## 2. Circuit Breakers.

A CB is a device that can open or close a high voltage ckt. in a fraction of a second. The opening & closing of a ckt. is achieved by the separable contacts of CB. The function of a CB, under the control of protective relays is to open or close the ckt. as per requirements.

When the movable contacts begin to separate, the CB begins interrupting the current. As a result, the contact area decreases. This results in high current density, which finally vapourises the metal and an arc is generated betn the contacts. In spite of physical separation of the contacts, current flows continuously because of the presence of arc. This arc ~~must be~~ plasma must be cooled and extinguished in a systematic way so that the gap betn the contacts can again withstand the voltage in the circuit.

The arc plays an imp. role in the behaviour of CB. The interruption of dc arcs is relatively more difficult than ac arcs. In ac arcs, as the current reaches to zero during the regular cycle, the arc vanishes & it is prevented from restriking.

The techniques adopted for arc extinction can be classified as -

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1. High resistance interruption –

The resis. of the current path is increased rapidly resulting in increased voltage drop. The arc gets extinguished when the sys. voltage can no longer maintain the arc due to high value of voltage drop. The principle is used in dc CBs and air break type CBs of relatively low capacity (few hundred MVA)

2. Current zero interruption –

The arc is interrupted at natural current zero of the alternating current wave and the dielectric strength of the contact gap is increased to such an extent that it can withstand the vltg. stress across it.

3. Artificial current zero interruption –

This principle is used for breaking dc currents in HVDC sys. In dc circuit breakers, the waveform ~~does~~ ~~not~~ does not have natural current zero. Therefore the problem of arc extinction is severe. Hence, by introducing a parallel L-C circuit, the arc current is subjected to oscillations. These oscillations are severe & have several artificial current zeros. The breaker extinguishes the arc at one of the artificial current zeros.

## High resistance interruption

It is obtained by increasing the resistance of arc.

$$R_{arc} = \frac{V_{arc}}{I_{arc}}$$

Assuming $i_{arc}$ to be constant, the resistance of the arc can be increased by increasing the voltage of the arc.

* The volt-ampere char. of a steady arc is given by the eqn,

$$V_{arc} = A + Bd + \frac{C + Dd}{i_{arc}}$$

where, A, B, C, D → constant.
$V_{arc}$ → Vtg across the arc
$i_{arc}$ → current in the arc
d → length of the arc

Hence the arc voltage & eventually the arc resistance can be increased by increasing length of the arc.

The voltage of the arc is increased till it is more than the system voltage across the contacts. At this point the arc gets extinguished.

The arc resis. can be increased by following methods.

a) Lengthening the arc by means of arc runners.

Arc runners are horn like blades of conducting material, which are connected to arcing contacts with their tips radiating

upwards in 'V' shape. The arc originates at the bottom & blows upwards by electromagnetic force. The arc moves upwards along the arc runner rapidly. The length of the arc increases and it is extinguished.

b) Splitting of arc —

The arc is elongated & split by arc splitters. These ~~are~~ are specially made plates of resin bonded fibre glass. These are placed in the path perpendicular to the arc and the arc is pulled into them by electromagnetic force experienced by the arc by means of magnetic field applied in proper direction so as to pull the arc upwards. When the arc is pulled in space betn the plates, it gets elongated, split & cooled. Because of this effect the arc gets extinguished.

The blow out coil produces a magnetic field in ~~the~~ the contacts for the purpose of lengthening & extinguishing the arc. This magnetic field produced is approx. perpendicular to the arc. The interaction betn the arc current & the magnetic field produces a force driving the arc in the direction perpendicular to both, the magnetic field & arc current.

c] Cooling of arc — At the time of contact separation, due to high local

temperature, the gases betn contact space are ionized by thermal ionization by collision. The space betn the contacts is in the state of plasma & hence, is conducting. Thus the arc discharge takes place betn the contacts.

Cooling of the arc brings about recombination of ionized particles. Cooling is brought about by bringing the arc in contact with the air.

Current zero arc extinction -

This method is employed in ac. arc extinction. Actually the alternating current passes through zero 100 time in 1 sec. in 50 Hz freq. At every current zero the arc vanishes for a brief moment, but appears again with the rising current.

To extinguish the arc at current zero, the space betn the contacts is deionized quickly by introducing fresh unionized medium such as oil or fresh air, or $SF_6$ gas betn the contacts. The dielectric strength of the contact space increases to such an extent that the arc does not continues after current zero.

A high Vtg. may appears across the contacts. The voltage may re-establish the arc if the dielectric strength of the gap is less than the restriking voltage. In that case, the arc continues for another half cycle and may get extinguished at next current zero.

