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

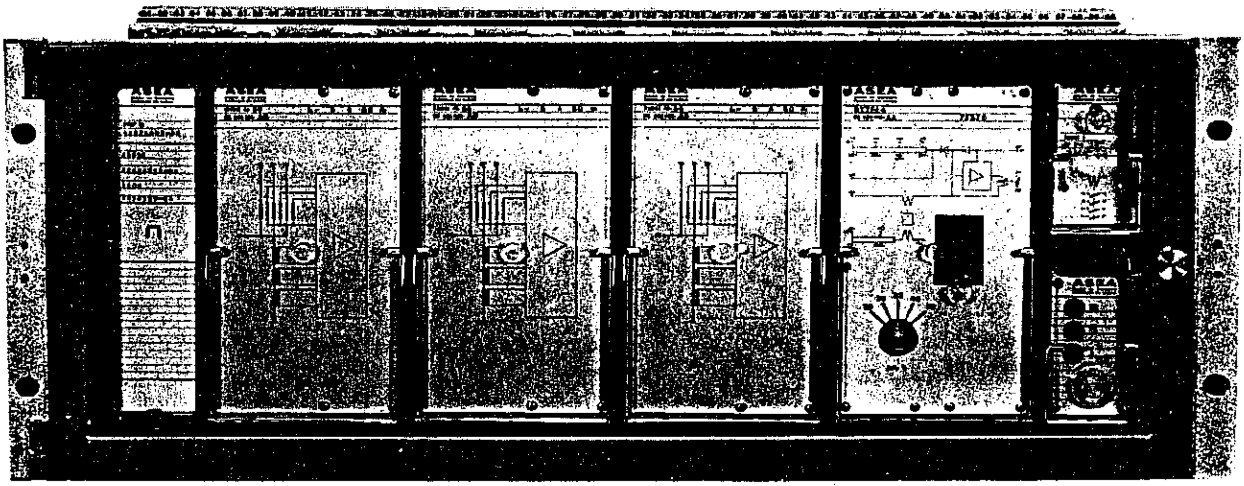

Fig. 25. Three phase transformer differential relay type RADSE

INTRODUCTION

The purpose of these Test Instructions is to augment the information in the Application Guide on acceptance and routine testing of the DSE. Generally the information in the AG is adequate for checking the performance of the DSE relay. The following instructions will deal with other aspects of startup testing and also provide more details on the individual components of the relay. These instructions are based on the user being familiar with the testing information in the AG and on the availability of the AG for reference to drawings and details provided in that publication. (Note: Figures numbered below 25 and Tables numbered below 10 are in the Application Guide, those figures numbered 25 and above and Tables 10 and above are in this Test Instructions.) These instructions contain adequate detail for servicing these relays. However, for those interested in a more complete explanation of the COMBIFLEX system and the method of marking, they can refer to Reference publications.

Reference Publications

a. Sales Information	62–10 SI
b. Application Guide	62–10 AG
c. Test Instruction (This publication)	62–10 TI
d. COMBIFLEX System	
Sales Information	92–10 SI
Application Guide	92–10 AG
e. COMBITEST System	
Sales Information	92–11 SI
Application Guide	92–11 AG
f. Accessories:	
(1) Auxiliary Relays RXMS 1	21–16 SI
Lock-out Relays RXMVB 4	25–10 SI

® Reg. trade mark

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TEST INSTRUMENTS AND THEIR USE

The relay has been tested and calibrated using sine wave currents plus specific values of harmonics. The meters used for calibration are rms (not rectifier) type for ac measurements and true dc, moving coil, (averaging) type for dc measurements. It is essential that similar type meters be used in the field if reliable, consistent, results are to be attained.

When the rectified dc method is used as the source of 2nd harmonic, the formula given in the AG for calculating the amount of 2nd harmonic is based on reading the dc with a true dc ammeter (of moving coil type) as well as reading the ac with a true rms type ac meter. When a separate 2nd harmonic (or 5th harmonic) generator is used to supply the harmonic restraint current, its magnitude should also be measured with a true rms meter, accurate at that frequency.

DC voltages should be read with a 10,000 ohms per volt dc voltmeter with a true dc characteristic.

When insulation measurements are to be made it is prudent to use as low a voltage as feasible for the desired results. The relay has been production tested with voltages up to 2.5 kV, but such test voltages are not recommended for field testing. Any measurements made on the inter-module wiring should be at a voltage not to exceed that normally expected on that wire and from a high impedance source of at least 10.000 ohm/volt. In general, measurements on inter-module wiring beyond those given in the trouble shooting section are not recommended. Many of these circuits terminate in diodes and transistors. The results of measurements made on these circuits are the consequences of the test equipment characteristics as much as on the status of the circuit itself, and hence are meaningless and are not recommended.

STARTUP TESTING

There are no unusual requirements for commissioning a set of DSE transformer differential relays. However, in view of the several interrelated components, the following is offered as a guide.

1 General inspection: Inspect all name plates for proper ratings of equipment. Confirm the proper taps on main CT's and auxiliary CT's and correct voltage taps.

2 Current circuits connections:

a) Primary current injection: where CT ratios are low enough, using a low voltage source, apply a reasonable current in the primary circuit of each main CT. By means of an ammeter inserted into the various secondary circuits confirm the current wiring and ratios of each main and auxiliary CT.

b) Secondary current injection: As an alternate to the primary current test, insert current at each main CT secondary terminal in parallel with CT secondary.

c) These current tests do not check phasing or polarity of the CT's. Phasing checks are usually deferred until load checking. Polarity check can be made with the dc "kick-test". Connect a dc voltmeter of a moving coil (not rectifier) type to the secondary of the CT, with the meter + on the polarity mark. Momentarily connect across the primary winding a dc voltage of 1 1/2 to 6 volts from a dry battery. With the battery positive to the CT primary polarity mark, the meter should kick up scale when battery is connected. It should go negative when battery is disconnected.

3 Inspect other wiring and compare with drawings provided with the transformers and relay for obvious errors or omissions. Depending on individual practices, circuit continuity can be checked with ohmmeter or by other methods. Any of these methods are suitable to check the proper functioning of the test switch and associated plugs for proper opening or shorting as indicated on the drawings.

