BASIC OPERATION OF PWRC2 / BattChg SYSTEMs - INTI TEST CENTER FOR SMALL WIND TURBINES

REV.(iv) upd 02-2024 – R.Oliva / L&R Ing.

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I) Introduction

PWRC2 systems (BattChg / wind-charger version) are dedicated dataloggers designed to meet the requirements for the verification of power curves in Small Wind Turbines (SWTs), according to IEC 61400-12-1/Annex H [IEC61400-12-1,2005] and local agencies such as CREE (Regional Wind Energy Center). The equipment is easy to install and remove without altering the characteristics of the system. It can be adapted to different battery bank voltages (12, 24 to 48 V) and different current sensors (50, 100 or 150A) through a configurable external module. Similar models (PWRC2-HV) are used for grid-connected systems.

They are powered through an external 24V supply, with a consumption of less than 4.5W. Newer versions operate from an industrial supply from 220 VAC / 50 Hz.

The PWRC2 has a simple user interface via LCD, a 4-contact touch keyboard and two operation switches, through which most functions can be adjusted. The operation switches located on the front panel (S1 - Operation and S2 - Setup) allow users to select the basic operating modes (Figure 1). PWRC2s can be connected to a PC through a serial or USB cable to modify special or calibration parameters (Setup mode), using a specific application or a standard terminal type program[1]. On top left of the front panel the socket for the 2GB Kingston SD card that serves as storage unit for the test files can be accessed.
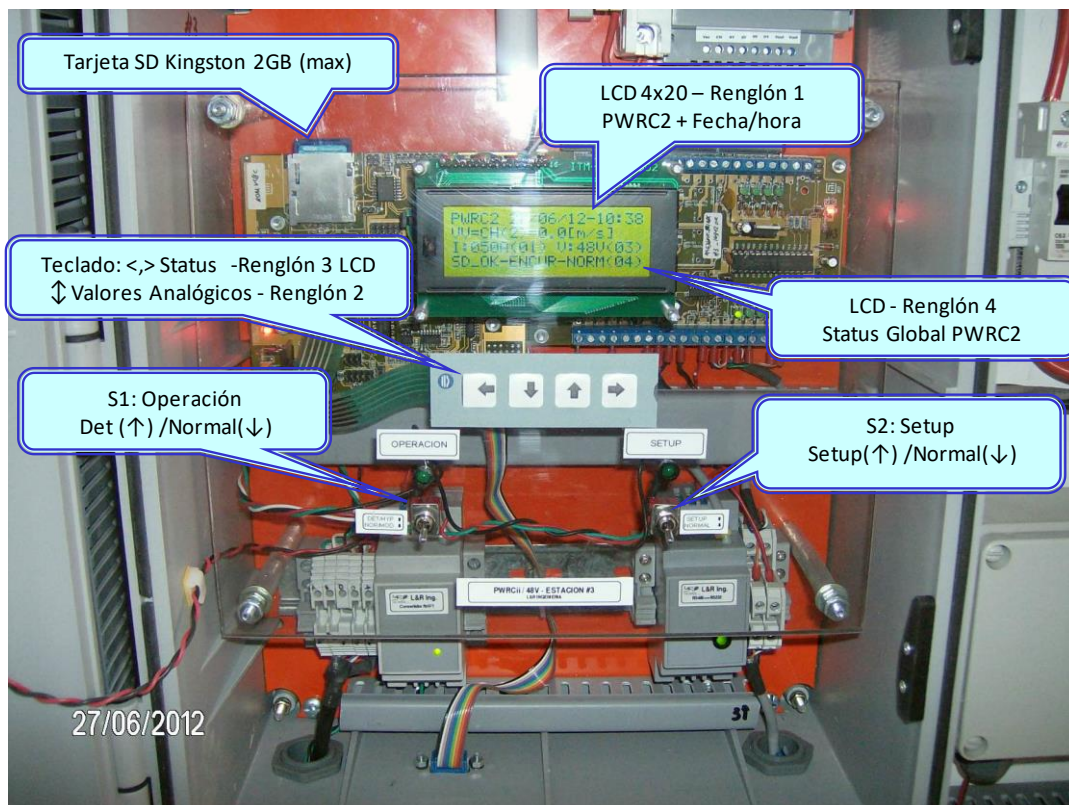

Figure 1– PWRC2 system unit #3, configured for 48V/50A (INTI Cutral-Co – Neuquén)

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[1]References to "Hyperterminal" (formerly included with Windows OSs) indicate a Terminal or CLI (Command Line Interface) type program through a real or virtual serial port, any variant such as Teraterm, Putty or similar can be used.

II) Principles of operation and basic diagram of PWRC2 equipment

The basic relationship between power production P [W] of a wind turbine and the wind speed (or intensity) V [m/s], can be expressed through the following equation:

¡Error! Objeto incrustado no válido. (Eq.1)

Where:

ρ is the density of air [kg/m3]
D is the diameter of the rotor [m]
η_{ts} is the efficiency of the generator and mechanical transmission [ ].
C_p is the dimensionless aerodynamic coefficient of rotor power
 (which depends on wind and rotation speed)
V wind speed [m/s]
P is the electrical power generated, in [W].

As indicated in Eq.1, the $P(V)$ relationship is cubic with wind speed V, a strongly random variable. In Figure 2 this relationship is shown expressed as power per unit area (specific power [W/m^2]), with the upper curves being those of the specific power of free wind, the theoretical specific power (sometimes called Betz limit) and the lower one corresponding to a typical wind turbine, fundamentally affected by the aerodynamic coefficient C_p.
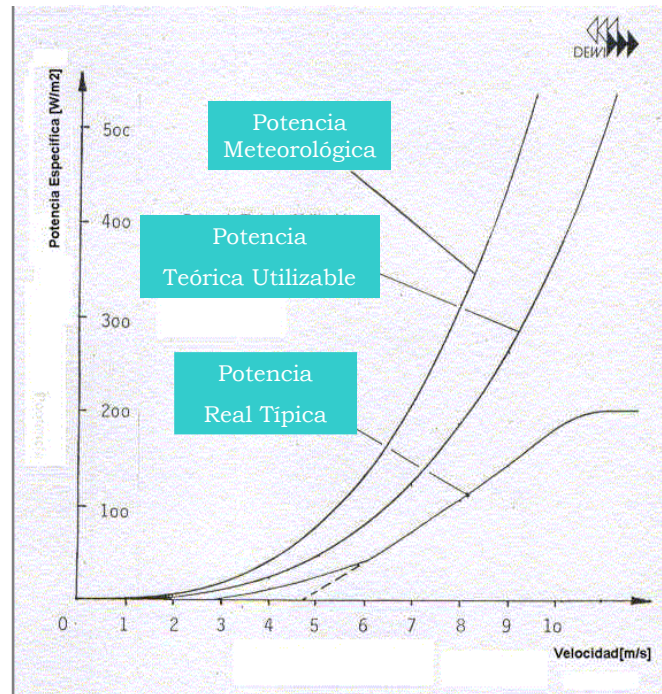
Figure 2 – Meteorological and theoretical specific powers contained in the wind, and real specific power of a typical wind turbine

Furthermore, Eq.1 implies a linear dependence with air density ρ. The calculation of this density can be derived from Eq.2 as follows:

¡Error! Objeto incrustado no válido. (Eq.2)

Therefore, an accurate measurement requires evaluating temperature T and barometric pressure B conditions at the test site.

International agreement on the methodology to measure a statistically valid power curve, and what is known as AEP or expected Annual Energy Production for each wind turbine, was a lengthy process started in the 1980s. It was first summarized in the International Electrotechnical Commission (IEC) standard [IEC61400-12-1, 2005]. The measured power curve is determined, according to this standard, by collecting simultaneous measurements of wind speed and power production at the test site over a period long enough to establish a statistically significant database over a range of wind speeds, and under varying atmospheric conditions. The AEP is calculated by applying the measured power curve to reference wind speed frequency distributions, assuming 100% availability. Uncertainty calculations on the measurements are mandatory and are also covered by the IEC61400-12-1 standard.

PWRC2 equipment facilitates the application of this standard and is based on the simultaneous acquisition of wind turbine variables (for power measurement) and meteorological variables from a measurement tower located so as to capture the wind incident on the turbine at the rotor height (Figure 3).
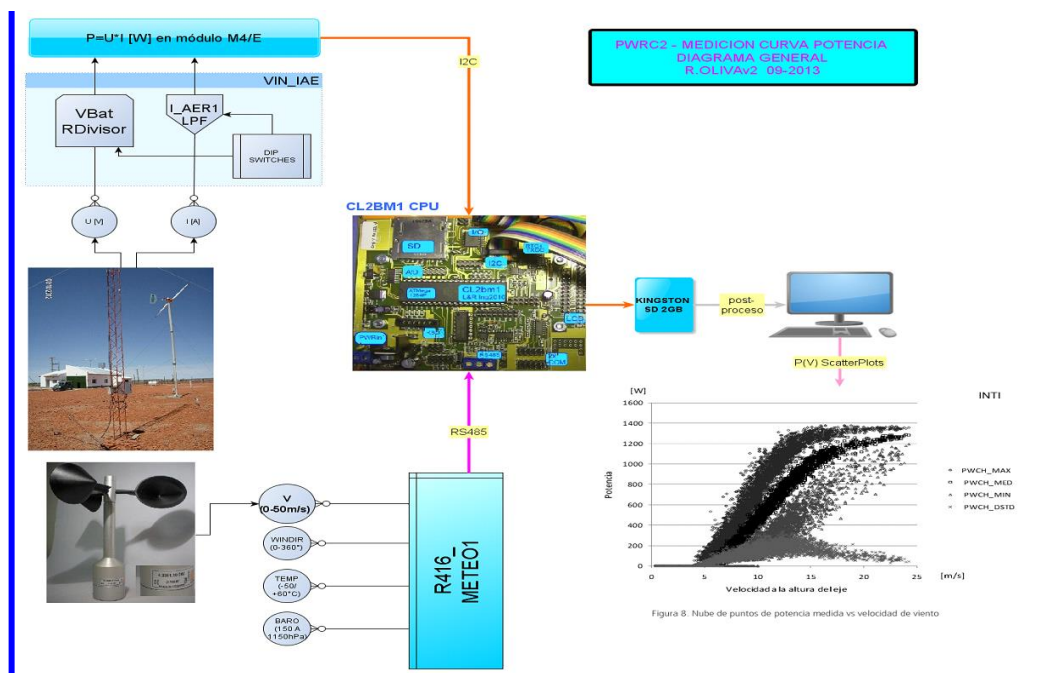
Figure 3 – Principle of operation of the PWRC2/BattChg System for testing power curves in small wind chargers

