NIGERIAN ELECTRICITY MANAGEMENT SERVICES AGENCY

Development and Production of Electrical Installation and Construction Standards Guideline Manual for the Distribution Subsector of the Power Industry

PRESENTED BY: ENGR. PAUL I. AUDU
FOR

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AGENDA

GENERAL INTRODUCTION, STANDARDS & SPECIFICATIONS (Vol. 1)

- Introduction to Electrical Installation and Construction Guideline
- Line/Cable Standards & Specifications

Electrical Installations and Construction GuidelineManuak

- Vol. 2 – Overhead Lines and U/G Cables
- Vol. 3 – Switchgears and Substations
- Vol. 4 – Power System Protection and Control, Inspection, Testing & Commissioning
- Vol. 5 - **Electricity Distribution Safety Manual**

THE PRESENT CHALLENGE IN DISTRIBUTION SUB-SECTOR

Compromised Installation Standards

POLE MOUNTED TRANSFORMER INSTALLED ON UNGALVANIZED (RUSTED) CHANNEL IRON AND IN CLOSE PROXIMITY TO A BUILDING

POLE MOUNTED TRANSFORMER INSTALLED ON GALVANIZED CHANNEL IRON AND NOT IN CLOSE PROXIMITY TO A BUILDING

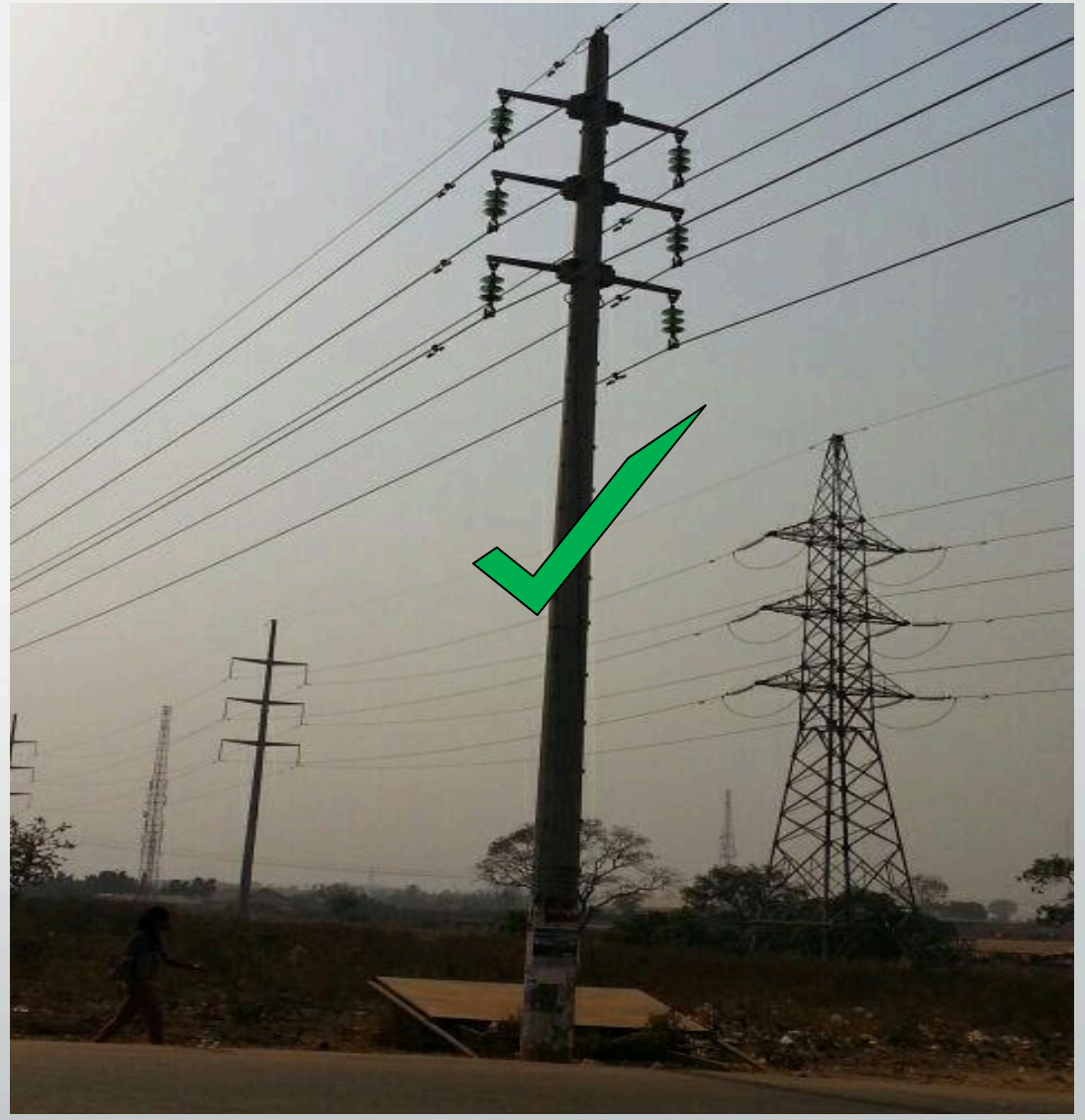
Compromised Installation Standards

A BILL BOARD WAS USED AS A HIGH TENSION POLE WHERE 33KV POT INSULATORS WERE MOUNTED IN PLACE OF CROSS ARM.

A GOOD CONSTRUCTION OF INTERMEDIATE POLE WITH ENOUGH CLEARANCE FROM THE BILL BOARD.

Compromised Installation Standards

USE OF EXTENDED UNGALVANIZED (RUSTED) CHANNEL IRON FOR THE CONSTRUCTION OF 33KV DOUBLE CIRCUIT FOR ADEQUATE CLEARANCE



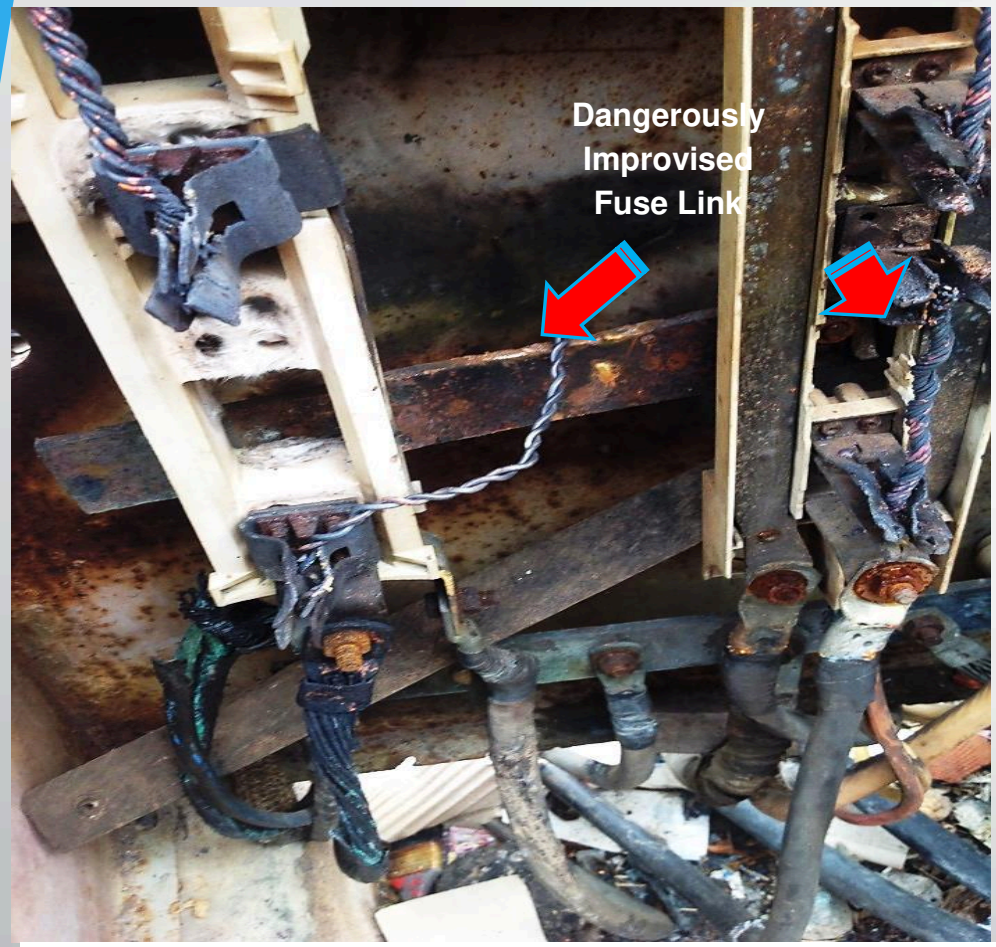
STANDARD CONSTRUCTION OF 33KV DOUBLE CIRCUIT

Compromised Installation Standards

A NEWLY INSTALLED TRANSFORMER WITHOUT FENCING

A NEWLY CONSTRUCTED SUBSTATION WITH STANDARD FENCING AND GRAVELLING.

STATE OF DISTRIBUTION SUBSTATIONS



Improvised Fuse-link directly on bus-bar

EXPOSED SUBSTATION IN PUBLIC PLACES

STATUS OF OUR FEEDER-PILLARS/SUBSTATIONS

INTRODUCTION TO THE GUIDELINES MANUAL

GENERAL PROVISIONS

- The Nigerian Electrical Installations and Construction Guidelines Manual is a practical manual to provide instructions and operational guidelines for good electrical installations and construction practice
- The application of this manual will ensure uniformity of technical standards and specifications in the Nigerian Electricity Supply Industry (NESI) with particular reference to Power Distribution Networks.
- It will also serve as a benchmark for NEMSA electrical inspectors for their inspection testing and certification activities.
- When this Nigerian Electrical Construction and Installation Guidelines Manual comes into force, non-standard installations will become a thing of the past.

PURPOSE

- The intent of these guidelines is to Establish a clear and definite standard of installation and construction practices among the DISCOs and all practitioners in the distribution sector of Nigeria Electricity Supply Industry (NESI).
- With detailed and clear Sketches, Illustrations and Dimensions, the Guidelines Manual will:

1. Establish the step-by-step approach to design and construction of different sub-transmission power lines and town distribution/reticulation networks and all types of injection/distribution substations.
2. Address the hows and whys of electrical materials and equipment specifications and standards for various aspects of the electrical installations activities.
3. Define the nitty-gritty of overhead and underground network construction methodologies
4. Dwell extensively on Protection Systems/schemes, SCADA and other allied matters as they relate to distribution networks.
5. Provide basis for Safety considerations that are paramount in construction, installation, operation and maintenance of electrical distribution networks.

ADEQUACY OF COMPLIANCE

- It is important to note that compliance with the provisions of the Nigerian Electrical Construction and Installation Guidelines Manual can effectively:
  - Ensure best practices in installation and Construction Standards in NESI.
  - Minimise Electrical accident/hazards in the Power Distribution system.
  - Minimise Losses in the Electrical Distribution System.

NORMATIVE REFERENCES

- Several normative documents contain provisions, which, through reference in this text, constitute provisions of these guidelines Manual.
- The Nigerian Electrical Installation and Construction Guidelines Manual addresses critical Engineering and Safety issues in alignment with reference to the following National and International Regulatory, codes and Standards.
  - Nigerian Electricity Supply and Installation Standards (NESIS 2015).
  - The retained regulations of the Electricity Act (CAP 106)

NORMATIVE REFERENCES

- ❑ Nigerian Industrial Standard Specifications (NIS)
- ❑ The International Electro-technical Commission (IEC) Standards.
- ❑ British Standards Institution (BSI),
- ❑ American National Standards Institute (ANSI)
- ❑ Institute of Electrical and Electronics Engineers
- ❑ National Electrical Code (NEC)
- ❑ Occupational Safety and Health Administration (OSHA)
- ❑ International Organisation for Standardisation (ISO)
- ❑ Several other Internationally recognised Standards.

➢ Users are encouraged to apply most recent editions

SCOPE:

- The Guidelines Manual applies to all Electrical Power Distribution systems and networks - indoors and outdoors.
- Installation of conductors and equipment in all the Distribution Companies networks, franchise area and anywhere on the load-side of the point of connection to the serving utility, and they must comply with the provisions given in the Nigerian Electricity Installation and Construction Guidelines Manual.
- This guideline is designed for all Electrical Power Distribution Systems within 33/11/0.415KV voltage ranges as specified in the Nigerian Electricity Supply and Installation Standards (NESIS 2015) and The Retained Regulations of Electricity Act (CAP 106 LFN 1990).
- Particular provisions for Power Generation, Transmission, Electric Traction, which are components of the Power Supply System are not covered in this guideline.
- However, the scope of this Guidelines includes the installation of optical fiber cable and ancillary, *as* part of the high-technology for Micro-controllers, SCADA and Substation Automation Systems (SAS).

ARRANGEMENT

- The Electrical Installation and Construction Guidelines Manual is arranged in five volumes. These include:
  - Volume 1: Gen. Introduction, Line Standards & Specifications
  - Volume 2: Installation and Construction Guidelines for Overhead Lines and Underground Cables
  - Volume 3: Installation and Construction Guidelines - Switchgears and Substations
  - Volume 4: Protection Control and Metering - Substation Automation, SCADA, Inspection, Testing and Commissioning
  - Volume 5: Electricity Distribution Safety Precautions Manual
- It is arranged in a way that the user can easily access information with specific reference to particular aspect of required construction. The Slides that follow give summary of each volume.

