Tab 5 - Overview of Power Distribution System Equipment

Distribution Systems Engineering - Course 1
Distribution Substation, 46 kV to 12.5 kV
TWO 3-PHASE TRANSFORMERS
HV = 23 KV DELTA
LV = 12.5 KV GRD. WYE

THREE 12.5 KV THREE-PHASE FEEDERS

4-WIRE MULTI-GROUNDED NEUTRAL

1-PHASE 200 AMPERE RECLOSERS SET FOR 2 FAST AND 2 SLOW OPERATIONS
Substation for Suburban/Rural Area (continued)

- **EQUIPMENTS WITHIN RURAL SUBSTATION**

  - 23 KV BORIC ACID FUSES ON HV SIDE OF EACH TRANSFORMER
  - 200 AMP 1-PHASE RECLOSERS ON 12.5 KV FEEDERS
  - 200 AMP 1-PHASE RECLOSER BYPASS SWITCH
Substation for Suburban Area
4.16 kV Distribution

23 KV DISCONNECT SWITCHES

FUSES ON 23 KV SIDE OF SUBSTATION TRANSFORMER

23 KV TO 4.16 KV TRANSFORMER

4 KV METAL CLAD SWITCHGEAR FOR 4.16 KV FEEDER BREAKERS.

23 KV DISCONNECT SWITCHES

FUSES ON 23 KV SIDE OF SUBSTATION TRANSFORMER

23 KV TO 4.16 KV TRANSFORMER

4 KV METAL CLAD SWITCHGEAR FOR 4.16 KV FEEDER BREAKERS.
Substation for Large Metropolitan Area
138 kV to 13 kV

• NEW YORK CITY, MURRAY HILL SUBSTATION, WEST 30TH STREET, CON EDISON
• **138 KV TO 23 KV FOR 3-Φ 4-WIRE MULTI-GROUNDED NEUTRAL DISTRIBUTION**

![Image of Substation Transformer](image)

- **138 KV BUSHINGS**
- **SURGE ARRESTERS**
- **RADIATORS AND COOLING FANS**

**23 KV Neutral Bushing**

**23 KV Φ Bushings**
Substation Transformer (continued)

- Circuit Switcher on HV side
- Delta-Wye Winding Connections
- Neutral Grounding Reactor on MV side
- Surge Arresters on HV and MV side of Transformer
- Grounding Conductor from Neutral Reactor to Station Ground Mat

Neutral Bushing
Substation Transformer (continued)

- Transformers have nameplates which provide data.
  - Size, voltages, impedance, taps, weights, connection diagrams

- Transformers also have temperature gauges/accessories
  - Used to display the internal oil temperature
  - Pressure relief valve to vent high pressures that can damage tank
• NAMEPLATE FROM 2000/2240 KVA NETWORK TRANSFORMER

55°C C KVA RATING

WINDING RATED VOLTAGES

HV WINDING TAP VOLTAGES

BIL’S OF HV & LV WINDINGS

IMPEDANCE IN %

QUASSI PHASOR DIAGRAM
DELTA HIGH VOLTAGE,
WYE LOW VOLTAGE, 30° PHASE SHIFT
Substation Circuit Breakers

- **Typical breaker/structure is shown here**
  - Breakers are quantified with a voltage rating, continuous current rating, and short circuit interrupting rating
  - Insulation mediums are air, oil, or gas
  - Interrupting mediums are air, oil, gas, and vacuum
  - There are many different bus structures and configurations in distribution substations
Substation Circuit Breakers (continued)

FREE-STANDING 13.2 KV FEEDER CIRCUIT BREAKERS WITH:

1. AIR FOR LINE-TO-LINE AND LINE-TO-GROUND INSULATION

2. VACUUM BOTTLES FOR INTERRUPTING MEDIUM
Substation Circuit Breakers (continued)

- 4 KV SUBSTATION WITH METAL CLAD SWITCHGEAR

FACTORY ASSEMBLY

INCLUDES BREAKERS, BUSSES, RELAYS, AND CONTROL DEVICES

DIGITAL RELAYS

CIRCUIT BREAKERS ARE VACUUM, AIR-MAGNETIC, OR GAS

CIRCUIT BREAKERS ARE “DRAW-OUT”

BUS SCHEMATIC: DOUBLE BUS DOUBLE BREAKER
• THREE-PHASE CIRCUIT BREAKER WITH OIL FOR INSULATION AND INTERRUPTING MEDIUM

CONTROL CABINET

BUSHINGS

TANK WITH OIL AND INTERRUPTERS
(Tank can be lowered to inspect and repair components)
Substation Circuit Breakers (continued)

OLD VS NEW TECHNOLOGY CIRCUIT BREAKERS

OIL CIRCUIT BREAKERS
THREE SINGLE-TANK BREAKERS WITH COMMON OPERATING MECHANISM
THE INTERRUPTER FOR EACH PHASE IS IN A SEPARATE TANK

