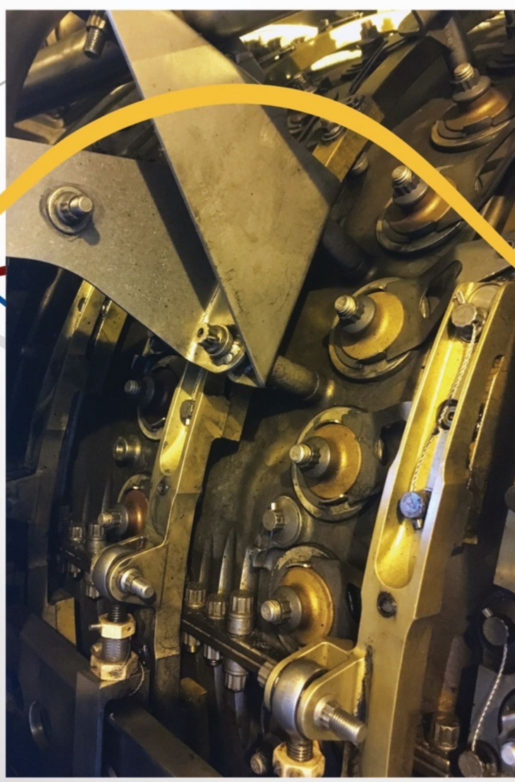
DYNAMIC CONTROLS
CANADA INC.

Training Manual Volume 2

RDEX 5 – Generator Excitation System



30A Aerospace Blvd., Slemon Park, PE, Canada, C0B 2A0

www.dynamic-controls.ca

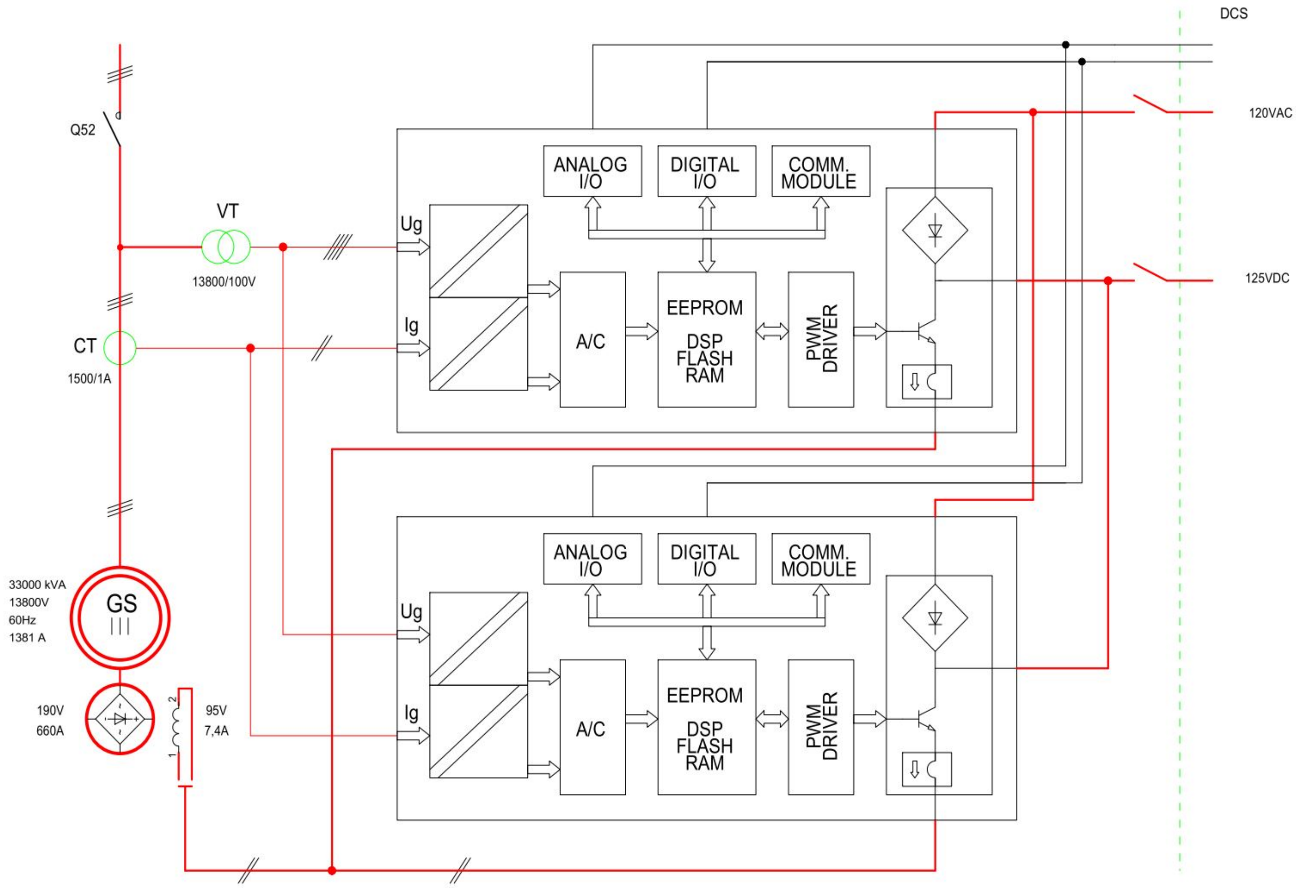
VOLUME II: RDEX-5 Excitation System

Table of Contents:

Notice to Reader: RDEX-5 Overview

The RDEX-5 is a redundant excitation system developed by Dynamic Controls Canada Inc. and is designed to operate on any synchronous generator utilizing a brushless excitation system for a DC field current requirement up to 50A.

The RDEX -5 system is designed using two P100C-SX controllers manufactured by the Institute of Power Engineering (IEN). Either P100C-SX can control generator excitation, but it is configured to operate in a primary/secondary mode in the event of failure of the partner P100C-SX.



1 P100C-SX OVERVIEW

Figure 1-1: Outline of P100C - SX

When considering the operation of the AVR it may be an advantage to consider the operation and function of the P100C-SX.

This AVR is typical of the systems available and contains a level of sophistication common to all commercially available AVR systems on the market today.

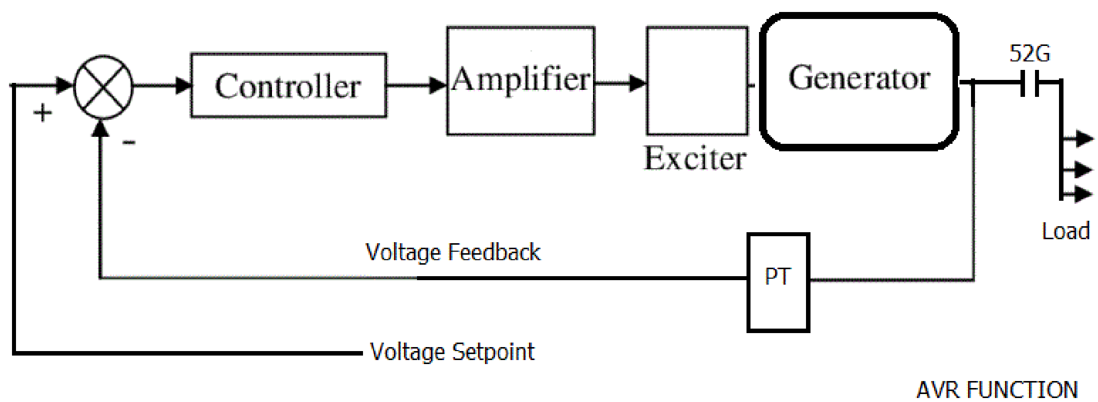


Figure 1-2: AVR Control of P100C-SX

Generator nominal parameters:

- Ugn – generator nominal voltage
- Ign – generator nominal current
- Ufn – excitation nominal voltage
- Ifn – excitation nominal current

2 TYPICAL APPLICATIONS

2.1 Single channel

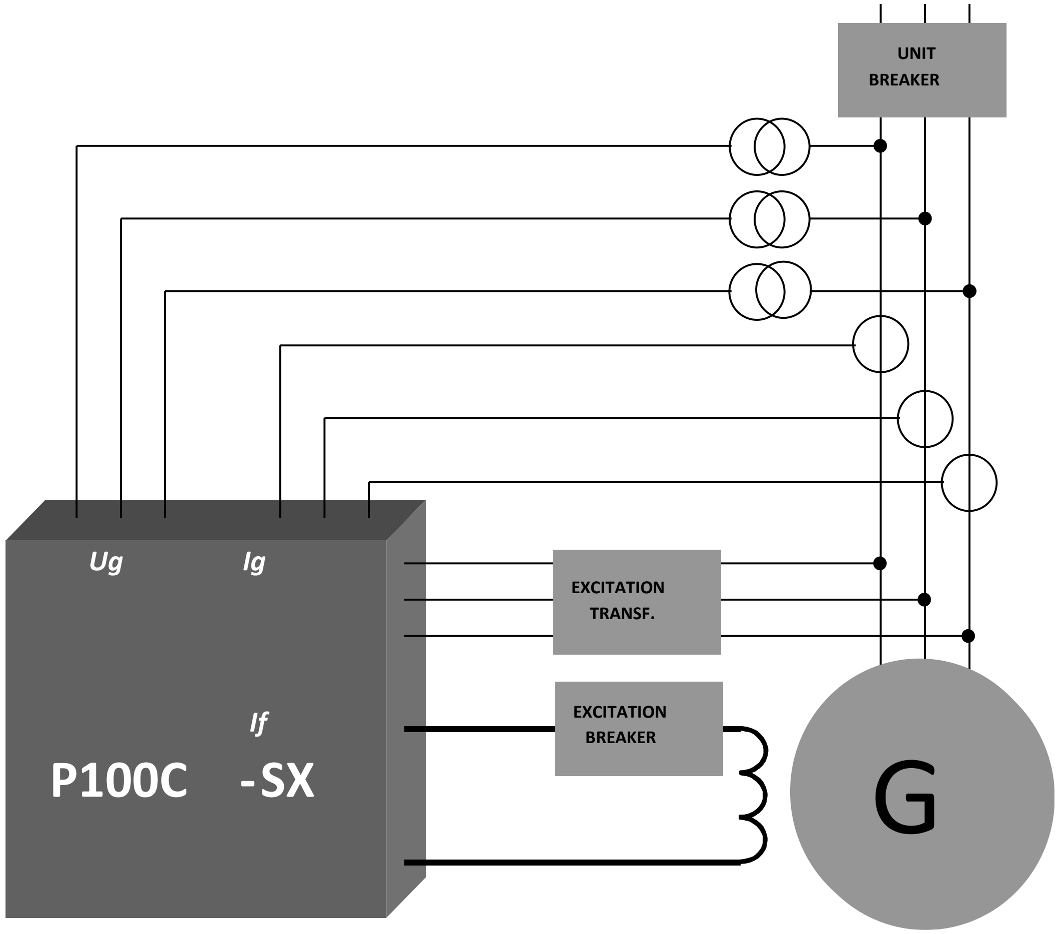


Figure 2-1: Single channel application

In the application shown in Figure 2-1 a single P100C module controls the exciter field current of a synchronous generator. In this case the sensing voltage Ug is stepped down to 110VAC. Operating power is taken from the generator output through an excitation transformer. Ig, generator current sensing is in this case three phases.

