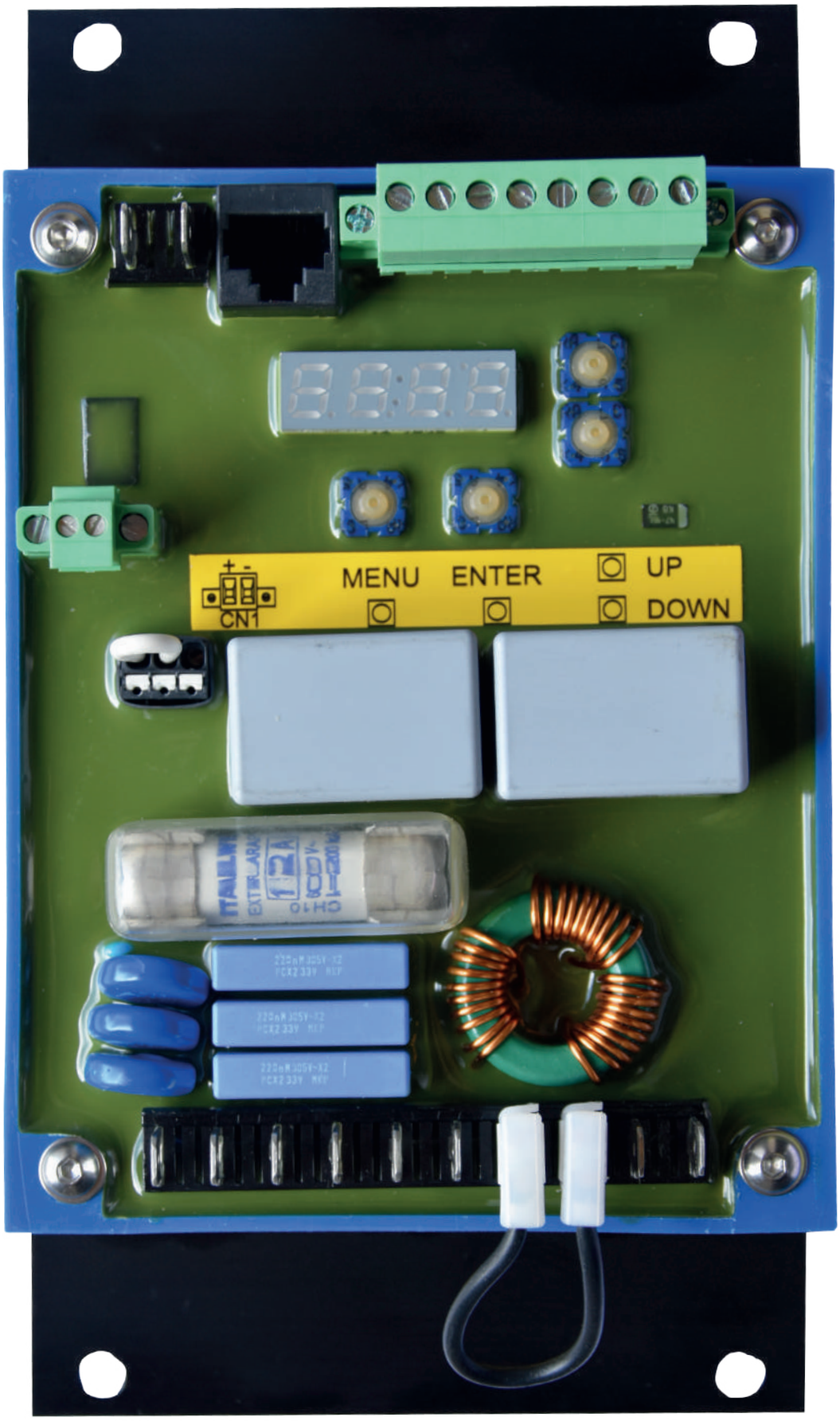
S

USER'S MANUAL

2022

BELTRAME
CENTRO SERVIZI ENERGIA

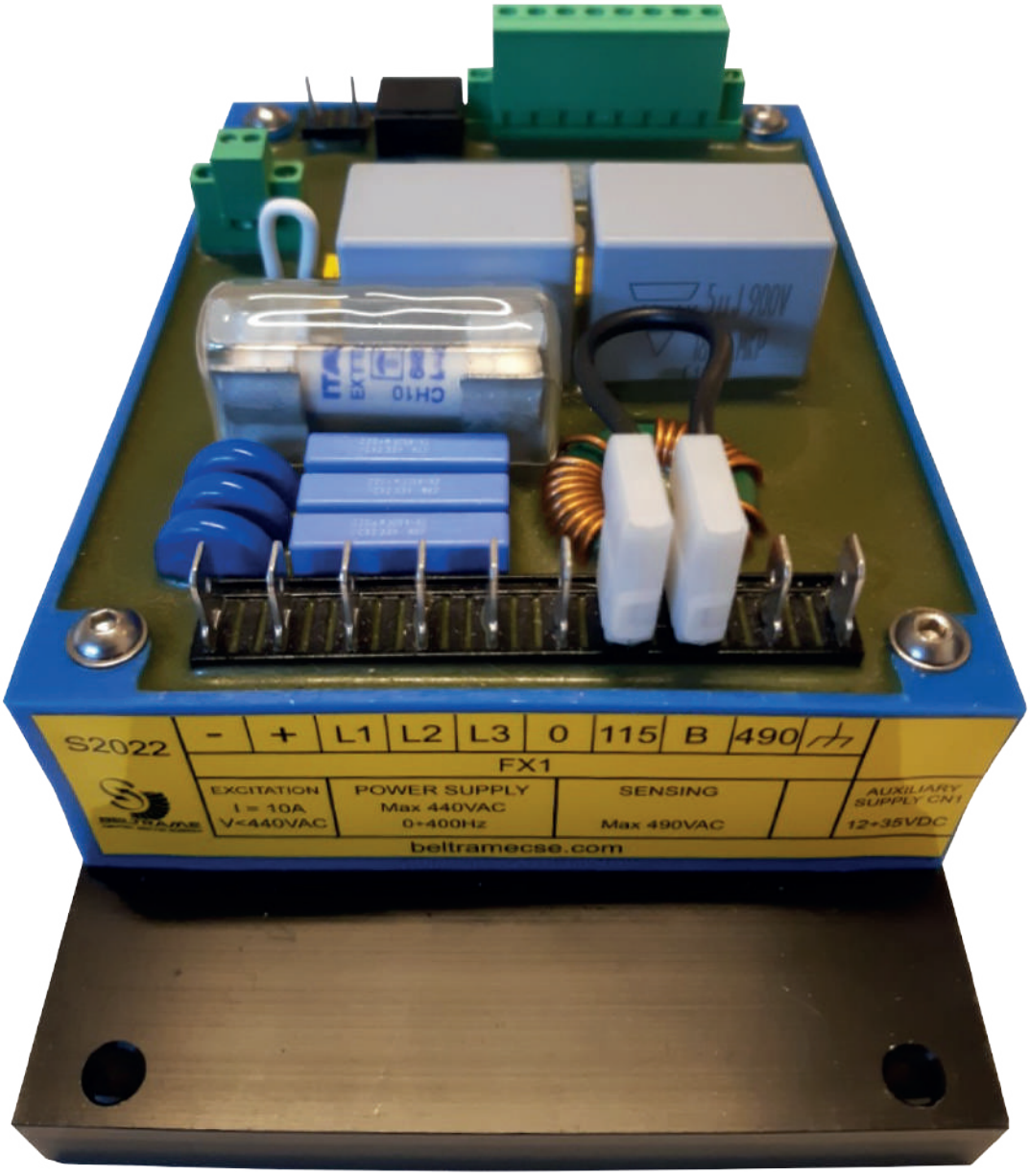


Rev. 4.0

CONTENTS

IMPORTANT INFORMATION

Our experience has shown that, if the information and recommendations contained in this Operating Instructions are observed, the best possible reliability of our products is assured. The data contained herein purports solely to describe the product and it is not a warranty of performance or characteristics. It is with the best interests of our customers in mind that we constantly strive to improve our products and keep them abreast of advances in technology. This may, however, lead to discrepancies between a product and its "Technical Description" or "Operating Instructions". This document has been carefully prepared and reviewed, however should in spite of this the reader find an error, he is requested to inform us at his earliest convenience. It is scarcely possible for the operating instructions for technical equipment to cover every eventuality, which can occur in practice. We would therefore request you to notify us or our agent in the case of all unusual behavior that does not appear to be covered by these operating instructions. It is pointed out that all local regulations in force must be observed when connecting and commissioning this equipment in addition to these operating instructions. We cannot accept any responsibility for damage incurred as a result of mishandling the equipment regardless of whether particular reference is made in these operating instructions or not.



1. ISTRUZIONI PER LA SICUREZZA

1.1 General

The safety instructions shall be followed during installation, commissioning, operation and maintenance of the excitation system. Read all instructions carefully before operating the device and keep this manual for future reference.

Required Qualification

Personnel involved in installation work and commissioning of the S2022 must be familiar, specially instructed and informed about the residual danger areas according to the regulations currently in force. Operating personnel is not permitted to work at the control system. Only specially instructed personnel must carry out maintenance and repair work. The maintenance personnel must be informed about the emergency shutdown measures and must be capable of turning off the system in case of emergency. The maintenance personnel must be familiar with the accident prevention measures at their workplace and must be instructed in first aid and firefighting. It is the owner's responsibility to ensure that each person involved in the installation and commissioning of the S2022 has received the appropriate training or instructions and has thoroughly read and clearly understood the safety instructions in this chapter.

1.2 Istruzioni di sicurezza

The safety instructions precede any instruction in the context where a potentially dangerous situation may appear. The safety instructions are divided into three categories, each represented by a symbol and description:

DANGER!
This symbol indicates an imminent danger resulting from mechanical forces or high voltage. A non-observance leads to life-threatening physical injury or death.

WARNING!
This symbol indicates a dangerous situation. A non-observance may lead to bad or life-threatening physical injury or death. It may cause also possible damages to the devices.

NOTICE!
This symbol emphasizes important information. A non-observance may cause damage to the device or to objects close to it.

2. DEVICE DESCRIPTION

2.1 Introduction

S2022 is a last generation Automatic Voltage Regulator for Generators excitation control. The unit contains the most advanced microprocessor technology together with IGBT semiconductor technology (Insulated Gate Bipolar Transistor).

A practical and simple-to-operate on board panel is used for all control operations. In addition, user friendly software facilitates the commissioning and allows the optimization of the performances.

2.2 S2022 Main Specifications

MECHANICAL DETAILS	Weight: Protection class: Dimensions (LxWxH)	Approx. 1400 gr IP2X (limited by fast-on type terminals) 200x110x75 mm
AMBIENT CONDITION	Temperature range for operation: Temperature range for storage: Vibration:	From -40 to 65 °C From -40 to +80 °C 5 mm, 2 G, 5<f<150 Hz
ELECTRICAL DETAILS	Power electronics supply: Excitation output:	230 Vac from 0 to 500Hz 300 Vdc Max continuous current 10 A Current reduction for ambient temperatures > 50 °C: 0.2A/degree Forcing (max 10 s): 20 A
	Power electronics supply:	from 10 to 500 Hz
Other	Accuracy	< ±0.25%
	Voltage inputs	Not insulated
	Ambient condition	AVR has to be protected against dust, moisture, rain

2.3 CE / EU Compliance

This product has been evaluated and complies with the relevant essential requirements requested by the EU legislation.

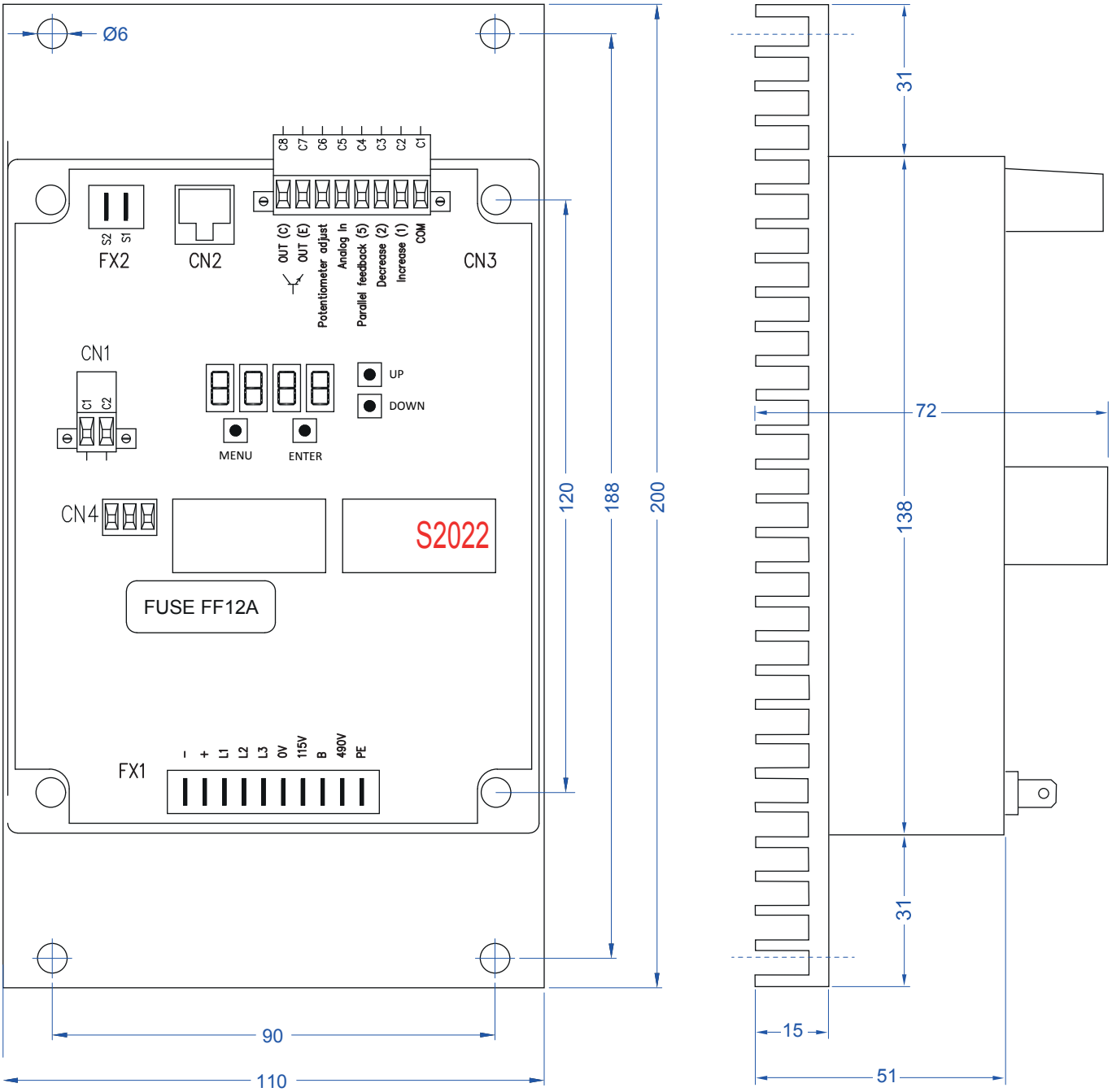
It complies with the following EU Directives:

- LVD 2014/35/EU;
- EMC 2014/30/EU;
- ROHS 2 2011/65/EU.

The harmonized standards used for the evaluation are:

- EN 50178 - Electronic Equipment for use in Power Installations;
- EN 61000-6-4 - Electromagnetic Compatibility (EMC), Generic Standards, Emission Standard for Industrial Environments;
- EN 61000-6-2 - Electromagnetic Compatibility (EMC), Generic Standards, Immunity for Industrial Environments.

2.4 Overall Dimensions and Fixing Holes



2.5 Application Area

This AVR is used for the excitation of synchronous machines. This unit is suitable for this only application area.
The AVR can manage several regulations. Among them:

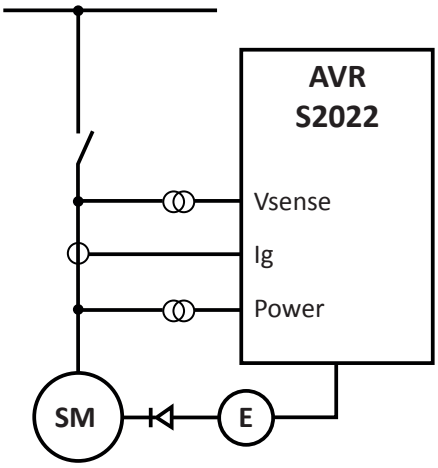
- Voltage regulation;
- Field Current Regulation (FCR);
- Power factor regulation (PF);
- Reactive power regulation (VAR).

2.6 Basic Insertion Configurations

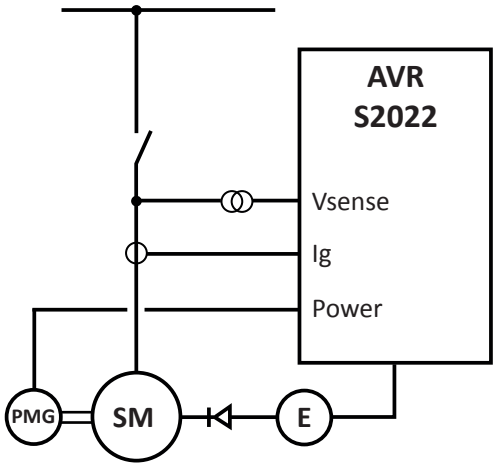
The following SLD show some basic insertion configurations of the S2022.

SM: Synchronous Machine **E**: Exciter **PMG**: Permanent-Magnet-Generator **D**:Direct Current machine

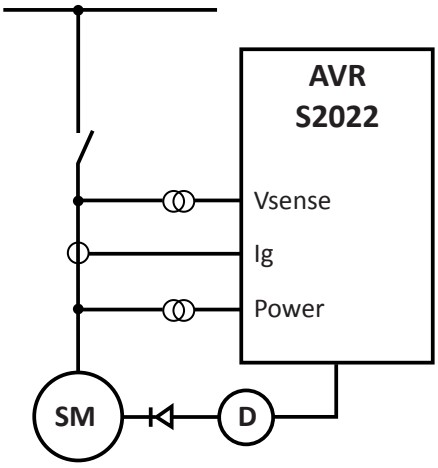
In this configuration the AVR is powered directly from the generator output (or from an auxiliary winding). The AVR DC output is feeding the stator of the exciter.



