Jawaharlal Nehru Engineering College

Laboratory Manual

POWER SYSTEM PROTECTION

For

Final Year (EEP) Students

Manual made by

Prof. Pranjali Kothawade

FOREWORD

It is my great pleasure to present this laboratory manual for final year **ELECTRICAL ELECTRONIC & POWER** engineering students for the subject of Power System Protection. Keeping in view the vast coverage required for visualization of concepts of Power System Protection with simple language.

As a student, many of you may be wondering with some of the questions in your mind regarding the subject and exactly what has been tried is to answer through this manual.

Faculty members are also advised that covering these aspects in initial stage itself, will greatly relive them in future as much of the load will be taken care by the enthusiasm energies of the students once they are conceptually clear.

H.O.D. (EEP)

LABORATORY MANUAL CONTENTS

This manual is intended for the final year students of **ELECTRICAL ELECTRONIC & POWER** engineering branch in the subject of Power System Protection. This manual typically contains practical/Lab Sessions related Power System Protection covering various aspects related to the subject to enhance understanding.

Although, as per the syllabus, only descriptive treatment is prescribed, we have made the efforts to cover various aspects of Power System Protection subject covering types of different protective schemes, their operating principals, their characteristics and Applications will be complete in itself to make it meaningful, elaborative understandable concepts and conceptual visualization.

Students are advised to thoroughly go through this manual rather than only topics mentioned in the syllabus as practical aspects are the key to understanding and conceptual visualization of theoretical aspects covered in the books.

Good Luck for your Enjoyable Laboratory Sessions

Prof. Pranjali Kothawade

SUBJECT INDEX

1. Do’s and Don’ts

2. Lab exercise:

EXPERIMENT. NO.	TITLE
1	To realize the various Time-current characteristics using over-current relay and Earth fault relay.
2	To study Buchholz Relay
3	To study Parallel feeder protection.
4	Application of differential protection scheme for transformer protection.
5	To study Radial feeder protection.
6	To study Air Circuit Breaker
7	To study Distance Relays
8	Introduction to Static relays

1. DOs and DON'Ts:

DO's in Laboratory:

1. Understand the equipment to be tested and apparatus to be used .
2. Select proper type (i.e. A. C. or D. C.) and range of meters.
3. Do not touch the live terminals.
4. Use suitable wires (type and size).
5. All the connections should be tight.

DONT's in Laboratory:

1. Do not leave loose wires (i.e. wires not connected).
2. Get the connection checked before switching 'ON' the supply.
3. Never exceed the permissible values of current, voltage, and / or speed of any machine, apparatus, wire, load, etc.
4. Switch ON or OFF the load gradually and not suddenly.
5. Strictly observe the instructions given by the teacher/Lab Instructor

Instructions for Laboratory Teachers:

1. Submission related to whatever lab work has been completed should be done during the next lab session. The immediate arrangements for printouts related to submission on the day of practical assignments.

2. Students should be taught for taking the observations /readings of different measuring instruments under the able observation of lab teacher.

3. The promptness of submission should be encouraged by way of marking and evaluation patterns that will benefit the sincere students.

EXPERIMENT NO: 1 Date:

AIM: To realize the various Time-current characteristics using over-current relay and Earth fault relay.

- Introduction:

A protective relay, which operates when the load current exceeds a preset value, is called an over-current relay. The value of the present current above which the relay operates is known as it pickup value. An over current relay is used for the protection of distribution lines, large motors, power equipment etc. A scheme which incorporates over-current relays for the protection of an element of a power system, is known as an over current scheme or over current protection. An over current scheme may include one or more over current relays.

- Time – Current Characteristics :

A wide variety of time-current characteristics is available for over current relays.

(i) Definite – time over current relay

A definite-time over current relay operates after a predetermined time when the current exceeds its pick-up value. The operating time is constant, irrespective of the magnitude of the current above the pick-up value. The desired definite operating time can be set with the help of an intentional time – delay mechanism provided in the relaying unit. Curve (a) of Fig. 1 shows the time-current characteristic for this type of relay.

(ii) Instantaneous over current relay

An instantaneous relay operates in a definite time when the current exceeds its pick-up value. The operating time is constant, irrespective of the magnitude of the current, as shown by the curve (a) of Fig. 1 There is no intentional time – delay. It operates in 0.1s or less. Sometimes the term like "high set" or "high speed" is used for very fast relays having operating times less than 0.1s.

(iii) Inverse-time over current relay

An inverse-time over current relay operates when the current exceeds its pick up value. The operating time decreases as the current increases. Curve (b) of Fig. 1 shows the inverse time-current characteristic of this type of relays.

(iv) Inverse definite minimum time over current (I.D.M.T.) relay

This type of relay gives an inverse-time current characteristic at lower values of the fault current and definite-time characteristic at higher values of the fault current. Generally, an inverse-time characteristic is obtained if the value of the plug setting multiplier is below 10. for values of plug setting multiplier between 10 and 20, the characteristic tends to become a straight line, i.e. towards the definite time characteristic. Fig. 2 shows the characteristic of an I.D.M.T. relay along with other characteristics. I.D.M.T. relays are widely used for the protection of distribution lines.

(v) Very inverse – time over current relay

A very inverse-time over current relay gives more inverse characteristic than that of a plain inverse relay or the I.D.M.T. relays. Its time-current characteristic lies between an I.D.M.T. characteristic and extremely inverse characteristic, as shown in Fig. 2 The very inverse characteristic gives better selectivity than the I.D.M.T.

Characteristic. Hence, it can be sued where an I.D.M.T. relays fails to achieve good selectivity.

(vi)Extremely inverse – time over current relay

An extremely inverse time over current relay gives a time-current characteristic more inverse than that of the very inverse and I.D.M.T. relays, as shown in Fig. 2 When I.D.M.T. relays and very inverse relays fail in selectivity, extremely inverse relays are employed

- Method of defining shape of Time-current characteristics

The general expression for time-current characteristics is given by

$$t = \frac{K}{I^n - 1}$$

The approximate expression is

$$t = \frac{K}{I^n}$$

For definite-time characteristic, the value of *n* is equal to 0. According to the British Standard, the following are the important characteristics of over current relays.

(i) I.D.M.T. : $t = \frac{0.14}{I^{0.02} - 1}$

(ii) Very Inverse: $t = \frac{13.5}{I - 1}$

(iii) Extremely Inverse: $t = \frac{80}{I^2 - 1}$

- Settings of over current relays:

(i) Current Setting : The current above which a over current relay should operate can be set .If time-current curves are drawn, taking current in Amps on the X-axis, there will be one graph for each setting of the relay. To avoid this complex situation, the plug setting multipliers (PSM) are taken on the X-axis.

The actual r.m.s. current flowing in the relay expressed as a multiple of the setting current (pick up current) is known as the plug setting multiplier (PSM)

Suppose, the rating of the relay is 5A and it is set at 200% i.e. at 10A.If the current flowing through the relay is 100A, then the PSM will be 10.

Hence, PSM can be expressed as

$$PSM = \frac{\text{Secound}}{\text{Rleycset}}$$

$$= \frac{\text{Prmartucfftcm}}{\text{Rraysefia}}$$

If P.S.M. is taken on the X-axis, there will only one curve for all the settings of the relay. The curve is generally plotted on log/log graph.

(ii) Time Setting : the operating time of the relay can be set at a desired value.

There are 10 steps in which time can be set. The term time multiplier setting (TMS) is used for these steps of time settings. The values of TMS are 0.1, 0.2……0.9,1.

Suppose that at a particular value of current or PSM, the operating time is 4s with TMS = 1. The operating time for the same current with TMS = 0.5 will be 4X0.5 = 2s

The operating time with TMS = 0.2 will be 4X0.2 = 0.8s

- Observation Table:

(1) For TMS = 1

Sr. No.	PSM (Plug Setting Multiplier)	Time in seconds
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

CONCLUSION :

QUIZ:

1. What are the various types of over current relays?
2. What is PSM and TSM?

Earth Fault Protection

A fault which involves ground is called an earth fault. Examples are – single line to ground (L-G) fault and double line to ground (2L-G) fault. Faults which do not involve ground are called phase faults. The protective scheme used for the protection of an element of a power system against earth faults is known as earth fault protection.

