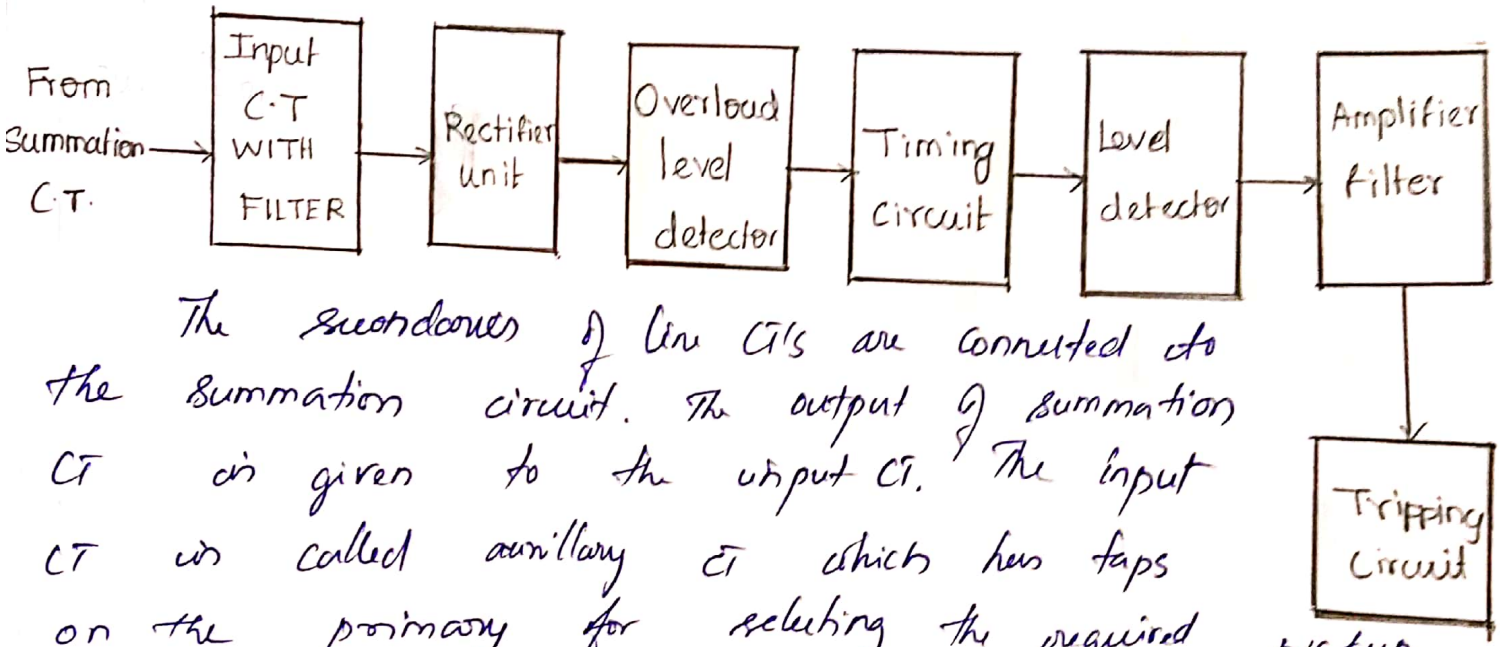
1. Draw and explain the block diagram of static overcurrent relay.

STATIC OVERCURRENT RELAY

This is nothing but instantaneous overcurrent relay. The following diagram of static time current relay



The secondaries of the CTs are connected to the summation circuit. The output of summation CT is given to the input CT. The input CT is called auxillary CT which has taps on the primary for selecting the required pickup and current range.

Then the output of auxiliary CT is rectified and smoothened.

It is then applied to overload level detector and RC timing circuit.

When the voltage across the timing capacitor reaches to a critical value then it triggers the level detector.

The output of the level detector is amplified as per the requirement and given to the tripping circuit.

This operates the output devices. The charging of capacitor in a timing circuit is achieved by a voltage derived from CT current.

This voltage is obtained across a non linear resistor by passing rectified current through it.

The proper selection of non-linear resistor and RC timing circuit allows to obtain desired shape of time current characteristics.

