HV*control*

HV Test Control Unit

User Manual

Rev. e3.22

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I General

This manual describes the hardware and usage of the HV*control* in its current version. Some of the hardware features of the most recent versions are not available with earlier versions of the instrument (see the section 'Annex' for older hardware layouts). It is possible to upgrade most of the previous instruments to the features of the current instruments. Please contact Power Diagnostix for details.

This manual describes the HV*control* including its miscellaneous function. Some of these functions have to be ordered separately and are marked as optional. For information regarding the accessories and special applications of the HV*control* please contact Power Diagnostix

II Hardware

Power Diagnostix' HV*control* is designed to control high voltage (HV) testing plants manually. Several piezo push buttons indicate and change the state / condition of the plant. The display shows the key / benchmark data like:

- Primary voltage ($U_{prim.}$)
- Primary current ($I_{prim.}$)
- Secondary current ($I_{sec.}$)

For a save operation, it is possible to set current limits which will trigger the master contactor via relay contacts. Further, a detachable key ensures that only authorised staff can work with the control unit. This key switch can also turn off other measurement equipment.

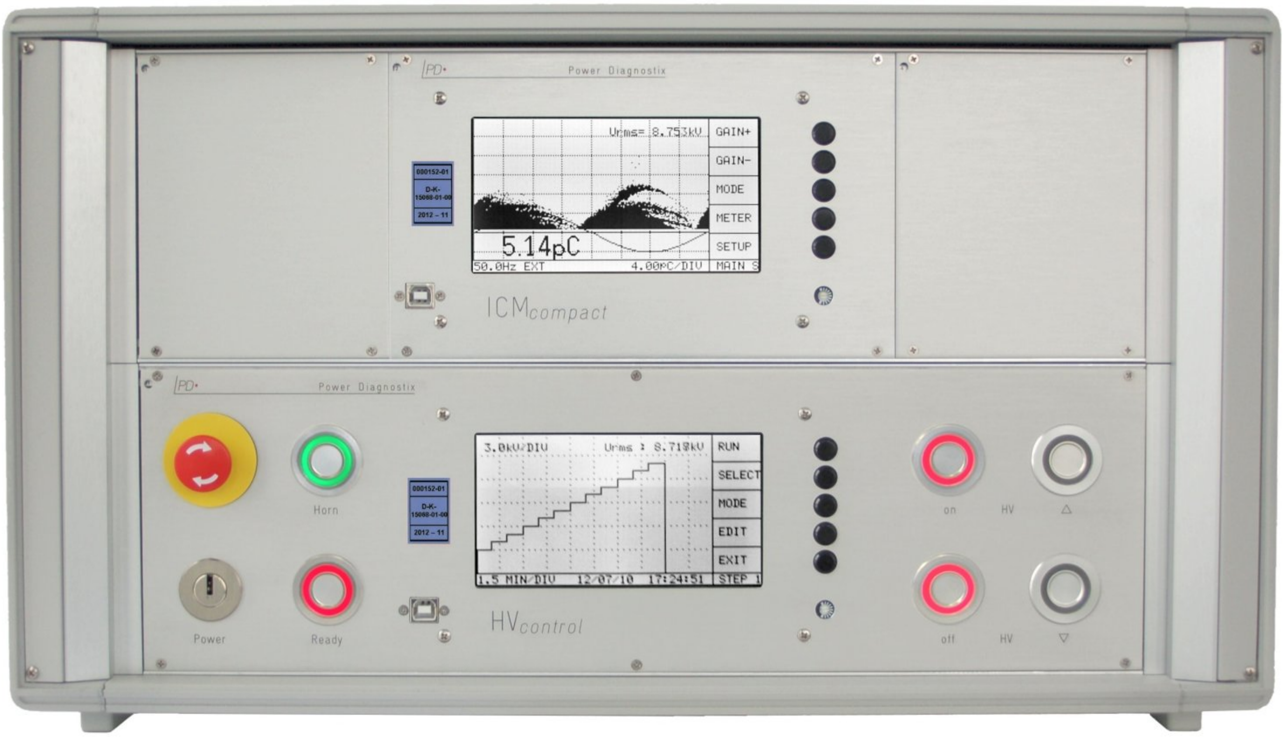


Fig. II.1: Front view of the HV*control* together with the ICM*compact*

The basic version of the HV*control* can isolate and amplify the output control signals. It can be extended with the following options:

- A STEP functionality for automatic voltage control
- The ICM*compact* to measure partial discharge
- The TDA*compact* to measure tan delta
- An IPC with the software HV*pilot* to measure, store, and process the data

The connections to the HV testing plant and further measurement units are on the rear panel. There are six terminal connectors (X1 to X6) for the connection of actors and sensors to and from the plant. Two power outlets are provided for further measurement units, which are controlled by the key switch.

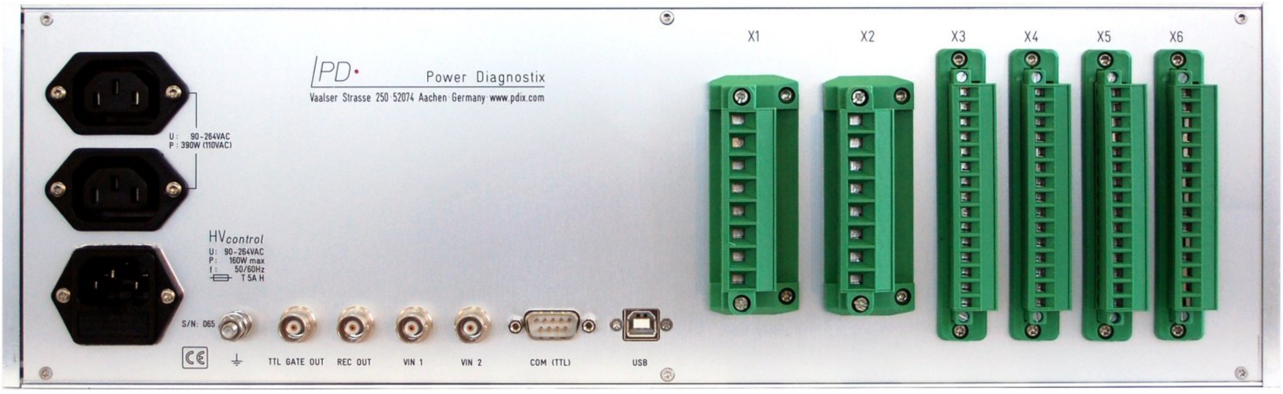


Fig. II.2: Rear panel of the HV*control*

TTL GATE OUT: For the TTL gating function of the ICM*compact.*

REC OUT: The REC OUT terminal may optionally be connected to a paper recorder or other device to provide a graph of the average charge magnitude.

VIN1 Input connector for voltage signal

VIN2: Currently not in use.

COM (TTL): This terminal provides a USB connection via fibre optic cable to a personal computer for remote communications. The cable as well as the optional software can be provided by Power Diagnostix. See also chapter V.

USB: USB connector, used to connect the instrument to a common PC for remote communication.

Please refer to section III.1 and section IV for an explanation of the connector blocks X1 to X6.

III Instrument Safety

Before using the HV*control*, read the following safety information and this manual carefully. Especially read and obey the information that are marked with the words ‘Warning’ and ‘Caution’. The word ‘Warning’ is reserved for conditions and actions that pose hazards to the user, while the word ‘Caution’ is reserved for conditions and actions that may damage the instrument, or its accessories, or that may lead to malfunction.

Always obey the safety rules given with the warnings and with this chapter.

Warning:

- The control unit may only be used by qualified personnel.
- Never operate the instrument without protective grounding. Use the wing nut terminal on the unit's rear side for additional grounding in general.
- Avoid working alone.
- Do not allow the instrument to be used if it is damaged or its safety is impaired.
- Inspect the ground leads and signal cables for continuity.

To calculate the minimum distances of HV and earthed devices (e. g. barrier) following rule of thumb can be used:

- AC and DC voltage : 50 cm per 100 kV
- Impulse voltage : 20 cm per 100 kV, minimum 50 cm

Before first using the HV*control* the following points have to be checked (usually done by the customer engineer):

- Connection between HV*control* and variable transformer
- Earthing of the HV*control* to the common ground of the HV plant
- Supply voltage
- Interlock connection with screened cables

The HV*control* is not to be opened by the customer. If for any reason this is necessary, the mains supply must be disconnected.

III.1 Interlock

It is necessary to have a barrier around the hazard area to prevent unintended access. Warning signs and cordons are not sufficient. The back panel of the HV*control* provides an interlock connector (X2:1, 2), which must be connected to the door contacts and safety loop (barrier) around the HV test area. It is not sufficient to use common limit switches as door contacts. Guard safety interlock switches will ensure an opening of the contact, even when it's mechanically defect or with weakened springs. The interlock function will automatically turn off and de-energise (earth) the HV supply. To avoid interferences via the interlock connection, the cable must be screened. This screen must be put through connectors and switches. The termination of the cable is a short circuit socket.

The NO contacts X2:5–X2:8 can be used to monitor the status of the HV*control*'s safety circuit. If the HV*control* is turned off or the emergency button is pushed, the contacts are open.

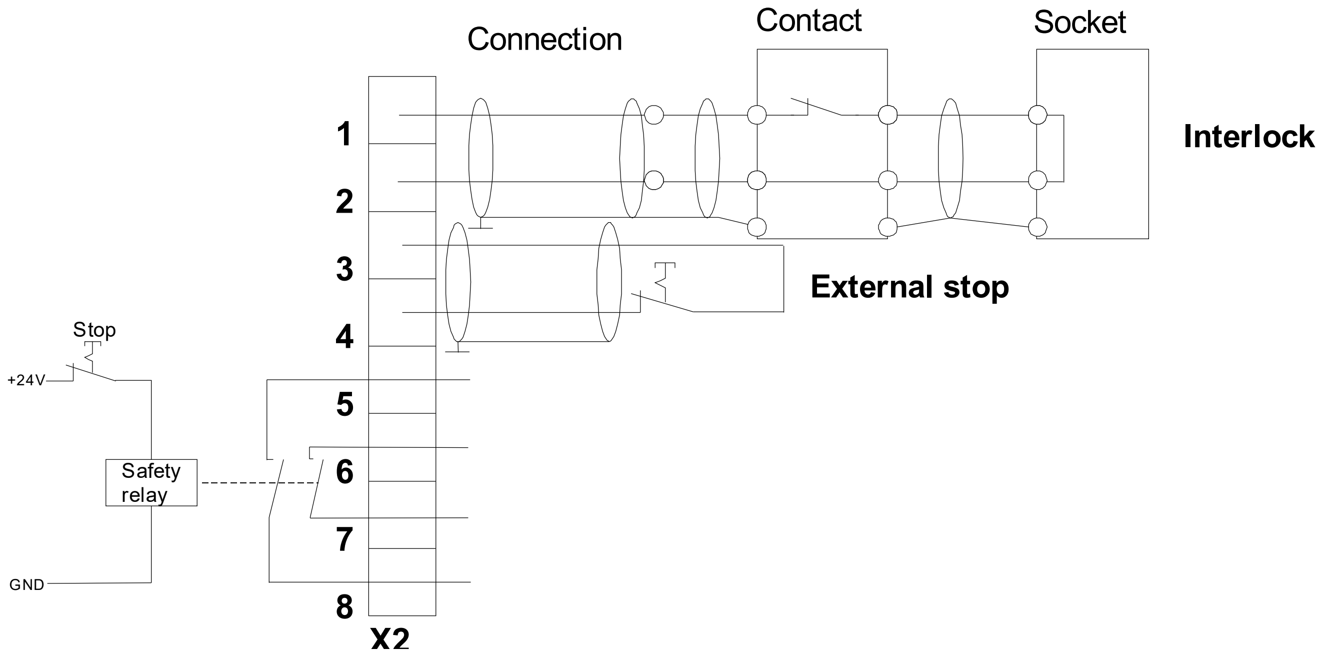


Fig. III.1: Connection block X2

Caution:

The interlock connection has to be done with screened cable. The screen must be put through the switch and sockets. We recommend using metal cases for the switches and sockets. The termination of the interlock loop is done by a short circuit socket.

