Protection of electrical networks

Chapter 1: Introduction to protection

Chapter 2: Elements of the protection system

Chapter 3: Protection of network elements

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1- Transformer protection

1-1- Role of transformers

Transformers play a crucial role in the field of electricity by facilitating the efficient conversion of electrical voltage. Here are some of their primary roles:

- **Voltage Conversion:** Transformers are used to increase or decrease the electrical voltage of an alternating current while maintaining its frequency. This allows electricity to be transported over long distances with minimal energy losses, as higher voltage reduces losses due to Joule heating in transmission lines.
- **Impedance Matching:** Transformers can also be used to match the electrical impedance between two systems, maximizing power transfer between them.
- **Electrical Isolation:** Transformers provide electrical isolation between the primary and secondary circuits, which is crucial for equipment and personnel safety.
- **Power Distribution:** In electricity distribution networks, transformers are used to adjust voltage to appropriate levels for consumer power supply.
- **Rectification and Current Conversion:** In some cases, transformers can be used in conjunction with other components to convert alternating current to direct current or vice versa, depending on the application requirements.

In summary, transformers are versatile devices essential in the field of electricity, used for transmission, distribution, and efficient conversion of electrical energy.

The faults that may affect the transformer are:

- ❑ Short circuit between phases inside and outside the tank.
- ❑ Short circuit between turns.
- ❑ Tank grounding.

The transformer is equipped with the following basic protections:

- ❑ BUCHHOLTZ protection, which protects the transformer against any fault occurring inside the tank.
- ❑ Differential protection.
- ❑ Tank grounding protection.

These protections complement each other.

1-2-the protections against internal and external faults of transformers

1-2-1-Protections against internal faults:

- **Thermal protection relay:** Monitors the transformer's temperature to prevent overheating due to overload or internal faults.
- **Differential current protection relay**: Compares the input and output currents of the transformer to detect internal faults such as short circuits or ground faults.
- **Overcurrent protection relay**: Monitors load currents to detect temporary or permanent overloads.
- **Overvoltage protection relay:** Protects the transformer against transient overvoltages that could damage internal insulation.
- **Undervoltage protection relay**: Protects the transformer against voltage drops that could result in improper operation or damage.
- **Phase fault protection relay:** Monitors the system phases to detect voltage imbalances or phase faults.

1-2-2-Protections against external faults:

1.Surge arresters: Protect the transformer against overvoltages induced by lightning or load switching in the network.

2.Lightning rod: Channels atmospheric electrical discharges to protect the transformer against lightning damage.

3.Protective enclosure: Physically shields the transformer against mechanical damage, weather conditions, and intrusions.

4.Remote monitoring systems: Utilize sensors and monitoring devices to detect abnormal environmental conditions or potential intrusions.

By combining these different protection methods, transformers can be safeguarded against a wide range of internal and external faults, ensuring reliable and safe operation of the electrical grid.

3-2- Alternator Protection

3-2-1- Introduction :

Three-phase synchronous generators or alternators are electromechanical converters that transform mechanical energy provided by the turbine into three-phase electrical energy.
Alternator protection serves a dual role as it allows for:
Protecting the alternator against internal faults:

- ❖ Protecting the alternator against internal faults.
- ❖ Protecting the grid against malfunctions that could disrupt it.

Protections against internal faults should be selective and instantaneous, while protections against external faults should be coordinated with the relevant elements.
The main issues affecting alternators connected to the grid are:

- Overloading.
- External phase-to-phase short circuits.
- Internal phase-to-phase short circuits.
- Fault between the rotor and ground.
- Phase loss or swapping of two phases.
- Loss of excitation.
- Motor operation.
- Low or high frequency.
- Low or high voltage.
- Loss of power supply from the distributor during operation coupled with it.

3-2-2- Alternator protection

Protection for alternators is crucial to ensure their safe and reliable operation within electrical systems. Here are some of the primary protection methods used for alternators:

1. **Overcurrent Protection:** Monitors the phase and neutral currents of the alternator to detect overloads and short circuits. Overcurrent relays are used to trigger alarms or emergency shutdowns if predefined current thresholds are exceeded.
2. **Under-Voltage and Over-Voltage Protection:** Monitors the output voltages of the alternator to detect abnormal variations that could indicate incorrect load conditions or faults in the electrical system. Under-voltage and over-voltage relays are used to protect the alternator against improper operating conditions.
3. **Over-Frequency and Under-Frequency Protection:** Monitors the frequency of the electrical grid supplying the alternator. Significant frequency variations can indicate load imbalances or malfunctions in the electrical system. Over-frequency and under-frequency relays are used to protect the alternator against non-standard operating conditions.

4. Phase Sequence Protection: Monitors the phase sequence of the supply voltages to the alternator to detect imbalances that could indicate connection issues or internal faults.