2.2 Duplex System

In the application shown in Figure 2-2: P100C-SX Dual system a pair of P100C-SX modules control the exciter field current of a synchronous generator. In this case, the voltage sensing and operating power is taken from the same source for both modules.

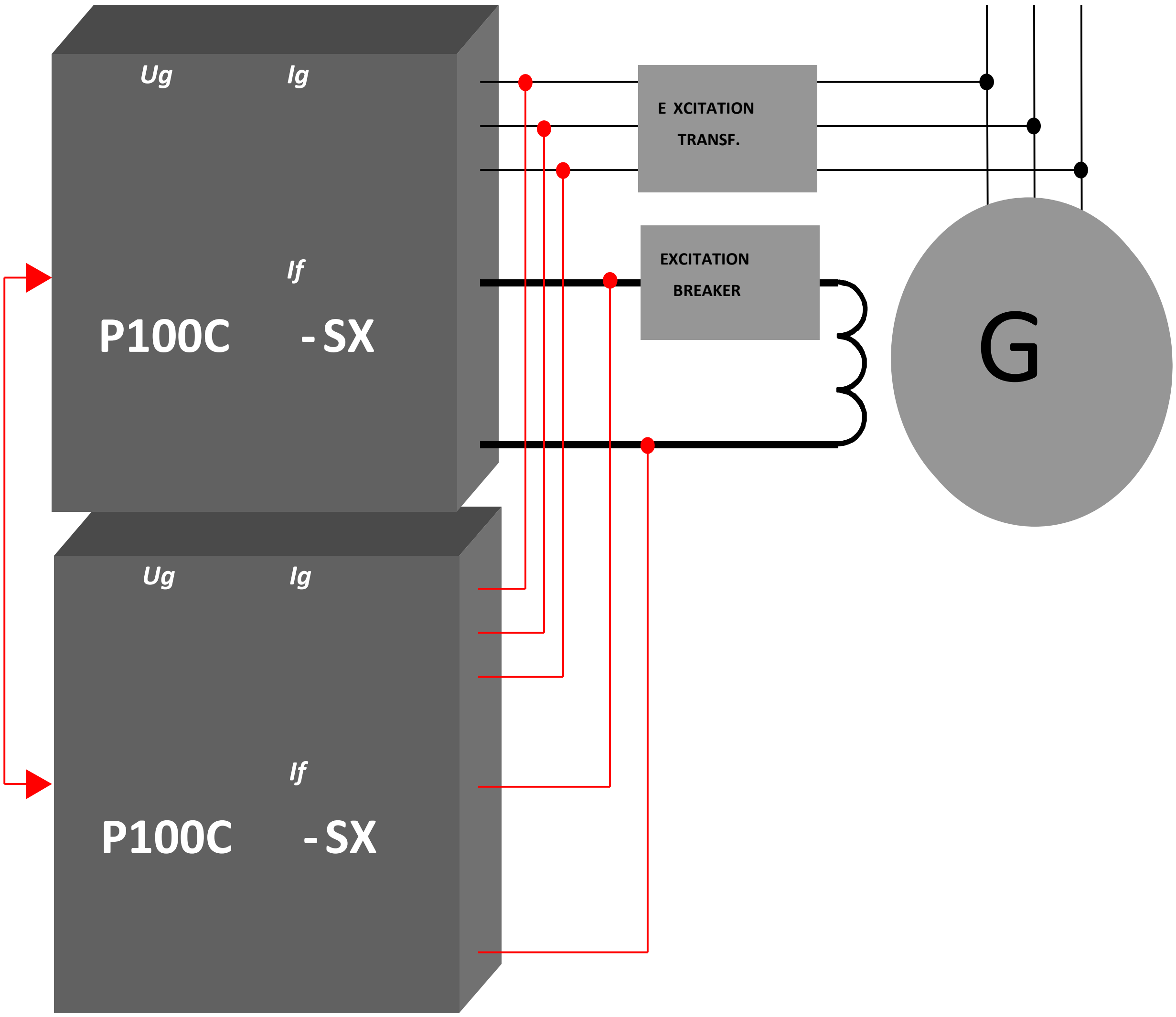


Figure 2-2: P100C-SX Dual system

3 HARDWARE OF THE P100C-SX

The block diagram shown depicts the exciter field while station AC and DC power are used to supply the internal electronics relays and sensors.

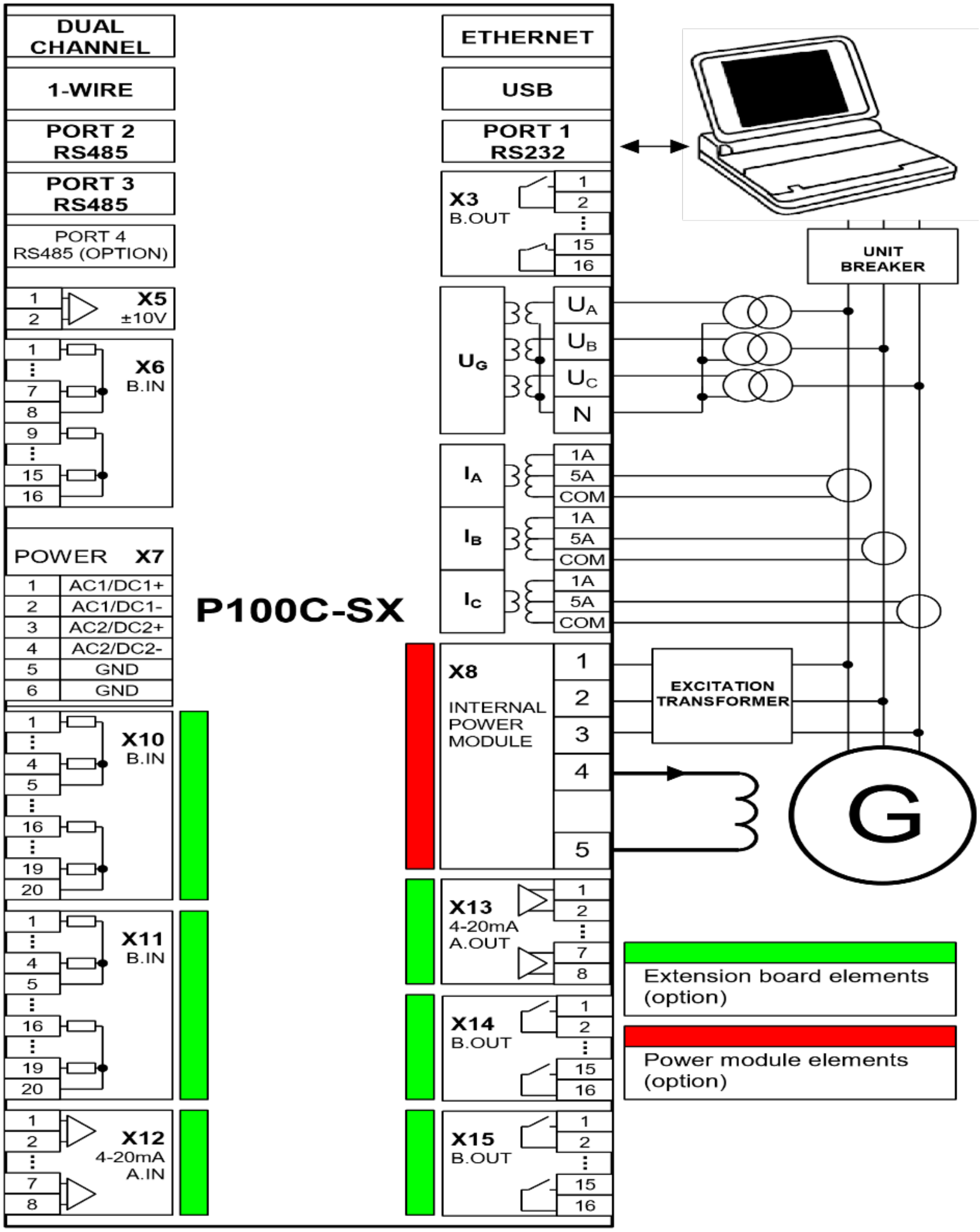


Figure 3-1: Typical wiring diagram for P100C-SX

3.1 Input circuits

Input circuits powered by isolated 24 Vdc or 125VDC provide operational input control for the P100C-SX. If the start and stop inputs should become active at the same time, the stop input has priority. If the AVR and FCR inputs should become active at the same time, the FCR input has priority. Each of the eleven inputs, their functions, and input requirements are defined as follows.

Start

This input accepts a momentary contact closure and enables the AVR.

Stop

This input accepts a momentary contact closure and disables the AVR. The Stop input also takes precedence over the Start input.

AVR (Automatic Voltage Regulation)

This input accepts a momentary contact closure that places the P100C-SX in the AVR mode. Once the unit is in AVR mode, this input has no effect.

FCR (Field Current Regulation)

This input accepts a momentary contact closure that places the P100C-SX in the FCR mode. Once the unit is in FCR mode, this input has no effect. The FCR input takes precedence over the AVR input and is automatically enabled on loss of sensing.

