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3. Basic Principles for Setting the Test Set

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3. Basic Principles for Setting the Test Set

3.1. Settings

3.1.1. Parameters

The test set XS92b enables three voltages and three currents of a fault on a three-phase system to be simulated. The parameters can be entered either as fault current, voltage and phase-angle, as source and fault impedances or as absolute values. The desired method is determined by entering the test mode or the control parameter MOD.

3.1.2. Injection voltages

The setting range of the three phase-to-neutral injection voltages is 0 to 70.0 V AC (25 VA at 70 V using AU92). The smallest increment is 0.1 V.
One voltage (L1 phase) can also be varied in the range 0 to 220.0 V AC (20 VA using AU92) in steps of 0.1 V.

3.1.3. Injection current

The current setting range is 0 to 20.00 A r.m.s. and the smallest increment is 0.01 A. The maximum output voltage must not exceed 5 V r.m.s. (100 VA at 20 A).

3.1.4. Frequency

The rated frequency of the test signals can be set between 40.00 and 70.00 Hz in steps of 0.01 Hz and a frequency gradient (df/dt) of 0.4 to 5 Hz/s in steps of 0.1 Hz/s.

3.1.5. Phase-angle

The phase-angles between the voltages and currents are either determined by the processor on the basis of the kind of fault simulated or can be entered directly. The setting range is 0 to 359°. The smallest increment is 1°.

Note:

In the case of impedance relays, this angle is defined as being positive in the anti-clockwise direction in relation to the **current** phasor. This simplifies the representation in the R/X plane. For all other relays (e.g. power relays) the positive direction is also defined as being anti-clockwise, but referred to the **voltage** phasor.

3.1.6. Impedances

The test set can also determine the injection current and voltages from impedance values (amplitude and phase-angle) which have been entered.

Source impedance Z_S:

Setting range 0 to 220.0 Ω
Increments 0.1 Ω
Phase-angle 0 to 90°
Smallest increment 1°

Zero-sequence compensation k_S:

The zero-sequence compensation k_S is necessary to simulate ground faults accurately and is defined as:

$$k_S = \frac{Z_{ES}}{Z_S} = \frac{Z_{S0} - Z_S}{3 Z_S}$$

where Z_{ES} = ground impedance of the source
Z_{S0} = zero-sequence source impedance
Z_S = positive-sequence source impedance

Setting range $|k_S|$ = 0 to 5
Smallest increment 0.1
Phase-angle φ_{k_S} = 0 to -90° (the absolute difference $|\angle Z_{ES} - \angle Z_S|$ = 0 to 90° is set)

Smallest increment 1°

Fault impedance Z_L:

Setting range 0 to 99.99 Ω
Increment 0.01 Ω
Phase-angle 0 to 359°
Smallest increment 1°

Line zero-sequence compensation k_{0L}:

The zero-sequence compensation k_{0L} is necessary to simulate ground faults accurately and is defined as:

$$k_{0L} = \frac{Z_E}{Z_L} = \frac{Z_0 - Z_L}{3 Z_L}$$

where Z_E = ground impedance of the line
Z_0 = zero-sequence line impedance
Z_L = positive-sequence line impedance

Setting range $|k_{0L}|$ = 0 to 5
Smallest increment 0.1
Phase-angle $\varphi_{k_{0L}}$ which is defined as ($\angle Z_E - \angle Z_L$) is +90° to -180°
Smallest increment 1°

Positive angles of 90° to 1° corresponds to settings of 270° to 359° (i.e. 360° less the desired angle).
Zero and negative angles of 0° to -180° correspond to the input of the same angles without any sign.

3.1.7. Fault duration

The duration of injection (fault duration TF) can be set in a range of 0 to 999 s. The actual duration is rounded to the next full period of the current signal by the processor. The smallest setting increment is 1 ms.
The minimum injection time is not zero, but the time required to calculate the values for the next injection and this is dependent on the mode of calculation.

3.1.8. Pre-fault injection of load or zero voltages

In the case of dynamic testing (see Section 5.2.), a time can also be set between 100 and 9999 ms during which the voltages applied to the relay under test are either at their pre-fault load level or at zero.

