37

Testing and Maintenance of Protective Relays

Importance of maintenance — Tests — Acceptance tests— commissioning tests — Inspection prior to test — Testing of instantaneous relays — Inverse relay — Differential relays — Distance relays — Restricted earth fault protection, Routine maintenance — Deterioration of relays — Maintenance schedule — Manufacture tests — Electrical tests — Mechanical tests — Environmental tests — Buchholz relay — Equipment for tests.

37.1. IMPORTANCE OF MAINTENANCE AND SETTING

Unlike the rotating machines or other equipment, the protective relays remain standstill and without operation until a fault develops. However, the relay should be vigilant at all times. For reliable service of protective relaying excellent maintenance is a must. Lack of proper maintenance may lead to failure to operate.

Every relay has a provision of setting.

Setting determines pick-up value/time.

Settings of various relays need co-ordination.

37.2. TESTS ON RELAYS

Tests are conducted by the manufacturer at manufacturer's works, and by the user at site during commissioning and periodic maintenance. These tests are further divided into types, tests and routine tests.

Tests are conducted before accepting relay.

Tests are conducted on site before commissioning.

Tests are conducted during periodic maintenance.

There is generally a good deal of co-operation between electricity boards and relay manufacturers regarding relay testing. Quality control is given foremost consideration in manufacturing of relay.

Tests can be grouped into following four classes :

1. Acceptance tests.

— One new relays, first time testing.

— Tests on each product received.

2. Manufacturer's tests.

3. Commissioning test on relays and protective systems.

4. Maintenance tests.

Acceptance tests are generally performed in the laboratory. Acceptance tests fall into two categories : (*i*) On new relays which are to be used for the first time. On such products, intensive testing is desired to prove its characteristics and to gain information about it. (*ii*) On relay types which have been used earlier, only minimum necessary checks should be made. Acceptance tests are performed in presence of the customer or by the customer.

Installation tests are field tests to determine that the protection operates correctly in actual service. These are not repeated unless incorrect operation occurs. Most frequently they are performed by simulating test conditions by means of portable test sets. Other methods include :

— tests using primary current injection.

— operating tests with reduced primary voltage.

— system fault tests (faults are applied on the protected system internal/external to protected zone).

Such tests are conducted on every new installations only. The protection circuits, CTs, VTs are also checked.

Maintenance testing is done in field periodically.

Repair tests, involve recalibration and are performed after major repairs. These are generally performed in laboratory. Minor repairs done on field need not follow complete recalibration.

Manufacturers tests include development tests and type and routine tests.

37.3. TEST EQUIPMENT

(*a*) Primary Current Injection Test Sets

Most protective systems are fed from a current transformers on the supply cable or bus bars PRIMARY current injection testing checks all parts of the protection system by injecting the test current through the primary circuit, of protective CTs.

The primary injection tests can be carried out by means of primary injection test sets. These sets are standard portable sets comprising :

— current supply unit

— control unit

— accessories.

The test set can give variable output current. The output current can be varied by means of built-in auto-transformers. The primary injection test set is connected to a.c. single phase supply. The output terminals can be connected to in the primary circuit of CT (37.1). The primary current can be varied by means of the injection set.

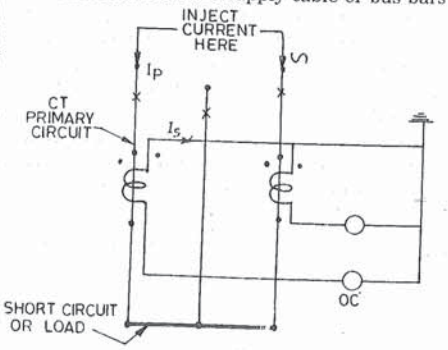

Fig. 37.1. Primary injection.

(*b*) Secondary Current Injection Test Sets

Secondary injection checks the operation of the protective system but does not check the primary circuit of the current transformer. However, it is rare for a fault to occur in the current transformer and the secondary test is sufficient for most routine maintenance. The primary test is essential when commissioning and new installation as it tests the whole protection system and will detect current transformers connected with incorrect polarity or relays that have been set in the wrong sequence in differential systems.