PWRC2 systems perform the calculation and storage on a removable card of the averages and other statistical parameters of these variables. This allows the creation of "scatter plots" that can be post-processed to produce a valid *P(V)* curve. In Figure 4 a block diagram of the system for a single wind turbine is shown illustrating the operation of the battery wind charger PWRC2 version. The communication of the meteorological subsystem [METEO, 2022] (module that acquires wind data in intensity and direction, temperature and barometric pressure, on the left in Figure 4) is via RS485 but in a unidirectional configuration, and one METEO module is used for every two wind turbines.
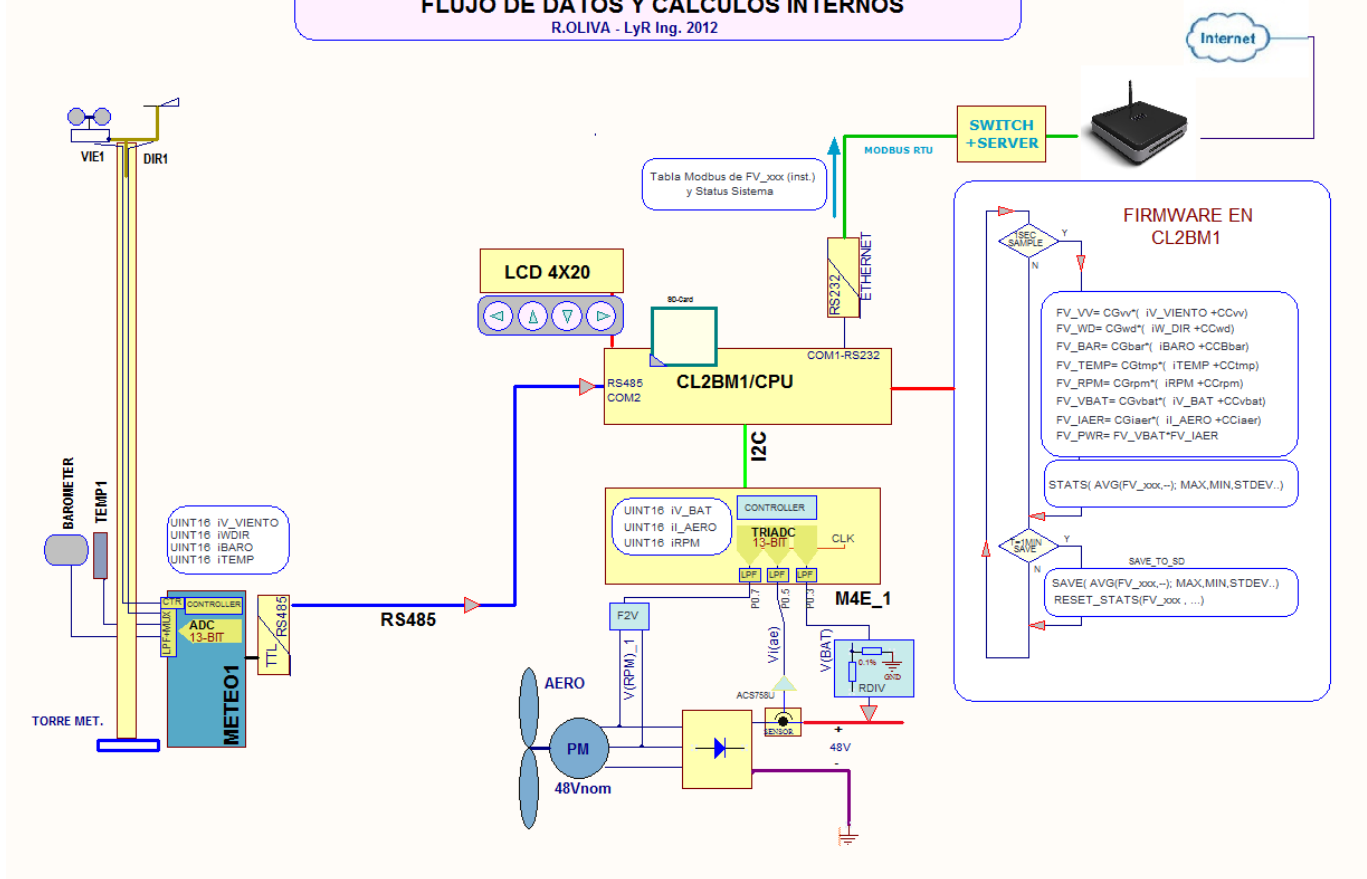
Figure 4 – PWRC2 block diagram in normal operation.

In Figure 5 the distribution of system components can be observed from the operator's point of view, in their normal working condition. Here it is assumed that the equipment has been previously configured, and the test launched.

SISTEMA PWRCii
Banco de Pruebas INTI CutralCo - Pequeños Aerogeneradores
Ing. R.Oliva - 31/05/2012

ESTADO -> S2: NORMAL; S1: NORMAL; CONFIG.HARD:OK

PRUEBA LANZADA OK
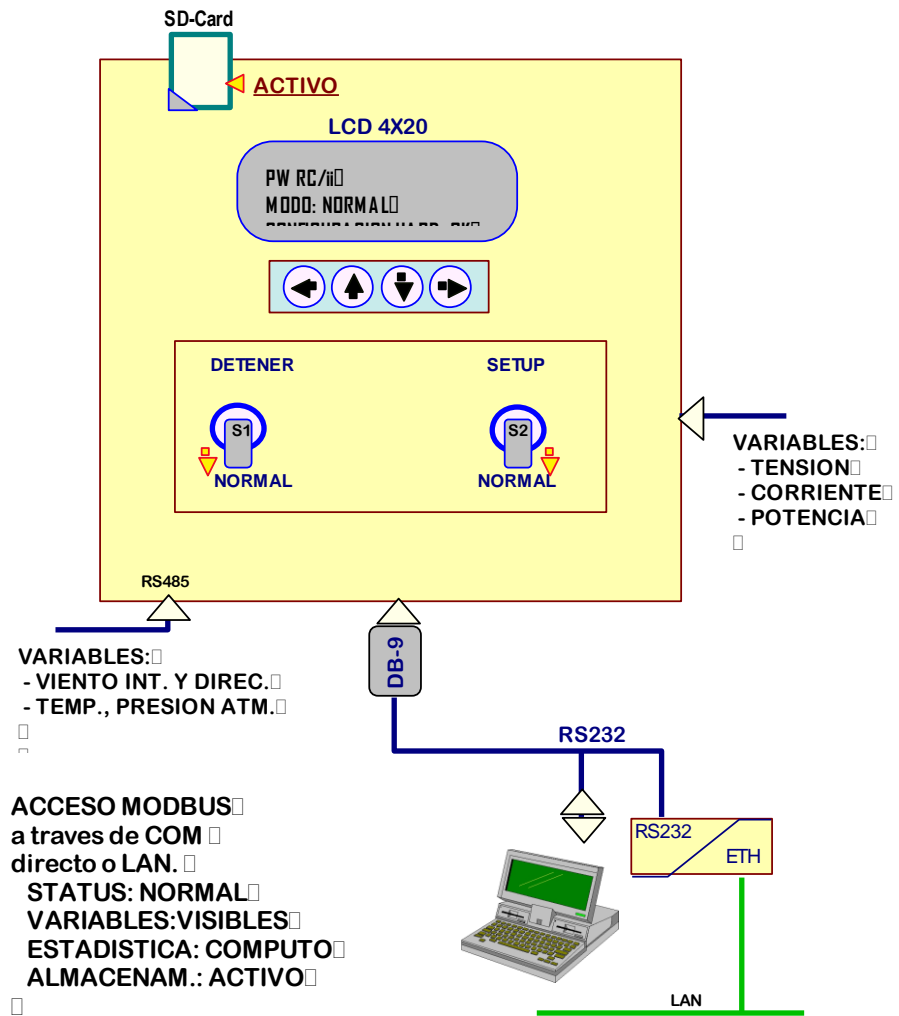
Figure 5 – Diagram from the operator's point of view, of the PWRC2 in normal operation.

III) SD Card Removal – (PWRC2/BattChg with Firmware from [06-2012])

The correct sequence for removing the SD card is shown in Figure 6 and Figure 7.

III.1) Cut off the power supply to the PWRC2, through (I) the indicated thermal switch or the S1 switch (Ib) in versions with AC connected industrial power supply.

III.2) Remove (II, IIb) the SD Card from the socket on the CPU board [CL2-board-LyRIng, 2022]

III.3) Copy the latest Pxddmmaa.csv and Exddmmaa.csv (x would be A to D) files to a PC via an SD card reader.

III.4) Reinsert the SD Card into the socket with PWRC2 off.

III.5) Turn on the PWRC2. If the test was launched, a normal start with both keys S1,S2 down resumes the test.
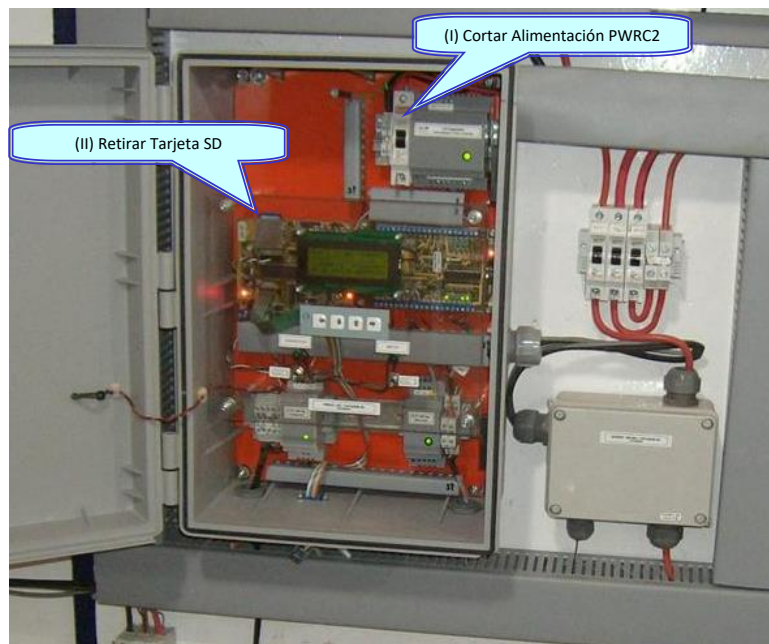
Figure 6 – SD card removal sequence in PWRC2, firmware v2012 and 24 Vdc power source.
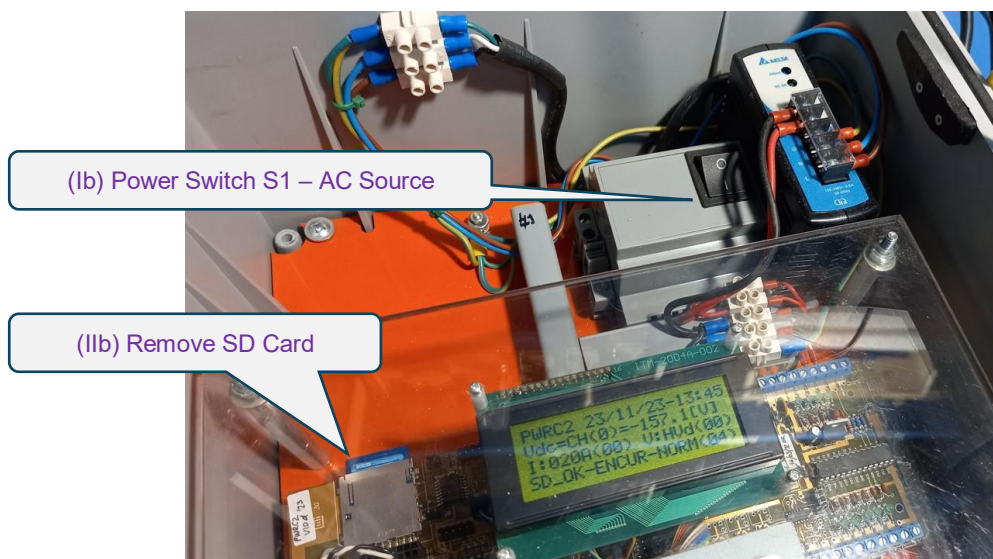
Figure 7 – Sequence for the case of PWRC2 with AC Power Supply