4 Insulation tests: The DSE is production tested to 2–2.5 kV. In the field the current circuits are usually meggered to earth with 500 V max. This test can also be used to confirm that there is only a single protective ground on each current circuit. Confirm that each ground connection is restored correctly before proceeding to test another circuit. DC circuits are usually checked for grounds with a lower test voltage to avoid inadvertent damage to other equipment.

a) The DSE has been type tested with a 5 kV impulse, a 2.5 kV SWC test and a 4-8 kV showeri arc test in addition to the noted dielectric tests These type tests are usually not repeated in the field.

5 Trip circuit continuity tests: Manually operate the MS 1 output tripping relay by inserting a pin or small screw driver through the available opening in the cover. Confirm that the RTXP 18 test switch trip circuits are wired according to the appropriate diagram. Use the red trip-block plug RTXB (AG Fig. 8) to open the respective trip circuits in the RTXP 18 switch.

a) The MS 1 output relay may be electrically operated by applying the rated dc + voltage to terminal 143:222 on the rear of the TEE 4 module. (See Fig. 17a for physical location).

b) Using the RTXH 18 test plug handle inject current into the various DSE inputs (see AG Fig. 7, TI Fig. 27, or appropriate drawing for test switch detail) and observe that the MS 1 output relay picks up and that the operation indicator in the TEE 4 functions. If the SG 1 phase indicator is provided the respective phase indication should also occur.

c) These two tests provide a complete check of the tripping capability of the relay system. However, if it is a testing requirement that an overall tripping test be made in one test, i.e., current into relay to breaker tripping, a modification of the above procedure will be required. Remove the RTXH 18 test plug handle. To block the tripping of one or more breakers insert the red RTXB trip-block plug in the respective test switch positions. Prepare two leads each with a 20 A, COMBIFLEX female terminal crimped to one end. Connect these leads from a source of test current (preferably an ungrounded source) to the respective positions on the B (left) side of the rear of the RTXP 18 test switch. (See Fig. 7 in AG for the proper test switch positions). If there is also load current in the relay, the injected test current required to cause relay operation may not relate to any calibration value. However, since the overall tripping operation is still conformed as occuring just at a relay pickup, the purpose of the test is satisfied fully.

6 Set the relay: Refer to AG, Testing Section, for procedures for confirming the characteristics of the relay. There are only two settings to be made: (a) the minimum pickup current is set by means of the selector switch on the face of the TEE 4 measuring unit: (b) the unrestrained instantaneous unit is set by means of the jumpers on the rear of the TEE 4 unit as shown in Fig. 11 of the AG.

7 Initial energizing of transformers: This should not be done until after the relay is set and after the trip circuits are known to be functioning. With the test switch normal so the relay can trip, energize the associated transformer from the least critical source. If the relay operates, locate the fault or the inadequacy in the relay system before proceeding. If no fault is found, a wiring error should be suspected if the relay had been previously set correctly. The most likely cause would be a significant error in a CT ratio such as to cause the unrestrained unit to trip on excessive CT secondary current. Minor ratio errors or incorrect phasing of auxiliary CT's should not cause this type of incorrect tripping upon energizing without load.

a) To minimize the frustrations from such a situation it is usual to take oscillographic records of the initial energizations of large transformers. When this is not practical, the energizing source may be selected so as to minimize the possibility of a severe inrush causing a improperly installed relay to operate. Inrush is minimized by:

(a) Energizing the higher voltage winding.
(b) Energizing from the weakest source.
(c) Energizing a delta connected winding.

Seldom can all of these conditions be satisfied. Their relative merits for reducing inrush are about in the order listed. A maladjusted circuit breaker should be suspected if no other cause is located. If feasible, inrush can be minimized on the initial energizing by temporarily reconnecting the main transformer taps to include more turns on the winding to be energized.

b) Occasionally it may be desirable to initially energize a transformer from a separate, lower voltage test source. This can eliminate most inrush considerations. But it creates a hazard if a fault should exist in the transformer, there may be insufficient current to operate the protective relays and extensive internal damage might result.

8 Load checks: Load checks are most conveniently made with at least a 30 % load on the respective CT's. When this is not feasible, care should be used to make allowance for CT performance at low currents when evaluating results. Also the effect of the high burdens of low current ammeters must be allowed for. The various currents are measured by using an ammeter connected to the RTXM test plug inserted in the RTXP 18 test switch. Refer to detail drawings for the proper location of the various currents on the test switch. It is customary to insert red, trip-block plug into the RTXP 18 test switch to avoid inadvertent tripping while load checking. But this practice must be weighed against the hazard of a new piece of equipment faulting without primary protection in service.

a) Note that with multirestraint models which require two test switches, the neutral differential phase currents have two contacts in parallel, see Fig. 7(d). Thus to measure the differential currents it is recommended to use two test plugs, one for each test switch. Connect the 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 differential current. If, on the other hand, only one test plug is available the differential current can be measured by inserting the test plug in the test switch 101 and, on the A side of the switch, temporarily open the connection to terminal 14 on the test switch 501.

b) Load Tap Changer transformers are usually checked out on a mid-tap position. But frequently the taps are deliberately run off normal to develop a "circulating current" with another transformer for improved metering accuracy. The results are then converted to a neutral position by inversely proportioning the currents to the respective tap voltages.

c) When there are three or more windings, or sources, they are usually checked out in pairs, but this is not a requirement.

9 Wiring errors: When the differential current of any phase is more than a few percent of the input currents there is either a wiring error, such as a phase shift error in the auxiliary CT's or a ratio error somewhere in the system. Note that the magnetizing current in the power transformer can cause a higher percentage of differential current if the load current is lower than the rated value. The following are some of the more likely errors.

a) Same, small differential current in each phase – a wrong set of CT ratios or primary and secondary of auxiliary CT's interchanged, or LTC off calculated tap.

b) Differential currents higher than any of the restraint currents – reversed auxiliary CT ratio (or combination of c and d below).

c) Differential currents about equal to restraint currents – the delta of auxiliary CT's probably made up in reverse sequence from the main power transformer.

d) Differential currents $\sqrt{3}$ times restraint (on a two winding load test) – a "roll" in the phasing of one set of currents. On multiple winding transformers there could be more than one such error.

e) Unequal differential currents in the three phases – some type of asymmetrical wiring error. If there is current in two phases only and zero differential in one phase, probably an interchange of two phases from one source.

f) No current in a differential circuit – this should not be assumed to mean correct wiring, there may be a short circuit or an open circuit in the differential circuit. To test for one of these conditions observe the differential current when one of the restraints is removed from the relay. This can be accomplished as follows:

With the trips blocked and ammeter plug with meter connected inserted into the differential circuit, connect the A side (black lead) of a second ammeter plug to the same A side of the differential ammeter plug. Insert this second plug into one of the input circuits. The differential ammeter should now read the current which was thus bypassed from the relay. Be sure to make the connection between the two plugs before inserting the second plug to avoid an open CT condition.