Raise

This input increases the active operating set-point. This function is active as long as the contact is closed. The raise increment is a function of the set-point range of adjustment and the active mode traverse rate. The increments are directly proportional to the adjustment range and inversely proportional to the traverse rate. This input has no effect when the active pre-position mode is Maintain.

Lower

This input decreases the active operating set-point. This function is active as long as the contact is closed. The lower increment is a function of the set-point range of adjustment and the active mode traverse rate. The increments are directly proportional to the adjustment range and inversely proportional to the traverse rate. This input has no effect when the active pre-position mode is Maintain.

Pre-Position

This input accepts a continuous contact closure that causes all set-points to be changed to the pre-position (pre-defined) value. If the active pre-position mode is Maintain, then the pre-position input will override the raise and lower inputs to maintain the set-point at the pre-position value while the contact is closed. If the active pre-position mode is Release, then the pre-position input will change the set-point to the pre-position value and respond to raise and lower inputs.

If the non-active pre-position mode is MAINTAIN and internal tracking is enabled, the non-active mode will maintain the non-active set-point at the pre-position value and override the tracking function. If the non-active pre-position mode is Release and internal tracking is enabled, then the pre-position input will change the set-point to the pre-position value and respond to the tracking function.

Typically, this input is connected to a 52b auxiliary contact on the generator breaker. When the generator breaker opens, all set-points are forced to the pre-position settings. This is especially helpful if FCR mode is active and the generator is under a load. Utilizing a 52b contact will force the FCR set point to its preposition setting which could be preset to the generator's no-load, nominal voltage.

3.2 Control Power

Control power is supplied to an internal power supply that provides +5 Vdc, ±12 Vdc, ±15 Vdc and +24 Vdc to the P100C-SX internal circuitry.

Both units accept nominal control power inputs of 120 Vac and 125Vdc. Both AC and DC operating power are applied simultaneously for redundant power supply operation.

3.3 SCR Bridge

Can be either internal of external on the P100C-SX.

In cases where excitation current is limited to less than 40 Amps an internal hardware configuration is utilized (GCU Board installed) or Output transistors.

An External Bridge can be up to 6000 amps where controlled output from the P100C-SX is on 6 SCR firing circuits.

3.4 Internal Thyristor Bridge – GCU

For build-in thyristor configuration, supply voltage and load must be connected directly to the GCU board. No external field current measurement is required as it is taken directly from internal LEM.

An example of wiring for GCU with internal LEM is presented below. Additional AC field breaker is shown on the diagram (Figure 3-2).

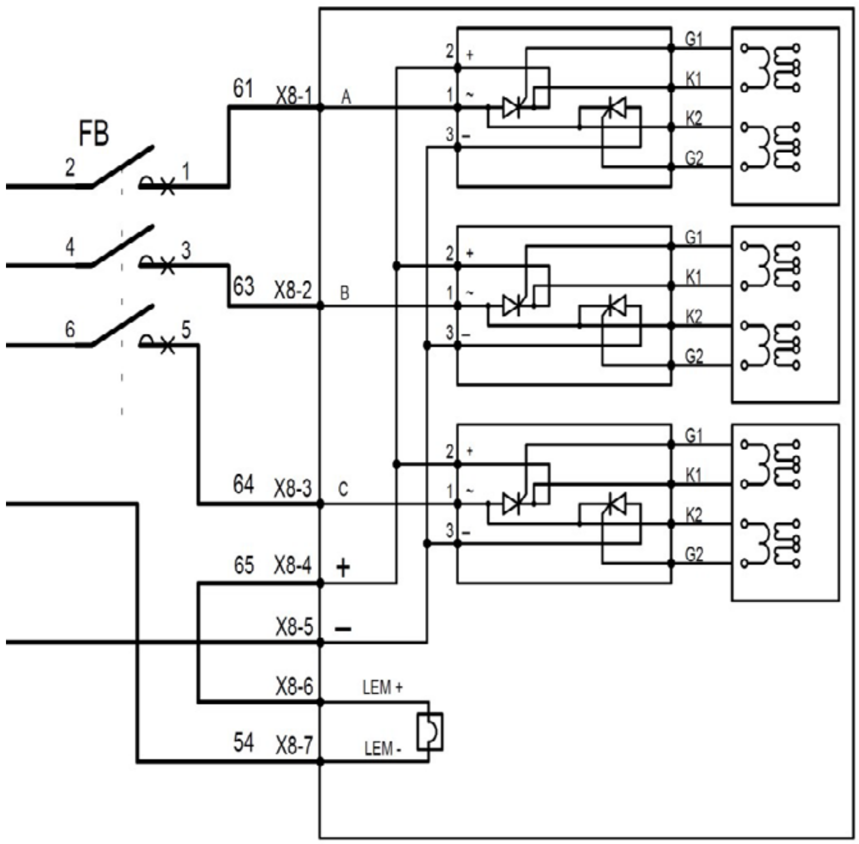


Figure 3-2 Internal thyristor brigde connection diagram

3.5 Internal Transistor - IGBT

An example of wiring for MSP with internal LEM is presented below. Additional fuses are present on power supply side as well as additional capacitor connected to the boosting terminals. Supply voltage and load must be connected directly to the MSP board. No external field current measurement is required as it is taken directly from build-in LEM sensor.

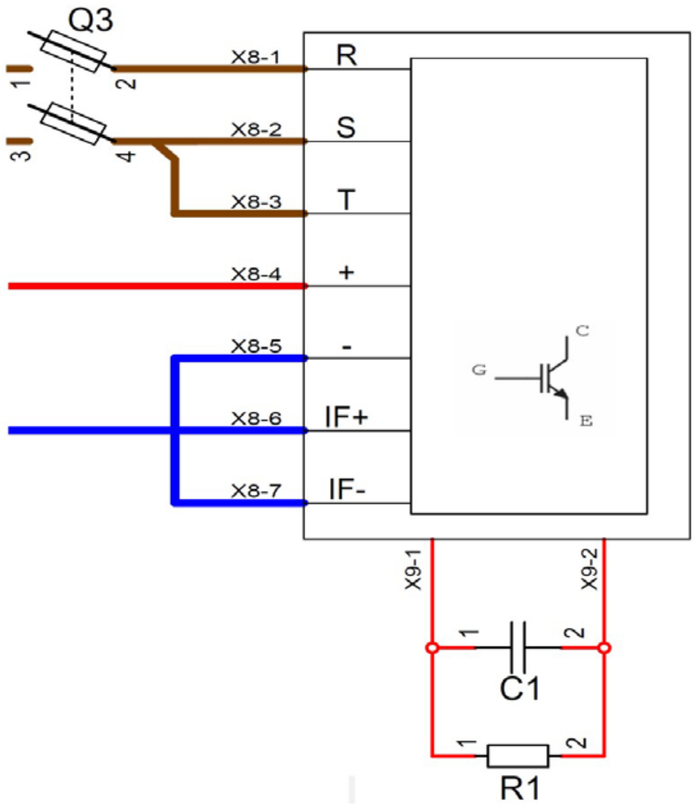


Figure 3-3: Internal transistor – IGBT Connection diagram

3.6 External Thyristor Bridge - GCU

For external thyristor bridge controlled directly from GCU, supply voltage (synchronization voltage) must be connected to GCU board as well as external field current LEM sensor or different 4-20mA field current transducer. Additional firing pulses transformers must be used to provide insulation between firing pulses and thyristors.

Synchronization voltage:

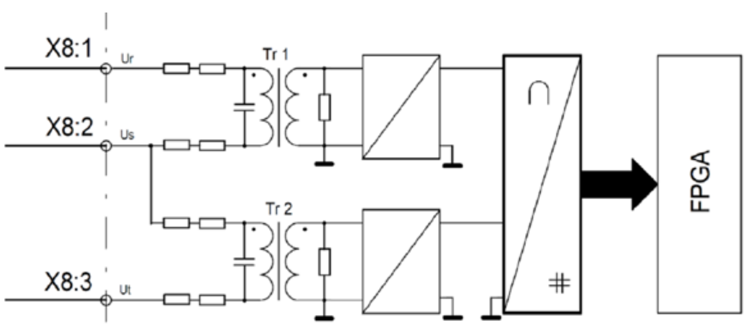


Figure 3-4: External - Syn Voltage

Firing pulses connection:

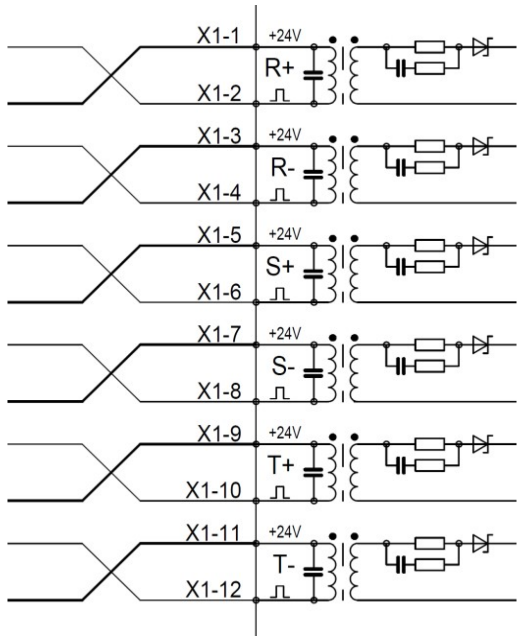


Figure 3-5: External – Firing connection diagram

3.7 SOFTWARE OF P100C-SX

3.7.1 AUTOMATIC REGULATION and IEEE Std. 421.5

The automatic regulation loop means regulation of the generator voltage. This loop is considered to be primary control loop of excitation system.