Earth Fault Relay and Over-current Relay

Relay which are used for the protection of a section (or an element) of the power system against earth faults are called earth fault relays. Similarly, relays used for the protection of a section of the power system against phase faults are called phase fault relays or over-current relays. The operating principles and constructional features of earth fault relays and phase fault relays are the same. They differ only in the current levels of their operation. The plug setting for earth fault relays varies from 20% to 80% of the C.T. secondary rating in steps of 10%. Earth fault relays are more sensitive than the relays used for phase faults. The plug settings for phase fault relays varies from 50% to 200% of the C.T. secondary rating in steps of 25%. The name phase fault relay or phase relays is not common. The common name for such relays is over-current relay. One should not confuse this term with the general meaning of over-current relay. In a general sense, a relay which operates when the current exceeds its pick-up value is called an over-current relay. But in the context under consideration, i.e. phase fault protection and earth fault protection, the relays which are used for the protection of the system against phase faults are called over-current relays.

Earth Fault Protective Schemes

An earth fault relay may be a residual current as shown in fig. (a) i_a, i_b and i_c are currents in the secondary of C.T.s of different phase. The same ($i_a + i_b + i_c$) is called residual current. Under normal conditions the residual current is zero. When an earth fault occurs, the residual current is non-zero. When it exceeds pick-up value, the earth fault relay operates. In this scheme, the relay operates only for earth faults. During balanced load conditions, the earth fault relay carries no current; hence theoretically its current setting may be any value greater than zero. But in practice, it is not true as ideal conditions do not exist in the system. Usually, the minimum plug setting is made at 20% or 30%. The manufacturer provides a range of plug settings for earth fault relay from 20% to 80% of the C.T. secondary rating in steps of 10%.

The magnitude of the earth fault current depends on the fault impedance. In case of an earth fault, the fault impedance depends on the system parameter and also on the type of neutral Earthing. The neutral may be solidly grounded, grounded through resistance or reactance. The fault impedance for earth faults is much higher than that for phase faults. Hence, the earth fault current is low compared to the phase fault currents. An earth fault relay is set independent of load current. Its setting is below normal load current. When an earth fault relay is set at lower values, its ohmic impedance is high, resulting in a high C.T. burden.

Figure (b) and (c) show an earth fault relay used for the protection of transformer and an alternator, respectively. When an earth fault occurs, zero sequence current flows through the neutral. It actuates earth fault relay.

Figure (d) shoes the connection of an earth fault relay using a special type of C.T. known as a core-balance C.T., which encircles the three-phase conductors.

Combined Earth Fault and Phase Fault Protective Scheme

Figure 3.16 shows two over-current relays (phase to phase fault relays) and one earth fault relay. When an earth fault occurs, the burden on the active C.T. is that of an over-current relay (phase fault relay) and the earth fault relay in series. Thus, the C.T. burden becomes high and may cause saturation.

Directional Earth Fault Relay

For the protection against ground faults, only one directional overcurrent relay is required. Its operating principle and construction is similar to the directional overcurrent relays discussed earlier. It contains two elements, a directional element and an IDMT element. The directional element has two coils. One coil is energized by current and the other by voltage. The current coil of the directional element is energized by residual current and the potential coil by residual voltage as shown in fig. 3.18 (a). This connection is suitable for a place where the neutral point is not available. If the neutral of an alternator or transformer is grounded, connections are made as shown in fig. 3.18(b). If the neutral point is grounded through a P.T., the potential coil of the directional earth fault relay may be connected to the secondary of the PT. The IDMT element has a plugsetting of 20% to 80%.

A special five limbs P.T. which can energize both the earth fault relay as well as the phase fault relays, as shown in fig.3.19, may be used.

Now-a-days STATIC relays and MICROPROCESSOR-BASED relays are extensively used in place of ELECTROMAGNETIC relays.

CONCLUSION:

QUIZ:

(1) Distinguish between an F/F relay and an O/C relay.
(2) Why E/F relay is provided with current setting range of 20 to 80 % of rated current compared to current setting range 50 to 200 % for O/C relays.

EXPERIMENT NO: 2 Date:

Aim: - To study Buchholz Relay

THEORY :

A modern transformer is an extremely reliable equipment. There are certain incipient or minor faults in the transformer, which can not be detected by current operated relays such as differential and R.E.F. schemes. Such typical faults are given below :

(a) Core bolt insulation failure.
(b) Short circuited core laminations
(c) Bad electrical contacts.
(d) Local overheating.
(e) Loss of oil due to leakage.
(f) Ingress of air into the oil system.

It can be noted that all the faults listed above involve gas or oil and a relay dependent upon the presence of these will detect the faults in the incipient stages. Such a relay is Buchholz relay. So, in other words Buchholz relay is used for the protection of transformer and is based upon the principle of a gas operated relay installed in oil immersed transformer.

CONSTRUCTION :

Figure (1) shows the constructional details of the Buchholz relay. It takes the form of a dome shaped vessel placed in the connecting pipe between the main tank and the conservator. The device has two elements. The upper element consists of a mercury switch attached to a float. The lower element contains a mercury switch mounted on a hinged type flap located in the direct path of the flow of oil from the transformer to the conservator.

WORKING :

The working principle of Buchholz relay can be explained in the following ways:

(i) Normally the device is full of oil. The floats, due to their buoyancy are lifted up and the electrical contacts are not made.

In case of incipient faults within the transformer, the arc is produced. Thus the heat generated by this arc will cause the decomposition of some transformer oil in the main tank. The product of decomposition contain more than 70% of hydrogen gas, which being light, rises upwards and tries to go into the conservator. Due to collection of these gases, the oil level in the relay falls. When sufficient gas is accumulated and as the oil level goes low, the upper float rotates and at a certain level of oil allows the mercury to bridge the contact. The upper float is normally connected to alarm circuit only and as soon as the alarm comes the load from this transformer if possible should be switched 'OFF' and isolated to investigate the cause for the alarm. Thus Buchholz relay gives an alarm, so that the transformer can be disconnected before the incipient fault grows into a serious one.

(ii) In the event of a heavy fault within the transformer, the gas generated is more violent and the oil displaced by the gas bubbles rushes through the connecting pipe to the conservator tank. The baffles in the Buchholz relay get pressed by the rushing oil so, it causes the lower float at the Buchholz relay to tilt to actuate the mercury switch which trips the transformer from both sides so as to isolate it completely.

Generally, the following serious faults operate the lower float and trip the transformer.

(a) Short circuit between phases.
(b) Winding earth fault.
(c) Winding short circuit.
(d) Puncture of bushing.

FAULT DETECTION:

The decomposition of transformer oil starts at about 350°. The gas accumulated in the upper portion of the relay can be tapped. This gas, if analysed at regular intervals will give timely warning of any unhealthy conditions.

The oil generally consists of 2871 estimated liquid hydrocarbon components. Only nine out of these are looked for in the oil.

- Hydrogen
- Oxygen
- Nitrogen
- Methane
- Carbon monoxide
- Ethane
- Carbon dioxide
- Ethylene
- Acetylene

These gases are usually produced as a result of the stress acting upon organic insulations. A generally accepted list of gases and associated conditions are given as follows:

No.	Detected Gas	Interpretations
1.	Carbon dioxide and carbon monoxide.	Transformer overload, operating hot, causing some cellulose breakdown, check operating conditions.
2.	Hydrogen	Corona discharge, electrolysis of water or rusting.
3.	Hydrogen,methane with small amounts of ethane and ethylene	Sparking or other minor fault causing breakdown of oil.
4.	High hydrogen and other hydrocarbons including acetylene	High energy arc causing rapid deterioration of oil
5.	High hydrogen methane, high ethylene and some acetylene	High temperature arcing of oil but in a confined area, poor connections or interturn shorts are examples.