In this configuration the AVR is powered from a PMG. The AVR DC output is feeding the stator of the exciter.



This configuration shows a possible replacement of a Direct Current excitation machine.



2.7 Hardware

Structure:

The device is assembled inside a plastic case with aluminum base, and it is fixed on a heat dissipater.
The connection terminals are integrated on the top of the circuit boards.

Power electronics:

- The power circuit is designed with IGBT semiconductors.
- A fuse protects the output against short-circuits.

Control elements:

- The operating keys and the display are located on board.
- The communication port connector is located on the front of the AVR.

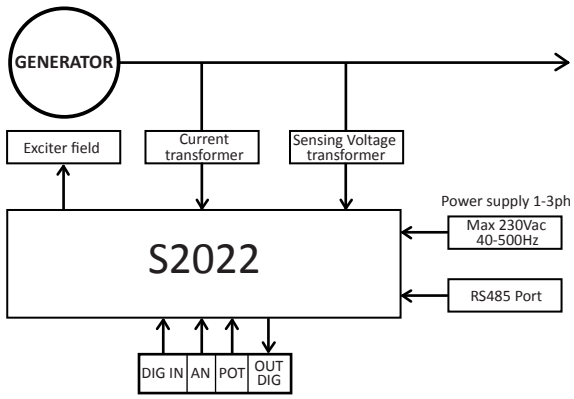
Installation:

- The site of installation must be dry and free of dust. The AVR can be installed in vertical or in horizontal position.

Mounting:

- The AVR must be installed inside the Generator or inside the control panel in order to obtain protection against accidental contacts. To fasten the regulator, use the diam 6 holes in the 4 corners holes. It is recommendable to use self-locking nuts. It is recommended also to bind the regulator back on a metal plate for better heat dissipation.

Connection block diagram:



2.8 Control elements and interfaces

Carrying out settings on the unit

The displays and the four keys allow complete operation.
All settings can be carried out directly on the unit without additional equipment.

- Inputs and outputs configuration;
- Parameter setting;
- Selection on the display of the main measured values.

Interface with PC (see the dedicated chapter)

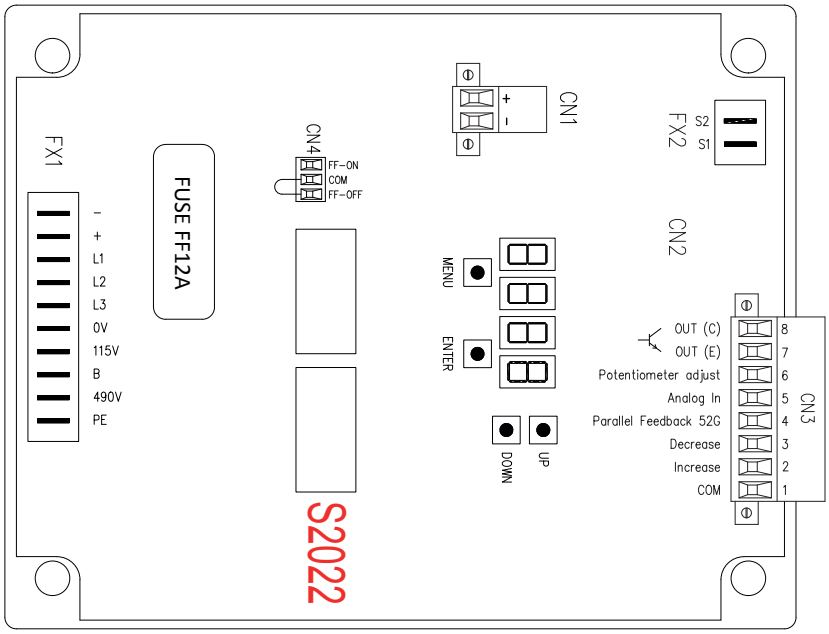
Parameter setting and optimization is possible using the user-friendly software Beltrame Configurator for Microsoft Windows. Using an USB/RS485 cable (made by Beltrame - Optional), with USB insulator, for the connection between PC and AVR, is possible to:

- Configure inputs and outputs;
- Set all parameter;
- Select on the display all the measured values;
- Download, upload, save and open config files;
- … and a lot more.

IMPORTANT!
Parameters can be read or modified only through the on board display and/or only from PC through the dedicated software (supplied as optional from Beltrame CSE).
Note: The interface is not isolated from the power supply: in order to connect with a pc or other devices an interface isolator must be used.

2.9 Terminal blocks

Overview of the device connections:



Description of the terminals:

CN2 – RS 485 Serial Interface	**CN3 – Control connections**	
GND	**C1**	Common
GND	**C2**	Increase reference adjust
-RESERVED-	**C3**	Decrease reference adjust
LINK –	**C4**	52G status (parallel feedback)
LINK +	**C5**	±5V analog input
-RESERVED-	**C6**	1Kohm Potentiometer input
-RESERVED-	**C7**	OUT (E)
-RESERVED-	**C8**	OUT (C)
Note: the reserved pins have to be left unconnected		
FX1 - Power connections	**FX2 – CT sensing input**	
Excitation output (Field -)	**S1**	C.T. input S1
Excitation output (Field +)	**S2**	C.T. input S2
Power supply	**CN1 – Auxiliary AVR power supply**	
Power supply	**1**	+12÷35 Vdc
Power supply	**2**	GND (-)
Sensing reference	**CN4 – Field Flashing**	
Sensing	**ON**	FF ON
Bridge B-115V if sensing >100V	**com**	Common
Sensing	**OFF**	FF OFF
GND		

3. DEVICE CONNECTIONS

Required Qualification

Personnel involved in installation work and commissioning of the S2022 must be familiar, specially instructed and informed about the residual danger areas according to the regulations currently in force.

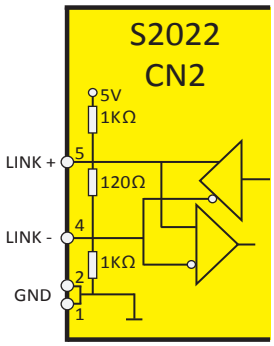
Only specially instructed personnel must carry out maintenance and repair work.

3.1 Input/Output power connection / rated data

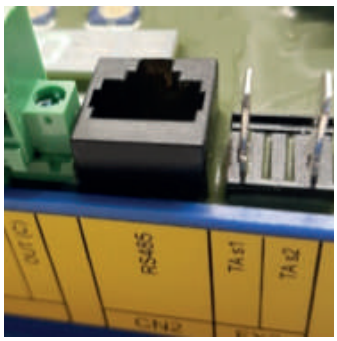
Terminal designation (CN1, FX1 AND FX2)	Terminals	Signal	Specifications
Main power supply (CN1)	+ , -	DC Input voltage	12÷35 Vdc
Main power supply (*) (FX1)	L1, L2, L3	Input voltage mono/three phase	Rated 230 Vac - (max 300 Vac) 0÷500 Hz
		DC Input	0÷300 Vdc
Measurements inputs (FX1) (FX2)	0-115-B-490	Generator voltage	0÷115Vrms 0÷490 Vrms (with bridge between 115V and B)
	TA s1 – TA s2	Generator current	0-5 Arms
Excitation output (Field) (FX1)	-, +	Excitation voltage	300Vdc max
		Excitation current	0÷10 A (20 A per 10 s) Ta < 50°C

*** IMPORTANT**: S2022 allows the sudden application of the full power supply voltage (230V)

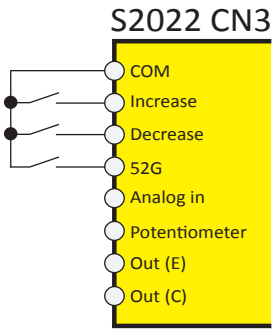
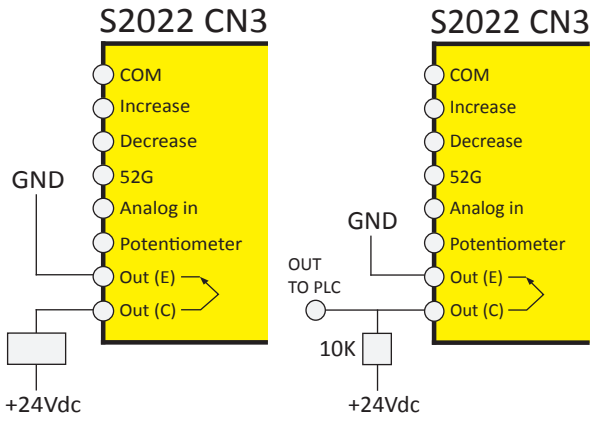
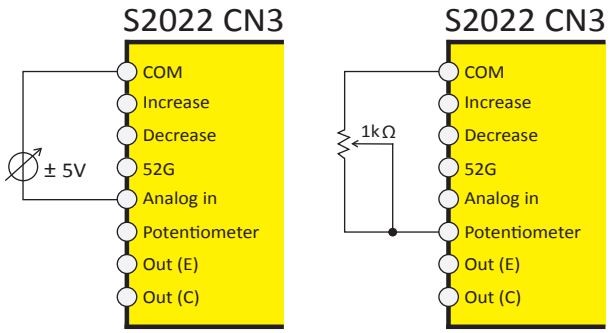
3.2 Device connections: CN2 Interface

Terminal designation	Description	Diagram
Communication	Modbus RTU and proprietary protocols half duplex Isolated from Main power supply **Not isolated from auxiliary power supply** 	

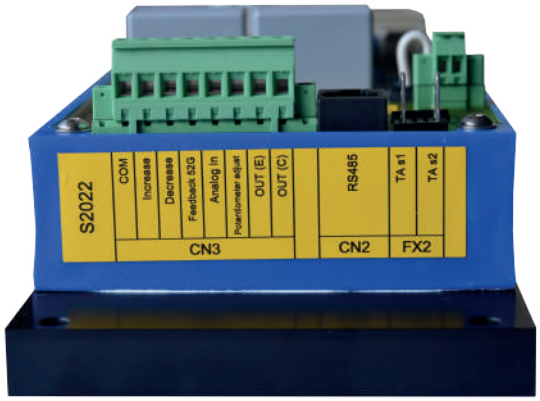
CN2 picture:



3.3 Device connections: CN3 I/O control signals

Terminal designation	Description	Diagram
CN3 Digital inputs	3 programmable digital inputs • 4mA max current • Up / Down / programmable function • AVR/FCR/PF/VAR mode	
CN3 Digital outputs	N.1 programmable digital output **Max Load 65mA 24Vdc**	
2x Analog inputs	Analog input signals to remote adjust the setpoint **The voltage analog input is not isolated from power supply** 	 Analog input: ± 5V | Potentiometer input: 1kohm

CN3 picture:

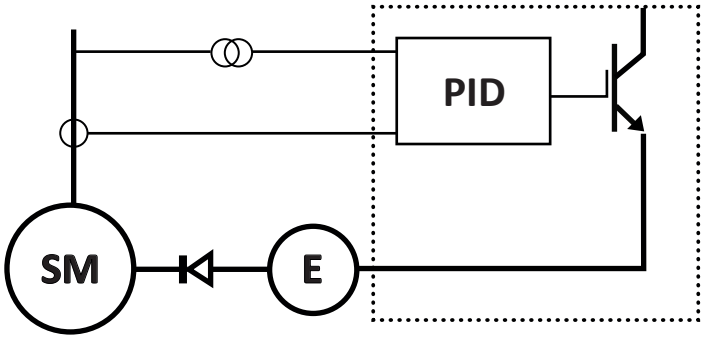


4. OPERATING MODES

S2022 allows bump less changeover between all operation modes:

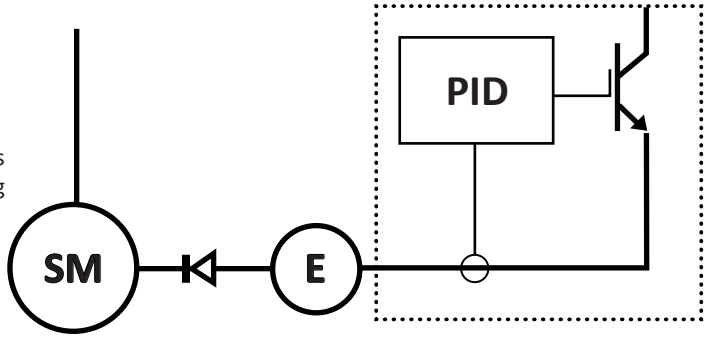
Automatic voltage regulator (AVR)

It regulates the output voltage of the synchronous machine.
Note: Output Generator Current measurement is optional: it is used only for droop compensation



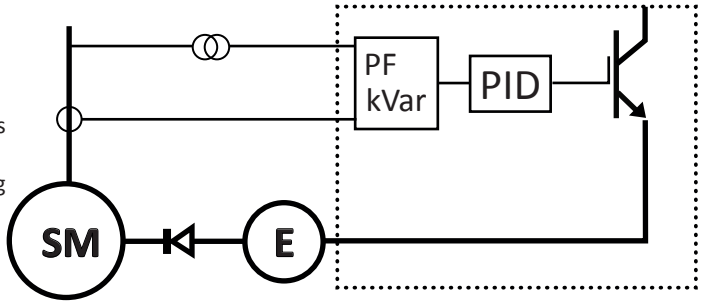
Field Current Regulation (FCR)

It regulates the excitation (field) current of the synchronous machine. This operation mode is quite useful during commissioning and/or troubleshooting.



PF or Var regulation (PF, Var)

Regulates the power factor or reactive power of the synchronous machine.
Note: these functions are available only if the machine is working in parallel (and with closed 52G signal).

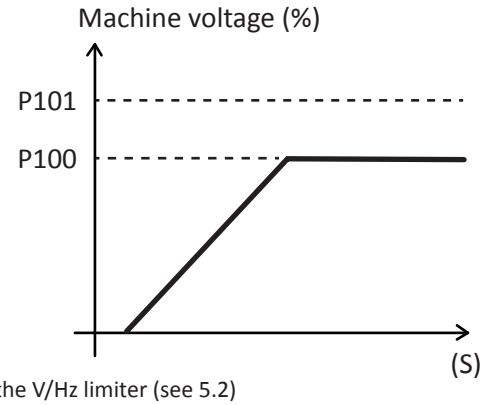


5. FUNCTIONS DESCRIPTION

5.1 Soft Start

Setting the following parameters, it is possible to set up the excitation ramp of the Generator (Output Voltage vs Time):

Parameter	*Description (short)*	*Description*
P.100	*Gen rated voltage*	Generator rated voltage [V]
P.101	*Max Gen voltage*	Generator maximum voltage [%]
R.002	*Ramp slope*	Ramp slope [%/s]

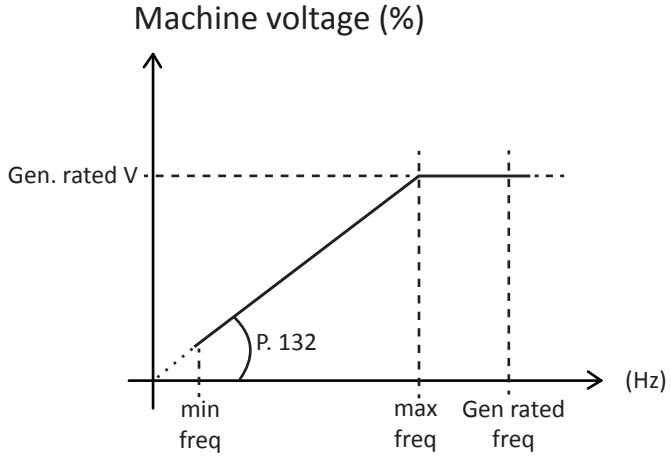


The voltage ramp is controlled also by the V/Hz limiter (see 5.2)

5.2 V/Hz Limiter (Under-frequency protection Effects)

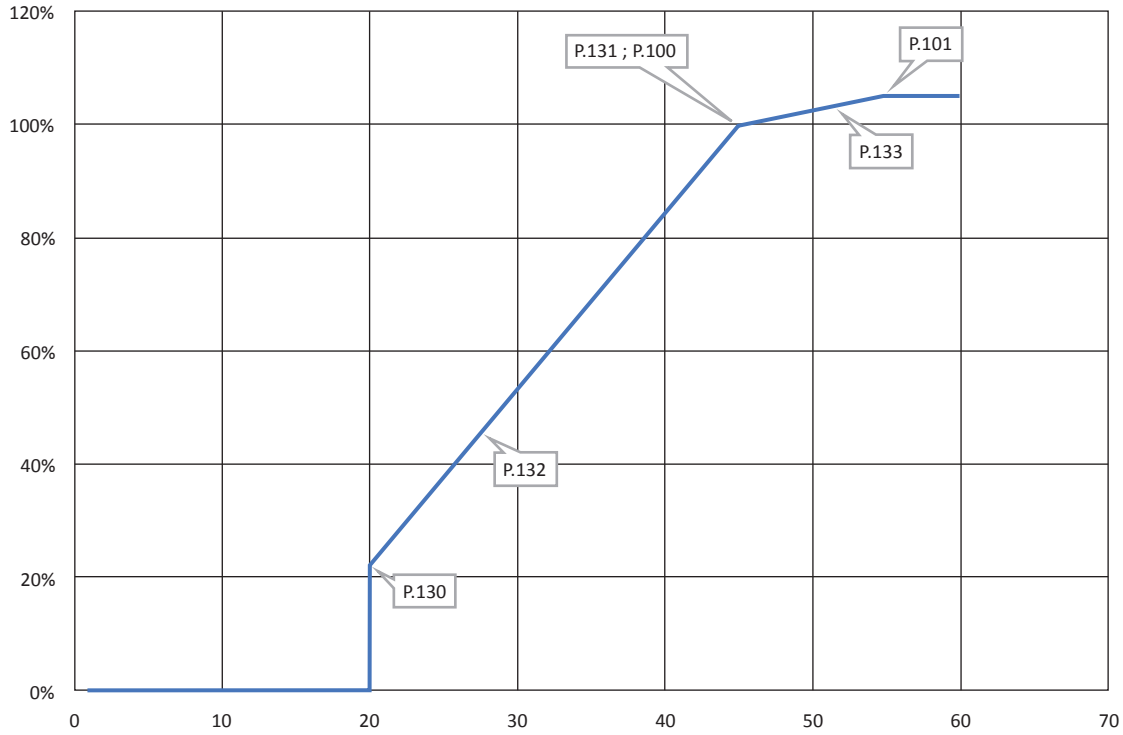
The ramp of the generator voltage is influenced by the frequency. The V/Hz limiter is always active in order to avoid overflux situation. It reduces the voltage when the frequency (the speed) drops below the knee point.

