ASEA

Catalogue RK 62-10 E
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Transformer differential relay type RADSE

RADSE is a static, transformer differential relay with outstanding speed, sensitivity and security. Only one relay is required to protect the three phases of a transformer. The relay can be applied to transformers with a large number of windings or to many breakers which may be associated with any one transformer winding.

Solid state circuitry is used to create three separate restraints:

1. The variable percentage (biased) restraint circuitry provides both high security towards external faults and sensitivity to internal faults.
2. The 2nd harmonic restraint circuitry provides effective inrush suppression derived from all three phases.
3. A 5th harmonic restraint, also developed from all three phases, is used to prevent relay operation due to excess exciting currents during transformer overexcitation.

The relay has two operating circuits. One for restrained operation, settable at 20, 25, 32, 40 and 50 % of rated current (minimum pick-up value), and one for unrestrained operation at 8, 13 and 20 times rated value.

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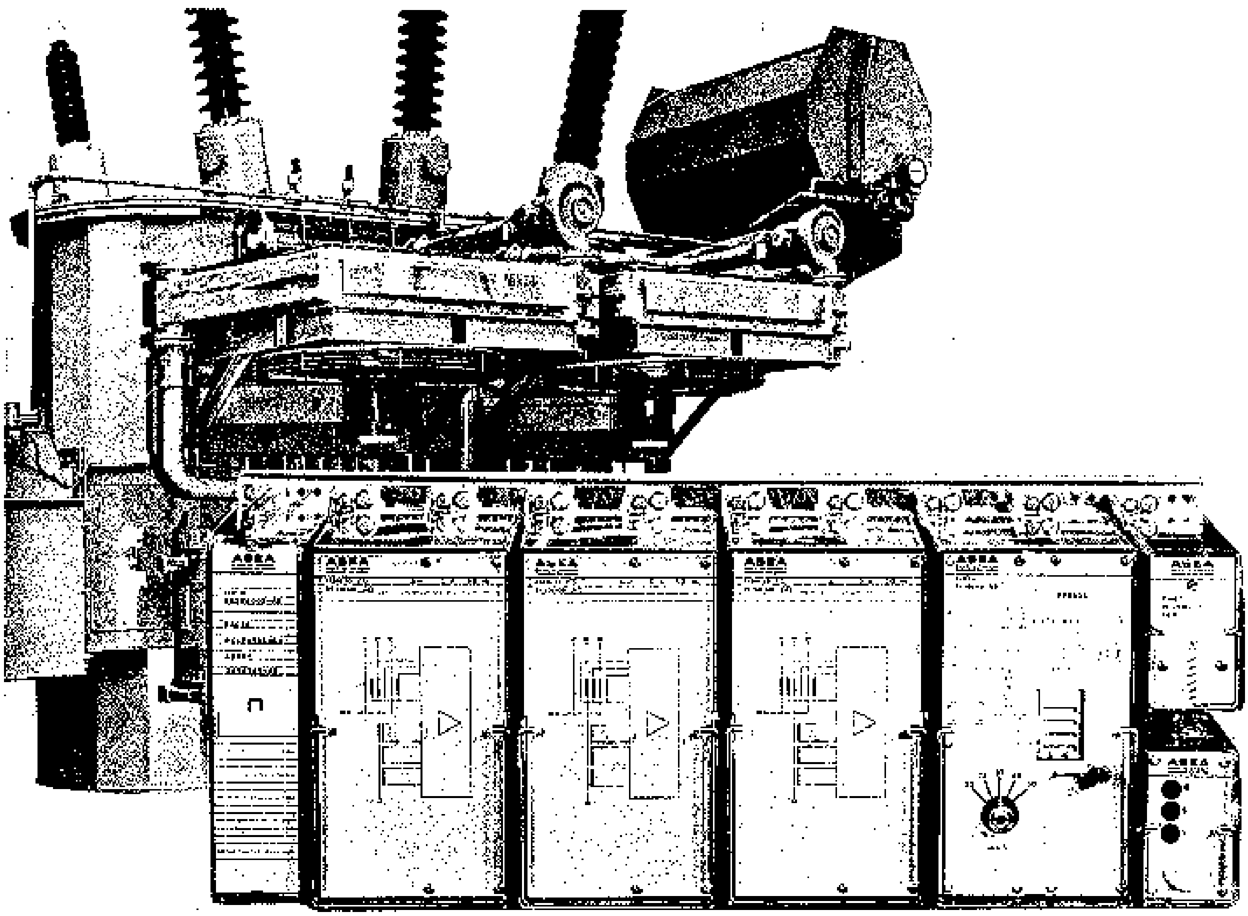


Fig. 1. Three-phase transformer differential relay, type RADSE. (92495, 83288)

Applications

RADSE is an instantaneous, three phase differential relay with three separate percentage restraint input circuits per phase. Additional restraint input circuits, when required, are provided for by the use of RXTUC 4 three phase input-restraint units. These units have input circuits identical to the basic RADSE relay.
Typical applications are:

1. Two-winding transformer
The basic three-winding relay, fig. 1, is used. The unused, third input is left open circuited. All of the described relay characteristics are applicable for this usage.

2. Three-winding transformer
The complete three input relay is used as shown in Fig. 1.

3. Auto-transformer
Diagram, Fig. 7 (a), for a wye-wye-delta connected transformer is applicable. This includes provisions for load on a tertiary winding. When there is no load, or when there is no tertiary winding, this input to the relay is left unconnected, as with a two-winding transformer, Fig. 7 (b).

4. Two-winding transformer with dual breakers on one winding
This would occur with a ring bus, double bus, or breaker and a half bus configuration. The complete three input relay is used without concern for matching any specific relay input circuit with any breaker location.

5. Any transformer with four or more breakers
This configuration could result from a two-winding transformer with dual breakers on each winding, or from multiple-winding transformers, with or without additional breakers associated with any winding. Fig. 3 (b) shows an example.
The basic three phase input relay is used, plus as many additional RXTUC 4 three phase input restraint units as are required.
To provide the necessary test facilities a second RTXP 18 test switch is provided. The general arrangements for these relay versions are shown in Fig. 3 (a).

6. Long transformer leads
The differential zone of the relay can include appreciable lengths of transformer leads. Up to one kilometer of high voltage cable, or comparable capacitance, can be included within the differential zone. While the steady-state phasors would suggest no problem, system disturbances have been known to shock excite these configurations into high current oscillations at frequencies unrelated to the power system frequency. Adequate filtering is within the RADSE to make it secure during these abnormalities without jeopardising its short operating time.

7. Long CT secondary leads
Current transformers may be located at an appreciable distance from the RADSE relay location. When this requirement is overly severe, supplemental auxiliary current transformers may be installed at each end of the long CT leads to greatly reduce the effective CT burden. A 5/1 or even a 5/0.5 A auxiliary CT at the two ends can reduce the burden of 1.5 kilometers of secondary leads at standard 5 A input to 5 VA, including the required auxiliary CT's. The RADSE will function correctly with such an arrangement of the secondary CT circuits.

8. Y, D and zig-zag configurations
The RADSE is provided with separate auxiliary CT's for ratio and phase angle matching and containment of zero sequence current as required with certain power transformer configurations. Thus there are no restrictions on the type of connections used on the main CT's.

9. Use of instantaneous unit
The RADSE has an un-restrained instantaneous unit which is responsive to the total differential current, less any d.c. component. Its setting is selected with regard to the transformer inrush considerations only. The main purpose of the un-restrained instantaneous unit is to provide slightly faster and redundant operation for severe internal faults.

10. Use of sensitivity setting for minor faults
The relay sensitivity to internal faults can be set by means of a selector switch at 20, 25, 32, 40 or 50 per cent of the relay rated current. The 20 per cent setting, in particular, provides improved sensitivities for small windings on large, multiple-winding transformers.
These small windings may be on separate bushings or they may be one of several parallel coils which constitute one main winding of the transformer. In either case the difficulty of making definite fault current calculations for turn to turn faults makes a differential relay setting that is as sensitive as possible under the circumstances very desirable.
The 20 per cent sensitivity may also be desired where large CT ratios are dictated by other system conditions such as the transformer breakers in a ring bus or with a breaker and a half configuration.

11. Use of variable restraint for external fault security
The variable percentage restraint characteristic of the RADSE provides exceptional restraint for severe external faults. For example, an error of 40 per cent in the effective turns ratio of one set of CT's can be tolerated without improper trip out during an extreme external fault. When expressed in terms of the lesser of the fault currents to the relay, the restraint approaches 90 per cent, even when the relay is set on the above illustrated 20 per cent sensitivity. This characteristic makes the relay suitable for use with autotransformers or in a system configuration wherein one transformer winding is directly connected to two or more breakers. In either of these cases external faults may result in very large secondary currents because they are not limited by the usual 5–15 per cent transformer impedance.

Design

RADSE is available in four standard versions, each with or without a phase operation indicator RXSG 1. The versions are for three-, four-, five- and six-winding transformers, respectively according to fig. 3.

The basic version, the three phase, three-winding RADSE relay occupies 4S 60 C in a 19" equipment frame. The basic version without phase indicator is shown in Fig. 2 together with the standard test plug handle RTXH 18.

The components are:

1. Test switch, RTXP 18

In fig. 2 the test switch has the test plug handle RTXH 18 inserted. This test facility permits complete testing of the relay from this one location without any additional, or co-ordinated actions. Load checks are made from this same device. Also, should it be necessary to block relay tripping, a trip-block plug RTXB is inserted into the RTXP 18 without affecting the functioning parts of the relay.

