SIEMENS

Transformer differential protective relay system
7UT92 (RT22c)

and accessories

Instructions Order No. C73000–B1176–C19–1

Transformer differential protective relay	**7UT92** (RT 22c)
Stabilizing unit	**7UT93** (RT 23)

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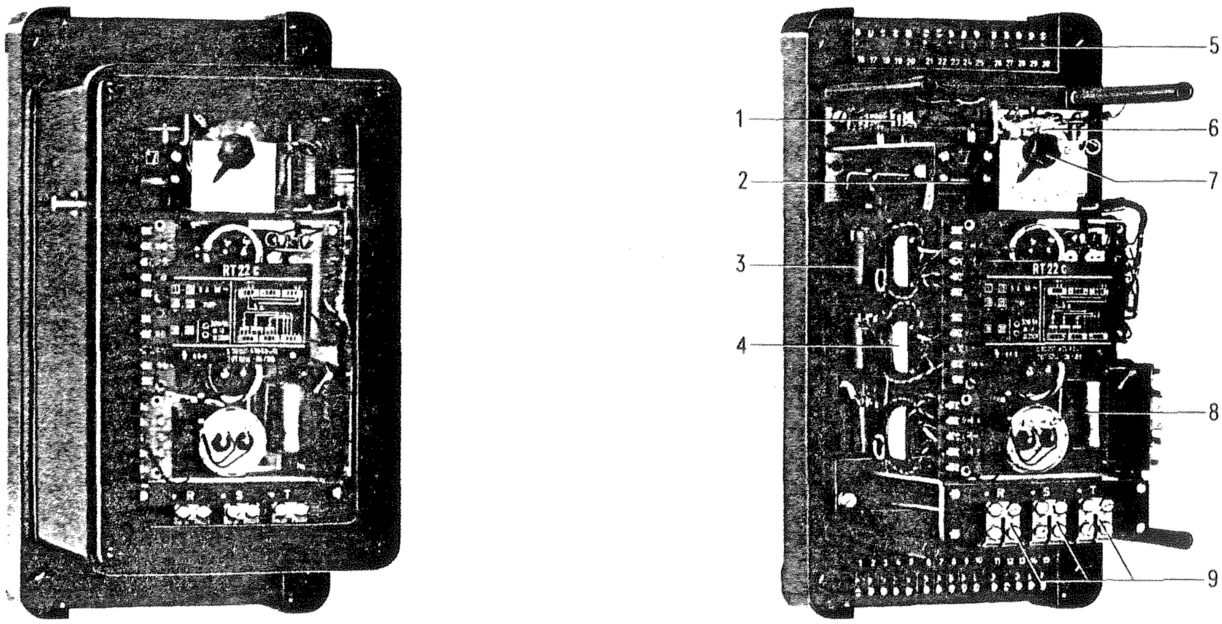


1 Resistors r28 to r31
2 Tripping target indicator
3 Stabilizing current transformer (f1 to f3)
4 Tripping current tra-former (f4 to f6)
5 Terminals
6 Measuring relay D (7RC 72)
7 Setting knob (pick-up value)
8 Filtering current transformer f7 (inrush current stabilization)
9 Links (fault-current measuring point)

Fig. 1 Transformer differential protective relay system 7UT92 (RT 22c)

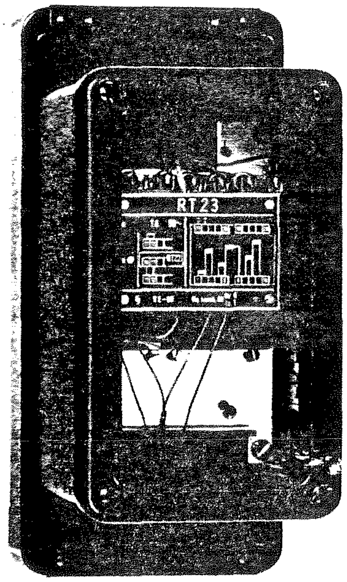
Description

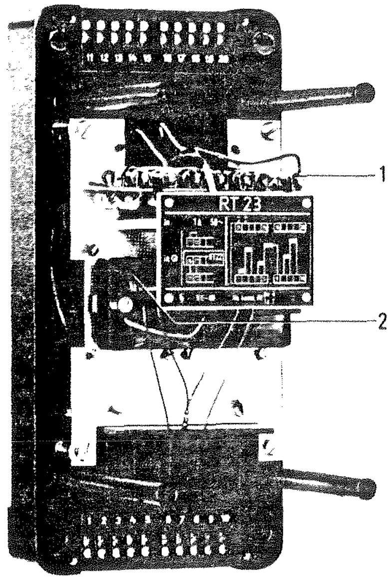
Application

The differential protective relay system 7UT92 (RT 22c) detects all short-circuit-like faults within its protection zone which is marked by the current transformers.

In the case of transformers which have more than two windings brought out (multi-winding transformers), the differential relay system is supplemented by stabilizing unit 7UT93 (RT 23).

Differential protective relays should always be provided for transformers rated at 5MVA and above, as well as for parallel-connected transformers from 1MVA upwards for selectively tripping the faulted transformers.





1 Stabilizing rectifiers (n1 to n4)
2 Stabilizing current transformers (f1 to f6)

Fig. 2 Stabilizing unit 7UT93 (RT 23)

Technical data

For both 7UT92 (RT 22c) and 7UT93 (RT 23)

Degree of protection	IP50 to DIN 40 050	Providing protection against contact with implements of all kinds, and harmful dust deposits in the interior; no protection against water.
Ambient temperature	−5 to +40 °C	
Test voltage	2000 V, 50 Hz	
Conductor connected	6 mm², circular	
Resistance to vibration	max. 2 g	$g = 9.81\ m/s^2$
Allocation of terminals	7UT92: see Fig. 22 7UT93: see Fig. 23	
Specifications	VDE 0435	

Transformer differential relay system 7UT92

Rated current I_N	5 A or 1 A	
Rated frequency	50 Hz or 60 Hz	
Overload capacity of the current circuits	60 × rated current 20 × rated current 1.5 × rated current	for 1 s for 10 s continuously
Power consumption		
– per phase at rated current: Stabilizing circuit	0.12 VA	per half of centre-tapped current transformers f1 to f3
– per phase at rated current: Tripping circuit	0.25 VA	per winding of current transformers f4 to f6
– per phase at rated current: Filtering transformers in phase R and T	approx. 0.4 VA	per winding f11
– D.C. circuit	0 to 2.5 W; depending on the magnitude of the auxiliary voltage, plus 1 to 6 W	in normal operation during tripping
Auxiliary rated d.c. voltage	24 V 60 V 110 V 220 V	The particular auxiliary voltage is obtained by a built-in combination of resistors r28–r31 (please specify in an order)
Range	80 to 110 %	
Current transformer	.../5 A .../1 A	Minimum 10 VA, accuracy class 10 P 10 (previously 3 %, saturation factor greater than 10) If losses in the leads are considerable (> 2 to 3 W at rated current), larger current transformers should be used.
Measuring relay D	Current relay	Special model
Setting range (Steplessly variable)	0.2 to 0.4 × rated current, referred to a three-phase short-circuit	
Relay H	Cradle relay N	Suitable for operation on associated auxiliary tripping relay 7PA10 or 7PA50
Contacts	1 NO contact	
Switching current	1 A maximum	
Switching voltage	250 V maximum	
Switching capacity	30 W/VA	Making or breaking
Material of contact face	Silver	
Target indicator	Electrically operated	Reset from outside
Tripping time with a setting of 0.2 × rated current (excluding associated auxiliary tripping relay		at twice the rated current
	35 to 55 ms 20 to 30 ms	at 2 × rated current at 10 × rated current
Minimum response time	15 to 25 ms	
Enclosure	7XP7 02.–2 (EG 12)	
Weight	Approx. 6.8 kg	

Stabilization unit 7UT93

Rated current	5 to 1 A	
Frequency	50 to 60 Hz	
Overload capacity of current circuits	60 × rated current 20 × rated current 1.5 × rated current	for 1 s for 10 s continuously
Power consumption per phase at rated current	Approx. 0.12 VA	f1 to f6
Enclosure	7XP7 01.–2 (EG 11)	
Weight	4.0 kg	

Mounting

The base is of cast aluminium; the cover with glass front is of drawn sheet (Figs. 1 and 2). The cases comply with degree of protection IP 50. All cases are lead-sealed before delivery. Depending on the design they can be used for surface-mounting or flush mounting on switchboards (with rubber cover frame). On terminal strip at the top and one at the bottom of the case enable the relay to be connected from the front or rear.

Relay system 7UT92 incorporates three current transformers (f1 to f3) in the stabilizing circuit and three current transformers (f4 to f6) in the tripping circuit. Another current transformer (f11) is provided for the built-in stabilizing device to guard against the effects of inrush current (harmonic filter).

A rectifier bridge circuit with measuring relay D and a non-linear resistor combination establishing the operating time characteristic of the relay are provided on the secondary side of the current transformers f1 to f11. Measuring relay D has two windings:

The first is the measuring winding; voltage is impressed on the second by the current inrush stabilization device in the restraining sense only (see "Operation").

The resistors r28 to r31 matches the auxiliary d.c. voltage to switching relay H. The resistors can be easily replaced should a change in the d.c. voltage of the transformer substation make this necessary. The switching relay energizes a separate auxiliary relay, the contacts of which operate the circuit-breaker.

The protective relay is stabilized so as to be proof against spurious currents caused by:

- inaccuracy of the current transformer;
- saturation effects of the current transformer due to large currents;
- tap-changing control of the transformer within 75 and 125 % of its rated voltage;
- inrush currents of any magnitude and time characteristic occurring in actual practice.

The stabilizing unit 7UT93 incorporates six instrument transformers (f1 to f6).

The secondary side of the instrument transformer is connected to a rectifier circuit which, in turn, is connected via terminals 11 and 12 to the stabilization side of the rectifier bridge in the differential relay system 7UT92. This system represents a d.c. bridge whose stabilization side carries the arithmetic sum of the stabilizing currents produced by the main current transformers (see "Operation").

The protective system is equipped with separate matching transformers to feed equal currents to the differential relay from both ends of the zone of protection. These matching transformers are used to match the magnitude and phase relations of the secondary currents e.g. type 4AM5.

Mode of operation

Comparison of currents

The differential protective relay compares the currents at the end of the protection zone. All points of an electrical conductor from which no current is derived or to which no current is fed carry a current equal in direction and magnitude at each particular instant (Also in an a.c. circuit the electrons flow in the same direction at a particular instant). Consequently, the inflowing and outflowing currents at both ends of the protection zone are equal as long as the system is in an unfaulted condition. Any difference between the two currents indicates that there is a connection to a circuit external to the protected line and, unless this connection is an integral part of the circuit, a fault exists in the zone of protection.

Fig. 3 shows a fault in the zone of protection owing to a connection at "F" with another external circuit. In this condition the currents I_1 and I_2 flow into the zone of protection if infeed is from both ends. The direction of the current flowing into the protection zone will be referred to in the following as "positive". This agrees basically with the balance comparison system of a differential relay and is used to advantage when systems, particularly those having more than two outgoing feeders, are analysed mathematically.

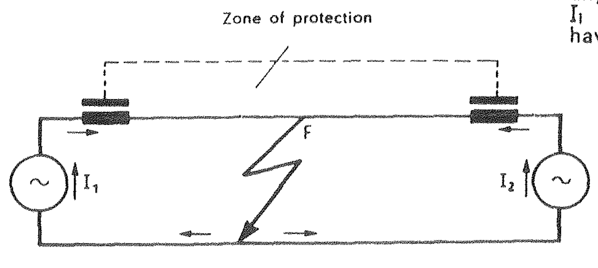


Fig. 3 Internal fault on line fed from both ends

The short-circuit is established through a phase or earth conductor. The currents flowing into the protection zone from both ends are checked by the relay system. The short-circuit current $I_1 + I_2$ flowing at the faulted point F is the fault current to which the comparison protection system responds.

In a healthy condition one of the two currents flows in a direction opposite to that shown in Fig. 3. i.e. it has the opposite sign. Moreover, both currents are of equal magnitude in this case. In a plant having "n" outgoing feeders, the vectorial sum of all currents is zero in the unfaulted condition:

$$I_1 + I_2 + \ldots + I_n = 0$$

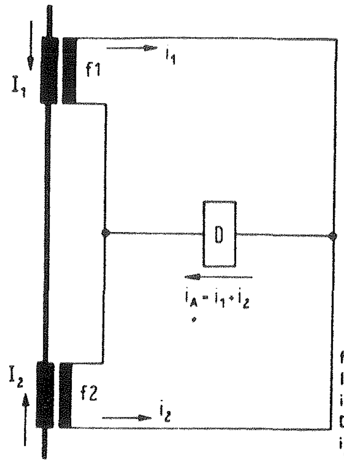
The currents flowing in the high-voltage system are fed to the relay via current transformers located at the limits of the protection zone of the differential relay system (Fig. 4).