Parameter	*Description (short)*	*Description*
P.100	*Gen rated voltage*	Generator rated voltage [V]
P.101	*Max Gen voltage*	Generator maximum voltage [%]
P.130	*Gen V – Min Frequency*	Starting of the excitation process (Hz)
P.131	*Gen V – Max Frequency*	Below this frequency the voltage starts to decrease (knee point)
P.132	*Gen V/Hz slope*	Slope of the voltage vs frequency line from P.130 to P.131
P.133	*Gen V/Hz slope over*	Slope of the voltage vs frequency line over P.131 (with P.101 limit)



See also following example:

Example	
P.100	100%
P.101	105%
P.130	20Hz
P.131	45Hz
P.132	2%/Hz
P.133	0,5%/Hz



Note: The voltage corresponding at the minimum frequency (P.130) results from:

Vgen @ Fmin = Vgen_nom * (Fmin / Fmax) / Slope

This, introducing the parameters, means:

Vgen @ Fmin = P.100 * (P.130 / P.131) / P.132

5.3 Field Flashing and 'Keep Alive'

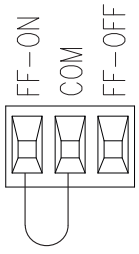
To manage the self excitation of the machine it is necessary to properly set Field Flashing and Keep Alive functions. With Filed Flashing ON, during the start-up of the synchronous machine, the S2022 triggers the field flashing that supplies an impulsive current until the AVR has enough input voltage to control and regulate the machine output voltage at the set value. After that phase the field flashing will be disabled.

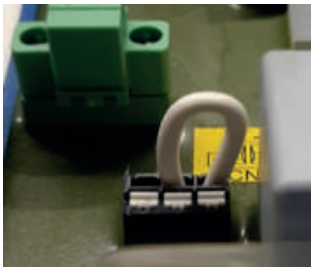
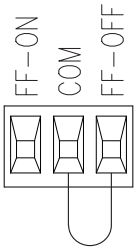
Conditions	***Recommended Field Flashing setting***
AVR powered from generator terminals	FF ON
AVR powered from internal auxiliary winding	FF ON
AVR powered from PMG	FF OFF
AVR powered from external auxiliary power supply	FF OFF

As general rule: if at P.130 the AVR power supply circuit is already alive, the Field Flashing has to be set to OFF.

if at P.130 the AVR power supply circuit has not voltage, the Field Flashing has to be set to ON.

The enable/disable operation of the Field Flashing has to be done moving the jumper on the CN4 connector:

Field Flashing ON (enabled):		

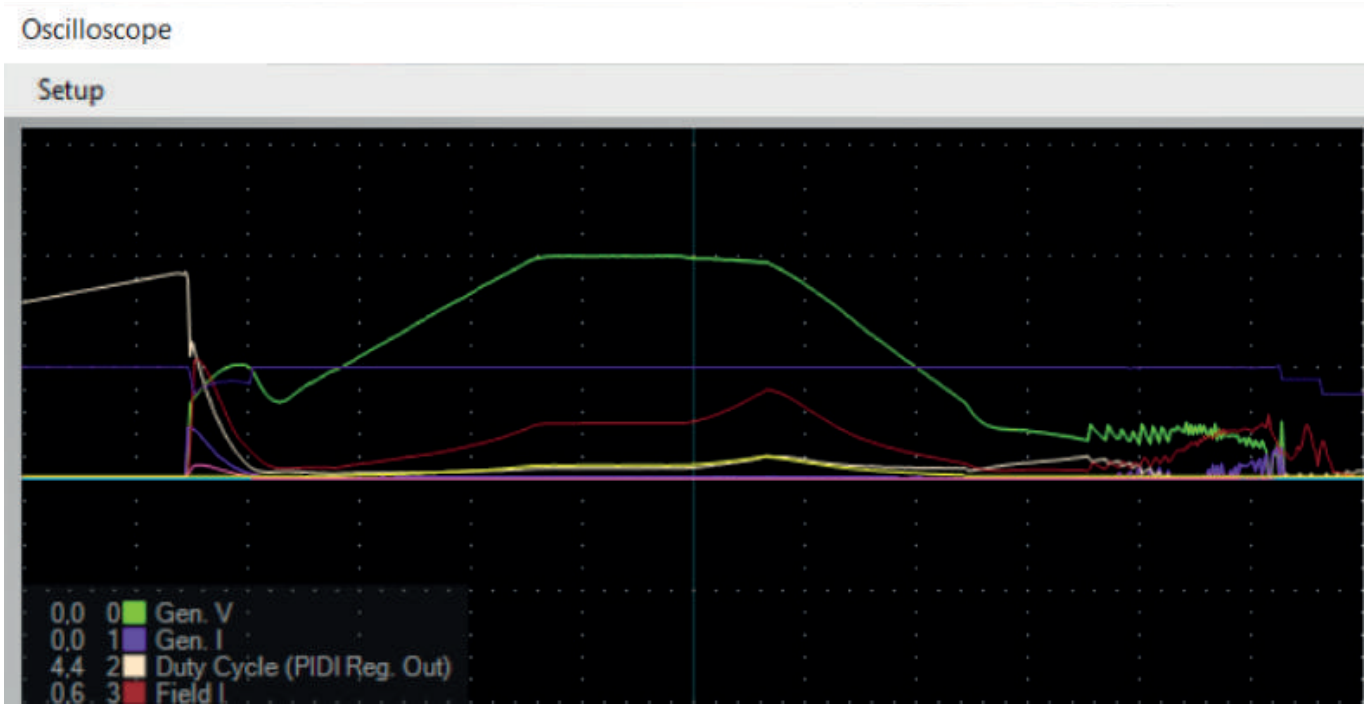
Field Flashing OFF (disabled):		

Field Flashing and self-excitation procedure is influenced also by the Keep Alive function. The **"keep alive"** feature allows to maintain a minimum excitation current even when the Generator frequency drops below the minimum (P.130). The minimum excitation current value can be adjusted using parament P.250; this setting must be done based on the power source (set up to 0 if the power is from PMG or auxiliary). With "keep alive" enabled (P.250>0), the S2022 will try to keep a minimum excitation current during the start-up (and during the shutting down*). As default P.250 is adjusted to 5. This means that the S2022, during the start-up (and shut-down), will try to keep the excitation current to 5% of the rated excitation current (P.000). Once the frequency will be higher the P.130 (Generator minimum frequency), the AVR will leave the "keep alive" area and will enter in the V ramp area.

In case the AVR is powered with a PMG or with an external power source the "Keep Alive" function has to be disabled (set P.250=0). With P.250=0 also the Field Flashing is disabled, does not matter the bridge position described above.

* = To keep alive the regulator

Parameter	*Description (short)*	*Description*
P.250	*KeepAlive min I*	% of the rated exc current (P.000) from 0Hz to P.130 Hz
P.130	*Gen. V/f min freq*	Generator minimum frequency (Hz)



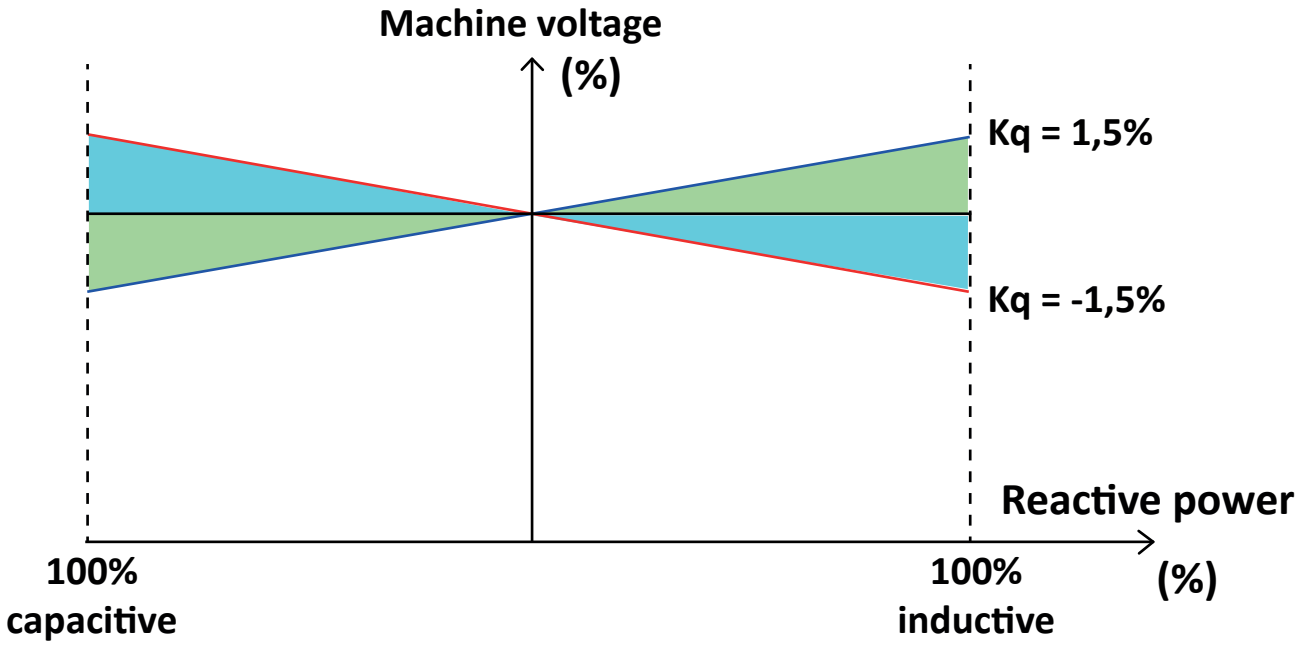
Above screenshot shows the Field Flashing and the Keep Alive functions effects during generator starting up and shutting down. Once the frequency drops below P.130 the AVR activates the keep alive function and works in order to maintain the excitation current to the P.250 keep alive setting (in this case 5%).

5.4 Compensation and Droop functions

The compensation function (K> 0) is used in order to reduce the voltage drop created by the possible presence of a power transformer mounted after the Generator. The 'droop' function (K<0) is recommendable in case of operation with more generators in parallel. It applies a machine output voltage reduction according to the reactive power output. The "droop" function reduces the output voltage according the reactive power output (higher is the reactive power, lower will be the output voltage).

Compensation and droop functions require:

- AVR mode;
- alternator current reading;
- digital input 3 programmed as I002= 4 (52G closed + Droop regulation).



Parameter	*Description (short)*	*Description*
P.400	*Voltage comp K*	Voltage comp [%]

5.5 Limiters

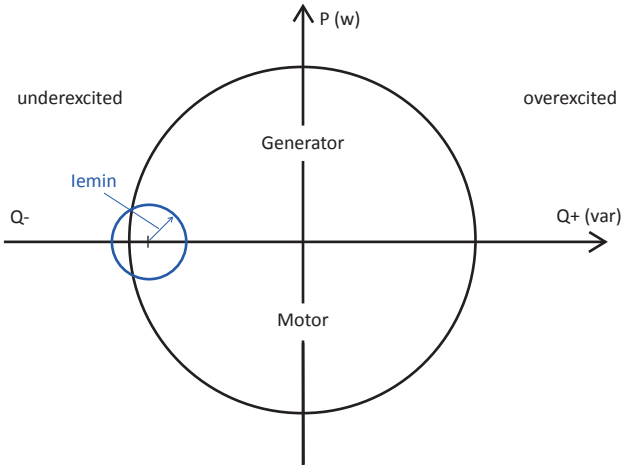
5.5.1 V/f Limiter

The V / Hz limit is active during the voltage control phase. It works by limiting the Generator voltage as the frequency falls below the maximum frequency P.131. This operation can avoid the Generator over-flushing in case of a reduction of speed.
V/Hz limiter function and setting is described in 5.2.

5.5.2 Minimum excitation current: Under Excitation limiter

The limit of minimum excitation current is only active when the Generator is in parallel [digital input 52G (machine in parallel) closed].

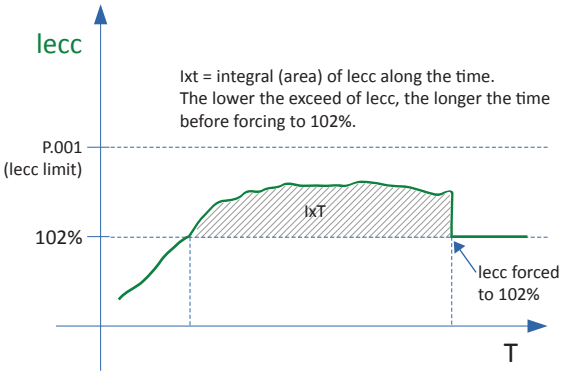
IMPORTANT!
It represents the minimum excitation current below which the Generator cannot work.
As default configuration the limit P.002 is adjusted to zero.

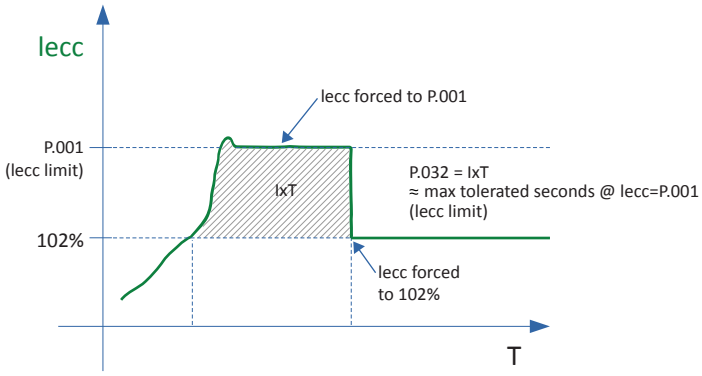


Parameter	*Description (short)*	*Description*
P.002	*F. UE Lim*	OE/UE Lim reg TI
r.900	*OE/UE Lim reg KP*	OE/UE Lim. Reg. KP
r.901	*OE/UE Lim reg TI*	OE/EU Lim. Reg. TI

5.5.3 Maximum excitation current: Over Excitation limiter

The limit of maximum excitation current operates a limitation on the maximum excitation current.
The limit works in order to avoid to overtake the P.001 value, and if the excitation current remains on P.001 for longer than P.032, the AVR reduce the excitation current to 102%. If the excitation current goes in the area between P.000 and P.001, the AVR calculate the i*t integral and once P.001xP.032 is reached, the AVR reduces the excitation current to 102%.

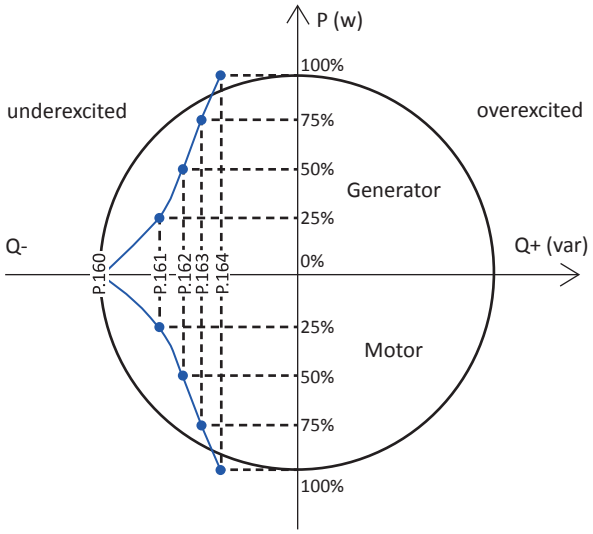




Parameter	*Description (short)*	*Description*
P.000	*F. rated I*	Field rated I [A]
P.001	*F. OE Lim*	Field OE Lim. [%]
P.004	*% F. rated I @ min freq*	It allows to reduce the rated field current at low speed. The rated Field Current goes linearly from the two points: A: (P.130; P.004) → B: (P.131; P.000)
P.032	*F. OE Lim time*	Field OE Lim time [s] Time of permanence (dwell time) of excitation current on values between 102% and P.001 (inverse time curve). Three cases can be distinguished: 1. If Iecc≤102% the limiter is disabled 2. If 102%<Iecc≤Ioe integral IxT is feeded/incremented 3. If Iecc≥Ioe the AVR limits to Ioe for the time set in P032. Once the time has passed, the AVR reduced the current to 102%.
r.900	*OE/UE Lim reg KP*	OE/EU LIM reg KP
r.901	*OE/UE Lim reg TI*	OE/EU LIM reg TI

5.5.4 Minimum capability: Q- limiter

The curve of minimum capability represents the reactive power limit absorbed by the machine. It is determined by interpolating 5 data:

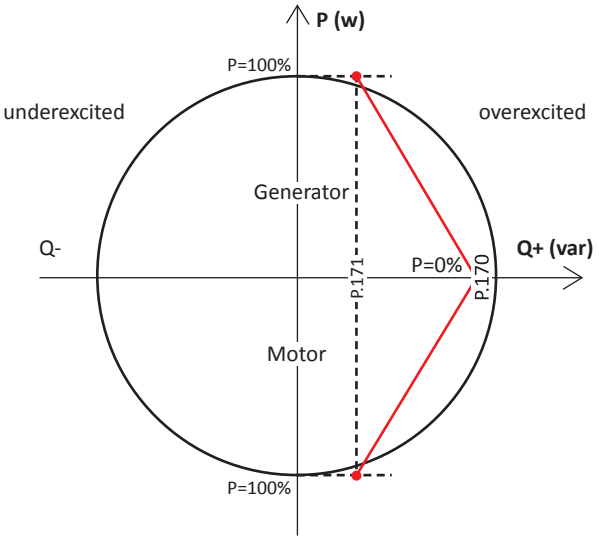


Parameter	*Description (short)*	*Description*
P.160	*Q – lim @ P 0%*	Limit Q- a P=0%
P.161	*Q – lim @ P 25%*	Limit Q- a P=25%
P.162	*Q – lim @ P 50%*	Limit Q- a P=50%
P.163	*Q – lim @ P 75%*	Limit Q- a P=75%
P.164	*Q – lim @ P 100%*	Limit Q- a P=100%