GENERAL INSTALLATION REQUIREMENTS

- Other aspects of Electrical Installations that are not particularly covered in details in these five volumes are addressed in the general introduction as follows:
- DISTRIBUTION FEEDER VOLTAGE REGULATION
  - Because of the necessity to regulate the distribution voltage and in order to ensure that these drops stay within a permissible range, methods of distribution voltage regulation is introduced.
  - Voltage drops, above the permissible level, that have negative consequences which result in an increase in the system maintenance cost, decrease in the safety and sub-optimal performance of the network must be avoided.
  - Optimum Voltage Regulation for 11KV & 33KV Overhead Lines & Cables are evaluated for acceptable feeder lengths

GENERAL INSTALLATION REQUIREMENTS

➢ CABLE SIZE CALCULATION

❑ Five simple steps to calculating the right size of cable for a particular load is introduced. These are as follows:

1. Design current (I_b) Calculation. This is the normal current drawn by the load.
2. Selection of the type and current rating of the overcurrent device (I_n).
3. Application of the relevant correction factors to obtain the tabulated current (I_t) in accordance with BS 3036, BS 7671 and IEC 60364 .
4. Selection of the current-carrying capacity of the cable (which is termed I_z) in compliance with BS 7671, IEC 60364.
5. Calculate the voltage drop to ensure that it is not excessive and within regulation at full load current.

GENERAL INSTALLATION REQUIREMENTS

- ELECTRICAL ENERGY EFFICIENCY
  - Because of enormous technical and commercial losses encountered in the distribution networks and the attendant inefficiencies in power supply, this aspect is exhaustively addressed in this segment
  - Generic or case-specific cost/benefit analysis required to justify expenditure for these system improvements are suggested.
  - Listed below are the areas which will be of the most interest to the Discos and the Public at large:
    1. Financial appraisal and the cost of the energy losses to industry and the potential savings to be made by specifying a high-efficiency installation.
    2. Appraisal of capital expenditure
    3. Economic justification for purchasing high-efficiency equipment

GENERAL INSTALLATION REQUIREMENTS

- ELECTRICAL ENERGY EFFICIENCY

4. Evaluation of transformer losses and its impact on system efficiency
5. Evaluation of line losses and its impact of reliable power supply
6. Cost considerations of cable selection and economic justification on total installation costs.

- There is not a uniformly defined approach across the industry because each utility's electrical system is unique and the availability of information and data varies from utility to utility.
- Since we in NESI have a uniformly defined approach in the Basic Electrical Supply and Distribution System, it is pertinent we seek to adopt a uniform step to evaluating our technical losses by looking at various methodologies.
- This has been actualised in this guidelines.

SUMMARY OF THE VARIOUS VOLUMES

LINE/CABLE STANDARDS AND SPECIFICATIONS

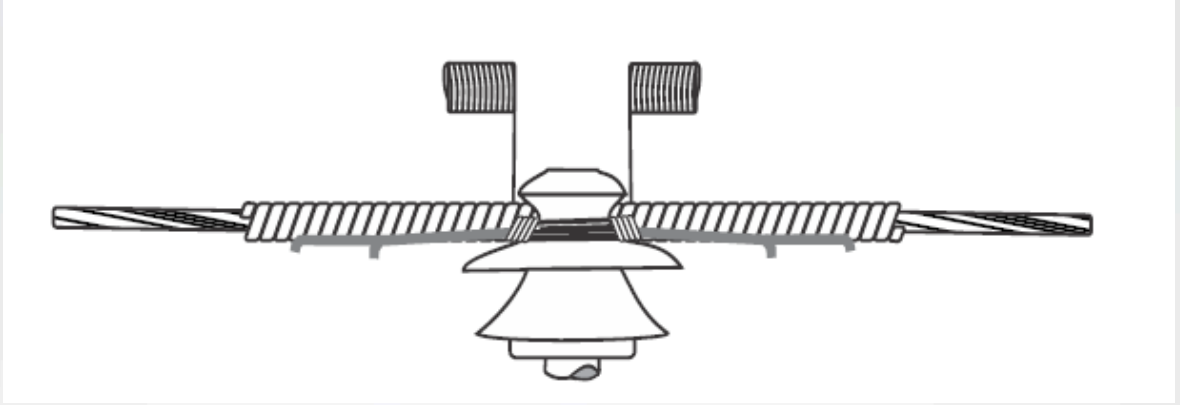
- This Volume sets the basis for the Design Standards and Specifications adopted in the Lines Installation and Construction Guideline Manuals (Vol.2).
- Specifications and design Standards required for construction and Installations are defined and outlined in this volume.
- These include specifications and standards for Overhead Lines and Poles as well as Cables.

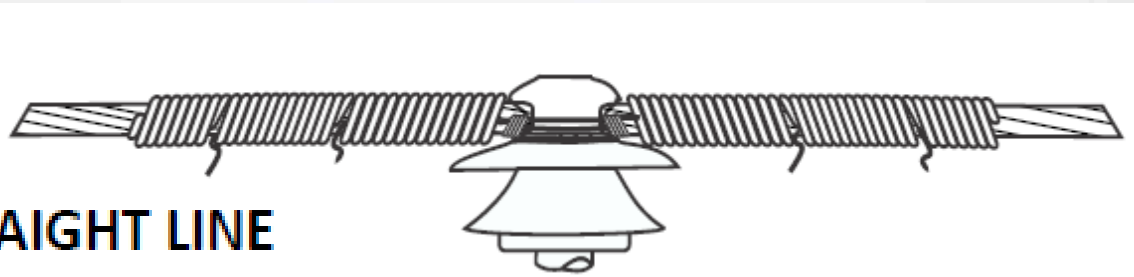
OVERHEAD LINES AND UNDERGROUND CABLES

- This volume is specifications for overhead line construction Manual.
- It includes General Specification for HV Lines, General Specification for LV Lines, Index of Line Designs, Line Designs.
- The volume establishes the foundation for standard forms of overhead constructions for the Medium and Low Voltage installations Specific materials and component for standard overhead line construction provided.

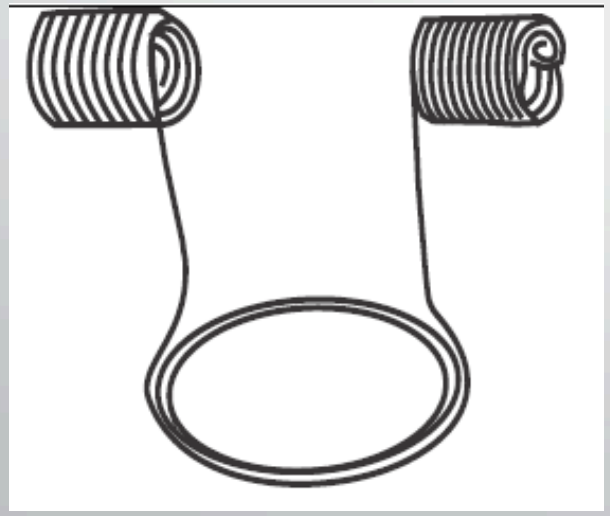
OVERHEAD LINES AND UNDERGROUND CABLES

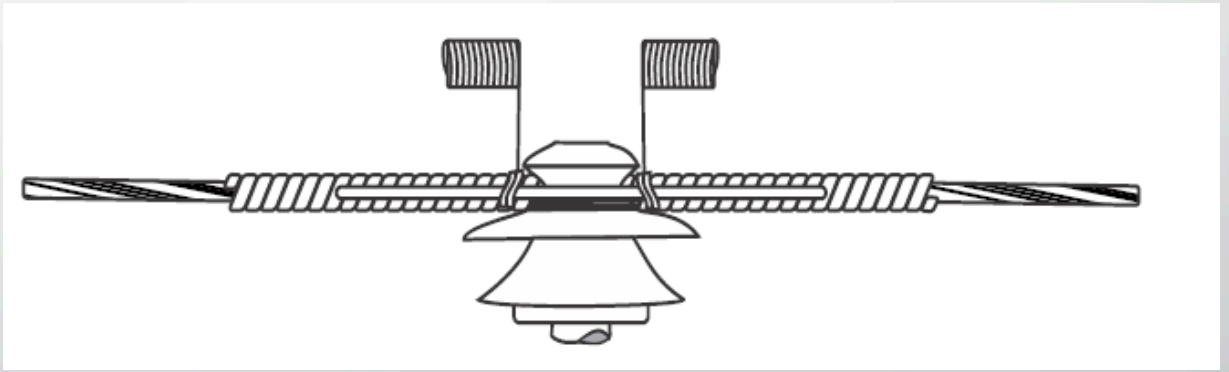
- These include:
  - Line Supports and dimensions,
  - Poles and Pole Planting depths,
  - Minimum heights of poles carrying ancillary equipment,
  - Installation Specifications,
  - Permissible angles on insulator pins and line deviations,
  - Specification for insulators,
  - Standard tables of material specifications,
  - Standards for clearances at various locations, conductors, poles and line material dimensions.
- Various line design and construction standards for general site installations and special site requirements as well as associated construction material, equipment and provisions are also specified.

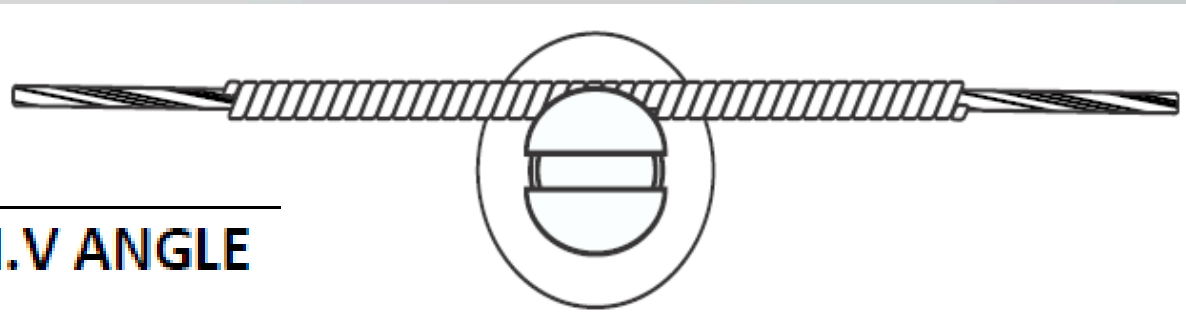




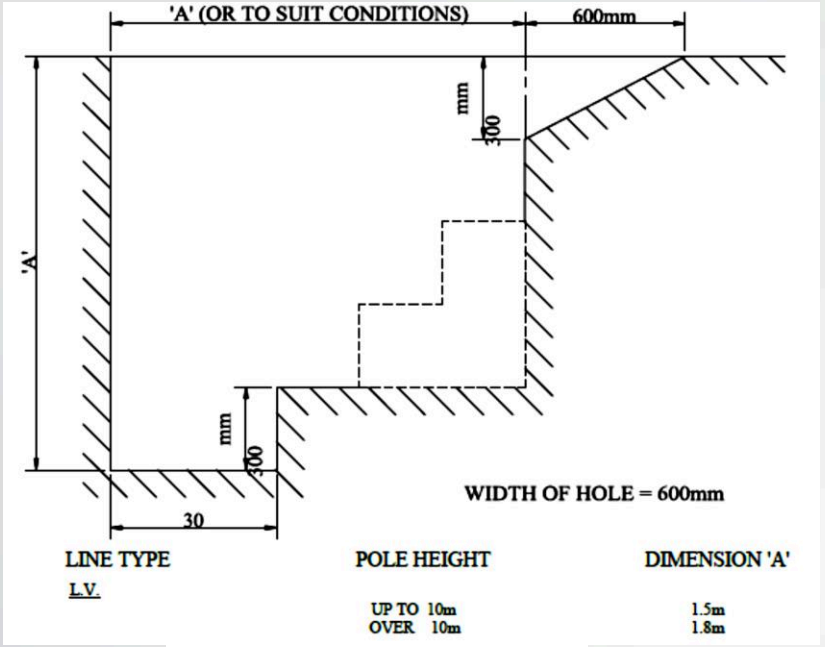
CONDUCTOR BINDING-IN H.V STRAIGHT LINE







CONDUCTOR BINDING-IN H.V ANGLE

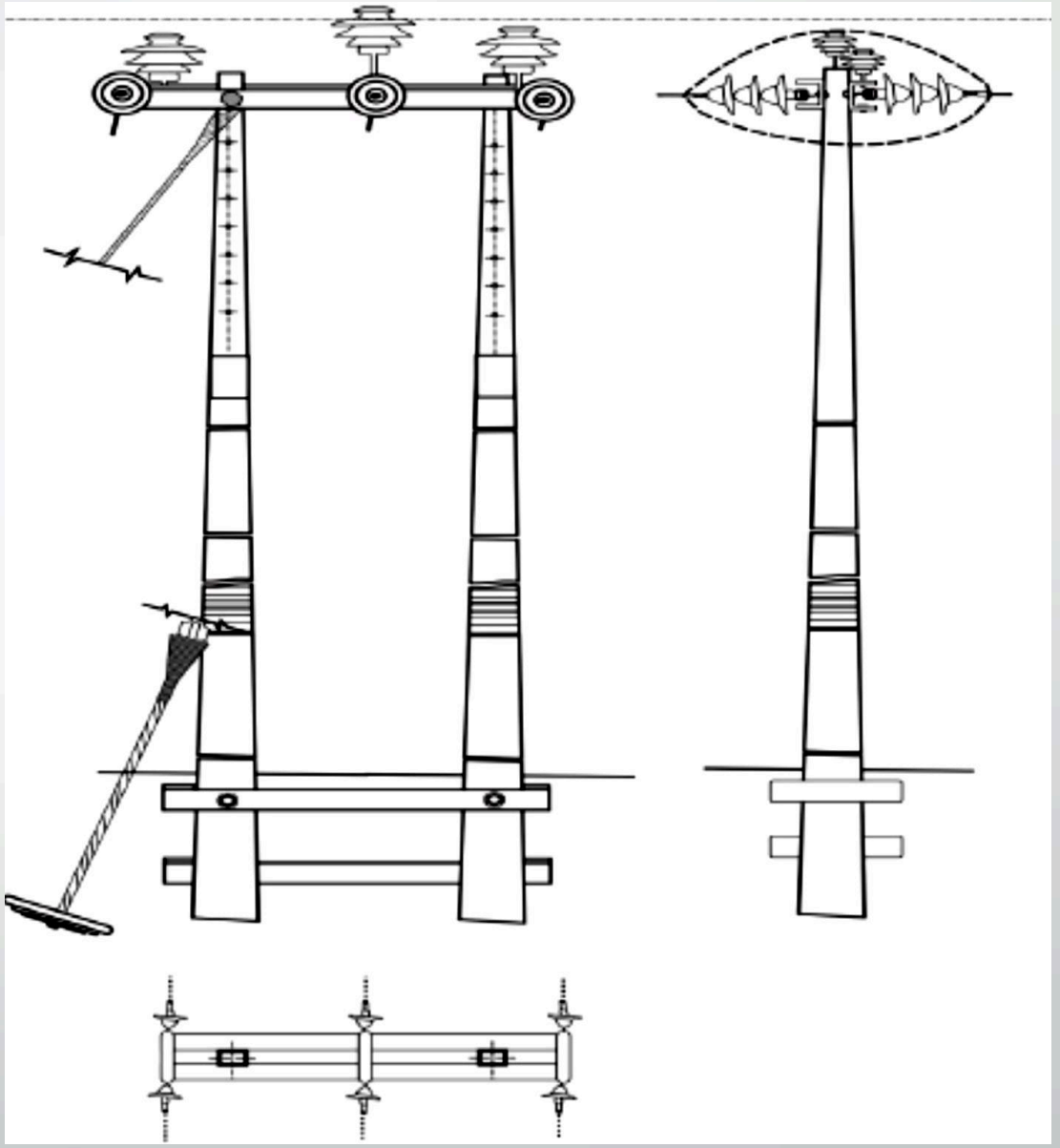


STANDARD POLE HOLE

Pole type	Minimum Height
Terminal Single Pole with Bolt-on Transformer (25 kVA Max) without fuses	9m
Terminal Single Pole with Bolt-on Transformer (25 kVA Max) with fuses	10m
Terminal Single or H Pole with Platform-mounted Transformer without fuses	9m
Terminal Single or H Pole with Platform-mounted Transformer with fuse	10m
Terminal Single or H Pole with platform-mounted Transformer & Cable Termination with or without fuses.	11m

The lengths given are the overall length of the pole including planting depth.