2. Phase units, RXDSE 43

Each of these plug-in units, one for each phase, occupies a space of four modular relay seats.

Each unit includes the circuitry for three inputs, namely, three sets of air-gapped transformers and three pairs of power diodes. In addition, the required variable percentage restraint circuitry and the harmonic restraint filters together with threshold detectors for each phase are located in these three RXDSE 43 units.

Four short-circuiting connectors type RTXK are inserted in each of the three terminal bases for the phase units. These automatically short-circuit the secondary circuits of the supplying line or auxiliary current transformers when any phase unit is removed.

3. Measuring and output unit, RXTEE 4

This plug-in unit also occupies four seats. It includes the measuring circuits, sensitivity range selector switch, power supply regulating circuitry, dry-reed relay and operation indicator. The mechanical output target in this unit may be reset mechanically or electrically by a remote pushbutton.

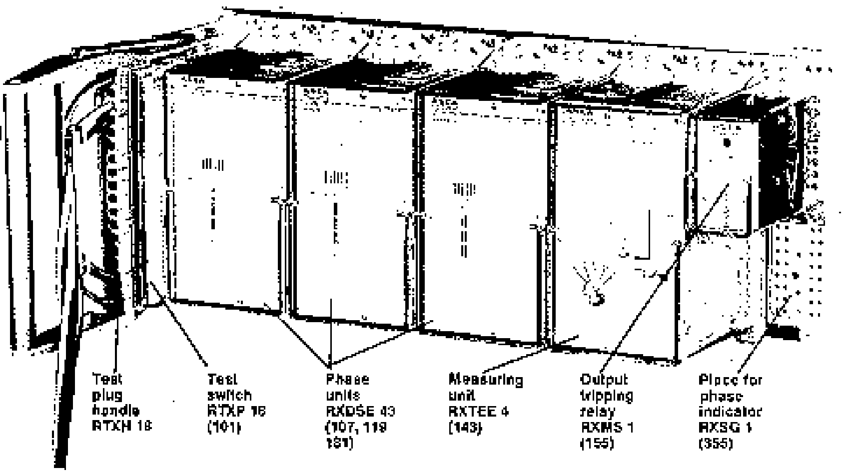


Fig. 2. Type RADSE, basic version, with test plug handle inserted. The numbers in brackets denote seat location of the units (92498)

4. Output tripping relay, RXMS 1

This one-seat relay with a pick-up time of 3 ms is driven by the measuring unit. The relay has six output contacts, each capable of tripping a circuit-breaker. One contact is used for energising the operation indicator in the measuring unit.

5. Phase indicator, RXSG 1 (shown in Fig 1)

The RADSE can be furnished with this one-seat indicator. It indicates which phase unit has operated the output trip circuitry.

Versions without the indicator RXSG 1 have a component block type RTXE mounted on the rear of the measuring unit.

6. Input-restraint units RXTUC 4 (not shown in Fig. 2)

Input-restraint unit, RXTUC 4, is used when more than three input-restraint circuits are required, as shown in Fig. 4. This unit also occupies four seats. Each RXTUC 4 is a three phase unit inserted in a terminal base equipped with three short circuiting deices. It includes three single-phase air-gap transformers plus three pairs of power diodes. Each RXTUC 4 has three output circuits, one for each phase. These connect to the respective RADSE 43 input-restraint units. There is no practical limit to the number of RXTUC 4's which can be added to the RADSE relay.

When RXTUC 4's are required, an additional test switch RTXP 18 is also needed.

Various combinations are shown in Fig. 3. A typical system which would require five inputs is shown in Fig. 4.

Fig. 5 shows such a relay.

Three input circuit restraints, **basic version**

RTXP 18	RXDSE 43	RXDSE 43	RXDSE 43	RXTEE 4	RXMS 1 / 355

Four input circuit restraints

RTXP 18	RXDSE 43	RXDSE 43	RXDSE 43	RXTEE 4	RXMS 1 / 355
RTXP 18	RXTUC 4			543	

Five input circuit restraints

RTXP 18	RXDSE 43	RXDSE 43	RXDSE 43	RXTEE 4	RXMS 1 / 355
RTXP 18	RXTUC 4	RXTUC 4		543	

Six input circuit restraints

RTXP 18	RXDSE 43	RXDSE 43	RXDSE 43	RXTEE 4	RXMS 1 / 355
RTXP 18	RXTUC 4	RXTUC 4	RXTUC 4	543	

Fig. 3. Standard versions of RADSE.

Note 1: All versions can be delivered with phase indicator RXSG 1 or additional RXMS 1 on seat 355.

Note 2: All versions except the basic can be delivered with a third test switch and a lock-out relay RXMVB 4 on seat 543, see Fig. 5.

7. Lock-out relay RXMVB 4

Another option is a trip unit consisting of a third test switch and a lock-out relay RXMVB 4. The relay is energised through the 3 ms RXMS 1 output tripping relay contacts. These additional components mount on an additional 4S apparatus frame identical to that used in the equipment frame for the basic relay. The relay then occupies an 8S equipment frame.

8. Wiring and auxiliary current transformers (CTs)

RADSE is shipped with the interconnected wiring between the individual modules in place ready for the connection of the CT leads, battery and trip circuits. When additional input units are required, the relay is assembled and wired in a double sized equipment frame as shown in Fig. 5.

Auxiliary ratio matching and phase shifting transformers type SLCE 12 are furnished for mounting separately. They are shown in Fig. 6

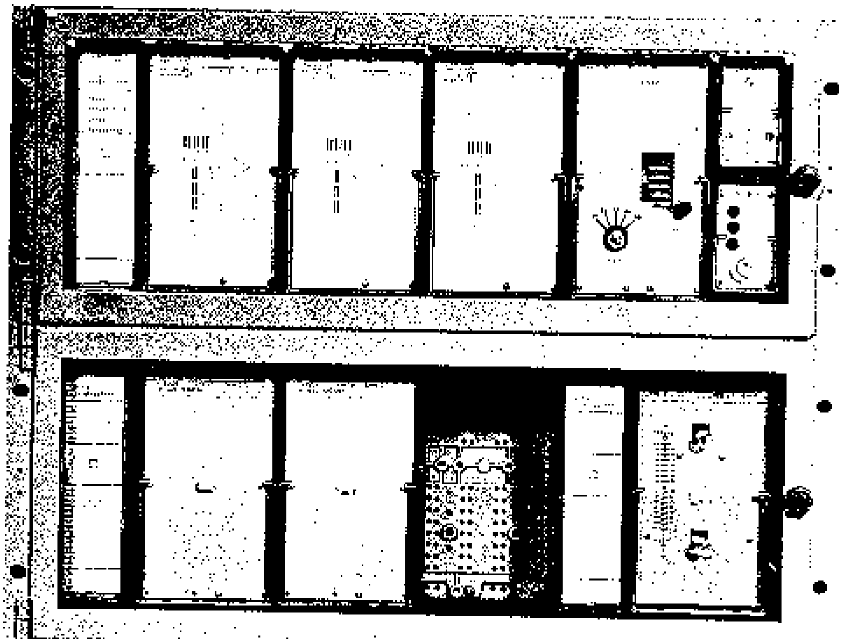


Fig. 5. Two additional input restraint unit RXTUC 4's (lower left) and one trip unit (lower right) in a RADSE with five input-restraints. (90152)

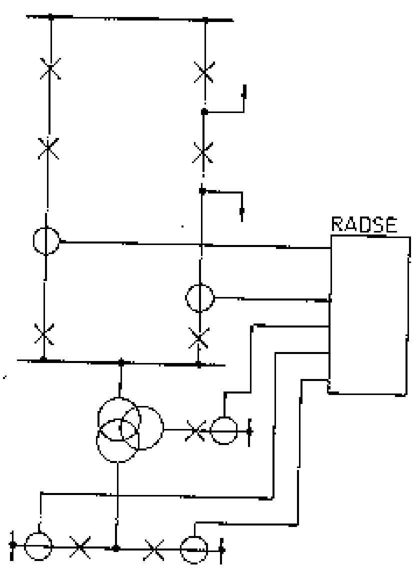


Fig. 4. One line diagram showing an application of a five-input RADSE transformer differential relay.

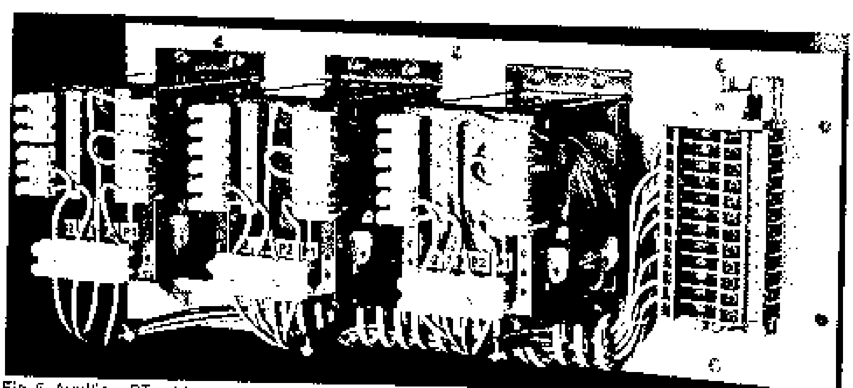


Fig. 6. Auxiliary CT set for one three-phase winding mounted on a 4S (7" high) 19" apparatus plate. (90142)

Installation requirements

Fig. 7 a shows the connection of RADSE to a three-winding transformer. The figure shows two sets of auxiliary current transformers but in some cases three sets are necessary. The standard three-winding design can be used for a two-winding transformer and then the inputs on the test switch for a third winding are left unconnected, see Fig. 7 b—7 d.

