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4. Introduction to Testing (manual operation)

4.1. Test Procedure

4.1.1. General

The user can control the test procedure in one of two ways:

- manually by entering the required parameters and pressing 'START'
- by running a test program which he has either written himself or acquired from ABB Power Automation Ltd.

In both cases, the test set can be controlled by the following devices:

- handheld terminal YB92 (see Sections 2.2.4. and 4.5.)
- external computer, e.g. PC with DOS, WINDOWS 95 or WINDOWS NT operating system (see Section 7.2.).

After the program "XSWIN" has started, the following functions are available for selection.

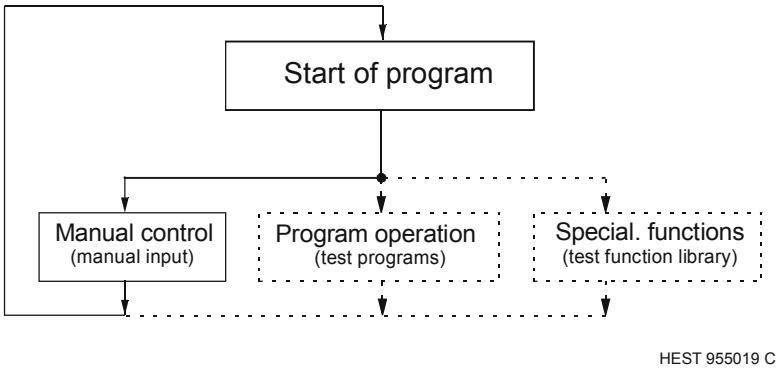


Fig. 4.1 Test set control modes

The testing procedure in the manual mode is briefly as follows:

- The test set is connected to the relay to be tested
- The main switch and the auxiliary DC supply switch are switched on
- The parameters for the kind of test to be injected are entered
- The test is started
- The test cycle runs through and terminates
- The library of test functions contains a number of test routines for automatically testing the different kinds of faults.

4.2. Detailed description of entering test parameters

4.2.1. Kinds of parameters

The microprocessor in the control unit calculates the signals for injection from the parameters entered according to the equations in Section 3, i.e. it calculates the voltages and currents and then injects them.

Parameters can be of the following kinds:

- Main parameter
  The calculation of the injection signals is based on these parameters, e.g. "I" for the injection current (fault current).
- Step increment parameters and limits
  These are assigned to the various main parameters and determine the increment or decrement by which they are varied. By entering minimum and maximum limiting values a permissible range can be defined for a main parameter, e.g. to save testing time by not passing through uninteresting parameter values.
- Control parameters
  These determine how the injection quantities are to be calculated and injected and also control other functions of the test set.

Every parameter has a unique name with a maximum of three letters referred to below as parameter designator. The designator is used to call the parameter, for example, to assign a value to it.

The parameters are divided into lists according to function (see Section 4.3.). Each list of parameters has a unique name referred to below as list designator. The latter are displayed after the respective menu names in the XSWIN selection lists.

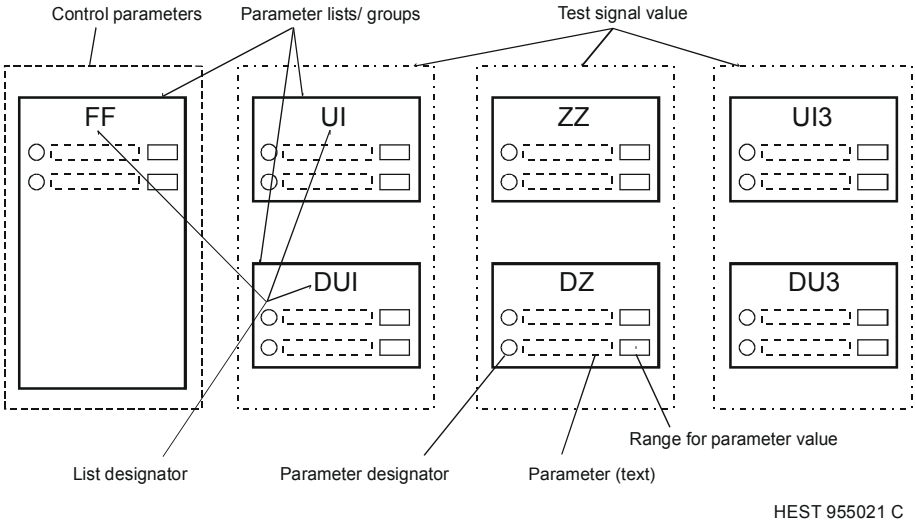


Fig. 4.2 Parameter lists

4.3. Significance of the parameters

All the possible lists, the parameter designators, their significance and the corresponding ranges are given below. Those values which are bold are set automatically (default values) when the test set is switched on or after a general reset (see Section 6.3.4.). All the step parameters are set to zero at the same time, i.e. they are not activated.

The parameter lists have the following denominations (e. g. ZZ):

- FF Control parameters for display and printer.
- ZZ Parameters for entering impedances (Section 3.2.3.).
- DZ Step parameters and limits for entering impedances.
- UI Parameters for entering fault voltage and current (see Section 3.2.2.).
- DUI Step parameters and limits for entering fault voltage and current.
- UI3 Parameters for directly entering injection voltages and currents (see Section 3.2.1.).
- DU3 Step parameters when directly entering voltages and currents.
- UU Parameters for entering 2 three-phase voltage systems.

4.3.1. FF list: Control parameters for display and printer

(see Sections 5.1. to 5.7. for explanation)

Parameter designator	Parameter significance	Range/Value
FR=xx.xx	Injection signal frequency Injection signals for fault codes 02 or 03	**50.00** or 60 Hz 40.00...70.00 Hz (0.01)
DFR=x.xx	Frequency step settings for FR:	
	disabled only fault codes 02 and 03	**0** 0.01...1.00 Hz (0.01)
DF=x.x	Frequency rate-of-change df/dt:	
	disabled only fault codes 02 and 03	**0** 0.4...5.0 Hz/s (0.1)
FC=xyz	Fault code (x = current direction)	
	forwards reverse	**0** 1
	Fault code (yz = kind of fault)	
	Off-load voltage (57.7 V)	**00** (only steady-state injection possible)
	R phase current, voltage (up to 220 V)	01 (only steady-state injection possible)
	R phase voltage (up to 220 V) with variable frequency	02 (only steady-state injection possible)
	Phase-to-phase voltage R-S (up to 140 V) with variable frequency	03 (only steady-state injection possible)
	Ground faults	
	R-0; S-0; T-0	11 or 12 or 13
	Phase-to-phase faults (no ground contact)	
	R-S; S-T; T-R	21 or 22 or 23
	Three-phase fault (R-S-T)	
	XS92b (R-S-T phase current) XS92a (R phase current) XS92a (S phase current) XS92a (T phase current) XS92a (current in R and S in parallel and T)	31 or 32 or 33 31 32 33 34

Parameter designator	Parameter significance	Range/Value
SQ=x	**Steady-state** injection Zero injection Injection of off-load voltage	**2** only using program 0 1
SQ=xyz	**Dynamic** injection signals 0, 1 as above F fault injection	0F0,1F0,0F1,1F1
A=x	No automatic search sequence Automatic search with interruption for increasing injection signal	**0** 1
	Automatic search with interruption for decreasing injection signal	2
IRA=x IRA=xy	Current range for 1 current: Current range for 3 currents:	
	0.00...20.00 A 0.00... 1.30 A	**0** or 30 1 or 31
	xy value only possible with ancillary equipment rack (current amplifiers, see Sections 7.3. and 10.2.2.)	
T0=xxxx	Duration of zero injection	**100**...9999 ms
TL=xxxx	Duration of off-load voltage injection	**100**...9999 ms
TF=xxxx	Duration of fault injection	**0**...9999 ms
IN1=xxxx	Combination of digital inputs which determine the interrupt condition	**1** / 0...3777
IN2=xxxx	Combination of digital inputs which determine whether 0 or 1 in IN1 should be evaluated (from V 2.63)	**0** (...3777)
OU1=x	Digital output OUT set to:	
	Disabled logical ‘1’ during injection	0 **1**
OU2=xxx	Digital output settings on YU92a (from V 2.64)	**0** (...377)

Parameter designator	**Parameter significance**	**Range/Value**
TI=x	Test set response when interrupt condition fulfilled:	
	No response	0
	No response excepting time measurement of **dynamic** injection	1
	Interruption of fault injection with time measurement of **dynamic** injection	**2**
	Steady-state injection: Injection of the last value	3
	Dynamic injection: Interruption of fault injection with time measurement	
TT=x	Function of the time measurement for **dynamic** injection:	
	Measures operating time (from the start of fault injection)	**0**
	Measures resetting time (from the interruption of fault injection)	1
T=XXXX	Displays measured time	only value
MOD=xxx	Calculation mode (specifies corresponding parameter list)	
	Impedance	**ZZ**
	Fault voltage and current	UI
	Injection voltages and currents	UI3
MT=xxx	Parameter TF multiplier (TF in ms)	**1,** 10, 100
OP=x	No software options (see Section 5.6. for software options)	**0**

4.3.2. ZZ list: Parameters for entering impedances

Parameter designator	Parameter significance	Range/Value
ZL=xx.xx	Positive-sequence line impedance (fault impedance)	**0**...99.99 Ω
PZL=xxx.x 1) 3)	Line impedance phase-angle	**0**...360°
ZS=xxx.x	Positive-sequence source impedance	**0**...220.0 Ω
PZS=xx.x 1) 3)	Source impedance phase-angle	**0**...90.°
K0=x.x	Line zero-sequence compensation	0...**1.0**...5.0
PK0=xx.x 2) 3)	Line zero-sequence comp. angle K0	-180...**0**...90.°
KS=x.x	Source zero-sequence compensation factor	**0**...5.0
PKS=xx.x 2) 3)	Source zero-sequence comp. angle KS	**0**...90.°

1) Since the accuracy is +1°, only whole angles should be entered. The decimal point is intended for an option which calculates the time constant of the system.

2) The actual values of PK0 and PKS to be entered are defined in section 3.1.6. (zero-sequence compensation).

3) Reduction of the "healthy" voltages, see next page.

