UNIT-V
STATIC AND DIGITAL RELAYS

Essential components of static relays:

The essential components of static relays are shown in the figure here the relaying quantity i.e., the output of act or pt of a transducer is rectified by a rectifier. The rectified circuit 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 measuring unit is amplified by amplifier and fed to the output device, which is usually an electro-magnetic one .The output energizes the trip coil only when relay operates.

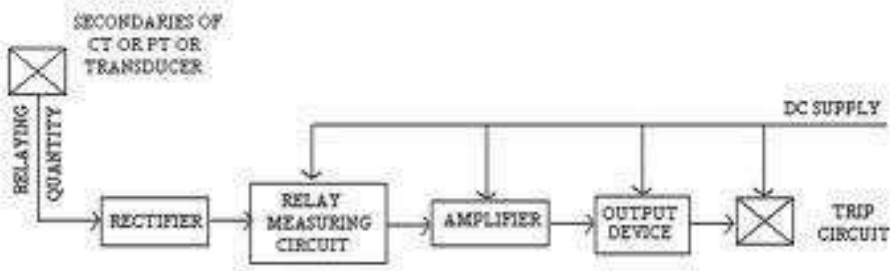


fig 20

In a static relay the measurement is carried out by static circuits consisting of comparators, level detectors, filters etc., while in a conventional electromagnetic relay it is done by comparing operating torque or restraining torque. In individual relays there is a wide variation. 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.

Static relays can be arranged to respond electrical inputs. The other type of inputs such as heat, light, magnetic field, travelling waves etc, can be suitably converted into equivalent analogue or digital signals and then supplied to the static relays. A multi input static relay can accept several inputs. The logic circuit in the multi input digital static relay can determine conditions for relay response and sequence of events in the response.

Comparison of static and Electro-magnetic Relays:

The conventional electro-magnetic relays are robust and quite reliable ., but are required to operate under different forces under fault conditions. This lead to delicate setting small contact gaps , special bearing systems , special clutch assemblies and several measuring problems. These require instrument transformers (CTs and PTs) with high burden and are bulky in size also.

The static relays in comparison to the corresponding electro-magnetic relays have many advantages and a few limitations.

Advantages of static relays:

1. The consumption in case of static relay is usually is much lower than that in case of their electro-mechanical equivalents. Hence burden on the instrument transformers is reduced and their accuracy is increased, possibility of use of air gaped CTs is there , problems arising out of CT saturation are eliminated, and there is an overall reduction in cost of CTs and PTs.
2. Quick response, long life, shock proof, fewer problems of maintenance, high reliability and high degree of accuracy.
3. Absence of moving contacts and associated problems of arcing, contact bounce, erosion, replacement of contacts etc.
4. Quick reset action a high reset value of overshoot can be easily achieved because of absence of mechanical inertia and thermal storage.
5. There is no effect of gravity on operation of static relays and therefore they can be installed in vessels, aircrafts etc.
6. Ease of providing amplification enables greater sensitivity to be obtained.
7. Use of printed or integrated circuits avoids wiring errors and facilitates rationalization of batch products.
8. The basic building blocks of semiconductor circuitry permit a greater degree of sophistication in the of operating characteristics, enabling the practical realization of relays with threshold characteristics more closely approaching the ideal requirements.
9. By combining various functional circuits ,several conventional relays can be substituted by a single ststic relay .For example a single static relay can provide over current ,under voltage, single phasing, short circuit protection in an ac motor by incorporating respective functional blocks.
10. Static relays are very compact. A single static relay can perform several functions. The space required for installation of protective relays and control relays etc, are reduced.
11. The characteristics of static relays are accurate and superior. They can be altered within certain range as per protection needs.
12. Static relays assisted by power line carrier can be employed for remote back-up and network monitoring.
13. Static relays can be designed for repeated operations. This is possible because ofabsence of moving parts in measuring circuits.
14. The risk of unwanted tripping is less with static relays.
15. Static relays are quite suitable for earth quake prone areas, ships, vehicles, locomotives, aero planes etc. This is because of high resistance to shock and vibration.
16. The static relays are provided with integrated features for self monitoring, easy testing and servicing. Defective module can be replaced easily.
17. A static protection control and monitoring system can perform several functions such as

protection, monitoring, measurement, memory, indication, data communication etc.