According to Figs. 7 c and 7 d with a Y(d)y0 connected transformer the auxiliary current transformer shall be provided with windings in order to equatise the current to the relay during external earth faults. This can be done either with two sets of Yd-connected auxiliary current transformers as in Fig. 7 c or with one set Ydy-connected auxiliary current transformers as in Fig. 7 d. The neutral point of the current transformers must not be connected with the neutral terminal of the relay because, when earth faults arise outside the protected zone, fault current can otherwise pass through the differential circuit of the relay and cause unnecessary operation.

The relay is provided with all internal wiring in place. At time of ordering, the proper dc voltage should be specified for RXMS 1 tripping relay. The target electrical reset can be energised by a 48—60 or 110—250 dc source, separate from the relay, if desired.

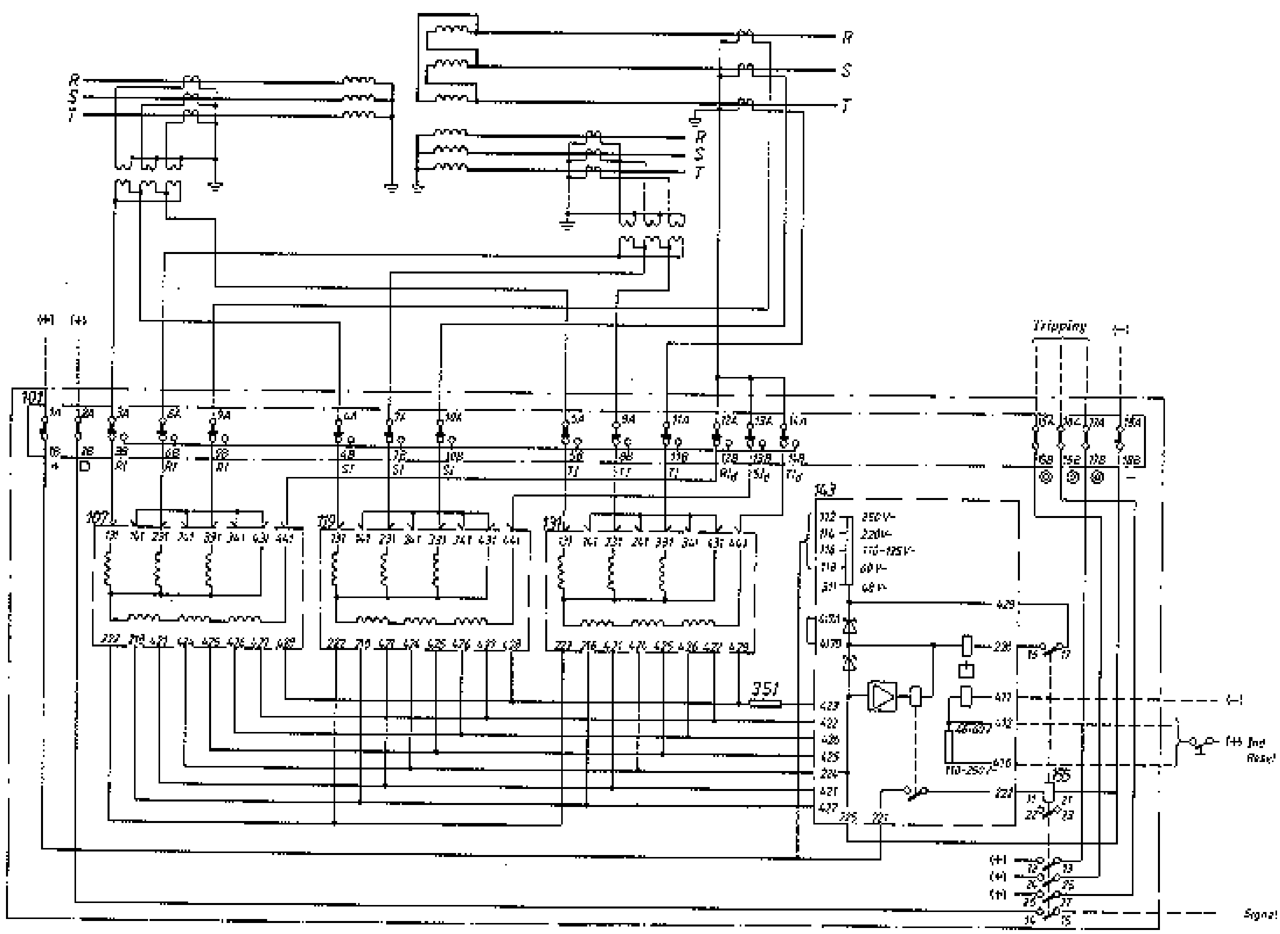


Fig. 7 a. Connection diagram for RADSE connected to a three-winding Yyd-connected transformer.

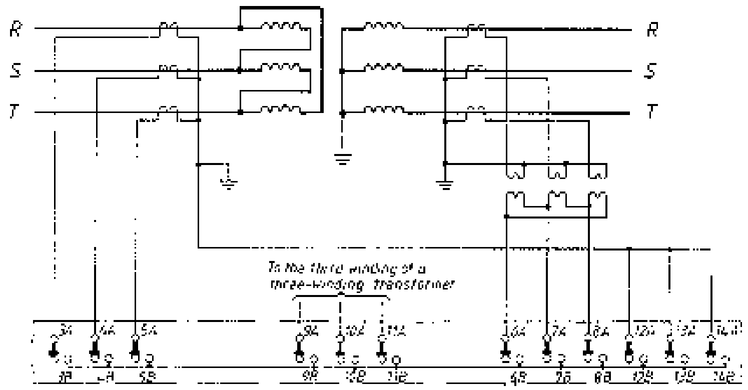


Fig. 7 b. Connection to a Dy 11-connected transformer.

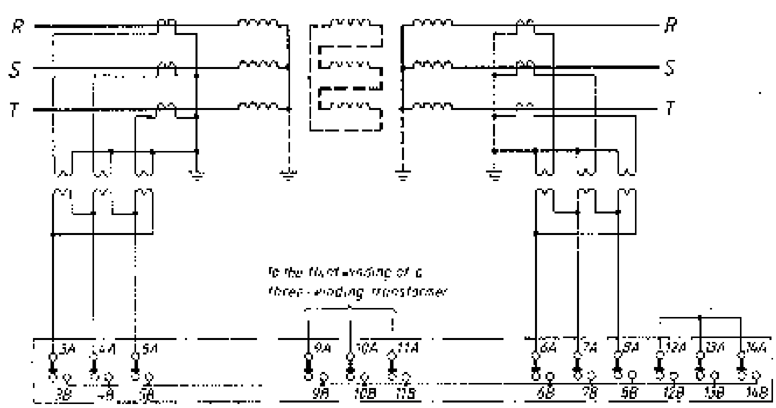


Fig. 7 c. Connection to a Y(d)y0-connected transformer alternative 1.

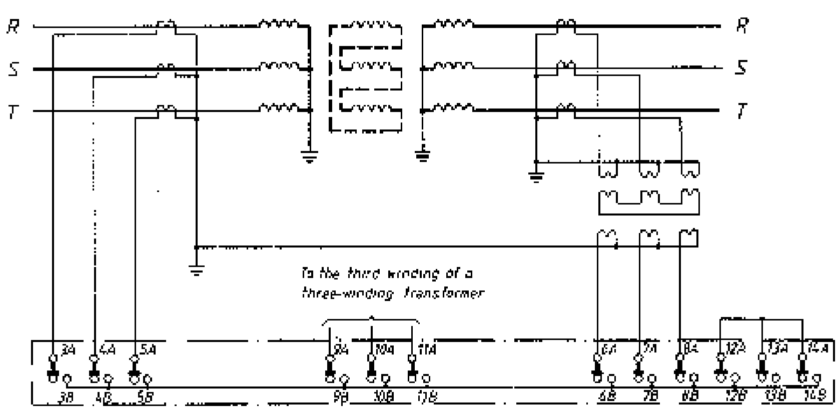


Fig. 7 d. Connection to a Y(d)y0-connected transformer alternative 2.

Current transformers

The differential relay should preferably be fed from its own current transformer cores, which are then only loaded by the secondary leads, and by possible auxiliary current transformers used. The power consumption of the relay itself is negligible. The line as well as the auxiliary current transformers, with the secondary burden that is prevalent, should have an overcurrent factor which corresponds to the maximum through-fault current and should be at least 30.

The ratio and the connections of the auxiliary current transformers are determined so, that the secondary currents are balanced. The secondary currents of power transformers with tap-changers should be balanced at the average ratio of the transformers. The auxiliary current transformers are delivered for separate mounting and can be obtained as reconnectible ones or with special ratios.

When the relay is to be installed at a large distance from the line C.T.s, it may be necessary to locate the auxiliary C.T.s close to the line C.T.s. These auxiliary C.T.s should have a current rating that reduces the power consumption, of the secondary leads to the relay, to a value acceptable in each case. This is especially the case when the differential relay also protects a long feeding cable (transmission cable). In such a case it is often necessary to reduce the rated current of the secondary leads (the pilot-wires) to 0.4 or 0.5 A. For this purpose a set of auxiliary C.T.s are used with the line C.T.s at the line-end, and a further set close to the differential relay, to obtain a rated current of 1 or 5 A for the relay. When the quality or location of the secondary leads (the pilot-wires) is such, that risk of failures exists, a protective resistor or similar component should be connected across the leads. Open secondary circuits may mean damage to the line C.T.s, as well as the auxiliary C.T.s.

