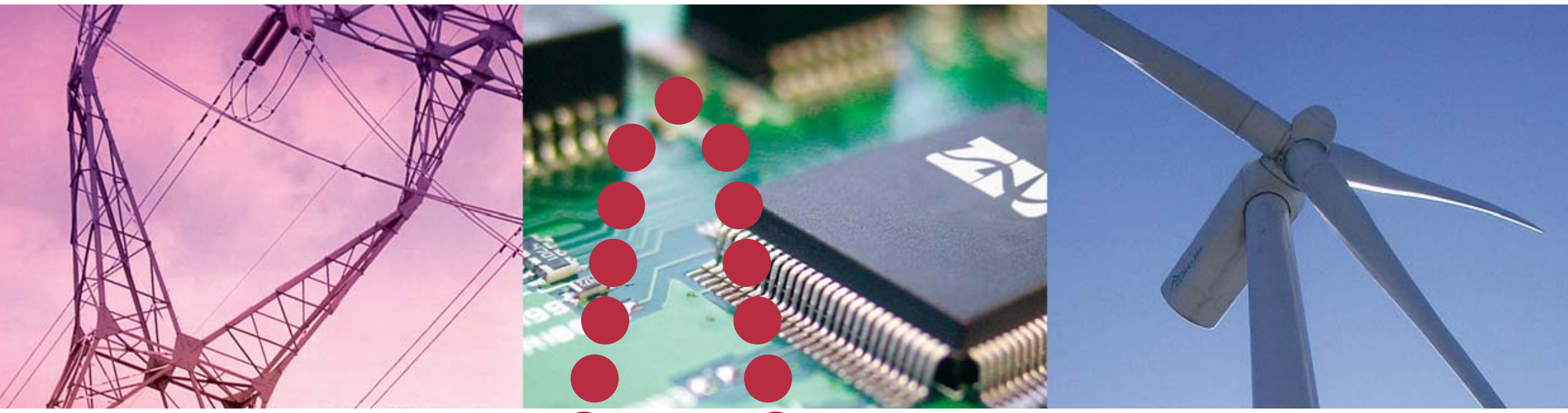

FGI

Maximum / Minimum Frequency Protection

Instructions Manual

BFGI1011Av01

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Table of Contents

1. Description

FGI represents a family of protection digital systems. The **FGI** relay provides protection functions of overfrequency and underfrequency, overvoltage and undervoltage, zero sequence voltage, micro outages or out of step apart from measuring functions and communications.

Overfrequency and underfrequency **FGI** units are designed to be integrated in systems where a stable frequency value must be achieved. Therefore, a permanent equilibrium between generation and consumption must exist. Overfrequency and underfrequency relays will actuate whenever this equilibrium is altered. Network underfrequency is caused by an excessive load on the system. Partial load shedding must be performed to correct such a situation. After the system frequency returns to normal, the previously shed loads must be restored.

The purpose of the out of step element is to quickly disconnect synchronous generators working in parallel with the grid when a grid disturbance occurs: grid failure or short grid outage.

1.1 Functions

- **Frequency Protection Element (81 M/m)**

One analog voltage input to obtain frequency readings and two frequency units are included in each **FGI** terminal. Each frequency unit is equipped with a time-delayed element that can also implement as an instantaneous element.

In **FGI-A/C** models frequency elements can be independently adjusted as overfrequency elements, or as underfrequency elements. In models **FGI-B** one of the elements is used as overfrequency element and the other as underfrequency element.

It is possible to enable or disable the frequency units through user settings.

- **Minimum Voltage Element**

A minimum voltage element is included on each **FGI** terminal. When enabled, it prevents frequency and out of step elements (depending on the model), from operating for measured voltage values below the setting.

- **Voltage Protection [3x (27 or 59) and 3x (27 or 59) + 1x59N)]. FGI-C**

It has three phase voltage measurement analog inputs, the open delta being calculated internally. Phases have two associated protection elements with their corresponding separate settings. Elements can be selected either as overvoltage or undervoltage elements. Also, there exists a ground protection element (open delta).

Every phase voltage protection element consists of an instantaneous element, with additional settable time, and a fixed time or inverse curve element. The open delta consists of only one instantaneous element with additional settable time. Element pickup can be enabled or disabled through settings.

- **Out of step element (78). FGI-C**

It has an out of step element that can be enabled or disabled through a setting.

Out of step protection detects anomalies much faster than other types of protections, as is the case for voltage or frequency protections. For the latter, the time lapse before the disturbance changes the operating magnitudes can reach hundreds of milliseconds, owing to the electrical inertia of the power grid and the mechanical inertia of the generator.

Because of the measuring principle of the out of step protection the disturbance is detected within the same cycle during which it occurs, resulting in break times smaller than 100 ms, including the breaker operating time.

1.2 Additional Functions

- **LED Targets**

Terminal unit front panel indication consists of eight LEDs. Seven of the LEDs are user definable. The eighth LED is assigned to indicate the terminal unit is "Ready" (powered up, self-test OK). A list of available outputs is defined in Chapter 6.

- **Status Contact Inputs**

The terminal unit has two status contact inputs, both are configurable. A list of available outputs is defined in Chapter 6.

- **Auxiliary Contact Outputs**

There are three auxiliary contact outputs, two of which are configurable. Auxiliary output AUX – 3, which corresponds to “Terminal Unit In Service” (powered up, self-test OK), is not programmable. A list of available outputs is defined in Chapter 6.

- **Trip Output. FGI-C**

FGI-C relays are provided with a trip output consisting of two NO or NC contacts configurable via internal jumpers.

- **Local Information (display)**

Display of:

- **Events:**

  Last relay operation (trip)
  Status contact inputs status
  Auxiliary contact outputs status
  Protection elements pickup

- **Measuring:**

  Voltage and Frequency (depending on the model).

- **Self-Test Program**

A continuously running diagnostic self-test program verifies the correct operation of the terminal unit and alerts the user of potential problems.

1.3 Model Selection

	FGI		0	B								
1		2			3	4	5	6		7	8	REV.

1	**Mount Type**			
	3	Vertical Mount	**8**	Horizontal Mount
2	**Functions**			
	A	Over / Under Frequency (81 M/m)	**C**	81 M/n + Out of Step (78) + 3x(27/59) +1x59N
	B	81 with Load Shedding		
3		**Voltage Supply**	**Status Contact Inputs**	
	1	24 - 48 Vdc (*)	24 - 48 Vdc	
	2	110 - 125 Vdc (*)	24 - 125 Vdc	
	3	220 - 250 Vdc (*)	48 - 250 Vdc	
4	**Rated Voltage / Frequency / Language**			
	1	110 & 110/3V, 50Hz, Spanish	**D**	120 & 120/3V, 60Hz, Spanish
	3	120 & 120/3V, 60Hz, English	**F**	120 & 120/3V, 60Hz, Portuguese
	B	110 & 110/3V, 50Hz, English		
5	**Communications**			
	1	RS232 + RS232	**3**	RS232 + Glass FO (SMA)
	2	RS232 + Plastic FO (1 mm.)	**4**	RS232 + Glass FO (ST)
	5	RS232 + RS485		
6	**0**	Standard	**1**	Remote RS232**
7	**Special Models**			
	00	Standard	**01**	Voltage inhibition (20-90%)Un + Temp. 0-30s
8	**Enclosure Type**			
	D	6U x 1/7 of 19" rack	**V**	1U x 19" rack mount

*** ±20**
****Only if COMMUNICATION option = 1.**

- **Functions**

81M	Overfrequency.
81m	Underfrequency.
78	Out of Step.
27	Undervoltage Protection.
59	Overvoltage Protection.
59N	Neutral Overvoltage Protection.

2. Technical Data

2.1 Power Supply Voltage

Selectable range depending on the unit:	
	24 - 48Vdc (±20%)
	110 -125Vdc (±20%)
	220 - 250Vdc (±20%)

Note: In case of power supply failure, a maximum interruption of 100 ms is allowed for 110Vdc input.

2.2 Power Supply Burden

Quiescent	**7 W**
Maximum	**11 W**

2.3 Voltage Analog Inputs

Rated a.c. Voltage	**Vn = 110 V / 50 Hz**
	Vn = 120 V / 60 Hz
Thermal Withstand Capability	**2Vn (phases)** (continuously)
Voltage Circuit Burden	**Vn = 110V < 0.5VA**

2.4 Measurement Accuracy

Measured voltages	
Internal measure accuracy	**< 5 %**
Display measure accuracy	**< 5 % ±1V**
Measured frequencies	
Internal measure accuracy	**< 0.005 Hz**
Display measure accuracy	**< 0.01 Hz**
Measuring times	
Characteristic	**<5 %** or **<25ms** (sync. by U)
	<5 % or **<100ms** (sync. by f or ϕ)
	(in both cases, the greater)
Measuring angle	
Characteristic	**< 3 º**

2.5 Repeatability

Operating Time	**2 %** or **25 ms** (the greater)

2.6 Digital Inputs

Two electrically separate, user programmable digital inputs

Digital Input Voltage Range	**24 - 125 Vdc (±20%)**
(range selectable depending on the model)	**48 - 250 Vdc (±20%)**
Current Drain	**<5 mA**

2.7 Trip Outputs and AUX-1

Two trip contacts internally configurable as NO or NC
AUX -1 switched contact internally configurable as NO and/or NC

I DC maximum limit (with resistive load)	**5 A** (30 s)
I DC continuous service (with resistive load)	**8 A**
Close	**2500 W**
Breaking capability (with resistive load)	**150 W** - max. 8 A - (48 Vdc)
	55 W (80 Vdc - 250 Vdc)
	1250 VA
Switching Voltage	**250 Vdc**
Momentary close time trip contacts remain closed	**40 ms**

2.8 Auxiliary Outputs AUX-2 and AUX-3

Contact internally configurable as NO or NC

I DC maximum limit (with resistive load)	**5 A** (30 s)
I DC continuous service (with resistive load)	**3 A**
Close	**2000 W**
Breaking capability (with resistive load)	**75 W** - max. 3 A - (48 Vdc)
	40 W (80 Vdc - 250 Vdc)
	1000 VA
Switching Voltage	**250 Vdc**

2.9 Communications Link

Remote communications	Glass FO; Plastic FO; RS232
Local communications	RS232

Glass Fiber Optics	
Type	**Multimode**
Wavelength	**820 nm**
Connector	**ST**
Transmitter Minimum Power	
50/125 μm fiber	**- 20 dBm**
62.5/125 μm fiber	**- 17 dBm**
100/140 μm fiber	**- 7 dBm**
Receiver Sensitivity	**- 25.4 dBm**

Plastic Fiber Optics (1 mm)	
Wavelength	**660 nm**
Transmitter Minimum Power	**- 16 dBm**
Receiver Sensitivity	**- 39 dBm**

RS232C Port Signals	
Terminal unit DB-9 (9-pin) front and rear connectors	**Pin 5 - GND**
	Pin 2 - RXD
	Pin 3 - TXD

3. Standards and Type Test

3.1 Insulation

Insulation Test (Dielectric Strength)	*IEC-60255-5*
Between all circuit terminals and ground:	**2 kV, 50 Hz**, during 1 minute
Between all circuit terminals:	**2 kV**, **50 Hz**, during 1 minute
Voltage Impulse Test	*IEC-60255-5 (UNE 21-136-83/ 5)* **5 kV**; **1.2/50** μ**s**; **0.5 J**

3.2 Electromagnetic Compatibility

1 MHz Burst Test	*IEC-60255-22-1 Class III* *(UNE 21-136-92/22-1)*
Common mode:	**2.5 kV**
Differential mode:	**1.0 kV**
Fast Transient Disturbance Test	*IEC-60255-22-4 Class IV* *(UNE 21-136-92/22-4)* *(IEC-61000-4-4)* **4 kV** ±**10 %**
Radiated Electromagnetic Field Disturbance	*IEC-61000-4-3*
Amplitude modulated *(EN 50140)*	**10 V/m**
Pulse modulated *(EN 50204)*	**10 V/m**
Conducted Electromagnetic Field Disturbance	*EN 50141*
Amplitude modulated	**10 V**
Electrostatic Discharge Test	*IEC-60255-22-2 Class III* *(UNE 21-136-92/22-2) (IEC-61000-4-2)* **±8 kV** ±**10 %**

Radio Frequency Emissivity	*EN 55011 (IEC-61000-4-6)*

3.3 Environmental Test

Temperature	*IEC-60255-6*
Operating range:	**-10 ºC** to **+ 55 ºC**
Storage range:	**-25 ºC** to **+ 70 ºC**
Humidity:	**95 %** (non-condensing)

3.4 Power Supply

Power Supply Ripple	*IEC-60255-11 / UNE 21-136-83 (11)*
	< 20 %

3.5 Mechanical Test

Vibration Test (sinusoidal)	*IEC-60255-21-1 Class I*
Mechanical Shock and Bump Test	*IEC-60255-21-2 Class I*

The models comply with the EEC 89/336 standard of electromagnetic compatibility

4. Physical Architecture

4.1 General

FGI protection terminals consist of a circuit board with the following functions:

- Power Supply
- Control Processing Unit
- Analog Input Transformers
- Contact Inputs and Outputs

Depending on the terminal settings, contact inputs / outputs may be used or remain as spare signals.

Following figures show terminal unit front panels for **3FGI** series and **8FGI** series, respectively.

Keypad, alphanumeric display, LED targets, and local communications port are allocated on front panel.

The rear panel contains terminal connectors. Following figures represent the external appearance of the **3FGI** and **8FGI** models respectively. There are two terminal connector groups, one corresponds to power supply input and contact inputs and outputs (total of 20 connectors) and the other corresponds to transformer secondary analog inputs (5 or 10 connectors, depending on the model).

The relay is provided with communications connectors both in the front and the rear.

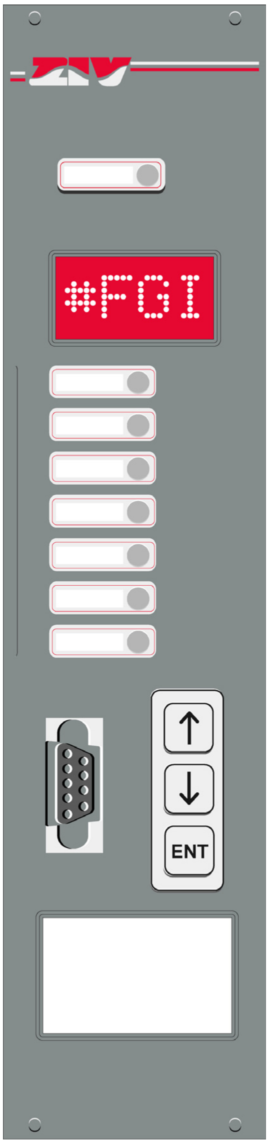


Figure 4.1: 3FGI Front View.

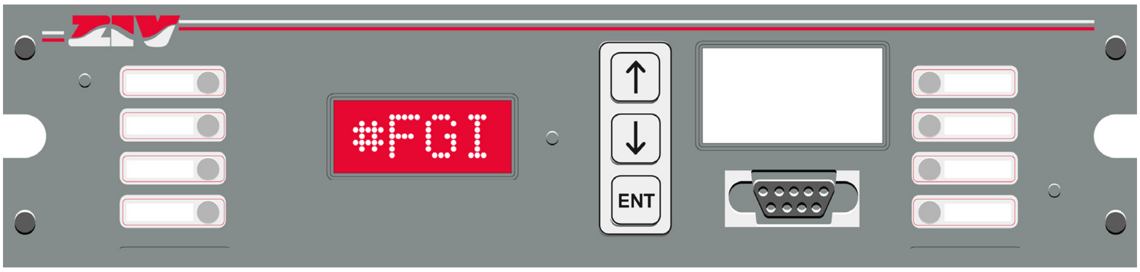


Figure 4.2: 8FGI Front View.

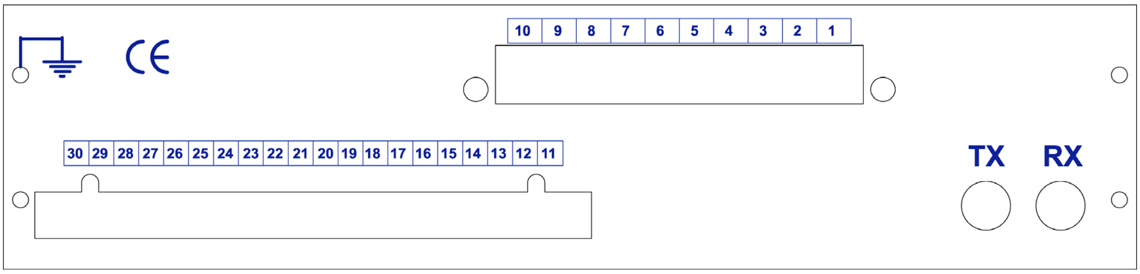


Figure 4.3: 8FGI Rear View.

