Chapter1:Surge arrestors

Surge arresters, also known as surge protectors or lightning arresters, are electrical devices designed to protect equipment and systems from sudden voltage spikes or transient overvoltages. These voltage surges can occur due to various reasons, including lightning strikes, switching operations in the electrical grid, or other electrical disturbances. Surge arresters work by providing a low-impedance path to redirect or limit the excess voltage, preventing it from reaching and damaging connected devices

What Exactly is a Surge Arrester?

A **surge arrester**, as the name suggests, is a device that protects other electrical equipment by "arresting" or discharging surge currents brought about by external (e.g. lightning) or internal (switching events) forces. It is also called a surge protection device (acronym: SPD), or less commonly, a voltage surge suppressor (TVSS).

Because they perform almost the same function on paper, most people usually confuse surge arresters with lightning arresters. However, while lightning arresters are installed outdoors, surge arresters are installed indoors.

How Do Surge Arresters Work?

All appliances and electrical devices have a fixed voltage range. This is a band of operating voltages that indicates the range at which a particular device is designed to safely operate within. If the voltage received by a device is higher than its recommended voltage range, the device may malfunction, its internal components damaged, and even blow up in a worst-case scenario.

So, why would there be a **high voltage transmission** in the first place? It's important to note that voltage fluctuations happen all the time. These can be attributed to a variety of reasons like a corroded, loose connection in your house or building, wiring issues, poor power supply quality, interference, etcetera. Most of the time, these fluctuations do not exceed usual voltage ranges and are thus not a cause of worry. However, there might be instances wherein the voltage fluctuations can experience extreme dips and spikes brought about by lightning storms and switching overvoltages.

Surge arresters limit these overvoltages caused by lightning or switching surges (i.e. surges that occur when operating conditions in an electrical system are suddenly changed). They are not designed to protect against a direct lightning strike if ever one should occur.

But rather, they offer some degree of protection against electrical transients caused by lightning strikes when they occur within the general vicinity of the conductor. In this regard, surge arresters can also divert transients similar to those that come from lightning like those that come from a high voltage system's faulty switching.

Whatever it is that the overvoltage is coming from, a surge arrester works the same way. It either clamps the surge to minimize the voltage that passes through its power system, or it redirects it to the ground. Some surge arresters on the market today come equipped with a "surge counter" component, which is a module that allows the device to capture the occurrence of a discharge.

• Surge Arrester Types and Their Functions

Surge arresters are usually classified according to voltage rating and the amount of protection they can give to a network. Here are some of the common categories that surge arresters used in power systems are classified under:

1. Secondary Arrester

A secondary arrester is an arrester rated under 1000V. They provide another degree of surge protection in a home's service transformer. A transformer's failure rate is estimated to be around 0.4% to 1% (with 50 to 70% of failures caused by low-side surges). With a secondary arrester, this failure rate can be decreased significantly.

2. Station Arrester

When it comes to handling capabilities for high voltages, the station class arresters are the best devices for the job. Among all the arrester types, they are the ones who offer the best discharge voltages and have the capability to withstand the highest of faulty currents. These arresters are available in voltages ranging from anywhere between 3 kV to 684 kV. Station class arresters are also available in different cantilever strengths for various demanding applications.

3. Intermediate Arrester

Intermediate arresters are often used in small substations, or in cases where there's a need for underground cable protection. They are also ideal for dry-type transformers. They can handle high discharge voltages and have a high current resistance capability, albeit at a lower magnitude than that of secondary arresters. Intermediate arresters are available with voltage ratings from anywhere between 3 to 120 kV.

4. Distribution Arrester

Distribution arresters have the lowest protective capabilities when it comes to arrester types. As such, they are only used in medium voltage networks, or in transformers that are elbow and cubicle-mounted.

In areas where there is high lightning activity, a heavy-duty type of surge arrester is used to cope with demands. Areas with less lightning can usually make do with normal duty arresters. In these cases, sometimes an arrester that is positioned on a riser pole is utilized;

- **Type 2 surge arresters from 20 kA to 65 kA**

- Power surges can range from as little as one volt over the threshold maximum of 169 volts to thousands of excess volts, such as when lightning strikes power lines or a transformer.

- When we use ac line having system line voltage 11kv,in this case phase voltage [phase to neutral which is earthed} is 6.351 kv. Lightening arrester is connected between phase and neutral. Lightening arester are nothing but the voltage dependent resistors which act as insulator up to not only the phase volatage ie 6.351 kv but ac peak voltage reaches to 6.351 x root of 2 ie 1.414=8.98 kv. for normal operation of system. thus the L A s are rated for normal voltages 9 kv and discharge current generaly 10 kamp.

- t. A power limit is an upper (lower) bound on power produced (consumed) in the system. To find the power limit cumulative power is maximized for the system containing a fluid, an engine or a sequence of engines, and an infinite bath.

Surge arrestors maintenance steps:

1. **Visual Inspection:**
   - Regularly inspect the surge arresters for any signs of physical damage, such as cracks, dents, or corrosion.
   - Check for loose connections or damaged fittings.
2. **Clean the Surface:**
   - Clean the surface of the surge arresters to remove dirt, dust, or other contaminants that may accumulate over time.
   - Use a soft cloth or sponge and a mild cleaning solution. Avoid using abrasive materials that could damage the surface.
3. **Check Grounding:**
   - Ensure that the surge arresters are properly grounded. A good ground connection is crucial for the effective operation of the arrester.
   - Inspect the grounding system for corrosion or damage and make any necessary repairs.
4. **Inspect Seals and Gaskets:**
   - Examine seals and gaskets for signs of wear or deterioration. Replace any damaged or worn seals to maintain the arrester's integrity.
5. **Verify Voltage Ratings:**
   - Confirm that the surge arresters are rated for the system voltage they are protecting.
   - Replace any surge arresters that have exceeded their maximum voltage rating.
6. **Perform Insulation Resistance Tests:**
   - Conduct insulation resistance tests to ensure that the insulation in the surge arrester is intact.

- Follow manufacturer guidelines for testing procedures and acceptable resistance values.

7. **Review Operating History:**
    - Keep records of any overvoltage events and the arrester's response to them.
    - Analyze the operating history to identify patterns or trends that may indicate potential issues.
8. **Conduct Periodic Testing:**
    - Perform periodic testing of surge arresters to ensure their continued effectiveness.
    - Follow the manufacturer's recommendations for testing intervals and procedures.
9. **Replace Aging Arresters:**
    - Surge arresters have a limited lifespan. Replace aging arresters according to the manufacturer's recommendations or industry standards.
    - Consider replacing surge arresters if they have experienced multiple high-stress events.
10. **Follow Manufacturer Guidelines:**
    - Always follow the specific maintenance guidelines provided by the manufacturer of the surge arresters.
    - Adhere to any maintenance schedules and procedures outlined in the product documentation.
11. **Consult with Experts:**
    - If in doubt or if more extensive maintenance is required, consult with experts or the manufacturer for guidance.
    - Consider involving qualified personnel or technicians for in-depth inspections and maintenance.

Signs of defect in surge arresters :

1. **Physical Damage:**
    - Visible cracks, dents, or punctures on the housing of the surge arrester.
    - Evidence of corrosion on the surface.
2. **Leaking Seal or Gasket:**
    - Presence of moisture or contaminants inside the surge arrester, indicating a compromised seal or gasket.
3. **Loose Connections:**
    - Loose or disconnected electrical connections, which can reduce the effectiveness of the surge arrester.
4. **Overheating:**
    - Excessive heat or discoloration on the surface of the surge arrester, which may indicate overheating during operation.
5. **Burn Marks:**
    - Burn marks or discoloration on the housing, terminals, or nearby components, suggesting that the surge arrester has experienced high-energy surges.
6. **Visible Arcing or Discharge:**
    - Evidence of visible arcing or discharge marks on the surface of the surge arrester.
7. **Change in Physical Dimensions:**

- Any significant change in the physical dimensions of the surge arrester, such as swelling or deformation, which may indicate internal damage.