For further information regarding calculation and choice of auxiliary CT's, see Information RK 626-101 E and RK 795-300 E.

Technical data

Rated current I_n	1 or 5 A
Rated frequency	50 or 60 Hz
Restraint operating value I_{sr}	settable 20, 25, 32, 40 or 50 per cent of I_n
Un-restrained instantaneous operating value I_{su}	reconnectible to 8, 13 or 20 times I_n
Operating time at $I_d=3\times I_{sr}$ at $I_d=10\times I_{sr}$ at $I_d=2\times I_{su}$	approx. 30 ms approx. 27 ms 10–20 ms
Impulse limit time for I_{sr} for I_{su}	approx. 15 ms approx. 3 ms
Overload capacity 1 A version 5 A version	 10 A continuously; 100 A for 1 s 20 A continuously; 250 A for 1 s
Permissible ambient temperature	−20 to +55 °C for auxiliary voltage ≤125 V dc −20 to +40 °C for auxiliary voltages 220 and 250 V dc
Auxiliary voltage U_n	48, 60, 110, 125, 220 or 250 V d.c. Permissible voltage deviation is maximum −20 and +10 per cent of U_n. (−15 % for 48 V version)
Power consumption: Totally per phase at I_n=1 A at I_n=5A In differential circuit per phase at 0.2 times I_n at I_n=1 A at I_n=5 A In the auxiliary voltage circuit at 48 V at 60 V at 110 V at 125 V at 220 V at 250 V	 approx. 0.02 VA approx. 0.18 VA approx. 0.01 VA approx. 0.02 VA approx. 3.0 W approx. 3.5 W approx. 5 W approx. 6.5 W approx. 9 W approx. 10 W
Test voltage	2.5 kV, 50 Hz in current circuits 2 kV, 50 Hz in other circuits
Impulse test IEC publ. 255-4, app. E	5 kV, 1.2/50 μs, 0.5 joule
Showering arc test SEN 36 15 03	4–8 kV peak value
Disturbance test IEC publ. 225-4, app. E	2.5 kV, MHz, repeated each 2.5 ms during 2 s Decaying time: 3–6 periods.
Weight, basic version	approx. 9.7 kg

Contact data for output tripping relay RXMS 1
Making and breaking capacity indicated below can be increased by series and/or parallel connection of the contacts, see Catalogue RK 21-10 E.

Current carrying capacity		
continuously		4 A
for 1 s		20 A
for 10 ms		100 A
Making capacity		30 A (200 ms)
Breaking capacity,		
a.c., P.F. ≥0.1 at max.	220 V	10 A
d.c., L/R ≤40 ms, at max.	48 V	1 A
	55 V	1 A
	110 V	0.3 A
	125 V	0.25 A
	220 V	0.15 A
	250 V	0.1 A

Aux. current transformer SLCE (see information RK 795–300 E)
Three versions of auxiliary CTs type SLCE 12, taps available in 4–6 per cent steps:

0.65–2.60 A/1A
2.55–9.60 A/1A
2.85–9.70 A/5A

Overload capacity, 1 A version	3 A continuously, 100 A for 1 s
5 A version	15 A continuously, 250 A for 1 s
Power consumption	1.0–2.8 VA

Theory of RADSE operation

There are ten interrelated functions within the RADSE, see in Fig. 8.

1. Input circuitry

Air-gapped isolating transformers are used to convert each restraint current to a voltage. The d.c. component is thus largely suppressed in the case of asymmetrical fault current. The voltages are then each rectified with two power diodes, D_1 through D_6. Fig. 8 shows the arrangement for one phase only. This input circuitry is identical in the RXTUC 4 three-phase supplemental input-restraint unit and in the main RADSE relay, except for the manner of packaging the three phases, as shown in Fig. 8.

2. Percentage restraint circuitry

The rectified restraint voltages of each phase are applied in parallel to a centre tapped resistor, R_1, R_2 as shown in Fig. 8. When such d.c. voltages which have been derived from air-gapped isolating transformers are connected in parallel, the resulting voltage is equal to the largest applied voltage, and the lesser voltages have little effect on the resultant.

In addition, the use of R_1 and R_2 as two arms of the rectifier bridge provides a further valuable characteristic. In the conventional four diode bridge, the output has no sense of input polarity. But with a bridge composed of two diodes and two resistors, the d.c. output voltage becomes sensitive to the **relative polarity** of the applied a.c. voltages. If two applied a.c. voltages are of the same polarity (as during an internal fault), only the larger one will cause a current flow through R_1 on one half cycle and through R_2 on the other half cycle.

But if two applied a.c. voltages are of opposite polarity (as during an external fault), one voltage will cause current to flow through R_1 and R_2 on alternate half cycles, as described, and at the same time the other voltage will cause currents to flow through R_2 and R_1 on the same half cycles. Thus the sum of the two applied voltages results when they are of opposite polarity, but only the maximum of the two results when they are of the same polarity.

Thus, this two-diode two-resistor type bridge, plus air-gapped current transformers results in a desirable type of restraint action. During an internal fault all of the lesser of the various input currents cause no restraint action. But on an external fault the restraint is increased to the sum of the largest of the input currents and the largest of the outgoing currents.

Another desirable feature of this circuit is that all current sources other than these respective maximum ones are isolated from the common restraint output resistors by virtue of their own rectifier diodes. Thus, additional input restraints via RXTUC 4 input unit can be added without practical limit, with minimum effect on the relay characteristic.

Mathematically, if I_x is the maximum (CT secondary) current into, and I_y the maximum current out of the protected transformer; in Fig. 8, the restraint voltage, as developed by this circuit is: $U_1 = k(I_x + I_y)$

where k is the proportionality between voltage and current of the entire circuit. For internal faults I_y will usually be zero (i.e. no current flowing out of the faulty power transformer). The actual restraint voltage is U_5. This is made non-linear with respect to U_1 by means of zener diodes D_7 and D_8 and resistors R_3, R_4 and R_5. Thus more restraint voltage is developed proportionately at large input currents.

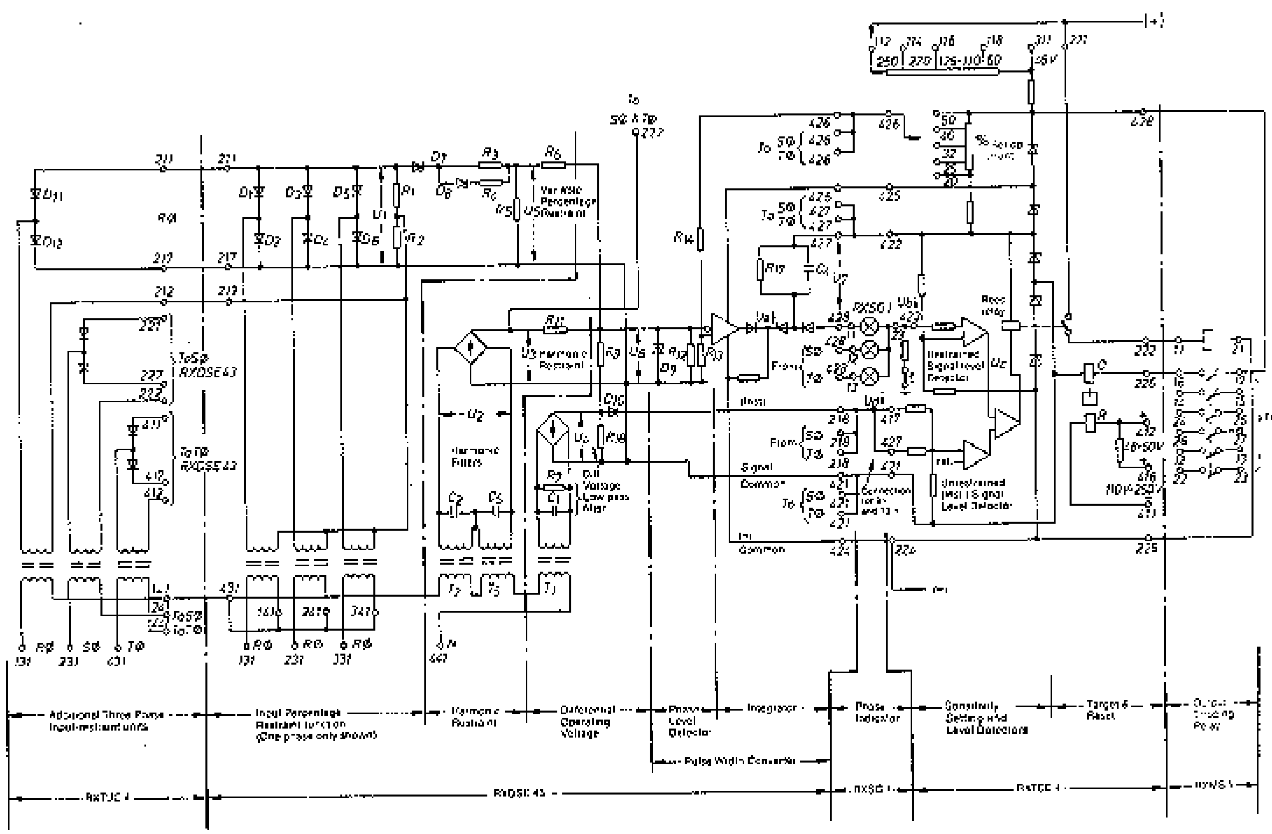


Fig. 8. Functional relations within RADSE including supplemental input restraint unit RXTUC 4 and phase indicator RXSG 1.