## Transient Recovery Voltage (TRV)

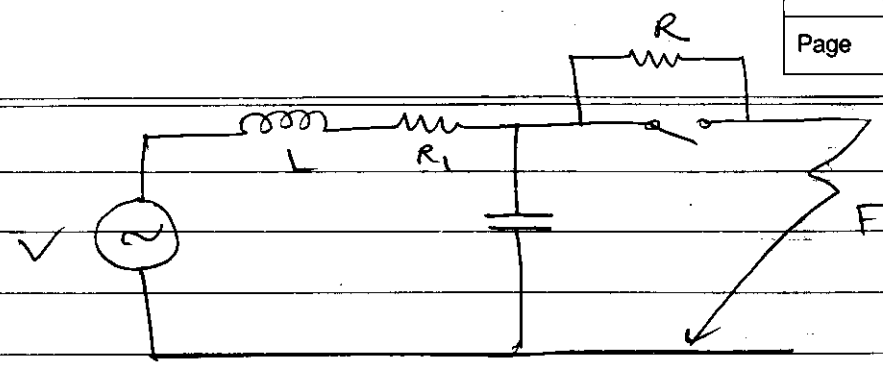
### Resistance Switching

In a.c. CBs, the current interruption takes place at natural zero. After a current zero, the arc gets extinguished if the rate of rise of TRV b/w the contacts is less than the rate of gain of dielectric strength. This voltage has a profound influence on the arc extinction process. This voltage is a transient voltage of higher freq. superimposed on the power freq. sys. vtg.

### Resistance Switching

A fixed connection of resistance in parallel with the contacts or the arc is called resistance switching. Resis. switching is used in CBs having high post zero resistance of contact space. The resistance switching is mainly used for reducing the restriking voltage and the transient voltage surge.

Severe voltage occurs in the system because of two reasons, firstly because of breaking of low voltage current and secondly because of breaking of capacitive current. The severe voltage may endanger the operation of the system. It can be avoided by resistance switching.




When the fault occurs, the contacts of the CB are open and an arc is struck betn the contacts. With the arc shunted by resis. R, a part of arc current is diverted through the resis. This results in the decrease of arc current ~~and an ionization~~ increase in the rate of deionization of the ~~arc~~ arc path.

Thus the arc resis. is increased, leading to the further increase in the current through the shunt resis. R. This process continues until the current becomes so small that it fails to maintain the arc. Now the arc is extinguished.

The shunt resis. also helps in limiting the oscillatory growth of restriking vltg. transients.

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# Interruption of Low Magnetizing current, Current Chopping.

The necessity of interrupting small inductive current arises while disconnecting transformers on no load. No load currents of x'mer ie magnetising currents are almost at zero p.f. lag. The current is smaller then normal current rating of the CB. The breaking of such a low current is imp. duty on the CB.

When interrupting low inductive currents, such as magnetizing currents of x'mer, the rapid deionization of contact space & blast effect may cause the current to be interrupted before its natural zero. This phenomena of interruption of current before its natural zero is called current chopping.

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## Air Break CB.

Refer Lab write-up

## Air Blast CB.

In air blast CB, high pressure air is forced on the arc through a nozzle at the instant of contact separation. The ionized medium betn the contacts is blown away by the blast of the air. After the arc extinction, the chamber is filled with high pressure air, which prevents restrike

Construction – Three hollow insulator columns are mounted on reservoir with valves at their base. Double arc extinguishing chambers are mounted on the top of the hollow insulator chambers. The current carrying parts connect the three arc extinction chambers to each other in series. Since there exists a very high voltage betn the conductors and the air reservoir, the entire arc extinction assembly is mounted on insulators.

Each arc extinction chamber consists of one twin fixed contact & two moving contacts. The moving contacts can move axially so as to open & close

Operation – The operating mechanism operates the rod when it gets a signal. The valves open so as to send high

pressure air in the hollow insulator columns. The high pressure air rapidly enters the double arc extinction chamber. Due to this air, the pressure on the moving contacts becomes more than spring pressure and contacts open. The contacts travel through a short distance against the spring pressure. At the end of contact travel, the port for outgoing air is closed by the moving contacts and the entire arc extinction chamber is filled with high pressure air.

While closing, the valve is turned so as to close the connection bet^n the hollow insulator & the reservoir. The valve lets the air from hollow insulator to the atmosphere. As a result, the pressure of air in arc extinction chamber is dropped down & the moving contacts close over the fixed contacts by spring pressure.

Air blast CBs were preffered for arc furnace duty and in traction system, because they are suitable for repeated duty. But now vacuum CB are preferred.

In case of axial air flow, the air flows from high pressure reservoir to the atmospheric pressure through a convergent divergent nozzle. The difference in pressure & the design of nozzle is

such that as the air expands into low pressure zone, it attains almost supersonic velocity. The air flowing at high speed axially along the arc causes removal of heat from the periphery of the arc & the dia. of the arc reduces to a low value at current zero. At this instance, the arc is interrupted & the contact space is flushed with fresh air flowing through nozzle. The flow of fresh air ensures removal of hot gases & rapid building up of dielectric strength.