Limitations of static relays:

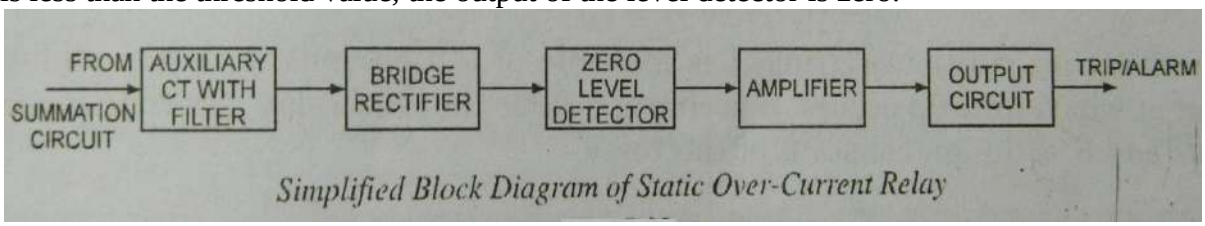
1. Auxiliary dc supply is required. However, this drawback is not very important as auxiliary dc supply can be obtained from station battery supply and conveniently changed as per local needs.
2. Semiconductor components are sensitive to electrostatic discharges. Some components are more sensitive than others. Even small discharges can damage the components and therefore precautions are necessary in the manufacturing of static relays to avoid component failure due to electrostatic discharges.
3. Static relays are sensitive voltage spikes or voltage transients. Special measures are taken to avoid such problem.
4. The characteristics of static relays are influenced by ambient temperature and ageing. However, temperature can be provided by using thermistor circuits and digital measuring techniques etc. While ageing can be minimized by pre-soaking for a several at a relatively high temperature.
5. The reliability of the system depends upon the large number of small components and their electrical connections.
6. The static relays have low short-time over-load capacity compared with electro-magnetic relays.
7. Static relays are costlier, for example and single function, than their equivalent electro-mechanical counter parts. But for multi function protection, static relays prove economical. The production technology of plug in type static relays on the panel permits the manufacturing of standard relays in mass and customers needs can be met quickly by incorporating required relay units on the panel. Static relays with ICs are cheaper than those with discrete components.
8. Static relay characteristic is likely to be affected by the operation of the output device but this is not so in case of electro-magnetic relay because its operation is based on the comparison between operating torques/forces.
9. Highly trained person are required for their servicing.
10. Static relays are not very robust in construction and affected by surrounding interference.

Static over current relays:

The block diagram of an instantaneous over-current relay is shown in the fig. The same construction may be used for under-voltage or earth fault relays too.

The secondaries of the line CTs are connected to the summation circuit (not shown in the figure). The output of this summation CT is fed to an auxiliary CT, whose output is rectified, smoothed and supplied to the measuring (level detector). The measuring unit determines whether the quantity has attained the threshold value (set value) or not.When the input to measuring unit

is less than the threshold value, the output of the level detector is zero.



Simplified Block Diagram of Static Over-Current Relay

For an over-current relay

For $I_{input} < I_{threshold}$; $I_{output} = 0$

For $I_{input} > I_{threshold}$; I_{output} = present

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

After operation of the measuring unit , the output is amplified by the amplifier. The amplified output is given to the output circuit to cause trip/alarm.

If time delay is desired , a timing circuit is introduced before the level detector. Smoothing circuit and filters are introduced in the output of the bridge rectifier. Static over-current relay is made in the form of a single unit in which diodes, transistors, resistors, capacitors etc. are arranged on printed board and are bolted with epoxy resin.The general equation for the time characteristics is given as

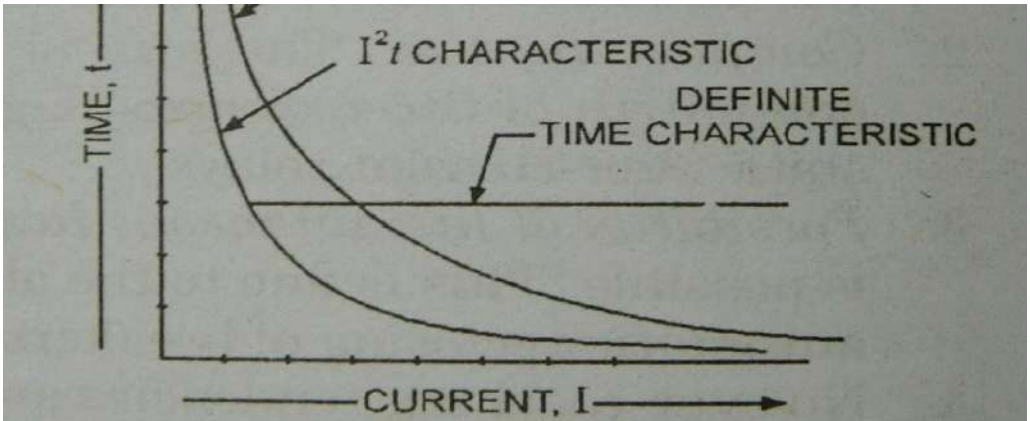
$$I^n t = K$$

Where I is the relay current, t is the time of operation and n is the characteristic index of relay and K is constant

In conventional electro-magnetic relays, n may vary between 2 and 8. The characteristic become a straight line parallel to current axis for n=0 .Such a characteristic is known as definite time characteristic of over current relay.