3. Differential circuitry

The differential current is derived in the conventional manner by summing all of the currents associated with each phase. This current is then used to develop the harmonic restraint as well as the operating voltages.

Again air-gapped transformers are used to suppress the d.c. component in the operating voltage.

They are also used in the harmonic restraint circuitry and low pass filter to additionally provide the inductive branch of these L−C filters.

The total differential current is used to develop the differential voltage U_d. However, the high frequency components are suppressed in the low pass filter T_1, R_7 and C_1, before rectification in a conventional four diode bridge. This filter prevents relay operation from frequencies above 500 Hz.

4. Harmonic restraints

The 2nd and 5th harmonics are segregated by means of T_2-C_2 and T_5-C_5 respectively. These two harmonic voltages are totalled (U_2) before rectifying in a four diode bridge. The rectified harmonics from all three phases are brought together via terminals 222 and the resultant, U_3, used for restraint on each of the three phases. The net effect of this method of harmonic for restraint is to provide an improved restraint with minimum reduction in speed or sensitivity to internal faults.

5. Phase threshold circuitry. (Pulse width convertor)

The rectified operating and restraint voltages are summed up in a resistor type summation circuit R_6, R_9, R_{11} and R_{12} as shown in Fig. 8 as U_8. There is a substantial a.c. component in this summation because of filtering. This complex wave form is then compared to a d.c. reference developed by R_{13}, R_{14}.

Any signal above the reference is converted in the operational amplifier circuit to a variable pulse width signal which is then integrated in C_4 and R_{17}.

6. Measurement circuitry

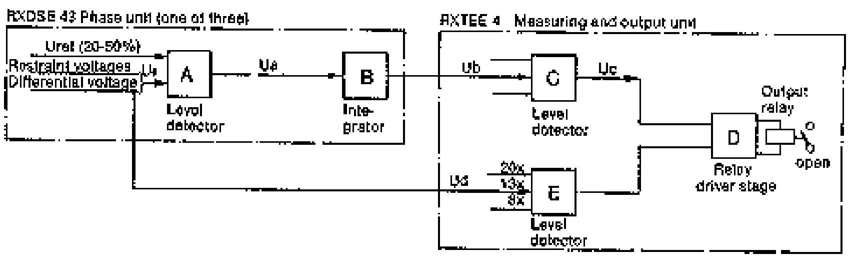
The integrated output pulses from each of the three, phase-threshold integrators are fed to a common measuring unit. When the width of the pulse to any phase threshold-integrator circuits exceeds 4.1 ms (out of an 10 ms period), the biases on the transistor output amplifier are shifted to provide the desired trip output.

Fig. 8 illustrates the method by which this measurement is made. Fig. 9 shows the wave shapes and the action of the various components in these circuits which determines if a trip condition exists.

7. Un-restrained trip circuitry

This is also an instantaneous function, with a signal as short as 3 ms capable of causing a trip output condition. This signal U_4, is derived from the differential current. It is taken from the rectified output of the differential voltage circuit through diode D_{10}.

A separate measuring circuit in the three-phase measuring unit determines if this signal is above the set value of 8, 13 or 20 times the relay rating. The desired setting is made by means of a COMBIFLEX wire jumper between terminals 417 and 427, as described in section SETTING.



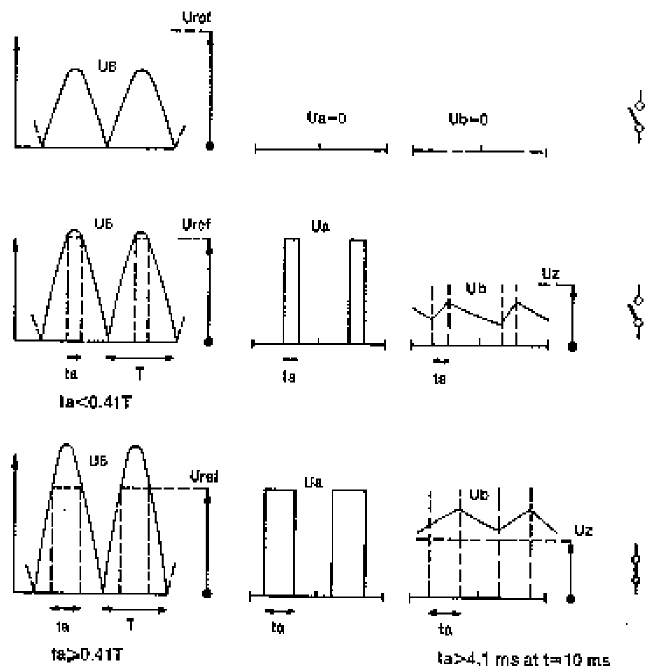


Fig. 9. Wave shapes and pulse width integrating action required to develop trip signals.

8. Setting circuitry
Within the three-phase measuring unit is a set of tapped resistors wired to a front mounted selector switch for the 20, 25, 32, 40 or 50 per cent restraint pickup current setting. These resistors plus R_{13} and R_{14} set the bias on the operational amplifiers in the RXDSE 43 units. This sets the calibration of the individual phase threshold-integrators to the value marked on the selector switch.

9. Output circuitry
The output amplifier drives a 1 ms dry-reed relay.
The reed relay energises a 3 ms six contact, RXMS 1 output tripping relay. Each contact is capable of tripping a breaker. Wiring functions are shown in Fig. 7 a. The RXMS 1 relay contacts are all NO and the relay can be energised continuously. Thus the circuitry can seal in this relay so as to provide a self-contained lockout function.

10. Ancillary functions

a. Target
One contact on the RXMS 1 output tripping relay energises the coil O of an operation indicator, T. This is a mechanical and electrical resettable device. It has no restrictions on the source of voltage for the reset function, R. As shown in Fig. 8, a dropping resistor is included to allow resetting with any voltage from 48 to 250 V dc.

b. Phase indication
When specified, type RXSG 1 Individual phase indicator unit is provided. This is a one seat device and locates in the available seat 355 in the basic assembly. Electrically the targets are electronically controlled light emitting diodes located in the output of each phase threshold circuit as shown in Fig. 8. The targets are reset by a front mounted pushbutton on RXSG 1.

c. The method of zener diode regulation of auxiliary voltages to correct value regardless of value of supply voltage between 48 and 250 V is also shown in Fig. 8.

Performance characteristics

All characteristics are based on the a.c. component of the applied currents, since the RADSE has airgapped transformers which suppress the dc component.
The basic relay is a three-phase, three input restraint relay. The described performance is also applicable when the relay is used only with two three phase inputs. Similarly, additional inputs in conjunction with RXTUC 4 three phase input units will result in the same described relay performance.

Through-fault restraint
The variable percentage restraint characteristics of the RADSE are shown in Fig. 10 and 11. The abscissa is the average of the maximum current entering the protected zone and the maximum current leaving the zone. These are the two currents which develop the restraint within the relay. The average value of the current rather than the sum is used to provide a quantity whose value is comparable to the flow-through fault current during an external fault.
The ordinate of Fig. 10 and 11 is the usual operating current flowing in the differential circuit.
The percentage slope plotted in Fig. 12, is the ratio of the ordinate to abscissa of Fig. 10.
This same set of characteristics is applicable for internal faults. Normally all currents would flow into such a fault. The correct value of restraint to use with these curves then becomes one-half of whichever current is the maximum infeed.

Note: It is apparent that the plotted slope of a differential relay is a function of the method of presenting the restraint data as well as the actual operating characteristic of the relay.

The RADSE fundamental frequency characteristic is further illustrated in Fig. 10 by points E and I. Point E is the plot of a heavy external fault as might occur in a ring bus or breaker and a half scheme with a through-fault current of 30 times CT ratings and a ratio error in one set of CT's of 35 per cent. With such severe distortion, of course, the harmonic content of the secondary currents must also be considered.
Point I is a small internal fault of four times transformer rating supplied from only one source.
Heavy load currents will have very little effect on the sensitivity of the RADSE even to minor fault currents. These two currents, load and fault, will normally be nearly 90° out of phase to each other in at least one phase. The phase threshold measurement is made on an instantaneous basis, since there is no filtering in the rectified signal circuits. Thus the fault current measurement is made during the periods of the cycle when the load currents are at a minimum.

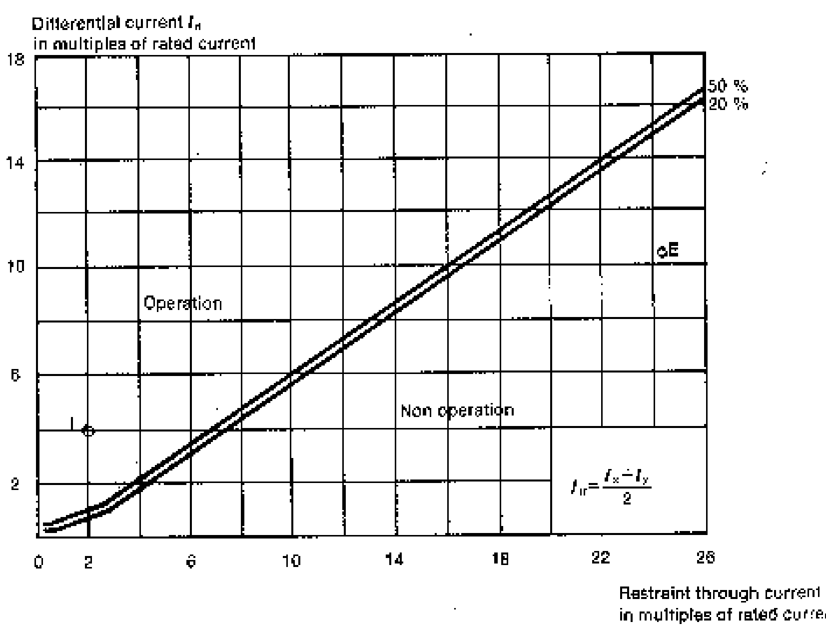


Fig. 10. Through current restraining characteristic at large current value for set operating currents, I_d=20 and 50% of rated current I_n.

