 22)
Frozen Counter Event (Object 23)
Analog Inputs (Object 30)
Analog Input Changes (Object 32)
Analog Deadbands (Object 34)</td></tr>
<tr><td>Maximum Data Link Frame Size (octets):
Transmitted: 292
Received: 292</td><td>Maximum Application Fragment Size (octets):
Transmitted: 240
Received: 2048</td></tr>
<tr><td>Maximum Data Link Re-tries:
☐ None
Fixed at 2
☐ Configurable</td><td>Maximum Application Layer Re-tries:
None
☐ Configurable</td></tr>
<tr><td colspan="2">Requires Data Link Layer Confirmation:
Never
☐ Always
☐ Sometimes
☐ Configurable</td></tr>
</table>

DNP V3.00 DEVICE PROFILE DOCUMENT (Sheet 2 of 3)

Requires Application Layer Confirmation:

☐ Never

☐ Always

When reporting Event Data

When sending multi-fragment responses

☐ Sometimes

☐ Configurable

Timeouts while waiting for:

Data Link Confirm:	☐ None	**Fixed at 3 s**	Variable	Configurable
Complete Appl. Fragment:	**None**	☐ Fixed at	Variable	Configurable
Application Confirm:	☐ None	**Fixed at 4 s**	Variable	Configurable
Complete Appl. Response	**None**	☐ Fixed at	Variable	Configurable

Others:

Transmission Delay:	**No intentional delay**
Inter-character Timeout:	**50 ms**
Need Time Delay:	**Configurable (default = 24 hrs.)**
Select/Operate Arm Timeout:	**10 s**
Binary Input change scanning period:	**1 s**
Packed binary change process period:	**1 s**
Analog Input change scanning period:	**1 s**
Counter change scanning period:	**1 s**
Frozen counter event scanning period:	**1 s**
Unsolicited response notification delay:	**1 s**
Unsolicited response retry delay:	**Configurable 0 to 60 s**

Sends/Executes Control Operations:

WRITE Binary Outputs	**Never**	☐ Always	☐ Sometimes	☐ Configurable
SELECT/OPERATE	☐ Never	**Always**	☐ Sometimes	☐ Configurable
DIRECT OPERATE	☐ Never	**Always**	☐ Sometimes	☐ Configurable
DIRECT OPERATE – NO ACK	☐ Never	**Always**	☐ Sometimes	☐ Configurable
Count > 1	**Never**	☐ Always	☐ Sometimes	☐ Configurable
Pulse On	☐ Never	☐ Always	**Sometimes**	☐ Configurable
Pulse Off	☐ Never	☐ Always	**Sometimes**	☐ Configurable
Latch On	☐ Never	☐ Always	**Sometimes**	☐ Configurable
Latch Off	☐ Never	☐ Always	**Sometimes**	☐ Configurable
Queue	**Never**	☐ Always	☐ Sometimes	☐ Configurable
Clear Queue	**Never**	☐ Always	☐ Sometimes	☐ Configurable

DNP V3.00 DEVICE PROFILE DOCUMENT (Sheet 3 of 3)

Reports Binary Input Change Events when no specific variation requested: ☐ Never **Only time-tagged** ☐ Only non-time-tagged ☐ Configurable	**Reports time-tagged Binary Input Change Events when no specific variation requested:** ☐ Never **Binary Input Change With Time** ☐ Binary Input Change With Relative Time ☐ Configurable (attach explanation)
Sends Unsolicited Responses: ☐ Never **Configurable** ☐ Only certain objects ☐ Sometimes (attach explanation) **ENABLE/DISABLE unsolicited Function codes supported**	**Sends Static Data in Unsolicited Responses:** **Never** ☐ When Device Restarts ☐ When Status Flag Change No other options permitted
Default CounterObject/Variation: ☐ No Counters Reported ☐ Configurable (attach explanation) **Default Object: 20** **Default Variation: 1**	**Counters Roll Over at:** ☐ No Counters Reported ☐ Configurable (attach explanation) ☐ 16 Bits **32 Bits** ☐ Other Value: ______ **Point-by-point list attached**
Sends Multi-Fragment Responses: **Yes** ☐ No	

8.3 IMPLEMENTATION TABLE

The following table shows objects, variations, function codes and qualifiers supported by F650 units, both in requests and responses for DNP3 protocol. For static (non-change-event) objects, requests sent with qualifiers 00, 01, 06, 07 or 08, will be responded with qualifiers 00 or 01. Static object requests sent with qualifiers 17 or 28 will be responded with qualifiers 17 or 28. For change-event objects, qualifiers 17 or 28 are always responded.

The grey background indicates functionality higher than DNP3 implementation level 2.