The connectors X2:3, 4 must be bridged if no external stop is connected.

IV Installation

The HV*control* is designed to control high voltage test plants, which are provided with a motor driven voltage regulator (servomotor). Figure IV.1 shows the HV path of a typical test setup. Two contactors (‘K1’ and ‘K2’) can disconnect the supply voltage from the voltage regulator and from the HV transformer. The earthing bar switch ensures that the system is de-energised after a shutdown.

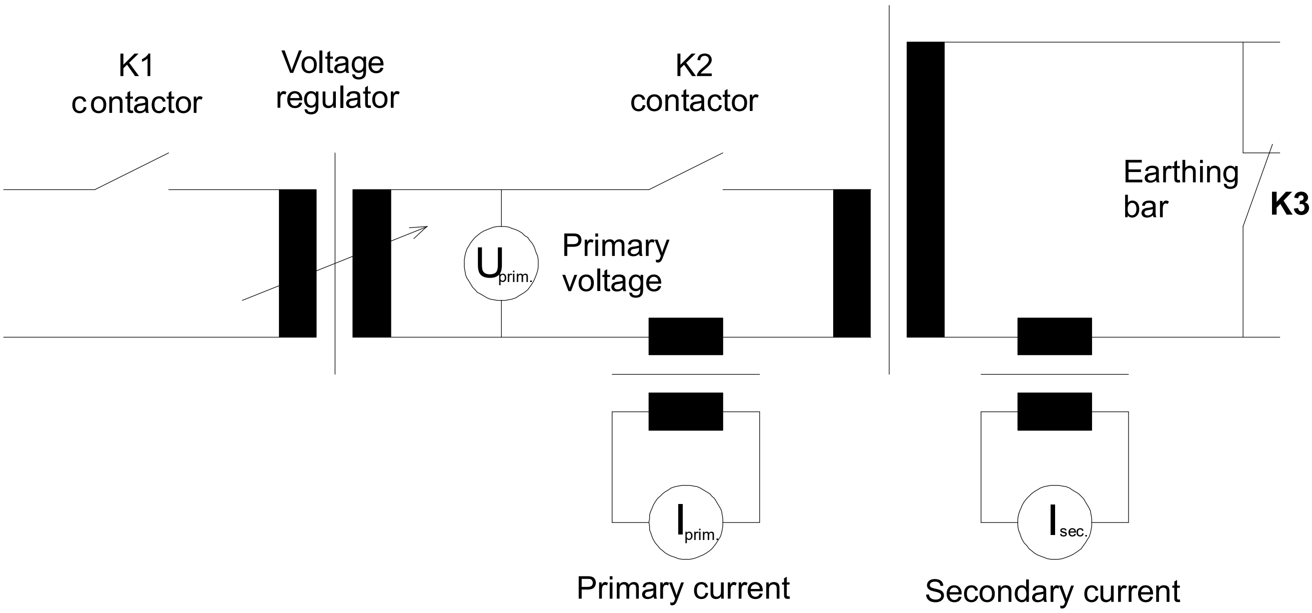


Fig. IV.1: Circuit diagram of a typical HV test supply

Beside the circuit breakers, the voltage, and current signals there are further safety signals like interlock, transformer protection, earthing bar switch, which must be linked to the HV*control*. To connect the sensors and actors there are six terminal connector blocks labelled ‘X1’ to ‘X6’. An overview of the instruments and how to connect them is given in figure IV.2.

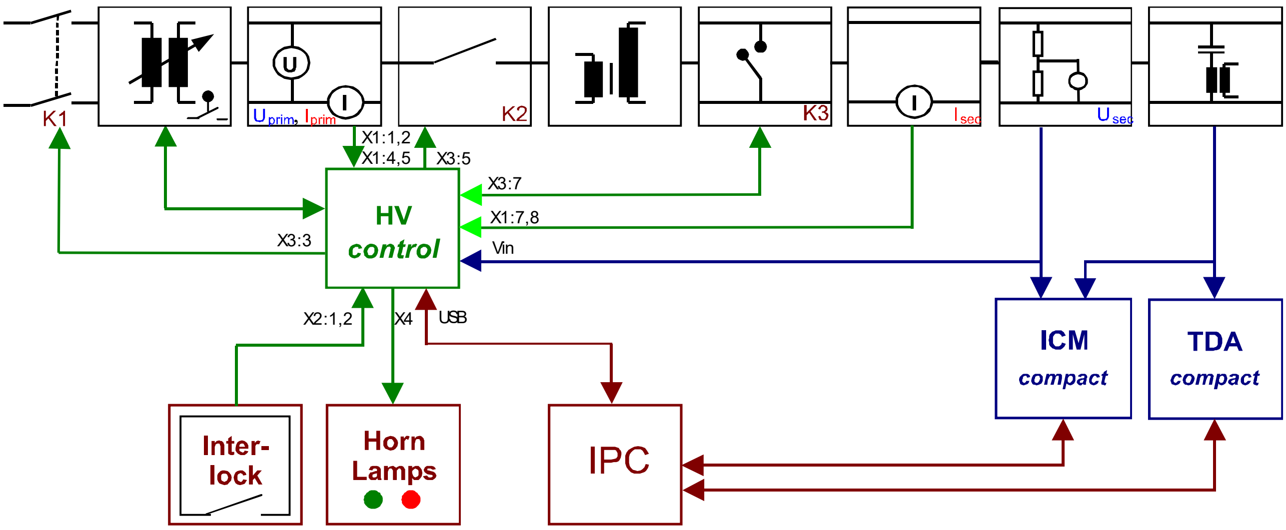


Fig. IV.2: Principle diagram for the connections from and to the HV*control*

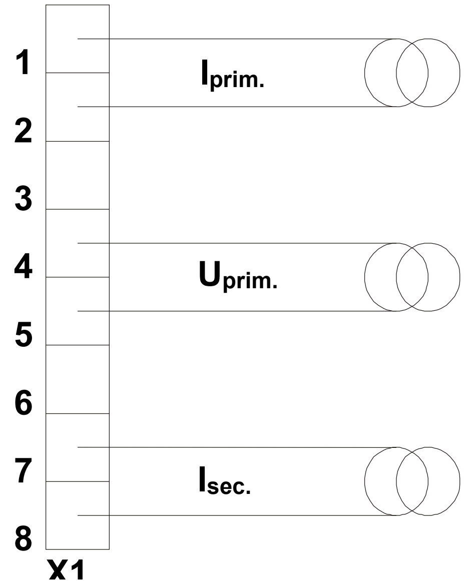


Fig. IV.3: Connection block X1

IV.1 Analog Input Connector

The three analog signals, which are displayed on the front panel, are fed into the connection block ‘X1’. The inputs are not grounded and have a maximum voltage input 400 V. This voltage level has to be specified on order. Alternatively, the input can be ordered as current input with a maximum of 0.5 A, 1 A, or 5 A. The hardware configuration can be displayed in the STATUS menu (STATUS -> I/O -> ANALOG)

Caution: Never supply more than the maximum input value!

IV.2 Digital Input Connector

For the connection of the input signals at ‘X5’ only the internal 24 V supply should be used. The system will not start if the three safety switches are not closed (earthing switch, transformer protection, interlock).

- Earthing switch’ is the feedback signal from the earthing bar.
- 'Zero position switch' (zero-start contact) and 'End position switch' are the two limit switches from the voltage regulator.
- ‘Transformer protection’ are signals like overload, oil level, oil temperature, oil expansion, gas (Buchholz relay).
- Since the interlock is wired into the safety loop together with the emergency stop, this switch is feed separately.

In case the main contactors K1 and K2 have an extra signal switch, they can be used as feedback signals. The 24 V must be taken from X5:1 and connected to X5:6 and X5:7 as shown in the figure IV.4.

The HV*control* will not turn on the high voltage, if the feedback signals of X5:6 or X5:7 are missing or always closed (e. g. relay sticking).

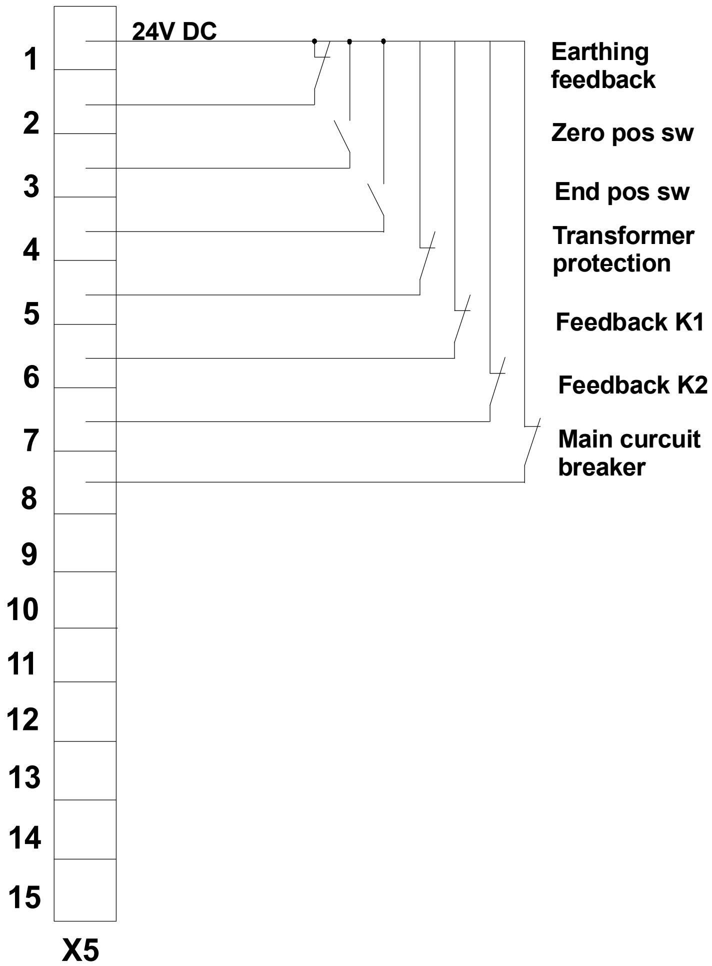


Fig. IV.4: Relay block X5

In case the main contactors K1 and K2 have **no** extra signal switch, the setup option “Feedback K1/K2” needs to be set to disabled.

If no feedback of the main circuit breaker of the HV transformer is available, X5:8 needs to be connected to 24 V (X5:1).

IV.3 Output Connector Block

The connector blocks ‘X3’ and ‘X4’ are the output terminals. Each of them offers six single-pole single-throw contacts NO (normally open). The supply voltage for the three relays of the first connector block must be connected to the contact no. 2. The switched NO contacts are no. 3, no. 4 and no. 5. The supply for the relay's second connector block must be connected to contact no. 9.