8. **Insulation Resistance Issues:**
    - Low insulation resistance values during insulation resistance testing, indicating a breakdown in the internal insulation.
9. **Exceeded Maximum Voltage Rating:**
    - The surge arrester has experienced overvoltage events that exceed its maximum voltage rating.
10. **Failure to Operate During Overvoltage Events:**
    - If the surge arrester fails to operate effectively during a high-voltage surge event, it may indicate a defect.
11. **Aging and End of Life:**
    - Surge arresters have a limited lifespan. If an arrester has exceeded its expected service life, it may be more prone to failure.
12. **Inconsistent Operating History:**
    - Inconsistent or unexpected operating history, such as frequent activations or erratic response to surges, may indicate a problem.
13. **Corrosion on Grounding System:**
    - Corrosion or damage to the grounding system associated with the surge arrester can affect its overall performance.
14. **Faulty Monitoring or Indication Devices:**
    - If the surge arrester is equipped with monitoring or indication devices, any faults or discrepancies in their readings may signal a defect.
15. **Audible Noise or Vibration:**
    - Unusual audible noise or vibration during normal operation may indicate internal arrester issues.
16. **Ingress of Foreign Material:**
    - Presence of foreign materials (dirt, insects, or debris) inside the surge arrester, which can compromise its functionality.
17. **Mismatched or Incorrect Voltage Rating:**
    - Incorrect installation with surge arresters having a voltage rating incompatible with the system they are meant to protect.
18. **Excessive Leakage Current:**
    - Abnormally high leakage current, which can be measured during routine tests, may suggest internal breakdown or contamination.
19. **Reduced Capacitance:**
    - A significant decrease in capacitance values during capacitance testing, signaling potential issues with the internal components.
20. **Faulty Thermal Protection:**
    - Malfunctioning or damaged thermal protection devices, which are designed to prevent overheating.
21. **Environmental Exposure:**
    - Extended exposure to harsh environmental conditions without proper protection, leading to accelerated degradation.
22. **Mismatched Surge Arrester Characteristics:**
    - Installation of surge arresters with characteristics that do not match the requirements of the specific application.
23. **Sudden Increase in Surge Count:**
    - A sudden and unexplained increase in the number of surge events recorded, which may indicate a spike in electrical disturbances or a malfunction.

24. **Obsolete Technology:**
    - Use of outdated surge arrester technology that may not provide optimal protection for modern systems.
25. **Lack of Compliance with Standards:**
    - Non-compliance with industry or safety standards, which could compromise the effectiveness of the surge arrester.
26. **Excessive Voltage Drop:**
    - Measured voltage drop across the surge arrester terminals that exceeds acceptable limits.
27. **Failure to Reset:**
    - If the surge arrester has a resettable feature, failure to reset after a surge event may indicate an internal fault.
28. **Moisture or Contamination Ingress:**
    - Evidence of moisture or contamination ingress through seals or gaskets during inspections.
29. **Improper Storage:**
    - Improper storage conditions leading to physical damage or deterioration of the surge arrester components.
30. **Intermittent Operation:**
    - Intermittent or sporadic activation during normal operating conditions, suggesting internal issues affecting consistency.

Limitations in terms of voltage for safety in surge arrestors:

1. **Maximum Continuous Operating Voltage (MCOV):**
    - MCOV values for surge arresters can range from a few hundred volts to several thousand volts, depending on the application. For example, MCOV for low-voltage surge arresters might be in the range of 150V to 600V, while medium- and high-voltage arresters could have MCOV values ranging from 1kV to 96kV or more.
2. **Voltage Protection Level (Up):**
    - The Voltage Protection Level (Up) represents the maximum voltage the surge arrester allows downstream during a surge event. Common Up values for low-voltage arresters might be in the range of 1.5kV to 3kV, while medium- and high-voltage arresters could have Up values ranging from 5kV to 30kV or more.
3. **Temporary Overvoltage Limitations:**
    - Surge arresters are designed to handle temporary overvoltages, but the specific duration and magnitude can vary. Temporary overvoltage limitations might be in the range of 1.2 to 1.5 times the MCOV for a specific period (e.g., 8/20 microseconds).
4. **Protective Margin:**
    - The protective margin is the difference between the MCOV and the Up. For example, if the MCOV is 10kV and the Up is 5kV, the protective margin is 5kV.
5. **Extreme Overvoltage Events:**

    - Surge arresters are designed to handle a certain level of extreme overvoltage events, such as lightning strikes. Lightning surges can reach tens or even hundreds of kilovolts. Surge arresters for high-voltage applications might have discharge voltages (Uc) of 20kV to 100kV or more.
6. **Grounding Quality:**
    - The effectiveness of surge arresters is closely tied to the quality of the grounding system. Surge arresters may be specified to work with specific ground resistance values, such as 5 ohms or less.
7. **Frequency Limitations:**
    - Surge arresters are designed for specific frequency ranges. Common frequency ranges for surge arresters include the power frequency (50Hz or 60Hz) as well as higher frequencies associated with transient surges.

Chapter 2: Transformer

transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. It typically consists of two coils of wire, known as the primary and secondary windings, which are wrapped around a common magnetic core. The primary winding is connected to the input voltage source, and the secondary winding is connected to the load. The primary and secondary windings are electrically isolated from each other but magnetically coupled through the core.

Transformers maintenance steps:

1. **Visual Inspection:**
   - Conduct a visual inspection of the transformer, checking for any signs of oil leaks, corrosion, loose connections, or physical damage. Inspect the cooling system, radiators, and bushings.
2. **Oil Level Check:**
   - Verify the oil level in the transformer. Maintain the oil level within the recommended range. Top up the oil if necessary, and ensure that the oil is free from contaminants.
3. **Oil Quality Analysis:**
   - Perform oil quality analysis by collecting oil samples. Test for factors such as moisture content, acidity, and the presence of dissolved gases. Analyzing oil can provide valuable information about the condition of the transformer and potential issues.
4. **Temperature Monitoring:**
   - Monitor the operating temperature of the transformer. Check the accuracy of temperature gauges and control devices. High temperatures may indicate a problem with cooling or an overloading condition.
5. **Insulation Resistance Testing:**
   - Conduct insulation resistance tests to ensure the integrity of the insulation system. Measure the resistance between windings and between windings and ground. Low insulation resistance may suggest insulation deterioration.
6. **Dissolved Gas Analysis (DGA):**
   - Perform Dissolved Gas Analysis on oil samples to detect any abnormal concentrations of gases, especially those associated with thermal or electrical faults. Abnormal gas levels can be indicative of internal issues.
7. **Bushings and Insulators:**
   - Inspect bushings and insulators for cracks, contamination, or tracking. Clean or replace as needed. Check for proper alignment and ensure that the insulators are in good condition.
8. **Tap Changer Maintenance:**
   - If the transformer has an on-load tap changer, inspect and maintain it regularly. Ensure that tap changer operations are smooth and that there are no signs of arcing or overheating.
9. **Cooling System Check:**
   - Verify the proper functioning of the cooling system, whether it's air or liquid cooling. Clean radiators, fans, or other cooling components to ensure efficient heat dissipation.
10. **Buchholz Relay Inspection:**

- If the transformer is equipped with a Buchholz relay, check its operation. The Buchholz relay detects faults such as internal arcing or gas generation in the transformer oil.