The current at which the level detector trip is called threshold current denoted as $I_{threshold}$.

Thus for an overcurrent relay

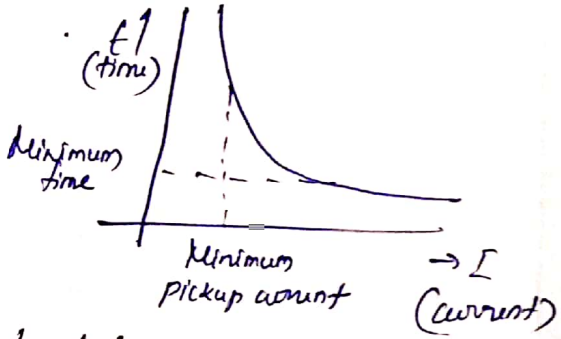
when $I_{in} > I_{threshold}$, level detector does not trip

When $I_{in} \geq I_{threshold}$, level detects trips.

Static time - current characteristics.

The time-current characteristics is inverse type of characteristics and given by

$$t = \frac{K(TMS)}{I^2 - I_p^2}$$

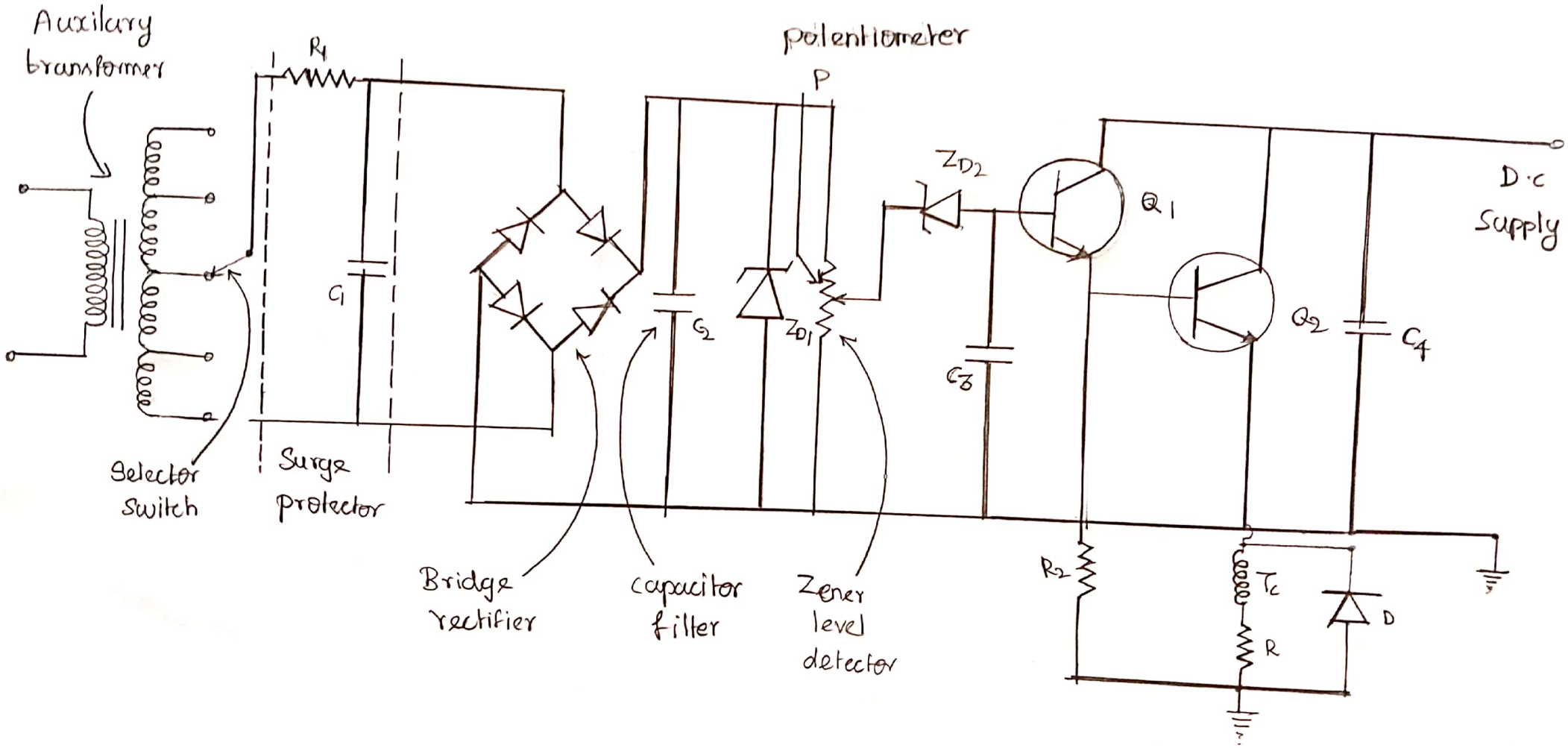


Q. Static Instantaneous Overcurrent Relay.

The detailed circuit diagram of instantaneous static overcurrent relay is shown below.

The auxiliary transformer gives output voltage proportional to the fault current. The main circuit is

STATIC INSTANTANEOUS OVERCURRENT RELAY



protected from the voltage surges by using R, C, circuit at the input.

This is surge protector. The output voltage from the transformer is then rectified and smoothened using capacitor filter C2.

The level of this voltage is compared with the voltage level decided by Zener diode ZD_1.

This Zener limits the rectified voltage to a safe value though the fault current is very high.

Part of this voltage, as decided by the potentiometer P is compared with the breakdown voltage as decided by the potentiometer P is compared with the breakdown voltage of another Zener diode ZD_2. When the rectified voltage is greater than voltage of ZD_2, the transistor Q_1 conducts.

This increases drop across R_2 due to which Q_2 conducts.

This energizes the trip coil Tc of the relay.

When the trip coil opens it develops high inverse voltage (back emf).

To protect Q_2 from such a high back emf a diode D is connected across the trip coil.

With the help of potentiometer P different pick up values can be obtained.

3. Explain the operation of static inverse time Over current relay.

Under normal conditions Q_1 get biasing from dc supply applied through R_4 and R_2 conducts. Hence capacitor C is short circuited.

When fault current exceeds the pick up value set by the potentiometer P_3 and selector switch then the transistor Q_1 becomes OFF.

The capacitor C starts charging through R_3 and D_1 by the voltage developed across R.

This charging time varies as per the severity of the fault. More severe is the fault, more the voltage developed across R_1 and less is the time for charging capacitor C to a critical value of level.