10 Repetive energizing of the transformer to prove no maloperation is not recommended. When proof of performance is a requirement it is recommended that an oscillograph be used to record actual current wave shapes, thus minimizing the number of inrush tests which must be made.

11 Staged fault tests: This technique of proving no wiring errors or malfunctioning relays is the perogative of the user. It is not necessary from a relay commissioning viewpoint.

12 Placing in service: After all temporary startup facilities have been removed it is good practice, when feasible, to initiate a tripping from the DSE relay to confirm that the protection has been returned to working order, including targets, which should of course then be reset.

13 When one or more TUC 4 input-restraint modules are used, two RTXP 18 test switches are utilized as shown in Fig. 7 AG. However, to fully interlock the decommissioning of the tripping with the insertion of a test plug handle into either test switch certain dc circuit complexities have been introduced. Also as noted in item 8 above, the differential currents are parallelled in the two test switches at positions 12, 13 and 14. Thus, refer to proper drawing for the specific installation detail before load checking.

AUXILIARY CURRENT TRANSFORMERS

The various methods of connecting auxiliary CT'S to provide the desired phase shift and zero sequence performance are given in AG Fig. 9. Appendix of the DSE AG provides complete information on the SLCE 12 auxiliary CT turns ratios and winding development. The kneepoint voltage of these auxiliary CT's is 0.41 volt per turn. This can be used to confirm the general adequacy of the CT application, escpecially if there are any appreciable lead lengths between the auxiliary CT's and a 5 A rated relay.

RELAY ACCEPTANCE TESTS

The acceptance test procedures given in the AG will confirm all of the operating parameters of the DSE except 5th harmonic restraint. (This in treated in a separate section of this TI). Other tests which one may wish to make initially might include: (Refer to AG Fig. 16 and 7 for proper terminals for the various tests).

1. Operating time of the MS 1 tripping relay and any other tripping or lockout relays.
2. Operating sensitivity of tripping relays, and targets and target reset. Note: The phase operation indicators are all electronic and their threshold cannot be conveniently checked.
3. Influence of level of dc on performance of relay: To check for low dc voltage, connect a 5 KΩ 5 W rheostat between the 125 V and 220 V dc taps on the TEE 4 measuring unit (for a 125 V supply). Move the 125 V battery supply lead to the 220 V tap. Measure the voltage on the 125 V tap and adjust the rheostat for 100 V.

   This is the –20 % specification for proper performance of the relay. Make such performance tests as desired. Remove rheostat, return battery to proper 125 V tap and recheck relay for proper performance. (A comparable procedure may be used for other supply voltages). To check performance on high dc voltage, increase battery charger input to raise voltage to 140 V overcharge condition (on 125 V system). Test relay to extent desired.
4. Simultaneous tripping of all breakers: This is more of a test of battery capacity and fusing practises than of relay performance since each trip circuit is routed through a separate relay contact. Also, all test switch positions are used below their conservative ratings.
5. Dielectric Tests: Each relay is production tested to the specifications given in the AG under ratings, i.e. 2.5 kV, 50 Hz – 1 minute for the current circuit, 2 kV for all other circuits. Field testing to 75 percent of this value is permitted by applicable standards.
6. SWC Test: The relay has been type tested with the standard 2.5 kV 1 MHz signal with a 3–6 cycles decay time. There are no applicable standards for a SWC field test.
7. DC interrupt test: General prudence suggests that no relay be left connected for tripping when the dc auxiliary voltage is interrupted or restored. However, the DSE is secure against such maloperation and it may be tested to confirm this without damage to the relay.
8. Other tests at time of acceptance or commissioning: For those wishing to establish bench marks for future reference in case of trouble, see section on Voltage Measurements for suggestions.

PERIODIC TESTING

Periodic routine testing can conform to the users established practices. There are no unusual requirements. Suggestions as to typical practices are given in the AG.