IMPLEMENTATION TABLE (Sheet 1 of 4)

OBJECT			**REQUEST**		**RESPONSE**	
Object No.	Variation No.	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes	Qualifier Codes (hex)
1	0	Binary Input (Variation 0 is used to request default variation)	1 (read) 22 (assign class)	06 (no range, or all) 00,01 (start-stop) 07,08 (limited qty) 17,28 (index)		
1	1	Binary Input	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
1	2	Binary Input with Status *(default – see Note 1)*	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
2	0	Binary Input Change - All Variations See Note 1	1 (read)	06 (no range, or all) 07,08 (limited qty)		
2	1	Binary Input Change without Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
2	2	Binary Input Change with Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol. resp.)	17, 28 (index)
10	0	Binary Output - All Variations	1 (read)	06 (no range, or all) 00,01 (start-stop) 07,08 (limited qty) 17,28 (index)		
10	2	Binary Output Status See Note 1	1 read	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
12	1	Control Relay Output Block	3 (select) 4 (operate) 5 (direct op) 6 (dir.op, noack)	00,01 (start-stop) 07,08 (limited qty) 17, 28 (index)	129 (response)	echo of request
20	0	Binary Counter - All Variations	1 (select) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz.cl. noack) 22 (assign class)	06 (no range, or all) 00,01 (start-stop) 07,08 (limited qty) 17,28 (index)		
20	1	32-Bit Binary Counter See Note 1	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz.cl. noack) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded).

Note 3: Cold restarts are implemented the same as warm restarts – The F650 is not restarted, but the DNP process is restarted.

IMPLEMENTATION TABLE (Sheet 2 of 4)

OBJECT			REQUEST		RESPONSE	
Object No.	Variation No.	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes	Qualifier Codes (hex)
20	2	16-Bit Binary Counter	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz.cl. noack) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
20	5	32-Bit Binary Counter without Flag	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz.cl. noack) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
20	6	16-Bit Binary Counter without Flag	1 (read) 7 (freeze) 8 (freeze noack) 9 (freeze clear) 10 (frz.cl. noack) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
21	0	Frozen Counter - All Variations	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)		
21	1	32-Bit Frozen Counter See Note 1	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
21	2	16-Bit Frozen Counter	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
21	9	32-Bit Frozen Counter without Flag	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
21	10	16-Bit Frozen Counter without Flag	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
22	0	Counter Change Event - All Variations	1 (read)	06 (no range, or all) 07,08 (limited qty)		
22	1	32-Bit Counter Change Event without Time See Note 1	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17, 28 (index)
22	5	32-Bit Counter Change Event with Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17,28 (index)
23	0	Frozen Counter Event - All Variations	1 (read)	06 (no range, or all) 07,08 (limited qty)		
23	1	32-Bit Frozen Counter Event without Time See Note 1	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17,28 (index)
23	5	32-Bit Frozen Counter Event with Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17,28 (index)

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded).

Note 3: Cold restarts are implemented the same as warm restarts – The F650 is not restarted, but the DNP process is restarted.

IMPLEMENTATION TABLE (Sheet 3 of 4)

OBJECT			REQUEST		RESPONSE	
Object No.	Variation No.	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes	Qualifier Codes (hex)
30	0	Analog Input - All Variations	1 (read) 22 (assign class)	06 (no range, or all) 00,01 (start-stop) 07,08 (limited qty) 17,28 (index)		
30	1	32-Bit Analog Input See Note 1	1 (read) 22 (assign class)	000,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
30	2	16-Bit Analog Input	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
30	3	32-Bit Analog Input without Flag	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
30	4	16-Bit Analog Input without Flag	1 (read) 22 (assign class)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00, 01 (start-stop) 17,28 (index) See Note 2
32	0	Analog Change Event - All Variations	1 (read)	06 (no range, or all) 07,08 (limited qty)		
32	1	32-Bit Analog Change Event without Time See Note 1	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17, 28 (index)
32	2	16-Bit Analog Change Event without Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17, 28 (index)
32	3	32-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17,28 (index)
32	4	16-Bit Analog Change Event with Time	1 (read)	06 (no range, or all) 07,08 (limited qty)	129 (response) 130 (unsol.resp)	17,28 (index)
34	0	Analog Input Reporting Deadband	1 (read)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)		
34	1	16-Bit Analog Input Reporting Deadband See Note 1	1 (read)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00,01 (start-stop) 17,28 (index) See Note 2
34	2	32-Bit Analog Input Reporting Deadband See Note 1	2 (write)	00,01 (start-stop) 07,08 (limited qty) 17,28 (index)		

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded).

Note 3: Cold restarts are implemented the same as warm restarts – The F650 is not restarted, but the DNP process is restarted.