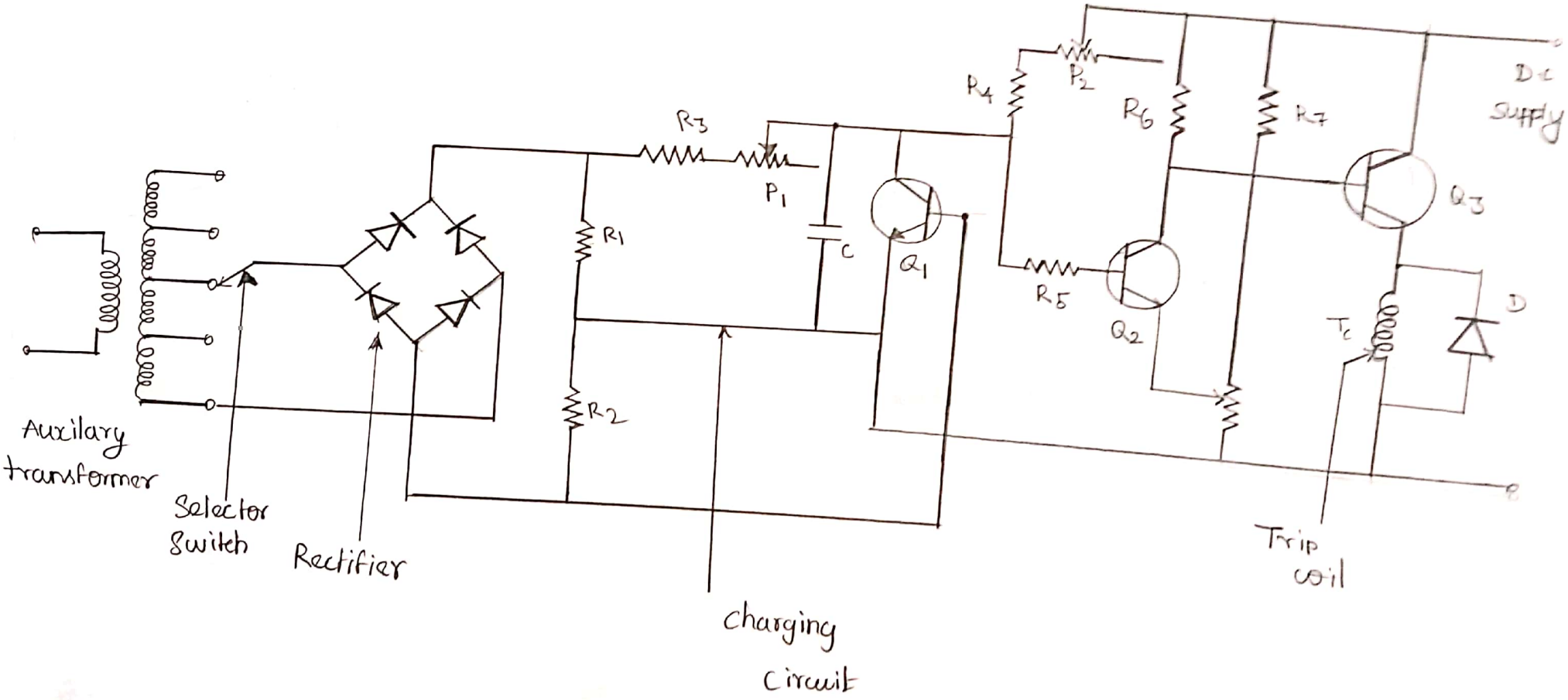
When voltage across the capacitor reaches to a predetermined level set by the potentiometer P_3 then the transistor Q_3 conducts.

This energizes the trip coil and the circuit breaker opens.

The diode D protects the transistor from the high reverse voltage.

Thus more is the fault current, less is the time required to operate relay hence it is inverse time - current relay.