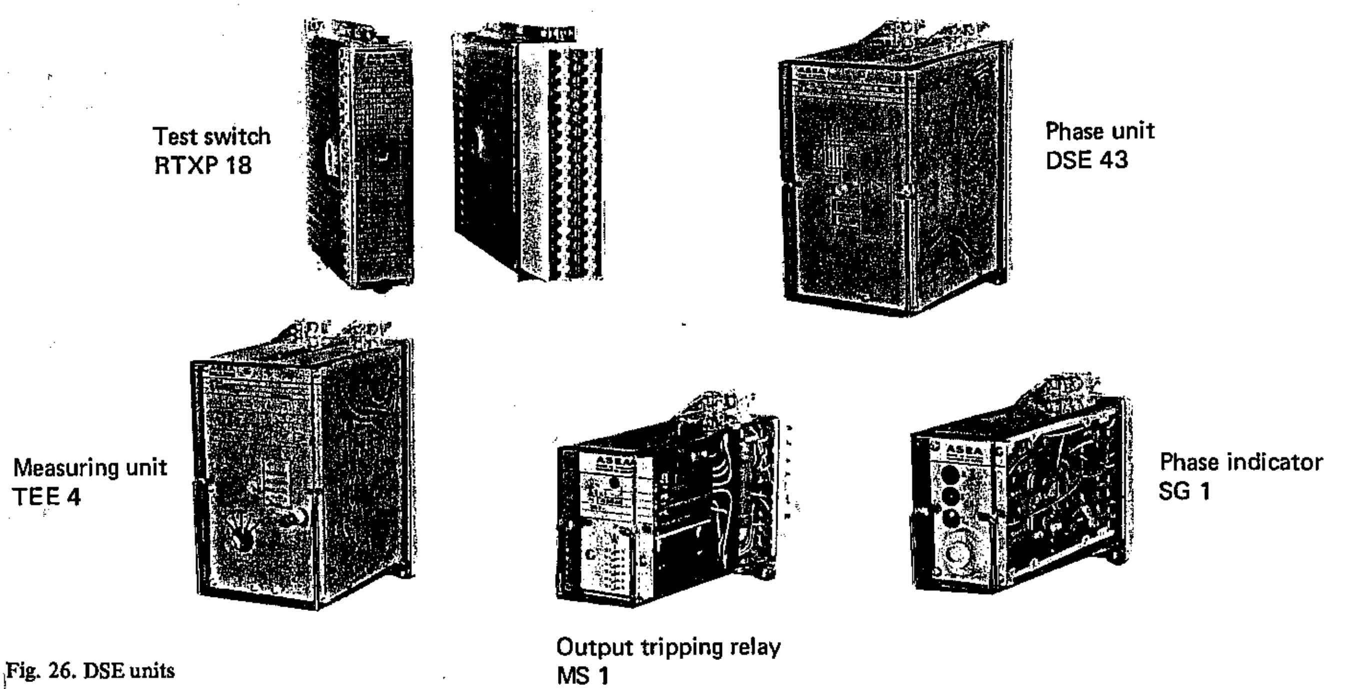


Fig. 26. DSE units

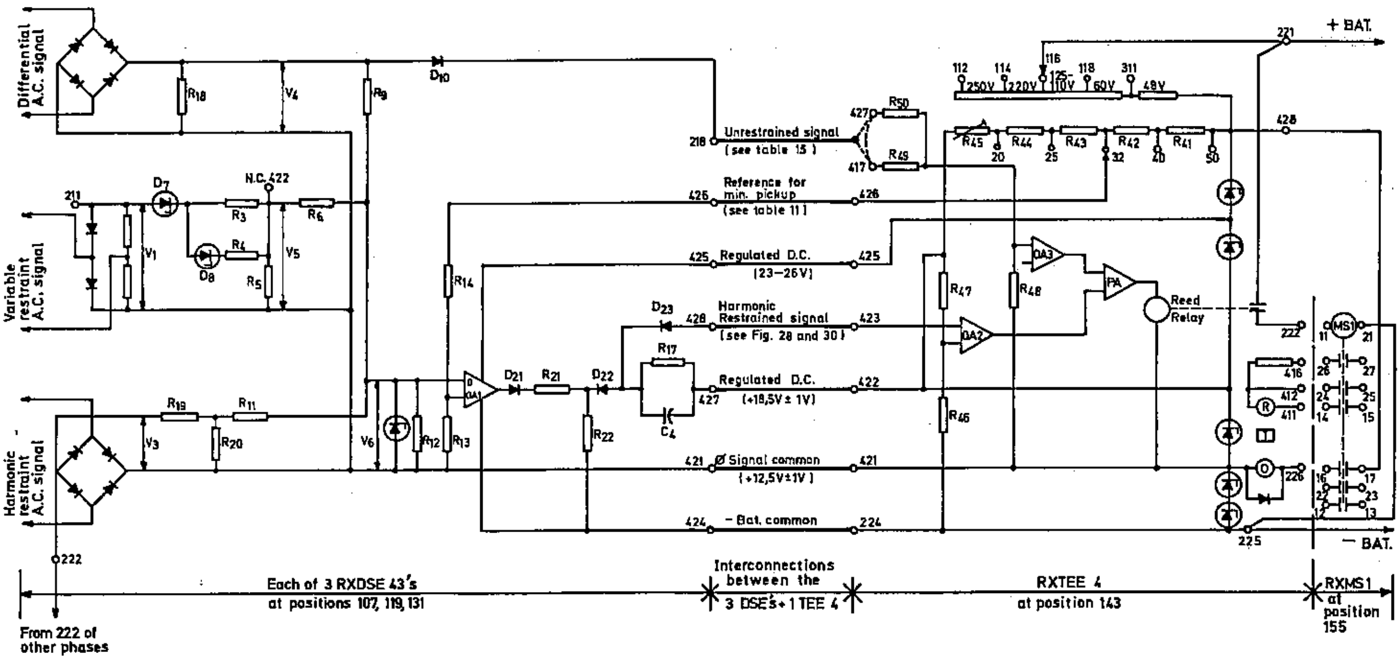


Fig. 27. D.C. interconnections between units of DSE
(Internal relay details are only shown functionally)

DESCRIPTIVE PHYSICAL DETAIL

The AG provides in the first 6 illustrations and related text a physical description of each unit which makes up a DSE relay and the way the relay is assembled in the COMBIFLEX equipment frame. The AG also describes the relay on a functional basis with AG Fig. 14 showing in which unit each major function is located. Figures 26–32 herein show additional detail of each unit. Note: It is not the intent that this detail be used to facilitate internal repairs to any unit. The purpose is to make the functional relations shown in AG Fig. 14 more meaningful and to make trouble shooting between units more readily accomplished.

WIRING INTERCONNECTIONS BETWEEN MODULES

Fig. 27 shows the functional purpose of each of the interconnections between the DSE 43's and the TEE 4 measuring module. This enlarges on the information given in Fig. 7 and relates the overall operating details of Fig. 14 to the actual wiring.

Fig. 28 shows the connections to the SG 1, individual phase target module when this optional component is used. Note that these targets are operated only by the restrained signal. However, they will function when the instantaneous, unrestrained unit causes the tripping, because the function of this second tripping circuit is only to accellerate the operating speed of the relay. The restraint unit will always function a few milliseconds after the instantaneous unit.

Versions without the indicator RXSG 1 has a component block type RTXE with three built-in resistors mounted on the rear of the measuring unit.

When more than three inputs are used, a TUC 4 input module is added for each additional input. The connections between the RTXP 18 test switch and the DSE 43's and TUC 4's are shown in Figure 7. More detail is shown of these interconnections in Fig. 29. The TUC 4's are three phase units. The DSE 43's are single phase units with three inputs per phase. Thus each TUC 4 connects to all three DSE 43's.

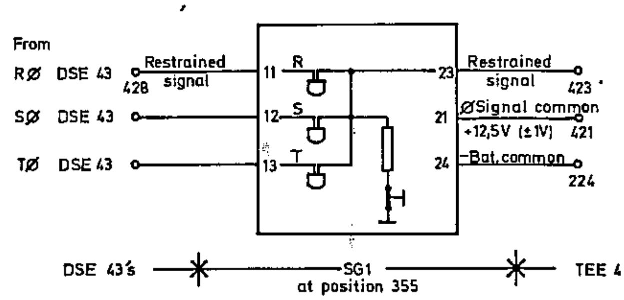


Fig. 28. DC interconnections to phase indicator SG 1.

