Prerequisites:

- None

Objectives: Given the Construction Standards Manual, you will be able to identify and explain the function of the apparatus required for an underground distribution system.

Rationale: There are many different types of apparatus used on an underground distribution system. Understanding the function of this underground apparatus will enable individuals to operate the system safely with minimal power disruptions.

Learning Objectives

- Identify and explain the function of a reactor.
- Identify and explain the function of a switching cubicle.
- Identify and explain the types of single-phase transformers.
- Identify and explain the types of three-phase transformers.
- Identify and explain the function of fault indicators.
- Recognize the hazards associated with manhole work.

Learning Methods

- Self-learning + On-the-job
- Self-learning + On-the-job
- Self-learning + On-the-job
- Self-learning + On-the-job
- Self-learning + On-the-job
- Self-learning + On-the-job

Evaluation Methods

- Written test
- Written test
- Written test
- Written test
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- Written test
STUDENT RESOURCES

- None

Learning Steps

1. Read the Learning Guide.
2. Follow the steps outlined in the Learning Guide.
3. Clarify any questions or concerns you may have.
4. Complete the Practice and Feedback.
5. Complete the Evaluation.

Introduction

The underground distribution system uses several types of apparatus to perform various functions within the system. An operator must be able to identify each apparatus and understand its function.
Lesson 1: Function of a Reactor

Learning Objective: Identify and explain the function of a reactor.
Learning Method: Self-learning + On-the-job
Evaluation Method: Written test

Introduction

Reactors (XL) are installed in rural underground distribution to offset the capacitance (XC) of the underground cable. Inductive reactance is put into the system to counteract the capacitive reactance of the primary underground cable.

Uncompensated capacitive reactance causes a voltage rise that affects the adjoining three-phase system. This creates high voltage on the phase it is connected to. This uncompensated capacitive reactance also causes a leading power factor due to the fact that a capacitor causes the current to lead the voltage. This can cause problems in three-phase motors and equipment.
Types

At present, 100 and 200kVAR reactors are being utilized in loop systems.

There are some 250kVAR reactors in the existing system; these reactors will be phased out when they are not required or as they become defective.

Measuring Ground Current

Ground current can be measured on the reactor to identify whether it is working. All the ground wires attached to the reactors must be measured and their values added together. Normally, two ground leads are present; the total current measured on the ground wires will be an approximate value.

Reactors should have the following ground current values, assuming a 14,400V system.

- 100kVAR - 7 amps
• 200kVAR - 14 amps
• 250kVAR - 17 amps

---Note---

A 200 amp load break elbow is capable of breaking 200 amps of resistive load current, yet it is capable of breaking only 10 amps of reactive current.

Switching Procedures

The RUD system is designed to operate with one reactor out of service. If this situation arises, the reactor should be isolated at the adjacent transformers. No more than 10 miles of uncompensated cable should be energized. This is done to prevent high voltage on the system caused by uncompensated cable. This will be determined by a voltage test on each side of the new open point.

CAUTION

Do not use the fuse to operate a reactor, and never switch at an energized reactor.
Lesson 2: Switching Cubicle

Learning Objective: Identify and explain the function of a switching cubicle.  
Learning Method: Self-learning + On-the-job  
Evaluation Method: Written test

Introduction

A switching cubicle is incorporated into an underground system to enable switching of the distribution system. Switching may be required to:

• open a circuit  
• close a circuit  
• change the connection of a circuit (direction of feed)
Various types of switching cubicles are used in the electrical system:

**Single-Phase and Three-Phase, Low Profile, 25kV Switching Cubicles**

Single-phase and three-phase switching cubicles consist of a single unit board or buss bar for single-phase and three unit boards or buss bars for three-phase application. Load break elbow terminations are used and provisions are made for parking stands.

This type of switching equipment must not be operated within a manhole or any other confined space; furthermore, all safety and workplace rules apply.

---Note---

In the event of a suspected switch failure, protect against the hazards of coming in contact with by-products of SF6 combustion.