4.2 Dimensions

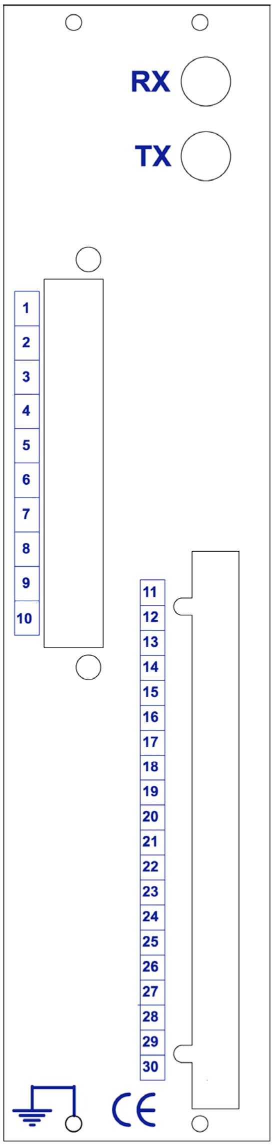


Figure 4.4: 3FGI Rear View.

FGI protection terminal unit case dimensions are 1/7 of a 19” rack wide, and 6 standard rack units high (10½”). **3FGI** terminals are vertical mount units, and **8FGI** terminals are horizontal mount units. The equipment is intended to be installed either semi-flush mounted on panels or inside a 19” rack. The **FGI** comes equipped with a transparent cover, which can be sealed for security purposes. The enclosure colour is graphite.

Note: the 8FGI model can be fitted with a panel that has been designed to adapt to a full 19” Rack x 2U. The dimensions of this module are enclosed at the end of this manual.

4.3 Connection Elements

4.3.1 Terminal Connectors

Terminal connectors are permanently attached to the rear edge of the printed circuit board to facilitate external wiring and are arranged in rows or columns depending on the model: one row or column of 10 or 5 terminal connectors (depending on the model) for transformer secondary inputs and one row or column of 20 terminal connectors for power supply input and contact inputs and outputs.

Voltage analog input terminals and the remaining circuit terminals accept up to #14 AWG wire. Communications connectors are provided on both front and rear equipment panels.

4.3.2 Removing Printed Circuit Boards (Non Self-Shorting)

The equipment has been designed to enable removal of the printed circuit board. The printed circuit board is attached to the case using self-tapping screws. These screws must be removed before the board is withdrawn. It is also necessary to remove the screws on the terminal connectors. Whenever this operation is performed, the **FGI** terminal should be placed in the "Not In Service" mode, and turned off.

4.3.3 Internal Wiring

The equipment uses traditional printed circuit board connections and internal buses to minimize internal wiring.

5. Settings

5.1 Configuration Settings

Communications (Local and Remote Ports Settings). FGI-A Models	
Setting	**Range**
Terminal address	0 to 254
Baud Rate	300 to 19200 Bauds
Stop bits	1 or 2
Parity	1 (even) / 0 (none)

Communications (Remote Port Settings). FGI-B/C Models	
Setting	**Range**
Terminal address	0 to 254
Baud Rate	300 to 19200 Bauds
Stop bits	1 or 2
Parity	1 (even) / 0 (none)
Communications Timeout (only **FGI-B**)	0 to 100 ms (steps of 1)

Communications (Local Port Settings). FGI-B/C Models	
Setting	**Range**
Terminal address	All
Baud Rate	4800 Bauds
Bits	8
Stop bits	1
Parity	Even

Time and Date
Adjustable through communications

Language	
Setting	**Range**
Language	Spanish English Portuguese

Frequency	
Setting	**Range**
Frequency	50 Hz / 60 Hz

5.2 General Settings

General Settings		
Setting	**Range**	**Step**
PT Ratio	1-4000	1
Event masking (only through communications)	All the events	

5.3 Protection Elements Settings

Frequency Protection Settings		
Setting	**Range**	**Step**
Frequency Elements (Unit 1 and Unit 2 settings)		
Element enable	YES / NO (1)	
Element type	Overfrequency	
	Underfrequency	
Element pickup	40.00-70.00 Hz	0.01Hz
Time delay (FGI-A/C models)	0 - 20 s	0.1 s
Time delay (FGI-B models)	0 - 300 s	0.1 s
Subvoltage auxiliary element (2)		
Pickup enable by voltage	YES / NO (1)	
Minimum voltage level	40 - 120 V	1 V

(1) Pickup can be disabled from the HMI by setting the pickup to 0 º and cancelling the pickup enable in the *ZIVercom*® communications program.
(2) In model FGI-C, this element affects both to frequency and out of step protections.

Voltage Protection Settings. FGI-C Models		
Setting	**Range**	**Step**
Phase Elements (Unit 1 and Unit 2 settings)		
Element type	Overvoltage	
	Undervoltage	
Time Element		
Enable	YES / NO (1)	
Time pickup	20,00-140,00 V	1 V
Curve type	Fixed Time	
	Inverse	
Inverse curve time index (DIAL)	0.05 - 1	0.05
Fixed time curve time delay	0 - 99.9 s	0.1 s
Instantaneous Element		
Enable	YES / NO (1)	
Instantaneous pickup	20.00-220.00 V	1 V
Instantaneous time delay	0 - 99.9 s	0.1 s
Ground Element		
Element type	Overvoltage	
	Undervoltage	
Enable	YES / NO (1)	
Instantaneous pickup	4 - 60 V	1 V
Instantaneous time delay	0 - 99.9 s	0.1 s

(1) Pickup can be disabled from the HMI by setting the pickup to 0 º and cancelling the pickup enable in the *ZIVercom*® communications program.

Out of Step Protection Settings [1]. FGI-C Models		
Setting	**Range**	**Paso**
Enable	YES / NO [1]	
Pickup	1º - 25º	2º
Duration of temporary blocking	0.05 - 20.00 s	0.01 s
Trip duration	0 - 20.00 s	0.01 s

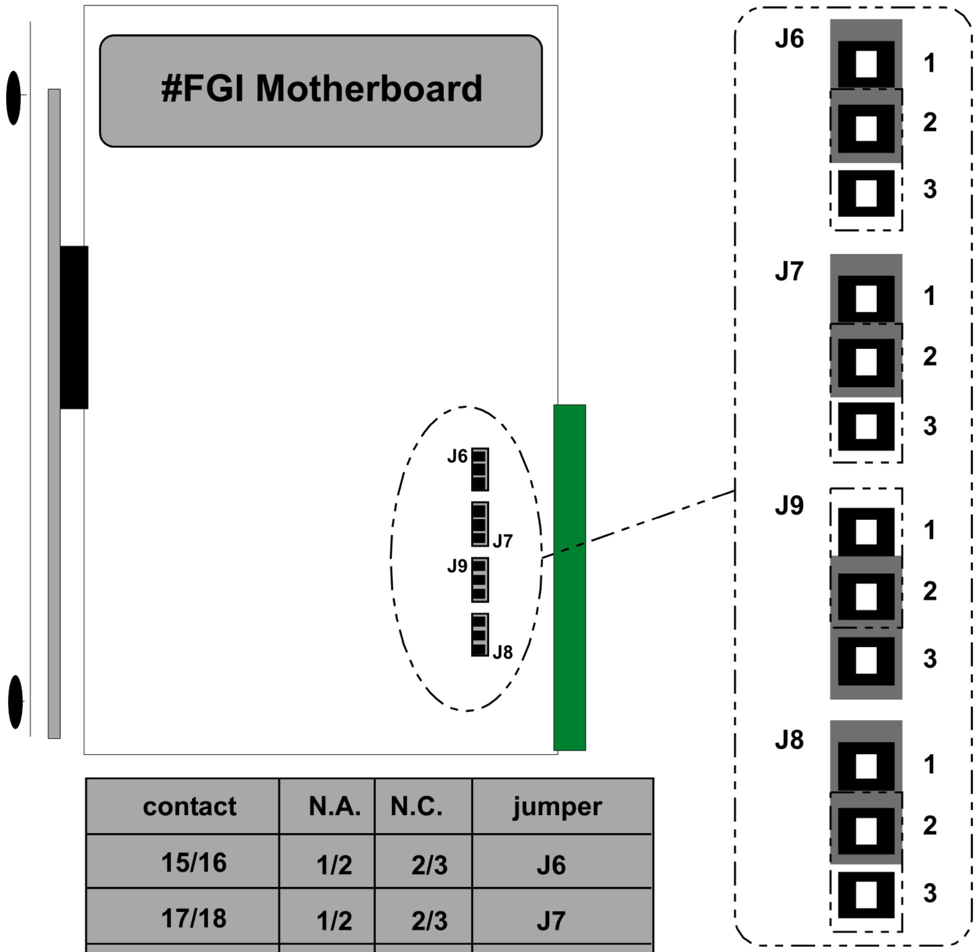
(1) The out of step protection is affected by the auxiliary undervoltage blocking element (see frequency settings).
(2) Pickup can be disabled from the HMI by setting the pickup to 0 º and cancelling the pickup enable in the *ZIVercom*® communications program.

5.4 Logic Settings

Logic Settings		
Logic settings correspond to the frequency, voltage elements, ground element and out of step element masks. The following elements may be masked by the user from the operator interface or via communications.		
Setting	**Range**	**Paso**
Trip Masks		
Frequency element #1	YES/ NO	
Frequency element #1	YES/ NO	
Break command (FGI-B models)	YES/ NO	
Voltage element#1 instantaneous (FGI-C models)	YES/ NO	
Voltage element#1 timer (FGI-C models)	YES/ NO	
Voltage element#2 instantaneous (FGI-C models)	YES/ NO	
Voltage element#2 timer (FGI-C models)	YES/ NO	
Ground element (FGI-C models)	YES/ NO	
Out of step element (FGI-C models)	YES/ NO	
Fail break delay (FGI-B models)	0.02 - 2.00 s	0.01 s
Fail close delay (FGI-B models)	0.02 - 2.00 s	0.01 s

5.5 Digital Inputs, Auxiliary Outputs and LED Targets

Digital Inputs, Auxiliary Outputs and LED Targets
It is possible to redefine or reallocate the auxiliary outputs via the local communication port using the communications program ***ZIVercom***®. It is also possible to configure trip output and AUX-1 as NO or NC contacts, by changing the internal jumpers as indicated in figure 5.1.



contact	N.A.	N.C.	jumper
15/16	1/2	2/3	J6
17/18	1/2	2/3	J7
19/20	1/2	2/3	J8
19/21	2/3	1/2	J9

Figure 5.1: Internal Jumpers.

6. Description of Operation

6.1 Frequency Units

FGI terminals contain two frequency units. The basic operation of each unit is identical. Frequency is calculated with phase A voltage. Each frequency unit can be configured as an overfrequency or an underfrequency unit. Each unit includes a time-delayed element that can also be set as an instantaneous element. The following settings are available for each element:

- Pickup
- Time delay

The frequency level detector interprets frequency changes. There is a setting to select whether an individual unit will detect overfrequency or underfrequency, along with respective pickup setting values. For an overfrequency unit pickup, the measured value should exceed the adjusted value by a given magnitude. For an underfrequency unit pickup, the measured value should be less than the adjusted value by a given magnitude.

Unit pickup will activate the timer function. The timer function begins incrementing a counter that activates the output element when the set time delay value is reached. Trip contacts will remain closed for a minimum time of 100 ms.

6.1.1 Frequency Unit Block Diagram

Following figure includes the block diagram describing a frequency unit.

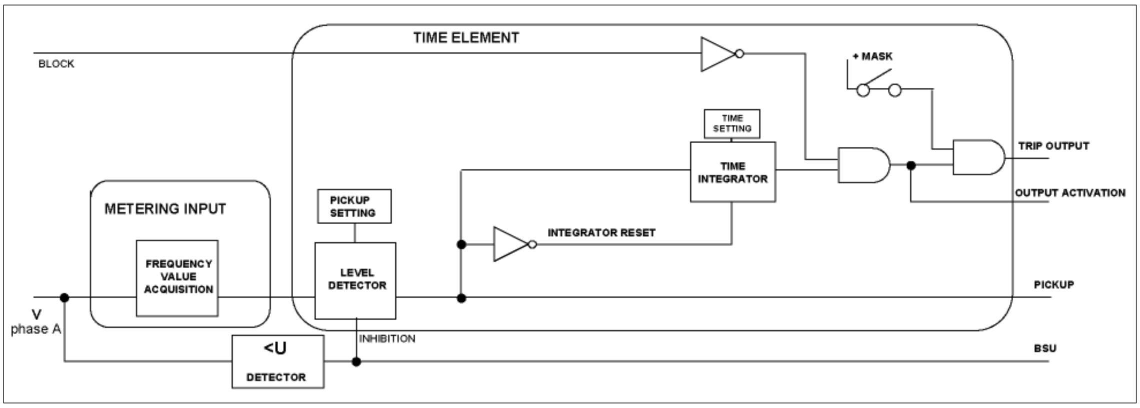


Figure 6.1: Frequency Unit Block Diagram.

6.1.2 Overfrequency Element

The overfrequency element measures the frequency value of the phase A (depending on the model) analog input voltage.

Pickup occurs when the measured frequency value is greater than or equal to the pickup setting value (100% of the setting) during 3 consecutive cycles. Reset takes place when measured value is less than 99.9% of the pickup setting, or when the measured frequency remains under 100% of the setting for longer than 30 cycles.

6.1.3 Underfrequency Element

The underfrequency element measures the frequency value of the phase A (depending on the model) analog input voltage.

Pickup occurs when the measured frequency value is less than the pickup setting value (100% of the setting) during 3 consecutive cycles. Reset takes place when measured value exceeds 100.1% of the pickup setting, or when the measured frequency remains over 100% of the setting for longer than 30 cycles.

6.1.4 Element Interlock

Frequency elements feature an external interlock. This interlock signal will block the frequency elements if energized before the unit trips. Therefore, the interlock will not reset an active trip command. To enable the interlock feature it is necessary to configure an auxiliary contact input using the communications software.

6.1.5 Undervoltage Element

Pickup occurs when the measured voltage value is less than the pickup setting value (100% of the setting). Reset takes place when measured value is greater than or equal to 105% of the pickup setting.

Enabling the undervoltage element will prevent the frequency elements (and the out of step element in **FGI-C** models) to operate when the measured voltage is below the user defined setting.

In models **FGI-B**, even if the minimum voltage element is disabled, the relay quickly detects a lack of signal, preventing the frequency elements from improper operation.

In **FGI-A** and **FGI-C** models, the protection cannot measure frequency for an inferior voltage to 10 volts, so, in these conditions, the elements of frequency (and the out of step element in **FGI-C** models), do not work.

6.1.6 Trip Masks

In models **FGI-B** the action of these masks is subordinated to whether the applicable element is enabled or not, for if the element is disabled the pick up process is not initiated. Trip masks set to NO will disable the corresponding element trip output after element pickup.

6.1.7 Breaker Failure Time

In models **FGI-B**, after issuing an open or close command, should the breaker change of state not be received before the breaker failure timer times out (settable separately for opening and closing), open command failure or close command failure events activate. Also, the relay will keep the open or close command during the time setting, if the operation is not executed before this timer times out.

If the relay should not received an open breaker signal before the open failure timer times out, the close command issued by the overfrequency element is prevented when the line frequency is recovered.

6.1.8 Operation Logic (Load Shedding)

In models **FGI-B**, the close commands (**OC**) and open commands (**OA**) could be issued provided the trip masks (**Mhz1**, **Mhz2** y **Moa**) are set to YES and the elements are not blocked (**BLQ**).

The operation of the overfrequency element is conditioned both by the previous operation of the underfrequency element **(APSUB**) and open breaker status (**IA**), as shown on the logic diagram in following figure.

In order for the relay to issue a close command, a previous open command must have been issued by the underfrequency element.

The activation of overfrequency elements (**HZ1**) and underfrequency elements (**HZ2**) will or will not be allowed through the pick up enable setting.