DZ list: Step parameters and limits for entering impedances

Parameter designator	Parameter significance	Range/Value
DZL=xx.xx	Step value for ZL	0.01...10.00 Ω 3)
DPL=xx.x 1)	Step value for PZL	1...30° 3)
LZH=xx.xx	Upper limit for ZL	**99.99** Ω
LZL=xx.xx	Lower limit for ZL	**0.00** Ω
LPH=xxx.x 2)	Upper limit for PZL	**359°**
LPL=xxx.x 2)	Lower limit for PZL	**0.**°

1) Only whole angles should be entered (see also list ZZ).

2) If it is required that the angle PZL be varied, for example from 300° to 90° passing through 0°, then LPH must be set to 90 and LPL to 300 (i.e. LPH < LPL).

3) Default value = **0** without step parameter
(≠ 0 with step parameter).

3) **Reduction of "healthy" voltages** (note concerning ZZ list)

If approximately the same amplitudes but different angles are entered for the source impedance ZS and the fault impedance ZL (ZZ list), the calculation of the injection signals (see Section 3.2.3.) can produce a fault voltage which is higher than the rated voltage (up to almost ∞). In this case, the test set limits the fault voltage to 70 V and reduces the amplitude of the "healthy" (rated) voltages by the corresponding factor for the injection sequences SQ=1F0 and SQ=1F1.

The warning "UN <<" is displayed briefly during injection when the "healthy" voltages are reduced. The voltages can only be reduced, however, to a minimum of 10 V. The error message "er 6 UN < 10 V" is displayed should the calculated correction factor be greater (see Section 10.1.6.).

The voltage reduction method is also applied if the fault current is calculated to exceed 20 A. The warning "UN <<" is also displayed.

Voltage reduction extends the field of application of the test set.

Note: The jump produced in the "healthy" voltages from the off-load to fault statuses does not occur in practice and can cause some relays to pick up briefly and incorrectly. In such cases, measurements in this range should not be carried out.

4.3.3. UI list: Parameters for entering fault voltage and current

Parameter designator	Parameter significance	Range/Value
U=xxx.x	Fault voltage	
	phase-to-ground phase-to-phase special fault code in R phase	**0.0**... 70.0 V **0.0**...100.0 V **0.0**...220.0 V
I=xx.xx 1)	Fault current	**0.0**...20.00 A
PHI=xxx.x 2) 3)	Angle between fault voltage and current	**0**...359°

1) The range of the control parameter IRA in the FF list can be limited to 0.0...1.30 A to improve accuracy at low values.

2) Only integers should be entered (see list ZZ).

3) The angle PHI rotates counter-clockwise and is referred to the current I. The direction of power flow must also be taken into account, i.e. where fault code FC=0yz was selected, **180° must be added to the angle** (see Section 5.1.1.).

DUI list: Step parameters and limits for entering fault voltage and current

Parameter designator	Parameter significance	Range/Value
DU=xx.x	Step value for U	0.1...10.0 V 3)
DI=x.xx	Step value for I	0.01...1.0 A 3)
DPH=xx.x	Step value for PHI	1...30° 3)
LUH=xxx.x 1)	Upper limit for U	**220.0 V**
LUL=xxx.x	Lower limit for U	**0.0 V**
LIH=xx.xx	Upper limit for I	**20.00 A**
LIL=xx.xx	Lower limit for I	**0.00 A**
LPI=xxx.x 2)	Upper limit for PHI	**359**°
LPO=xxx.x 2)	Lower limit for PHI	**0**°

1) The faulted voltage U (UI list) entered is checked in relation to the kind of fault and the maximum value of the range, if LUH is greater than this value.

2) If it is required that the angle PZL be varied, for example, from 300° to 90° passing through 0°, then LPH must be set to 90 and LPL to 300 (i.e. LPH < LPL).

3) Default value = **0** without step parameter
(≠ 0 with step parameter).

4.3.4. UI3 list: Parameters for directly entering injection voltages and currents

Parameter designator		Parameter significance	Range/Value
UR=xx.x	1)	R phase voltage	**0.0**...70.0 V
US=xx.x		S phase voltage	**0.0**...70.0 V
PUS=xxx		Voltage US angle	**0**...359°
UT=xx.x		T phase voltage	**0.0**...70.0 V
PUT=xxx		Voltage UT angle	**0**...359°
IR=xx.xx		R phase current	**0.0**...2000 A
PIR=xxx		Current IR angle	**0**...359°
IS=xx.xx		S phase current	**0.0**...20.00 A
PIS=xxx		Current IS angle	**0**...359°
IT=xx.xx		T phase current	**0.0**...20.00 A
PIT=xxx		Current IT angle	**0**...359°
The following parameters can be called from this list, but do not appear directly in the list:			
IA= xx.x		L1 phase current for the I2 system	**0.0...**20.0 A 2)
IB= xx.x		L2 phase current for the I2 system	**0.0...**20.0 A 2)
IC= xx.x		L3 phase current for the I2 system	**0.0...**20.0 A 2)
PIA = xxx		Phase-angle of IA phase current	**0**...359°
PIB = xxx		Phase-angle of IB phase current	**0**...359°
PIC = xxx		Phase-angle of IC phase current	**0**...359°

1) All angles rotate counter-clockwise and are referred to R phase voltage. The direction of power flow must also be taken into account, i.e. where fault code FC=0yz was selected, **180° must be added to the angle** (see Section 5.1.1.).

2) The three-phase current system I2 can be connected via the YU92a unit to a separate current amplifier AI93.

DU3 list: Step parameters when directly entering voltages and currents

Parameter designator	Parameter significance	Range/Value	
DUR=xx.x	Step value for voltage UR	0.1...10.0 V	1)
DUS=xx.x	Step value for voltage US	0.1...10.0 V	1)
DPS=xx	Step value for angle PUS	1...30°	1)
DUT=xx.x	Step value for voltage UT	0.1...10.0 V	1)
DPT=xx	Step value for angle PUT	1...30°	1)
DIR=x.xx	Step value for current IR	0.01...1.0 A	1)
DRP=xx	Step value for angle PIR	1...30°	1)
DIS=x.xx	Step value for current IS	0.01...1.0 A	1)
DSP=xx	Step value for angle PIS	1...30°	1)
DIT=x.xx	Step value for current IT	0.01...1.0 A	1)
DTP=xx	Step value for angle PIT	1...30°	1)
The following parameters can be called from this list, but do not appear directly in the list:			
DIA = x.x	Step value for current IA	**0**.01...1.00 A	
DIB = x.x	Step value for current IB	**0**.01...1.00 A	
DIC = x.x	Step value for current IC	**0**.01...1.00 A	
DAP = xx	Step value for angle PIA	**0**...10°	
DBP = xx	Step value for angle PIB	**0**...10°	
DCP = xx	Step value for angle PIC	**0**...10°	

1) Default value = **0** without step parameter
(≠ 0 with step parameter).

4.3.5. UU list: Parameters when directly entering two three-phase voltage systems

Parameter designator	Parameter significance	Range/Value
FR2=xx.xx	U2 system frequency	**50** ; 60 Hz
U1=xx.x	U1 system phase-to-ground voltage	**0.0**...70.0 V
U2=xx.x	U2 system phase-to-ground voltage	**0.0**...70.0 V
PH2=xxx	Phase-angle between U1 and U2 systems	**0**...359° 1)
DU1=x.x	Step value for voltage U1	0.1...1.0 V
DU2=x.x	Step value for voltage U2	0.1...1.0 V
DP2=xx	Step value for angle PH2	1...10°

1) If PH2 = 0 is entered, the phase-angle between U1 at the sockets on the YU92 and U2 at the sockets on the AX91/92 is 180°, because it is assumed that the amplifier will rotate the voltage U1 back 180° again (as is the case, for example, with AU92).

4.3.6. Parameters with special functions
(Entering in the FF list)

Parameter designator	Parameter significance	Range/Value
	Harmonics	
HAR = x	Order of harmonic	0…9
API = xx	Percentage of harmonic in the fault current	0...50 %
APU = xx	Percentage of harmonic in the fault voltage	0...50%
DHI = x.x	Step for the harmonic in the current	0.1...1.0%
DHU = x.x	Step for the harmonic in the voltage	0.1...1.0%
	Low-level signal output	
SSI = xxx	Enables low-level signal output via the YU93 unit	0 / 100 / 110 (UN)
	External test start via input In10	
EXT = x	Enables In10 for input of external test start	0 / 1

4.4. Operating the test set

4.4.1. Preparation

It is important for the user to be familiar with the contents of Sections 1 to 3 before proceeding with the preparations for testing.

After connecting a PC or handheld terminal and the relay to be tested to the test set (see Section 1.3.), switch on the main switch (Fig 2.4) and switch 2 in Fig. 2.5.

Only the green LED's (light emitting diodes) may be lit on the various units of the test set (see Sections 2.1.3. and 2.1.4.).

The sequence when loading the parameters from the XS92b and the readiness for entering them are shown on the PC.

All four LED's on the handheld terminal must light for about 2 s and the display should show "4800 BAUD". The test set is ready for operation when the display on the handheld terminal changes to "*XS92b ready*" (ready for data input, see Sections 2.2.7. and 7.1.6.). You can now make entries via the key pad.

4.4.2. Operator program 'XSWIN.EXE'

4.4.2.1. Summary

The purpose of this program is to be able to control the test set XS92b using a personal computer (PC). Any PC running Microsoft WINDOWS 3.1, WINDOWS 95 or NT is suitable. The program's main features are:

- Menu-guided program
- Cascaded windows for setting and control
- Direct entry of XS92b parameters on the screen (instructions given in ‘help’ windows)
- Graphical presentation of parameter settings
- Error messages and warnings
- Input and editing of values using either the numerical keys, spin buttons or by dragging phasors with the mouse
- Routines for testing of various relay functions
- Data input in the terminal mode
- Program transfer and saving.