The P100C-SX Tuning Software allows user to choose one of three structures of the automatic regulation loop, according to IEEE Std. 421.5. Structures are shown below:

- ST1A – LEAD/LAG structure
- AC5A – LEAD/LAG structure
- AC8B/ST4B (PID) – PID structure

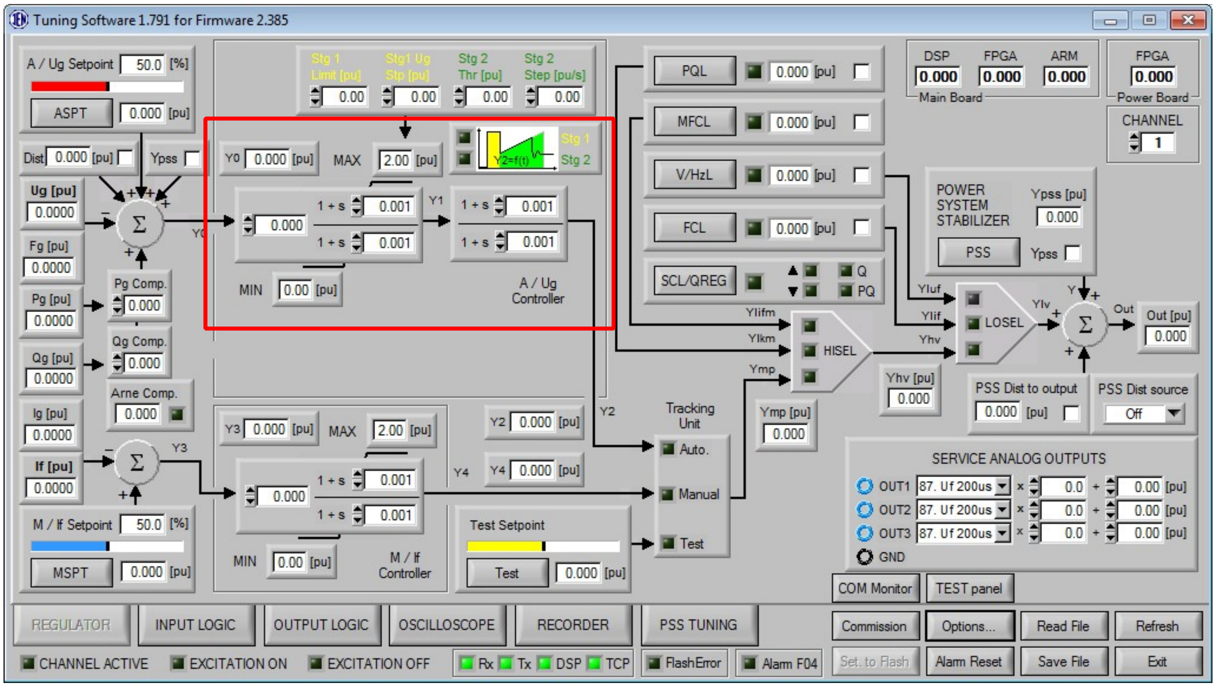


Figure 3-6: Automatic regulation loop ST1A settings section

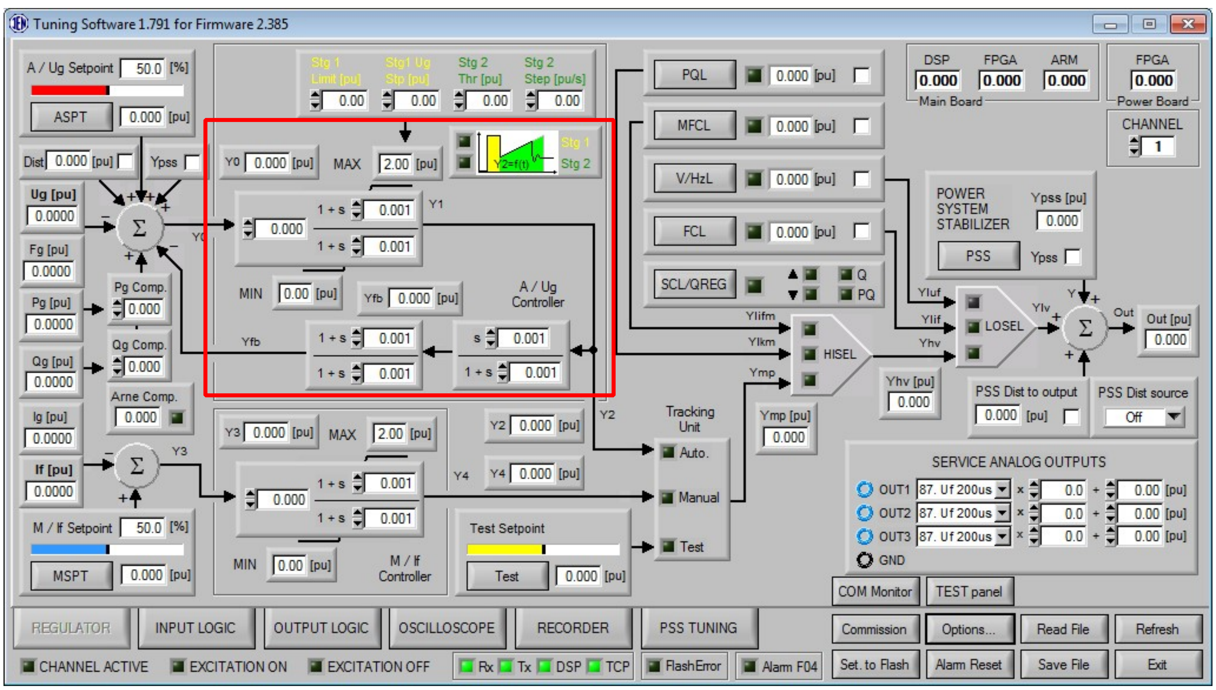


Figure 3-7: Automatic regulation loop AC5A settings section

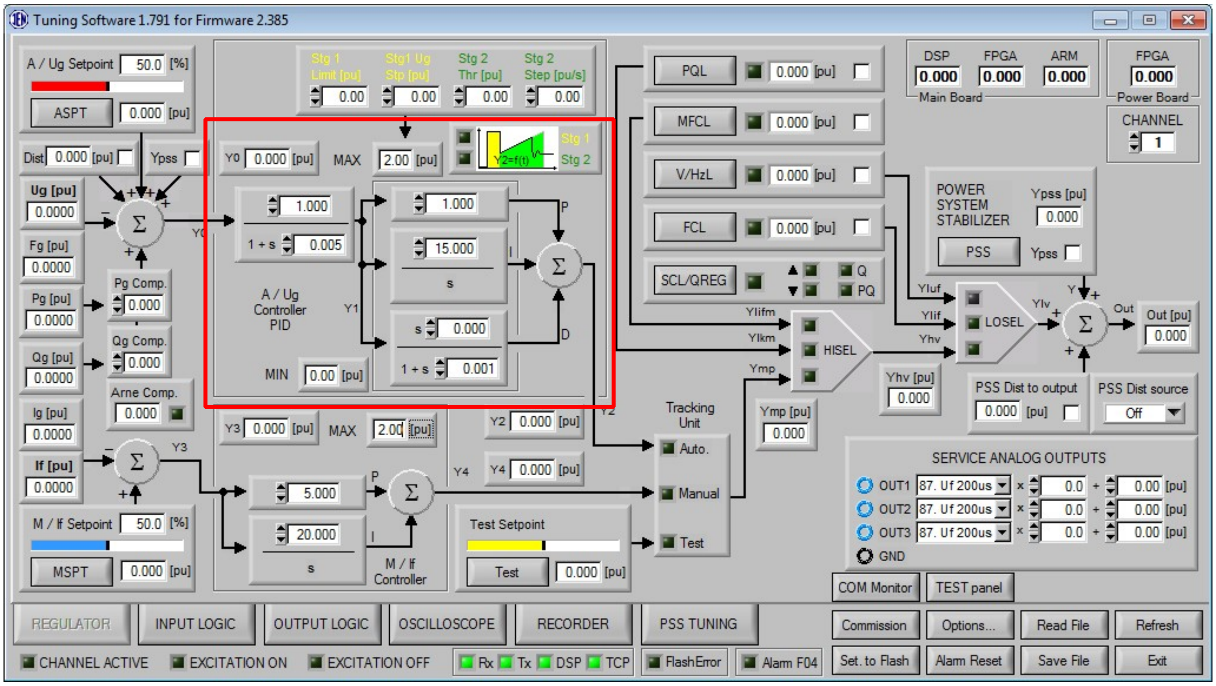


Figure 3-8: Automatic regulation loop AC8B (PID) settings section

Switching between manual regulation loop can be done through Options/Misc. “Excitation system structure” where:

- ST1A – LEAD/LAG structure
- AC5A – LEAD/LAG structure
- AC8B/ST4B (PID) – PID structure

3.7.2 Input limitation

To avoid control signal overshoot or oversaturation limitation a component has been introduced to the input of automatic control loop in ST1A or AC5A configurations.

It limits input signal of automatic control loop according to the equation:

$$limit = \frac{1.45 \cdot \mathrm{Tb}}{\mathrm{Ka} \cdot \mathrm{Ta}}$$

Where:
Ka – Gain
Ta – Lead component
Tb – Lag component
Limitation value can vary from ±0.11 pu to ±2.0 pu and is calculated automatically.

4 INTERFACING TO P100C-SX

4.1 SAFETY INSTRUCTIONS

Discharge any static electricity you may have accumulated. If you communicate with the P100C-SX using a computer through the serial port, please ensure that the computer is grounded to the same ground as the relay. One of the ground terminals (terminal strip X1, terminals 5, 6) and the enclosure of the P100C-SX must be correctly grounded.

In case of using a portable computer, it is recommended to have it disconnected from its power supply, as in many cases they are not correctly grounded either due to the power supply itself or to the connector cables used. Powering the portable PC with its internal battery drastically decreases the possibility of producing permanent damage to the computer or the P100C-SX.

This is required not only for personal protection, but also for avoiding a voltage difference between the P100C-SX serial port and the computer port, which could produce permanent damage to the computer or the P100C-SX.

4.2 COMMUNICATION & SYSTEM REQUIREMENTS

The P100C-SX Tuning Software application interface is the preferred method to view and edit settings of controller.

Tuning Software can communicate with the P100C-SX via the faceplate RS232 port or the Ethernet port. To communicate with the P100C-SX via the RS232 port, a standard “straight through” serial cable is used (1:1). The DB9 male end is connected to the P100C-SX and the DB9 female end is connected to the PC.