5.5.5 Maximum capability: Q+ limiter

The curve of maximum capability represents the reactive power limit delivered by the machine. It is determined by interpolating 2 data:

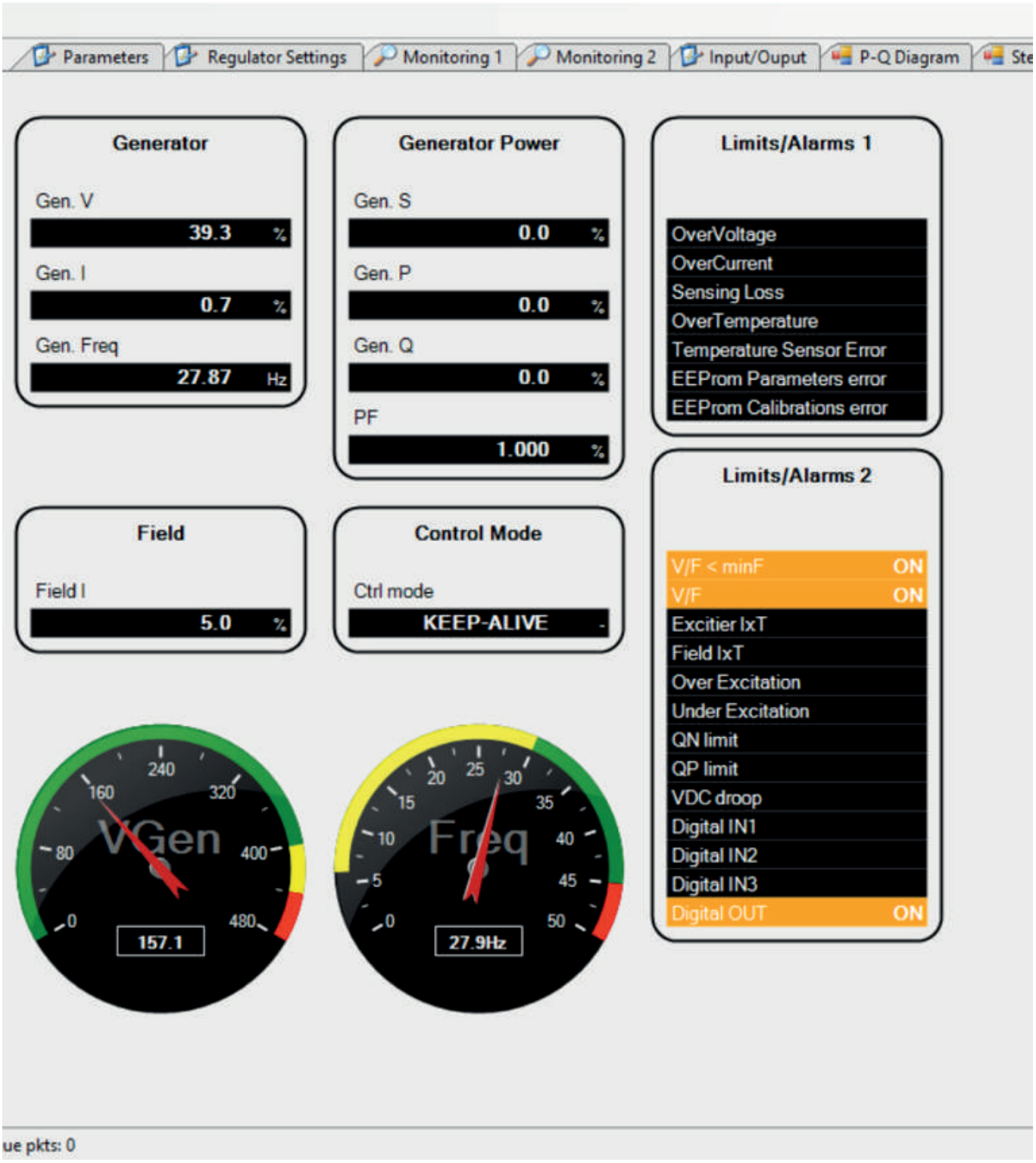
- Q+ limit a P=0% P.170 [%]
- Q+ limit a P=100% P.171 [%]



Parameter	*Description (short)*	*Description*
P.170	*Q + lim @ P 0%*	Limit Q+ a P=0%
P.171	*Q + lim @ P 100%*	Limit Q+ a P=100%

5.5.6 S2022 Beltrame Configurator: Limiters status

The Beltrame Configurator software reports an overview of the limiters status:



The reported limiters status shows that the V/Hz (underfrequency or underspeed) limiter is active.

From the image above it is possible to notice also:

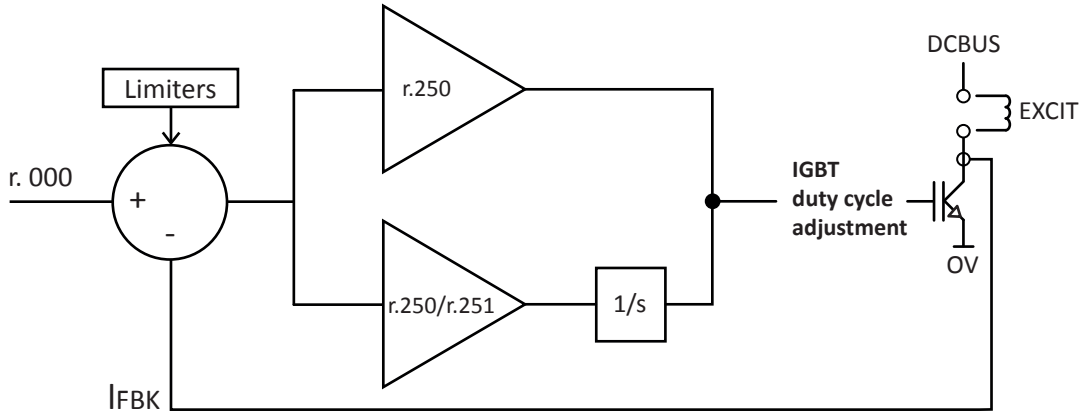
- That the Frequency is lower than the min frequency (P.130);
- That the Keep Alive is active, with the field current maintained at the 5%.

6. WORKING MODE AND REGULATIONS

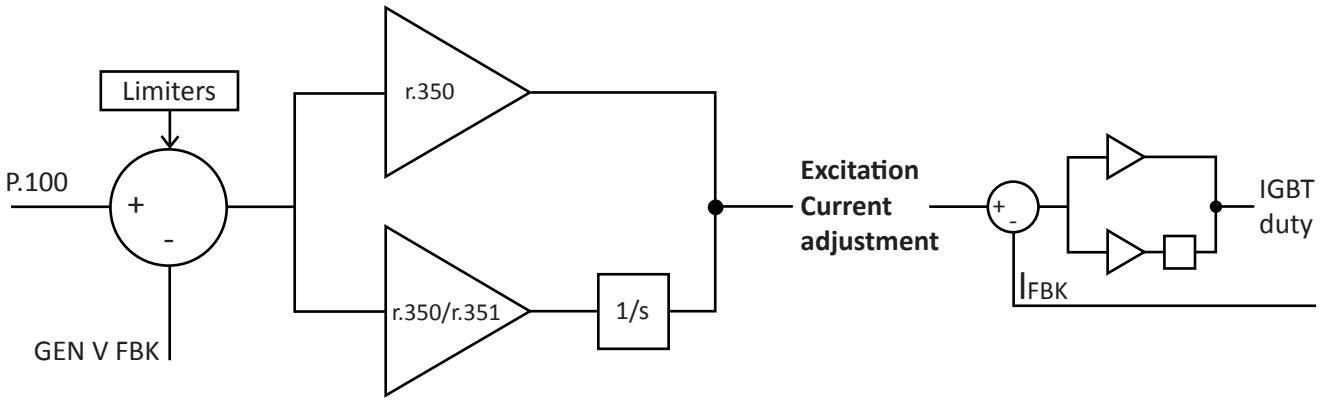
Basically, there are 4 working modes (4 regulation mode):

- **FCR** [Field Current Regulation]: S2022 works in order to keep the excitation current to the ref value.
- **AVR** [Automatic Voltage Regulator]: S2022 works in order to keep the output voltage to the ref value.
- **PF Control** [Power Factor Regulator]: S2022 works in order to keep the PF to the ref value.
- **VAR Control** [Reactive Power Regulator]: S2022 works in order to keep the Reactive Power to the ref value.

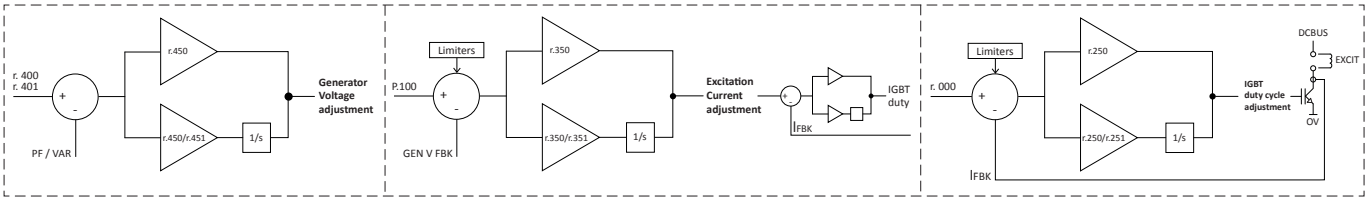
1. FCR [Field Current Regulation]



2. AVR [Automatic Voltage Regulator]



3. PF/VAR [Control]



6.1 Automatic voltage regulator (AVR)

The AVR automatically controls the output voltage at the generator terminals.
This is the main working mode.
The AVR function is active if P300=1.
As alternative it is possible to activate the AVR function programming the digital input I002=4, and closing the external contact.

Parameter	*Description*	*Note*
P.100	*Generator rated voltage*	*V rms*
r.002	*Ramp slope*	*%/s*
r.350	*Generator V Reg KP*	
r.351	*Generator V Reg TI*	
r.010	*Delta Ref calibrator*	*% (See chapter 6.5)*
r.011	*Delta Ref analog*	*% (See chapter 6.6)*
r.012	*Delta ramp slope*	*%/s*

If AVR is activated from zero (S2022 in OFF situation), after the start, the S2022 will go to P.100 generator voltage value following the R.002 ramp slope.

If AVR mode is activated from another working mode situation (FCR, PF, VAR), the S2022 will keep the generator voltage at the moment of

6.2 Field Current Regulation (FCR)

WARNING!
This working mode allows to control the AVR output field current. In this case the AVR controls only the output current to the regulator excitation terminals, without considering other effects. This situation can be potentially dangerous. This functioning mode could become useful during the regulator commissioning, or in case of troubleshooting activities.

FCR function will be activated setting **P300=0**.
As alternative it is possible to activate the FCR function programming the digital input I002=3, and closing the external contact.

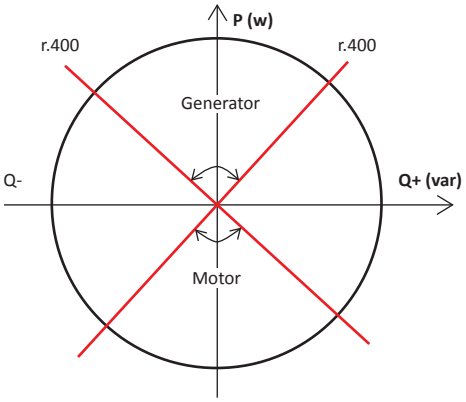
Parameter	*Description*	*Note*
r.000	*F. I digital*	*% compared to P.000*
r.002	*Ramp slope*	*%/s*
r.250	*Field I Reg KP*	
r.251	*Field I Reg TI*	
r.010	*Delta Ref Calibrator*	*% (See chapter 6.5)*
r.011	*Delta Ref analog*	*% (See chapter 6.6)*
r.012	*Delta ramp slope*	*%/s*

If FCR is activated from zero (S2022 in OFF situation), after the start, the S2022 will go to r.000 field current following the R.002 ramp slope. Pay attention that, as default, r.000 is set to zero. When r.002 is over, it will be possible to adjust the field current using, for example, the increase/decrease command(calibrator).

If FCR is activated while the S2022 is working (with voltage on the alternator terminals), the S2022 will keep the field current at the moment of the FCR activation. The passage from any working mode to FCR (and vice versa) is bumpless.

6.3 Power Factor regulation (PF)

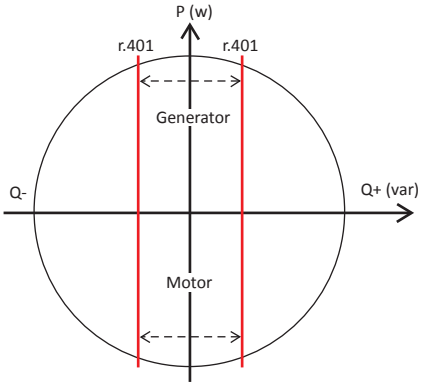
The AVR controls in automatic mode the power factor at generator terminals. The PF function is active when P300= 1, and I002= 5; once the 52G digital input (generator in parallel) is closed, the PF function starts to work. Generator current reading is necessary to use this function. Be aware of the correct PF reading.



Parameter	Description	Note
r.400	*Generator PF digital ref*	
r.402	*Ramp slope*	*%/s*
r.450	*PF/VAR Reg KP*	
r.451	*PF/VAR Reg TI*	
r.410	*Delta Ref Calibrator*	*(See chapter 6.5)*
r.411	*Delta Ref analog*	*(See chapter 6.6)*
r.412	*Delta ramp slope*	

6.4 Reactive power regulation (VAR)

The AVR controls in automatic mode the reactive power at generator terminals. The VAR function is active when P300= 1, and I002= 6; once the 52G digital input (generator in parallel) is closed, the VAR function starts to work. Generator current reading is necessary to use this function. Be aware of the correct VAR readin



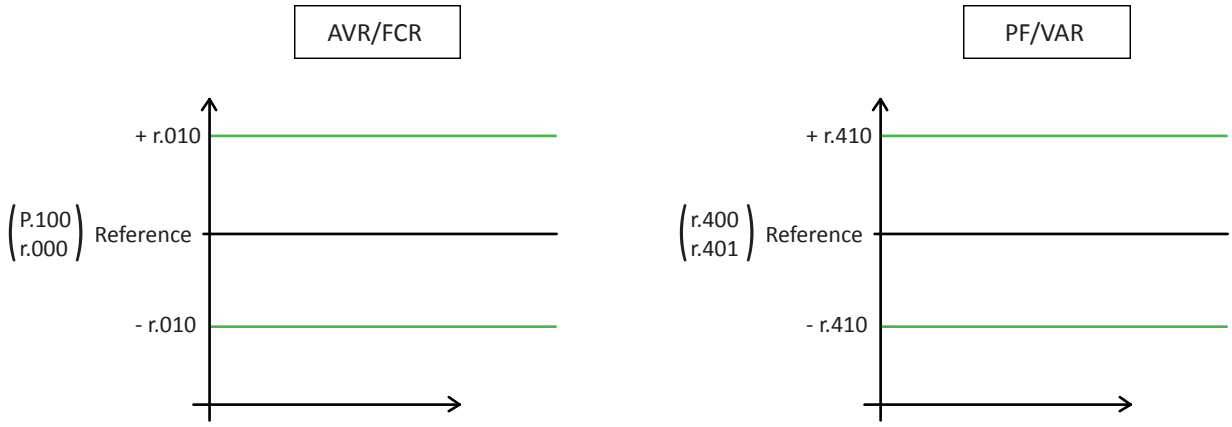
Parameter	Description	Note
r.400	*Generator PF digital ref*	*% compared to P.100 xP.110*
r.402	*Ramp slope*	*%/s*
r.450	*PF/VAR Reg KP*	
r.451	*PF/VAR Reg TI*	
r.410	*Delta Ref Calibrator*	*(See chapter 6.5)*
r.411	*Delta Ref analog*	*(See chapter 6.6)*
r.412	*Delta ramp slope*	

6.5 Digital reference adjustment by calibrator (Up/Down)

In AVR mode, by programmed digital inputs (I.000=1 increase, I.001=2 decrease) on CN3 connector, it is possible to adjust the nominal voltage set point in a range between -r.010% and +r.010%. The same function is available in FCR mode, in this case the UP/DOWN input is influencing the excitation current. The setpoint transition speed is set by par r.012.

After closing of 52G (programmed as I.002=5 (Parallel + PF regulation)), the “increase” and “decrease” commands increase or decrease the Power Factor value.

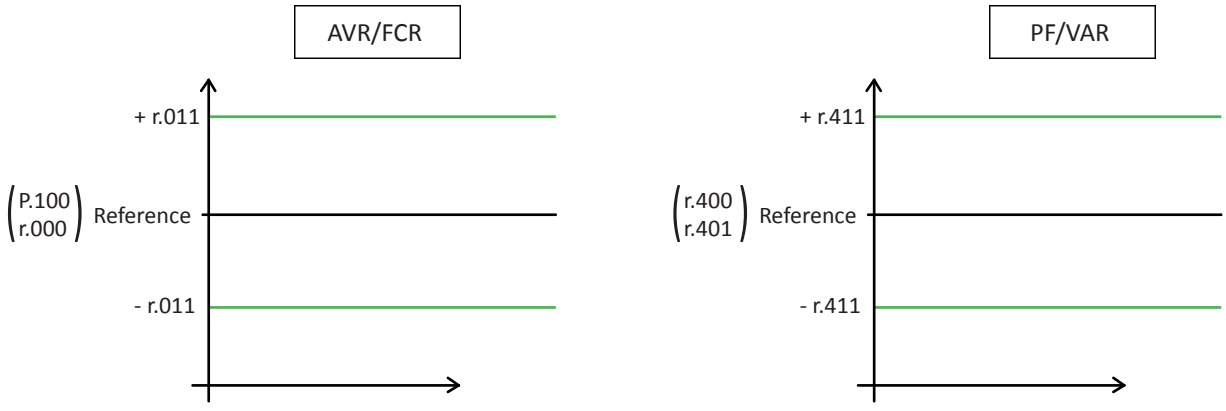
After closing of 52G (programmed as I.002=6 (Parallel + VAR regulation)), the “increase” and “decrease” commands increase or decrease the Reactive Power value.