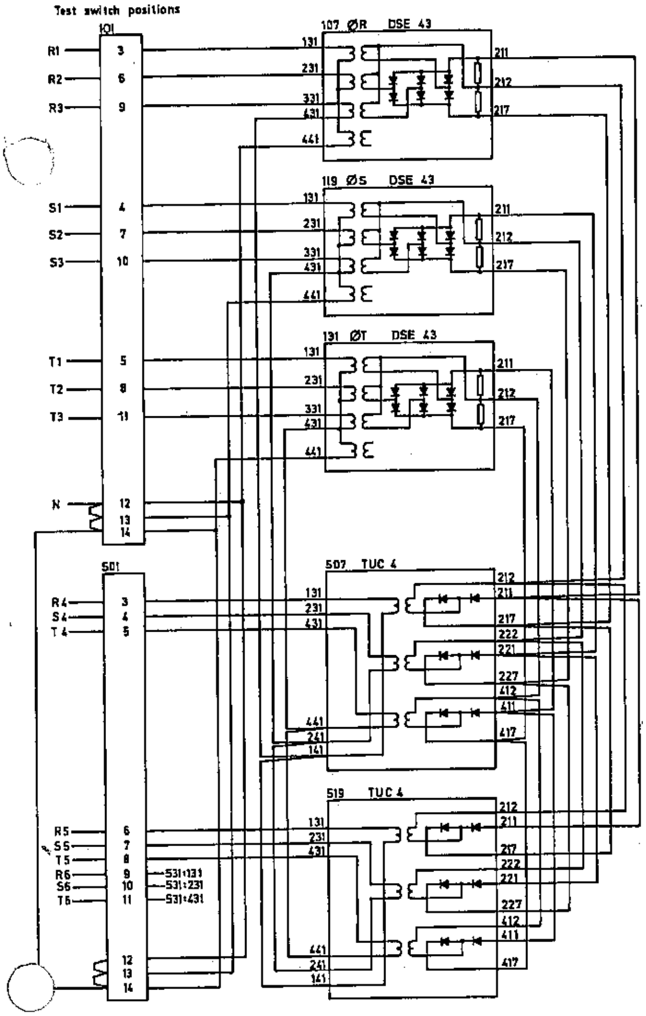


Fig. 29. Interconnections between DSE 43's and TUC 4's

VOLTAGE MEASUREMENTS

Auxiliary, reference and signal voltages may be measured and logged for future reference using a 10 kΩ per volt dc voltmeter. (See section on Test Instruments and Their Use Before Proceeding). This is not a necessary part of the commissioning procedures, nor is it necessary for future trouble shooting since the values given in this Instruction are adequate for locating any possible malfunction. The relay should be energized for three to five minutes before measurements are taken to allow for minor warm up drift of regulating circuits. This is not a restriction on placing the relay in service, it is only a procedure for assuring that an accurate set of bench mark readings are secured.

Auxiliary voltages

Apply 250 V between TEE 4 terminals 225 (–) and [illegible] (+) and confirm that voltages are according to Table 10.

If 250 V is not available apply the highest available connected to the proper voltage tap as given in Fig. 27. All voltages below this value should conform to Table 10.

Note: This test voltage may be applied to the RTXP 18 test switch at positions 18 (–) and 1 (+); however, be certain the TEE 4 voltage connection is on the correct tap before energizing.

TABLE 10

TEE 4 Positive DC Voltages Referenced to Terminal 224

Terminal	(+) Voltage
112	250
114	210 – 225
116	100 – 110
118	47 – 55
311	37 – 43
428	29 – 33 *
425	23 – 26 *
422	17.5 – 19.5 *
421	11.5 – 13.5 *

* These are zener stabilized voltages; as such their consistency once measured will be better than shown in the Table.

Connect the normal auxiliary supply voltage to proper terminals and reconfirm all pertinent voltages in Table 10. Increase the battery voltage to the rated overcharge value. All regulated voltages i.e., those at terminal 428 and below should be within the maximum values given in Table 10.

Minimum pickup reference voltages

With rated auxiliary voltage applied to the relay, the minimum pickup reference voltage on terminal 143:426 with respect to signal common, terminal 143:421 should be according to Table 11. The burden of the DSE 43's should be in place, i.e. no wiring disconnected.

TABLE 11

Minimum Pickup Reference Voltage, TEE 4 Terminal 143:426 with respect to Signal Common, Terminal 143:421

Min. Pickup Setting Percent	Voltage (+volts)
20	7.6 – 8.6
25	9.3 – 10.4
32	11.5 – 12.8
40	14.2 – 15.8
50	17.5 – 19.5

TABLE 12. Test point values for RADSE

Testing of unit	Checking of		Current 1): Connect to RTXP 18 at seat 101–terminal	Current 1): Value times I_n	Test terminals	Typical voltage values 2): 50 Hz relay	Typical voltage values 2): 60 Hz relay
DSE 43 at seat 107	Diff. voltage	V4	3 and 12	1	+ 218, – 421	6.5 – 8.5	7.5 – 9.5
				3		23 – 29	25 – 32
	Percentage restraint	V1	3 and 12	1	+ 421, – 211	1.8 – 2.6	2.2 – 3.2
				3		7 – 8.5	8.5 – 10.5
	Variable percentage	V5	3 and 12	1	+ 421, – 422	0	0
	restraint			3		1 – 2	1 – 2
	Harmonic restraint	V3	3 and 12	1	+ 421, – 222	5 – 7	6 – 8
				3		19 – 23	22 – 27
	Output voltage	V7	3 and 12	1	+ 427, – 428	6 – 7	6 – 7
				3		6 – 8	6 – 8
DSE 43 at seat 119	Same as above		4 and 13		Same as above	Same as above	
DSE 43 at seat 131	Same as above		5 and 14		Same as above	Same as above	
TEE 4 at seat 143	Stabilization of aux. voltage		–	0	+ 428, – 224	29 – 33	
	+ 12 V supply		–	0	+ 425, – 421	11.5 – 13.5	
	– 12 V supply		–	0	+ 421, – 224	11.5 – 13.5	
	Minimum pickup reference voltage		–	0	+ 426, – 421	11.3 – 13.0	
	Voltage to indicator		5 and 14	1	+ 226, – 421	17.5 – 20	
	Voltage to output relay		5 and 14	1	+ 222, – 225	Equal to connected battery voltage	

1) Sine wave of rated frequency.
2) Measured with a voltmeter of moving-coil type, highohmic (≥10 k Ω /V) with rated auxiliary voltage connected to terminals 1 (+) and 18 (–) on RTXP 18 test switch at seat 101. Minimum current pickup selector switch set at 32 percent.