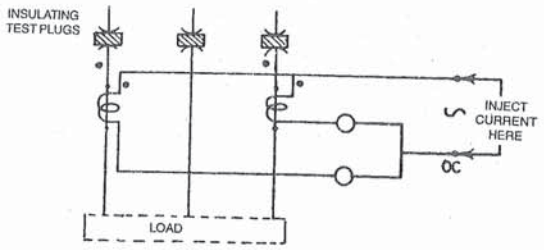

Fig. 37.2. Secondary injection tests on overcurrent relays.

Secondary current injection sets are very useful for conducting these tests.

The Standard Secondary Current Injection Testing Equipment consists of a 50 A current injection set, separate waveform filter unit and a digital counter. The equipment is designed as a portable kit for on-site testing of protective devices, circuit-breakers, trip coils motor overloads and similar apparatus. The Filter Unit should be used when testing saturating core type relays to ensure that the test current has a substantially sinusoidal waveform.

(*c*) **Test Benches**

Test benches comprise calibrated variable current and voltage supplies and timing devices. These benches can be conveniently used for testing relays and obtaining their characteristics.

D. **Testing Equipment with Manufacturer**

The testing equipment with manufacturer includes :

— artificial transmission lines
— heavy current test plant
— special test benches, etc.

37.4. ROUTINE MAINTENANCE TESTS

The performance of protective relay is affected by maintenance. Basic requirements of sensitivity, selectivity, reliability and stability can be satisfied only if the maintenance is excellent. In this section some basic aspects of maintenance and periodic tests are discussed.

(*a*) **Deterioration of protective relays.** The relay does not normally deteriorate by use but other adverse condition cause the deterioration. Continuous vibrations can damage the pivots or bearings.

Dampness causes weakness of insulation. The insulation strength is reduced because of absorption of moisture, polluted atmosphere affects the relay contacts, ligaments and relay parts. Dust affects insulation and rotating system. Relay room should, therefore, be made dust-proof.

Insects and vermins can cause menace. Switchgear room should be vermin-proof.

Relay maintenance generally consists of :

— Inspection and burnishing of contacts.
— Adjustments checking
— Screws checked for tightness.
— Maintenance tests.
— Foreign matter removal.
— Breakers tripped by manual contact closing.
— Covers cleaning.

(*b*) **Maintenance Schedule**

(*i*) **Continuous Observation**

Pilot supervision.
Trip circuit supervision.
Relay voltage supervision.
Battery earth fault supervision.
Bus-bar protection CT circuit supervision.

These items need continuous supervision. A trained person should be on duty to observe the above mentioned aspects.

(*ii*) **Daily Inspection**

Relay flags (every shift)

(*iii*) **Once a Week**

Carrier current protection testing.

(*iv*) **Monthly Tests**

Inter-tripping channel tests without tripping any switches.

(*v*) **Six Monthly**

Inspections.
Tripping tests.
Insulation resistance tests.
Battery biasing equipment check.

(*vi*) **Yearly**

Check tripping angle of phase comparison method.
Secondary injection tests.
Buchholz relay tests.
Test on earthing resistors.

(*vii*) **Two Yearly**

Secondary injection tests.

(*c*) **Periodic Relay Testing**

Periodic relay testing is a part of preventive maintenance. Thus, procedures and records should be planned with preventative maintenance as the guide. The tests themselves will reveal failures which would have prevented the relay from performing when called upon to operate, while properly maintained records will reveal any trends which could lead to such failures.

The interval of testing is subject to many variables, including type of relay, environment and of course history and experience. However, an annual or semi-annual schedule of maintenance is a good starting point.

Electrical Tests and Adjustments

1. **Contact function.** Manually close (or open) contacts and observe that they perform their required function, *i.e.* trip, reclose, block etc.