With n=1 ;It=k .The characteristic becomes inverse characteristic.

With higher value of n , the characteristic becomes more and more inverse .With n=7 or 8, the characteristic becomes extremely inverse.



Time Characteristics of Over-Current Relays

Fig. 7.93

The static instantaneous over-current relays can have operating time of as small as 10 or 20 ms while in case of a conventional electro-magnetic relays it is of the order of 0.1 second.

Definite time over-current relays are used for wide variations of systems conditions, as back-up relays for differential and distance protection and differential protection of transformers to avoid mal operation during magnetization in rush-currents. Inverse – time relays are used where the source impedance is much smaller than the line impedance. Extremely inverse over current relays are used for the fuse coordination and thermal protection of transformers and induction motors.

The general expression for the operating time of a static time-current relays may be given as

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

Where M is time multiple settins , I is multiple of tap current ; I p is the multiple of tap current at which pick-up occurs ,n is characteristic index of relay , t is time of operation in seconds and K is design constant of the relay.

If the relay picks up at top value current i.e ., $I_p = 1$, then $t = \frac{KM}{I^n - 1}$

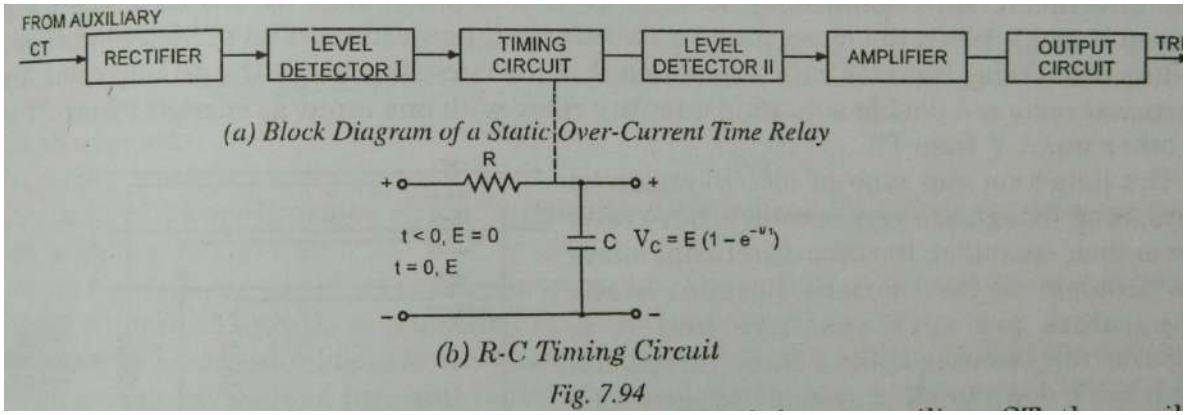
The static over-current time relays have the following typical characteristics

I D M T standard inverse $t = \frac{0.14}{I^{0.02} - 1}$

Very inverse $t = \frac{13.5}{I - 1}$

Extremely inverse $t = \frac{80}{I^2 - 1}$

In static relays it is advantageous to choose a circuit accommodating a wide range of alter native inverse time characteristics , precise minimum operating levels , definite minimum times and additional high set features if necessary. The block diagram of a static over-current time relay is shown in fig 7.94(a)