## Resistance switching in ABCB.

The post zero resis. of contact space is high in air blast CB. This is because the contact space is filled with high pressure air after final current zero & high pressure air has high dielectric strength. Because of this high post zero resistance, the voltage appearing across the contacts does not damp out. Also voltage of order of several times the normal voltage appear across the contacts. If this voltage is not allowed to discharge, it may cause breakdown of insulation of the CB or the neighbouring equipment. To overcome this difficulty, resistance switching is adopted.

When the air enters the arc extinguishing chamber, it separates main contacts & pushes the auxiliary contacts. As the auxiliary contacts close, the resistors are connected

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across the arc for a short time of arcing. The aux. contacts are located in the inclined V-shaped insulators while the resistors are located in the vertical insulators.

Immediately after arc extinction, the pressure on either side of piston of aux. contacts gets so adjusted that the aux. contacts open & resistor circuit is interrupted.

& dielectric medium

## Bulk Oil CB or Tank type CB.

Oil CBs were used before 1960, but however they are rarely used. A breaker which uses a large quantity of oil for arc extinction is called bulk oil CB or tank type CB. The quantity of oil required in this CB depends on the sys. voltage. Oil is used arc quenching medium as well as as insulation.

The contact separation takes place in the steel tanks filled with oil. The gases formed due to the heat of the arc expand & set the turbulant flow in the oil.

The tension rod is raised by operating mechanism while closing the CB. The opening and closing is obtained by lowering & raising the tension rod. As the cotacts separate, and arc is drawn. This arc is extinguished by the oil & by gases formed by the decomposition of oil.

The arc control devices are normally connected to the fixed contact assembly, such that contact separation takes place inside this semi-enclosed device. The gas produced in the device produces high pressure in it. Thus

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the arc extinction is quick. As the moving contacts leave the arc control device, the trapped gas gets released from the arc control device. While doing so, the arc is extinguished by blast effect

Major disadvantages -

1. Large quantity of oil is necessary in the CB even though only small quantity is required for arc extinction. Large quantity is necessary to provide insulation bet live parts.
2. Entire oil in the tank is likely to get deteriorated due to sluge formation in the proximity of arc. Then entire oil needs replacement.
3. Tanks are too big at 36 kV & above & thus loses its simplicity.

These causes led to development of minimum oil CB. As per name, it requires less oil.

## Minimum oil Circuit Breaker (MOCB)

Also known as poor oil or small oil CB. In MOCB, the current interruption takes place inside the 'interrupter'. The enclosure of interrupter is made of insulating material like porcelain. One pole of a three-pole outdoor MOCB is shown in diag.

There are two chambers, separated from each other, but both filled with oil. The upper chamber is arc extinction chamber. The oil from this chamber does not mix with that in lower chamber. Lower chamber acts like a dielectric support.

Arc extinction device is ~~fixed~~ fitted to the upper fixed contact. The lower fixed contact is ring shaped. The moving contact makes a sliding contact with the lower fixed contacts. A resin bonded glass-fibre cylinder encloses the contact assembly. This cylinder is also filled with oil. Porcelain cylinder encloses the fibre glass cylinder.

The operating rod is operated by operating mechanism. The three poles operate simultaneously. Under normal operating conditions, the moving contact & fixed contacts are in engaged position. During abnormal conditions, the moving contact is pulled down by the tripping springs. With the separation of contacts, an arc is struck betn them. The energy in the arc causes ~~pa~~ vaporisation of oil. This produces ~~gases at~~ high pressure in gases. The pressure built up & the flow

of gases is influenced by the design of arc control device, speed of contact travel, energy liberated by the arc, etc. The gas flowing near the contact zone causes cooling & splitting of the arc. The contact space is filled with fresh dielectric oil after the final arc interruption at a current zero.

Arc control device is fitted to the fixed contact of MOCB. Arc control devices are enclosures of dielectric material fitted to contacts of CB such that actual contacts are separated inside the cavity of the device. At current zero of the wave, the arc diameter is very small and the gas flow is able to interrupt the arc. The interruption of arc stops the generation of gas & flow of oil. The contact space contains hot gases during the brief period after the interruption of arc and high rate of rise of TRV can cause a restrike. To avoid this, the contact travel is extended well beyond the arc control devices so that fresh dielectric oil fill the contact space after the arc extinction.

Advantages:-

1. Quantity of oil required is small
2. Space required is also small
3. Risk of fire is reduced.

Disadvantages -

1. Due to smaller quantity of oil, the degree of carbonisation is increased.
2. The gases are difficult to be removed from the contact space in time.
3. Dielectric strength of oil decreases rapidly as degree of carbonisation is high

Applications -

MOCBs are available for all voltages now.