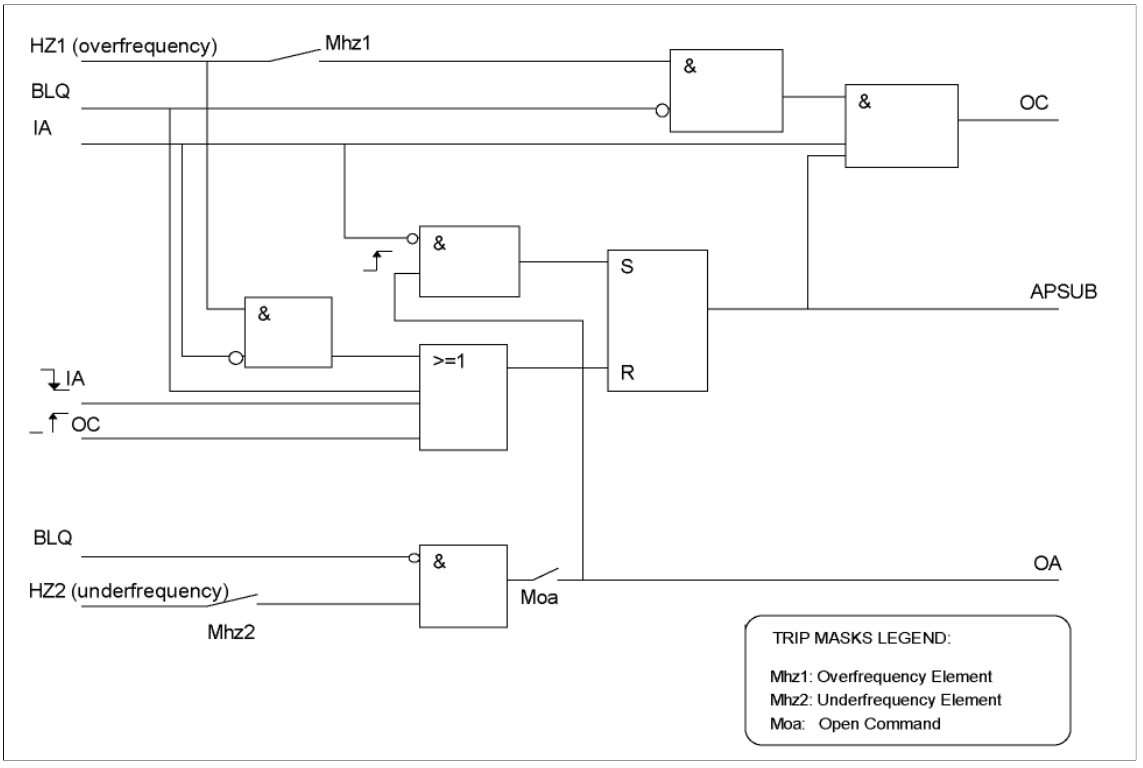


Figure 6.2: Logic Diagram.

6.2 Voltage Units

- **Phase elements**

FGI-C relay is provided with two voltage elements. Each voltage element can be configured as maximum or minimum voltage element. These elements are composed of a time element and an instantaneous element, each of which has the following settings:

- Pickup
- Time

The setting of the time element included into voltage elements corresponds to the selection of **fixed time** or **inverse curve** type.

6.2.1 Voltage Unit Block Diagram

Following figure shows the block diagram for one of the voltage elements.

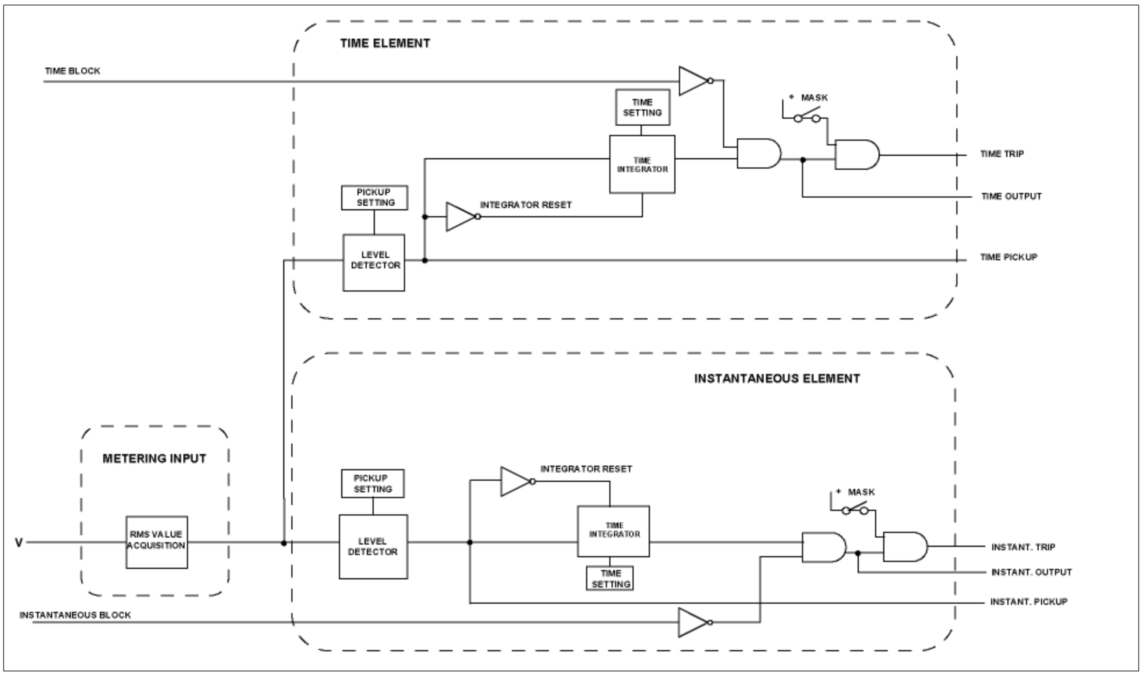


Figure 6.3: Block Diagram for one of the Voltage Elements.

Associated to the level detection block are a setting to define whether the element operates as undervoltage or overvoltage and a pickup value setting. In this way, if the element is defined as overvoltage, and the measured value is greater than the setting value, the element picks up. And if the element is defined as undervoltage, it picks up if the measured value is below the setting value by a given quantity.

On the other hand, pickup activation enables the time function. This is carried through counter increments until reaching the time limit that triggers the time element operation. When the measured value rms is below the pickup setting value, the counter resets quickly. The output activates if the element remains picked up until the counter times out. Any reset brings the counter to initial conditions, so that for a new operation the counter starts from zero.

- **Ground Element**

The **FGI-C** ground element is not associated to an analog input channel, but takes the voltage value from the vector sum of the three phases divided by three, this calculation being made internally.

$$Un = \frac{Va + Vb + Vc}{3}$$

The ground element is composed of an instantaneous element, with additional settable time, the working model of which is identical to instantaneous phase elements.

6.2.2 Maximum Voltage Elements

Maximum voltage element operation is carried out over input voltage rms values. Element picks up when the measured value is equal to or greater than the pickup value (100 percent of the setting), and resets at around 95 percent of the setting.

6.2.3 Minimum Voltage Elements

The same than for maximum voltage elements, minimum voltage element operation is carried out over voltage input rms values. Element picks up when the measured value coincides or is below the pickup value (100 percent of the setting), and resets in this case when the voltage is greater than 105 percent of the setting.

6.2.4 Voltage / Time Characteristic

Following figure shows characteristic voltage time curve families available for time overvoltage elements in **FGI-C** models.

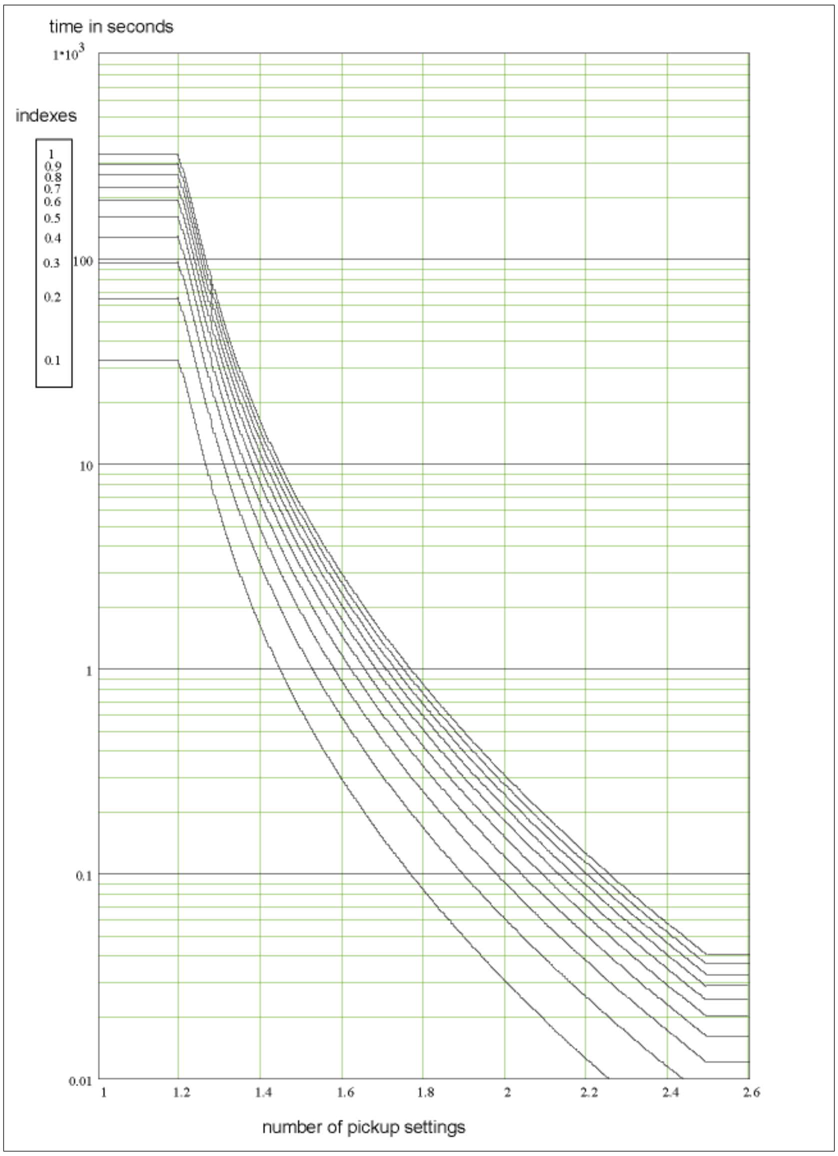


Figure 6.4: Overvoltage Inverse Curve.

Following figure shows voltage time characteristic curve families available for time undervoltage elements in **FGI-C** models.

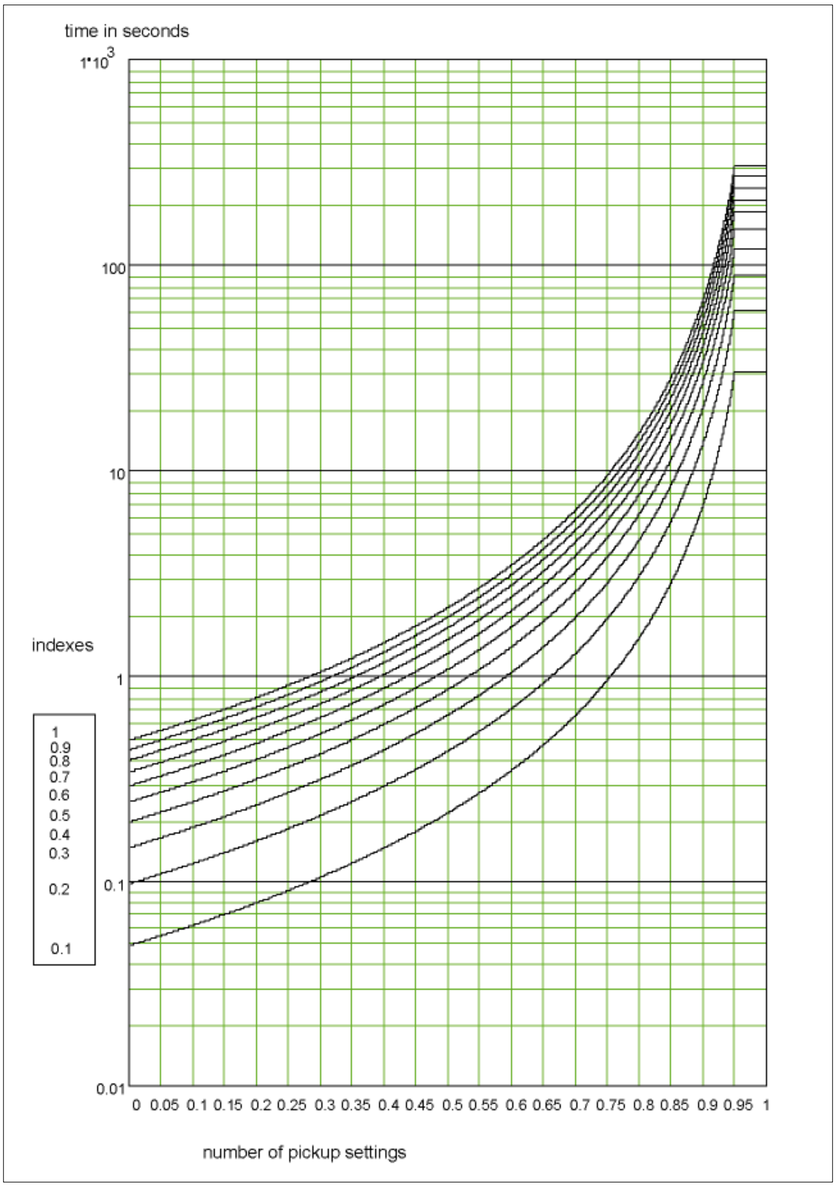


Figure 6.5: Undervoltage Inverse Curve.

6.3 Out of Step Element

Out of Step elements aim at quick disconnecting synchronous generators working in parallel with the system when a system disturbance occurs: failure in the system proper or short system voltage outage. This element is available in **FGI-C** models.

Out of Step protection detects anomalies much sooner than other types of protection, such as voltage or frequency protection. Operate magnitudes for these protection elements are modified by the disturbance in times that can reach hundreds of milliseconds, due to both system electrical inertia and generator set mechanics.

6.3.1 Measuring principle

Out of Step measuring principle allows detecting the disturbance within the cycle in which it is produced, resulting into disconnection times of less than 100ms, including breaker operating time.

The operation of a synchronous generator is such that a phase difference between terminal voltage (V1) and rotor electromotive force (Eg) exists; the generated current (I1) and thus the supplied power, are a function of this phase difference.

The following figure on the left concisely represents a generator equivalent circuit and the relationship between the electrical magnitudes involved. The following figure on the right represents voltage magnitudes involved and their phase angle relationship.

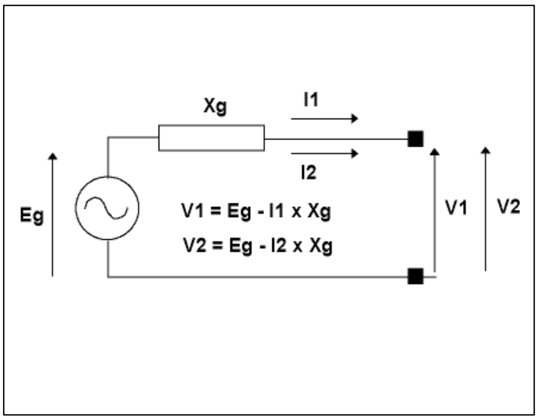


Figure 6.6: Generator Equivalent Circuit.

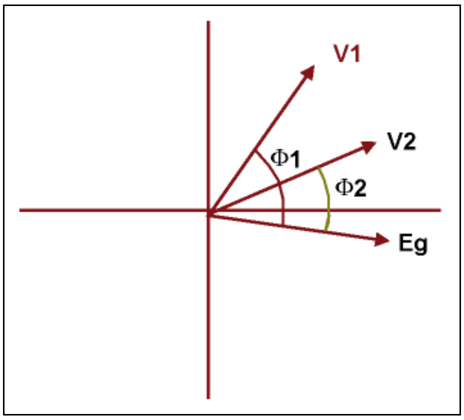


Figure 6.7: Circuit Magnitudes.

When system disturbance occurs, current changes abruptly to I2, whereas voltage keeps its value for a longer time period due to electrical and mechanical inertia. As the relationship between the electrical magnitudes shown in figure 6.6 do not change, a change in the current results into a change in the voltage (V2) phase angle with respect to rotor electromotive force.

As a result of the above, a phase difference exists between generator terminal voltage before and after the disturbance.

$$\Delta\Phi = \Phi 2 - \Phi 1$$

This change in phasor angle or magnitude is only present during the system cycle in which the disturbance occurs, as later cycles keep the new F2 phase angle with respect to the rotor electromotive force.

Representing the above by means of voltage waveforms, as shown in following figure, will contribute to explain how the disturbance is detected.