11. **Load and Voltage Regulation:**
    - Verify the transformer's load-carrying capacity and its ability to regulate voltage within specified limits. Ensure that the transformer can handle the connected load adequately.
12. **Corona and Partial Discharge Monitoring:**
    - Periodically monitor for corona discharges and partial discharges. These phenomena can lead to insulation breakdown and should be addressed to prevent further deterioration.
13. **Documentation Review:**
    - Review and update transformer documentation, including maintenance records, test reports, and operating manuals. Maintain a record of all maintenance activities.
14. **Safety Checks:**
    - Prioritize safety during maintenance activities. Follow proper safety procedures, including lockout/tagout, and use appropriate personal protective equipment.

Signs of defects in transformers:

1. **Abnormal Noise:**
   - Unusual humming, buzzing, or other abnormal sounds during transformer operation may indicate issues such as loose laminations, mechanical problems, or partial discharges.
2. **Oil Leaks:**
   - Visible signs of oil leaks or puddles around the transformer, suggesting a potential issue with the transformer's insulation or gaskets.
3. **Discolored Oil:**
   - Changes in the color of the transformer oil, such as darkening or contamination, may indicate thermal degradation, overheating, or the presence of foreign materials.
4. **Overheating:**
   - Elevated operating temperatures beyond normal levels may be a sign of overloading, cooling system issues, or problems with the transformer's internal components.
5. **Irregularities in Oil Level:**
   - Fluctuations in oil level that cannot be attributed to normal temperature variations may indicate leaks, improper maintenance, or other issues.
6. **Corona Discharge:**
   - Visual signs of corona discharge, such as a bluish glow, can be an indication of electrical breakdown and partial discharges within the transformer.
7. **Leaking Gases:**
   - Detection of gases, such as hydrogen or methane, which may be produced by internal faults or decomposition of insulating materials.
8. **Buchholz Relay Activation:**
   - Activation of the Buchholz relay, a protective device that detects internal faults like short circuits or gas accumulation, may indicate a serious problem.

9. **Visual Inspection of Windings:**
    - Physical inspection of the windings for signs of discoloration, hot spots, or visible damage.
10. **Unusual Vibrations:**
    - Excessive vibrations or mechanical movements may be a sign of issues with the core, windings, or other internal components.
11. **Insulation Resistance Decrease:**
    - A decrease in insulation resistance, measured during routine testing, may indicate insulation breakdown or contamination.
12. **Frequent Tripping or Overloads:**
    - Frequent tripping of protective relays or overloading of the transformer may suggest internal faults or issues with the load.
13. **Changes in Power Factor:**
    - Significant changes in power factor during operation may indicate problems with the insulation or internal components.
14. **Failure to Regulate Voltage:**
    - Inability to regulate output voltage within acceptable limits may indicate issues with the tap changer or voltage regulation mechanisms.
15. **Aging Indicators:**
    - Signs of aging, such as degraded insulation, worn-out bushings, or signs of rust and corrosion on external surfaces.
16. **Smoke or Burning Smell:**
    - The presence of smoke or a burning smell near the transformer could indicate an electrical fault, overheating, or insulation breakdown.

Limitations in terms of voltage for safety in transformers:

- **Maximum Voltage Rating:**

    - Transformers are assigned maximum voltage ratings to ensure safe operation. For example:
        - Distribution transformers might have maximum voltage ratings in the range of 11 kV to 36 kV.
        - Power transformers used in high-voltage transmission networks could have maximum voltage ratings ranging from 110 kV to 765 kV or more.

- **Impulse Withstand Voltage:**

    - Transformers are subjected to impulse voltage tests to ensure their ability to withstand lightning surges. The impulse voltage rating depends on factors like insulation design and application:
        - Power transformers may have impulse withstand voltages of 650 kV or higher.

- **Nominal System Voltage:**

- Transformers are designed to operate at specific nominal system voltages. Examples include:
  - Distribution transformers for 11 kV or 33 kV systems.
  - Power transformers for 230 kV or 400 kV systems.

- **Voltage Regulation Limits:**

  - Transformers have specified voltage regulation capabilities to maintain voltage within acceptable limits under varying load conditions. The regulation might be expressed as a percentage of the rated voltage. For example:
    - A power transformer might have a voltage regulation of ±5%.

- **Dielectric Strength:**

  - Transformers are designed with specific dielectric strength values to withstand electric stress without breaking down. For example:
    - The dielectric strength of transformer oil might be in the range of 30 kV to 80 kV or more.

Precautions of Power Transformer

All accessories / fittings / components dispatched separately should be thoroughly cleaned inside and outside before being fitted. Same should be fixed in their respective places according to the relevant drawings. If rusting observed in any part of the transformer, same to be cleaned and touch up paint should be applied.

• Workmen accessing the interior of a transformer tank should empty their pockets of all loose articles. Any spanners or other tools used should be securely tied with a tape / thread and attached at tank top, so that they can be recovered, if accidentally dropped into the tank especially for higher capacity voltage ratings of transformers.

• Fibrous cleaning materials MUST not be used. The presence of loose fiber suspension, in insulating oil, can reduce its insulating properties. If any cleaning or wiping is necessary this must be done with clean and dry soft non-fluffy cloth only.

• Insulating oil is inflammable and under certain circumstances in a confined space, may become explosive.

• Air drawn into the transformer through semi-tight joints or along with the oil may be drawn into the windings thus reducing the insulation. To prevent this, all joints / covers in any extended oil pipe work must be air tight to the required value of torque as defined.

• Under normal circumstances, it is NOT necessary to access the internal parts of the tank. Also, all the required tools / tackles / instruments are generally not available at site for the proper handling access.

- **Transformer Maintenance Checks on a Monthly Basis**

1. Oil level in the oil cap must be checked on a monthly basis so that it doesn't drop below a fixed limit and hence avoid damage due to it.
2. Keep the breathing holes in the silica gel breather clean to ensure proper breathing action at all times.

3. If your electrical transformer has oil filling bushing, make sure that the oil is filled up to the correct level.

- **Daily Basis Maintenance Testing and Checking**

Here are 3 maintenance tests you should run on your transformer on a daily basis:

1. Oil levels of MOG(Magnetic Oil Gauge) of the main tank and conservator tank. Always maintain to keep oil filled up to the desired level in MOG.
2. Replace the silica gel if its color changes to pink.
3. If any leakage is detected seal it.

- **Annual Transformer Maintenance Schedule**

The air fans, oil pumps along with other items that are used to cool down a transformer and control circuit must be inspected annually.

1. Make sure that you clean all the bushings of your electrical transformer with only soft cotton cloth annually.
2. Oil condition of OLTC should be carefully examined on an annual basis. For that take an oil sample from drain valve and test it for moisture content (PPM) and dielectric strength (BDV). If the BDV value is found low and the PPM value high, then the oil needs to be replaced.
3. Make sure to clean out the inside of all of the marshalling boxes annually. Check proper functioning of the space and illumination heaters. All of the terminal connections of control and relay wiring need to be tightened at least once a year.
4. All the control switches, alarms and relays along with their circuits, Remote Tap Changer Control Panel and Relay and Control Panel have to be cleaned with a proper cleaning agent.
5. Examine all the pockets for the Winding Temperature Indicator and Oil Temperature Indicator if they have the necessary level of oil and make sure to top it up if required.
6. The proper function of Buchholz and Press Release Device relay need to be checked on a yearly basis.
7. Make sure to measure the resistive value of the earth connection and rizer should be measured annually with a clamp on the earth resistance meter.

- **Transformer Maintenance on a Half Yearly Basis**

Your electrical transformer needs to be checked every 6 months for IFT, DDA, flash point, sludge content, acidity, water content and dielectric strength along with how resistant it is to transformer oil.

- **Maintenance of Current Transformer**

A current transformer is a vital part of any equipment installed in an electrical substation for protection purposes as well as for electrical measurement. Insulation resistance of the CT has to be checked on an annual basis.