4.4.2.2. Installation

Connect the serial interface of the PC to the nine-pin socket marked "Handheld terminal" on the XS92b. The characteristics of the communications link and the cable connections are given in b) and c) below.

a) **Minimum PC requirements**

- A PC 386 or higher
- Operating system: DOS Version 3.0 or later and WINDOWS 3.1 or later or WINDOWS 95 or NT
- 8 MB RAM
- Hard disc with minimum space of 5 MB available
- 1 floppy drive (3½")
- 1 serial port RS-232C
- 1 parallel port (Centronix).

b) **Serial communication parameters**

The PC's RS-232C serial port is initialised by the control program for transferring data to the test set XS92b.

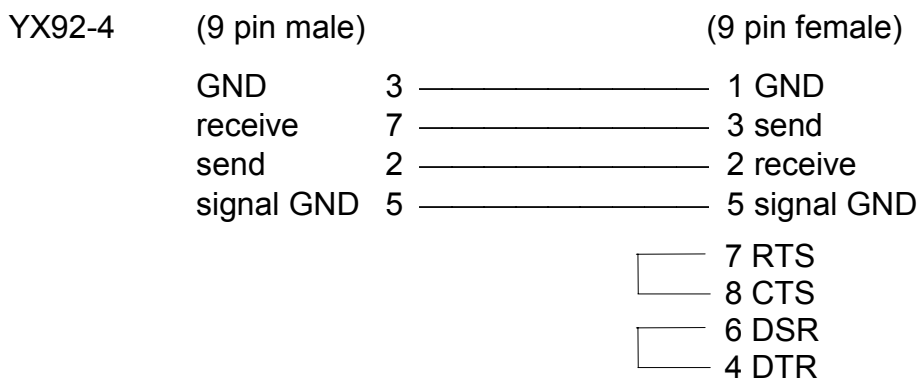
The default settings are as follows:

Baud rate	: 4800
Parity	: none
Data bits	: 8
Stop bits	: 2
Handshake	: XON/XOFF
Port	: COM1

Settings which have been changed using the HMI program XSWIN are saved before closing the program and loaded again when the program is started the next time.

c) **Serial link connecting cable between PC and XS92b**

ABB type	**XS92b end**			**PC end**
YX92-2	(9 pin male)			(25 pin female)
	GND	3	———	1 GND
	receive	7	———	2 send
	send	2	———	3 receive
	signal GND	5	———	7 signal GND
				4 RTS
				5 CTS
				6 DSR
				20 DTR



4.4.2.3. Installing the program

The program is delivered either on three 3½" floppies or a CD.

1. Start your PC and wait for Windows to load.
2. Insert the floppy disc 1 into drive A:\ or the CD into your CD drive (e.g. “E”).

WINDOWS 3.1 or 3.11:

1. Select the Program Manager and open the drive A:\ directory.
2. Select the file “setup.exe” and run it by opening the “Files” menu and selecting “Open”.
3. Follow the instructions displayed on the screen.

WINDOWS95 or NT:

1. Click on the “Start” button on the toolbar.
2. Select “Run…”.
3. Enter the drive and “setup.exe” in the dialogue that opens and click on “OK”.
4. Follow the instructions displayed on the screen.
5. If your CD drive is set to ‘Autorun’, the XSWIN start window will appear shortly after the CD is inserted. In this case, simply click on the “Install XSWIN” button.

4.4.2.4. General description of the program structure

The XSWIN program has 4 folders which contain the different XSWIN functions:

Test Mode

Manual testing
- Calculation using impedance values
- Calculation using U and I values
- Direct input of voltages and currents
- Direct input of 2 three-phase voltage systems

Test function library

Terminal

XS92 terminal function with a number of predefined command buttons

RS232C transfer

Setting of COM port and Baud rate

File and curve transfer between XS92 and the PC and saving or loading sets of XS92 parameters

User Manual

XS92b User Manual with advanced search support.

4.4.2.5. Starting the XSWIN program

(Start at step 3 if you wish first run the program in the demonstration mode first.)

1. Check that all the connections to the test set XS92b are correct.
2. Check that the COMx port of the PC is connected to the interface marked “Handheld terminal” on the test set by a cable type YX92-4.
3. To start the program, either click at the “XSWIN” pyramid symbol in the program manager window or select xswin.exe and then open the “Files” menu and select “Open”.

4. The logo appears first and you can choose one of the languages available and one of three possible operating modes: The “Standard mode” guides the user through all the operations, but especially the stetting procedure for the control parameters.
   The “**Advanced user mode**” permits the experienced user to set the control parameters quickly using test set codes.
   In the “**Demonstration mode**”, parameters can be set without the without the test set being connected to the PC.

5. After selecting the desired language and operating mode, click on the “Continue” button to open the “Test mode” folder. Should an error message appear next to the first folder, check the connection or click on “Cancel” and open the folder “3. RS232C/Tools” and correct the COM port settings. An “Auto detect” button is provided which enables the Baud rate set on the XS92b to be detected (see Section 4.4.2.8.).

4.4.2.6. “Test mode” settings

This folder contains all the settings required for the **manual test mode**.

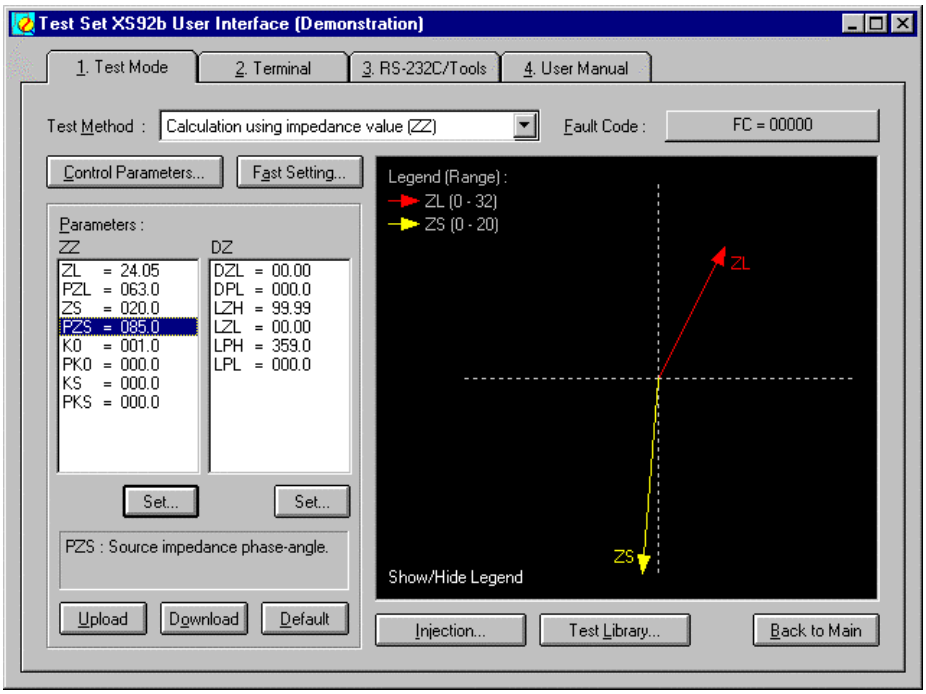


Fig. 4.3 “Test mode” window

The method of calculating the injected test signals is selected from the "**Test method**" list.

- Input of impedances (ZZ)
- Input of U, I and phase-angles (UI)
- Input of three-phase voltages and currents (UI3)
- Input of 2 three-phase voltage systems U1 and U2 (UU)

The methods of calculation are described in chapter 3 and in section 4.3.2. to 4.3.5. of the operating instructions.

A list of parameters and a diagram corresponding to the method of calculation chosen are then displayed. A parameter in the list is set by either:

- clicking on it and then on the "Set.." button
- clicking on it and then pressing the "Enter" key
- double-clicking on it

Whichever alternative is used, a dialogue is opened that permits the settings to be made either by entering the desired value at the keyboard or by using the mouse and the spin buttons.

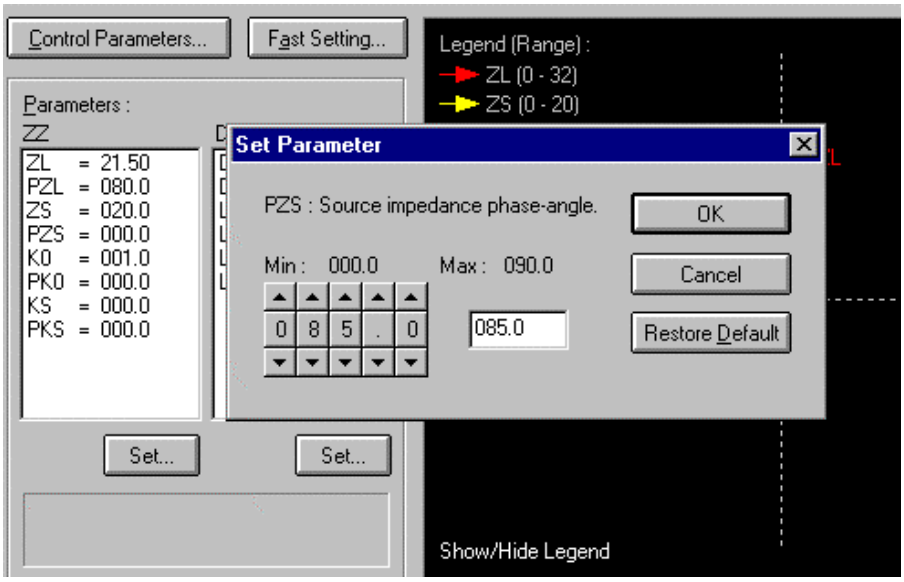


Fig. 4.4 Dialogue for entering parameter settings

The diagram shows the parameter's vector. The settings can also be made by dragging and rotating it. This is done by pointing to the tip of the vector with the mouse, pressing the left mouse button (the pointer changes to a hand) and dragging the tip of the vector to the position corresponding to the desired phase-angle and amplitude. While the vector is being moved, the respective values are displayed numerically at the bottom right next to the diagram. To change the colour of the vector, point to the corresponding arrow at the top left of the screen.

The "**Control parameters**" button enables all the parameters described in Section 4.3.1 to be set. Fig. 4.5 shows the dialogue for fault code (FC) control parameter.