ADVANTAGES:

1. It is the simplest form of transformer protection.
2. It detects the incipient faults much earlier than is possible with other forms of protection.

LIMITATIONS:

1. It can only be used for oil immersed transformers equipped with conservator tanks.
2. Possibility of involved gases being trapped in the transformer cover without reaching the Buchholz relay.
3. Inability to perform satisfactorily on transformers filled with degassified oil.
4. The device can detect faults only below oil levels.
5. Setting of the mercury switch can not be too sensitive otherwise there can be a false operation by vibrations, earthquakes, mechanical shocks to the pipe, sitting of birds etc.
6. The relay is slow, minimum operating time is 0.1 second, average time is 0.2 second. Such a slow relay is unsatisfactory.

7. Buchholz relays are not provided for transformers below 500 kVA. This is for economical considerations.
8. A separate Buchholz relay has to be provided with the tap changer to detect the incipient faults in the tap changer. This does not respond to a small arcing.

CONCLUSION:

QUIZ:

1. What are incipient faults?
2. Which are the incipient faults occurs in transformer?
3. What is breather and why it is required?

EXPERIMENT NO: 3 Date:

Aim : To study Parallel feeder protection

THEORY :

To obtain discrimination where power can flow to the fault from both the directions, with circuit breaker on both sides should trip, so as to disconnect faulty line. Such cases occur in parallel feeders, ring mains T feeders and interconnected lines. Directional time and current graded system are suitable in such cases.

Directional over-current protection comprises over-current element and directional element in s single relay casing. The directional element is arranged to respond to the direction of power flow and when it operates it will complete shading coil circuit of IDMT element. Further directional over-current relay requires two operating quantities current and voltage.

Let us consider the parallel feeders AB and CD as shown in figure. IN the diagram, the double headed arrow ↔ indicates non-directional relay and directional relay can operate for fault current flowing in a particular direction shown by arrow ←.

Under healthy conditions or under fault conditions (e.g. fault at F3) , the current flow is in the direction i.e. from A to B and C to D. Thus negative torque is produced in directional elements of relays RC and RD. If there is a fault in feeder AB at F1, the fault point will be fed via both the feeders (i.e. through direction AF1 and CDBF1). The fault direction in this case is positive for relay RC and RD. Hence relay RC will operate and trip the circuit breaker 3, which is required. However, the fault current may trip relays RA and RB. Relay RA is required to trip but relay RB should not operate. To ensure this discrimination, time setting multiplier of relays R1 and RB is kept higher than that of relays RC and RD such that discrimination time of about 0.4 second is maintained between relays RA and RD and also between RB and RC. For fault at F1, if RC fails to operate or if circuit breaker 3 fails to open, relay RB will operate as a back-up and thus will give back-up protection. For normal operation relay RA and RC will trip for fault at F1 and isolate the line AB. Normal power can flow through line CD, because relay RD will not operate, in this case, and hence healthy feeder will not be affected.

Similarly when fault is at F2 on line CD, relays RB and RD will operate and trip the circuit breakers 2 and 4 in the same manner. Again, here RA will operate as a min protection but it will give back-up protection if circuit breaker 4 may fail to disconnect the faulty feeder CD.

The explanation above suffers from two problems. One of these problems is close-in fault. should there be a fault immediately near breaker 3 and 4, there will be no potential supply for directional element and hence directional element will remain inoperative when it should operate.

The scheme also suffers due to a specific fault situation explained as follows:

If the fault current is less than the rated current of the feeder, the direction of the fault current will not reverse in the directional relays. In the scheme explained the correct operation is dependent on the reversal of direction of current, in the faulty feeder at the load end. If the direction is not reversed, the directional element will remain inoperative and hence both the feeders will be tripped by non-directional relays at the source end. The solution in such a case is to employ transverse differential scheme of protection.

RELAY SETTINGS:

The following points should be considered while setting the relays used for parallel feeder protection.

- Select the plug setting of all relays such that after cut-off of faulty feeder from the system, another feeder remains healthy. i.e. it supplies power.
- Plug setting and time multiplier settings of relays RA and RB (source end relays) should be same.
- Plug setting and time multiplier setting of relays RC and RD (load end relays) should be same.
- Keep the discrimination time of 0.4 second between the relays on the load side and those on the source side.

PROCEDURE:

(1) Understand Power Circuit.

(2) "Switch-ON" supply M.C.B., check whether Red-indicating lamp glows, it indicates flow of normal load current and all relays are healthy.

(3) Apply 240 V A.C. Supply through 1- ϕ variac.

(4) In order to create fault on feeder - 1,

- Close switch S_1 then press Fault Push Button (Green Push Button)

Observations:

- Relay R_C (Directional Relay) and then Relay R_A (Non-Directional Relay) will operate one after the other.

(5) Repeat above procedure i.e. step no. 4 to create fault on feeder - 2 by operating S_2

(6) Write down observations

(7) Now, deliberately make directional relay of faulty feeder inoperative and see how back up protection is operating.

- For a fault in Feeder – 1, relay R_A will operate as main relay and relay R_B will operate as a back up protection.

- For a fault in Feeder – 2, relay R_B will operate as main relay and relay R_A will operate as a back up protection.

➢ Since both lines are tripped by CBs at sending end, receiving end is without electrical power. (This is biggest disadvantage of parallel feeder protection.)

(8) Now, "Switch-OFF" S_1 or S_2, which is ON and reset tripped relays and then by pressing Reset Push Button (Red Push Button), reset the circuit.

(9) "Switch-OFF" the main supply

Note: Discuss with your instructor, what phenomenon occur for malfunctioning of parallel feeder protection scheme.

RELEVENT IS:

1. IS 2705 (PT 1): 1992 Current transformers : Part 1 General Requirements
2. IS 2705 (PT 2): 1992 Current transformers : Part 2 Measuring current transformers.
3. IS 2705 (PT 3): 1992 Current transformers : Part 3 Protective current Transformers.
4. IS 2705 (PT 4): 1992 Current transformers : Part 4 Protective current transformers for special purpose applications
5. IS 4201 : 1983 Application guide for current transformers
6. IS 3842 (PT 1): 1967 Application guide for ac systems : Part 1 Over-current relays for feeders and transformers
7. IS 3842 (PT 10): 1967 Application guide for ac systems : Part 10 Relay for transverse differential protection.
8. IS 3231 (PT 3/SEC 4): 1987 Electrical relays for power system protection : Part 3 requirements for particular group of relays, Section 4 Direction relays and power relays.

CONCLUSION:

QUIZ:

(1) What is meant by directional relay?
(2) What is difference between simple o/c relay and directional o/c relay?

EXPERIMENT NO: 4 Date:

Aim: - Application of differential protection scheme for transformer protection.

THEORY:

"A differential relay responds to vector difference between two more similar electrical quantities".
Form this definition the following aspects are known:

1. The differential relay has at least two actuating quantities say I_1, I_2
2. The two or more actuating quantities should be similar i.e. current/current.
3. The relay responds to the vector difference between the two i.e. to $I_1 - I_2$, which includes magnitude and / or phase angle difference.

Differential protection is generally a unit protection. The protected zone is exactly determined by location of C.Ts The vector difference is achieved by suitable connections of current transformer or voltage transformer secondary.

APPLICATION OF DIFFERNTIAL PROTECTION:

Most differential relays are current differential relays in which vector difference between the current entering the winding and current leaving the winding is used for relay operation.

Differential protection principle is used in the following applications.

- Protection of generator, protection of generator-transformer unit.
- Protection of transformer.
- Protection of feeder (transmission line) by pilot wire differential protection.
- Protection of transmission line by, phase comparison carrier current protection.
- Protection of large motors.
- Bus-zone protection.