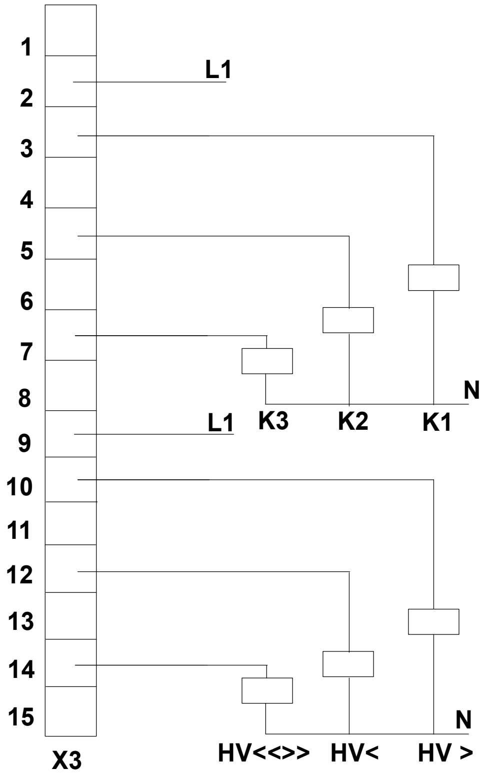


Fig. IV.5: Relay block X3

The circuit breaker and the automatic earthing bar must be connected to X3 as described earlier and seen in figure IV.1.

K1 is the contactor for the supply voltage to the voltage regulator.
K2 is the contactor to the HV transformer.
K3 is the contactor to the earthing bar, which short circuits the HV bus bar.

Please also note the HV circuit diagram figure IV.2.

The connector block X3 offers the relay outputs to the motor driven voltage regulator. The relay ‘HV<<>>’ is an optional output for servomotors with a fast mode. It is only supported by the HV*control* and will be activated after ‘HV ∆’ and ‘HV ∇' is pressed longer than the value entered in the setup "rapid drive delay”. The drawing shows an example how to connect ~250 V relays from the servomotor control.

HV ∆: Relay switch for high voltage up signal

HV ∇: Relay switch for high voltage down signal

HV<<>>: Relay switch for fast up or fast down signal

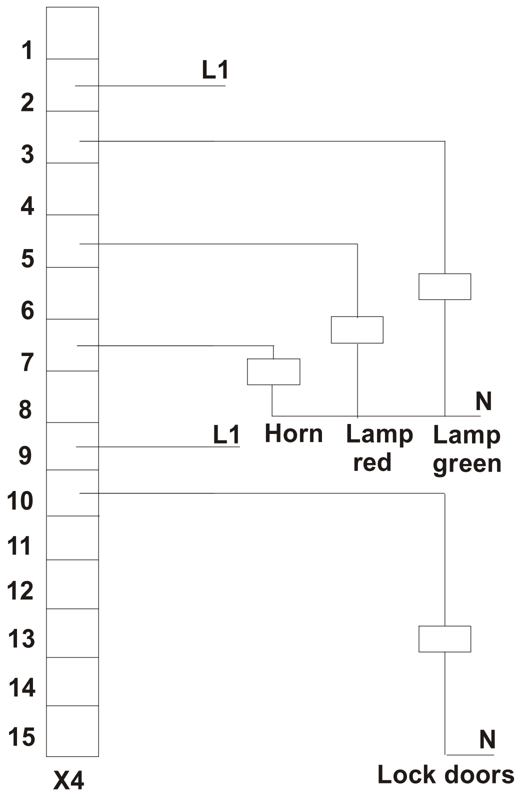


Fig. IV.6: Relay block X4

For safety reason two warning lamps (red and green) and a horn should be installed at an HV test area. They can be connected to the connector X4. If the internal voltage supply is used, the total load should not exceed 1 A. This includes any other use of the supply.

When the HV*control* is on, the green light is turned on while the test area is safe. The red light is turned on as a warning not to enter the test area. It is active as far as the HV*control* is in 'Ready for operation' status. It will stay on until the circuit breaker K2 opens the supply to the HV transformer and the automatic earthing is closed.

The door lock should be used to unlock the doors to the test area. If the HV*control* is on and the green warning lamp is on, the relay is closed, and the applied voltage unlocks the doors. If the HV*control* is off or the red warning lamp is on, the contact is opened, and the door should be locked.

Note: It is necessary, that the door lock has an emergency function, so that someone in the test area has the chance to exit the hazard area at every time!

The warning horn can be used at any time the HV*control* is on.

The internal 24 V DC supply may also be used externally for e. g. to drive contactors or the signal lamps. Caution: Regard the maximum load of this voltage source. To use this internal supply, the connections ‘1’ and ‘2’ have to be bridged for the first relay block. The same applies for the second relay block: the connections ‘1’ and ‘9’ have to be bridged. This will feed all six outputs (’3’, ’5’, ‘7’, ’10’, ‘12’, ‘14’) on the same terminal block.

If you want to use a separate voltage supply (e. g. 240 V AC) it must be connected to ‘2’ for the first three relays and to ‘9’ for the respective terminal block. Caution: Don’t put any voltage or grounding on connection ‘1’.

Note: It is possible to use the internal 24 V supply for one relay block while an external 230 V supply is used for the other block.

Note: Each of the relay blocks can be supplied individually either by the 24 V or by an external 230 V.

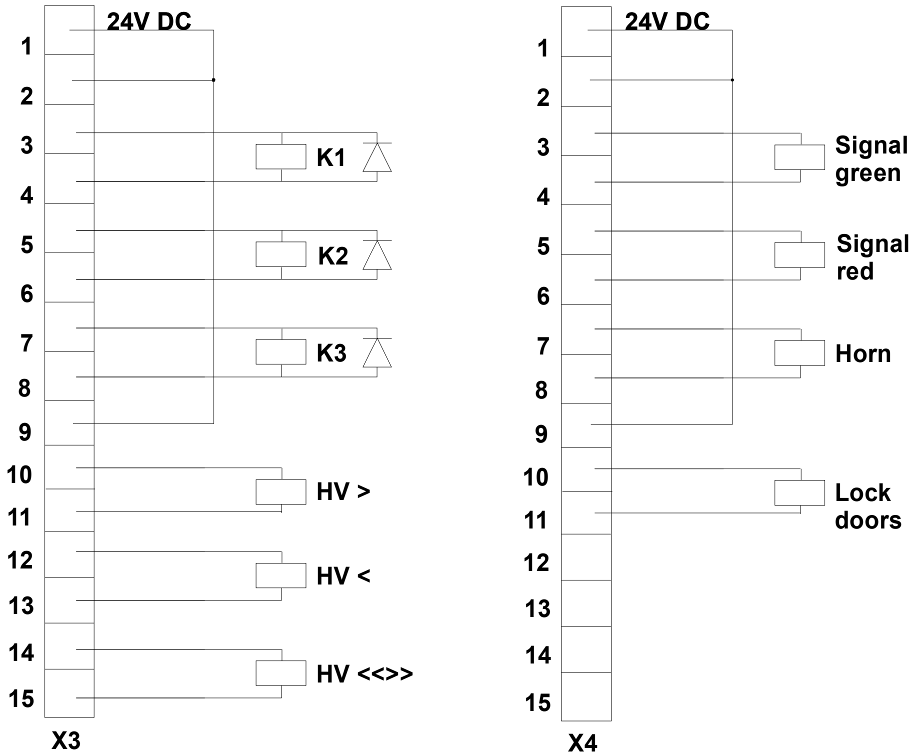


Fig. IV.7: Relay blocks X3 and X4 with bridged connections

Caution: Use only relays with flyback diodes to eliminate the sudden voltage spike seen across an inductive load when its supply voltage is reduced or removed.

The connector block 'X6' is currently not in use.

V Operation

V.1 MAIN Menu

After switching on the HV*control*, the LCD screen shortly displays the HV*control* logo and software version. In the following MAIN menu, the voltage waveform and values are shown.

Provided, the input voltage signal is big enough (> ~0.5 V) and the frequency is found between 20 Hz and 510 Hz, the voltage waveform is displayed in a way that one cycle can be seen. The voltage curve is scaled automatically, when the signal reaches 10% of its nominal value (~10 V). The scaling factor of the graticule can be found in the lower line next to the synchronisation frequency.

From the acquired waveform, the instrument calculates the peak voltage (Up), the effective voltage (U_{rms}), and the peak voltage divided by the square root of two ($\hat{U}/\sqrt{2}$), the crest factor ($\hat{U}/U_{rms}$) and, if 'U DC' is selected, the mean voltage. The period to calculate the mean value of 'U_{DC}' is taken from the synchronisation frequency which is shown in the lower left corner (usually 50 or 60 Hz). Additionally, the display shows the values of primary voltage ($U_{prim.}$), primary current ($I_{prim.}$), and secondary current ($I_{sec.}$).

The HV*control* menu offers several possibilities to select, which of the four values U DC/Up√2/U_{rms}/Up is shown using large characters. This setting additionally selects, which of the voltage values is recorded in the menu RESULT and which value is used for the LVD (either $\hat{U}/\sqrt{2}$ or U_{rms}). The symbol ▶ indicates which of the values is selected (see figure V.1). If the DC voltage is selected, the display of the waveform will change accordingly.

By using the five control buttons the following menus can be selected. A detailed description of these submenus can be found in the following sections.

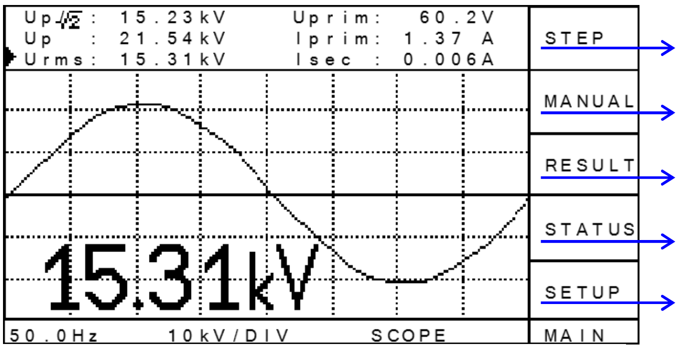


Fig. V.1: Screenshot of the MAIN menu

Automatic mode for **step** tests, selection and editing voltage time curves	(V.6)
Manual operation of the voltage control	(V.4)
Test results, reason for cancellation, measurement values	(V.7)
Plant **status**	(V.8)
Setup menu for plant parameter settings	(V.2)

(Related chapters are in parentheses.)

CAUTION: The MAIN menu only displays the voltage; there is no safety supervision (as described later in this menu).

Figure IV.2 gives an overview of the HV*control*'s menu structure. Functions that are labelled with 🔒 can be locked with the KEY LOCK function (see page 15).