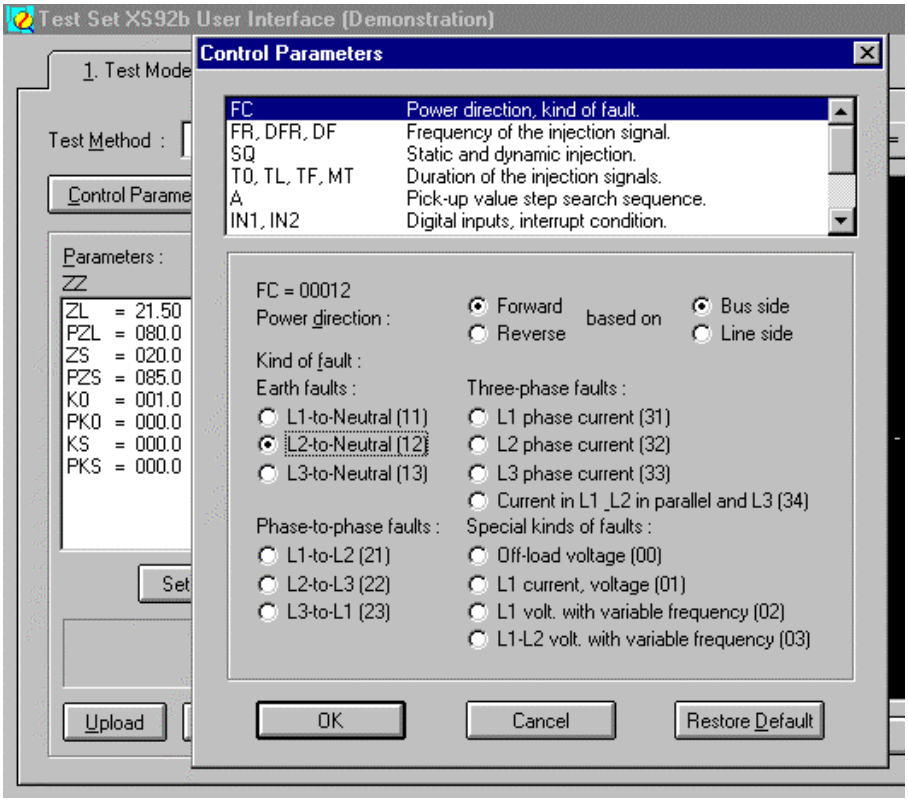


Fig. 4.5 Fault code control parameter

A "**Fast setting**.." button is proved which enables the most commonly needed parameters to be set during the test procedure. Fast access for setting the kind of fault is given by the "**Kind of fault:**" button at the top of the screen.

Click on the "**Test…**" button to start testing. A small dialogue with the buttons "Start", "Stop", "+" and "-" appears which is the same as for the terminal mode (see Fig. 4.6).

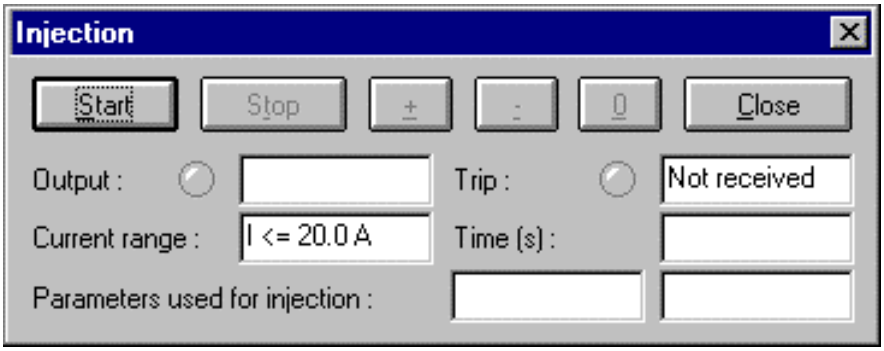


Fig. 4.6 "Injection" dialogue

Injection is started by clicking on the "Start" button which is indicated by the fact that the LED "Injection" lights green. The values are changed either manually or automatically in steps using the buttons "+", "-" and "0". When a trip signal is received (binary interrupt condition), the LED "Trip" lights red and the measured or recorded time is displayed in the text box "Time (s):". The parameter that was varied and its actual value appear in the tex box "Parameters used for injection:".

Injection is stopped by clicking on the "Stop" button. No entry can be made in the main window unless the "Stop" button has been operated.

A choice of **automatic testing programs** for creating new programs is accessed by clicking on the "**Test library**" button for the various protection functions (Fig. 4.7).

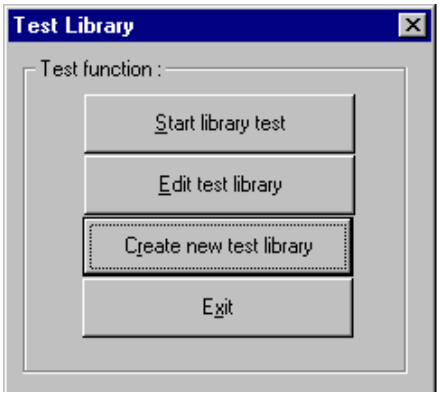


Fig. 4.7 Selection or creation of automatic testing programs

After clicking on the “Test library” button, the desired function, i.e. create a new program, edit and existing program or start an existing program, can be selected by clicking on either “Create new test library”, “Edit test library” or “Start library test”.

4.4.2.6.1. Create new test library

Clicking on the “Create new test library” button opens a dialogue for choosing the various test functions which can then be linked to form a test program (Fig. 4.8).

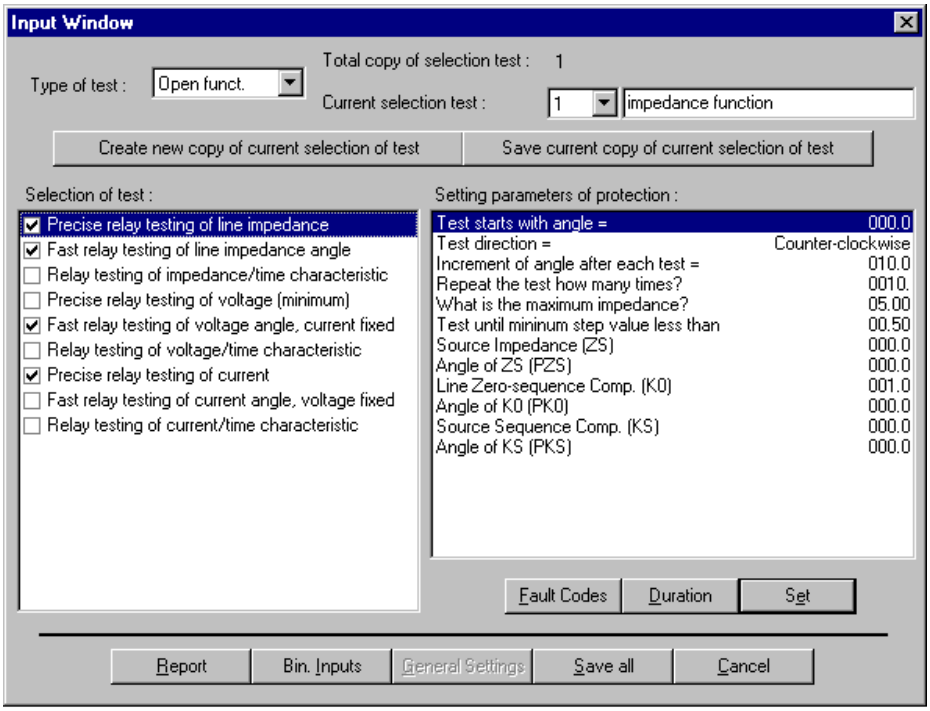


Fig. 4.8 Selecting test functions to be included in a test program

The test functions are selected in the list on the left that are linked sequentially to form a test program. The parameters for which entries have to be made for the test function that is selected on the left appear on the right.

One or several kinds of faults to be tested one after the other can be entered for each test function using the “**Fault codes**” button. The “**Duration**” determines how long the test signals are injected and applies for the kinds of faults that have been selected for the particular test function.

The binary inputs required for the interrupt condition can be selected after clicking on the “**Bin. inputs**” button.

The “**Report**” button opens a dialogue that enables the format of the test results to be selected (Fig. 4.9).

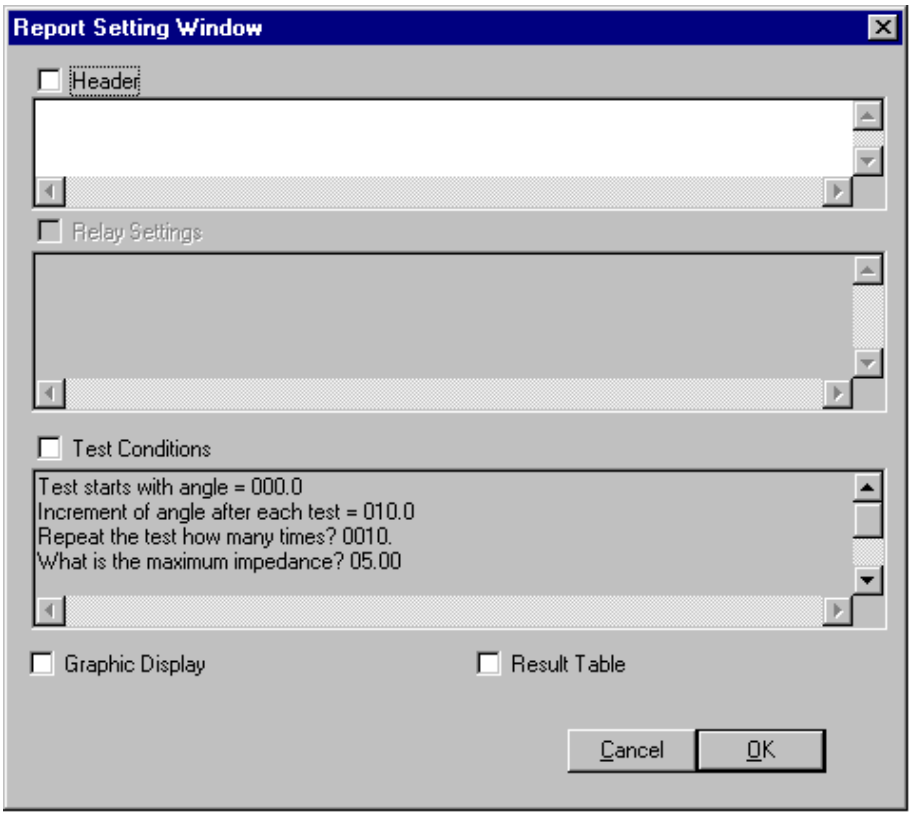


Fig. 4.9 Dialogue for setting the format of the test results

Provision is made for entering a suitable title in the “**Header**” text box that appears at the top of the test results for the particular test function.

