40

Static Overcurrent Relays

Advantages — Single Actuating Quantity Relays, Double Actuating Quantity Relays — Instantaneous Overcurrent Relays — Timing Circuit — Time Delay Overcurrent Relays — Directional Overcurrent Relays — Block Diagrams — Summary.

40.1. INTRODUCTION TO STATIC OVERCURRENT RELAYS

The applications of conventional electromagnetic overcurrent relays have been discussed in Ch. 27. The conventional electromagnetic overcurrent relays are at present commonly used in many applications. However, static overcurrent relays offer several advantages such as :

— Reduced VA consumption (7 m VA to 100 m VA) as compared with electromagnetic relays (1000 m VA to 3000 m VA). Therefore the performance of CT under short-circuit condition is improved. The size of CT core is also reduced.

— Static relays are compact. The size of a single three phase overcurrent relay may be about one-fourth of three electromagnetic relays.

— Static overcurrent relay is not affected by vibrations.

— The static relays can have more accurate time-current characteristic.

— Static overcurrent relays can be of following types.

Overcurrent relay without time lag.

Overcurrent relay with time lag.

Directional overcurrent relay with time lag.

The applications of these relays have been discussed in Ch. 27.

The static overcurrent relay has generally the following functional blocks. (Ref. Sec. 391.1)

— *input circuit* comprising Main CT, auxiliary CT, current setting switch RC Filter.

— *rectifier* with smoothing circuit (Ref. Ch. 39)

— *level detector* (Ref. Ch. 39)

— *amplifier* (Ref. Ch. 38)

— tripping relay (Ref. Ch. 38)

In overcurrent time delay relays a time delay circuit is added between the rectifier and level detector to achieve desired time characteristic.

The overcurrent relays without directional feature are as a rule single actuating quantity relays. The directional overcurrent relays are as a rule double actuating quantity relays, the direction of power flow is sensed by sensing the phase angle between current and voltage.

The various functional blocks mentioned above are standardised by the manufacturer. Depending upon the type of relay, the required functional blocks are connected in the final assembly.

40.2. SINGLE ACTUATING QUANTITY RELAYS

A brief description of rectifier relays has been given in Sec. 26.14.

The protective relays at either single actuating quantity relays such as overcurrent, under-voltage, earth fault relay or double actuating quantity relays such as distance relay, differential relay. Fig. 40.1 given a simplified block diagram of a single actuating quantity rectified current relay.

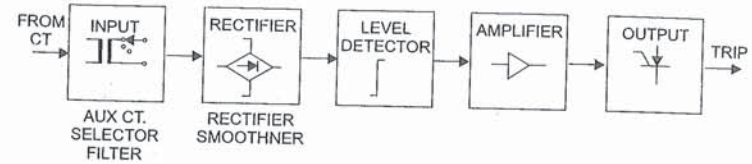


Fig. 40.1. Simplified block-diagram of a single actuating quantity.

The secondaries of CT's are connected to a summation circuit (not shown). The output of the summation circuit is given to the intermediate current transformer. The output of the current transformer is supplied to full wave rectifier bridge. The rectified output is given to *measuring element* (level detector). The measuring element determines whether the quantity has reached the threshold value or not. The measuring element detects the level of the input signal. The measuring element can be one of the following three types :

— moving coil permanent magnet relay — polarised moving iron relay

— static relay

In some cases the output of the rectifier is amplified and fed to electromechanical relay.

The static measuring element comprises d.c. amplifiers with transistors. The amplifier is single stage, two-stage or three stage and is usually feedback type. The feedback ensures progressive rise of output power when the input to the measuring unit reaches a certain level.

When input to measuring unit is less than threshold input, the output of the level detector is zero. For an overcurrent relay,

for $I_{in} < I_{th}$, $I_{out} = 0$

for $I_{in} > I_{th}$, $I_{out} = \text{Present}$

where, I_{in} = Input to measuring unit

I_{out} = Output of measuring unit.

I_{th} = Threshold value of input.

In an actual, relay, I_{th} can be adjusted.

After operation of the measuring element (level detector) the output of the level-detector is amplified by amplifier.

The amplified output is given to the output device. The trip coil of the circuit-breaker is connected in the output stage.

If time-delay is desired, a timing circuit is introduced before the level detector.

Smoothing circuit (Ref. Sec. 34.13) and filters are introduced in the output of the rectifier.

The above mentioned description applies to a static overcurrent relay. The protection operates if $I_{in} > I_{th}$ with a set time delay. Static overcurrent relay is made in form of a single unit in which transistors, diodes, resistors, capacitors etc. are arranged on printed board and are bolted with epoxy resin.