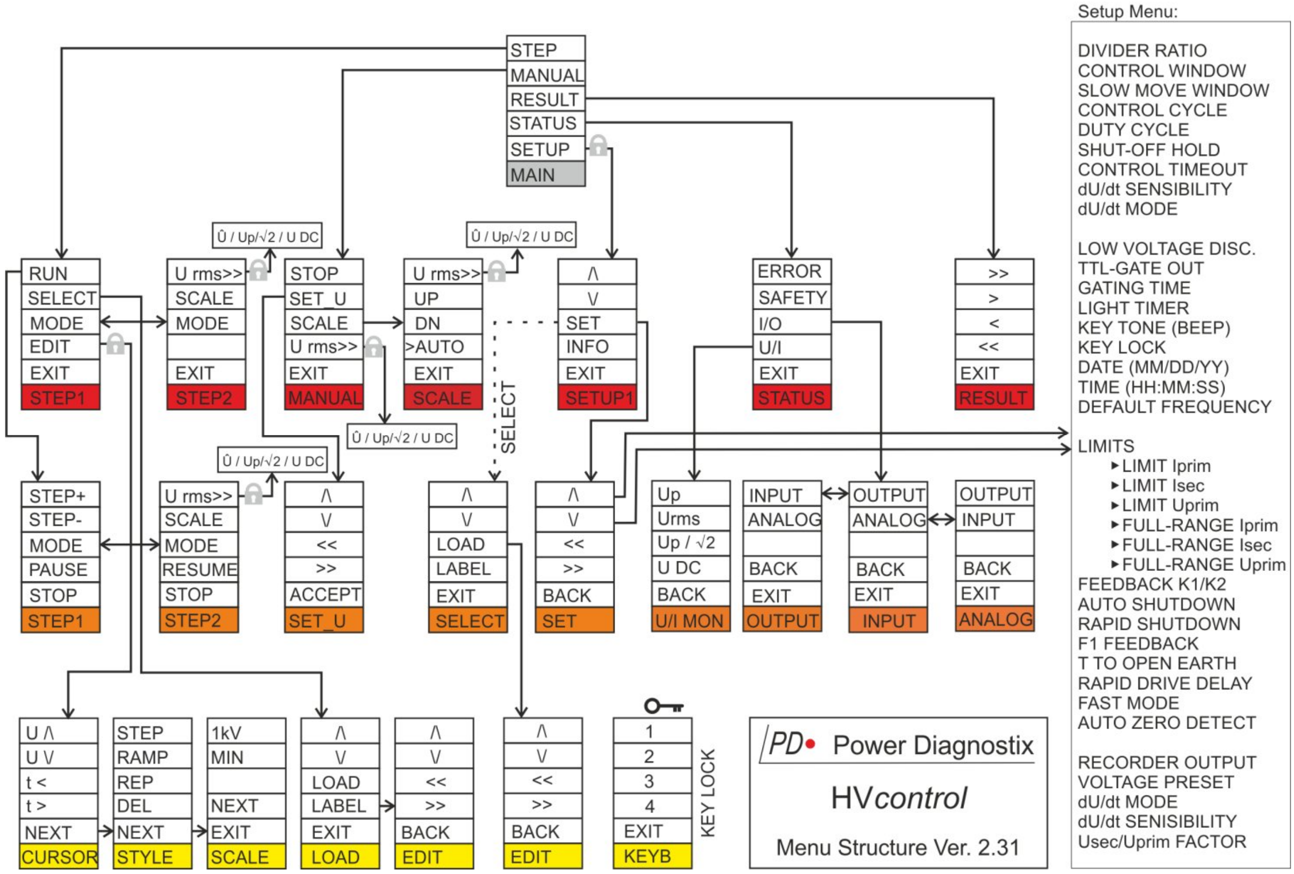


Fig. V.2: Menu structure of the HV*control* with STEP option

V.2 SETUP

In the SETUP menu parameter can be set to suit the instrument to a special transformer. This needs to be done before using the HV*control* for the first time. If the instrument is used at different locations, up to seven different sets of set-up parameter can be saved. The whole setup can be changed and labelled in the menu ‘SELECT’, which is accessible by selecting the top line of the SETUP1 menu.

Within the menu ‘SELECT’ the button ‘LOAD’ activates the selected setup. This activated setup is shown underneath the seven setup names. CAUTION: An inappropriate setup may damage your system!

The button ‘LABEL’ will switch to the menu EDIT, where the setup-name (label) can be changed. Valid characters for the label are the 10 digits, the underscore, and all capital letters. The changed value/character is saved immediately without confirmation.

A more convenient way to alter the label and the parameter setups is provided with the software HV*pilot*. This software runs on a regular PC and is linked to the HV*control* via the serial interface RS232.

Within the menu ‘SETUP1’ single parameters of the active setup can be changed. The button ‘SET’ leads to a menu, where the value can be modified. The menu ‘INFO’ shows details about the hard- and software version of the instrument, as well as contact details of Power Diagnostix.

```
 1 SETUP_NO_1                                | /\
>DIVIDER RATIO       :      1000        <    | \/
 CONTROL WIN MODE    :      ABSOLUTE         |
 CONTROL WINDOW      :      2.00 kV          |
 WINDOW OFFSET       :         1 %           |
 SLOW MOVE WINDOW    :      3.00 kV          | SET
 CONTROL CYCLE       :         5 s           |
 DUTY CYCLE          :        20 %           | INFO
 SHUT-OFF HOLD       :        10 s           |
 CONTROL TIMEOUT     :        20 s           |
 PAGE DOWN                                   | EXIT
*50.0Hz                  Urms=0.000kV        | SETUP1
```

⇨ SET changes single parameter values

⇨ INFO opens the INFO menu

Fig. V.3: Screenshot of the SETUP1 menu

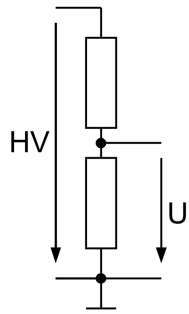
Below, the parameters are described in detail:

One possible way to get the correct parameter is described in italic letters after each parameter description.

Caution: This description might not be suitable for every plant. Observe the manuals of the related devices.

- DIVIDER RATIO
  The divider ratio of the HV voltage divider has to be inserted as a factor of 1:x. E. g. With a divider factor of 1000, a maximum measuring range of 100 kV is possible, when the maximum voltage input is: V_in max. = 100 V_{eff}.

  The calculated voltage is shown in the bottom line at right hand side. After pressing the SET button, the value can be increased (‘/\’) or decreased (‘\/’) digit by digit until the voltage equals a known voltage value, given by e. g. sphere gap calibration or a temporarily installed meter.



- CONTROL WIN MODE
  The window mode determines whether the maximum difference of the set voltage (U_set) and the actual voltage is an absolute value (ABSOLUTE) given in kV or a relative (RELATIVE) value given in percent.

- CONTROL WINDOW
  The maximum difference of the set voltage (U_set) and the actual voltage, when the voltage will not be further adjusted. If this value is set too small, the control is likely to oscillate around the set value and, thus, will stress the servomotor unnecessarily.

  The CONTROL WINDOW *should be smaller than the required precision of the voltage. E. g. if steps of 200 V are done, a steady-state error voltage of 0.1 kV might be sufficient. If this value is set too small in relation to the* DUTY CYCLE *and* CONTROL CYCLE *values, again, the system starts oscillating.*

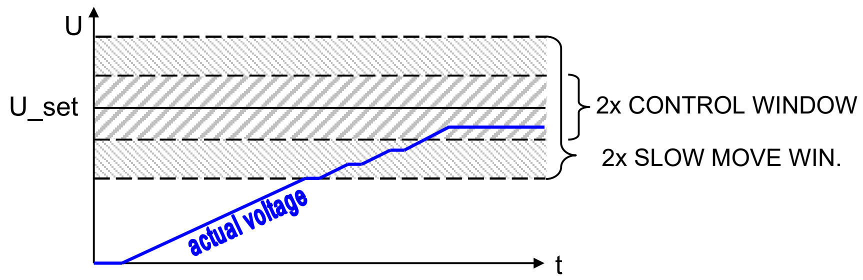
- WINDOW OFFSET
  Offset for the value of CONTROL WINDOW. A value of 100 % assures that the actual voltage never underruns the set voltage, while a value auf -100 % guarantees that the actual voltage never exceeds the set voltage.

- SLOW MOVE WINDOW
  The voltage range around U_set, where the ‘HV up’ and ‘HV down’ relay is operated intermittently. This allows approaching the U_set with reduced speed (pulsed) and thus avoids oscillatory effects around the set value. Setting this value has to be done in compromise of mechanical inertia and wear-out of the servomotor.

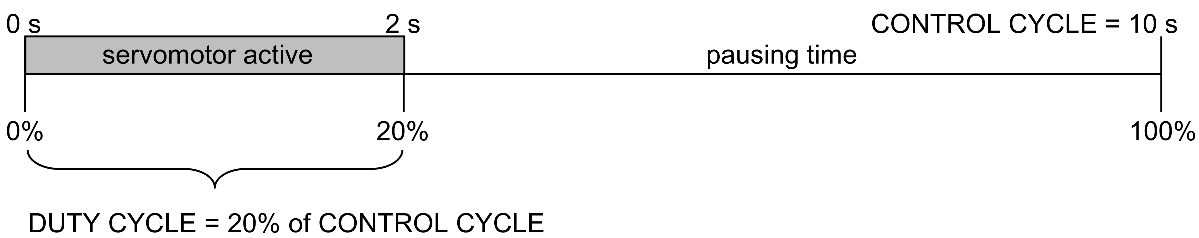
  In order to determine the correct values, both, SLOW MOVE WINDOW *and the* CONTROL WINDOW*, are set to 0.1 kV. In the menu* MANUAL *a new voltage is set, which will take about two seconds for the drive to reach. CAUTION: The user should be prepared to stop this test by using* STOP *or* EXIT*, since the HVcontrol will start oscillating around the set value. The first overshot voltage (voltage above the set voltage) minus the set voltage is a good start value for the* SLOW MOVE WINDOW*.*

  Once the whole setup is adjusted, this value can be increased, if there is still an unwanted overshot. Or, it can be decreased, if the slow move time (pulsing time to reach the set value) is too long.

  If a timeout error occurs during this test phase, the CONTROL TIMEOUT *value can be increased to e. g. 30 s. This value will be adjusted later.*



- CONTROL CYCLE
  The maximum time in seconds for one cycle of activating and pausing the servomotor. This time will be started, when the actual voltage is between the limits set in the SLOW MOVE WINDOW and the CONTROL WINDOW.



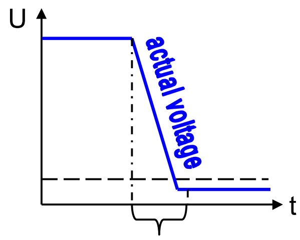
  In order determining the dead time of the system, a new voltage is set in the MANUAL *menu. The dead time can be observed best, while the voltage is in the* SLOW MOVE *window. The* CONTROL CYCLE *should exceed the dead time (time found between sending the pulse to the servomotor and detecting a voltage change at the HVcontrol. If this value is set too small, the system is likely to oscillate.*

- DUTY CYCLE
  The clocking time for the SLOW MOVE window in percent. This value determines the ratio of time for moving and pausing the servomotor. 100% means, no pause at all. 50% means half of the time the servomotor is active (set in CONTROL CYCLE), and the servomotor will pause the other half. E. g. if the CONTROL CYCLE is set to 10 s and the DUTY CYCLE to 20%, the motor drive will move for 2 s and pause for 8 s while the voltage is within the slow move window. This value has to be set according to the mass inertia of the servomotor. Roughly, the DUTY CYCLE is equal to the percentage of the reduced speed versus the maximum speed of the motor.

  The DUTY CYCLE *should be set, so that the voltage step, which is done during one pulse, is equal the voltage value set in the* CONTROL WINDOW*.*

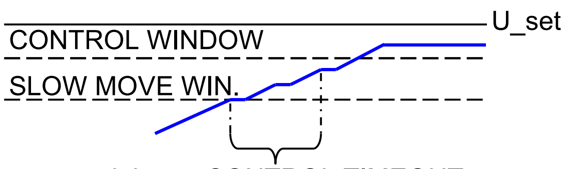
- SHUT-OFF HOLD
  The time duration where the HV down relay is on, after the dU/dt LIMIT is exceeded. When using the HV*control* from Power Diagnostix this time can be set short (e. g. 1 s), since the HV*control* already ensures returning the transformer to the zero position.