2. **Pick up.** Gradually apply current or voltage to see that pickup is within limits. Gradually applied current of voltage will yield data which can be compared with previous or future data and should not be clouded by such effects as transient over reach, etc.

3. **Dropout or reset.** Reduce the current until the relay drops out or fully resets. This test will indicate excess friction. Should the relay be sluggish in resetting or fail to rest completely, then the jewel bearing and pivot should be examined. A 4*X* eye loupe is adequate for examining the pivot, and the jewel bearing can be examined with the aid of needle which will reveal any cracks in the jewel. Should dirt be the problem, the jewels can be cleaned with a thin brush while the pivot can be wiped clean with a soft, lint free cloth. No lubricant should be used on either the jewel or pivot. Vacuum pump is used for sucking dust.

37.5. INSPECTION AND TESTING FOR ACCEPTANCE

Acceptance tests are done once and generally in the laboratory. These separate into the two types, first on (*i*) new products which have not been previously used, extensive testing on a sample may be desired to prove it, gain experience and knowledge, and/or additional technical information. The second type (*ii*) test on each product received from the manufacturer should be streamlined to a minimum including only important practical check points to assume that the product is up to the manufacturer's standards. After receiving the shipment, the relay should first be visually examined for damage in the transit. The relay should be unpacked carefully so as not to bend the light parts. The precautions to be taken can be enumerated.

1. *Avoid handling contact surfaces.* It tends to removal of material coating.
2. The cover should be removed before dusting it. It should not be dusted in assembled position.
3. The packing pieces are removed lightly and armature is checked for free movement manually.
4. Do not take steel screw-drivers near the permanent magnets, if any.

After the initial check, detailed acceptance tests (*i*) or (*ii*) mentioned above are carried out.

37.6. SOME TESTS ON CT'S

(*a*) **Testing polarity of CT by Flick Test.** A centre zero voltameter is connected across CT secondary. A 1.5 V battery is touched to primary of CT. The deflection of pointer should be similar in case of each CT to be connected in the same protection.

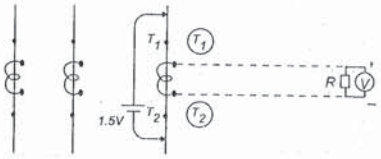

Fig. 37.3. Flick test.

(*b*) **Magnetisation Curve Tests.** These are conducted on CT's to prove that the turns of CT's are not short circuited and to establish the CT characteristic and to establish the capability of CT. A typical magnetization curve is shown in Fig. 37.4. Magnetisation curves are obtained by applying sinusoidal voltage to secondary winding of CT and measuring magnetising current flowing for different values of applied voltage. Test is conducted only upto knee point which is at a point where 10% increase in applied voltage results in 30% increase in magnetising current.

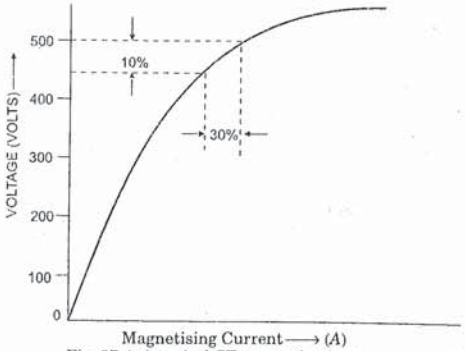

Fig. 37.4. A typical CT magnetisation curve.

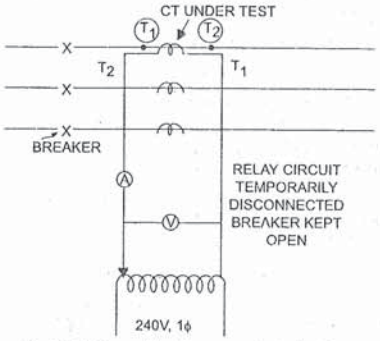

Fig. 37.5. Magnetisation curve test circuit.

(*c*) **Ratio Test.** The current is injected as shown in Fig. 37.6. The ratio A_1/A_2 gives the CT ratio.