Magnetising inrush restraint

The 2nd and 5th harmonic restraint voltages for each phase are paralleled and the resultant used for harmonic restraint for each phase. This resultant will be proportional to the sum of the harmonic currents. These restraints are linear with respect to the operating current magnitude. A 2nd harmonic current in the differential operating circuit of any phase will block the operation of the relay if it exceeds 20 per cent of the value of the fundamental differential current in any phase. Tests and analysis show that magnetising inrush currents which are greater than the minimum pick-up current of the RADSE will contain more than 20 per cent 2nd harmonic in at least phase.

Over-excitation restraint

A 5th harmonic current in the differential operating circuit of any phase greater than 35 per cent of the fundamental differential current in any phase will also block relay operation. Tests and analysis show that transformer exciting currents due to high voltage which are greater than the minimum pick-up current of the RADSE will contain sufficient 5th harmonic current to block relay operation. However, very large over-excitation currents can quickly cause transformer damage. Overvoltages of about 1.5 per unit will result in exciting currents approaching to the full load rating of the transformer. At these very high exciting currents, the percentage of 5th harmonic drops below the 35 per cent restraint value of the RADSE. Thus if the overvoltage is sufficient to seriously jeopardise the transformer in a very short time, the RADSE will operate to protect the transformer. Every transformer design will result in some differences in overvoltage excitation characteristics. But the basic mathematics of overexcitation currents shows that the 5th harmonic is larger than the amount required to block the RADSE up to exciting currents about 50—70 % of transformer full load rating. And above this current, the percentage 5th harmonic becomes less and the relay will operate to prevent transformer damage. However, it is important that the RADSE characteristic has been designed to prevent tripout on overexcitation and it should not be the sole protection if extremely large, damaging excitation currents are possible.

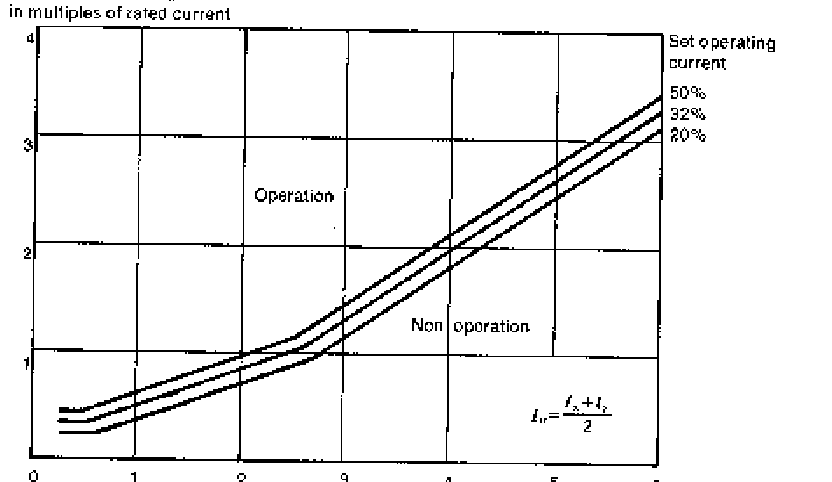


Fig. 11. The low current region of Figure 10.

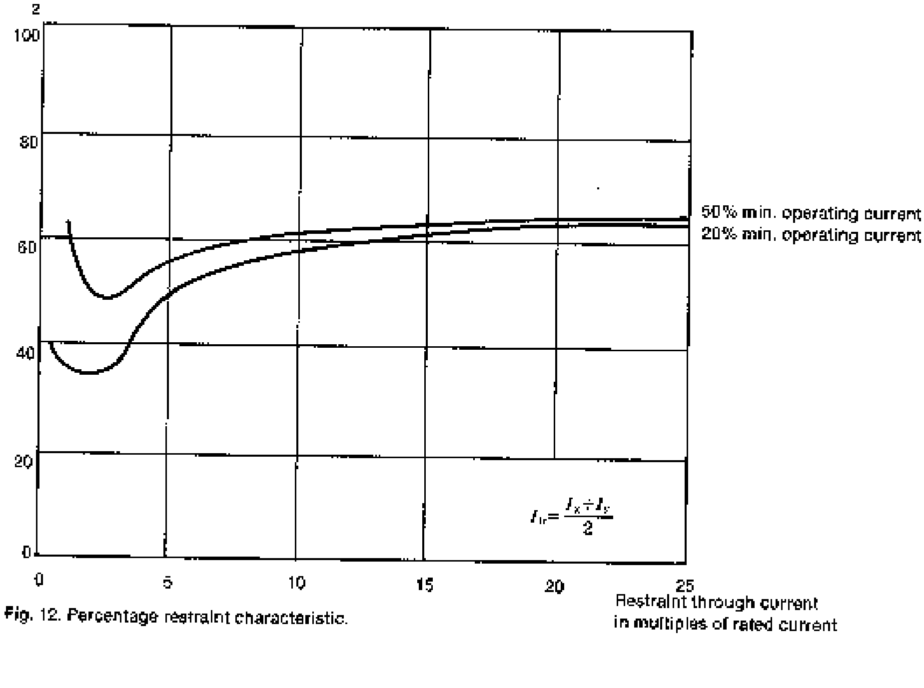


Fig. 12. Percentage restraint characteristic.

Setting determinations

Restraint operating value I_{o}
The setting for minimum current sensitivity (20, 25, 32, 40 or 50 per cent of relay rating) is done with a knob on the measuring unit RXTEE 4 and should be selected based on estimated CT performance during small current conditions. As shown in Fig. 12 this setting is not a slope setting. It has minimal effect on the relay performance at high currents. It also has minimum effect on the percentage restraint action of the 2nd and 5th harmonics. Thus a sensitive setting will not cause trip-outs due to magnetising inrush.
The 20 per cent sensitivity is suitable for CT turns ratio mismatch errors up to about 5 per cent. When transformes with on-load tap changers are being protected, a minimum current sensitivity of about 15 percentage points greater than the worst turns ratio mismatch at the tap changer extreme should normally be selected.

Un-restraint operating value I_{su}
The un-restrained, instantaneous relay setting is not functionally related to any other setting of the relay. Nor need its setting determination be based on the setting of the restrained unit or on CT characteristics. The relay is shipped with this unit set at 20 times relay rating. It can be reset to 8 or 13 times rating by means of shifting leads on the relay terminals as shown in Fig. 13. This unit is not responsive to the d.c. component in an asymmetrical current. It is responsive to approximately the peak value of the a.c. component of the applied differential current and is calibrated in rms current for an equivalent sine wave. At high currents it will respond to a current pulse of only 3 ms, (as from a saturating CT). But it is unaffected by transient spikes of less than this time duration.

This function of the relay should be set above any anticipated inrush currents. The following table of suggested settings is based on experience with typical transformers.
Versions with RXTUC 4 input-restraint units have no change in the setting procedures.

DC Voltage Taps
Taps for the d.c. voltage should conform to the available voltage, per Fig. 6. The RXMS 1 output tripping relay should have the proper coil for the available voltage. The voltage taps of the RXTEE 4 are only for the static circuits.

Transformer connection[1])	Transformer size MVA	Instantaneous setting when energised from H.V. side	L.V. side
–	<10 MVA	20 X	20 X
Yy	10–100 MVA	13 X	13 X
Yy	>100 MVA	8 X	8 X
Yd	–	13 X	13 X
Dy	<100 MVA	13 X	20 X
Dy	>100 MVA	8 X	13 X

[1]) Primary side is supposed to be H.V. side

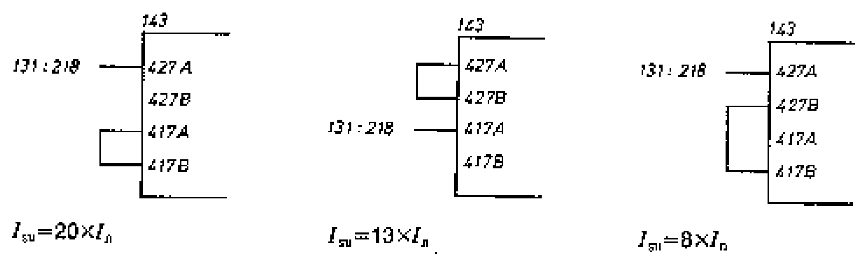


Fig. 13. Un-restrained instantaneous operating current I_{su} setting adjustments by means of jumper positions at the rear of the RXTEE 4 module.

Ordering tables

Type RADSE for three input circuit restraints

When ordering the RADSE for two or three input circuit restraints it is sufficient to state the Cat. No. from the table and desired text on the legend plate of the test switch. The relay is in these cases mounted on apparatus bars 60 C on delivery.