  To find the SHUT-OFF HOLD, *the high voltage should be increased to its maximum. After changing into the* MANUAL *menu, the* STOP *button can be used to lower the voltage to 0 V (if the* LOW VOLTAGE DISC. *is set correct). The required time while the control motor reduces the voltage, should be used as* SHUT-OFF HOLD *time.*



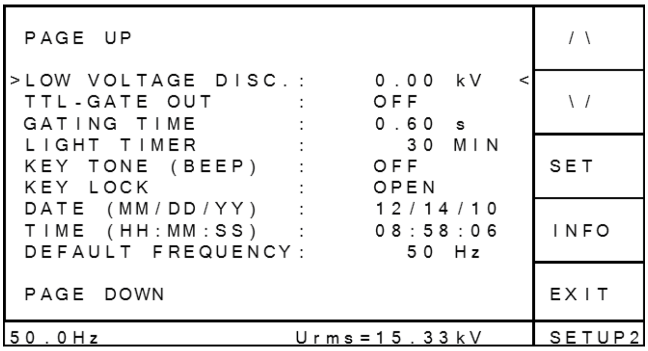
- CONTROL TIMEOUT
  The maximum time to reach the set voltage. If this time is exceeded without any voltage change, the servomotor will turn down the voltage (HV down) and the break off relay will be triggered.

  This value should be at least twice as high as the value of the CONTROL CYCLE *time to enable the HVcontrol changing the voltage before the control timeout stops the system.*



minimum CONTROL TIMEOUT

Remember: In some cases, due to a load dependent change of harmonics, the Û/√2 may stay stable or even decrease despite increasing the primary voltage. This effect may require setting the CONTROL TIMEOUT to larger values.

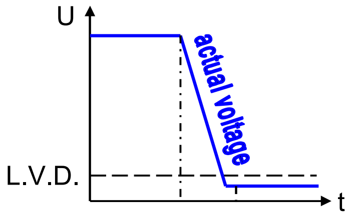


Selecting the bottom line 'PAGE DOWN' in the menu 'SETUP1' will lead to menu 'SETUP2'. Data stored in this setup is also saved in a non-volatile memory. However, this data will not be changed when switching to another setup.

Fig. V.4: Screenshot of the SETUP2 menu

- LOW VOLTAGE DISC.
  Voltages below this value will be displayed and recorded as zero volt.

  After the divider ratio is set, the voltage should be decreased slowly until the control motor of the voltage regulator reaches the lower end position switch. The voltage being displayed now, plus 10% extra, can be used as a LOW VOLTAGE DISC. *value. For instance, if the control motor cannot reduce the voltage below 125 V (while the main connectors are still on), the* LOW VOLTAGE DISC. *can be set to 0.14 kV.*



- TTL-GATE OUT
  This output terminal provides a TTL signal each time the HV up or HV down relay is triggered. Since in some test setups the relay bouncing leads to disturbances on the ICM*compact*, this signal can be used to gate this noise. Three different modes can be selected:

  OFF - Gating output inactive.

  ON - TTL signal is active while an output is switched, or the regulation transformer is in operation.

  PULSED - TTL signal is only active during the GATING TIME.

- GATING TIME
  Gating time in seconds

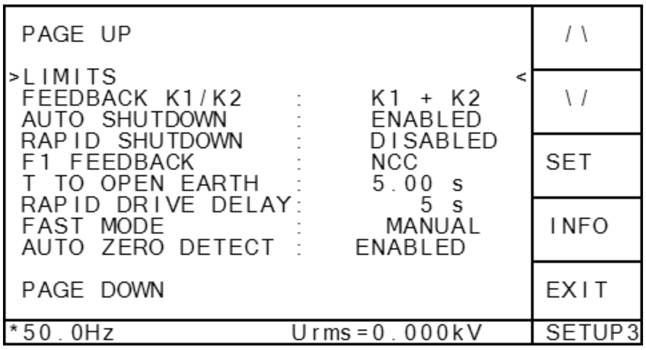
- LIGHT TIMER
  The back light of the LC display is turned off automatically when no button is pressed. The time delay can be set from 1 to 60 minutes. A shorter time helps saving lifetime of the LCD.

- KEY TONE 'BEEP'
  The sound when pressing one of the five keys can be modified or turned off.

- KEY LOCK
  This function allows locking the keyboard, leaving only those functions available, which will not affect the parameters of the instrument. The locked functions are labelled in the menu structure (figure V.2) with 🔒. To unlock the keyboard a sequence of the numbers 2321 must be entered.

- DATE
  The date has the format Month / Day / Year. It will change automatically and is battery backed up.

- TIME
  The time is displayed in 24-hour format. It is only used for internal time stamps of the measurements (see RESULT, STARTED and FINISHED).

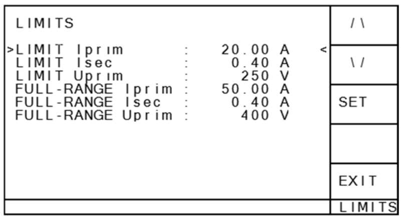


Selecting the bottom line ‘PAGE DOWN’ in the menu 'SETUP2' will lead to menu ‘SETUP3’.

Fig. V.5: Screenshot of the SETUP3 menu

For hardware relevant settings a password is required: 3213.

- LIMITS



  - LIMIT Iprim
    The allowed maximum of primary current. If the current is higher than this value, the HV*control* will go back to initialisation, where all components are switched off.

  - LIMIT Isec
    The allowed maximum of secondary current. If the current is higher than this value, the HV*control* will go back to initialisation but the regulating transformer will stay on.

  - LIMIT Uprim
    The allowed maximum of primary voltage. If the voltage is higher than this value, the HV*control* will go back to initialisation, where all components are switched off.

  - FULL-RANGE Iprim
    The value indicates the primary current, which will flow, when the maximum input voltage/current is reached. E. g.: The hardware is equipped with a 10 V input, then the current, which produces the 10 V, needs to be entered here.

  - FULL-RANGE Isec
    The value indicates the secondary current, which will flow, when the maximum input voltage/current is reached. E. g.: The hardware is equipped with a 5 A input, then the current, which produces the 5 A, needs to be entered here.

  - FULL-RANGE Uprim
    The value indicates the primary voltage when the maximum input voltage is reached. E. g.: If the hardware is equipped with a 10 V input, then the voltage, which correlates to 10 V, needs to be entered here.

- FEEDBACK K1/K2
  If the relay K1 and K2 has no NC feedback signal, FEEDBACK K1/K2 has to be set to DISABLED.

- AUTO SHUTDOWN
  If auto shutdown is enabled, HV*control* will drive the regulating transformer to its zero position automatically when an emergency stop is initiated. When disabling this function, the regulating transformer needs to be driven to its zero position manually, before you can switch on again.

  Note: This is only working if the motor unit is independent from the regulating transformer supply.

- RAPID SHUTDOWN
  The rapid shutdown function allows the HV*control* to use the fast mode to reduce the voltage after HV is switched off.

  Note: HV*control* will only change to fast mode when it is possible to measure the primary voltage.

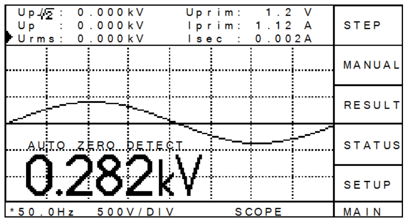
- F1 FEEDBACK
  If the fuse F1 has no NC feedback signal, F1 FEEDBACK has to be set to DISABLED.

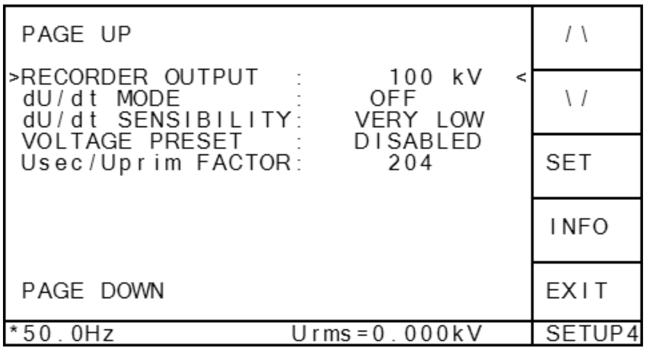
- T TO OPEN EARTH
  When using an automatic earth bar, it can take some time to open up the grounding. This time should be entered here in order to inhibit an error.

- RAPID DRIVE DELAY
  In manual mode this is the time you need to press the button until HV*control* will switch to fast mode. In STEP mode the HV*control* will automatically switch to fast mode after this time.

- FAST MODE
  Determines whether the HV*control* can only switch to fast mode if the MANUAL mode is active or if the HV*control* ALWAYS switches to fast mode after a period that is defined with RAPID DRIVE DELAY.

- AUTO ZERO DETECT (automatic LLD)
  In state “In operation” when zero switch is reached, HV*control* sets the voltage reading for the software and step test to zero. In the main window the actual voltage is displayed in big letters with the remark AUTO ZERO DETECT. The auto zero detect is very helpful to be able to reach the zero voltage programmed in a step test, when the minimum voltage is changing due to different test objects.





Selecting the bottom line ‘PAGE DOWN’ in the menu 'SETUP3' will lead to menu ‘SETUP4’.

Fig. V.6: Screenshot of the SETUP4 menu

- RECORDER OUTPUT
  The REC OUT terminal may optionally be connected to a paper recorder or other device to provide a graph of the voltage magnitude. The voltage output gives 0 to 10 V and corresponds linearly to the displayed voltage.

  This value should be set above the maximum expected voltage value. E. g. if a step curve goes up to 65 kV, the RECORDER OUTPUT can be set to 100 kV. This is the displayed voltage which equals the maximum output voltage (=10 V) at the REC OUT terminal. A displayed voltage of 60 kV will then refer to 6 V at the REC OUT terminal. The REC OUT voltage is altered together with the change of the display of Û, Û/√2, U_{RMS}.

- dU/dt MODE
  Activating the dU/dt protection allows the detection of single voltage dips, caused by a single breakdown or flash over. There are three possible options:

  OFF - Disables the dU/dt detection.

  RELAY - When detecing a dU/dt fault the high voltage source will be switched off, the test will be aborted, and an error message will be shown.

  COUNTER - The detected dU/dt faults will be counted and displayed, but no further action will be taken.

- dU/dt SENSIBILITY
  To detect a voltage dip the actual measured wave forms are compared with their predecessors. If percentage change exceeds the allowed limit a dU/dt-fault will be shown. Five sensibilities are available:

  VERY LOW - A difference up to 60 % between two consecutive waveforms is allowed.

  LOW - A difference up to 50 % between two consecutive waveforms is allowed.

  MEDIUM - A difference up to 35 % is allowed.

  HIGH - A difference up to 22 % is allowed.

  VERY HIGH - A difference up to 14 % is allowed.

  Please note that VERY LOW, LOW, and MEDIUM use an additional discriminator during voltage up or down steps to compensate deformations caused by the driving servo-transformer, while HIGH and VERY HIGH will detect every single voltage dip.

  The following functions are only available on request:

- VOLTAGE PRESET
  When automatic test sequences are programmed with an initial step, HV*control* will use the Usec/Uprim FACTOR to calculate the secondary voltage by the use of the primary voltage for the calculation. This option should only be enabled with complete test sets from Power Diagnostix!

- Usec/Uprim FACTOR (optional)
  Multiplication factor in between secondary voltage and primary voltage, used for the voltage pre-set function. Ensure that the factor is appropriate for the test setup in use.