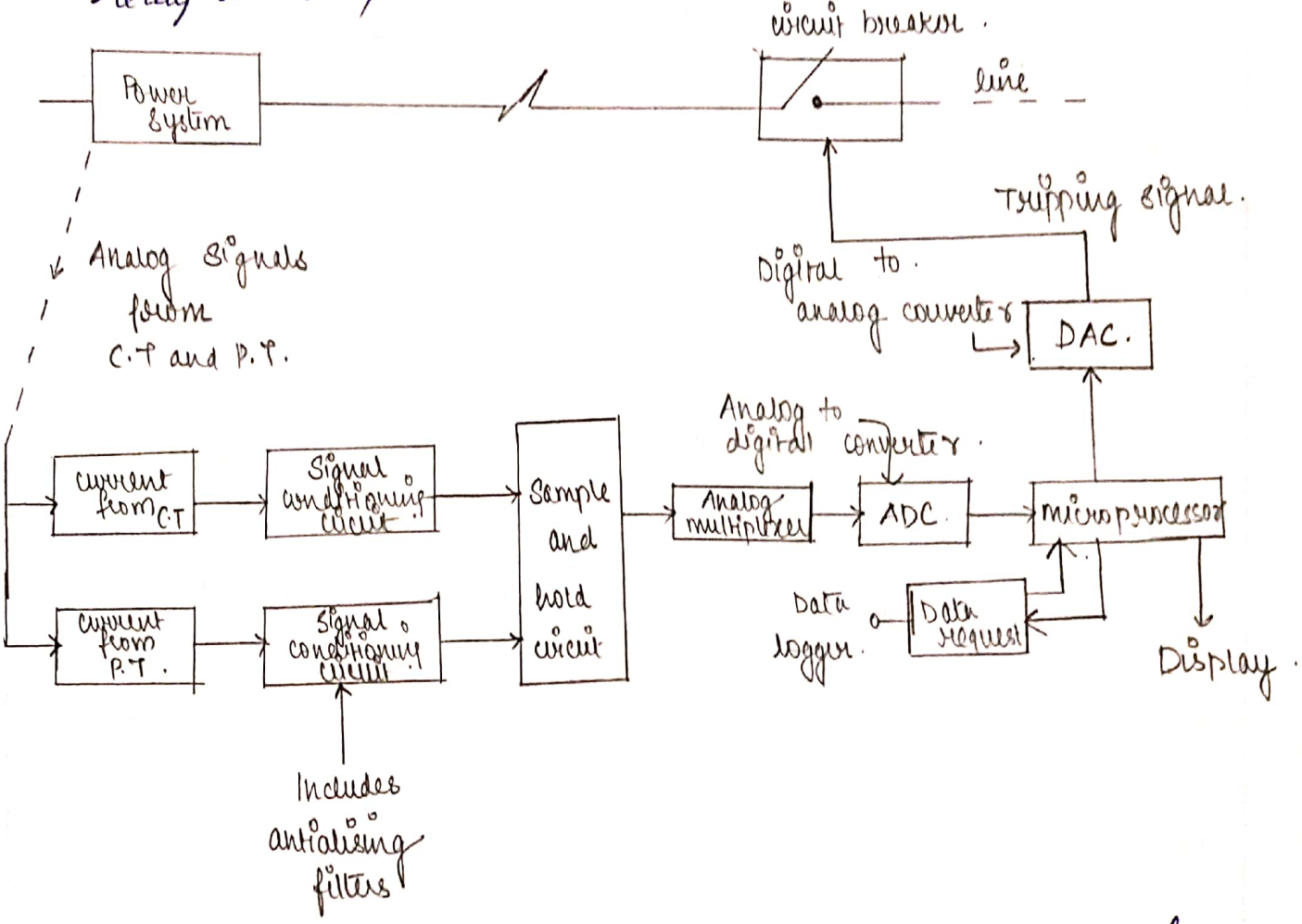
INVERSE TIME CURRENT RELAY



4. Explain the block diagram of numerical relay with necessary diagram.

BLOCK DIAGRAM OF NUMERICAL RELAY

A relay using digital device like microprocessor for decision making based on digital numbers representing instantaneous values of the signals is called numerical relay, digital relay, microprocessor based relay or computer based relay.



The voltage and current signals on the power system are brought down to suitable level using CT and PT.

These signals can not be converted to digital form. It is necessary to remove high frequency components which may appear as low frequency components.

This is called aliasing which distorts the required signal.

Then the signal from CT and PT are given to the antiliasing filter which are low pass filters. This removes unwanted frequency components.

The signals from signal conditioning circuits are sampled using sample and hold circuit.

With the help of analog multiplexer and analog to digital converter (ADC), the equivalent digital form of analog input signal is achieved.

The analog multiplexer gives the facility to accomodate a large number of input signals.

The digital output of ADC is given to microprocessor or microcontroller where it is stored in memory.

The signal is processed with the help of numerical relaying algorithm & accordingly trip decision is made.

The trip signal is digital hence converted to analog using digital to analog converter (DAC). This tripping signal is given to the trip coil of relay.

