High Speed Phase and Ground Protection for Multiple-Winding and Auto-Transformers

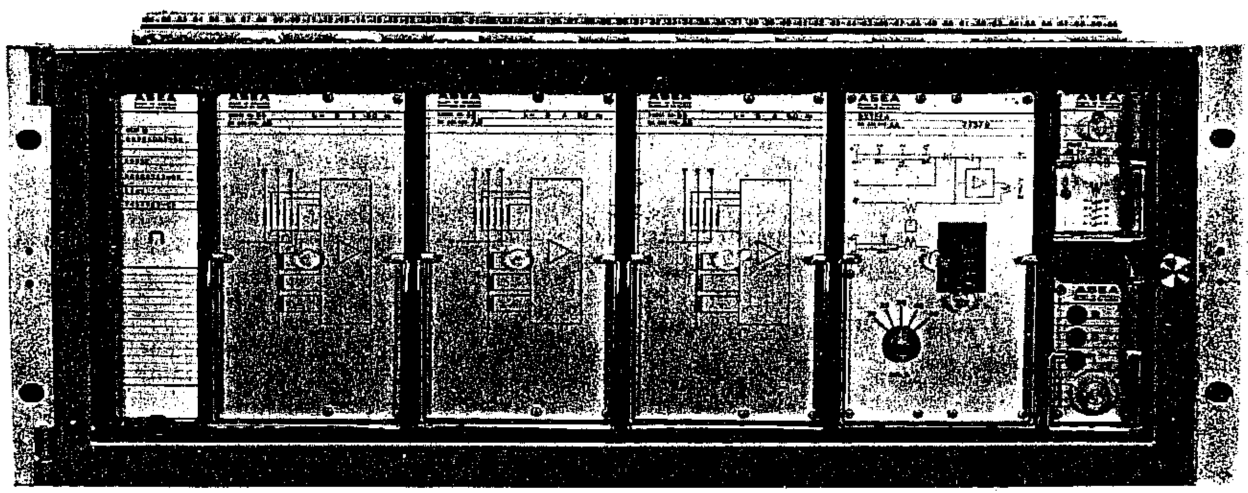

Fig. 1. Three-phase transformer differential relay, type RADSE, occupies one 4S (7" high) COMBIFLEX® equipment frame for mounting on a 19" equipment rack. Auxiliary CT's for ratio and phase matching are provided for separate mounting.

GENERAL

The DSE 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. There is no limitation in the application of the relay as to the number of transformer windings, or to the number of breakers which may be associated with any one transformer winding.

Solid state circuitry is used to create three separate restraints:

1. The variable percentage restraint circuitry provides both improved security to external faults and improved sensitivity to internal faults.
2. The 2nd harmonic restraint circuitry provides improved inrush suppression. It is derived from all three phases. It has a minimum effect on relay sensitivity to an internal fault if one occurs during the transformer energizing period.
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 5th harmonic is preferable to the 3rd for this function because the 3rd harmonic currents may circulate mostly in the transformer delta winding and not appear in the relay restraint circuit. The 5th harmonic is also to be preferred when considering possible current distortions due to CT saturation during an internal fault. Under such conditions tripping is desired and the 5th harmonic provides less restraint than the 3rd.

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  - Sales Information — 92–10 SI
  - Application Guide — 92–10 AG

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APPLICATIONS

The DSE is an instantaneous, 1/2–2 cycle, 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 DSE relay. They mount in the COMBIFLEX 19" frame with the other DSE modular components. Typical applications are:

1. Two-winding transformer; auto-transformer
The basic three-winding relay, Figure 1, is used. The unused, third input is left open circuited. See wiring diagram Figure 7 (a). 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 Figure 7 (b).

3. Auto-transformer
No special treatment is required. Wiring diagram, Figure 7 (b), 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 DSE is left unconnected, as with a two-winding transformer, Figure 7 (a).

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. See Figure 7 (c). Also note section on CT calculations, page 14.

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.
The basic three phase input relay is used, plus as many additional TUC 4 three phase input restraint units as are required. There is no practical limit to the number of additional TUC 4 units, nor need they be assigned to any specific relay input source. Thus inputs from strong or weak sources need no special treatment. Figure 7 (d) is typical of this application. To provide the necessary test facilities a second RTXP 18 test switch is provided. The general arrangements for these basic relays are shown in Figure 3 (a).

6. Long transformer leads
The differential zone of the DSE can include appreciable lengths of transformer leads. Up to one-half mile 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 DSE to make it secure during these abnormalities without jeopardizing its 1/2–2 cycle operating time.

7. Long CT secondary leads
Current transformers may be located at an appreciable distance from the DSE 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 a mile of secondary leads at standard 5 A input to 5 VA, including the required auxiliary CT's. The DSE will function correctly with such an arrangement of the secondary CT circuits.

8. Wye, delta and zig-zag configurations
The DSE 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. Various CT and auxiliary CT arrangements are shown in Figure 9. When main CT's are connected in delta at the main CT location the equivalent burden the leads to the relay location is increased by a factor of two. Thus the comments in item 7 above may be applicable for even moderate distances.

9. Use of instantaneous unit
The DSE has an un-restrained instantaneous unit which is responsive to the total differential current, less any dc component. Its setting is selected with regard to the transformer inrush considerations only. It need not be coordinated with the setting of the restraint unit of the DSE because the restrained relay is not restrained by 3rd harmonics. Thirds are the predominant harmonic in the secondary current from a saturated CT. Hence, CT saturation has no effect on the DSE restraint unit during internal faults. 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 percent of the relay rated current. The 20 percent 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 as sensitive as feasible very desirable. The 20 percent sensitivity may also be desired where

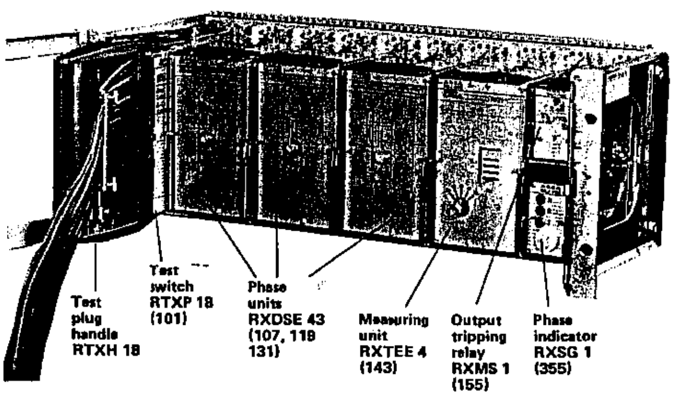
large CT ratios are dictated by other system conditions such as the transformer breakers in a ring bus or with a breaker and a half configuration.

11 Use of variable restraint for external fault security
T variable percentage restraint characteristic of the DSE provides exceptional restraint for severe external faults. For example, an error of 40 percent in the effective turns ratio of one set of CT's can be tolerated by the DSE 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 percent, even when the relay is set on the above illustrated 20 percent 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 percent transformer impedance.

DESCRIPTION

The DSE is available in four standard versions, each with or without a phase operation indicator SG 1, and/or MVB 4 lockout relay. The versions are for three-, four-, five- and six-winding transformers respectively.

The basic three phase, three-winding DSE relay occupies 19 or 20 module seats of a 4S (7" high) C BIFLEX equipment frame prewired and ready for mounting on a 19" equipment rack or on a switchboard with suitable cut outs made. The basic version with phase indicator is shown in Figure 2 together with the standard test plug handle RTXH 18. The multi restraint model layouts shown in Fig. 3 (a) illustrate the flexibility of the COMBIFLEX design. Any model can be simply expanded to more inputs or tripping outputs if future conditions should change. Fig. 3 (b) is one type of system configuration which may result from enlargements over the years.



F Three-phase variable percentage differential relay with test plug ha e inserted. The numbers within brackets denote seat location of the units.

The components are:

1. Test switch, RTXP 18
   In Figure 2 the 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 coordinated actions. Load checks are made from this same device. Also, should it be necessary to block relay tripping, a trip-block plug RTXB inserts into the RTXP 18 without affecting the functioning parts of the relay. Figure 7 (a) to 7 (f) show how this test switch connects into the relay external wiring. Figure 8 shows how the plugs and other accessories are used with this switch.
2. Phase units, RXDSE 43
   Each of these plug-in units, one for each phase, occupies four seats in the COMBIFLEX frame, 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 DSE 43 units.
   Four short-circuiting devices type RTXK are inserted in each of the three terminal bases for the phase units. These devices short-circuit automatically 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 by a remote push-button as shown in Figure 7 (a).
4. Output tripping relay, RXMS 1
   This one seat 3 ms relay is driven by the measuring unit. The relay has six output contacts, each capable of tripping a circuit-breaker. One contact is used for energizing the operation indicator in the measuring unit.
5. Phase indicator, RXSG 1
   The DSE can be furnished with this one seat indicator. It indicates which phase unit has operated independent of the output trip circuitry. When not specified, the seat is left vacant.
6. Input-restraint units RXTUC 4 (not shown in Figure 2)
   Additional input-restraint units, TUC 4, are used when more than three input-restraint circuits are required, as shown in Figure 4. This unit also occupies four seats. Each TUC 4 is a three phase unit inserted in a terminal base equipped with three short-circuiting devices. It includes three single-phase air-gap transformers plus three pairs of power diodes.

Each TUC 4 has three output circuits, one for each phase. These connect to the respective DSE 43 input-restraint units. These is no practical limit to the number of TUC 4's which can be added to the DSE relay. When TUC 4's are required, an additional test switch RTXP 18 is also needed. 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 (14" high) COMBIFLEX equipment frame. Various combinations are shown in Figure 3 (a). A typical system which would require six inputs is shown in Figure 3 (b).

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 shown at lower right of Figure 4. The MVB 4 is energized through the 3 ms MS 1 output tripping relay contacts. This trip unit occupies six seats.

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	RXDSE43	RXDSE43	RXTEE 4	RXMS 1 / 355
RTXP 18	RXTUC 4			543	

Five input circuit restraints

RTXP 18	RXDSE 43	RXDSE43	RXDSE 43	RXTEE 4	RXMS 1 / 355
RTXP 18	RXTUC 4	RXTUC4		543	

Six input circuit restraints

RTXP 18	RXDSE 43	RXDSE43	RXDSE43	RXTEE 4	RXMS 1 / 355
RTXP 18	RXTUC 4	RXTUC 4	RXTUC 4	543	

Fig. 3 (a). Standard versions of DSE.

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

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

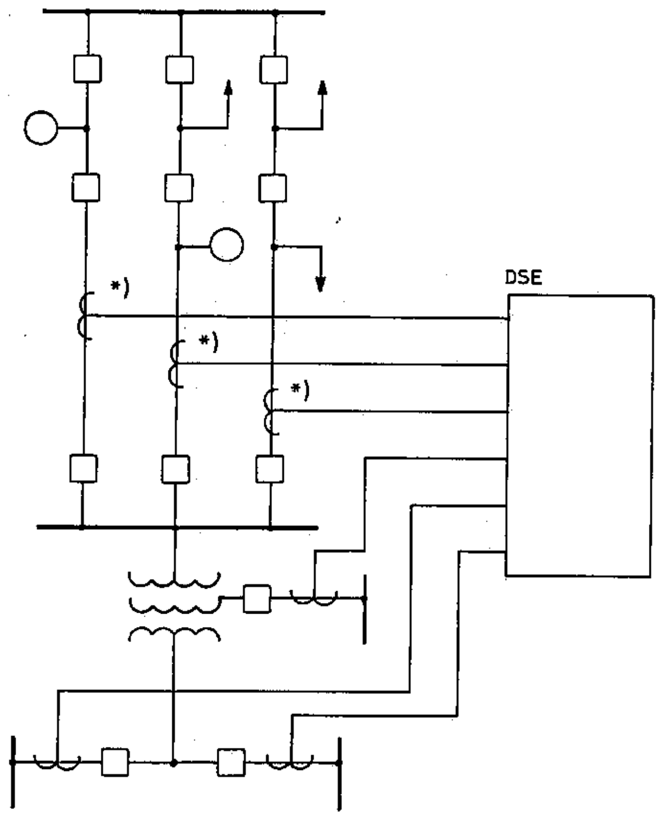


Fig. 3 (b). One line diagram showing an application of a six-input DSE transformer differential relay.

*) Note: Depending on system conditions two or more of these CT's may be summed up to one restraint input.

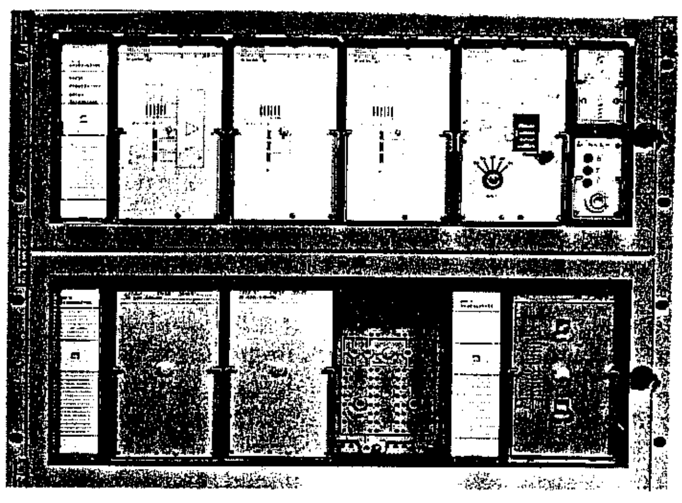


Fig. 4. Two additional input restraint unit TUC 4's (lower left) and lock-out relay MVB 4 (lower right) in a DSE with five input-restraints.

Figure 5 is a rear view of the DSE showing the interconnected factory wiring between the individual modules. The relay is shipped with this wiring 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 Figure 4. The full options of the COMBIFLEX modular approach can be used for specific application situations without affecting the relay characteristics. This includes specifying the relay modules in a RHGX 20 relay case for mounting on a switchboard.

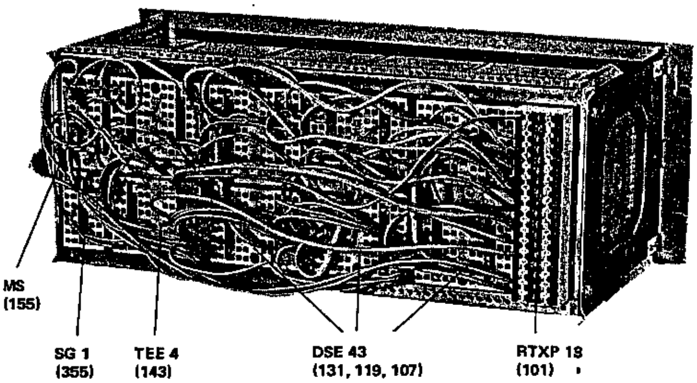


Fig. 5. Rear view of the basic DSE showing factory installed interconnected wiring between the modules.

Auxiliary ratio matching and phase shifting transformers are furnished for mounting separately. They are shown in Figure 6. See page 11 and appendix 1 for more information on the auxiliary CT's.

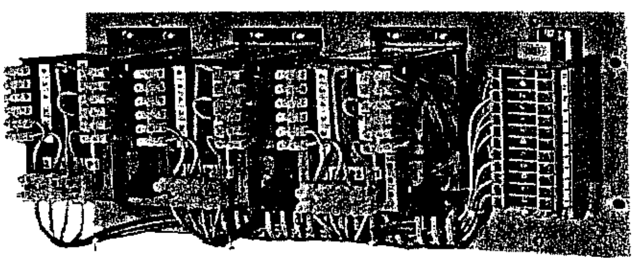


Fig. 6. Auxiliary CT set for one winding mounted on a 4S (7" high) 19" apparatus plate.

INSTALLATION REQUIREMENTS

The DSE relay has only nominal physical requirements for a successful installation. It is designed to mount in a standard 19" equipment frame. The complete basic version occupies 7" of rack space.

The individual modules are protected by securely fitted clear plastic covers. All terminals and connections of the COMBIFLEX system are silver plated, contact pressures are substantial, leads terminate in connectors which directly mate with the module terminals to which the interconnected wiring or the switchboard leads have been crimped. Corrosive atmosphere and high humidity should be avoided as a matter of general prudence.