IV) PWRC2 Interface with the rest of the system

In Figure 8 the interaction of several PWRC2 units at the INTI low-power wind turbine Test Site in Cutral Có, Neuquén is shown. Blocks of variables that appear "published" for each unit via the Modbus protocol are also shown.
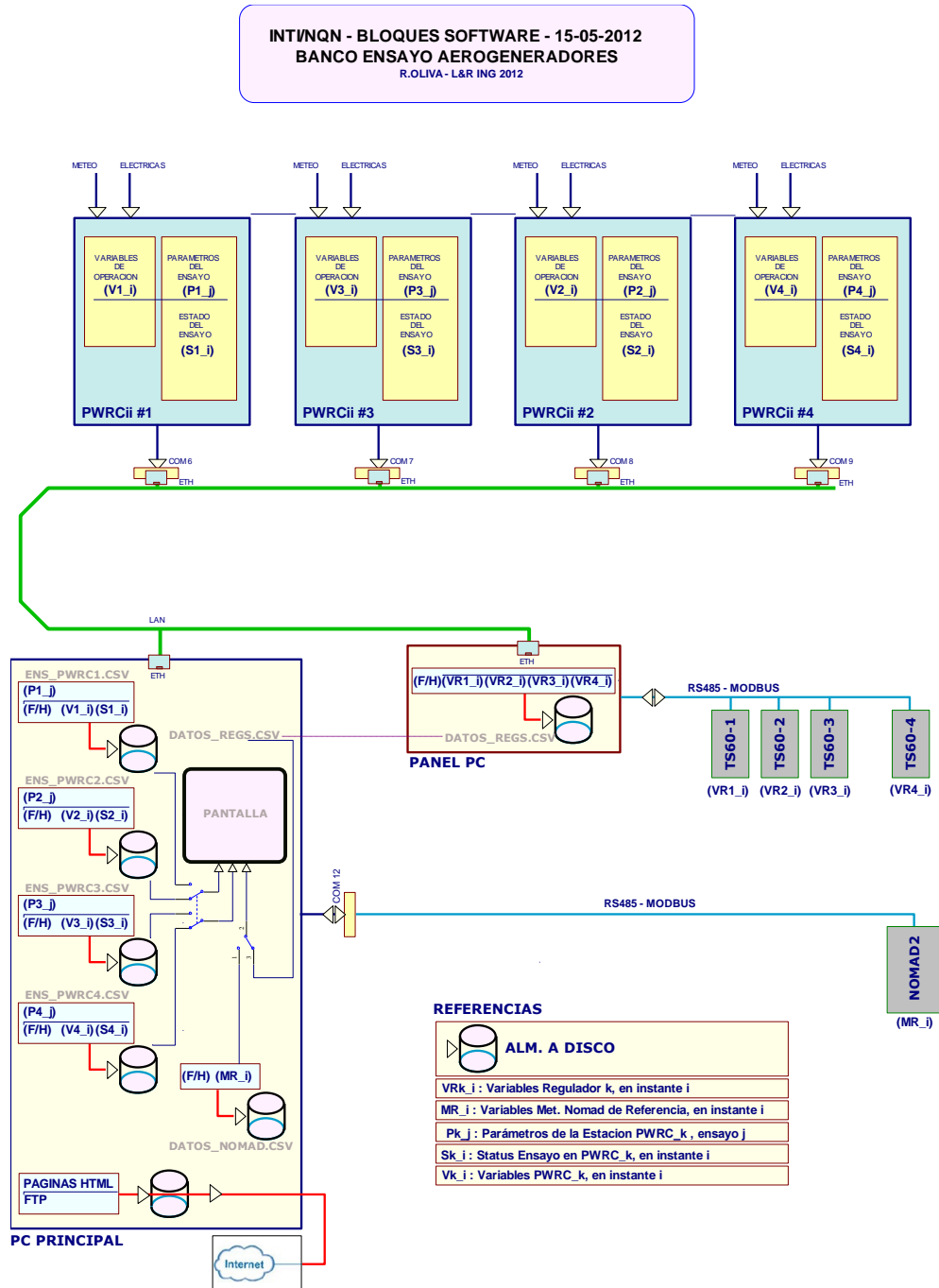
Figure 8 – Network block diagram with multiple PWRC2s

V) Internal operation of PWRC2 systems

V.1 Startup (boot) process without configuration or launched test.

In a boot without prior configuration, the system performs a basic initialization and test of connected elements. Additionally, the system reads the parameter values loaded in non-volatile EEPROM memory. Parameters read are:

V.1.a) Status of the sensor configuration DIP switches. This is required because the calibration constants that are loaded to read the voltage and current channels will depend on the configuration of the DIP switches on the sensor board (Figure 9). The user can change the constants via the Firmware when a different type of sensor is deployed. Furthermore, the selection of the default voltage values for each test level and the test voltage thresholds depend on the voltage DIP settings.
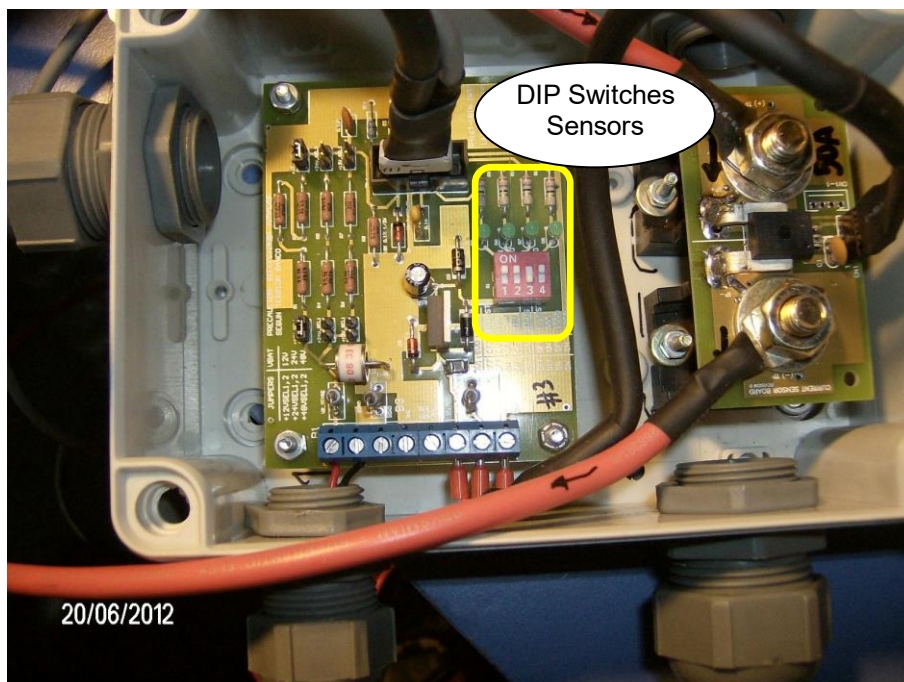
Figure 9 – Sensor module for set for 48 V and 50 A current, and DIP Switches configured, connected to a PWRC2

V.1.b) Status of the SD card (connected and initialized properly). The card may or may not be inserted in its socket.

V.1.c) Status of the front panel switches S2,S1 These S2, S1 switches appeared in Figure 1 and in Figure 3, and determine the following:

V.1.c.1) S2 -> Setup Mode or Normal Mode

V.1.c.2) S1 -> Stopped Test or Normal Test. If S2 is in Setup, then S1 controls whether the setup is done via Modbus (not implemented) or through the classic Terminal menu.

Reading these two switches configures an internal variable FRP_Status (Front Panel Status) that can take the values indicated in Table 1:

S2	S1	FRP_Status
0	0	0 = Normal
0	1	1 = Stop test
1	0	2 = Setup (Modbus)
1	1	3 = Setup (Hyperterm.)

Table 1- Values of FRP_Status set by the PWRC2 user with front panel switches

Also during boot, error messages are transformed into EVENTS if the SD card is connected and active, which are stored in an Exddmmaa.csv file (x indicates one of the four letters A,B,C,D to indicate the PWRC2 station). This file is not associated with a particular test. If the system cannot find the last Event file it created, it creates a new one during the boot sequence.

On the other hand, the DATA file Pxddmmaa.csv is associated with a test, and is created during its launch. The possible states of a test (associated with the internal variable SYS.Meas_Status) are:

1. NOT INITIALIZED   00

2. IN PROGRESS – NORMAL   01

3. CONFIGURATION ERROR   10

4. FINISHED   11

In a no-configuration boot as shown, the system defaults to this UNINITIALIZED test state. The user can enter a SETUP menu via Terminal, define the test parameters and LAUNCH the test. If everything is correct, the test status becomes IN PROGRESS – NORMAL. If the system is turned off for any reason (card removal, power failure, etc.) and during a subsequent boot it does not find the corresponding DATA file, the test rolls back to the NOT INITIALIZED state. Otherwise, the system returns to the IN PROGRESS – NORMAL state.

In addition to the test status, the factors that define what is known as the global system status (Global_Status) are the previously mentioned: V.1 a) installed sensors, V.1.b) status of the SD card, and V.1.c) S1 and S2 switches managed by the user.

This Global_Status variable (permanently displayed in line 4 of the LCD, see Figure 1) is what controls the future evolution of the program. It is computed as a weighted sum:

$$Global\_Status = FLAG\_NO\_SD*(2**4)+(SYS.Meas\_Status)*(2**2)+ FRP\_Status$$

and can take one of the values indicated in Table 2:

Tabla 1 - Valores de Estado Global	Valor		Descripcion			
STAT_SDOK_NOINIC_NORM	0		SD OK no inicializado			
STAT_SDOK_NOINIC_NDET	1		SD OK no inicializado			
STAT_SDOK_NOINIC_MBSETUP	2		SD OK no inicializado - Setup via Modbus			
STAT_SDOK_NOINIC_HYSETUP	3		SD OK no inicializado - Setup via Hyperterminal			
STAT_SDOK_ENCURSO_NORM	4		SD OK prueba en curso - Normal			
STAT_SDOK_ENCURSO_NDET	5		SD OK prueba en curso - Detenido			
STAT_SDOK_ENCURSO_MBSETUP	6		SD OK prueba en curso - Setup via Modbus			
STAT_SDOK_ENCURSO_HYSETUP	7		SD OK prueba en curso - Setup via Hyperterminal			
STAT_SDOK_ERRCFG_NORM	8		SD OK Error Configuracion			
STAT_SDOK_ERRCFG_NDET	9		SD OK Error Configuracion			
STAT_SDOK_ERRCFG_MBSETUP	10		SD OK Error Configuracion - Setup via Modbus			
STAT_SDOK_ERRCFG_HYSETUP	11		SD OK Error Configuracion - Setup via Hyperterminal			
STAT_SDOK_TERMIN_NORM	12		SD OK prueba terminada			
STAT_SDOK_TERMIN_NDET	13		SD OK prueba terminada			
STAT_SDOK_TERMIN_MBSETUP	14		SD OK prueba terminada - Setup via Modbus			
STAT_SDOK_TERMIN_HYSETUP	15		SD OK prueba terminada - Setup via Hyperterminal			
STAT_NOSD_NOINIC_NORM	16		SD NOT OK no inicializado			
STAT_NOSD_NOINIC_NDET	17		SD NOT OK no inicializado			
STAT_NOSD_NOINIC_MBSETUP	18		SD NOT OK no inicializado - Setup via Modbus			
STAT_NOSD_NOINIC_HYSETUP	19		SD NOT OK no inicializado - Setup via Hyperterminal			
STAT_NOSD_ENCURSO_NORM	20		SD NOT OK prueba en curso - Normal			
STAT_NOSD_ENCURSO_NDET	21		SD NOT OK prueba en curso - Detenido			
STAT_NOSD_ENCURSO_MBSETUP	22		SD NOT OK prueba en curso - Setup via Modbus			
STAT_NOSD_ENCURSO_HYSETUP	23		SD NOT OK prueba en curso - Setup via Hyperterminal			
STAT_NOSD_ERRCFG_NORM	24		SD NOT OK Error Configuracion			
STAT_NOSD_ERRCFG_NDET	25		SD NOT OK Error Configuracion			
STAT_NOSD_ERRCFG_MBSETUP	26		SD NOT OK Error Configuracion - Setup via Modbus			
STAT_NOSD_ERRCFG_HYSETUP	27		SD NOT OK Error Configuracion - Setup via Hyperterminal			
STAT_NOSD_TERMIN_NORM	28		SD NOT OK prueba terminada			
STAT_NOSD_TERMIN_NDET	29		SD NOT OK prueba terminada			
STAT_NOSD_TERMIN_MBSETUP	30		SD NOT OK prueba terminada - Setup via Modbus			
STAT_NOSD_TERMIN_HYSETUP	31		SD NOT OK prueba terminada - Setup via Hyperterminal			

Table 2- Global_Status values in PWRC2

Suppose the system is configured as S2:S1 = 11, Setup-Hyperterminal. In turn, the sensor board has all the DIP switches at 00 (not installed) and this is coincident with the state saved in EEPROM, so the test state remains at NOT INITIALIZED==00 (otherwise, at this point it would go to CONFIGURATION_ERROR==10). Likewise, let's assume that the SD card is inserted, and that its initialization was correct, so SD appears as OK.

Calculating Global_Status through the indicated expression for this case gives:

$$\text{Global\_Status} = 0*(2**4)+(00b)*(2**2)+(11b) = 3,$$

which corresponds to the state STAT_SDOK_NOINIC_HYSETUP. This would imply that the system accepts the classic initialization menu via Terminal at 19200,N,8,1 and remains in this state until the values re-entered.