The following minimum requirements must be met for the P100C-SX Tuning Software to properly operate on a PC:

- Pentium® class or higher processor (Pentium® II 300 MHz or higher recommended)
- Windows® 2000, Windows® XP (Service Pack 3) or higher
- 64 MB of RAM (128 MB recommended)
- 40 MB of available space on system drive
- RS232C serial or Ethernet port for communications to the P100C-SX

4.3 SOFTWARE INSTALLATION

After ensuring the minimum requirements for using P100C-SX Tuning Software are met (see previous section), use the following procedure to install software from the enclosed CD.

1. Click the “Setup.exe”, then the following window appears:

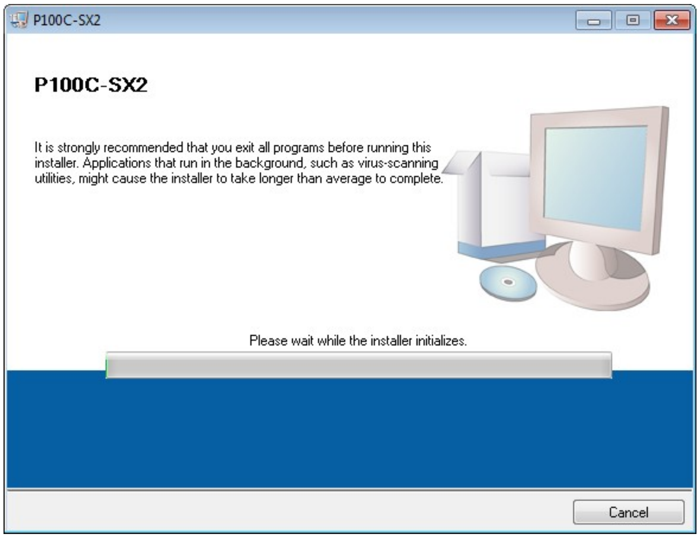


Figure 4-1: 1 First window of the installation process

2. Select the installation directory in the following window and click “Next”.

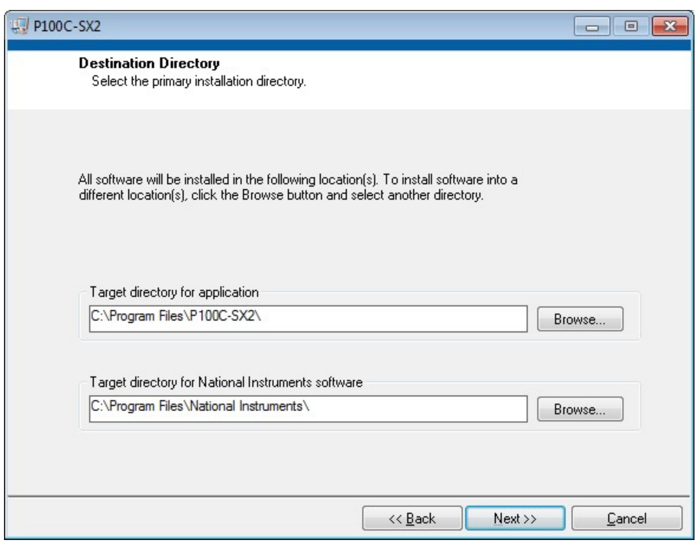


Figure 4-2: Select the installation directory window

3. When the “installation-ready” window will appear, click “Next” and start the installation process.

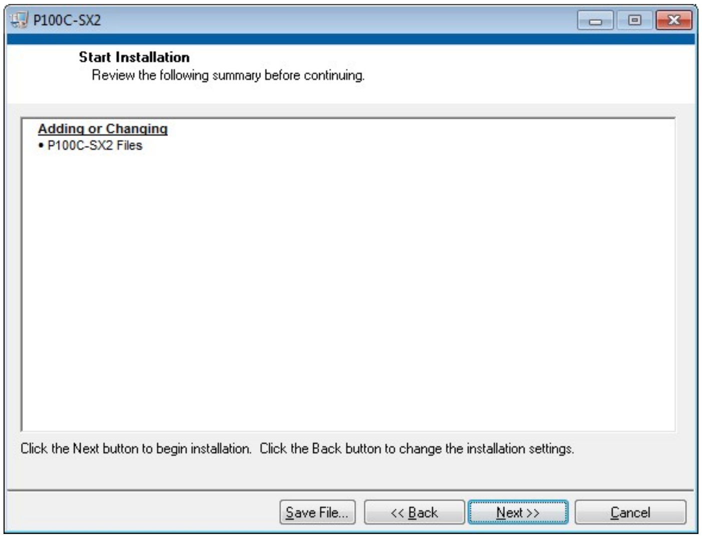


Figure 4-3: Installation-ready window

4. To finish with the installation process, click “Finish”.

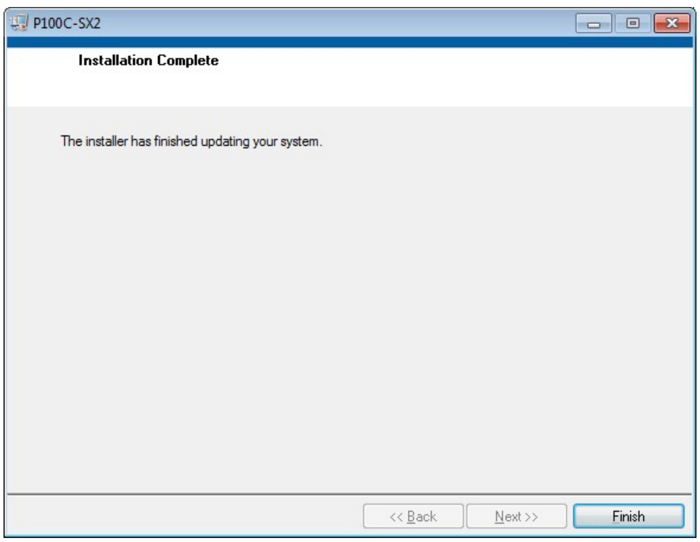


Figure 4-4: Last window of the installation process

5. After installation it is recommended to restart your computer.

4.4 DEMO MODE

DEMO mode gives access to all features of the application without the necessity to connect with a real controller. It helps to familiarize with a Tuning Software environment before connecting with a real system.

It allows to prepare a settings file for a future project and save it on hard drive using SAVE FILE button.

It also allows to read settings file from existing project using READ FILE button for analysis or modification.

To enter DEMO mode, run Tuning Software application from shortcut or go to install directory and run AVR32.exe file, then the following window of the P100C-SX Tuning Software appears:

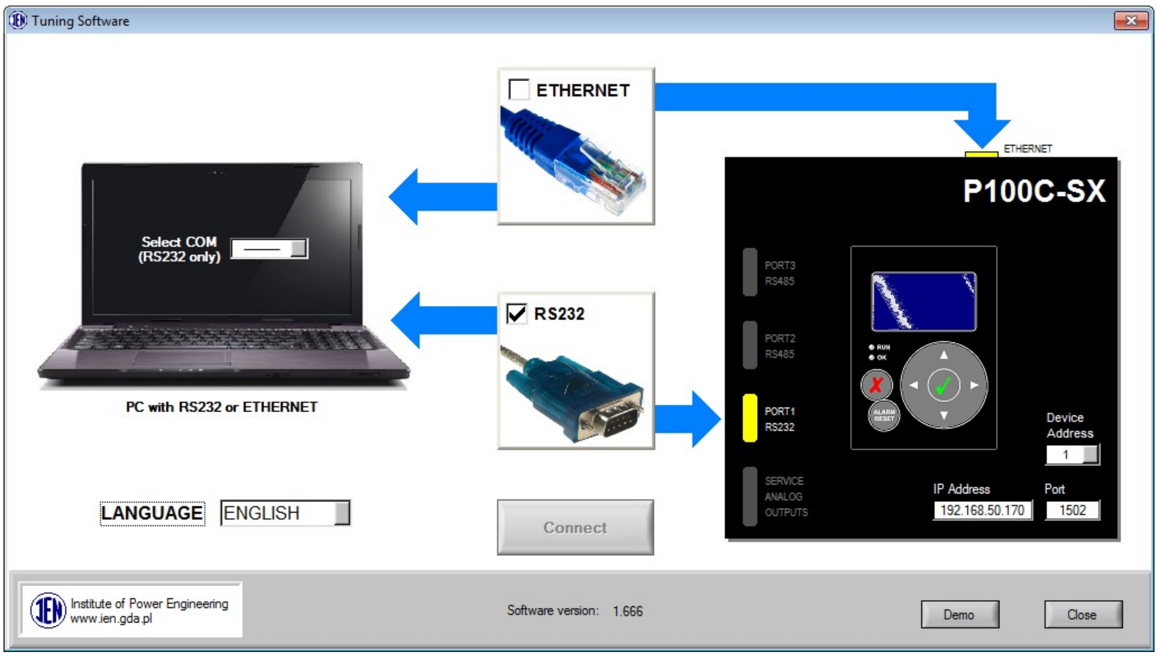


Figure 4-5: First window of the P100C-SX Tuning Software

4.5 FACEPLATE KEYPAD & DISPLAY

The 7-key keypad and a 128x64 pixels LCD display (shown below) are used as elementary local HMI of the P100C-SX.