40.3. DOUBLE ACTUATING QUANTITY RELAYS (Ref. Sec. 26.14)

In distance relays, differential relays, directional relays, etc. two quantities are fed into the measuring unit. Fig. 40.2 gives a block diagram of a double actuating quantity rectifier relay.

The outputs of CT/PT are fed to summation units. The output of summation unit is rectified and fed to comparator. When the output of comparator increases to a certain value the output of level detector is initiated.

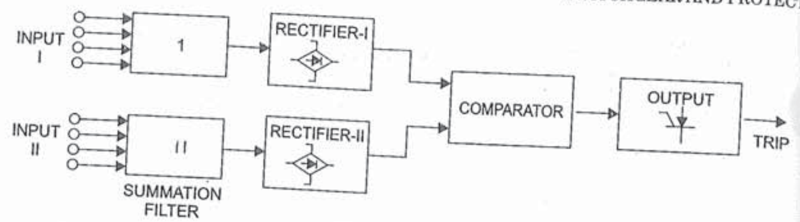


Fig. 40.2. Block diagram of a double actuating quantity relay. Level detector and amplifier not shown Refer (Fig. 40.1 above).

In Fig. 40.2, Level detector and Amplifier blocks (between comparator and output) are not shown for simplicity.

40.4. BASIC PRINCIPLE OF STATIC OVERCURRENT RELAYS

Figs. 40.1, and 40.3 illustrate simplified functional blocks in a single actuating quantity static overcurrent relays. The blocks diagrams of complete relay are given in Fig. sec. 40.8 and 40.9.

Ref. Fig. 40.3. The secondary current of line CT is generally not suitable for static relay operations. It is higher. The line CT may be selected with a suitable higher current ratio (such as 4000/5).The intermediate CT (Auxiliary CT) reduces the current further to 1 Amp. so that it is suitable for static relay circuits. The input Functional Block comprises the following :

— Auxiliary CT (Ref. 35.15)
— Current detector
— Filter for suppressing harmonics (Ref. sec. 38.31)
— Spike suppressor for protecting static relays from over-voltage spikes which are harmful to the relay components.

The desired current range can be selected by setting the tap at desired position. The alternating current derived from auxiliary CT may contain harmonics particularly under short-circuit condition. The high voltage spikes in the waveform are harmful to the semi-conductor devices in static relays. Hence, filters and spike suppressors are provided in the input stage of the static relay.

The current rectified in fullwave rectifier and is smoothened (Ref. Sec. 38.27 and Sec. 38.28) in smoothing circuit comprising resistors and capacitor. The smoothing circuit eliminates the ripple in the output waveform of the rectifier. The output of rectifier is proportional to the r.m.s. value of input a.c. waveform.

The output of rectifier is supplied to level detector (Ref. Sec. 39.13 to Sec. 39.16).

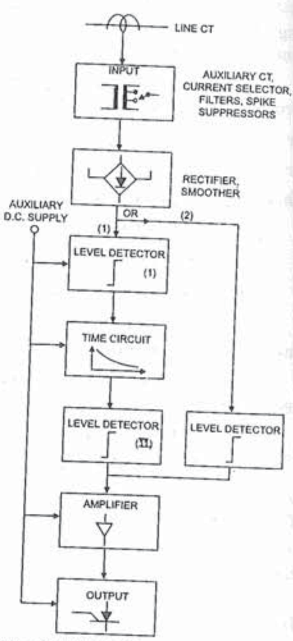


Fig. 40.3. Block diagram of static overcurrent relay (1) with time delay. (2) without time delay block.

In instantaneous overcurrent relay without intentional time delay. (Ref. Definition in Sec. 25.8) time delay functional block is not necessary. In instantaneous relays, the output of rectifier is given to level detector and then to amplifier (Route 2 Fig. 40.3).

In time overcurrent relay, the rectifier output is supplied to level detector (*I*) and a timing circuit is added in between the level detector (*I*) and level detector (*II*). Route 1. Fig. 40.3.

The output of level detector is amplified in Amplifier. The output of amplifier is given to output stage of static relay. The amplifier amplifies the signals from level detector.

The output of static overcurrent relay may be any of the following :

— moving coil permanent magnet d.c. relay.
— thyristor in series with trip coil (Ref. Sec. 38.7.5.).

The auxiliary d.c. supply is necessary for level detectors, amplifiers output stage of static relay.

In single actuating quantity relay, comparators are generally not necessary.