The secondary windings of current transformers f1 and f2 are connected in series. A measuring relay D connected in the diagonal does not carry any current when the system is healthy because $I_1 + I_2 = 0$ (in the unfaulted condition I_1 and I_2 have opposite signs).

Should a short-circuit occur within the protection zone, a tripping current i_A proportional to the short-circuit current $I_1 + I_2$ on the high-voltage side flows through the measuring relay D.

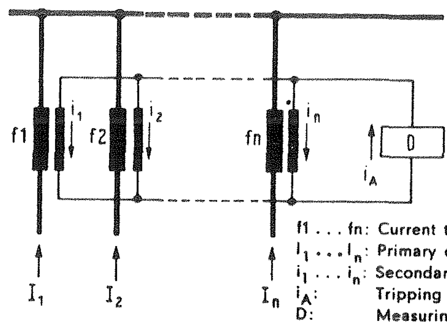
This principle applies also to plants fed from several ends (Fig. 5). In the event of a short-circuit in the protection zone, a tripping current proportional to the short-circuit current on the high-voltage side operates measuring relay D in the residual-current circuit.

$$i_A = i_1 + i_2 + \cdots + i_n$$



f1/f2: Current transformers
I_1/I_2: Primary currents
i_1/i_2: Secondary currents
D: Measuring relay
i_A: Tripping current

Fig. 4 Differential relay for a plant fed from two ends



f1 ... fn: Current transformers
$I_1 \ldots I_n$: Primary currents
$i_1 \ldots i_n$: Secondary currents
i_A: Tripping current
D: Measuring relay

Fig. 5 Differential relay in a plant fed from "n" ends

Owing to transformation errors of the current transformers f1 ... fn, the tripping current i_A in healthy systems is other than zero.

If a fault current traverses the protection zone of the differential relay, the primary sides of the current transformers f1 ... fn carry a multiple of the rated current and may reach their state of saturation. This may entail considerable errors with respect to the magnitude and phase relation of the secondary currents.

In tap-changing transformers, the ratio of primary to secondary current is governed by the particular tap. Since the differential relay system is calibrated for a definite transformation ratio, any other tap position will, even in unfaulted systems, cause a tripping current which is proportional to the load current.

The differential relay therefore has a stabilization feature to prevent undesirable tripping due to currents flowing in unfaulted systems and when high short-circuit currents are passing through.

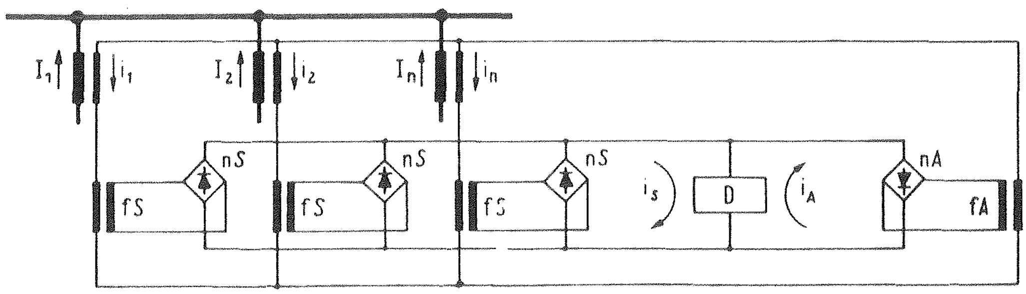
Stabilization against through fault currents

The likelihood of undesirable tripping is the greater the larger the current flowing through the protection zone is. For this reason, this current is used as the stabilization quantity by being fed to the measuring relay D in opposition to the tripping current i_A.

In a plant with "n" ends, the tripping current i_A is obtained initially by forming the vectorial sum of the individual currents $i_1, i_2 \ldots i_n$ (Fig. 6). The resulting a.c. current is fed to relay D through an interposing transformer f_A and a rectifier n_A. Ideally (i.e., no saturation of the current transformer), i_A would be zero in a healthy system.

The stabilization current is obtained first by stepping the individual currents $i_1, i_2 \ldots i_n$ down in an interposing current transformer f_s and rectifying them in rectifier n_s, the d.c. currents then being added arithmetically by parallel connection.

$$i_S = |i_1| + |i_2| + \ldots + |i_n|.$$



$I_1, I_2 \ldots I_n$: Primary currents

$i_1, i_2 \ldots i_n$: Secondary currents

fA: Interposing current transformer for tripping
nA: Tripping current rectifier
fS: Interposing current transformer for stabilization
nS: Stabilizing rectifier
D: Measuring relay

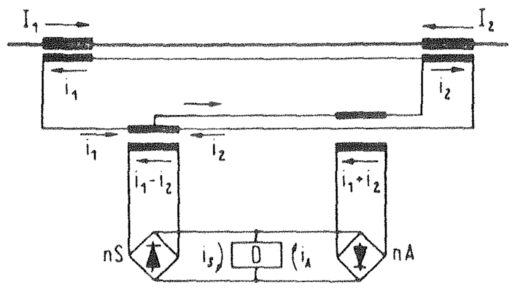
Fig. 6 Stabilized differential relay system for "n" outgoing feeders

Interposing transformer f_S steps the current down to a lower value than does interposing transformer f_A. Thus, in the event of a short-circuit in the protection zone fed from only one end, the tripping current i_A is larger than the current of interposing transformer f_S, and relay D picks up.

In plants having only two outgoing feeders the circuit design of the differential relay system is simplified. The stabilizing current i_S is formed by the vectorial difference $i_1 - i_2$ (Fig. 7).

If the short-circuit in the protection zone is fed from both ends, the stabilization effect is weakened, i.e. the sensitivity of the differential relay system is enhanced.

For transformers with two loaded groups of windings, the differential relay system is wired as shown in Fig. 7. For transformers having more than two loaded groups of windings the relay system is wired as in Fig. 6 since no definite difference can be formed if more than two variables are involved.



I_1, I_2: Primary currents
i_1, i_2: Secondary currents
n_S: Stabilizing rectifier
n_A: Rectifier for tripping
i_S: Stabilizing current
i_A: Tripping current
D: Measuring relay

Fig. 7 Stabilized differential relay system fed from two ends

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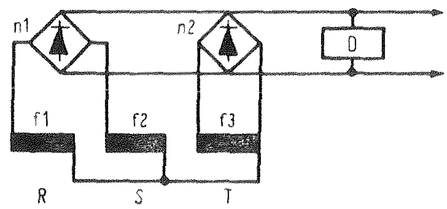
Circuit arrangement for three-phase relay systems

The comparison protection system for three-phase transformers and generators is established on the basis of Figs. 6 and 7.

The result is a full-wave rectifier circuit consisting of a single bridge and one measuring relay D (Fig. 8).



n1, n2: Stabilizing rectifiers
f1, f2, f3: Stabilizing current transformers
D: Measuring relay

Fig. 8 Rectification of three-phase current on the stabilizing side

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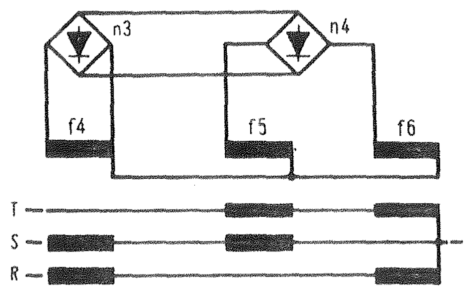
Increased sensitivity to earth faults

In the case of earth faults on either side of the protection zone limit (one fault within, one outside the protection zone), the fault current of a phase flows through the current transformers at both ends of the protection zone, thus affording a high degree of stabilization. The latter is cancelled by the interposing transformers on the tripping side which are connected in such a way that the currents of any two phases are summated (Fig. 9). This method affords doubled sensitivity of the relay for single-phase current, which is desirable particularly for double earth faults.

In balanced three-phase systems, the sum of two phase currents is effective in each of the three interposing transformers. This sum is equal in magnitude to the (negative) current of the third phase. This circuit affords the same sensitivity as would be the case if the phase current were fed to each interposing current transformer through one winding only.



n3, n4: Tripping rectifiers
f4, f5, f6: Tripping current transformers

Fig. 9 Interposing transformers and rectifiers on the tripping side

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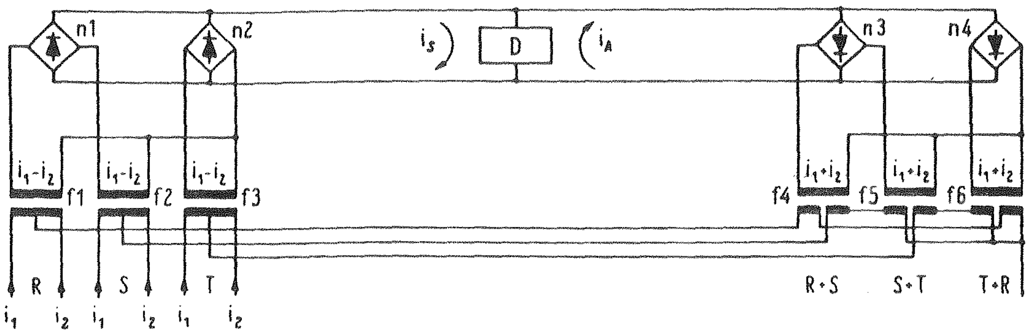
Sensitivity to the various kinds of fault

The complete circuit of the three-pase differential relay system (Fig. 10) shows the current flow in the interposing current transformers and rectifiers.

The analysis of the current flow in the interposing transformers and rectifiers indicates that, with equal magnitude of the impressed a.c. currents, the resulting d.c. current varies as a function of the share which the three phases and the neutral conductor have in the total current. From this it follows that the protective relay system as shown in Fig. 10 has different response values for the various kinds of fault.



Stabilizing side

Tripping side

Fig. 10 Three-phase differential relay system with increased sensitivity to earth faults

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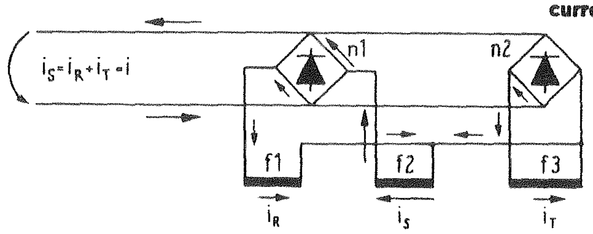
Three-phase current

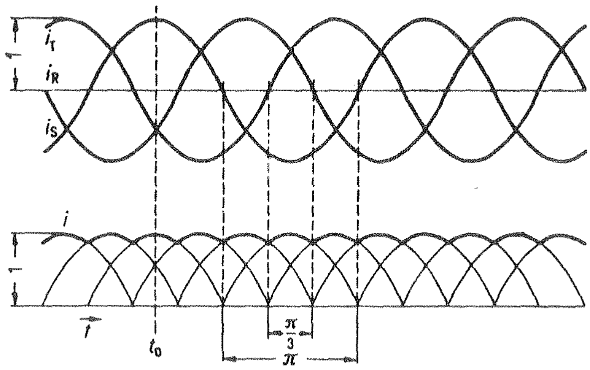
Fig. 11a shows the current flow at instant t_0 when phase S is carrying its maximum current $i_S = i_R + i_T$ (instantaneous value). The resulting d.c. current is then $i = i_S$. Since the three displaced phase currents are symmetrical, the d.c. current corresponds to the largest phase current also at any other instant. The change between two phases takes place when the third phase passes zero. Since the cycle time is 2π, any one phase carries the largest current for the period of $\pi/3$.