V.3 Buttons

V.3.1 Functions

In addition to five push buttons on the right-hand side of the LCD the front panel of the HV*control* is fitted with a detachable-key switch, an emergency stop, and 6 piezo push buttons, that are described below:

Power	The HV*control* unit is turned on by the detachable-key switch. This will also power up the 4 inlet connectors on the back plate linked for e. g. to the ICM*compact*, IPC ... The illuminated push button will blink in green colour. This indicates that the push button 'Ready' can be pressed. By doing so the circuit breaker 'K1' will be closed and the button lights in green colour permanently. The unit is ready for operation.
Ready	If the push button 'Ready' is blinking in red colour, then the STOP switch is pushed and has to be released by turning clockwise. If after pushing the button 'Ready' the illumination is permanent red, consult the error messages in the STATUS menu.
Ready **HV On**	After pushing the button 'Ready' twice, the illumination for the 'HV On' button turns green. By pushing this button, the automatic earthing will be opened and the HV connector 'K2' will be closed. The illumination for 'HV On' changes from green to red and 'HV Off' changes from red to green. If the automatic earthing bar can't be opened, this action is blocked.
HV ∆	The illumination for 'HV ∆' turns green and 'HV ∇' turns red, since the zero-voltage position switch is still on. Each time the voltage is changed the respective illumination for '∇' and '∆' will turn red. If the regulating transformer reaches an end position, the respective illumination '∇' and '∆' will stay red. If the unit is in automatic mode, the illumination for '∇' and '∆' will also change colour when active. A manually change of the voltage is then not possible.
HV Off	The HV can be turned off by the 'Off' button. If the voltage regulator has not reached the zero-voltage position, the connector 'K2' will open and the 'HV ∇' relay will move the voltage regulator to the end position. The automatic earthing is closed and the illumination 'Ready' will turn to green. If the voltage is controlled by a step test, test procedures will finish in the same way than pushing the 'HV Off' button. If the current limit is triggered, the HV will be turned off and the automatic earthing is closed. A trip of the primary and secondary current is indicated by an error message display and a green blinking 'Ready' button. The main connectors K1 and K2 are turned off. To reset this status, press 'BACK'. If the transformer protection switch is tripped e.g., by oil temperature then 'HV ∆', 'HV Off', 'HV On' and 'Ready' are illuminated red and the HV is turned off. The indication is reset automatically after the fault is removed. The HV*control* will turn down the voltage if the interlock door is opened, the emergency stop activated or any further safety signal tripped (transformer protection switch, limits for primary or secondary current). While the variable transformer (variac) is moving down, the 'HV ∇' is illuminated red. This function can be changed, so that the variac remains in its position while the voltage is turned off. In order to change this mode, the setup option "auto shutdown" needs to be set to 'disabled'. This mode should only be changed by an expert.
HV ∇	When the HV*control* is turned on and the illumination of 'HV ∇' is green and 'HV Off', 'HV ON' and 'Ready' stays red; this indicates that the variable transformer is not in its zero-position. The HV can only be turned on when the variac is on end-position. For this the 'HV ∇' button has to be pressed until it is illuminated red.
STOP	Pressing the emergency button 'STOP' is indicated by a red blinking illumination of the 'Ready' button. This will open the main circuit breaker (K1) and close the automatic earthing. To release the 'STOP' button it has to be turned clockwise.
Horn	Before a hazard voltage is turned on in the HV area a horn should be used to warn people around. This can be done by the button 'Horn'. The green illumination of the 'Horn' button indicates that the main power for the HV*control* is turned on.

V.3.2 Signal Interpretation

Pushbutton	**Colour**	**Interpretation**
Horn	not illuminated	No power supply, key switch is off, fuse blown
Ready	red blinking	Safety loops not closed. E.g., STOP is pressed: turn button clockwise.
Ready	green blinking	If the red warning lamp is lit and pushing this button will have no action, the feedback of K1 or K2 is broken (X5:6, X5:7).
Ready	red	Interlock circuit is open. If the red warning lamp is lit, the automatic earthing is not closed.
Ready	green	Ready for operation
HV On	green	Ready to turn HV on If the red warning lamp is lit and pushing this button has no result, the feedback of K2 is broken (X5:7).
HV Off	green	Status 'Ready to switch on' or 'In operation' reached. It is possible to switch on HV, or HV is turned on ('HV On' is red)

V.4 Manual Control (MANUAL)

This menu offers setting and control of a voltage. The criteria for the control are described in section V.3. The voltage control is active only in the menus MANUAL and STEP, and in their submenus, respectively. The menu MAIN merely displays the waveform and voltage level, without any control or dU/dt detection and, thus, is used when the unit is used as voltage meter, only.

Changing from MAIN to MANUAL or STEP will put the actual voltage as the set voltage (U_set) by pressing the START button. The HV*control* will now try keeping this value stable, while supervising indications for a potential break down. In the MANUAL menu the voltage can be changed by the submenu SET U. Each digit of the voltage value (U_new) can be changed separately, starting with the position for 1 kV. The changed voltage (U_new) will be taken to the new set voltage (U_set) pressing the ACCEPT button.

STOP releases the voltage control and allows to change the voltage via the piezo pushbuttons. To switch off and shutdown the voltage, press the 'HV Off' button.

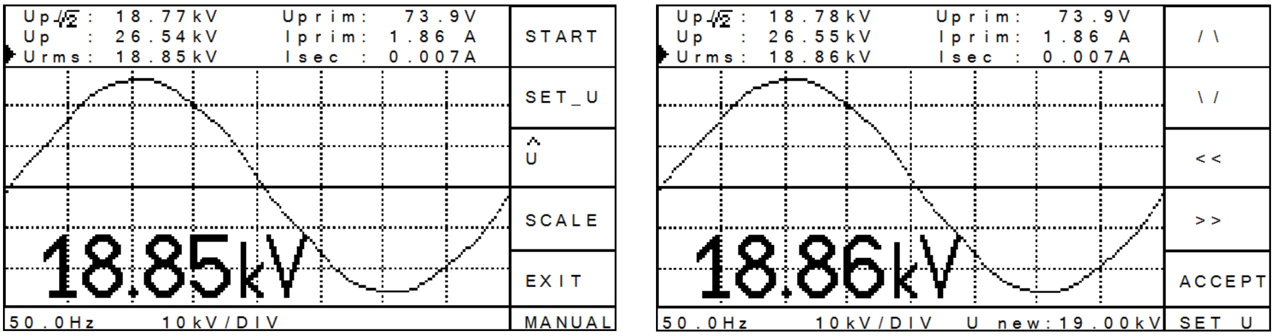


Fig. V.7: MANUAL and SET_U menu

V.5 Manual Scaling (SCALE)

The voltage curve is by default scaled automatically. When the voltage signal is about 10% (10 V signal voltage), the waveform fills the respective area in the LCD. However, for observation purpose it is sometimes useful to manually adjust and fix the scaling. This can be done in the menu SCALE. The button 'UP' and 'DN' (down) will turn off the automatic mode and increase / decrease the maximum size of the waveform. The automatic scaling function is active when the label >AUTO is marked by '>'. Turning on and off this function can be done by the button AUTO. This status is fixed for all menus. Changes of the scaling have no impact on the calculated values, which are displayed in the top lines of the LCD. The SCALE menu can also be accessed in the menus MANUAL and STEP2.

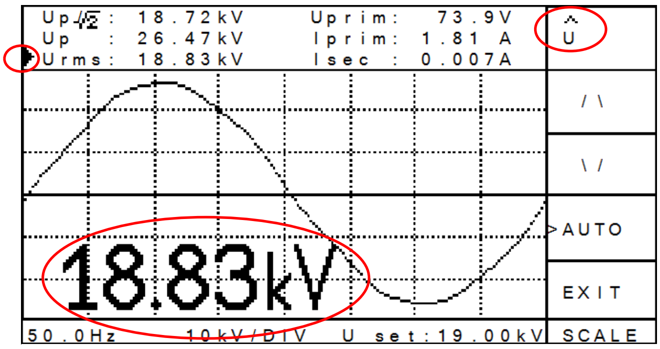
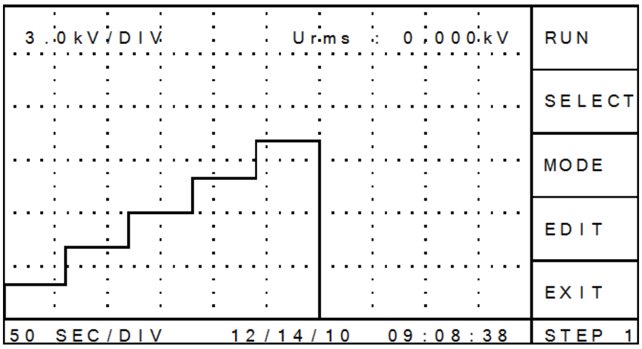


Fig. V.8: SCALE menu for voltage display

One voltage value is displayed in large characters in the lower left corner of the LCD. This value can be selected among U DC, U_{rms}, Û, and Û/√2 by pressing the respective button. Active is the ticked '>' voltage value. The U_{RMS} value is shown in figure V.8. The selected value is also used for the REC OUTPUT (0 to 10 V).

The crest factor is calculated by Û / U_{RMS} hence, crest=1.41 (√2) for ideal sine waves.

V.6 Automatic Step Test Function (STEP, Optional)



In the menu STEP, various voltage time curves can be managed, edited, and run. The display is twofold. The first display STEP1 shows the active voltage time curve. The second display STEP2 shows the waveform of the actual voltage. The button MODE toggles between these two displays.

Fig. V.9: STEP1 menu

V.6.1 RUN

The RUN button starts the active curve. While the test is running, it is not possible to exit the menu STEP or to edit any voltage time curve. Toggling with the MODE button between the displays has no impact on the actual control function. Figure V.10 shows the STEP2 menu during a running test.

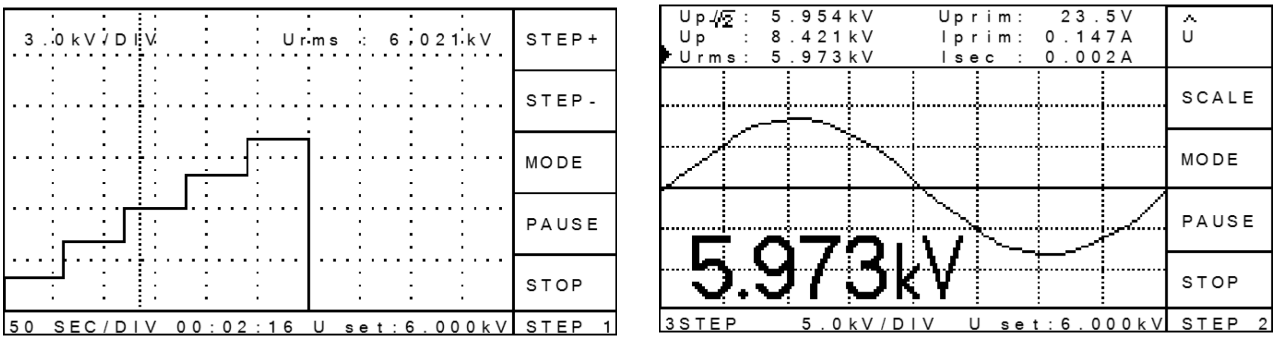


Fig. V.10: STEP2 menu in the two different modes: step voltage curve (left) and voltage curve (right)

V.7 Test results (RESULT)

After the HV*control* has tripped the voltage, or when a test has been successfully finished, results can be observed in this menu. Start time (STARTED) and completing time (FINISHED) are logged only when an automatic step test was run. The DURATION time is a value including any pausing or skipping of steps of the whole automatic test procedure.