PRINCIPLE OF CIRCULATING CURRENT DIFFERNTIAL PROTECTION:

(MERZ-PRIZE PROTECTION):

Figure (1) illustrates the principle of differential protection of generator and transformer. X is the winding of the protected machine. Where there is no internal fault, the current entering in X is equal in phase and magnitude to current leaving X. The C.Ts are of such a ratio that during the normal conditions or for external faults (through faults) the secondary currents are equal. These currents say I_1 and I_2 circulates in the pilot wires. The polarity connections are such that the currents I_1 and I_2 are in the same direction in pilot wires, during normal conditions or external faults. Relay operating point is connected at the middle of pilot wires. Relay is of over-current type.

During normal condition and external fault the protection system is balancd and the ratio of C.Ts are such that secondary currents are equal. These currents circulate in pilot wires. The differential current $I_1 - I_2$ which flows through the relay coil is zero.

$I_1 - I_2 = 0$ (Normal condition or external fault)

This balance is disturbed for internal faults. When fault occurs in the protected zone, the current entering the protected winding is no more equal to that leaving the winding, because some current flows to the fault. The differential current $I_1 - I_2$ flows through the relay operating coil and the relay operates if the operating torque is more than the restraining torque.

The currents I_1 and I_2 circulate constantly in the secondary circuit. Hence C.Ts do not get damaged. Polarities of C.Ts are considered such that the circulating currents I_1 and I_2 are as shown in Fig. (1) for normal condition.

CT connections:

There is an inherent phase displacement between the voltage induced in the high voltage winding and low voltage winding , in case of star – delta transformer. Hence the load current on high voltage side is displaced in phase with respect to load current on low voltage side. The power transformers are grouped according to the phase displacement, e.g.,

Group 1: Star – Star, Phase displacement = 0°

Group 2: Star – Star, Phase displacement = 180°

Group 3: Delta – Star, Phase displacement = -30°

Group 4: Delta – Star, Phase displacement = +30°

In circulating current differential protection, the phase displacement in line current on two sides introduces phase differences in secondary currents of C.Ts on two sides.

The C.T connections should be such that the resultant currents fed into the pilot wires from either side are displaced in phase by an angle equal to the phase shift between the primary and secondary currents.

To get this arrangement, following rules are adopted:

- Secondaries of C.Ts on star connected side of power transformer are connected in delta.
- Secondaries of C.Ts on delta connected side of power transformer are connected in star.

With this arrangement, the phase displacement between currents gets cancelled with the phase displacement due to star / delta connections of C.T secondaries.

CT ratios :

Current ratios of C.Ts on each side will be different depending upon the line currents of power transformer and connections of C.Ts. The currents fed into pilots from each side should be the same for normal condition. Suppose current required in the pilot wire is 5 Amp. than secondary rating of the C.T which is connected on star side of power transformer must be equal to 5 Amp. and secondary rating of the C.T which is connected on the delta side of power transformer must be equal to $5 / \sqrt{3}$ Amp.

(Refer fig. (3) which gives differential protection scheme for Y/Δ power transformer considering C.T connection and C.T ratio aspects.)

Difficulties in differential Protection:

- Difference in pilot wire lengths*:*

  The current transformers and the machine to be protected are located at different sites and normally it is not possible to connect the relay coil to the equi-potential points. The difficulty is overcome by connecting adjustable resistor in series with the pilot wires. These are adjusted on site to obtain the equi-potential points.

- C.T ratio errors during short circuit*:*

  The current transformer may have almost equal ratio at normal currents. But during short-circuit conditions, the primary currents are unduly large. The ratio errors of C.Ts on either side differ during these conditions due to :

  (a) Inherent difference in C.T characteristic arising out of difference in magnetic circuit, saturation conditions etc.

  (b) Unequal d.c. component in the short circuit currents.

- Saturation of C.T magnetic circuits during short circuit condition:

  Due to these causes the relay may operate even for external faults. The relay may loose its stability for through faults.

To overcome this difficulty, the Percentage differential, or ‘ Biased differential relay’ is used. It is essentially a circulating current differential relay with additional restraining coil. The current flowing in the restraining coil is proportional to ($I_1 + I_2$) / 2 and this restraining current prevents the operation during external faults. Because, with the rise in current the restraining torque increases and ($I_1 - I_2$) arising out of difference in C.T ratio is not enough to cause the relay operation.

- Magnetizing current inrush in transformer while switching in:
  When the transformer is connected to supply, a large (6 to 10 times full load) current inrush takes place. This certainly causes operation of differential relay though there is no fault in the transformer. To avoid this difficulty Harmonic Restraint is provided for the differential relay. This relay filters the harmonic component from the in-rush current and feeds it to the restraining coil. The magnetizing current contains a large content of several harmonics. This harmonic content is used for obtaining restraining torque during switching in of transformer.

- Tap-changing:
  The tap changing causes change in transformation ratio of a transformer. Thereby the C.T ratios do not match with the new tap settings, resulting in current in pilot wires even during healthy condition. This aspect is taken care of by biased differential relay.

BIASED OR PERCENT DIFFERENTIAL RELAY:

The reason for using this modification is circulating current. Differential relay is used to overcome the trouble arising out of difference in C.T ratios for high values of external short-circuit currents. The percentage differential relay has an additional restraining coil connected in the pilot wire as shown in figure (2).
In this relay the operating coil is connected to the mid-point of the restraining coil. The total number of ampere-turns in the restraining coil becomes the sum of ampere turns in its two halves, i.e. (I_1N + I_2N)/2 which gives the average restraining current of ($I_1 + I_2$)/2 in N turns. For external faults both I_1 and I_2 increases and thereby the restraining torque increases which prevents the mal-operation.
The ratio of differential operating current to average restraining current is a fixed percentage. Hence the relay is called ‘ Percentage differential relay ‘. The relay is also called ‘ Biased differential relay ‘ because the restraining coil is also called a biased coil as it provides additional flux.

RELEVANT I.S.:

IS 3231(PT 3/SEC 3):1987 Electrical relays for power system protection: Part 3 Requirements of particular group of relays, Section 3 Biased (percentage) differential relays.

IS 3842(Pt 12):1976 Application guide for electrical relays for ac systems :Part 12 Differential relays for transformers

IS 3231:1965 Specification for electric relays for power system protection

IS 3231 (PT 0):1986 Electrical relays for power system protection: Part 0 General introduction and list of parts

IS 3231 (PT 1/ SEC 1):1986 Electrical relays for power system protection: Part 1 General requirements , Section 1 Contact performance

IS 3231 (PT 1/ SEC 2):1986 Electrical relays for power system protection: Part 1 General requirements , Section 2 Insulation tests

IS 8686:1977 Static protective relays.

IS 2705(PT 1):1992 Current transformers: Part 1 General Requirements

IS 2705(PT 2):1992 Current transformers: Part 2 Measuring current transformers

IS 2705(PT 3):1992 Current transformers: Part 3 Protective current transformers

IS 2705(PT 4):1992 Current transformers: Part 4 Protective current transformers for special purpose applications

IS 4201:1983 Application guide for current transformers

CONCLUSION:

QUIZ:

1. What do you mean by equi-potential points?
2. If pilot wire lengths are different how will you get equi-potential points?
3. What is the characteristic of percentage differential relay?
4. What is the relationship between operating current and restraining current?

EXPERIMENT NO: 5 Date:

Aim: - To study Radial feeder protection.