Entering all the values required by the Setup and the Launch Test commands will call a routine to verify the consistency between the hardware set by DIP switches and that provided in Setup. If everything is OK, and the SD card is still OK, the system performs the following sequence:

a) Creates the file Pxddmmaa.csv (x would be from A to D) which would be the data for the power curve to be built. This file will have a short header, after which rows will be "appended" once per minute with the averages. One minute is the default setting for SWTs according to the IEC Standard – Annex H.

b) Record the launch in the Exddmmaa.csv Events file.

c) Change the test status to IN PROGRESS - NORMAL == 01

The system state machine calculates the new value:

Global_Status=0*(2**4)+(01b)*(2**2)+(11b)= 4+3 = STAT_SDOK_ENCURSO_HYSETUP.

At this point, if we change the S2 key from Setup to Normal, and the S1 key from Stopped to Normal, we have:

Global_Status = 0*(2**4)+(01b)*(2**2)+(00b) = 4 = STAT_SDOK_COURSE_NORMAL.

Under these conditions, through the main COM port of the PWRC2 the status of the equipment can be accessed with an interface (Ensayo23b.exe by R.Vallejos) that uses the Modbus protocol, as shown in Figure 10. It should be noted that when operating in Modbus, the SETUP mode menu system stops operating.
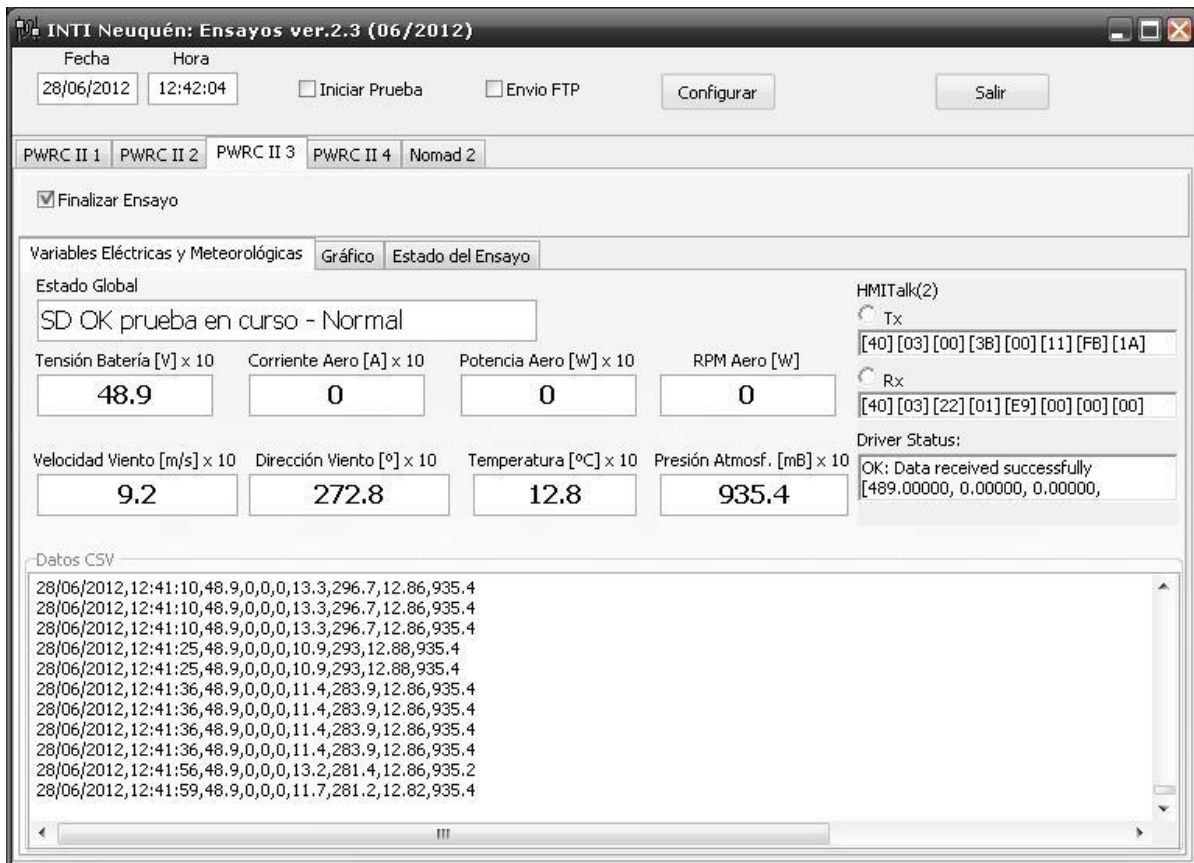
Figure 10 – Modbus remote interface (Ensayo23) of one of the PWRC2s in NORMAL mode – IN PROGRESS

V.2 Startup due to shutdown or power loss from IN_COURSE.

In this case, the System repeats the basic initialization and testing of connected elements, and records ERROR if there is any failure. In addition, it reads again (a) the configuration DIP switches and with it the default values of the analog channels parameters loaded in EEPROM, and other required parameters.

Following operation is (b) Status of the SD card (connected and initialized properly) and finally (c) Status of the front panel switches S2,S1.

This information together with the previous test status memory (in this case it is assumed that it was in NORMAL –IN PROGRESS=01) and the set values of the sensor configuration, allows the PWRC2 to calculate the Global_Status variable. In this case, if there have been no adjustments to the DIP switches or keys, and the SD continues as before, this variable should contain:

$$Global\_Status=0*(2**4)+(01b)*(2**2)+(00b)=4 =STAT\_SDOK\_COURSE\_NORMAL.$$

If the card is OK, at this startup the existence of the files being worked on will be checked. If they are found, the same test status continues. Otherwise, it goes to SYS.Meas_Status==00 (Not Initialized) since the test must be restarted.

V.3 Startup in different conditions after a RESET from IN_COURSE.

In this case, if the PWRC2 upon repeating the basic initialization, testing of connected elements, and reading the values from EEPROM, verifies that the configuration has changed (e.g. (i) DIP switches for a different voltage or current than the configured one, or (ii) absence of SD card) a change of Global_Status will be forced:

(i) Global_Status = 0*(2**4)+(10b)*(2**2)+(00b) = 2*4 = 8 = STAT_SDOK_ERRCFG_NORMAL.

Here the system does not continue with the test and the display warns of the error, and prompts the user to go to Setup to solve it.

(ii) Global_Status =1*(2**4)+(01b)*(2**2)+(00b)= 1*16+1*4 = 20 = STAT_NOSD_NORMAL_COURSE.

Here the system does not continue with the test until the SD insertion and correct operation is detected again.

V.4 Step to STOP_TEST from IN_COURSE.

Changing Switch S1 from 0 to 1 (DET) from IN_PROGRESS mode implies temporarily stopping the test. In future firmware versions, the SD card will be de-energized and will allow it to be removed, for example to copy the files (in the current version you must turn off the device, see procedure in III).

When user reinserts the SD card and applies power again, as long as it is still in DET mode there will be no activity. By changing S1 to NORMAL again (S2==NORMAL) the test will be resumed from where it was.

VI) Configuration and status in Terminal PC program (Teraterm, Hyperterminal or sim.)

VI.a – Configuration in Hyperterminal: The operations for setting up the test are described below, as mentioned in V.1.c). The front panel keys S2,S1 have the functions S2 (right)-> Setup Mode or Normal Mode, and S1 (left)-> Stopped Test or Normal Test. If S2 is "up" in Setup, then S1 "up" implements the classic Hyperterminal menu. This is the initialization position indicated in Figure 11.

INGENIERIA
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T. DE LOQUI 58 - 9400 RIO GALLEGOS

SISTEMA PWRCii
Banco de Pruebas INTI CutralCo - Pequeños Aerogeneradores
Ing. R.Oliva - 26/08/2012

ESTADO: CONFIGURACION VIA HYPERTERMINAL
S2: SETUP, S1: DETENER/HYPERT
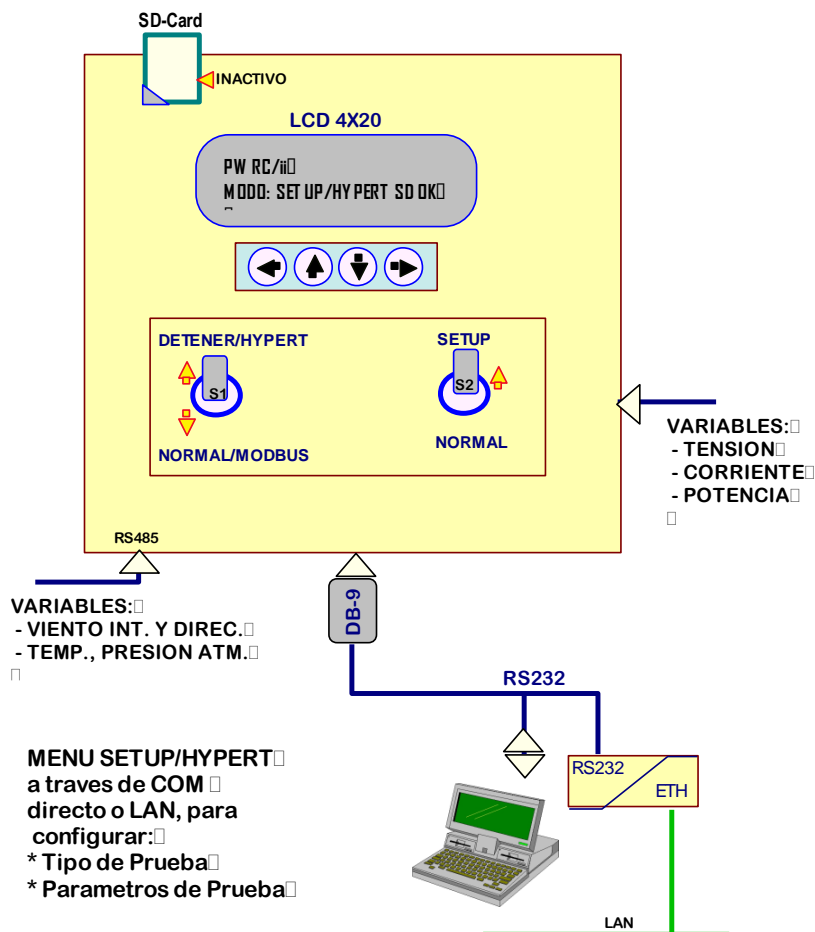
Figure 11 – PWRC2 from Setup/Hyperterminal Mode, from the user point of view.

With the two keys in the upper position, the system can enter one of the states with _HYSETUP ending of Table 2 (3, 7, 11, 15, 19, 23, 27 or 31). If everything is operating satisfactorily and this is an initial configuration, the status should be: 3 =STAT_SDOK_NOINIC_HYSETUP

In this mode of operation, as can be seen in Figure 12, it is possible to access the PWRC2 directly using an RS232 port and a Terminal type program (Hyperterminal, Teraterm[2], Putty[3]or similar) using the settings 19200,N,8,1, or through the supplied LAN. In the first case, whether it is a physical RS232 port or a USB emulator, the correct COM number must be selected for direct communication between the PC and the PWRC2.