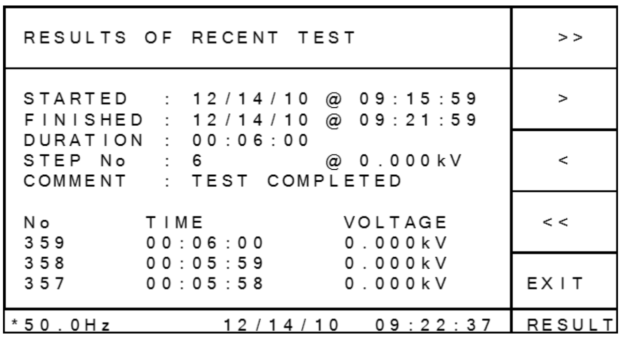
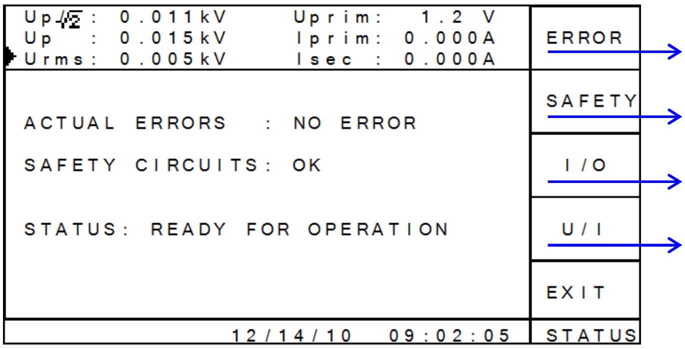


Fig. V.11: RESULT menu

During a test the two values (time duration and voltage) are permanently logged in a non-volatile memory. For the whole test, up to 2000 values are logged and can be viewed by scrolling the last three rows.

V.8 Plant Status (STATUS)

The status menu gives an overview about the test set. It is possible to monitor input, output, voltage, safety circuit and errors. If there is any problem or if it is not possible to power up the HV please check the STA-TUS -> ERROR menu there you can find actual errors if available. If the error was just temporary, you can find the last error with time stamp at the bottom of the display.



Actual **errors** and information about the last temporary error

Status information about **safety**-relevant circuits

Overview about **input** and **output**, as well as analogue input configuration (U_{prim}, I_{prim}, I_{sec})

Display and choice of actual measuring values (incl. crest)

Fig. V.12: STATUS menu

There are four different machine states: 'Initialisation', 'Ready for operation', 'Ready to switch on'; and 'In operation'. The actual state can be checked in the main STATUS screen.

Initialisation
In that state the supply for the regulating transformer (K1), the HV transformer (K2) and the grounding relay is switched off. The relay contact for the door lock is closed.

By pressing the ready button, the HV*control* will go to ready for operation.

Ready for operation
In 'Ready for operation' status the relay K1 will be switched on to energise the regulating transformer. The supply for the HV transformer is still disconnected. By pushing the ready button, the HV*control* will change to 'Ready to switch on'.

Ready to switch on
In this state the red warning lamp is switched on, and the doors will be locked, while the HV busbar is still grounded and HV is off. By pushing 'HV On', the relay K3 will open the ground connection, when the ground connection is open The HV transformer (K2) will be switched on. The actual state is then 'In opera-tion'.

In Operation
In this state HV is switched on, with pressing HV Up and HV Down the voltage can be increased and de-creased as long the end switches are not reached.

By pressing 'HV Off' the HV*control* will go back to 'Ready for operation'.

V.8.1 Error Messages

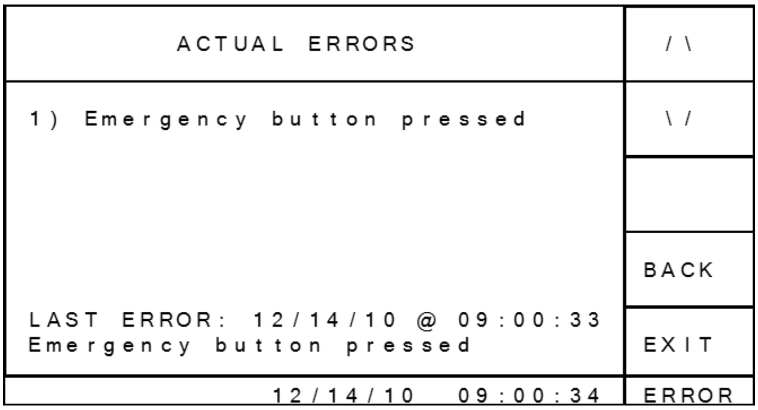


Fig. V.13: Example of an error message

Error message / warning		**Troubleshooting**
Emergency button pressed	→	Check internal push button (turn it clockwise)
Interlock open	→	Interlock circuit open (between X2:1 and X2:2)
Ext. EMO pressed	→	External push button pressed
Missing feedback K1	→	No feedback signal from K1, check if relay is open/closed
Missing feedback K2	→	No feedback signal from K2, check if relay is open/closed
Circuit breaker F1 open	→	No feedback signal from F1, check if the circuit breaker is blown
I_{sec} too high	→	Secondary current too high (check error limit in SETUP)
I_{prim} too high	→	Primary current too high (check error limit in SETUP)
Transformer protection	→	Overload of HV transformer
Zero switch not reached	→	Decrease voltage by pressing HV down
End switch reached	→	Voltage regulator reached upper limit switch
Missing earth signal	→	Relay not closed
Earth relay not opened	→	Check earth relay or feedback to HV*control* X5:2 (NC)
Earth signal (HV was on)	→	Earth signal while HV was on
Check Full-Range up/ip/is	→	Setup is not correct, check entered values
Warning I_{prim} >=95% I_{max}		
Warning I_{sec} >=95% I_{max}		

VI The HV*control* Software: HV*pilot*

A software package is available to communicate through a PC with the HV*control,* an ICM*compact*, and a TDA*compact* (tan delta analyser). Herewith it is possible to set up and run a step test. Up to all three devices can be connected and their data can be collected (voltage, PD, tanδ). While the PC is connected it is possible to control and observe the HV*control* remotely. The display on the HV*control* will change accordingly.

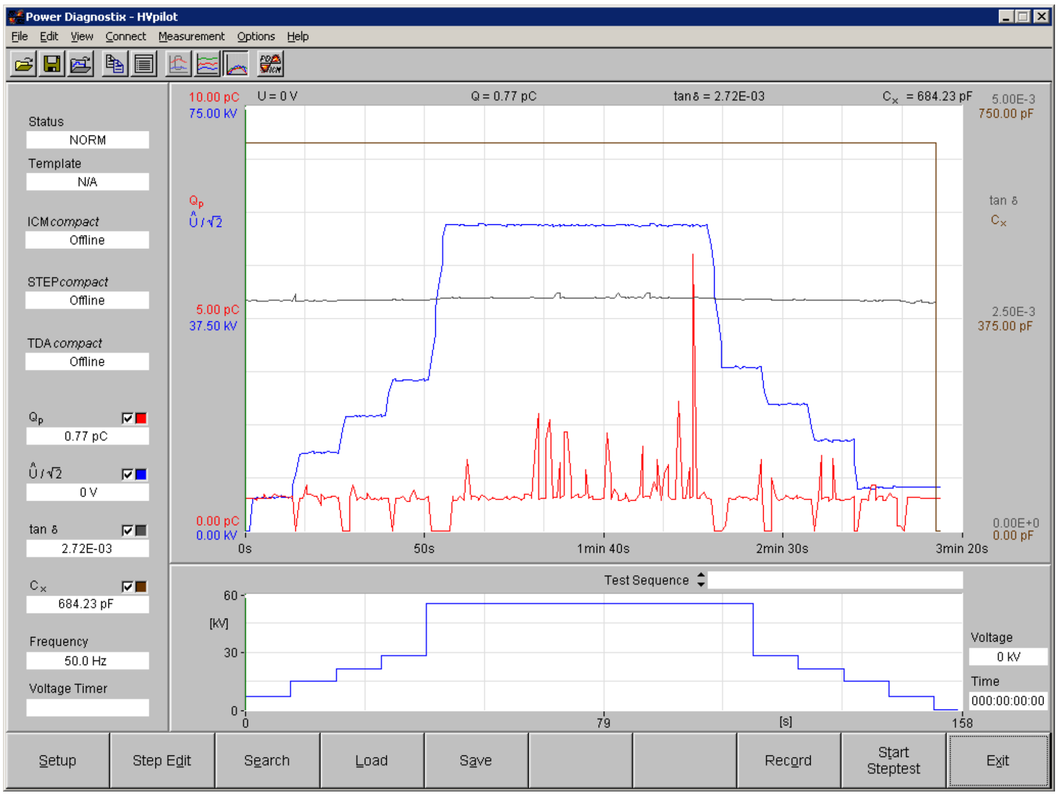


Fig. VI.1: Screenshot of the HV*pilot* software

Each of the seven parameter setups as described in section V.2 can also be changed with the HV*pilot* software. The button 'Setup' / 'Next' will alter through the seven setups. 'Send' or 'OK' will send the changes from the PC to the connected device. It is also possible to load, change and store the setups from each connected device in a data file (suffix *.hvp).

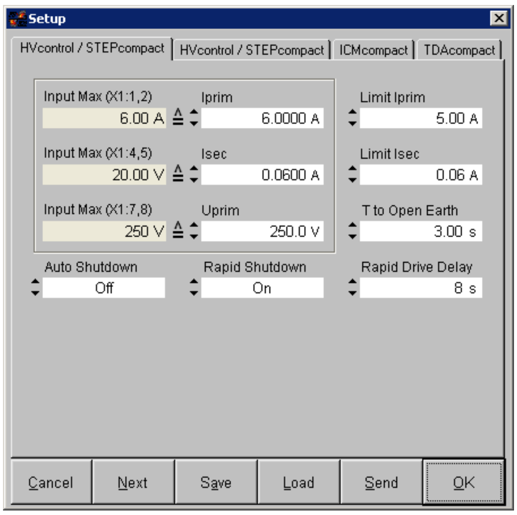


Fig. VI.2: Screenshot of the HV*pilot* SETUP menu

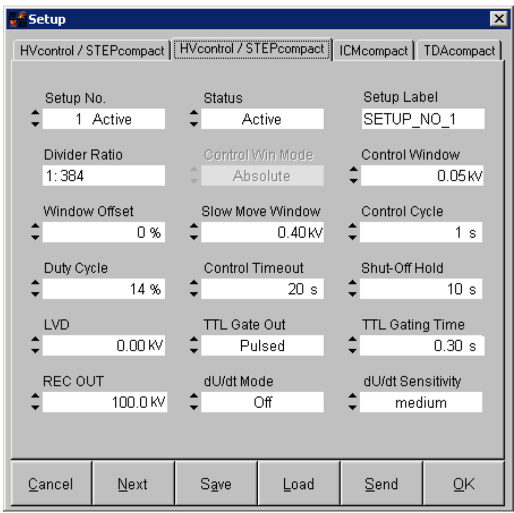


Fig. VI.3: Screenshot of the HV*pilot* SETUP menu

The ‘Step Edit’ menu offers an easy way to create step voltage curves. In here it is possible to save and load voltage curves from the PC hard drive (suffix *.hvc).

The program is able to create a predefined test report with the processed results.