THEORY:

A simplified single line diagram of a radial feeder is shown in figure (1). Power is generated at 11 kV and stepped up by a step-up transformer 11 / 132 kV. Power is, then, transmitted at 132 kV to a receiving substation where voltage is stepped down to 66 kV for further transmission to a distribution substation. At distribution substation, voltage is further stepped down to 11 kV for feeding to the distribution system. 11 kV feeders will be terminated at the pole-mounted transformer 11 kV / 415 V. 415 V distributors, in turn, will feed the final consumers. The distributors are protected against faults by kit kat fuses. The recent practice is to use moulded case circuit breakers (MCCBs) instead of fuses. Pole mounted transformer is protected by drop-out fuses. 11 kV feeders are protected by overcurrent and earth-fault relays. Current transformers will transform the current at a value suitable for relay. Relays upon operation, will signal the circuit breaker for clearing the faults in feeders. Two overcurrent and one earth fault scheme of protection is used for such a protection. In case of faults in distribution system, kit kat fuses or MCCBs should operate to isolate the faulty section. Should the MCCB or the fuse fail to trip, relay R_3 in the distribution substation will act as a back-up protection to clear the fault. Similarly 66 kV transmission line and 132 kV transmission lines are protected by relays R_2 and R_1 respectively. It is to be noted that relay R_1, R_2 or R_3 means a group of relays, because figure (1) is a single line diagram.

Protective relaying scheme must have two important properties : selectivity and speed. Selectivity means the operation of the relay only for the faults in the zone which is assigned to the relay. In figure (2), R_3 must operate for the faults in section III, R_2 must operate for the faults in section II and provide remote back-up for the faults in section III should the protective system at relaying point R_3 fail to clear the fault and similar protection must be offered by relay R_1. Speed means the minimum possible time of isolating the faulty section from the healthy system from the instant of fault inception.

The selectivity or discrimination can be achieved by three methods:

1. Current discrimination
2. Time discrimination
3. Current - Time discrimination

In current discrimination, instantaneous overcurrent relays are used and they are set to reach for the faults at the far end of their zone of protection. In figure (2) relay R_1 must reach for the fault at substation B and not beyond that. Hence the pick-up values of R_3, R_2 and R_1 will be progressively increasing. This method of discrimination suffers from following disadvantages:

1. It does not provide back-up protection.
2. Instantaneous overcurrent relays suffer from the problem of over-reach. Thus they would mal-operate for the faults external to their assigned zone.
3. If source impedance Z_s (impedance from source to the relaying point) is large compared to the line impedance Z_1 (impedance of line to be protected), this method fails to discriminate - between in-zone faults and external faults.
4. The relaying system does not exploit the fault current capability of the equipment to be protected.
5. It also does not take into account the transient stability limit of the synchronous machines. As such the generators can feed short circuit power for some time without losing synchronism and the transient fault may vanish within this time.

Time discrimination is used to overcome these difficulties. In this method relays R_3, R_2 and R_1 are definite time over-current relays and are set to operate at times progressively increasing. This means that relay R_1 operates after maximum time-delay. (figure (3))

Where there are many sections in series, the tripping time for a fault near the power source may be dangerously high. This is obviously undesirable because such faults involve large currents and are very destructive if not removed quickly. Thus the fundamental weakness of time-graded over current relays is the fact that the heaviest fault is cleared the slowest. This difficulty can be overcome by introducing an instantaneous overcurrent element inbuilt in the definite time unit. In this case the faults nearer to the relaying point are cleared instantaneously and those away from the relaying point are taken care by definite time unit (figure-3). The shaded area in figure (3) shows the saving in time of operation of relay achieved by employing instantaneous feature.

It is also observed from the figure (3) that back-up protection is provided. The problem of un-called tripping of relays due to over-reaching can be solved by setting the instantaneous units to reach upto 80% of the section to be protected.

Foregoing discussion concludes that farther the fault from the source, more time can be allowed to clear it and nearer the fault to the source, less time should be taken to clear it. This fact is the basis for employing current time discrimination for obtaining selectivity and speed of the protective system. In inverse time-current relays, the time of operation of the relay is inversely proportional to the current magnitude. The time distance characteristics of such relays compared with those of definite time overcurrent relays are shown in figure (4), which clearly proves that the inverse time overcurrent relays can provide faster clearing times than the definite time relays, still maintaining selectivity and back-up protection. The tripping time can be still further reduced by using the relay having very inverse time current characteristics.

The in-built instantaneous units attached to inverse time-current relays can further reduce the tripping time for the faults nearer to the relaying point, as is the case with definite time relays.

The inverse time over-current relays suffer from the following disadvantages :-

(1) In inverse time-current relays, the tripping time for very high fault current is very small. For a radial feeder as shown in figure (4), if the fault is in the beginning of the second section (particularly a three phase bolted short circuit immediately after feeder breaker) the fault current would be very high. For such a high fault current, the selectivity cannot be maintained considering an adequate discrimination time between operating times of relays R_1 and R_2. As such relay setting becomes very difficult. Definite time relays are not subjected to this difficulty because their operating time is independent of the current magnitude. A solution to this problem of inverse time-current relays can be solved by a relay which has a combined characteristic of definite time relay and inverse time relay. This means that the relay has inverse time-current characteristics for small over currents and practically definite time characteristics for large over currents. Such a characteristic is known as Inverse Definite Minimum Time Lag (IDMTL) characteristic and the relays are termed as IDMT relays.

(2) If Z_s is high, ratio $Z_s / (Zs + Z_1)$ is not sufficiently lower than unity to give any appreciable reduction in tripping times. This will occur at the end of a long radial feeder where Z_s is large as given in the figure (5).

For a fault at F_1,

$$I_{f1} = E / (Z_s + Z_1)$$

where E is the induced emf (ph - n) of generator, and for a fault af F_2.,

$$I_{f2} = E / (Z_s + Z_2)$$

But as $Z_s >> Z_1$ and $Z_s >> Z_2$, there will not be any significant difference between the magnitudes of I_{f1} and I_{f2}. Accordingly, the difference between the tripping times of the relay R_3 will also be insignificant. Therefore the application of inverse time-current relay giving characteristic IT = K will not be justified. Such an application is justified for $Z_s / Z_1 < 2$.

The remedy is to employ very inverse time-current relays giving steeper characteristic ($I^2t=k$) than normal inverse relays. These relays give more difference in tripping times than the normal inverse relays for the same difference in fault current magnitudes.

(3) The third problem is the variation of generating capacity, Z_s will vary if the generating capacity is varied, becoming larger during slack load period. This increase in Z_s will not interfere with selectivity because the time discrimination increases at low currents, but it does increase the tripping times and hence defeats its purpose of reducing them.

In case of wide variations in generating conditions, the minimum fault current may be below the maximum load current. This makes it impossible to decide the relay - settings. This problem can be overcome by monitoring the overcurrent relays by under voltage relays.

RULES FOR SETTING THE IDMT RELAYS :

1. The relay must reach at least upto the end of the next protected zone; e.g. in figure (2) relay R_1 must reach upto substation C with minimum fault current (for phase relays, this is the phase-to-phase fault at minimum generation)
2. The current setting must not be less than the maximum load, unless monitored by an under-voltage relay.
3. In estimating the current setting, allowance must be made for the fact that the relay pick-up varies from 1.05 to 1.3 times the plug setting.
4. The time multiplier setting must be chosen to give the lowest possible time for the relays at the end of the radial feeder. In preceeding sections towards the source the time-multiplier should be chosen to give the desired selective interval from the previous relay at maximum fault conditions (for phase relays this is a three-phase fault just beyond the next bus with maximum generation). In figure (2) TMS of R_2 is based on three-phase fault just after relaying point of R_3. The time multiplier setting should allow not only for the time of the breaker but also for the overshoot of the relay and allowable time-errors in the successive relays. It is a common practice to use a fixed selective interval of 0.4 seconds (considering five cycle breakers) between the successive relays, but it would be much better to use an interval of 0.2 + 0.1 t where t is the operating time of the next relay (R_3 in figure 2) away from the source at maximum fault conditions.