A list of the parameters entered is given in the “**Test conditions**” box.

If “**Graphic display**” is checked, a simple diagram, e.g. an impedance plane, is plotted with the measuring points.

“**Result table**” prints a table of the results.

The various items are included in the report by checking the corresponding box.

In the case of a test program comprising several test functions, the individual reports are joined to form a single report.

Once all the required tests have been selected and all the parameters configured, it is saved as test “1” by clicking on the “Save current copy of current selection of test” button. A key word for the test can be entered in the text box next to the number.

Further tests can be added to the first group of tests by clicking on the “Crete new copy of current selection of test” button. The same dialogue as before is opened and one or several more tests can be selected in the same way, which upon being saved are added to the first group when they are saved.

This procedure enables test functions to be used several times. For example, to test the four impedance zones of a distance relay, four selections are made for the test function “Precise relay testing of line impedance” with the settings for the four zones.

The following test functions are available in the “Test library “:

- **Precise relay testing of line impedance**
  This program searches for impedance pick-up values in the impedance plane for different phase-angles by an iterative procedure which halves the impedance step several times.

  Data entered:
  - Test starts at angle = starting angle in the impedance plane
  - Test direction = Clockwise / Counter-clockwise
  - Increment of angle after each test = the angle between two measurements in the impedance plane
  - Repeat the test how many times ? How many angles have to be measured
  - What is the maximum impedance? The highest pick-up value to be expected in the range being tested
  - Test until minimum step value less than … The minimum iterative step which defines the accuracy of the test
  - The remaining inputs concern the source impedance and zero-sequence compensation factor for ground faults.

- **Fast relay testing of line impedance angle**
  A search is made for pick-up values on a straight impedance line defined by the starting and stopping impedances for “ZL” by varying the phase-angle. (This is used, for example, to record a directional characteristic.)

  Data entered:
  - Test starts with impedance = Starting point on the impedance line
  - Test direction = Forward / Backward
  - Increment of impedance after each test = Increment between 2 tests on the impedance straight line
  - Repeat the test how many times? How many impedances have to be measured
  - Start angle for the test = Angle at which the search for the pick-up point on the impedance straight line starts
  - Stop angle for the test = Angle at which the search for the pick-up point on the impedance straight line stops
  - How accurate (%) do you want the result to be?
  - The remaining inputs concern the source impedance and zero-sequence compensation factor for ground faults.

- **Relay testing of impedance/time characteristic**
  This program measures the operating times at specified intervals on a straight impedance line determined by the start and stop impedances "ZL". (This is used, for example, to record the time step characteristic of a distance relay.)

  Data entered:
  - Test starts with impedance = Starting point on the impedance line
  - Test direction = Forward / Backward
  - Increment of impedance after each test = Increment between 2 tests on the impedance straight line
  - Repeat the test how many times ? How many impedances have to be measured
  - What is the maximum time allowed? The maximum tripping time to be expected at the highest impedance
  - The remaining inputs concern the source impedance and zero-sequence compensation factor for ground faults.

- **Precise relay testing of voltage (at a fixed current)**
  This program searches for pick-up voltage iteratively by halving the voltage step a given number of times. Starting and stopping values and the number of measurements have to be entered.

  Data entered:
  - Test starts with angle = The angle between voltage and current at which measurement starts
  - Test direction = Clockwise / Counter-clockwise
  - Increment of angle after each test = Amount by which the angle is increased between 2 tests
  - Repeat the test how many times? How many voltages have to be measured
  - What is the maximum voltage? The maximum pick-up voltage to be expected
  - Test until minimum step value less than … The minimum iterative step which defines the accuracy of the test
  - At what current? The constant current at which the measurements will be made (this may be set to zero).

- **Fast relay testing of voltage angle (at a fixed current)**
  The pick-up voltage is found by changing the phase-angle with respect to the phase-angle of a reference current. Desired voltage and phase-angle ranges and the step change value have to be entered.

  Data entered:
  - Test starts with voltage = Voltage at which the measurement starts
  - Test direction = Forward / Backward
  - Increment of voltage after each test = Amount by which the voltage is increased between two measurements
  - Repeat the test how many times ? How many voltage values have to be measured
  - Each test starts with angle = Angle at which the search for the pick-up voltage on the impedance straight line starts
  - Stop angle for the test = Angle at which the search for the pick-up voltage on the impedance straight line stops
  - How accurate (%) do you want the result to be? The accuracy depends on the smallest measurement step
  - At what current? The constant current at which the measurements will be made (this may be set to zero).

- **Relay testing of voltage/time characteristic**
  This program measures operating times in a voltage range determined by the start voltage "U" and a given number of incremental voltage steps. (This is used, for example, to determine a voltage-dependent time characteristic.)

  Data entered:
  The data which has to be entered correspond to those for the impedance time characterisitic.

- **Precise relay testing of current (at a fixed voltage)**
  This program searches for pick-up current iteratively by halving the current step a given number of times. Starting and stopping values and the number of measurements have to be entered.

  Data entered:
  - Test starts with angle = The angle between voltage and current at which measurement starts
  - Test direction = Clockwise / Counter-clockwise
  - Increment of angle after each test = Amount by which the angle is increased between 2 tests
  - Repeat the test how many times? How many currents have to be measured
  - What is the maximum current? The maximum pick-up current to be expected
  - Test until minimum step value less than … The minimum iterative step which defines the accuracy of the test
  - At what voltage? The constant voltage at which the measurements will be made (this may also be set to zero).

- **Fast relay testing of current angle (at a fixed voltage)**
  The pick-up current is found by changing the phase-angle with respect to the phase-angle of a reference voltage. Desired current and phase-angle ranges and step change values have to be entered.

  Data entered:
  - Test starts with current = Current at which the measurement starts
  - Increment of current after each test = Amount by which the current is increased between two measurements
  - Repeat the test how many times ? How many current values have to be measured
  - Each test starts with angle = Angle at which the search for the pick-up current starts
  - Stop angle for the test = Angle at which the search for the pick-up curent stops
  - How accurate (%) do you want the result to be? The accuracy depends on the smallest measurement step
  - At what voltage? The constant voltage at which the measurements will be made (this may be set to zero).

- **Relay testing of current/time characteristic**
  This program measures operating times in a current range determined by the start current "I" and a given number of incremental current steps. (This is used, for example, to determine an IDMT characteristic.)

  Data entered:
  The data that have to be entered in this case are correspond essentially to those for the impedance/time characteristic.

Save Test

Once all the setting for all the parameter have been entered, the test program that has been created can be saved in any desired directory by clicking on this button.

4.4.2.6.2. Edit test library

This button provides facility for loading and editing an existing test program.

If you do not want to execute a test function that you have already entered, simply click on the check box on the left to cancel the selection. This does not change or delete the parameter settings that have been made. It is thus possible to omit certain tests and reinstate them again later.

A test program can be saved under its original name or under a new one.

4.4.2.6.3. Start library test

An existing test program is selected from a list and loaded ready to run. The test window is displayed on the screen (see Fig. 4.10).

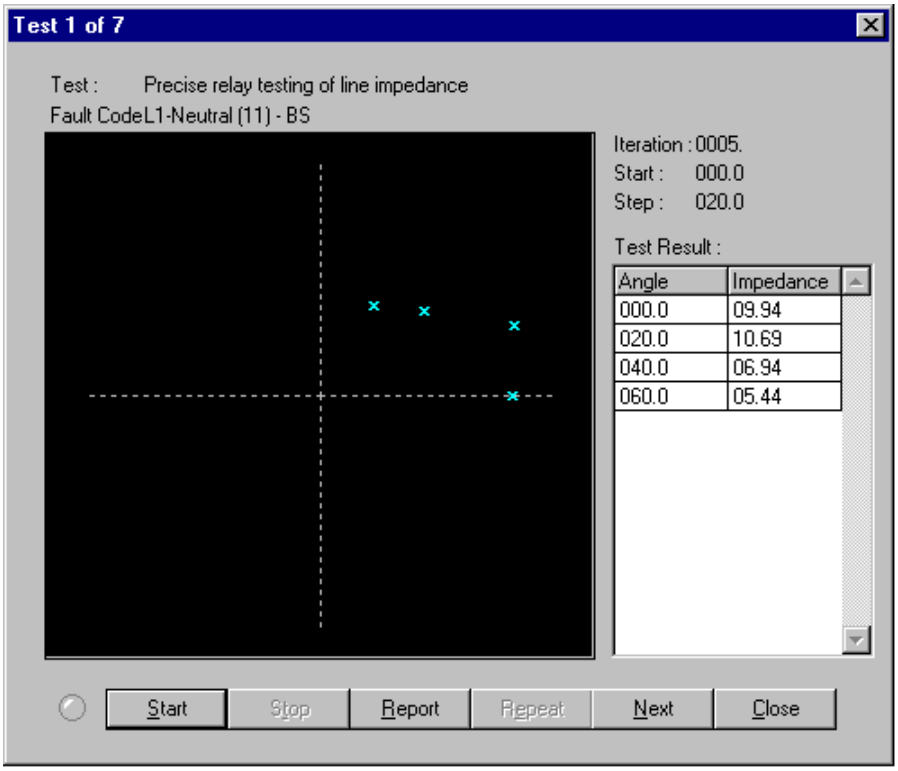


Fig. 4.10 Window displayed while testing is in progress

A diagram is displayed which for the most part shows the measuring points entered for the active test and next to it a table with the results.

Testing is started by clicking on the “**Start**” button, after which it runs automatically through all the test functions that have been selected. Testing can be interrupted by clicking on “**Stop**”. Clicking on “**Repeat**” then causes the last test function to the repeated, otherwise the program can be rerun from the beginning.