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# Sulphur Hexafluoride ($SF_6$) CB.

$SF_6$ is an inert, heavy gas having good dielectric and arc extinguishing properties. The dielectric strength of the gas increases with pressure. $SF_6$ is now very widely used in electric equipments like high vltg. metal clad switchgear, CBs, CTs, bushings, etc. This gas liquifies at certain low temp. & the liquification temp. increases with pressure.

Physical properties of $SF_6$ gas:-

- Colourless
- Odourless
- Non-toxic
- Non-inflammable
- Stable - gaseous at normal temp. & pressure
- Heavy gas density nearly 5 times than that of air at 20°C temp. and atmospheric pressure.

Chemical properties:-

- Stable upto 500°C
- inert.- Life of metallic contacts is longer in $SF_6$ gas.
- electronegative gas
- During arc extinction process, $SF_6$ is broken ~~into~~ down to some extentent $SF_4$ & $SF_2$. The products recombine upon cooling to form the original gas. The products of decomposition are toxic & hence

proper care must be taken for their disposal.

## Dielectric properties

1. Dielectric strength of $SF_6$ at atmospheric pressure is 2.35 times that of air and it is 30% less than that of dielectric oil used in oil CB.
2. Dielectric strength of $SF_6$ increases at higher pressure.
3. Rough electrode surfaces reduces the breakdown voltage because with rough surface the ionisation starts early near sharp points on conductors.

## Arc Extinction in $SF_6$ CB.

The arc extinction process is different in $SF_6$ CB than air blast CB.

During the arcing period, $SF_6$ gas is blown axially along the arc. The gas removes the heat from the arc by axial convection & radial dissipation. As a result, the arc diameter reduces & it is small during current zero. Turbulent flow is introduced around current zero to extinguish the arc.

## Merits:-

1. Outdoor EHV $SF_6$ CB has less no. of interrupters per pole than ABCB and MOCB.
2. It is less costly, maintenance free & compact.
3. Same gas is recirculated in the ckt.

4. The breaker is silent & does not make sound like ABCB during operation.
5. Maintainence requirement is low.
6. Ability to interrupt low & high fault currents, magnetizing currents, capacitive currents, etc.
7. Excellent insulating & arc extinguishing properties
8. No frequent contact replacement

Demerits.

1. Due to problem in sealings, imperfect joints lead to leakage of gas.
2. Influx of moisture in the breaker is very harmful to $SF_6$ gas.
3. Arced $SF_6$ gas is poisonous & should not be inhaled or let-out.
4. Special facilities are needed for transportation of gas.

# Vacuum Circuit Breaker

When two current carrying contacts are separated in a vacuum, the arc is drawn betn them. An intense hot spot is created at the instant of contact separation from which metal vapour shoots off, constituting plasma. The amount of ~~vapour~~ Plasma in the ~~plasma~~ Vapour is proportional to the rate of vapour emission from the electrodes, hence to the arc current. With alternating current arc, the current decreases during a portion of wave, and tends to zero. Thereby the rate of vapour emission tends to zero & the amount of plasma tends to zero. Soon after natural current zero, the remaining metal vapour condenses & the dielectric strength builds up rapidly, and restriking of arc is prevented.

This principle is used in vacuum CB. This is an imp. feature of vacuum as an arc quenching medium which will assist arc extinction & restriking of arc is preventedng. The VCB consists of one or more vacuum interrupter units per pole. The unique quality of vacuum interrupters is that the contacts are required to be travelled by small distance & less weight of moving contacts. Many repeated operations can be performed with this type of breaker.

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## Construction -

It consists of vacuum chamber in which fixed contact, moving contact and arc shield. The moving contact is connected to the control mechanism. The contacts are made of large stem with large disc shaped faces. The disc is provided with symmetrical grooves such that segments of two contacts are not along the same line. This geometry facilitates the rapid movement of arc instead of remaining stable at one point & arc remains in diffused state. The outer envelope of the VCB is made up of glass because the glass envelope help in the examination of the breaker from outside after the operation. If the glass becomes milky, then it indicates that breaker is losing vacuum. The metallic bellows made of stainless steel is used to move the moving contacts.

## Working -

When contacts are separated due to some abnormal conditions, an arc is struck betn them. The arc is produced due to ionisation of metal and depends very much on material of contacts. The separation of contacts causes release of vapour which is filled in contact space. The density of vapour depends on the current in the arc. When current decreases, the rate of vapour release decreases and after current zero, the medium regains the dielectric strength if vapour density is

When current to be interrupted is very small in vacuum, the arc has several parallel paths. The total current is divided into many parallel arcs which repel each other & spreads over contact surface. This is called diffused arc which can be interrupted easily. The interruption of arc is possible if the arc remains in diffused state. If it is quickly removed from the contact surface, the arc will be restriked.