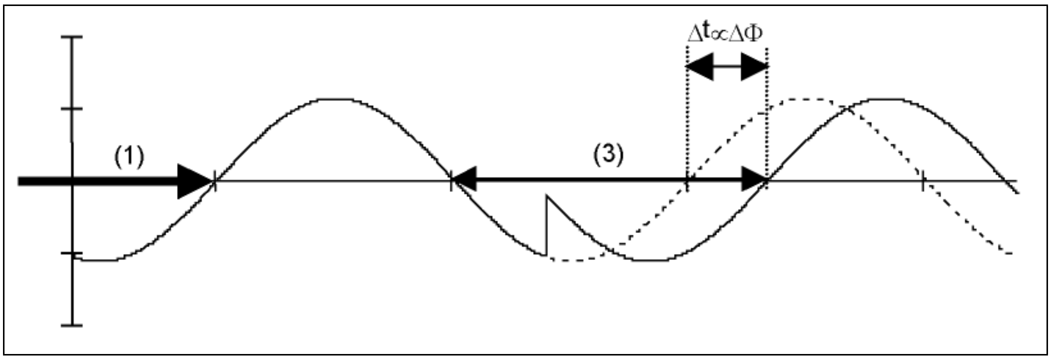


Figure 6.8: Voltage Waveform Representation.

The duration of the half cycle in which the disturbance occurs will be different from previous and later cycles, the difference of which is proportional to ΔΦ phase variation that can therefore be used as measurement characteristic magnitude.

Relay detects zero crossings: the time lapse between two consecutive zero crossings is measured and the difference between values obtained for two consecutive half periods of same voltage sign is calculated. In the figure, the time difference Δt that makes the element to operate is obtained by the difference in duration of half cycles (1) and (3).

6.3.2 Logic of Out of Step Measurement Element

Out of Step element operation logic is shown in following figure below:

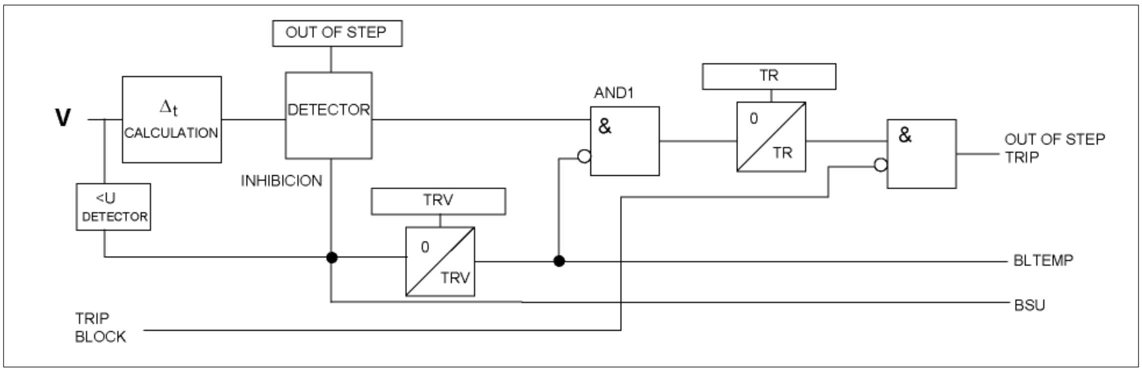


Figure 6.9: Block Diagram of Out of Step Element.

Input magnitude used is A-phase voltage or AB voltage if phase-to-phase voltage is used. The value of Δt is calculated from input voltage zero crossings; Δt is compared with Detector setting value. Setting is introduced in terms of degrees and relay obtains from said value in degrees the equivalent time value:

$$\Delta t(ms) = \Delta\Phi \cdot \frac{1000}{360 \cdot F}$$

where F represents the frequency of system voltage in Hz.

- **Undervoltage Blocking**

DETECTOR operation is supervised by the **minimum voltage blocking function**, so that output will not take place until A-phase or AB voltage input is below the blocking voltage setting value.

DETECTOR output signal is supervised by the output of settable timer TRV, the aim of which is to block the element during a settable time, after applying the measured voltage. Timer TRV output can be connected to programmable outputs or LEDs in order to have an external indication of the BLOCKED condition.

DETECTOR output is a temporary signal that, as mentioned above, disappears in the following half cycle. A settable timer (TR) guarantees a minimum duration of the trip output.

- **Element Blocking**

An input connected to any of the programmable digital inputs can be used to block element operation.

6.4 General Settings

- **Transformer Ratio**

The transformer ratio settings (phase and/or ground, depending on model) only affect to the analog values displayed on the HMI. A transformer ratio setting of 1 will display the secondary values of the CTs. A setting equivalent to the CT transformation ratio will display the primary values of the system.

- **Event Masking**

It is possible to mask unneeded events or those events without importance for the study of protection behaviour. Event masking can be done only through communications.

6.5 Logic (Trip Masks)

In models **FGI-A**, the operation of logic elements may or may not be allowed through a setting.

In **FGI-C** models, the relay can be tripped by any of the protection elements, except the auxiliary minimum voltage blocking element. Trip mask settings allow preventing one or more elements from tripping even if they are activated.

In both models, action of the setting defined in trip mask depends also of the activation of the corresponding unit, within its own protection settings, as if the unit is deactivated, pickup of the unit is not initiated.

The trip mask setting set to **NO** prevents the trip contact or a mask output to operate. This setting still allows the unit to realize all the process, from the pickup to the trip generation.

6.6 Event Records

Protection functions that are monitored by the sequence of events portion of the terminal unit are listed in the following table.

Table 6-1: Event Record

Function	Event	Byte	Bit
Initialization [1]	Cold Load Pickup	1	4
	Change of Settings Initialization	1	5
Frequency Protection [45]	Time Element Pickup (freq. element #1)	1	1
	Time Element Activation (freq. element #1)	1	2
	Time Element Pickup (freq. element #2)	1	3
	Time Element Activation (freq. element #2)	1	4
	Undervoltage Element Pickup Trip Enable (FGI-C)	1	5
	Frequency check enable (undervoltage element) (FGI-A)		
	Frequency check disable (undervoltage element) (FGI-A)		
	Timed reset (overfrequency) (FGI-B)		
	Timed output deactivated (overfrequency) (FGI-B)		
	Timed reset (underfrequency) (FGI-B)		
	Timed output deactivated (underfrequency) (FGI-B)		
	Undervoltage element reset for permissive tripping (FGI-B)		
Voltage Protection [22]	Phase A Time Element Pickup Voltage #1 (FGI-C)	1	1
	Phase B Time Element Pickup Voltage #1 (FGI-C)	1	2
	Phase C Time Element Pickup Voltage #1 (FGI-C)	1	3
	Phase A Inst. Element Pickup Voltage #1 (FGI-C)	1	5
	Phase B Inst. Element Pickup Voltage #1 (FGI-C)	1	6
	Phase C Inst. Element Pickup Voltage #1 (FGI-C)	1	7
	Phase A Time Elem. Output Activ. Voltage #1 (FGI-C)	2	1
	Phase B Time Elem. Output Activ. Voltage #1 (FGI-C)	2	2
	Phase C Time Elem. Output Activ. Voltage #1 (FGI-C)	2	3
	Phase A Inst. Elem. Output Activ. Voltage #1 (FGI-C)	2	5
	Phase B Inst. Elem. Output Activ. Voltage #1 (FGI-C)	2	6
	Phase C Inst. Elem. Output Activ. Voltage #1 (FGI-C)	2	7
	Phase A Time Element Pickup Voltage #2 (FGI-C)	3	1
	Phase B Time Element Pickup Voltage #2 (FGI-C)	3	2
	Phase C Time Element Pickup Voltage #2 (FGI-C)	3	3
	Phase A Inst. Element Pickup Voltage #2 (FGI-C)	3	5
	Phase B Inst. Element Pickup Voltage #2 (FGI-C)	3	6
	Phase C Inst. Element Pickup Voltage #2 (FGI-C)	3	7
	Phase A Time Elem. Output Activ. Voltage #2 (FGI-C)	4	1
	Phase B Time Elem. Output Activ. Voltage #2 (FGI-C)	4	2
	Phase C Time Elem. Output Activ. Voltage #2 (FGI-C)	4	3
	Phase A Inst. Elem. Output Activ. Voltage #2 (FGI-C)	4	5
	Phase B Inst. Elem. Output Activ. Voltage #2 (FGI-C)	4	6
	Phase C Inst. Elem. Output Activ. Voltage #2 (FGI-C)	4	7

Table 6-4: Event Record			
Function	**Event**	**Byte**	**Bit**
Breaker recorder [91]	Close command (FGI-B)		
	Open command (FGI-B)		
	Close command failure (FGI-B)		
	Open command failure (FGI-B)		
Codes 33100	Code 99 (FGI-C)	1	6
	Code 11 (FGI-C)	2	1
	Code 22 (FGI-C)	2	2
	Code 33 (FGI-C)	2	3
	Code 44 (FGI-C)	2	4
	Code 66 (FGI-C)	2	5
	Code 77 (FGI-C)	2	6
	Code 88 (FGI-C)	2	7
	Code 55 (FGI-C)	2	8
Out of Step 33500	Out of Step Output Activation (FGI-C)	1	1
	Temporal Block Output Activation (FGI-C)	1	2
Ground Element 33600	Ground Element Instantaneous Pickup (FGI-C)	1	2
	Ground Element Instantaneous Activation (FGI-C)	1	4

- **Organization of Event Record**

The event record keeps a list of the last 100 events generated, where new events replace the oldest events. The saved information in each of the records includes:

- **Phase and Ground voltage and frequency measured at the moment the event was generated**
- **Event date and time**

In **FGI-C** models event recording management is optimised in order that simultaneous events generated by the same function are not located into separate records. In this way, they will use only one recorder position. If events do not occur simultaneously, two different annotations will take place. Events are deemed simultaneous when they occur within a time interval of less than 1 ms, this being the time resolution of the annotator.

Important: It is convenient to mask those events which could be generated in excess, given that the record could be filled (100 events) with these and erase other previous events that are more important.

- **Consulting Records**

The communications program ***ZIVercom***®, has an access system for the event record. The information appears separately for each of the events in the table.

- **Event Masking**

Depending on the model, it is possible to mask unneeded events or those events without importance for the study of protection behaviour. Event masking can be done only through ***ZIVercom***® communications software, and is accessible through the General Settings menu.

6.7 Contact Inputs / Outputs & LED Targets

FGI terminal units are provided with programmable inputs and outputs enabling user configuration of flexible logic designs. The following paragraphs contain a description of the programming structure to configure protection inputs, outputs and signalling. Factory default settings may be modified using the ***ZIVercom***® software program.

6.7.1 Status Contact Inputs

The terminal unit metering elements, and logic functions use the Logic Input Signals listed in following table below. Any of these Logic Input Signals can be assigned to one of the two Status Contact Inputs of the terminal unit. The closure of a contact will thereby activate those Logic Input Signals assigned to it. Several different Logic Input Signals can be assigned to one Status Contact Input, but a given Logic Input Signal can only be assigned to one Status Contact Input.

Table 6-2: Status Contact Inputs

Num.	Name	Description	Function
1	IA	Open breaker position (FGI-B/C)	Controls the breaker status.
2	BLQ	Frequency Unit Block (FGI-B)	Activating this unit before a trip prevents the activation of the unit. If the input is activated after the trip, it resets.
2	BHZ1	Over/underfrequency Unit 1 Trip Block (FGI-A/C)	
3	BHZ2	Over/underfrequency Unit 2 Trip Block (FGI-A/C)	
4	BDT_1F	Phase Time Unit 1 Trip Block (FGI-C)	
5	BDI_1FF	Instantaneous Phase Unit 1 Trip Block (FGI-C)	
6	BDT_2F	Phase Time Unit 2 Trip Block (FGI-C)	
7	BDI_2F	Instantaneous Phase Unit 2 Trip Block (FGI-C)	
8	BDI_N	Ground element trip blocking (FGI-C)	
9	BDELTA	Out of step element trip blocking (FGI-C)	

6.7.2 Auxiliary Contact and Trip Outputs

- **Auxiliary Contact Outputs**

Terminal unit metering elements and logic functions generate a series of Logic Output Signals during terminal unit operation. Each of these signals has either a “True” or “False” value and this status can be used as an input to either of the combinational logic gates shown in following figure.

Each block has 8 possible input signals. One of them is an **OR** gate (one activated signal activates the output) and the other is an **AND** gate (all signals are needed to activate the output). Between these two blocks both **OR** and **AND** operations can be executed.

In **FGI-A** models the desired final **“AND”** or **“OR”** output from the logic cell can then be connected to any one of the two programmable Auxiliary Contact Outputs (AUX-1 and AUX-2) available in the terminal unit. Auxiliary Contact Output (AUX-3) which corresponds to Relay in Service, is not programmable.

In models **FGI-B** there are two programmable auxiliary outputs, one physical and the other virtual. There is a third non-programmable auxiliary output, of Relay in service, associated to terminals 25/26/27.

In **FGI-C** models this output can be connected to one of the relay auxiliary programmable physical outputs (AUX1 and AUX2). There is a third non-programmable auxiliary output (AUX3), corresponding to relay “**in service”**.

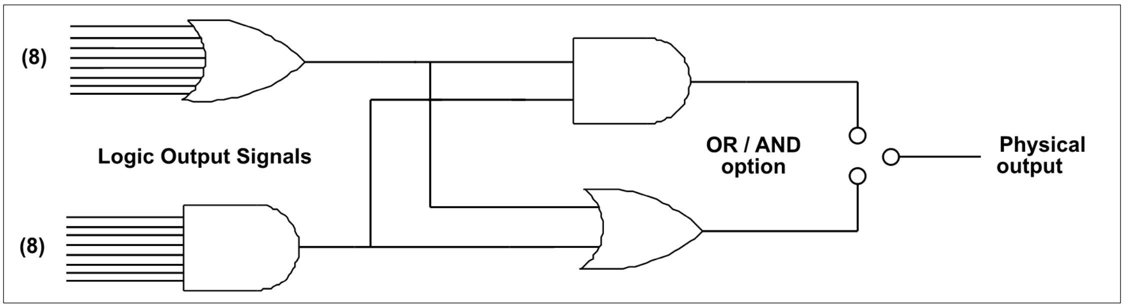


Figure 6.10: Auxiliary Contact Output Logic Cell Block Diagram.

The available Logic Output Signals are described in following table.

Table 6-3: Logic Output Signals

Num.	Name	Description	
1	CSFU	Enable Undervoltage Element Frequency Check (FGI-A/B)	Its activation prevents the operation of the frequency elements.
1	BSU	Underfrequency blocking (FGI-C)	Frequency and out of step element blocking.
2	ARR1	Time Element Pickup (over/underfrequency element #1)	Over/underfrequency element pickup.
3	ARR2	Time Element Pickup (over/underfrequency element #2)	
4	HZ1	Time Element Trip (over/underfrequency element #1)	Tripping of over/underfrequency elements (not affected by their corresponding trip mask).
5	HZ2	Time Element Trip (over/underfrequency element #2)	
6	ED1	Status Contact Input DI-1 Active (FGI-C)	Activation of configurable inputs.
7	ED2	Status Contact Input DI-2 Active (FGI-C)	
7	OA	Open Command (FGI-B)	Sending the breaker open / close command.
8	OC	Close Command (FGI-B)	
9	APSUB	Close enable by overfrequency (FGI-B)	Previous operation of the underfrequency element (open command).
8	ST_V_1A	Time Trip (Voltage element 1 phase A) (FGI-C)	Phase voltage element trip (element 1) (not affected by their corresponding trip mask).
9	ST_V_1B	Time Trip (Voltage element 1 phase B) (FGI-C)	
10	ST_V_1C	Time Trip (Voltage element 1 phase C) (FGI-C)	
11	ED1	Status Contact Input DI-1 Active (FGI-A/B)	Activation of configurable inputs.
12	ED2	Status Contact Input DI-2 Active (FGI-A/B)	
11	SI_V_1A	Instant. Trip (Voltage element 1 phase A) (FGI-C)	Phase voltage element trip (element 1) (not affected by their corresponding trip mask).
12	SI_V_1B	Instant. Trip (Voltage element 1 phase B) (FGI-C)	
13	SI_V_1C	Instant. Trip (Voltage element 1 phase C) (FGI-C)	
14	ST_V_2A	Time Trip (Voltage element 2 phase A) (FGI-C)	Phase voltage element trip (element 2) (not affected by their corresponding trip mask).
15	ST_V_2B	Time Trip (Voltage element 2 phase B) (FGI-C)	
16	ST_V_2C	Time Trip (Voltage element 2 phase C) (FGI-C)	
17	SI_V_2A	Instant. Trip (Voltage element 2 phase A) (FGI-C)	
18	SI_V_2B	Instant. Trip (Voltage element 2 phase B) (FGI-C)	
19	SI_V_2C	Instant. Trip (Voltage element 2 phase C) (FGI-C)	

Table 6-3: Logic Output Signals			
Num.	**Name**	**Description**	
20	AT_V_1A	Time Pickup (Voltage element 1 phase A) (FGI-C)	Phase voltage element pickup (element 1).
21	AT_V_1B	Time Pickup (Voltage element 1 phase B) (FGI-C)	
22	AT_V_1C	Time Pickup (Voltage element 1 phase C) (FGI-C)	
23	AI_V_1A	Instant. Pickup (Voltage element 1 phase A) (FGI-C)	
24	AI_V_1B	Instant. Pickup (Voltage element 1 phase B) (FGI-C)	
25	AI_V_1C	Instant. Pickup (Voltage element 1 phase C) (FGI-C)	
26	AT_V_2A	Time Pickup (Voltage element 2 phase A) (FGI-C)	Phase voltage element pickup (element 2).
27	AT_V_2B	Time Pickup (Voltage element 2 phase B) (FGI-C)	
28	AT_V_2C	Time Pickup (Voltage element 2 phase C) (FGI-C)	
29	AI_V_2A	Instant. Pickup (Voltage element 2 phase A) (FGI-C)	
30	AI_V_2B	Instant. Pickup (Voltage element 2 phase B) (FGI-C)	
31	AI_V_2C	Instant. Pickup (Voltage element 2 phase C) (FGI-C)	
32	A_N	Ground element pickup (FGI-C)	Ground voltage element pickup.
33	S_N	Ground element trip (FGI-C)	Ground voltage element trip (not affected by its trip mask).
34	SALTV	Out of step element trip (FGI-C)	Out of step element trip (not affected by its trip mask).
35	BLTEMP	Temporal block trip (FGI-C)	Out of step element blocking.
36	DISP	Trip output (FGI-C)	Element OR logic.
37	AUX_1	Auxiliary output activation AUX_1 (FGI-C)	Activation of auxiliary outputs.
38	AUX_2	Auxiliary output activation AUX_2 (FGI-C)	
39	AUX_3	Auxiliary output activation AUX_3 (FGI-C)	

- **Trip Outputs**

FGI-A/C models are provided with a trip output relays, each with two contacts rated for breaker trip operations. These contacts are internally configurable to NO or NC. Trip contacts correspond to terminal connectors 15-16 and 17-18.