Field Wiring

Field wiring is mostly terminated in the RTXP 18 test switch. Position No. 1 is at the top, position 18 at the bottom. The wires must be fitted with the ASEA COMBIFLEX terminal connectors for insertion into the respective positions. These connectors are designed electrically for a secure, low resistance contact. The mechanical design provides a secure capture. They are not removable without using the provided tool. This extractor, RTXD, is shipped with the relay.

Depending on the application, some external wiring may need to be connected directly to the relay terminals without going through the test switch. This is shown by the slashed lines in Figure 7. The same ASEA wire terminal connectors are used in all cases. The 20 A (larger) connector should be used for all current circuits and for all connections to the RTXP 18 test switch. It can accomodate up to No. 12 wire. The smaller, 10 A, connector should be used for all other connections. It can take up to No. 14 wire.

The location of each relay terminal can be determined from its number on the wiring diagrams, Figure 7 (a) to 7 (f). Figure 7 (g) shows the physical location of the wiring in Figure 7 (a) which connects directly to the relay modules without going through the test switch. Figure 7 (g) also illustrates the COMBIFLEX numbering system. The test system is described in more detail in Figure 8.

A typical DSE installation wiring diagram for two- and three-winding transformers is shown in Figure 7 (a) to 7 (c). A lock-out, No. 86 function, can be provided internally within the DSE relay. This may be done by electrically sealing in the MS 1 relay via the contact shown on the alarm function. Or an additional MVB 4 magnetic latch relay can be provided. When so specified the MVB 4 relay is wired into the system as shown in Figure 7 (f). Figure 7 (f) also shows the external wiring for five inputs. This might be a three-winding transformer where two of the windings have two breakers each. The same basic arrangement is used for four inputs as shown on Figure 7 (d). More than six inputs can be provided by simple addition of more TUC 4 modules.

Device 101 is the RTXP 18 test switch, shown in more detail in Figure 8. All wiring shown as full lines to the right of this in all of these diagrams is the interconnection wiring between the relay modules. The relay is normally provided with this wiring in place. At time of ordering, the proper dc voltage should be specified for the MS 1 tripping relay. The target electrical reset can be energized by a 48–60 or 110–250 V dc source, separate from the main relay, if desired. For additional details on the COMBIFLEX system and the use of the RTXP 18 test switch refer to Publications 92–10 SI, 92–10 AG and 92–11 SI and 92–11 AG, respectively.

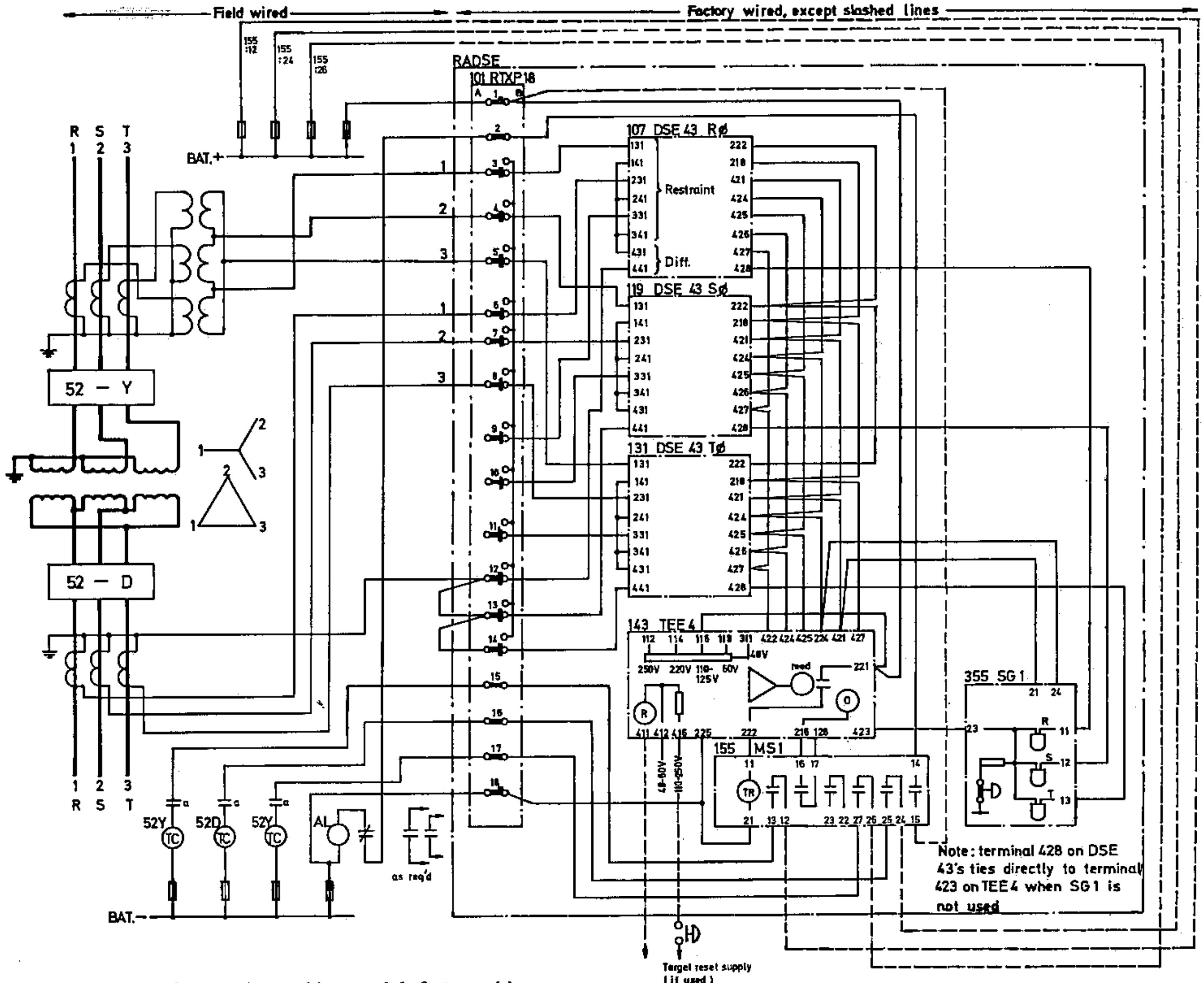


Fig. 7 (a). DSE external connections and intermodule factory wiring for protection of two-winding transformers. (Optional SG 1 phase indicator is also shown)

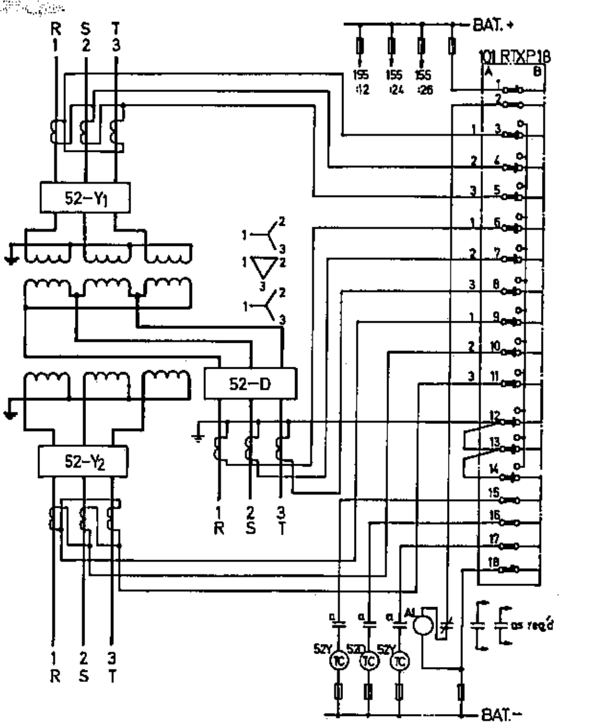
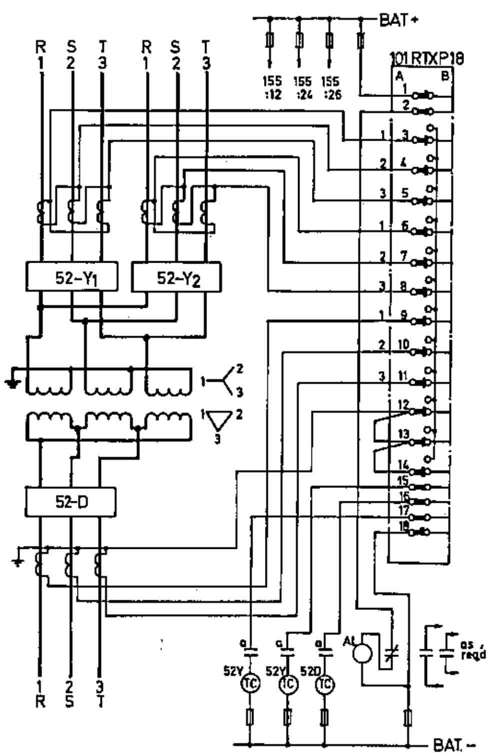


Fig. 7 (b). DSE external connections for protection of three-winding transformers. See Figure 7 (a) for additional field wiring within the DSE. (Add auxiliary CT's for ratio matching if required. This same connection is used for protection of autotransformers. (Delete 3rd DSE-input if there is no delta winding).



7 (c). DSE external connections for protection of two-winding transformer with two breakers on one winding. See Figure 7 (a) for additional field wiring within the DSE.

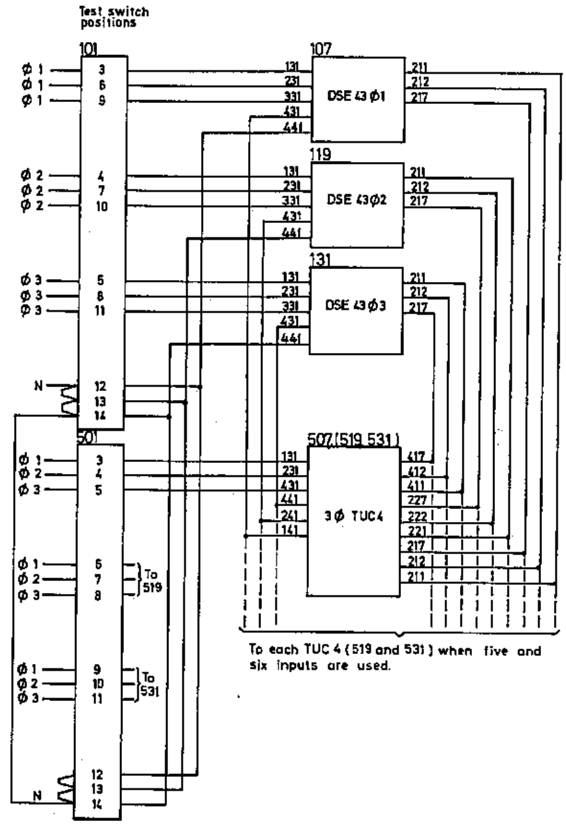


Fig. 7 (d). Factory wiring of TUC 4 to test switch and interconnections to DSE 43's (Typical of four-, five- or six inputs).

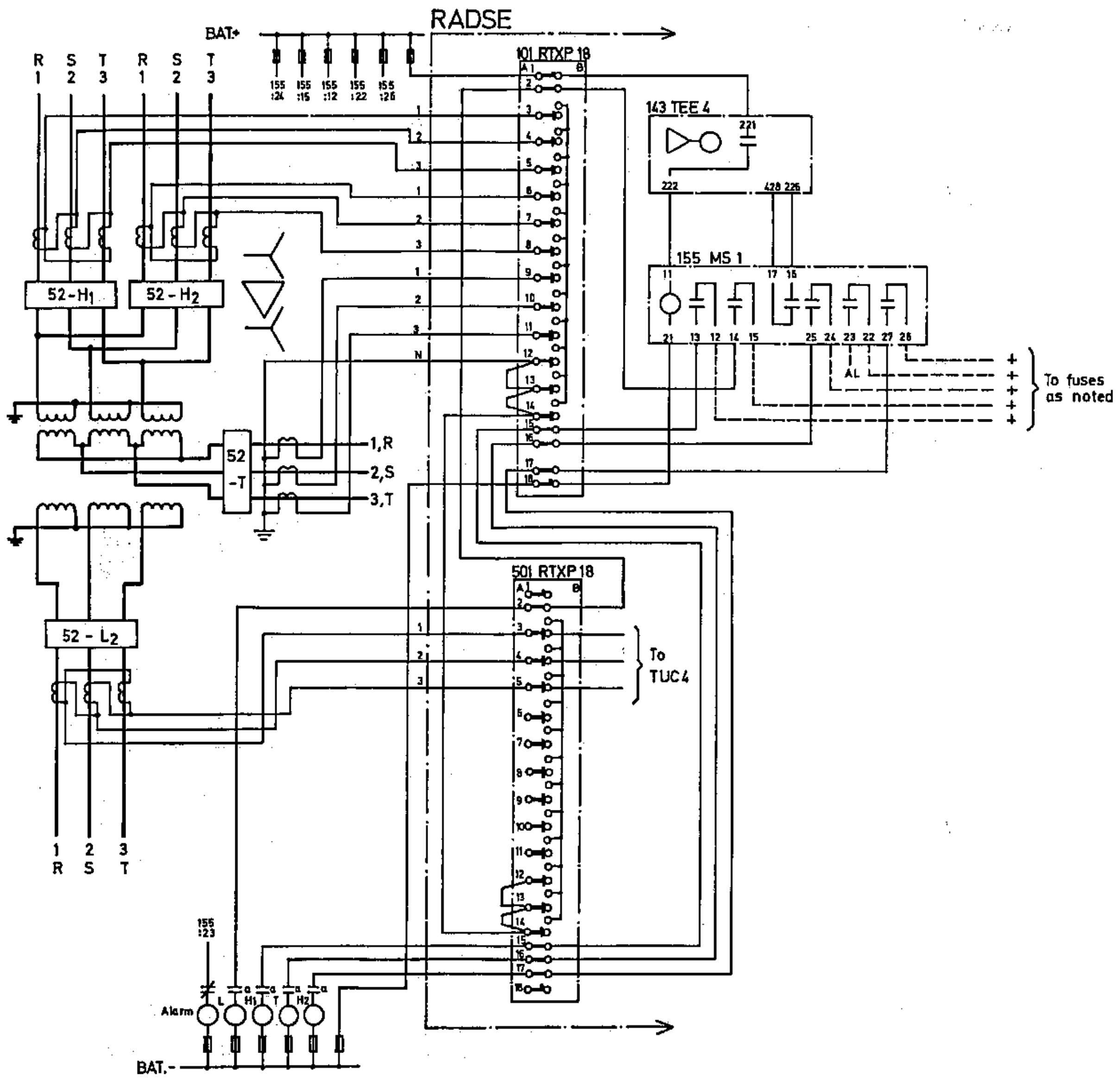


Fig. 7 (e). DSE external connections for protection of three-winding transformer with four circuit-breakers using one TUC 4.