After final arc interruption, there is rapid building up of dielectric strength, which is imp. char. of VCB.

Advantages:-

1. Compact in size, longer life.
2. No fire hazards
3. No generation of gas during operation
4. No restriction on interruption of fault current.
5. Quiet in operation.
6. Can withstand lightning surges.
7. Low inertia & hence small power is required for control mechanism

Disadvantages:-

Main disadvantage is there is erosion of material from electrodes

Applications

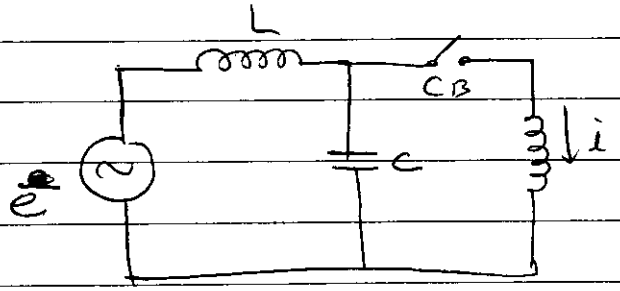
Used in outdoor installations ranging from 22 kV to 66 kV

# Interruption of Low magnetizing Current (Current Chopping).

The necessity of interrupting small inductive current arises while disconnecting transformers on no load. No load currents of x'mer, ie magnetizing currents are almost at zero p.f. lag. The current is smaller than normal current rating of the breaker. The breaking of such a low current presents a severe duty on the CB.

CBs in which the dielectric strength across the contact gaps gets rapidly re-established after current interruption (VCB, ABCB), there is no re-ignition of arc after current chopping & this can lead to inadmissible high switching overvoltage.

When interrupting low inductive currents such as magnetizing currents of x'mer, shunt reactor, the rapid deionization of contact space and blast effect may cause the current to be interrupted before its natural zero. This phenomenon is called current chopping.




Ckt. diag. showing interruption of inductive current

Let the arc current be $i$ when it is chopped down to zero value. The stored energy in the inductor ie $\frac{1}{2}Li^2$ will be discharged in to the capacitor so that the capacitor is charged to a prospective vltg. V such that,

$$\frac{1}{2}Li^2 = \frac{1}{2}CV^2$$

$$\therefore V = i\sqrt{L/C} \quad \text{volts.}$$

This prospective vltg. is extremely high as compared to the normal sys. vltg.

For example, 220 kV CB interrupting a magnetizing current of 10 A rms of x'mer. Let the current be chopped at the instantaneous value of 7 A. Let the value of inductance & capacitance be 35 H & 0.002 μF.

Assuming that all inductive energy is transferred to capacitance, using above formula,

$$V = 7\left[\sqrt{\frac{35}{0.002 \times 10^{-6}}}\right]$$

$$= 926 \text{ kV}$$

This vltg. will appear across CB contacts. Due to such a high transient vltg, there will be restriking of arc at some point. If the arc restrikes, further chop may occur. Thus before final interruption of current, there will be many chops and the CB will fail to clear the fault. Alternately, if the restrike does not occur, severe vltg. stress will appear across CB contacts.

After first chopping, the deionizing force which is still in action, acts and second chop of current takes place. But the arc current is now smaller than the previous one and arc current collapses and restriking voltage is again built. Thus sequence of chops will occur and arc will continuously decrease until a final chop brings arc current to zero. There will not be further restriking as the gap is almost deionized.

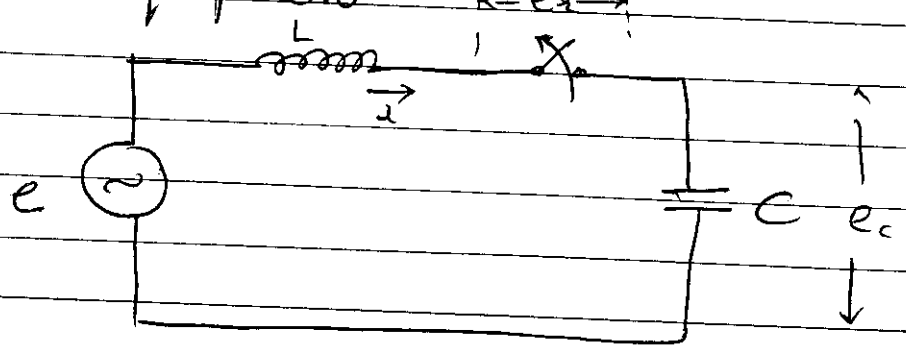
# Interruption of Capacitive Currents.

While opening capacitor banks, the reignition and restriking can occur in an interrupter.