VACUUM CIRCUIT BREAKER
AIR FOR PHASE-TO-PHASE AND PHASE-TO-GROUND INSULATION.
INTERRUPTION IN VACUUM
Substation Circuit Breakers (continued)

CIRCUIT BREAKER ON HV (46 KV) SIDE OF MAIN POWER TRANSFORMER

SF-6 GAS FOR INSULATION AND INTERRUPTING MEDIUM

CURRENT TRANSFORMERS FOR PROTECTIVE RELAYING
Substation Circuit Breakers (continued)

BULK OIL CIRCUIT BREAKER (138 kV) IN SWITCHING SUBSTATION
OIL FOR INSULATION AND INTERRUPTING MEDIUMS

VOLTAGE TRANSFORMERS FOR PROTECTIVE RELAYING

ONE TANK FOR EACH PHASE, WITH COMMON OPERATING MECHANISM
• THREE SINGLE-PHASE VOLTAGE REGULATORS
Substation Capacitor Bank Connected in Floating Wye

- Capacitor Can Fuses
- Capacitor Cans, Single Bushing
- Vacuum Switches for Energizing & De-energizing Capacitor Bank
They usually do not look this confusing
- Newer designs frequently use underground getaways
Types of Overhead Construction

- Three phase “cross arm” construction
  - Four-Wire Multi-Grounded Neutral Distribution Line (Feeder)
Three phase “cross arm” construction

- Three-Wire 4800 Volt Ungrounded (DELTA) Distribution Line
- Single-phase two-wire tap line with fuse cutouts from three-phase line
Three phase “cross arm” construction
- Four-Wire Uni-grounded Neutral Distribution Circuit
- Neutral conductor grounded only at source, Neutral on full insulator
Types of Overhead Construction
Two 3-Phase Primary Circuits on Cross Arms

**TOP CIRCUIT:**
23 KV SUB TRANSMISSION, 3-WIRE UNI-GROUNDED

**BOTTOM CIRCUIT:**
4.16 KV DISTRIBUTION, 3-PHASE 4-WIRE MULTI-GROUNDED NEUTRAL

**COMMON NEUTRAL CONDUCTOR FOR**
4.16 KV CIRCUIT AND 120/240-VOLT SINGLE-PHASE THREE-WIRE SECONDARY CIRCUIT
Types of Overhead Construction
Three 3-Phase Circuits on Cross Arms

TOP CIRCUIT:
23 KV SUB TRANSMISSION, 3-WIRE UNI-GROUNDED

MIDDLE CIRCUIT:
23 KV DISTRIBUTION, 3-PHASE 4-WIRE MULTI-GROUNDED NEUTRAL
Note:
Insulators used on 23 kV distribution line are smaller than insulators on 23 kV subtransmission line. Also, cross arm is not as wide.

BOTTOM CIRCUIT:
4.16 KV DISTRIBUTION, 3-PHASE 4-WIRE MULTI-GROUNDED NEUTRAL

NEUTRAL CONDUCTOR, MULTI-GROUNDED FOR 23 KV & 4.16 KV DISTRIBUTION CIRCUITS
Types of Overhead Construction

Three-Phase 4-Wire Multi-Grounded Neutral

CON EDISON TRI MOUNT

CON EDISON ARMLESS

PHASE CONDUCTORS

NEUTRAL CONDUCTOR
Types of Overhead Construction
Three-Phase 4-Wire Multi-Grounded Neutral

VERTICAL CONFIGURATION FOR PHASE CONDUCTORS

- Insulated Phase Conductors (Tree Wire)
- Bare Multi-Grounded Neutral Conductor
- Bare Phase Conductor and Metallic Tie Wire
- Arcing Protective Devices at Insulation (to minimize chance of conductor burn down for phase-to-phase fault)
Single phase multi-grounded neutral (MGN) line

- Pole top pin insulator with the phase wire
- Neutral wire on LV spool insulator on side of pole
- Neutral is multi-grounded per National Electric Safety Code (NESC)
Types of Overhead Construction (continued)

- Single phase primary & secondary, MGN
  - Pole top post insulator with the primary phase wire
  - 120/240-Volt secondary with neutral conductor common to primary and secondary system
  - Pole top extension added when circuit phase-to-neutral voltage converted from 2.4 kV to 13.2 kV
  - Neutral conductor is multi-grounded per National Electric Safety Code (NESC)
Types of Overhead Construction (continued)

TWO PHASE THREE-WIRE MULTI-GROUNDED NEUTRAL LINE (“V PHASE”)

TWO PHASE WIRES ON CROSSARM

NEUTRAL ATTACHED TO POLE

Note: Neutral conductor is smaller size than phase wires

3-PHASE 4-WIRE 240/120 VOLT DELTA SERVICE CAN BE SUPPLIED FROM TWO-PHASE MULTI-GROUNDED NEUTRAL PRIMARY LINE WITH THE OPEN-WYE OPEN-DELTA TRANSFORMER BANK
Types of Overhead Construction (continued)

• PHASE REACTORS IN 23 KV OH DISTRIBUTION CIRCUIT IN SUBURBAN AREA

TO LIMIT SHORT CIRCUIT CURRENT TO WITHIN RATING OF DOWNSTREAM SECTIONALIZERS AND FUSES.

