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ASEA BROWN BOVERI

modures®
Static Distance Relays
Types LZ91, LZ92, LZ92-1

Instructions for Installation and Operation

Baden/Switzerland

4th edition

CONTENTS

List of abreviations and symbols

I_R, I_S, I_T : phase currents

I_Σ : neutral current

I_B : load current

I_{Bmax} : max. load current possible

I_A : balancing current

I_N : rated current

I_K : fault current

U_R, U_S, U_T : phase-to-neutral voltages

$|k_o| e^{j\varphi k_o}$: ratio of zero to positive-sequence impedances (neutral current factor)

φ, φ_L : phase-angle of line

U_Δ : difference voltage (difference between fault voltage and replica impedance voltage)

U_Σ : sum voltage (sum of fault voltage and replica impedance voltage)

X_A, X_B : forwards resp. reverse replica reactances of the underimpedance starters of LZ92 or LZ92-1

X_L : reactance of line

Z_i : impedance of zone i

$Z_L = R_L + jX_L$: positive-sequence impedance of line

Z_{oL} : zero-sequence impedance of line

Index i : zone No.

Index p : primary values

Index s : secondary values

1. APPLICATION

The solid-state distance relays LZ91, LZ92 and LZ92-1 have been designed for high-speed discriminative protection applications, primarily in medium-voltage systems. They are equally suitable for cable and overhead line circuits and the power systems may be ungrounded, impedance or solidly grounded.

When protecting extremely short lines, the distance relays are already equipped with the logic to operate in a directional comparison scheme (permissive overreaching transfer tripping) with pilot wires. The corresponding pilot wire ancillaries have the type designations ER91 and NR91.

The relays are also prepared for operating in conjunction with an auto-reclosure relay (e.g. type WT91 for three-phase reclosure).

All the relays are of the switched type, having starting units (fault detectors) which apply the correct fault quantities to a single direction and distance determining measuring system. The starting units of the LZ91 operate on overcurrent, so that the relay is simpler and more economical, but can only be applied in systems in which the lowest fault current is clearly greater than the maximum load current. Both the LZ92 and the LZ92-1 are equipped with true underimpedance units (not just voltage-controlled overcurrent) and are thus capable of detecting weak faults at times of low generation with fault currents below the maximum load currents at peak periods.

A full description of their operation is contained in publication CH-ES 23-92.10E "Solid-state distance relays types LZ91, LZ92 and LZ92-1" and their technical data is given in data Sheet CH-ES 63-92.10 E.

2. MECHANICAL DESIGN

The various plug-in units which make up the relays are accommodated in standard 19" electronic equipment racks, and these in turn are either grouped together with other relays in cubicles, or fitted into casings for surface or semiflush switchpanel mounting. The corresponding dimensioned drawings are in the appendices to these instructions.

The plug-in units have a standard height of 3,5 U (U = 44.45 mm) and varying widths given as a number of divisions T (T = 17 mm). One 19" rack has space for plug-in units adding up to a maximum of 24 T.

The standard versions of the distance relays LZ91, LZ92 and LZ92-1 only require 20 T, which is less than one full rack.

The distance relays comprise the following plug-in units:

- input transformer unit type EW91, width 6 T, also containing signal conditioning circuits, measuring sockets and auxiliary tripping relay.
- main processing unit: KI91 for LZ91, KZ91 for LZ92 or KZ91-1 for LZ92-1. The terminals of the main processing units are compatible and they have the same width.

- signalling unit AV91 and/or AV94 (1 T).
- auxiliary supply unit NF92 (3 T), a DC/DC converter for generating the internal relay supply voltages.
- test socket connector XX91 (option) (3 T).
- auto-reclosure relay WT91 (option) (4 T).
- pilot wire units ER91 and NR91 (option) (4 T each).

These instructions apply to the basic versions of the distance relays, i.e. relays equipped with EW91 and either KI91, KZ91 or KZ91-1 and also an auxiliary supply unit.

There are two versions of the input transformer and main processing units available, which have resulted from further technical development and which are described in these instructions (see Section 3.12).

3. DETERMINING THE SETTINGS

All important settings on the distance relays LZ91, LZ92 and LZ92-1 are thumbwheel switches. The corresponding setting formulas are printed on the frontplate (see Figures 9.3 to 9.8).

In each case the setting in the correct dimensions is obtained by inserting the number indicated on the thumbwheel switches in the formula and working it out. The settings themselves (e.g. impedance of the underimpedance starting units) are printed in italics.

Settings which are normally only made once during commissioning are miniature switches located on the PCB's. Information relating to these settings is marked on the frontplate of the KI91, KZ91 respectively KZ91-1 behind the hinged flap of the equipment rack (Figures 9.3 to 9.8). A symbol shows on which PCB the particular functional switch is to be found. The PCB's in the units KI91, KZ91 respectively KZ91-1 are numbered from left to right seen from the front and as marked on the frontplate. (There is no PCB 3 in KI91.) Further information on this can be found in Section 3.9.

3.1 Selecting the operating mode

3.1.1 Distance relay LZ91

A choice can be made between two operating modes using miniature switch 1 on PCB 1 of unit KI91 (Fig. 9.21):

Mode ⅄ : for solidly grounded systems, i.e. earth faults have to be tripped.

Mode △ : for ungrounded or impedance grounded systems, but only with acyclical phase-preference for cross-country faults.

3.1.2 Distance relay LZ92

As with the distance relay LZ91, a choice can be made between the modes ⅄ and △ using miniature switch 1 on PCB 1 of unit KZ91. In this case, however, mode △ also permits cyclical (L0 in the code) as well as acyclical (L1 in the code) phase-preference for cross-country faults. This change is made by appropriately positioning soldered link LB7 on PCB 1 (see Fig. 9.22).

Standard phase-preferences are R before T before S (acyclically) respectively R before T, T before S, S before T (cyclically).

3.1.3 Distance relay LZ92-1

In solidly grounded systems in which it is essential that earth faults be tripped mode ⅄⏚ should be set.

In ungrounded or impedance grounded systems the same phase-preference must be set as is used in the rest of the system.

The operating mode is set on the main processing unit KZ91-1 with the aid of switch 1 (Fig. 9.23). This switch has four sections which have to be set in accordance with Table 3.1. The same information is printed on the frontplate behind the withdrawing handle (Fig. 9.8).

Switch section *				Mode	
No. 1	No. 2	No. 3	No. 4	Phase preference	Setting
OFF	ON	ON	OFF	grounded systems	⏚
OFF	OFF	ON	OFF	RTS acyclically	RTS acyc.
ON	ON	OFF	OFF	RTSR cyclically	RTSR cyc.
OFF	ON	OFF	OFF	TRS acyclically	TRS acyc.
ON	OFF	OFF	OFF	TRST cyclically	TRST cyc.
ON	OFF	ON	OFF	TSR acyclically	TSR acyc.
ON	ON	ON	ON	RST acyclically	RST acyc.
OFF	OFF	OFF	OFF	STR acyclically **	STR acyc.
OFF	OFF	OFF	ON	SRT acyclically **	SRT acyc.

* In position "ON" the white lever is toward the PCB.
** Only for units with the designation "AEND.:B" on PCB 1.

Table 3.1 - Positions of the switch sections of switch 1 on PCB 1 of unit KZ91-1 in relation to operating mode

3.2 Setting the starting units

3.2.1 Overcurrent starting

The pick-up setting of the overcurrent units must be at the very least so high that it cannot be reached by the maximum current in healthy phases. The following must be taken into account when calculating this current:

- In the case of double-circuit lines the load current can briefly double when one line is tripped.

- An additional balancing current I_A can flow in the healthy phases during earth faults.

A relay which has picked up must also be able to reset at the level of the maximum load current I_{Bmax} after a fault has been tripped in the first zone of another relay. Taking the reset ratio and accuracy of the relay into account, the lowest permissible setting is given by:

$$\left(\frac{I}{I_N}\right)_{min} \geq \frac{\left|\vec{I}_{Bmax} + \vec{I}_A\right|}{I_N \times 0.9} + 0.06$$

The maximum permissible setting $(I/I_N)_{max}$ is calculated from the minimum fault current I_K for a fault at the remote end of the next section of line.

Should $(I_K/I_N)_{min}$ be less than $(I/I_N)_{min}$ according to the above relationship, then a relay with underimpendance starting, e.g. LZ92 or LZ92-1, must be used instead of a distance relay LZ91.

When used in ungrounded or impedance grounded systems (mode △), the current measuring elements of unit KI91 are connected to R, T and E. The sensitivity of the neutral element in the standard versions is twice that of the phase elements (I_Σ/I_{Ph} = 0.5, I/.../ in the code of the KI91). If some other sensitivity is specified, it can be seen from the relay ordering code:

I/.../sensitivity factor

Should it be impossible to set the phase elements such that they pick up reliably at the lowest phase fault level, but do not pick up at the maximum earth fault current, then a distance relay LZ92 or LZ92-1 must be used.

3.2.2 Underimpedance starting

The following two frontplate (KZ91 or KZ91-1) settings apply to the underimpedance starting units:

- the pick-up of the neutral current element
- the reach of the underimpedance elements.

3.2.2.1 Neutral current earth fault detector

The criterion for the highest setting is:

- The earth fault detector must pick up for all earth faults in grounded systems, respectively all cross-country faults in ungrounded or impedance grounded systems which lie within the set reach of the underimpedance units.

The criterion for the lowest setting is:

- The earth fault detector may not pick up for an earth fault on a single conductor of an ungrounded or impdance grounded system.

- The earth fault detector may not pick up during heavy phase faults due to spurious neutral currents caused by c.t. errors.

A typically recommended value is I_Σ = 0.8 to 1.0 x I_N for LZ92 and LZ92-1 (standard version of the LZ91: I_Σ/I_N = 0.5).

If there is no setting which satisfies both these limits, a neutral voltage polarising ancillary must be added to operate in conjunction with the neutral current element:

- This is available as a separate voltage relay to be inserted into the equipment rack of the distance relay.

- Either an OR or an AND interlocking logic can be used (see parts of the ordering code headed EK1 or EK2 in the tables of features Table 9.17, Table 9.18 and also Fig. 9.25).

The LED signal labelled "E" will only light up when both the earth fault detector and at least one underimpedance phase element have picked up.

3.2.2.2 Reach of the underimpedance elements

Standard characteristic

The standard underimpedance starting characteristic is a circle with its centre at the origin of the impedance plane. The relationships for an earth fault R-0 are:

$$\vec{U}_{\Delta R} = \vec{U}_R - 2\, X_A e^{j90°}\, \vec{I}_R$$

$$\vec{U}_{\Sigma R} = \vec{U}_R + 2\, X_B e^{j90}\, \vec{I}_R$$

with $X_A = X_B$
X_A replica reactance in forward direction
X_B replica reactance in backward direction

Criterion for pick-up: $\vec{U}_{\Delta R} \perp \vec{U}_{\Sigma R}$, $\varphi \geq |90°|$

The reach for radial lines and the different kinds of faults is:

- phase-to-phase fault: same as setting
- three-phase fault : $\frac{2}{\sqrt{3}}$ x setting
- earth fault : $\frac{2}{1 + k_{oL}}$ x setting

  ($k_{oL} = K_o$ of the line)

ABB has a computer programme for checking the relay settings for all kinds of faults and fault locations where complex system conditions prevail.

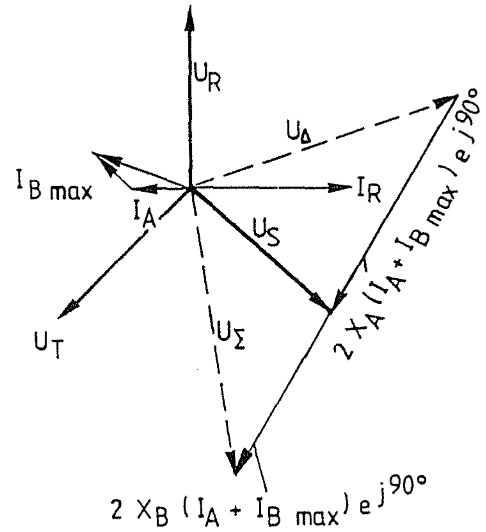
Minimum reach of the underimpedance starting elements

The starters must reliably pick up for a fault at the end of the next section of line (back-up zone). Where the back-up zone is not being taken specifically into account, the setting must be at least 1.3 times the impedance of the protected line. The influence of arc resistance must also be considered in the case of short lines.

Maximum reach of the underimpedance starting elements

- The considerable increase of load current which can occur on the healthy line when one line of a double circuit is tripped must be taken into account.

- Balancing currents I_A in the healthy phases during an earth fault must not cause their starters to pick up. The corresponding limit can be determined as follows:



RO earth fault; S starter

I_A : balancing current

I_{Bmax} : max. load current

$2X_A\ (I_A + I_{Bmax})\ e^{j90}$: replica voltage

$2X_B\ (I_A + I_{Bmax})\ e^{j90}$: (S phase)

criterion for pick-up: $\vec{U_\Delta} \perp \vec{U_\Sigma}$

$$\vec{U_\Delta} = \vec{U_S} - 2\,X_A e^{j90°}\,\vec{I_S}$$

$$\vec{U_\Sigma} = \vec{U_S} + 2\,X_B e^{j90°}\,\vec{I_S}$$

$$\frac{\vec{U_\Delta}}{\vec{U_\Sigma}} = \frac{\dfrac{\vec{U_S}}{2\vec{I_S}} - X_A e^{j90°}}{\dfrac{\vec{U_S}}{2\vec{I_S}} + X_B e^{j90°}} = \frac{\vec{A} - X_A e^{j90°}}{\vec{A} + X_B e^{j90°}} \qquad \text{with } \vec{A} = \frac{\vec{U_S}}{2\,\vec{I_S}}$$

Fig. 3.2 - Example for $X_A \neq X_B$

The limits can be expressed mathematically as follows:

- in grounded systems

$$Z = \frac{U}{2\,|(\vec{I_{Bmax}} + \vec{I_A})|} \quad \text{(Ohm/Phase)}$$

- in ungrounded or impedance grounded systems

$$Z = \frac{U_v}{2\ I_{Bmax} \times 1,25} \qquad \text{(Ohm/Phase)}$$

where

U lowest phase-to-neutral voltage of the healthy phases for an earth fault ($U = 0.85 \times$ min. rated voltage)

U_v lowest phase-to-phase rated voltage

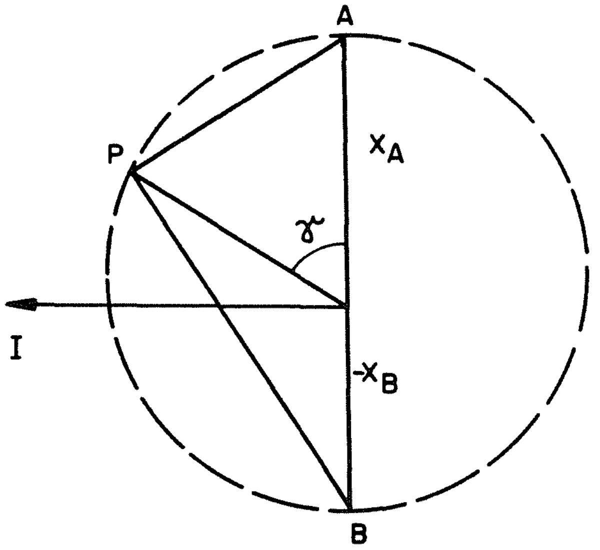
1.25 safety factor

3.2.2.3 Special underimpedance starting characteristics

If it is impossible to satisfactorily set the reach according to Section 3.2.2.2, then the following procedure should be tried.

The influence of the balancing currents must be carefully analysed. For examining the S phase equations for an R-0 earth fault see Section 3.2.2.2.

The relationship X_B/X_A may be changed and the forward reach and the backward reach become different. The origin of the circular characteristic is shifted in the X-direction.

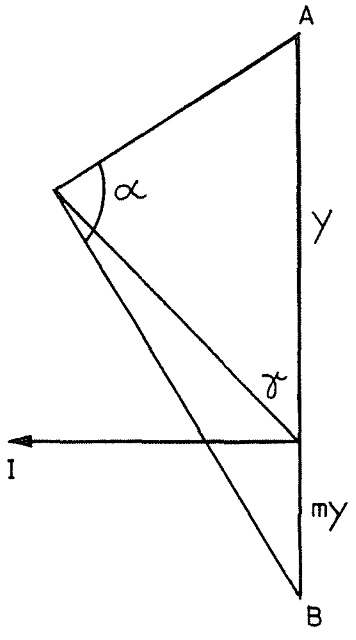


The diameter of circular loci of the pick-up point P is AB.

Fig. 3.3 - Circular underimpedance starting characteristic

The angle γ is depending on the network conditions. With the aid of computer calculations γ was found to be $\geq 30°$.

It is possible to change the angle α from 90° to 108°, in which case the characteristic is no longer a circle (see Fig. 3.4).



α = 90° or 108°
m = off-setting factor = X_B/X_A
y = permissible setting related to a concentric circle

Fig. 3.4 - Special characteristic

γ[°]	Settings		
	α[°]	m	Y
0...90	90	1	1
30	90	0,57	1,04
30	108	1	1,18
(90)	(108)	(1)	(1,38)
30	108	0,57	1,22

Table 3.5 - Permissible settings in relation to a circular characteristic

Such characteristics have a considerably extended reactive reach compared with a circle concentric to the origin. The equation for a solidly grounded system then becomes:

$$X_A = \frac{U \times Y}{2\,(|I_A| + |I_L|)\,n} \qquad (X_A > X_B)$$

where

$$n = \frac{1 + k_o}{2}$$ for starting (Z///.../ in the order number)

It is permissible to use the algebraic sum instead of the geometric sum ($\vec{I}_A + \vec{I}_L$), since it represents the worst case.