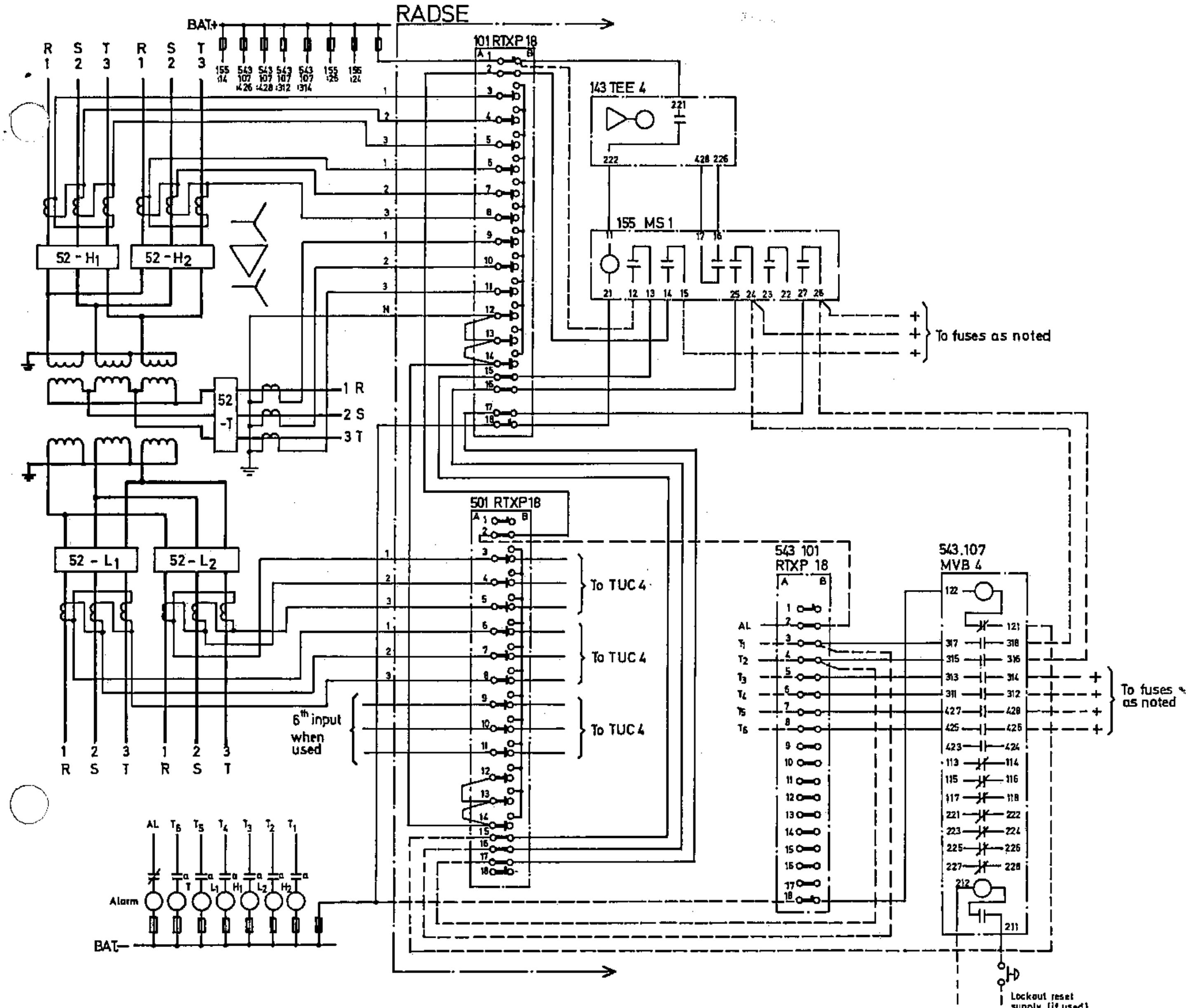
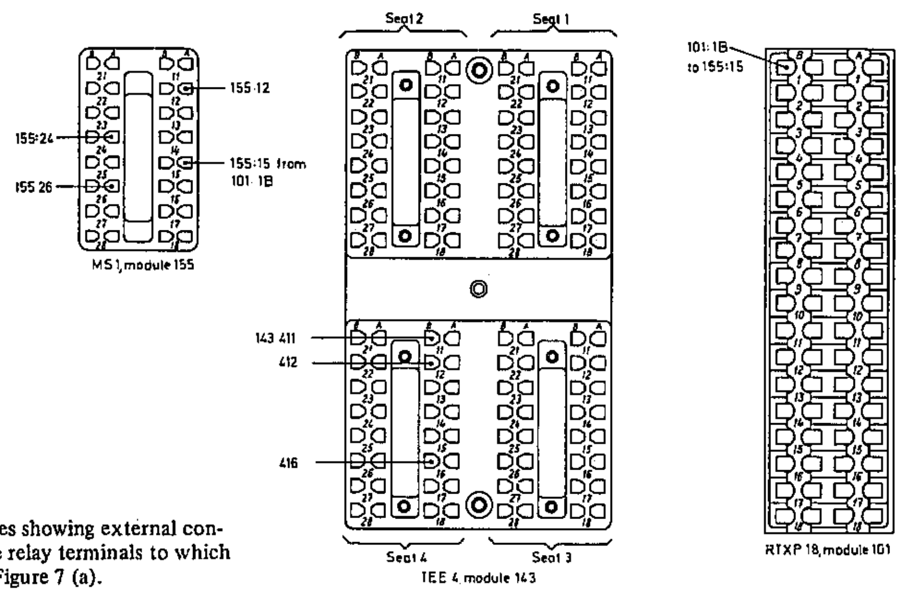


Fig. 7 (f). DSE connections for five- and six inputs and circuit-breakers.

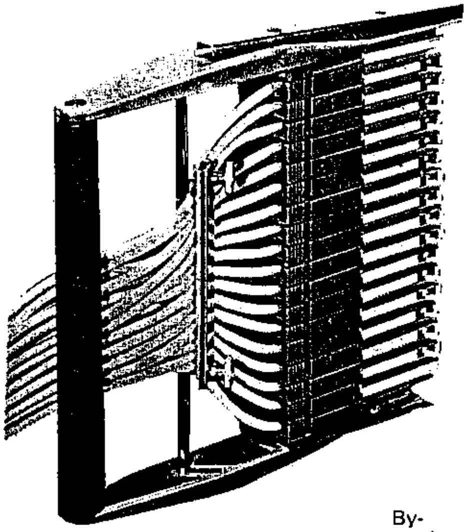


The module number is identified by the location of the top right corner of the relay seat. The 100 series in the location system represents the top of 4 mounting levels in a 4S equipment frame. When plug-in modules are used however, only levels 100 and 300 are used. See also Figure 17 and publication 92–10 AG.

All external wires connect to A side of the test switch

Fig. 7 (g). Rear view of DSE modules showing external connections – physical locations of the relay terminals to which field wiring connects according to Figure 7 (a).

Test plug handle RTXH 18

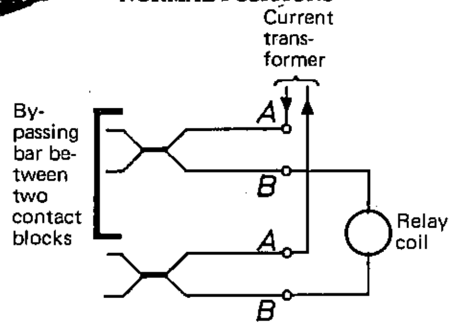


Test plug handle includes

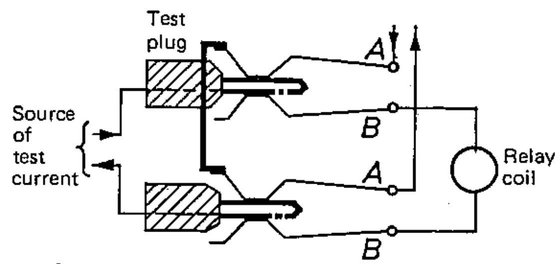
2 plug pins for + and – located at the top and bottom of the test plug handle. Used for supply of dc voltage to the test equipment. This pin does not open any contacts.

16 test plugs fitted in all remaining spaces in the test plug handle. These isolate both types of contacts i.e., those having a contact tip near the front of the test switch, intended for trip circuits, and those with a contact tip further inside, intended for current and voltage circuits.

NORMAL POSITIONS

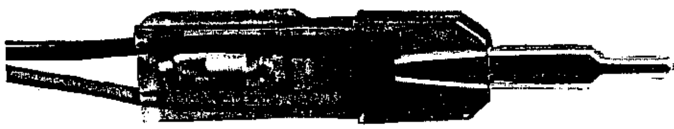


TEST POSITIONS

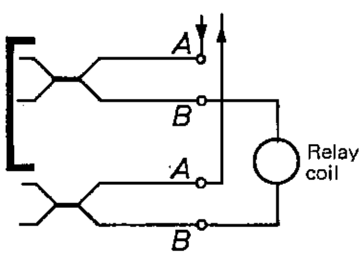


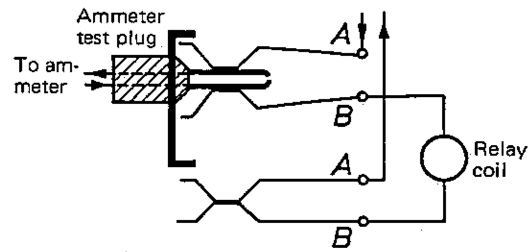
Current testing of relay. (positions 3 to 14)

Loose plugs



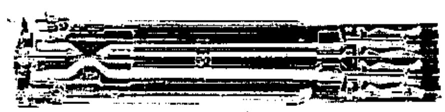
The ammeter test plug RTXM is used separately for service current measurement. It incorporates an overvoltage protection consisting of a gas tube. An arc occurs at approx. 300 V and short circuits the current if this is opened by mistake or if the plug is inserted in the test switch without an ammeter connected to the plug. A bimetal contact is heated up by the arc and takes over the short circuiting.



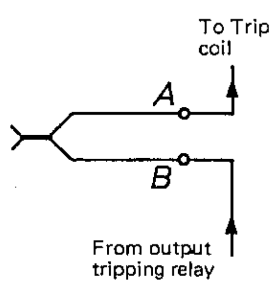


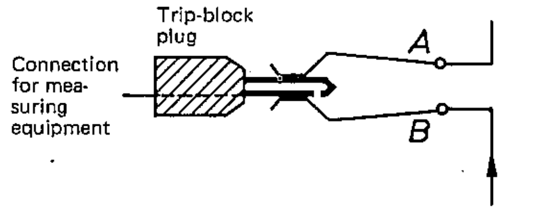
Load current measurement. (positions 3 to 14)

Test switch contact for current circuits (positions 1, 3-14, 18)



The trip-block plug RTXB is short and is used separately for blocking trip circuits. It can also be used for measurement purposes in trip circuits. The plug is red to draw attention to the fact that blocking has been carried out. The door of the COMBIFLEX equipment frame can be closed while the plug remains inserted in the test switch.





Interruption or blocking of a dc circuit or for time measurement of trip pulses etc.

Test switch contact for trip circuits (positions 2, 15, 16, 17)

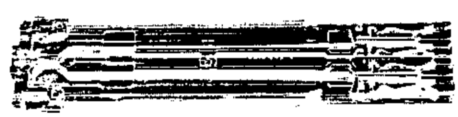


Fig. 8. Details of test plug handle, various test plugs, test switch contacts and method of use.

Other Installation Requirements

The type MS 1 output tripping relay has five output contacts in addition to the one used for the operation indicator. Each is capable of tripping a circuit-breaker. Four contacts are factory wired through the RTXP 18 test switch. There are no polarity or other restrictions on how there MS 1 contacts are utilized within their rating. The RTXP 18 test switch has a continuous rating of 20 A per contact. It can accomodate a total of four output trip circuits in the basic relay. When one or more TUC 4's input restraint units are used, an additional RTXP 18 test switch is provided with a total of 18 additional test circuits as shown in Figure 7 (d), (e) and (f). Electrical and mechanical details of the RTXP 18 test switch are shown in Figure 8.

Current Transformers

Type SLCE 12 multi-ratio current transformers are furnished for ratio and phase angle matching, one set for each of the specified inputs. These are mounted in sets of three on 4S (7" x 19") apparatus plates as shown in Figure 6, for installing in any convenient location. Appendix 1 provides complete mechanical details as well as information for selecting the desired turns ratios within ± 3 percent, and the ampere rating. Current transformer accuracy requirements are based on their performance during external faults, not internal. At high currents the DSE has a 0.65 slope. This allows over a 40 percent error in CT ratio before undersired over-tripping would occur. Selection of CT's with 10 percent accuracy at maximum external fault current or at 20 times rating which ever is greater is suggested. This will allow adequate margins for possible CT saturation due to any dc component. When X/R ratios during external faults are over 75 severe CT saturation may not be preventable. In such cases symmetry in the affected CT secondary circuits and equal burdens will enchance the security of the system. These situations only occur with breaker and a half or other configurations where the power transformer size has little relation to the external fault current magnitudes.

For rated accuracy at 20 times rated current the 1 A model of the SLCE 12 can accept 2 Ω secondary lead burden or about 1000 feet of secondary wiring; the 5 A model can accept 0.1 Ω or about 50 feet of wiring between the CT's and the relay. Appendix 1 provides complete details on SLCE 12 capabilities.

When the DSE relay is to be located a significant distance from the main CT's, total CT burden can be reduced by locating the auxiliary CT's near to the main CT's. By using a DSE relay rated 1 A and converting to this current level with the auxiliary CT's. the burden of long CT leads can be greatly reduced with no ill affect on the overall relay performance. For exceptionally long CT leads, (over 1000 feet), an intermediate current level of 0.5 A is suggested. This may require a second set of SLCE 12 auxiliary CT's at the relay location to convert back to the rated 1 A or 5 A value of the DSE if the full sensitivity of the relay is desired.

CT Connections

The determination of the turns ratio of the auxiliary CT's and the phasing connections is conventional. In general, prudence in transformer differential relay circuits suggests no additional devices connected into the differential CT circuits. However, from a burden viewpoint, the DSE burden is negligible and with suitable capability in the main CT's additional devices can be included in the DSE circuitry.

When additional burdens on the DSE CT's are a requirement, the flexibility of the separate ratio matching CT's can be further utilized. The main CT ratios and phase connections (wye or delta) can be selected to meet the requirements of the additional devices. The ultimate ratio and phase relations for the DSE can then be provided by the SLCE 12 auxiliary CT's.

The phase relations of the current circuits should be determined before the auxiliary CT ratios are calculated. There are three requirements for the auxiliary CT's.

1. Bring the currents from every source of a given phase into phase.
2. Bring the current magnitudes from every source into harmony.
3. Suppress the zero sequence (ground current) component to avoid improper operation on external faults.

Figure 9 shows the several methods of connecting the main and auxiliary CT's for reaching these objectives.

With the power transformer connected wye-delta, these objectives are most easily satisfied by connecting the main CT's inversely, that is in delta/wye respectively. A zig-zag winding of a power transformer will have a phase relation similar to a delta which usually requires wye connected CT's. But since the zig-zag neutral is usually grounded, the CT's on a zig-zag winding should be in delta or otherwise to suppress the zero sequence flow. Two such zero-sequence suppression arrangements are shown in Figure 9 (d) and (e).

The CT connections will have no effect on the harmonic restraint action of the DSE. This is because the rectified 2nd and 5th harmonics from each of the three phases are combined for a common harmonic restraint. Thus, the relative effect of these harmonics to the fundamental at the relay will be independent of the connections of the power transformer and the CT's. The 3rd harmonic is the one most affected by CT connections and this is not utilized for restraint in the DSE. Special CT connections are not required for the 5th harmonic overexcitation restraint.

Some power transformers, due to their construction, have "hidden" tertiary winding effects. This results in some of the currents, normally assumed to be flowing in the delta, to flow in fact in the transformer case and other mechanical parts of the transformers during severe external ground faults. Therefore, connection of main CT's inside the delta of main CT's inside the delta of a power transformer may not measure the total effective delta current. This connection is usually not recommended with the DSE. The 5th harmonic restraint characteristic of the DSE does not require this connection with its attendant complex calculations.

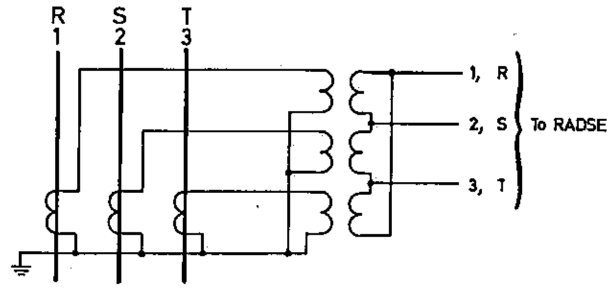


Fig. 9 (c). Auxiliary CT connections for wye-delta phasing with or without ratio matching requirements.

Note: Auxiliary CT delta should be made up with the same polarities and interphase wiring as the power transformer.