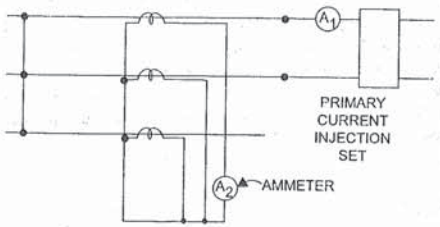

Fig. 37.6. The ratio test by means of primary current injection.

37.7. SOME TESTS ON PT'S

(*a*) **Polarity test on PT.** As mentioned in Sec. 37.6 (*a*) for CT Battery should be touched to primary winding.

(*b*) **Ratio Check.** Primary is first made alive by energising main circuit.

Secondary voltage (measured) is compared with other existing PT connected in the same circuit.

(*c*) **Phase Sequence Check.** The phase sequence of three terminals is checked by means of phase sequence meter.

37.8. SOME TEST CIRCUITS AND PROCEDURES FOR SECONDARY INJECTION TESTS

Injection Tests. The relay coils are energized and the calibration of relay is tested.

There are several types of relays. Tests are conducted in general as follows. The lowest tap including all the turns of the coil is taken and relay operating characteristic is obtained for various time settings. The procedure is repeated for all the plug settings.

(*i*) **Instantaneous Relays**

These are actuated by current or voltage and are usually Attracted Armature Type. The currents are increased slowly till the operation occurs. The current prior to operation should be noted. This gives pick-up value. The current is then gradually reduced till the relay resets. The values of pick-up current and reset current are noted for different spring tensions.

Secondary injection current sets can be conveniently used for testing. Instantaneous relays are checked as follows. A synchronous timer with one second sweep and ten second register is incorporated in the test circuit. To begin with, the relay coil is shunted and the current is set to a low value shunt is removed. The switch is closed and the relay operation is observed. The current is gradually increased till the relay operates. The following readings are taken :

— minimum current to give operation for each current setting

— maximum current at which relay resets for each setting.

If felt desirable, response to transient overcurrent is obtained by means of CRO or U.V. Recorder.

(*ii*) **Inverse Time or Definite Time Overcurrent or Earth Fault Relays**

(*iii*) **Inverse Definite Minimum Time Relays (IDMT) or Inverse Time Relays**

A timer is necessary to test this type of relay. A typical test circuit is given in Fig. 37.7. The timer starts measuring time as soon as switch S is closed. The timer stops measuring time as soon as the relay closes its contacts and short circuit the timer circuit. The time is of the order of several seconds.

Plug setting corresponds to the minimum value of current at which the relay should start operating. However, due to friction and inertia, the relay must not start operating at values near the plug setting value. The time setting corresponds to multiplying factor to be used with operating time with time setting as unity (Ref. Sec. 26.11).

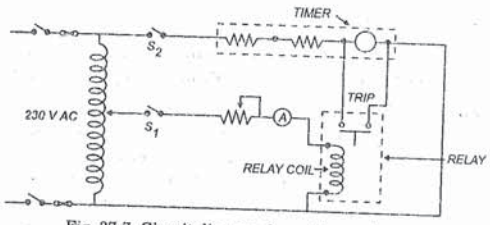

Fig. 37.7. Circuit diagram for setting an inverse overcurrent relay. (Main Switch : S)

Instantaneous relays are sensitive to transient overcurrents, but inverse overcurrent relays are not.

In this testing, the readings of operating time are taken for various values of operating currents for a time setting and plug setting. The test is repeated for various time settings and the same plug setting. Thus for a given plug setting, several characteristics are obtained corresponding to various time settings. The procedure is repeated for other plug settings. The characteristics are verified with the characteristic given by the manufacture. (Ref. Fig. 26.14).