Version	Auxiliary supply voltage V, d.c.	Cat. No. Rated current 1A 50 Hz	60 Hz	Rated current 5 50 Hz	60 Hz
Three input circuit restraints, without phase indicator Diagram 7454 315-AF	48	RK 626 321–BH	–CH	RK 626 325–BH	–CH
	110	–BN	–CN	–BN	–CN
	125	–BP	–CP	–BP	–CP
	220	–BS	–CS	–BS	–CS
	250	–BT	–CT	–BT	–CT
Three input circuit restraints, with phase indicator unit type RXSG 1 Diagram 7454 315-CE	48	RK 626 331–BH	–CH	RK 626 335–BH	–CH
	110	–BN	–CN	–BN	–CN
	125	–BP	–CP	–BP	–CP
	220	–BS	–CS	–BS	–CS
	250	–BT	–CT	–BT	–CT

Type RADSE for four, five or six input circuit restraints.

When ordering the RADSE for four, five or six input circuit restraints state besides the Cat.No. also rated current, frequency, auxiliary voltage, with or without a third test switch and a lock-out relay RXMVB 4 and possible text on the legend plate of the test switch. In these versions the relay is mounted in an 8S equipment frame on delivery.

Version	Cat. No	Diagram
Four input circuit restraints		
without phase indicator	RK 626 400–DA	7454 338–DB
with phase indicator	–CA	–CA
Five or **six** input circuit restraints,		
without phase indicator	RK 626 500–AA	7454 338–AB
with phase indicator	–BA	–BA

Receiving, handling and storage

These relays are shipped in cartons designed to protect them from damage when not included as part of a cubicle or control panel. Upon receipt the relay should be inspected for physical damage.

It is recommended that the relay is replaced in its shipping carton after inspection for delivery to job-site. Also the relay should preferably be left in its shipping carton until time for actual installation.

The relay is not critical as to humidity. But general prudence suggests that it is stored in a dry, moderate temperature environment.

Reference publications

Reconnectible ratio-matching multi-tapped auxiliary current transformers type SLCE 12 for transformer differential relays	Information RK 795-300 E
Commissioning instruction for transformer differential relay RADSE	Information RK 626-100 E
Calculation and connection guide for auxiliary current transformers	Information RK 626-101 E
Auxiliary relay RXMS 1	Catalogue RK 21-10 E
Overexitation relay RATUA	Catalogue RK 62-11 E
Modular system COMBIFLEX	Catalogue RK 92-10 E
Testing system COMBITEST	Catalogue RK 92-11 E
Index of printed matter	Information RK 000-100 E

Dimensions

RADSE for three input circuit restraints in a 4S-equipment frame. The equipment frame is **not included** in the Cat. No. and must be specified separately.

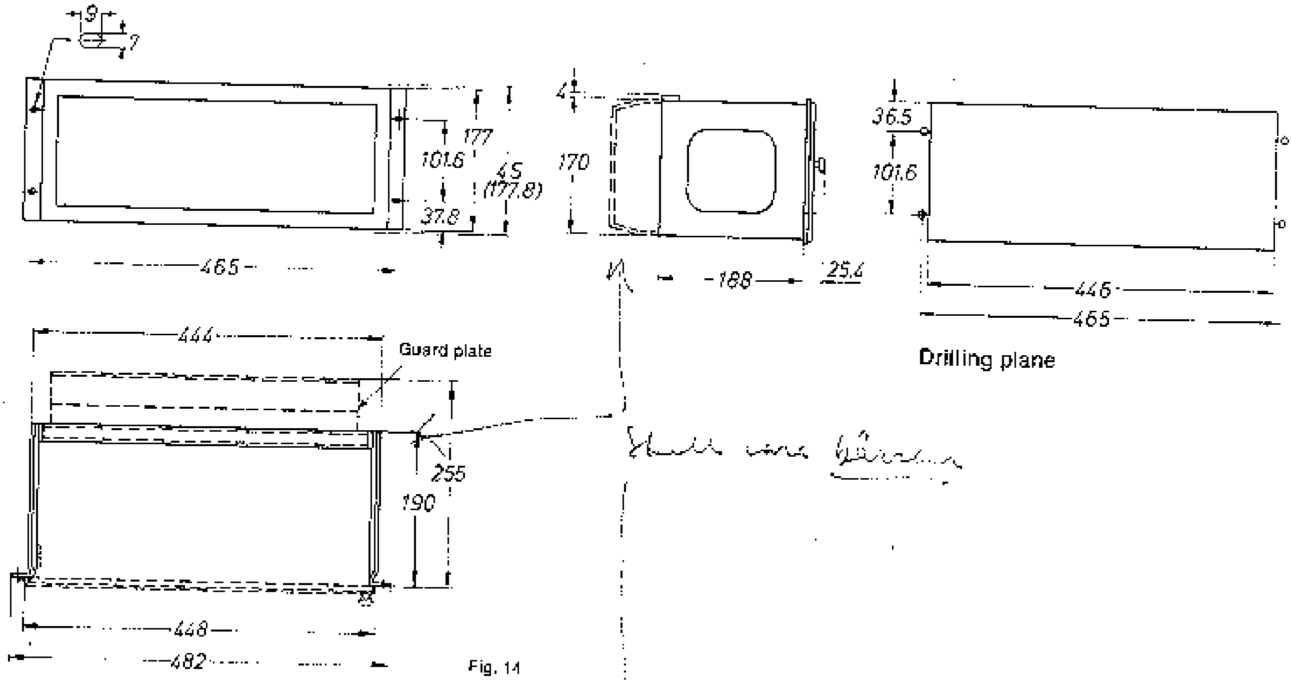


Fig. 14

RADSE for four, five or six input circuit restraints in an 8S-equipment frame. The equipment frame is in this case **included** in the Cat. No.

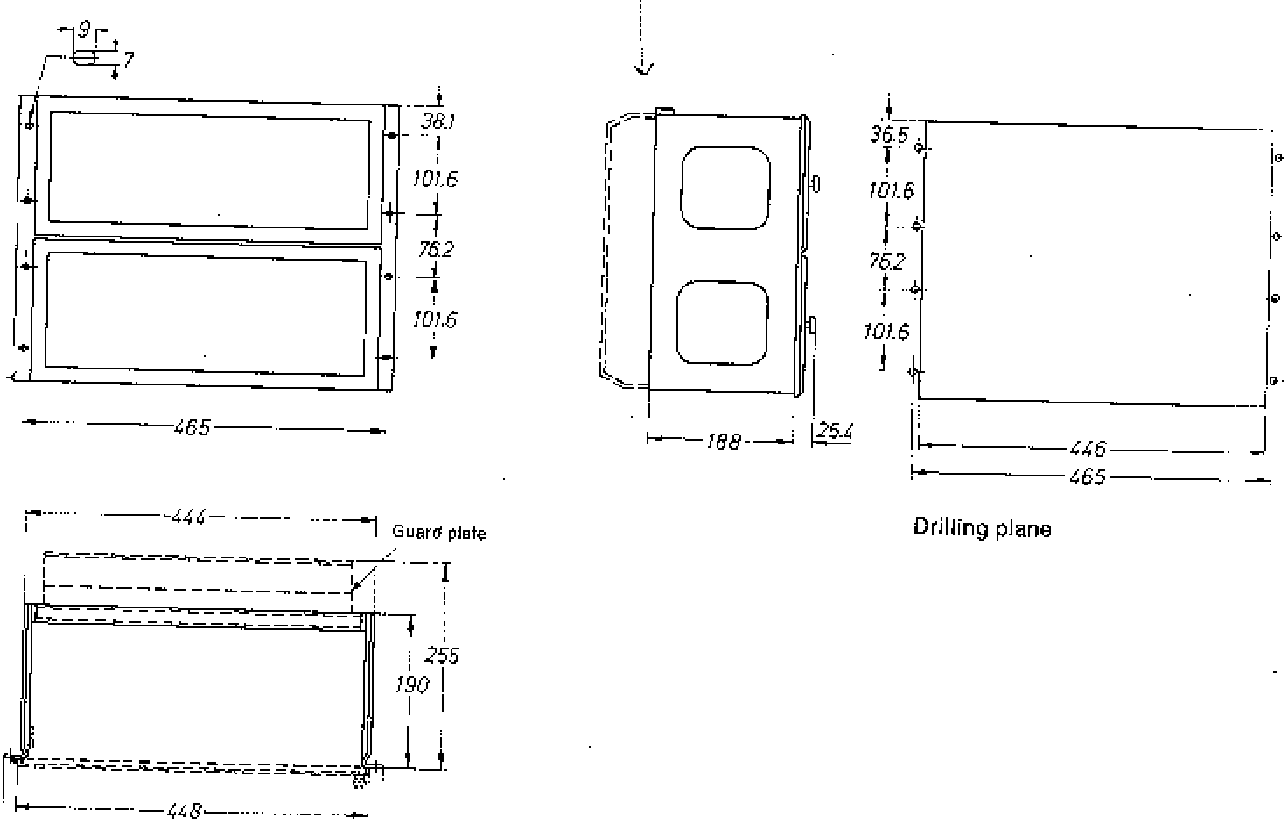
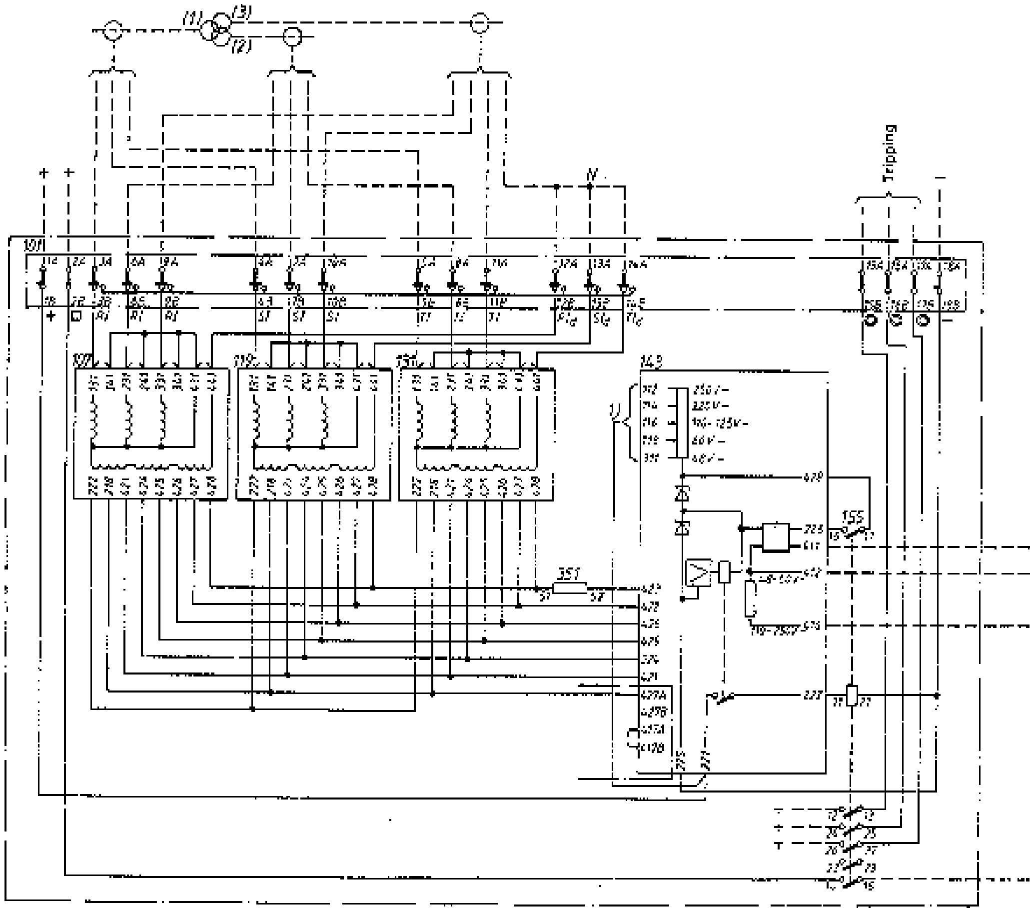
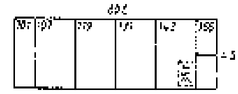