3.2. Determining the settings

The procedure for entering settings is described in Section 4.2.

3.2.1. Entering three voltages and three currents

Values for the three phase voltages U_R (UL1), U_S (UL2) and U_T (UL3), the currents I_R (IL1), I_S (IL2) and I_T (IL3) and the phase-angles may be entered directly. **For this purpose, the R (L1) phase voltage U_R (UL1) is the reference for the phase-angles of the other five variables** and the anticlockwise direction is defined as being positive.

3.2.2. Entering fault current and voltage

The parameters current I, voltage U and phase-angle φ are entered together with the kind of fault (parameter FC, see Section 4.3.1.).

The voltage U to be entered is the voltage across the fault impedance loop, i.e. for a fault between the phases R (L1) and S (L2), U is the phase-to-phase voltage U_{RS} (U_{L1-L2}).

The corresponding current I is entered according to the kind of fault, i.e. for a fault between R and S (L1-L2) the current is $I_R = I_S$ ($I_{L1} = I_{L2}$).

The angle φ is the angle between the simulated fault current I (reference) and the voltage U — in this example between the current I_R and voltage U_{RS} (see Fig. 3.1). The relationship between the voltages under load and under fault conditions is given in Figures Fig. 3.1 and Fig. 3.2.

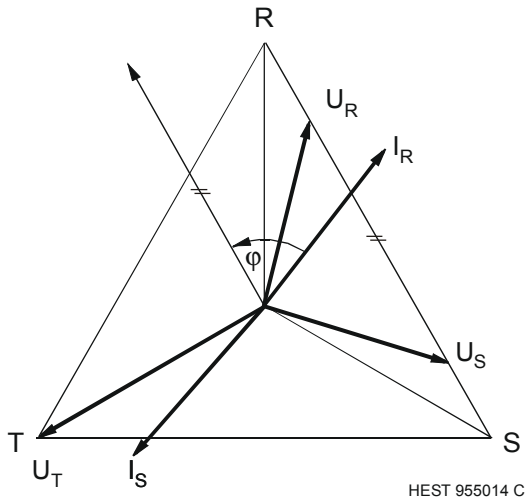

Fig. 3.1 Voltage and current phasors for a phase-to-phase fault R to S

The processor determines the three voltages and the current to be applied to the relay for the desired fault from the parameters and the kind of fault entered. For the R to S fault of Fig. 3.1, these are the voltages U_R, U_S and U_T and the current I_R respectively I_S.

Fig. 3.2 shows the diagram for a phase-to-ground fault on T phase. In this case the voltage U and current I to be entered are U_T and I_T. The angle φ is the one between I_T and U_T.

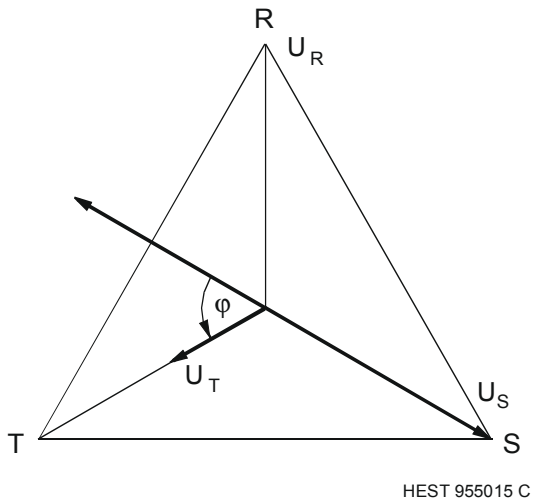

Fig. 3.2 Voltage and current phasors for a phase-to-ground fault on T phase

3.2.3. Entering impedances

The phases concerned in the fault are also determined in this case by the kind of fault FC entered (see Section 4.3.1.).

The test current and the three test voltages to be entered are derived from the values of source impedance Z_S and the fault impedance ZL (φ_S and φ_L are the corresponding phase-angles). The zero-sequence compensation factors k_{0L} and k_S are also taken into account for the simulation of ground faults.