SIMULATION OF A RADIAL FEEDER:

Live laboratory model of a radial feeder is developed in the Power system laboratory. Referring to a.c. circuit, three substations A, B and C are radially connected to the power source. Radial transmission line is divided into three sections each of line impedance 9 ohms. As this experiment does not deal with transient behaviour of the power system, rheostats of 9 ohms are used to simulate a transmission line. Each section can be isolated from the source by a contactor simulating a circuit breaker. The contactors can be charged or tripped manually by remote push buttons or can be automatically tripped by a signal given by the respective relays. IDMT overcurrent relays are used for the purpose. The relays sense, the fault current which is duly transformed by current transformers. The end of section III is connected to a MCB which simulates an MCCB or kit kat fuses used in the secondary of pole - mounted transformer. For the sake of simplicity, transformers are not incorporated in the model. The distributor and load are simulated by two variable rheostats 185 ohms and 350 ohms connected in series. The status of the contactors (whether OFF or ON) is indicated by semaphor indicators on the panel. The fault current in the distributor can be varied by varying load rheostats. Also, faults can be created in any section by fault switches S_1 , S_2 and S_3. For avoiding dead short - circuiting of the source, fault resistance of 18 ohms, is permanently connected. The fault can be created anywhere on the line section by variable slider of the line rheostat. The automatic isolation of the faulty section can be demonstrated by creating the fault. Also tripping of MCB can be shown by increasing the current in the load rheostat. The back-up protection can also be demonstrated. The visual and audible indication is given when the fault is cleared. The fault can be accepted by an ‘Accept’ push button PB_3 which discontinues the alarm.

PROCEDURE

1. As per circuit diagram, adjust the single phase voltage to approx. 230 V on source side by single phase variac (terminal no. 1 & 2)

2. Adjust current approximately to10 ampere with the help of load rheostats.

3. For effective protection, the relay time setting increases progressively from far end to source. For the fault occurring in section-CD (by making Fault Selector Switch “SF3” ON), relay provided for section-CD will operate and other two relays provided for section-AB & section-BC are having higher settings so they will not operate. In case of failure of protection scheme provided for section-CD, relay provided for section-BC will operate after some time delay depending upon its time setting. Thus it acts as a back up protection for section-CD. If this relay of section-BC also fails to operate, relay in section-AB (nearer to source) will operate after little more time delay.

4. Similarly to simulate fault in section – BC, close the fault selector switch SF_2. as the fault current is not flowing in section – CD, protection scheme provided for section – CD remains inoperative. The fault current flows in sections – AB and BC only, but due to lower time setting of the relay provided for section – BC compared to that of relay provided in section – AB, the relay of section – BC will operate first. In case of failure of relay for section – BC, relay provided for section – AB will operate after some time delay (depending upon its time setting).

5. For the fault occurring in section - AB (nearer to source), only the relay in section - AB will operate and relays in section - BC and section - CD will not operate as no fault current is flowing in section – BC and CD

CONCLUSION:

QUIZ:

1. What is the base of selection of different zone and their range?
2. What do you mean by relay over reaching?

EXPERIMENT NO: 6 Date:

Aim: - To study Air Circuit Breaker.

This type of circuit breakers, is those kind of circuit breaker which operates in air at atmospheric pressure. After development of oil breaker, the medium voltage **air circuit breaker** (ACB) is replaced completely by oil circuit breaker in different countries. But in countries like France and Italy, ACBs are still preferable choice up to voltage 15 KV. It is also good choice to avoid the risk of oil fire, in case of oil circuit breaker. In America ACBs were exclusively used for the system up to 15 KV until the development of new vacuum and SF6 circuit breakers.

Working principle of Air Circuit Breaker

The working principle of this breaker is rather different from those in any other types of circuit breakers. The main aim of all kind of circuit breaker is to prevent the reestablishment of arcing after current zero by creating a situation where in the contact gap will withstand the system recovery voltage. The **air circuit breaker** does the same but in different manner. For interrupting arc it creates an arc voltage in excess of the supply voltage. Arc voltage is defined as the minimum voltage required maintaining the arc. This circuit breaker increases the arc voltage by mainly three different ways,

It may increase the arc voltage by cooling the arc plasma. As the temperature of arc plasma is decreased, the mobility of the particle in arc plasma is reduced; hence more voltage gradient is required to maintain the arc.

It may increase the arc voltage by lengthening the arc path. As the length of arc path is increased, the resistance of the path is increased, and hence to maintain the same arc current more voltage is required to be applied across the arc path. That means arc voltage is increased.

Splitting up the arc into a number of series arcs also increases the arc voltage.

Types of ACB

There are mainly two types of ACB are available.

1) Plain air circuit breaker

2) Air blast Circuit Breaker.

Operation of ACB

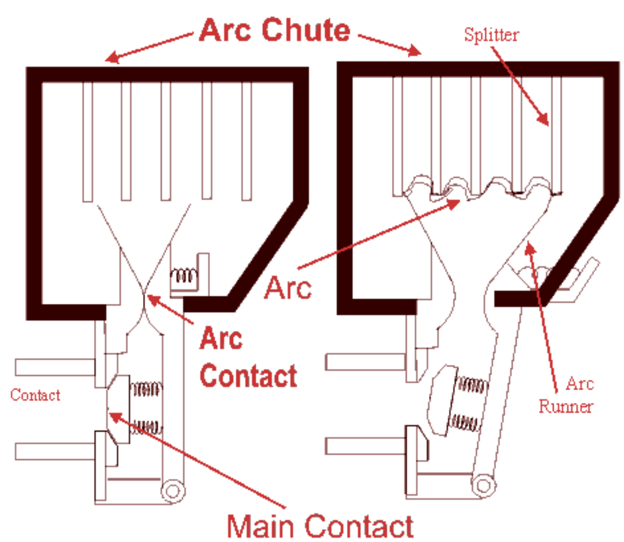
The first objective is usually achieved by forcing the arc into contact with as large an area as possible of insulating material. Every air circuit breaker is fitted with a chamber surrounding the contact. This chamber is called ‘arc chute’. The arc is driven into it. If inside of the arc chute is suitably shaped, and if the arc can be made conform to the shape, the arc chute wall will help to achieve cooling. This type of arc chute should be made from some kind of refractory material. High temperature plastics reinforced with glass fiber and ceramics are preferable materials for making arc chute.

The second objective that is lengthening the arc path, is achieved concurrently with fist objective. If the inner walls of the arc chute is shaped in such a way that the arc is not only forced into close proximity with it but also driven into a serpentine channel projected on the arc chute wall. The lengthening of the arc path increases the arc resistance.

The third technique is achieved by using metal arc slitter inside the arc chute. The main arc chute is divided into numbers of small compartments by using metallic separation plates. These metallic separation plates are actually the arc splitters and each of the small compartments behaves as individual mini arc chute. In this system the initial arc is split into a number of series arcs, each of which will have its won mini arc chute. So each of the split arcs has its won cooling and lengthening effect due to its won mini arc chute and hence individual split arc voltage becomes high. These collectively, make the over all arc voltage, much higher than the system voltage.

This was **working principle of air circuit breaker** now we will discuss in details the operation of ACB in practice.

The air circuit breaker, operated within the voltage level 1KV, does not require any arc control device. Mainly for heavy fault current on low voltages (low voltage level above 1 KV) ABCs with appropriate arc control device, are good choice. These breakers normally have two pairs of contacts. The main pair of contacts carries the current at normal load and these contacts are made of copper. The additional pair is the arcing contact and is made of carbon. When circuit breaker is being opened, the main contacts open first and during opening of main contacts the arcing contacts are still in touch with each other. As the current gets, a parallel low resistive path through the arcing contact during opening of main contacts, there will not be any arcing in the main contact. The arcing is only initiated when finally the arcing contacts are separated. The each of the arc contacts is fitted with an arc runner which helps, the arc discharge to move upward due to both thermal and electromagnetic effects as shown in the figure. As the arc is driven upward it enters in the arc chute, consisting of splitters. The arc in chute will become colder, lengthen and split hence arc voltage becomes much larger than system voltage at the time of **operation of air circuit breaker**, and therefore the arc is quenched finally during the current zero.