40.5. TIME CHARACTERISTIC

We will recall that the time characteristic of a protective overcurrent relay is plotted with operating quantity (current) on *x*-axis and operating time on *y*-axis. (Ref. Sec. 27.4, Fig. 27.2) the details described in this section may please be referred).

The general equation for time characteristic is given by

$$I^n\, t = K$$

where I = Current sensed by relay
k = Constant
t = Time of operation
n = Characteristic index of relay

In conventional electromagnetic relays, n can vary from 2 to 8. Let us consider three possibilities on n.

(*i*) With $n = 0$

$$I^{\circ}\, t = K$$
$$t = K$$

The characteristic is a straight line parallel to current axis.

It is known as definite characteristic.

(*ii*) With $n = 1$

$$It = K$$

The characteristic is called inverse characteristic.

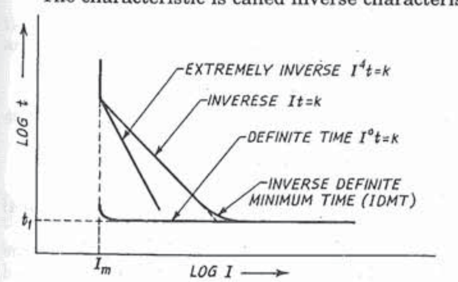


Fig. 40.4. Time characteristics of overcurrent relays.

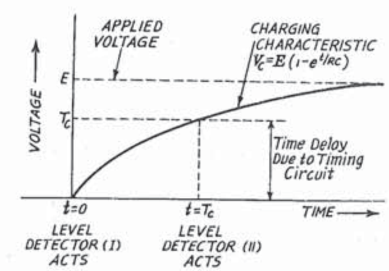


Fig. 40.5. Characteristics of time circuit.

(*iii*) With $n = 8$, the characteristic becomes extremely inverse.

Instantaneous characteristic with conventional electromagnetic relays can have approximate time of the order of 0.1 second. However in static overcurrent relays instantaneous overcurrent relays can be with half cycle or one cycle operating time. (10 to 20 ms).

The general expression for operating time of a time-circuit relays can also be expressed as,

$$t = \frac{KM}{I^n - I_p^n}$$

I = Tap current multiplier

where I_p = Multiple of tap current at which pick-occurs.

K = Design constant of the relay.

M = Time Multiple setting.

In the above expression if the relay picks up at tap-current, *i.e.* $I_p = 1$, then

$$= \frac{KM}{I^n - 1}$$

The static overcurrent time relays can have the following typical characteristics :

IDMT standard inverse :

$$t = \frac{0.15}{I^{0.20} - 1}$$

Vary inverse : $t = \frac{14}{I} - 1$

Extremely inverse : $t = \frac{70}{I^2 - 1}$

The same relay can be given different characteristics by changing its components.

40.6. TIMING CIRCUIT

When d.c. e.m.f. (E) is applied to a capacitor, the voltage across the capacitor (V) does not increase instantaneously. Initially it is zero. The voltage increases exponentially, given by

$$V_c = E\left(1 - e^{-\frac{1}{RC}}\right) \quad ...(40.3)$$

where E = d.c.e.m.f.

V_c = Voltage across capacitor

$RC = \tau$ = Time constant of RC circuit where R is Thevenins equivalent resistance viewed from capacitance. (Ref. Fig. 40.6)

at $t = 0$, when e.m.f. is applied.

$V_c = E\,(1 - e^{-0}) = 0$

at $t = \tau$, time constant

$V_c = E\,(1 - e^{-1})$

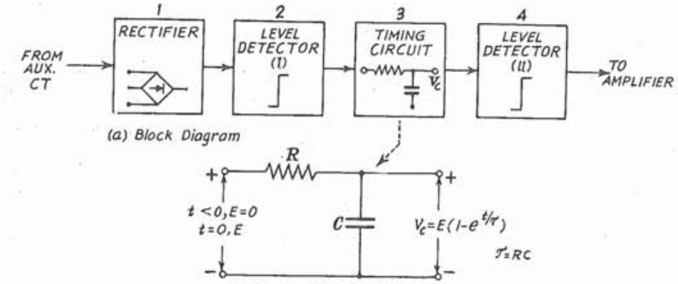
$= E\left(\frac{e-1}{e}\right)$

The charging time from $t = 0$ at $V_c = 0$ to $t = T_c$ at $V_c = V_t$ is given by