OVERBUILD IS 23 KV SUB TRANSMISSION

REACTORS ARE FOR 23 KV DISTRIBUTION CIRCUIT
Distribution Transformers
(Supply Utilization Voltage-120/240 1Φ, 208Y/120 3Φ, etc.)

- **Overhead – Single Phase**
  - Two or One High Voltage Bushing
  - Two, Three, or Four Low Voltage Bushings
  - Common kVA ratings are 10, 15, 25, 37.5, 50, 75, 100, 167, 250, & 333 KVA
  - Can be ‘banked’ together to supply three-phase loads

- **Overhead – Three Phase**
  - Triplex or Duplex Design
  - Common ratings are 30, 45, 75, 112.5, 150, 225 kVA
  - Used extensively by Con Edison
• OVERCURRENT AND OVERVOLTAGE PROTECTIVE EQUIPMENT IS AN INTEGRAL PART OF THE CSP DISTRIBUTION TRANSFORMER (Used by Con Edison)

CONNECTED DIRECTLY TO PRIMARY PHASE WIRE

TANK CONNECTED TO MULTI-GROUNDED NEUTRAL CONDUCTOR OF PRIMARY SYSTEM

X2 BUSHING CONNECTED TO MULTI-GROUNDED NEUTRAL CONDUCTOR AND NEUTRAL CONDUCTOR OF SECONDARY SYSTEM
Distribution Transformers (continued)

- **Single Phase Overhead CSP**
  - Note that there is no HV fuse cutout on the HV side of the transformer

- **Single Phase Overhead Recloser**
  - Note that there is not any secondary connection
• TYPE CSP TRANSFORMER (Con Edison 13 kV System)

- HOT LINE CLAMP
- LINE LEAD
- HV BUSHING

NOTE:
THERE IS NO FUSED CUTOFF ON THE HV SIDE. FUSE IS INTERNAL TO THE TRANSFORMER

- RISERS TO SUPPLY 120/240 VOLT SECONDARY CIRCUITS
- TANK GROUND LEAD TO MULTI-GROUNDED NEUTRAL CONDUCTOR
• **TYPE CSP XFR**

- **HV BUSHING**
- **SURGE ARRESTER IN PORCELEAN HOUSING**
- **BREAKER SIGNAL LIGHT**
- **SECONDARY BREAKER OPERATING HANDLE**

Note:
Transformer has only one HV bushing. Primary winding is connected from phase to neutral in a multi-grounded neutral system.

120 V
240 V
LV BUSHINGS
Distribution Transformers (continued)

- CONVENTIONAL TRANSFORMER WITH 4 LOW-VOLTAGE BUSHINGS FOR SINGLE-PHASE 3-WIRE SERVICE

  EXPULSION FUSE CUTOUT

  BACKUP CURRENT-LIMITING FUSE

  HV BUSHING

  HV SURGE ARRESTER

NOTE:

4 LOW VOLTAGE BUSHINGS PER SPECIFICATION OF UTILITY. STANDARD TRANSFORMERS RATED 100 KVA AND BELOW HAVE JUST 3 LV BUSHINGS
• THREE - PHASE POLE TOP

CONVENTIONAL XFR:
225 KVA
*EXTERNAL* FUSE CUTOUTS,
TANK MOUNTED ARRESTERs,
208Y/120 VOLT SECONDARY

TRIPLEX CONSTRUCTION:
3 ONE-PHASE CORE COIL
ASSEMBLIES IN ONE TANK,
DELTA-WYE OR WYE-WYE
CONNECTIONS OF HIGH -
VOLTAGE & LOW - VOLTAGE
WINDINGS
Distribution Transformers (continued)

• THREE-PHASE POLE TOP

CSP TRANSFORMER:
150 KVA,
INTERNAL FUSES AND SECONDARY CIRCUIT BREAKER,
TANK MOUNTED ARRESTERS,
208Y/120 VOLT SECONDARY

TRIPLEX CONSTRUCTION:
3 ONE-PHASE CORE COIL ASSEMBLIES IN ONE TANK,
DELTA-WYE OR WYE-WYE CONNECTIONS OF HV & LV WINDINGS
Distribution Transformers (continued)
3-ϕ Pole Top, Triplex Construction

- High-voltage leads
- Secondary circuit breaker
- Low-voltage leads to circuit breaker
- Primary & secondary winding for phase “A”
- Primary & secondary winding for phase “B”
- Primary & secondary winding for phase “C”