Fig. 15

Circuit diagrams

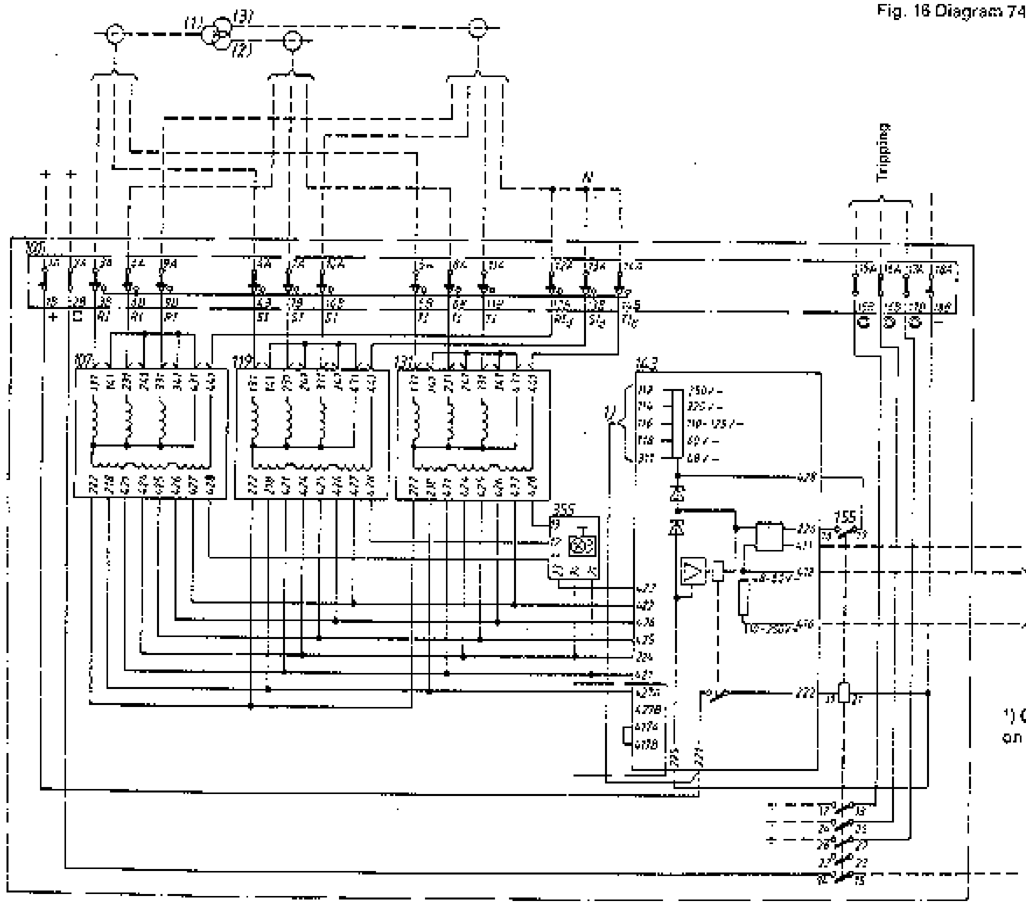


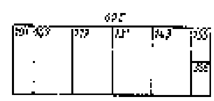


101	RTXP 18
107, 119, 131	RXDSE 43
143	RXTEE 4
155	RXMS 1

¹) Connected to actual voltage at delivery

Fig. 16 Diagram 7454 315 – AF





101	RTXP 18
107, 119, 131	RXDSE 43
143	RXTEE 4
155	RXMS 1
355	RXSG 1

¹) Connected to actual voltage on delivery

Fig. 17 Diagram 7454 315 – CE

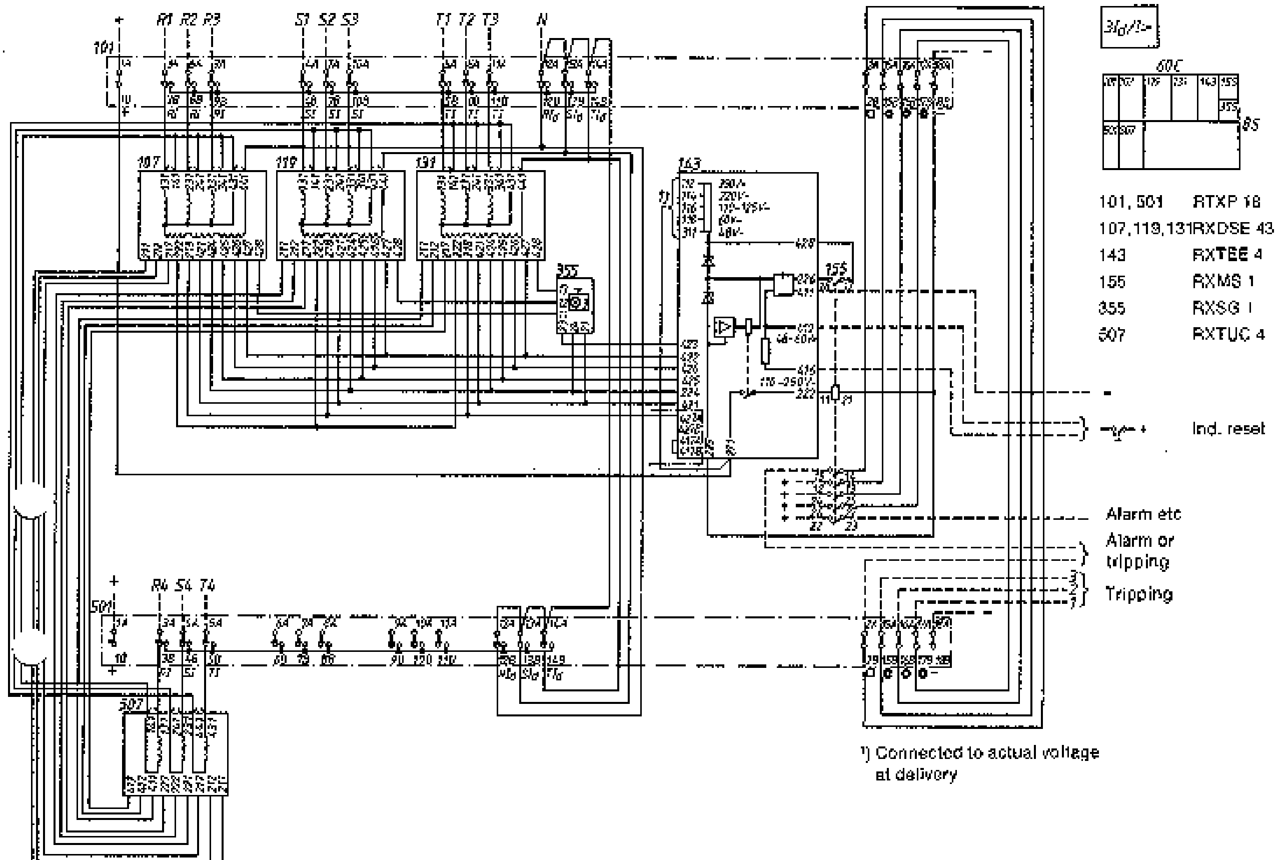


Fig. 18 Diagram 7454 338 – CA

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