U = min. phase-to-neutral voltage = 0.85 U_{Bmin}
(0.85 x min. rated voltage)

The effective reach along the line is dependent on the characteristic angle of the line and the kind of fault (see Tables 3.6 to 3.8):

Line angle φ_L [°]	Characteristic			
	Circle $X_B = X_A$	Circle $X_B = 0.57\ X_A$	Lense $X_B = X_A$	Lense $X_B = 0.57\ X_A$
90	1	1	1	1
80	1	1	0.94	0.94
70	1	0.99	0.89	0.88
60	1	0.97	0.85	0.82
50	1	0.94	0.81	0.76
40	1	0.91	0.78	0.70
30	1	0.87	0.76	0.66
20	1	0.83	0.74	0.61
10	1	0.79	0.73	0.59
0	1	0.76	0.73	0.55

Lens: α = 108°

Table 3.6 - Relative reach in relation to characteristic and line angle for a phase-to-phase fault

Line angle φ_L [°]	Characteristic			
	Circle $X_B = X_A$	Circle $X_B = 0{,}57\ X_A$	Lense $X_B = X_A$	Lense $X_B = 0{,}57\ X_A$
90	1.15	1.11	0.98	0.95
80	1.15	1.08	0.94	0.88
70	1.15	1.04	0.89	0.82
60	1.15	1	0.88	0.76
50	1.15	0.94	0.85	0.72
40	1.15	0.92	0.84	0.67
30	1.15	0.87	0.84	0.64
20	1.15	0.83	0.83	0.61
10	1.15	0.79	0.85	0.59
0	1.15	0.75	0.88	0.58

Table 3.7 - Relative reach in relation to characteristic and line angle for a three-phase fault
(referred to the reach of a circle about the origin for a phase-to-phase fault)

Line angle φ_L [°]	Characteristic			
	Circle $X_B = X_A$	Circle $X_B = 0{,}57\ X_A$	Lense $X_B = X_A$	Lense $X_B = 0{,}57\ X_A$
90	1.15	1.11	0.98	0.95
80	1.15	1.08	1.0	0.94
70	1.15	1.06	1.0	0.93
60	1.15	1.04	1.03	0.93
50	1.15	1.02	1.05	0.95
40	1.15	1.01	1.08	0.97
30	1.15	1.0	1.11	0.98
20	1.15	1.0	1.12	1.0
10	1.15	1.0	1.16	1.02
0	1.15	1.0	1.21	1.05

Table 3.8 - Relative reach in relation to characteristic and line angle for a three-phase fault
(referred to the reach of the same characteristic for a phase-to-phase fault)

Reverse reach

The effective forwards (X_A) and reverse (X_B) reaches can be entered in the diagram of Fig. 3.2. The ratio X_B/X_A is set on PCB 3 by inserting the appropriate value for resistor Wi4 from 0.26 to 3.91 (Z./0.26/ to /Z.3.91/ in the ordering code, see Fig. 9.26).

Extreme forwards reaches

Values of X_B/X_A greater than 1 are of consequence when an extreme forwards reach is needed. This is achieved by reversing the primary current connections to the distance relay and then reversing the measuring direction of the distance unit (using switch 8b on PCB 8, order number HESG 439 686, respectively switch I $\rightleftarrows$ on the front of PCB 8, HESG 440 718). The forwards reach then corresponds to the frontplate setting multiplied by the set ratio X_B/X_A.

Lenticular characteristic (Z2/.. in the ordering code)

The pick-up criterion in the diagram of Fig. 3.2 is no longer determined by $\vec{U}_\Delta \perp \vec{U}_\Sigma$, but instead by $\measuredangle (\vec{U}_\Delta, \vec{U}_\Sigma) = 108°$. The change is made with the aid of the soldered link LB3 on PCB 3 (see Fig. 9.26).

Earth fault reach (Z.///.../ in the ordering code)

The reach for earth faults corresponds to the frontplate setting providing the k_o factor for the starting units matches that of the line ($k_{oA} = k_{oL}$). The starter k_o is set using resistor Wi5 on PCB 2 in KZ91 or KZ91-1 (see Fig. 9.25).

The above changes may be used singly or in conjunction with each other!

3.3 k_o factor for the distance measuring system

The compensation of the zero-sequence impedance is calculated from the positive-sequence impedance Z_L and zero-sequence impedance Z_{oL} of the line or cable.

$$|k_o| \, e^{j \varphi k_o} = \frac{1}{3} \cdot \frac{\vec{Z}_{oL} - \vec{Z}_L}{\vec{Z}_L}$$

This zero-sequence compensation factor k_o is set on the front of the EW91 (according to HESG 438 454) as follows:

EW91 code K.0: Only the magnitude of ($|k_o|$) is set.
This is generally all that is necessary in the case of overhead lines (thumbwheel switch φk_o set to zero).

EW91 code K.1: Both the magnitude ($|k_o|$) and phase-angle (φk_o) are set, which is of consequence above all in cable systems.

It is always possible to set the magnitude and phase-angle in the case of the input transformer unit according to HESG 440 754 (see Section 3.12).

The k_o factor only bears an influence on the distance measuring system.

3.4 Impedance settings of the various zones

3.4.1 Determining the reaches of the distance zones

In order to calculate the settings the fault impedances and the phase-angles of the sections of line to be protected must be known.

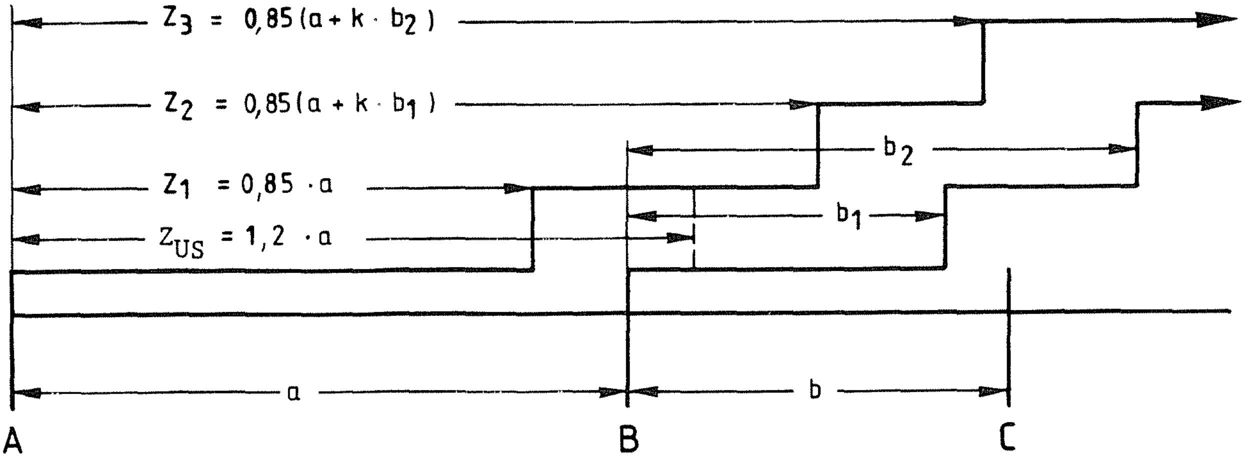


Fig. 3.9 - Reaches of the various distance zones

Z_1, Z_2, Z_3, Z_4	zone impedances
$k \geq 1$	infeed factor which takes into account an intermediate infeed and the consequential apparent increase in the impedance by the relay
a, b	corresponding line impedances
Z_{US}	overreach zone impedance $Z_{US} = 1.5\ Z_1$

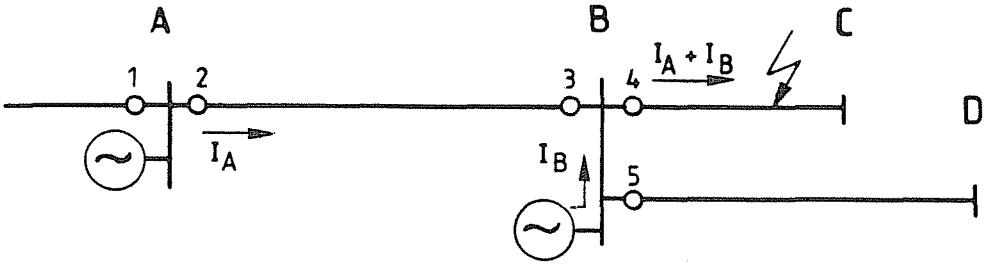


Fig. 3.10 - Exampel for the calcuation of k;
check the overreach for k > 1 in the event that the source
for B is out of operation:

$$k = \frac{I_A + I_B}{I_A} \geq 1$$

where

I_A	max. possible fault current
I_B	min. possible fault current
1 to 5	distance relays

3.4.2 Determining the settings m_i and N_i

Secondary line impedances

$$Z_{Ls} = \frac{Z_{Lp}}{\frac{r_U}{r_I}} = \frac{Z_{Lp}}{r_Z}$$

where

Z_{Lp} : primary line impedance
Z_{Ls} : secondary line impedance
r_U : main p.t. ratio
r_I : main c.t. ratio
r_Z : impedance ratio

The secondary resistance and reactance values are calculated in the same manner.

Calculating X_i

Before the values m_i and N_i can be set on the main processing unit it is necessary to calculate the reactances X_i. These are not exactly equal to the line reactances X_L (line impedance $Z_L = R_L + jX_L$), because of the inclination of the relay reactance characteristic by the angle α.

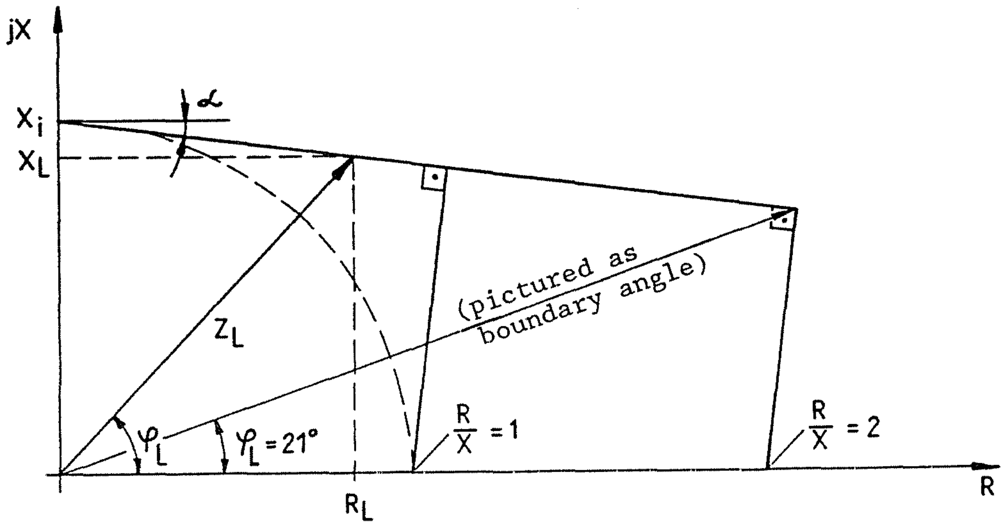


Fig. 3.11 - Line impedance Z_L entered in the relay characteristic

Thus to obtain the reactances X_i, the line reactances have to be corrected by the factor k_X:

$$X_i = X_{Li} \cdot k_X$$

The correction factor k_X is given by:

$$k_X = 1 + \frac{\tan \alpha}{\tan \varphi}$$

If the phase-angle φ_L is less than 40°, as can be the case in cable systems, there are two possibilities for grading as follows:

- grading in relation to X_L
- grading in relation to R_L

Grading with X_L:
If the setting R/X is greater than 1, e.g. R/X = 2 (see Fig. 3.11), then the factor k_X according to the table 3.12 is used.

Grading with R_L:
If the setting of the polygon is made in relation to the line resistance RL with the arch resistance compensation R/X = 1 (see Section 3.5), then R_{Li} is used instead of X_{Li} and k_R instead of k_X for grading (see Table 3.12).

Where for $\varphi_L < 40°$: $X_i = k_R \cdot R_{Li}$; with $k_R = 1 \tan\alpha \cdot \tan\varphi$

Line angle φL (°)	R/X = 1		R/X = 2
	k_X	k_R	k_X
0	-	1	-
5	-	0,992	-
10	-	0,985	-
15	-	0,977	-
20	-	0,968	-
21	-	0,966	1,228
25	-	0,959	1,188
30	-	0,95	1,152
35	-	0,939	1,125
40	1,104	0,927	1,104
45	1,087	-	1,087
50	1,073	-	1,073
55	1,061	-	1,061
60	1,05	-	1,05
65	1,041	-	1,041
70	1,032	-	1,032
75	1,023	-	1,023
80	1,015	-	1,015
85	1,008	-	1,008
90	1	-	1

Table 3.12 - Factors k_X and k_R in relation to φ (α= 5°)

Example:

System voltage	: U	= 60 kV
P.t. ratio	: K_U	= (60 kV / $\sqrt{3}$) / (110 V / $\sqrt{3}$) = 545.45
C.t. ratio	: K_I	= 200 A / 5 A = 40
Primary zone impedances	: Z_{Lp1}	= 4 Ohm, Z_{Lp2} = 6 Ohm, Z_{Lp3} = 8 Ohm
Phase-angle of line	: φ	= 60°
Relay ratings	: I_N	= 5 A, U_N = 110 V
Reactance line slope	: α	= 5°

Firstly the secondary reactances must be calculated from the primary values:

$$X_L = X_{Lp} \cdot x \frac{\ddot{u}_I}{\ddot{u}_U} \quad \text{and} \quad X_{Lp} = Z_{Lp} \text{ x } \sin \varphi$$

The line reactances for the three zones become:

X_{L1} = 0.254 Ohm, X_{L2} = 0.381 Ohm, X_{L3} = 0.508 Ohm

The correction factor k_X is:

$$k_X = 1 + \frac{\tan 5°}{\tan 60°} = 1.05$$

The zone reactances X_i can now be calculated:

$$X_i = X_{Li} \cdot k_X$$

$$X_1 = 0.267 \text{ Ohm}, \; X_2 = 0.4 \text{ Ohm}, \; X_3 = 0.533 \text{ Ohm}$$

Calculating the setting factors m_i and N_i

The factors m_i and N_i can be calculated from the following formula by inserting the reactances X_i and the relay ratings:

$$X_i = \frac{H}{I_N} \cdot m_i \cdot \frac{100}{N_i} \qquad (1)$$

where

H	factor depending on the rated voltage, H = 1 for U_N = 100 to 130 V H = 2 for U_N = 200 to 260 V (see ordering code U.. on the rating label)
I_N	relay rated current 1 A, 2 A, 5 A (see ordering code A.. on the rating label)
m_i	impedance measuring range (see Table 3.13)
N_i	"percentage" impedance setting for the distance zones
i	index denoting the distance zone, i = 1 for zone 1 etc.

The quotient H/I_N takes the relay ratings into account, so that the same setting formula can be used for all the relays.

The setting range m can be set individually for each of the zones on the frontplate of the KI91, KZ91 respectively KZ91-1 (see Table 3.13 and Figures 9.5 to 9.8).

Switch m_i setting	I	II	III
m_1	0.1	0.5	5
m_2 or m_3	0.1	1	10

Table 3.13 - Values of the factor m for zones 1 to 3 represented by the settings of switch m_i

The percentage N can also be set from 0 to 99 in steps of 1 individually for each zone. The reciprocal setting has the advantage of a fine setting for short zones.

The m setting should permit N to be set as accurately as possible, i.e. the value of N should be as high as possible. An N of 100 is therefore inserted initially in order to determine the best setting range m.

From (1) with N = 100:

$$m_i = \frac{X_i}{H/I_N}$$

The value of m obtained in this way is then rounded to the next smaller value as given in Table 3.13.

By inserting this value of m in equation (1) the actual N setting can now be obtained.

$$N_i = \frac{H}{I_N} \cdot \frac{m_i}{X_i} \cdot 100$$

Example:

$X_1 = 0.26$ Ohm $X_2 = 0.4$ Ohm $X_3 = 0.54$ Ohm

Ratings factor $H/I_N = 0.2$ with $H = 1$ for $U_N = 110$ V and $I_N = 5$ A

measuring range: $m_1 : \frac{0.26}{0.2} = 1.3$ rounded to $m_1 = 0.5$ (see Table 3.13)

$m_2 : \frac{0.4}{0.2} = 2$ rounded to $m_2 = 1$

$m3 : \frac{0.54}{0.2} = 2.7$ rounded to $m_3 = 1$

percentage settings: $N1 = 0.2 \cdot \frac{0.5}{0.26} \cdot 100 = 38$

$N2 = 0.2 \cdot \frac{1}{0.4} \cdot 100 = 50$

$N3 = 0.2 \cdot \frac{1}{0.54} \cdot 100 = 37$

Main processor unit settings:

thumbwheel switch m_1 = II
m_2 = II
m_3 = II

thumbwheel switch N_1 = 38
N_2 = 50
N_3 = 37

3.5 Arc resistance compensation

The ratio R/X can be set between 1 and 5 in steps of 1 on a control on the front of the main processing unit. The actual setting depends on the value of arc or earth resistance to be expected in relation to the reactance of the line.

Typical settings for overhead lines: R/X = 1, 2 or 3.

A setting of R/X = 1 is permissible in cable systems, since high arc resistance are not to be expected. Where the phase-angle of the positive-sequence impedance is less than 40° the ratio R/X is set to 1 and the R_L is used for grading the relays.

According to van C. Warrington arc resistance can be calculated from:

$$R_B = \frac{28700\ d}{I^{1.4}}$$

where

d length of the arc in m
I current in A
R_B arc resistance in ohms

In the impedance plane it can be seen that the influence of arc resistance varies with the kind of fault, because the unit is ohms per phase. A given fault resistance R_F in the R/X plane is as follows:

- earth fault : $R = R_F \ / \ (1 + |k_o|)$ (for overhead lines)
- phase-to-phase fault : $R = R_F \ / \ 2$

In grounded systems R_F will be greatest for an earth fault. For a given line impedance $Z_L = R_L + jX_L$ the required arc resistance compensation thus becomes:

$$R/X = \frac{R_L + R}{X_L}$$

3.6 Direction of measurement

The direction of measurement is determined by the position of switch 8b on PCB 8 of the main processing unit (up to order number HESG 439 686, see Section 3.12). From order number HESG 440 718 (PCB 8) provision is made for selecting the direction of measurement on the frontplate of the main processing unit with the control marked I $\rightleftarrows$ (see Figures 9.6 and 9.8). In either case there is no influence on the starting units.

With the switch in position I → and the relay connected according to the wiring diagram, i.e. with the neutral of the c.t's at the ends of the windings nearest the busbars, the relay measures into the line.