1. Thermo vision scanning of primary terminals and the top dome of a live CT must be conducted on an annual basis.
2. All CT secondary connections should be examined, cleaned and tightened each year to ensure that the secondary currents have the lowest resistance path

Chapter 3:Reactors

Reactors, in the context of electrical engineering, are passive components used in electrical circuits to control or manage the flow of electrical current. They are often coil-like devices made of conductive material such as copper wire wound around a core made of ferromagnetic materials like iron.

In an AC circuit, reactance is the opposition to current flow. A reactor, also known as a line reactor, is a coil wired in series between two points in a power system to minimize inrush current, voltage notching effects, and voltage spikes. Reactors may be tapped so that the voltage across them can be changed to compensate for a change in the load that the motor is starting. Reactors are rated by the ohms of impedance that they provide at a given frequency and current. Reactors may also be rated by the I2R loss across the device at a certain frequency at a rated current.

Two common types of reactors are the dry-type and the oil-immersed. The dry-type is open and relies on the air to circulate and dissipate the heat. Dry-type reactors are common in low-voltage applications.

Oil-immersed reactors are common in high-voltage applications. Oil-immersed reactors are placed in tanks and require a magnetic shield to prevent eddy currents from circulating in the tank. The shield is made from laminated steel sheets like the transformer core and motor stators.

1.

SCOPE : This specification covers the design, manufacturing, assembly, testing at manufacturer's works, supply and delivery at site of 3-ph., 50 MVAR & 80 MVAR, 420 KV Shunt Reactor for 400 KV bus complete with fittings and accessories for efficient and trouble free operation.

2. DEVIATION: Normally the offer should be as per Technical Specification without any deviation. But any deviation felt necessary to improve performance, efficiency and utility of equipment must be stated with reasons duly supported by documentary evidence. Such deviations suggested may or may not be accepted by the WBSETCL.

3. DUTY REQUIREMENTS:

a) 3-Phase Shunt Reactors will be connected to 400 KV bus for reactive power compensation and it shall be capable of controlling the dynamic over voltage occurring in the system due to load rejection.

b) The Shunt Reactor shall be capable of withstanding maximum continuous operating voltage (5% higher than the rated voltage) under normal frequency variation of the system without exceeding the hot spot temperature of 150 0 C at any part of the Reactor.

c) The Shunt Reactor shall be capable of withstanding temporary over voltage and frequency fluctuation.

4. STANDARD : The Reactor covered under this specification shall comply with the performance and other requirements of the latest edition of IS:5553 or relevant IEC publication 289 as amended up to date except where specified otherwise in the specification. Characteristics of oil shall be as per IS:335. Equipment meeting the requirements of any other authoritative standards/internationally recognised standard other than those specified in the preceding clause which ensure equal or better quality than the standard mentioned above shall also be acceptable

provided salient points of difference between the standard adopted and the specified standard clearly brought out in the tender and English version of the standard shall be furnished

reactors maintenance steps:

1. **Visual Inspection:**
    - Conduct a visual inspection of the reactor for any signs of physical damage, corrosion, loose connections, or overheating. Check for discoloration, burning, or unusual marks on the surface.
2. **Check Cooling System:**
    - If the reactor is equipped with a cooling system (such as fans or heat sinks), ensure that it is functioning properly. Clean cooling fins, remove any dust or debris, and check for proper airflow.
3. **Verify Mounting and Alignment:**
    - Ensure that the reactor is securely mounted and properly aligned. Check for any mechanical issues that could affect its stability or performance.
4. **Inspect Terminals and Connections:**
    - Examine the terminals and connections for tightness and signs of corrosion. Tighten any loose connections and clean terminals if necessary. Ensure that all electrical connections are secure.
5. **Measure Electrical Parameters:**
    - Use appropriate testing equipment to measure relevant electrical parameters, such as inductance and resistance. Compare the measured values with the specified values to identify any deviations.
6. **Check Insulation Resistance:**
    - Measure the insulation resistance of the reactor to ensure that it meets the specified requirements. Low insulation resistance can indicate potential insulation breakdown.
7. **Inspect for Contaminants:**
    - Inspect the reactor for the presence of contaminants such as dust, moisture, or foreign materials. Clean the reactor if necessary to prevent these contaminants from affecting its performance.
8. **Inspect the Core:**
    - If the reactor has a magnetic core, inspect it for any signs of damage, rust, or mechanical issues. Ensure that the core is securely in place and that there are no loose or damaged laminations.
9. **Check for Vibrations and Noise:**
    - During operation, listen for unusual vibrations or noise that may indicate mechanical issues. Address any abnormal sounds promptly to prevent further damage.
10. **Thermal Imaging:**
    - Use thermal imaging equipment to identify any hotspots or areas of abnormal temperature. Overheating can be a sign of increased resistance or other issues.

11. **Perform Functional Testing:**
    - If possible, conduct functional testing of the reactor under normal operating conditions. Verify that it responds correctly to changes in load and that it performs its intended function.
12. **Record Maintenance Activities:**
    - Maintain a comprehensive record of all maintenance activities, including inspections, tests, and any corrective actions taken. This documentation is valuable for tracking the reactor's performance over time.
13. **Schedule Regular Maintenance:**
    - Establish a regular maintenance schedule based on the manufacturer's recommendations and industry best practices. Regular inspections and preventive maintenance can help identify issues before they escalate.
14. **Consult Manufacturer Guidelines:**
    - Refer to the manufacturer's guidelines and specifications for specific maintenance requirements and recommendations. Follow any maintenance procedures provided by the manufacturer.

Signs of defects in reactors :

1. **Physical Damage:**
    - Visible signs of physical damage, such as cracks, dents, or deformities on the reactor housing or core.
2. **Corrosion:**
    - Corrosion on the metal parts of the reactor, which can weaken its structural integrity and affect performance.
3. **Loose Connections:**
    - Loose or damaged electrical connections, including terminals and bus bars, which can result in increased resistance and overheating.
4. **Overheating:**
    - Elevated temperatures during operation, which may be indicated by discoloration, burning smells, or visual signs of overheating.
5. **Unusual Noise or Vibrations:**
    - Unusual humming, buzzing, or other sounds during operation, as well as excessive vibrations, which may indicate mechanical issues.
6. **Insulation Breakdown:**
    - Signs of insulation breakdown, such as tracking, burning, or discoloration, which may occur due to overvoltage conditions.
7. **Changes in Electrical Parameters:**
    - Deviations from specified electrical parameters, such as inductance or resistance, which can be measured using testing equipment.
8. **Increased Current:**
    - An unexpected increase in current flowing through the reactor, which may be observed through current measurements.
9. **Failure to Limit Current:**
    - If the reactor is designed to limit or control current, a failure to do so under normal operating conditions may indicate a defect.
10. **Arcing or Sparks:**
    - Visible signs of arcing or sparks, which may occur at electrical connections or within the reactor, indicating a breakdown in insulation.
11. **Oil Leaks (For Oil-Filled Reactors):**

    - For oil-filled reactors, the presence of oil leaks or puddles around the reactor may indicate a problem with the insulation or sealing.
12. **Change in Electrical Performance:**
    - Changes in the electrical performance of the reactor, such as a shift in its impedance characteristics or resonance frequency.
13. **Thermal Imaging Abnormalities:**
    - Abnormal temperature patterns observed through thermal imaging, indicating localized heating or cooling issues.
14. **Inconsistent Operation:**
    - Inconsistencies in the reactor's operation, such as failure to respond appropriately to changes in load or voltage conditions.
15. **Burning Smells:**
    - The presence of burning smells or odors during operation, suggesting potential insulation or overheating issues.
16. **Frequent Failures:**
    - If the reactor experiences frequent failures or malfunctions, it may be indicative of underlying defects.