Models **FGI-B** are provided with two physical operating outputs. The trip output features two contacts (internally configurable to NO or NC), corresponds to terminal connectors 15-16 and 17-18, and the close output features a switchover contact (configurable internally to NO or NC) associated to terminals 19-20-21. These outputs are not configurable. Open and close outputs are activated for a minimum of 100 ms.

6.7.3 LED Targets

FGI terminal units are provided with eight optical indicators (**LEDs**) located on the front panel. Seven of the **LEDs** are user definable. The eighth **LED** is always assigned to indicate the terminal unit is **"Ready"** (powered up, self-test OK).

The logic cell structure, shown in the block diagram of following figure, permits the user to create combinational logic equations for the **LED** Target Outputs. To configure **LED** Target Outputs, Logic Output Signals are assigned to a **LED** Target Output.

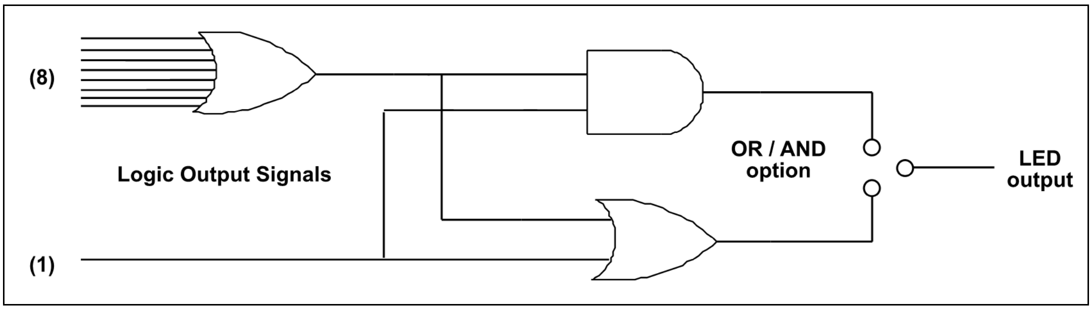


Figure 6.11: LED Target Output Logic Cell Block Diagram.

Each **LED** can be defined as latched or unlatched. If an **LED** is latched it will remain illuminated until reset, even after a condition has disappeared.

The **LED** reset function is accomplished via the keypad (see Chapter 7: Alphanumeric Keypad and Display). The latching function resides in the volatile memory section of the microprocessor. A power supply loss will cause any latched **LED** to be reset.

Each **LED** is pre-programmed with default logic. This logic can be modified by using the local communications port and the ***ZIVercom***® software.

Each **LED** can be assigned to any Logic Output Signal contained in Logic Output Signal table, to which the values shown in following table must be added, which are exclusive of optical indicators:

Table 6-4: LEDs

Num.	Name	Description
13	DISP	Trip 1 Output Active (Synchronism)
14	AAUX1	Auxiliary Contact Output AUX 1 Active
15	AAUX2	Auxiliary Contact Output AUX 2 Active
16	AAUX3	Auxiliary Contact Output AUX 3 Active

6.8 Communications

6.8.1 Communications Settings

Communications settings are listed in Chapter 5 (Settings) and include **terminal unit address**, **baud rate**, **stop bits**, and **parity**.

6.8.2 Communications Types

FGI terminal units contains two communication ports. The local port allocated on the front panel is an RS232 with fixed settings. The remote port is optional and it can be glass fiber optics, 1mm plastic fiber optics, RS232 or RS485 type. Technical data relative to these ports is listed in Chapter 2 (Technical Data).

6.8.3 Communicating with the Unit

Communications with the unit through the communication ports is achieved using the ***ZIVercom***® software application. This software is designed to connect with units of the **FGI** family, allowing operations such as programming, settings configuration, event recording, activity reports, etc.

ZIVercom® contains passwords to provide access only to authorized personnel. ***ZIVercom***®is a user friendly software tool running under WINDOWS™. The software allows easy navigation and access to available setting and actions through a series of intuitive menus and graphical user interfaces.

In **FGI-A** models communication ports settings are adjusted through the operator interface. To establish communications, the settings and terminal unit address in the unit and in the software must match.

In **FGI-B/C** models the communications configuration executed through the HMI corresponds to the rear port, as for the front port the settings are fixed to 4,800 bauds, 1 stop bit and even parity. These models are provided with two controllers, one for each communications port, such that communications can be established through both ports at the same time.

Terminal unit status information can be accessed either in local or remote mode. The following data can be retrieved:

- Metering data
- Last trip information
- Protection element status
- Contact inputs/outputs status
- Settings
- Auxiliary outputs & LED targets
- Event records

6.9 Application

Frequency is a reliable indicator of an overload situation. A frequency drop is caused by an excessive load on the system. Therefore, underfrequency relays must be used to perform load shedding; equalizing the generation with the consumption to avoid system collapse. When the frequency is restored to its rated value and the system stabilizes, the loads are then reconnected in to the system. This reconnection is done by the overfrequency relay.

Underfrequency causes electrical systems to become unstable, with an inherent risk of damaging generators. The greatest danger is present in steam turbines. A variation in the rotation speed of the turbine will create vibrations. Such vibrations will create mechanical stress on the turbine blades. This situation causes cumulative damage that increases every time the turbine experiences an underfrequency condition.

Typically, underfrequency relays are installed in substations and industrial plants where a load shedding system is required. Such loads could be fed by either local generation or a combination of local generation and a transmission line. In the second case (part a of the following fiugre), when a fault occurs in the transmission line, local generation will experience an overload causing a rapid frequency drop in the system. Under this situation, the system will need fast load shedding controlled by underfrequency relays. In the case where the transmission line feeds several plants and is disconnected at the remote end (part b of the following figure), the plant local generation will supply power to the transmission line while its own frequency will drop. This power output could be avoided by using protection relays against reverse power. If system overload is still present after opening the transmission line, the frequency relay should disconnect the local loads of less importance.

Without generation in play, frequency protection is also provided in distribution substations where a load shedding scheme with a priority level in disconnecting loads is required. When the rated frequency value is restored, load reconnection is also performed in the order of priority.

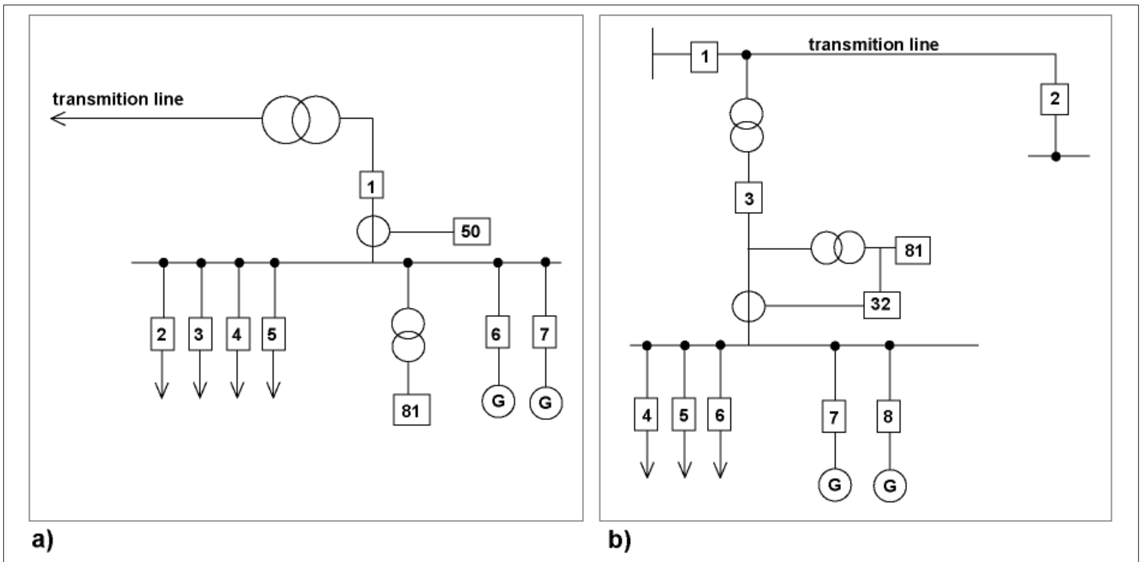


Figure 6.12: Load Shedding System in an Industrial Plant.

Following figure represents an application example where the IN1 input is used to block relay operation and the IN2 input to control the breaker position (open “1”). Outputs 17-18 and 22-24 are used to block or unblock the close operation when the open operation is carried out by the relay proper.

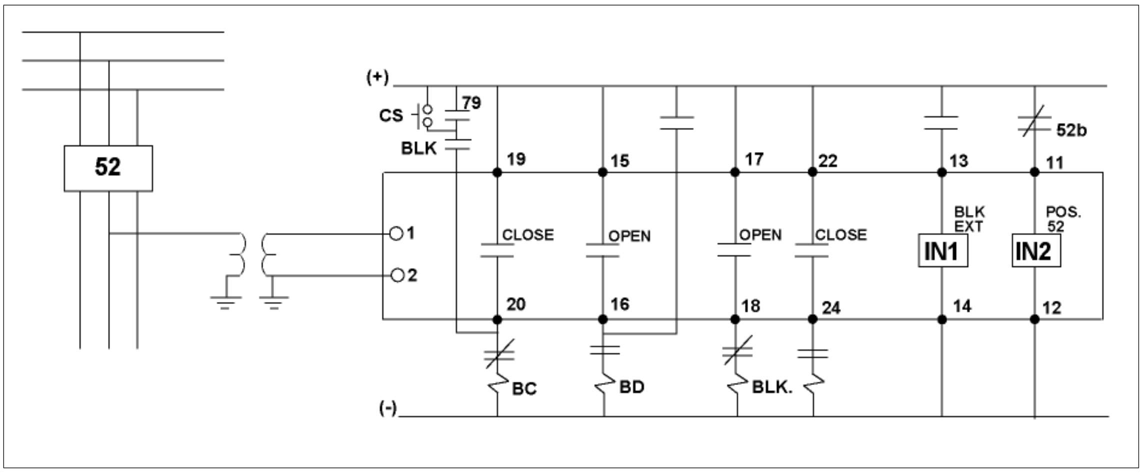


Figure 6.13: Application Example.

7. Alphanumeric Keypad and Display

7.1 Alphanumeric Display and Keypad

The liquid crystal alphanumeric display has 1 row, 4-column matrix, with each position in the matrix containing 7x5 pixels. The display provides information on terminal unit alarms, settings, metering, status, etc. The default display shows the relay model as described in the figure on the right.

Figure 7.1: Alphanumeric Display.

The **FGI** keypad consists of 3 keys as shown in the figure on the right. If the relay has its cover installed, only the down arrow ↓ key is accessible.

From the default screen, there are two ways of operating with the keyboard: using a single key or using the three keys.

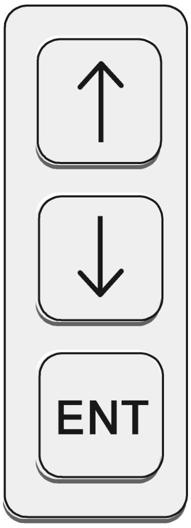


Figure 7.2: Keypad.

7.2 Keys, Functions and Operation Modes

- **Option Selection**

The two arrow keys (🡅🡇) provide access to any of the options shown in the display, and scroll the screen up or down to display other options. The **ENT** key is used to confirm the selected option.

The arrow key 🡇 is used to reach the various settings. Once you have found the wanted option, press the confirmation key **ENT** to select it; the current value of the setting is displayed. You can change it by pressing **ENT** again; the value is now flashing and can be modified.

- **Change of Settings (Range)**

To set a number proceed as follows: with key 🡅 search for the value of the first digit (blinking). Once it is found, press key 🡇 and then set, again with key 🡅, the value of the second digit and so on until the setting is completed. If it is decided not to set the blinking digit, press key 🡇 and the system jumps to the following digit without introducing any change for the previous digit. When completing the desired setting, press ENT to confirm and return to the setting screen. Press key 🡇 for a new setting.

The system does not allow a value for a setting outside of the range defined for each setting. If, a value outside the setting range is introduced, the zero value is displayed, and the blinking cursor moves again to the first digit, and the setting process must be started again.

- **Change of Settings (Options)**

When the setting consists in selecting an option (pre-established), that option will be looked for indistinctively with the arrow keys 🡅 and 🡇. Once the option has been found, press **ENT** to confirm the selection and return to the screen identifying the setting. To move on to a new setting press the down arrow key 🡇.

- **Exit Menus or Settings**

Once an operation has been performed, press 🡅 to return to the immediate previous level in the menu.

7.3 Screens Sequence Using a Single Key

From the default screen, the following data screens can be sequentially displayed by pressing the down arrow key ↓:

- Voltage metering
- Frequency metering
- Units or unit tripped (overfrequency or underfrequency)
- Last trip date and time
- Reset LEDs

Following figure present the sequence of screen accessible by pressing the down arrow key ↓, when the protection has tripped.

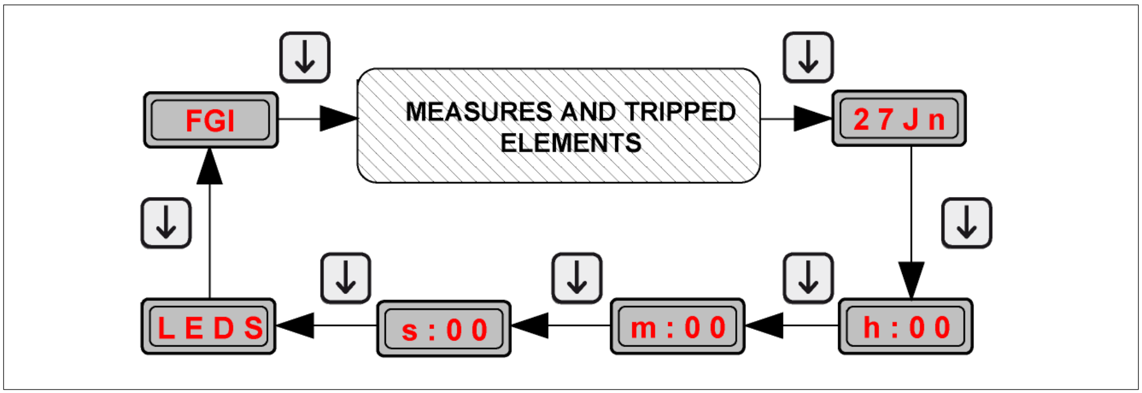


Figure 7.3: Display Screens Sequence Using the↓ Key.