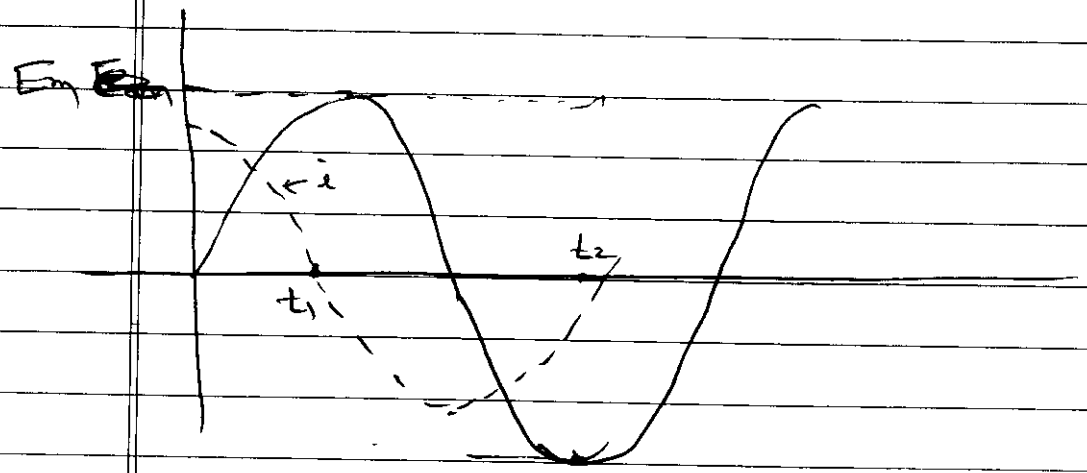
Capacitor banks are connected in the network to provide reactive power at leading p.f. The vltg across a capacitor cannot change instantaneously.

The currents supplied to the capacitor is generally of small order & the CB can interrupt such currents invariably at first current zero.

The application of shunt capacitor banks has become special tool for improving the p.f. It is common practice for utilities to switch on and off the shunt capacitors as per daily load variations. Switching on & off of unloaded T.L. and connecting & disconnecting shunt capacitor banks from the system create a few unique challenges since the vltg across capacitor cannot change instentaneously. This switching causes unwanted high freq voltage & current transients across the CB contacts, which may damage the equipment.



Due to 90° phase difference, the vltg. across capacitor is at max. value ($e_c$) at instant $t_1$ and capacitor remains charged at this vltg ($e_c$).




After half cycle, ie at $t_2$, the recovery voltage reverses and hence the voltage across the breaker is twice the peak value of e ie ($2E_m$) where $e_m$ denotes the max. vltg. and the total vltg. across the CB is sum of the two vltgs,

ie $e_m + e_c$

~~Therefore, restrike is possible~~

Thus a recovery voltage of order of $2E_m$ appears across the CB poles at instant $t_2$, ie after 1/2 cycle of current zero. Therefore restrike is possible.

If a restrike will occur, the LC ckt. will oscillate at a freq. given by $f = \frac{1}{2\sqrt{LC}}$.

This current tries to maintain the arc. The voltage across the CB continues to increase & rises to $4E_m$ after one restrike & $6E_m$ after further restrike.

The energy $\left(\frac{1}{2}CV^2\right)$ dissipated during such arcs is quite large and the interrupters may get damaged in the process.

Hence, the CBs used for capacitor duty should be "restrike free" and should have adequate rating for capacitive current switching so that severe voltage transients can be avoided.

# Static Relays. (Solid state relays).

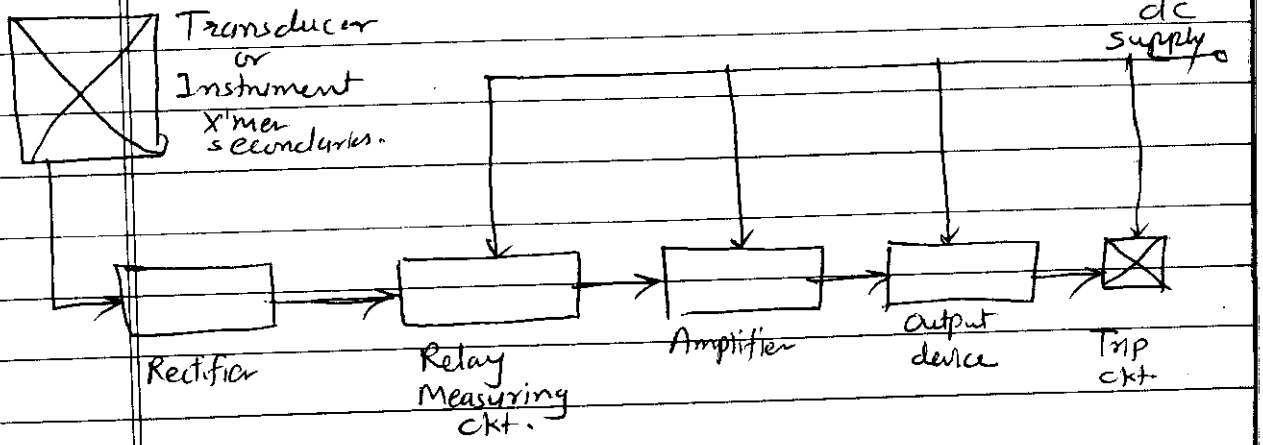
The static relay is the next generation relay after electromechanical type. These relays first introduced in 1960s. The term static implies that the relay has no moving mechanical parts in it. During 1980's, static relays & microprocessor-based integrated, programmable protection, control & monitoring systems have been introduced. The versatile systems perform several tasks including monitoring, protection, data aquisition, display, control etc tasks.