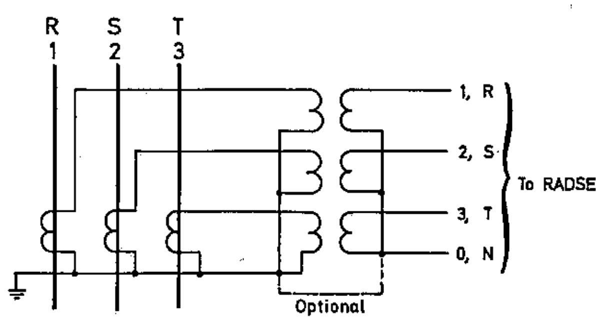


Fig. 9 (a). Auxiliary CT connections with wye connected main CT's for ratio matching only.

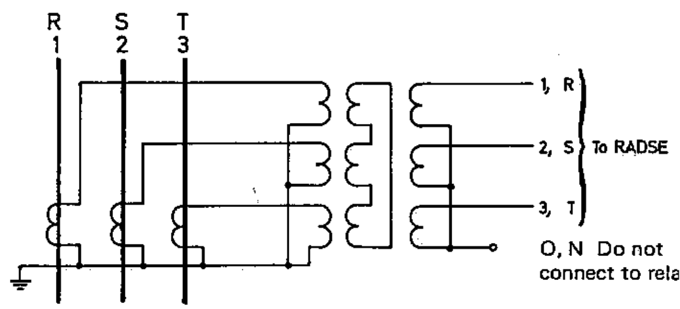


Fig. 9 (d). Auxiliary CT connections for zero sequence suppression when wye-delta phase shift is not acceptable.

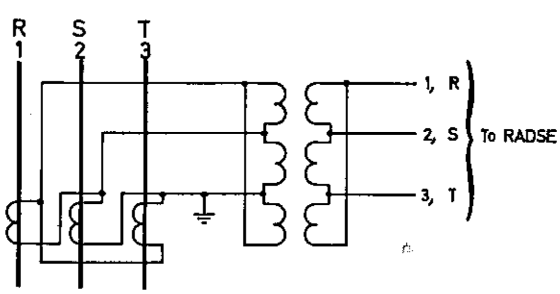


Fig. 9 (b). Auxiliary CT connections with delta connected main CT's for ratio matching only.

Note: Main CT delta should be made up with the same polarities and interphase wiring as the power transformer winding.

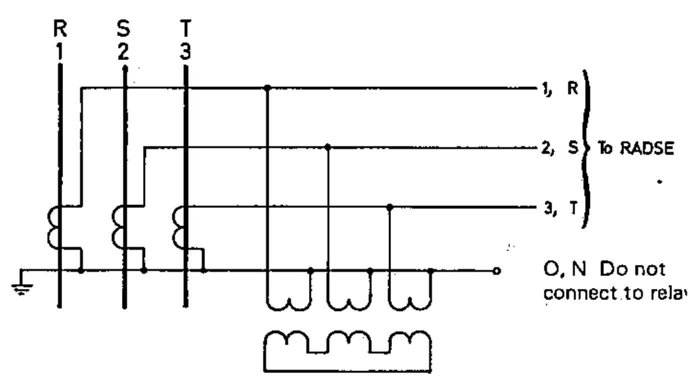


Fig. 9 (e). An alternative of Figure 9 (d) for zero sequence suppression when ratio matching is not needed.

CT Calculations

The following illustrated procedure will result in the proper sizes and ratios for the main and the auxiliary CT's.

1. State the problem by listing all voltages*), kVA ratings, overload requirements, line currents*), wye and delta windings, dual breakers, etc. For example: A 138/34.5/13.8 kV, delta-wye-wye power transformer with a rating of 100/60/60 MVA on the respective windings, see Figure 10 has a 135 percent overload requirement. The 34.5 kV winding will tie into the system with two breakers in a ring bus scheme. The exact voltage taps will be determined in the field, but it is judged they will be within 5 percent of the nominal values.

*) Note: These voltages and currents should be the selected tap values of the power transformer, not the system nominal voltages. In the case of tap changing under load transformers, it is customary to select the mid value of the operating range.

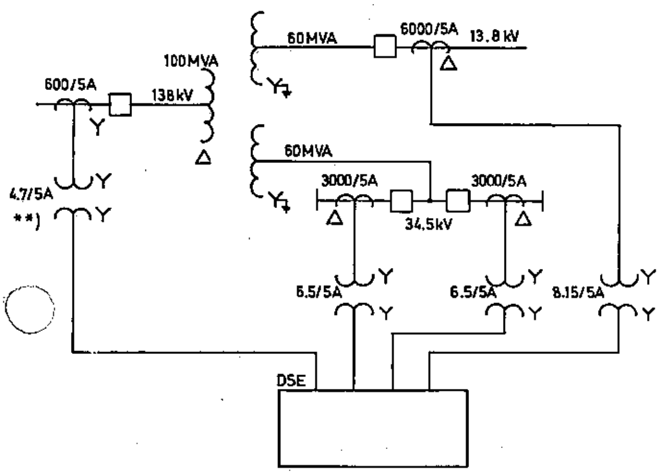


Fig 10. Example used in sample CT calculations.

**) Note: Auxiliary CT not generally needed, see item 2 below.

Determine the maximum line currents for each winding:

$$I_{line} = \frac{\text{kVA of winding}}{\sqrt{3} \times (\text{line-line kV})} \times \text{overload factor}$$

$$I_{138} = \frac{100.000}{\sqrt{3} \times 138} \times 1.35 = 418 \times 1.35 = 565 \text{ A}$$

$$I_{34.5} = \frac{60.000}{\sqrt{3} \times 34.5} \times 1.35 = 1001 \times 1.35 = 1360 \text{ A}$$

$$I_{13.8} = \frac{60.000}{\sqrt{3} \times 13.8} \times 1.35 = 2510 \times 1.35 = 3390 \text{ A}$$

2. Select an overall CT ratio for the largest kVA winding to yield about 5 A to the DSE.

$$\frac{565}{5} = 113/1 \text{ on 138 kV winding}$$

(But note, as in step 5, that the load flow through the two 34.5 kV breakers may be the maximum kVA value to which the system must be designed). Other requirements would probably suggest a main CT ratio of 120/1 or 600/5 A. No auxiliary CT would be needed with a ratio this near to desired value. However, assume exactly 5 A is desired at the relay.

auxiliary ratio =

$$\frac{113 \text{ (desired)}}{120 \text{ (main CT)}} = 0.942/1.0 \text{ or } 4.71/5 \text{ A}$$

From table 3 of appendix 1 the turns ratio of SLCE 12 for this input current should be 44/42.

3. Determine the overall CT ratios for the other two windings, these will be inversely proportional to the voltages (ignore the kVA):

$$34.5 \text{ kV ratio} = 113 \times \frac{138 \text{ kV}}{34.5 \text{ kV}} = 452/1$$

If 400/1 main CT ratio (2000/5) has been selected for other purposes, the auxiliary ratio becomes:

$$\frac{452 \text{ (desired)}}{400 \text{ (main CT)}} = 1.13/1 \text{ or } 5.65/5 \text{ A on 34.5 kV winding}$$

The turns ratio for the SLCE 12 would be 31/36, except for the delta considerations — see step 4.

Note: The dual 34.5 kV breakers do not normally affect this calculation, but see step 5.

$$13.8 \text{ kV ratio} = 113 \times \frac{138 \text{ kV}}{13.8 \text{ kV}} = 1130/1$$

If the main CT's have already been chosen to be 1200/1, (6000/5), the auxiliary ratio should be:

$$\frac{1130}{1200} = 0.942/1 \text{ or } 4.71/5 \text{ A on 13.8 kV winding}$$

The turns ratio for the SLCE 12 would be 44/42, except for step 4.

4. For those windings requiring delta connected CT's, increase the overall ratio by 1.73. It does not matter where the delta is made up, in the main CT's or in the auxiliaries, the overall ratio will be brought into harmony in the auxiliary CT's. In this example, both the 34.5 kV and the 13.8 kV will need delta CT's, so the auxiliary ratios become:

   1.73 x 5.65/5 = 9.76/5 A, or 22/42 turns on SLCE 12 for the 34 kV

   1.73 x 4.71/5 = 8.15/5 A, or 22/36 turns on SLCE 12 for the 13 kV.

5. Review other operating requirements for other CT needs. The two breakers on the 34.5 kV winding may have an additional requirement of being able to transfer power through the bus in addition to the transformer load. If this results in possible currents in excess of the 2000 A rating of the selected CT, then a higher rated main CT would be required. Assume a 3000 A capability may be needed and a 3000/5 or 600/1 main CT is selected. The auxiliary CT then becomes:

   $$\frac{452\ \text{(desired)}}{600\ \text{(main CT)}} = 0.753/1 \text{ or } 3.77/5\ \text{A}$$

   And since this winding requires a delta CT connection, the selected auxiliary CT ratio would be

   1.73 x 3.77/5 = 6.5/5 A with SLCE 12 turns ratio of 31/40 for both sets of 34.5 kV CT's.

   Since the overall ratio has not been changed, the current to the DSE from these CT's during the 3000 A emergency through loading becomes:

   3000/452 = 6.64 A

   This is well within the rating of the DSE. However, the capability of the auxiliary CT's at this higher current level should also be checked. Also, if this requirement should have resulted in a relay current larger than desired, then this larger primary current should be used as the determining maximum kVA and the other ratios brought into agreement with it.

6. Determine if any of the auxiliary CT's can be eliminated. In this example the 138 kV auxiliaries are within 6 percent of a 1/1 ratio. Thus they could be eliminated with only a 6 percent reduction in relay current. The overall ratio becomes 120/1 on this largest winding and the other CT ratios would then be recomputed to maintain this overall ratio. However, since it was noted that operating experienc may require a change in taps on the main CT, th auxiliary CT's would probably still be used to pr vide for future conditions.

7. Tabulate the burden on each set of CT's based o the final ratios as determined in step 6. For the illustration, assume (for the 34 kV CT's):

CT secondary winding: 2.5 milliohm per turn x 600 turns	= 1.5 Ω
Secondary leads: 500' (x 2 way) No. 9 wire 75°C	= 1.0 Ω
Auxiliary CT (2 VA burden rating at 5 A) x 2	= 0.16
DSE restraint burden (0.18 VA at 5 A x $(5/6.5)^2$ x 2)	= 0.01
Other burdens	–
Total burden, as imposed on main 34 kV CT's	= 2.67

8. Calculate maximum secondary voltage on the ma CT's, which could occur for a severe external faul ignore possible asymmetry:

   $$E_{sec} = I_{sec} \times Z_{sec}$$

   Assume: 40,000 A (2,400 MVA) can flow throug one of the 34 kV breakers for an external bus fau CT secondary current = 40,000/600 = 66.7 A CT secondary voltage = 66.7 x 2.67 = 178 V Determine this for each set of CT's. If the auxilia CT's are to be located a significant distance from the DSE relay, the capability of the SLCE 12 CT' should also be checked as shown in Append. . 1. In this example, and allowing 0.1 Ω for the switch board wiring from the SLCE's to the DSE, the SLCE's maintain their accuracy up to 125 A.

9. Specify CT secondary voltage accuracy class no le than this maximum voltage calculated in step 8, o a C 200 in this illustration. Additional margin is not necessary. For inrush considerations, the voltage accuracy class should be at least equal to the voltage developed at 20 times rated current or to the actual inrush current if known.

   Note: There is no need to make any CT calculatio for internal faults. The relay will properly respond to internal faults up to 100 times rated current (500 A at the relay).

10. Where available CT's cannot provide the voltage needed in step 9, there are several options available.

    a) Install auxiliary CT's at the main CT's to reduce the current to a 1 A level and use a 1 A DSE relay. This solution greatly reduces lead burden.

b) Use larger wire for the secondary leads to reduce the lead burden. This expense is usually not warranted in view of the other options noted.

c) Install auxiliary CT's at the main CT's to reduce the current level in the secondary wiring to 1/2 – 1 A range, with a compensating current step up adjustment in the auxiliary CT ratio at the relay. The one ohm lead burden in the illustration can be substantially eliminated by this method, but requires an additional set of CT's.

d) When auxiliary CT's are not needed for ratio correction or wye-delta phase shift, the burden can be reduced by selecting main CT ratios to yield only 2 – 3 A during maximum load conditions. This of course reduces the sensitivity of the relay, but the DSE has a minimum pick-up setting as low as 20 percent of the 5 A (or 1 A) rating which may still yield a satisfactory sensitivity.

e) Connect main CT's to a higher ratio and compensate with a current step up ratio in the auxiliary CT's at the relay location. The lead burden will be reduced by the square of the increased CT ratio. In the illustration, doubling the main CT ratio will reduce the required secondary voltage to 72 percent. Note that the internal resistance of the CT increases with an increase in the number of secondary turns, thus reducing the net benefit gained from this solution.

BURDENS

The DSE is available as a 1 A or 5 A relay. The respective burdens at nominal rated current are:

1 A relay, 0.02 VA
5 A relay, 0.18 VA

In the differential circuit, at 20 percent rated current, the burdens are:

1 A relay, 0.01 VA
5 A relay, 0.02 VA

The relay burden is not affected by the minimum sensitivity adjustment.

Auxiliary current transformers are type SLCE 12 with an insertion loss of 1.0 to 2.8 VA depending on turns ratio at nominal rating. See Appendix 1 for specific data.

POWER CONSUMPTION

The DSE relay has the necessary components internally for operation at any dc control voltage, 48 V and above. The higher voltages require more power in view of the nearly constant current requirements of the internal voltage stabilizing circuits.

Approximate continuous dc power requirements at rated tap voltages:

48 V	3.0 W
60 V	3.5 W
110 V	5.0 W
125 V	6.5 W
220 V	9.0 W
250 V	10.0 W

The MS 1 output tripping relay requires an additional 7 W when it operates.

RATINGS

Input current circuits:

Frequency – 50 or 60 Hz

Nominal rating	Overload capability Continuous	1 s	Instantaneous
DSE Relay			
1 A	10 A	100 A	180 A
5 A	20 A	250 A	500 A
SLCE 12 ratio matching CT's	2.5 times nominal rating	75 times nominal rating	
reconnectible rated current ratios: 0.65 – 2.60/1 A; 2.55 – 9.60/1 A; 2.85 – 9.70/5 A			

Output contacts of type MS 1 relay:

Continuous	4 A
1 s	20 A
10 ms	100 A
Make and carry for 200 ms	30 A

DC auxiliary voltage:

Nominal relay tap values are 48, 60, 110, 125, 220, 250 V dc + 10 percent, – 20 percent (– 15 percent for 48 V version).

MS 1 output tripping relay is available in any one of these voltages, as specified.

Ambient temperatures:

– 25°C to + 55°C (–13°F to + 131°F), except if auxiliary voltage is 220 or 250 V, top temperature is reduced to + 40°C (104°F)

Dielectric and surge withstand:

Insulations tests:

current circuits, 2.5 kV, 50 Hz, 1 minute
all other circuits, 2 kV, 50 Hz, 1 minute

Impulse tests for all circuits:

5 kV, 1/50 μ sec., 0.5 joule

Surge withstand capability test:

2.5 kV, 1 MHz, decay time, 3–6 cycles, repeated each 2.5 ms for 2 s.

OPERATING SPECIFICATIONS

(See Section on Settings on page 22 for Setting Procedure Details)

Operating currents

Minimum operating current:

Settings of 20, 25, 32, 40 and 50 percent of the rated current of 1 A or 5 A

Un-restrained instantaneous unit operating current:

Tap settings of 8, 13 or 20 times the relay rating of 1 A or 5 A. See Figure 11 for method of making settings.