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[2]Teraterm:https://teratermproject.github.io/index-en.html
[3]Puttyhttps://www.chiark.greenend.org.uk/~sgtatham/putty/latest.html
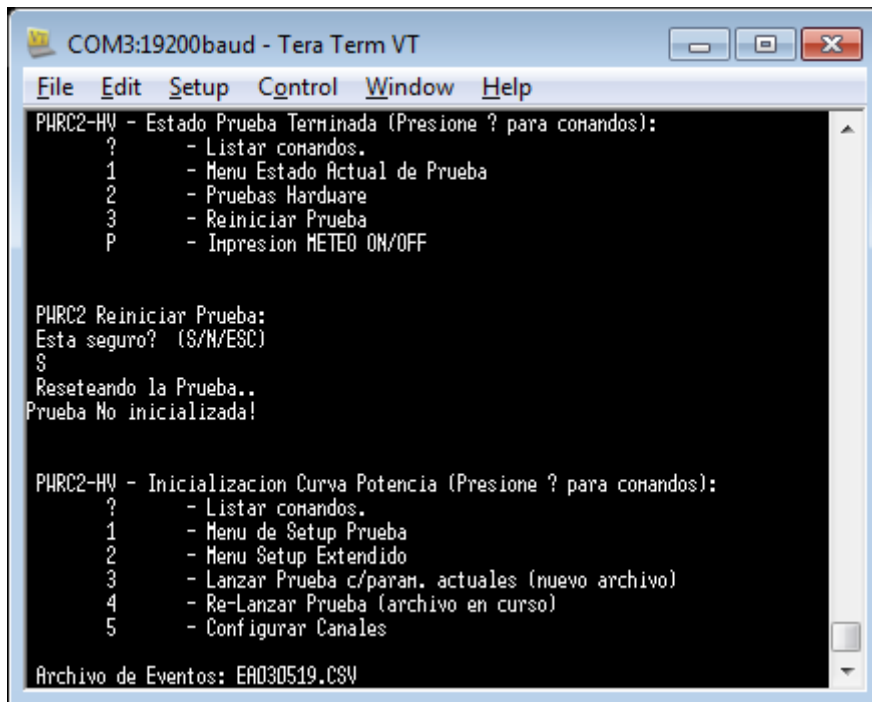
Figure 12 – Access to PWRC2 (HV version) via TeraTerm

The usual connection will be through the LAN, using the Exemys serial port to Ethernet converter [Exemys SSE, 2020] installed on the system, in which case the corresponding virtual COM port will also be accessible from Windows through the LAN. The configuration of these virtual ports (in general it is not necessary to redo it) is carried out through a browser as indicated in Figure 13.
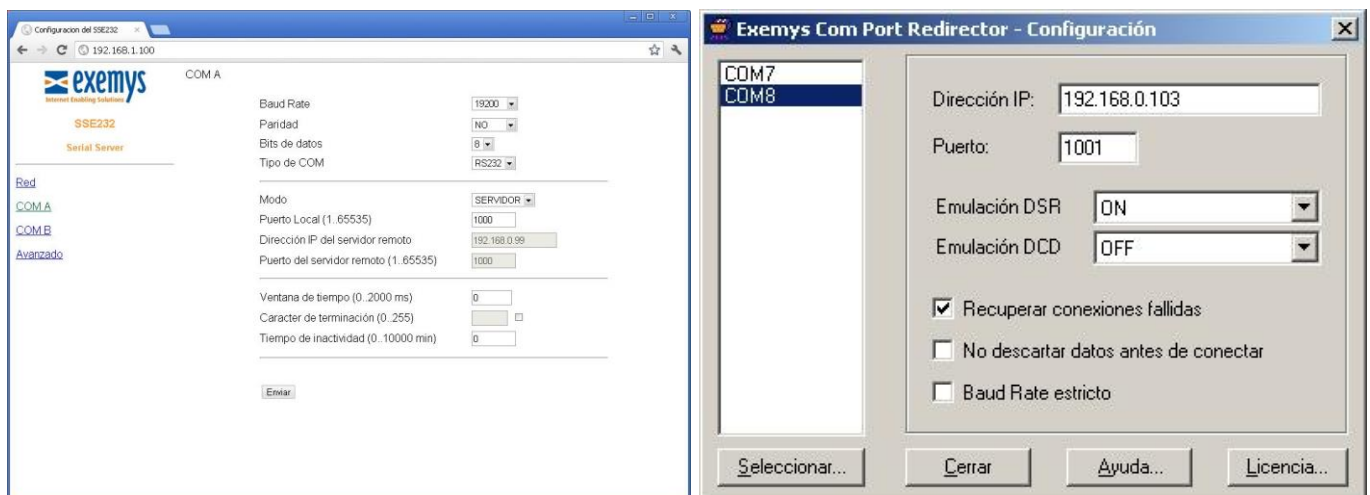
Figure 13 Exemys Virtual Port Configuration on SSE232-2 module (2 COM ports), and ECPR Port Redirector

Within the Terminal program, user must first make sure that it is "Disconnected" in the Status indicated on the screen. Then enter "connection", select the appropriate direct COM and configure the serial port for 19200 baud, 8 bits, no parity, 1 stop bit and no flow control.

It is recommended to implement text capture or LOG in the Terminal program. Select a name and directory for a Capture file (.LOG or .TXT) of your choice, to record the operations carried out while accessing the PWRC2.

If the system was turned off, and the Port was properly configured, when the system is turned on, an initialization is performed (which appears in the Terminal), leading to the Initialization Menu. If the system is already on, just press "?" for this menu to appear, as follows:

```
PWRC2 - Power Curve Initialization (Press ? for commands):

      ?- List commands.
      1- Test Setup Menu
      2- Extended Setup Menu
      3- Launch Test w/param. current (new file)
      4- Re-Launch Test (file in progress)
      5- Anemometer Coefficients - Manual Status Initialization
```

Note: since v9 of the Firmware the '5' option is called "Configure Channels" and allows loading the user constants of all the sensors.

The Test Setup Menu (option 1) allows the user to configure the parameters and perform the following actions:

```
PWRC2 - Power Curve Setup Menu (Press ? for commands):

      ?- List commands.
      C- Set Date and Time
      c- Read Current Date and Time.
      A- Set Storage Time to 1 minute..
      B- Set Storage Time to 5 minutes..
      E- Set Storage Time to 10 minutes..
      D- Set Storage Time to 15 minutes..
      F- Show Current Test Settings..
      N- Enter Station Name (25c max)
      n- Read Station Name
      I- Enter Station ID (25c max)
      i- Read Station ID.
      W- Enter Excluded DIR Limits (min, max °)
      w- Read Excluded DIR Limits (min, max °)
      V- Enter Test Voltage Level (N/A/B)
      v- Read Test Voltage Level (N/A/B)
      M- Modify Nominal Voltage Levels
      m- Read Nominal Voltage Levels
      S- Space available in SD and Number of Days
      s- List Files in SD and size
      p- Show and enter No. Bins p/Compl.
      x- Return to previous Menu
```

Note that access to the different items is through a single letter and is "case sensitive" (n and N are different commands). The parameters, once initialized, are stored in non-volatile EEPROM memory, and persist until they are reconfigured again, even if the system is completely turned off.

The user can view stored information of test settings. For example, given the Menu option 'F' the following information is available (it is a system configured for 48 V nominal).

```
File to use: PAddmmaa.csv
 Station Name CUTRALCO1
 Test ID PWRC_1
```

```
Test Voltage Level:
Nominal level:
Average 1min Voltage Thresholds:
V_Level +K: 52.92 [V]
V_Level -K: 47.88 [V]
Testing hours required: 60
Minimum No. Bins Compl. (10=def.)= 10..
 EXCLUDED SECTORS:
WDIR MIN (degrees from N):, 0.0, [deg]
WDIR MAX (degrees from N):, 0.0, [deg]
Operation Cessation Voltage:, 0.00, [V]
Last test: PO Resets:, 0
Last test: WD Resets:, 0
Last test: Other Resets:, 0
```

For example, if user types 'I', the menu requests:

```
Enter Station ID. (Max.25c + ENTER, ESC exits)
```

When the desired ID is completed, the following appears:

```
 Entered OK: PWRC_3
 ..and copied to EEPROM..
```

With the 'W' command, wind directions excluded from the test can be entered. All the values are recorded but in the "ELIGIBILITY" column there will be a value other than 0 (= ELIGIBLE) if the direction on average over a minute is between two extremes Dmin, Dmax, in degrees referred to the 0º (North):

```
 ADDRESSES Excluded from the test.
 Measurements between Dmin < D < Dmax are excluded.
 Enter Minor Address Dmin (0.0 to 360.0)
 >
```

When entering the desired Dmin angle (e.g. 22º), the following appears:

```
 Dmin value entered: 22.0
 Enter Major Address Dmax ( > Dmin)
 >
```

When entering the desired Dmax angle (e.g. 322º), the following appears:

```
 Dmax value entered: 322.0
 >
```

In this case, measurements between 22º and 322º measured from N will be excluded (will be NOT ELIGIBLE). Once again entering the Menu option 'F', the following parameters are adjusted.

```
Test Parameters:
Alm. Time = 1 minute..
 File to use: PAddmmaa.csv
 Station Name CUTRALCO1
 Test ID PWRC_3
 Test Voltage Level:
 Nominal level:
 Average 1min Voltage Thresholds:
 V_Level +K: 52.92 [V]
 V_Level -K: 47.88 [V]
 Testing hours required: 60
 Minimum No. Bins Compl. (10=def.)= 10..
```

```
EXCLUDED SECTORS:
WDIR MIN (degrees from N):, 22.0, [deg]
WDIR MAX (degrees from N):, 322.0, [deg]
Operation Cessation Voltage:, 0.00, [v]
Last test: PO Resets:, 0
Last test: WD Resets:, 0
Last test: Other Resets:, 0
```

Always with the letter 'x' it is possible to go up to the previous Menu level, and with '?' the available commands are shown. Going up again with 'x' to the main menu, users can enter the Extended Setup with the command '2', which has the following options:

```
PWRC2 - Extended Power Curve Setup (Press ? for commands):

    F- Enter Equipment Manufacturer (25c max)
    f- Read Equipment Manufacturer.
    M- Enter Equipment Model (25c max)
    m- Read Equipment Model.
    D- Enter Rotor Diameter [m] (10c max)
    d- Read Rotor Diameter.
    H- Enter Cube/Tower Height (integer 0-500) [m]
    h- Read Cube Height.
    P- Enter Nominal Aero Power (integer) [W]
    p- Read Nominal Aero Power.
    V- Enter minimum battery voltage to operate x10 (integer) [V]
    v- Read minimum battery voltage to operate x10 (integer).
    I- Enter Test ID (25c max).
    i- Read Test ID.
    S- Enter Station Number (1-255).
    s- Read Station Number.
    B- Enter the Modbus Address of the Station (1-255).
    b- Read Modbus Address of the Station.
    T- Show Extended Setup Values.
    g- ON/OFF printing Float Values.
    y- Watchdog Test (RESET!)
    x- Return to previous Menu
```

As can be seen, this level allows other parameters of the equipment under test to be adjusted, although the operation is identical to that of the conventional Menu Setup.

By default, the system assumes that the test will be performed at the NOMINAL voltage, for example 50.4 V if it is a 48 V device, that the storage period will be 1min, and that the 1 minute average voltage thresholds will be +/- K% = +/-5% by default, as required by IEC61400-1-12. Note that according to the previous 'F' command, the settings are:

```
V_Level +K: 52.92 [V]
V_Level -K: 47.88 [V]
```

These last levels will define the values at which the test will be considered ELIGIBLE battery voltage. In addition to the NOMINAL, the HIGH- and LOW-Test voltage levels can be selected through the 'V' command (within the conventional Setup Menu).

Within the Main Initialization Menu, option '5' allowed (up to v9 of the Firmware) to enter the calibration coefficients of the anemometer to be used associated with the METEO unit. For example, the command '5' in such versions:

```
* PWRC2 Manual Entry Coefs. Anemometer Calibration
* Format: V_Wind = G_Anem * Freq + K_Anem
```

```
 * A) Current coefficient: G_Anem=1.000
 * Modify? (Y/N/ESC)
 yes
 * Enter G_Anem Value:
0.757
 * Value entered: 0.757
 * Redo last step? (Y/N/ESC)
 n

 * G_Anem Updated value..
 * B) Current coefficient: K_Anem=0.000
 * Modify? (Y/N/ESC)
 yes
 * Enter K_Anem Value:
0.290
 * Value entered: 0.290
 * Redo last step? (Y/N/ESC)
 n
```