5. Explain the numerical over current protection and numerical transformer differential protection.

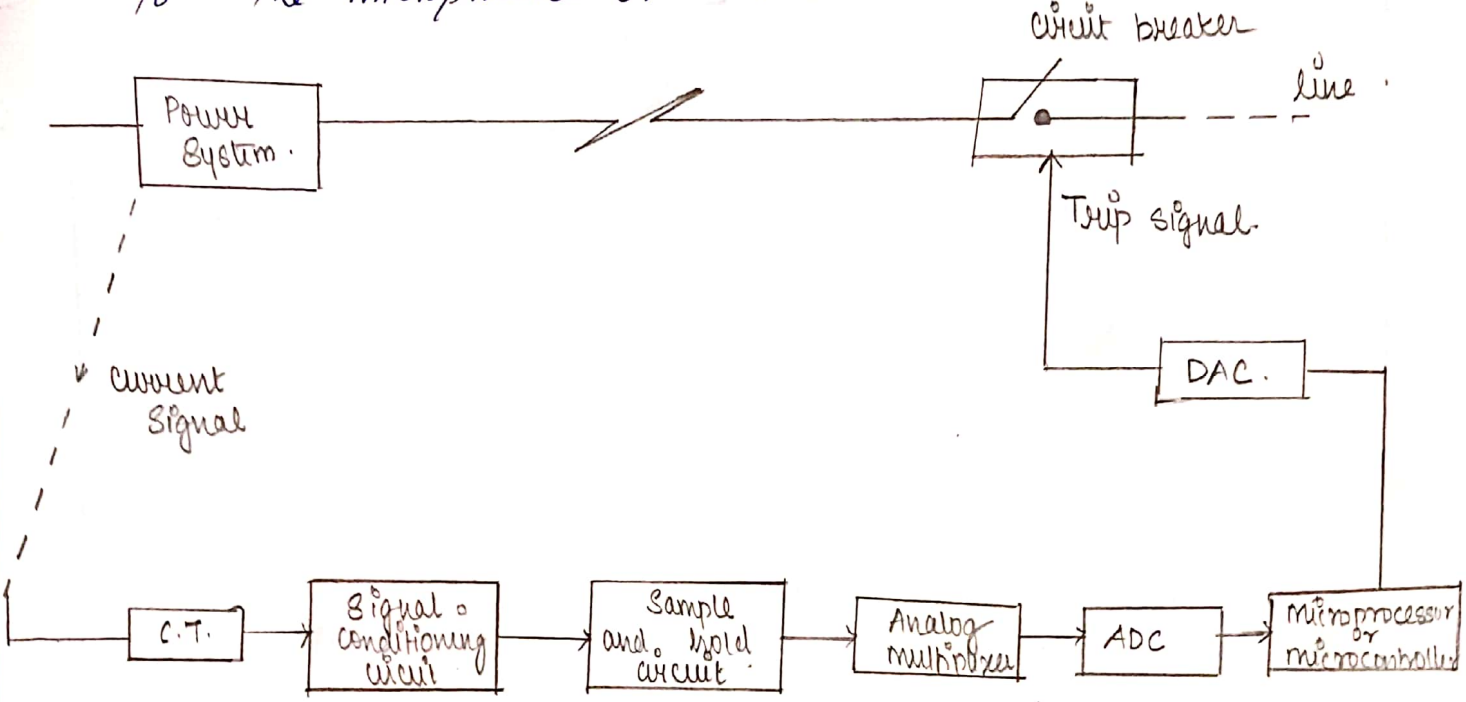
Numerical Overcurrent protection.

The below figure shows the block diagram of numerical overcurrent protection scheme.

The current signal from the power system is brought to the desired level using C.T.

The signal is converted to equivalent digital NUMERICAL OVERCURRENT RELAY Sample and hold circuit, analog multiplexer and ADC in cascade.

The digital voltage signal is then applied to the microprocessor or microcontroller.



It is processed by numerical filter algorithm.

The microprocessor stores the setting such as type & characteristics to be implemented, the pick up value of current, time setting multiplier, the delay if required etc.

The numerical algorithm calculates the rms value of the fundamental component of the fault current.

The dc offset is filtered using fourier transform

Then the rms value of fundamental component of current is compared with the stored pick up value of current to calculate the

plug setting multiplier.