Screen descriptions are:

2 7 J n Indicates last operation date (day and month). Months are represented by a two letter code specific of the selected language. If no events are recorded, current date is on display.

h : 0 0 Indicates last operation hour. If no operations are recorded, displayed hour would be 00.

m : 0 0 Indicates last operation minute. If no operations are recorded, displayed minutes will be 00.

s : 0 0 Indicates last operation seconds. If no operations are recorded, displayed seconds will be 00.

L E D S There are two modes of operation from the **L E D S** screen. Pressing the ↓ key for more than two (2) seconds resets the LEDs and returns to the default screen. Pressing the ↓ key for less than two (2) seconds returns to the default screen without resetting the LEDs.

Metering elements and last trip data screens (shaded area in Figure 7.3), and keypad operation are shown bellow.

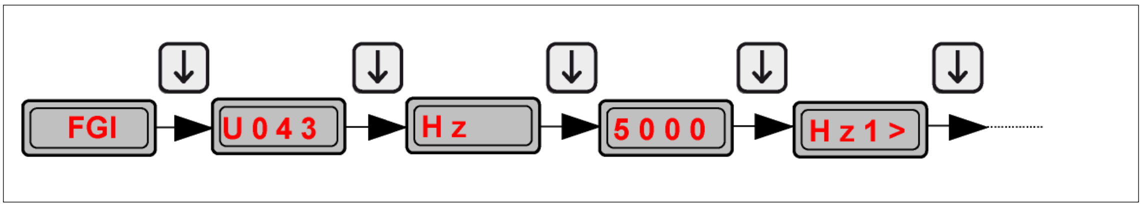


Figure 7.4: Metering Elements Screen Sequence.

Mnemonics for said screens are as follows:

U 0 4 3 Phase voltage measurement.

H z Line frequency.

5 0 0 3 Shows the measurement in hundredths of Hz.

H z 1 > Means overfrequency element 1 has operated. The following screens can be displayed for trip identification, as a function of the settings configured:

Hz1>	Unit 1, overfrequency
Hz1<	Unit 1, underfrequency

H z 2 > Means overfrequency element 2 has operated. The following screens can be displayed for trip identification, as a function of the settings configured.

Hz2>	Unit 2, overfrequency
Hz2<	Unit 2, underfrequency

7.4 Screen Sequence Using the Complete Keypad

From the default screen, there are a series of screen sequences with loop structure. Press the selection keys (↑ ↓) and the **ENT** key to access last relay operation data, and the following screen sequences.

- **Settings**
  General
  Protection
  Logic
- **Information**
  Contact Input Status
  Contact Output Status
  Frequency Elements Status
- **Configuration**
  Communications
  Language

For a global display of the screen sequence and the keys used to move forward in the sequence, below is a table describing the process.

- **General Settings: HMI Access**

MOD. FGI-A/B

SETT	**GNRL**	**R_TF**	**0000**
INFO	PROT		
CONF	LOGI		

MOD. FGI-C

SETT	**GNRL**	**R_TT**	**0000**
INFO	PROT		
CONF	LOGI		

- **Protection Settings: HMI Access**

MOD. FGI-A/B

SETT	GNRL	**FREQ**	**Hz1M**
INFO	**PROT**	U<	**Hz1m**
CONF	LOGI		**Hz1>**
			Hz1<
			TEMP

MOD. FGI-A/B

SETT	GNRL	FREQ	
INFO	**PROT**	**U<**	**40**
CONF	LOGI		

MOD. FGI-C

SETT	GNRL	**VOLT**	**U1Mx**
INFO	**PROT**	FREQ	**U1mn**
CONF	LOGI	U<	**U1>**
		SV	**U1<**
			CURV
			DIAL
			TFIJ
			U1>>
			U1<<
			TEMP

MOD. FGI-C

SETT	GNRL	VOLT	**Hz1M**
INFO	**PROT**	**FREQ**	**Hz1m**
CONF	LOGI	U<	**Hz1>**
		SV	**Hz1<**
			TEMP

MOD. FGI-C

SETT	GNRL	TENS	
INFO	**PROT**	FREC	
CONF	LOGI	**U<**	**40**
		SV	

MOD. FGI-C

SETT	GNRL	TENS	**SV>**
INFO	**PROT**	FREC	**BL_T**
CONF	LOGI	U<	**PULS**
		SV	

- **Logic Settings: HMI Access**

MOD. FGI-A

SETT	GNRL	**MASK**	**U1 S**
INFO	PROT		**U1 N**
CONF	**LOGI**		**U2 S**
			U2 N

MOD. FGI-B

SETT	GNRL	**MASK**	**U1 S**
INFO	PROT	TFOA	**U1 N**
CONF	**LOGI**	TFOC	**U2 S**
			U2 N

MOD. FGI-B

SETT	GNRL	MASK
INFO	PROT	**TFOA**
CONF	**LOGI**	**TFOC**

MOD. FGI-C

SETT	GNRL	**MASK**	**UT1S**
INFO	PROT		**UT1N**
CONF	**LOGI**		**UI1S**
			UI1N
			UT2S
			UT2N
			UI2S
			UI2N
			UN S
			UN N
			F1 S
			F1 N
			F2 S
			F2 N
			SV S
			SV N

- **Information Menu: HMI Access**

SETT	**INPT**
INFO	**OUPT**
CONF	**PCKP**

- **Communications Configuration: HMI Access**

MOD. FGI-A/C

SETT		**ADDR**
INFO	**COMM**	**BAUD**
CONF	LANG	**STOP**
		PARI

MOD. FGI-B

SETT		**ADDR**
INFO	**COMM**	**BAUD**
CONF	LANG	**STOP**
		PARI
		TOUT

- **Language Configuration: HMI Access**

SETT		**ESP**
INFO	COMM	**ENG**
CONF	**LANG**	**POR**

8. Receiving Tests

8.1 General

Improper handling of electrical equipment is extremely dangerous; therefore, only skilled and qualified personnel familiar with appropriate safety procedures and precautions should work with this equipment. Damage to equipment and injury to personnel can result when proper safety precautions are not followed. The following general safety precautions are provided as a reminder:

- **High magnitude voltages are present in auxiliary supply and measuring circuits even after equipment has been disconnected.**
- **Equipment should be solidly grounded before handling or operating.**
- **Under no circumstances should the operating limits of the equipment be exceeded (auxiliary voltage, current, etc.).**
- **The auxiliary supply voltage (AC or DC) should be disconnected from the equipment before extracting or inserting any module, otherwise damage may result.**

The number, the type and the specific characteristics of the acceptance tests for the **FGI** units are detailed in the following table.

FGI	Preliminary inspection
	Insulation test
	Voltage measuring test
	Over / Undervoltage elements test (FGI-C)
	Frequency measuring test
	Over / Underfrequency elements test
	Out of Step element test (FGI-C)
	Status contact inputs & LED targets test
	Communications test

8.1.1 Accuracy

The results obtained in electrical testing greatly depend on the accuracy of the measuring instruments and test source signals (auxiliary power supply voltage, AC currents and AC voltages). Therefore, verification of the information specified in the Technical Data section of this manual can only reasonably be achieved using accurate test equipment under nominal reference conditions with tolerances as indicated in national and international testing standards **UNE 21-136** and **IEC255**.

It is extremely important that there is little or no distortion (<2%) present in the test source signals as harmonics can affect measuring element precision when levels are above reference conditions used to certify the performance accuracy of equipment.

Unless there is absolute compliance with these standards and practices, acceptance tests performed on equipment should only focus on operation verification and not on measurement accuracy.

8.2 Preliminary Inspection

The following equipment aspects should be examined:

- The unit is in good physical condition, mechanical parts are securely attached and no assembly screws are missing.
- The unit model number and specifications agree with the equipment order.

8.3 Insulation Test

While testing for insulation in racks or cabinets, to test the rigidity of external cables, it is recommended to disconnect the terminal unit to avoid damage to the cable or if there is a risk of cable returns, since insulation testing has already been performed by the manufacturer:

- **Common Mode**

Wire all rear connection terminals together except for terminal 30 (and for terminal 10, in **FGI-C** models) and all the terminals connected to a power supply. Apply 2000 Vca for 1 minute between interconnected terminals and metal case.

- **Transverse Mode**

Divide the terminals into terminal groups as indicated below:

* 1-2 (1-2-3-4-5-6 in **FGI-C** models)
* 11-12-13-14
* 15-16-17-18-19-20-21-22-23-24-25-26-27
* 28-29

Apply 2000 Vca for 1 minute between each pair combination of terminal groups.

Note: Internal capacitors can generate an elevated tension if insulation-testing points are removed and the test voltage has not decreased.

8.4 Voltage Measuring Test

- **FGI-A/B Models**

Connect the equipment to a suitable power supply (rated Vdc). Ready LED will illuminate

To avoid trips while performing this test, protection elements must be disabled. Apply the a.c. voltage values indicated in following table to the Voltage Analog Input - terminal connectors 1 and 2. Verify that the metering values in the alphanumeric display are within the specified range for Measured Value.

Table 8-1: Voltage Measurement Test	
Applied Voltage	**Measured Value**
40 Vca	38 - 42 Vca
50 Vca	47.5 - 52.5 Vca
75 Vca	71.25 - 78.75 Vca
125 Vca	118.75 - 131.25 Vca

Repeat the procedure applying the same voltage values (see preceding table) and varying the frequency. Verify that the measured values are within the specified range.

- **FGI-C Models**

Power will be supplied through terminals 28 (+) and 29 (-) at rated voltage. Ready LED will illuminate.

Phase Voltage Measurement

Set the relay to rated frequency. Then apply voltage as shown in following table and check that measured values are within the specified range. Voltage shall be applied between terminals 1 and 2 for phase A, 3 and 4 for phase B and 5 and 6 for phase C.

Table 8-2: Phase Voltage Measurement Test	
Applied Voltage to phases A, B and C	**Measured Value in phases A, B and C**
X Vca	0.95 X - 1.05 X

Ground Voltage Measurement

Ground element zero sequence voltage is calculated from the samples taken for phase voltages Va, Vb and Vc.

Voltages shall be applied at relay rated frequency setting checking that ground voltage measurement is within the range shown in following table.

Table 8-3: Ground Voltage Measurement Test			
Applied Voltage			**Measured Value**
Phase A	**Phase B**	**Phase C**	**Ground Voltage**
100 / 0º	100 / 240º	100 / 120º	0 - 5
100 / 0º	100 / 0º	100 / 0º	95 - 105

8.5 Over / Undervoltage Protection Test

This test will be carried out for models **FGI-C**. Power will be supplied through terminals 28 (+) and 29 (-) at rated voltage. Ready LED will illuminate.

Apply all voltages at rated frequency setting. Select the voltage element 1 and set it as **undervoltage**. Disable non-tested elements.

Pickup and reset

Check, for settings in following table, that undervoltage element 1pickup status flag sets to “1” in stable form when the voltage reaches a value between VA_MIN and VA_MAX, for each phase.

Bear in mind that undervoltage element pickup is checked starting from a voltage higher than the measured voltage. Said voltage shall be applied between terminals 1 and 2 for phase A, 3 and 4 for phase B and between terminals 5 and 6 for phase C.

Also check in each case that reset occurs for the values shown in following table.

Table 8-4: Reset Values (Undervoltage Test)

Setting	VA_MIN	VA_MAX	VR_MIN	VR_MAX
X	0.95 X	1.05 X	0.95 x (1.05 X)	1.05 x (1.05 X)

Times

- Inverse Curve Characteristic

Set the pickup value to X Vca and the curve type to **inverse curve**. Starting with a voltage of 1.2 X Vca, reduce the voltage (in only one step) to the value shown in followings tables and check, with the curve index (DIAL) set to 0.5 and 1, that time elapsed from the moment the voltage is reduced to the moment element 1 trips, is within the ranges specified.

Table 8-5: Index = 0.5 (Undervoltage Test)

Final Voltage	T_MIN	T_MAX
X/2	1.045	1.155
X/4	0.437	0.483

Table 8-6: Index = 1 (Undervoltage Test)

Final Voltage	T_MIN	T_MAX
X/2	2.090	2.310
X/4	0.874	0.966

- Fixed Time Characteristic

Select the type of curve as **fixed time**. Set the pickup value to X Vca. Reduce the voltage to X/2 Vca (in only one step). Then check that the times are within the ranges specified in following table.

Table 8-7: Fixed Time Settings (Undervoltage Test)		
Time Settings	**T_MIN**	**T_MAX**
0.1	0.075	0.125
1	0.95	1.05

After completion of the above described tests proceed with the selection of element 2 as **overvoltage** element, disabling, in turn, the elements not under test.

Pickup and reset

Apply voltage through terminals 1 and 2 for phase A, 3 and 4 for phase B and between terminals 5 and 6 for phase C. Check, for settings in table 8-8, that time overvoltage element 2 pickup status flag sets to “1” in stable form when the voltage reaches a value between VA_MIN and VA_MAX (for every three phases). Also check in each case that reset occurs for the values shown in table.

Table 8-8: Reset Values (Overvoltage Test)				
Setting	**VA_MIN**	**VA_MAX**	**VR_MIN**	**VR_MAX**
X	0.95 X	1.05 X	0.95 x (1.05 X)	1.05 x (1.05 X)

Times

- Inverse curve characteristic

Set the pickup value to X Vca and the curve type to **inverse curve** and curve index (DIAL) set to 0.5 and 1.Apply voltage and check that times are within the ranges specified in following tables.

Table 8-9: Index = 0.5 (Overvoltage Test)		
Final Voltage	**T_MIN**	**T_MAX**
1.4 X	7.647	8.453
2 X	0.145	0.1575

Table 8-10: Index = 1 (Overvoltage Test)		
Final Voltage	**T_MIN**	**T_MAX**
1.4 X	15.294	16.906
2 X	0.285	0.325

- Fixed Time

Repeat the test, selecting this time the **fixed time** characteristic, setting the pickup value to X Vca and applying a voltage of 2X Vac. Check then the values specified in following table.

Table 8-11: Fixed Time Settings (Overvoltage Test)		
Time Setting	**T_MIN**	**T_MAX**
0.1	0.075	0.125
1	0.95	1.05

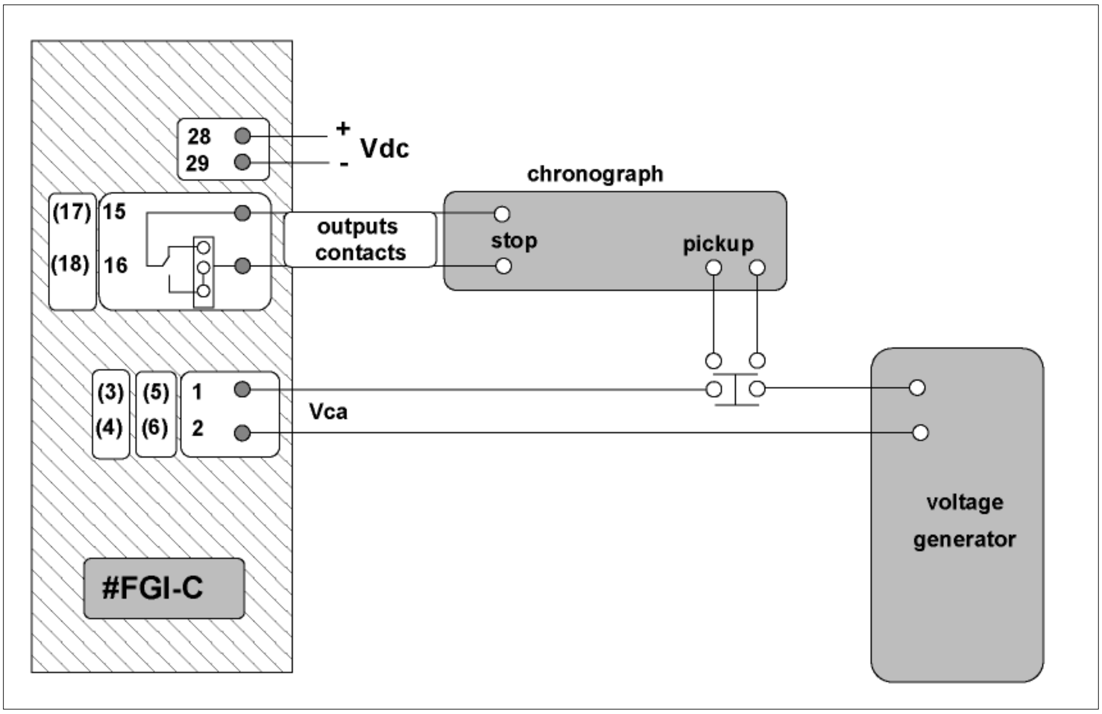


Figure 8.1: Operating Time Test Setup (FGI-C Models).