Where the relays LZ92 or LZ92-1 are being used with an off-set circular or lenticular starting characteristic, the reach of the starters must be checked and where necessary the c.t. connections reversed (see Section 5.3).

Depending on the main processing unit code (KI91, KZ91 or KZ91-1) in the ordering code, one zone can be arranged to measure in the reverse direction. This is done with switch respectively plug-in link 8a on PCB 8 (see Figures 9.30 and 9.31).

Code R0.:	no provision made for zone reversal (only main processing units with PCB 8 according to HESG 439 686)
Code R1.:	reversal of zone 1 selectable
Code R2.:	reversal of zone 2 selectable
Code R3.:	reversal of zone 3 selectable
Code R4.:	reversal of zone 4 selectable
Code R5.:	remote zone reversal control

From the above it follows that it is necessary to state which zone is to be reversed when ordering. However, should it be found during commissioning that a different zone than the one ordered should be reversed, then the change can be made with the soldered link LB9 on PCB 6 of the main processing unit KI91, KZ91 or KZ91-1 (see Fig. 9.28).

The PCB switch 8a (plug-in link 8a from order number HESG 440 718) on PCB 8 then determines whether all zones measure in the forwards direction (position 1), or whether the zone according to the ordering code (1, 2, 3 or 4) should measure in the reverse direction (position 2). This is not fitted in the case of code R0. and order number HESG 439 686 (PCB 8).

The directional sensitivity of the LZ91 and LZ92 is 100 mV (U_N = 100 to 130 V). The directional sensitivity of the cross-polarized LZ92-1 is unlimited for all earth and phase-to-phase faults; a memory feature provides the polarizing voltage to facilitate measurement of three-phase faults.

3.7 Zone 4

Normally the operating characteristic of zone 4 is that of the starting unit, which is permitted to trip on its own after the time t (code for KI91 and KZ91: E00, links LB11 and LB12 on PCB 7 soldered in).

Provision is made for using the X or R limits of zone 3 as blinders for zone 4 (code E $\neq$ 0), which is achieved by removing the corresponding soldered link on PCB 7 (X blinder with LB11 removed and R blinder with LB12 removed).

Switch 7 on PCB 7 (Fig. 9.29) enables zone 4 to operate either directionally (position 1) or non-directionally (position 2). Non-directional operation means that the whole of the starting characteristic is used for zone 4, compared with directional operation with the starting characteristic cut off by the directional measurement so that tripping can only take place in the forwards direction.

3.8 Time step characteristic

The operating times of zone 2 and higher include the basic operating time of the relay without any intentional delay plus the corresponding set time delay.

No provision is made for delaying zone 1 in the main processing units PCB 8 acc. to HESG 439 686 (Section 3.12). If it is desired to delay zone 1 in this case, then the normal zone 1 can be blocked with PCB switch 6a so that zone 2 becomes zone 1 with an operating time t2 etc., the relay having a total of three zones.

Zone 1 can be delayed separately in the case of main processing units with PCB 8 acc. to HESG 440 718 (Section 3.12) between 0 and 15 x T_N (T_N = period of rated system frequency). The desired time is set using soldered link LB18 on the soldered side of PCB 8 (see Fig. 9.32).

The delays of the zones 2 and 4 are set digitally on thumbwheel switches in the following ranges:

2nd. time step:	0 to 0.99 s in steps of 0.01 s
3rd. time step:	0 to 0.99 s in steps of 0.01 s and
	0 to 9.9 s in steps of 0.1 s
4th time step:	0 to 9.9 s in steps of 0.1 s

The alternative setting ranges for the 2nd. time step are determined by selecting the factor k_t with PCB switch 6b (see Fig. 9.28).

The minimum grading time between different LZ91 respectively LZ92 relays should not be less than the sum of the circuit-breaker operating time plus 150 ms. The 150 ms are the sum of relay operating time + relay reset time + a safety margin.

3.9 Symbols and significance of the switches on the main processing unit

The legend below the white line on the frontplate of the KI91, KZ91 or KZ91-1 (see Figures 9.5 to 9.8), which is behind the hinged lower flap when the unit is in the rack, shows the symbols, the number of the PCB's and the locations of the PCB switches. The numbers 1 to 8 (from left to right) refer to the PCB's, below which can be found the symbols corresponding to the switch positions and an indication of the switch location on the PCB.

For example, the designation 6a refers to the first switch from the frontplate towards the rear on PCB 6. Just so 6b is the second switch from the front on PCB 6. The locations of the switches can also be seen from the PCB drawings in the appendicies.

The symbols and functions of the switches are as follows:

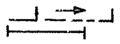
switch 1	position 1	⅄	for grounded systems
	position 2	△	for non-grounded systems
switch 6a	position 1	$\cancel{t}_1$	zone 1 blocked
	position 2	t_1	zone 1 in operation

switch 6b	position 1	$k_t = 0.1$	multiplier for the 3rd. time step
	position 2	$k_t = 1$	multiplier for the 3rd. time step
switch 7	position 1	t_4 →	zone 4 directional
	position 2	t_4 ↔	zone 4 non-directional

PCB 8 according to HESG 439 686 (see Section 3.12)

switch 8a	position 1	8b	direction has indicated on 8b
	position 2	t ⮌	direction as indicated on 8b, but one zone reversed (see Section 3.6). Switch 8a is not fitted in all versions.
switch 8b	position 1	I ←	reverse direction
	position 2	I →	forwards direction, if relay connected as in our diagram.

PCB 8 according to HESG 440 718 (see Section 3.12)

plug-in link 8a	position 1	I ⇄	direction as set on I ⇄ on the front-plate
	position 2	t ⮌	direction as set on I ⇄ on the front-plate, but one zone reversed.
plug-in link 8b	position 1		overreaching (intertripping scheme, see Section 3.10)
	position 2	PUTT	permissive underreaching transfer tripping (where fitted).

3.10 Main processing unit equipped for intertripping schemes

Main processing units with PCB 8 acc. to HESG 440 718 (see Section 3.12) are equipped as standard with the auxiliary components for operating in intertripping schemes. On these units either an acceleration scheme (zone extension) or permissive underreaching transfer tripping can be selected using plug-in link 8b on PCB 8 (see Fig. 9.31). In the case of an acceleration scheme a signal from the opposite station causes the receiving relay to switch to overreaching, whilst in the permissive underreaching scheme the relays have a normal underreaching setting and the receiving relay trips, providing a starting unit has picked up. In special cases the PUTT scheme can also include the directional measurement of the receiving relay (soldered link LB20, see Fig. 9.32).

3.11 Frontplate signals

Depending on the ordering code of main processing units with PCB 8 acc. to HESG 439 686, the frontplate signals are either in operation (code FA1) or are suppressed (code FA2).

In the case of main processing units with PCB 8 acc. to HESG 440 718 (see Section 3.12) and code FA1 a further choice can be made using soldered link LB19 on PCB 8 (see Fig. 9.32) between:

- LED indication of all faults maintained until reset (LB19 open)
- LED indication of all faults, but only maintained if the relay itself trips (LB19 closed).

3.12 Versions of the input transformer and main processing units

There are several versions of the units EW91, KI91, KZ91 and KZ91-1, which can be recognised in the first place from the different arrangements of their frontplates (compare Figure 9.3 with 9.4 and Figures 9.1 and 9.2 with Figures 9.5 to 9.8). The differences concern essentially PCB 1 of the input transformer unit EW91 and PCB 8 of the main processing unit. The units and PCB's can, of course, be distinguished by their part numbers on their rating plates.

The part numbers of the earlier versions are:

input trasformer unit EW91	HESG 438 454 R1 to R16
PCB 1 of EW91	HESG 438 048 (see Fig. 9.19)
input transformer unit EW91	HESG 440 754 R1 to R8
PCB 1 of EW91	HESG 440 752 (see Fig. 9.20)
main processing unit KI91	HESG 440 079 R1 to R4
main processing unit KZ91	HESG 440 080 R1 to R4
main processing unit KZ91-1	HESG 440 342 R1, R2
PCB 8 in the main processing unit	HESG 439 686 (see Fig 9.30)

The part numbers of today's versions are:

input transformer unit EW91a	HESG 441 721 R1 to R8
PCB 1 of EW91a	HESG 441 585 (see Fig. 9.20)
main processing unit KI91	HESG 440 079 R11 to R14
main processing unit KZ91	HESG 440 080 R11 to R14, R22
main processing unit KZ91-1	HESG 440 342 R11 to R14, R22
PCB 8 in the main processing unit	HESG 440 718 (see Fig 9.31)

Since these instructions refer to all versions, the part number is always stated in order to distinguish the units. The PCB-drawings necessary for the settings may be found in the appendices.

4. CHECKING THE SHIPMENT

Unpacking, visual inspection

Should the shipment be found to be damaged upon receipt, a claim must be lodged immediately in writing with the last carrier and the facts notified to ABB Relays AG, Department ESA-R, CH-5401 Baden.

Checking the equipment ratings

- Check that the relay rated current agrees with the c.t. secondary rated current.
- Check that the relay rated voltage agrees with the p.t. secondary rated voltage.
- Check that the rated frequency of every unit is the same as the local system frequency.
- Check that the ordering code of each unit (given on the rating plate) agrees with the one given in the order (see Table of Versions and Ordering Codes in the appendices).

5. INSTALLATION AND WIRING

5.1 Relay location and ambient conditions

Since every piece of technical equipment can be damaged or destroyed by inadmissible ambient conditions,

- the relay location should not be exposed to excessive air pollution (dust, aggressive substances)

- severe vibration, extreme changes of temperature, high levels of humidity, surge voltages of high amplitude and short rise time and powerful magnetic fields should be avoided as far as possible.

In any event it is essential for the limits and ranges given in the section "General Data" of the corresponding Data Sheet to be observed.

5.2 Checking the wiring

- Check that the relay has been wired in strict accordance with the corresponding wiring diagram (see appendicies).

- Check that the phase references of c.t. and p.t. connections correspond.

- Check that the ratings of c.t's, p.t's and auxiliary supply agree with the those of the relay (EW91, DC/DC converter and optp-coupler unit).

- Check that the same phase is used as R phase in all the stations.

- Check that the phase-sequence is correctly R-S-T.

5.3 C.t. connections

Generally the c.t's are wound in the sense and have the terminal designations shown in Fig. 5.1. With the normal arrangement of K connected towards the busbar and L towards the line, the secondary terminals k and l are connected in strict accordance with the wiring diagram. Should the primary of a winding be connected in the reverse sense, i.e. L towards the busbar and K towards the line, the secondary connections to the terminals k and l must also be reversed.

Should there be any doubt as to the sense of any of the windings, the following method can be used to determine the polarity of the secondaries. Terminals K and L are connected to a d.c. source of about 4 V and k and l to a polarized voltmeter as shown in Fig. 5.1. The polarity is correct, if there is a positive deflection when the switch S is closed.

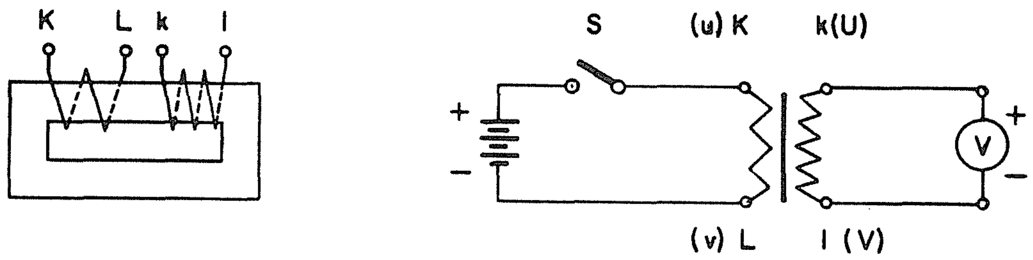


Fig. 5.1 - Instrument transformer terminals and polarity check
(U, u, V and v apply to p.t's)

If the star-point of the c.t. windings is not on the busbar end of the windings as shown in the wiring diagram, provision is made on the relay for reversing the direction of measurement with the switch I ⇄ (switch 8b respectively frontplate switch). The position of this switch has no influence on the starting units (see Section 3.6).

It is particularly important for the connections and c.t. circuit shorting links of the input transformer unit EW91 with part number HESG 438 454 (see Section 3.12) to be carefully checked. The terminals must be connected in accordance with the rated current as follows:

I_N = 1 A	A1(R), A4(S), A7(T)
I_N = 5 A	A2(R), A5(S), A8(T)
common	A3(R), A6(S), A9(T)

Input transformer units with the part number HESG 440 754 resp. HESG 441 721 only have terminals for the rated current as ordered.

5.4 P.t. connections

Should there be doubt as to the sense of the p.t. windings, then their polarity can be ascertained in the same manner as for c.t's. In this case, however, the battery is connected to the secondaries (see terminal references in brackets in Fig. 5.1). Caution! First switch the voltmeter to a high voltage range. All the phases of three-phase p.t's must be tested. For each relay the p.t's must be fused at a rating of 10 A.

The secondary circuits of both c.t's and p.t's should be grounded at only one point.

5.5 Auxiliary supply

Check that the polarity of the auxiliary d.c. is correct. The auxiliary d.c. supply must remain within the permissible range of variation of the DC/DC converter supplied with the relay under all operating conditions (see technical data of the DC/DC converter).

5.6 Loading of tripping and signalling contacts

Check the section "Contact Data" of the corresponding Data Sheet to ensure that the ratings of the contacts are adequate for the duty.

5.7 Opto-coupler inputs

Check the voltage against the order code and the polarity of all opto-coupler inputs (opto-coupler unit: M115, inputs A12 and B12 of the input transformer unit EW91 and any other opto-couplers in interfacing units). If the opto-coupler input of the EW91 is used to block the relay by an auxiliary N/O contact of an m.c.b. in the p.t. circuit (auxiliary contact closed when the main contacts are closed), the link W61 must be changed to output Q (see Figures 9.19 respectively 9.20).

6. COMMISSIONING

6.1 Checking the settings prior to commissioning

Before commissioning the relay, that is before the protected unit is energised, it is necessary to:

- perform all the checks according to Sections 4 to 5.7
- set the relay as described in Section 3.

6.2 Inserting the relay and switching on the auxiliary supply

> It is only permissible to insert or withdraw the plug-in units with the auxiliary supply switched off!

Care must be taken that each plug-in unit is inserted in its designated position in the equipment rack. Insert the respective unit carefully with the withdrawing handle horizontal until resistance is felt. Now raise the withdrawing handle, which acts as a lever to complete the insertion of the relay, to the vertical position and push it fully home ensuring that it latches securely. A unit is correctly inserted, if the hinged flaps at the front top and bottom edges of the rack can be lowered, respectively raised, without difficulty.

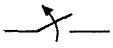
It is only permissible to switch on the auxiliary supply after all the units have been inserted.

6.3 Test points on the unit EW91

The most important signals are available for measurement at ten respectively twelve sockets (see Section 3.12) on the front of the input transformer unit EW91. These signal outputs are short-circuit-proof, but on no account should they be used for injecting singals. The inner diameter of the sockets is 2 mm and a normal multi-meter may be used for measurement, providing its internal resistance on the range being used is greater than 1 MOhm.

The following signals and quantities are available at the sockets:

0	Common zero for measuring the voltages at all the other sockets (clean supply 0 V).
B1	Blocking signal. The normal voltage at this socket is 10 V, but when the relay is blocked by either the auxiliary supply monitoring circuit or an external blocking signal the voltage falls to ≤ +2 V.
-o/o-	Tripping signal. This socket is at +10 V whilst the relay is emitting a tripping signal to the circuit-breaker. The signal is tapped off just before the auxiliary tripping relay and thus appears 2 to 5 ms before the tripping contact actually closes.

I_R, I_S, I_T	Voltages proportional to the phase currents taken from across the replica impedances are available at these three sockets (see Section 6.4 for details).
U_R, U_S, U_T	Phase voltages. The voltages are taken from behind the input transformers (see Section 6.4 for details).
k_o, I	Zero-sequence compensation. A voltage U_M can be measured at this socket which is proportional to the product of the neutral current I_Σ and the compensating factor $\vert k_o \vert$. The relationship is: U_M (V) = 0.125 x $\dfrac{\vert k_o \vert \times I_\Sigma \text{ (A)}}{I_N \text{ (A)}}$
⚠ 	Input transformer units with the part number HESG 440 754 resp. HESG 441 721 have these two sockets in addition. Caution! The circuit breaker can be tripped by connecting these sockets and pressing one of the starter test buttons. This procedure energizes the auxiliary tripping relay in the EW91 without the distance relay having to measure, providing terminal E11 of the EW91 is connected to terminal E63 of the main processing unit (with PCB 8 according to HESG 440 718).

6.4 Checking load voltages and currents

Load voltages and currents can be measured at the sockets on the front of the unit EW91 as follows:

- First switch on the auxiliary d.c. supply.
- The phase-to-neutral voltages are reduced by a factor of 15 for rated voltages between 100 and 130 V (code U1) and a factor of 30 for rated voltages between 200 and 260 V (code U2).
- The load currents are converted into proportional voltages according to the relationship 0.125 x I/I_N (V).
- The neutral current should be approximately zero under load conditions.
- The phase sequence of the voltages and currents can also be checked using an oscilloscope.
  The voltage proportional to the current of a particular phase lags the phase voltage by approx. 90° if an ohmic load current flows towards the protected line and the relay is conected according to Fig. 9.9.

Note: The replica voltages can contain more harmonics than the primary currents due to the physical properties of the replica impedances, but this has no influence on the operation of the relay.

6.5 Testing the distance relay using the test buttons

- In order to test the relay using the test buttons, load voltages must be applied and a load current in excess of 0.2 x I_N must be flowing.
- Pressing a starter test button simulates a fault on the corresponding phase or phases.