In versions after v9, the channel configuration menu was introduced, which included the calibration constants of the anemometer to be used associated with the METEO unit, and the constants of all the other channels. The '5' command in current versions has the structure indicated in the form of a flowchart in Figure14.
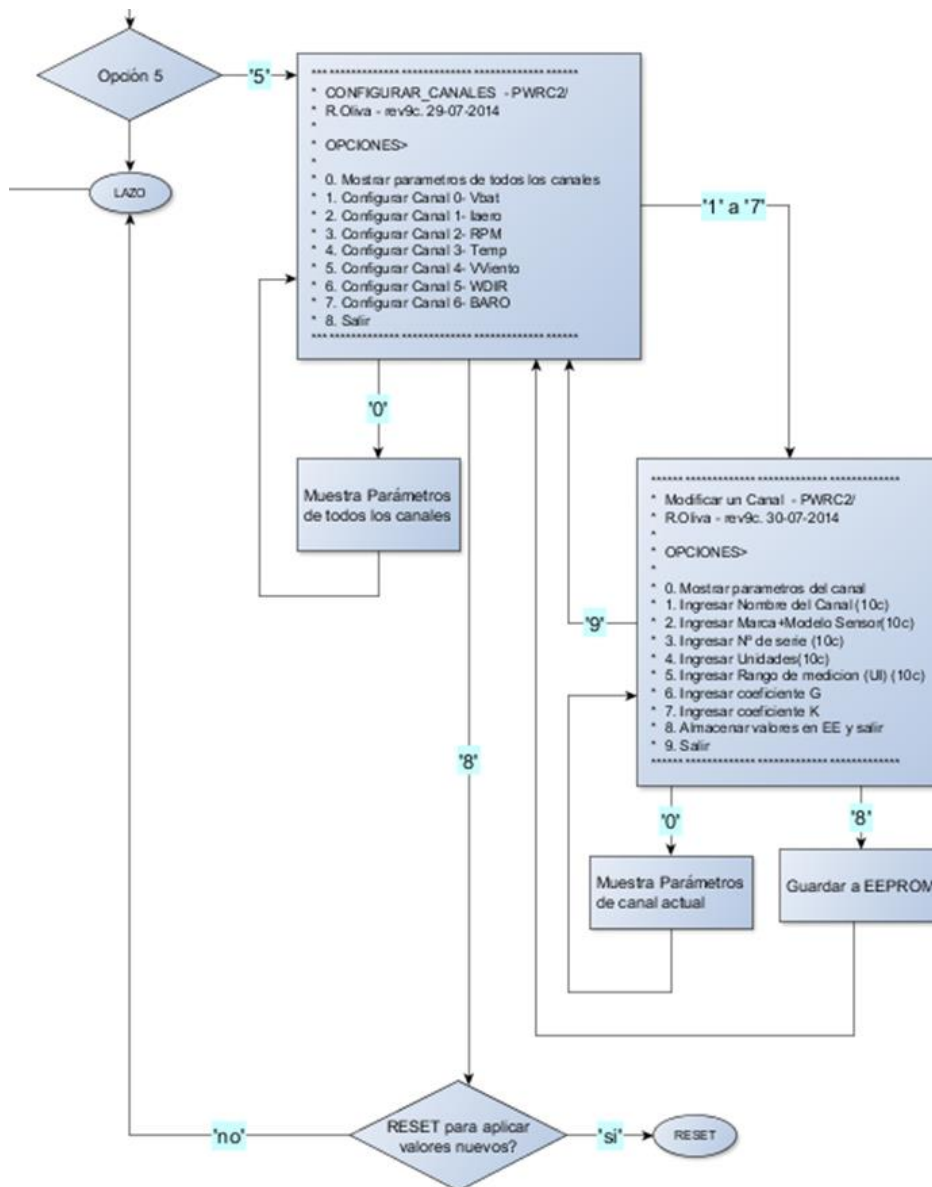
Figure14 Structure of command '5' "Configure channels" in versions later than v9 of the PWRC2 Firmware

Finally, within the Main Initialization Menu, if '3' is selected the test can be launched. It is important to check before doing so the value of the adjusted parameters, using the 'F' command within Menu Setup. (Remember that the SD card must be inserted to launch the test, see point III to remove-insert SD cards). The stations are named PWRC2 A,B,C and D, and create PXddmmaa.csv files, where X can be any of those 4 letters. In the following case, the response is from station C (Eolux/48V in the first tests) which creates the file PC200612.csv:

```
PWRC2 - Power Curve Initialization (Press ? for commands):

    ?- List commands.
    1- Test Setup Menu
    2- Extended Setup Menu
    3- Launch Test w/param. current (new file)
    4- Re-Launch Test (file in progress)
    5- Anemometer Coefficients -Manual
```

3

```
Event File: EC200612.CSV
 Create New Main File:
 New File: PC200612.CSV
 File to use: PC200612.CSV
Main Fcreate enter..
Main Fcreate (OK)..
OKCrF:PC200612.CSV

PW Fcreate (OK=exiting)..

File ResCreation = 1

File to use: PC200612.CSV
Event Archive:
Test Started!

Opening file: PC200612.CSV
OK- f/App
PC200612.CSV
 Size: 1093 bytes
 Created: 06/20/2012 11:46:52
 Modified: 06/20/2012 11:47:02
 Attributes: 0x0
PB Arch.OK!
OKFil:PC200612.CSV
```

With which the test is launched.

VI.b – LCD display in configuration mode:
Regarding the LCD Display, in the case of Test not Initialized, SD card Readable, both switches S1, S2 facing up and assuming correct loading of parameters from EEPROM, on startup it presents the following:

PWRC2 dd/mm/yy -hh:mm
Vbat = CH(0) = 49.6 [V]
I:050A(01) V:48V(03)
SD_OK_NOIN_HYSETUP(03)

a) The first line always identifies the equipment and shows the date and time.
b) The second shows the analogue or weather channel (via METEO) that is active on the display, and can be changed with the up arrow keys (↑)or down (↓)of the keyboard. The channels available in the battery charging versions are:

1. **Vbat = CH(0) Battery Voltage [V]**
2. **Iaer = CH(1) Wind turbine current [A]**
3. **VV = CH(2) – Wind speed [m/s]**
4. **VDIR = CH(3) – Wind direction [º]**
5. **PB = CH(4) Barometric pressure [mB]**
6. **RPM = CH(5) Rotational speed []**
7. **Temp = CH(6) External Temperature [ºC]**
8. **Pot = CH(7) Wind turbine instantaneous power [W]**

c) The third line shows the sensor configuration by default. By pressing the Left arrow keys (←) or Right (→) this third line shows:

c.1) Hours and minutes of operation
c.2) The file used .CSV
c.3) % of Bins completed

d) The fourth line identifies the state in which the equipment is, one of 32 possible.

Once the PWRC2 is configured via Terminal, and the test is launched with command '3' (SEE END OF VI.a), and if the switches S1, S2 are not changed, the Display will look like this:

PWRC2 dd/mm/yy -hh:mm
Vbat = CH(0) = 49.6 [V]
I:050A(01) V:48V(03)
SD_OK-ENCUR_HYSETUP(07)

For the test to progress and establish Modbus communication with the central system, once launched, both switches S1, S2 must be lowered to the Normal/Modbus position (as in Figure 2). In this case, the display will be as shown in Figure 15 indicating the state SD_OK-ENCUR_NORM (04). Here through the keys above (↑) or below (↓), Channel 2 has been selected, which is the wind speed read from the outdoor METEO station.
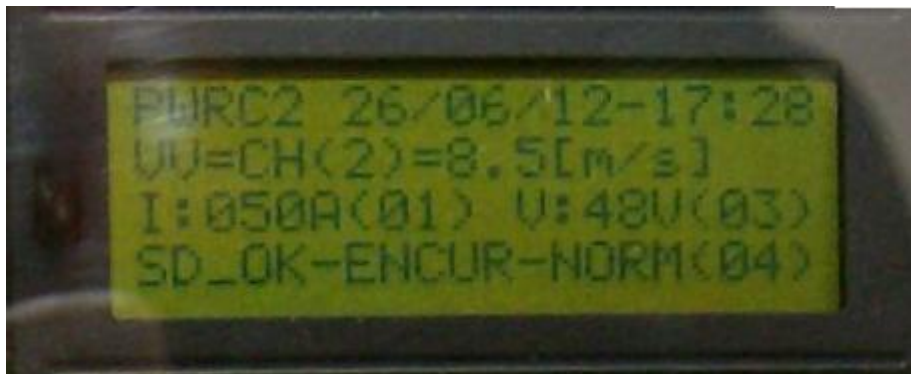
Figure 15 LCD in Normal Test / in progress with Modbus communication

VI.c – Menu flowchart in Setup Mode in versions after v9.

In Figure 16 the flow chart of the Setup/Initialize menu is shown, with the commands Setup ('1'), Extended Setup ('2'), Test Launch ('3') (and re-launch '4') and the more recent Configure Channels command '5'. It can be seen that the initial Setup menu is very similar to the previous ones, changing option '5' which now allows configuring the channels (Configure_Channels() block). To the right the sequence that the user sees and the items configurable for each channel are shown. When configuring each channel, option '8' (record in EE) must be used to store the values, and then configure the next channel.

MENU INICIO

FRONT PANEL SWITCHES (HYP / SETUP)

MODIFICACIONES V9b 22-07-2014
Reemplaza opciones 5 6 En Menu inicializacion
(5 Coef. Anem. 6 Otros coef.) de v2012,
por un unico menú:
'5 Configurar Canales, que llama a funcion Configurar_Canales()

PWRC2 (Calibracion v2)
MAPA DE MENU - ESTADO SETUP.INIT
Menu01 - Via terminal
L&R Ing. /R.OLIVA v9d 2-08-2014
LOCATION> main1284.c

PWRC2 - Inicializacion Curva Potencia (Presione ? para comandos):
- ? Listar comandos
- 1 Menu de Setup Prueba
- 2 Menu Setup Extendido
- 3 Lanzar Prueba c/param. actuales (nuevo archivo)
- 4 Re-Lanzar Prueba (archivo en curso)
- 5 Configurar Canales y reiniciar

Opción 3 → '3' → Lanza Prueba c/param. actuales (nuevo archivo) → **MENU EN CURSO**

Opción 4 → '4' → ReLanza Prueba (archivo en uso)

Opción 5 → '5' →
****
* CONFIGURAR_CANALES - PWRC2/
* R.Oliva - rev9c. 29-07-2014
*
* OPCIONES>
*
* 0. Mostrar parametros de todos los canales
* 1. Configurar Canal 0- Vbat
* 2. Configurar Canal 1- Iaero
* 3. Configurar Canal 2- RPM
* 4. Configurar Canal 3- Temp
* 5. Configurar Canal 4- VViento
* 6. Configurar Canal 5- WDIR
* 7. Configurar Canal 6- BARO
* 8. Salir
****

'1' a '7'

Opción 1 → '1' →
PWRC2 - Menu Setup Curva Potencia (Presione ? para comandos):
- ? Listar comandos.
- C Setear Fecha y Hora
- c Leer Fecha y Hora Actual.
- A Fijar Tiempo Almacenamiento a 1 minuto ..
- B Fijar Tiempo Almacenamiento a 5 minutos ..
- E Fijar Tiempo Almacenamiento a 10 minutos ..
- D Fijar Tiempo Almacenamiento a 15 minutos ..
- F Mostrar Seteos Actuales de la Prueba ..
- N Ingresar Nombre Estacion (25c max)
- n Leer Nombre Estacion
- I Ingresar ID Estacion (25c max).
- i Leer ID Estacion.
- W Ingresar Limites DIR Excluidos (min, max °)
- w Leer Limites DIR Excluidos (min, max °)
- V Ingresar Nivel de Tension de Prueba (N/A/B)
- v Leer Nivel de Tension de Prueba (N/A/B)
- M Modificar Niveles de Tension Nominales
- m Leer Niveles de Tension Nominales
- S Espacio disponible en SD y N° Dias
- s Listar Archivos en SD y tamaño
- p Mostrar e ingresar Nro Bins p/Compl.
- x Volver a Menu anterior

'0' → Muestra Parámetros de todos los canales

****
* Modificar un Canal - PWRC2/
* R.Oliva - rev9c. 30-07-2014
*
* OPCIONES>
*
* 0. Mostrar parametros del canal
* 1. Ingresar Nombre del Canal (10c)
* 2. Ingresar Marca-Modelo Sensor(10c)
* 3. Ingresar N° de serie (10c)
* 4. Ingresar Unidades(10c)
* 5. Ingresar Rango de medicion (UI) (10c)
* 6. Ingresar coeficiente G
* 7. Ingresar coeficiente K
* 8. Almacenar valores en EE y salir
* 9. Salir
****

'9'