The injection signals are calculated as follows:

Earth faults (e.g. S phase)

$$I_S = \frac{U_{SN}}{Z_S e^{j\varphi_S}\ (1 + k_S e^{j\varphi k_S})\ +\ Z_L e^{j\varphi_L}\ (1 + k_{0L} e^{j\varphi k_{0L}})}$$

$$I_R = 0,\ I_T = 0$$

$$U_S = U_{SN} \frac{(1 + k_{0L} e^{j\varphi k_{0L}})\ Z_L e^{j\varphi_L}}{Z_S e^{j\varphi_S}\ (1 + k_S e^{j\varphi k_S})\ +\ Z_L e^{j\varphi_L}\ (1 + k_{0L} e^{j\varphi k_{0L}})}$$

$$U_R = U_{SN}\, e^{j+120^\circ} - I_S \cdot Z_S e^{j\varphi S} \cdot k_S e^{j\varphi k_S}$$

$$U_T = U_{SN}\, e^{j-120^\circ} - I_S \cdot Z_S e^{j\varphi S} \cdot k_S e^{j\varphi k_S}$$

Zero-sequence compensating factors:

Line: $$k_{0L} e^{j\varphi k_{0L}} = \frac{Z_E e^{j\varphi_E}}{Z_L e^{j\varphi_L}}\ ;$$

Source impedance: $$k_S e^{j\varphi k_S} = \frac{Z_{ES} e^{j\varphi_{ES}}}{Z_S e^{j\varphi_S}}$$

where

N	:	suffix for rated voltage (57.7 V) of the particular phase
Z_E	:	amplitude of the ground path impedance
φ_E	:	phase-angle of the ground path impedance
Z_{ES}	:	amplitude of the ground path impedance of the source
φ_{ES}	:	phase-angle of the ground path impedance of the source.

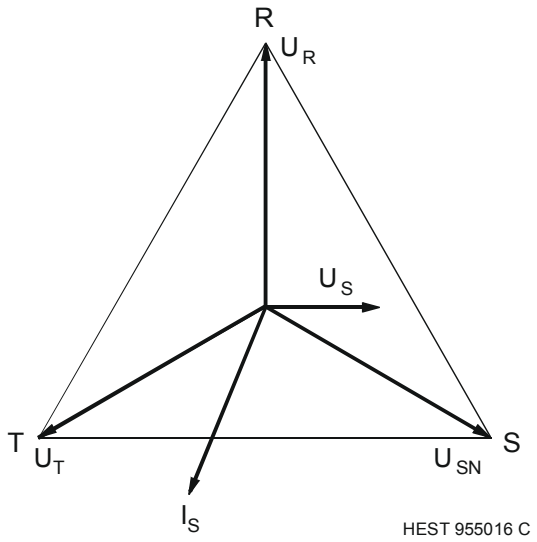

Fig. 3.3 Voltage and current phasors for a ground fault on S phase

Phase-to-phase faults (e.g. between R and S phases)

$$I_R = \frac{U_{RN} - U_{SN}}{2\,(Z_S e^{j\varphi_S} + Z_L e^{j\varphi_L})}$$

$$I_S = -I_R \;;\quad I_T = 0$$

$$U_R = \frac{U_{RN} + U_{SN}}{2} + I_R\; Z_L e^{j\varphi_L}$$

$$U_S = \frac{U_{RN} + U_{SN}}{2} - I_R\; Z_L e^{j\varphi_L}$$

$$U_T = U_{TN}$$

Three-phase faults

$$I_R = \frac{U_{RN}}{Z} \;;\; I_S = \frac{U_{SN}}{Z} \;;\; I_T = \frac{U_{TN}}{Z}$$

$$U_R = U_{RN}\frac{Z_L e^{j\varphi_L}}{Z} \;;\; U_S = U_{SN}\frac{Z_L e^{j\varphi_L}}{Z} \;;\; U_T = U_{TN}\frac{Z_L e^{j\varphi_L}}{Z}$$

$$Z = Z_S e^{j\varphi_S} + Z_L e^{j\varphi_L}$$