The time is calculated using the expression

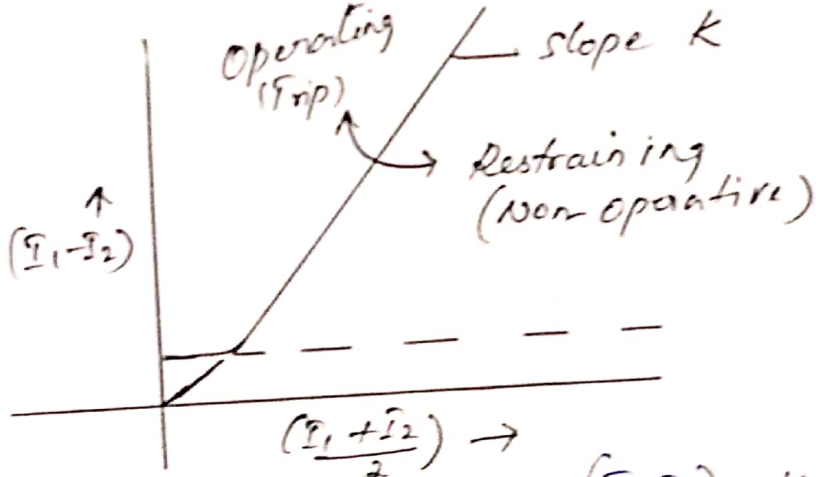
$$t = \frac{K}{I^n - 1}$$

According to the computational result, the microprocessor generates tripping signal.

This is given to the trip coil after passing through DAC, to operate the Circuit breaker

Numerical Differential protection of transformer.

In the percentage differential protection of transformer, the operating coil of the relay carries a differential current which is proportional to the phasor difference $(I_1 - I_2)$ while the restraining coil carries the current proportional to $\frac{(I_1 + I_2)}{2}$