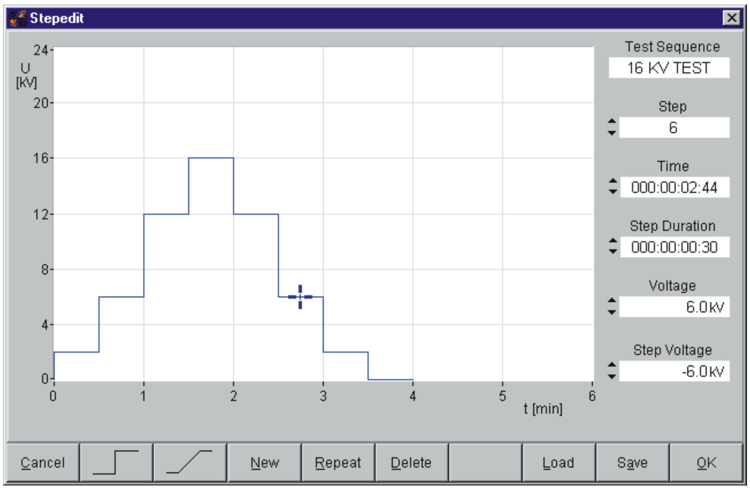
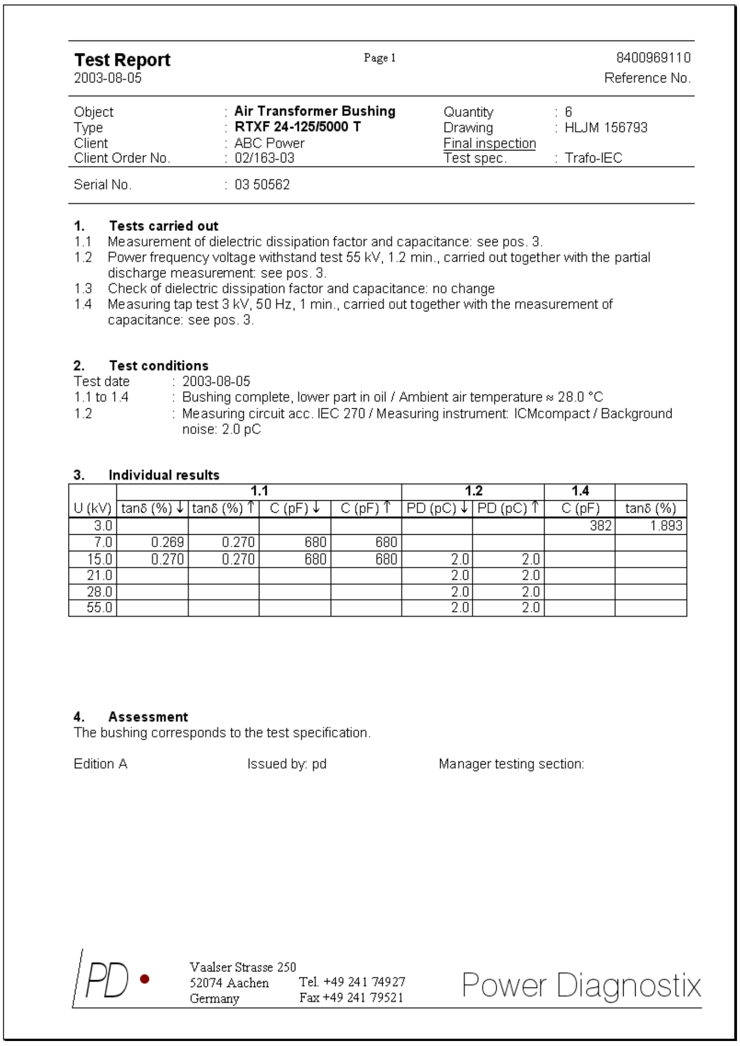


Fig. VII.2: Screenshot of the HV*pilot* STEP EDIT menu



Test Report Page 1 8400969110

2003-08-05 Reference No.

Object : **Air Transformer Bushing**
Type : **RTXF 24-125/5000 T**
Client : ABC Power
Client Order No. : 02/163-03

Quantity : 6
Drawing : HLJM 156793
Final inspection
Test spec. : Trafo-IEC

Serial No. : 03 50562

1. Tests carried out

1.1 Measurement of dielectric dissipation factor and capacitance: see pos. 3.
1.2 Power frequency voltage withstand test 55 kV, 1.2 min., carried out together with the partial discharge measurement: see pos. 3.
1.3 Check of dielectric dissipation factor and capacitance: no change
1.4 Measuring tap test 3 kV, 50 Hz, 1 min., carried out together with the measurement of capacitance: see pos. 3.

2. Test conditions

Test date : 2003-08-05
1.1 to 1.4 : Bushing complete, lower part in oil / Ambient air temperature ≈ 28.0 °C
1.2 : Measuring circuit acc. IEC 270 / Measuring instrument: ICMcompact / Background noise: 2.0 pC

3. Individual results

	1.1				**1.2**		**1.4**	
U (kV)	tanδ (%) ↓	tanδ (%) ↑	C (pF) ↓	C (pF) ↑	PD (pC) ↓	PD (pC) ↑	C (pF)	tanδ (%)
3.0							382	1.893
7.0	0.269	0.270	680	680				
15.0	0.270	0.270	680	680	2.0	2.0		
21.0					2.0	2.0		
28.0					2.0	2.0		
55.0					2.0	2.0		

4. Assessment

The bushing corresponds to the test specification.

Edition A Issued by: pd Manager testing section:

PD • Vaalser Strasse 250 52074 Aachen Germany Tel. +49 241 74927 Fax +49 241 79521 Power Diagnostix

Fig. VII.1: Example of an automatically generated report

Miscellaneous

VII.1 Maintenance

The HV*control* does not require any maintenance on a regular basis. There is no fine adjustment on a regular basis required.

VII.2 Shipment Instructions

In case a unit needs to be returned to the factory, make sure the instrument is packed safely. As the units are relatively small, shipment by couriers, such as DHL, FedEx, or equivalent is the recommended mode of transportation. If possible, declare the instrument as 'used instruments for evaluation' at a relative low value. Consult Power Diagnostix for further details. Additionally, Power Diagnostix may provide you with a temporary replacement unit, in case of urgent needs.

VII.3 Declaration of Conformity

Power Diagnostix Instruments GmbH
Vaalser Strasse 250
52074 Aachen
Germany

declares, that the instrument as specified below, meets the requirements of the standards and/or normative documents as listed below.

Product: HV*control*

Description: High Voltage Test Control Unit

Guidelines: Low Voltage Directive 2014/35/EU
EMC Directive 2014/30/EU
RoHS Directive 2011/65/EU

Standards: IEC 61010-1:2010, IEC 61010-2-030:2010,
EN 61326-1:2013,
DIN EN IEC 50191; DIN EN 50110-1; DIN EN ISO 13850
EN IEC 63000:2018

Date:

Dr. Mihai Huzmezan
(Managing director)

VIII Technical Data

Instrument Requirements

Mains supply:	90–264 V_{AC} (automatic)
Frequency:	47–63 Hz
Line fuse:	5 A
Display:	Backlit LCD
Display resolution:	128 x 240 pixels b/w
Switched inlet connector:	4 x 1 A max.
Operation:	6 illuminated pushbuttons (red/green) 1 emergency stop 1 detachable-key switch
Size:	19'' x 3 RU
Depth:	38 cm (including connectors)
Weight:	Approx. 7 kg

Meter (X1)

AC ammeter:	0.5, 1 A or 5 A max. / ~24 V (depending on version!)
Frequency:	0 to 100 Hz (sine)
AC voltmeter:	10–400 V (depending on version!)
Input impedance:	24 kΩ to 250 kΩ (depending on version!)
Frequency:	0 to 100 Hz

Relay Output (X3, X4)

Max. relay voltage:	250 V
Max. relay current:	2 A (each contact)

Analog Output (REC OUT, Optional)

Recorder Output:	0–10 V with R_0=100 Ω

Measurement Input (VN1, Optional)

Synchronisation:	20 Hz–510 Hz with U_{DC} selected, the supply frequency is used
Input impedance:	5 MΩ // 200 pF
Maximum level:	± 200 V_{peak}
A/D converter:	±11 bits
Precision:	<1.5 % (typical)
Samples:	197 samples per cycle

IX Annex

IX.1 Older Hardware Versions

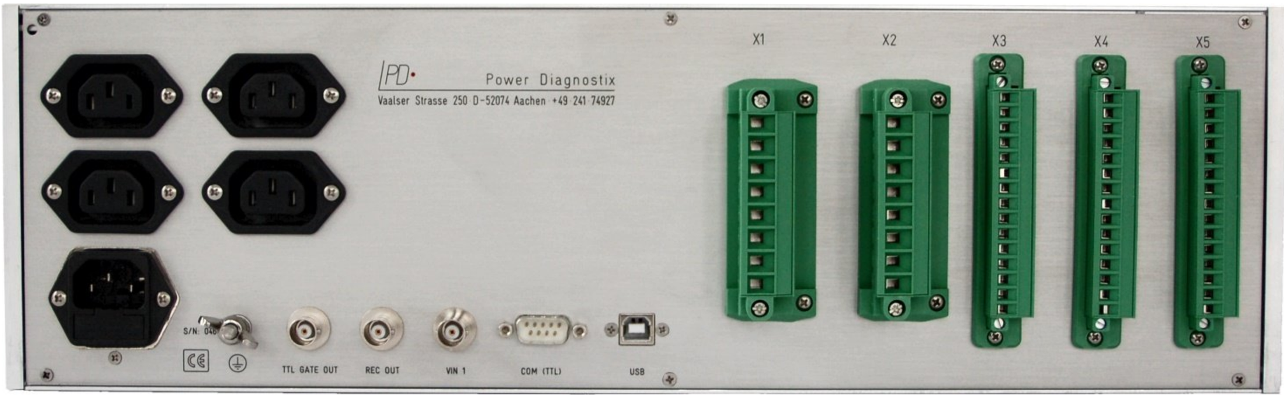


Fig. IX.1: Layout of the HV*control*'s back panel of model prior to 2017

Please refer to section II, section III.1, and section IV for an explanation of the connectors.

IX.2 Buffer Battery of the Programmable Logic Controller

Some older models (production date ≤ 2010) of the HV*control* are fitted with a Siemens programmable logic controller (PLC) with a buffer battery. If this battery is empty, the HV*control* forgets the current and voltage limits, and maybe it's impossible to switch on the instrument.

To change the buffer battery, please take the following steps:

1. Turn off the instrument and unplug the power cord.
2. Loose the fixing screws and remove the instruments housing.
3. Unplug the battery housing and take out the battery board.
4. Pull off the clamping bracket that holds the battery in place.
5. Change the battery and fix it with the clamping bracket.
6. Put battery board into the battery housing.
7. Plug the housing into its socket.

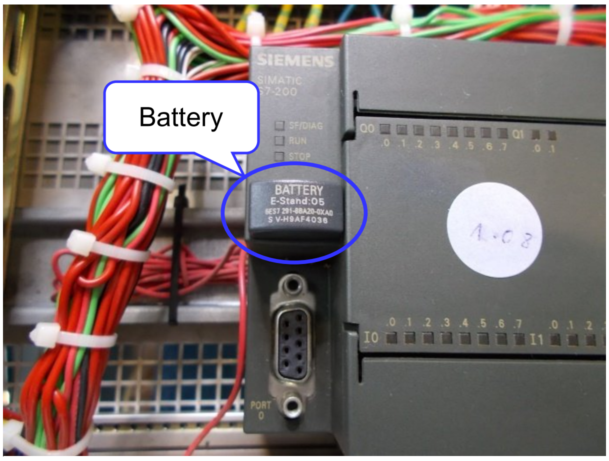


Fig. IX.2: Siemens PLC with buffer battery

Fig. IX.4: Unplugged battery housing

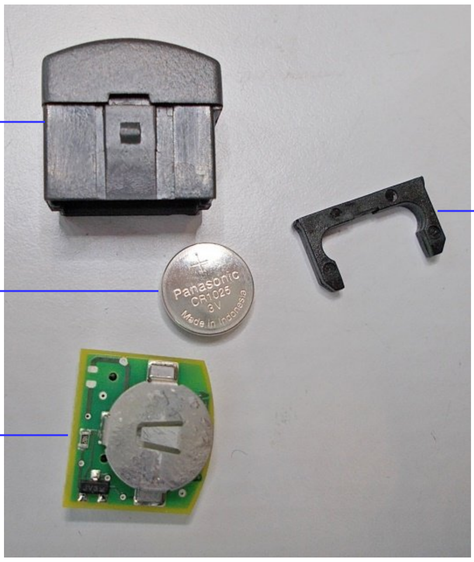


Fig. IX.3: Parts of buffer battery