(*iv*) **Distance Relays**

Distance relays are commonly high speed permanent magnet moving coil type in which the coils move axially or radially. In some types the relay has only one coil which is connected to rectifier bridge comparator which compares V and I so that the relay measures impedance. In other type relay has two coils on the same former. One coil is fed from rectified voltage, giving restraining

torque proportional to voltage. The other supplied from rectified current which gives operating torque. The current and voltage are separately varied to simulate the fault impedance. Readings are taken and the protective gear is calibrated. Portable test set kits are available for testing distance relays. Fig. 37.8 illustrates a test circuit.

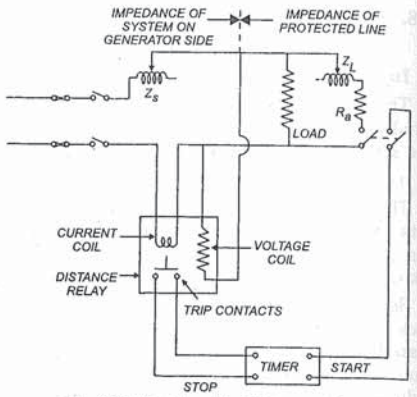

Fig. 37.8. Test circuit of distance relays.

Z_s is a high adjustable reactive impedance representing the part of the circuit upto the line containing generator, transformer etc. and Z_L, the impedance of the line having adjustable X and R. The connections of the relay which include a timer, contactor etc.

The timer is started by closing the fault switch. The timer stops by operation of the relay.

Portable test for distance relays comprise

— supply unit — control unit
— fault impedance unit and external CT unit.

The various test can be simulated by means of these test sets, *e.g.*,

— phase fault injection test
— phase to neutral injection test
— testing of distance schemes
— testing of Mho/Impedance/Reactance measuring elements, etc.

(*v*) Directional Relays

These relays accompany over-current or distance or other types of relays. Tests are conducted on directional relays that they will not operate with only one actuating quantity.

Further, the phase angle between V and I to obtain zero torque, *i.e.* the point at which the relay torque changes in direction is noted. Then the phase of applied voltage is moved through 90° to get angle of maximum torque. In this position minimum operating current is required to cause relay operation at rated voltage. Fig. 37.9 gives a typical arrangement of directional relay testing.

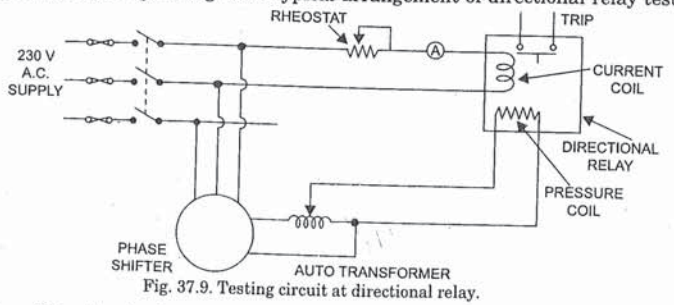

Fig. 37.9. Testing circuit at directional relay.

Description. Directional relay has two coils one energized by current the other by voltage. In the circuit of Fig. 37.9, the phase shifter can be adjusted to get desired phase angle between V and I, (Ref. Fig. 37.12 also).

(*vi*) Restricted Earth Fault Protection Testing

The polarities of CT's should be tested first. The polarity of CT in neutral connection can be tested by short circuiting one phase of star connection. The relay is replaced by an ammeter. The ammeter should read zero for correct polarity of CT's. The set up is illustrated in Fig. 37.10.

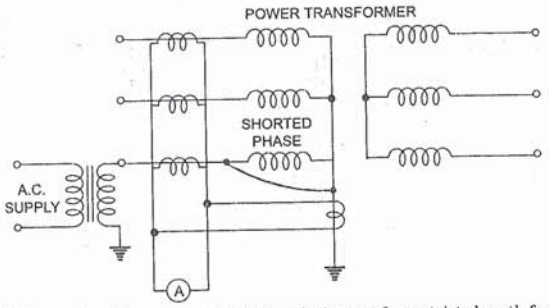

Fig. 37.10. Relay replaced by an ammeter. A.C. polarity test for restricted earth fault relay.