The “**Next**” button enables the next test function to be omitted either at the beginning of the program of after a stop.

“**Report**” displays the results of the entire test program or just the last test function. Other buttons that then appear permit the report to be printed by the printer connected to the PC or to be saved as a file in any desired directory.

4.4.2.7. Terminal folder

When "Terminal" folder is selected, the PC functions as a terminal connected to the test set XS92b.

In this mode, the parameter codes in the XS92b parameter list can be entered directly via the PC keyboard (see Section 4.3.).

Some buttons are provided for starting and stopping the test sequence and others are shortcuts for frequently used commands, generally those needed for editing programs.

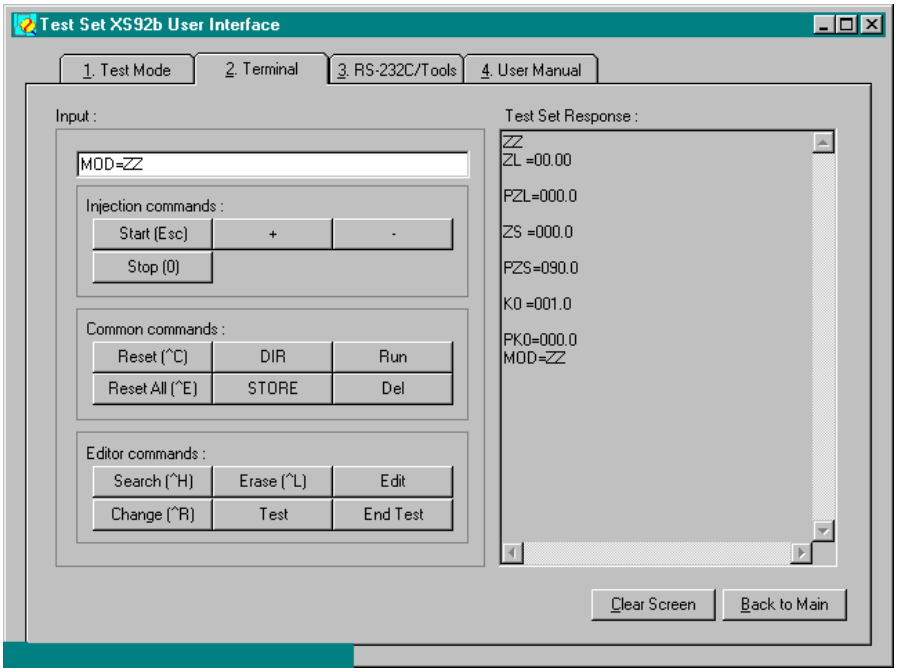


Fig. 4.11 Terminal simulation window

Data can only be entered when the cursor is in the text box below “Input”. It may be necessary to reset the XS92b using the “Reset [^C]”.

Data is entered basically as described in Section 4.4.3. Lines can be entered with the parameter code and its setting, or alternatively the parameters can be selected from a list and added to the window by clicking on “Enter” each time and adding the value.

On the left of the terminal simulation window there are 3 fields with buttons for doing the following:

Injection commands

Start (Esc)	Start of injection
+	One step up
-	One step down
Stop (0)	Discontinues injection.

Common commands

Reset (^C)	Resets the XS92b to the input mode.
DIR	Opens the program directory on the memory board YS92.
Run	Starts a test program (written in the XS92 programming language) after it has been loaded.
Reset All (^E)	Resets the XS92b completely.
STORE	Saves the test program as a file in the RAM on the memory board YS92.
Del	Deletes the data in the RAM or a file on the memory board YS92.

Editor commands (see Section 6.2.)

Search (^H)	Searches for a line with the same text.
Erase (^L)	Deletes the last line of the program.
Edit	Loads a program from the YS92 for editing.
Change (^R)	Changes the numerical value of a program line.
Test	Runs the program step-by-step.
End Test	Resets the test mode.

4.4.2.8. RS-323C/Tools folder

The COM port settings and Baud rate are set in this folder.

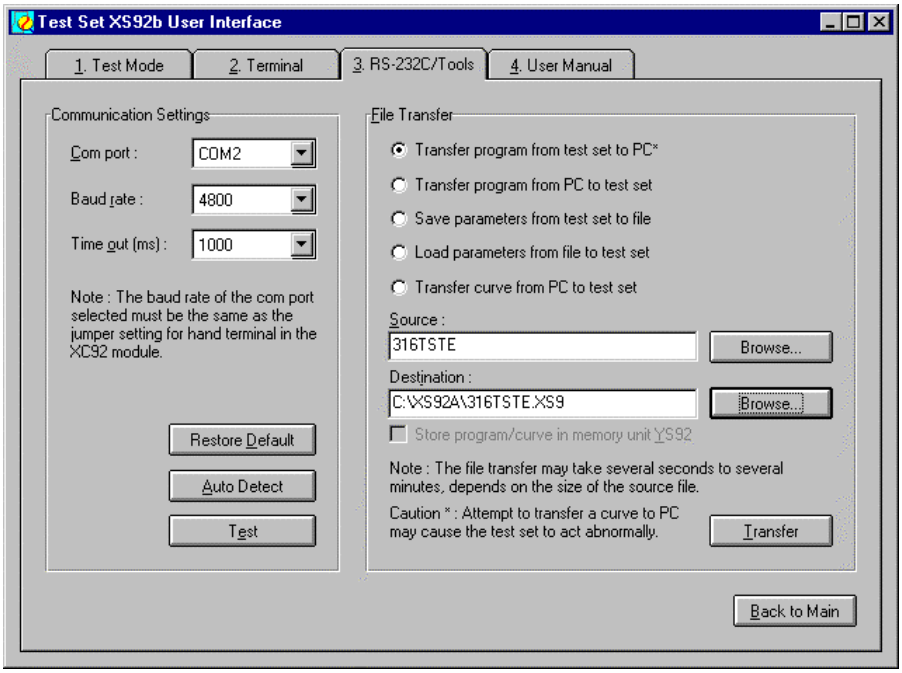


Fig. 4.12 Configuration of the serial interface und program transfer

The "**Test**" button is for checking the integrity of the communication with the XS92b and the "**Auto-detect**" button determines the Baud rate set on the XC92 module in the test set.

The kind of transfer function between the PC and the test set XS92b is selected in the "**File transfer**" box:

- Transfer program from test set to PC (application programs)
- Transfer program from PC to test set (application programs)
- Save parameters from test set to file (saves the test set setting to a file)
- Load parameters from file to test set (loads a set of parameters from a file)
- Transfer curve from PC to test set (computed control characteristic or characteristic obtained from fault recorder data).

1. **Transfer program from test set to PC**

   This function transfers application programs line-by-line from the test set to the PC.

2. **Transfer program from PC to test set**

   This function transfers application programs line-by-line from the PC to the test set. To store the application program on the memory board YS92, check the “Store program/curve in memory unit YS92” box.

3. **Save parameters from test set to file**

   This menu item transfers all the test set parameters to the PC. The function becomes necessary, if the parameters were not transferred when booting the system or a set of special parameters has to be saved for future use.

4. **Load parameters from file to test set**

   This menu item transfers test set parameters stored on a file in the PC to the test set. It enables the user to use his own set of default parameters.

5. **Transfer curve from PC to XS92b**

   "Curves" in this context signifies fault recorder files, which were converted to the XS92 format, or injection signal data (currents and voltages) calculated by some other program and formatted according to the rules in Section 9.1.2.3. with a corresponding header. This kind of data transfer and control of injection signals is only available from firmware Version 2.6 onwards. Use the checkbox below the “Destination” box to save the curve on the memory board YS92a.

The “**Browse**..” buttons are for selecting the source and target directories on the YS92 module and the PC according to the direction of transfer.
The transfer operation is started by clicking on the “**Transfer**” button.

4.4.3. Entering parameters in the terminal mode

The parameters can be divided into two main groups:

a) parameters for controlling the output control parameters (list FF)

b) parameters for determining the injection signals (lists ZZ, DZ, UI, DUI, UI3 and DU3).

- Parameters for entering impedances (ZZ)
- Step parameters and limits for entering impedances (DZ)
- Parameters for entering fault voltage and current (UI)
- Step parameters and limits for entering fault voltage and current (DUI)
- Parameters for directly entering injection voltages and currents (UI3)
- Step parameters when directly entering voltages and currents (DU3)
- Parameters for entering two three-phase voltage systems U1 and U2 (UU).

Fig. 4.13 shows the relationship between the ready status of the test set when "*XS92b ready*" is displayed on the handheld terminal in the terminal mode and the relationship between the lists up to the point when injection is initiated by pressing the 'START' key.

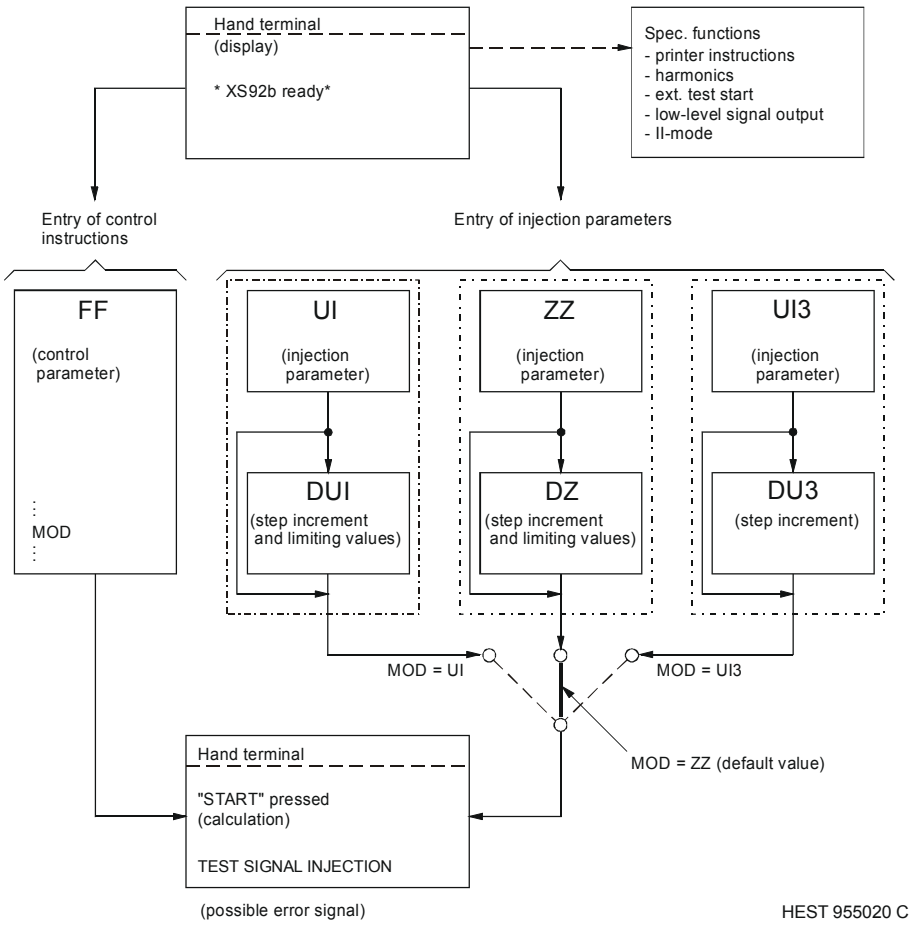


Fig. 4.13 Relationship between the parameter lists

The injection signals are defined by the control parameters in list FF and the injection parameters.