$$T_c = RC \log_e \left[\frac{E}{E - V_t}\right] \quad ...(40.4)$$

Consider timing circuit (Fig. 40.6). When the output of rectifier reaches a threshold value, the level detector (I) gives output ray $E \cdot$ (at $t = 0$). Before $t = 0$, the output of level detector (1) zero and there is no input to timer. As the level detector (2) acts voltage E is applied to timer. The capacitor starts getting charged. The voltage V_c increases exponentially. Suppose V_T is the threshold value of the level detector (4). Time required to reach this voltage depends upon time for charging the capacitor C given by,

$$T_c = RC \log_e \left[\frac{E}{E - V_T}\right] \quad ...(40.5)$$

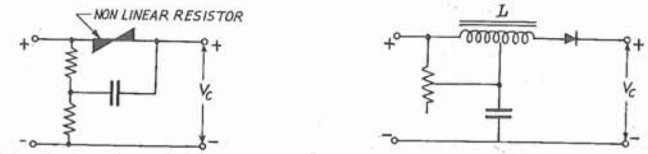


(b) Timing circuit of Block 3.

Fig. 40.6. Function of timing circuit in overcurrent time relay. (Ref. Fig. 40.5).

Hence time delay given by the time delay circuit is given by the above expression. By varying values of R, C the time can be varied without difficulties. The basic R, C circuit can be also arranged in several series parallel combinations to charge equivalent value R and τ.

Non-linear resistors are used to get other time characteristics (Ref. Fig. 40.7).



(a) Timing circuit with non-linear resistor. (b) Timing circuit with diode.

Fig. 40.7. Some forms of timing circuits.

Instantaneous Characteristic

The time delay circuit containing C is omitted from the block diagram. Such a circuit would need only one level detector. As there is no moving parts operating times of the order of 1 cycle can be achieved in static relays.

Applications

Time delay overcurrent relays are used in overcurrent protection of utility equipment, distribution circuits, protection of generators, motors, transformers etc. Instantaneous overcurrent relays are used for short circuit protection of large equipment.

Instantaneous overcurrent relays are also useful in other protective relay systems. (Ref. Ch. 27).

40.7. DIRECTIONAL OVERCURRENT RELAY

(Please Ref. Sec. 27.11 -Directional overcurrent protection.)

Directional relay senses direction of power flow by means of phase angle between V and I. When this angle exceeds certain predetermined value, the directional relay operates with a condition that the current is above in pick-up value. Hence directional relay is a double actuating quantity relay (Fig. 40.2) with one input as current I from CT and the other input as voltage V from VT.

With the electromagnetic directional overcurrent relays, discrimination is affected when voltage drops down (under fault condition) for faults very close to the location of VT. With static directional overcurrent relays, this voltage drop does not cause a problem.

Because the static comparators used in directional overcurrent relay can be made sensitive to voltage and static directional overcurrent relays can give reliable performance upto 1% of system voltage.

Block Diagram

Ref. Fig. 40.8. The directional overcurrent relay has two inputs (I and V). The inputs are supplied to phase comparator. A phase shifter is added in voltage input circuit before supplying it to phase comparator to achieve maximum output of phase comparators under phase faults/earth fault condition.

The output of phase comparator is given to level detector and then to amplifier.

If time delay is necessary, a timer is added in the block diagram.

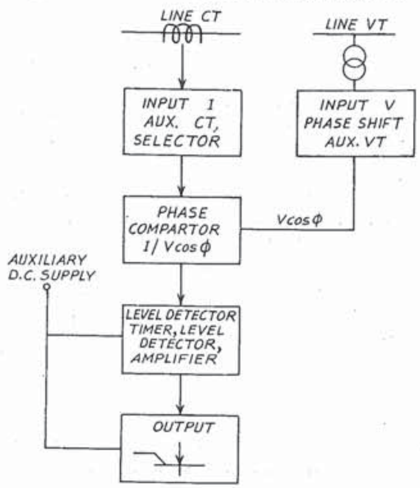


Fig. 40.8. Simplified block diagram of static directional overcurrent relay.

Directional Units for Directional Overcurrent Relays

The choice of directional unit depends upon the type of comparator. (Ref. Ch. 39). The comparator used in directional overcurrent relay may be one of the following :

1. *Hall Effect* generator (Ref. Sec. 38.12).
2. Rectifier bridge comparator (Ref. Sec. 38.12, 39.2).
3. Instantaneous coincidence comparator (Ref. Sec. 39.9).
4. Integrating coincidence phase comparator (Ref. Sec. 39.10).

Block Diagram Development

With the earlier background we can develop the Block Diagram for the following. It will be an interesting and useful exercise.