5.Thermal Overload Protection: Monitors the temperature of the alternator and electrical connections to detect overheating caused by excessive operating conditions or internal faults.

6.Ground Fault Protection: Monitors ground faults to detect current leaks or short circuits that could damage the alternator or other electrical equipment.

7.Fast Disconnection Protection: In case of detecting a serious fault or hazardous operating condition, fast disconnection devices are used to quickly isolate the alternator from the rest of the electrical system to prevent extensive damage.

These protection methods are often integrated into complex relay systems that continuously monitor the operating conditions of the alternator and trigger appropriate actions upon detection of abnormal conditions.

3-3- Protection of busbars

Role of busbars:

Busbars are points where multiple departures converge. They consist of one or more metal bars. Their role is crucial in configuring the network, especially in distributing power.

Constraints and issues with busbars:

The main issue with busbars is the occurrence of short circuits. The emergence of a short circuit and therefore a fault arc between busbars is an accident whose probability is extremely low if the installation is well-designed.

➢ Causes of short circuits on busbars :

Short circuits on busbars, which are assemblies of electrical conductors used to distribute electricity within an electrical system, can be caused by several factors. Here are some of the most common causes:

1. **Insulation fault**: If the insulation between the conductors is damaged or insufficient, it can result in a short circuit when the conductors come into contact with each other.
2. **Faults in electrical components**: Defects in electrical components themselves, such as circuit breakers, switches, transformers, etc., can cause short circuits.
3. **Debris or contaminants**: The presence of debris, dust, or other contaminants between the conductors can create a path of conductivity between them, leading to a short circuit.
4. **Electrical overloads**: An electrical overload on the system can cause an increase in the temperature of the conductors, which can eventually lead to a short circuit.
5. **Manufacturing or installation defects**: Manufacturing or installation errors during the construction or maintenance of the busbars can create conditions conducive to short circuits.
6. **Environmental conditions**: Extreme environmental conditions such as humidity, corrosion, vibrations, or temperature variations can also contribute to the occurrence of short circuits.
7. **Mechanical damage**: Physical damage to the conductors or components of the busbars, caused by shocks, collisions, or other factors, can lead to short circuits.

Consequences of Short Circuits on Busbars:

It is essential to note that these short circuits are highly violent and can lead to very serious consequences such as:

- Melting of conductors,
- Fire and danger to individuals,
- Electrodynamical forces, causing deformation of the busbars,
- Cable detachment,
- Overheating due to increased joule losses, with the risk of insulation deterioration,
- Voltage dips during the fault elimination period, ranging from a few milliseconds to several hundred milliseconds,
- Partial or complete shutdown of the network depending on its layout and the selectivity of its protections,
- Dynamic instability and/or loss of synchronization of machines,
- Disturbances in control command circuits..

Protection of busbars :

- ✓ **Overcurrent relays:** These relays detect abnormally high currents that could indicate a short circuit or overload in the busbars. They then trigger cutting devices to isolate the affected area.
- ✓ **Phase difference relays:** These relays compare the phases of the incoming and outgoing currents of the busbars. Any significant difference indicates a potential fault, thus triggering a protective action.
- ✓ **Distance relays:** These relays measure the distance between the fault location point and the busbars. They are used to quickly detect and locate faults in the feeder lines connected to the busbars.
- ✓ **Earth fault relays:** These relays detect earth faults in the busbars, which can be dangerous to equipment and people. They trigger appropriate protective actions to isolate the fault.

3-4- High Voltage Line Protection

Protection of high voltage lines is crucial to ensure the safety of the electrical network and prevent potentially dangerous outages. Here are some common protection measures used for high voltage lines:

- **Protection Relays:** Relays are electronic devices that continuously monitor the conditions of the electrical network. They detect abnormalities such as overvoltages, undervoltages, overcurrents, short circuits, etc., and trigger cut-off devices to isolate the faulty part of the network.

- **Disconnectors and Circuit Breakers:** These are cut-off devices that allow for quickly isolating faulty sections of the network. Disconnectors are generally used for maintenance and temporary isolation operations, while circuit breakers are designed to interrupt current during emergency situations such as short circuits.

- **Grounding:** High voltage lines are equipped with grounding systems to divert leakage current in case of a ground fault. This helps prevent the risk of electric shock and equipment damage.

- **Surge Arresters:** These devices protect lines against transient overvoltages, which can be caused by lightning or other events. Surge arresters divert overvoltages to the ground, thus protecting sensitive equipment from damage.

- **Remote Monitoring:** Remote monitoring systems allow network operators to monitor the conditions of high voltage lines in real-time. This enables them to quickly detect abnormalities and take preventive measures to avoid outages.