Although this type of circuit breakers have become obsolete for medium voltage application, but they are still preferable choice for high current rating in low voltage application.

Air Blast Circuit Breaker

These **types of air circuit breaker** were used for the system voltage of 245KV, 420KV and even more, especially where faster breaker operation was required. Air Blast Circuit Breaker has some specific advantages over oil circuit breaker which are listed as follows,

1) There is no chance of fire hazard caused by oil.

2) The breaking speed of circuit breaker is much higher during **operation of air blast circuit breaker**.

3) Arc quenching is much faster during **operation of air blast circuit breaker**.

4) The duration of arc is same for all values of small as well as high currents interruptions.

5) As the duration of arc is smaller, so lesser amount of heat realized from arc to current carrying contacts hence the service life of the contacts becomes longer.

6) The stability of the system can be well maintained as it depends on the speed of operation of circuit breaker.

7) Requires much less maintenance compared to oil circuit breaker.

There are also some disadvantages of air blast circuit breakers

1) In order to have frequent operations, it is necessary to have sufficiently high capacity air compressor.

2) Frequent maintenance of compressor, associated air pipes and automatic control equipments is also required.

3) Due to high speed current interruption there is always a chance of high rate of rise of re-striking voltage and current chopping.

4) There also a chance of air pressure leakage from air pipes junctions.

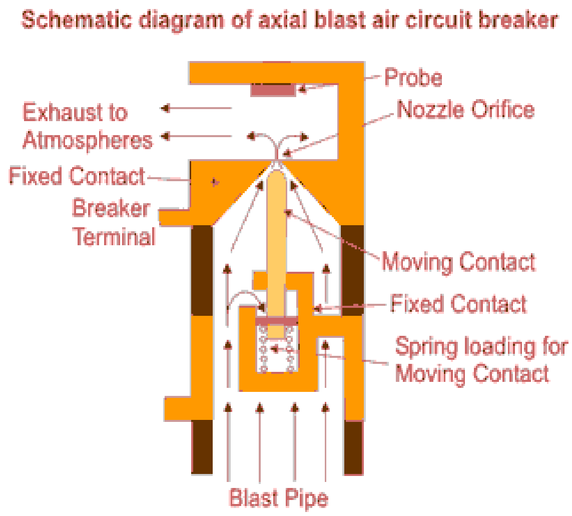
As we said earlier that there are mainly two types of ACB, plain air circuit breaker and air blast circuit breaker. But the later can be sub divided further into three different categories.

a) Axial Blast ACB.

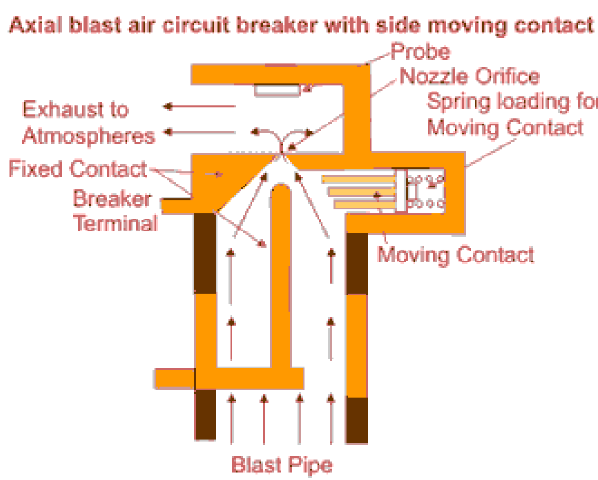
b) Axial Blast ACB with side moving contact.

c) Cross Blast ACB.

Axial Blast Air Circuit Breaker



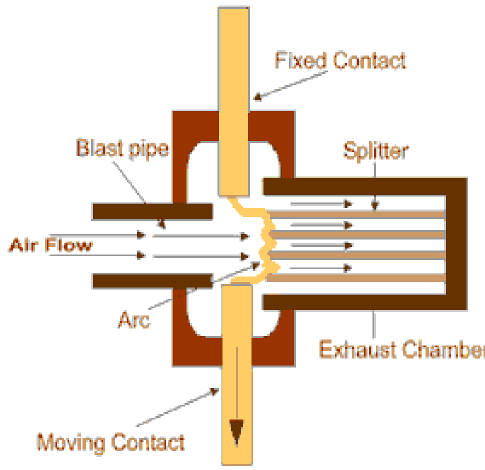
In Axial Blast ACB the moving contact is in contact with fixed contact with the help of a spring pressure as shown in the figure. There is a nozzle orifice in the fixed contact which is blocked by tip of the moving contact at normal closed condition of the breaker. When fault occurs, the high pressure air is introduced into the arcing chamber. The air pressure will counter the spring pressure and deforms the spring hence the moving contact is withdrawn from the fixed contact and nozzle hole becomes open. At the same time the high pressure air starts flowing along the arc through the fixed contact nozzle orifice. This axial flow of air along the arc through the nozzle orifice will make the arc lengthen and colder hence arc voltage become much higher than system voltage that means system voltage is insufficient to sustain the arc consequently the arc is quenched.



Axial Blast ACB with side moving contact

In this type of axial blast air circuit breaker the moving contact is fitted over a piston supported over a spring. In order to open the circuit breaker the air is admitted into the arcing chamber when pressure reaches to a predetermined value, it presses down the moving contact; an arc is drawn between the fixed and moving contacts. The air blast immediately transfers the arc to the arcing electrode and is consequently quenched by the axial flow of air.

Cross Blast Air Circuit Breaker



Principle of Cross Blast Air Circuit Breaker

The working principle of Cross Blast Air Circuit Breaker is quite simple. In this system of air blast circuit breaker the blast pipe is fixed in perpendicular to the movement of moving contact in the arcing chamber and on the opposite side of the arcing chamber one exhaust chamber is also fitted at the same alignment of blast pipe, so that the air comes from blast pipe can straightly enter into exhaust chamber through the contact gap of the breaker. The exhaust chamber is spit with arc splitters. When moving contact is withdrawn from fixed contact, an arc is established in between the contact, and at the same time high pressure air coming from blast pipe will pass through the contact gap and will forcefully take the arc into exhaust chamber where the arc is split with the help of arc splitters and ultimately arc is quenched.

CONCLUSION:

QUIZ:

1. What Is An Air Circuit Breaker?

2. Why Does a Circuit Breaker Trip?

3. How Do I Test a Circuit Breaker?

EXPERIMENT NO: 7 Date:

Aim: - To study Distance Relays.

Distance relays respond to the voltage and current, i.e., the impedance, at the relay location. The impedance per mile is fairly constant so these relays respond to the distance between the relay location and the fault location.

As the power systems become more complex and the fault current varies with changes in generation and system configuration, directional overcurrent relays become difficult to apply and to set for all contingencies, whereas the distance relay setting is constant for a wide variety of changes external to the protected line.

There are three general distance relay types as shown in Fig. 1. Each is distinguished by its application and its operating characteristic.

Impedance Relay

The impedance relay has a circular characteristic centered at the origin of the R-X diagram. It is nondirectional and is used primarily as a fault detector.

Admittance Relay

The admittance relay is the most commonly used distance relay. It is the tripping relay in pilot schemes and as the backup relay in step distance schemes. Its characteristic passes through the origin of the R-X diagram and is therefore directional. In the electromechanical design it is circular, and in the solid state design, it can be shaped to correspond to the transmission line impedance.

Reactance Relay

The reactance relay is a straight-line characteristic that responds only to the reactance of the protected line. It is nondirectional and is used to supplement the admittance relay as a tripping relay to make the overall protection independent of resistance. It is particularly useful on short lines where the fault arc resistance is the same order of magnitude as the line length.

Figure 1 shows a three-zone step distance relaying scheme that provides instantaneous protection over 80–90% of the protected line section (Zone 1) and time-delayed protection over the remainder of the line (Zone 2) plus backup protection over the adjacent line section. Zone 3 also provides backup protection for adjacent lines sections. In a three-phase power system, 10 types of faults are possible: three single phase-to-ground, three phase-to-phase, three double phase-to-ground, and one three-phase fault.