*Figure 3. Three-Phase Low Profile Switching Cubicle*
Lesson 3: Single-Phase Transformers

Learning Objective: Identify and explain the types of single-phase transformers.
Learning Method: Self-learning + On-the-job
Evaluation Method: Written test

Introduction

There are two types of single-phase transformers that are utilized in an underground electrical distribution system: live front, load break and dead front, load break.
Live Front, Load Break

The live front, load break transformer is made up of two parts: a kiosk and a transformer. The kiosk and transformer are connected forming one complete unit.

The kiosk is separated into two compartments. A low voltage compartment, which encloses all the secondary terminations, and a high voltage compartment.

The high voltage compartment houses the buss work which makes up a single-phase feed through. This buss work is connected at one end to the termination of the line side high voltage cable, and the load side at the other end. Solid blade disconnects or 200A load break arc stranglers

DANGER

The front bars are energized.
are used to make this connection or isolate the buss bar from the high voltage cables. In the center of the buss work is a mount for a load break NX silver sand fuse. Its function is to connect the primary bushing of the transformer to the buss work while protecting the transformer from overcurrent. The fuse and disconnects must be operated with a hotstick.

All of the high voltage termination, buss work, disconnects, fuses and high voltage bushings are exposed inside the kiosk, therefore, the name live front seems fitting.

**Dead Front, Load Break**

*Figure 5. Single-Phase Transformer*

Dead front, load break padmount transformers consist of a transformer tank and a cable compartment hinged together to form a low profile, weatherproof, tamperproof unit.

The low voltage terminals, high voltage terminals, transformer fuse and grounding connections are enclosed in one compartment.
The low profile padmount transformer is rated at 14,400-120/240 for use on 25,000 ground-wye systems. It is a single-phase, oil immersed, self-cooled unit having no tap changer.

The cable compartment cover is bonded by a single, removable copper ground strap. The sill is removable, in order to facilitate positioning the unit over a cable during change out. An eye is attached for padlocking the compartment cover and there is a threaded bolt to secure the lid.

The two high voltage universal bushings (suitable for approved load break bushing inserts) are connected internally for feed through operation. They are located to facilitate parking high voltage elbow terminations onto a parking stand.

The opposite end of the coil is grounded through the tank and case ground.

The epoxy molded insulator type secondary terminals are externally clamped to the tank wall.

The low voltage neutral bushing is connected with an external grounding strap connected to the grid and is the lowest bushing. A ground bar is provided adjacent to H1A and H1B bushings for grounding the concentric neutral of the primary cable. The bushings are identified by the markings adjacent to the bushing (i.e. X1 - H1, etc.).

The transformer is protected by a draw out, load break, bayonet type fuse. An isolation link, which is factory coordinated, is installed internally.

---Note---
It is recommended that the bayonet not be closed in underload in case of a fault condition.

The overload sensing fuse protects the transformer against overload and the isolation link against high fault currents. The overload sensing fuse is replaceable by simply removing the bayonet from the transformer and the fuse. If the isolation link blows, the transformer has to be removed
from service and sent to the factory for replacement.

---

**CAUTION**

Prior to removing the bayonet fuse holder, always release any internal pressure by using a hotstick to operate the pressure relief valve.

---

*Figure 6. Underground Transformer Components*
Lesson 4: Three-Phase Transformers

Learning Objective: Identify and explain the types of three-phase transformers.

Learning Method: Self-learning + On-the-job

Evaluation Method: Written test

Introduction

There are two types of three-phase transformers that are utilized in the system. The dead front dead break and the dead front load break. Both types of transformers are set up in a similar manner:

The three-phase padmount transformer consists of a transformer tank and cable compartment built as a unit with hinged doors for access to high and low voltage bushings. The transformer is completely self-contained.

The cable compartment is enclosed by the use of two doors and is weatherproof and permanently bonded to the tank. The doors are designed to provide maximum access and can be secured in 90 degree and 120 degree open positions; the doors are bonded to the cable enclosures by a strap. They have a single padlocking feature where high voltage doors cannot be opened without the low voltage door being opened first. In addition, a special safety screw is provided to lock both doors.