Figure 4-6: P100C-SX keypad and display view

 Ok, go deeper into menu tree, accept changes

 Cancel, go to higher level of menu tree, discard changes

 Up arrow

 Down arrow

 Left arrow

 Right arrow

 Alarms reset

RUN RUN Communication module processor is working correctly

OK OK Regulator processor is working correctly

Access to “COMMUNICATION” menu parameters is protected with a password as it allows to switch important parameters of P100C-SX regulator which affects communication with external systems. Password for this menu is as follows:

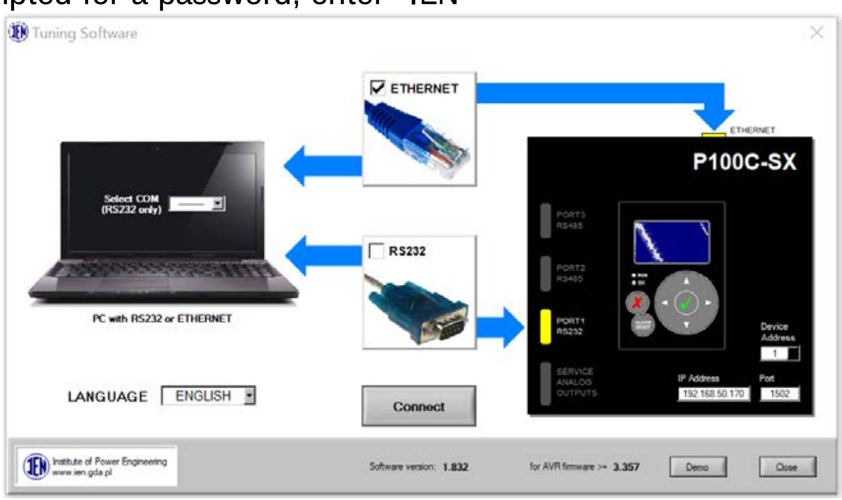
Figure 4-7: P100C-SX keypad buttons and LED's description

4.6 RS232 Connection

1. Connect to the RS232 port of the P100C-SX
2. Identify which com port you have connected on your PC
3. Open the Tuning Software and select the com port shown on the laptop screen software
4. The “CONNECT” button should now be enabled and will allow you to click
5. When prompted for a password, enter “IEN”

4.7 Ethernet Connection

1. Connect to the Ethernet port of the P100C-SX
2. Identify the IP address of the P100C-SX by navigating on the HMI to the Communication Menu
    a. OK to enter
    b. Left Arrow until you reach “System Parameters”
    c. Under “System Parameters” navigate to “Communications”
    d. Enter the Password noted above
    e. Page 2/5 displays the IP address, Subnet Mask, Gateway IP, and Modbus TCP Port
3. Change the IP address of your PC as required to communicate with the P100C-SX. (IE: If the P100C-SX IP is 192.168.50.170, you could set your PC IP address at 192.168.50.171.) Refer to the following link for changing an IP address. https://kb.netgear.com/27476/How-do-I-set-a-static-IP-address-in-Windows
4. Select the Ethernet connection on the tuning software
5. The “CONNECT” button should now be enabled and will allow you to click
6. When prompted for a password, enter “IEN”



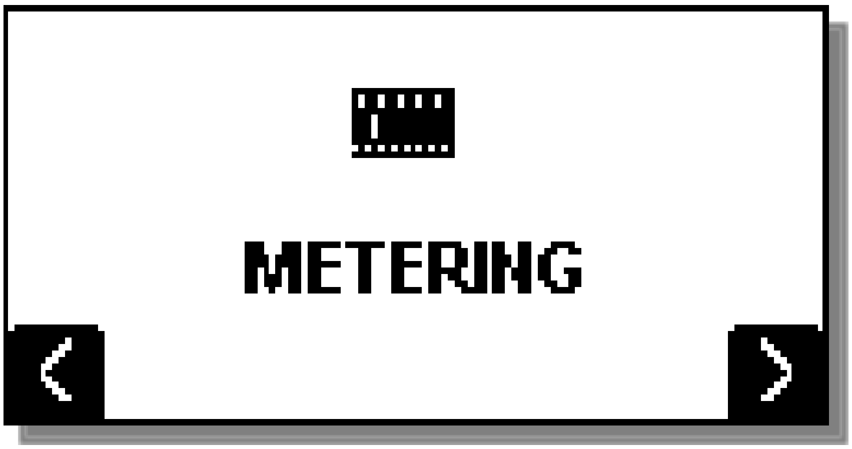
5 P100C-SX TESTING

5.1 Preparation before test:

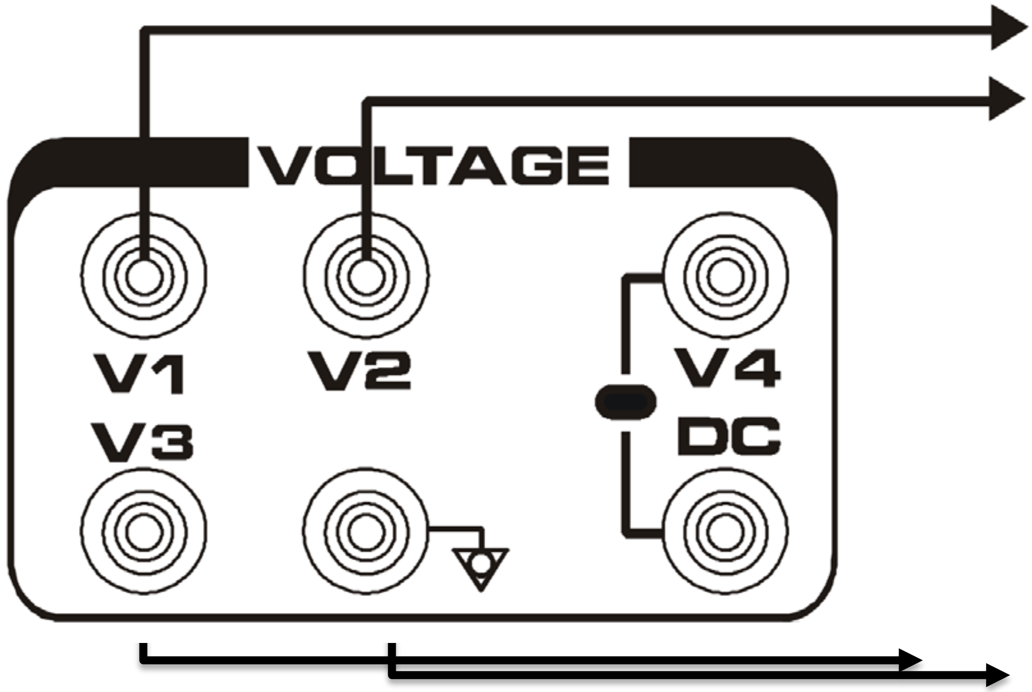
- One table of setting values need to be made by a professional engineer. Ensure the setting values are uploaded to P100C-SX
- Professional test set, multimeter, test wires, ….
- One correct connection diagram of P100C- SX

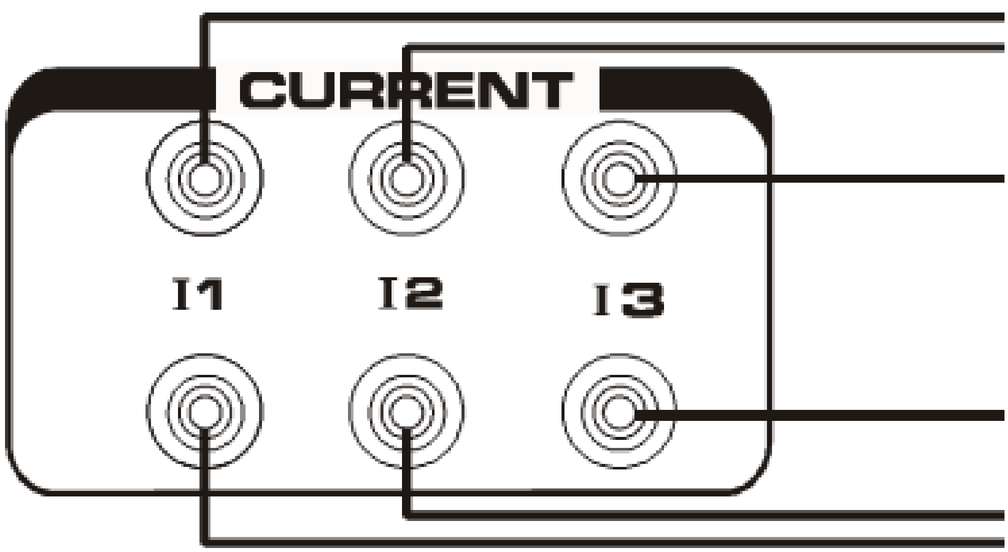
5.2 Metering test.

- Go to METERING menu on the P100C
- Check the metering values on the LCD display on P100C



- Inject 3 phase current and voltage by the test set



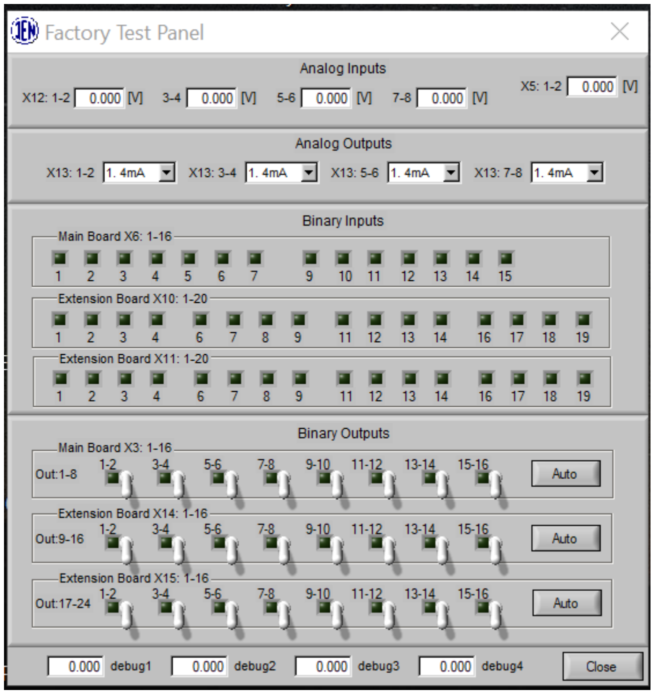


Notes:

- Make sure the setting values for VT ratio and CT ratio on P100C are correct
- Calculate injected current and voltage values equivalent to [pu] on P100C