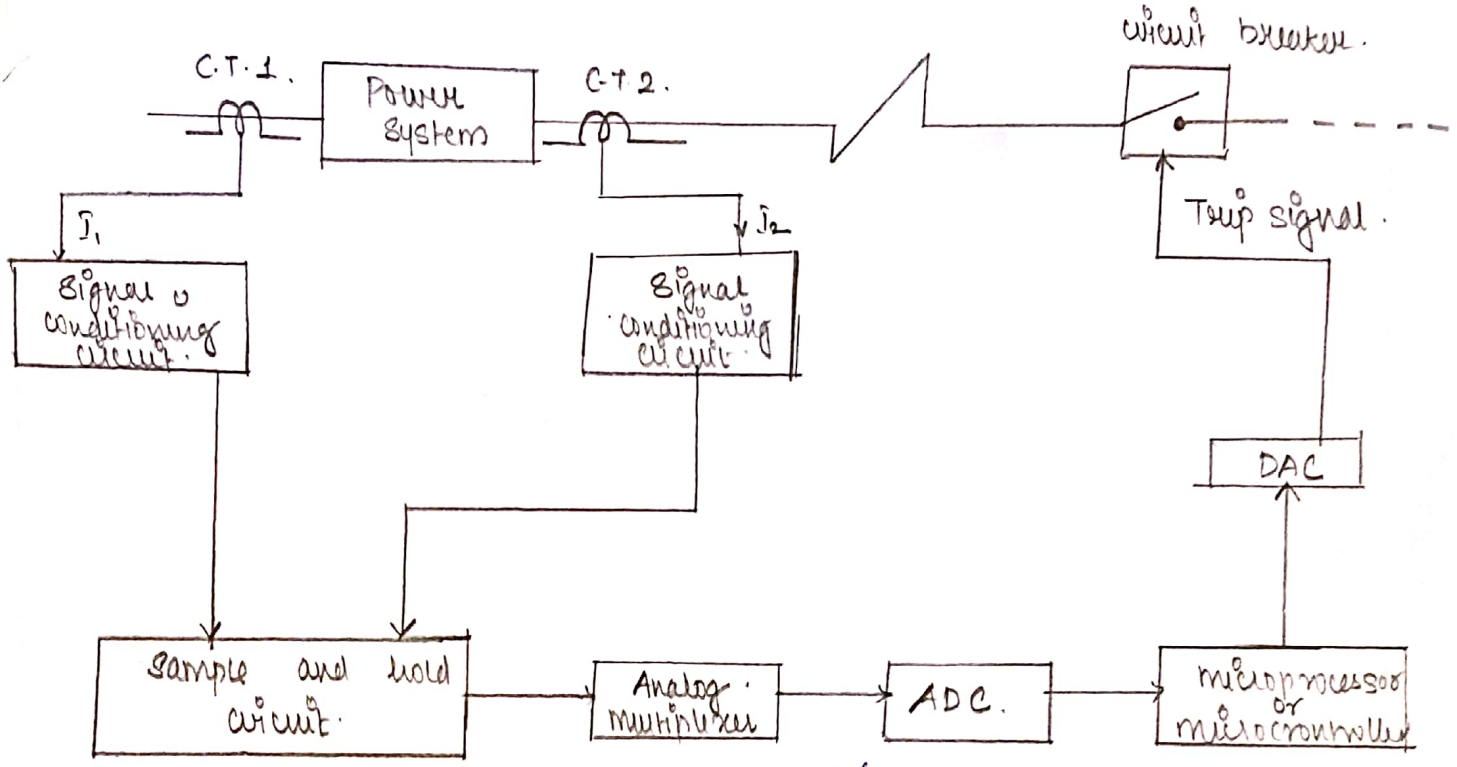


The trip law is $(I_1 - I_2) \geq K \left(\frac{I_1 + I_2}{2}\right)$ → (1)

NUMERICAL DIFFERENTIAL PROTECTION OF TRANSFORMER

where k is the bias i.e slope of the characteristics whose value is between 0.15 to 0.6

From the below figure the currents I_1 and I_2 are sensed by the two CTs and given to



the signal conditioning circuits.

These circuits converts the signals to the proportional voltage signals and extract the signals proportional to the fundamental frequency components of the currents.

The output of signal conditioning circuits is given to the sample and hold circuit.

with the help of sample and hold circuit analog multiplexer and ADC, the equivalent digital signals proportional to I_1 and I_2 are obtained.

These digital signals are given to the microprocessor where they are stored in the memory.

The numerical algorithm is used to check the necessary condition given by equation (1). If it is satisfied, the microprocessor generates a tripping signal.

This signal is given to the trip coil through (DAC). This operates the circuit breaker.

In this type of relay false tripping of a relay because of magnetizing inrush current and over excitation inrush current.

Hence along with the trip law, the following blocking or restraining law is also confirmed by the numerical algorithm.

$$\left.\begin{aligned}(\bar{I}_1 - \bar{I}_2)_2 &\geq 0.15 \quad (\bar{I}_1 - \bar{I}_2)_1 \\ (\bar{I}_1 - \bar{I}_2)_5 &\geq 0.08 \quad (\bar{I}_1 - \bar{I}_2)_1\end{aligned}\right\} \text{Blocking law} \longrightarrow (2)$$

where $(\bar{I}_1 - \bar{I}_2)_2$ is second harmonic,
$(\bar{I}_1 - \bar{I}_2)_5$ is fifth harmonic
$(\bar{I}_1 - \bar{I}_2)_1$ is the fundamental component.

The numerical filtering algorithm is used to extract fundamental, second and fifth harmonic components.