The manual control mode described above is activated by entering a parameter or list designation (see Section 4.3.) after "*XS92b ready*" appears. The following examples are written from top to bottom in sequence.

Example1: Defining a parameter using a list designation by entering the following:

Entry	Display	New memory contents	(Remarks)
UI 'ENTER'			(UI list)
	U = 000.0		
12.3 'ENTER'			
		U = 12.3	
	I = 00.00		
5 ’ENTER’			
		I = 05.00	
	PHI = 000.0		
35 'ENTER'		PHI = 035.0	
	U = 012.3		

Entering 12.3 'ENTER', 5 'ENTER' and 35 'ENTER' (parameter values) replaces the initial values (**default values** set when switching on, see Section 4.3.2.) for U, I and PHI.

Example2: Entering individual parameters in various lists with the parameter designator:

Entry	Display	New memory contents	(Remarks)
U = 45.6 'ENTER'			(UI list)
	U = 45.6	U = 45.6	
23.6 'ENTER'			
		U = 23.6	
	I = 00.00		
ZL = 12.3 'ENTER'			(ZZ list)
	ZL = 12.3	ZL = 12.3	
'ENTER'			
	PZL = 000.0		
DU = 0.1 'ENTER'			(DUI list)
	DU = 000.1	DU = 0.1	
FR = 60 'ENTER'			(FF list)
	FR = 60.00	FR = 60	
MOD = UI 'ENTER'			(FF list)
	MOD = UI	MOD = UI	

- Entering U = 45.6 'ENTER' (injection parameter) changed the initial value (0.0) and it was changed again by entering 23.6 'ENTER'.
- ZL = 12.3 'ENTER' jumps from the UI list to the ZZ list.

- 'ENTER' is pressed for the next parameter in the same list.
- A step increment was selected by entering DU = 0.1 'ENTER' (the limits of the step range may also be used).
- The frequency (control parameter) was changed to 60 Hz by the entry FR = 60 'ENTER'.
- The calculation takes the FF and UI lists into account when MOD = UI 'ENTER' (calculation mode) is entered.

If a variable injection signal is desired, the corresponding step increment parameter and possibly its upper and lower limits must be entered from the appropriate lists (list designations DZ, DUI and DU3). It should be noted that only one step increment can be effective at any one time. Thus where several are entered, only the last one is of consequence.

As can be seen from Example 2, entries may be made in different parameter lists. **Only one parameter list is taken into account, however, for the injection signal** and must be selected by the user using the parameter designator MOD (see parameter list FF).

Manual control is terminated by entering 'CTRL' and 'C' (^C) (see Section 6.4.7., List of control codes and instructions), after which "*XS92b ready*" appears on the display.

4.4.4. Injection signal output

The following are performed in sequence when the 'START' key is pressed:

a) The permissible limits of the parameters from list FF and the selected list are checked and an error signal is generated (see Section 10.1.6.), if a parameter is too high or too low. The sequence continues with b) and c), providing there is no error signal.

b) The value of the injection signal is calculated by the test set.

c) Injection commences.

4.4.5. Terminating the testing procedure

According to the control parameter from list FF, **injection** is either **automatically discontinued** when the relay under test trips or is **stopped by pressing '0'**.

The user has a choice of one of the following after testing has terminated:

- repeat the test with the same injection signals by pressing 'START'
- make new entries in the parameter lists by pressing 'ENTER'
- leave the manual control mode by pressing 'CTRL' and 'C', after which "*XS92b ready*" appears on the display.
- switch the test set off.

The influence of the control parameters on the injection signal is dealt with in Sections 5.1. to 5.7. (Functions of the various control parameters).

4.5. Examples of how the test set is controlled using the hand-held terminal YB92

The following is a practical introduction into how to operate the test set XS92b using the handheld terminal.

4.5.1. General

In the following examples, the symbols signify:

'E' 'ENTER' key

T one or a series of keys to be pressed, e.g.:
TYP = keys 'T' 'Y' 'P'

{ } upper line of the display
{ } lower line of the display.

* If the shift key is pressed and causes the red LED to light, the upper row of characters on the keys apply.

º If the shift key is pressed and causes the red LED to go out, the lower row of characters on the keys apply.

Since when using a PC only upper case characters are permissible and the CAPS LOCK must always be activated, the characters * and º do not change.

Note on the data input procedure

Upon entering a parameter value or code, the display moves on to the next parameter in a list. This also happens, when after the first entry, key 'E' is pressed repeatedly. The names and significance of the parameters are to be found in Section 4.3 of the Operating Instructions.

If an error has been made while entering data

Providing 'E' has not been pressed, the last character can be deleted using 'DEL'. Should {er 1 Syntax?} appear on the display, the correct value or code can be entered and the entry concluded by pressing 'E'.

4.5.2. Injecting a current

Example 1:

First remove the jumper between (I) and I and then connect an ammeter with a range of 2 A to the sockets "+I//" and "-I//" on AC93.

Input		Display	Remarks
Resetting the XS92b to its default values			
*'CTRL' and 'C'			Press both keys together!
DEL'E'		{DEL } {* XS92b ready * }	Enter the characters 'D', 'E' and 'L' and do not to press the 'DEL' key.
Start of data entry			
1.	MOD'E'	{MOD= ZZ } {_ }	MOD signifies the kind of calculation and injection.
2.	UI'E'	{MT =00001 } {_ }	UI is the code for injecting of current and voltage. MT is the next parameter, which is not changed.
3.	FC'E'	{FC =00000 } {_ }	FC is the code for the kind of fault and the phase(s) to be used for injection.
4.	^{o}1'E'	{SQ = 2 } {_ }	Since FC = 1 has been set, a voltage (U_R) and a current (I_R) can be injected.
5.	*I'E'	{I =00.00 } {_ }	Selects parameter I for the current.
6.	^{o}1.5'E'	{PHI=000.0 } {_ }	Sets the value to 1.5 A.
Checking the value entered for the current			
*I'E'		{I =01.50 } {_ }	The value which has bee set is displayed.
Starting injection			
7.	^{o}'START'	{Out: } {I =01.50 }	XS92b continuously injects the current and the ammeter reads 1.5 A (accuracy < ± 1 %).
Stopping injection			
8.	'0'	{Stop } {I =01.50 }	The injection current is switched off.

Steps 7 and 8 may be repeated several times.

Returning to the "ready" state

9.	'E'	{I =01.50 {_	} }	It is now possible to enter a new value and return to step 7 or enter a new parameter, e.g. U, as in step 5.

4.5.3. Injection and variation of a current in steps

Example 2a:

First remove the jumper between (I) and I and then connect an ammeter with a range of 2 A to the sockets "+I//" and "-I//" on AC93.

Input		Display		Remarks
Start of data entry				
1.	MOD'E'	{MOD= ZZ {_	} }	MOD signifies the kind of calculation and data output.
2.	UI'E'	{MT =00001 {_	} }	Injection of current and voltage. MT is the next parameter which is not changed.
3.	FC'E'	{FC =00000 {_	} }	FC is the code for power direction and kind of fault injected.
4.	º1'E'	{SQ = 2 {_	} }	Since FC = 1 has been set, a voltage (U_R) and a current (I_R) are injected.
5.	*I'E'	{I =00.00 {_	} }	Selects parameter I for the current.
6.	º1.5'E'	{PHI=000.0 {_	} }	Sets the value to 1.5 A.
7.	*DI'E'	{DI =00.00 {_	} }	DI is the value of the current decrement.
8.	º0.1'E'	{DPH=000.0 {_	} }	Sets the current step to 0.1 A.
Starting injection				
9.	º'START'	{Out: {I =01.50	} }	XS92b continuously injects the current and the ammeter reads 1.5 A.
Reducing the current				
10.	'-'	{DI =00.10 {I =01.40	} }	The values of the decrement and the new current are displayed.
Repeating step 10 five times				
		{DI =00.01 {I =00.90	} }	The current reaches 0.9 A.

Increasing the current

11.	'+'	{DI =00.01	}	The current increases again by 0.1 A
		{I =01.00	}	to 1 A.

The current can be increased or decreased as required using the '+' and '-' keys. Caution! Pay attention to the range of the ammeter.

Stopping injection

12.	'0'	{Stop	}	The injection current is switched off.
		{I =01.00	}	

Returning to the "ready" state

13.	'E'	{DPH=000.0	}	A new value may now be entered at
		{_	}	step 7.

Example 2b: Varying the current automatically

First follow Example 2a as far as step 13.