Example 40.1. *Develop Block Diagrams of following relays indicating the functional blocks from input to output stages. Describe the function of each block and the basic principle of its circuit. Indicate the auxiliary d.c. supply, line CT and VT.*

1. Static overcurrent relay
2. Static overcurrent time delay relay.
3. Static directional overcurrent relay without time delay.
4. Static directional overcurrent relay with time delay.

The student may compare his block diagrams with some of the following diagrams.

40.8. STATIC INSTANTANEOUS A.C. MEASURING RELAYS

Courtesy : ASEA, Sweden.

(A) General

Static instantaneous a.c. measuring relays include instantaneous overcurrent relay, instantaneous under-current, instantaneous over-voltage relay and instantaneous under-voltage relay. The application include high-set instantaneous over-current protection of motors, transformers, feeders, distribution lines; under-voltage protection of busbars feeding several motors, etc. Instantaneous protection is provided where time-lag is not desirable and differential protection is not justified economically. Static instantaneous a.c. relays have the following important features :

— Measuring circuits built-up of static components.
— Setting of maximum and minimum values (over/under) in the same relay.
— Wide scale range, with ratio 1 : 3
— Stepless setting of operating values
— High resetting ratio.
 $\geq$ 95% for maximum operation
 $\geq$ 105% for minimum operation
— Low power consumption, current relay : 0.3 m VA
 Voltage relay : 20 m VA
— Standard current relay completely insensitive to d.c. components.
— High resistance of shocks and vibrations due to absence of moving parts.
— Auxiliary voltage stabilization provided with the relay.
— Compact.

(B) Principle of Operation

The block-diagram Fig. 40.9 explains the functional arrangement in a static current-under-current relay. The auxiliary-input transformer shown in the figure, is connected to the secondary of main current transformer (not shown). The input transformer has an air gap (except those for extremely low power consumption). The functions of various static components are described in Ch. 34. The relay can be fed from auxiliary voltage such as 24 V, 48-60 V, 110-125 V, 220-250 V d.c. Resistor ratio box is provided internally.

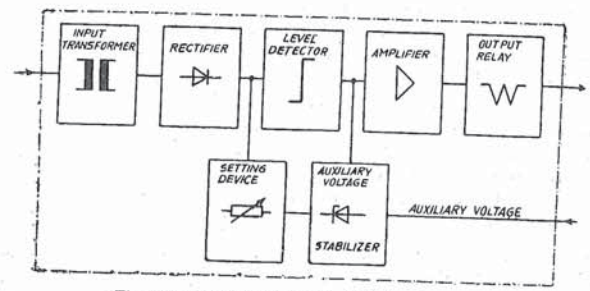


Fig. 40.9. Block diagram of static instantaneous overcurrent/under-current relay.

The rectified input is compared with a quantity derived from stabilized auxiliary reference voltage. The difference is fed to the level detector. When the input quantity reaches a certain threshold condition, the level detector detects the condition and gives output. The same is amplified so as to operate the auxiliary relay in the output stage.

(C) Technical Data on Static Instantaneous Current Relay and Instantaneous Voltage Relay

— Maximum voltage between line 500 V a.c.
— Rated frequency : 50 to 60 Hz
— Power consumption at lowest setting

Current relay : Measuring circuit : 7 m VA to 100 mVA auxiliary voltage circuit : 2 to 4 W

Voltage relay : Measuring circuit : 20 m VA auxiliary voltage circuit : 2 to 4 W

— Temperatures permitted : – 5°C to + 50°C
— Impules test : according to BEAMA 219
— Power frequency test : 2000 V, 50 Hz, 1 sec.
— Operating time : 30 to 55 m sec.

40.9. STATIC TIME-LAG OVER-CURRENT RELAYS

(A) Applications

Static over-current time-lag relays can be used for short circuit protection of generators, transformers, motors and also in simple supply networks at medium-distribution voltages. When combined with directional relays the over-current relays can be used for directional overcurrent protection of simple inter-connected systems. They can also be used as starting elements, in conjunction with longitudinal differential relays for protection of lines. The designs, include both inverse time-lag and independent time lag design, for use in single phase of three phase systems.