Mode	Test button	Simulated fault 1)	Starter	Signals	Voltage used for meas.
⅄ corresponds to position 1 switch 1 (KI91)	R	RO	R	R	RO
	S	SO	S	E	SO
	T	TO	T	T	TO
	RS	RS	RS	RS	RS
	ST	ST	ST	ST	ST
	TR	TR	TR	TR	TR
	RST	RST	RST	RST	RST
△ corresponds to position 2 switch 1 (KI91)	R	RS	R	R	RS
	E	rSO, StO	E	E	SE
	T	ST	T	T	TS
	RE	RSO, RsO, RtO	RE	RE	RE
	TE	STO, sTO, TrO	TE	TE	TE
	TR	TR, RST	TR	TR	TR
	RTE	RSTE, RTE	RTE	RTE	RE

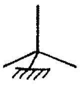
1) Small letters: more distant cross-country fault

Table 6.1 - Faults simulated by the test buttons of the distance relay LZ91

Mode	Test button	Simulated fault 2)	Starter	Signals	Voltage used for meas.
⅄ corresponds to position 1 switch 1 (KZ91)	R	RT	R	R	RT
	S	SR	S	E	SR
	T	TS	T	T	TS
	E	--	--	E_{ext}	--
	RE	RE	RE	RE	RE
	SE	SE	SE	SE	SE
	TE	TE	TE	TE	TE
	RS	RS	RS	RS	SR
	ST	ST	ST	ST	TS
	TR	TR	TR	TR	RT
	RSE	RSE	RSE	RSE	SR
	STE	STE	STE	STE	TS
	TRE	TRE	TRE	TRE	RT
	RST	RST	RST	RST	RT
	RSTE	RSTE	RSTE	RSTE	RT
△ corresponds to position 2 switch 1 (KZ91)	R	RT	R	R	RT
	S	SR	S	S	SR
	T	TS	T	T	TS
	E	--	E	E_{ext}	--
	RE	RsO, tRO	RE	RE	RE
	SE	StO, rSO	SE	SE	SE
	TE	sTO, TrO	TE	TE	TE
	RS	RS	RS	RS	SR
	ST	ST	ST	ST	TS
	TR	TR	TR	TR	RT
	RSE	RSE	RSE	RSE	RE(SE) 1)
	STE	STE	STE	STE	TE
	TRE	TRE	TRE	TRE	RE
	RST	RST	RST	RST	RT
	RSTE	RSTE	RSTE	RSTE	RT

1) Letters in brackets: cyclical phase-preference
2) Small letters: more distant cross-country fault

Table 6.2 - Faults simulated by the test buttons of the distance relay LZ92

Mode	Test button	Simulated fault 1)	Starter	Signals	Distance measured using	Direction determined using 2)
	R	RT	R	R	RT	ST
	S	SR	S	S	SR	TR
	T	TS	T	T	TS	RS
switch 1	E	--	--	E_{ext}	--	--
(KZ91-1)	RE	RE	RE	RE	RE	ST
	SE	SE	SE	SE	SE	TR
1 OFF	TE	TE	TE	TE	TE	RS
2 ON	RS	RS	RS	RS	SE	TR
3 ON	ST	ST	ST	ST	TS	RS
4 OFF	TR	TR	TR	TR	RT	ST
	RSE	RSE	RSE	RSE	SR	TR
	STE	STE	STE	STE	TS	RS
	TRE	TRE	TRE	TRE	RT	ST
	RST	RST	RST	RST	RT	ST
	RSTE	RSTE	RSTE	RSTE	RT	ST
R before	R	RT	R	R	RT	ST
T before	S	SR	S	S	SR	TR
S	T	TS	T	T	TS	RS
acyclical	E	--	E	E_{ext}	--	--
	RE	RsO, tRO	RE	RE	RE	ST
switch 1	SE	StO, rSO	SE	SE	SE	TR
(KZ91-1)	TE	sTO, TrO	TE	TE	TE	RS
	RS	RS	RS	RS	SR	TR
1 OFF	ST	ST	ST	ST	TS	RS
2 OFF	TR	TR	TR	TR	RT	ST
3 ON	RSE	RSE	RSE	RSE	RE	ST
4 OFF	STE	STE	STE	STE	TE	RS
	TRE	TRE	TRE	TRE	RE	ST
	RST	RST	RST	RST	RT	ST
	RSTE	RSTE	RSTE	RSTE	RT	ST

1) Small letters: more distant cross-country fault
2) Directional measurement: same current as distance meas.

Table 6.3 - Faults simulated by the test buttons of the distance relay LZ92-1

Mode	Test button	Simulated fault 1)	Starter	Signals	Distance measured using	Direction determined using 2)
T before T	R	RT	R	R	RT	ST
R before S	S	SR	S	S	SR	TR
S before T	T	TS	T	T	TS	RS
cyclical	E	--	E	E_{ext}	--	--
	RE	RsO, tRO	RE	RE	RE	ST
	SE	StO, rSO	SE	SE	SE	TR
	TE	sTO, TrO	TE	TE	TE	RS
switch 1	RS	RS	RS	RS	SR	TR
(KZ91-1)	ST	ST	ST	ST	TS	RS
	TR	TR	TR	TR	RT	ST
1 ON	RSE	RSE	RSE	RSE	RE	ST
2 OFF	STE	STE	STE	STE	SE	TR
3 OFF	TRE	TRE	TRE	TRE	TE	RS
4 OFF	RST	RST	RST	RST	RT	ST
	RSTE	RSTE	RSTE	RSTE	RT	ST
R before S	R	RT	R	R	RT	ST
before T	S	SR	S	S	SR	TR
	T	TS	T	T	TS	RS
acyclical	E	--	E	E_{ext}	--	--
	RE	RsO, tRO	RE	RE	RE	ST
	SE	StO, rSO	SE	SE	SE	TR
switch 1	TE	sTO, TrO	TE	TE	TE	RS
(KZ91-1)	RS	RS	RS	RS	SR	TR
	ST	ST	ST	ST	TS	RS
1 ON	TR	TR	TR	TR	RT	ST
2 ON	RSE	RSE	RSE	RSE	RE	ST
3 ON	STE	STE	STE	STE	SE	TR
4 ON	TRE	TRE	TRE	TRE	RE	ST
	RST	RST	RST	RST	RT	ST
	RSTE	RSTE	RSTE	RSTE	RT	ST

1) Small letters: more distant cross-country fault

2) Directional measurement: same current as distance meas.

Table 6.3 - Continuation

Checking the direction of measurement

As soon as one or more of the test buttons (R, S or T) are pressed, the corresponding starting unit or units pick up and the auxiliary tripping relay is interlocked to prevent operating the circuit-breaker inadvertently.

The starting units apply phase quantities to the measuring unit according to the kind of fault being simulated.

The relay will pick up in some stage or other depending on the load current at the time and the relay settings. (If the values and phase-angle of the load quantities is known, it is even possible to test the various zones by suitably changing the settings.)

Providing the fourth zone is non-directional, the relay must at very least pick-up in the fourth zone (red LED lights up).

The fourth zone must be made directional and all the zones be measuring in the forwards direction in order to check the relay's ability to determine direction. The corresponding switch positions are: switch 8a in position 1, switch 8b in position 1 or 2 depending on input transformer connection and switch 7 in position 1.

Caution! Units may only be withdrawn from the rack when the auxiliary supply is switched off.

Under the above conditions the relay must pick up when the load energy is flowing in the forwards direction and block when the energy direction is reversed by operating switch 8b (part number HESG 439 686) or the frontplate switch I⇄ (part number HESG 440 718), or vice versa.

The ability of the relay to pick up and block must be tested in this way for all kinds of faults.

Withdrawing a relay with non-directional fourth zone can be avoided by setting the thumbwheel switch N of the corresponding zone to 0% (infinite reach).

Should the direction be incorrect for a particular kind of fault, the polarity of all c.t's, p.t's, leads and connections must be checked (see Sections 5.3 and 5.4). If the direction is incorrect for all kinds of faults, all the current connections must be reversed. In the case of relays LZ92 and LZ92-1 with off-set starting characteristics care must be taken that the longest reach of the starters is in the desired direction (see Section 3.6).

Testing the tripping circuit

Provision is made on the input transformer unit EW91 from part number HESG 440 754 to apply a signal manually to the auxiliary tripping relay and thus trip the circuit-breaker. This operation, however, is interlocked for safety reasons. Firstly terminal E11 of the input transformer unit must be connected to terminal E63 of the main processing unit. Then the sockets ⚠ and —/— must be connected. Finally a starting button must be pressed. It is not possible to test the tripping circuit, if the connection E11-E63 is not made.

6.6 Testing the distance relay using a test set

Providing the relay is equipped with a test socket XX91, a test set can be simply connected by means of the test connector YX91. As soon as the test connector is inserted, a signal is emitted (providing it is appropriately wired via an auxiliary signalling relay in the unit AV91 respectively AV94) to indicate that the relay is no longer standing by (V.0 in the code of the main processing unit).

When it is plugged in the test connector:

- short-circuits the main c.t's
- isolates the relay input from c.t's and p.t's
- interrupts the tripping circuit
- blocks the external signals (driver outputs and signals to ancillaries, e.g. AV91, AV94 etc.) for starting, tripping and timer (where fitted) for the duration of testing
- connects the p.t. voltages to the test set (where necessary)
- connects the current and voltage inputs of the relay to the test set.

Facility is provided in the test connector for enabling the signal outputs for ancillary units if necessary.

A sample test report for testing with a test set can be found in the appendicies.

6.7 Instructions for modifying relay operation

Normally the desired relay operation is defined by the ordering code and supplied from the works with the corresponding connections etc., already made.

However, should changes become necessary during commissioning, then small changes (soldered link or value of a resistor on soldering posts) can be done with the aid of the Table of Features and corresponding PCB drawing in the appendicies. This work may only be performed by correspondingly qualified personnel.

The principal versions are defined as follows:

Plug-in unit EW91	Code	U1 A1 K11 E7 F5
(HESG 438 454)		U1 A5 K11 E7 F5
Plug-in unit EW91	Code	U1 A1 K11 E13 F5
(HESG 440 754 resp.		U1 A5 K11 E13 F5
EW91a HESG 441 721)		(U1 A1 K11 E13 F6)
		(U1 A5 K11 E13 F6)
Plug-in unit KI91	Code	F5 I1/0.5/ US 1.5 R20 X5 E00 FA1 V10
Plug-in unit KZ91	Code	F5 Z1 EK1 L0 US 1.5 R20 X5 E00 FA1 V10
Plug-in unit KZ91-1	Code	F5 Z1 EK1 L4 US 1.5 R21 X5 E00 FA1 V10

7. OPERATION AND MAINTENANCE

Where no remote reset is fitted, the LED signals must be reset each time the relay picks up (providing the signals are in operation, i.e. main processing unit code FA1). Please refer to Section 3.11 for main processing units with PCB 8 acc. to HESG 440 718 . The relay continues to operate correctly whether the signals are reset or not, but the signals may no longer be related to the fault concerned.

The relay requires no special maintenance. However, as is usual with all safety systems, it should be tested at regular intervals. This can be carried out as described in Section 6.5.

The test buttons on the frontplate permit a simple functional test to be carried out with the relay connected to load quantities. The latter can also be measured at the test sockets on the frontplate. Furthermore the tripping circuit including the circuit-breaker can be tested with input transformer units with part number HESG 440 754 resp. 441 721 and main processing unit with PCB 8 acc. to HESG 440 718.

Since the simple tests above can be carried out at relatively short intervals, comprehensive testing with a test set is only necessary at two-yearly intervals. But quantitive testing is essential after this period regardless of whether the relay is equipped with a test socket XX91 or not. Where it is not, either signals must be injected at the terminals after appropriately isolating the main c.t's and p.t's, or the plug-in units can be withdrawn and inserted into a separate equipment rack wired to the test set.

7.1 Ancillaries and spares

When ordering ancillaries and spares, it is essential that the type and serial number of the unit for which they are intended be stated. If a number of identical relays are installed in a plant, we recommend stocking spare units.

Spares must be stored in a clean dry room at moderate temperatures. It is further recommended that spares also be tested at the same time as the periodic testing of the protective equipment in operation, i.e. every one or two years.

8. TROUBLE-SHOOTING

Should the relay appear defective, proceed as follows:

- Check that the thumbwheel switch of the neutral current element in the KZ91 or KZ91-1 is not set to zero.

- Check the ± 15 V and ± 24 V auxiliary supplies are in order at the edge connector of each plug-in unit (see relative instructions for the terminal designations of the DC/DC converter).

- Check the correctness of the signals at the sockets on the front of the EW91 (see Section 6.3). If not, check the relay wiring.

- Localise a defect by withdrawing the KI or KZ unit and rechecking the signals at the sockets on the EW91. If they are in order, a defective main processing unit is to be suspected.

- Replace the defective unit.

Should it not be possible to locate and clear a defect, then the complete relay or plug-in unit concerned must be returned to the nearest BBC agent, or directly to ABB Baden, Switzerland.

9. APPENDICIES

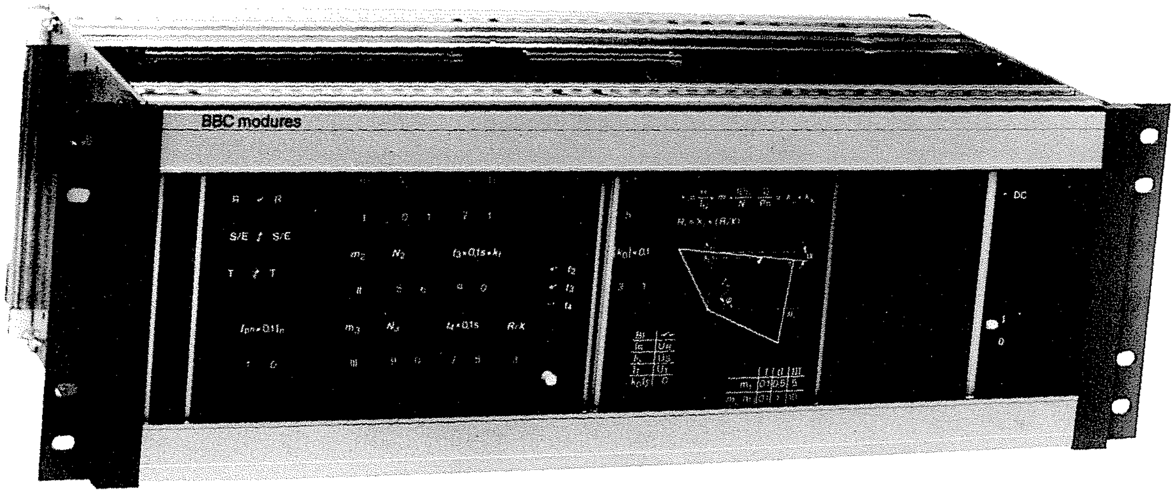


Fig. 9.1 - Distance relay LZ91 with plug-in units KI91, EW91 and NF92

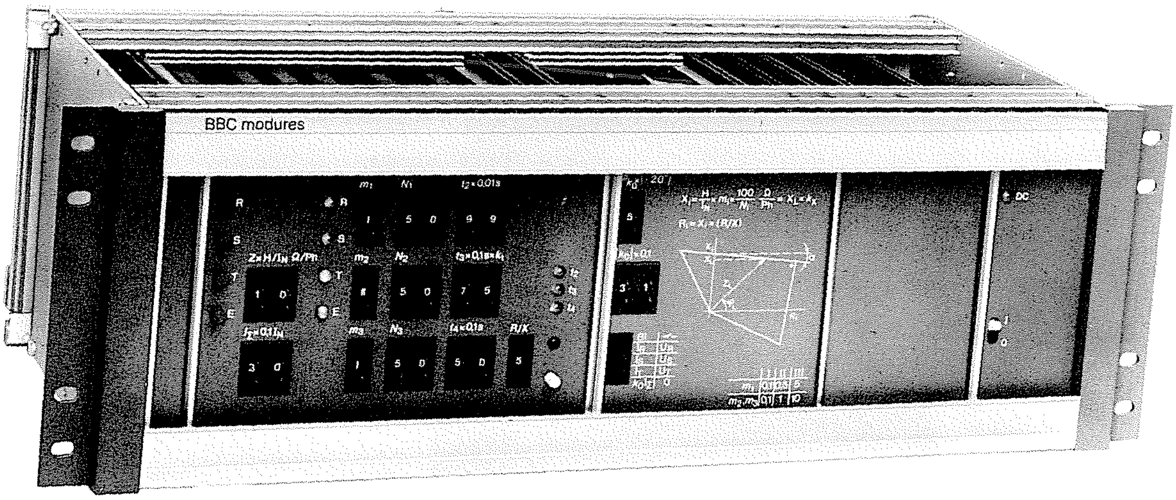


Fig. 9.2 - Distance relay LZ92 with plug-in units KZ91, EW91 and NF92

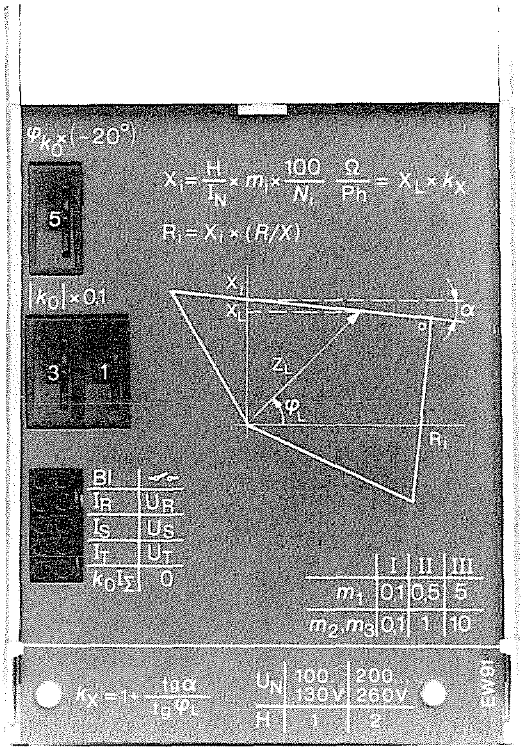


Fig. 9.3 - Input transformer unit EW91, Part No. HESG 438 454 (photo 185 680)