This full-wave rectification of balanced three-phase current gives the following mean d.c. current, assuming a peak value of 1 for each phase:

$$|i| = \frac{3}{\pi}\int_{-\frac{\pi}{6}}^{+\frac{\pi}{6}} \cos\varphi \, d\varphi = \frac{3}{\pi} \cdot 2\sin\frac{\pi}{6} = \frac{3}{\pi}$$



a) Current flow in the bridge circuit at the instant t_0



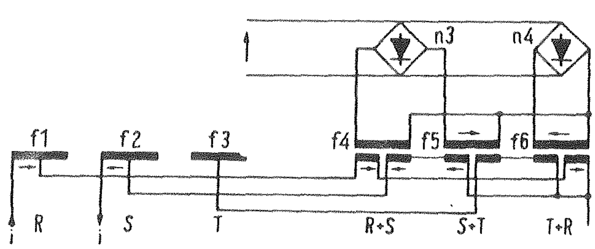
b) Three-phase current and d.c. current plotted versus time

Fig. 11 Rectification of balanced three-phase current

Two-phase current

Fig. 12 shows the rectification process specially for the tripping side of the protective relay system (to Fig. 10) in the event of a two-phase short-circuit. The usual full-wave rectification of a.c. current is used. The resulting mean d.c. current is

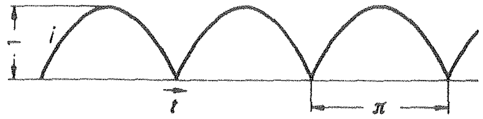
$$|i| = \frac{1}{\pi}\int_{-\frac{\pi}{2}}^{+\frac{\pi}{2}} \cos\varphi \, d\varphi = \frac{1}{\pi} \cdot 2\sin\frac{\pi}{2} = \frac{2}{\pi}$$



Stabilizing side

Tripping side

a) Current flow in the circuit system



b) D.C. current plotted versus time

Fig. 12 Rectification in the system shown in Fig. 10, with a two-phase short-circuit fed from one end

Single-phase current

In the event of an earth fault within the protection zone, or two earth faults with one fault point within the protection zone, a single-phase current flows on the tripping side. Its effect (Fig. 13) is double that of the two-phase current shown in Fig. 12.

As Figs. 11 and 13 show, the ratio of the d.c. currents on the tripping side varies as a function of the number of phases involved, assuming phase currents of equal magnitude:

$$\frac{\text{Fault}}{\text{single/two/three-phase}} = \frac{\text{D.C. current}}{4:2:3}$$

A definite d.c. current flowing through measuring relay D in the tripping sense is required to cause the relay system to respond. Accordingly, the tripping currents required under the various fault conditions (number of faulted phases) are inversely proportional to the above d.c. currents:

$$\frac{1}{4}:\frac{1}{2}:\frac{1}{3} = 3:6:4.$$

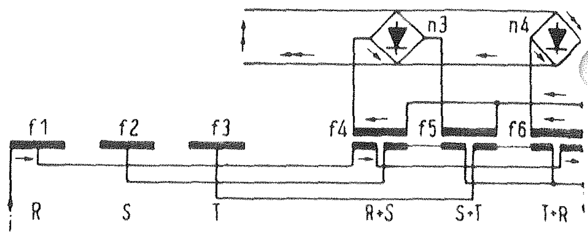


Fig. 13 Doubled effect of a single-phase current on the tripping side

Consequently, the ratio of the sensitivity of the differential relay system in Fig. 10 is 3 : 6 : 4.

Bent tripping current characteristic

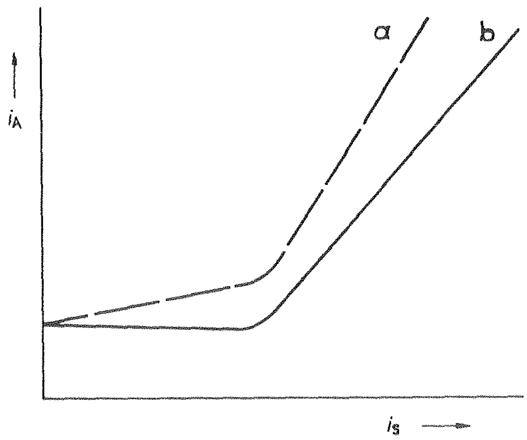
The influence of the stabilizing current i_s is not constant in differential relay systems for generators and transformers. The current transformers to which the relay is connected reach their specified accuracy within the range of about 5 to 10 times the rated current. This region of the characteristic curve therefore requires no powerful stabilization. The sensitivity of the protective relay to faults occurring within the zone of protection should be approximately constant, fully or almost independently of the load current traversing the zone of protection.

However, if a large fault current traverses the protection zone (short-circuit outside the protection zone), causing large transformation errors of the current transformers and thus setting up fault currents (saturation of the current transformers), a powerful stabilization effect must be established to prevent spurious tripping. To comply with these requirements, the differential protection relay system has a bent characteristic curve (Fig. 14).

The circuit arrangement necessary to obtain the desired characteristic is shown in Fig. 15.

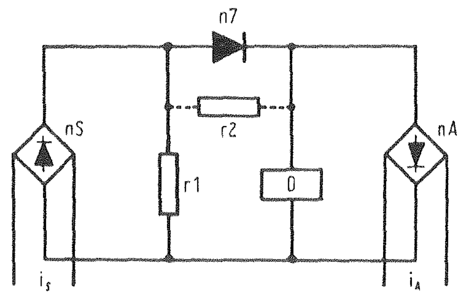
With this characteristic, only the tripping current i_A flows through the measuring relay D, the stabilizing side terminating at resistor r1 (resistor r2 is disregarded here). The half-wave rectifier n7 acting as an electrical valve becomes conductive only when the applied voltage has reached a predetermined value (threshold value). When the sum of the cumulative voltage drops occurring across the relay coil and resistor r1 reaches the threshold voltage of n7, exchange of current between the two-way rectifier bridges commences.

The stabilizing current i_S flows partly through measuring relay D, thus making the stabilizing feature operative. The time-current characteristic is flat at the beginning and bends upwards sharply as the stabilizing current increases (Fig. 14).



a) Characteristic of transformer protective relay system
b) Characteristic of generator protective relay system

Fig. 14 Operating characteristic curve

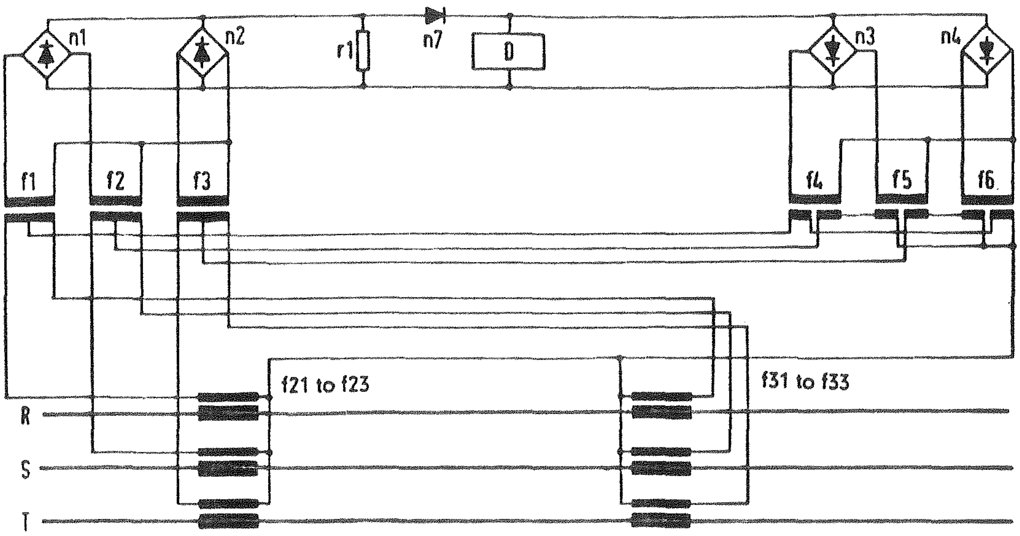


nS: Full-wave rectifier bridge, stabilizing side
nA: Full-wave rectifier bridge, tripping side

Fig. 15 Circuit arrangement for obtaining a bent characteristic

Stabilized differential relay system in three-phase connection

Fig. 16 shows the basic diagram of the stabilized differential relay system for three-phase current. The interposing transformers f1 to f3 feed the stabilization side, and f4 to f6 the tripping side of the d.c. bridge.



f11-f13: Current transformers at input end
f14-f16: Current transformers at output end
f1-f3: Interposing transformers on the stabilization side
f4-f6: Interposing current transformers on the tripping side
n1, n2: Full-wave rectifiers, stabilizing side
n3, n4: Full-wave rectifiers, tripping side
D: Measuring relay
n7: Half-wave rectifier
r1: Ohmic resistor

Fig. 16 Basic circuit diagram of a stabilized three-phase differential relay system

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Tap changing of transformers

If the differential protective relay system is matched to a definite transformation ratio of the transformers, a change in the transformation ratio (tap changing) causes a balancing current to flow. The voltage-variation range of transformers may be up to ± 20 %.

A differential relay calibrated at the central tap position will thus carry a balance current of about 20 % if rated current is flowing and the tap changer is in an extreme position. The current characteristic of the relay system is therefore slightly rising in its initial portion (broken line in Fig. 14). This is achieved by connecting ohmic resistor r2 and half-wave rectifier n7 in parallel (Fig. 15).

The magnitude of resistor r2 determines the initial slope of the curves. The curve of the 7UT92 unit is such that the pickup value is about 20 % higher at rated through-current than at zero through-current.

No-load current

The no-load current of a transformer acts on the differential relay like a fault current. However, since the no-load current will not normally exceed 5% of the rated transformer current, it is negligible in view of the high setting range of the differential relay system.

Starting inrush current

Depending on the instant at which the transformer is energized, the starting inrush current involves high current peaks which simulate a fault current to the differential relay. The inrush current is displaced in the coordinate system by a d.c. component which decays only gradually.

The starting inrush current is a multiple of the rated current and is characterized by a considerable harmonics content. For instance, the second harmonic (double the rated frequency) which is almost completely missing from a short circuit accounts for about 35 % of the inrush current.

The third harmonic (three times the rated frequency) has a considerable share in short-circuits, but plays no part in the inrush current.

The differential relay 7 UT 92 is therefore equipped with a filter through which the tripping current flows; this filter is of the high-pass type and is impermeable to the rated frequency and the third harmonic, so that, if designed for 50 Hz, it short-circuits the 50- and 150-Hz waves. The 100-Hz wave and the higher harmonics pass through the filter, following which they are rectified and fed to the second winding of the measuring relay D in the restraining sense. This ensures stabilization against spurious tripping due to inrush currents (inrush stabilization).

Fig. 17 shows the frequency characteristic of the inrush stabilization device. The voltage of the restraining winding of measuring relay D is brought out to terminals 21–22 of the unit. Fig. 17 shows this voltage plotted versus the frequency of the sinusoidal current of current transformers f1 to f3.

In addition to the filter, the stabilizing side of the measuring bridge also shares in the inrush stabilization. The interrelationship of these elements is shown in Fig. 18.

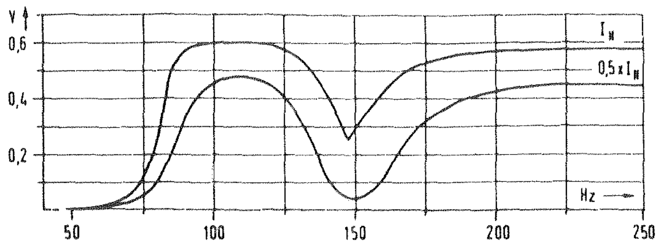


Fig. 17 Frequency characteristic of the inrush current stabilizing device

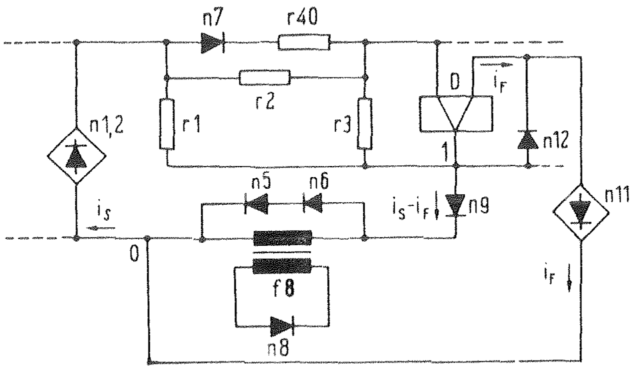


Fig. 18 D.C. inrush current stabilization

Rectifier set n11 is fed from filter u, and rectifiers n1 and n2 from current transformers f1 to f3 (see the overall circuit diagram, Fig. 22).

Assuming that diode n9 is short-circuited, it is immediately obvious that the d.c. current i_F flowing through the inrush stabilizing device is independent of the total d.c. current i_s of the current stabilizing device (through-current). Diode n9 couples the two stabilizing devices. A commensurate stabilizing current is supplied from n1 and n2 on each current inrush. The current $i_s - i_F$ flows via n9 and builds up the threshold voltage of this diode. The d.c. share i_F supplied from rectifier n11 is contained in current i_s flowing at point "0", branches off at "1" and returns to rectifier n11 via the right-hand winding of relay D. Diode n12 limits the voltage of the right-hand relay winding. The voltage drop across n9 relieves n11 and thus current transformer f7. Fig 22.