Differential Current to Voltage: Transfer Constant

The differential operating circuit can be checked by applying ac current to the relay and observing the positive dc signal voltage on the unrestrained instantaneous signal wire on terminal 218 on the DSE 43 with respect to the signal common, terminal 421. This is voltage V4 in Table 12. Table 12 includes other data for the complete checking of the DSE 43's and the TEE 4.

Restraint Current to Voltage: Transfer Characteristic

The restraint current functions through a rectifier and a non-linear circuit so as to provide the variable restraint characteristic. A determination of the functioning of the rectification separate from the basic nonlinear network is possible by measuring the negative voltage on terminals 211 and 422 with respect to 421 of the DSE 43's. These values are shown as V1 and V5 in Table 12.

Harmonic Current to Voltage: Transfer Characteristics

The 2nd and 5th harmonic current restraints are mixed together from each phase after rectification. These harmonic filters are designed with broad characteristics so that there is a definite amount of fundamental signal passed through. This fact can be used to test these filters with fundamental frequency current so as to establish dc voltage bench marks for these circuits. Table 12 shows the restraint voltage, V3, on terminal 222 referred to 421 to be expected for rated fundamental frequency ac inputs to terminals on the test switch.

Integrated Output Voltage

The performance of the phase level detectors and output integrating circuitry can be checked by measuring the DSE output voltage across terminals 427 and 428. The expected values are shown as V7 in Table 12.

TABLE 13 Test point values for TUC 4

Testing of unit	Checking of	Current: Connect to RTXP 18 at seat 501 – terminal	Current: Value times I_n	Test terminals	Typical voltage values: 50 Hz relay	Typical voltage values: 60 Hz relay
TUC 4 at seat 507	Percent restraint voltage V1	3 and 12	1	+ 217, – 211	1.8 – 2.6	2.2 – 3.2
			3		7 – 8.5	8.5 – 10.5
		4 and 12	1	+ 227, – 221	Same as above	Same as above
			3			
		5 and 12	1	+ 417, – 411	"	"
			3			
TUC 4 at seat 519	Percent restraint voltage V1	6 and 12	1	+ 217, – 211	"	"
			3			
		7 and 12	1	+ 227, – 221	"	"
			3			
		8 and 12	1	+ 417, – 411	"	"
			3			
TUC 4 at seat 531	Percent restraint voltage V1	9 and 12	1	+ 217, – 211	"	"
			3			
		10 and 12	1	+ 227, – 221	"	"
			3			
		11 and 12	1	+ 417, – 411	"	"
			3			

TEE 4 CALIBRATION CHECKS

The signals from the DSE 43's which activate the TEE4 measuring circuits can be simulated with dc voltages to confirm the performance of the TEE 4 separate from the DSE 43 units. Note: As described previously, the actual signals are unfiltered rectified waves, modified by an integrating circuit with unequal charge and discharge time constants. Thus one should not expect to find a direct relationship between the dc signals from the DSE 43's as measured and the performance of the TEE 4 as determined from the following dc signal tests. However, for developing bench marks, these are good tests and observations for confirming the proper performance of the relay.

Restrained Signal Level Detector

A negative going signal from the quiescent state on the TEE 4 signal terminal 423, will cause relay operation. With no ac into the relay the voltage on 423 should be 6 – 7 V negative with respect to 422.
To establish a more negative signal, so as to cause operation, Fig. 30 shows how to do this by connecting a potentiometer between 224 and 422 with the slider going to 423. Monitor the output contacts of the reed relay by means of a small indicating lamp. Resistor values are not critical. The relay should operate per Table 14.

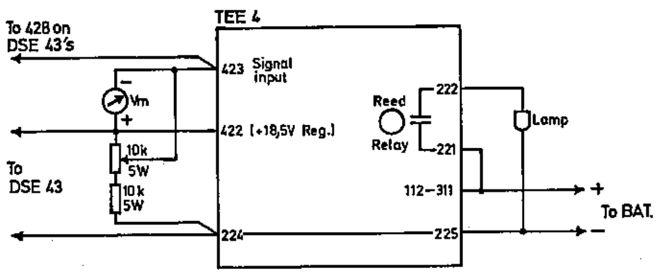


Fig. 30. D.C. signal simulation for checking calibration of restrained signal level detector in TEE 4.

TABLE 14

DC Calibration Check of TEE 4 Restrained Signal. Pickup and Dropout negative Voltages on terminal 143:423 with respect to 143:422

Pickup	(6.0–6.7) V plus the percentage deviation of voltage on 422 from the 18.5 V nominal value (Note: The observed voltage will drop about 0.2 V when the relay operates due to designed circuit interaction).
Dropout	(2–4) V

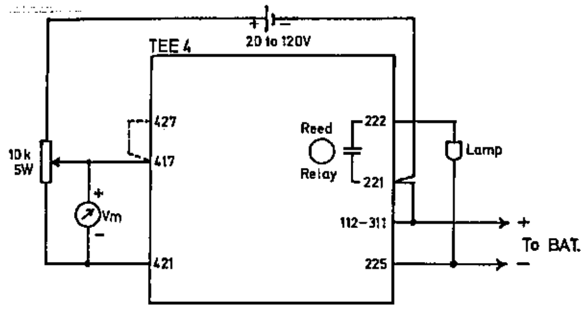


Fig. 31. D.C. signal simulation for checking calibration of unrestrained, instantaneous signal level detector.

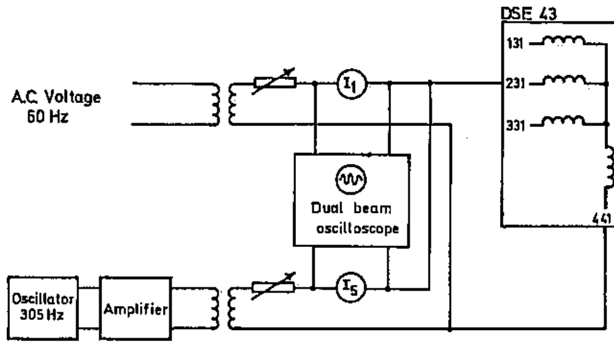


Fig. 32. Testing circuit and procedures for 5th harmonic restraint.

Unrestrained Signal Level Detector

A positive going signal from the quiescent state on the TEE 4 signal terminals 417 or 427 will cause relay operation. With no ac current into the relay the voltage on 417 and 427 should be a small positive value with respect to 421. To establish a more positive signal so as to cause relay operation, connect a variable resistor between terminals 143:417 and 143:221 of the TEE 4. Details are shown in Fig. 31. The relay should operate per Table 15.