Siemens Industry Inc., Siemens Power Technologies International
• THREE-PHASE POLE TOP, 4.16 KV SYSTEM

- SURGE ARRESTERS
- LOW-VOLTAGE BUSHINGS
- HV BUSHINGS SIDE-WALL MOUNTED
- NEUTRAL CONDUCTOR OF 4.16 KV SYSTEM
- LV SERVICE 1
- LV SERVICE 2
• THREE-PHASE POLE TOP

CSP TRANSFORMER:
INTERNAL FUSES AND SECONDARY CIRCUIT BREAKER,
TANK MOUNTED ARRESTERS
208Y/120 VOLT SECONDARY

DUPLEX CONSTRUCTION:
TWO ONE-PHASE CORE COIL ASSEMBLIES IN ONE TANK,
T CONNECTIONS FOR HV & LV WINDINGS
3-ϕ Pole Top, Duplex Construction

T-T CONNECTIONS FOR HV & LV WINDINGS

LOW-VOLTAGE LEADS

HIGH-VOLTAGE LEADS

PRIMARY WINDING 1 & SECONDARY WINDING 1

PRIMARY WINDING 2 & SECONDARY WINDING 2

Distribution Transformers (continued)
• SCENERY NOT FAR FROM T-T POLE TOP TRANSFORMER ON PREVIOUS SLIDE
3 Single-phase transformers cluster mounted to provide three-phase four-wire wye service.

- FUSE CUTOUTS ON FIBERGLASS RODS (BACKUP CL FUSES ON BOTTOM TERMINAL OF FUSE CUTOUT)
- HV SURGE ARRESTERS MOUNTED ON TRANSFORMER TANK
- QUADRUPLEX SERVICE CABLE (THREE PHASE CONDUCTORS AND ONE NEUTRAL CONDUCTOR)
3 Single-phase transformers cluster mounted to provide three-phase three-wire ungrounded 240-volt (delta) service

- **HV Windings**: Connected in grounded wye
- **LV Windings**: Connected in floating wye

**CSP Transformers**

1. **Backup CL Fuse in Bushing on HV Side**, **Internal Weak Link Fuse Inside Tank**
2. **Secondary Circuit Breaker**
3. **Tank Mounted HV Surge Arresters**
Note:

TWO HALVES OF EACH SECONDARY WINDING CAN BE CONNECTED IN SERIES TO SUPPLY A 480-VOLT UNGROUNDED (DELTA) SYSTEM

SECONDARY WINDINGS CONNECTED IN FLOATING WYE

SECONDARY WINDINGS CAN NOT BE CONNECTED IN DELTA AS THIS creates a ground source for the 23 KV PRIMARY SYSTEM

GROUNDED WYE PRIMARY TO AVOID FERRORESONANCE

13279

UNGROUNDED 240 V SERVICE

138.5

240 V

240 V

TWO HALVES OF SECONDARY IN PARALLEL

SECONDARY PHASE LEADS

SECONDARY NEUTRAL CONNECTION
3 Single Phase transformers cluster mounted to provide three-phase four-wire delta service (240/120-volt)

HV WINDINGS
CONNECTED IN DELTA

LV WINDINGS
CONNECTED IN DELTA WITH CENTER TAP GROUND ON LIGHTING LEG

CONVENTIONAL TRANSFORMERS
1. FUSED CUTOUTS ON HV SIDE
2. SURGE ARRESTERS ON TOP CROSSARM
3. NO SECONDARY CIRCUIT BREAKER IN XFRS.
VIEW FROM THE MOUNTAIN ABOVE THE DELTA-DELTA TRANSFORMER BANK ON PREVIOUS SLIDE
Two single-phase transformers cluster mounted to provide three-phase four-wire delta service (240/120-volt)

HV WINDINGS
CONNECTED IN OPEN WYE

LV WINDINGS
CONNECTED IN OPEN DELTA WITH CENTER TAP GROUND ON LIGHTING LEG XFR

CP TRANSFORMERS
1. INTERNAL EXPULSION FUSE ON HV SIDE
2. LIGHTING LEG = 100 KVA
3. POWER LEG = 25 KVA
VIEW ABOUT FIVE BLOCKS SOUTH FROM OPEN-WYE OPEN-DELTA BANK ON PREVIOUS SLIDE
Distribution Transformers (continued)

- DUAL VOLTAGE SINGLE-PHASE POLE-TOP TRANSFORMER

  TWO HIGH-VOLTAGE BUSHINGS
  HV WINDING RATED 2.4 KV X 7.2 KV
  SWITCH FOR SELECTING PRIMARY VOLTAGE ON BACK SIDE OF TRANSFORMER

  THREE LOW-VOLTAGE (LV) BUSHINGS
  LV WINDING RATED 120/240 VOLTS.
  X2 BUSHING BONDED TO TANK.