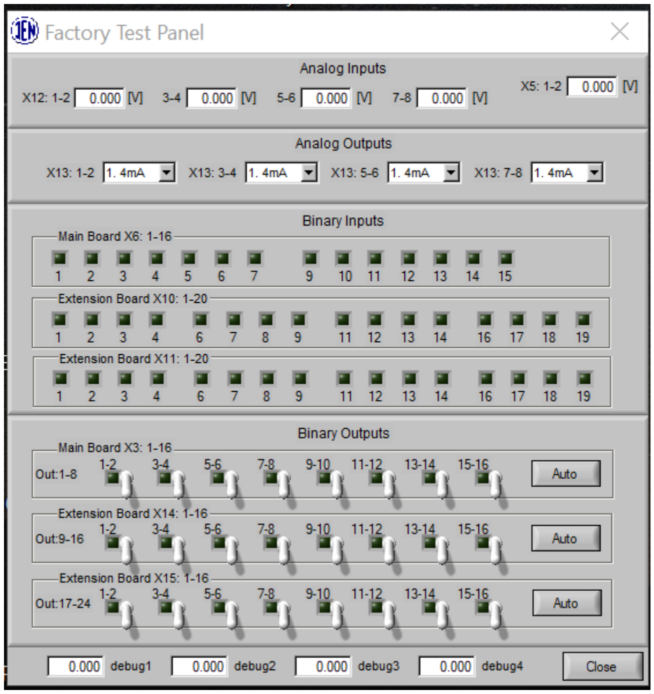
5.3 Binary input

- Go to the TEST PANEL on tuning software
- Supply DC voltage to input terminals and monitor the LED's on the TEST PANEL



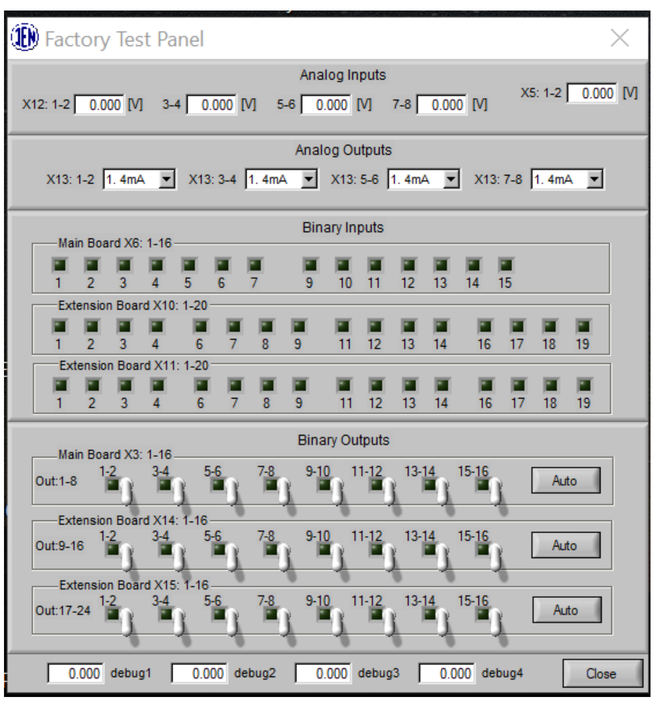
5.4 Binary output

- Use a multimeter, set to continuity to check the output terminals. Set the buzzer test for short circuit.
- Go to the TEST PANEL on the tuning software and choose the outputs required for test



5.5 Analog input

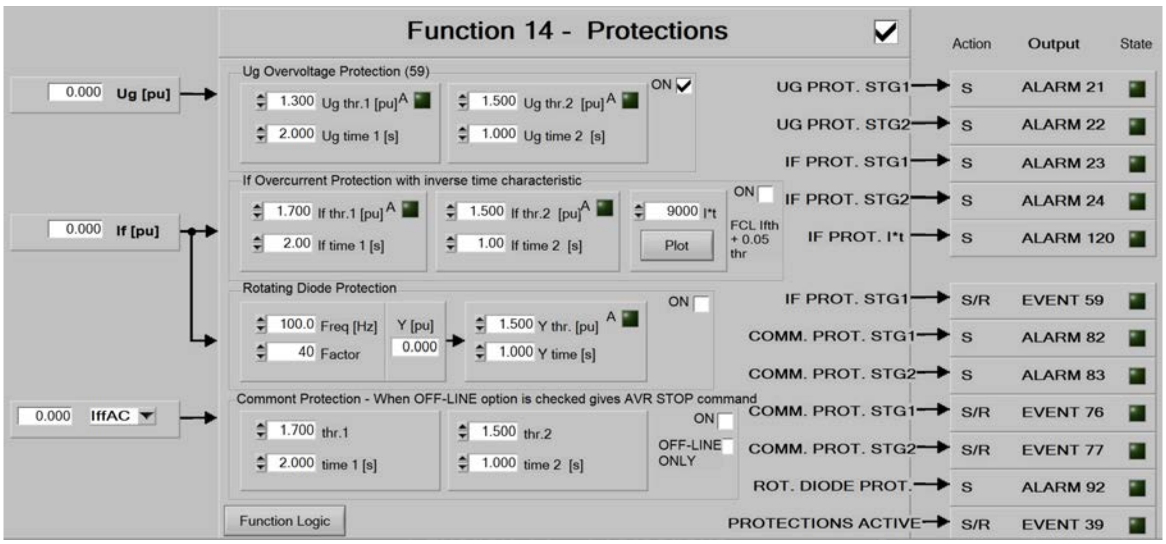
- Supply DC voltage from the test set into equivalent terminals of the analog inputs
- Go to “TEST PANEL” on tuning software and check the voltage values on the TEST PANEL



5.6 PROTECTION FUNCTION TEST

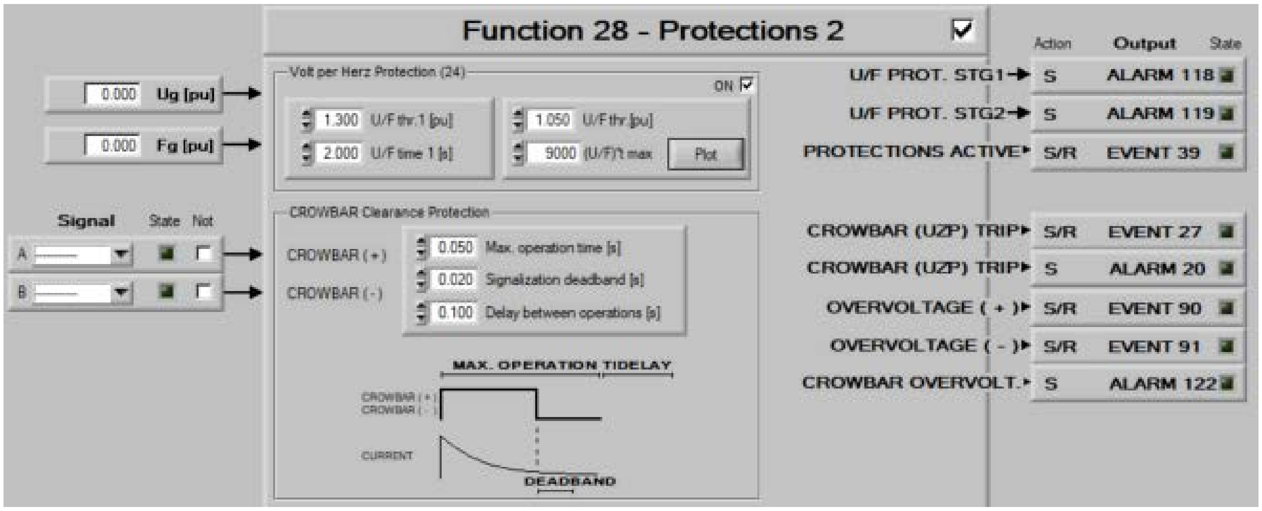
5.6.1 Generator overvoltage – Ug (59)

- Go to INPUT LOGIC then FUNCTION 14-PROTECTIONS
- Enable Function 14 and Ug Overvoltage protection (59)
- Check setting values of the function
- Inject voltage to P100C
- Measure pick-up values of current for stage 1 and stage 2
- Measure operating times for Overvoltage stage 1 and Overvoltage stage 2



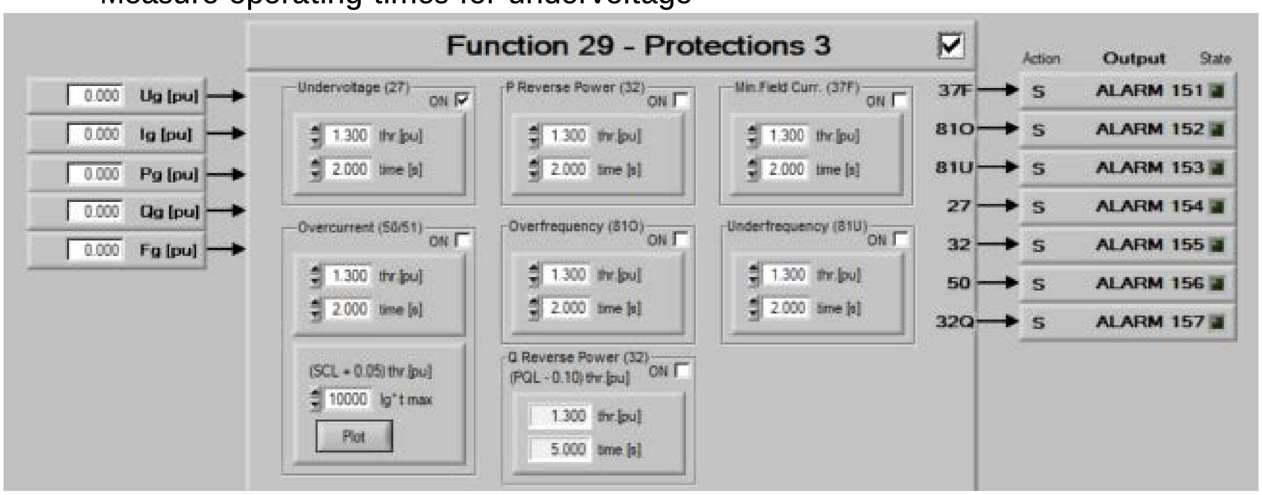
5.6.2 Volt per Hertz protection – V/Hz (24)

- Go to INPUT LOGIC then FUNCTION 28-PROTECTIONS 2
- Enable Function 28 and Volt per Hertz
- Check setting values of the function
- Inject voltage to P100C and adjust ratio of voltage and frequency
- Measure pick-up values of V/Hz for stage 1 and stage 2
- Measure operating times for V/Hz stage 1 and V/Hz stage 2