(a) Block Diagram of a Static Over-Current Time Relay

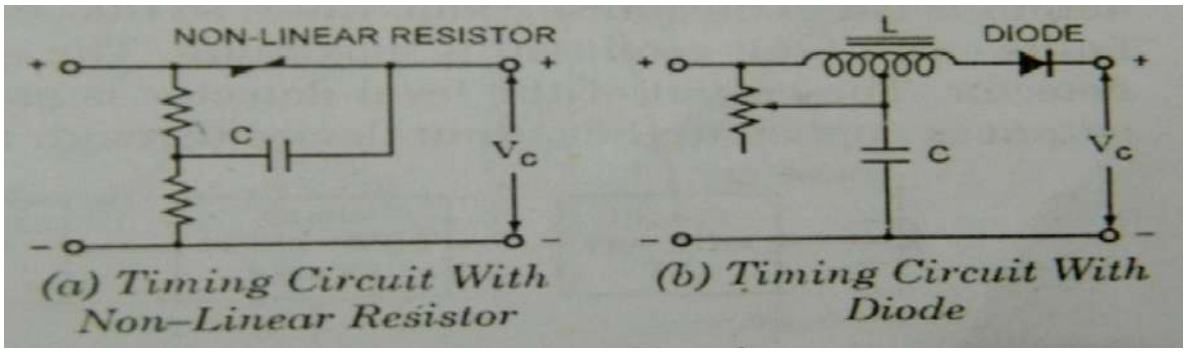
(b) R-C Timing Circuit

Fig. 7.94

The current from the line CT is reduced to 1/1000 th by an auxiliary CT, the auxiliary CT has taps on the primary for selecting the desired pick-up and current range and its rectified output is supplied to level detector (1) (over-load level detector) and an R-C timing circuit. When the voltage on the timing capacitor Vc attains the threshold value of the level detector (2), tripping occurs.

Where Vt is the threshold value of the level detector (2)

By varying values of R and C the time can be varied without difficulties. The basic R-C circuit can also be arranged in several series-parallel combinations to have different values of Tc.



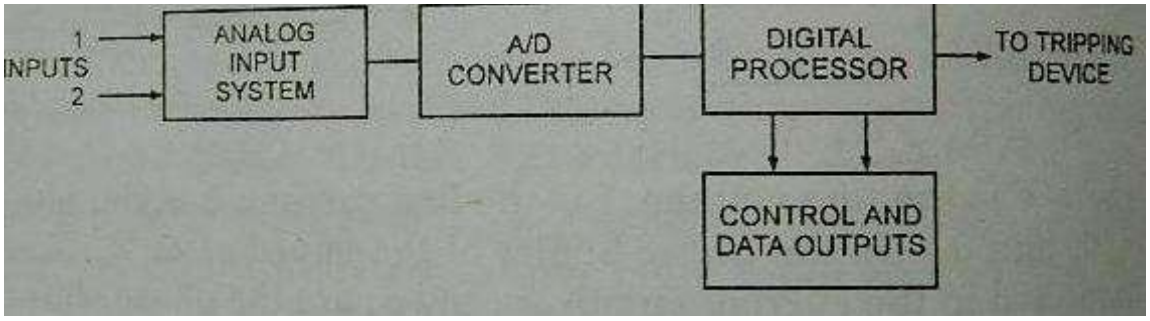
Non-linear resistors are used to have other time characteristics fig.

Time delay over-current relays are used in over-current protection of utility equipment, distribution circuits , protection of transformers , generators , motors etc.

In instantaneous over-current relays, the time delay circuit shown in fig. is detected Such a circuit would need only one level detector. As there is no moving part , operating time of the order of 0.02s (1 cycle) can be achieved. Instantaneous over current relays are used for short-circuit protection of large equipment. Instantaneous over-current relays are also useful in other protective relay systems.

MICROPROCESSOR BASED DIGITAL RELAYS:

With the fast development in fast scale integrated (LSI) technology, sophisticated and fast microprocessors are now available. With the rapid growth of modern complex large power system net works , fast , accurate and reliable protective schemes are essential . Microprocessor based schemes are becoming more and more popular for power system several protection as they offer attractive compactness and flexibility. They reduce the number of types of relay units. An interface employing op-amps, analog multiplexer analog-digital (A/D) converter voltage comparators and passive elements have been developed to provide the characteristics of various types of relays such as definite time relays, Inverse time over current relays, phase comparators relays and reverse power relays etc.



A block diagram of a microprocessor based digital programmable static relay is shown in figure.

The three phase A.C. quantities received from the power system through CTs PTs are sampled simultaneously or sequentially at uniform time intervals (4 to 32 samples per cycle).they are then converted into the digital form through an A/D converter and transfer to digital processor. digital signals are in the form of coded square pulses which represents discrete data .the signals are in binary form .the microprocessor/digital processor being set with the recommended values compares the dynamic inputs and decides accordingly to generate trip /alarm signal to the output device.

Microprocessor based relays have numerous advantages .they have a very small burden on the CTs and PTs .saturation can be avoided by using air gap CT having a limited output, they can process and display the signals very efficiently, accurately and in a fastest possible manner .due to their programmable characteristics ,they can be applied extensively in the protection of electrical power systems .moreover one microprocessor unit may be able to perform relaying function of systems .microprocessor relays are more reliable and secure to relay engineers because they can alert the user to a mal function before a false trip or failure to trip occurs .however the microprocessor should be properly shielded from external influences and the system earthing must be very good from which they receive their control voltage.