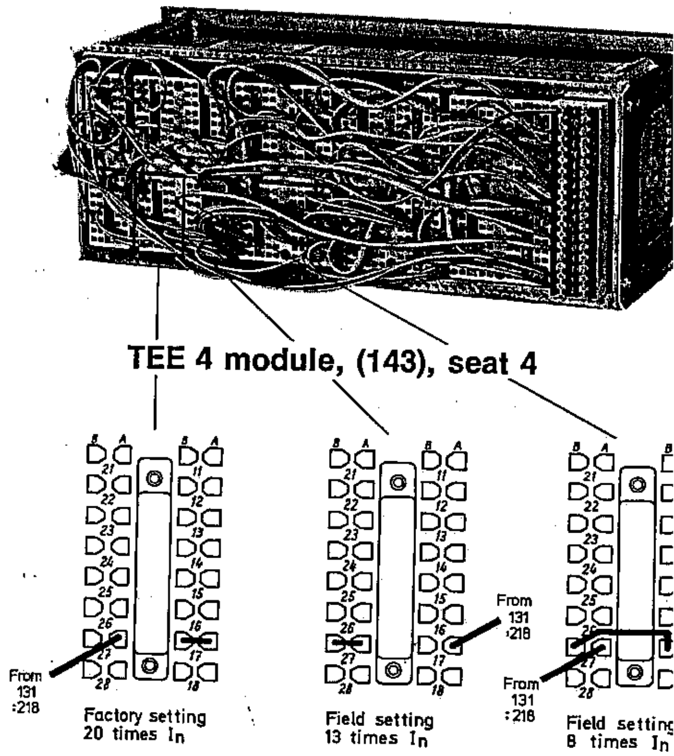


Fig. 11. Un-restrained instantaneous operating current setting adjustments by means of jumper positions at the rear of the TEE 4 module

Auxiliary CT's type SLCE 12, taps available in 4–6 percent steps, as shown in Appendix 1.

From 0.65 A to 9.6 A primary to 1 secondary
From 2.85 A to 9.7 A primary to 5 A secondary

Operating time

Restraint unit:

At 3 times pickup current;	30 ms
At 10 times pickup current;	27 ms
Impulse time limit;	> 15 ms

Un-restrained unit:

At 2 times pickup current;	10–18 ms
Impulse time limit; approx.	3 ms

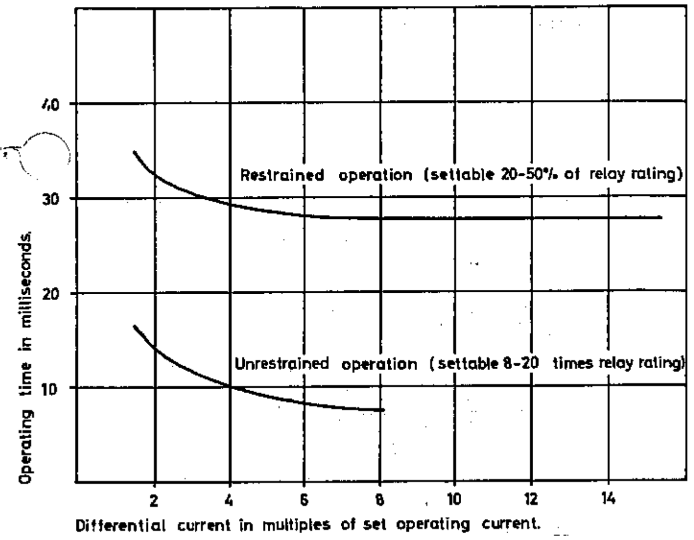


Fig. 12. Operating time-current characteristics for DSE relay.

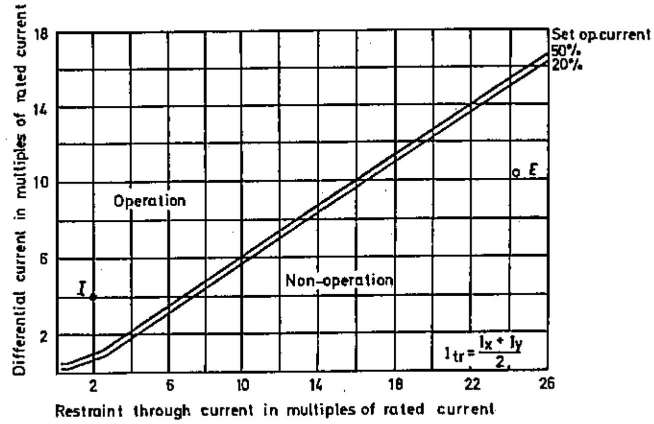


Fig. 13 (a). Through current restraining characteristic at larger current values. Minimum pickup setting of 20 and 50 percent of rated current. The through restraint current I_{tr} = the average of the maximum current I_x entering the protected zone and the maximum current I_y leaving the zone. See page 21 for points "I" and "E".

Restraints

Percentage: Variable from 35 percent to 70 percent, depending on magnitude of through current and on minimum sensitivity setting, nonsettable. Figure 13 (a) and (b) show the relation between differential current and restraint current for relay operation. Figure 13 (c) shows this data presented as percent operating differential current vs through restraint current i.e. the percent slope characteristic. (See next section, THERY OF OPERATION, page 19 for method of describing restraint current).

2nd harmonic: 20 percent 2nd harmonic content in the differential current will prevent operation.

5th harmonic: 35 percent 5th harmonic content in the differential current will prevent operation.

Notes: (1) The 3rd harmonic contributes no harmonic restraint action. The 3rd harmonic current will contribute a small restraint due to the harmonic filter characteristic. However, this is offset by an operating voltage developed in the differential operate circuit by the 3rd harmonic.

(2) Frequencies above the 5th harmonic are filtered out of the operating circuit and have little effect on relay performance.

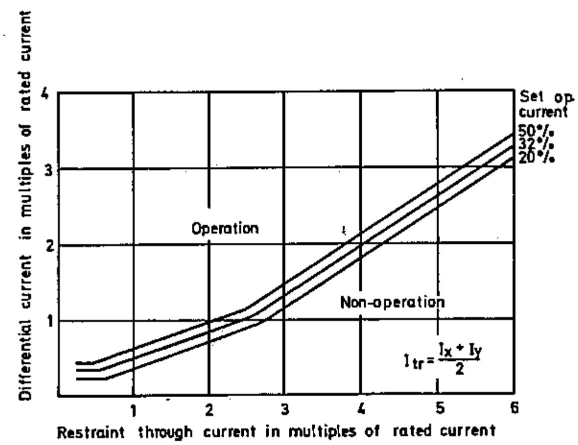


Fig. 13 (b). The low current region of Figure 13 (a).

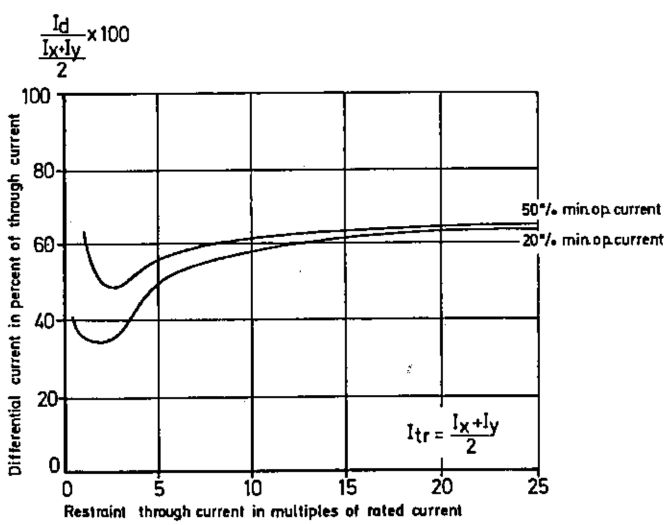


Fig. 13 (c). Percentage restraint characteristic.

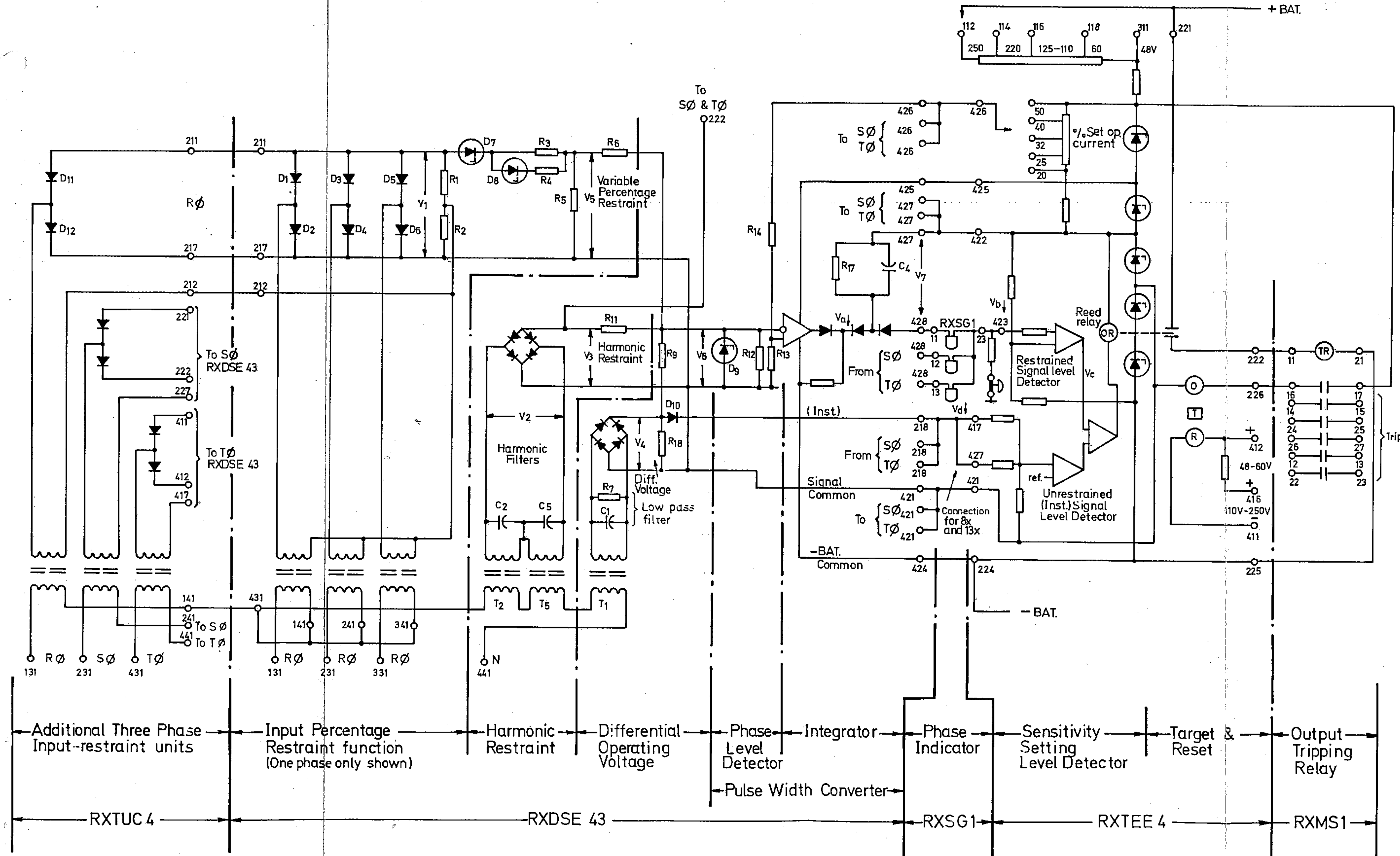


Fig. 14. Functional relations within DSE including supplemental input-restraint unit TUC 4.

THEORY OF DSE OPER

There are ten interrelated as shown in Figure 14.

1. Input circuitry

Air-gapped isolating trans each restraint current to a is thus also largely suppres rical fault current. These a formers in order to get the entire range of input curre These individual phase vol with two power diodes, D shows the arrangement fo circuitry is identical in the mental input-restraint unit except for the manner of p as shown in Figure 14.

2. Percentage restraint circ

The rectified restraint volt applied in parallel to a cen as shown in Figure 14. Wh have been derived from air formers are connected in p age is equal to the largest a ser voltages have little effe

In addition, the use of R1 rectifier bridge provides a tic. In the conventional fo has no sense of input polar posed of two diodes and t voltage becomes sensitive t the applied ac voltages. If of the same polarity (as du the larger one will cause a one half cycle and through But if two applied ac volta (as during an external fault current to flow through R cycles, as described, and at voltage will cause currents on the same half cycles. Th applied voltages results wh polarity, but only the maxi when they are of the same

Thus, this two-diode-two-r air-gapped current transfor type of restraint action. Du of the lesser of the various restraint action. But on an is increased to the sum of t rents and the largest of the

Another desirable feature c rents sources other than th

Next page shows functional relations within DSE

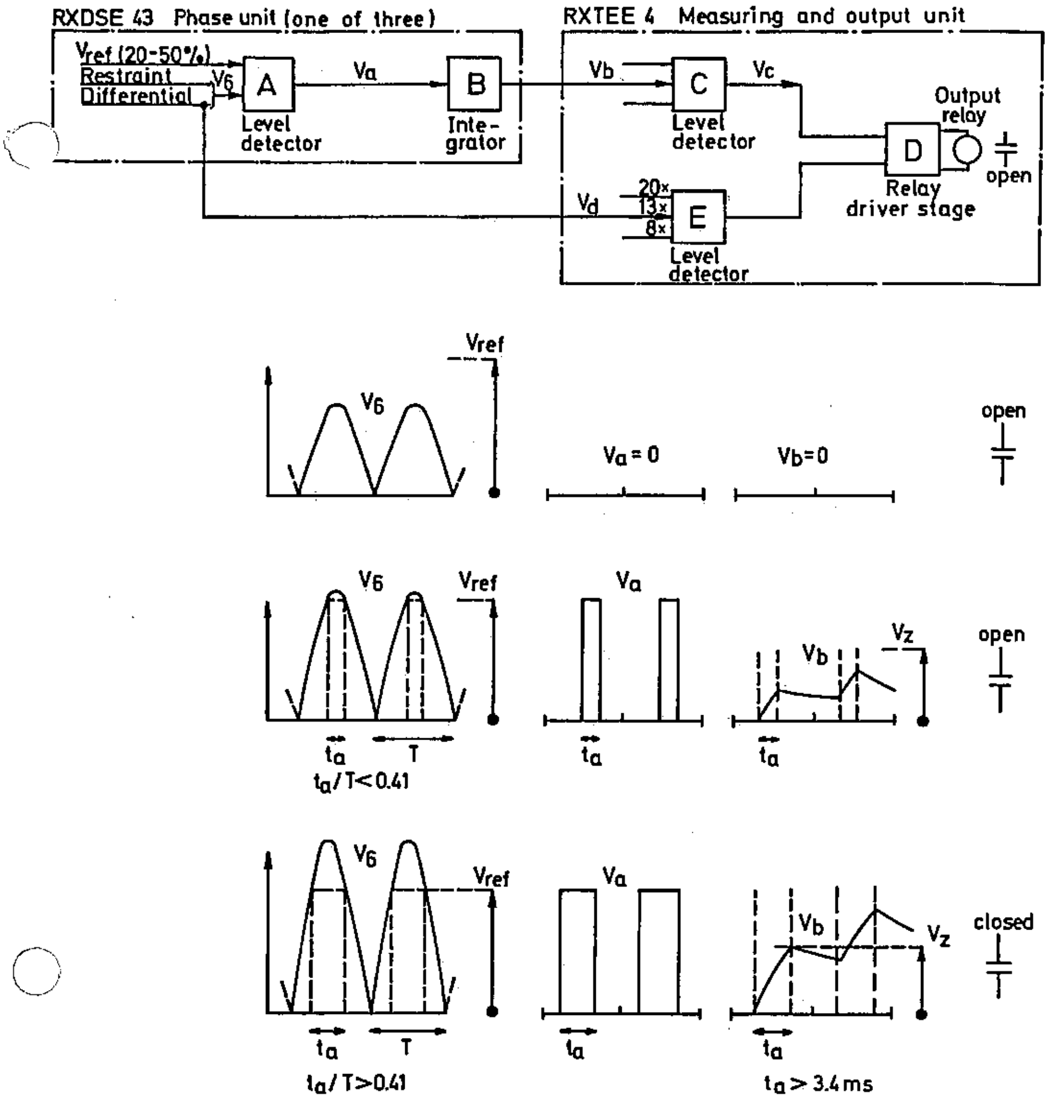


Fig. 15. Wave shapes and pulse width integrating action required to develop trip signals.

of very little filtering. This complex wave form is then compared to a dc 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 3.4 ms (out of an 8.3 ms period), the biases on the transistor output amplifier are shifted to provide the desired trip output. At this threshold value several pulses will be required to bias the amplifier into a trip condition. Figure 14 illustrates the method by which this measurement is made. Figure 15 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 V_4, is derived from the differential current. It is taken from the rectified output of the differential voltage circuit through diode D_{10} prior to mixing with any of the restraint voltages. It is free of any dc component of the ac current due to asymmetry because of air-gapped input transformer T1.