Static relay is an electrical relay in which the response is developed by electronic/ magnetic/ optical or other components, without mechanical motion of components.

A relay which is composed of both static & mechanical units in which the response is accomplished by static units is also called static relay. This is because, the static units obtain the response & electromagnetic unit is only used for switching operation.

In static relays, the measurement is performed by electronic/ magnetic/ optical or or other components without mechanical motion. However additional electromechanical relay units may be used in output stage as auxiliary relays.

The block diag. shows essential components of static relays.




- The output of CTs, PTs, or transducers is rectified in rectifier
- The rectified O/P is fed to the measuring unit. The measuring unit comprises comparators, level detector, filters, logic ckts, etc.
- The output signal from relaying unit (measuring ckt.) is obtained only when the signal reaches the threshold value.
- The O/P of relay measuring unit acts as I/P to the amplifier.
- The amplifier amplifies the signal & gives the O/P to the O/P devices. The O/P device activates the trip coil only when the relay operates. The output is obtained from the O/P device only when the measurand has the well-defined value. The O/P device is activated & gives the trip command to the trip ckt.

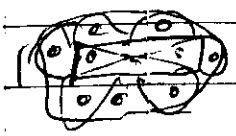
The static relays ~~give~~ only give response to the electrical inputs. The other forms of inputs such as heat, light, magnetic field, travelling waves, etc. first converted to ~~with~~ the analog or digital signals & then

fed as i/p to the static relays.

A multi-input static relay can accept several inputs. The logic ckt of the multi-input static relay can determine the conditions for relay response & sequence of events in the response.

A programmable protection & control system has a microprocessor or microcomputer in its circuit. With the help of the logic circuits and microprocessors, the integrated protection & control system can perform several functions of data acquisition, data processing, data transmission, protection & control. Earlier, for each of these functions separate electromechanical or static units were used along complex wiring.

The types of electronic circuits in the static protection includes analog ckts., digital ckts, ~~hy~~ & hybrid ckts. For very simple functions, ~~alarm~~ analog ckts. are preferred but for complex functions, digital ckts are preferred.



Advanced digital static relays may have programmable sys. A static relay may have one or more programmable units such as a microprocessor. Such relays are called Programmable relays or microprocessor based relays.

The total interconnected power sys is managed by Supervisory Control and Data Aquisition (SCADA) sys; Energy Management

sys. (EMS) and Automatic Generation control (AGC) sys.

Integrated protection and control programmable systems installed in generating station control rooms, substation control rooms and load control centres form the subsystem of SCADA, EMS and AGC sys. These protection & control systems at different locations are linked by means of data transmission channels such as Power line Carrier (PLC), Microwave, fibre optic cables, etc.

Static Vs Electromagnetic Relays.

Choice betn the two depends upon technical requirements, protective functions and overall cost.

For simple protective functions & protection of simple low power equipment, electromechanical relays are preferred.

For complex protection functions requiring accurate characteristics and for protection of costly, large equipment, static relays are preferred.

For integrated protection & monitoring systems, programmable microprocessor controlled static relays are preferred.

## Advantages of Static Relays

1. Low power consumption – it is much lower than their electromechanical equivalent. Due to low power consumption the merits are,
   - less VA rating of CT & PT.
   - Accuracy of CT & PT increases.
   - Problems due to CT saturation are avoided.
   - reduction in cost.

2. Resetting time & Overshoots – can be reduced by using special ckts. & thereby selectivity can be improved.

3. No moving contacts – and problems associated with it like arcing, erosion, replacement of contacts, etc.

4. There is no effect of gravity on operation of static relays.

5. Single relay for several functions – by combining various functional ckts, a single static relay can replace several conventional relays.

6. Compactness – these are compact

7. Superior Characteristic & accuracy – The characteristics of static relays are accurate & superior. They can be altered within certain range as per requirement.

8. Transducers – Several electrical & non-electrical quantities can be converted into electrical

quantities and can be fed to static relays.

9. Static relays can think - Complex protection schemes can employ logic circuits. Logic means process of reasoning, induction or deduction.