Note: Add a 20 – 120 V dry battery in series as needed with the adjustable resistor if voltage on 143:221 is insufficient to develop adequate bias on 417/418.

TABLE 15

DC Calibration Check of TEE 4 Unrestrained Signal. Pickup and Dropout positive Voltages on terminal 143:417/427 with respect to 143:421

Setting		8 x 1)	13 x 2)	20 x 3)
Pickup,	60 Hz	80–100	140–170	215–265
	50 Hz	80–100	135–165	210–260
Dropout		Just below pickup		

1) 8 x setting is with connections to both 417 and 427
2) 13 x setting is with connections only to 417
3) 20 x setting is with connections only to 427
(See Fig. 11 in AG)

Output Relay, Target and Phase Indicator

The MS 1 output relay should be energized with whatever auxiliary voltage is connected to terminal 221 when the TEE 4 reed relay operates. To check its pickup margin connect a 10 KΩ variable resistor between TEE 4 terminals 143:221–222 and observe the voltage across terminals 155:11–12 of the MS 1 (or 143:222–225 of the TEE 4) when the MS 1 operates. The MS 1 operating time can also be checked by shorting across 143:221–222 to energize the relay at full voltage.

The target in the TEE 4 is energized through an MS 1 output relay contact from a regulated dc supply within the TEE 4. To check for its margin of operation connect a 10 KΩ variable resistor between TEE 4 terminals 143:226 and 428 and observe the voltage across the target coil when it operates by measuring across 143:226–421. The electrical reset can be similarly checked by suitable energizing across terminals 143:411–412 or 416.

The individual phase indicators when used, can be checked with the circuit shown in Fig. 30. However in place of connecting the test voltage and voltmeter on terminal 143:423 of the TEE 4, they are connected onto terminal 428 of each of the DSE 43 phase units in turn. They should turn on at a voltage shown in the Table 14 for the restrained signal operating threshold.

OVERALL PERFORMANCE TESTS

The acceptance tests outlined in the AG pages 23 to 27 form the basis of the overall performance tests. For convenience Fig. 16 and 17(a) and Tables 2, 3, 4, 5 and 6 showing details of connections to be made for various tests are repeated here.

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

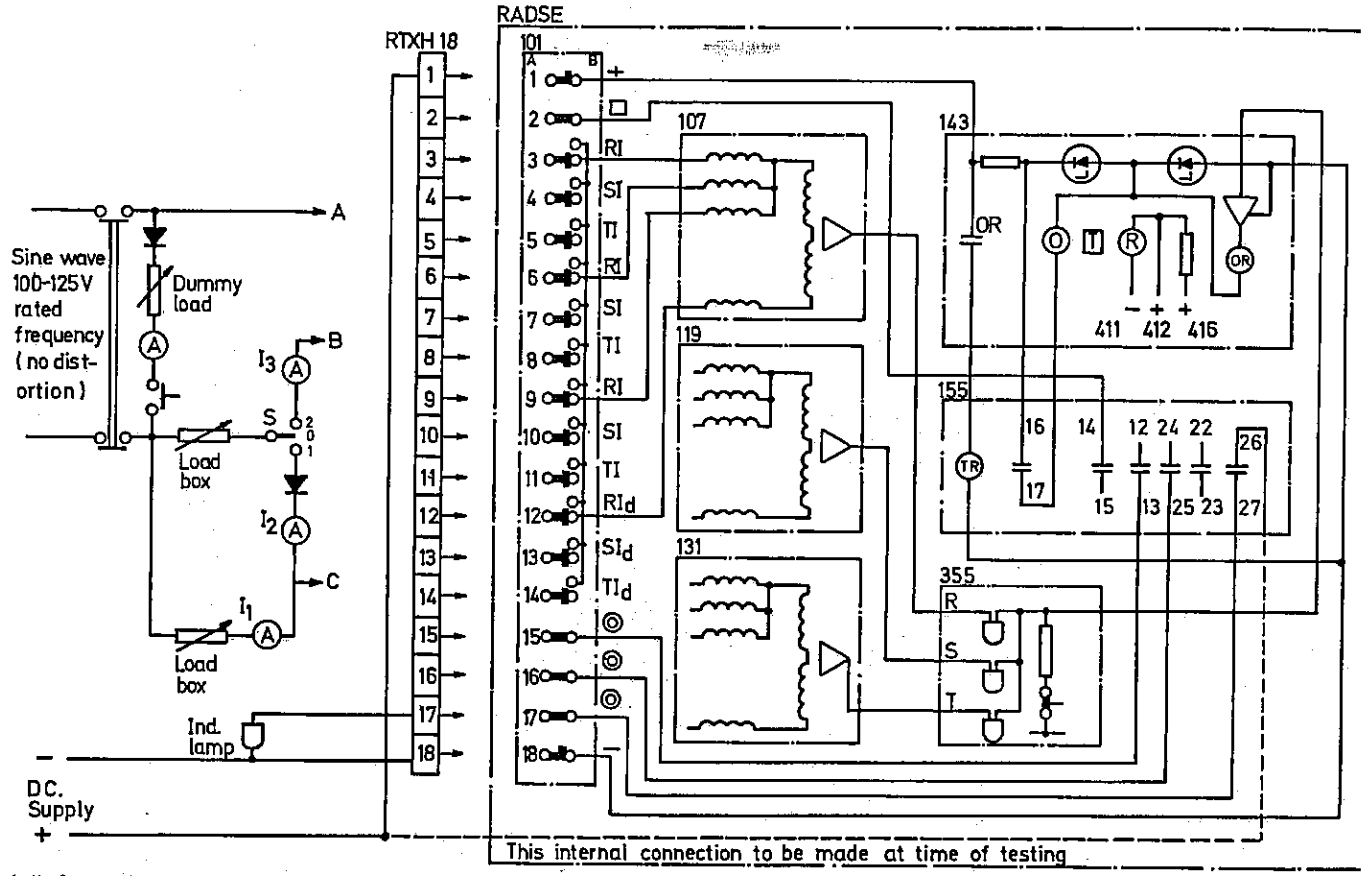
To be used with Figure 16 and Figures 7 (d) and (f)

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.



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.

OR: Output relay
TR: Output tripping relay
T: Operation indicator
O: Operating coil
R: Resetting coil

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

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 settings should be within 10 percent of the calibrated value. 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 unrestrained 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.