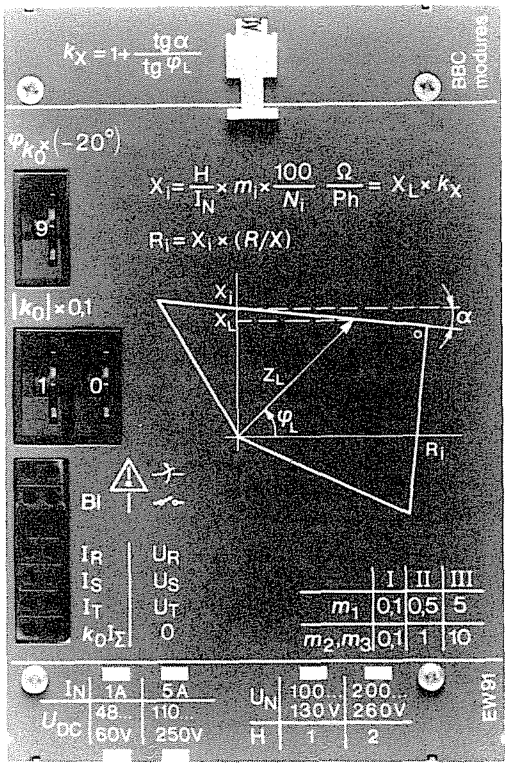


Fig. 9.4 - Input transformer unit EW91, Part No. HESG 440 754 (photo 214 280)

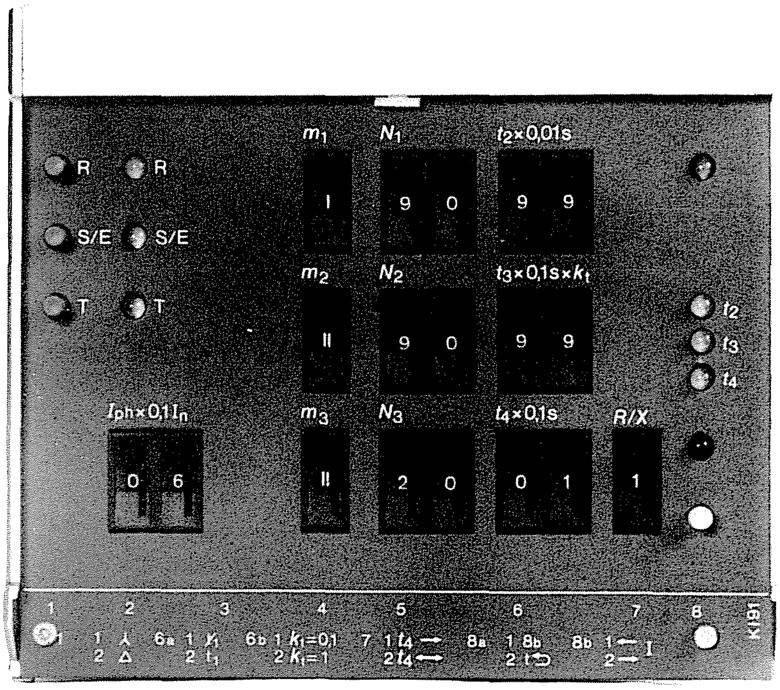


Fig. 9.5 - Main processing unit KI91, Part No. HESG 440 079 R1...R4 (photo 188 349)

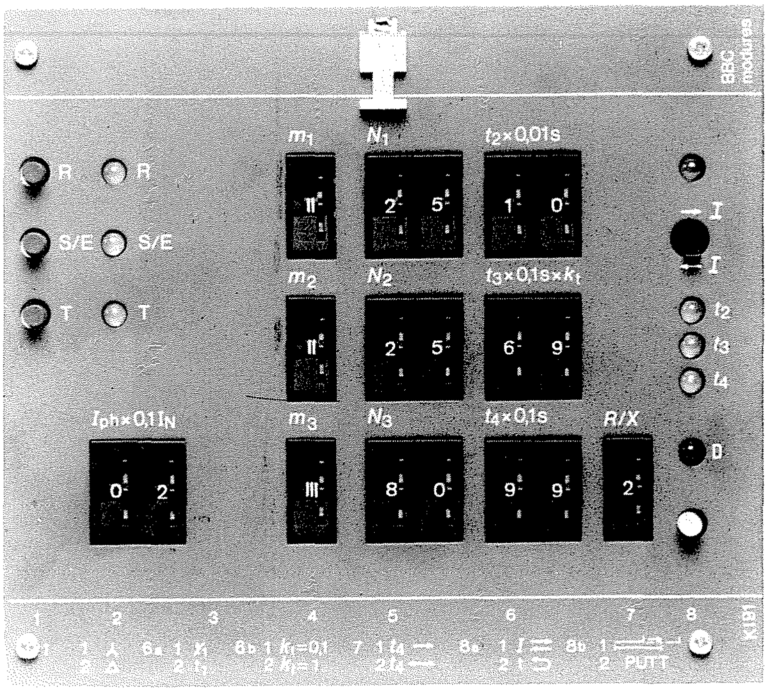


Fig. 9.6 - Main processing unit KI91, Part No. HESG 440 079 R11...R14 (photo 214 281)

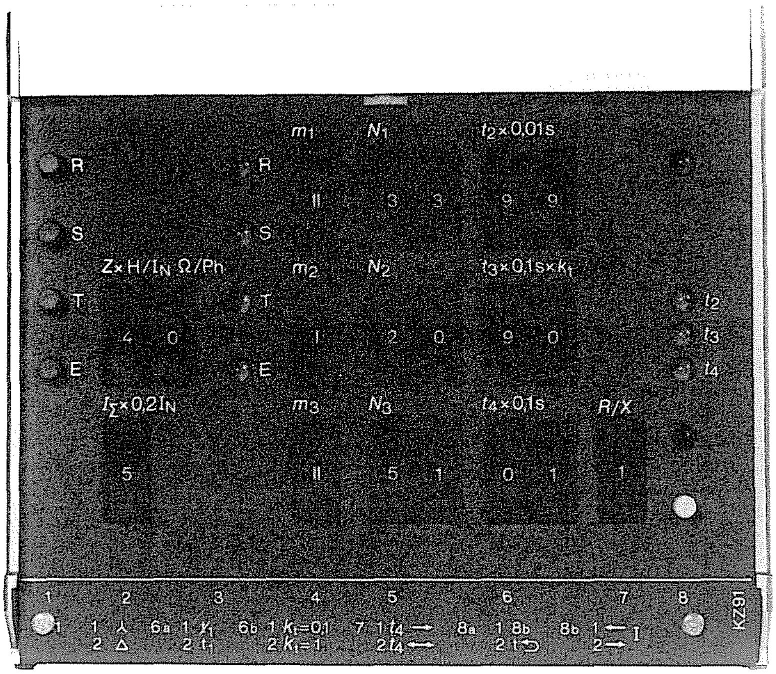


Fig. 9.7 - Main processing unit KZ91, Part No. HESG 440 080 R11...R14, R22
(photo 188 350)

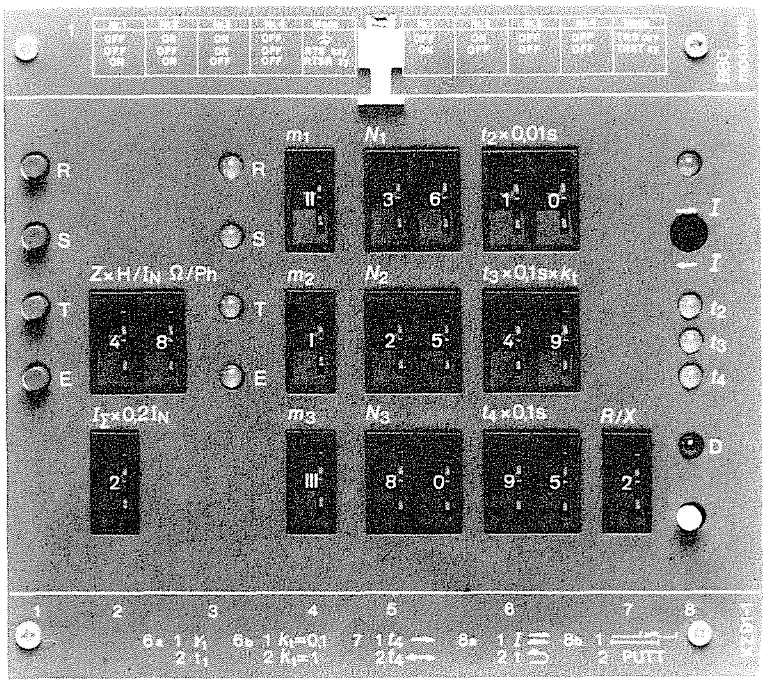
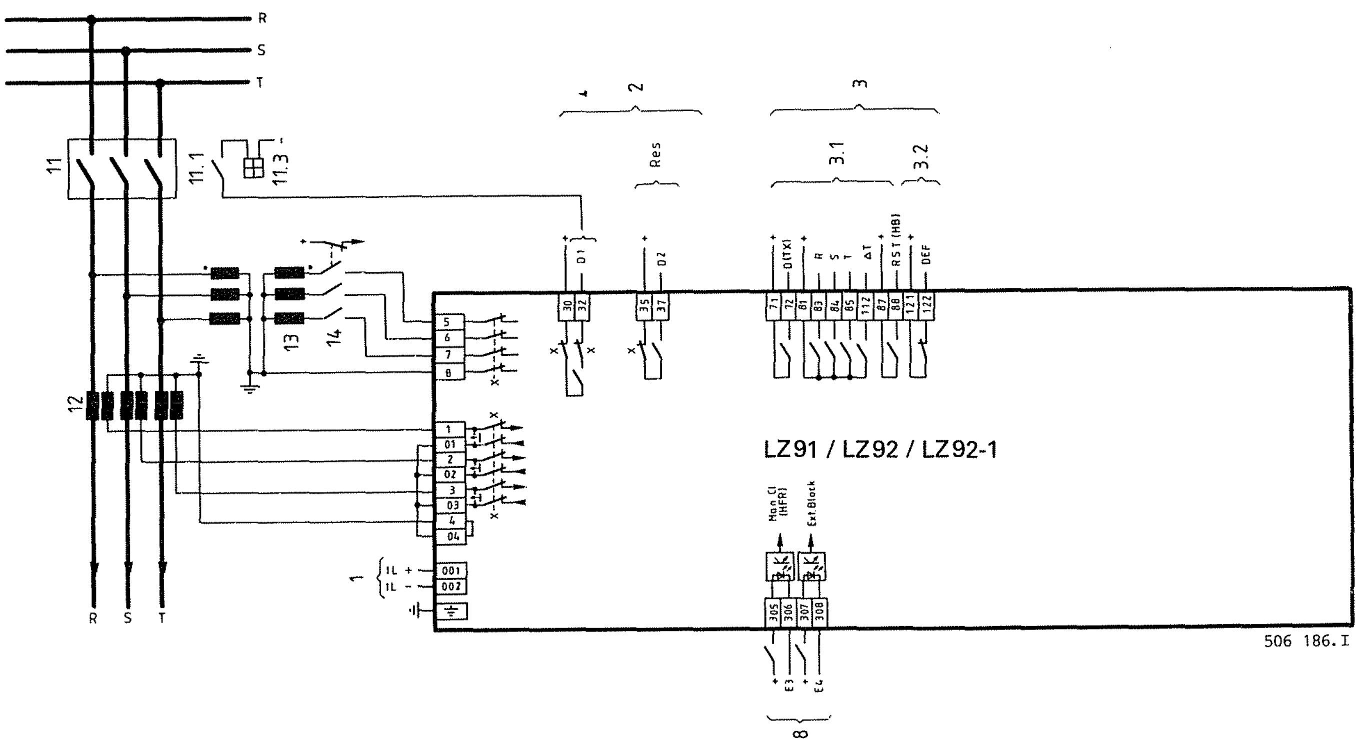


Fig. 9.8 - Main processing unit KZ91-1, Part No. HESG 440 342 R11, R12, R22
(photo 214 279)

This wiring diagram serves only as an example



1 = aux. supply from station battery
2 = tripping contacts
3 = signalling contacts
  3.1 = operating signals
  3.2 = relay defect
8 = opto-coupler inputs
11 = circuit-breaker
  11.1 = circuit-breaker aux. contact
  11.3 = tripping coil
12 = c.t's
13 = p.t's
14 = m.c.b. with aux. contact

Fig. 9.9 - Wiring diagram

Code	Feature	Specification/Component change
U1 U2	Rated voltage 100 to 130 V a.c. Rated voltage 200 to 260 V a.c.	depending on component ratings
A1 A5 A2	Rated current 1 A a.c. Rated current 5 A a.c. Rated current 2 A a.c.	HESG 438 454 choice of terminals (see Sec. 5.3) HESG 438 454 acc. to components fitted
A1 A2 A5	Rated current 1 A a.c. Rated current 2 A a.c. Rated current 5 A a.c.	HESG 440 754 resp. HESG 441 721 depending on component ratings and calibration on PCB 1
F5/F6 F5/F6	Rated frequency 50 Hz/60 Hz Rated frequency 50 Hz/60 Hz	HESG 438 454 W115 and R44, R45, R46 and Ei HESG 440 754 resp. HESG 441 721) W15, W16, W17, W18 and Ei
K.0 K.1 K1. K0.	k_o amplitude k_o amplitude and phase-angle with tripping unit without tripping unit	HESG 438 454
K11	k_o amplitude and phase-angle	HESG 440 754 resp. HESG 441 721
E0 to E8	Opto-coupler input voltage	HESG 438 454 R25, R26
E11 to E13	Opto-coupler input voltage	HESG 440 754 resp. HESG 441 721 R144, R146
E1 to E4 E5 to E8	Opto-coupler input Q Opto-coupler input $\overline{Q}$	HESG 438 454 W61
-	Opto-coupler input Q, $\overline{Q}$	HESG 440 754 resp. HESG 441 721 W61

Ei	works calibration (module No.)
LB.	soldered link No.
LO	PCB lay-out change at the works (different PCB)
Wi	resistor No.

Table 9.15 - Features of plug-in unit EW91

Code	Feature	Specification/Component change	
F5	Rated frequency 50 Hz	PCB 6 (HESG 439 684)	LB1
F6	Rated frequency 60 Hz	PCB 7 (HESG 439 685)	Ei(M85)
I1/0.5	Standard selection logic	PCB 1 (HESG 439 679)	LO
I2/0.5	TRS selection logic	PCB 1 (HESG 439 680)	LO
I./.../	$I_{\Sigma}/I_{Ph} \neq 0.5$	PCB 2 (HESG 439 681)	Wi2
US1.5	Overreach 1.5 x Z_1 (standard)	PCB 5 (HESG 439 683)	Wi8
US...	Overreach ≠ 1.5 x Z_1		
R10	Reverse direction zone 1	PCB 6 (HESG 439 684)	LB9
R20	Reverse direction zone 2		
R30	Reverse direction zone 3		
R40	Reverse direction zone 4		
R50	Reverse direction external	PCB 6 LB9 and PCB 8 (HESG 439 686) or PCB 8 (HESG 440 718)	LB17 LB17
X5	Reactance inclination 5°	PCB 7 (HESG 439 685)	Ei(M85)
X...	Reactance inclination ≠ 5°	PCB 7 (HESG 439 685)	Ei(M85)
E0.	Zone 4 less reactance	PCB 7 (HESG 439 685)	LB11
E1.	Zone 4 plus reactance		LB11
E.0	Zone 4 less resistance		LB12
E.1	Zone 4 plus resistance		LB12
FA1	Frontplate signals operational	PCB 2 (HESG 439 681)	LB13
FA2	Frontplate signals non-operational	PCB 8 (HESG 439 686) ot PCB 8 (HESG 440 718)	LB15 LB15
V10	With defect signalling during testing via test socket	PCB 8 (HESG 439 681) or PCB 8 (HESG 440 718)	LB16 LB16
V11	Without defect signalling during testing via test socket	PCB 8 (HESG 439 681) or PCB 8 (HESG 440 718)	LB16 LB16

Ei	works calibration (module No.)
LB	soldered or plug-in link
LO	works PCB-layout (different PCB)
Wi	resistor No.