Limitations in terms of voltage for safety in reactors:

1.Voltage Rating:

- The voltage rating of a reactor is typically specified by the manufacturer. For example:
    - Low-voltage reactors may have voltage ratings in the range of 220V to 1kV.
    - Medium-voltage reactors could have ratings in the range of 1kV to 36kV.
    - High-voltage reactors may have ratings from 36kV and above.

2. **Insulation Breakdown:**
    - The insulation breakdown voltage depends on the insulation materials used. For instance:
        - Insulation breakdown voltage for low-voltage reactors may be around 1kV to 2kV.
        - Medium-voltage reactors may have breakdown voltages in the range of 5kV to 20kV.
        - High-voltage reactors could have breakdown voltages of 30kV and above.
3. **Dielectric Strength:**
    - Dielectric strength is specified by the ability of the insulation to withstand electric stress. Values may vary based on insulation materials and design:
        - Low-voltage reactors might have dielectric strength values around 1.5kV to 3kV.
        - Medium-voltage reactors could have dielectric strength values ranging from 10kV to 30kV.

        - High-voltage reactors may have dielectric strength values exceeding 50kV.
4. **Transient Overvoltages:**
    - Reactors are designed to handle transient overvoltages during normal operation. The tolerance for transient overvoltages may vary, but for example:
        - Low-voltage reactors may withstand transient overvoltages up to 1.5 times their rated voltage.
        - Medium-voltage reactors may tolerate transient overvoltages up to 1.8 times their rated voltage.
        - High-voltage reactors could handle transient overvoltages up to 2 times their rated voltage.
5. **Harmonic Overloading:**
    - Reactors used for harmonic filtering should be capable of handling specific harmonic current levels. For example:
        - A reactor designed for harmonic mitigation in a 480V system may be specified to handle harmonics up to the 11th order.
6. **Partial Discharge:**
    - The partial discharge inception voltage (PDIV) is a critical parameter. For example:
        - Medium-voltage reactors may have PDIV values in the range of 15kV to 25kV.
        - High-voltage reactors may have PDIV values exceeding 40kV.

Chapter 4:Circuit Breaker

A circuit breaker is an electrical switching device designed to protect an electrical circuit from damage caused by overcurrent, short circuit, or other electrical faults. It functions by automatically interrupting or breaking the electrical flow in the circuit when certain conditions occur, preventing damage to equipment and minimizing the risk of fire. Circuit breakers play a crucial role in electrical systems by providing a means to isolate faulty sections of a circuit quickly

- **CIRCUIT BREAKER**

Oil circuit breakers have been widely used in the utility industry in the past but have been replaced by other breaker technologies for newer installations. Two designs exist: bulk oil (dead tank) designs dominant in the United States and minimum oil (live tank) designs prevalent in some other parts of the world. Bulk oil circuit breakers were designed as single-tank (see Figure 4.38) or three-tank (see Figure 4.39) devices, 69 kV and below ratings were available in either single-tank or three-tank configurations and 115 kV and above ratings in three-tank designs. Bulk oil circuit breakers were large and required significant foundations to support the weight and impact loads occurring during operation. Environmental concerns and regulations forced the necessity of oil containment and routine maintenance costs of the bulk oil circuit breakers coupled with the development and widespread use of the SF6 gas circuit breakers have led to the selection of the SF6 gas circuit breaker in lieu of the oil circuit breaker for new installations and the replacement of existing oil circuit breakers in favor of SF6 gas circuit breakers in many installations. Oil circuit breaker development had been relatively static for many years. The design of the interrupter employs the arc caused when the contacts are parted and the breaker starts to operate. The electrical arc generates hydrogen gas due to the decomposition of the insulating mineral oil. The interrupter is designed to use the gas as a cooling mechanism to cool the arc and also to use the pressure to elongate the arc through a grid (arc chutes) allowing extinguishing of the arc when the current passes through zero. Vacuum circuit breakers use an interrupter that is a small cylinder enclosing the moving contacts under a hard vacuum. When the breaker operates, the contacts part and an arc is formed resulting in contact erosion. The arc products are immediately forced to be deposited on a metallic shield surrounding the contacts. Without a restrike voltage present to sustain the arc, it is quickly extinguished. Vacuum circuit breakers are widely employed for metal clad switchgear up to 38 kV class. The small size of the vacuum breaker allows vertically stacked installations of vacuum breakers in a two-high configuration within one vertical section of switchgear, permitting significant savings in space and material compared to earlier designs employing air magnetic technology. When used in outdoor circuit breaker designs, the vacuum cylinder is housed in a metal cabinet or oil-filled tank for dead tank construction popular in the U.S. market. Gas circuit breakers employ SF6 as an interrupting and insulating medium. In “single puffer” mechanisms, the interrupter is designed to compress the gas during the opening stroke and use the compressed gas as a transfer mechanism to cool the arc and also use the pressure to elongate the arc through a grid (arc chutes), allowing extinguishing of the arc when the current passes through zero. In other designs, the arc heats the SF6 gas and the resulting pressure is used for elongating and interrupting the arc. Some older dual pressure SF6 breakers employed a pump to provide the high-pressure SF6 gas for arc interruption. Gas circuit breakers typically operate at pressures between 6 and 7 atm. The dielectric strength and interrupting performance of SF6 gas reduce significantly at lower pressures, normally as a result of lower ambient temperatures. For cold temperature applications (ambient temperatures as cold as −40°C), dead tank gas circuit breakers are commonly supplied with tank heaters to keep the gas in vapor form rather than allowing it to liquefy; liquefied SF6 significantly decreases the breaker's interrupting capability. For extreme cold temperature applications (ambient temperatures between −40°C and −50°C), the SF6 gas is typically mixed with another gas, either nitrogen (N2) or carbon tetra fluoride (CF4), to prevent liquefaction of the SF6 gas. The selection of which gas to mix with the SF6 is based upon a given site's defining critical criteria, either dielectric strength or interrupting rating. An SF6–N2 mixture decreases the interrupting capability of the breaker but maintains most of the dielectric strength of the device, whereas an SF6–CF4 mixture decreases the dielectric strength of the breaker but maintains most of the interrupting rating of the device. Unfortunately, for extreme cold temperature applications of gas circuit breakers, there is no gas or gas mixture that maintains both full dielectric strength and full interrupting 4-26 Electric Power Substations Engineering rating performance. For any temperature application, monitoring the density of the SF6 gas is critical to the proper and reliable performance of gas circuit breakers. Most dead tank SF6 gas circuit breakers have a density switch and a two-stage alarm system. Stage one (commonly known as the alarm stage) sends a signal to a remote monitoring location that the gas circuit breaker is experiencing a gas leak, while stage two sends a signal that the gas leak has caused the breaker to reach a gas level that can no longer assure proper operation of the breaker in the event of a fault current condition that must be cleared. Once the breaker reaches stage two (commonly known as the lockout stage), the breaker either will trip open and block any reclosing signal until the low-pressure condition is resolved or will block trip in the closed position and remain closed, ignoring any signal to trip, until the low-pressure condition is resolved. The selection of which of these two options, trip and block close or block trip, is desired is specified by the user and is preset by the breaker manufacture

- **Oil circuit breaker**

Oil circuit breakers can be classified in two different styles. In one style, the tank of the breaker is grounded (dead tank); in the other style the tank of the breaker is at the potential of the circuit in which it is connected (live tank or minimum oil). Most Reclamation facilities utilize the dead tank style. In a dead tank oil circuit breaker, the oil is not only used to extinguish the arc, but it is also used as an insulator between the energized parts and the outer tank. A live tank oil circuit breaker is also known as a minimum oil breaker since the oil is primarily used to extinguish the arc and not as an insulator. This FIST focuses on testing procedures required for dead tank oil circuit breakers, but testing on live tank oil circuit breakers should be similar. In either case, always refer to the breakers Operation and Maintenance Manual for specific maintenance procedures that may not be covered in this document.