Fig. 19 shows the voltages at all points of interest. The data in brackets apply when the diode n9 is short-circuited. Let the voltage drop across diode n9 be U_9, that across the relay winding be U_D, and the forward voltage of the individual diodes of rectifier n11 be U, then the voltage delivered by the filter is:

$$+ U - (- U_D - U) = 2 U + U_D$$
with n9 short-circuited

$$+ U - (U_9 - U_D - U) = 2 U - U_9 + U_D$$
with n9 not short-circuited

Thus, n9 relieves the filter by the amount of the forward voltage U_9.

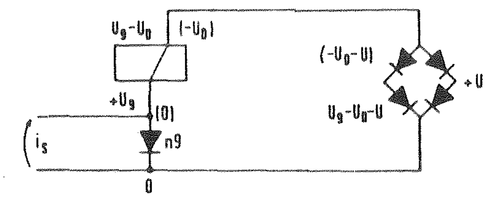


Fig. 19 Relieving the filter

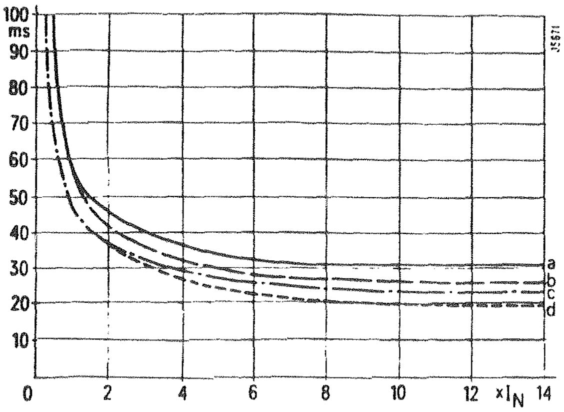
At the beginning of the procedure described, the interposing current transformer f8 acts as a reactor so that, initially, the threshold voltage of n5 and n6 is effective, causing the whole current is to flow via the right-hand relay winding. This takes 8 ms and bridges the time delay of filter u, but decays quickly as the d.c. current begins to flow through f8. Rectifier n8 causes a d.c. current to flow through the secondary winding of f8, keeping the latter saturated.

Response time

The response time of the protective system is the sum of the operating times of measuring relay D and switching relay H.

Measuring relay D is moderately damped and has an inverse-time characteristic. The associated relay H has an operating time of 10 ms. Fig. 20 shows the time-current characteristic of the 7UT92 unit for the various kinds of fault, measuring relay D being set at the minimum pickup value of 20 % I_N (rated current).

To these times is added the inherent delay of the external auxiliary switch (used for raising the switching capacity).



a) Fault RST fed from one side
b) Fault RST fed from two sides
c) Fault RE* fed from one side
d) Fault RE fed from two sides

Fig. 20 Tripping times of the differential relay system 7UT92, with relay D set at 20 % rated current

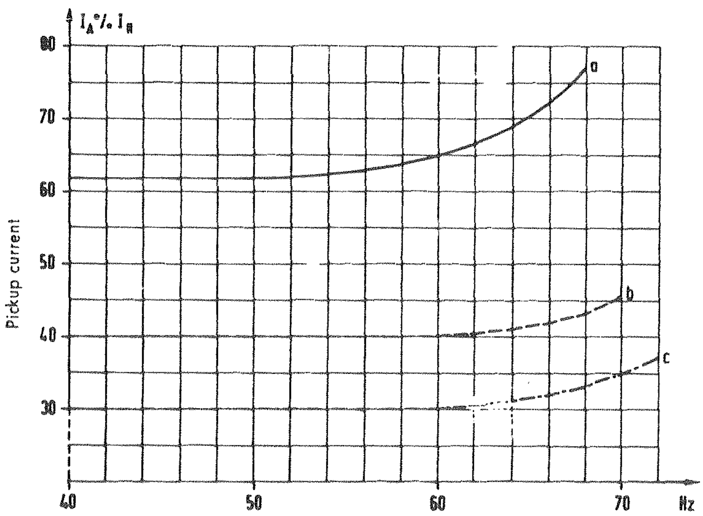
Influence of frequency

The inrush stabilization filter renders the 7UT92 unit frequency-dependent to a certain degree. Any fluctuations in frequency, however, will not affect the inrush stabilization effect since the filter has a wider band width.

In the healthy condition, the stabilizing effect becomes noticeable only on exceedingly great deviations from the rated frequency. But these are not likely to occur in actual practice.

Fig. 21 shows the pickup current plotted versus the frequency for 50 Hz rated frequency.

The general basic single-line diagram of relay system 7UT92 is given in Fig. 22. For better understanding, the components are designated as in the individual partial diagrams.



a) Fault RT, setting 0.4 × rated current
b) Fault RST, setting 0.4 × rated current
c) Fault RT, setting 0.2 × rated current
All faults are fed from one side

Fig. 21 Pickup current plotted against the frequency, rated frequency 50 Hz

Note

The comprehensive circuit diagram, which contains also those parts which are not required for the basic single-line diagram, is glued into the cover of the relay.

Legend for single-line diagram, Fig. 22:

f1 to f3:
Current transformers of the stabilizing side

f4 to f6:
Current transformers of the tripping side

f7:
Current transformer of the filter

u:
Filter (high-pass) for blocking the fundamental frequency and the third harmonic, for inrush stabilization

n1, n2:
Rectifiers of the stabilizing side

n3, n4:
Rectifiers of the tripping side

r1, r40, n7:
Resistor-rectifier group providing a bent characteristic curve (Fig. 14 and 15)

r 2:
Resistor providing a flat start of the characteristic curve

r3:
Calibration resistor

D:
Measuring relay (moving-coil type) with two windings:
left: measuring winding,
right: restraining winding (inrush stabilization)

H:
Switching relay (moving coil) operated by D; serves to raise the switching capacity of d and to operate the external tripping relay

S:
Electrically operated indicator target

r28 . . . r31:
Resistor combination for matching the auxiliary circuit to the d.c. voltage of the substation
The resistor combination is exchangeable (see "Installation")

n9:
Diode for relieving the filter u

n11:
Rectifier of filter u

n12:
Diode for limiting the inrush stabilization

f8, n5:
n6, n8:
Interposing current transformers and rectifiers for accelerating the inrush stabilization effect

20.6:
Links, fault-current measuring points

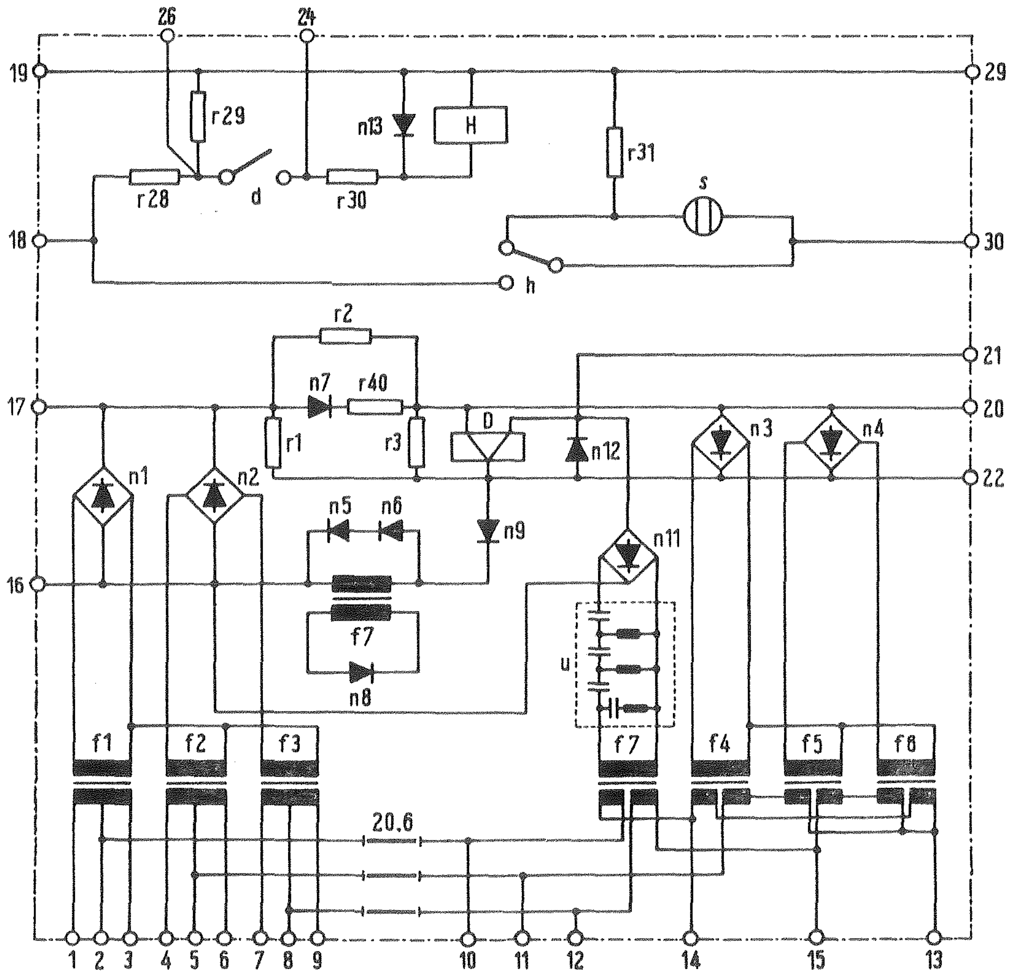


Fig. 22 Transformer differential protective relay system 7UT92, basic circuit diagram

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Differential relay systems for transformers having more than two outgoing feeders require a stabilizing unit 7UT93. The internal circuit arrangement of the 7UT93 unit is identical to the stabilizing side of the 7UT92 unit. The 7UT93 unit incorporates 6 interposing current transformers f1 to f6 and 4 rectifiers n1 to n4 since in plants with more than two outgoing feeders each feeder has to be protected individually.

Stabilizing unit 7UT93

The stabilizing d.c. current is picked off from terminals 11 and 12 and passed to the measuring bridge circuit of the 7UT92 unit.

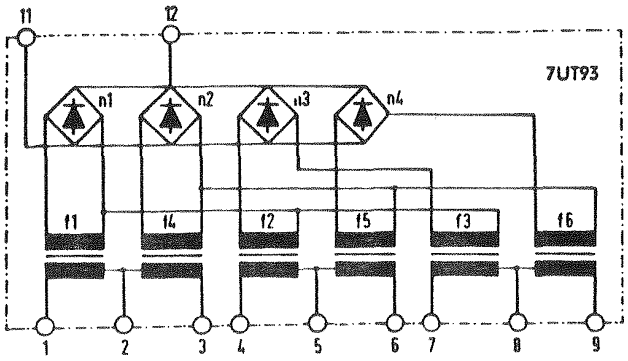


Fig. 23 Stabilizing unit 7UT93, basic single-line diagram

Overall circuit diagram

Fig. 24 shows the overall circuit diagram of the differential relay system for a two-winding transformer. Since the protective relay system 7UT92 can compare only currents of equal magnitude and phase relation, the system is equipped with a set of matching transformers 4AM51 50–7AA [1]) which adapt the magnitude and phase relation of the secondary c.t. currents (at both ends of the transformers to be protected) to each other.

The vector group of the matching transformer is governed by that of the transformer to be protected, the physical position of the neutral points of the current transformers being duly allowed for. Current magnitude and phase relation can be matched to the differential protective relay with any transformer and current transformer vector group.

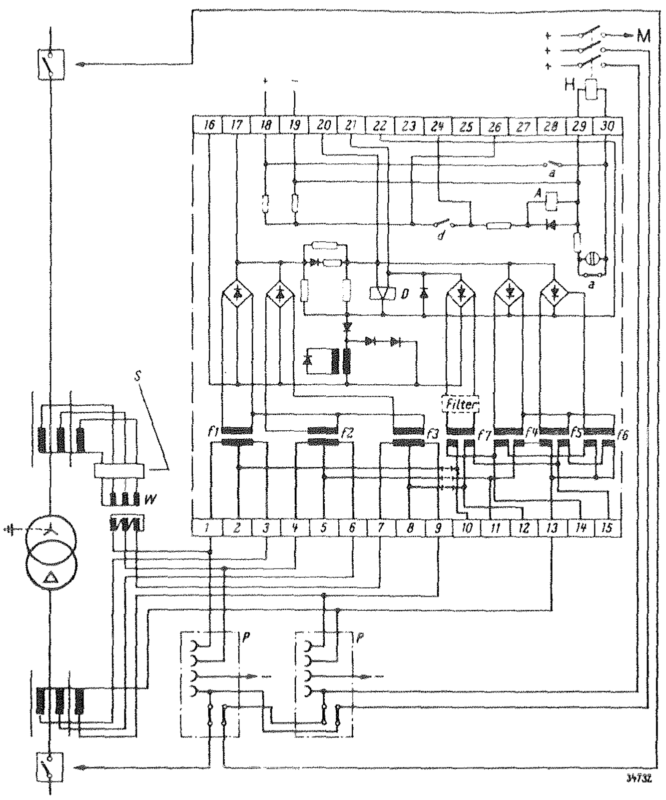
If short-circuits occur beyond the protection zone of the differential protective relay, short-circuit currents pass through the transformer. To prevent damage to the transformer in this case, the protection system incorporates back-up protection which after a predetermined time interrupts the short-circuit currents flowing through the circuit.