Minimum heights of poles carrying ancillary equipment



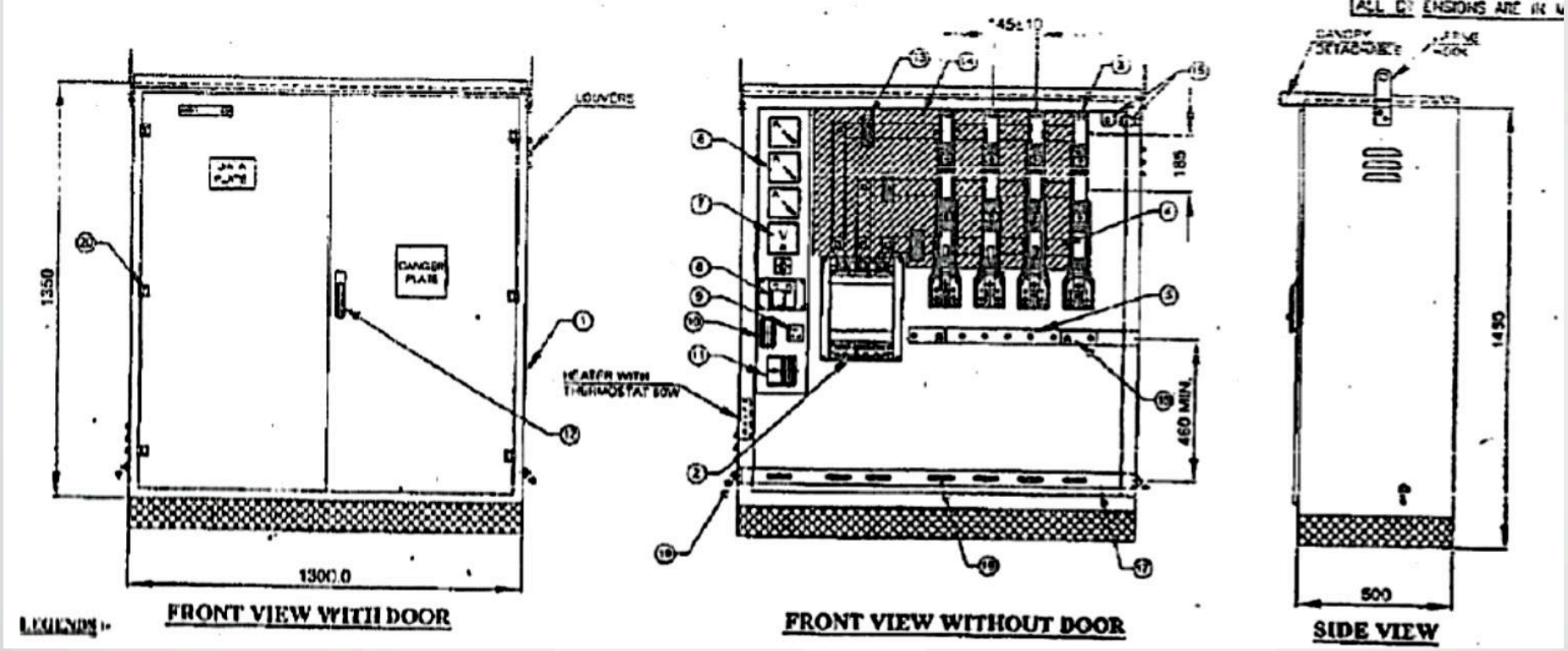
SECTION H POLE (Concrete)

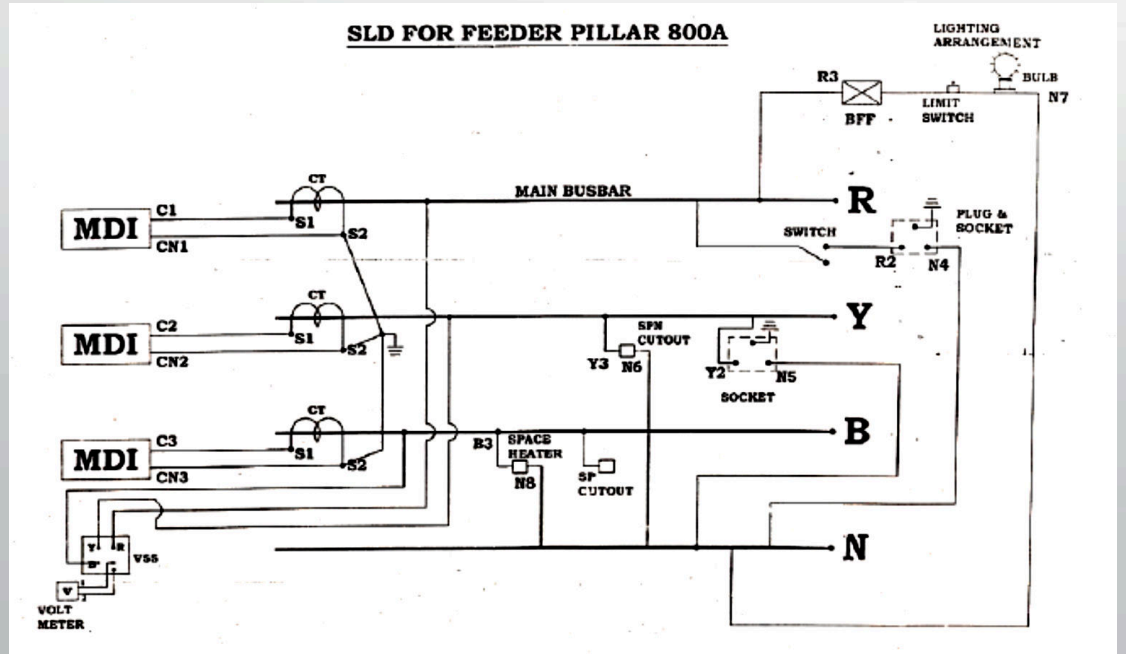
OVERHEAD LINES AND UNDERGROUND CABLES

- Standard tables for material specifications and required line tensions, sags as well several ambient conditions that impact on particular line installations, drawings and standard construction guides are sufficiently provided.

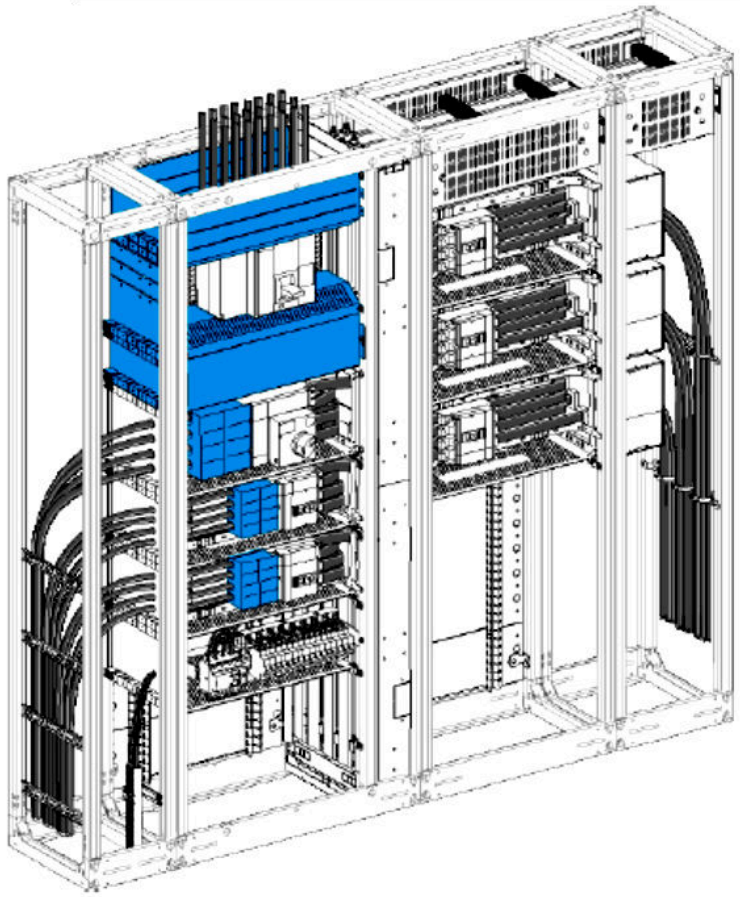
SWITCHGEARS AND SUBSTATIONS

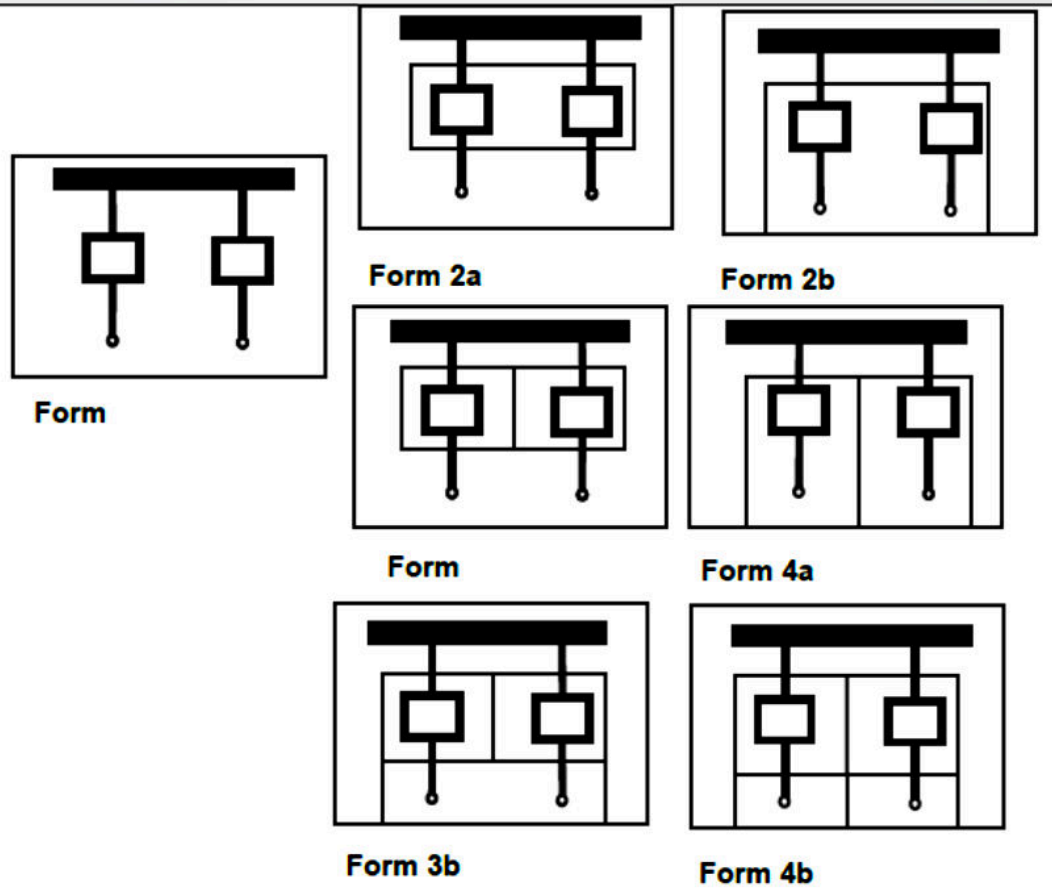
- Standard specifications and installation guidelines for switchgear and substation equipment are provided in volume 3.
- These include specification and construction instructions based on National and international standards.
- Details of Switchgear design and installations, including Feeder-pillars, Line and load-break disconnectors, Medium Voltage fuses, Circuit Breakers and Ring-main-units are sufficiently addressed.
- Substation and substation equipment installations in accordance with National and international standards are adequately addressed.