As default r.010 is programmed to 0%, this means the Up/Down function is disabled.
Set the desired adjustment range to activate the function.

6.6 Digital reference adjustment by analog inputs

As above, using the analog inputs (Potentiometer or ±5Vdc) on CN3 connector, it is possible to adjust the set point in a range between -r.011% and +r.011% (AVR/FCR) or between -r.411% and +r.411% (PF/VAR). The setpoint transition speed is set by par r.412.



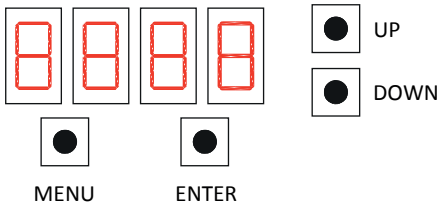
As default r.011 is programmed to 0%, this means the Up/Down function is disabled. Set the desired adjustment range to activate the function.

IT IS RECOMMENDED TO DO NOT USE SIMULTANEOUSLY ANALOG AND DIGITAL INPUTS FOR SET POINTS MODIFICATIONS.

7 OPERATOR INTERFACE

In this chapter, it is described how parameters are managed by using the on-board programming keypad.

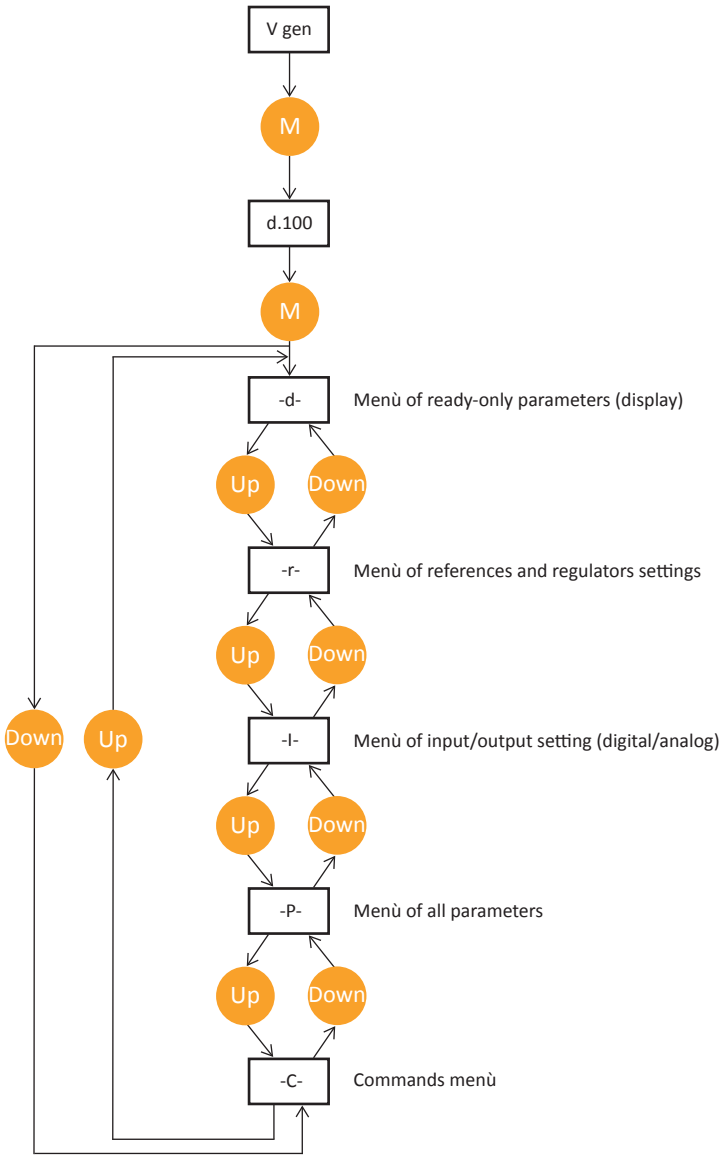
7.1 Control Keypad and display



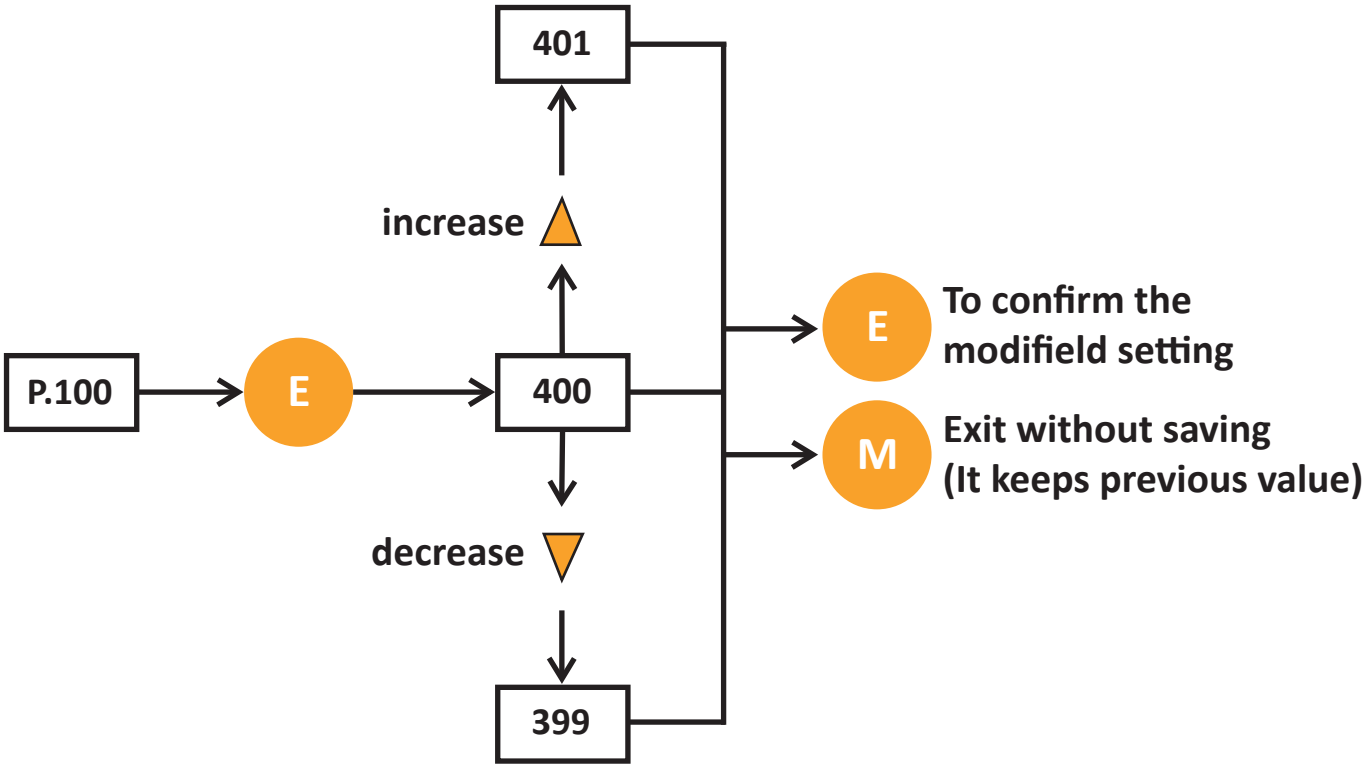
MENU: allows to quit a parameter or a menu.
ENTER: allows to enter a parameter or a menu.
UP: allows to move from a parameter or menu to the following one and /or increase the value.
DOWN: allows to move from a parameter or menu to the previous one and/or decrease the value.

7.2 Navigating inside the menus

Once the S2022 is ON, the display shows automatically the parameter d100 (Generator voltage).

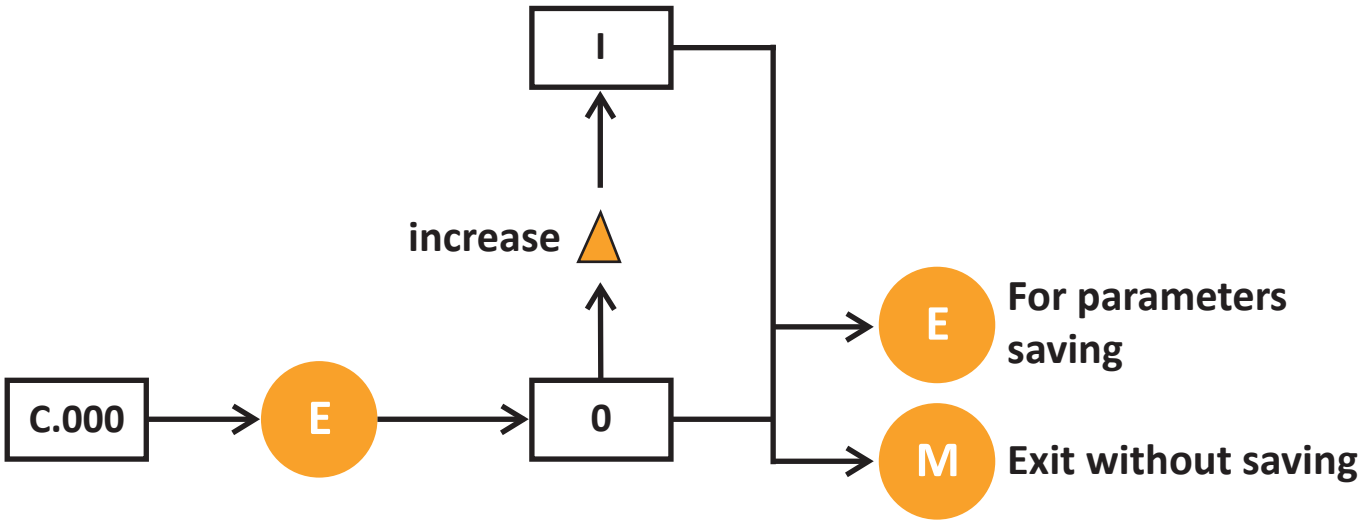


Example: how to change the rated voltage generator setting.



7.3 Parameters Saving

IMPORTANT!
Even if the modifications on the parameters are immediately active, they are not automatically saved. To save them you need to use command “C.000” [save parameters].



7.4 Menù Description

7.4.1 Menù "d" – Display (readings)

DISPLAYS	Terminals	IPA	Description	[U.M.]	Min	Default	Max	Notes, values
Field data	**d.000**	0	Field Current	%	0,0	-	200,0	% of P.000
	d.001	1	Limit Active	%	0,0	-	100,0	0=> no limits. 1 => one or more limits active
Generator data	**d.100**	2	Gener. Rated V	%	0,0	-	-	% of P.100
	d.104	3	Gener. Rated Freq.	Hz	0,00	-	440,0	
	d.110	4	Gener. Current	%	0,0	-	-	% of P.110
	d.111	5	Gener. PowerFact	-	0,25 c	-	0,25 i	Capacitive / Inductive
	d.120	6	Gener. Power S	%	0,0	-	-	% of P.100xP.110
	d.121	7	Gener. Power P	%	0,0	-	-	% of P.100xP.110
	d.122	8	Gener. Power Q	%	-	-	-	% of P.100xP.110
AVR data	**d.120**	9	FW ver. & rev.	-	-	-	-	xx.yy(hex)
	d.121	10	SN	-	-	-	-	y.nnn
	d.122	11	Heatsink Temp.	°C	-5	-	110	

7.4.2 Menù "r" – References and Regulators

REFERENCES & REGULATORS	Terminals	IPA	Description	[U.M.]	Min	Default	Max	Notes, values
Primary regulator (AVR,FCR)	**r.000**	200	F. I digital ref	%	0	**0,0**	P.001	% of P.000
	r.002	201	Ramp slope	%/s	0,1	**0,5**	999,9	
	r.010	202	Delta Ref calib	%	0	**0**	200	
	r.011	203	Delta Ref analog	%	0	**0**	200	
	r.012	204	Delta ramp slope	%/s	0,1	**1,0**	10,0	
Field current regulator	**r.250**	205	F. I Reg KP	-	0,25 c	**0,01**	0,50	
	r.251	206	F. I Reg TI	1/(2*AuxF)	0,0	**0,1**	20,0	related to Aux supply period
Generator voltage regulator	**r.350**	207	G. V Reg KP	-	0,25 c	**0,01**	0,50	
	r.351	208	G. V Reg TI	1/(2*GenF)	0,0	**0,1**	20,0	related to generator period
Secondary regulator (PF,VAR)	**r.400**	209	G. PF dig. ref	-	0,50c	**1,00**	0,50i	Capacitive / Inductive
	r.401	210	G. VAR dig. ref	%	-100	**0**	100	% of P.100xP.110
	r.402	211	Ramp slope	%/s	0,1	**1,0**	100,0	
	r.410	212	Delta Ref calib	%	0	**20**	100	
	r.411	213	Delta Ref analog	%	0	**0**	100	
	r.412	214	Delta ramp slope	%/s	0,1	**1,0**	10,0	
PF,VAR	**r.450**	215	PF/VAR Reg KP	-	0,01	**0,50**	99,99	
	r.451	216	PF/VAR Reg TI	10/(2*GenF)	0,1	**20,0**	100,0	related to generator period
Limiters regulator	**r.900**	219	OE/UE LIM Reg KP	-	0,01	**0,25**	99,99	
	r.901	220	OE/UE LIM Reg	1/(F reg)	0,1	**40,0**	100,0	related to generator period
	r.920		Manual PWM duty	%	0	**0**	100,0	Available when P300=2 (Manual PWM), internal use only

7.4.3 **Menù "I" – Inputs and outputs**

I/Os	Name	IPA	Description	[U.M.]	Min	Default	Max	Notes, values
Digital inputs	**I.000**	600	Dig inp 1 cnf	-	0	**1**	6	0 NONE 1 INCREASE CALIB 2 DECREASE CALIB 3 FCR Remote enabling 4 52G: Parallel + DROOP 5 52G: Parallel + PF reg. 6 52G: Parallel + VAR reg.
	I.001	601	Dig inp 2 cfg	-	0	**2**	6	
	I.002	602	Dig inp 3 cfg	-	0	**5**	6	
Digital outputs	**I.100**	603	Dig out 1 cnf	-	0	**3**	4	0 NONE 1 FAULT 2 NOT FAULT 3 LIMIT 4 NO LIMIT
RS485	**I.400**	604	RS485 config	-	0	**0**	4	0 custom protocol 1 MODBUS RTU 8N1 2 MODBUS RTU 8E1 3 MODBUS RTU 8O1 4 MODBUS RTU 8N2
	I.401	605	RS485 bitrate	-	0	**3**	5	0 4800 1 9600 2 19200 3 38400 4 57600 5 115200
	I.402	606	RS485 Modbus node ID	-	1	**1**	247	
	I.404	607	RS485 Modbus delay	s	0,000	**0,001**	0,100	Delay between Modbus reception and answer.

7.4.4 **Menu "C" – Commands**

COMMANDS	Name	IPA	Description	[U.M.]	Min	Default	Max	Notes, values
Utility commands	**C.000**	1600	Params save	-	0	**0**	1	Saves parameters in persistent memory
	C.002	1601	Default Params reload	-	0	**0**	1	(*)
	C.200	1602	Test step	-	-8192	**0**	8192	8192=100%
	C.201	1603	Test step type	-	0	**1**	3	0= Field I ref 1= Generator V ref 2= Generator PF ref 3= Generator VAR ref

(*) IMPORTANT: programming C.002=1 the S2022 reload the default setup. The default parameters are loaded in rutime memory. If you want to save them in persistent memory, please use command C.000."

7.4.5 **Menu "P" – Parameters**

This is the most important menu for normal operation.
In the majority of the applications it will be necessary to access to the Parameter menu only.

PARAMETERS	Name	IPA	Description	[U.M.]	Min	Default	Max	Notes, values
Field excitation data	**P.000**	1000	F. rated I	A dc	1,0	**10,0**	10,0	
	P.001	1001	F. OE Lim	%	100	**150**	250	% of P.000
	P.002	1002	F. UE Lim	%	0	**0**	50	% of P.000
	P.004	1003	F. rated I @ min Fred	%	0	**100**	100	% of P.000
	P.032	1004	F. OE Lim time	s	1	**10**	240	
Generator data	**P.100**	1005	G. rated V	V rms	50	**400**	500	
	P.101	1006	G. max V	%	105	**120**	120	% of P.100
	P.110	1007	G. rated I	A rms	0,20	**5,00**	5,00	(*)
	P.130	1008	G. V/f min freq	Hz	20	**30**	150	
	P.131	1009	G. V/f max freq	Hz	P.130	**45**	250	
	P.132	1010	G. V/f slope	%/Hz	1,0	**2,0**	4,0	
	P.133	1011	G. V/f slope over max freq	%/Hz	1,0	**0,0**	4,0	
	P.160	1012	Q – lim @ P 0%	%	-100	**-100**	-5	% of P.100 x P.110
	P.161	1013	Q – lim @ P 25%	%	-100	**-100**	-5	% of P.100 x P.110
	P.162	1014	Q – lim @ P 55%	%	-100	**-100**	-5	% of P.100 x P.110
	P.163	1015	Q – lim @ P 75%	%	-100	**-100**	-5	% of P.100 x P.110
	P.164	1016	Q – lim @ P 100%	%	-100	**-100**	-5	% of P.100 x P.110
	P.170	1017	Q + lim @ P 0%	%	5	**100**	100	% of P.100 x P.110
	P.171	1018	Q + lim @ P 100%	%	5	**100**	100	% of P.100 x P.110
Power supply	**P.250**	1019	KeepAlive Field I	%	0	**5**	100	% of P.000 set 0 for PMG or other independent Power Supply
Control mode	**P.300**	1020	Primary reg.	-	0	**1**	2	0 FCR 1 AVR 2 Manual PWM: Warning, internal use only
Voltage Droop Compensation	**P.400**	1021	Voltage comp K	%	-10,0	**0,0**	10,0	
Access control	**P.981**	1022	Password	-	0	**1**	9999	For S2022 the password is disabled

(*) P.110 setting influences the power readings. Following example will help to understand how to manage this setting:

- Rated Generator Power = 500kVA
- Rated Generator Voltage= 400V
- Rated Generator Current= 722A
- CT mounted on the Generator= 1000/5 (CT ratio = 200)

With above configuration, the rated power of the generator (100%) is reached when the CT will read 722/200= 3.61A
In this case it is correct to set P.110=3.61 A

8. TROUBLE SHOOTING

DANGER!
The AVR is NOT insulated from the power supply and from field circuit.
The maintenance operations MUST be done ONLY when the AVR is disconnected and the protection devices are mounted and/or activated.