The differential relay system must disconnect the transformer completely from the system. Consequently, the associated auxiliary relay operates both circuit-breakers. The back-up protection relay, which is usually a definite- or inverse-time overcurrent relay, serves only to open the circuit and therefore trips one circuit-breaker only.

The principles applicable to two-winding transformers are valid also for multi-winding transformers, except that the combination of 7UT92 with 7UT93 is used for the comparison circuit. The stabilization part in the 7UT92 unit is only half utilized since only one outgoing feeder is connected to one half of the stabilizing transformers f1 to f3. Because of the vectorial addition, the stabilizing effects of the currents of two feeders feeding an external fault via the transformer would offset each other if they were both passed through the 7UT92 unit. The 7UT93 unit is therefore fed from two, and the 7UT92 unit from one, feeder. Consequently, four-winding and five-winding transformers require two 7UT93 units.

The differential relay system causes the circuit-breakers of all feeders to be tripped. The basic circuit diagram of the differential protective relay system is shown in Fig. 25.

1) Previous designations: J 0,5 D and 4AM22 20–2AA.



H Auxiliary relay 7PA10, 7PA50 or 7PA28
M Alarm
S Overcurrent time and distance relay system
W Matching current transformer 4AM51 50–7AA
P Test sockets 7XV50

Fig. 24 Differential and back-up system for a two-winding transformer, connection diagram

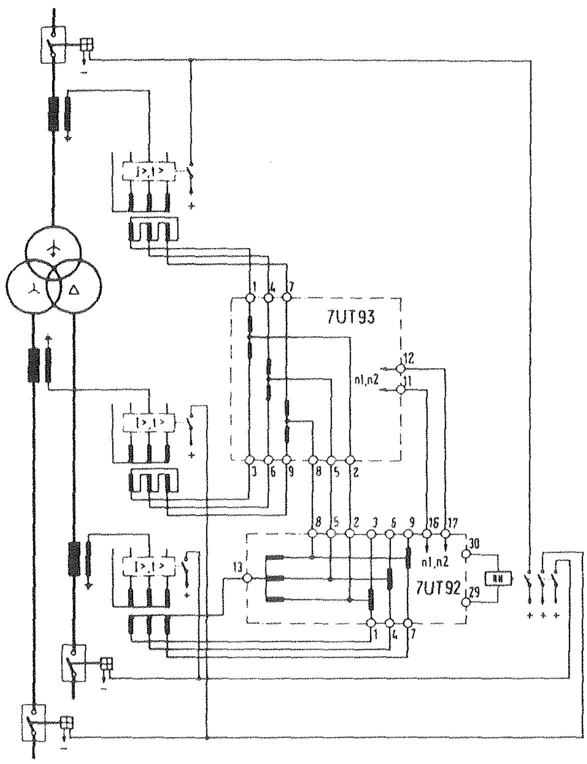


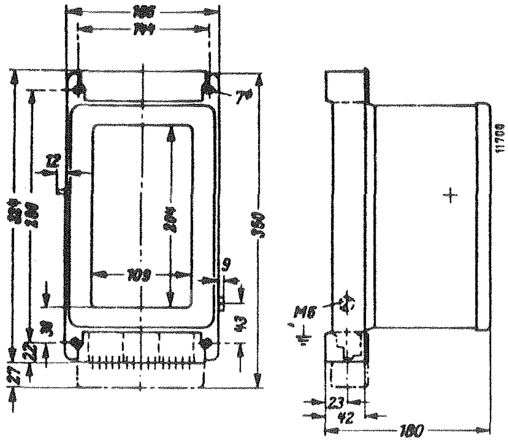
Fig. 25 Differential and back-up protection system for a three-winding transformer, basic circuit diagram

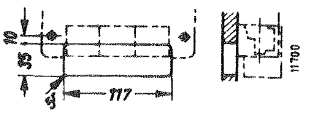
Installation

Dimensions in mm

Surface-mounted units are fixed with four M6 screws (DIN 84)

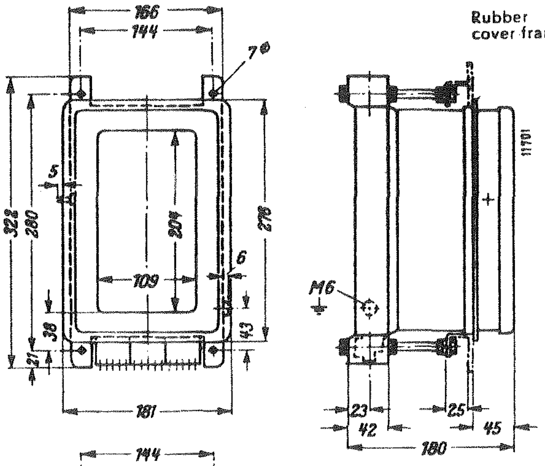
Enclosure for 7UT92 (RT22c)

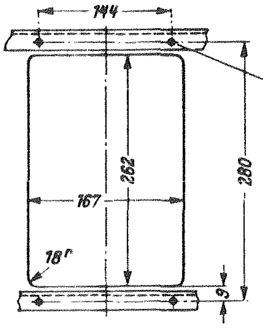




Panel cutout for front connection and long terminal covers

Enclosure 7XP7 02. (EG 12); for surface-mounting





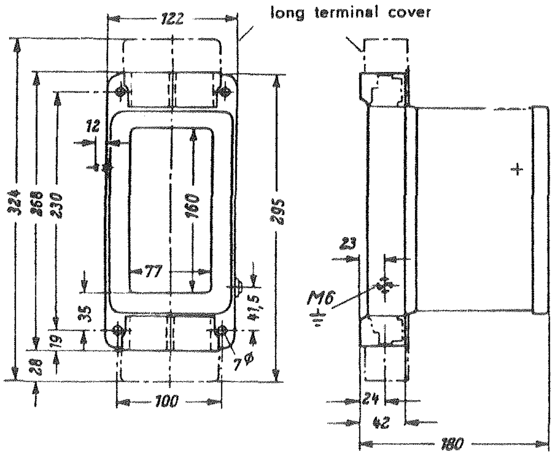
Holes 7 mm dia in the angle bars only

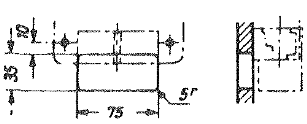
Panel cutout

Enclosure 7XP7 02. (EG 12); for flush mounting

Enclosure for 7UT93 (RT 23)

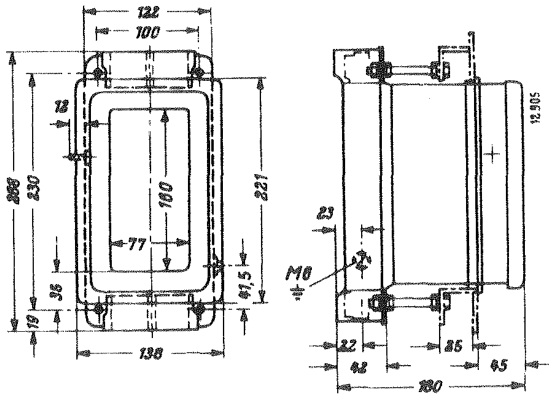
Dimensions in mm

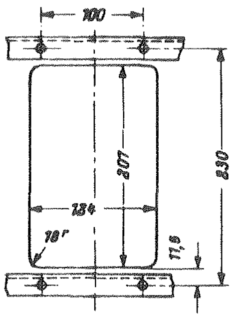




Panel cutout for front connection and long terminal covers

Enclosure 7XP7 01. (EG 11); for surface-mounting





Holes 7 mm dia in the angle bars only

Panel cutout

Enclosure 7XP7 01. (EG11); for flush mounting

Connection

The sleeve terminals are suitable for solid conductors from 2.5 to 6 mm². Solid conductors of 1.5 mm² and less as well as stranded conductors up to 6 mm² should be clamped by means of end sleeves only (do not solder).

When two conductors have to be connected to one terminal, the conductors should be of equal cross sections.

When the relay is bolted directly to a sheet-meta panel which is included in the protection system the protective earth conductor need not be connected to ⏚; otherwise an at least 4 mm² coppe conductor should be used for earthing.

Conductors brought up to the relay from the rear of the panel have to be protected from mechanical damage in accordance with VDE Specifications 0100. Provide an adequate cutout in the panel at a distance of about 30 mm from the relay and fit an oval rubber grommet into the cutout. Deburr the cutout carefully.

Auxiliary d.c. voltage

The auxiliary d.c. circuit is matched to the existing d.c. voltage by resistors r28 to r31 (see "Description", Fig. 1). The resistors are mounted on a detachable plate held by screws. This makes the entire resistor combination easily replaceable.

The resistance of control relay H is 1.7 kΩ, that of indicator target S 1.2 kΩ. These values permit the consumption of the auxiliary circuit to be determined for the various voltages applied.

The d.c. ranges and the respective resistors (see Fig. 22 of the "Description") are tabulated below:

Auxiliary d.c.	r28		r29		r30		r31	
voltage (V)	kΩ	W	kΩ	W	kΩ	W	kΩ	W
24	0	–	∞	–	0	–	0.18	4
60	3.3	1.5	∞	–	0	–	2.7	4
110	6.8	4	∞	–	0	–	4.7	4
220	10	4	10	4	2.2	2	10	6

Fig. 28 Resistors r28 to r31 and auxiliary d.c. voltages

Matching transformers

A simple method of checking the matching transformers 4AM51 50–7AA against the circuit diagram of the plant for the correct phase relation is shown in Fig. 29.

Plot the current flowing at a definite instant in the event of a two-phase short-circuit outside the protection zone of the differential relay. A two-phase fault entails only a.c. currents of opposing directions in the two phases. Enter only the direction arrows for these currents. The transformer ratio is assumed to be 1 : 1 and can be neglected. Fig. 29 shows this procedure for a transformer with vector group Yy6.

If the c.t. currents happen to be equal right from the beginning, the use of matching transformers is nevertheless recommended in order to isolate the circuits galvanically.

When checking the connection of the matching transformer system observe both the vector group and the conditions of earthing. If the neutral point of the transformer is earthed solidly or through a resistance or reactance (e.g. Petersen coil), a phase-to-earth short-circuit is completed on the earthed side through the neutral. No earth current flows through the other side. Consequently, in the event of a single-phase earth fault outside the differential relay protection zone a zero-sequence current flows and normally causes spurious tripping of the relay.

This is avoided by a delta-connected group of windings of the matching transformers which short-circuits the zero-sequence current circuit and prevents it from flowing through the relay. The current transformer circuit is closed, but the tripping side of the relay system remains de-energized.

Fig. 30 shows the current path of a star/star-connected transformer with one side earthed in the event of an earth fault outside the differential relay protection zone. This is the usual arrangement for power transformers with provision for earthing the neutrals.

It is important that the matching transformers be connected between the differential relay system and the c.t. set located on the earthed side of the transformer.

Leave the matching transformer starpoint associated with the relay system open.

Use a relay system with two stets of star/delta matching transformers for transformers with two earthed neutrals (see Fig. 31). The neutral-point connection (terminal 13 of 7UT92) remains free in this case.

It is immaterial for the differential relay whether the transformer is earthed directly at the neutral or through an earthing reactor located in the protection zone of the differential relay. Block the relay in any case and in basically the same manner. Any earthing outside the protection zone has no influence on the protection system.

In the case of differential relay systems for star/delta transformers, the matching transformers are connected between the relay system and the c.t. set of the star side [1]). The matching transformers then also have to be connected in star/delta in order to ensure correspondence of the phase relation. This results in the connection shown in Fig. 32 for a transformer with vector group Yd5.

The star side is separated from the differential relay system by the fact that the matching transformers are connected in delta. The conditions of earthing are immaterial in this case. Insert a set of matching transformers with balancing delta on the delta side only if the system is earthed through a Petersen coil or through earthing reactors on the delta side in the differential relay protection zone (between transformer and c.t. set).

1) This arrangement is imperative if there is some form of earthing of the transformer starpoint.