Maintenance of Air circuit breakers

1. Visual & Mechanical Inspection

A straightforward visual inspection is an excellent way to identify physical problems like inadequate lubrication, overheating or loose connections. Some components to inspect include:

- the housing and general condition
- grounding and anchorage
- arc chutes
- all contacts

- correct operation of any protective devices or auxiliary features, such as ground-fault trip devices, zone interlocking or tip and pickup indicators
- bolts, which should have appropriate torque levels

Before even touching the circuit box, a visual inspection can reveal problems like water, rust, evident physical damage or pests that could make operation hazardous. If none of these are present, a technician can open the circuit breaker and look for any loose components or discoloration. Discoloration on connections is a sign of overheating. Other signs of burning, arcing or heat need to be addressed.

In addition to merely looking at the circuit breaker parts and functions, they should be exercised, just like a muscle, every so often. Moving the handle a few times to ensure linkages are free, opening the door several times repeatedly and tripping the breaker with a push-to-trip button are things you can do to ensure the mechanical system is working correctly. If the breaker is stiff or sticks, it could lead to a delay that adds a significant amount of risk to the possibility of an arc flash that could exceed the ratings for most personal protective equipment.

2. Testing

There are a few different types of tests that can tell someone about the condition of a circuit breaker.

In an MCCB, a millivolt drop test displays abnormalities like loose connections or eroded or contaminated contacts. It uses low DC voltage at 50A-100A.

An overload tripping test checks the trip system by applying 300 percent of the breaker-rated continuous current to the poles. Tripping times, which can be affected by other environmental conditions, are less valuable than the circuit breaker's ability to automatically open.

A medium-voltage oil circuit breaker also needs to be tested for the dielectric strength of the oil. If this is below 22kV, then the oil must be filtered or replaced.

A ground-fault trip test measures the effectiveness of a circuit breaker's ability to provide ground-fault protection on equipment with adjustable pickup and delay values. A breaker with a ground-fault delay feature determines the time that elapses before it initiates a trip during a ground fault. Testing the ground-fault delay can ensure that the timing is adequate and within safe limits.

3. Insulation Resistance

An insulation resistance (IR) test is a simple test that checks the integrity of the insulation material. Its goal is to resist the flow of current and keep it contained to the conductor. Insulation wears down during its lifetime, and sound insulation can maintain high resistance levels.

An IR test is temperature-sensitive, and readings vary significantly in different temperatures. Based on the class of the equipment, a technician applies voltage to the insulation and takes readings at 30 seconds and one minute. If a winding is present, like a motor or transformer, the technician also performs another 10-minute reading. With these numbers, they can calculate the Dielectric Absorption Ratio. This number is found by dividing the one-minute reading by the 30-second reading. Another figure that may be needed is the polarization index. This reading is available with the help of the 10-minute reading, if taken. To find the polarization index, divide the 10-minute reading by the one-minute reading. Finally, these numbers can help determine the condition of the insulation across several grades, ranging from dangerous to excellent.

Dielectric Absorption Ratios above 1.6 are excellent, and those between 1.0 and 1.25 are questionable. For the polarization index, values above four are excellent, while those below one are dangerous. These values are somewhat tentative, as factors like temperature, humidity and moisture can heavily influence them. IR readings over time are good indicators of how insulation may be degrading. Take measurements of those miscellaneous factors as well, so you know the conditions in which each was taken.

4. Contact Resistance

When checking for contact resistance, you measure how much the electrical connections, like terminations, joints and busbar sections, contribute to the total resistance in a system. This data can tell you about the health of a system's contacts. If contacts are damaged, they can cause arcing or fire and be serious detriments to an electrical system as a whole.

Ductor testing is another term for the contact resistance test, performed with an Ohmmeter, which may use micro- or milli-ohms. To test contact resistance, one would use the Ohmmeter to inject a fixed current through the contacts. Three phases within the current path are measured and compared. The change in voltage drop can help to calculate the resistance value using Ohm's law. If the highest reading exceeds the lowest one by more than 150 percent, it is an indication of a problem in the circuit breaker. The technician should compare this number to the one provided by the manufacturer.

5. Over-Potential

This type of test is similar to the IR test but is more common on medium- and high-voltage breakers. It involves putting high DC voltage through an insulation system, which stresses it to bring moisture, dirt and weak insulation to light. The overpotential test is also used in vacuum breakers, but a specific test set must be used, or it will wreck the vacuum bottle. Check the manufacturer specifications to see what type of high-potential voltage is needed. If an arc occurs inside the vacuum bottle during the test, X-Ray radiation may occur, so the tester should take appropriate precautions and maintain distance.

6. Timing

Timing a circuit breaker ensures that it performs at manufacturer specifications. The process varies based on the type of breaker.

Low-voltage circuit breakers use either primary or secondary injection test sets. Primary injection, typically the preferred method, trips the breaker by pushing current through the whole current path. Secondary injection applies the current to the current input terminals on the breaker's overcurrent device. Both are measured with the correct characteristic curve for that combination of breaker and overcurrent.

Medium- and high-voltage circuit breakers have similar tests, but with different equipment, such as a travel analyzer. In this setup, a transducer connects the breaker linkage to the analyzer. The transducer sends a signal to the analyzer as soon as the trip coil on the breaker is activated. With the breaker opened, the analyzer records the movement of the contacts. The resulting travel trace allows a tester to measure several factors, including the opening speed of the contacts, the total distance of contact travel, any binding on the linkage that may affect travel or opening speed and contact bounce at the end of the opening stroke. All three phases need to be monitored to look for contact synchronization.

7. Cleaning

Earlier, we mentioned that circuit breakers should be exercised regularly to check for normal functioning and to avoid rust or dirt accumulation. Aside from regular operation, proper cleaning can help prevent these problems as well by keeping rust, dirt, grime and other foreign materials at bay. If these substances have time to accumulate inside a breaker, they can cause disruptions in the power supply, potentially leading to blown fuses, interrupted currents or fires. Cleaning out a breaker should only be completed by a trained, experienced professional with the right tools for the job, such as a grounding mat, anti-static wristbands and non-abrasive cleaning materials that won't remove plating or insulation.

Another risk that could occur with breakers that have been left untouched has to do with lubrication. When they come from the manufacturer, circuit breakers have appropriate lubrication to keep things moving, but this can wear away over the years. The formation of rust or added friction in the operation of the system can reduce torque in certain connections. As rust gathers, it can slow down the entire system past manufacturer limits. Keeping the system well-lubricated improves its safety.

One way to keep a breaker in optimal condition is through restoration. When restoring a circuit breaker, a technician will completely take it apart and reassemble it, paint or powder-coat it, replate it and retest it. This overhaul of a system can increase its longevity.

8. Re-Testing, Certification and Test Reports

A facility should retest its circuit breakers often. Each time they are tested, you gain more information about their status. Any performance improvements that maintenance brings or degradation in quality throughout the years show up in these tests. Another component of quality that may be desirable is certification. Circuit breaker certification provides third-party evidence that your breakers are up to par and can protect the building and its occupants from various electrical hazards. Depending on the type of circuit breaker you're working with, it could help to seek certification that shows adherence to specific standards like those of the American National Standards Institute and the National Electrical Manufacturers Association

Circuit breaker maintenance steps:

1. **Visual Inspection:**

- Conduct a visual inspection of the entire circuit breaker, including the contacts, insulation, and control wiring. Look for signs of physical damage, corrosion, or loose connections.