8.6 Frequency Measurement Test

Supply power at the auxiliary rated voltage. The "**Ready**" led lights up.

Apply voltage at the frequencies specified in following table, and check the measured values are within the ranges specified. Voltage is applied between terminals 1 and 2.

Table 8-12: Frequency Measurement Test	
Applied Frequency	**Measured Value**
X Hz	(X-0.01) Hz - (X+0.01) Hz

8.7 Over / Underfrequency Element Tests

- **Pickup and Reset**

Set the desired pickup values for both elements and inject voltage modifying the frequency, checking pickup and reset values. This checking can be carried out displaying the information menu - Pickup where element status is shown or by means of an auxiliary output contact programmed for that purpose. Pickup and reset intervals are specified in following table.

Table 8-13: Over / Underfrequency Element Tests				
Applied Frequency			**Measured Value**	
Setting	Pickup	Reset	Pickup	Reset
XHz	X±0.005Hz	(X×0.999)±0.005Hz	X±0.005Hz	(X×1.001)±0.005Hz

- **Time Measurement**

For time measurement the voltage generator must generate an up or down frequency ramp, as a function of the element to test, and at the same time give an output to initiate the timing of a clock when the pickup frequency is reached.

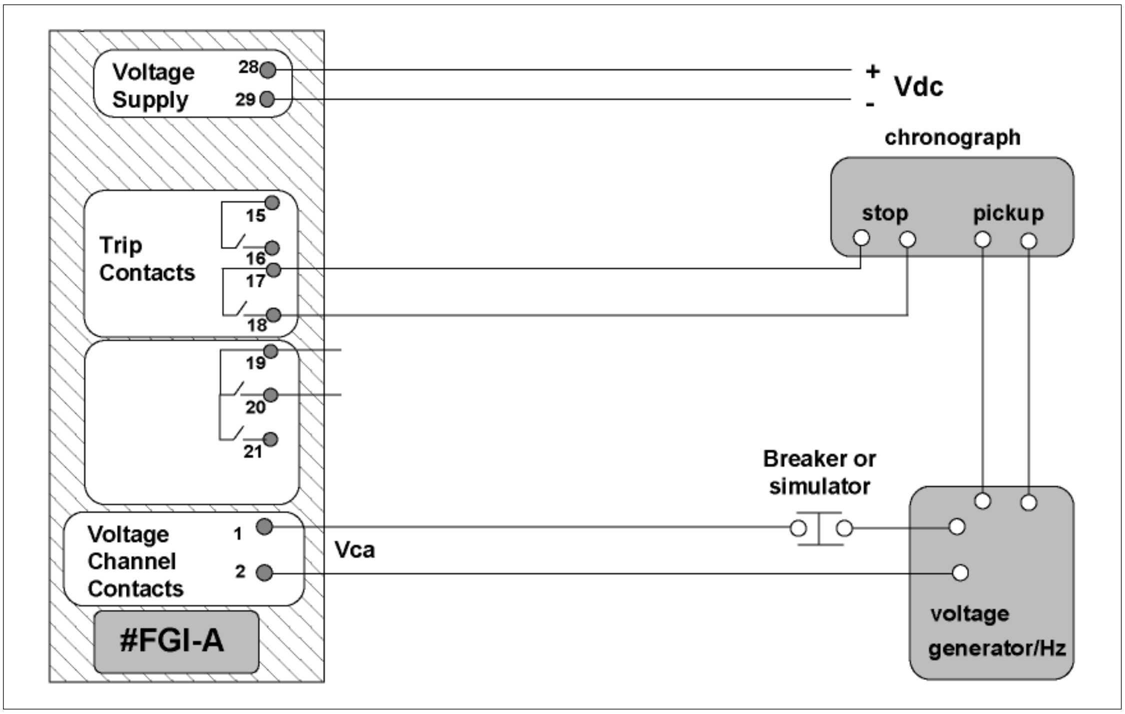


Figure 8.2: Operating Time Test Setup (FGI-A Models).

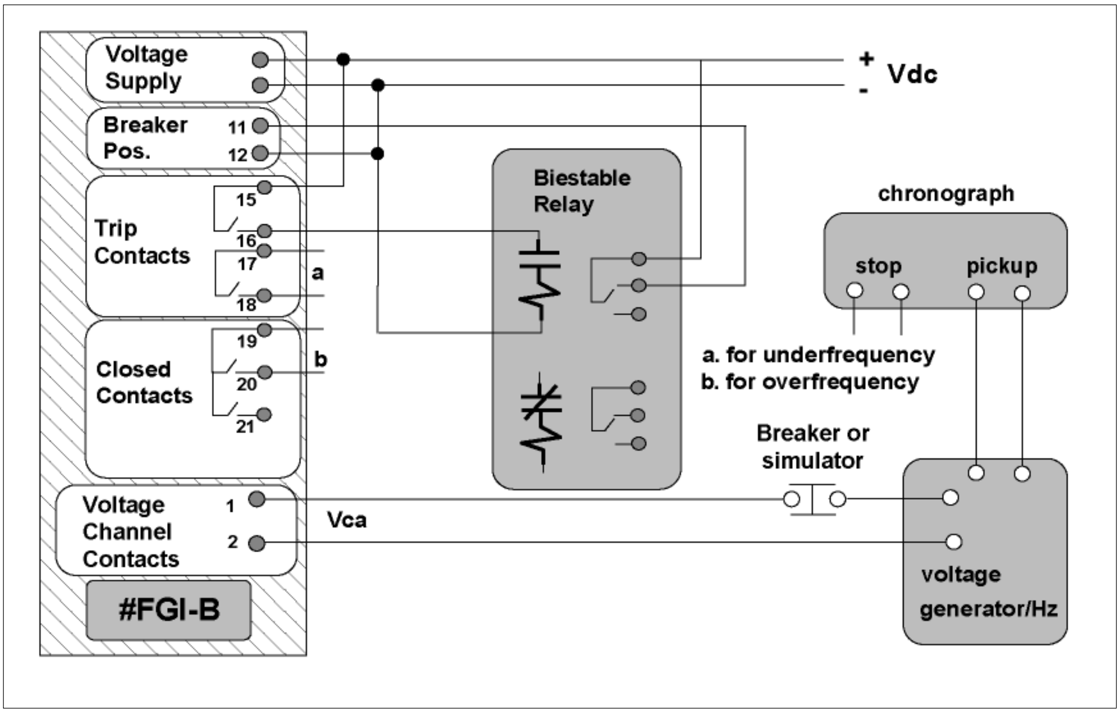


Figure 8.3: Operating Time Test Setup (FGI-B Models).

During this test, in model **FGI-B**, the relay operation logic must be taken into account. For the underfrequency element there are no impediments except for the tripping mask, element disable or external blocking, but for the overfrequency element, apart from the impediments indicated for the underfrequency element, an underfrequency trip must have occurred first and an open breaker signal must have been received before the open failure timer times out.

Operating times for X settings, must be between (1.05 × X - 0.95 × X) or between (X+25ms - X-25ms) (X+40ms - X-40ms, in **FGI-C** models). If the setting is 0, the operating time will be close to 60ms (70 ms in **FGI-C** models).

The way the frequency ramp is generated and the moment the clock starts timing are important for the operating time. Setting the frequency of the generated signal very close to the test threshold and generating a jump as large as possible is recommended.

8.8 Out of Step Element Test

This test will be carried out for models **FGI-C**. Set the out of step element values as follows:

Pickup:	10 º
Reset time:	5 s
Time blocking:	3 s
Blocking voltage:	50 V
Frequency:	50 Hz

Proceed to disable all elements except the out of step element.

The **time blocking** signal will be active. Apply voltage of 65 V at rated frequency. Check that the **time blocking** signal drops in a time between 2.85 and 3.15 s.

Change the frequency of the input voltage in 5 Hz such that the frequency change occurs just when the voltage signal goes through zero. Check that the element output activates for a time between 4.75 and 5.25 s.

Disconnect measured voltage.

8.9 Contact Inputs, Auxiliary Outputs and LED Targets Test

Connect the equipment to a suitable power supply. Ready LED will illuminate.

- **LEDs**

Press the ↓ key to scroll through the screen sequence until the screen **L E D S** is reached. Then, press the ↓ key for 2 seconds and verify that all the LEDs illuminate. Release the ↓ key and verify that all the LEDs turn off.

- **Status Contact Inputs**

Apply rated voltage to the contact input connectors 11(+) - 12(-) and 13(+) - 14(-). Select from the information menu the inputs status screens (refer to Chapter 7 Operator Interface) and verify that both signals are **ON**. Disconnect the test probes and verify that both signals are **OFF**.

- **Auxiliary Outputs**

To test the auxiliary outputs, you will have make them trip depending on how they have been configured. If they do not have any configuration, the outputs can be configured as activation of the physical inputs. That way at the same time as the inputs are being tested, correct tripping of the output contacts AUX1 and AUX2 is verified.

8.10 Communication Test

Connect the equipment to a suitable power supply. Ready LED will illuminate.

Test will be performed through local communications port, allocated on front panel:

Baud Rate	**4800 Bauds**
Stop Bits	**1**
Parity	**1 (even)**

Connect to the terminal unit through the local communications port using a DB9 (9-pin) serial connection wire. Synchronize time using the ***ZIVercom***® software program. Disconnect the communications wire and disconnect the terminal unit power supply and wait for two minutes. Afterwards, connect the power supply and connect to the terminal unit through the remote communications port. Activate the "*cyclical*" mode in the ***ZIVercom***® software program and verify that time actualizes properly.

8.11 Installation

8.11.1 Location

The location where the terminal unit is to be installed should meet the following minimum conditions to ensure correct operation, long service life, and ease of installation and maintenance:

- Absence of dust
- Absence of dampness
- Absence of vibration
- Adequate lighting
- Easy access
- Horizontal or Vertical mount

Mounting should be in accordance with the instructions regarding installations in the dimension diagram.

8.11.2 Connection

Terminal 30 should be solidly grounded to ensure disturbance-filtering circuits operate properly. The wire used for grounding these terminals should be stranded 14 AWG. Ground wire length should be minimized and should not exceed 12". The ground terminal of the enclosure located on the rear panel of the equipment should also be grounded.

A. Schemes and Drawings

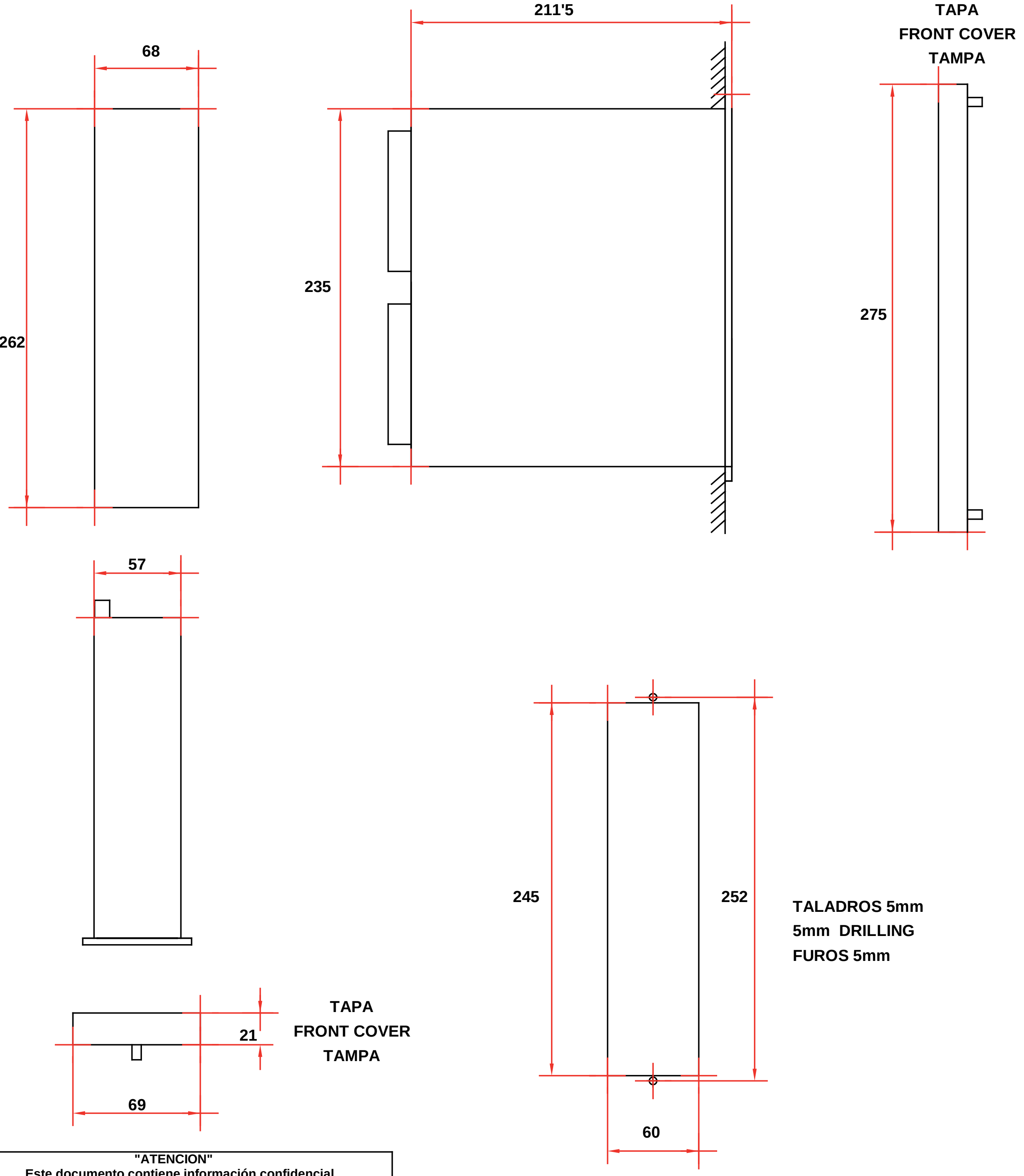
Dimension and Drill Hole Schemes

3FGI	>>4BF0100/0016
Adapter board to 19”x 2U / 8FGI	>>4BF0100/0026

External Connection Schemes

FGI-A	>>3RX0142/0015 (generic)
FGI-B	>>3RX0142/0014 (generic)
FGI-C	>>3RX0142/0016 (generic)

CAJA TIPO "D"
ENCLOSURE TYPE "D"
CAIXA TIPO "D"



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Rev. 2 14/2/02

NÚMERO: 4BF0100/0016

	Fecha	Nombre
Dibujado	3/5/96	J.C.S.
Aprobado	3/5/96	R.O.

Hoja: 1
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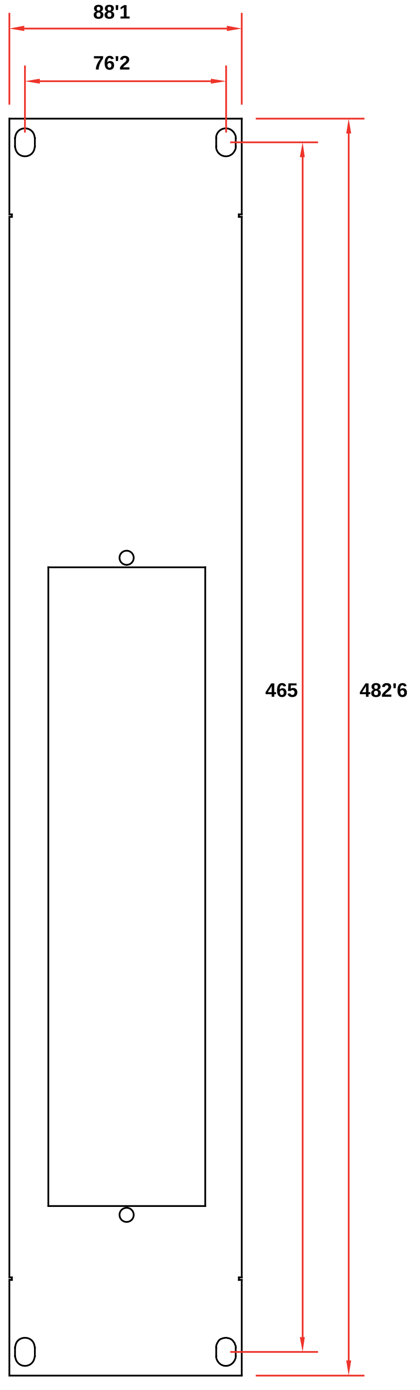

REVISIONES					
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11		12		13	
14		15		16	

ZIV Aplicaciones y Tecnología, S.L.