  SUPPLIES NATIONAL SKI PATROL CROSS COUNTRY WARMING HUT
3 Single-Phase Transformers Mounted Together on a Platform

- Convert from one primary voltage to another primary voltage
- Mounted on a support structure to allow for proper loading of the poles
Three Single-Phase 75 kVA Step Transformers Mounted on Pole

- Con Edison System in Tarrytown, NY
- Convert from 13.2 kV 4-wire multi-grounded neutral to 4.16 kv 4-wire multi-grounded neutral
- Fuse cutouts on 13.2 kV side
- Surge arresters (tank mounted) on 13.2 & 4.16 kV side
• Three Single-Phase Step Transformers (167 kVA)
  – Convert from 23 kV 4-wire multi-grounded neutral to 4.16 kV 4-wire multi-grounded neutral
  – Current-limiting backup fuses & expulsion fuse links inside transformers on 23 kV side
  – 1-phase oil circuit reclosers on 4.16 kV side
  – Surge arresters (tank mounted) on 23 kV & 4.16 kV sides
Distribution Step (Ratio) Transformers (continued)

- FRONT OF BUILDING FROM WHICH PICTURE ON PREVIOUS SLIDE WAS TAKEN

OFFICE OCCUPIED BY GEORGE WESTINGHOUSE IN THE LATE 1800’S
Three Single-Phase Step Transformers

- Convert from 23 kV 4-wire to 4.16 kV 4-wire multi-grounded neutral

- Current-limiting backup fuses & expulsion fuses (fuse cutouts) outside transformers on 23 kV side

- No overcurrent devices on 4.16 kV side

- Surge arresters on 23 kV & 4.16 kV sides (tank mounted)
Distribution Step (Ratio) Transformers
Floating Wye Delta or Grounded-Wye Delta

2400 OR 4800 VOLT CIRCUIT TO RIGHT

FUSED CUTOUTS ON 2400 OR 4800 VOLT CIRCUIT

13.2KV OR 34.5 KV CIRCUIT TO LEFT
FUSES AND SURGE ARRESTERS ONE
SPAN TO LEFT, OUT OF SITE.

NOTE: CIRCUIT ON LOWER CROSS ARM IS
NOT ASSOCIATED WITH THE STEP BANK

13.2 KV OR 34.5 KV
MULTI-GROUNDED
NEUTRAL CIRCUIT

STEP
BANK

2400 OR 4800 VOLT
UNGROUNDED CIRCUIT

UNGROUNDED
SOURCE

NEUTRAL CUTOUT - CLOSED WHEN
BACKFEEDING FROM THE DELTA
SYSTEM, OR WHEN ENERGIZING
BANK FROM WYE SIDE

CLOSED WHEN
BACKFEEDING

OPEN WHEN
BACKFEEDING

NEUTRAL CUTOUT (OPEN)
**Distribution Step (Ratio) Transformers (continued)**

- **Two Single-Phase Step Transformers**
  - Convert from 23 kV 3-phase 4-wire to 4.16 kV to supply two-phase line (2400 volts from each phase to neutral)
  - CL backup fuses & expulsion fuses inside each transformer on 23 kV side
  - Two single-phase hydraulic reclosers on 4.16 kV side for two phase line
  - Surge arresters on 23 & 4.16 kV side (tank mounted)
- **One Single-Phase Step Transformer**
  - Converts one phase of 23 kV 3-phase 4-wire system to 2400 volts to supply single-phase 2400 volt circuit (phase & neutral)
  - CL backup fuses & expulsion fuses inside step xfr. on 23 kV side
  - One single-phase hydraulic recloser on 4.16 kV side for single phase line
  - Surge arresters on 23 & 4.16 kV side (tank mounted)
Three Single-Phase Regulators installed in long line to provide independent voltage control of the three phases.

- Mounted on a support structure to allow for proper loading of the poles
- Notice the bypass switches and the drag hand windows
Three single-phase regulators installed in substation to regulate the three phase-to-ground voltages of the 12.5 kV feeders.

Used in lieu of LTC on substation transformer

- BY-PASS ARRESTER FOR SERIES WINDING
- POSITION INDICATORS
- CONTROL CABINET
- GROUND LEAD FOR MAIN (EXCITING) WINDING
Regulators Drag Hand

- Shows maximum, minimum and present setting
Distribution Underground Transformers

- Single Phase Pad-Mounted Transformer
  - Underground supplied, typical in residential applications
  - Larger units are installed on concrete foundations or pads

HV BUSHING WELLS
LV BUSHINGS
• SINGLE-PHASE PAD MOUNTED TRANSFORMER, LOOP FEED
  - PRIMARY WINDING CONNECTED PHASE TO GROUND (NEUTRAL)
  - SECONDARY WINDING SUPPLIES 120/240-V SINGLE-PHASE 3-WIRE SECONDARY
Banking of Two Single-Phase Pad-Mounted Transformers