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 shown in Figure 11.

8. Minimum sensitivity circuitry

Within the three-phase measuring unit is a set of tapped resistors wired to a selector switch for the 20, 25, 32, 40 or 50 percent minimum pickup current setting. These resistors plus R_{13} and R_{14} set the bias on the operational amplifiers in the DSE 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 energizes a 3 ms six contact, MS 1 output relay. Each contact is capable of tripping a breaker. Wiring functions are shown in Figure 14. The MS 1 relay contacts are all N.O. On special order double throw contacts can be provided. The MS 1 relay can be energized continuously. Thus the circuitry can seal in this relay so as to provide a self-contained lock-out function.

10. Ancillary functions

a. Target
   One contact on the MS 1 output tripping relay energizes the coil 0 of an operation indicator, T. This is a mechanical and electrical reset device. It has no restrictions on the source of voltage for the reset function, R. As shown in Figure 14, a dropping resistor is included to allow resetting with any voltage from 48 to 250 V dc.

b. Phase indication
   When specified, type SG 1 individual phase indicator unit is provided. This is a one seat device and locates in the available seat 355 in the basic COMBIFLEX DSE assembly. Electrically the targets are electronically controlled LED's located in the output of each phase threshold circuit as shown in Figure 14. The targets are reset by a front mounted push-button on SG 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 Figure 14.

PERFORMANCE CHARACTERISTICS

The variable percentage restraint characteristics of the DSE is shown in Figures 13 (a) and (b). 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 current during an external fault.

The ordinate of Figure 13 (a) and (b) is the usual operating current flowing in the differential circuit. The percentage slope plotted in Figure 13 (c), is the ratio of the ordinate to abscissa of Figure 13 (a).

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 wi these curves then becomes **one-half** of whichever cu rent is the maximum infeed.

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

As shown in Figure 13 (c) the minimum pickup sen tivity, settable at 20, 25, 32, 40 and 50 percent of r lay rating, has small effect on the percentage restrai at high current levels. The percentage restraint or sl shown in Figure 13 (c) will always exceed 35 percer of averaged restraint, regardless of sensitivity setting It will exceed 50 percent above 3 1/2 to 6 times rel rated current.

The DSE fundamental frequency characteristic is further illustrated in Figure 13 (a) by points E and I Point E is the plot of a heavy external fault as migh occur in a ring bus or breaker and a half scheme wit a through-fault current of 30 times CT ratings and a ratio error in one set of CT's of 35 percent. With su 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 th sensitivity of the DSE even to minor fault currents. These two currents, load and fault, will normally by nearly 90° out of phase to each other in at least one phase. The phase threshold measurement is made su stantially on an instantaneous basis, since there is little filtering in the several rectified signal circuits. Thus the fault current measurement is made during the periods of the cycle when the load currents are a a minimum.

The 2nd and 5th harmonic restraint voltages for eac 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 percent of the value of the fundamental differential current in any phase. Tests and analysis show that magnetizing inrush currents which are greater than the minimum pickup current of the DSE will contain more than 20 percent 2nd harmonic in at least one phase.

A 5th harmonic current in the differential operating circuit of any phase greater than 35 percent 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 pickup current of the DSE will contain sufficient 5^{th} harmonic current to block relay operation. However, very large overexcitation 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 5^{th} harmonic drops below the 35 percent restraint value of the DSE. Thus if the overvoltage is sufficient to seriously jeopardize the t transformer in a very short time, the DSE 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 5^{th} harmonic is larger than the amount required to block the DSE up to exciting currents about 70 % of transformer full load rating. And above this current, the percentage 5^{th} harmonic becomes less and the relay will operate to prevent transformer damage. However, it is important that the DSE 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.

The operating time of the variable percentage, harmonic restraint relay is instantaneous as shown in Figure 12. The operating time of the un-restrained instantaneous unit is also shown in Figure 12. All characteristics are based on the ac component of the applied currents, since the DSE has air-gapped 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 TUC 4 three phase input modules will result in the same described relay performance.

All calibrations of the relay are accurate to 10 percent. The operating current of any relay will be within 10 percent of the values shown on the variable restraint characteristic of Figure 13. The performance is as stated up to 100 times relay rating of 5 A, or optionally 180 times the 1 A relay rating.

SETTING DETERMINATIONS

The 5 A nominal rated relay should normally be selected for use with 5 A rated CT secondaries. The overall CT ratios are then selected to provide about 5 A to the relay at normal loads as described under CT calculations. The relay (and SLCE 12's auxiliary CT's when used) is then capable of carrying any emergency loading up to the 12.5 A continuous secondary rating of the SLCE 12's (or the 20 A of the DSE).

Harmonic restraints

There are no setting adjustments required for neither the 2^{nd} nor the 5^{th} harmonic restraint current.

Sensitivity Setting

The setting for minimum current sensitivity (20, 25, 32, 40 or 50 percent of relay rating) should be selected based on estimated CT performance during small current conditions. As shown in Figure 13 (c) this setting is not a slope setting. It has minimal effect on the relay performance at high currents. It also has minimal effect on the percentage restraint action of the 2^{nd} and 5^{th} harmonics. Thus a sensitive setting will not hazard trip-outs due to magnetizing inrush.

The 20 percent sensitivity is suitable for CT turns ratio mismatch errors up to about 5 percent. When tap changing under load transformers 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.

These sensitivity guide lines are based on normal transformer load of 5 A in the 5 A relay. With breaker and a half, ring bus, or other similar schemes, high ratio CT's must generally be used because of possible through current flow which does not enter the transformer. This will result in a reduction in transformer differential relay sensitivity in terms of the transformer rating. However, auxiliary CT ratios can be used which will utilize the continuous overcurrent rating of the DSE up to 200 % so as to minimize this effect. The CT ratio selection procedure is given above in the section on **CT Calculations.**

Where accurate knowledge is available on the limitations of the CT characteristics, an increase in the sensitivity of the DSE may be possible. Application of the DSE with currents up to twice the relay rating is acceptable and results in a sensitivity, in terms of the actual circuit rating, of twice the markings on the relay.

Instantaneous Setting

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 Figure 11 and 14. This unit is not responsive to the dc component in an asymmetrical current. It is responsive to approximately the peak value of the ac comp nent 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 un-

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affected 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

TABLE 1

Typical un-restrained relay settings based on full load current equal to nominal relay rating.

Transformer Connection	Transformer Size	When energized from: H.V. side	L.V. side
Y-Y	Less than 10 MVA	20 X	20 X
Y-Y	More than 10 MVA	13 X	13 X
Y-Delta (L.V.)	any	8 X	13 X

When additional TUC 4 input-restraint units are used there is no change in the setting procedures.

DC Voltage Taps

Taps for the dc voltage should conform to the available voltage, per Figure 14. The MS 1 output tripping relay should have the proper coil for the available voltage. The voltage taps and zener regulators of the TEE 4 are only for the electronic components.

TESTING

Acceptance Tests

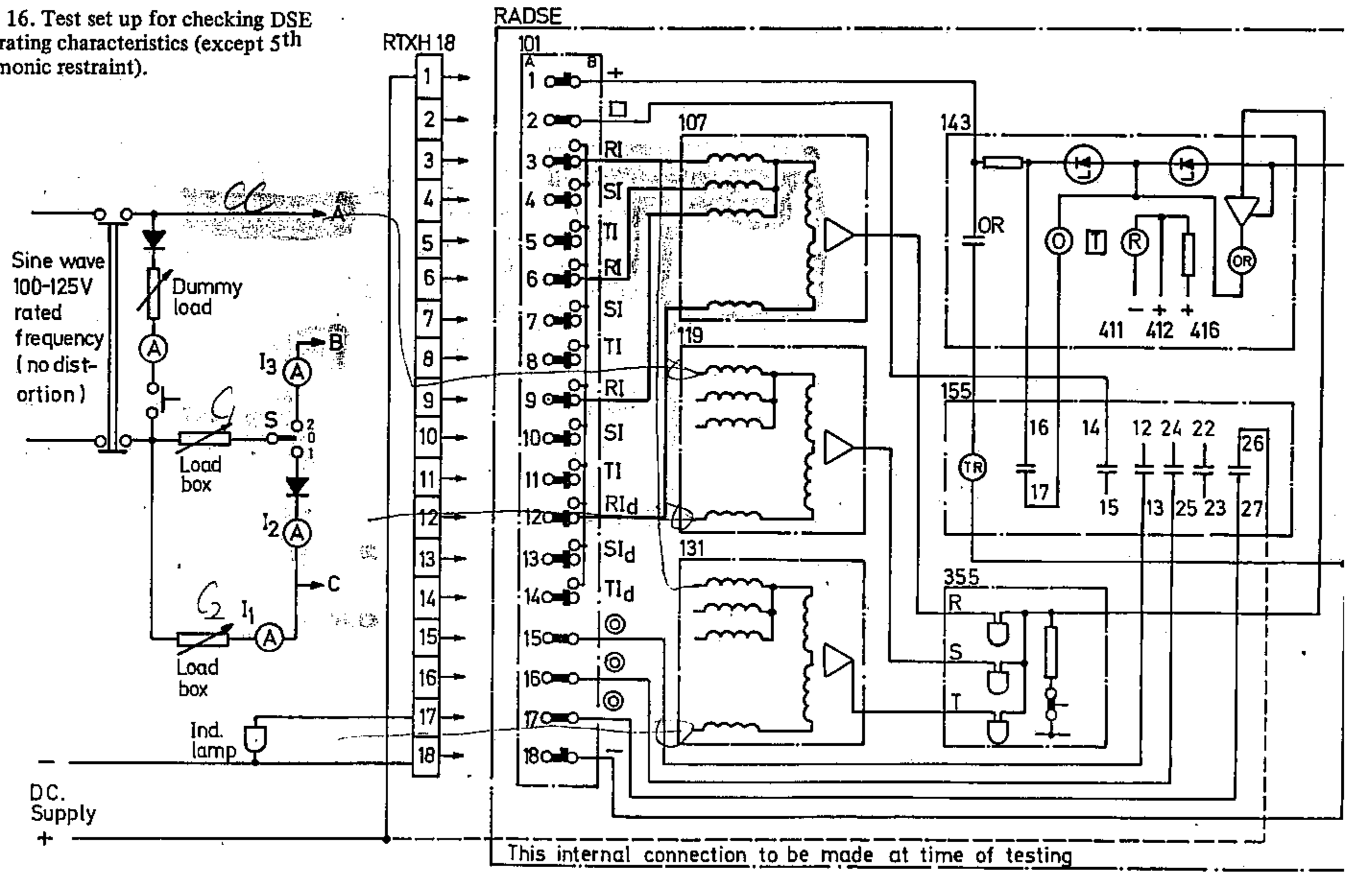
Check the name plate to assure that the relay mod(el) numbers, ratings and calibration ranges are as speci(-) fied in the requisitions. Visually inspect the relay t(o) assure that there has been no mechanical damage i(n) shipment or storage. Confirm that the dc voltage ta(p) corresponds to the available voltage.

The several operating characteristics for the three-winding relay can be individually checked with the conventional test circuit of Figure 16 by selecting t(he) proper connections from Table 2 for each characte-ristic of interest.

When more than three inputs are required, addition(al) restraint units, TUC 4, and a second test switch RT(XH) 18 are added to the relay as shown in Figures 3, 7 ((e) and (f). Note that in Figure 7 (e) the trip wiring is routed through two test switches so that insering the test plug in either opens all of the trip function(s) in the relay. The five and six input relays shown in Figure 7 (f) utilize three test switches for testing co(n)venience. The testing schedules for these models ar(e) shown in table 3, 4 and 5.

The electrical connections to the relay should be made through the test handle properly inserted in

Fig. 16. Test set up for checking DSE operating characteristics (except 5th harmonic restraint).



Note 1: Refer to Figure 7 (e) for internal connections when four inputs are used, and to Figure 7 (f) when five or six inputs are used.
Note 2: Connect test leads A, B and C to the RTXH 18 test handle according to the schedules in Tables 2, 3, 4 or 5.

the test switch. This will check the complete relay system including the output tripping relay. The details of these testing facilities are shown in Figure 8.

TABLE 2

To be used with Figure 16 and Figure 7 (a)

Test of basic DSE with three input-restraints

Test of	Phase	Connect lead A to terminal	Connect lead B to terminal	Connect lead C to terminal	Set switch S in position
Operating value	R	3 (6, 9)	–	12	0
	S	4 (7, 10)	–	13	0
	T	5 (8, 11)	–	14	0
2nd harmonic restraint	R	3 (6, 9)	–	12	1
	S	4 (7, 10)	–	13	1
	T	5 (8, 11)	–	14	1
Through-fault restraint	R	3	6	12	2
		3	9	12	2
	S	4	7	13	2
		4	10	13	2
	T	5	8	14	2
		5	11	14	2

Note: Connections shown to terminals within ( ) are optional for a more complete test of the relay input circuits.

TABLE 3

To be used with Figure 16 and Figures 7 (d) and (e)

Test of DSE with four input restraints (one TUC 4 and two test switches)

Test of	Phase	Connect lead A to terminal	Connect lead B to terminal	Connect lead C to terminal	Set switch S in position
Operating value	R	3 (6, 9, 3L)	–	12	0
	S	4 (7, 10, 4L)	–	13	0
	T	5 (8, 11, 5L)	–	14	0
2nd harmonic restraint	R	3 (6, 9, 3L)	–	12	1
	S	4 (7, 10, 4L)	–	13	1
	T	5 (8, 11, 5L)	–	14	1
Though-fault restraint	R	3	6	12	2
		9	3L	12	2
	S	4	7	13	2
		10	4L	13	2
	T	5	8	14	2
		11	5L	14	2

Note 1: Connections shown to terminals within ( ) are optional for a more complete test of the relay input circuits.

Note 2: L stands for terminals on the second test switch (501) in the lower left of the 8S equipment frame.

TABLE 4

To be used with Figure 16 and Figures 7 (d) and (f)

Test of DSE with five input restraints (two TUC 4's and two or three test switches)

Test of	Phase	Connect lead A to terminal	Connect lead B to terminal	Connect lead C to terminal	Set switch S in position
Operating value	R	3 (6, 9, 3L, 6L)	–	12	0
	S	4 (7, 10, 4L, 7L)	–	13	0
	T	5 (8, 11, 5L, 8L)	–	14	0
2nd harmonic restraint	R	3 (6, 9, 3L, 6L)	–	12	1
	S	4 (7, 10, 4L, 7L)	–	13	1
	T	5 (8, 11, 5L, 8L)	–	14	1
Through-fault restraint	R	3	6	12	2
		9	3L	12	2
		6L	3	12	2
	S	4	7	13	2
		10	4L	13	2
		7L	4	13	2
	T	5	8	14	2
		11	5L	14	2
		8L	5	14	2

Note 1: Connections shown to terminals within ( ) are optional for a more complete test of the relay input circuits.

Note 2: L stands for terminals on the second test switch (501) in the lower left of the 8S equipment frame.

TABLE 5

To be used with Figure 16 and Figures 7 (d) and (f)

Test of DSE with six input restraints (three TUC 4's and two or three test switches)

Test of	Phase	Connect lead A to terminal	Connect lead B to terminal	Connect lead C to terminal	Set switch S in position
Operating value	R	3 (6, 9, 3L, 6L, 9L)	–	12	0
	S	4 (7, 10, 4L, 7L, 10L)	–	13	0
	T	5 (8, 11, 5L, 8L, 11L)	–	14	0
2nd harmonic restraint	R	3 (6, 9, 3L, 6L, 9L)	–	12	1
	S	4 (7, 10, 4L, 7L, 10L)	–	13	1
	T	5 (8, 11, 5L, 8L, 11L)	–	14	1
Through-fault restraint	R	3	6	12	2
		9	3L	12	2
		6L	9L	12	2
	S	4	7	13	2
		10	4L	13	2
		7L	10L	13	2
	T	5	8	14	2
		11	5L	14	2
		8L	11L	14	2

Note 1: Connections shown to terminals within ( ) are optional for a more complete test of the relay input circuits.