2. **Check Operating Mechanism:**
   - Inspect the operating mechanism for proper alignment, lubrication, and freedom of movement. Lubricate moving parts if necessary, following the manufacturer's recommendations.
3. **Verify Tightness of Connections:**
   - Check all electrical connections for tightness, including connections to the control circuits, trip coils, and auxiliary devices. Loose connections can cause overheating and affect the circuit breaker's performance.
4. **Check Contact Wear and Alignment:**
   - Examine the condition of the main and arcing contacts. Measure the contact wear and check for proper alignment. Replace contacts if they are excessively worn or damaged.
5. **Measure Contact Resistance:**
   - Measure the contact resistance to ensure low resistance, which is crucial for effective current interruption. High contact resistance can lead to overheating and deteriorate the contacts.
6. **Inspect Insulation:**
   - Inspect the insulation components for signs of degradation, cracks, or contamination. Clean or replace insulation materials if needed to maintain the dielectric strength.
7. **Functional Testing:**
   - Perform functional testing to ensure that the circuit breaker operates correctly under simulated fault conditions. This includes testing the tripping mechanism, control circuits, and auxiliary devices.
8. **Check Arc Chutes:**
   - Inspect the arc chutes for signs of damage or contamination. Clean or replace the arc chutes if necessary to maintain effective arc interruption.
9. **Verify Spring Charging Mechanism:**
   - For spring-operated circuit breakers, verify the charging mechanism of the closing springs. Ensure that the springs are correctly charged for reliable closing.
10. **Check Trip Unit Calibration:**
    - If the circuit breaker is equipped with electronic trip units, check and calibrate the trip settings. Ensure that the trip unit operates within the specified tolerances.
11. **Inspect Gas (for Gas-Insulated Circuit Breakers):**
    - If the circuit breaker is gas-insulated, inspect the gas quality and pressure. Replace or refill the gas if needed, following manufacturer guidelines.
12. **Perform Infrared Thermography:**
    - Use infrared thermography to identify any abnormal temperature rises in the circuit breaker components. Elevated temperatures may indicate potential issues.
13. **Verify Interlocks and Safety Features:**
    - Check the interlocks and safety features to ensure that the circuit breaker can be operated safely. Ensure that all safety devices are functional.
14. **Record Keeping:**

- Maintain a detailed record of all maintenance activities, including inspections, tests, and any corrective actions taken. This documentation helps track the circuit breaker's performance over time.

15. **Schedule Regular Maintenance:**
    - Establish a routine maintenance schedule based on the manufacturer's recommendations and industry standards. Regular inspections and preventive maintenance contribute to the overall reliability of the circuit breaker.

Signs of defects in circuit breakers:

1. **Physical Damage:**
    - Visible signs of physical damage, such as cracks, dents, or deformities on the circuit breaker housing or frame.
2. **Corrosion:**
    - Corrosion on the metal parts of the circuit breaker, which can weaken its structural integrity and affect performance.
3. **Loose Connections:**
    - Loose or damaged electrical connections, including terminals, bus bars, and control wiring, which can result in increased resistance, overheating, and malfunctions.
4. **Overheating:**
    - Elevated temperatures during operation, which may be indicated by discoloration, burning smells, or visual signs of overheating.
5. **Arc Marks:**
    - Arcing or burn marks on the contacts, insulation, or surrounding areas, which may indicate a poor or faulty contact.
6. **Irregular Sounds:**
    - Unusual sounds during operation, such as buzzing, humming, or arcing noises, which may suggest mechanical or electrical issues.
7. **Failure to Trip:**
    - The circuit breaker fails to trip or open the circuit during a fault condition, indicating a malfunction in the tripping mechanism.
8. **Delayed Tripping:**
    - Delayed response or slower than usual tripping during a fault, which may pose a safety risk and result in equipment damage.
9. **Inconsistent Operation:**
    - Inconsistencies in the circuit breaker's operation, such as failure to close, failure to open, or erratic behavior.
10. **Trip Coil Issues:**
    - Problems with the trip coil, such as burnout or open circuits, preventing the circuit breaker from tripping when required.
11. **Contact Wear:**
    - Excessive wear on the main and arcing contacts, which may lead to poor contact resistance and deteriorated performance.
12. **Inadequate Lubrication:**
    - Lack of lubrication in moving parts, leading to increased friction, wear, and potential mechanical failures.

13. **Failure to Stay Closed:**
    - The circuit breaker fails to remain closed after an attempt to close it, indicating issues with the closing mechanism or interlocks.
14. **Inaccurate Trip Settings:**
    - Incorrect settings or calibration of electronic trip units, leading to incorrect tripping or failure to trip under the specified conditions.
15. **Smoke or Odors:**
    - The presence of smoke or unusual odors during circuit breaker operation, indicating potential overheating or insulation issues.
16. **Visible Damage to Insulation:**
    - Visible damage to insulation materials, such as cracks, breaks, or discoloration, which may compromise the dielectric strength.
17. **Failure of Secondary Disconnect Mechanism:**
    - Failure of the secondary disconnect mechanism to operate, preventing the circuit breaker from being opened manually.
18. **Faulty Indicator Lights:**
    - Malfunctioning indicator lights or alarms that are inconsistent with the actual status of the circuit breaker.

Limitations in terms of voltage for safety in circuit breakers:

1. **Voltage Rating:**
    - Low-voltage circuit breakers: Typically rated up to 600V.
    - Medium-voltage circuit breakers: Ratings from 1kV to 38kV.
    - High-voltage circuit breakers: Ratings exceeding 38kV.
2. **Dielectric Strength:**
    - Low-voltage circuit breakers: Dielectric strength around 2kV to 4kV.
    - Medium-voltage circuit breakers: Dielectric strength from 15kV to 60kV.
    - High-voltage circuit breakers: Dielectric strength exceeding 100kV.
3. **BIL (Basic Impulse Insulation Level):**
    - BIL for medium-voltage circuit breakers: Typically around 60kV.
    - BIL for high-voltage circuit breakers: Values ranging from 150kV to 650kV or higher.
4. **Transient Recovery Voltage (TRV):**
    - TRV for medium-voltage circuit breakers: Around 20% to 40% of rated voltage.
    - TRV for high-voltage circuit breakers: Values depending on system characteristics, often exceeding 60% of rated voltage.
5. **Switching Overvoltages:**
    - Switching overvoltages for medium-voltage circuit breakers: Typically less than 2.5 times the rated voltage.
    - Switching overvoltages for high-voltage circuit breakers: Typically less than 2 times the rated voltage.
6. **Frequency Limitations:**
    - Standard frequency for most circuit breakers: 50 or 60 Hz.

- Some circuit breakers designed for specialized applications may operate at higher frequencies.

7. **Mechanical Stress:**
    - Mechanical stress limits depend on the design and construction of the circuit breaker. Consult manufacturer specifications for specific values.
8. **Altitude Limitations:**
    - Altitude limitations may be specified for certain circuit breakers, often ranging from sea level to several thousand meters.
9. **Temperature Limitations:**
    - Operating temperature range for circuit breakers: -25°C to +40°C or higher, depending on the design.
    - Some circuit breakers may have extended temperature ranges for specific applications.
10. **Continuous Voltage Limitations:**
    - Continuous voltage limitations depend on the specific application and the type of circuit breaker. Exceeding continuous voltage ratings can lead to insulation breakdown.
11. **Phase-to-Ground Voltage:**
    - Phase-to-ground voltage limitations depend on the system voltage class (e.g., 208V, 480V, etc.) and the specific circuit breaker design.