8.1 First Inspection

When the system is shut-down, check the fastening of fast-on terminals on the AVR. Generally, check all connections to avoid loose contact.

8.2 Trouble shooting

The following instructions are supposed to help to find out the fault location within the whole excitation system. However, it is not possible to deal with all eventualities.

List of Possible Faults	Checks, action
Machine is not exciting	
• Field circuit interrupted	• Check connection wiring
• No electronics supply	• Measure power supply L1-L2-L3 • Check for tripped protective circuit-breaker • Check the built-in fuse • Check Field Flashing and Keep Alive settings
• Set point error	• Check operating mode • Check programmable digital input setting and connection • Check set point
Overvoltage during start-up	
• Overvoltage caused by voltage regulator	• Measure the Generator voltage directly on the voltage sensing input • Check configuration • Check set point • Check overvoltage threshold • Check regulator settings
Unstable Output Voltage in no-load operation	
• Regulator error	• Check operating mode • Check programmable digital input setting and connection • Check set point • Check parameters of voltage regulator • Check/adjust stability settings r.350 and r.351
• Set point error	• Unstable Increase/Decrease inputs • Unstable External analog input
• Control element fault	• Check wiring for loose contacts, check input voltages, check field current

Unstable or Low Output Voltage under load operation	
• Regulator error	• Compared excitation voltage with power supply voltage • Check programmable digital input setting and connection • Check parameters of voltage regulator • Check/adjust stability settings r.350 and r.351
• Set point error	• Unstable Increase/Decrease inputs • Unstable External analog input
• Control element fault	• Check wiring for loose contacts

Unstable parallel operation with grid **Periodic oscillation of reactive and active power (instability)**	
• Not correct regulator settings	• Were changes made to the grid configuration? • Are additional outputs, loads etc. installed? Yes: re-set regulator No: check parameters of Auto and PF, Var regulator • Check/adjust stability settings

Irregular instability, i.e. sporadic over - or under excitation which is not caused by grid variation	
• Poor effect of the Droop influence on the voltage regulator or C.T. defective measurement	• Check droop compensation setting • Check external current transformer circuit • Gen CB Closed Status not active • Check programmable digital input setting and connection
• Some limiters are active: machine within inadmissible operating range	• Bring machine into normal operating range by adjusting the set point. • Check setting of limiters

Problems with External (remote) controls	
• No external control voltage	• Measure control voltage • Check wiring
• Configuration of the digital or analog inputs are not correct	• Check configuration

8.3 Repairing

In case it is confirmed that the AVR is defective, we recommend to contact Beltrame CSE to agree about repairing conditions.
We strongly recommend to avoid to return back any devices without previous agreement.
The user is responsible for the correct packaging of the regulator.

9. CONNECTING DIAGRAMS

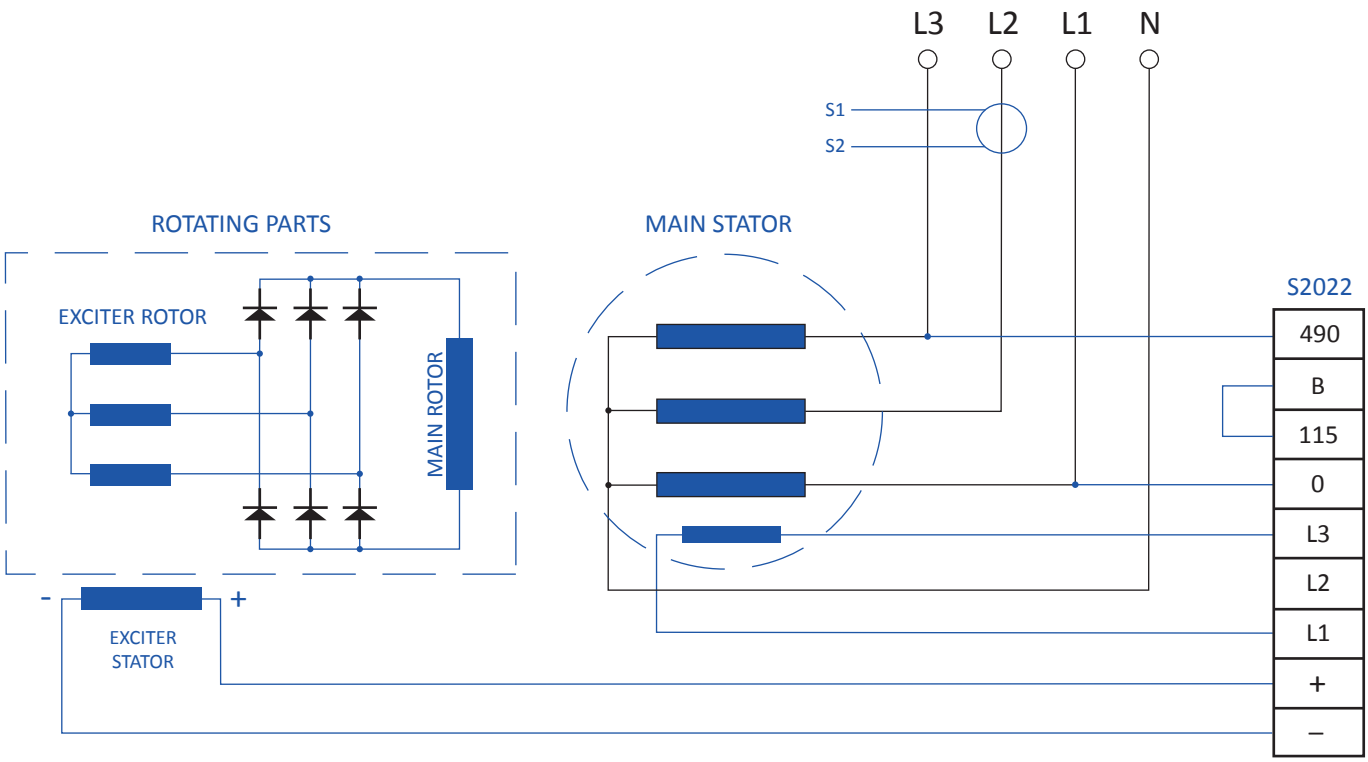
DANGER!
Only specially instructed personnel must carry out connection and repair activities.
Each person involved in the installation and commissioning of the S2022 has to have received the appropriate training or instructions and has thoroughly read and clearly understood the safety instructions reported in this manual.

9.1 Introduction

Basically, the S2022 AVR needs:

- A power supply source connected between L1, L2, L3
- A sensing input source, connected between 0 and 115V or 0 and 490V
- The connection of the exciter, between - and +

Following diagram shows a connection example of 3ph brushless alternator with internal 1ph auxiliary winding:



IMPORTANT!
CT has always to be connected in quadrature compared the sensing voltage. This means:

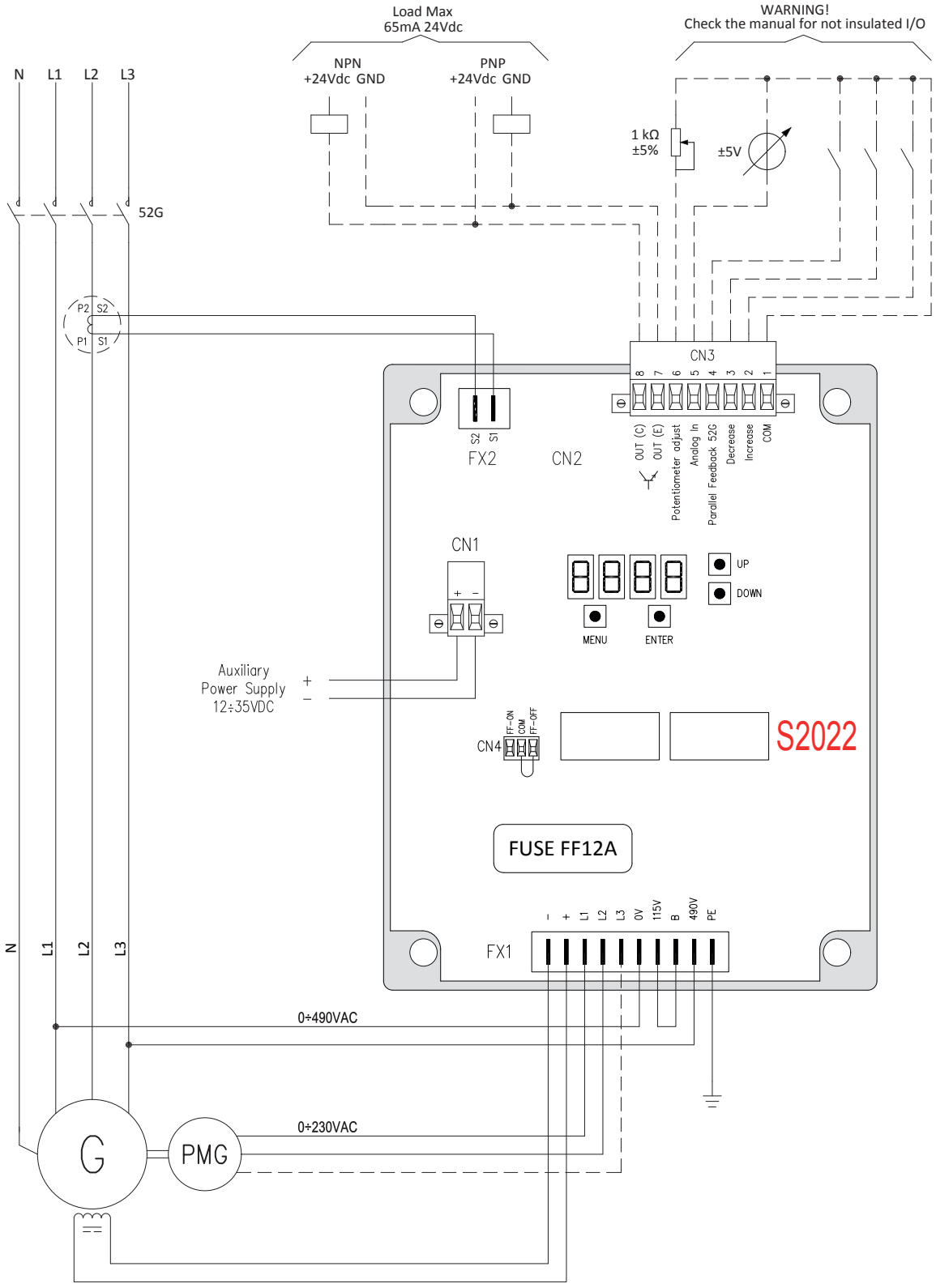
- With sensing voltage between L1 and L3, install the CT on phase L2 (as above)
- With sensing voltage between L1 and L2, install the CT on phase L3
- With sensing voltage between L2 and L3, install the CT on phase L1

9.2 Basic S2022 Connection Diagrams

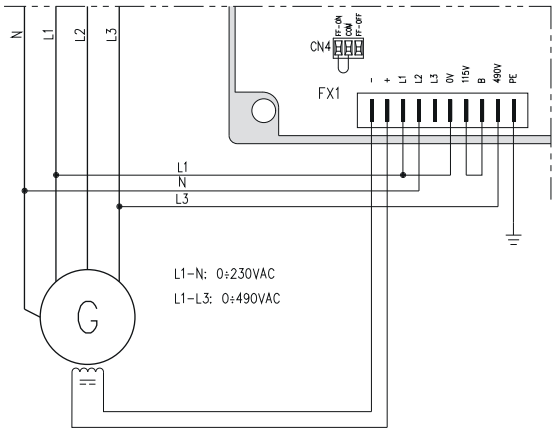
Following diagram shows how to connect the S2022 to a low voltage generator with:

- Sensing voltage between phase-phase (max 500Vac), L1 and L3
- Aux power supply between phase and neutral (max 300Vac)
- CT mounted on L2

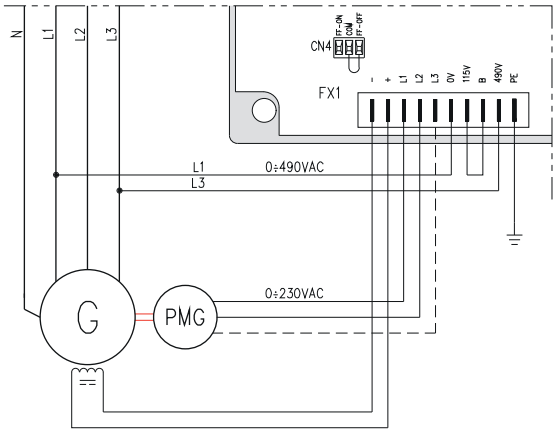
All other combinations can be obtained from this one.



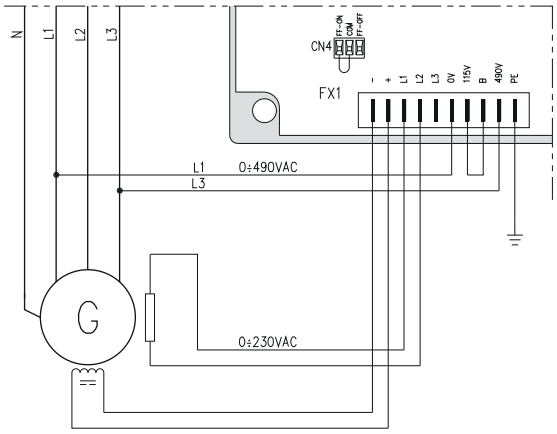
9.3 S2022 Connection Diagrams with Low Voltage Alternator



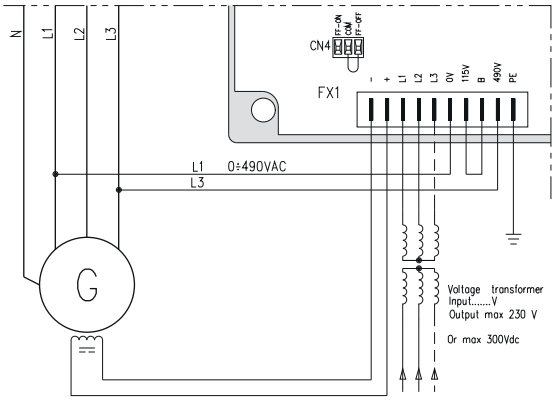
Basic Connection Diagram for LV alternator:
Sensing voltage: phase-phase (max 490Vac)
Aux power supply: phase and neutral (max 230Vac)
Field Flashing = ON



LV alternator with PMG:
Sensing voltage: phase-phase (max 490Vac)
Aux power supply: from PMG (max 230Vac 1ph or 3ph)
Field Flashing = OFF

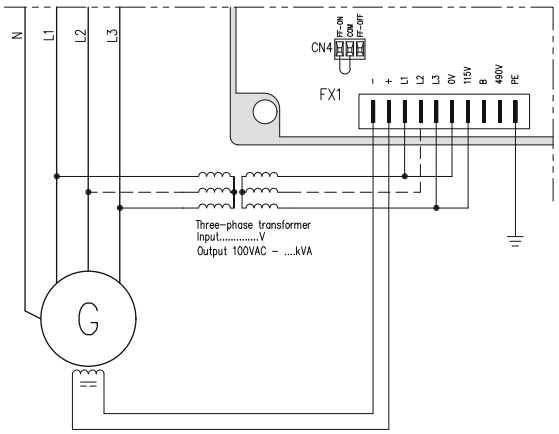


LV alternator with Aux winding:
Sensing voltage: phase-phase (max 490Vac)
Aux power supply: from Aux winding (max 230Vac)
Field Flashing = ON

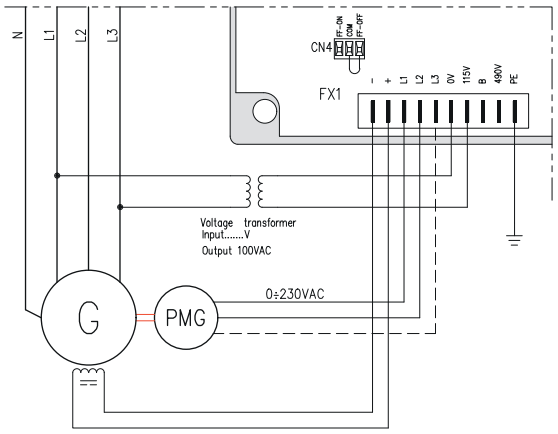


LV alternator with external power supply:
Sensing voltage: phase-phase (max 490Vac)
Aux power supply: from ext power supply (direct max 230Vac, or from ext power transformer (max 230Vac) or from DC power supply (max 300Vdc)
Field Flashing = OFF

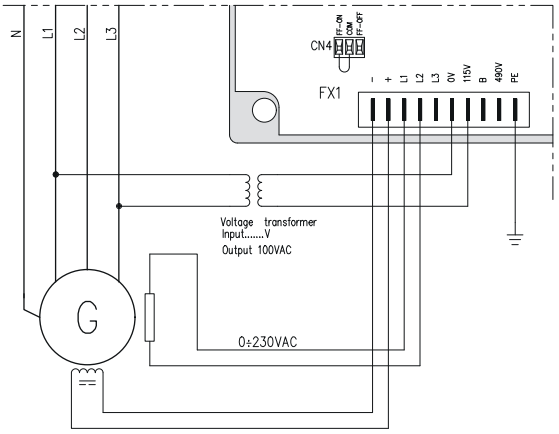
9.4 S2022 Connection Diagrams with Medium Voltage Alternator



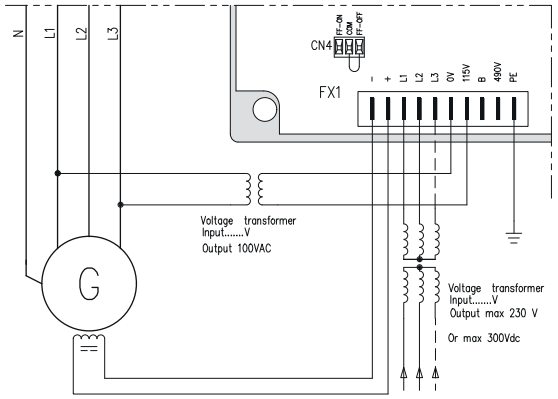
Connection Diagram for MV alternator:
Sensing voltage: from Volt Transf. (recommend. 100Vac)
Aux power supply: from Aux winding (max 230Vac)
Field Flashing = ON