- Connected open-wye on primary and open-delta on secondary
- Supplies 4-wire delta secondary system rated 240/120 volts
- Lighting leg transformer is 50 kVA
- Power leg transformer is 15 kVA
Distribution Underground Transformers
3-Φ Pad Mounted Supplied from OH Line

FUSED CUTOUTS FOR SHORT CIRCUIT PROTECTION AND SWITCHING

CABLE TERMINATOR & SURGE ARRESTER

120/240-VOLT SINGLE-PHASE SECONDARY FROM OH DISTRIBUTION. XFR. (NOT SHOWN)

3-Φ 112.5 KVA PAD MOUNTED TRANSFORMER FED FROM RISER POLE ON LEFT SUPPLIES 208Y/120-VOLT 3-Φ SERVICE TO APT. BLDG.
3-PHASE PAD MOUNT

2500 KVA
34.5 KV GROUNDED Y PRIMARY
480Y/277 VOLT SECONDARY FOR SERVICE TO HOTEL

METAL ENCLOSED BUS DUCT TO SUPPLY LOW VOLTAGE SWITCHGEAR AT HOTEL

HV FUSES AT RISER POLE (NOT IN PICTURE)
Three Phase Pad-Mounted Transformer – Loop Feed – Dead Front

NAMEPLATE FOR LOOP-FEED TRANSFORMER

- HIGH-VOLTAGE (PRIMARY) COMPARTMENT
- LOW-VOLTAGE (SECONDARY) COMPARTMENT
- 208Y/120 VOLT SECONDARY
- 2.01 % IMPEDANCE
Distribution Underground Transformers (continued)

- Three Phase Pad-Mounted Transformer – Radial Feed – Dead Front

**NAMEPLATE FOR RADIAL-FEED TRANSFORMER**

HIGH-VOLTAGE (PRIMARY) COMPARTMENT

LOW-VOLTAGE (SECONDARY) COMPARTMENT

480Y/277 VOLT SECONDARY
5.98 % IMPEDANCE
Capacitors

Typical single- and two bushing capacitor units

$3\Phi$ switched capacitor bank for pole-top installation

• **PURPOSES OF CAPACITORS:**
  1. SUPPLY REACTIVE CURRENT
  2. RELEASE EQUIPMENT CAPACITY
  3. REDUCE LINE & XFR. LOSSES
  4. REDUCE VOLTAGE DROP
  5. REGULATE VOLTAGE (SWITCHED)
Capacitor Bank – Switched – OH Line

- Surge Arresters
- Fused Cutouts for Short Circuit Protection
- Single-Phase Capacitors (One Can Per Phase)
- Oil Switches for Auto Switching of Bank
Capacitor Bank – Switched – 23 kV Overhead Line

BORIC ACID FUSES AND BACKUP CURRENT-LIMITING FUSES FOR SHORT CIRCUIT PROTECTION

10 KVA CSP DISTRIBUTION TRANSFORMER FOR CONTROL POWER (INTERNAL CL FUSE ON HV SIDE)

SURGE ARRESTER APPLIED ON 10 KVA XFR.

VACUUM SWITCHES FOR AUTO SWITCHING OF CAPACITOR BANK

TWO-BUSHING CAPACITORS CONNECTED IN GROUNDED WYE
FIXED CAPACITOR BANK

12.5 KV SUBURBAN LINE

FUSED CUTOUTS FOR MANUAL SWITCHING AND SHORT CIRCUIT PROTECTION

CAPACITORS CONNECTED IN GROUNDED WYE

SURGE ARRESTERS FOR LIGHTNING PROTECTION

Note:
Right capacitor unit is of a different shape than the other two capacitor units.
Capacitor Bank – Fixed – OH Line (continued)

FIXED CAPACITOR BANK

13.2 KV URBAN LINE

FUSED CUTOUTS FOR MANUAL SWITCHING AND SHORT CIRCUIT PROTECTION

THREE-PHASE CAPACITOR

SURGE ARRESTERS FOR LIGHTNING PROTECTION

Note:
Fused cutout to center terminal of three-phase capacitor is open (drop out position).
Capacitor Bank – Switched – Pad Mounted

- Switches, Single-Pole
- Bushing Wells
- Provisions for Fuses
- Single-Phase Capacitor Cans
Recloser, Three-Phase

- **SUBSTATION INSTALLATION 12.5 KV CIRCUIT**

  - VACUUM INTERRUPTERS IN OIL FILLED TANK
  - CABINET WITH OPERATING MECHANISM
  - CABINET WITH RELAYS AND CONTROL DEVICES
Recloser, Three-Phase (continued)

- **SUBSTATION INSTALLATION 12.5 KV CIRCUIT**

  - MANUAL OPERATING HANDLE
  - TANK WITH OIL AND INTERRUPTERS
  - CABINET WITH EITHER SOLID STATE OR MICRO PROCESSOR CONTROL UNIT
  - SUBSTATION FRAME