Chapter 5:Instrument transformers

Instrument transformers are devices used in electrical power systems to transform currents and voltages to levels that are suitable for measurement and protection equipment. They play a crucial role in ensuring the accuracy and safety of various instruments in power systems. There are two main types of instrument transformers: current transformers (CTs) and voltage transformers (VTs), also known as potential transformers (PTs)

Instrument transformers maintenance steps:

1. **Visual Inspection:**
    - Conduct a visual inspection of the instrument transformer, including the insulation, terminals, and external components. Look for signs of physical damage, corrosion, or contamination.
2. **Check Insulation:**
    - Inspect the insulation for any cracks, discoloration, or signs of aging. Clean the insulating surfaces if necessary. Ensure that there are no visible signs of tracking or partial discharge.
3. **Verify Grounding:**
    - Confirm that the instrument transformer is properly grounded to ensure safety and proper functioning. Check the integrity of grounding connections.
4. **Tighten Connections:**
    - Check all electrical connections for tightness. Loose connections can lead to increased resistance, heating, and inaccurate measurements. Tighten any loose bolts or nuts.
5. **Inspect Terminal Covers:**
    - If the instrument transformer has terminal covers, inspect them for damage and ensure that they are properly secured. Terminal covers provide protection against accidental contact.
6. **Check Nameplate Information:**
    - Verify that the nameplate information, including voltage and current ratings, accuracy class, and other specifications, is legible and matches the system requirements.
7. **Perform Insulation Resistance Testing:**
    - Conduct insulation resistance tests to ensure that the insulation between windings and between windings and ground is within acceptable limits. Follow manufacturer recommendations for testing voltages and duration.
8. **Verify Turns Ratio:**
    - If possible, perform turns ratio tests on voltage transformers to ensure that the transformer is operating at the specified turns ratio. Any significant deviation could affect the accuracy of measurements.
9. **Saturation Testing:**
    - For current transformers, consider performing saturation testing to assess the saturation characteristics under different fault conditions. This helps ensure accurate measurements during fault events.
10. **Functional Testing:**

    - Conduct functional tests by injecting known currents or voltages into the transformer and verifying that the secondary readings match the expected values. This ensures the accuracy of the transformer under normal operating conditions.
11. **Check for Oil Leaks (If Applicable):**
    - If the instrument transformer is oil-filled, check for oil leaks or signs of oil contamination. Address any leaks promptly and replenish oil levels as needed.
12. **Calibration (if applicable):**
    - Calibrate the instrument transformer periodically, especially if high accuracy is required for metering applications. Follow manufacturer guidelines for calibration procedures.
13. **Review Manufacturer's Guidelines:**
    - Refer to the manufacturer's documentation for specific maintenance recommendations and procedures. Follow any guidelines provided for the particular type and model of instrument transformer.
14. **Record Keeping:**
    - Maintain detailed records of all maintenance activities, including inspection results, test data, and any corrective actions taken. This documentation is valuable for tracking the performance of the instrument transformer over time.
15. **Schedule Regular Maintenance:**
    - Establish a routine maintenance schedule based on industry standards and manufacturer recommendations. Regular inspections and preventive maintenance contribute to the overall reliability of instrument transformers.

Signs of defects in instrument transformers :

Detecting signs of defects in instrument transformers is crucial for ensuring the accuracy and reliability of measurements and protection in electrical power systems. Here are common signs of defects in both current transformers (CTs) and voltage transformers (VTs or PTs):

Signs of Defects in Current Transformers (CTs):

1. **Saturation:**
    - Saturation occurs when the CT cannot accurately represent high currents. This leads to distorted waveforms and inaccurate measurements during fault conditions.
2. **Inaccurate Measurements:**
    - CTs providing inaccurate secondary current readings compared to the actual primary current may indicate a defect, affecting the reliability of protective relays and metering equipment.
3. **Open Circuit or Short Circuit:**
    - An open circuit in the secondary winding or a short circuit in the primary winding can disrupt the current flow, leading to inaccurate measurements or complete loss of signal.
4. **Abnormal Heating:**
    - Excessive heating in the CT, particularly in the core or windings, may indicate a defect. Causes can include loose connections, core damage, or overloading.

5. **Physical Damage:**
    - Visual inspection may reveal physical damage, such as cracks, dents, or bent cores, which can compromise the structural integrity and accuracy of the CT.
6. **Irregular Frequency Response:**
    - Changes in the frequency response or deviations from the specified frequency range may indicate a defect in the CT.

Signs of Defects in Voltage Transformers (VTs or PTs):

1. **Saturation:**
    - Similar to CTs, voltage transformers can experience saturation, leading to distorted waveforms and inaccurate voltage measurements, especially during high voltage conditions.
2. **Inaccurate Measurements:**
    - Incorrect secondary voltage readings compared to the actual primary voltage may indicate a defect, impacting the reliability of protective relays and metering equipment.
3. **Open Circuit or Short Circuit:**
    - An open circuit in the secondary winding or a short circuit in the primary winding can disrupt the voltage flow, leading to inaccurate measurements or complete loss of signal.
4. **Abnormal Heating:**
    - Excessive heating in the VT, particularly in the core or windings, may indicate a defect. Causes can include loose connections, core damage, or overloading.
5. **Physical Damage:**
    - Visual inspection may reveal physical damage, such as cracks, insulation breakdown, or damaged cores, which can compromise the structural integrity and accuracy of the VT.
6. **Irregular Frequency Response:**
    - Changes in the frequency response or deviations from the specified frequency range may indicate a defect in the VT.

General Signs for Both CTs and VTs:

1. **Oil Leaks (If Applicable):**
    - For oil-filled instrument transformers, any signs of oil leaks indicate a potential issue with the insulation or the transformer's integrity.
2. **Corrosion:**
    - Corrosion on the external surfaces of the transformer may indicate environmental degradation, potentially affecting insulation and reliability.
3. **Unusual Noise:**
    - Strange noises during operation, such as buzzing or humming, may signal mechanical or electrical issues within the transformer.
4. **Drift in Measurements Over Time:**
    - Gradual changes or drift in measured values over time, even within the specified accuracy limits, may indicate an emerging defect.
5. **Failure to Trip (Protection Applications):**
    - In protection applications, the failure of an instrument transformer to correctly operate protective relays during fault conditions is a critical sign of a defect.
6. **Failure to Close (Protection Applications):**

- In voltage transformer applications for protection, a failure to close or operate protective devices correctly during fault conditions indicates a potential issue.

Limitations in terms of voltage for safety in circuit breakers:

Current Transformers (CTs):

1. **Saturation:**
    - Saturation limits vary based on the CT design and material. For example, a CT might saturate at 120% of its rated primary current, with values such as 5 A or 1 A.
2. **Insulation Breakdown:**
    - Insulation breakdown voltages can range from a few kV to several tens of kV, depending on the application. For instance, a low-voltage CT might have an insulation breakdown voltage of 3 kV.
3. **Impulse Voltage:**
    - BIL values for CTs can range from a few kV to several tens of kV. As an example, a CT might have a BIL of 10 kV.

Voltage Transformers (VTs or PTs):

1. **Primary Voltage Limit:**
    - Primary voltage limits depend on the VT's design and application. For instance, a VT might have a primary voltage limit of 69 kV or 138 kV.
2. **Secondary Burden Limit:**
    - Secondary burden limits are specified in volt-amperes (VA) and can range from a few VA to several hundred VA. For example, a VT might have a burden limit of 100 VA.
3. **Insulation Breakdown:**
    - Insulation breakdown voltages for VTs can range from a few kV to several tens of kV. A high-voltage VT might have an insulation breakdown voltage of 25 kV.
4. **Impulse Voltage:**
    - BIL values for VTs can range from a few kV to several tens of kV. For instance, a VT might have a BIL of 150 kV.
5. **Frequency Limitations:**
    - VTs are designed for specific frequencies, typically 50 Hz or 60 Hz.

General Considerations:

1. **BIL (Basic Impulse Insulation Level):**
    - BIL values for both CTs and VTs can range from a few kV to several tens of kV. As an example, a BIL for a high-voltage instrument transformer might be 150 kV.
2. **Altitude Limitations:**
    - Altitude limitations for instrument transformers may vary. For example, a transformer might be designed to operate at altitudes of up to 1,000 meters or more.

3. **Temperature Limitations:**
    - Operating temperature ranges for instrument transformers can vary. A transformer might be designed to operate within a temperature range of -25°C to +40°C.