It is essential that the relays provided have the same setting regardless of the type of fault. This is possible if the relays are connected to respond to delta voltages and currents. The delta quantities are defined as the difference between any two phase quantities, for example, Ea – Eb is the delta quantity between phases a and b. In general, for a multiphase fault between phases x and y,

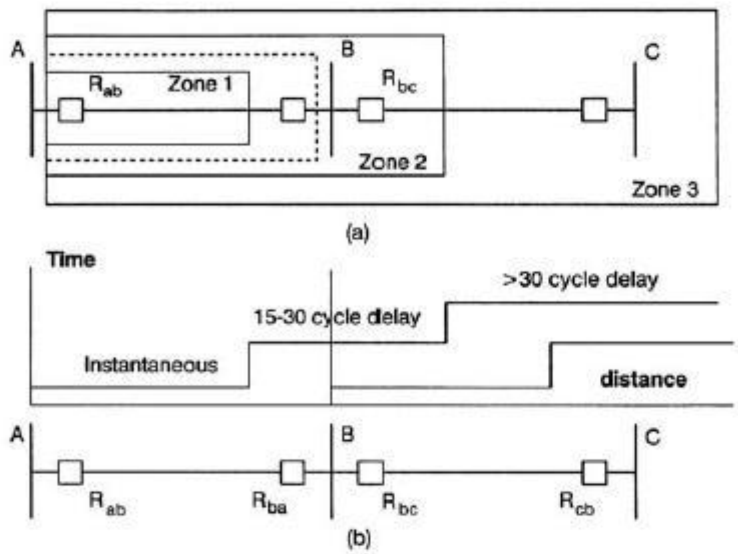


FIGURE 1
Three-zone step distance relaying to protect 100% of a line and backup the neighboring line.

$$\frac{Ex - Ey}{Ix - Iy} = Z1$$

where x and y can be a, b, or c and Z1 is the positive sequence impedance between the relay location and the fault. For ground distance relays, the faulted phase voltage, and a compensated faulted phase current must be used.

$$\frac{Ex}{Ix + mI_0} = Z_1$$

where m is a constant depending on the line impedances, and I_0 is the zero sequence current in the transmission line. A full complement of relays consists of three phase distance relays and three ground distance relays. This is the preferred protective scheme for high voltage and extra high voltage systems

CONCLUSION:

QUIZ:

1. What Is a Distance relay?

2. What are the types of Distance relays? Draw their characteristics?

EXPERIMENT NO: 8 Date:

Aim: - Introduction to Static Relays

The term 'static' implies that the relay has no moving parts. This is not strictly the case for a static relay, as the output contacts are still generally attracted armature relays. In a protection relay, the term 'static' refers to the absence of moving parts to create the relay characteristic.

Introduction of static relays began in the early 1960's. Their design is based on the use of analogue electronic devices instead of coils and magnets to create the relay characteristic. Early versions used discrete devices such as transistors and diodes in conjunction with resistors, capacitors, inductors, etc., but advances in electronics enabled the use of linear and digital integrated circuits in later versions for signal processing and implementation of logic functions.

While basic circuits may be common to a number of relays, the packaging was still essentially restricted to a single protection function per case, while complex functions required several cases of hardware suitably interconnected. User programming was restricted to the basic functions of adjustment of relay characteristic curves.

They therefore can be viewed in simple terms as an analogue electronic replacement for electromechanical relays, with some additional flexibility in settings and some saving in space requirements. In some cases, relay burden is reduced, making for reduced CT/VT output requirements.

A number of design problems had to be solved with static relays. In particular, the relays generally require a reliable source of d.c. power and measures to prevent damage to vulnerable electronic circuits had to be devised. Substation environments are particularly hostile to electronic circuits due to electrical interference of various forms that are commonly found (e.g. switching operations and the effect of faults).

While it is possible to arrange for the d.c. supply to be generated from the measured quantities of the relay, this has the disadvantage of increasing the burden on the CT's or VT's, and there will be a minimum primary current or voltage below which the relay will not operate. This directly affects the possible sensitivity of the relay.

So provision of an independent, highly reliable and secure source of relay power supply was an important consideration.

To prevent maloperation or destruction of electronic devices during faults or switching operations, sensitive circuitry is housed in a shielded case to exclude common mode and radiated interference. The devices may also be sensitive to static charge, requiring special precautions during handling, as damage from this cause may not be immediately apparent, but become apparent later in the form of premature failure of the relay.

Therefore, radically different relay manufacturing facilities are required compared to electromechanical relays. Calibration and repair is no longer a task performed in the field without specialised equipment.

A static relay refers to a relay in which there is no armature or other moving element and response is developed by electronic, magnetic and other components without mechanical motion. The solid-state components used are transistors, diodes, resistors, capacitors and so on. Static circuits accomplish the function of comparison and measurement. A relay using combination of both static and electro-magnetic units is also called a static relay provided that static units accomplish the response.

In static relays, the measurement is performed by electronic, magnetic, optical or other components without mechanical motion. Additional electro-mechanical relay units may be employed in output stage as auxiliary relays. A protective system is formed by static relays and electro-mechanical auxiliary relays.

BASIC STATIC RELAY

The essential components of static relays are shown in fig 20. Rectifier rectifies the relaying quantity i.e., the output from a CT or PT or a transducer. The rectified output is supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits. The output is actuated when the dynamic input (i.e., the relaying quantity) attains the threshold value. This output of the measuring unit is amplified by amplifier and fed to the output unit device, which is usually an electro-magnetic one. The output unit energizes the trip coil only when relay operates.

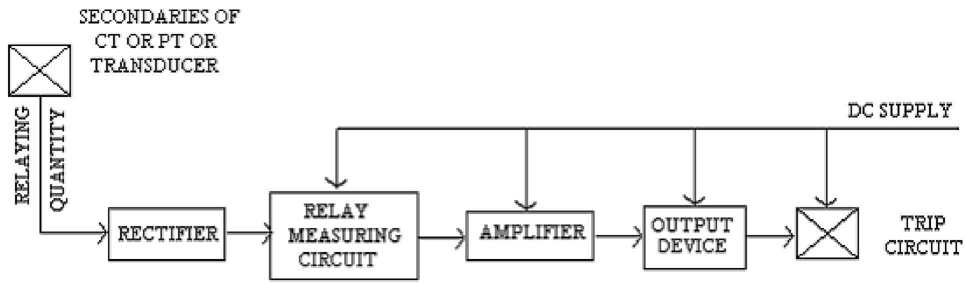


fig 20

In a static relay the measurement is carried out by static circuits consisting of comparators, level detectors, filter etc while in a conventional electro-magnetic relay it is done by comparing operating torque (or force) with restraining torque (or force). The relaying quantity such as voltage/current is rectified and measured. When the quantity under measurement attains certain well-defined value, the output device is triggered and thereby the circuit breaker trip circuit is energized.

ADVANTAGES OF STATIC RELAYS

Static relays in general possess the following advantages:

1. Low burden on current and voltage transformers, since the operating power is. in many cases, from an auxiliary d.c. supply.
2. Absence of mechanical inertia and bouncing contacts, high resistance to shock and vibration.
3. Very fast operation and long life.
4. Low maintenance owing to the absence of moving parts and bearing friction.
5. Quick reset action and absence of overshoot.
6. Ease of providing amplification enables greater sensitivity.
7. Unconventional characteristics are possible – the basic building blocks of semiconductor circuitry permit a greater degree of sophistication in the shaping of operating characteristics, enabling the practical utilization of relays with operating characteristics more closely approaching the ideal requirements.
8. The low energy levels required in the measuring circuits permit miniaturization of the relay modules.

CONCLUSION:

QUIZ:

1. What is a static relay?
2. What are the advantages of static relays?