(*vii*) Testing Differential Relays

A convenient method is to pass the main current through both the halves of the restraining coil and to superimpose the differential current on one-half of the restraining coil and the differential coil. A test circuit is given in Fig. 37.11.

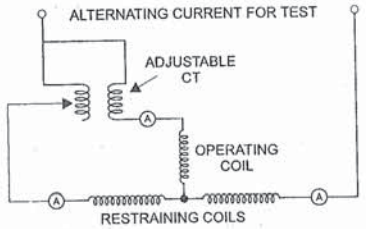

Fig. 37.11. Testing of differential Relay.

(*viii*) Buchholz Relays

A special test rig is set up to test Buchholz relays. The rig consists of two oil tanks with interconnecting pipes and valves. Compressed air is used to force the oil from one tank to other, while passing to the other tank the oil passes through the Buchholz relay.

Further, to test the performance on incipient faults, air at regulated pressure is passed through the relay. Adjustments are made until desired operation of alarm and trip circuit is obtained.

(*ix*) Test circuit for double actuating quantity relays

When only one quantity is required to operate the relay, the test circuit are straight forward and there are very few problems. However, with two or more variable a.c. quantities, more com-

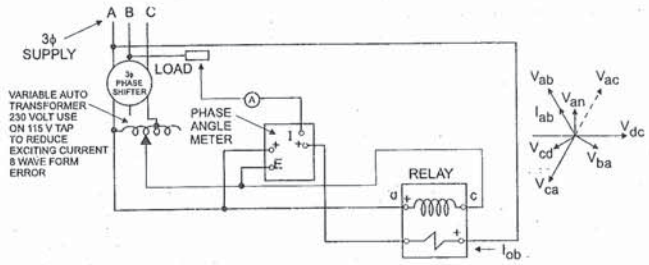

Fig. 37.12. The circuit for determining the phase angle curve of a relay operating on a current and voltage.

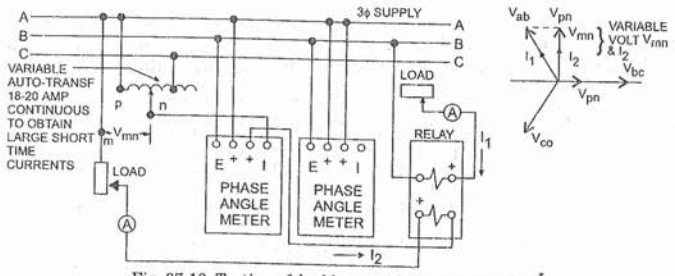

Fig. 37.13. Testing of double actuating quantity relay.*

plexity results, particularly when the phase angle between the quantities must be controlled. Typical test circuits are shown in Figs. 37.12 and 37.13.

37.9. MANUFACTURER'S TESTS*

A newly designed relay is subjected to a series of through tests by the manufacturer before it is manufactured on a large scale. Almost every possible aspect about relays is determined in these tests. Such tests are carried out on a few relays of each type. These tests are performed on a complete relay. Further, tests are conducted on protective systems including current transformers voltage transformers, and relays. The tests on relays cover :

(*i*) Electrical tests.

(*ii*) Mechanical tests.

(*iii*) Effect of environmental conditions.

After the exhaustive type tests the manufactures decides whether to go ahead with manufacture of the relay or some modifications are necessary in the design. The relays should conform the relevant B.S./Indian Standard/other Standards.

(*i*) Electrical Tests

Components of relays, sub-assemblies, relay units, complete relays, relay schemes are tested before despatching. These tests include checking number of turns in coils, to measure parameters, insulation, continuity etc. test on components. The test on complete relay include condition over their range. Slow speed relays have static tests. High speed relays have dynamic tests.

Differential relays are tested for heavy currents to make sure that the relay does not operate for through faults. Special equipment is used for heavy current testing.

Artificial transmission lines are used for testing relay schemes.

(*ii*) Mechanical Tests

These are conducted by the manufacture in the factory. These cover the mechanical performance of relay such as tendency to vibrate, effect of shocks, balancing of rotor, endurance tests, deviability of springs etc. Special test equipment is necessary to perform these tests.