TÍTULO: PLACA ADAPTACION A 19``X 2U

PROYECTO: RELE INDUSTRIAL

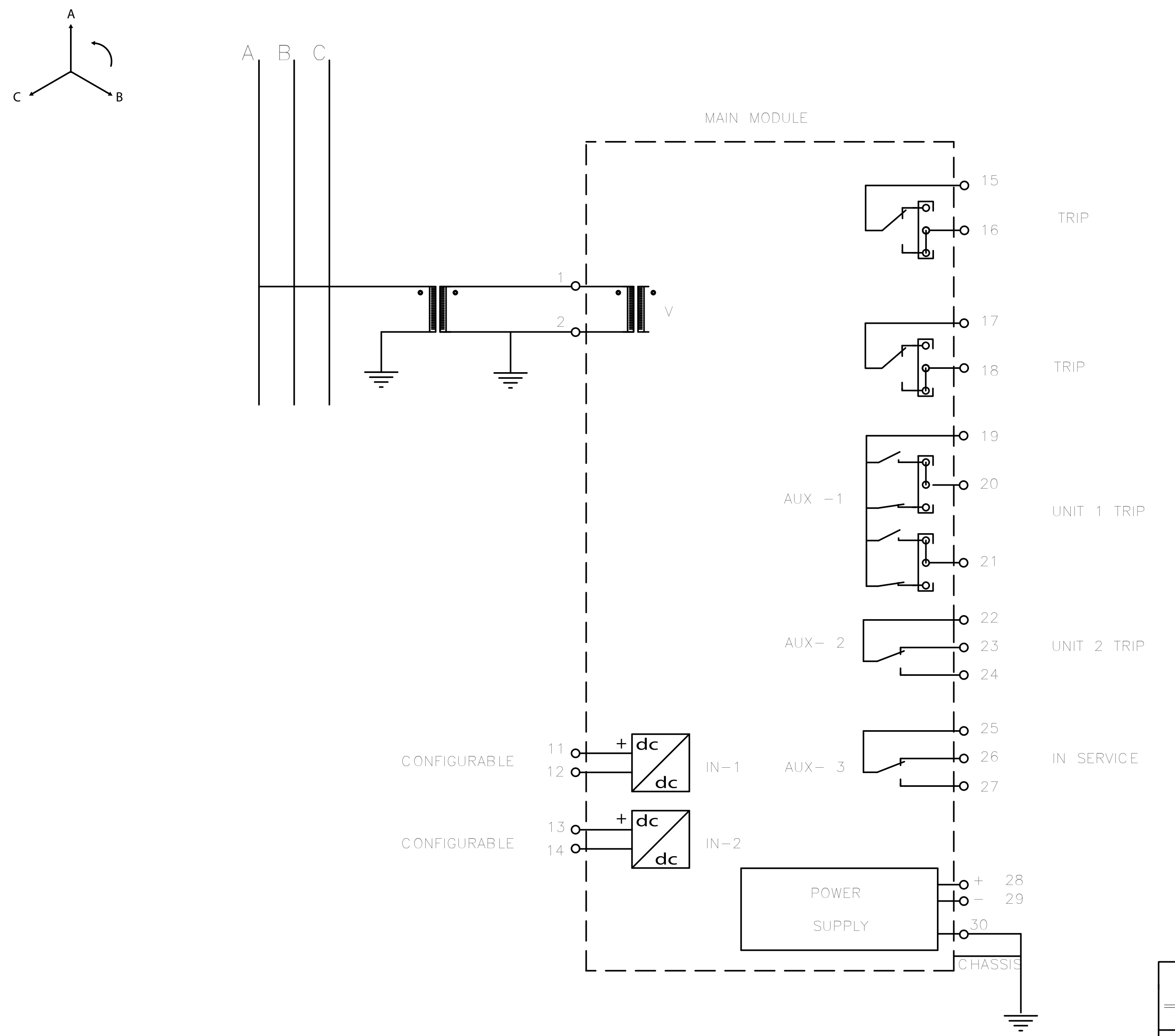
Rev. 0
Rev. 14/2/02

NÚMERO: 4BF0100/0026

	Fecha	Nombre
Dibujado	29/4/99	J.C.S.
Aprobado	29/4/99	R.O.

Hoja: 1

Continua en Hoja:



LEDS

1.- UNIT 1 TRIP (MEM.).
2.- UNIT 1 PICK UP (NO MEM.).
3.- UNIT 2 TRIP (MEM.).
4.- UNIT 2 PICK UP (NO MEM.).
5.- CONFIGURABLE.
6.- CONFIGURABLE.
7.- CONFIGURABLE.

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REVISIONS	0	CD0411112	1		2		3		4	
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TITLE> EXTERNAL CONNECTIONS 3/8FGI-A

PROJECT> PROT. MAX./MINIMA FRECUENCIA

Rev.0

NUMBER> 3RX0142/0015

	Date	Name
Drawn	05/11/04	J.C.S.
Approved	05/11/04	P.A.

Sheet:1

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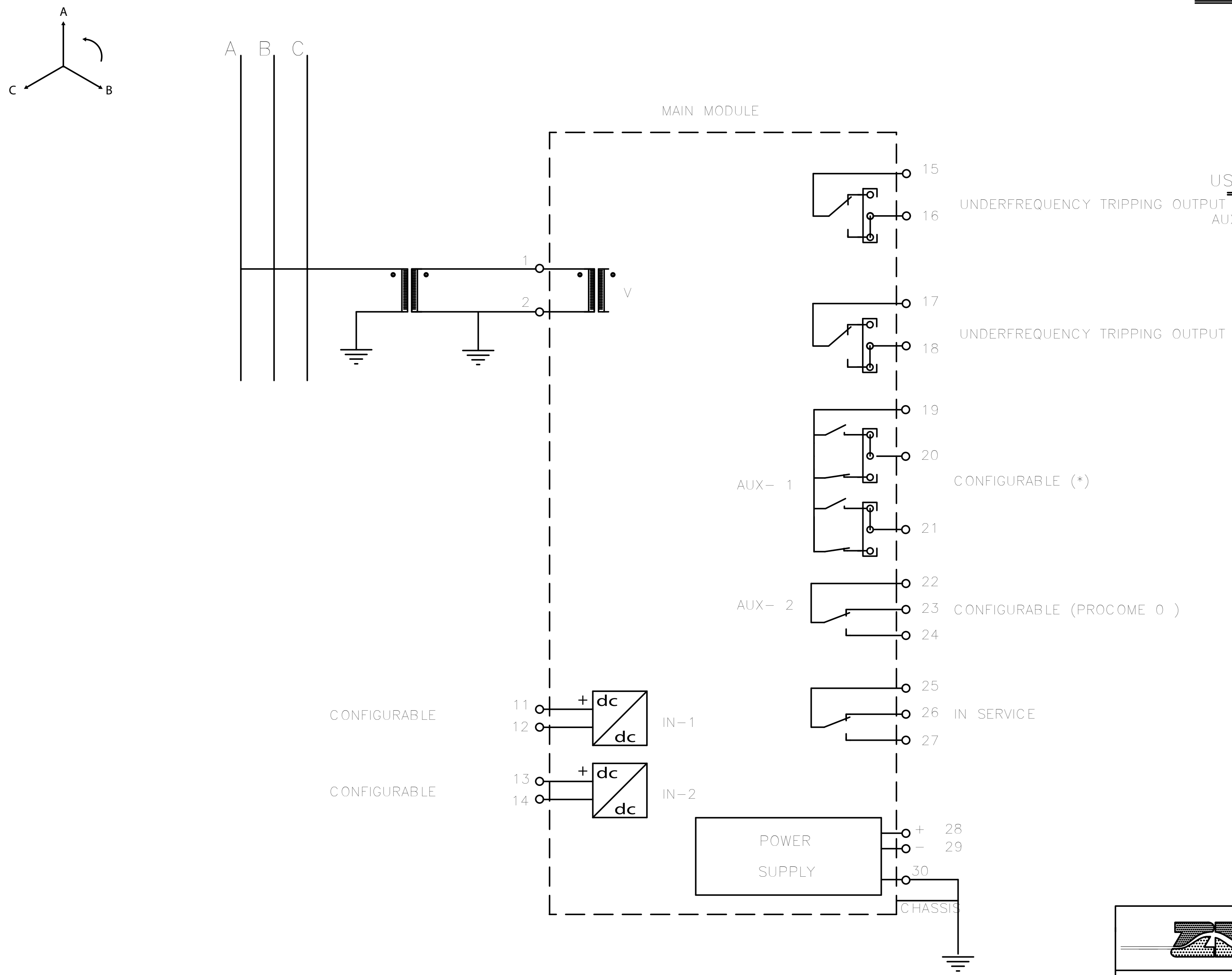

LEDS

1.- CONFIGURABLE.
2.- CONFIGURABLE.
3.- CONFIGURABLE.
4.- CONFIGURABLE.
5.- CONFIGURABLE.
6.- CONFIGURABLE.
7.- CONFIGURABLE.

USER DEFINED VIRTUAL OUTPUT

AUX-3.- CONFIGURABLE (PROCOME 1)

* USER PROGRAMMABLE OUTPUT CONFIGURABLE ONLY AS "CLOSE CONTACT DUE TO OVERFREQUENCY" FOR THE RELAY TO OPERATE CORRECTLY.

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REVISIONS	0	CD0407162	1		2		3		4	
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TITLE> EXTERNAL CONNECTIONS 3FGI-B

PROJECT> OVER/UNDER FREQUENCY RELAY

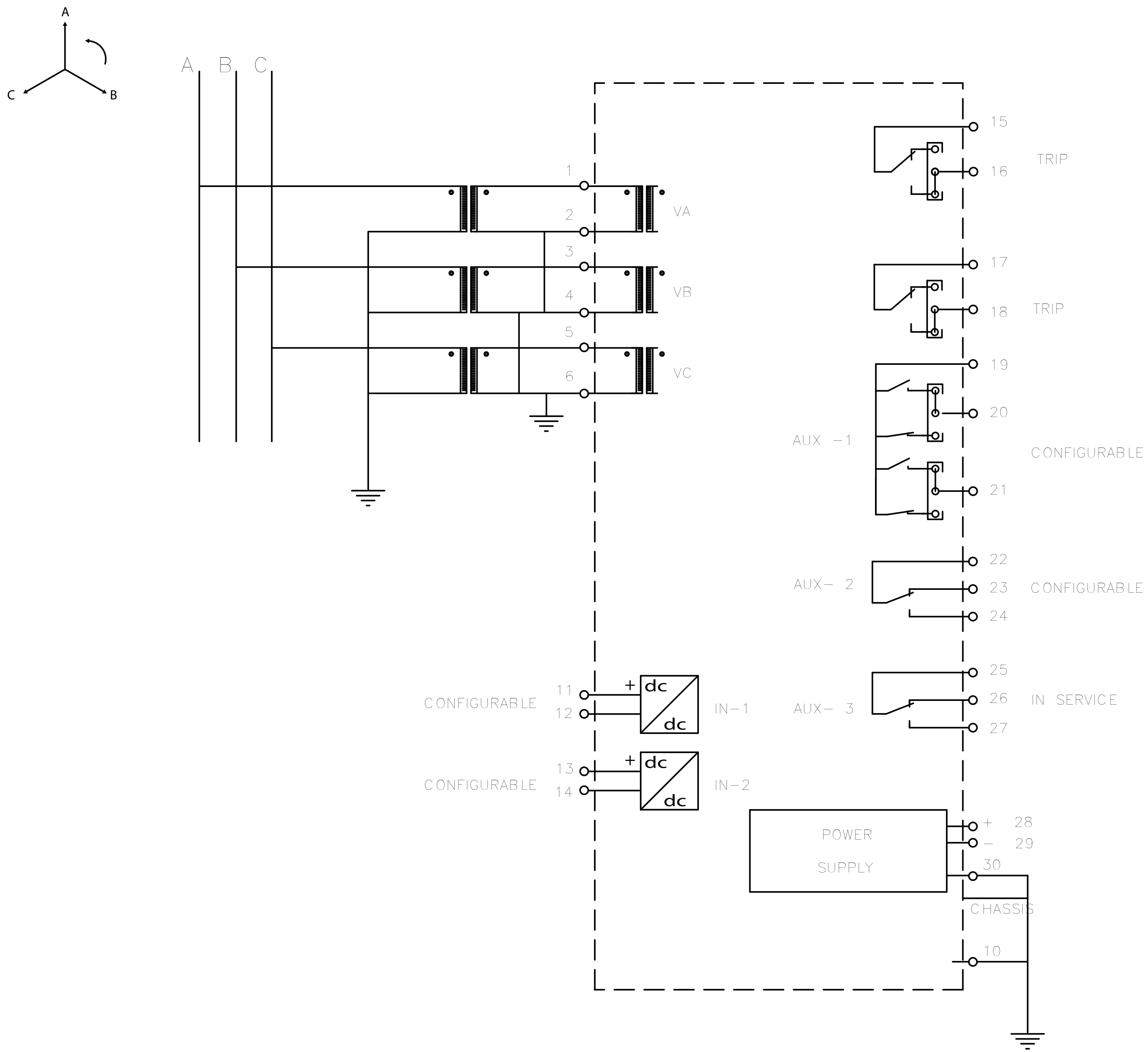
Rev.0

NUMBER> 3RX0142/0014

	Date	Name
Drawn	29/07/04	J.C.S.
Approved	29/07/04	P.A.

Sheet:1

Continued on Sheed:



LEDS

1.-CONFIGURABLE.
2.-CONFIGURABLE.
3.-CONFIGURABLE.
4.-CONFIGURABLE.
5.-CONFIGURABLE.
6.-CONFIGURABLE.
7.-CONFIGURABLE.

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REVISIONS	0	CD0901107	1		2		3		4	
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Z I V Aplicaciones y Tecnologia S.A.

TITLE> EXTERNAL CONNECTIONS FGI-C

PROJECT> OUT OF STEP

Rev.0

NUMBER> 3RX0142/0016

	Date	Name
Drawn	14/01/08	J.C.S.
Approved	14/01/08	R.Q.

Sheet:1

Continued on Sheed:

B. List of Illustrations and Tables

B.1 List of Figures

B.2 List of Tables

C. Warranty

ZIV GRID AUTOMATION, S.L.
Standard Product Warranty

All new products sold to customers are warranted against defects in design, materials, and workmanship for a period of ten (**10**) years from the time of delivery (at the moment the product leaves ZIV GRID AUTOMATION premises, as indicated in the shipping documents). Customer is responsible of notifying ZIV GRID AUTOMATION of any faulty conditions as soon as they are detected. If it is determined that the new product defect is covered by the warranty, ZIV GRID AUTOMATION will repair, or substitute the product at its own discretion to the customer at no charge.

ZIV GRID AUTOMATION may, at its own discretion, require the customer to ship the unit back to the factory for diagnosis before making a determination as to whether it is covered by this warranty. Shipping costs to the ZIV GRID AUTOMATION factory (including but not limited to, freight, insurance, customs fees and taxes, and any other expenses) will be the responsibility of the customer. All expenses related to the shipment of the repaired or replacement units back to the customer will be borne by ZIV GRID AUTOMATION.

Customers are responsible for all expenses related to the shipment of defective units back to ZIV GRID AUTOMATION when it is determined that such units are not covered under this warranty or that the fault is not ZIV GRID AUTOMATION´s responsibility. Units repaired by ZIV GRID AUTOMATION are warranted against defects in materials, and manufacturing for a period of one (1) year from the time of delivery (at the moment the product leaves ZIV GRID AUTOMATION premises, as indicated by the shipping documents), or for the remaining of the original warranty, whichever is greater.

ZIV GRID AUTOMATION warranty does not cover: 1) improper installation, connection, operation, maintenance, and/or storage, 2) minor defects not interfering with the operation of the product, possible indemnities, misuse or improper usage, 3) abnormal or unusual operating conditions or application outside the specifications for the product, 4) application in any way different from that for which the products were designed, 5) repairs or alterations performed by individuals other than ZIV GRID AUTOMATION employees or an authorised representative.

Limitations:

1) Equipment or products provided but not manufactured by ZIV GRID AUTOMATION. Such products may be covered by a warranty issued by the corresponding manufacturer.
2) Software: ZIV GRID AUTOMATION warrants that the licensed Software corresponds with the specifications included in the instruction manuals provided with the units, or with the specifications agreed with the end-customer. ZIV GRID AUTOMATION sole and entire liability, and customer exclusive remedy, with respect to any claims relating to the Software shall be to provide a new set of diskettes free of charge.
3) In the case that a bank guarantee or similar instrument be required to back up the warranty period, such warranty period, and only for these purposes, will be of a maximum of twelve (12) months from the time of delivery (at the moment the product leaves ZIV GRID AUTOMATION premises, as indicated in the shipping documents).

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