  **Note:**
  Transformer with load tap changer (LTC) behind recloser.
Reclosers – Three Single-Phase Pole Type

- **THREE-PHASE 12.47 KV MULTI-GROUNDED NEUTRAL LINE**

  RECLOSER BYPASS SWITCH

  200 AMP COIL SET FOR 2 FAST AND 2 SLOW OPERATIONS

  THREE FUSE HOLDERS ON POLE TO BYPASS RECLOSERS WHEN TAKEN OUT OF SERVICE
Reclosers – Single-Phase Pole Type

- SINGLE-PHASE LINE INSTALLATION

**CUTOUT HOLDER TO BYPASS RECLOSER WHEN RECLOSER REMOVED FOR SERVICE**

**PHASE WIRE**

**NEUTRAL WIRE**
Sectionalizer – Automatic Three Phase

DOES NOT INTERRUPT FAULT CURRENT

COUNTS OPERATIONS OF UPSTREAM RECLOSER OR BREAKER AND OPENS WHEN BREAKER/RECLOSER IS OPEN

WHEN EQUIPPED WITH RTU, CAN BE REMOTELY OPENED OR CLOSED

MAIN TANK, OIL FILLED WITH INTERRUPTERS

CONTROL POWER TRANSFORMER (10 KVA)
Fuses

■ Purpose
  – To isolate faulted equipment and components from unfaulted portion of system
  – To provide visible means of disconnect

■ Applications
  – Overhead line sectionalizing
  – Distribution transformers
  – Capacitors
  – Underground cable circuits
Distribution Fuse Cutouts

DISTRIBUTION TRANSFORMER PROTECTED WITH FUSE CUTOUT AND BACK-UP CURRENT LIMITING (CL) FUSE

EXPULSION FUSE CUTOUT

BACK-UP CL FUSE

SURGE ARRESTER

EXPULSION FUSE CUTOUT WITH LOAD BREAK ATTACHMENT
Distribution Fuse Cutout

- **SOURCE-SIDE LEAD**
- **HOOK EYE**
- **FUSE HOLDER**
- **HINGE**
- **LOAD-SIDE LEAD**

**PORCELEAN INSULATOR**
(provides line-to-ground insulation on both sides)
Distribution Fuse Cutouts (continued)

- **Fuse Link for Insertion in Cutout Fuse Holder**

- **Button Head**
- **Auxiliary Tube to Aid in Low Current Interruption**
- **Leader for Attachment to Cutout Mechanism**
Boric Acid Type Fuse in Dropout Mounting

- Porcelain insulator for line-to-ground insulation
- Boric acid type fuse (must be replaced following operation)
- Reusable top end fittings
- Reusable bottom end fittings
- Load-side lead
- Line (source) side lead
Cutaway of fuse that has melted and interrupted

- **Spring for moving arcing rod thru boric acid when the fusible element melts**

- **Boric acid interrupting medium. Heat of arc turns into boric anhydride and water vapor to help cool and extinguish arc at current zero**

- **Fusible element and strain element. Both are melted.**

- **Strain element holds arcing rod in boric acid chamber until fusible element melts**
Fuses – Components of Boric Acid Type (continued)
CUTAWAY OF 15.5 KV, 25 “C” AMPERE FUSE THAT HAS NOT MELTED

END FURULE

GLASS FILAMENT WOUND TUBE FOR CONTAINMENT AND SUPPORT OF FUSE ELEMENT (FILLED WITH FINE SILICA SAND)

MAIN ELEMENT WITH MULTIPLE NOTCHES TO FORM MULTIPLE ARCS UNDER HIGH CURRENT CONDITIONS.
PURE SILVER

AUXILIARY ELEMENT TO AID IN LOW-CURRENT CLEARING

GLASS RODS TO SUPPORT SPIRALED MAIN ELEMENT AND AUXILIARY ELEMENT
GENERAL PURPOSE CL FUSES CAN INTERRUPT ANY CURRENT WHICH CAUSES MELTING OF THE FUSIBLE ELEMENT IN ONE (1) HOUR OR LESS

IF THE CURRENT WHICH CAUSES MELTING REQUIRES MORE THAN 1 HOUR TO MELT THE FUSIBLE ELEMENT, THE GENERAL PURPOSE (GP) FUSE MAY NOT INTERRUPT.

BELOW IS AN EXAMPLE OF A GP CURRENT-LIMITING FUSE WHICH FAILED.
Fuses: Comparison of Current Let-Thru with Expulsion and Current-Limiting

- CURRENT LIMITING FUSE FOR HIGH AVAILABLE FAULT CURRENTS ABOVE THRESHOLD:
  1. LIMITS THE PEAK LET THRU CURRENT TO LESS THAN THE PROSPECTIVE CURRENT
  2. FORCES AN EARLY CURRENT ZERO
  3. LIMITS ENERGY INTO FAULTED APPARATUS
The purpose of the switch is to provide the utility the ability to redirect the source connection to the load, or manually isolate sections of the feeder/system.