2nd 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. 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):

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

The 2nd 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 2nd harmonic restraint characteristic.

The dc component of the 2nd harmonic test current will flow not only 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 2nd rectifier and dummy load to cancel the testing dc in the power source. This is also shown in the test circuit of Figure 16.

5th Harmonic Restraint Tests

A different test setup is needed to check the 5th harmonic restraint. A separate sine wave generator (usually an oscillator and power amplifier) are needed to provide the harmonic current. The test setup is shown in Fig. 32. Note that the fundamental and harmonic current sources are in parallel. Thus the current adjusting resistors serve the additional purpose of isolating the two sources from each other.

It is important that the 5th harmonic frequency not be exact. If it is made exact, it will beat with the residual harmonics in the fundamental and cause erratic operation of the relay. However, with a 5 Hz difference, the beat does not influence the relay operation, nor should any fundamental leakage into the oscillator cause frequency instability. Also if there is any harmonic in the fundamental it will be fully masked by the local oscillator. (An interfering signal of say 10 percent will cause only a percent effect on the rms value of the resulting wave).

The ammeter for measuring the harmonic current must of course be suitable for the frequency involved. The dual beam oscilloscope is an excellent method for confirming that the two signals are not interfering with each other; and of equal importance, that the ammeters are in fact properly indicating the respective currents.

The relay should not operate when I_5 at single phase tests is more than 35–45 percent of I_1. The relay should be set on the 32 percent minimum operating current tap to duplicate the factory calibration. A convenient method to check this is to apply 1.5 A of 5th harmonic (for a 5 A rated relay) and to then increase I_1 until the relay operates, which should be at 3.3 A, + 1 A – 0 A. The formula is:

$$I_1 \text{ operate} = \frac{I_5}{0.45} \text{ to } \frac{I_5}{0.35}$$

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 pickup 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.

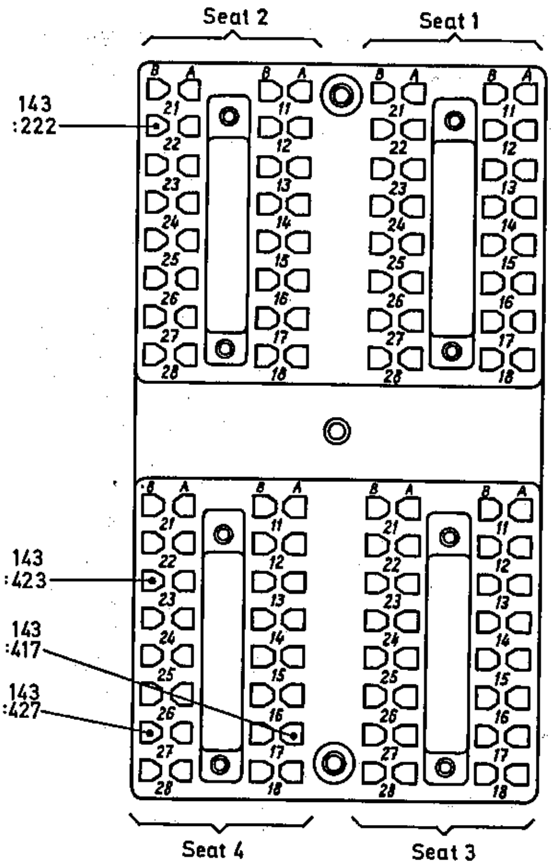


Fig. 17 (a). TEE 4 (143) measuring unit, rear view showing location of terminals used or opened during certain tests.

Inter-phase Tests

To check for the inter-phase action of the harmonic restraint it will be necessary to inject the 2nd 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 s 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 2nd harmonic restraint test, as in this case, it does not flow any 2nd harmonic component in the operating circuit. The percentage 2nd 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 2nd 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).

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 harmonics in the test current can be a significant effect on the relay operating characteristics.

When a DSE 43 or TEE 4 module is found outside of the noted range of performance, it is recommended to replace the unit and return the defective unit to the factory. The reason for this policy is that recalibration could mask a partial failure of some other component and result in the SWC or the overall performance being at variance with published characteristics. This policy also assures against inadvertent maladjustment of a relay due to nonsinusoidal test currents.

When a module is replaced with one known to be in good working condition, it is not necessary to repeat all of the calibration checks. Obviously it is good practice to make sufficient tests to assure that all of the wiring has been properly replaced.

SERVICING ELECTROMECHANICAL MODULES

The electromechanical modules may be serviced by referring to the manuals on the specific components:

Reed Relays	RK 21–10 E
Operation Indicator	RK 27–12 E
MS 1 Output Tripping Relay	RK 21–10 E
COMBITEST Test System	92–11 AG

The reed relay contact assembly can be replaced without disturbing the actuating coil.

The operation indicator in the TEE 4 unit is similar to the four units assembled as an RXSP 1.

The SG 1 individual phase targets are 100 percent static. If a malfunction develops, replace the entire module and return defective module to factory.

Note: If the SG 1 is removed, full operation of the relay will continue if the 3 DSE 43 terminals 107, 119 and 131:428 are jumpered directly to the TEE 4 terminal 143:423. This will maintain the phase trip circuit signal continuity.

TROUBLE SHOOTING

The cause of suspected maloperation can be identified by checking the various voltages as given in the previous sections on voltage measurements and TEE 4 calibration checks. A defective unit can also be located by evaluating the basic test data. For example, if all three phases are off calibration the trouble is in the common TEE 4, or a ground on one of the output circuits of a DSE 43 which is interacting into each of the three phase units. If only one DSE 43 phase unit is off calibration, the trouble is most likely in that unit. Similarly, the relative calibrations between the restrained and unrestrained functions can be a clue as to source of trouble.

When any interconnection wiring between units is lifted while searching for the malfunction, a minor change can be expected in the various voltages with some reaction on actual calibrations. These effects should not be confused with the effect of an actual defective component.

Similar modules may be interchanged and modules replaced with new modules without causing the overall relay calibrations to exceed the specified limits. This suggests module substitutions as an effective method of trouble shooting. However, this should not be undertaken before confirming that all voltages are within range on the inter-modules wiring shown in Fig. 27.

ACCESSORIES AND SPARE PARTS

1 RTXH 18 Test plug handle and test leads

2 Ammeter test plugs RTXM
Trip block plugs RTXB
See 92-11 SI

An adequate spare parts list consists of:

1 RXDSE 43

1 RXTEE 4

1 RXMS 1

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