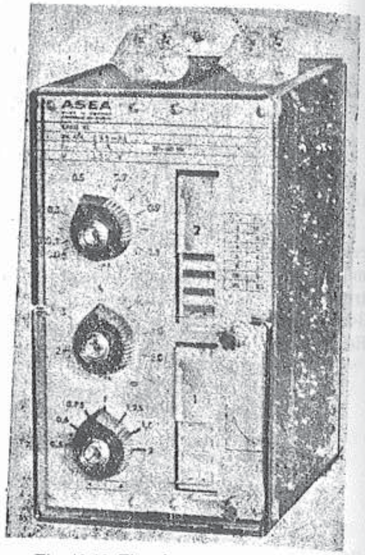


Fig. 40.10. Time-lag-over current relay.

(B) Design and Principle of Operation

[*Courtesy* : ASEA, Sweden]

The block diagram (Fig. 40.11) explains the circuit of a time-lag overcurrent relay developed and marketed by ASEA, Sweden. The applications of the relay are mentioned above. The relay has a built-in input current-transformer with several taps on secondary. Current setting can be obtained by selecting the tap.

From the switch for setting the operating current, a voltage connection is taken across resistor. The voltage is rectified, smoothed and compared with reference voltage. When the former voltage exceeds the reference voltage, the starting relay picks-up. At the same time, the *RC* circuit starts charging up.

The method of charging depends upon the type of relay. The charging in case of independent time lag relay is done from stabilized voltage. For a relay with inverse time lag characteristics, the charging is done by voltage proportional to current.

The inverse characteristics, in case of inverse-time-lag relays are obtained through combination of zener diodes, resistor employed in *RC* circuits.

When the capacitor in RC circuit charges up to a certain voltage level, the tripping relay pick-up.

In three phase design, the measuring circuit acquires voltage proportional to the largest of the three-currents.

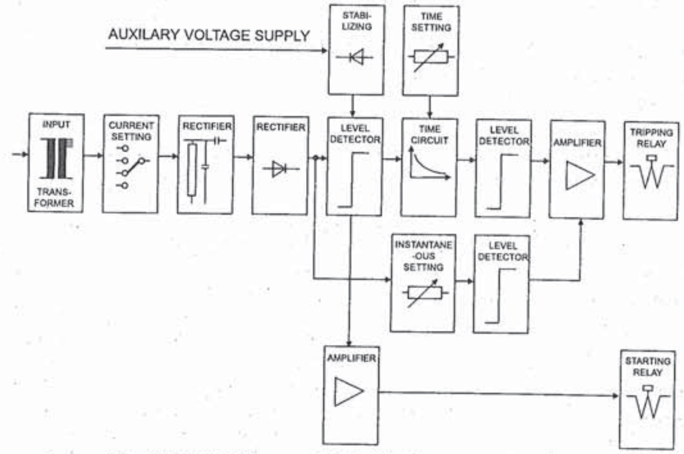


Fig. 40.11. Block diagram of static-time lag-overcurrent relay.
[*Courtesy* : ASEA, Sweden.]

Instantaneous operation is obtained through part of the voltage rectified from the transformer, being compared with reference voltage and when the latter is exceeded, an operational impulse is given to the tripping relay. Inductor flags are provided for both starting and tripping relays and are actuated by armature on corresponding output relay.

(C) Current Setting

The current setting is selected by turning a knob in the front of the relays thereby selecting the tap on secondary of input transformer. Typical example : Current scale for current setting graduated at 0.5, 0.6, 0.75, 1, 1.25, 1.5, 2, which multiplied by scale constant 1, 2, 4 or 8 A gives four current ranges 0.5 — 2, 1 — 4, 2 — 8, 4 — 16 A.

(D) Time Setting

The knob for time setting gives time multipliers. Thus if the time required from the graph or table is say 4 seconds for time multiplier of 1, then time will be $0.8 \times 4 = 3.2$ seconds for time setting of 0.8.

(E) Instantaneous Operation

Instantaneous operation is independent of d.c. component in short circuit current.

(F) Starting Operation

The contacts of starting relay can be utilized for :

Instantaneous tripping following by high speed auto-reclosure and delayed tripping.

Blocking of other relays in the event of overcurrents.

Blocking protection of radial fed busbars, transformers, cables.

Operating counters for recording number of faults which have not led to tripping.

Actuating separate indicating devices.

(G) Maintenance

Under normal condition, the relay requires no special maintenance. Burnt contacts on output relay should be carefully dressed with diamond file or extremely fine file.

Characteristics

The basic relay types offer variety of characteristics mentioned below :

— Extremely Inverse : BS 142 : 1966
— Very Inverse : "
— Normally Inverse : "
— Independent time lag : 0.2 — 2 s.
— Independent time lag : 0.6 — 6 s.

Voltage Ratings

Auxiliary d.c. voltages for various types : 24 V, 36, 48-55, 110, 125, 220, 250 V d.c.