IMPLEMENTATION TABLE (Sheet 4 of 4)

OBJECT			REQUEST		RESPONSE	
Object No.	Variation No.	Description	Function Codes (dec)	Qualifier Codes (hex)	Function Codes	Qualifier Codes (hex)
34	3	Short floating point Analog Input Reporting Deadband	1 (read)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00,01 (start-stop) 17,28 (index) See Note 2
50	0	Time and Date - All Variations	1 (read)	00,01 (start-stop) 06 (no range, or all) 07,08 (limited qty) 17,28 (index)	129 (response)	00,01 (start-stop) 17,28 (index) See Note 2
50	1	Time and Date See Note 1	1 (read) 2 (write)	00,01 (start-stop) 06 (no range, or all) 07 (limited qty=1) 08 (limited qty) 17,28 (index)	129 (response)	00,01 (start-stop) 17,28 (index) See Note 2
52	2	Time Delay Fine	1 (read) 2 (write)		129 (response)	07 (limited qty) quantity=1
60	0	Class 0, 1, 2, and 3 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all)		
60	1	Class 0 Data		06 (no range, or all)		
60	2	Class 1 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07,08 (limited qty)		
60	3	Class 2 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07,08 (limited qty)		
60	4	Class 3 Data	1 (read) 20 (enable unsol) 21 (disable unsol) 22 (assign class)	06 (no range, or all) 07,08 (limited qty)		
80	1	Internal Indications	2 (write)	00 (start-stop) (index must =7)		
		No Object (function code only) See Note 3	13 (cold restart)			
		No Object (function code only)	14 (warm restart)			
		No Object (function code only)	23 (delay meas.)			

Note 1: A default variation refers to the variation responded when variation 0 is requested and/or in class 0, 1, 2, or 3 scans.

Note 2: For static (non-change-event) objects, qualifiers 17 or 28 are only responded when a request is sent with qualifiers 17 or 28, respectively. Otherwise, static object requests sent with qualifiers 00, 01, 06, 07, or 08, will be responded with qualifiers 00 or 01 (for change-event objects, qualifiers 17 or 28 are always responded).

Note 3: Cold restarts are implemented the same as warm restarts – The F650 is not restarted, but the DNP process is restarted.

9. FREQUENTLY ASKED QUESTIONS

9.1 COMMUNICATIONS

Q1 Does the F650 support DNP and Modbus over the Ethernet port?

A1 Yes, F650 units support both protocols over both the asynchronous serial ports and the Ethernet LAN synchronous port using TCP/IP and UDP/IP layers over the Ethernet.

Q2 Does this equipment support dual IP access?

A1 Yes. It supports a maximum of 256 different IP addresses in aliasing mode, thanks to the use of Linux OS. It has only 1 MAC address as it communicates with a single Ethernet port.

Q3 Is the protocol IEC 870-103 supported by the F650?

A3 At this moment it is not supported. Only Modbus, DNP 3.0 and MMS/UCA 2.0, IEC61850 are supported, although there is not technical limitation to include other protocols in the near future.

Q4 Can the F650 be used as a DNP master station?

A4 Not at this moment. It works as a slave IED station for all protocols.

Q5 How many communication ports are included in the F650?

A5 The equipment has 2 different boards, one for asynchronous serial ports and another for a high speed synchronous Ethernet port. The first board has 2 comm ports, COM1 and COM2. COM1 is multiplexed with the front serial RS232 port, whereas the COM2 port is completely independent from COM1.
The synchronous LAN port is COM3.

Q6 Are there one or two Ethernet ports?

A6 The equipment has only 1 Ethernet port. For redundant fiber optic versions, redundancy is done at the physical level (fiber optic) but there is just one port.

Q7 How many different communication Ethernet sessions can be opened through the LAN port?

A7 Same as the UR, up to 4 sockets can be opened.

Q8 Does it support peer to peer horizontal communications? Is this going to interface with UR relays?

A8 Yes, utilizing GOOSE messaging system up to 16 different equipments can be communicated in a multicast approach. The equipment is compatible with the UR family for a remote I/O complete system through the LAN.

Q9 Does the 650 support glass fiber optic for the serial ports? Which connector does it use?

A9 Yes, it supports either plastic fiber optic or glass fiber optic. For glass fiber optic versions it uses an ST type connector that works with multimode signals.
The LAN port uses the same ST connector for fiber optic models for multimode signals too.

Q10 May I use the cooper 10/100 BaseT connection included in the basic model with all protocols?

A10 Yes, it may be used with all protocols. In extremely noisy substation environments and/or long distances, it is recommended to use fiber optic options due to much better EMC performance and immunity.

Q11 Distributed I/O CAN bus. Does it support DeviceNet protocol?

A11 No it does not support DeviceNet.