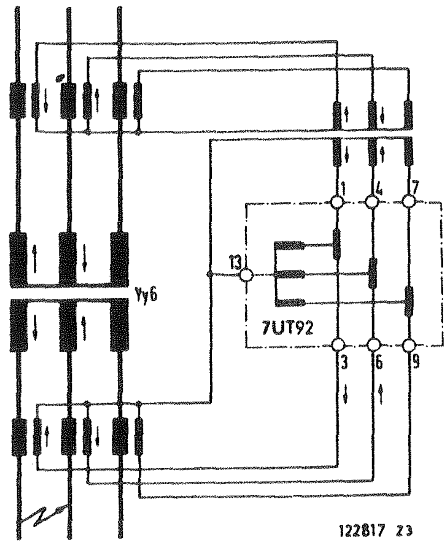


Fig. 29 Checking the matching transformer connection of a Yy-connected transformer

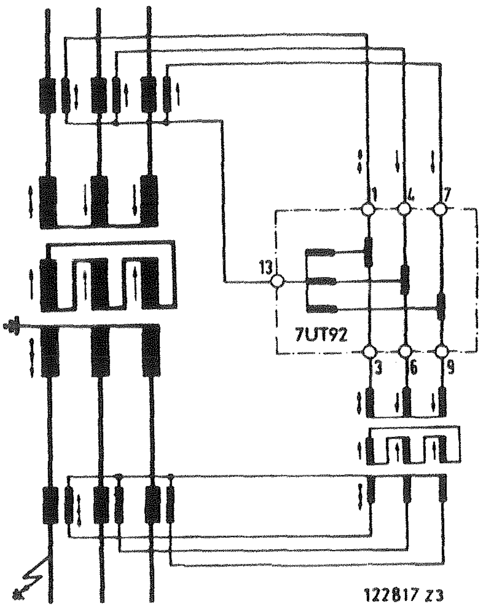


Fig. 30 Blocking the differential relay against the earth fault current

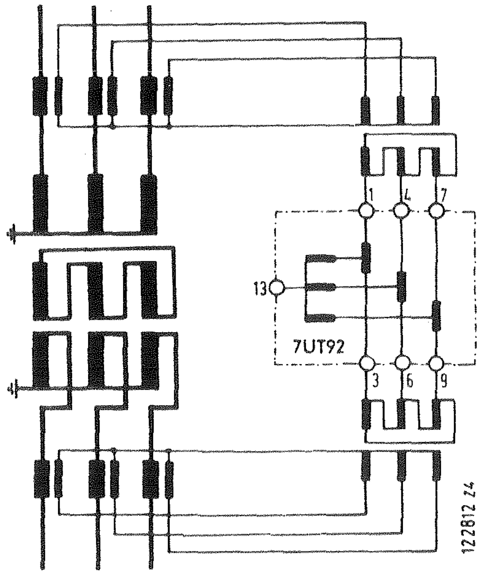


Fig. 31 Connection of the differential relay system for transformers earthed at both ends

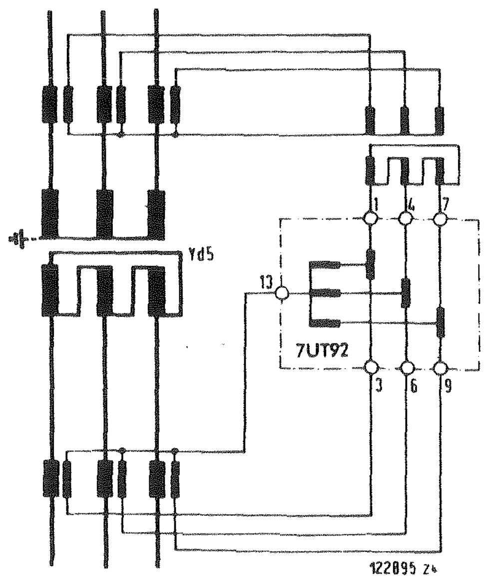


Fig. 32 Differential relay system for transformers in star/delta connection

Note the following in connection with Fig. 30 and 31:

The high sensitivity of the 7UT92 unit in the event of earth faults within the protection zone (with earthed neutral point of the system) and in the event of double earth faults (with systems having Petersen coils) is lost for the side whose residual current is kept away from the 7UT92 unit. This disadvantage is avoided by using the special connection shown in Fig. 33, which has a current transformer in the earth connection. The earth fault current detected by this current transformer is introduced in the delta connection of the matching transformer in such a way that no tripping current flows through the protective relay if an earth fault occurs outside the protection zone. The current flow in this condition is indicated by arrows in Fig. 33. This diagram assumes that the transformer is earthed through an earthing reactor. As a comparison with Fig. 30 shows, it is immaterial for the relay system whether this method of earthing or neutral earthing in the transformer is used.

A special transformation ratio of the matching transformers is required for each particular case in order to match both the phase relation and the magnitude of the secondary c.t. currents.

The particular ratio of the matching transformers is determined from the capacity, the rated voltages, the tap-changing range and the vector group of the transformer, the ratios of the current transformers and the vector groups of the matching transformers. In the case of tap-changing transformers, the ratio of the matching transformers should be based on the mean current of the variable side.

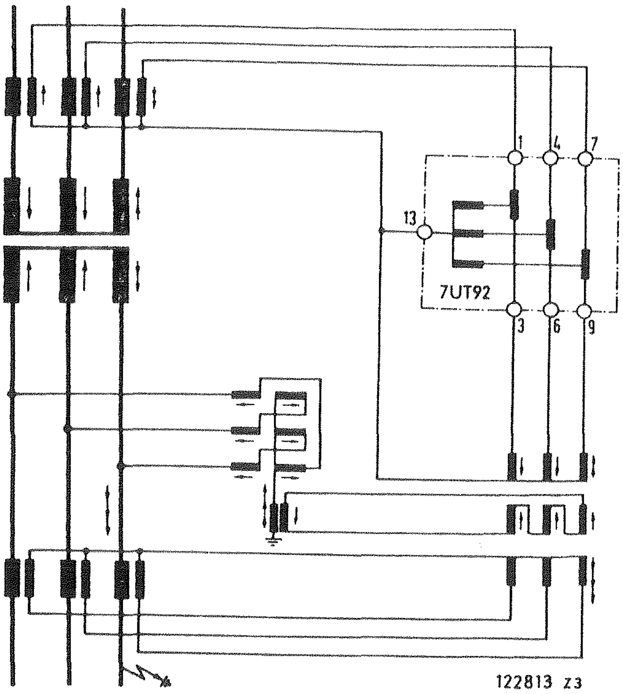


Fig. 33 **Differential relay with full sensitivity to earth faults**

Example:

Transformers 10 MVA, 110 kV ± 16%, 6.3 kV, vector group Yd5

Current transformer 110-kV side: 75/5 A

Current transformer 6-kV side: 1000/5 A

$$\text{110-kV side: } I_{1\,min} = \frac{10\,000\ \text{kVA}}{\sqrt{3}\,(110\ \text{kV} + 16\%)} = 45.2\ \text{A}$$

$$I_{1\,max} = \frac{10\,000\ \text{kVA}}{\sqrt{3}\,(110\ \text{kV} - 16\%)} = 62.6\ \text{A}$$

$$I_{1\,mean} = \frac{45.2 + 62.6}{2} = 53.9\ \text{A}$$

$$\text{6-kV side: } I_2 = \frac{10\,000\ \text{kVA}}{\sqrt{3}\cdot 6.3\ \text{kV}} = 915\ \text{A}$$

$$i_1 = \frac{53.9}{75}\cdot 5 = 3.6\ \text{A} \cdot i_2 = \frac{915}{1000}\cdot 5 = 4.57\ \text{A}$$

Vector group of the matching transformers Yd5:

$$\text{Thus } i_2 = \frac{4.57}{\sqrt{3}} = 2.64\ \text{A}$$

$$\text{Ratio of the matching transformers: } \ddot{U} = \frac{3.6}{2.64}$$

Establish the appropriate connection with the 8 windings of the matching transformer 4AM51 70–7AA [1]), noting the thermal capacity of the individual windings.

When calculating the ratios of the matching transformers, note the following:

Each output lead of a multi-winding transformer should always be rated on the basis of the maximum capacity of the transformer.

The maximum permissible load of the matching transformers and equipment, however, depends on the service currents.

Back-up protection

The back-up relay acts on the associated breaker. If there are more than two output leads, each lead is equipped with a back-up relay of its own.

The differential relay system responds only to the faults occurring within the protection zone defined by the main current transformers. Any external faults will not be cleared. If the respective circuit-breakers do not disconnect these in good time, the load will become unduly high and may result in damage to the transformer. This is prevented by the back-up protection superimposed on the differential protective relay.

Multi-winding transformers require back-up protection for each winding group which, owing to the generous rating of the transformer, may be considerably overloaded without overcurrents flowing at the same time in any of the other windings. The back-up relay may also be of the thermal type (thermal monitor, contact-making thermometer, etc.).

1) Previous designations: J 0,5 D and 4AM22 20–2AA.

The following relay types can be used for back-up protection:

Definite or inverse-time overcurrent relays, directional overcurrent relays or distance protection relays.

When setting the back-up relay, observe the time grading of the secondary system in order to make possible selective clearance of a fault in the secondary system without the back-up relay operating prematurely.

Definite-time or inverse-time back-up protection is sufficient for small transformers feeding supply systems of moderate extent, since in this case time grading does not entail long operating times. Large transformers, especially when used for network coupling, are generally provided with distance protection on both sides to ensure rapid clearance of busbar faults and long tripping times for remote faults.

Commissioning

Preparatory work

Before commissioning the relay, check the equipment and the matching transformers for proper connection. Make particularly sure that the differential relay is connected so as to cause tripping of the circuit-breakers of all feeders. For this purpose connect terminals 18 and 30 of 7UT92.

The auxiliary tripping relay must respond and the circuit-breakers of all feeders must trip out.

Check whether the data on the relay rating plate agree with the nominal current, voltage and auxiliary d.c. voltage.

It is essential for proper operation of the transformer differential relay that all c.t. circuits should be properly wired. By far the majority of malo-perations occurring in actual practice are due to incorrect wiring. Therefore the connection of all transformer circuits must be checked.

Differential relay systems can be connected to two or three current transformers. In the case of two-phase connection, the following should be noted:

If one fault of a double earth fault is within the protection zone in the phase having no c.t., this fault is not detected by the differential relay. Only the earth fault in the other phase outside the differential relay protection zone is cleared by the back-up relays. The earth fault within the differential relay protection zone persists. This kind of connection is therefore permissible only in systems with isolated neutral or with a Petersen coil.

Always use three current transformers in systems with solidly or low-resistance earthed neutral.

The current transformers need not necessarily match each other. Their minimum rating should be 10 VA in accuracy class 3, with a saturation factor of more than 10 (new designation 10 VA–Kl 10P 10). If losses in the leads exceed about 2 to 3 W, larger current transformers should be used. Extremely long leads require extra-large cross sections or a secondary rated current of 1 A, or extra-powerful current transformers.
A simple method of checking this is to follow all the leads through individually between the main current transformers, the matching transformers and the differential protective equipment.

Test with service current

Check all connections individually, then put the transformer into operation and test it with the service currents. The transformer should carry at least 40% of its rated current to enable correct conclusions to be drawn from the measured values. Carry out any re-connections on the c.t. circuits only when they are dead. Either short-circuit the current transformer or disconnect the transformer. Connect three a.c. ammeters in the tripping circuits. Connect an ammeter to the screws of the links on the right at the bottom in 7UT92, then open the links (see Fig. 34).

Only low fault currents will flow if the connection is correct. These are composed of the transformer magnetizing current and the ratio errors of the main transformers and matching transformers.

Note that an additional fault current arises in tap-changing transformers which corresponds to the transformer tap in action since the ratio of the matching transformers is designed for the mean tap. The maximum permissible fault current can be easily calculated from the individual components.