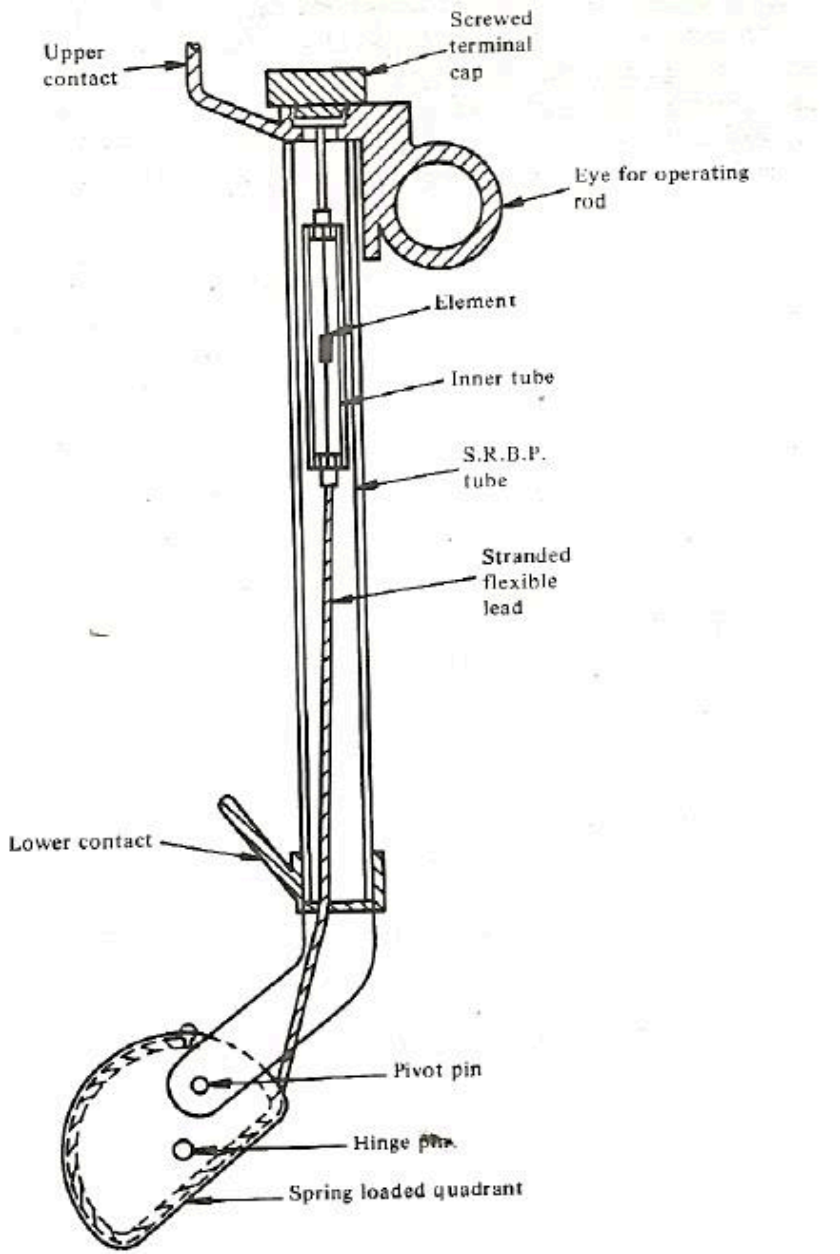


STANDARD REQUIREMENT FOR OUTDOOR FEEDER-PILLARS





STANDARD LV SWITCHGEAR PARTITIONING ACCORDING TO IEC 61439



SPECIFICATION FOR REFILLABLE AND NON REFILLABLE HV FUSES

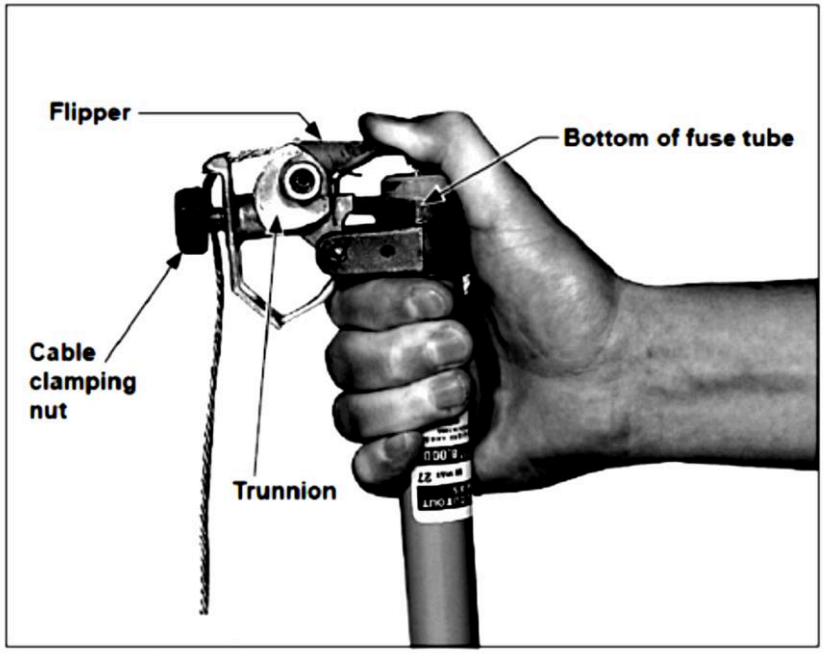


Figure 2a. Flipper fully pivoted.

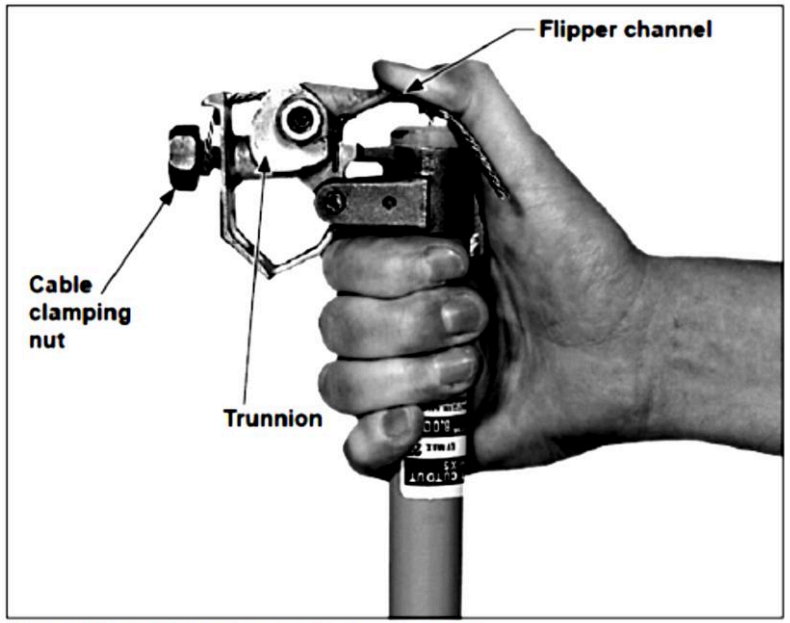


Figure 2b. Cable under tension around nut.

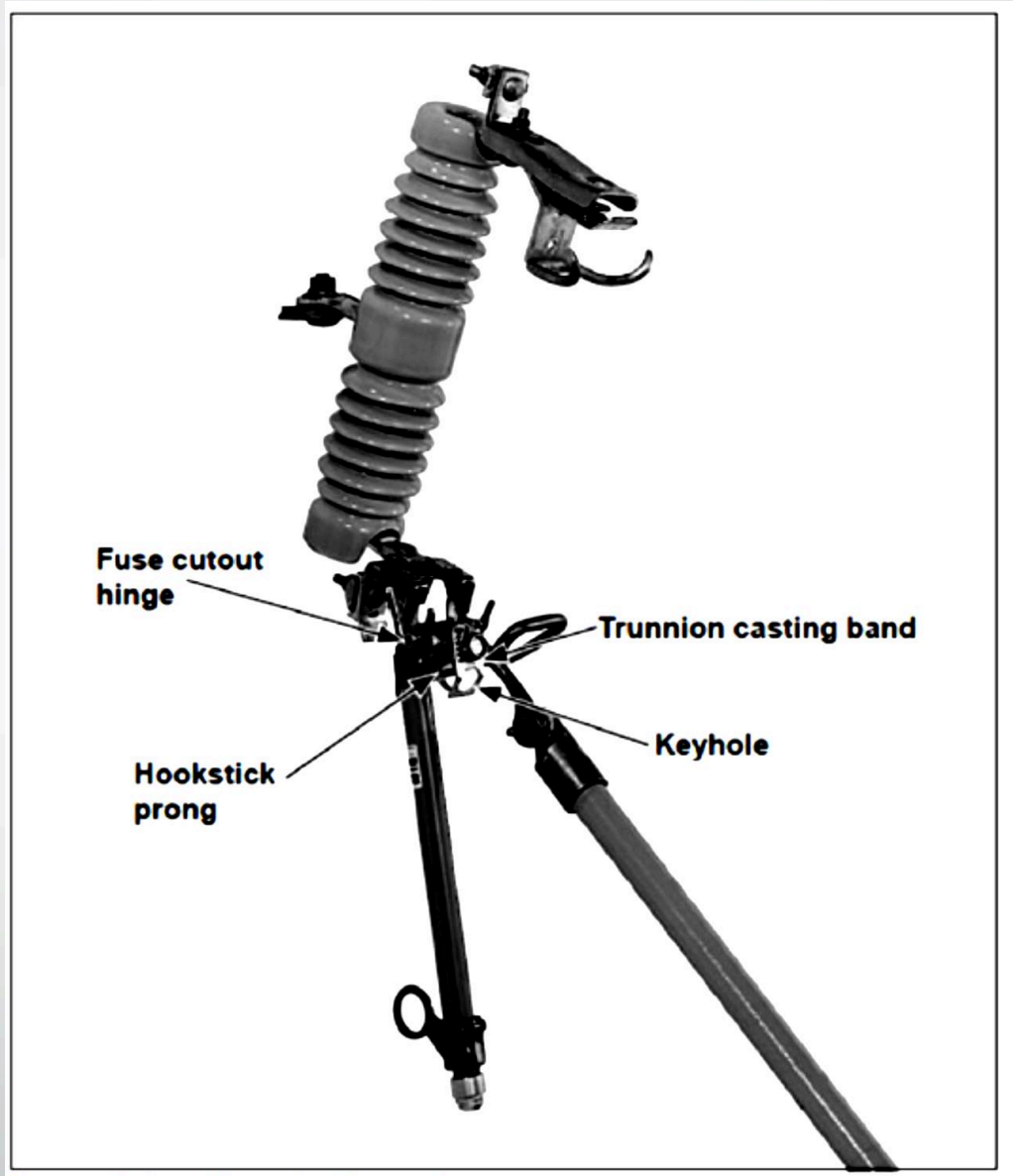


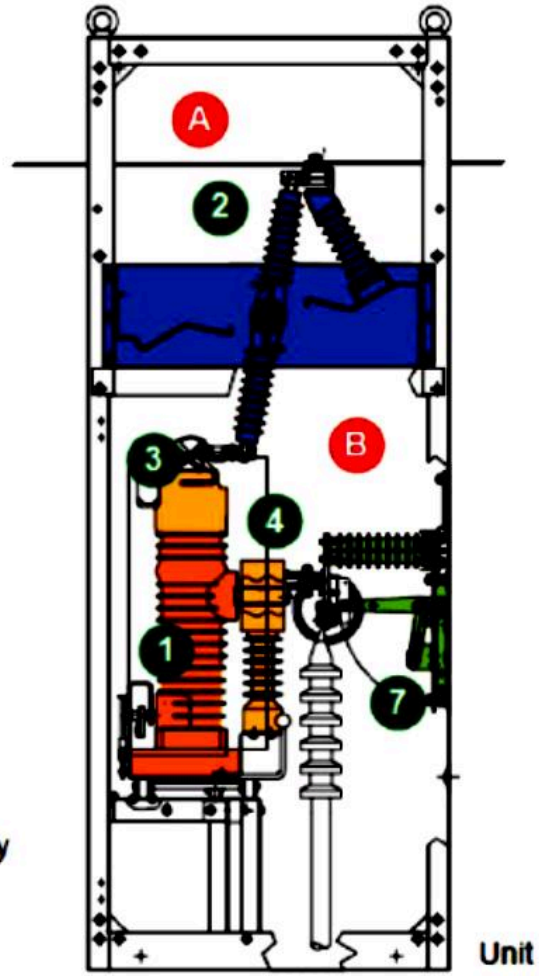
Figure 3. Installing the fuse tube.

INSTRUCTIONS FOR HV FUSE INSTALLATIONS

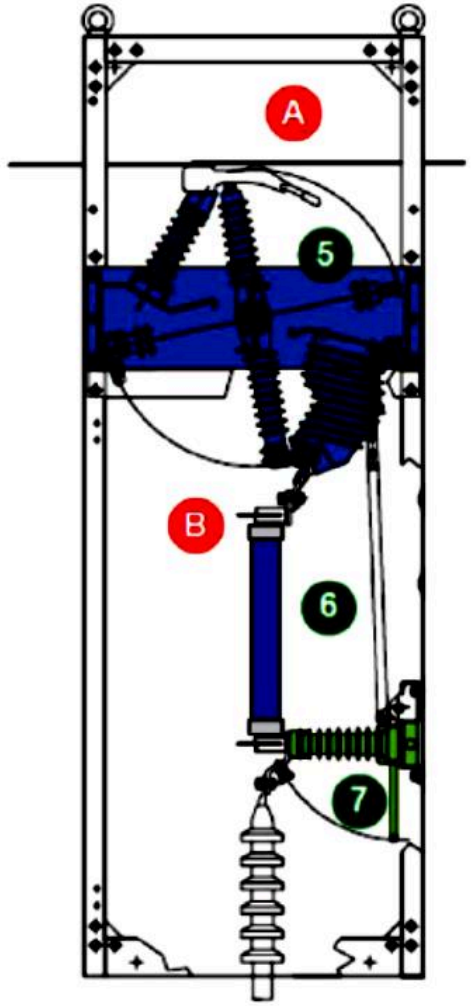
SWITCHGEARS AND SUBSTATIONS

- Specifications for indoor and outdoor Substations and substation equipment with standard dimensions are provided.
- Details of transformer specifications and installation for both Injection and Distribution substations are provided in this volume, including High Voltage Distributions Systems (HVDS) as well as packaged substations.
- This volume contains Substation Site Layout Specifications and construction design, planning and installation with adequate provisions for equipment and site dimensions.
- Factors taken into consideration for Design, Installation and Construction of Substation Equipment using physical site and location conditions.
- Factors and Standards taken into consideration for Erection of Indoor Equipment.
- Design and Installation of Substation/Equipment Grounding (Earthing).