9.2 PROTECTION

Q1 Does the F650 support IRIG-B signals? Which type and accuracy? How many units may be connected to the same source?

A1 Yes, the F650 includes an IRIG-B input for all models, including the basic ones.
It uses DC level format B. Formats used are B0000, B0002 and B0003.
Actual accuracy is 1 millisecond. Internal sampling rate allows true 1 ms accuracy time tagging.
The input burden is very low. The maximum number of units that may be connected to a generator depends on its output driving capability. Up to 60 units have been successfully connected with equipments commonly used in the market.

Q2 Does the equipment work with dry inputs in both AC and DC?

A2 The equipment works only with DC inputs.
Inputs should be driven with externally generated DC current. No special 48 Vdc or other outputs are included in the equipment to drive these inputs, therefore, contacts connected to the equipment should be connected to a DC source.

Q3 Is this equipment valid for Petersen coil grounded systems and ungrounded systems?

A3 Yes, there is a special model whose 5th current input is a very sensitive unit that measures from 5 mA up to 1.5 A, that is used for these systems. The algorithms used for protection are the same as the ones depicted for MIN M Family relays.

Q4 Is oscillography programmable?

A4 Yes, it is fully programmable, from the sampling rate (4, 8, 16, 32 or 64 samples per input) up to the depth, allowing recording up to 5 seconds for a more convenient post fault analysis.

Q5 Do I have to select a different model for 1 or 5 A?

A5 No. The same model is able to work with either /1 A or /5 A rated secondary currents. There are high accuracy sensing transformers that allow the use of any current input through the same terminals to reduce the spares and simplify wiring.

9.3 CONTROL AND HMI

Q1 Do I need to program interlocks?

A1 Most common interlocking schemes are already built in. All one has to do is select from the list. If other schemes are required it may be programmed via F650-PLC-LOGIC software.

Q2 Can we rotate the display 90 degrees to show feeders vertically?

A2 No. The product has been designed to view it in horizontal mode (landscape) due to the following reasons:

It is easier to read the LCD display because it has been designed for horizontal positions.
Compatibility between text display (4x20 characters) and LCD display (16x40 characters or 128x240 pixels).
Refresh speed is better in horizontal than vertical format.

Q3 Do I need a laptop or handheld to program the unit?

A3 No, all main operations can easily be performed with just the incorporated HMI. Handheld or laptops may help to download large quantities of information (such as oscillograms, etc.) but they are not mandatory for a conventional user that just needs to change settings, view measurements, states, alarms, etc.

10. TROUBLESHOOTING GUIDE

F650 units have been designed and verified using the most advanced and reliable equipment. Mounting and testing automation ensure a high consistency of the final product. Before sending a unit back to the factory, we strongly recommend you follow the recommendations below. Even if it will not always solve the problem, at least they will help define it better for a quicker repair.

If you need to send a unit back to the factory for repair, please use the appropriate RETURN MATERIAL AUTHORISATION process, and follow the shipping instructions provided by our Service Department, specially in the case of international shipments. This will lead to a faster and efficient solution of your problem.

Category	Symptom	Possible cause	Recommended action
Protection	The relay does not trip	-Function not permitted - Output not assigned	- Set the function permission to ENABLED - Program the output to the desired function using F650-PLC-LOGIC
General	When feeding the unit, no indicator is lit up	-Insufficient power supply -Fused fuse -Incorrect wiring	-Verify the voltage level using a multimeter in the power supply terminals, and check that it is within the model range -Remove power supply, dismount the power supply module and replace the fuse -Make sure that terminals labelled + and – are connected to the 9-pin connector corresponding to the power source
Communication	The relay does not communicate via the front RS232 port	-Incorrect cable -Damaged cable -Relay or PC not grounded -Incorrect baudrate, port, address, etc.	-Make sure you are using a straight cable -Replace the cable -Ensure ground connection -Test other ports, other baudrates, etc. Make sure that the communication parameters in the computer match the ones in the relay.
	The relay does not communicate via the RS485 port	-Relay or PC not grounded -Incorrect polarity -Incorrect protocol -Incorrect baudrate, port, address, etc.	- Ensure ground connection -Invert polarity -Select corresponding protocol (Modbus or DNP 3.0) Test other ports, other baudrates, etc. Make sure that the communication parameters in the computer match the ones in the relay.

Category	Symptom	Possible cause	Recommended action
	The relay does not communicate via the RS485 port	- The unit is communicating through the multiplexed front port, which has preference	- Disconnect the front port communication.
	The relay does not communicate directly from the PC to the Ethernet port	-Incorrect cable -Damaged cable -Incorrect protocol	-Make sure you are using a twisted Ethernet cable -Replace the cable - Select corresponding protocol (Modbus or DNP 3.0 over TCP/IP)