Note 2: L stands for terminals on the second test switch (501) in the lower left of the 8S equipment frame.

Fundamental Frequency Tests

a. Minimum pickup currents

With the selector switch in the mid (0) position (Figure 16), the minimum pickup currents and the un-restrained operating currents can be determined. The value should be within 10 percent of the settings. To eliminate any ambiguity as to which unit is operating, the restrained unit can be temporarily disabled by opening the connection to terminal 143:423 of the TEE 4 measuring unit. See Figure 17 for the physical location of this terminal. The extractor type RTXD provided for this purpose should always be used. Never attempt to remove a lead without the extractor.

Note: The output relay will normally pulsate when the un-restrained circuit is tested. However, the time in the first picked-up position is long enough to trip a breaker when the relay is in service.

b. Restraint characteristics

With the selector switch (Figure 16) in position 2 the restraint characteristics can be determined. The operating values should be within 10 percent of the curves of Figure 13 (a) or (b). For convinience these values, with their accuracy limits, at an ambient temperature of 20–25°C, are tabulated in table 6.

Observe that the un-restrained unit has to be connected for an operating value higher than the highest value of I_1, in table 6.

This means that terminal 143:417 must not be connected to 143:427 as at the setting 8 times rated current.

TABLE 6

Variable Restraint Test Data at 32 % Min. Op. Current

Relay rated current	I_3 (A) Restraint	I_1 (A) Differential
1 A	0	0.29–0.35
	1.5	0.66–0.94
	3	1.6–2.2
	10	7.8–10.4
5 A	0	1.45–1.75
	7.5	3.3–4.7
	15	8.0–11
	50	39–52

Caution: This is a harmonic restraint relay and it is essential that good sine wave test current be used for all fundamental frequency testing requirements.

Harmonic Restraint Tests

The 2nd harmonic restraint characteristic can be checked with the circuit of Figure 16 by placing the selector switch to position 1. The single diode rectifier provides a current wave shape rich in 2nd harmonics in addition to the dc component. By adjusting the two load boxes, various proportions of 2nd harmonic to fundamental can be established.

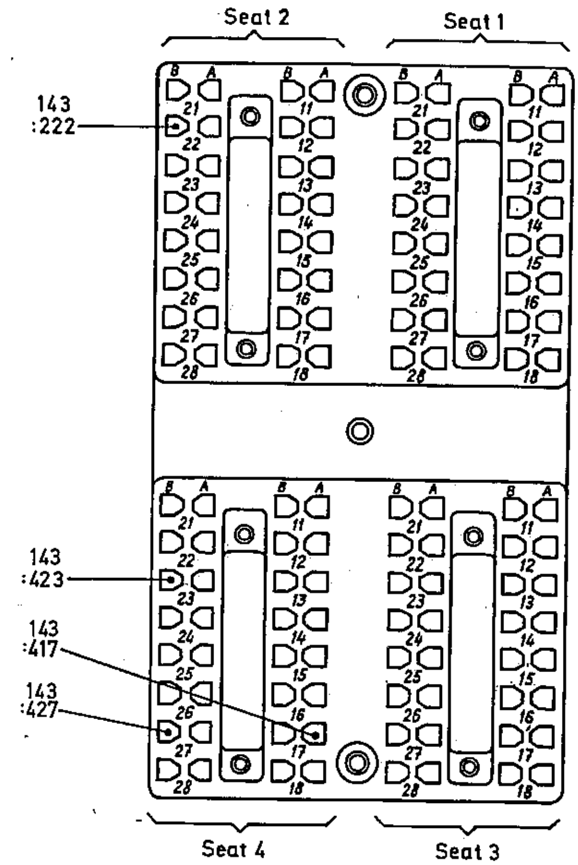


Fig. 17 (a). TEE 4 (143) measuring unit, rear view showing location of terminals used or opened during certain tests.

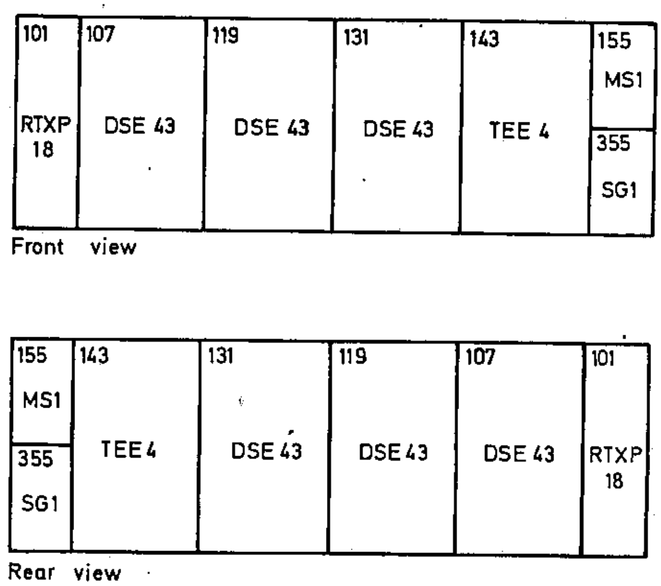


Fig. 17 (b). DSE, location and identification of modules.

Wave shape analysis shows that if the ac current I_1 is read on an ac ammeter and the dc current I_2 is read on a dc ammeter of moving coil type (neither of rectifier type) the following expression will be valid:

$$\text{percent } 2^{nd} \text{ harmonic} = \frac{0.47\, I_2}{1.11\, I_2 + I_1} \times 100$$

The 2^{nd} harmonic restraint has a 20 percent nominal value. A convenient check point is to adjust the dc current to 4 A and with the minimum pick up setting at 32 percent, gradually increase the ac current until the relay operates. For the 18–25 percent factory calibration this should be at 3.1–6 A ac. The minimum pickup sensitivity setting has little effect on this 2^{nd} harmonic restraint characteristic.

The dc component of the 2^{nd} harmonic test current will not only flow in the relay (and cause no significant effect because of the air-gapped transformers), but it will also flow in the supply circuit. This may cause dc saturation in the supply transformer and result in fuse blowing. More importantly it may result in test voltage distortion which may affect the relay characteristics without the tester being aware of it other than by observing a relay with apparent lack of sensitivity. Should such be the case, one solution is to supply the rectifier circuit from a separate ac source. Another solution is to add a 2^{nd} rectifier and dummy load to cancel the testing dc in the power source. This is also shown in the test circuit of Figure 16.

The 5^{th} harmonic restraint action cannot be conveniently checked in the field. In the test lab, the use of a power oscillator adjusted to the 5^{th} harmonic frequency is the most precise method of checking this characteristic. The relay will at three-phase be restrained with 5^{th} harmonic of 35 percent or more of the fundamental.

Indicator Tests

Check that the indicator flag in the TEE 4 unit drops when the relay operates and that the indicator flag resets when 110–220 V dc is connected to terminals 416 (+) and 411 (–) in the TEE 4 unit.

Three-phase Tests

The complexity of three-phase testing is not usually warranted. If a three-phase, fundamental frequency test is made with a pure sine wave, the minimum pick-up current will be increased from the calibration value by a factor of 1.4 to 2.0. This is inherent in the relay design and is not adjustable.

Inter-phase Tests

To check for the inter-phase action of the harmonic restraint it will be necessary to inject the 2^{nd} harmonic into one phase unit and the operating fundamental frequency into another.

To check the inter-action between S and R phase units proceed as follows:

1. Remove the test lead from ammeter I_2 to C, at C.
2. Connect this ammeter lead from I_2 to terminal 13, (S Ø)
3. Connect a jumper from terminal 4 to 3, (S Ø to R Ø)
4. Connect test lead A to terminal 3, (R Ø)
5. Connect test lead C to terminal 12, (R Ø)
6. Place switch S in position 1.
7. Adjust the d.c. current I_2 to 2 A (for a 5A relay) and with the minimum pick-up setting at 32 percent, gradually increase the a.c current I_1 until the relay operates. The fundamental current needed for operation will at this interphase test be proportionally higher than at the normal 2^{nd} harmonic restraint test, as in this case, it does not flow any 2^{nd} harmonic component in the operating circuit. The percentage 2^{nd} harmonic is in this case equal to

   $$\frac{0.47\, I_2}{I_1} \times 100$$

   and will at this test normally be 2–6 percentage points lower than at the 2^{nd} harmonic restraint test. Thus the 5 A-relay will operate for approx. 5–6 A.
8. Move test lead from 13 to 14 and jumper from 4 to 5 to check inter-action between TØ and RØ. To check the inter-action between TØ and SØ move the test lead A from terminal 3 (RØ) to 4 (SØ) and lead C from 12 (RØ) to 13 (SØ). move jumper 3 to 4

Note: This inter-phase harmonic relation does not involve the fundamental frequency restraints hence a total of three tests will completely check this feature regardless of the number of restraints.

Calibration

If any of the restraint characteristics appear to be off calibration, internal relay adjustments are not recommended.

However, before judging that a relay is off calibration confirm that the test current is a good sine wave. A small amount of 2^{nd} or 5^{th} harmonic in the test current can have a significant effect on the relay operating characteristics.

Functional in Service Check Out

Ratio checking of the current transformers and auxiliary transformers is conventional, as are the other functional tests such as circuit-breaker tripping and lockouts. In service load checks are most conveniently made with an ammeter and current test plug inserted in the respective current circuits at the RTXP 18 test switch. The location of the various currents on the test switch is shown in Figure 7. Good testing practice would include inserting the red trip blocking plug before taking any current readings. Note that with multi-restraint models which require two test switches, the residual phase currents have two contacts in parallel, see Figure 7 (d). Thus to measure the residual currents it is recommended to use two test plugs, one for each test switch. Connect the current test plugs in parallel to an ammeter. Insert the test plugs to the same position (12, 13 or 14) on the test switches. The ammeter then shows the total residual current. If, on the other hand, only onte test plug is available the residual current can be measured by insering the current test plug in one test switch and temporarily open the interconnection between the terminals 14, on the A side of the switches.

Routine Testing

Under normal conditions type DSE needs no special testing or maintenance. The covers of the plug-in modules should be fitted properly. Contacts in the output tripping relay or in the test switch which are burnt due to abuse should be carefully dressed with a diamond file or a very fine file. Emery cloth or similar abrasive materials are unsuitable for dressing relay contacts, as insulating grains from the abrasive material may be deposited on the contact surfaces, thereby causing mal-function and failures.

Routine electrical tests can conform in frequency to the users' established practice. Checking the pickup setting of the relay and timing it at a moderate multiple of pickup is usually adequate for the restrained unit. The un-restrained unit operation can be conformed by timing this unit about 150 percent of its pickup value. This time should be about 10–12 ms less than the restraint unit time when checked at a value just under the un-restrained pickup current. It is not recommended to routinely disconnect the wires on the TEE 4 unit to establish the complete in dividual performance of these two units.

Caution: The relay calibrations can only be checked accurately with pure sine wave currents because of tl harmonic restraint nature of the relay characteristic.

Spare Parts

There is normally no need for stocking spare parts bı this procedure also assures that a replaced relay is up the original factory quality and calibration standards

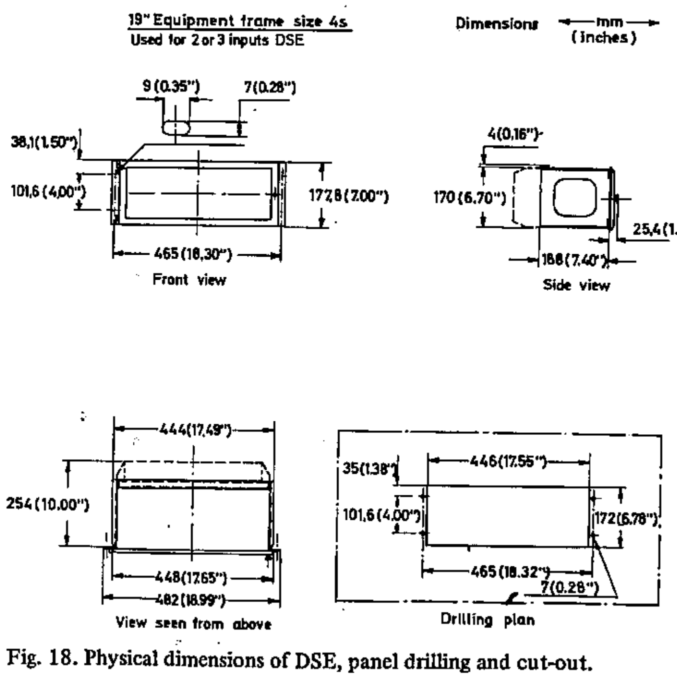
RECEIVING, HANDLING AND STORAGE

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 be replaced in its shipping carton after inspection for delivery to jobsit Also the relay should preferably be left in its shippin carton until time for actual installation.

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

DIMENSIONS



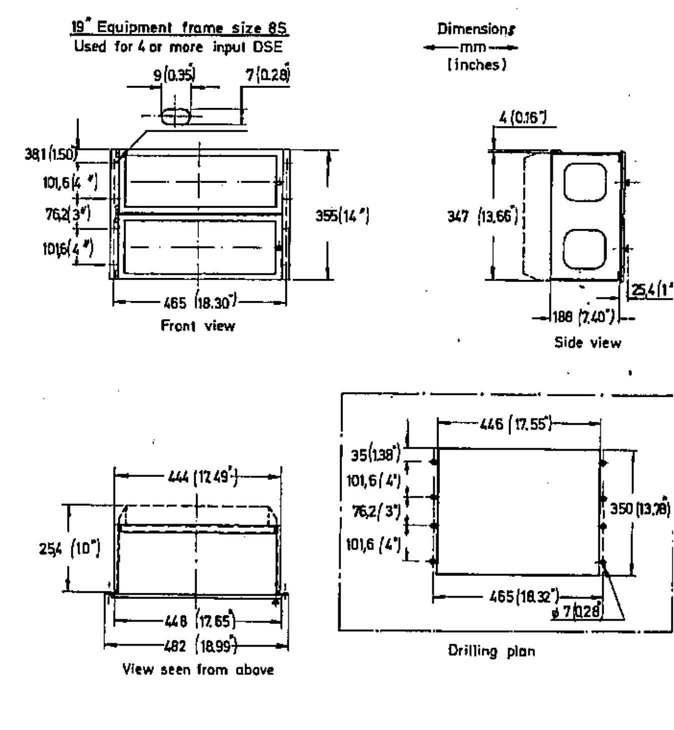


Fig. 18. Physical dimensions of DSE, panel drilling and cut-out.

MULTI-TAPPED SINGLE PHASE AUXILIARY CURRENT TRANSFORMERS TYPE SLCE 12

These are reconnectible auxiliary current transformers intended for use with 1 A or 5 A transformer differential protection type RADSE. Three different transformers are available to provide current ratios from 0.65–2.60/1 A, 2.55–9.60/1 A and 2.85–9.7/5 A. Sufficient taps are provided for setting the secondary current with an accuracy of ± 3 percent of any desired value.

Design

The transformers are equipped with three secondary windings connected to a terminal block with six terminals marked 1 to 6, and with two primary windings with intermediate tap connected to another terminal block with six terminals marked 7 to 12. The transformers have also a third terminal block with their terminals marked P1 – P2, S1 – S2, to which the external connections should always be made.

Tables 1, 2 and 3 on pages 30, 31 and 32 show the most suitable internal connections (and turns ratio) to obtain a standard secondary current of 1 A or 5 A for the listed primary current. If the transformer is ordered with a certain ratio it will be delivered connected for this ratio.

These tables can also be used to determine turns ratios and connections when secondary currents less than 1 A or 5 A are desired by directly proportioning the values.

For example, if $I_p = 3.6$ A and it is desired that $I_s = 4.5$ A:

Chose the 5 A transformer with the same current ratio, i.e.

$$\frac{X}{5} = \frac{3.6}{4.5} \quad \text{gives } X = 4.0$$

Hence from table 3 choose SLCE 12 current transformer 4785 040-VS with a current ratio 4.0/5 A, and turns ratio 53/42.

These tables are also suitable for wye delta connected transformers.