Table 9.16 - Features of plug-in unit KI91

Code	Feature	Specification/Component change	
F5	Rated frequency 50 Hz	PCB 6 (HESG 439 684)	LB1
F6	Rated frequency 60 Hz	PCB 7 (HESG 439 685)	Ei(M85)
Z1/	Starting char. circle	PCB 3 (HESG 439 692)	LB3
Z2/	Starting char. lense 108°		
Z.//	Starting char. about origin	PCB 3 (HESG 439 692)	Wi4
Z./.../	Starting char. off-set		
Z./...///	E/F compensation $(1+k_o)/2 = 1$	PCB 2 (HESG 439 691)	Wi5
Z.///.../	E/F compensation $(1+k_o)/2 \neq 1$		
EK1	E/F logic OR	PCB 2 (HESG 439 691)	LB6
EK2	E/F logic AND		
L0	RTS selection logic (standard)	PCB 1 (HESG 439 691)	LB7
L1	Cycl. RTSR selection logic		
L2	TRS selection logic	PCB 1 (HESG 439 690)	L0
L3	Cycl. TRST selection logic	PCB 1 (HESG 439 690)	L0 and LB7
US1.5	Overreach 1.5 x Z_1 (standard)	PCB 5 (HESG 439 683)	Wi8
US...	Overreach ≠ 1.5 x Z_1		
R10	Reverse direction zone 1		
R20	Reverse direction zone 2	PCB 6 (HESG 439 684)	LB9
R30	Reverse direction zone 3		
R40	Reverse direction zone 4		
R50	Reverse direction external	PCB 6 LB9 and PCB 8	LB17
		(HESG 439 686) or	
		PCB 8 (HESG 440 718)	LB17
X5	Reactance inclination 5°	PCB 7 (HESG 439 685)	Ei(M85)
X...	Reactance inclination ≠ 5°	PCB 7 (HESG 439 685)	Ei(M85)
E0.	Zone 4 less reactance		LB11
E1.	Zone 4 plus reactance	PCB 7 (HESG 439 685)	LB11
E.0	Zone 4 less resistance		LB12
E.1	Zone 4 plus resistance		LB12
FA1	Frontplate signals operational	PCB 3 (HESG 439 692)	LB14
FA2	Frontplate signals non-operational	PCB 8 (HESG 439 686) or	LB15
		PCB 8 (HESG 440 718)	LB15
V10	With defect signalling during testing via test socket	PCB 8 (HESG 439 681) or PCB 8 (HESG 440 718)	LB16 LB16
V11	Without defect signalling during testing via test socket	PCB 8 (HESG 439 681) or PCB 8 (HESG 440 718)	LB16 LB16

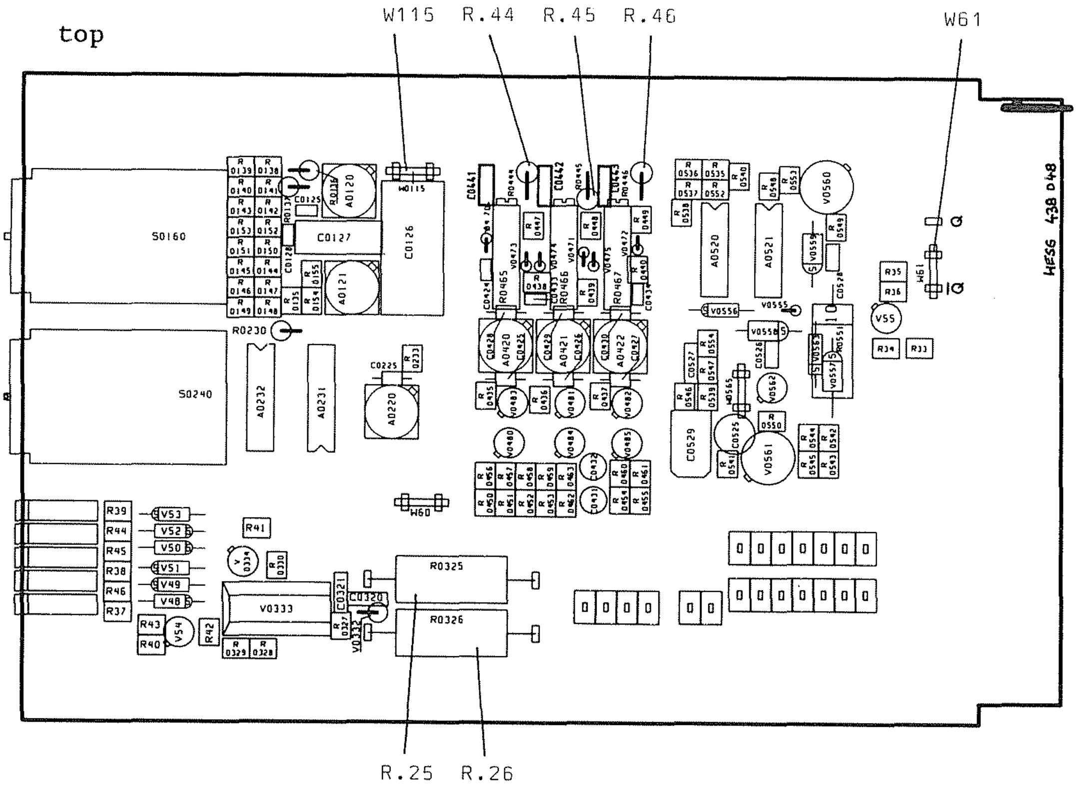
Ei	works calibration (module No.)
LB	soldered or plug-in link
LO	works PCB-layout (different PCB)
Wi	resistor No.

Table 9.17 - Features of plug-in unit KZ91

Code	Feature	Specification/Component change
F5	Rated frequency 50 Hz	PCB 6 (HESG 439 684) LB1
F6	Rated frequency 60 Hz	PCB 7 (HESG 439 685) Ei(M85)
Z1/	Starting char. circle	PCB 3 (HESG 439 692) LB3
Z2/	Starting char. lense 108°	
Z.//	Starting char. about origin	PCB 3 (HESG 439 692) Wi4
Z./.../	Starting char. off-set	
Z./...///	E/F compensation $(1+k_o)/2 = 1$	PCB 2 (HESG 439 691) Wi5
Z.///.../	E/F compensation $(1+k_o)/2 \neq 1$	
EK1	E/F logic OR	PCB 2 (HESG 439 691) LB6
EK2	E/F logic AND	
L4	Selection logic	PCB 1 (HESG 440 363) switch 1
US1.5	Overreach 1.5 x Z_1 (standard)	PCB 5 (HESG 439 683) Wi8
US...	Overreach $\neq$ 1.5 x Z_1	
R11	Reverse direction zone 1	
R21	Reverse direction zone 2	PCB 6 (HESG 439 684) LB9
R31	Reverse direction zone 3	
R41	Reverse direction zone 4	
R51	Reverse direction external	PCB 6 LB9 and PCB 8 LB17
		(HESG 439 686) or
		PCB 8 (HESG 440 718) LB17
X5	Reactance inclination 5°	PCB 7 (HESG 439 685) Ei(M85)
X...	Reactance inclination ≠ 5°	PCB 7 (HESG 439 685) Ei(M85)
E0.	Zone 4 less reactance	LB11
E1.	Zone 4 plus reactance	PCB 7 (HESG 439 685) LB11
E.0	Zone 4 less resistance	LB12
E.1	Zone 4 plus resistance	LB12
FA1	Frontplate signals operational	PCB 3 (HESG 439 692) LB14
FA2	Frontplate signals non-operational	PCB 8 (HESG 439 686) or LB15
		PCB 8 (HESG 440 718) LB15
V10	With defect signalling during testing via test socket	PCB 8 (HESG 439 681) or LB16 PCB 8 (HESG 440 718) LB16
V11	Without defect signalling during testing via test socket	PCB 8 (HESG 439 681) or LB16 PCB 8 (HESG 440 718) LB16

Ei	works calibration (module No.)
LB	soldered or plug-in link
LO	works PCB-layout (different PCB)
Wi	resistor No.

Table 9.18 - Features of plug-in unit KZ91-1



W115 Rated frequency 50 Hz, code F5: o--o (amplitude calibration also
60 Hz, code F6: -o o- necessary)

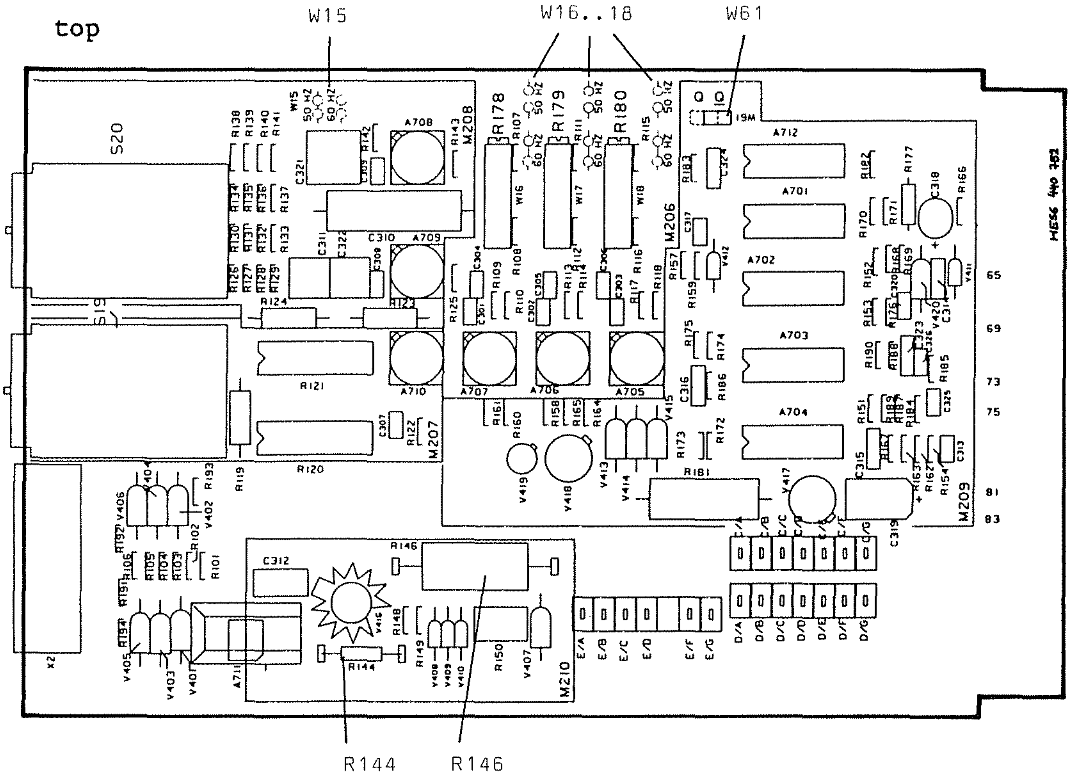
R.44 Rated frequency 50 Hz, code F5: R.44, R.45, R.46 = 5.6 kOhm
R.45 Rated frequency 60 Hz, code F6: R.44, R.45, R.46 = 3.9 kOhm
R.46

W61 direct opto-coupler input , code E1...E4, Q: o o--o
inverted opto-coupler input , code E5...E8, $\overline{Q}$: o--o o

R.25 opto-coupler input
R.26 voltage

Code	Voltage	R.25 = R.26
E1, E5	24 V	1,5 k 2 W
E2, E6	48... 60 V	3,3 k 2 W
E3, E7	110...125 V	6,8 k 2 W
E4, E8	220...250 V	18 k 2 W
E0		∞ and remove link W61

Fig. 9.19 - PCB 1 in EW91 (HESG 438 048)



W15...W18 Rated frequency 50 Hz, code F5 state link positions on PCB (amplitude calibration also necessary)
60 Hz, code F6

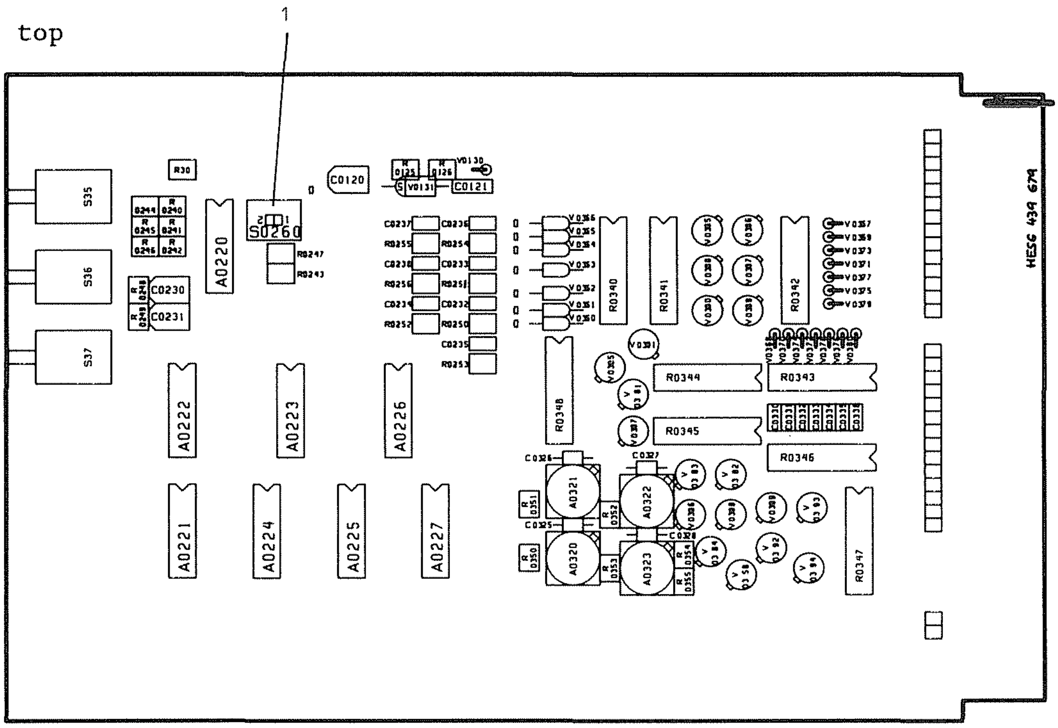
W61 direct opto-coupler output, without code Q: (o--o) o
inverted opto-coupler output, without code $\overline{Q}$: o (o--o)

R144 opto-coupler input voltage
R146

Code	Voltage	R144	R146
E11	20... 30 V	1 k 2W	4.7k 2W
E12	36... 75 V	2.7k 2W	27 k 2W
E13	82...312 V	15 k 2W	82 k 2W

PCB 1, unit EW91a: The arrangements of the elements on this
(HESG 441 585) PCB have been slightly modified. The above mentioned jumpers and resistors are in the same spot as in the EW91.

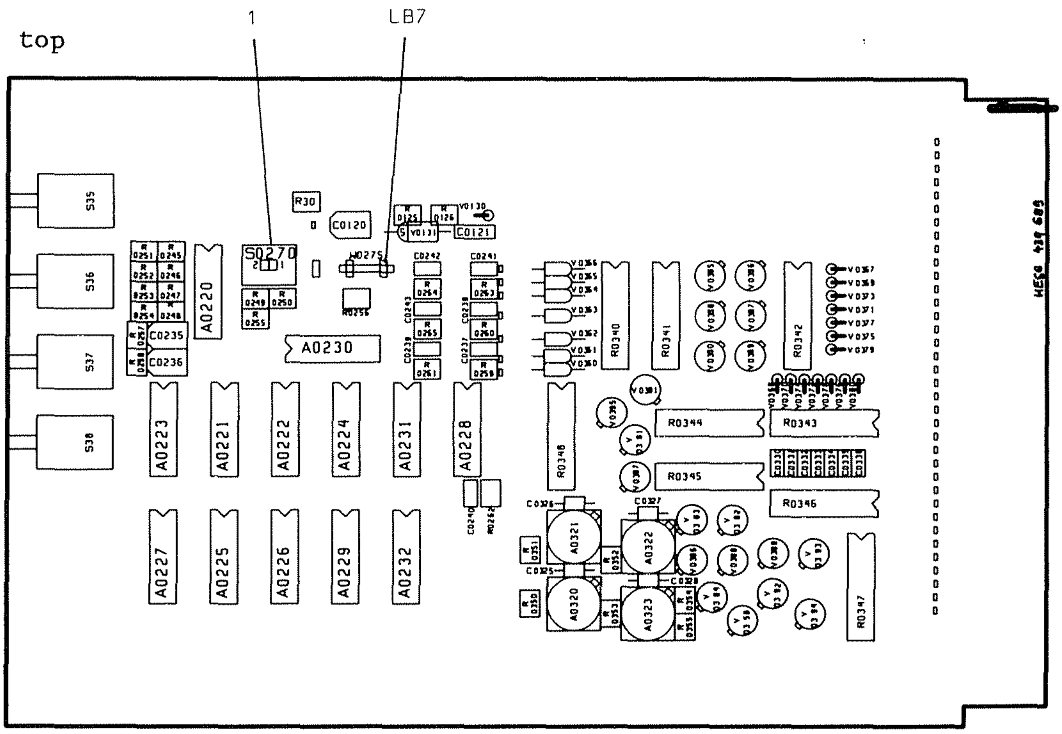
Fig. 9.20 - PCB 1 in EW91 (HESG 440 752)



1 Switch 1: position 1 for mode ⅄

position 2 for mode △

Fig. 9.21 - PCB 1 in KI91 (HESG 439 679/80)

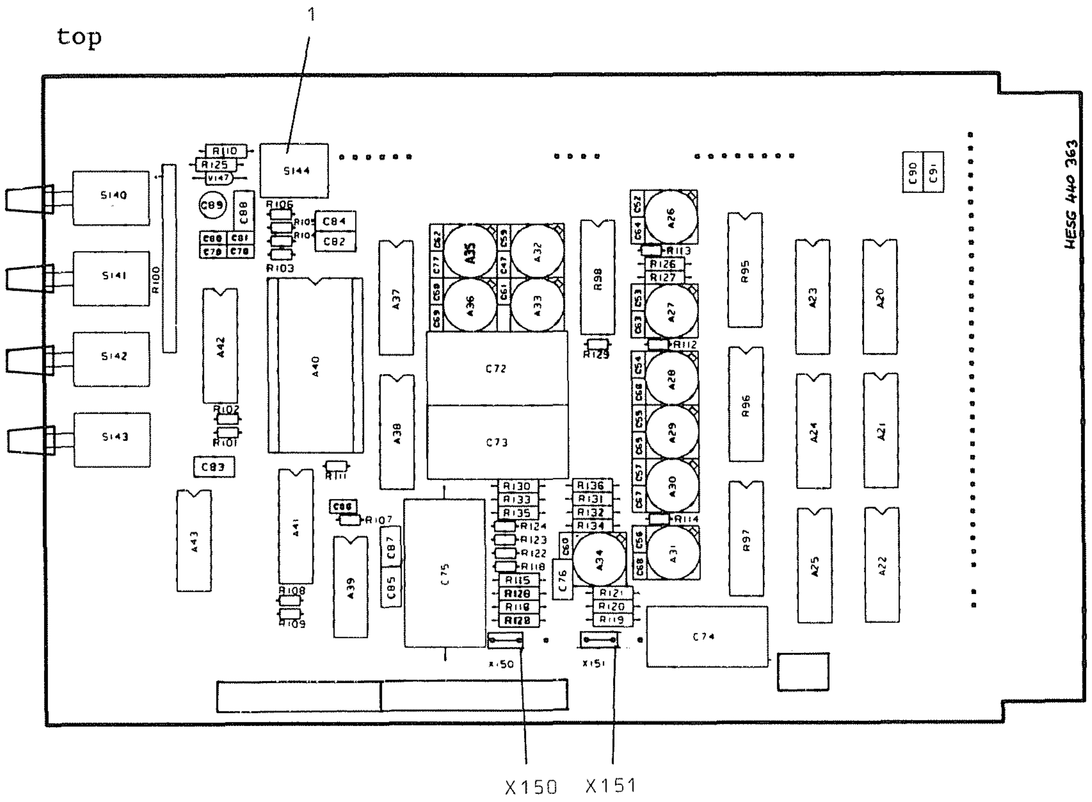


1 Switch 1: position 1 for mode ⅄

position 2 for mode △

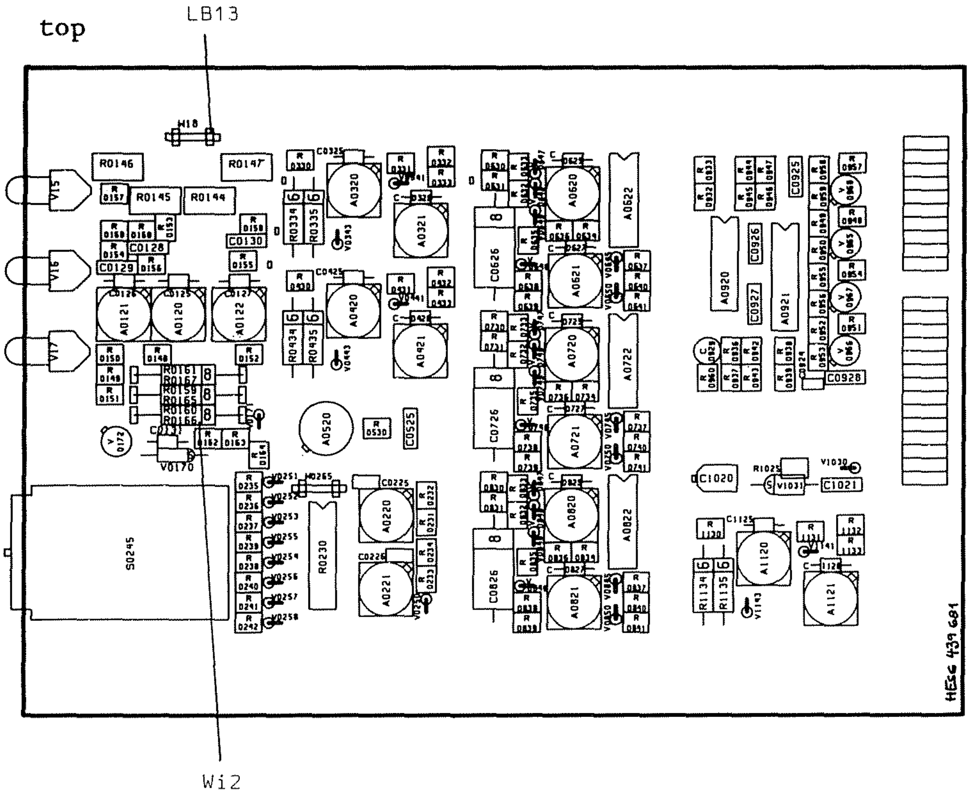
LB7 Acycl. RTS selection logic (standard), code L0: o o--o } HESG 439 689
Cycl. RTSR selection logic , code L1: o--o o }
Acycl. TRS selection logic , code L2: o o--o } HESG 439 690
Cycl. TRST selection logic , code L3: o--o o }