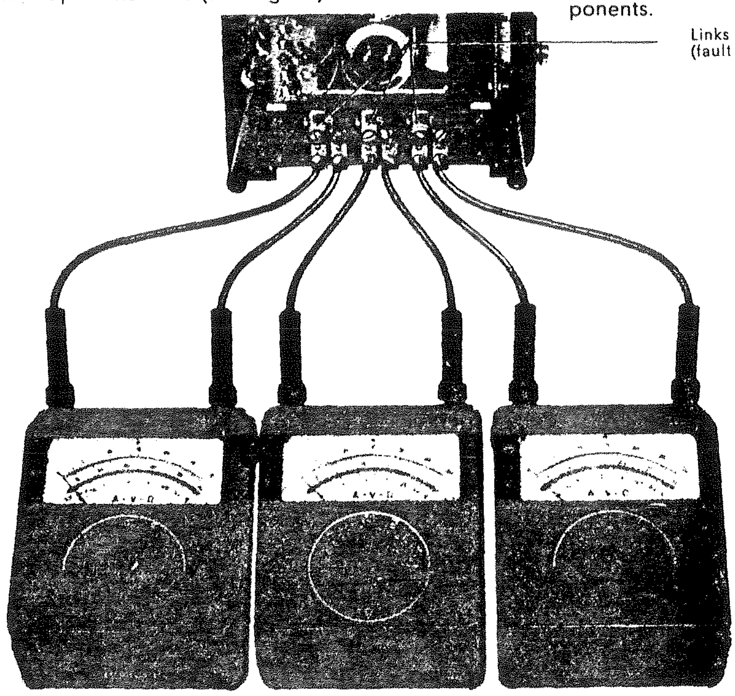


Fig. 34 Measuring of fault currents

Simulation of faults

If a generator is available for the test, make a short circuit within the protection zone and run the generator slowly up to speed and measure the pick-up currents. All three measuring instruments should be set to the same range which should be such that the current can be easily read off. Low measuring ranges involve a higher burden which is liable to suppress the currents. Then simulate a fault within the protection zone in the following manner:

Interchange the connections 1, 4 and 7 or 3, 6 and 9 of 7UT92 cyclically. The lines of the differential protection system then must carry $\sqrt{3}$ times the current in the lines on terminals 1, 4 and 7 (or 3, 6 and 9). If the load current of the transformer is higher than 12 % of the c.t. rated current, measuring relay D in 7UT92 responds if it is set to the lowest value of 20 % (1 A and 0.2 A at a rated current of 5 and 1 A, respectively). Prevent spurious tripping of the circuit-breakers by opening the tripping line (terminal 30 of 7UT92 for the tripping auxiliary relay). This test may also be carried out at load current.

Leave the Buchholz and back-up relays in the operative condition.

Incorrect connections

If the currents measured on links do not correspond to the c.t. tolerances, to the accuracy of the matching transformers and to the magnetizing current of the transformer or if the currents flowing on simulation of a fault differ from the specified values, the connection is incorrect.

Such faults can be quickly detected by reference to the three ammeters and, if necessary, by further measurements at rated load.

Fig. 35 shows the connection of the c.t.'s for star/star matching transformers.
Loop ammeter in at points a, b, c and d, and measure the currents.

Any current flowing at "a" indicates a fault of the c.t. group on the high-voltage side while a current at "c" indicates a fault in the c.t. group of the low-voltage side.

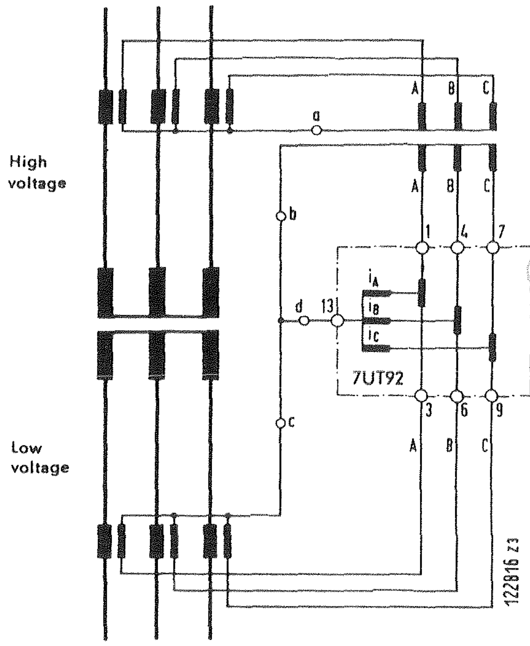
Possible faults: Wrong polarity of the secondary winding, internal defect, wrong transformation ratio of a current transformer.

Current at "b" indicates that the matching group is not symmetrical, i.e. at least one of the three matching transformers is connected with wrong polarity or has a different transformation ratio.

The measurement point "d" serves for checking purposes. If no current is flowing at "b" and "c", the current at "d" will also be zero.

If no currents flow at a, b, c and d, only very few possible sources of fault are left.

Fig. 36 shows the types of fault and the associated currents i_A, i_B, and i_C at the links. Currents i_A, i_B and i_C are assigned to phases R, S and T.



i_A, i_B, i_C : Currents measured at the links

a, b, c, d: Fault current measuring points

Fig. 35 Checking star/star matching transformers

No.	Theoretical values i_A	i_B	i_C	Numerical values i_A	i_B	i_C	Faults
0	0	0	0	0.00	0.00	0.00	
1	2	2	2	2.00	2.00	2.00	Wrong polarity of all three phases
2	0	$\sqrt{3}$	$\sqrt{3}$	0.00	1.73	1.73	Phases B and C interchanged
3	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$	1.73	1.73	1.73	The three conductors are cyclically interchanged
4	1	1	1	1.00	1.00	1.00	Wrong polarity and interchanging of the three phases
5	1	1	2	1.00	1.00	2.00	Wrong polarity of the three conductors, A and B interchanged

Fig. 36 Faulty connections and associated measured currents in the star/star matching transformer

If matching transformers in star/star connection with a delta-connected balancing winding are used, insert an ammeter in the balancing winding. If a balancing current flows, the phase polarity on one side of the matching transformers is wrong.

Open the balancing winding and provisionally connect terminal 13 of 7UT92 with the neutral of the matching transformers. Then check the system as described above.

Fig. 35 shows the circuit arrangement of the star/delta matching transformer. Correct circuit arrangement and functioning of the c.t. sets is necessary to enable correct interpretation of the currents i_A, i_B and i_C. The current in the neutral lines "a" and "b" must be zero. The table below shows some of the wrong connections which are then still possible. The conductor designations A, B, C or D, E, F are assigned to the phases R, S and T according to the sequence of the measured values. If the assumed vector group Yd5 of the matching transformers is not correct, the correlation of D, E, F with A, B, C changes.

This check can also be carried out in the described manner with the load currents on differential relay systems for transformers having more than two outgoing feeders, provided that only two feeders are carrying current; "n" feeders necessitate at least "n-1" different tests.

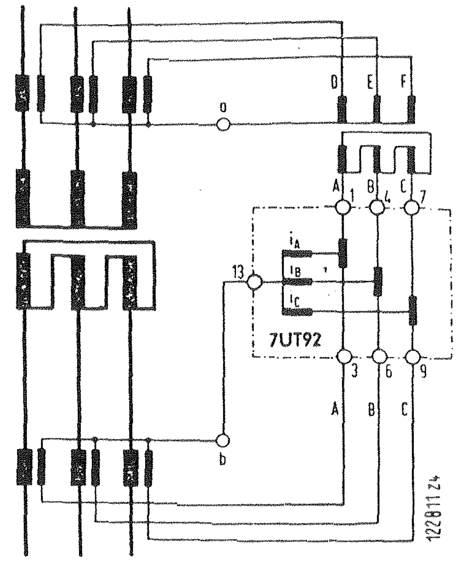


Fig. 37 Test circuit of the star/delta matching transformer

No.	Theoretical values i_A	i_B	i_C	Numerical values i_A	i_B	i_C	Faults
0	0	0	0	0.00	0.00	0.00	
1	0	$\sqrt{3}$	$\sqrt{3}$	0.00	1.73	1.73	B and C interchanged
2	$\sqrt{3}$	$\sqrt{3}$	$\sqrt{3}$	1.73	1.73	1.73	All phases interchanged cyclically
3	2	2	2	2.00	2.00	2.00	Two conductors of groups A, B, C and D, E, F interchanged (e.g. B with C and D with E)
4	1	1	1	1.00	1.00	1.00	Two conductors of groups A, B, C and D, E, F interchanged (e.g. A with B or A with C and D with E)
5	1	1	2	1.00	1.00	2.00	D and F interchanged
6	0	$2/\sqrt{3}$	$2/\sqrt{3}$	0.00	1.15	1.15	Matching transformer F has wrong polarity
7	1	1	2	1.00	1.00	2.00	Matching transformers D and F have wrong polarity
8	0	$1/\sqrt{3}$	$1/\sqrt{3}$	0.00	0.58	0.58	Matching transformer F has wrong polarity, conductor B interchanged with C
9	$2/\sqrt{3}$	$\sqrt{7/3}$	$\sqrt{3}$	1.15	1.53	1.73	Matching transformer E has wrong polarity, conductor B interchanged with C
10	$1/\sqrt{3}$	$\sqrt{7/3}$	$\sqrt{3}$	0.58	1.53	1.73	Matching transformer E has wrong polarity, A–B–C interchanged cyclically
11	$1/\sqrt{3}$	1	$\sqrt{7/3}$	0.58	1.00	1.53	Matching transformers E and F have wrong polarity, A–B–C interchanged cyclically
12	$\sqrt{7/3}$	$\sqrt{7/3}$	2	1.53	1.53	2.00	Matching transformers D and F have wrong polarity, A and B interchanged
13	1	$1/\sqrt{3}$	$2/\sqrt{3}$	1.00	0.58	1.15	E interchanged with F, and B with C, right-hand matching transformer has wrong polarity (Fig. 37).

Fig. 38 Faulty connections and measuring currents of star/delta matching transformers

Setting of 7UT92

The setting range is 20 to 40% of the relay rated current. Turn the knob (see "Description", Fig. 1) to the desired pickup level. The pickup levels are given on the scale in amperes and refer to a three-phase fault fed from one side. As a rule, it is recommended that the pickup level be fixed at 30% of the current flowing through the stabilization side of the 7UT92 (terminals 1 to 9) at rated load of the transformer. In the case of tap-changing transformers, set the pickup value about half the tap-changing range higher.

Setting of the back-up relay

Set the starting relays at 1.4 to 1.5 times the transformer rated current. Set the tripping time to suit the system time grading. Allow for the permissible transformer load due to currents passing through the transformer as a result of external faults. Determine the values for each particular case. Check the connection and the functioning of the back-up relay by reference to the pertinent instructions.

Maintenance

The differential relay system requires no special maintenance. The electrical service life will normally outlast the mechanical life. Should any repairs become necessary and no specialist personnel is available, return the complete relay to the works. When ordering spare parts, specify the type designation, rated current, auxiliary d.c. voltage and serial No. of the relay (complete last line on the rating plate).

Test the relay for proper functioning at regular intervals (about 6 months), using, for instance, a portable relay testing set 7VP44. Test the circuit-breakers annually for proper tripping.

Further technical details of the relay system are given below. These are required only for special tests which have to be carried out by specialist personnel.

Operating characteristic curve

I_S: stabilizing currents
I_A: tripping currents
r: ohmic resistors

Open the links

t points
s

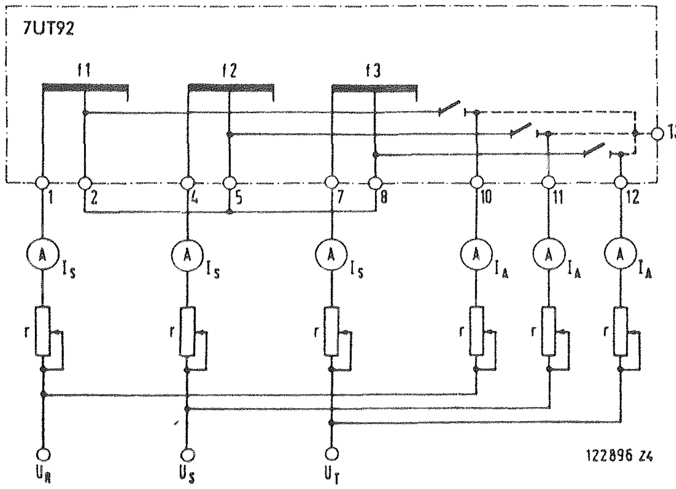


Fig. 39 Circuit arrangement for plotting the three-phase characteristic curve

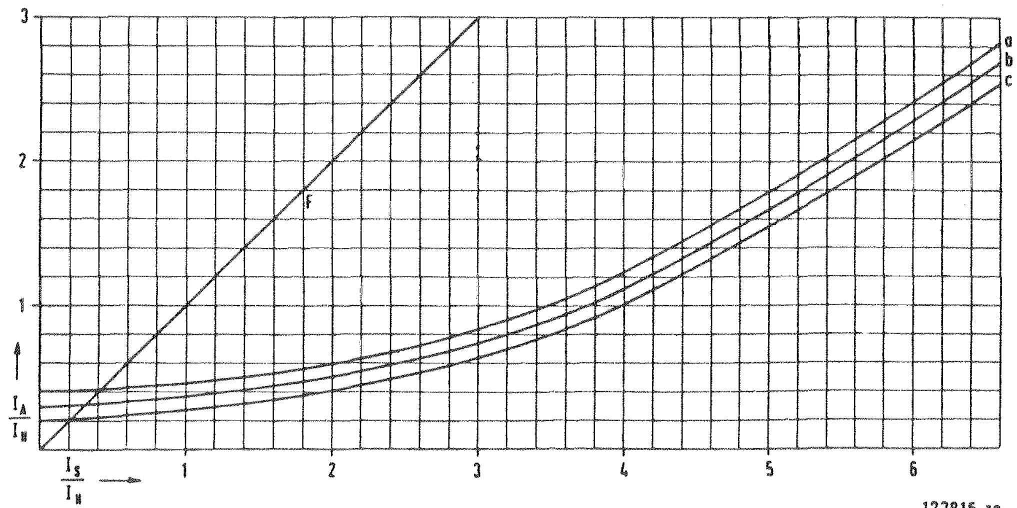
The circuit arrangement for plotting the operating characteristic curve is shown in Fig. 39. Units 7UT92 and 7UT93 are connected directly together so that the curves shown in Fig. 40 und 42 apply also when the two units operate together.