1 Circuit-breaker
2 Isolator
3 PR521 protection relay
4 Current sensors
5 Switch-disconnector
6 Fuses
7 Earthing switch

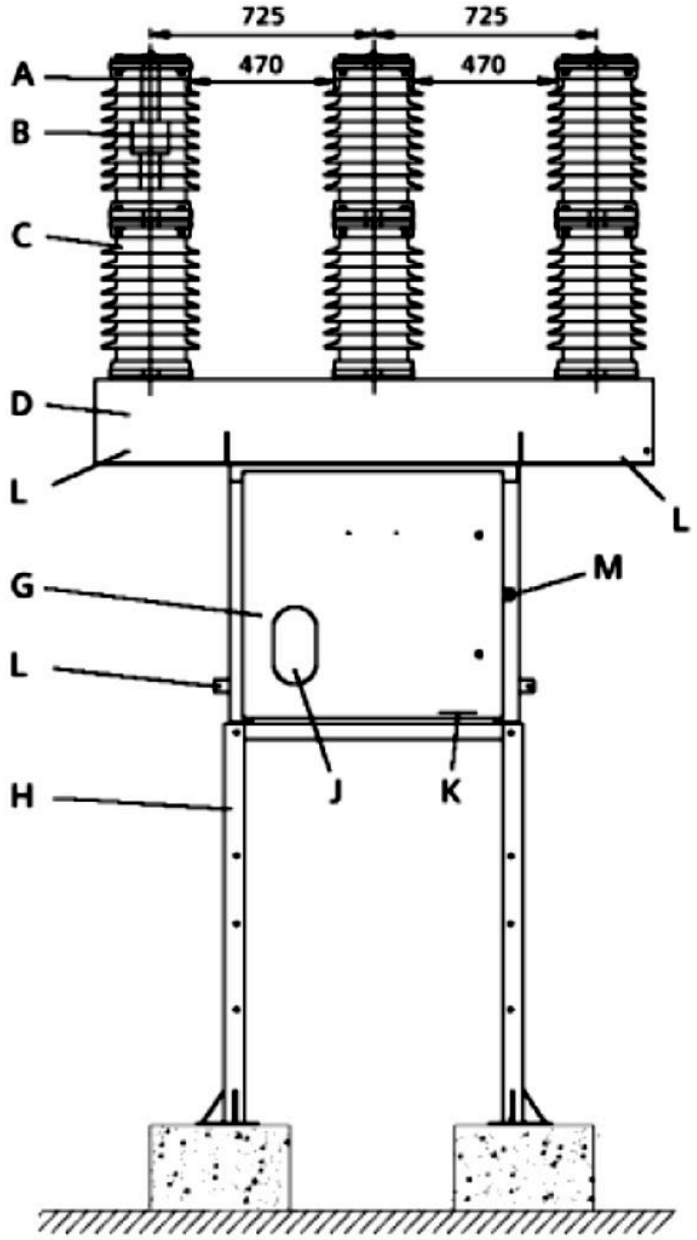


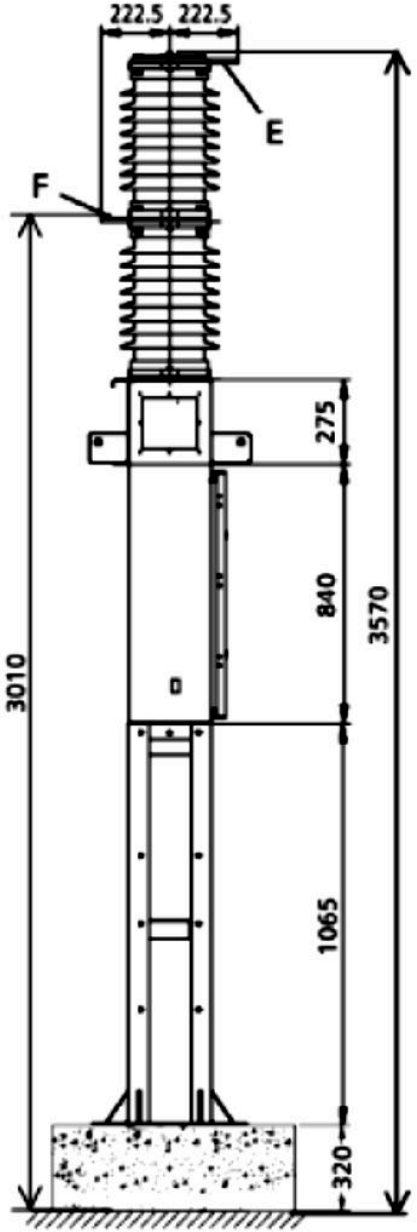
Unit with circuit-breaker.



Unit with switch-disconnector and fuses.

MECHANISM INTERACTION IN A TYPICAL 11KV SF6 BREAKER





A. Interrupter Assembly
B. Vacuum Interrupter
C. Support Insulator
D. Base Frame
E. Top Terminal
F. Bottom Terminal
G. Drive Mechanism Housing
H. Galvanised Steel Structure
J. Plexiglass for Viewing Mechanical Indications
K. Control Cable Gland Plate
L. Earthing Terminals
M. Facility for Padlock

TYPICAL INSTALLATION LAYOUT FOR 33KV OUTDOOR CIRCUIT BREAKER

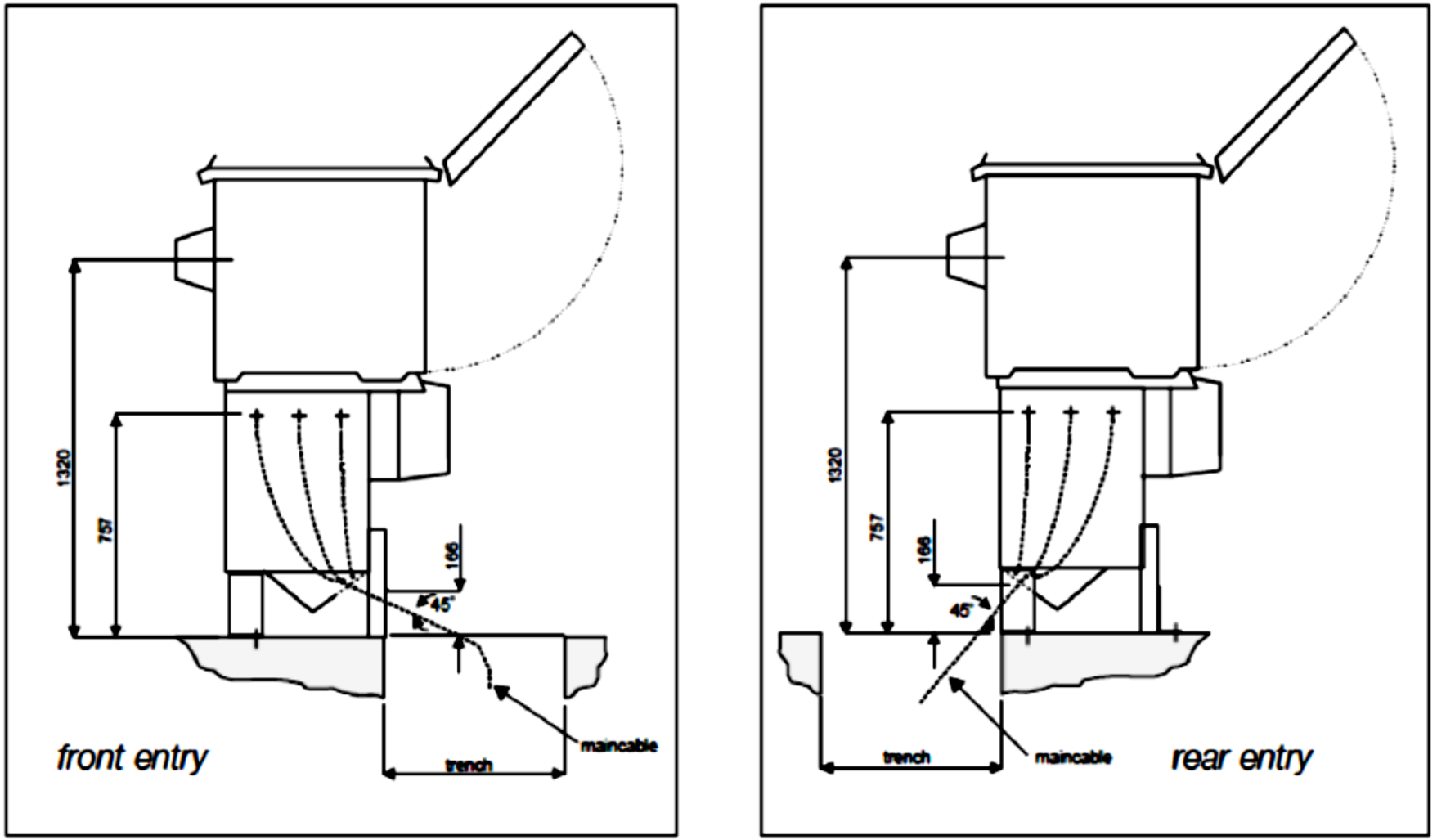
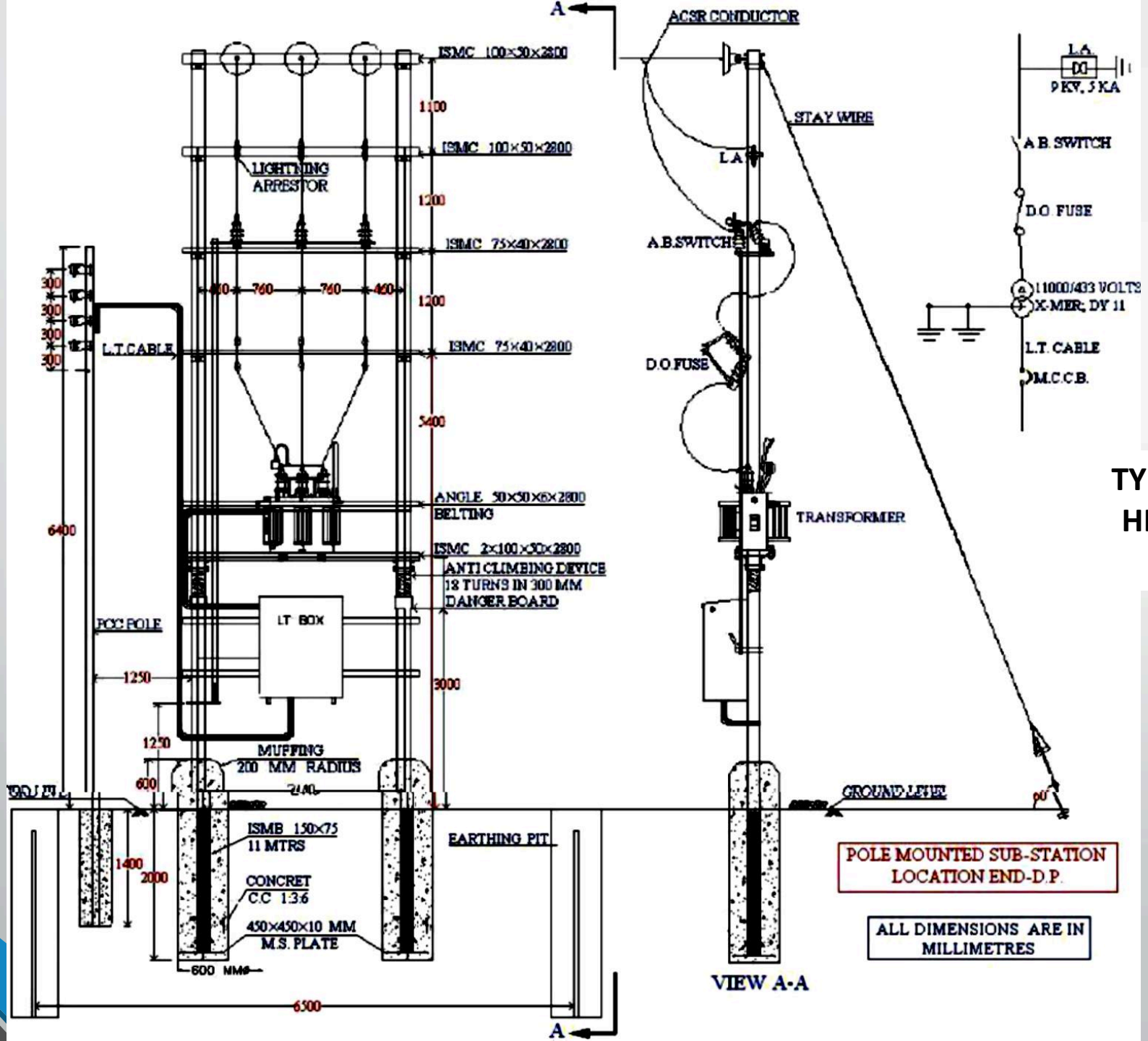
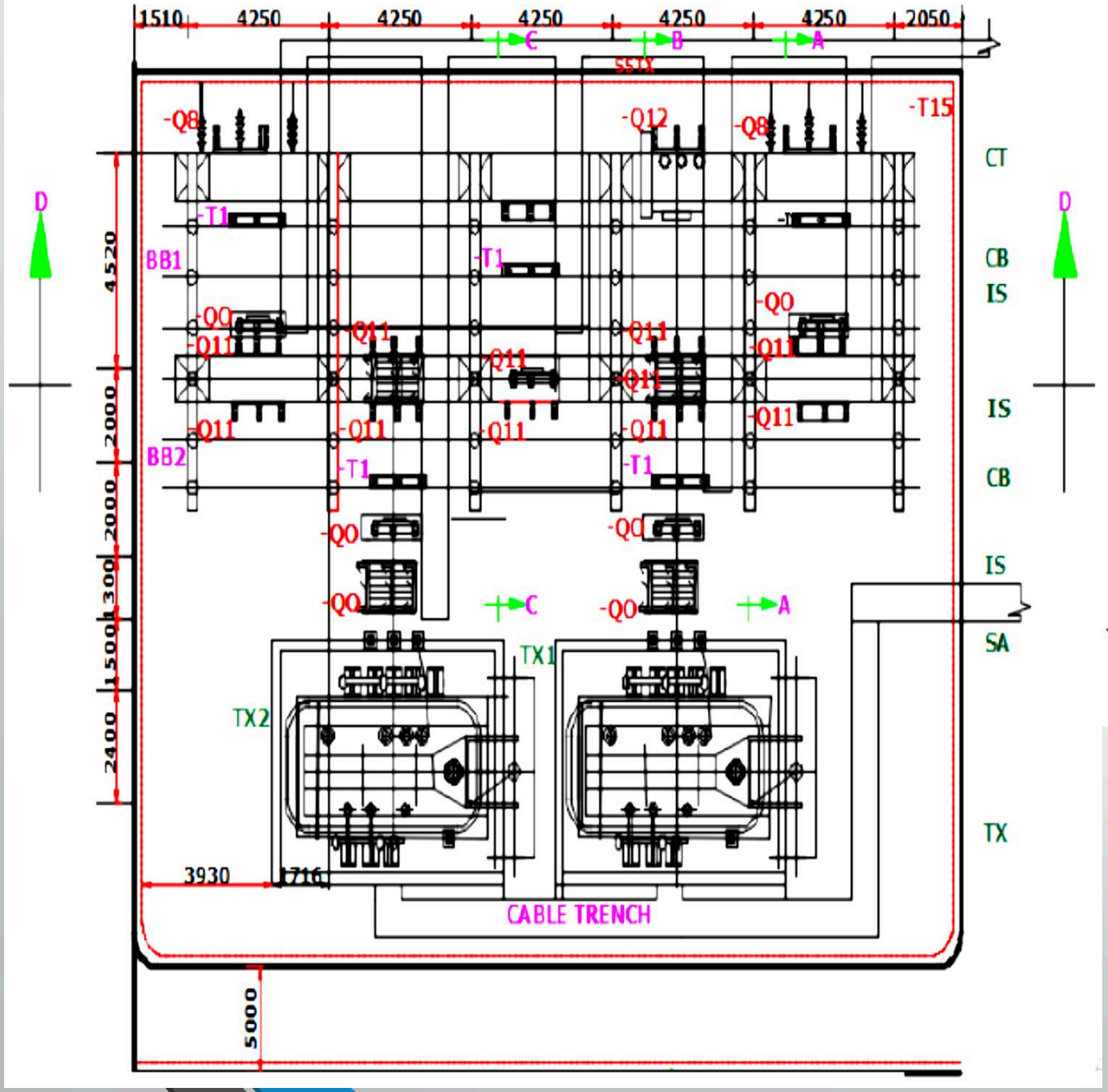