Fig. 9.22 - PCB 1 in KZ91 (HESG 439 689/90)



1	Switch 1 for selecting operating mode (settings see Table 3.1)
X150, X151	Rated frequency 50 Hz, code F5: (o--o) o Rated frequency 60 Hz, code F6: o (o--o)

Fig. 9.23 - PCB 1 in KZ91-1 (HESG 440 363)



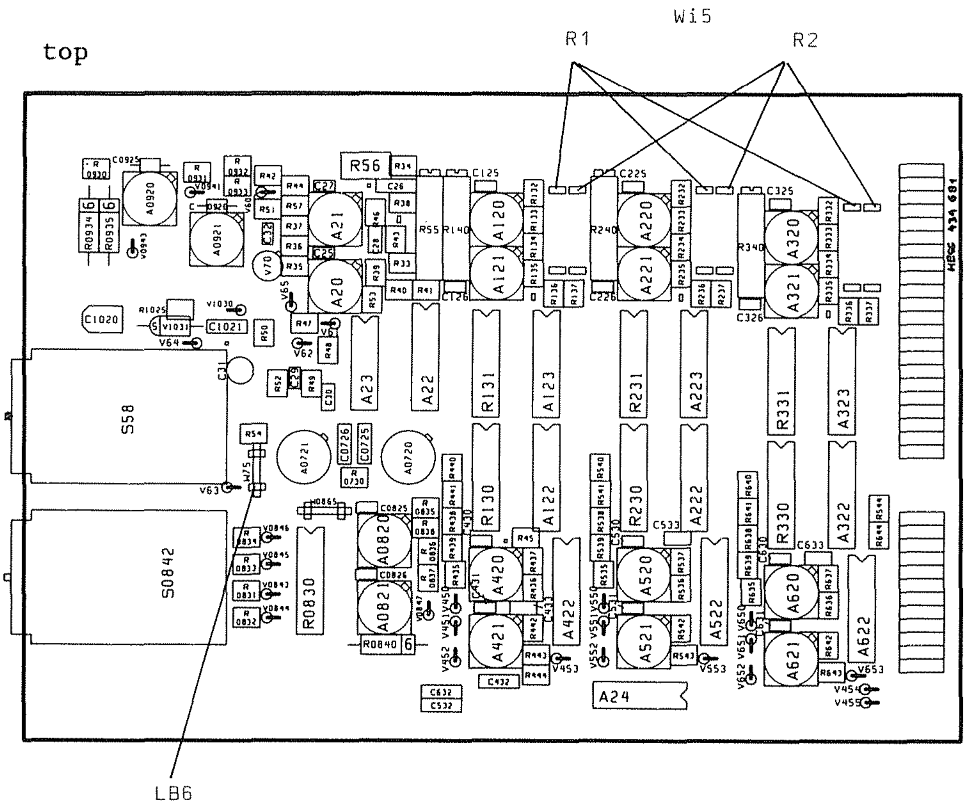
LB13 Frontplate signals operational, code FA1: o--o
Frontplate signals non-operational, code FA2: -o o-

Wi2

I_{Σ}/I_{Ph}	R..65	R..59	R..67	R..61	R..66	R..60
1	∞	∞	∞	∞	∞	∞
0.76	150k	∞	150k	∞	150k	∞
0.5 *	∞	47k	∞	47k	∞	47k
0.33	47k	47k	47k	47k	47k	47k

* standard

Fig. 9.24 - PCB 2 in KI91 (HESG 439 681)

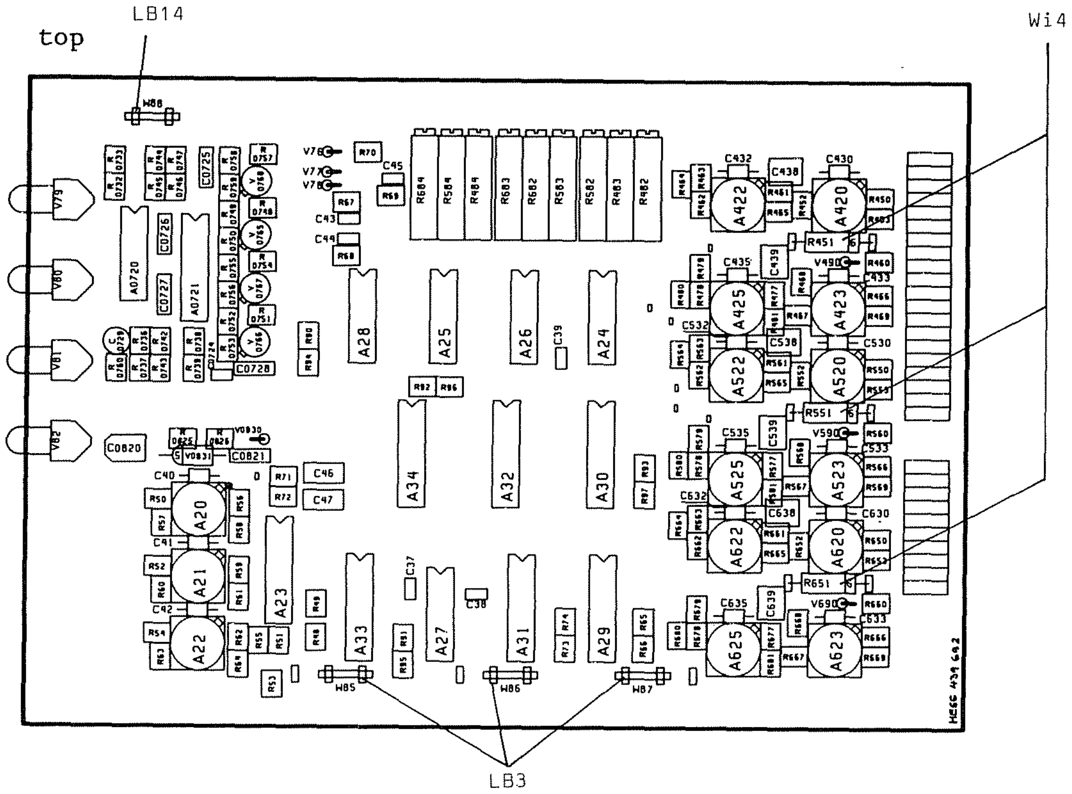


LB6 E/F logic OR, code EK1: o--o (I_Σ OR U_Σ)
E/F logic AND, code EK2: -o o- (I_Σ AND U_Σ)

Wi5 E/F compensation $(1+k_o)/2$, code Z./// .../: see table for R1 and R2

$k_o \leq 1$				$k_o \geq 1$							
k_o	$\frac{1+k_o}{2}$	R1	R2 (kΩ)	k_o	$\frac{1+k_o}{2}$	R1 (kΩ)	R2	k_o	$\frac{1+k_o}{2}$	R1 (kΩ)	R2
1	1	∞	∞	1	1	∞	∞	2.14	1.57	82	∞
0.82	0.91		1000	1.09	1.045	1000		2.38	1.69	68	
0.79	0,895		820	1.11	1.055	820		2.67	1.835	56	o
0.75	0.875		680	1.13	1.065	680		3.00	2.0	47	f
0.71	0.855		560	1.16	1.08	560		3.41	2.205	39	f
0.66	0.83	o	470	1.20	1.10	470	o	3.84	2.42	33	e
0.61	0.805	p	390	1.24	1.12	390	p	4.48	2.74	27	n
0.55	0.775	e	330	1.28	1.14	330	e	5.27	3.135	22	∞
0.48	0.74	n	270	1.34	1.17	270	n				
0.40	0.70		220	1.42	1.21	220					
0.31	0.655		180	1.52	1.26	180					
0.23	0.615		150	1.62	1.31	150					
0.12	0.56		120	1.78	1.39	120					
0.03	0.515	∞	100	1.94	1.47	100	∞				

Fig. 9.25 - PCB 2 in KZ91 and KZ91-1 (HESG 439 691)



LB3 Starting char.: circle, code Z1/: o o--o o o--o o--o o
Starting char.: lense 108°, code Z2/: o--o o o--o o o o--o

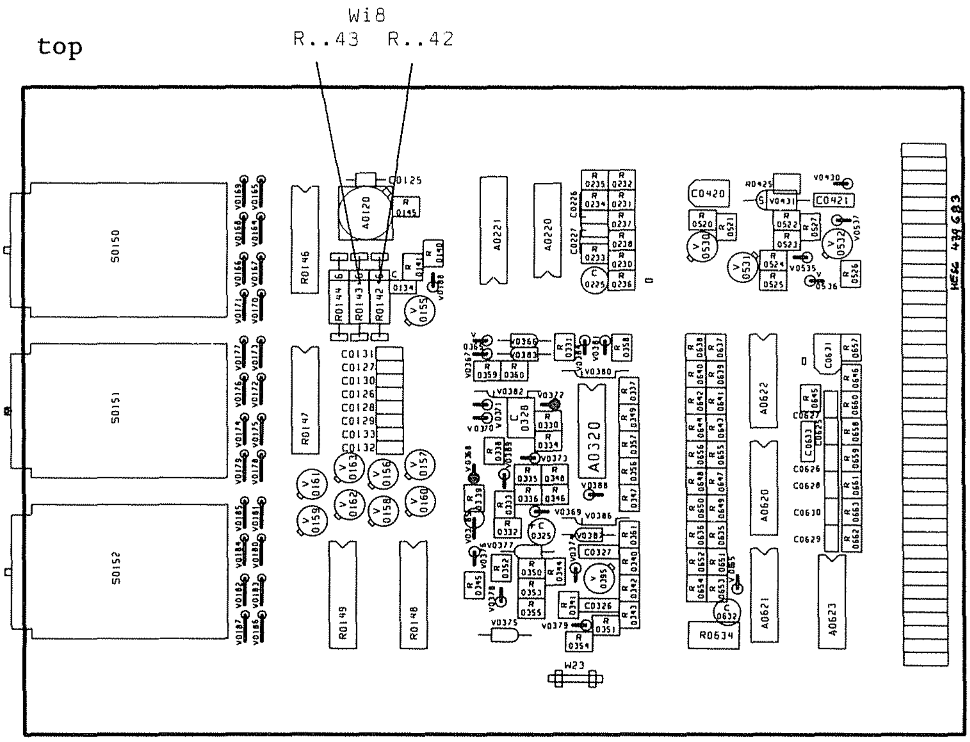
Wi4 Starting char. about origin, code Z./1/ R..51 47 k
Starting char. off-set, code Z./xy/ R..51 see table

xy	0.26	0.39	0.57	0.69	0.84	1	2.14	3.13	3.91
R..51 (kΩ)	180	120	82	68	56	47	22	15	12

Resistor rating: 0.25 W

LB14 Frontplate signals operational, code FA1: o--o
Frontplate signals non-operational, code FA2: -o o-

Fig. 9.26 - PCB 3 in KZ91 and KZ91-1 (HESG 439 692)

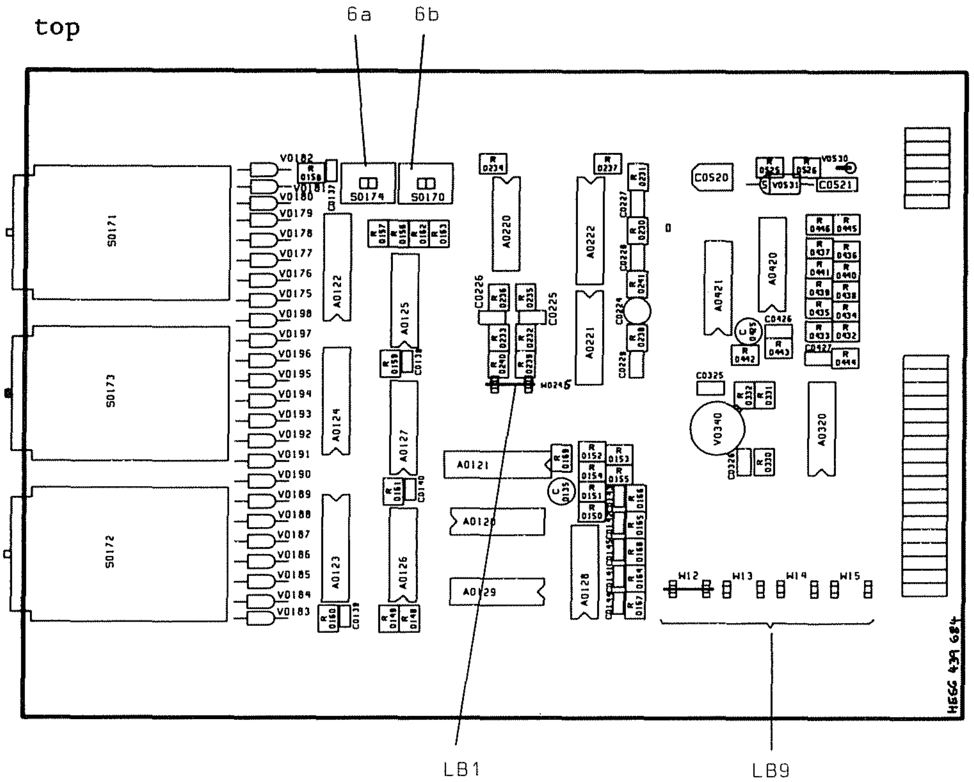


Wi8 Overreach $Z_{US} = 1.5 \times Z_1$, code US1.5 (standard)
Overreach $Z_{US} = 1.5 \times Z_1$, code US... see table

Z_{US}/Z_1	R..42 (kOhm) (1%)	R..43 (kOhm) (1%)	Z_{US}/Z_1	R..42 (kOhm) (1%)	R..43 (kOhm) (1%)
1	∞	∞	2	4.75	0
1.05	47.5	47.5	2.25	3.32	0.475
1.1	47.5	0	2.5	2.21	1
1.15	27.4	3.92	2.75	1.5	1.21
1.2	18.2	5.62	3	1.82	0.562
1.25	18.2	0.825	3.25	1.82	0.274
1.3	15	0.825	3.5	1.82	0.0825
1.35	12.1	1.5	3.75	1.5	0.221
1.4	10	1.82	4	1.5	0.0825
1.45	8.25	2.21	4.25	1	0.475
1.5	* 4.75	* 4.75	4.5	1.21	0.15
1.6	5.62	2.21	4.75	1.21	0.0562
1.7	3.92	2.74	5	1	0.182
1.8	5.62	0.332			
1.9	4.75	0.562			

* standard
(note: R..44 is always 4.75 kOhm)

Fig. 9.27 - PCB 5 in KI91, KZ91, KZ91-1 (HESG 439 683)



6a Switch 6a: position 1 $\cancel{t}_1$: zone 1 blocked
position 2 t_1 : zone 1 operational

6b Switch 6b: position 1 : zone 3 timer multiplier k_t = 0.1
position 2 : zone 3 timer multiplier k_t = 1

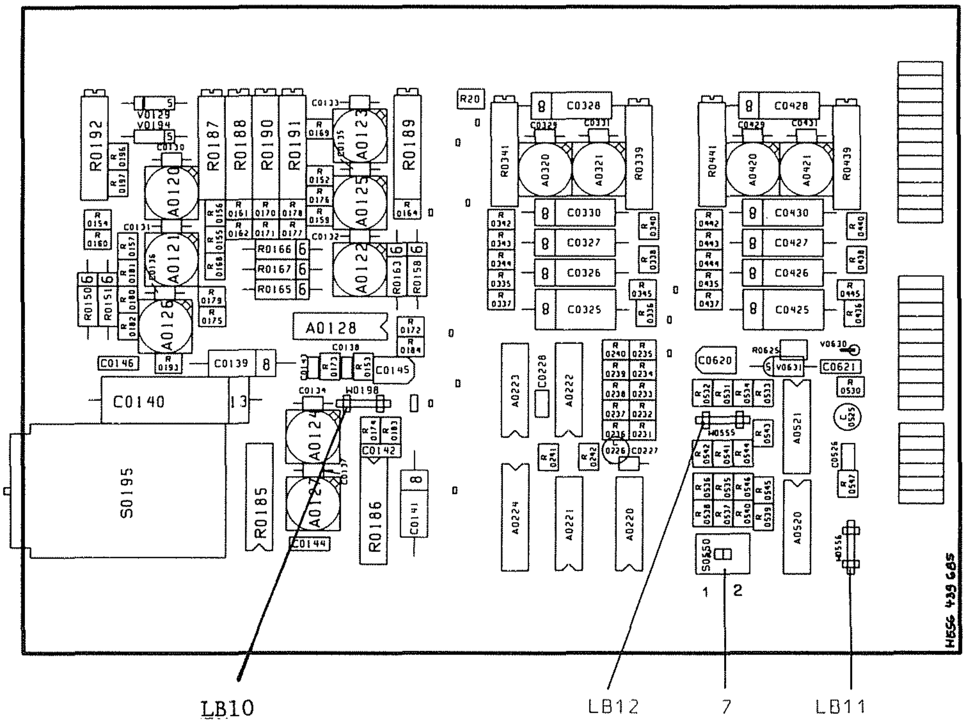
LB1 Rated frequency 50 Hz, code F5: soldered link LB1 closed
Rated frequency 60 Hz, code F6: soldered link BL1 open