Current Ratings

1 A in scale 0.2 02A
2 A in scale 1 — 4 A
5 A in scale 2 — 8 A
Frequency : 50-60 Hz.

Some Technical Data

Instantaneous operation, time : 50ms.
Starting operation, time : 20 ms.
Overshoot time : < 60 ms.

Power Consumption of Measuring Circuit

Rated current	*Power consumption at rated current*
1 A	0.02 — 0.07 VA
2	0.03 — 0.0 VA
5	0.05 — 0.13 VA

40.10. STATIC DIRECTIONAL RELAY

[*Courtesy* : ASEA, Sweden]

(A) General

Directional relay is double actuating quantity relay and senses phase angle between the two actuating quantities.

Let the phase angle between the current and voltage supplied to the relay be ϕ whilst the characteristic angle be α. When ϕ is equal to α, the relay has maximum sensitivity. This means that the relay operates when the supplied current I is as large as the set value I_s on the scale. For other values of I_s the relay operates when I, $\cos(\phi - \alpha) \geq I_s$. The angles are used in the formula with their signs and accordingly the angle ϕ is then negative for a capacitive phase displacement.

In three-phase systems, the operation of the relay is also determined by an angle β which is that angle between the phase voltage to which the current is related and that voltage supplied to the relay. Since the angle is positive when the current lags the phase voltage, the relay operates when $I \cos(\phi - \alpha + \beta) \geq I_s$.

When the relay is connected for 60° and 90° angles of phase displacement connection will mean that $\cos(\phi\ \alpha + \beta) = 1$ when the angle = 60° or 90°, the relay thus obtaining maximum sensitivity.

The reactive power Q has a phase-displacement of 90° in relationship to the active power P. It leads P when the phase displacement is inductive and is, therefore, positive.

Abbreviations

$U-$ = D.C. voltage
$U_{\sim}$ = A.C. voltage
U_n = Rated voltage
I_s = Set current
I = Current supplied to the relay
α = Characteristic angle of the relay
ϕ = Angle between current and voltage to the relay
β = Angle between the phase voltage to which the current is related and that voltage supplied to the relay.
ϕ_k = Angle between current and voltage to the relay at short-circuits.
P.F. = Power factor
P = Active power
Q = Reactive power.

Functional Circuit of a Directional Relay

The relay mainly comprised one current and one voltage transformer, a potentiometer, a converter, a smoothing circuit, a level detector with an amplifier and an electro-magnetic output relay, see Fig. 40.12. The current and voltage transformers, the potentiometer and the output relay are mounted individually, whilst the other components are on a printed-circuit board. The components together form a plug-in unit which occupies four relay seats in the plug-in system. The characteristic angles – 30° and – 90° are obtained by a capacitor in the voltage circuit, the angle + 65° being obtained by a capacitor in both the voltage and the current circuit.

As is apparent from Fig. 40.12 the current and voltage are fed *via* a phase shifting capacitor and transformers to a converter. The converter consists of two rectifier bridges and a resistor across which an average voltage value is extracted and supplied to the smoothing capacitor and the level detector.

The rectifier bridges are connected to the voltage transformer and the current transformer in such a manner that they pass conductive alternatively. In this way, a current is allowed to form the centre tapping of the current transformer through the resistor and rectifier bridge which is conductive at the time.

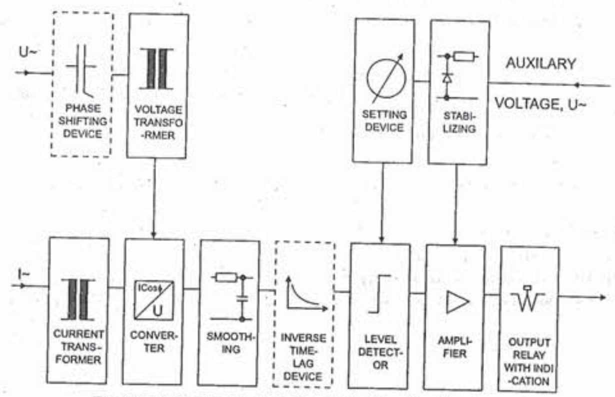


Fig. 40.12. Block diagram of a static directional relay.
[*Courtesy* : ASEA, Sweden.]

When $\phi = \alpha$ at the current flows through the resistor in the same direction the whole time and the average value of the voltage across the resistor, which is proportional to $I \cos(\phi - \alpha)$, thus provides maximum sensitivity, *i.e.* the relay operates for a current of the same value as the set value I_s.