(*iii*) Environmental Tests

These include ascertaining the effect of humidity, temperature, atmospheric pressure, etc. on the relay performance. All relays are generally tropicalized.

* Ref. Sec. 43.5 for Static Relays.

37.10. COMMISSIONING TESTS

While testing the protective system at site the protection system for each zone should be tested separately to begin with and then the protective systems for the neighbouring protective systems should be co-ordinated as per the plan for the entire plant. The objectives of site testing are to ensure that

- connections are correct.
- settings are correct.
- individual protection system is functioning satisfactorily.
- the co-ordination between various protection systems is as per broad plan given by designers.

Nothing should be taken for granted and no connection should be assumed to be correct until it has been tested and proved.

During testing, it may be necessary to change the relay setting. This setting should be restored after completion of tests.

All testing at site should be done methodically, systematically as per the plan. The anxiety to commission a plant should not be allowed to affect the test schedule.

Some relay coils are not continuously rated. They should not be energized beyond specified time.

Before working on HV circuits, the adequate precautions should be taken (Ref. Ch. 14).

The procedure for testing should be well studied and understood. The testing engineer should be thoroughly familiar with protection engineering.

The instruments for site testing should be robust and portable.

Correct size of pilot wires is necessary. Smaller size causes more burden on CT's. Following aspects should be checked :

- each point is securely connected and no dust, insulation or corrosion is interfering in the continuity.
- polarity of connections is correct.
- the correct connections with terminals at remote end can be checked by loop tests.

Portable primary injection test sets are used to pass heavy current through primary of CT's of the protection system.

The generator protection may be tested by simulating short-circuit condition. A short-circuit may be placed across the bus-bars and the machine is operated with reduced field current. The operation of relay, circuit-breaker on phase faults, earth-faults, are checked and relays are set.

Primary injection tests may be utilized to prove the polarity ratio of CT's connection and protective relays.

Secondary injection tests are conducted by means of test sets.

The commissioning tests include complete check of all closing, tripping, intertripping, sequence, alarm, indication. The test may be simulated by artificially closing the circuits by means of plugs, short circuiting clips, test switch ; special kits etc.

Switching in tests should be carried out on transformers to check that the protection does not operate due to magnetizing current in rush.

Buchholz relay is tested by admitting air through the cock at the bottom of the relay and later through inlet pipe of the relay.

Electronic relays (static relays) require test-bench with special facilities.

SUMMARY

Testing and maintenance of relays and protective devices is extremely important. A failure may result merely due to lack of proper maintenance.

Testings on relays can be classified as :

1. Test by manufacturer at his work.
2. Acceptance tests.
3. Commissioning tests at site.
4. Maintenance tests.

QUESTIONS

1. Explain the importance of testing of relays.
2. Describe the secondary of current injection test of the following relays—any two.
   (*a*) Instantaneous overcurrent relay. (*b*) Inverse overcurrent relay.
   (*c*) Differential relay. (*d*) Earth fault relay.
3. State tests performed on a relay group-wise.
4. Describe briefly the following test on relay :
   (*a*) Manufacturer's tests. (*b*) Commissioning tests.
   (*c*) Maintenance tests.
5. Describe procedure of CT polarity test.
6. Explain in about 20 sentences the insulation resistance measurements.
7. What are causes of relay deterioration ? Describe a maintenance schedule of a relay.
8. Describe the procedure of inspection of a relay scheme during periodic check-up.
9. Explain the procedure of commissioning tests on a protection system.
10. With the help of neat diagrams explain the laboratory test of an electromagnetic Distance Relay.
11. Describe the following terms of relays.
    — Plug setting — Time setting.
12. State whether true or false. Write correct statement.
    — IDMT relays are used in impedance protection.
    — Distance Relays sense vector difference between two quantities.
    — Earth fault relays are connected in the residual circuit.
    — Static Relays are used for Generator Protection.