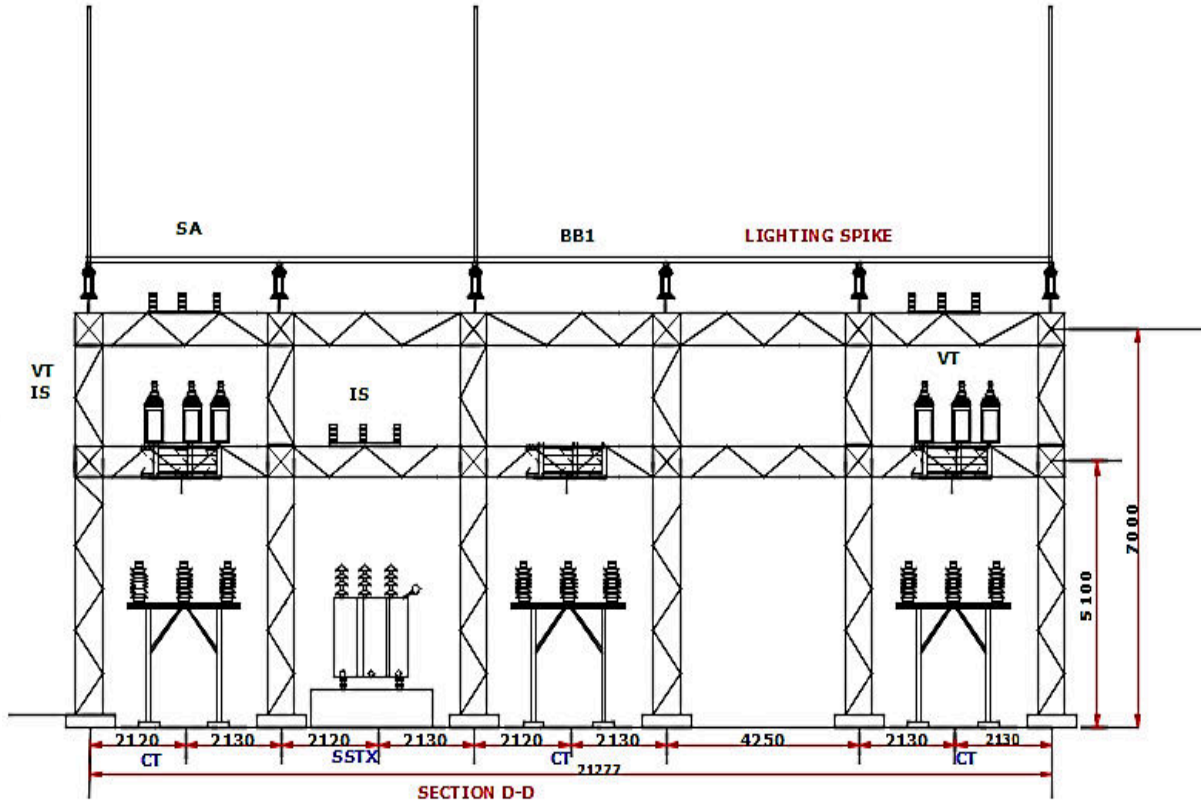
Fig. 3-106.6CABLE ENTRY ARRANGEMENT

TYPICAL INSTALLATION LAYOUT FOR OUTDOOR SF6 RING-MAIN-UNITS



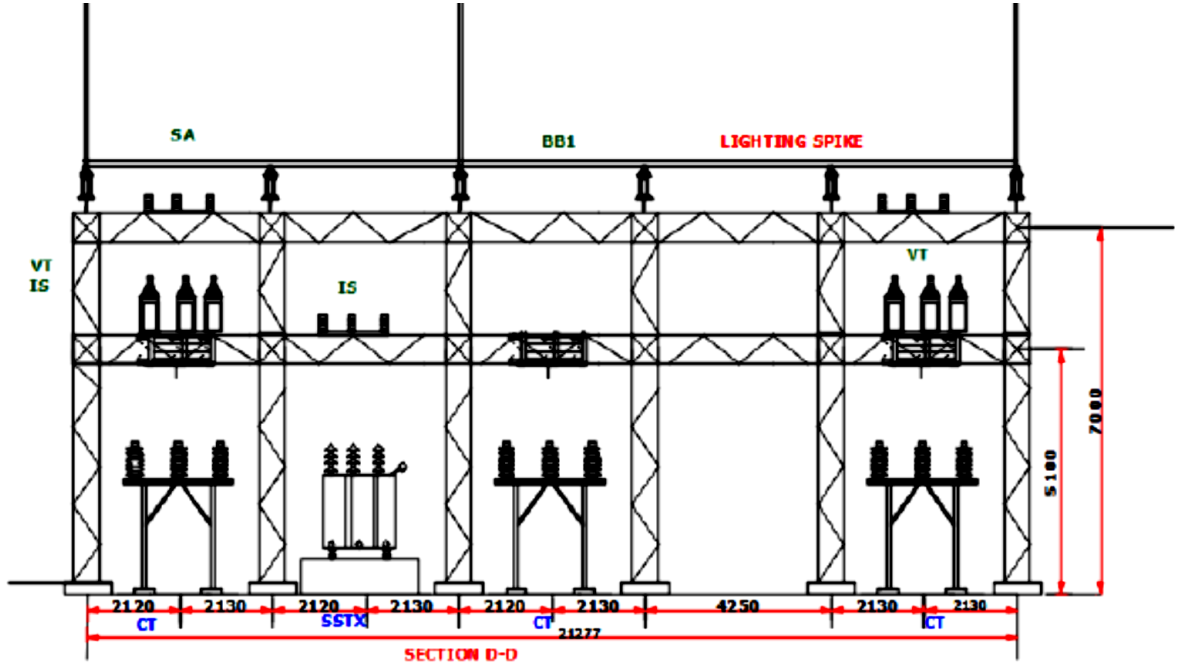
TYPICAL INSTALLATION LAYOUT HIGH VOLTAGE DISTRIBUTION SYSTEM (HVDS)



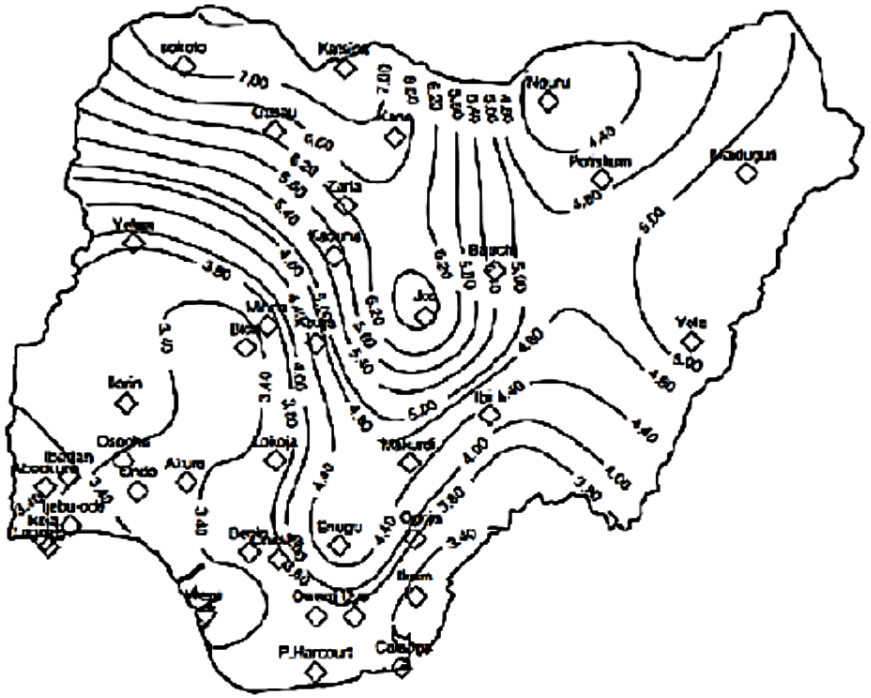


TYPICAL TWO 33/11KV 7.5/15MVA INJECTION SUBSTATION LAYOUT

TECHNICAL SPECIFICATIONS FOR SUBSTATION EQUIPMENT



- The design wind velocity for a given area is determined from the probable wind velocity over the design life of the structure
- This information can be obtained from Isovents Map of Nigeria taken for a period of 40years



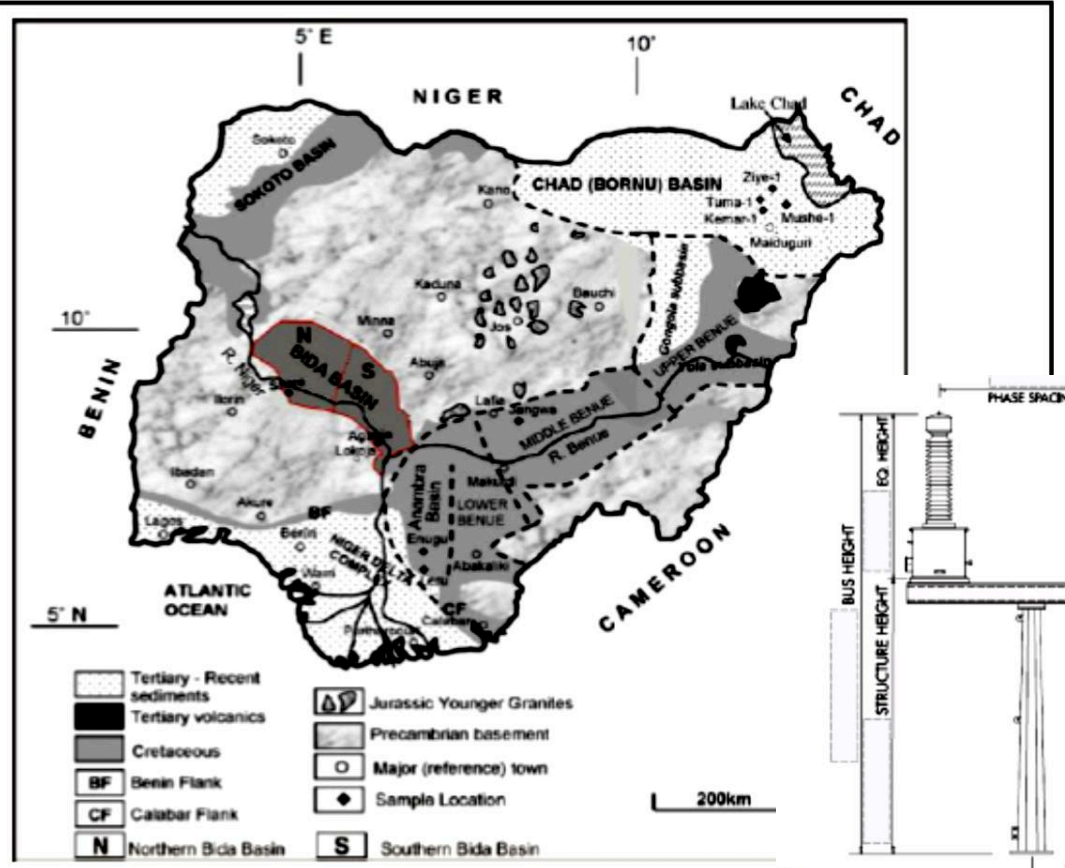
ISOVENTS MAPS

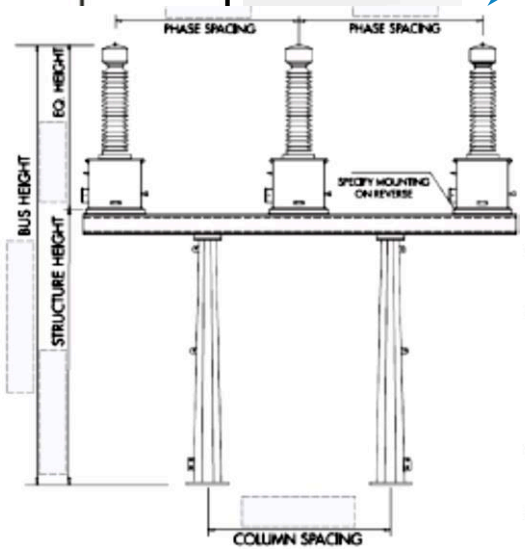
As a minimum, substations should be resistant to wind velocities and so we must make allowances for average wind velocities obtainable in various parts of Nigeria as shown in Figure.