Input		Display		Remarks
Input of additional data				
14.	*A'E'	{A =00000 {_	} }	Selects the parameter for the automatic search sequence.
15.	1'E'	{IRA=00000 {_	} }	Sets A = 1.
Starting injection				
16.	'START'	{Out: {IRA=00000	} }	XS92b continuously injects the current and the ammeter reads 1 A.
Reducing the current				
17.	'-'	{DI =00.10 {I =00.00	} }	The current reduces quickly to 0 A in steps of 0.1 A.
Slowing down the rate of changing current steps				
The current changed too quickly so the rate of changing steps is slowed down as follows:				
18.	'0"E'	{IRA=0000 {_	} }	Discontinues the test and returns to the data input status.
19.	*TF'E'	{TF =0000 {_	} }	TF is the parameter for determining the duration of a step or of fault injection.
20.	°2000'E'	{IN1=00001 {_	} }	Sets TF to 2000 ms.
Starting the test again				
21.	'START'	{Out: {IN1=00001	} }	The initial current is now 0 A.
Increasing the current				
Caution!	Injection must be stopped by pressing the '0' key before the limit of the ammeter range is reached.			
22.	'+'	{DI =00.10 {I =	} }	The current increases by 0.1 A every 2 seconds.
Stopping the current variation				
23.	'0'	{DI =00.01 {I =01.00 e.g.	} }	The current remains at the value reached.

It is now possible to continue increasing the current by pressing '+' or decreasing it by pressing '-'.

Stopping injection

24.	'0''E'	{IN1=00001 {_	} }	The unit is now in the data input state once again.

Note: If parameter A has been set and the variation of injection stated, the '0' key must be pressed twice to switch off the injection current.

Stopping automatically

Connect the N/O contact of a pushbutton between the sockets "+" and "–o/o–" (tripping signal input) on the AC93 unit.

25.	*TI'E'	{TI =00002 {_	} }	TI is the parameter for determining the response of the tripping input.

The default value TI=2 is acceptable, proceed to 'START'.

26.	°'START'	Current injection commences.
27.	'-'	The current is reduced every 2 seconds.

Press the pushbutton after 3 steps; the current continues down to 0 A.

28.	'+'	The current starts to increase.

Press the pushbutton when the display reaches {I =01.00} again.

{dI =00.10 {I =01.10	} }	The last value is shown after the time TF,

and:
- the current is switched off,
- the green LED marked "TRIP" lights up on the handheld terminal.

Note: The test set will only respond to a trip for an increasing injection signal when A=1 is set, respectively for a decreasing injection signal when A=2 is set.

By entering the following after step 25:

°3 'E'	(TI=3)	The variation of the current would have ceased at step 28, but the current would not have been switched off.
°0 'E'	(TI=0)	The test set would not have responded when the pushbutton was pressed.

To gain more practice, the above example should be repeated for A = 2 and different values for I, DI, TI and TF.

4.5.4. Faults on a three-phase system with variation of fault voltage

Example 3:

Firstly connect an ammeter with a range of 2 A to the sockets "+I//" and "-I//" and a voltmeter (100 V range) to the sockets "UR" and "N" on AC93.

Connect the N/O contact of a pushbutton between the sockets "+" and "–o/o–" (tripping signal input) on the AC93 unit.

Simulation of an earth fault on R phase

Input	Display	Remarks
Resetting XS92b to its default values		
* 'CTRL' AND 'C'		Press both keys together!
DEL'E'	{DEL } {*XS92b ready* }	Enter the characters 'D', 'E' and 'L' and do not to press the 'DEL' key.
Start of data entry		
1. *MOD^{o}=*UI'E'		Select mode UI, i.e. calculation and injection of fault current and voltage.
2. *FC^{o}=11'E'		Fault code 11 for an E/F on R phase.
		FC = 12: S-N 13: T-N 21: R-S 22: S-T 23: T-R 33: R-S-T
3. *A^{o}=2'E'		Automatic variation of the voltage and response for decreasing values.

Note: The parameter and the value can be entered on one line, but pay attention to the "SHIFT" key!

Entering the fault values

4.	*UI'E'	{U =000.0 {_	} }	Selects list UI for the input of fault voltage and current.
5.	°40'E'	{I =00.00	}	Fault voltage: 40 V
6.	1.2'E'	{PHI=000.0	}	Fault current: 1.2 A
7.	90'E'	{U =040.0	}	Phase-angle U/I: 90°

Check the values by pressing the 'ENTER' key three times.

Note: The parameters can be specified by the corresponding list and entering the desired values. Parameters which are not required are omitted by pressing 'E'.

Entering the voltage step DU for the voltage decrement

8.	*DU°=.2'E'	{DU =000.2	}	The voltage step is 0.2 V.

Starting injection

9.	'START'	The injection quantities are:	
		fault voltage	UR = 40 V
		healthy voltage	US = 57.7 V
		healthy voltage	UT = 57.7 V
		fault current	IR = 1.2 A
10.	'-'	Decreasing fault voltage.	

Press the pushbutton before the fault voltage reaches zero; injection is interrupted and the injection quantities are switched off.

Returning "ready" state

11.	'E'	{DU =000.2 {_	} }

4.5.5. Faults on a three-phase system with variation of fault impedance

Example 4:

Firstly connect an ammeter (10 A range) to sockets "+I//" and "-I//" and a voltmeter (100 V range) to sockets "UR" and "N" on AC93. (A storage CRO may also be used, in which case the current is measured with the aid of a 0.1 Ω / 10 A shunt and with the trigger input connected to the BNC socket on the right-hand side of XS92b.)

Connect the N/O contact of a pushbutton between the sockets "+" and "-o/o-" (tripping signal input) on the AC93 unit.

Simulation of an earth fault on R phase

The test set simulates a radial feeder with a source impedance ZS and the fault impedance ZL.

Input	Display	Remarks
Resetting XS92b to its default values		
* 'CTRL' AND 'C'		Press both keys together!
DEL'E'	{DEL } {*XS92b ready* }	Enter the characters 'D', 'E' and 'L' and do not to press the 'DEL' key.
Start of data entry		
Since you have now had some practice in entering data, the procedure using the lists shall now be used. The first list is the one with the control parameters some of which have already been used. The parameters in the list which are not required in this instance will be explained, but then omitted using the 'E' key.		
1. FF'E'	{FR =50.00 }	Frequency (50 or 60 Hz)
2. º'E'	{DFR=00.00 }	Frequency step for fault codes 2 and 3 (see Section 5.1.2.)
3. 'E'	{DF=000.0 }	Frequency rate-of-change for fault codes 2 and 3 (see Section 5.1.2.)
4. 'E'	{FC=000000 }	Select the fault code, once again No. 11 for an E/F on R phase. Refer to Example 3 for other kinds of faults.

5.	11'E'	{SQ = 2	}	Test sequence (steady-state or dynamic) **Steady-state injection** 2 - continuous injection **Dynamic injection** 1 - off-load voltages 0 - zero injection F - fault injection (see Section 5.2.1.)

Defining a timing sequence for the injection of the fault quantities

The sequence specifies the durations and the order of injecting off-load voltages → fault injection → zero injection and for this reason 1F0 is entered.

6.	1*F^{o}0'E'	{A =00000	}	Automatic variation with response to decreasing injection signals.
7.	2'E'	{IRA=00000	}	Current range
8.	'E'	{TO =0100	}	Duration of zero injection SQ set, e.g. to 200 ms.
9.	200'E'	{TL =0100	}	Duration of off-load voltage injection set, e.g. to 500 ms.
10.	500'E'	{TF =000	}	Duration of fault injection (TF) set, e.g. to 250 ms.
11.	250'E'	{IN1 =00001	}	Response of the digital inputs.
12.	'E'	{IN2 =00000	}	Response of the optional inputs.
13.	'E'	{OU1=00001	}	Logical output OU1 activated.
14.	'E'	{OU2=00000	}	Option
15.	'E'	{TI =00002	}	Response upon tripping: 0 = none 1 = only time measurement for dynamic injection 2 = injection stops with time measurement for dynamic injection 3 = injection stops with time measurement for dynamic injection; injection does not stop for static injection Alternative 2 is selected.

16.	'E'	{TT =00000	}	Switches over to measure the reset time.
17.	'E'	{MOD= ZZ	}	The impedance mode has already been selected for calculation and injection.
18.	'E'	{MT = 1	}	MT is a multiplier for TF, which can be set to 1, 10 or 100.

A change is now made from the list of control parameters to list ZZ for entering the impedances. This change could have been made after step 11.

19.	*ZZ'E'	{ZL =00.00	}	Any desired fault impedance may be entered, e.g. 12.56 Ω/Ph.
20.	^{o}12.56'E'	{PZL=000.0	}	Sets the phase-angle of the fault impedance, e.g. to 75'.
21.	75'E'	{ZS =000.0	}	Sets the source impedance to 10.0 Ω/Ph. Caution! For low values of ZL + ZS the injection current exceeds 20 A.
22.	10'E'	{PZS=000.0	}	Sets the phase-angle of the source impedance, e.g. to 85'.
23.	85'E'	{KO =0.000	}	Sets the E/F factor of the line to 0.7.
24.	0.7'E'	{PKO=00.00	}	Leaves the phase-angle between fault impedance and zero sequence impedance at 0°.
25.	'E'	{KS =0.000	}	Sets the E/F factor of the source.
26.	'E'	{PKS=00.00	}	Phase-angle of KS

The value for DZL to vary the fault impedance now has to be enetered.

27.	*DZL^{o}=.2'E'	{DZL=00.20	}	step value of DZL = 0.2 Ω

Starting injection

28.	'Start'	Dynamic sequence injection: off-load voltages → fault injection (set duration 250 ms) → zero injection
29.	'-'	The injection sequence is repeated successively, reducing the fault impedance by 0.2 Ω each time.

Press the pushbutton before the fault impedance reaches zero; injection is interrupted and the injection signals are switched off.

The time from the start of injection up to the instant the pushbutton was pressed is displayed as "t = xxx".

Returning "ready" state

```
30.   '0"E'      {DZL =000.2      }
                 {_               }
```

Further tests can be carried out by restarting and then increasing or decreasing ZL using '+' or '-' etc. For other kinds of faults it is only necessary to enter a different value for parameter FC (steps 4 and 5).

Another possibility is to vary the phase-angle of the impedance by making an entry for DPL instead of varying the impedance with DZL (step 27).

After completing the above exercises, test personnel are able to test virtually any impedance (or distance) relay manually, it only being necessary to connect the relay’s tripping contact in place of the pushbutton and set the fault duration (TF) to suit to the zone being tested.