Opcion 2 → '2' →
PWRC2 - Setup Extendido Curva Potencia (Presione ? para comandos):
- F Ingresar Fabricante del Equipo (25c max)
- f Leer Fabricante del Equipo.
- M Ingresar Modelo del Equipo (25c max)
- m Leer Modelo del Equipo.
- D Ingresar Diametro del Rotor [m] (10c max)
- d Leer Diametro del Rotor.
- H Ingresar Altura de Cubo/Torre (entero) [m]
- h Leer Altura de Cubo.
- P Ingresar Potencia Nominal Aero (entero) [W]
- p Leer Potencia Nominal Aero.
- V Ingresar Tension minima Bateria para operar x10 (entero) [V]
- v Leer Tension minima Bateria para operar x10 (entero).
- I Ingresar ID de la Prueba (25c max).
- i Leer ID de la Prueba.
- S Ingresar Numero de la Estacion (1-255).
- s Leer Numero de la Estacion.
- B Ingresar Direccion Modbus de la Estacion (1-255).
- b Leer Direccion Modbus de la Estacion (1-255).
- T Mostrar Valores Setup Extendido.
- g ON/OFF impresion Valores Float.
- y Test de Watchdog (RESET!)
- x Volver a Menu anterior

'8' → Muestra Parámetros de canal actual

'8' → Guardar a EEPROM

'0'

RESET para aplicar valores nuevos? — 'no' / 'si' → RESET

LAZO

Figure 16 Start/Setup Menu in firmware versions later than v9 in PWRC2

Once all the parameters have been adjusted with options '1' (Setup) and '2' (Extended Setup), the test can be launched with '3', and the system goes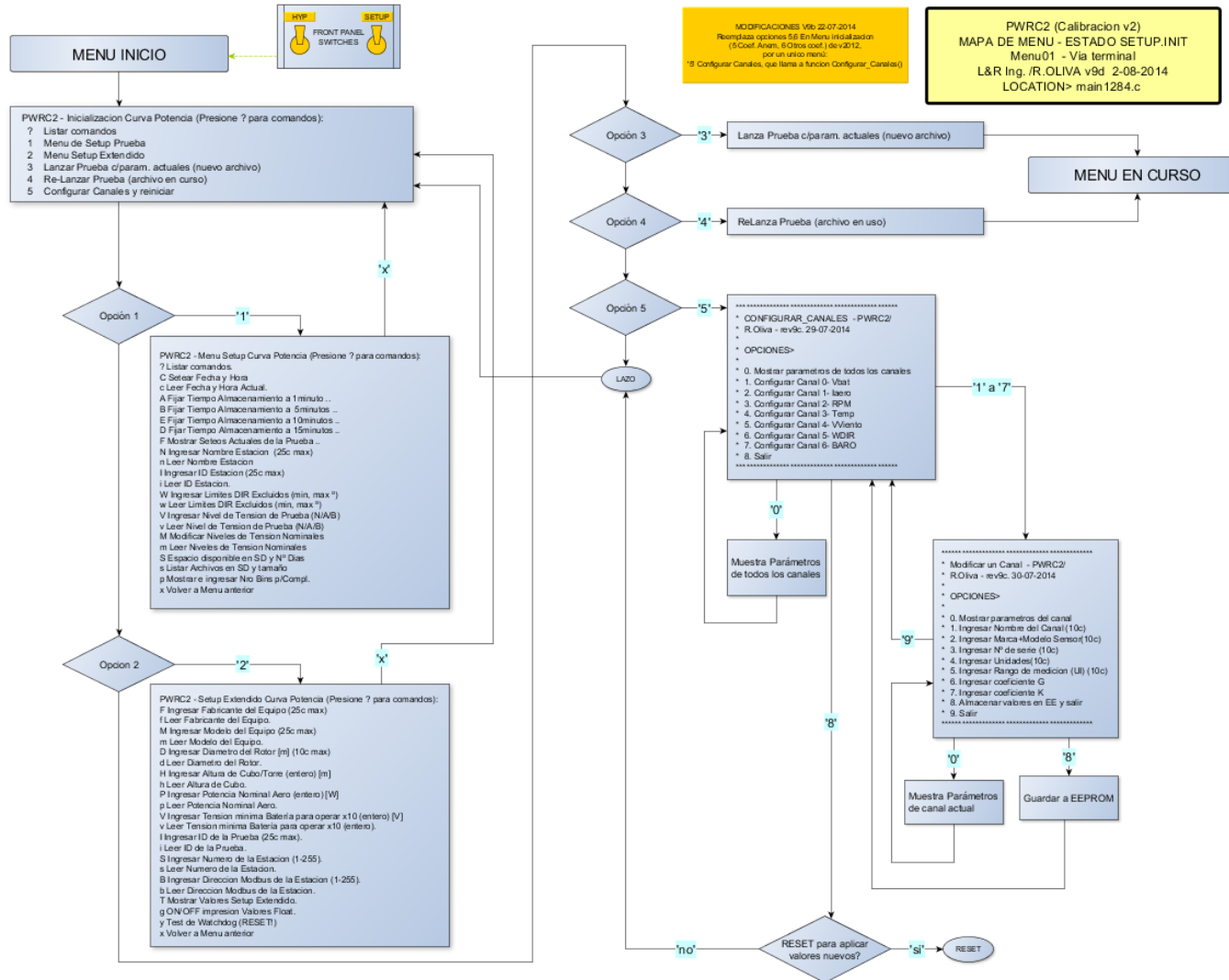 to the IN PROGRESS (EN CURSO) state, whose menu is identical to the previous one. Lowering both front switches to MOD/NOR activates the link under the Modbus protocol with the user or network, which is the normal state of the system.

VI.d – Detailed status display in Hyperterminal, during Test in Progress:
In the state **Test in Progress** with S1,S2 in Normal (down) the system assumes that a test has been configured correctly and launched, and the communications protocol is Modbus. It periodically calculates statistical values, and in the selected period (default 1 minute) the average, maximum, minimum and standard deviation values for each channel are stored on the SD card. The PWRC2 can respond to Modbus queries made by a central program (Ensayo24 or later), giving information of instantaneous readings and status. If this Test in Progress state is found when the PWRC2 is turned on, it assumes that the test has already been previously initialized (Command '3', see section VI.a) and/or that a restart occurred due to:

      a) Power Cycling (On/Off)
      b) Reset / WatchDog
      c) Low voltage cut off of the system

To obtain a detailed status of the test, it is possible to pull up both S1 and S2 switches during the test and access the system via Hyperterminal. It will be necessary to deactivate the COM port corresponding to the station within Ensayo24. The display will be back in the previous state:

PWRC2 dd/mm/yy -hh:mm
Vbat = CH(0) = 49.6 [V]
I:050A(01) V:48V(03)
SD_OK-ENCUR_HYSETUP(07)

It is advisable when entering the Terminal program to define a LOG file for the session, which should specify access date (see point VI.a). In Figure17 a structure of the Status Menu for the Test in Progress Mode is shown. (Note: This figure refers to the DIAG Mode introduced in versions later than v9 of the PWRC2 firmware, which is discussed in point VI.e of this manual).

PWRC2 (Calibracion v2)
MAPA DE MENU - ESTADO EN CURSO
Menu01B- Via terminal
L&R Ing. /R.OLIVA v9d 2-08-2014
LOCATION> main1284.c

NOTA V9D 2-08-2014
- Habitualmente switches estarán en HYP/SETUP, para observar via terminal el resultado de una prueba EN CURSO
- Si se pasa a modo DIAG (switches en MOD/SETUP) hay que detener la prueba (opción 3) para pasar a Menu DIAG (Hoja 3)

MENU EN CURSO

HYP   SETUP
FRONT PANEL SWITCHES

Ó TAMBIEN

MOD   SETUP
FRONT PANEL SWITCHES CON PRUEBA "EN CURSO"

PWRC2 - Estado Prueba en Curso (Presione ? para comandos):
? - Listar comandos.
1 - Menu Estado Actual de Prueba
2 - Menú Pruebas Hardware
3 - Reconfigurar Prueba
P - Impresion METEO ON/OFF

Opción 3   '3'

Reconfigurar prueba...

'x'

Opción 1   '1'

PWRC2 - Estado Actual de Prueba Curva Pot. (? para comandos):
?- Listar comandos.
c- Leer Fecha y Hora Actual.
F- Mostrar Seteos Actuales de la Prueba
S- Mostrar Estado Actual de la Prueba
s- Listar Archivos en SD y tamaño
x- Volver a Menu anterior

LAZO   'n'   Está seguro (S/N)?

's'

Enviando a modo "No Inicializado" ->
SYS.Meas_Status = ST_PRU_NOTINIT;

MENU INICIO

Opcion 2   '2'   'x'

m- ON/OFF impresion COM1/Meteo
f- ON/OFF impresion Valores Float.
y- Test de Watchdog (RESET!)
x- Volver a Menu anterior
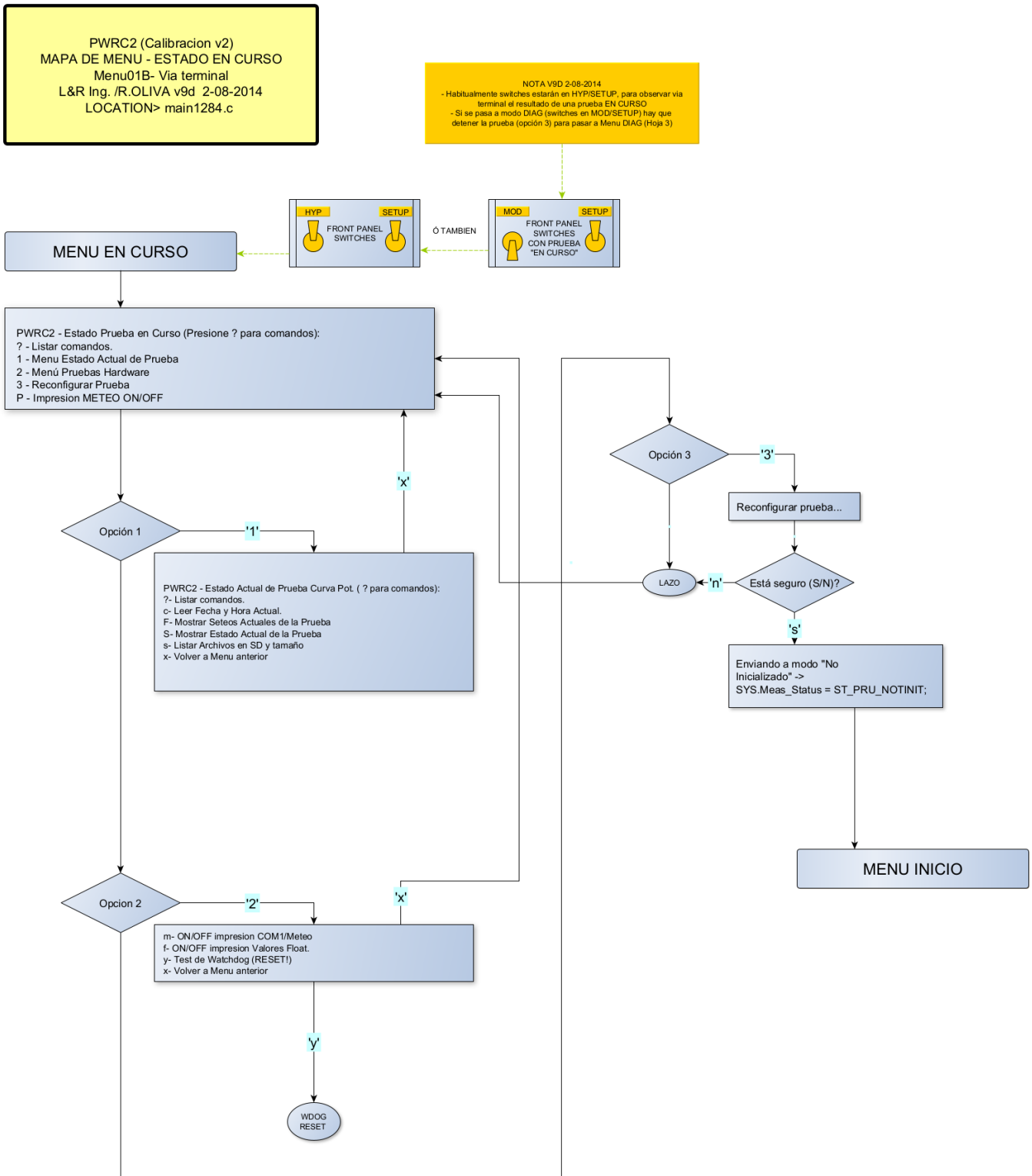
'y'

WDOG RESET

Figure17Menu Status Test in Progress in versions v9 and later of the PWRC2 Firmware