For example if the incoming line current $I_p = 1.31$ A and it is desired to have delta secondaries yield I_s = 1 A line current:

$$\frac{X}{1} = \frac{1.31}{1/\sqrt{3}} \quad \text{gives } X = 2.26$$

Hence from table 1 choose SLCE 12 current transformer 4785 040-VP with a current ratio 2.26/1 A and turns ratio 70/162.

Load Burden

The maximum permissible resistance in the wires between the auxiliary current transformers and the differential relay depends on the relay burden and the maximum primary current for which good performance is desired. For a given total secondary burden the maximum primary current $I_{p_{max}}$ for a 10 percent ratio error can be calculated according to the following formula:

$$I_{p_{max}} = n \cdot I_n$$

$$\text{where } n = \frac{a}{b+z}$$

I_n = rated current of the auxiliary CT's

a = constant (ohms), given in table 1, 2 and 3. This depends on the design of the CT and the frequency of the current.

b = resistance of the secondary winding according to table 1, 2 and 3.

z = impedance of the burden (wires and the differential relay).

This formula is valid for symmetrical primary current. Asymmetrical currents will saturate the core at a lower current. Good CT application practice suggests that n, the saturation factor, should correspond to the maximum through-fault current.

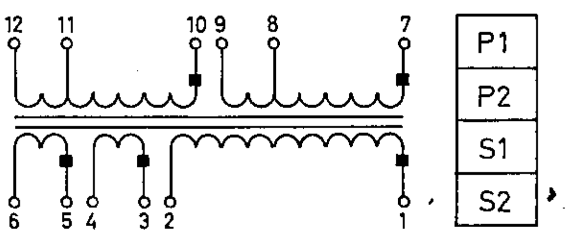


Fig. 1. Terminal markings for SLCE 12 auxiliary current transformer

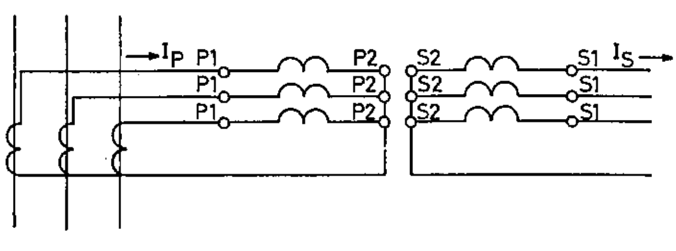


Fig. 2. Wiring diagram for three auxiliary current transformers connected wye-wye.

Ratings

Rated secondary current	1 A or 5 A
Rated current ratios	Reconnectible in 4–6 percent steps according to Tables 1–3 0.65–2.60 A/1 A 2.55–9.60 A/1 A 2.85–9.70 A/5 A
Rated frequency	60 Hz
Overload capacity	2.5 x rated current continuously 15 x rated current for 10 s 75 x rated current for 1 s
Burden (self consumption)	According to tables 1–3
Insulation test voltage	2500 V, 50 Hz
Maximum wire size to terminal block (P1-P2-S1-S2)	No 7 AWG (10.54 mm^2)
Dimensions	According to Figure 3
Weight	3.6 kg (8 lbs)

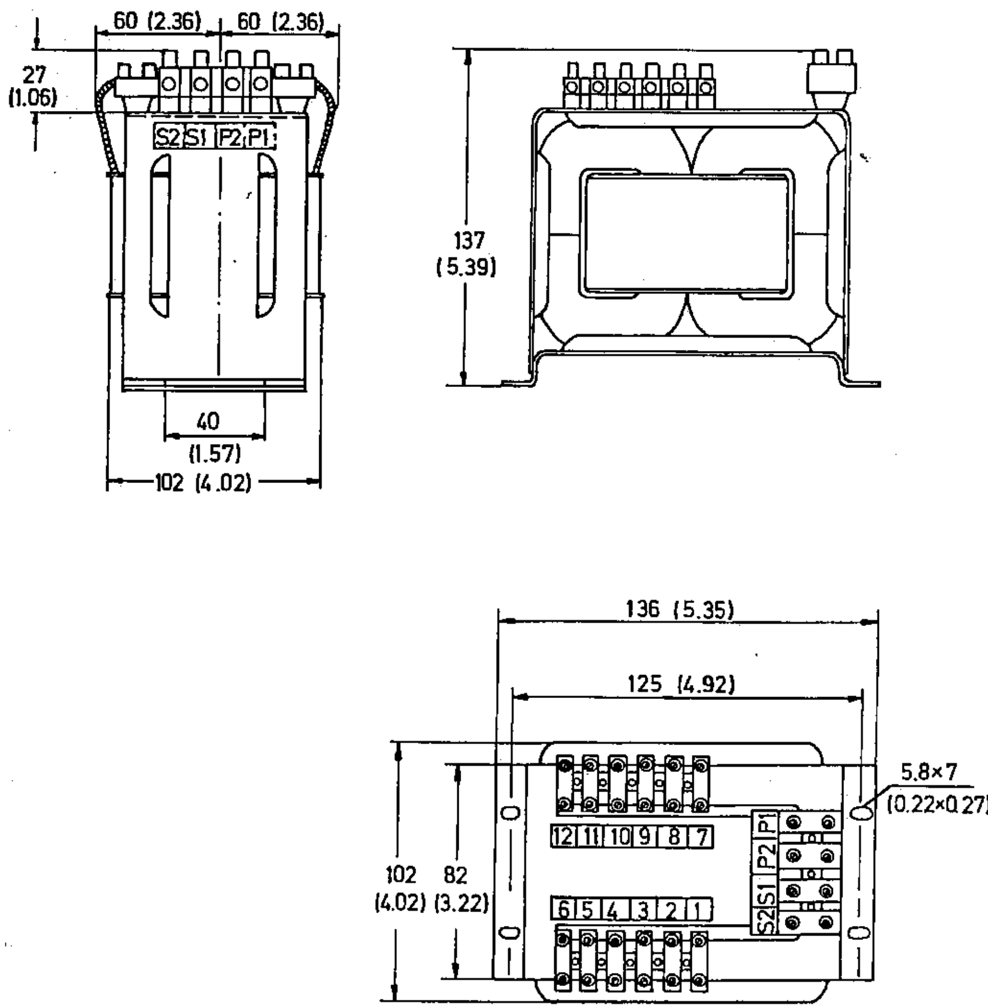


Fig. 3. Dimensions in mm (inch) for Auxiliary Current Transformer type SLCE 12.

TABLE 1: Connections for 1 A rated secondary

Transformer SLCE 12 for $I_p = 0.65 - 2.60$ A, $I_s = 1$ A
Ordering No. 4785 040-VP

Terminals	No. of turns	Resistance Ω
1–2	154	0.38
3–4	16	0.05
5–6	8	0.03
7–8	70	0.21
8–9	30	0.10
10–11	70	0.24
11–12	30	0.11

Primary current A	Turns ratio	Connections on primary side between terminals	Connections on secondary side between terminals	a [1] Ω	b Ω	Power consumption at $I_s = 1$ A VA
0.650–0.670	200/130	P1–7, 9–10, 12–P2	S1–1, 2–6, 4–5, 3–S2	56	0.47	1.0
0.671–0.710	200/138		S1–1, 2–4, 3–S2	60	0.44	1.0
0.711–0.750	200/146		S1–1, 2–6, 5–S2	63	0.42	1.0
0.751–0.790	200/154		S1–1, 2–S2	67	0.39	1.0
0.791–0.830	200/162		S1–1, 2–5, 6–S2	70	0.42	1.1
0.831–0.870	200/170		S1–1, 2–3, 4–S2	74	0.44	1.2
0.871–0.900	200/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.2
0.901–0.930	170/154	P1–7, 9–10, 11–P2	S1–1, 2–S2	67	0.39	1.2
0.931–0.980	170/162		S1–1, 2–5, 6–S2	70	0.42	1.2
0.981–1.02	170/170		S1–1, 2–3, 4–S2	74	0.44	1.4
1.03–1.07	170/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.4
1.08–1.12	140/154	P1–7, 8–10, 11–P2	S1–1, 2–S2	67	0.39	1.4
1.13–1.18	140/162		S1–1, 2–5, 6–S2	70	0.42	1.4
1.19–1.24	140/170		S1–1, 2–3, 4–S2	74	0.44	1.6
1.25–1.28	140/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.6
1.29–1.34	100/130	P1–7, P1–10, 9–P2, 12–P2	S1–1, 2–6, 4–5, 3–S2	56	0.47	1.0
1.35–1.42	100/138		S1–1, 2–4, 3–S2	60	0.44	1.0
1.43–1.50	100/146		S1–1, 2–6, 5–S2	63	0.42	1.0
1.51–1.58	100/154		S1–1, 2–S2	67	0.39	1.0
1.59–1.66	100/162		S1–1, 2–5, 6–S2	70	0.42	1.2
1.67–1.74	100/170		S1–1, 2–3, 4–S2	74	0.44	1.2
1.75–1.81	100/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.4
1.82–1.91	70/130	P1–7, P1–10, 8–P2, 11–P2	S1–1, 2–6, 4–5, 3–S2	56	0.47	1.2
1.92–2.01	70/138		S1–1, 2–4, 3–S2	60	0.44	1.2
2.02–2.14	70/146		S1–1, 2–6, 5–S2	63	0.42	1.2
2.15–2.25	70/154		S1–1, 2–S2	67	0.39	1.4
2.26–2.37	70/162		S1–1, 2–5, 6–S2	70	0.42	1.4
2.38–2.48	70/170		S1–1, 2–3, 4–S2	74	0.44	1.6
2.49–2.60	70/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.6

The value is valid for 50 Hz. It is 20 % higher at 60 Hz.

TABLE 2: Connections for 1 A rated secondary

Transformer SLCE 12 for $I_p = 2.55 - 9.60$ A, $I_s = 1$ A
Ordering No. 4785 040-VR

Terminals	No. of turns	Resistance Ω
1–2	154	0.38
3–4	16	0.05
5–6	8	0.03
7–8	18	0.017
8–9	7	0.007
10–11	18	0.018
11–12	7	0.008

Primary current A	Turns ratio	Connections on primary side between terminals	Connections on secondary side between terminals	a [1)] Ω	b Ω	Power consumption at $I_s = 1$ A VA
2.55–2.67	50/130	P1–7, 9–10, 12–P2	S1–1, 2–6, 4–5, 3–S2	56	0.47	1.2
2.68–2.84	50/138		S1–1, 2–4, 3–S2	60	0.44	1.2
2.85–3.00	50/146		S1–1, 2–6, 5–S2	63	0.42	1.2
3.01–3.16	50/154		S1–1, 2–S2	67	0.39	1.2
3.17–3.32	50/162		S1–1, 2–5, 6–S2	70	0.42	1.4
3.33–3.48	50/170		S1–1, 2–3, 4–S2	74	0.44	1.4
3.49–3.66	50/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.6
3.67–3.86	43/162	P1–7, 9–10, 11–P2	S1–1, 2–5, 6–S2	70	0.42	1.4
3.87–4.04	43/170		S1–1, 2–3, 4–S2	74	0.44	1.6
4.05–4.21	43/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.6
4.22–4.38	36/154	P1–7, 8–10, 11–P2	S1–1, 2–S2	67	0.39	1.6
4.39–4.61	36/162		S1–1, 2–5, 6–S2	70	0.42	1.6
4.62–4.83	36/170		S1–1, 2–3, 4–S2	74	0.44	1.8
4.84–5.07	36/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.8
5.08–5.35	25/130	P1–7, P1–10, 9–P2, 12–P2	S1–1, 2–6, 4–5, 3–S2	56	0.47	1.2
5.36–5.67	25/138		S1–1, 2–4, 3–S2	60	0.44	1.2
5.68–5.99	25/146		S1–1, 2–6, 5–S2	63	0.42	1.4
6.00–6.31	25/154		S1–1, 2–S2	67	0.39	1.4
6.32–6.64	25/162		S1–1, 2–5, 6–S2	70	0.42	1.4
6.65–6.95	25/170		S1–1, 2–3, 4–S2	74	0.44	1.6
6.96–7.17	25/178		S1–1, 2–3, 4–5, 6–S2	77	0.47	1.8
7.18–7.44	18/130	P1–7, P1–10, 8–P2, 11–P2	S1–1, 2–6, 4–5, 3–S2	56	0.47	1.4
7.45–7.88	18/138		S1–1, 2–4, 3–S2	60	0.44	1.6
7.89–8.33	18/146		S1–1, 2–6, 5–S2	63	0.42	1.6
8.34–8.77	18/154		S1–1, 2–S2	67	0.39	1.8
8.78–9.21	18/162		S1–1, 2–5, 6–S2	70	0.42	1.8
9.22–9.60	18/170		S1–1, 2–3, 4–S2	74	0.44	2.0

1) The value is valid for 50 Hz. It is 20 % higher at 60 Hz.

TABLE 3: Connections for 5 A rated secondary

Transformer SLCE 12 for $I_p = 2.85 - 9.70$ A, $I_s = 5$ A
Ordering No. 4785 040-VS

Terminals	No. of turns	Resistance Ω
1–2	42	0.031
3–4	4	0.004
5–6	2	0.003
7–8	22	0.020
8–9	9	0.009
10–11	22	0.023
11–12	9	0.010

Primary current A	Turns ratio	Connections on primary side between terminals	Connections on secondary side between terminals	a [1) Ω	b Ω	Power consumption at $I_s = 5$ A VA
2.85–2.98	62/36	P1–7, 9–10, 12–P2	S1–1, 2–6, 4–5, 3–S2	3.1	0.046	1.8
2.99–3.14	62/38		S1–1, 2–4, 3–S2	3.3	0.041	1.8
3.15–3.30	62/40		S1–1, 2–6, 5–S2	3.5	0.040	1.8
3.31–3.46	62/42		S1–1, 2–S2	3.6	0.035	1.8
3.47–3.62	62/44		S1–1, 2–5, 6–S2	3.8	0.040	2.0
3.63–3.78	62/46		S1–1, 2–3, 4–S2	4.0	0.041	2.2
3.79–3.91	62/48		S1–1, 2–3, 4–5, 6–S2	4.2	0.046	2.4
3.92–4.05	53/42	P1–7, 9–10, 11–P2	S1–1, 2–S2	3.6	0.035	2.2
4.06–4.24	53/44		S1–1, 2–5, 6–S2	3.8	0.040	2.2
4.25–4.43	53/46		S1–1, 2–3, 4–S2	4.0	0.041	2.4
4.44–4.65	53/48		S1–1, 2–3, 4–5, 6–S2	4.2	0.046	2.6
4.66–4.87	44/42	P1–7, 8–10, 11–P2	S1–1, 2–S2	3.6	0.035	2.2
4.88–5.11	44/44		S1–1, 2–5, 6–S2	3.8	0.040	2.4
5.12–5.34	44/46		S1–1, 2–3, 4–S2	4.0	0.041	2.6
5.35–5.62	44/48		S1–1, 2–3, 4–5, 6–S2	4.2	0.046	2.8
5.63–5.96	31/36	P1–7, P1–10, 9–P2, 12–P2	S1–1, 2–6, 4–5, 3–S2	3.1	0.046	2.0
5.97–6.28	31/38		S1–1, 2–4, 3–S2	3.3	0.041	2.0
6.29–6.61	31/40		S1–1, 2–6, 5–S2	3.5	0.040	2.0
6.62–6.93	31/42		S1–1, 2–S2	3.6	0.035	2.0
6.94–7.25	31/44		S1–1, 2–5, 6–S2	3.8	0.040	2.2
7.26–7.57	31/46		S1–1, 2–3, 4–S2	4.0	0.041	2.2
7.58–7.95	31/48		S1–1, 2–3, 4–5, 6–S2	4.2	0.046	2.4
7.96–8.40	22/36	P1–7, P1–10, 8–P2, 11–P2	S1–1, 2–6, 4–5, 3–S2	3.1	0.046	2.2
8.41–8.85	22/38		S1–1, 2–4, 3–S2	3.3	0.041	2.2
8.86–9.31	22/40		S1–1, 2–6, 5–S2	3.5	0.040	2.4
9.32–9.70	22/42		S1–1, 2–S2	3.6	0.035	2.4

1) The value is valid for 50 Hz. It is 20 % higher at 60 Hz.

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