The larger the difference between ϕ and α the smaller the average value of the voltage through the resistance will be at a constant current I. For a 0° difference, the average value will be zero irrespective of the value of the current.

The voltage over the resistor is smoothed fed to a transistorized level detector provided with an amplifier. By increasing the time constant in the smoothing circuit, it is possible to obtain a delayed operation with an inverse characteristic. The auxiliary voltage for the level detector and thus the operating value of the relay set by means of a potentiometer at the front of the relay. When operating, the amplifier feeds a voltage to the output relay which pick up, the indicating flag then becomes visible.

Summary

Static overcurrent relays have less burden compared electromagnet relays. They are compact and can give wide range of characteristics.

Basic static overcurrent relay has following functional blocks :

Input, Rectifier, Level detector, Amplifier, Output (Tripping).

In case of time lag overcurrent relay, an additional Time Delay Block is necessary.

Directional overcurrent relay, is basically double actuating quantity relay. It receives current input from CT and voltage input from VT. The rectified inputs are supplied to comparator. The comparator output is given to integrator or time delay circuit. The directional overcurrent relay can be instantaneous type of integrating type.

Static overcurrent relay circuit comprises the required functional blocks.

QUESTIONS

1. With the help of neat block diagram, explain the functioning of a static overcurrent relay without time delay. Explain function of each block.
2. Describe the circuit of a Directional Overcurrent Relay. Explain with the help of waveforms and block diagrams the use of integrating type coincidence phase comparator for directional overcurrent relay.
3. (*a*) Explain the principle of RC time delay circuit.

   Describe the use of such time delay circuit in a overcurrent time delay relay with the help of block diagram.

   (*b*) Explain the terms Inverse IDMT, Instantaneous overcurrent characteristics.
4. In a static relay, when the level detector operates, a voltage of 100 V DC applied across RC circuit having $R = 12\ k\Omega$, $C = 1\ \mu F$. Calculate time taken for the voltage across capacitor to reach threshold value of 60 V after operation of the level-detector.

   (**Hint.** Ref. Eqn. 39.5)
5. With the help of neat block diagram, explain the functioning of static overcurrent directional time delay relay.
6. Write short notes on any three :
   - — Time delay circuits in static relay
   - — Directional overcurrent relay
   - — Time characteristics of static relays
   - — Instantaneous overcurrent relay.
7. Write short note on merits of static overcurrent relay compared with electromagnetic overcurrent relay.

41

Static Differential Protection of Power Transformers

41.1. INTRODUCTION

The principle of differential protection was described in Ch. 28. Their application to protection of power transformer generator and station bus was covered in Ch. 32, 33 and 34. We will recall that the *differential protection responds to vector difference between two or more similar electrical quantities.* In differential protection, current transformer secondaries are connected in such a way that under internal fault condition, the out of balance secondary current flows through the operating coil of the relay. 'Bias'or 'Restraint' is provided to prevent maloperation during external faults and inrush currents. *This principle is applicable even for static differential relays. In static differential relays the two (or more) similar input quantities are compared in static comparators, usually the rectifier bridge comparators.* This gives wider flexibility in relay design regarding characteristic and range.

This differential relay measures the vector difference between two similar electrical quantities say voltage/voltage or current/current.

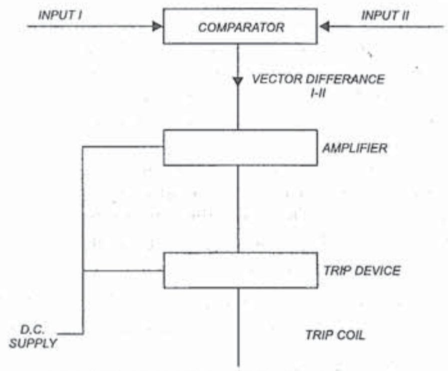


Fig. 41.1. Static differential relays principle. (Simplified block diagram)

Rectifier bridge comparator can be used conveniently in static differential relay. Block diagram is such a relay is given in Fig. 41.1.

Merits of Static Differential Protection

(*Courtesy* : Brown Boveri, Switzerland)

- — Three phase relay set with small dimensions.
- — Absolute stability for heavy through faults, hence ideally preferred for large transformers, generators.
- — High sensitivity for internal faults.
- — Extremely short tripping times regardless of magnitude of auxiliary voltage (*e.g.* 20-50 ms).
- — Accurate and absolutely stable tripping characteristic even for asymmetrical faults as each phase can have its own relay.
- — Inrush-proof, even during high-starting currents, inrush currents.