The trip decision is based on conditions given by the equations (1) and (2)

6. Compare static relays with electromagnetic relays.

	Static Relay	Electromagnetic Relay.
1.	Moving parts are absent	Moving parts are present
2.	Response is very quick	Response is slower compared to static relays.
3.	Power consumption is less	More power consumption.
4.	Depends upon temperature	The characteristics of components are not dependent on temperature
5.	Testing and servicing is easy	Servicing is complicated.
6.	Low short time Overload capacity	Higher short time Overload capacity
7.	Less robust	More robust.
8.	Susceptible to voltage fluctuation	Not susceptible to voltage fluctuations and transients.

7. Mention the advantages and limitations of Numerical Relay.

Advantages:-

It uses electronic circuits for functioning and hence is compact in size.

The numerical relay can be made

multifunctional with suitable modifications in software or with slight modification in hardware

Relay characteristics are stored in memory of microprocessor.

It can be easily interfaced with digital communication equipments.

It impose less burden on CT and PT

It has high pick up ratio and greater sensitivity

Tripping time of ½ cycle or less can be achieved with the use of numerical relay.

It has least resetting time.

One unit can perform relaying of several systems.

Very economical for large power systems

Useful for centrally co-ordinated back up protection.

Limitations.

Microprocessor units need properly shielded as gets affected by external interference and environment

proper care of earthing must be taken

It is multifunctional, then failure of one element affects all the systems

It has risk of hacking

The relay can be faster but of no use if circuit breaker operation is not as fast as relay.