It is essential for plotting the characteristic curve that the three voltages U_R, U_S and U_T be displaced by 120 deg. from each other and be of sinusoidal waveshape.

The three stabilizing currents I_S and the three tripping currents I_A must always be equal. The stabilizing currents I_S can also be brought through terminals 3, 6 and 9 instead of 1, 4 and 7. Open links of the 7UT92 when plotting the characteristic curve. The curves shown in Fig. 40 and 42 indicate the correlated values of Is and the pick-up level I_A for a particular setting of measuring relay D. The axes of the diagram show the multiples of the rated current in order to make the diagram apply for relay rated currents of either 5 A or 1 A.

The fault curve in Fig. 40 applies to an internal short-circuit fed from one side. The sensitivity of the relay can be tested under load conditions by reference to the operating characteristic curves (see "Simulation of faults"). Relay response is achieved by an appropriate setting of measuring relay D.

The distribution of the power over the individual outgoing leads is quite immaterial for the combination of 7UT92 and 7UT93 (for multi-winding transformers). In two-winding transformers, which are protected solely by the 7UT92, the currents fed from two ends counteract each other on the stabilization side. Before using the characteristic curve, therefore, first form the difference (I_s) between the currents flowing into the protection zone.



F: Fault curve
I_S: Stabilizing current
I_A: Tripping current

a: 40 %
b: 30 %
c: 20 %
Setting of the 7UT92

Fig. 40 Three-phase pickup characteristic curve of the 7UT92

The characteristic curves show that the stabilization effect increases gradually as a function of I_S. The slow transition to the steeply rising part of the curve is achieved by an appropriate design of the measuring bridge. For optimum matching of the characteristic of the relay and the c.t.'s the transition lies between the sensitivity and stabilization range since the transition of the c.t.'s from the range of high accuracy to the saturation range also takes place gradually.

Single-phase and two-phase faults

A single-phase a. c. current flows in the 7UT92 if two-phase or single-phase faults occur within the protection zone. For the sake of simplicity, any load currents flowing simultaneously with the short-circuit current (superimposed three-phase current) are neglected in the following considerations.

Fig. 41 shows the arrangement used for plotting the two-phase characteristic curves. It corresponds to a short-circuit between phases R and S in the protection zone fed from one side. This also provides the pickup characteristic which the 7UT92 has in the event of earth faults and double earth faults.

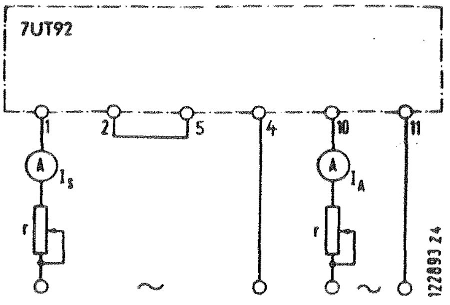
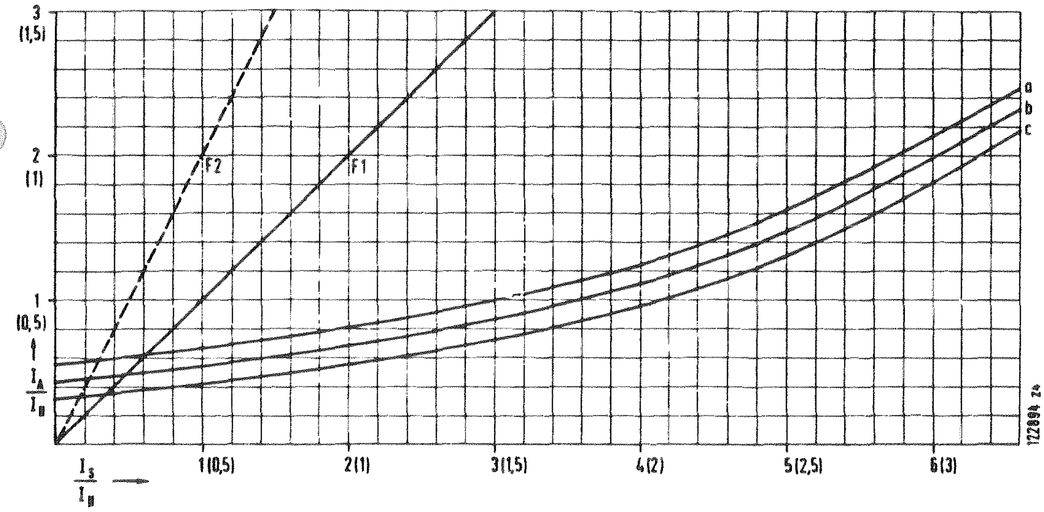


Fig. 41 System for plotting the characteristic curves of a fault between phases R and S



Setting of the 7UT92: a = 40 % I_N, b = 30 % I_N, c = 20 % I_N

F_1: Fault curve for double earth fault
F_2: Fault curve for single earth fault

Fig. 42 Pickup characteristic curves of single-phase and two-phase faults

As Fig. 42 shows, the fault curve and the operating curves intersect at a tripping current of 1.5 times the setting. The operating curves apply also for a single-phase earth fault in the protection zone and a double earth fault with one fault in the protection zone. Since the tripping current has a twofold effect in the latter case, half the value I_A/I_N is sufficient compared to a two-phase fault (see "Description", "Operation") for the same effect.

In Fig. 42, the values in brackets on the I_A/I_N axis apply to a single-phase fault; the relevant fault characteristic curve is shown dashed (characteristic curve F_2).

Fig. 43 shows a single-phase earth fault (in earthed system) within the protection zone fed from one side. The same current distribution results in the event of a double earth fault (faulted point within the protection zone).

If a double earth fault is fed through the transformer, the current distribution is as shown in Fig. 44:

In one phase the current flows through both winding halves of the stabilizing current transformer and doubles the stabilization effect. In order to achieve the same stabilization effect as in the case of a single-phase earth fault (see Fig. 42), only half the current is required. The tripping current must be the same, however. In the characteristic curves in Fig. 40, the values in brackets apply for this double earth fault (fault characteristic curve F_1).

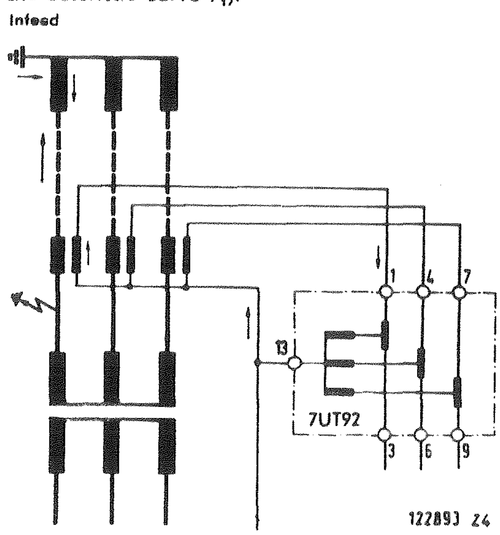


Fig. 43 Earth fault fed from one side

In a double earth fault which is fed from both sides the currents consist of two components, one corresponding to the single-phase fault in Fig. 43, and the other to the double earth fault in Fig. 44. The characteristic curves of Fig. 42 have the same tripping axis as in the case of a single-phase fault, while on the I_s axis the values lie somewhere between those of a single-phase fault and a double earth fault. The pertinent fault characteristic curve lies between the two fault lines F_1 and F_2. Its exact trace depends on the proportion of current flowing through the protection zone and on the magnitude of the fault current coming from the other side.

These examples make it possible under all current conditions where only symmetrical three-phase currents or single-phase currents flow in the 7UT92 or in the combination 7UT92 with 7UT93 to predict the characteristic of the relay system accurately, provided the setting is known.

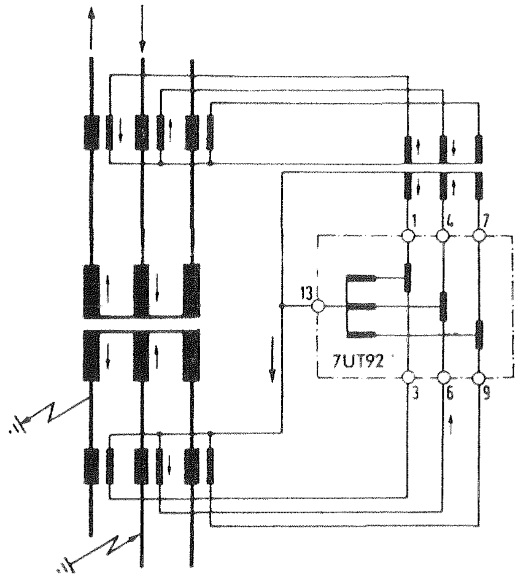
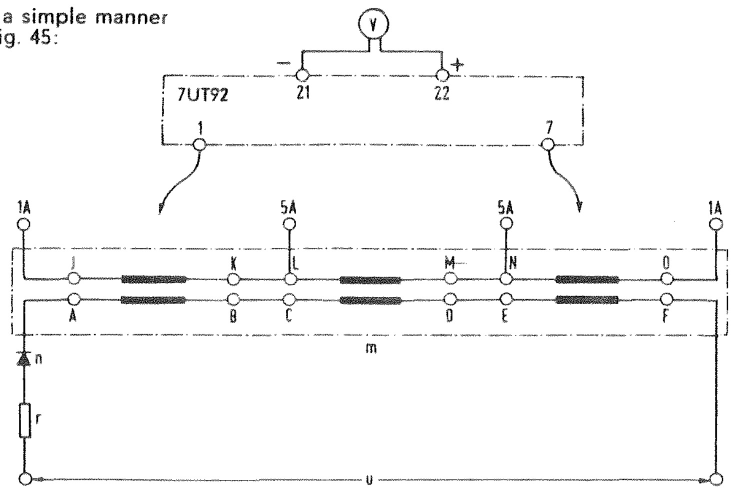


Fig. 44 Double earth fault through the transformer

Inrush stabilization

Inrush stabilization is effected in a simple manner with the arrangement shown in Fig. 45:



u: voltage source 220 V, 50 Hz
r: resistor 200 to 220 Ω, approx. 150 W
n: silicon diode, inverse voltage at least 350 V, 0.6 A
m: matching transformer 4AM51 70–7AA
V: d.c. voltmeter, internal resistance ≥1 kΩ

Fig. 45 Checking the inrush stabilization

122814 Z3

The half-waves of one polarity are filtered out of the system voltage by half-wave rectification for the purpose of simulating the inrush effect. The pulsating d.c. voltage thus obtained is like a marked inrush current (complete displacement of the magnetic flux). The matching transformer 4AM51 70–7AA relieves it of its d.c. component without essentially changing its waveshape, and if necessary adapts it to the rated current of the tested relay. The voltmeter V must indicate 0.15 to 0.20 V.

The arrangement shown in Fig. 45 can also be used to test the previous models of the transformer differential protection system RT 22a and RT 22b. The following distinction should be made between the three designs of the RT 22a.

Ms komb 70, TZ 153:

Test arrangement according to Fig.45, unchanged

Ms komb 70, TZ 129 and
Ms komb 70, TZ 180:

Connect voltmeter to the positive terminal 16 of the RT 22 A.

The measured values of RT 22b and RT 22c are equal.

If the voltmeter has an internal resistance of 10 kΩ or more, it may remain connected during operation since it has no disturbing influence. It enables the blocking effect to be observed by the deflection of the voltmeter on connection of the transformer. Since the inrush current depends on the point of the wave at which connection takes place, instrument deflections will differ.

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