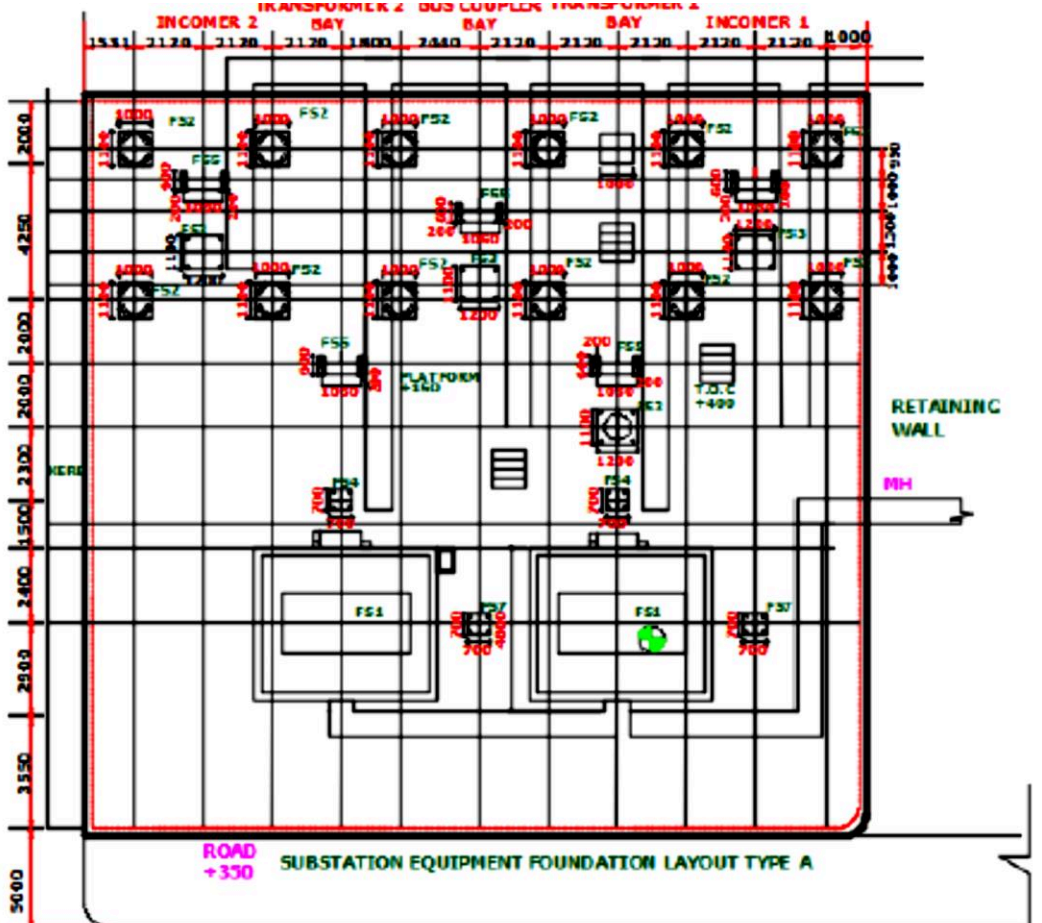
ISOVENTS MAP OF NIGERIA IN M/S, DETERMINED FROM 40 YEAR'S MEASUREMENTS AT 10M HEIGHT	Prepared by: APSEC Scale: NTS	DRAWING NO 3-300.2

FOUNDATIONS

- Foundation design primarily depends on the in-place density and strength/strain properties of the soil on or in which foundations are located.
- A thorough knowledge of geotechnical subsurface engineering parameters is essential to providing a reliable and cost-effective foundation design.

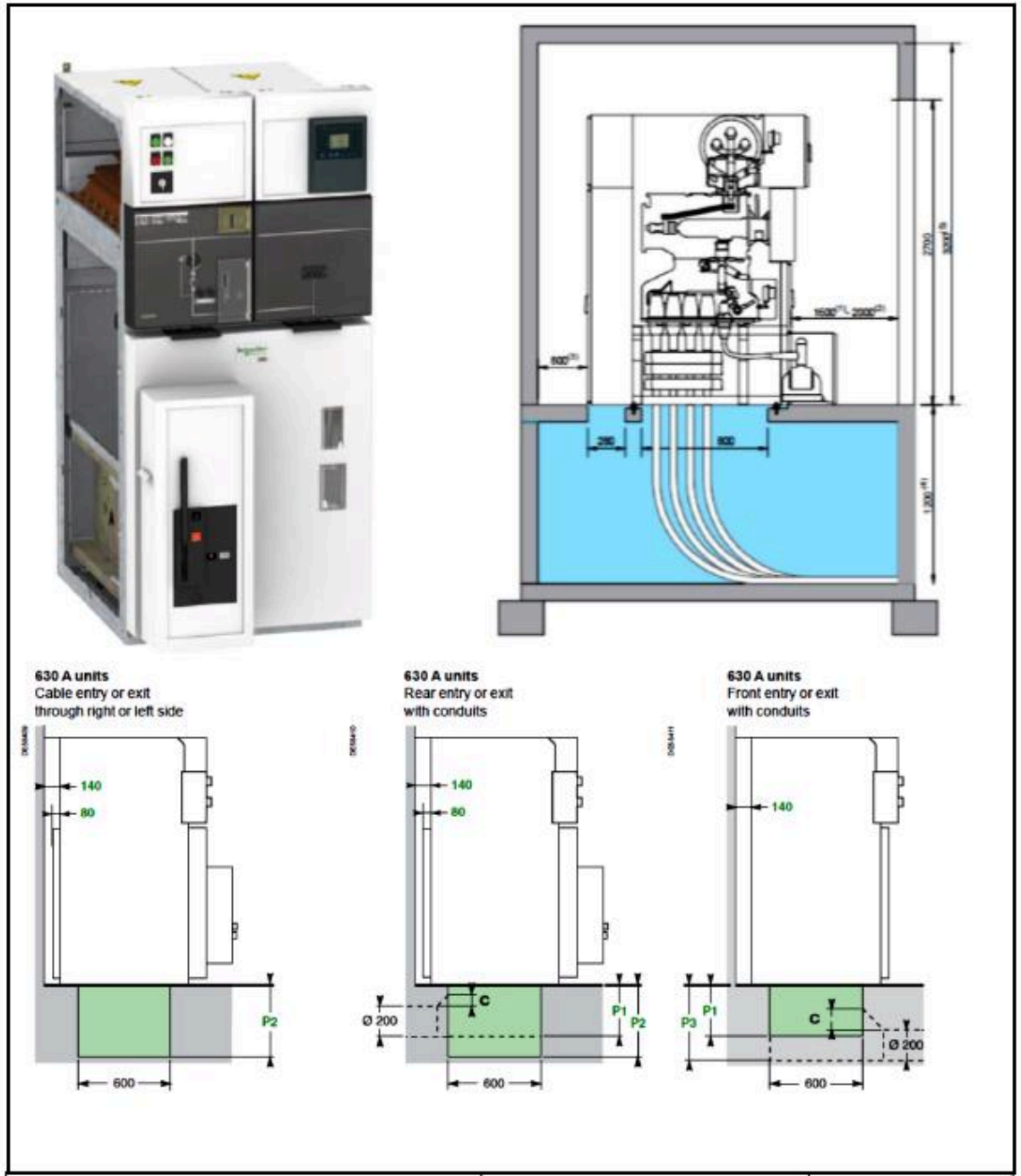






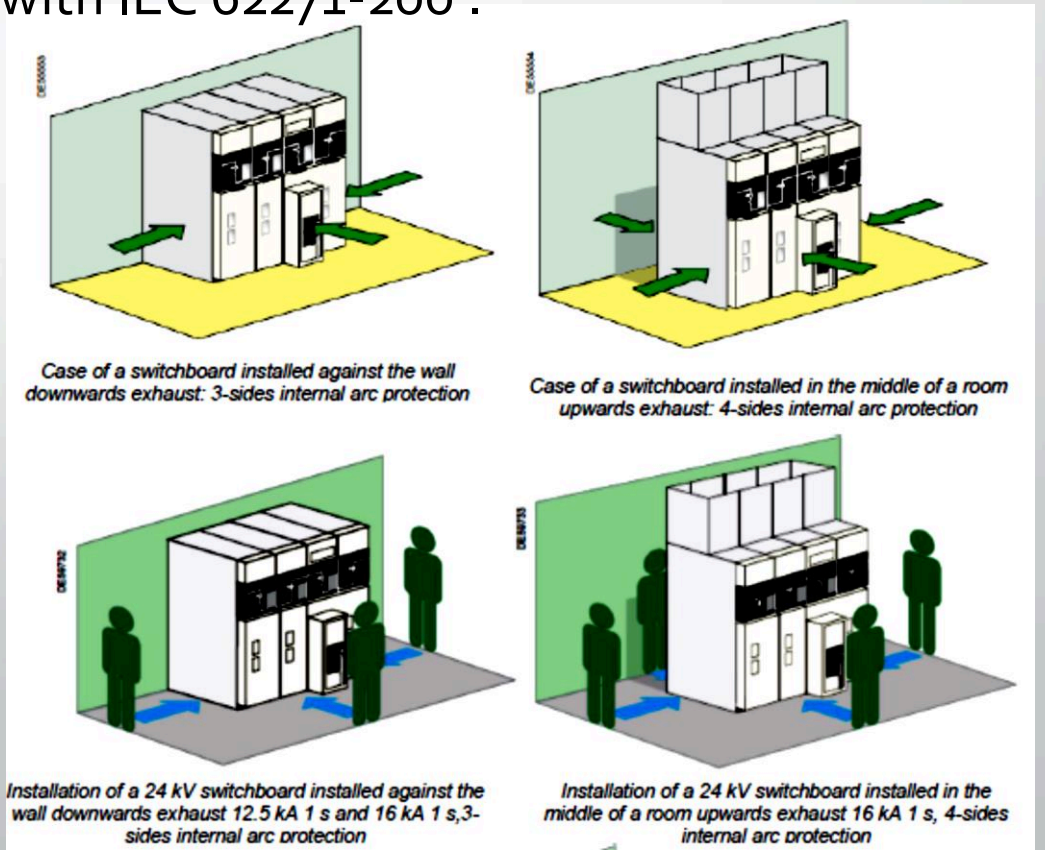
- When designing foundations, it is important to address the following design issues:
  - **The allowable load-bearing capacity of the subsurface materials**
  - **The allowable deformations permitted upon the structure/foundation under loading**

GEOLOGICAL MAP OF NIGERIA SHOWING VARIOUS SOIL TEXTURES	Prepared by: APSEC Scale: NTS	DRAWING NO 3-400.14



INSTALLATION OF INDOOR EQUIPMENT

- The installation of a switchboard requires a sufficiently flat and even concrete structure.
- The main gist of installation style, procedure and operational clearances is dependent on cable entry configurations and exhaust or pressure absorption system location, in line with IEC 62271-200 .



Case of a switchboard installed against the wall downwards exhaust: 3-sides internal arc protection

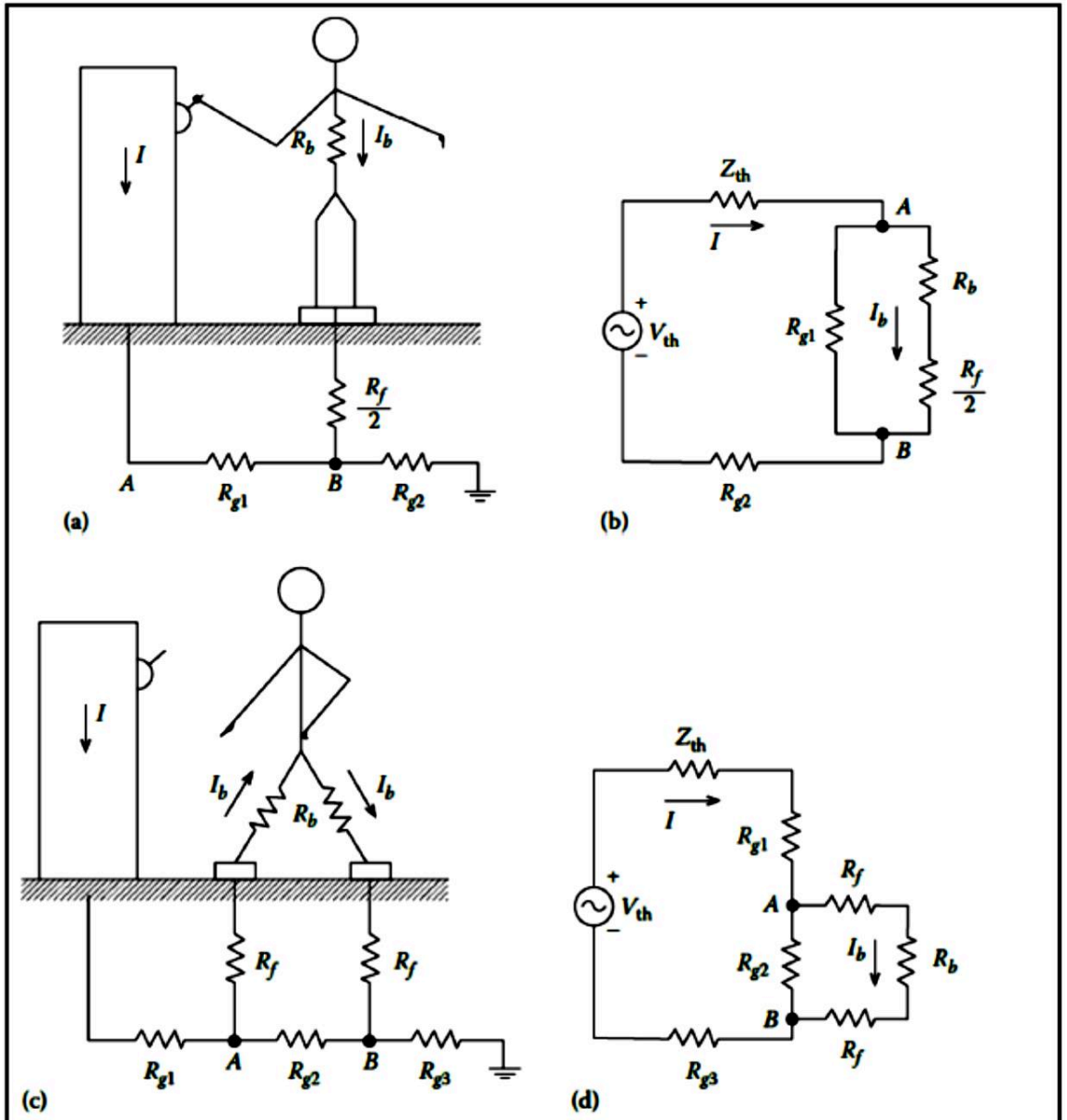
Case of a switchboard installed in the middle of a room upwards exhaust: 4-sides internal arc protection