The three-phase unit also has the following equipment:

- removable sill on the kiosk to help in the installation of cables
- emergency knockouts
- lifting lugs
- a manhole cover which features a built in automatic relief value (dead break only)
- external off-circuit tap changer with four, 2-1/2 percent taps
- transformer protection by three externally accessible, oil immersed, load break, load sensing isolating links
- a manual pressure relief valve which must be operated prior to drawing out bayonet fuse holders
- oil level gauge
- thermometer with a maximum temperature drag hand
- oil spill tray pan with drain
- three oil immersed group operated switches (two for loop feed and one for the transformer). The switches are rated 23kV, 200 amp, continuous and interrupting with 9,000 amps on momentary close and hold. The switch compartment is connected to the main tank by two filters so that contamination migration is reduced.

Figure 7. Three-Phase Underground Transformer Components

The H0 (ground) is brought out in the primary compartment through a bushing. There are four low voltage bushings with spade type terminals to connect the compression lugs to.
The ground buss extends through the high voltage and low voltage compartments located on the front of the tank at the top of the sill. The H0 and X0 bushings are solidly grounded by a grounding strap to a short ground buss extending into each compartment and it, in turn, is connected to the main ground buss located at the bottom of the transformer.

The real difference between the dead front dead break and the dead front load break is found in the high voltage connections.

The best way to tell that the transformer is dead break or load break is to look at the high voltage terminations (elbows and bushings).
Dead Front Dead Break

The dead break transformer has six clamp type, high voltage bushing wells to accept non-load break bushing inserts and six parking stands for non-load break accessories.

The bushings are slightly smaller along with the elbows. Also, the elbows are held in place by a clamp type system called a bail assembly.

CAUTION

A dead break indicates the elbows cannot be removed from the bushings while energized.

Figure 8. Three-Phase Dead Break Transformer
Dead Front Load Break

The load break transformer has six high voltage bushing wells to accept load break bushing inserts and six parking stands for load break accessories.

The bushings are slightly larger, as are the elbows. These elbows have a ridge inside that corresponds with a groove in the bushing which holds them in place.

As an additional indication of the load break capabilities, the elbows have a double white band attached to them.

Figure 9. Three-Phase Transformer - Most Common Model
Lesson 5: Fault Indicators

Learning Objective: Identify and explain the function of fault indicators.
Learning Method: Self-learning + On-the-job
Evaluation Method: Written test

Introduction

Fault indicators provide the ability to locate faults on the underground system quickly and accurately. These indicators are available in various types and current ratings. Proper installation and location is crucial to ensure reliability.

Operation

When a fault occurs, a large amount of current will flow (fault current) until the overcurrent protection operates (blowing a fuse). Fault indicators sense this large amount of current flow and trip. The trip will be indicated with either a red target flag or a red flashing (LED) light. We can determine the location of the fault by following the red lights and seeing where they stop (the fault will be in between the two fault indicators).

Location

The location of fault indicators is vital for their operation.

Indicators must never be clamped around the concentric neutral, or it will not operate.

Indicators should be installed on every transformer on the H1A bushing side, however there is no standard to support this placement.

---Note---

The majority of fault indicators can be reset with a magnet and Class 2 rubber gloves or will reset automatically after four hours.
**DANGER**

*The flag type Hortsman must be reset manually with a hotstick.*

---Note---

*It may be necessary to initiate the fault a second time if the fault indicators have stopped flashing.*
Lesson 6: Manhole Work

Learning Objective: Recognize the hazards associated with manhole work.
Learning Method: Self-learning + On-the-job
Evaluation Method: Written test

Introduction

A manhole is an underground enclosure which houses cable splices and other related electrical apparatus. The size and shape of a manhole is influenced by the following factors:

• racking of cables (any movement of cables)
• space required to rack and splice the largest cable installed
• ultimate number of cables to be installed
• direction in which the cables enter and leave the manhole
• available space in the roadway

Reference

For further information on manhole work, refer to Occupational Health & Safety Regulations, Confined Space Entry, Part XVIII.