Switches are usually located at strategic points with easy access.

Specific operating procedures must be followed when opening or closing a switch.
Gang operated 25kV Class Three-Phase Pole-Top With Load Break Capability: Operated From Ground Level

SURGE ARRESTERS ON BOTH SIDES OF SWITCH
THREE SINGLE-PHASE SWITCHES IN THREE-PHASE 4-WIRE LINE
HOOK STICK OPERATED

- **Phase Conductor**
- **Disconnect Switch for Indicated Phase Conductor**
- **Pole Guy**
- **Neutral Conductor Attached to Side of Pole, Out of View**
LOAD-BREAK SWITCH 
FOR 23 KV OH DISTRIBUTION 
SYSTEM 
CONTAINS SF6 INTERRUPTERS 

SWITCH IS REMOTELY 
CONTROLLED 
FOR SECTIONALIZING AND 
FAULT ISOLATION 

CONTAINS CURRENT & 
VOLTAGE SENSORS 
FOR CONTROL AND REMOTE 
MONITORING 

POSITION INDICATOR 

STORED ENERGY OPERATING 
MECHANISM
Switches (continued)

VOLTAGE REGULATOR BYPASS SWITCH
USED TO “BYPASS” THE REGULATOR WHEN TAKEN OUT OF SERVICE

SINGLE-PHASE POLE-MOUNTED VOLTAGE REGULATOR IN THREE-PHASE LINE.
VOLTAGE REGULATORS FOR OTHER PHASES ARE MOUNTED ON ADJACENT POLES.
Switches, Pad Mounted for UG Distribution

SWITCH ENCLOSURES TYPICALLY CONTAIN MANUALLY OPERATED SWITCHES AND FUSES FOR PROTECTION OF PRIMARY CIRCUITS
Switches, Pad Mounted for UG Distribution
Low-Profile “Vista Gear”

Contains switches, overcurrent devices, and cable terminations
Various underground connectors per a typical manufacturer’s product line
Underground Connectors (continued)

- Example Uses Of Underground Connectors
  - From the Elastimold Catalog
Elastimold Catalog Items For Cable Terminations
Typical riserpole termination and its application

PARALLEL SURGE ARRESTERS

CABLE TERMINATOR
Pad-mounted Substations
13.8 kV to 4.16 kV

Note: Three-Phase Transformer “out-of-site” behind switchgear enclosures
Pad-mounted Substations
34.5 kV to 12.47 kV

- Single Phase Voltage Regulators for 12.47 kV Circuit
- 34.5 to 12.47 kV Transformer And 12 kV Single-Phase Reclosers
- 35 kV Switchgear
Surge (Lightning) Arresters

Typical metal oxide polymer-housed distribution arrester (10 kV unit shown)

Typical intermediate and station-class metal oxide arresters (various voltage ratings shown)
Surge (Lightning) Arresters (continued)

Surge Arresters on Overhead 46 KV Sub-Transmission Line that Does Not Have a Shield Wire
SURGE ARRESTERS FOR PROTECTION OF UNDERGROUND CABLE CIRCUIT

Note:
Surge arrester is mounted close to the terminator to minimize the voltage drop in the surge arrester leads.
Surge (Lightning) Arresters (continued)

Note:
Surge arrester mounted above the terminator results in long leads and high voltage drop in the surge arrester leads when discharging lightning current.
Surge (Lightning) Arresters (continued)

- PARALLEL DISTRIBUTION SURGE ARRESTERS AT CABLE RISER POLE
Kilo-watt Hour Meter – Self Contained

- Electro-mechanical meter for single-phase 3-wire service
ELECTRONIC METER FOR SINGLE-PHASE 120/240-VOLT 3-WIRE INSTALLATION

THIS METER IS SELF CONTAINED. IT DOES NOT REQUIRE ANY CURRENT TRANSFORMERS OR VOLTAGE TRANSFORMERS

OPTICAL PORT FOR READING

SEAL TO AID IN DETECTION OF TAMPERING
Metering: Current Transformer Rated Installation

CURRENT TRANSFORMERS (ONE PER PHASE)

Note: No CT required for neutral conductors

CONDUITS WITH SERVICE ENTRANCE CONDUCTORS

ELECTRONIC METER FOR 3-PHASE SERVICE
An Early Pre-Pay Single-Phase KWHR Meter

**RATINGS:**
5 AMP
115 VOLT
2-WIRE

**INSTRUCTIONS:**
INSERT ONLY ONE QUARTER AT A TIME

COINS MUST NOT BE INSERTED BEYOND FULL POINT

Note:
Top most registers give the unused kWHr