LB9 One zone with reversed direction (see table)

code	W12	W13	W14	W15
R2.	o--o	o o	o o	o o
R1.	o o	o--o	o o	o o
R3.	o o	o o	o--o	o o
R4.	o o	o o	o o	o--o
R5.	o o	o o	o o	o o
zone	t_2	t_1	t_3	t_4

Fig. 9.28 - PCB 6 in KI91, KZ91, KZ91-1 (HESG 439 684)

top



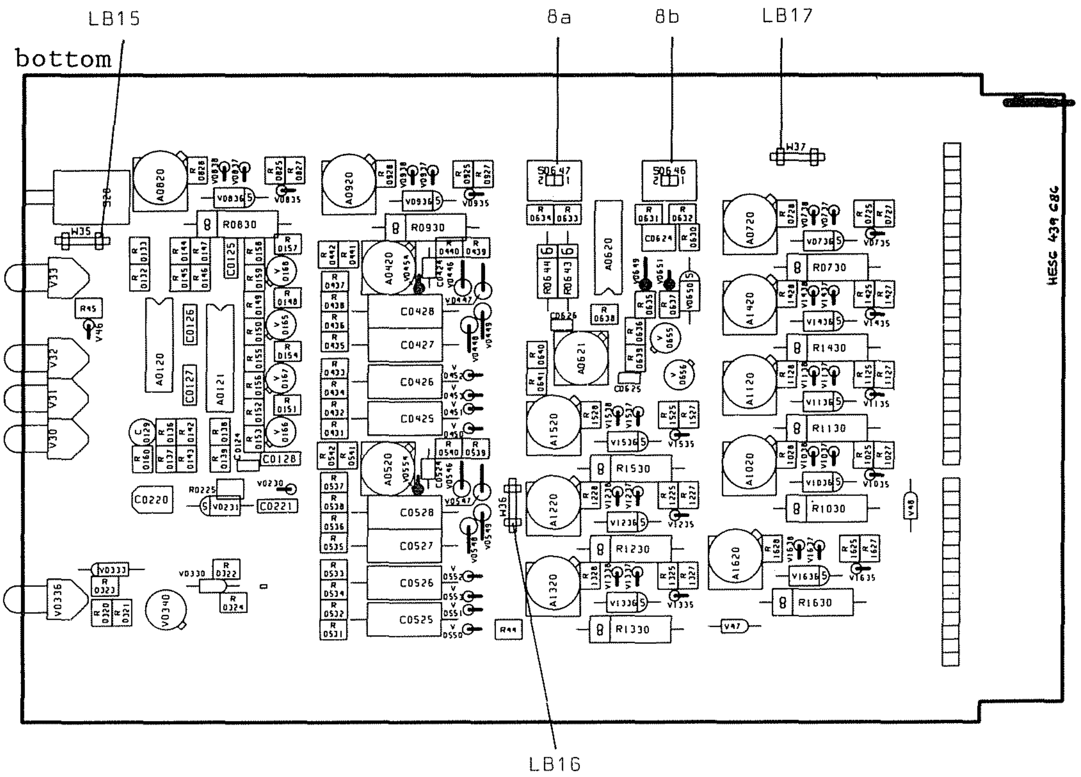
<u>7</u> Switch 7: position 1 $t_4 \rightarrow$: zone 4 directional
position 2 $t_4 \leftrightarrows$: zone 4 non-directional

<u>LB11</u> Zone 4 less reactance characteristic, code E0. : o--o
Zone 4 plus reactance characteristic, code E1. : -o o-

<u>LB12</u> Zone 4 less resistance characteristic, code E0. : o--o
Zone 4 plus resistance characteristic, code E1. : -o o-

<u>LB10</u> Reference voltage = fault voltage, without code: o--o o (for KI91, KZ91)
Reference voltage = fault voltage, without code: o o--o (for KZ91-1)

Fig. 9.29 - PCB 7 in KI91, KZ91, KZ91-1 (HESG 439 685)



8a Switch 8a: position 1 8b : direction as given on 8b
position 2 t ⮌ : direction as given on 8b, but one zone reserved

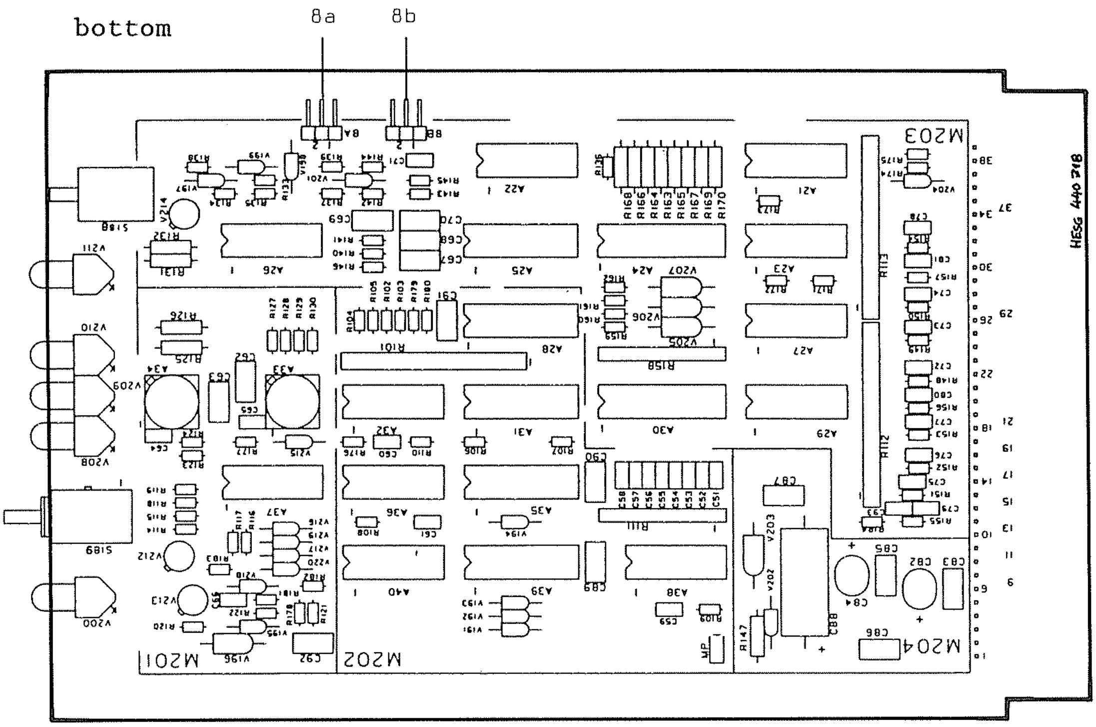
8b Switch 8b: position 1 I ← : direction reversed
position 2 I → : forwards direction into the line
(if wired according to wiring diagram)

LB15 Frontplate signals operational, code FA1 : o--o
Frontplate signals non-operational, code FA2: -o o-

LB16 With defect signalling during
testing via test socket, code V10 : o--o
Without defect signalling during
testing via test socket, code V11 : -o o-

LB17 Reversal of direction by external signal, code R5 : o--o
The position of LB17 is given for codes R1. to R4.
and correspondingly soldered at the works.

Fig. 9.30 - PCB 8 in KI91, KZ91, KZ91-1 (HESG 439 686)

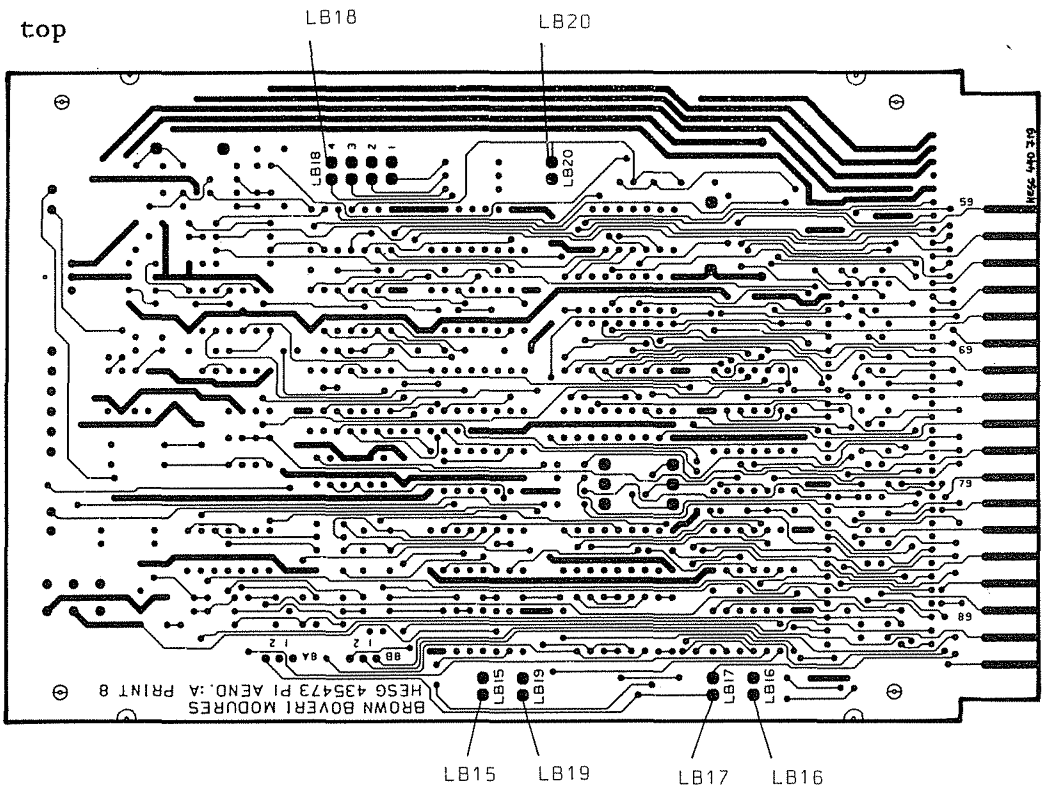


8a Plug-in link 8a:
position 1 I ⇄ : o (o--o) direction as set on frontplate switch I ⇄
position 2 t ⮌ : (o--o) o direction as set on frontplate switch I ⇄ but one zone reversed

8b Plug-in link 8b:
position 1 ⇄ : o (o--o) overreach (acceleration scheme)
position 2 PUTT : (o--o) o permissive underreaching transfer tripping (providing the scheme is wired)

LB15...LB20 see Fig. 9.32

Fig. 9.31 - PCB 8 in KI91, KZ91, KZ91-1 (HESG 440 718)



LB15 Frontplate signals (LED's on PCB 8)
operational — code FA1 : o--o
Frontplate signals (LED's on PCB 8)
non-operational — code FA2 : -o o-

LB16 With defect signalling during
testing via test socket, — code V10 : o--o
Without defect signalling during
testing via test socket, — code V11 : -o o-

LB17 Reversal of direction by external signal, — code R5. : o--o

LB18 Soldered links 1 to 4 open: no intentional zone 1 delay
One or more of the soldered links 1 to 4 closed:
Zone 1 delayed by the sum of the weightings times the power system period (T_N)

link 1: 1 x T_N : o--o
link 2: 2 x T_N : o--o
link 3: 4 x T_N : o--o
link 4: 8 x T_N : o--o

LB19 Signals maintained until reset : -o o-
Signals only maintained if relay trips : o--o

LB20 Directional measurement taken into account when operating in a PUTT scheme (plug-in link 8b in position 2 PUTT) : -o—o-

Fig. 9.32 - PCB 8 (soldered side) in KI91, KZ91, KZ91-1 (HESG 440 719)

ABB
ASEA BROWN BOVERI

Test Report for Distance Relay Type LZ91

Station: Line: Relay No.: Grading table dated:

Code No. EW91 .... KI91 ....

U_N = ...[V] I_N = ...[A] I_{Ph} x 0,1 I_N = ... [A]

m_1 = ... N_1 = ... X_1 = ...[Ω/Ph] t_1 = ... [s]

m_2 = ... N_2 = ... X_2 = ...[Ω/Ph] t_2 = ... [s]

m_3 = ... N_3 = ... X_3 = ...[Ω/Ph] t_3 = ... [s]

$|k_0|$ x 0,1 = ... φk_0 x (-20°) = ... R/X = ... t_4 = ... [s]

Relay test

Fault	Starting units				Measuring unit [Ω/Ph]							
	I_{Phase} [A]		I_Σ [A] *		1st zone		2nd zone		3rd zone		overreach	
	specified	measured	specified	measured	specified	measured	specified	measured	specified	measured	specified	measured
R - 0												
S - 0							—	—	—	—	—	—
T - 0							—	—	—	—	—	—
R - T	—	—	—	—			—	—	—	—	—	—
S - R	—	—	—	—			—	—	—	—	—	—
T - S	—	—	—	—								

	Time steps		Operating time t [s]									
	Test impedance		1st zone		2nd zone		3rd zone		4th zone		Overreach	
	[°]	[Ω/Ph]	specified	measured	specified	measured	specified	measured	specified	measured	specified	measured
R - 0												
T - S					—	—	—	—	—	—	—	—

PCB settings

1 : Mode

1 ⅄ ☐, 2 △ ☐ Selection logic ....

6a : 1 $\cancel{t}$ ☐, 2 t_1 ☐

6b : 1 k_t = 0,1 ☐, 2 k_t = 1 ☐

7 : 1 t_4 → ☐, 2 t_4 ↔ ☐

8a : 1 8b ☐, 2 t ↩ ☐ zone....

8b : 1 ← I ☐, 2 → I ☐

at HESG 440718 (Print 8)

8a : 1 I ⇄ ☐, 2 t ↩ ☐ zone ....

8b : 1 ⇄ ☐, 2 PUTT ☐

Overcurrent starting : $\frac{I_\Sigma}{I_{Ph}}$ = ...

Overreach: .... x X_1

Reactance slope 5° ☐, other angles ....

* Only for mode △

Remarks:

Circuit-breaker:
V.t's:
C.t's:

Ancillary equipment:

Tested by:
Date:
Signed:

83-01-21	Lo.		SK - HESG 5001

ABB
ASEA BROWN BOVERI

Test Report for Distance Relay Type LZ92 ☐, LZ92-1 ☐

Station: Line: Relay No.: Grading table dated:

Code No. EW91 .... KZ91 , KZ91-1 ....

U_N = ... [V]
I_N = ... [A]
Z x H/I_N = ... [Ω/Ph]
I_{Σ} x 0,2 I_N = ... [A]

m_1 = ...
N_1 = ...
X_1 = ... [Ω/Ph]
t_1 = ... [s]

m_2 = ...
N_2 = ...
X_2 = ... [Ω/Ph]
t_2 = ... [s]

m_3 = ...
N_3 = ...
X_3 = ... [Ω/Ph]
t_3 = ... [s]

$|k_0|$ x 0,1 = ...
φk_0 x (-20°) = ...
R/X = ...
t_4 = ... [s]

Relay test

Fault	Starting units			Measuring unit [Ω/Ph]							
	specified		measured	1st zone		2nd zone		3rd zone		Overreach	
	[°]	[Ω/Ph]	[Ω/Ph]	specified	measured	specified	measured	specified	measured	specified	measured
R - 0											
S - 0						—	—	—	—	—	—
T - 0						—	—	—	—	—	—
R - T						—	—	—	—	—	—
S - R						—	—	—	—	—	—
T - S											

	Time steps		Operating time t [s]									
	Test impedance		1st zone		2nd zone		3rd zone		4th zone		Overreach	
	[°]	[Ω/Ph]	specified	measured	specified	measured	specified	measured	specified	measured	specified	measured
R - 0												
T - S					—	—	—	—	—	—	—	—

PCB settings

1 : Mode (LZ92)
1 ⅄ ☐ , 2 △ ☐ Selection logic.........

1 : Mode (LZ92-1) Switch

Nr. 1	Nr. 2	Nr. 3	Nr. 4	Mode

6a : 1 $\cancel{t}$ ☐, 2 t_1 ☐
6b : 1 k_t = 0,1 ☐, 2 k_t = 1 ☐
7 : 1 t_4 → ☐, 2 t_4 ↔ ☐
8a : 1 8b ☐, 2 t ⮌ ☐ Zone........
8b : 1 ← I ☐, 2 → I ☐
bzw. ab HESG 440718 (Print 8)
8a : 1 I ⇄ ☐, 2 t ⮌ ☐ Zone........
8b : 1 ⇌ ☐, 2 PUTT ☐

Impedance starting: Circle ☐, Lense ☐
without off-set ☐, with off-set X_A / X_B =......
Factor $\frac{1+k_0}{2}$ = ...
Overreach: .... x X_1
Reactance slope 5° ☐, other angles ....

Remarks:

Circuit-breaker:
V.t's:
C.t's:

Ancillary equipment:

Tested by:
Date:
Signed:

83-01-20	Lo.		SK - HESG 5002

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It is scarcely possible for the operating instructions of technical equipment to cover every eventuality which can occur in practice. We would therefore request you to notify us or our agent in the case of all unusual behaviour, which does not appear to be covered by these operating instructions.

It is pointed out that all local regulations must be observed when connecting and commissioning this equipment in addition to these operating instructions.

Any work that has to be carried out inside the equipment, such as changing soldered links or fitting or removing resistors, may only be performed by correspondingly qualified personnel.

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