MV alternator with PMG:
Sensing voltage: from Volt Transf. (recommend. 100Vac)
Aux power supply: from PMG (max 230Vac 1ph or 3ph)
Field Flashing = OFF



MV alternator with Aux winding:
Sensing voltage: from Volt Transf. (recommend. 100Vac)
Aux power supply: from Aux winding (max 230Vac)
Field Flashing = ON



MV alternator with external power supply:
Sensing voltage: from Volt Transf. (recommend. 100Vac)
Aux power supply: from ext power supply (direct max 230Vac, or from ext power transformer (max 230Vac) or from DC power supply (max 300Vdc)
Field Flashing = OFF

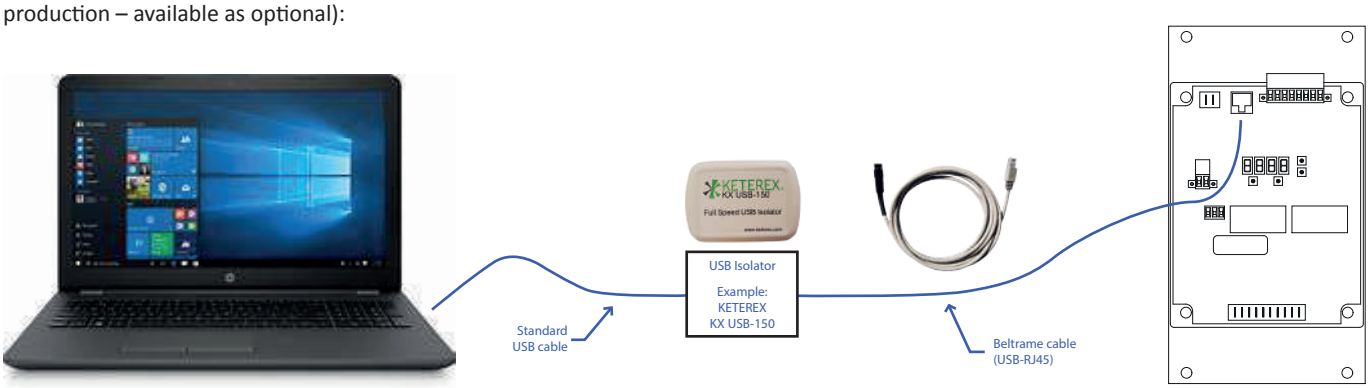
10. BELTRAME CONFIGURATOR: THE PC SOFTWARE

WARNING!
The PC software allows to modify the working mode and the settings of the AVR. The modification can be potentially dangerous. Only specially instructed personnel must carry out AVR's setting adjustments. The maintenance personnel must be informed about the emergency shutdown measures and must be capable of turning off the system in case of emergency.

The Beltrame Configurator is quite useful during the regulator commissioning, or in case of troubleshooting activities.

10.1 Connection between AVR and PC

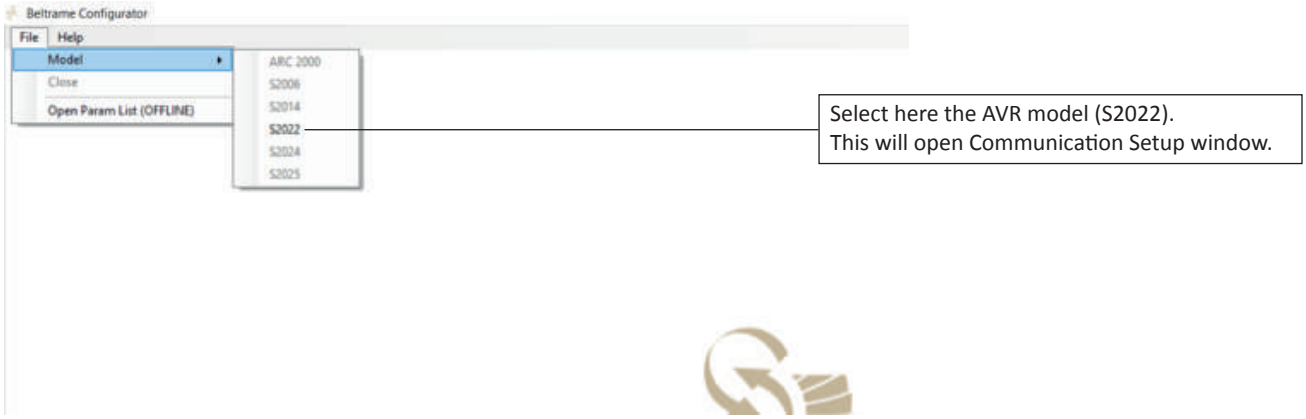
For the PC-AVR connection we recommend the following diagram, with USB isolator Using an USB/RS485 cable (Beltrame's production – available as optional):



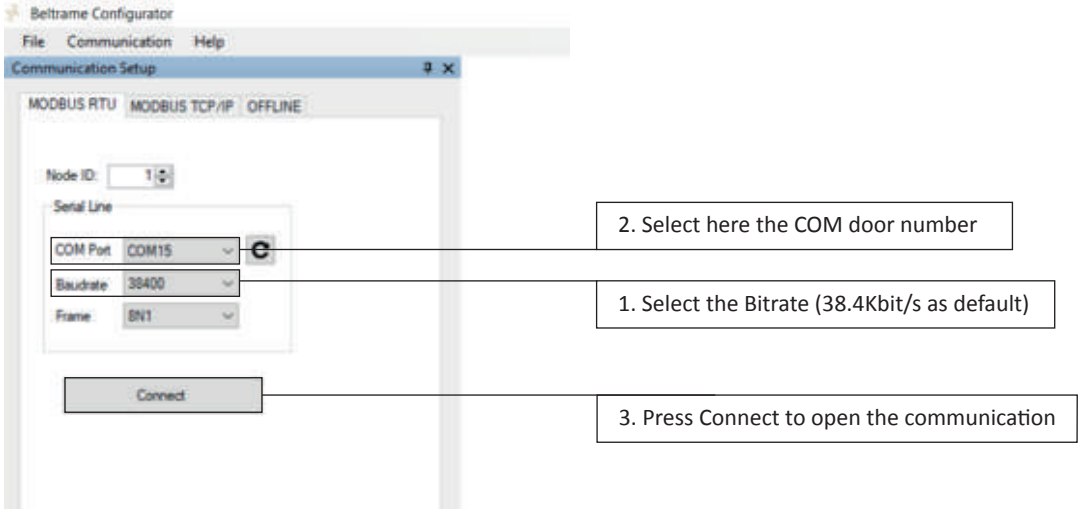
10.2 Installation and Communication setup

The Beltrame Configurator is distributed as a zip file. Once unzipped, the software will create a folder with inside the Configurator.exe:

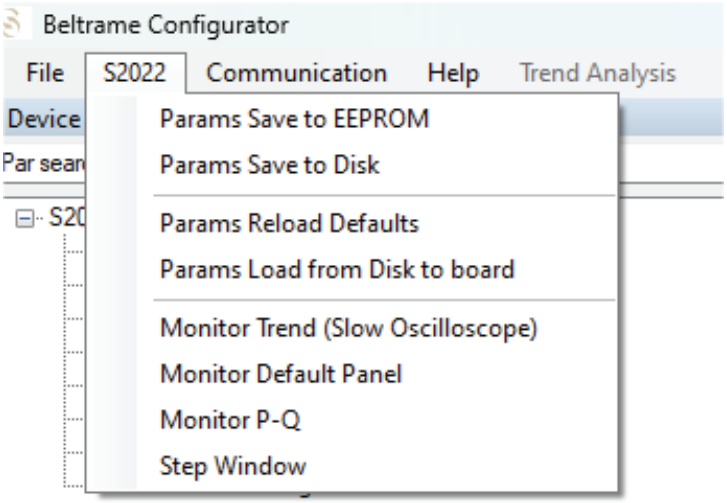
To run the program, double click on Configurator.exe.
The Beltrame Configurator is a suite from where it is possible to manage all the Beltrame CSE AVR's:



To operate it is necessary to establish the communication between PC and AVR, see the following instructions:



Once connected the S2022 menu will appear, see the following screenshots:



10.3 S2022 Menu commands

In reference at the above picture on the right, you can see:

Command	Description
Params Save to EEPROM	It saves the setting in the internal memory of the AVR. The AVR setting modification is immediate, but without saving the modification is lost in case of switching off
Params Save to disk	It saves in your PC a copy of the setting using a *.txt file
Params Reload Defaults	It reloads the the defaults settings (factory default)
Params load from Disk to board	It uploads a setting file (*.txt format) from PC to the AVR

10.4 Parameters setting: P.xxx

WARNING!

The Parameters modification can be potentially dangerous.
Only specially instructed personnel must carry out AVR's setting adjustments.

Parameters

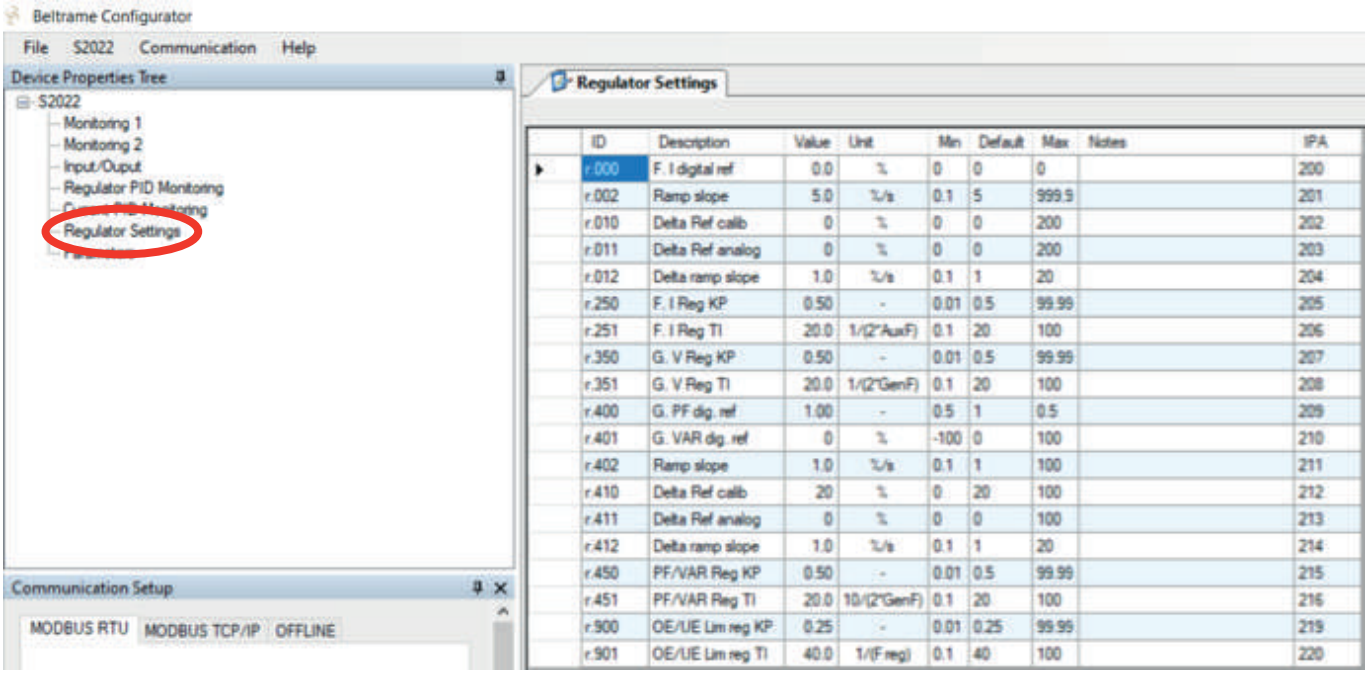
	ID	Description	Value	Unit	Min	Default	Max	Notes	IPA
▶	P.000	F. rated I	5.0	A dc	1	5	12		1000
	P.001	F. OE Lim	150	%	100	150	250		1001
	P.002	F. UE Lim	0	%	0	0	50		1002
	P.004	F. Rated I @ min freq	100	%	50	100	100		1003
	P.032	F. OE Lim time	10	s	1	10	240		1004
	P.100	G. rated V	400	V rms	50	100	500		1005
	P.101	G. max V	120	%	105	120	120		1006
	P.110	G. rated I	2.50	A rms	0.2	2.5	5		1007
	P.130	G. V/f min freq	30	Hz	6	30	150		1008
	P.131	G. V/f max freq	45	Hz	0	45	250		1009
	P.132	G. V/f slope	2.0	-	0.5	2	4		1010
	P.133	G. V/f slope over max freq	0.0	%/Hz	0	0	20		1011
	P.160	Q- lim @ P 0%	-100	%	-100	-100	-5		1012
	P.161	Q- lim @ P 25%	-100	%	-100	-100	-5		1013
	P.162	Q- lim @ P 50%	-100	%	-100	-100	-5		1014
	P.163	Q- lim @ P 75%	-100	%	-100	-100	-5		1015
	P.164	Q- lim @ P 100%	-100	%	-100	-100	-5		1016
	P.170	Q+ lim @ P 0%	100	%	5	100	100		1017
	P.171	Q+ lim @ P 100%	100	%	5	100	100		1018
	P.250	Keep Alive F. I	5	%	0	5	100		1019
	P.300	Primary reg.	AVR	-					1020
	P.400	Voltage comp K	0.0	%	-10	0	10		1021
	P.981	Password	1	-	0	1	9999		1022

Recommended procedure for parameters modification:

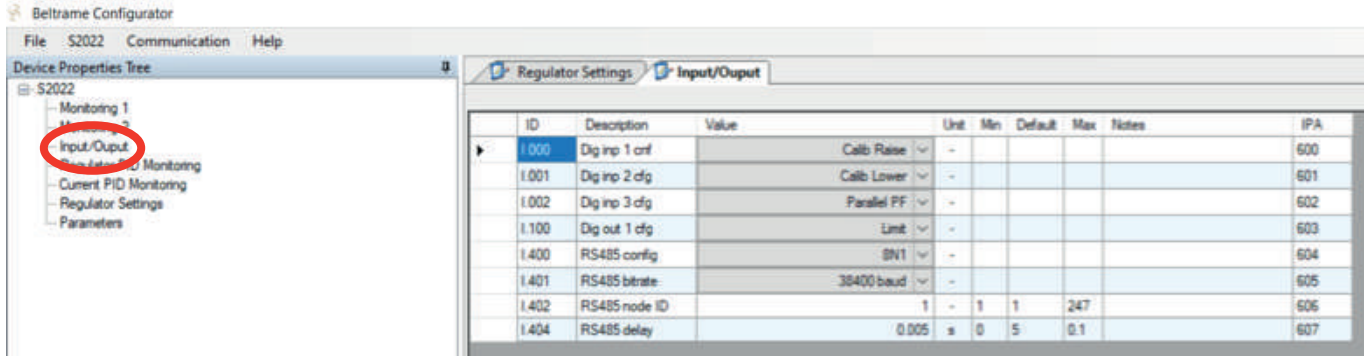
1. **Refresh**: press the Refresh button on the top right of the main window.
2. **Params Save to disk**: save the original AVR setting as a .txt file inside the PC. This allow to recover original setting
3. Modify the requested parameter. The modification is immediately active, but it is not stored inside the AVR memory. This means that if you switch OFF the AVR, the modification will be lost.
4. **Params Save to EEPROM**: If the modification is correct press Save to store the new setting inside the AVR. The modification will be active even after AVR switching off.
5. **Params Save to disk**: to save a copy of the new setting inside the PC (with a different name compared the original .txt filename)

10.5 Regulator Setting: R.xxx and Input Output setting: I.xxx

The same procedure described for the Parameter setting (10.4) is valid for Input and Output setting and for Regulator Setting:

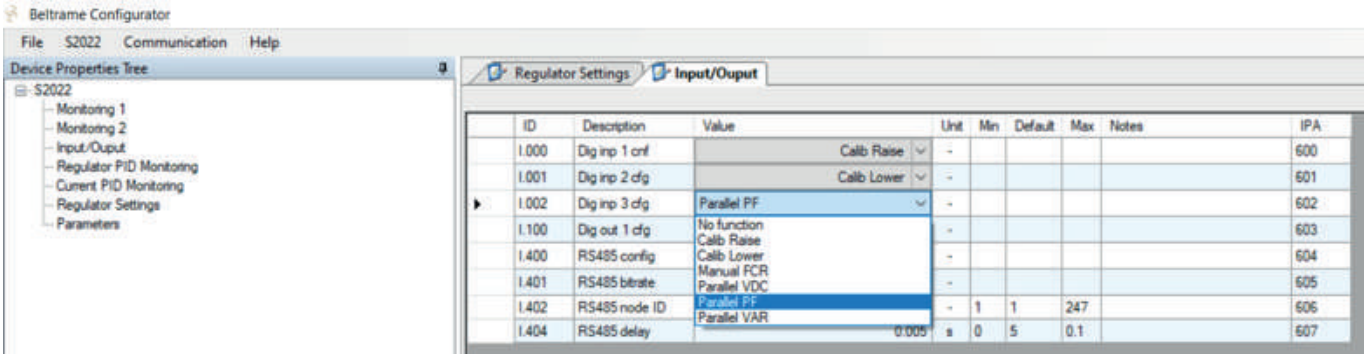


ID	Description	Value	Unit	Min	Default	Max	Notes	IPA
r.000	F. I digital ref	0.0	%	0	0	0		200
r.002	Ramp slope	5.0	%/s	0.1	5	999.9		201
r.010	Delta Ref calib	0	%	0	0	200		202
r.011	Delta Ref analog	0	%	0	0	200		203
r.012	Delta ramp slope	1.0	%/s	0.1	1	20		204
r.250	F. I Reg KP	0.50	-	0.01	0.5	99.99		205
r.251	F. I Reg TI	20.0	1/(2*AuxF)	0.1	20	100		206
r.350	G. V Reg KP	0.50	-	0.01	0.5	99.99		207
r.351	G. V Reg TI	20.0	1/(2*GenF)	0.1	20	100		208
r.400	G. PF dig. ref	1.00	-	0.5	1	0.5		209
r.401	G. VAR dig. ref	0	%	-100	0	100		210
r.402	Ramp slope	1.0	%/s	0.1	1	100		211
r.410	Delta Ref calib	20	%	0	20	100		212
r.411	Delta Ref analog	0	%	0	0	100		213
r.412	Delta ramp slope	1.0	%/s	0.1	1	20		214
r.450	PF/VAR Reg KP	0.50	-	0.01	0.5	99.99		215
r.451	PF/VAR Reg TI	20.0	10/(2*GenF)	0.1	20	100		216
r.900	OE/UE Lim reg KP	0.25	-	0.01	0.25	99.99		219
r.901	OE/UE Lim reg TI	40.0	1/(F reg)	0.1	40	100		220