10. Programmable operation - Program means sequential instructions that direct the µP in the relay to perform specific functions.

11. Static protection, control & monitoring sys. for substations, power stations, etc form a part of SCADA, EMS and AGC sys.

12. Static relays with PLC can be used for remote back up & network monitoring.

13. Due to no moving parts, repeated operations are possible.

14. Most of components of static relays are relatively indifferent to vibrations & shocks.

15. Self supervison (monitoring) of relay - Static relays have a facility of continuous & comprehensive self-monitoring by a special hardware called 'watchdog' and test software.

16. Static relays are easy in testing & servicing.

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Limitations –

1. Semiconductor components are sensitive to electrostatic discharges.
2. Static relays are sensitive to voltage spikes or VHg transients. Special measures are taken in static relays to overcome this problem.
3. The characteristics of semiconductors are influenced by ambient temperature.
4. For simple, single functions, the price of static relays are higher than equivalent electromechanical ~~relay~~ relays.

# Numerical Relays

Numerical relay is the relay in which the measured AC quantities are sequentially sampled and converted into numerical data that is mathematically and/or logically processed to make trip decisions.

The main driving force for advances in relaying systems was the need to improve reliability. This need caused the development of solid state relays.

Since numerical relays are based on digital technology, they are more or less immune to variation in parameters of individual components due to changes in temperature, ageing, etc. Numerical relays also help in reducing burden on CTs & PTs. This is desirable because, ideally sensor should not consume any power. Numerical relays offer very low impedance to the secondary of CT & hence reduce burden on CT.

Numerical relays permit much more flexibility than electromechanical & solid state relays. In electromechanical relays, the constructional details like magnetic path, air gap, etc are used to design various operating characteristics. Electromech- and static relays have fixed wiring and the setting is manual. Numerical relays, on the other hand, are programmable

relays where the characteristics and behaviour can be programmed. Numerical relays also permit storage of pre & post fault data

Numerical relays are basically digital relays for which manufacturers have developed specified hardware which can be used in conjuction with suitable software to meet different protection needs. It comprises both hardware & software. The hardware part includes - ① CPU, ② memory, ③ input module,

④ sample & hold (S/H) circuit
⑤ Multiplexer
⑥ ADC
⑦ Output module
⑧ software

- CPU is responsible for the processing of protection algorithms
- Memory (RAM & ROM) serves the purpose of retaining the i/p data & processing the data during compilation
- Analog signal from the P.S. is stepped down using CT & PT & then fed to numerical relay using low pass filter. The o/p from filter is then fed to S/H ckt.
- S/H ckt. is used to keep the rapidly changing instantaneous value constant during the period of conversion for processing
- ADC is used to convert analog signal to digital. In case more than one analog quantity is to be converted into digital

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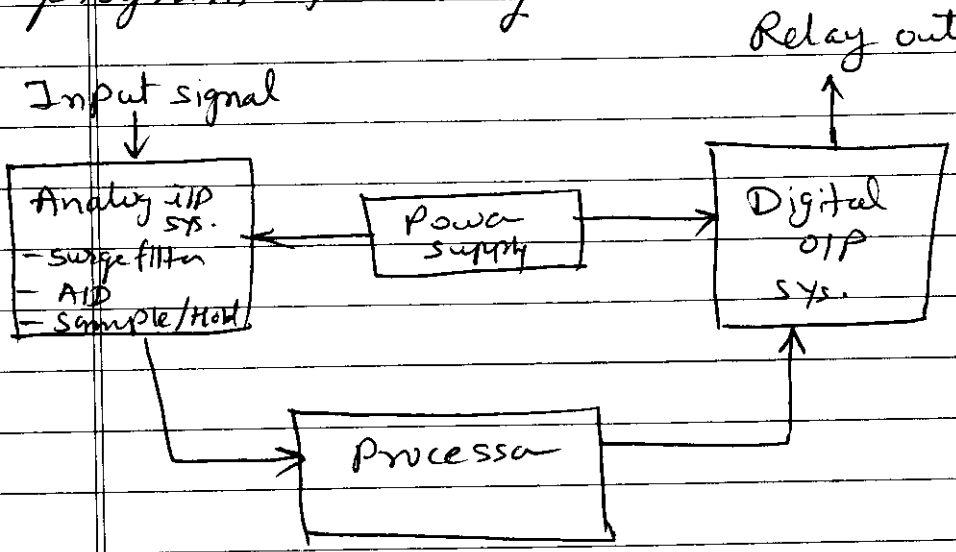
form, multiplexer is used for selecting any analog input at a time.

• Output module is digital contacts which are actuated when a trip decision is taken by the CPU. These output digital contacts are a pulse which is generated as response signal. The timing of the pulse can be changed by the user.

• Numerical relays are equipped with software to communicate with external device and to program the relay




Numerical relay block diag.