When working in manholes, some important rules to follow are:

• do not re-rack energized cables
• pump water out if any is present
• use a ladder when getting in or out
• use a gas detector and check for poisonous gas
• assure proper ventilation
• check the identification tags on the cable to ensure you have the correct one
• spear the cable(s) to be worked on with a grounding spear prior to entering the manhole
• never work alone
Summary

To summarize this module, you have learned:

- The function of a reactor.
- The function of a switching cubicle.
- The types of single-phase and three-phase transformers.
- The function of fault indicators.
- The hazards associated with manhole work.

Practice Feedback

Review the lesson, ask any questions and complete the self-test.

Evaluation

When you are ready, complete the final test. You are expected to achieve 100%.
Review Questions

T / F  1. Reactors put inductive reactance into the underground system.

T / F  2. Reactors put capacitive reactance into the underground system.

T / F  3. Reactors counteract the capacitive reactance which is caused by primary underground cable.

T / F  4. Reactors counteract the inductive reactance which is caused by primary underground cable.

T / F  5. The size of a reactor is measured using kVars.

T / F  6. The size of a reactor is measured by using kVA.

T / F  7. Switching cubicles may be used to:
   (a) Open a circuit.
   (b) Change the connection of a circuit.
   (c) Close a circuit.
   (d) All of these

T / F  8. Low profile 25kV switching kiosks use load break elbow terminations.

T / F  9. Switching equipment may be operated within a manhole.

T / F  10. Switching equipment must not be operated within a manhole.

11. The two types of single-phase underground transformers used are:
    (a) Live front, dead break and live front, load break.
    (b) Live front, load break and dead front, dead break.
    (c) Live front, dead break and dead front, load break.
    (d) Live front, load break and dead front, load break.
T / F 12. In a dead front, load break transformer, the low voltage and high voltage terminals are enclosed in the same compartment.

T / F 13. When all the high voltage components are exposed inside the kiosk, it is said to be a live front transformer.

T / F 14. A live front, load break transformer is protected by a NX silver sand fuse.

T / F 15. A dead front, load break transformer is protected by a bayonet fuse.

T / F 16. A dead front, load break transformer is protected by a NX silver sand fuse.

T / F 17. A live front, load break transformer is protected by a bayonet fuse.

T / F 18. Both types of transformers consist of a transformer tank and a cable compartment.

T / F 19. The NX Silver Sand fuse is used to protect three-phase underground transformers from overload.

T / F 20. There are a total of two group operated switches inside a three-phase underground transformer.

T / F 21. Both dead break and load break elbows are held in place with a bail assembly.

T / F 22. Load break elbows have a double white band attached to them.

23. The two types of three-phase underground transformers used are:
   (a) Dead front dead break and dead front load break.
   (b) Live front dead break and live front load break.
   (c) Live front live break and dead front load break.
   (d) Dead break live front and non-load break.

24. Fault indicators indicate a fault by a:
   (a) Red flashing light.
   (b) White flag.
(c) Green flashing light.
(d) None of these

T / F 25. Fault indicators should be installed on the H1A bushing cable side.

T / F 26. Fault indicators may be clamped on concentric neutrals.

T / F 27. Fault indicators must never be clamped on concentric neutrals.

T / F 28. It may be necessary to initiate the fault a second time if the fault indicators have stopped flashing.

T / F 29. Do not re-rack cables which are energized.

T / F 30. A manhole is an above ground enclosure which houses cable splices and other related electrical equipment.

T / F 31. A manhole is an underground enclosure which houses cable splices and other related electrical equipment.

T / F 32. Racking of cables refers to any movement of cables.

T / F 33. Racking of cables refers to any splicing of cables.

T / F 34. A gas detector is used to check for any poisonous gas.

T / F 35. When working in a manhole, never work alone.
## Review Question Solutions

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