5.6.3 Undervoltage protection – (27)

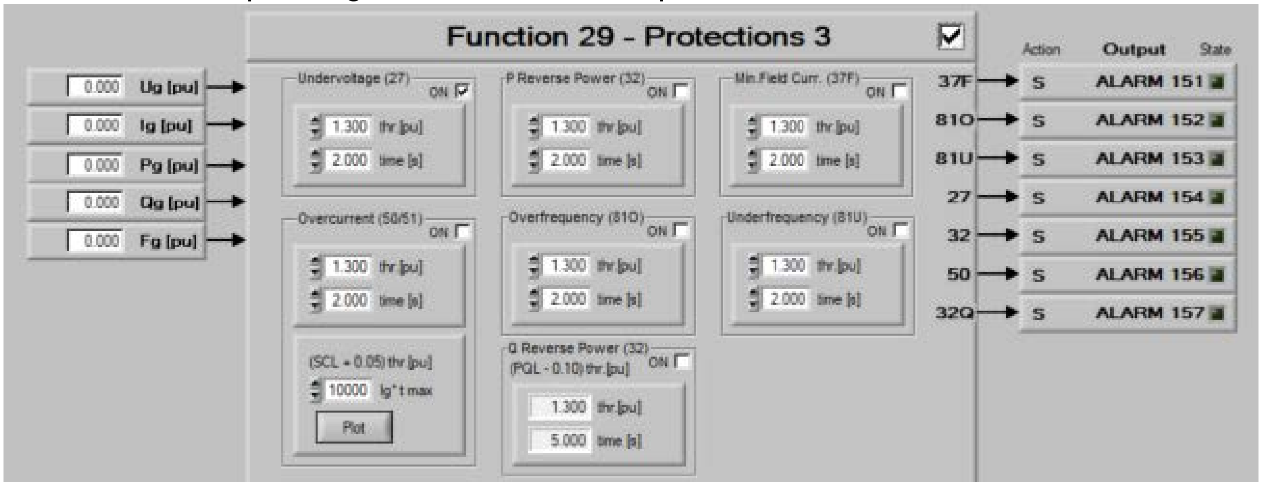
- Go to INPUT LOGIC then FUNCTION 29-PROTECTIONS 3
- Enable Function 29 and Undervoltage (27)
- Check setting values of the function
- Inject voltage to P100C and adjust voltage
- Measure pick-up values of U for stage 1 and stage 2
- Measure operating times for undervoltage



5.6.4 ACTIVE POWER REVERSE PROTECTION (32P)

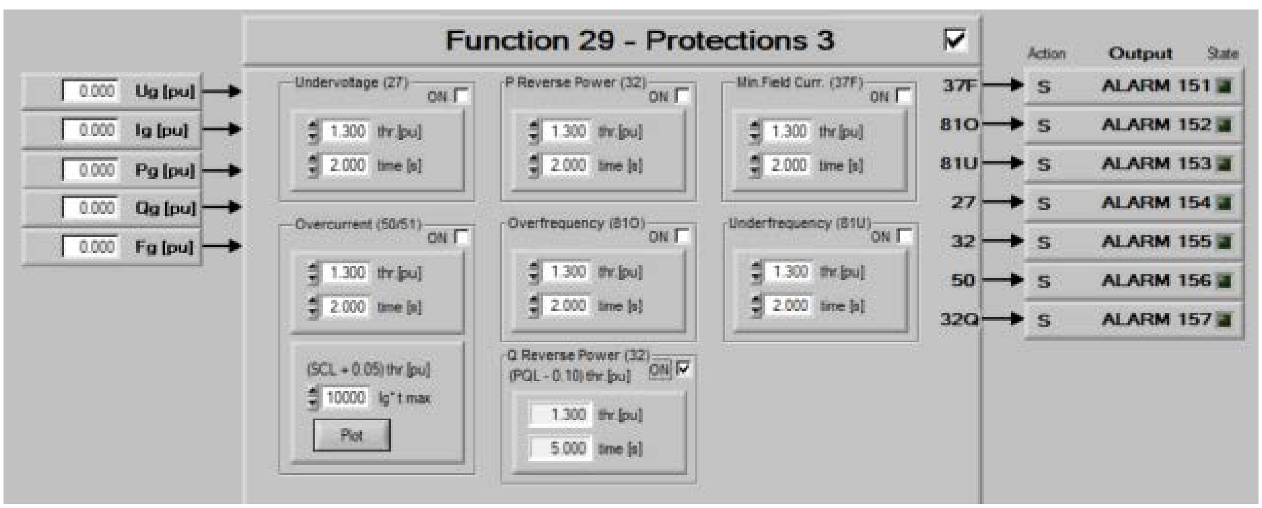
- Go to INPUT LOGIC then FUNCTION 29-PROTECTIONS 3
- Enable Function 29 and P Reverse power (32)
- Check setting values of the function
- Inject voltage and current to P100C
- Adjust angle between Voltage and current to find out Tripping zone and No-Tripping zone

- Measure pick-up values.
- Measure operating times for P Reverse power



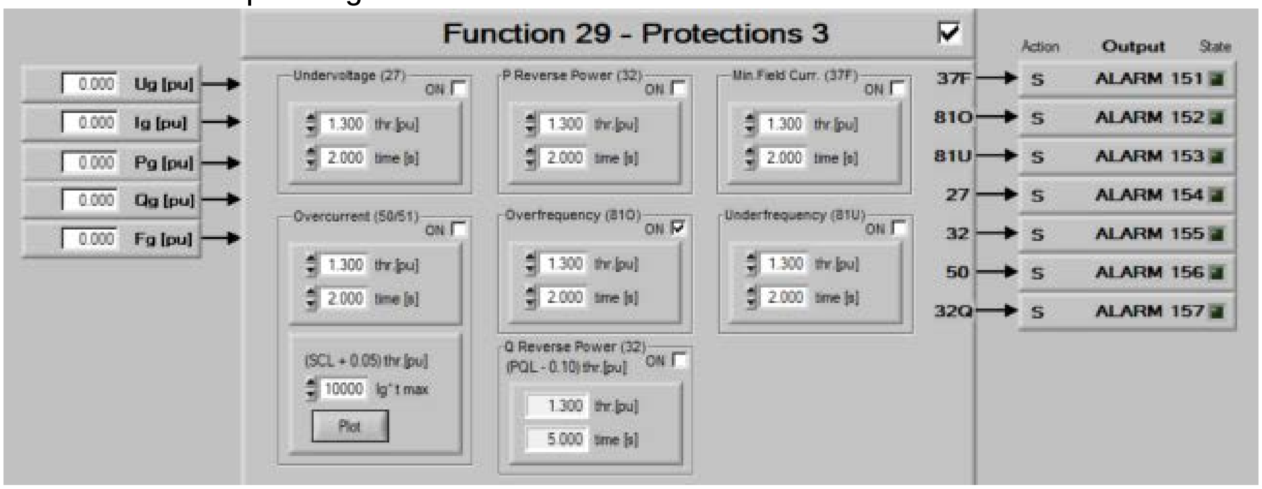
5.6.5 Reactive power reverse protection (32Q)

- Go to INPUT LOGIC then FUNCTION 29-PROTECTIONS 3
- Enable Function 29 and Q Reverse power (32)
- Check setting values of the function
- Inject voltage and current to P100C
- Adjust angle between Voltage and current to find out Tripping zone and No-Tripping zone
- Measure pick-up values
- Measure operating times for Q Reverse power



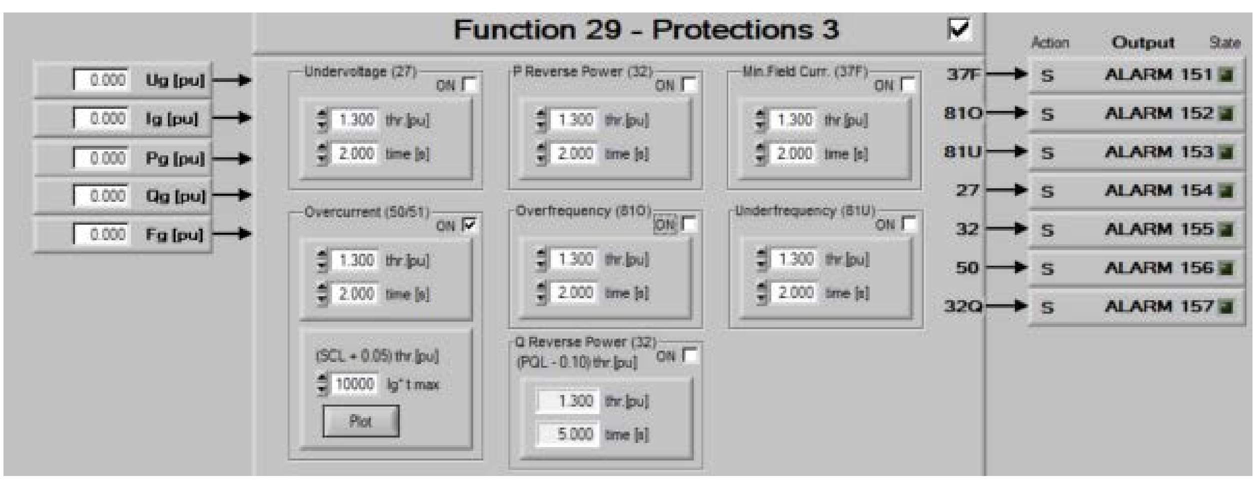
5.6.6 Over-frequency / Under-frequency protection (81O/81U)

- Go to INPUT LOGIC then FUNCTION 29-PROTECTIONS 3
- Enable Function 29 and Under-frequency, Over-frequency
- Check setting values of the functions
- Inject voltage to P100C
- Adjust frequency
- Measure pick-up values of under and over-frequency
- Measure operating times for the functions



5.6.7 Overcurrent protection (50/51)

- Go to INPUT LOGIC then FUNCTION 29-PROTECTIONS 3
- Enable Function 29 and Overcurrent
- Check setting values of the functions
- Inject current to P100C
- Measure pick-up values of over-current
- Measure operating times for the functions



www.dynamic-controls.ca