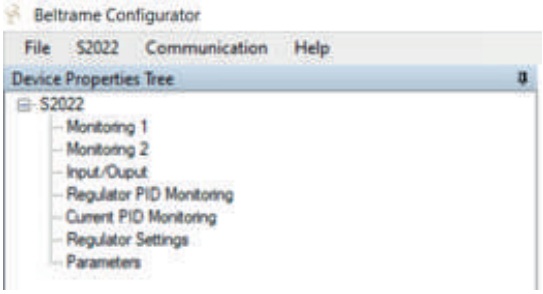
ID	Description	Value	Unit	Min	Default	Max	Notes	IPA
I.000	Dig inp 1 cnf	Calib Raise	-					600
I.001	Dig inp 2 cfg	Calib Lower	-					601
I.002	Dig inp 3 cfg	Parallel PF	-					602
I.100	Dig out 1 cfg	Limit	-					603
I.400	RS485 config	8N1	-					604
I.401	RS485 bitrate	38400 baud	-					605
I.402	RS485 node ID	1	-	1	1	247		606
I.404	RS485 delay	0.005	s	0	5	0.1		607

Where it is possible to select multiple choices, a drop-down list will appear. See below, for example, the list of functions you can associate to the I.002 digital input:



ID	Description	Value	Unit	Min	Default	Max	Notes	IPA
I.000	Dig inp 1 cnf	Calib Raise	-					600
I.001	Dig inp 2 cfg	Calib Lower	-					601
I.002	Dig inp 3 cfg	Parallel PF	-					602
I.100	Dig out 1 cfg		-					603
I.400	RS485 config		-					604
I.401	RS485 bitrate		-					605
I.402	RS485 node ID		-	1	1	247		606
I.404	RS485 delay	0.005	s	0	5	0.1		607

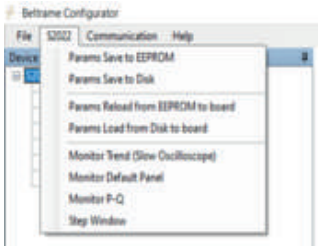
10.6 Other inside the Device Properties Tree



In reference at the above picture, you can find:

Command	Description
Monitoring 1	This corresponds to the d.xxx menu. It shows an overview on the main readings of the AVR. Press the refresh button to updated the values.
Monitoring 2	This offers a more detailed overview of the regulator status
Regulator PID Monitoring	This shows the real time regulator PID status (in AVR, PF, or VAR mode)
Current PID Monitoring	This shows the real time PID in current regulation mode (FCR) status

10.7 Monitoring features

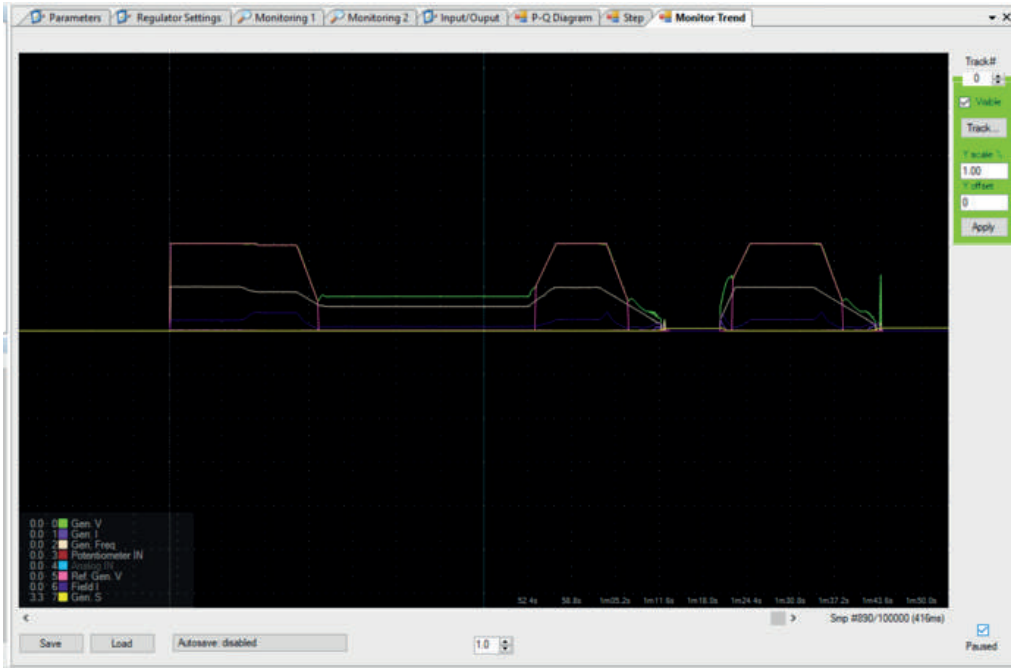


Inside the S2022 there are 4 commands that offer strong monitoring capability to the Beltrame Configurator suite:

- Monitor Trend: to use the PC software as an oscilloscope;
- Monitor Default Panel: to have an overview of the reading and the alarm/limiters status;
- Monitor P-Q: to identify the machine working point on the P-Q diagram;
- Step Window: to set the step function, useful for stability adjustment.

10.7.1 Monitor Trend

Following imagine is a screenshot obtained from the Monitor Trend. It shows excitation and de-excitation voltage ramps:

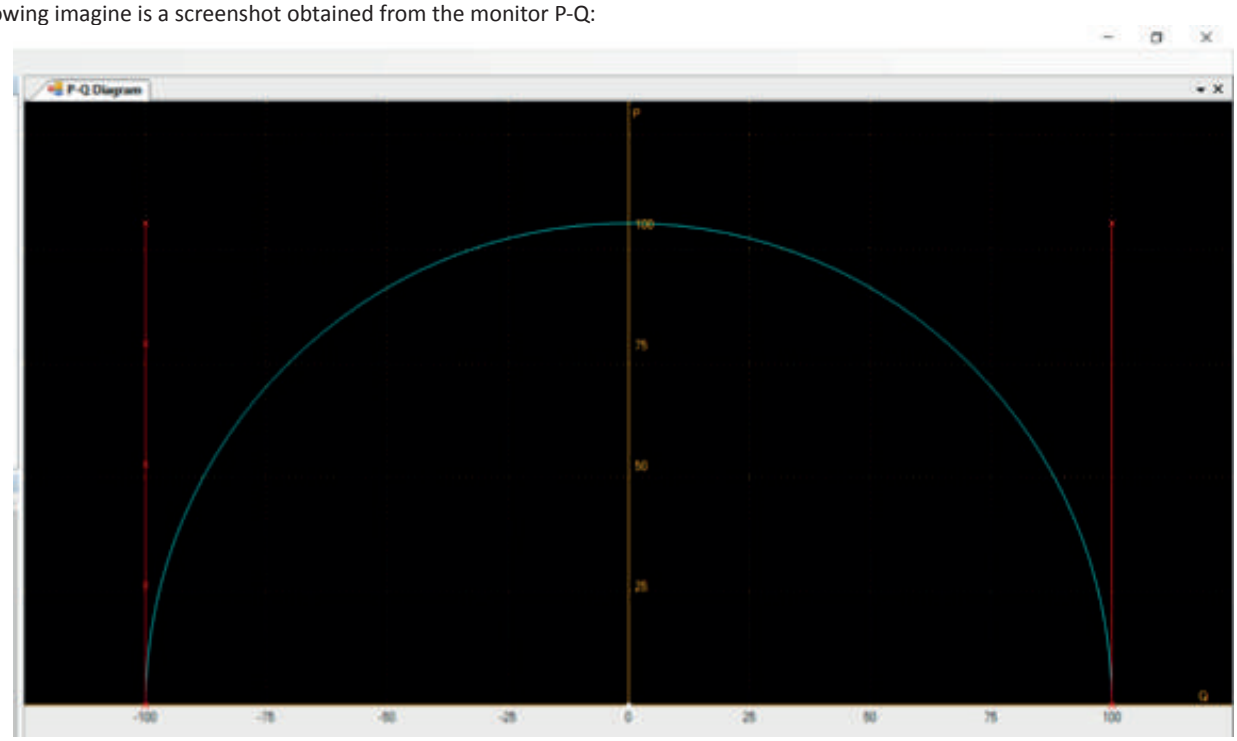


10.7.2 **Monitor Default Panel**

Following imagine is a screenshot obtained from the monitor default panel:

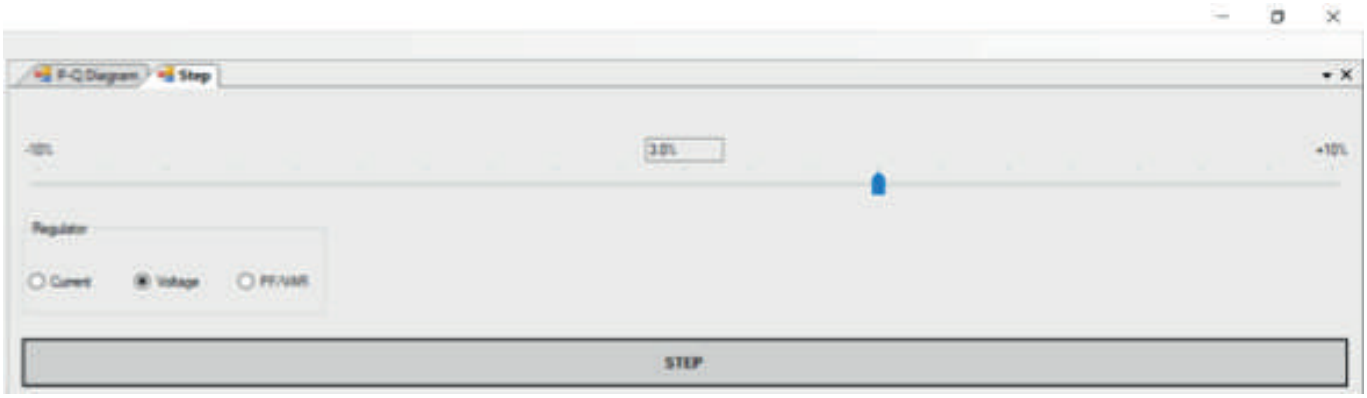
10.7.3 **Monitor P-Q**

Following imagine is a screenshot obtained from the monitor P-Q:



10.7.4 Step Window

Following imagine is a screenshot obtained from the step window.
This show a 3% step on the voltage reference.



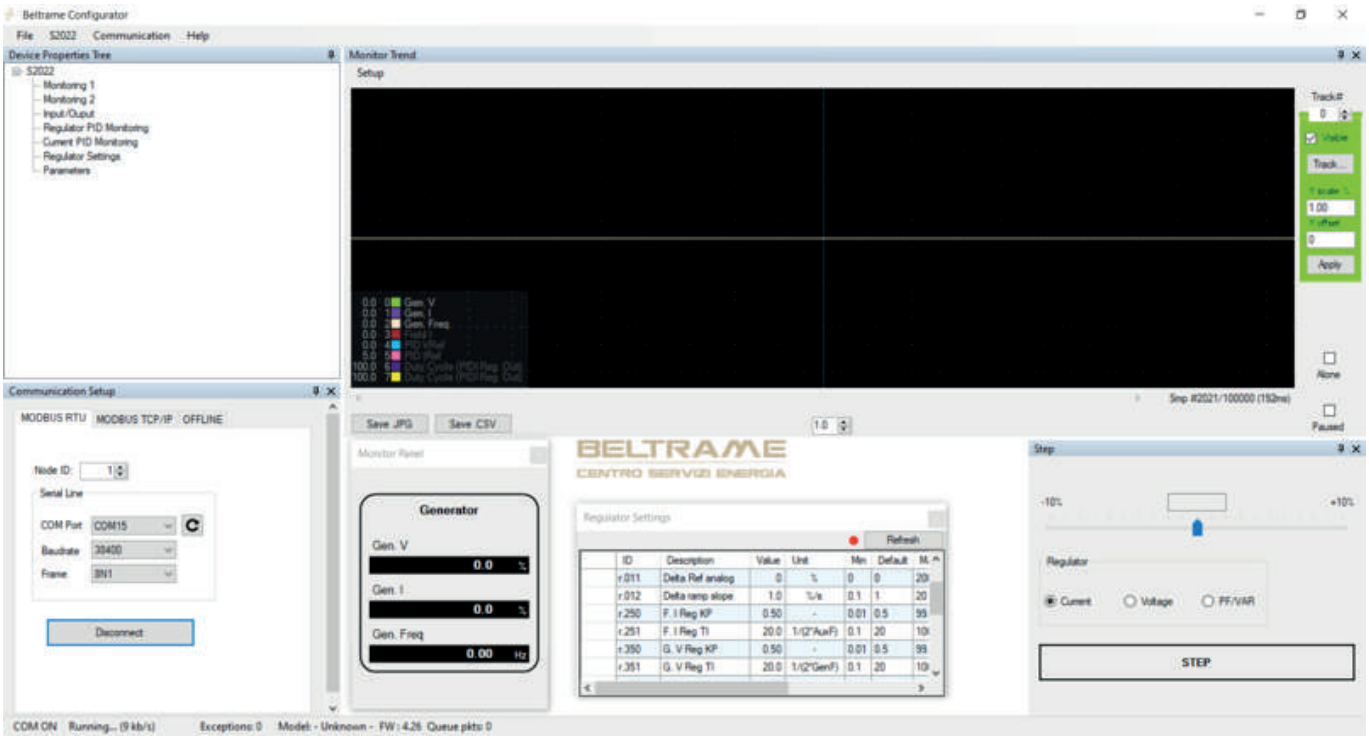
10.7.5 Multi Windows Capability

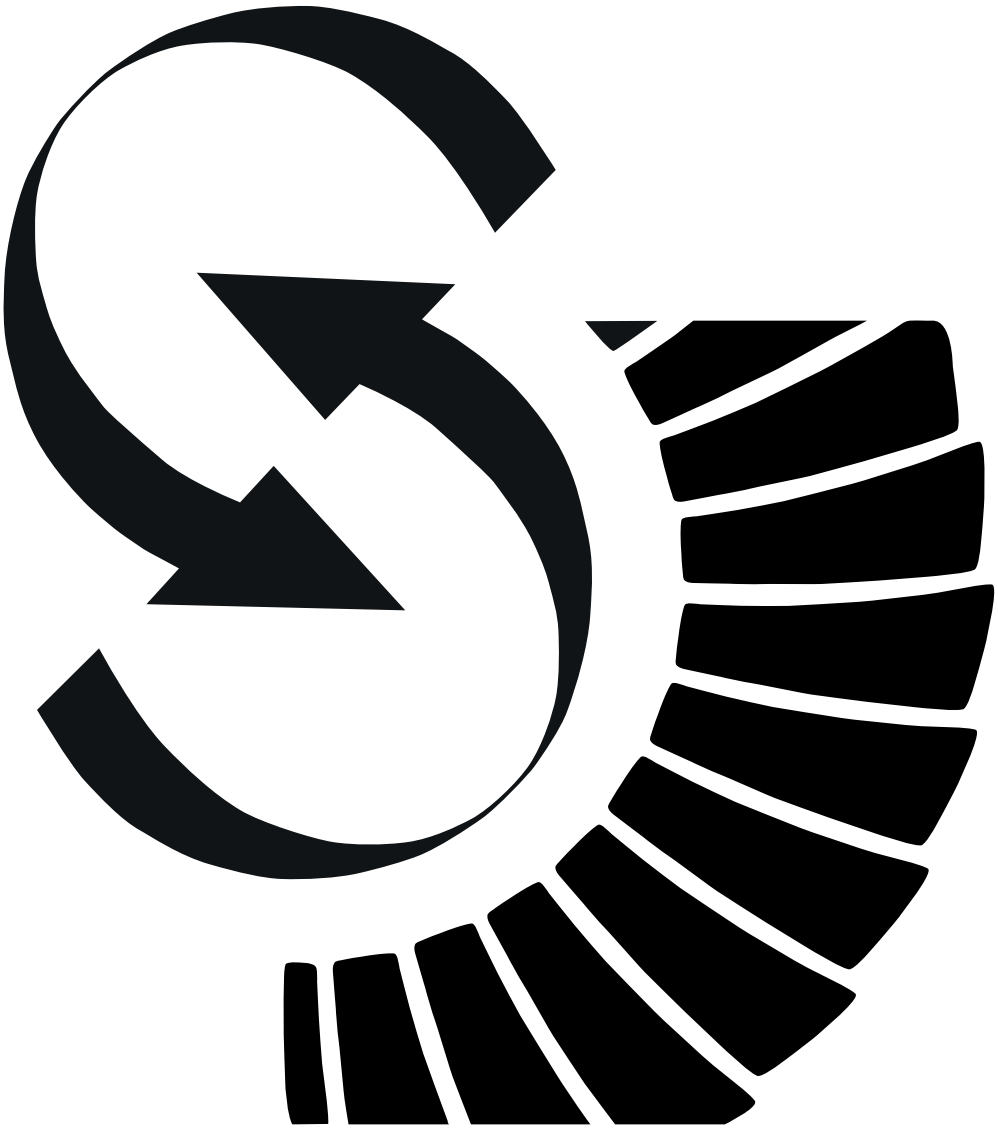
The Beltrame Configurator allows to open more than one window at the same time.

Following picture shows an example with:

- Trend monitoring window;
- Step window;
- Regulator Setup window (with PID paramenters);
- Generator voltage reading.

A similar arrangement can help to properly set the stability of the synchronous machine.





BELTRAME

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