Accessing at the normal 19200,N,8,1 configuration through an appropriate COM port in the Terminal program, the menu displayed is as follows ('?' to see the options):

```
PWRC2 - Test Status in Progress (Press ? for commands):

        ?- List commands.
        1- Menu Current Test Status
        2- Hardware Tests
        3- Reconfigure Test
        P- WEATHER Print ON/OFF
```

If we enter option '1' we have:

```
 PWRC2 - Current Power Curve Test Status (Press ? for commands):

        ?- List commands.
        c- Read Current Date and Time.
        F- Show Current Test Settings..
        S- Show Current Test Status
        s- List Files in SD and size
        x- Return to previous Menu
```
Yes

We enter 'S' (capital letter) to see Current Status of the test:

```
 Current Test Status:
 Elapsed Test Time: 0 h, 0 m
 on a Minimum of Hours required of:, 60
 Meteo OK Packages:, 5
 Lost Weather Packets: 0
 No. of PO Resets:, 0
 No. of WD Resets:, 0
 No. of Other Resets:, 0
 Show Histogram V_BINs? (Y/N/ESC)
```

yes

```
 VVmin, VVmax, VV_BinCtr, Full (0/1)
 0.000000, 2.250000, 0, 0
 2.250000, 2.750000, 0, 0
 2.750000, 3.250000, 0, 0
 3.250000, 3.750000, 0, 0
 3.750000, 4.250000, 0, 0
 4.250000, 4.750000, 0, 0
 4.750000, 5.250000, 0, 0
 5.250000, 5.750000, 0, 0
 5.750000, 6.250000, 0, 0
 6.250000, 6.750000, 0, 0
 6.750000, 7.250000, 0, 0
 7.250000, 7.750000, 0, 0
 7.750000, 8.250000, 0, 0
 8.250000, 8.750000, 0, 0
 8.750000, 9.250000, 0, 0
 9.250000, 9.750000, 0, 0
 9.750000, 10.250000, 0, 0

 Continue? (Y/N/ESC)
```
yes

```
 VVmin, VVmax, VV_BinCtr, Full (0/1)
 10.250000, 10.750000, 0, 0
 10.750000, 11.250000, 0, 0
 11.250000, 11.750000, 0, 0
 11.750000, 12.250000, 0, 0
 12.250000, 12.750000, 0, 0
 12.750000, 13.250000, 0, 0
 13.250000, 13.750000, 0, 0
 13.750000, 14.250000, 0, 0
```

```
14.250000, 14.750000, 0, 0
14.750000, 15.250000, 0, 0
15.250000, 15.750000, 0, 0
15.750000, 16.250000, 0, 0
16.250000, 16.750000, 0, 0
16.750000, 17.250000, 0, 0
17.250000, 17.750000, 0, 0

Continue? (Y/N/ESC)
yes

VVmin, VVmax, VV_BinCtr, Full (0/1)
17.750000, 18.250000, 0, 0
18.250000, 18.750000, 0, 0
18.750000, 19.250000, 0, 0
19.250000, 19.750000, 0, 0
19.750000, 20.250000, 0, 0
20.250000, 21.250000, 0, 0
21.250000, 22.250000, 0, 0
22.250000, 23.250000, 0, 0
23.250000, 24.250000, 0, 0
24.250000, 25.250000, 0, 0
25.250000, 26.250000, 0, 0
26.250000, 27.250000, 0, 0
27.250000, 28.250000, 0, 0
28.250000, 29.350000, 0, 0
29.350000, 30.250000, 0, 0

Show Degree of Completion? (Y/N/ESC)
yes

Minimum Number of Bins for Compl. (10=def.)= 10..
Total Bins: 47 Complete Bins: 0
Test Completion Degree (all bins) 0.0%
IEC Bins: 28 Full Bins: 0
Test completion grade (IEC) 0.0%
```

This 'S' command allows the user to see the status of each of the 47 defined wind bins, the number of 1-minute wind averages for each bin (VV_BinCtr) between its limits (VVmin, VVmax) and its degree of completion. By default, it will be considered complete if at least 10 1-minute measurements in each bin are filled. The IEC completion degree refers according to [IEC61400-12-1,2005] to completing the bins between 0 and 14m/s – (bin number up to 28), while the total completion degree refers to all 47 bins.

VI.e – DIAG mode introduced in versions later than v9 of the PWRC2 firmware: If the test is not in progress yet, lowering the S1-MOD switch with S2-SETUP raised, access the new Diagnostic/Configuration Mode (DIAG) is possible. The DIAG menu is shown in Figure 18. If the test is IN PROGRESS, it will have to be stopped from the corresponding menu to be able to enter DIAG mode. Entering this mode is indicated on line 4 of the Display as shown in Figure 19.

This mode allows (option '1') to configure the channels, and to select the station number (1 to 4) and its associated file name (PA/EAddmmaa.csv, etc.) according to the station being used (A, B, C or D). Option '2' enters monitoring mode, which allows user to monitor channels (via Terminal) and save (via LOG to Terminal) the current configuration of all channels and test parameters.

MENU DIAGNOSTICO

FRONT PANEL
SWITCHES
DIAG

PWRC2 (Calibracion v2)
MAPA DE MENU - ESTADO DIAGNOSTICO
Menu01C- Via terminal
L&R Ing. /R.OLIVA v9d 2-08-2014
LOCATION> main1284.c

PWRC2 - Estado Diagnóstico/Configuracion (Presione ? para comandos):
? - Listar comandos.
1 - Menu Configuracion
2 - Menú Diagnostico

Opción 1   '1'

'x'

PWRC2 - Menu Configuracion. (? para comandos):
?- Listar comandos.
A- Seleccionar Estación 1 - Archivo PA/EAddmmaa.csv
B- Seleccionar Estación 2 - Archivo PB/EBddmmaa.csv
C- Seleccionar Estación 3 - Archivo PC/ECddmmaa.csv
D- Seleccionar Estación 4 - Archivo PD/EDddmmaa.csv
1- Configurar Canales
2- Imprimir Configuracion actual completa
x- Volver a Menu anterior

'1'   '9'   LAZO

Configura Canales
(Idem '5' en Menu INICIO)   '8'

RESET para aplicar
valores nuevos?   'n'

'si'

RESET

Opcion 2   '2'

'x'

PWRC2 - Menu Diagnóstico (? para comandos):
?- Listar comandos.
E - ON/OFF Valores leidos en U.I.
e - ON/OFFValores leidos en Salida Sensor
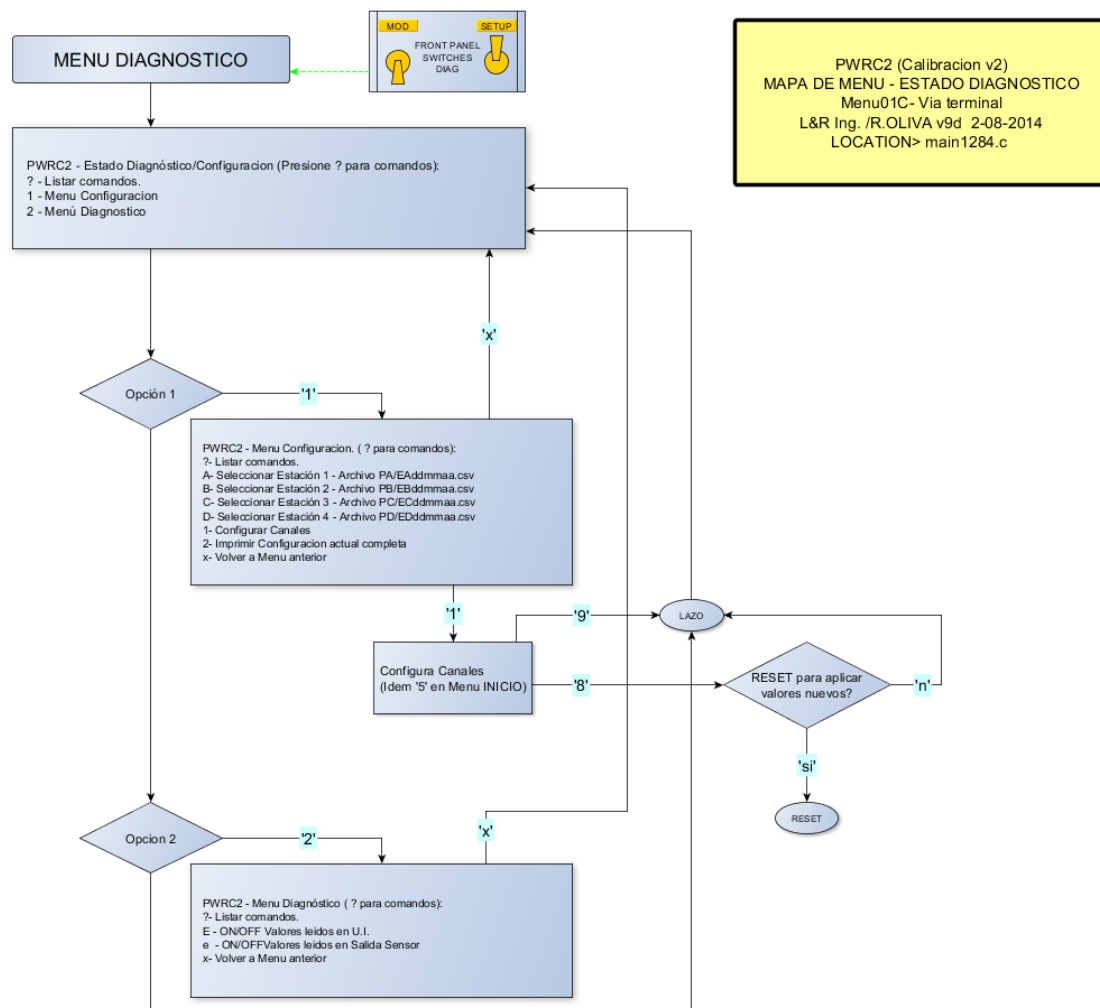x- Volver a Menu anterior

Figure 18 Diagnostic or DIAG menu in versions v9 and later of the PWRC2 Firmware

Figure 19 Indication in line 4 of Diagnostic Mode or DIAG

With this mode it is possible to test each channel separately (even those of the METEO module) before entering the sensors with the manufacturer's constants. For example, by injecting a calibration signal for the Barometric Pressure Channel in the METEO unit, the display on PWRC2 in sensor units is as seen in Figure 19. Simultaneously, in option '2' the continuous output of data from the sensors can be displayed on the Terminal screen, either in SENSOR mode (option 'e') or in UI or Engineering Units mode (command 'E') as shown in Figure20.

```
PWRC2 - Diagnostic Menu (Press ? for commands):

        ?- List commands.
        E- ON/OFF printing Values read in UI.
        e- ON/OFF printing Values read in Sensor Units.
        x- Return to previous Menu
AND

UI Print ON
PWRC2 - Diag Mode, Print channels in UI

TStamp,Vbat[V],Iaero[A],Pwr[W],RPM[],Vv[m/s],Wdir[deg],Temp[C],Baro[mB]
08/04/14,15:36:13,24.4,35.9,877.0,0.0 ,49.8,38.4 ,1.7,0.2
04/08/14,15:36:14,24.4,35.9,876.9,0.0,49.8,38.5,1.7,0.2
04/08/14,15:36:16,24.4,35.9,877.0,0.0,49.8,38.5,1.7,0.2
04/08/14,15:36:17,24.4,35.9,876.9,0.0,49.8,38.5,1.7,0.2
04/08/14,15:36:18,24.4,35.9,877.0,0.0 ,49.8,38.5 ,1.7,0.2
04/08/14,15:36:19,24.4,35.9,877.0,0.0 ,49.8,38.5 ,1.7,0.2
08/04/14,15:36:20,24.4,35.9,876.9,0.0,49.8,38.6,1.7,0.2
04/08/14,15:36:21,24.4,35.9,877.0,0.0 ,49.8,38.6 ,1.7,0.2
04/08/14,15:36:22,24.4,35.9,876.9,0.0,49.8,38.6,1.7,0.2
```

Figure20 Extract from a Log in Hyperterminal in DIAG mode / Command 'E'

-0-

Version:rev(iv) 02/10/2024 based on rev (iii) 08/28/2012 and Firmware updates from v9.

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