Installation of a 24 kV switchboard installed against the wall downwards exhaust 12.5 kA 1 s and 16 kA 1 s,3-sides internal arc protection

Installation of a 24 kV switchboard installed in the middle of a room upwards exhaust 16 kA 1 s, 4-sides internal arc protection

DESIGN OF A SUBSTATION GROUNDING SYSTEM

- The grounding of equipment and the components installed are specified in accordance with the National and International standards.
- Several parameters that define the geometry of the grid, the area of the grounding system, the conductor spacing, and the depth of the ground grid and have the most impact on the mesh voltage are mainly considered.
- If the calculated mesh and step voltages of the grid design are below the maximum values for touch and step voltage, then the design is considered adequate.
- Drawing No 3-400.35 shows two basic situations involving a person and grounded facilities during fault



Typical electric shock hazard situations: (a) touch potential; (b) its equivalent circuit; (c) step potential; (d) its equivalent circuit.

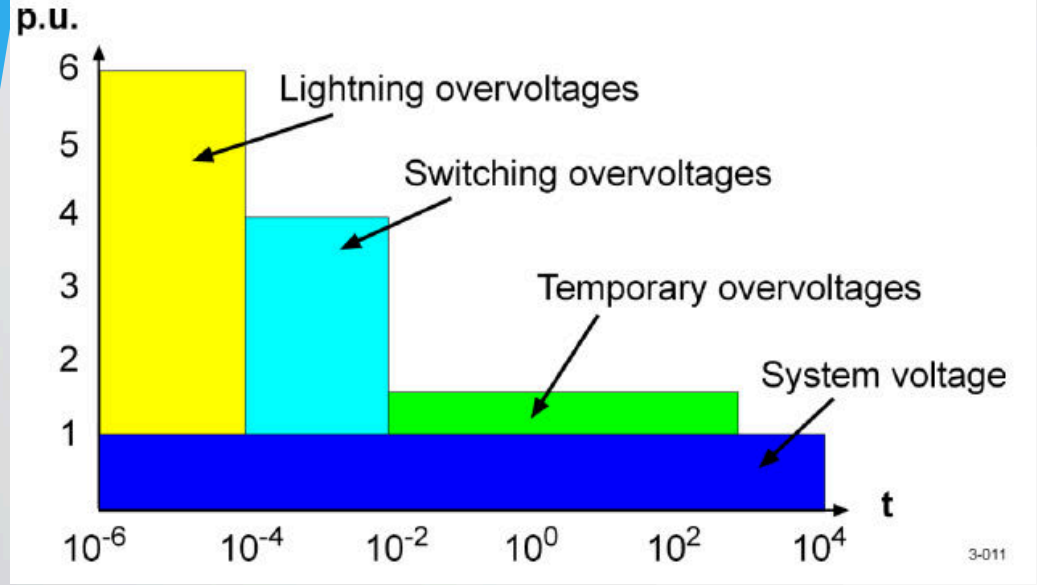
DIFFERENT TYPES OF SHOCK HAZARDS ASSOCIATED WITH THE EARTHING SYSTEM	Prepared by: APSEC Scale: NTS	DRAWING NO 3-400.35

PROTECTION, CONTROL AND METERING

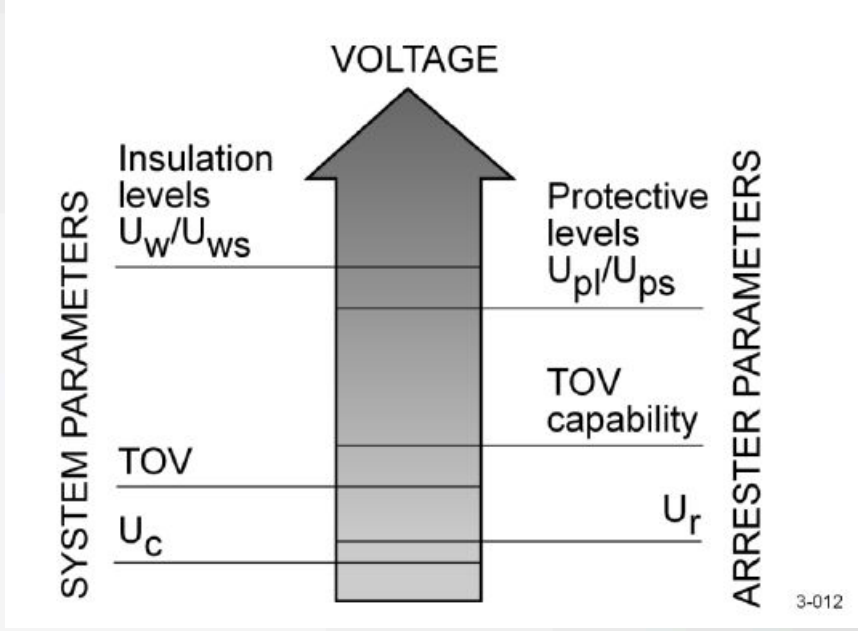
- This includes Substation Automation, SCADA, Inspection, Testing and Commissioning.
- This volume addresses various aspects of Power System Protection with up to date equipment specifications and State-of-the-art protection technology.
- These include:
  - Microprocessor relay,
  - Intelligent Electronic Devices (IEDs),
  - Programmable Logic Controllers (PLCs),
  - Substation Automation and SCADA Provisions.
- Comprehensive Protection Schemes for Distribution networks, including detailed provisions for Basic Insulation Coordination are included.
- Sample calculation on Unit Protection and Relay Coordination is provided, and Case-studies on specific projects are used as examples for specifications and installations.

PROTECTION, CONTROL AND METERING

- Sample calculation on Feeder Protection Coordination is provided, and Case-studies on specific projects are used as examples for specifications and installations.
- Detailed SCADA Installation procedure is provided in this volume, from Survey and Design Specification to Construction Stage.
- For instance, survey, design specification and installation processes followed in Abuja Pilot project is provided as hands-on illustration of a SCADA scheme design, specification and installation.
- For the section on Inspection and Testing, efforts have been made to cover all perceive-able equipment used in the Electricity Distribution Sub-sector, particularly in the substations.
- Modern Test equipment and procedures in Power Distribution industry are presented, including Infrared Thermography, Ultrasound Detector, and Portable Gas in oil Analyser (PGA).



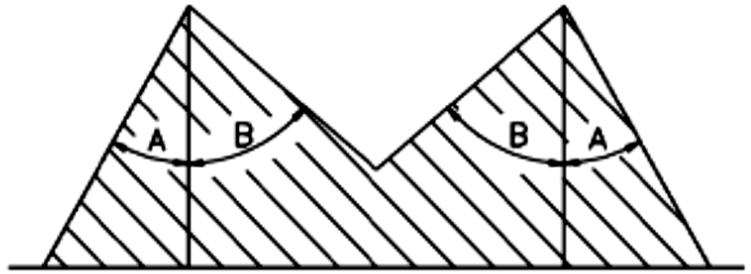
Principal overvoltage classification



Coordination between system and surge arrester

ANGLE	RANGE	RECOMMENDED
A	20° TO 60°	30°
B	40° TO 60°	45°

SINGLE MAST OR SHIELD WIRE



TWO MASTS OR SHIELD WIRES

Zones of Protection for Masts and Shield Wires Using Fixed Angle Method

TOV capability is the surge arrester's capability to withstand the temporary over-voltages

U_c is the continuous operating voltage

U_r is the rated voltage

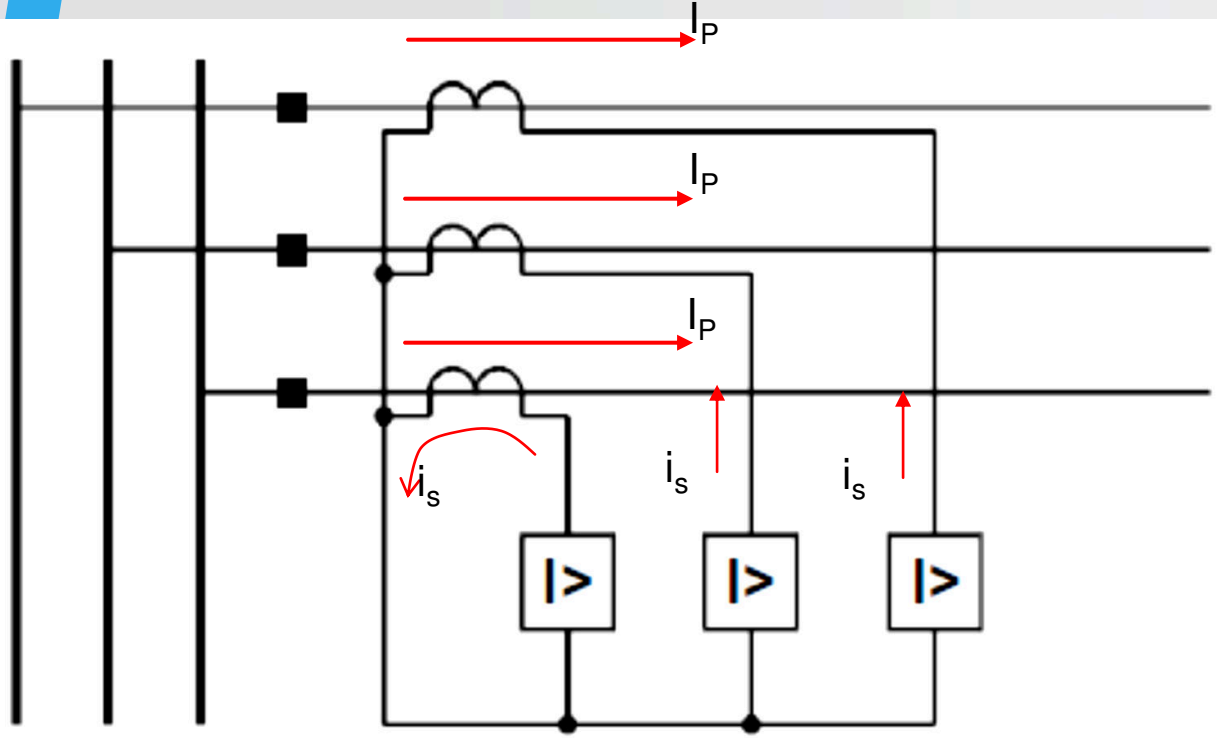
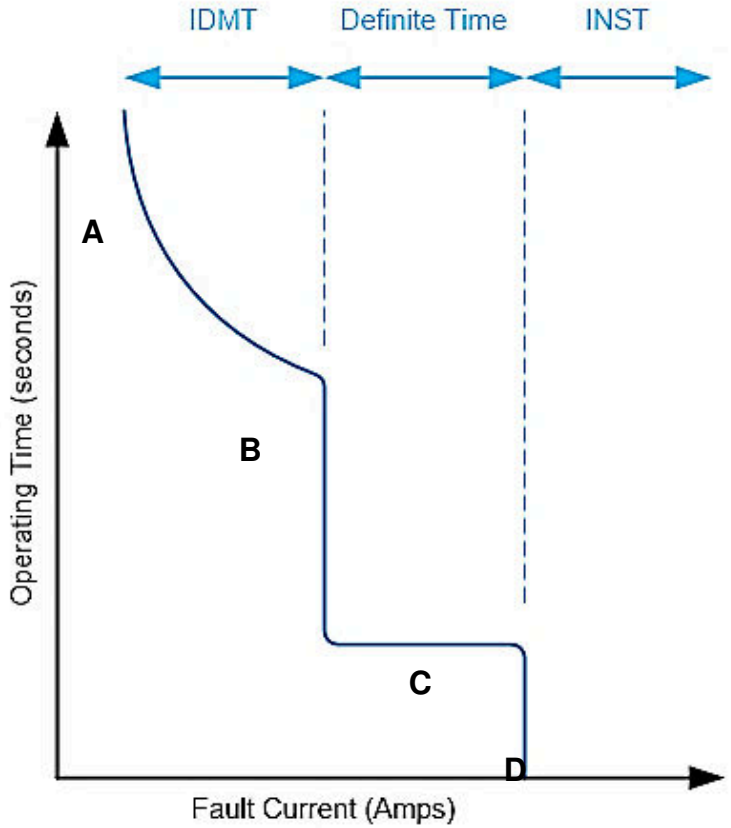


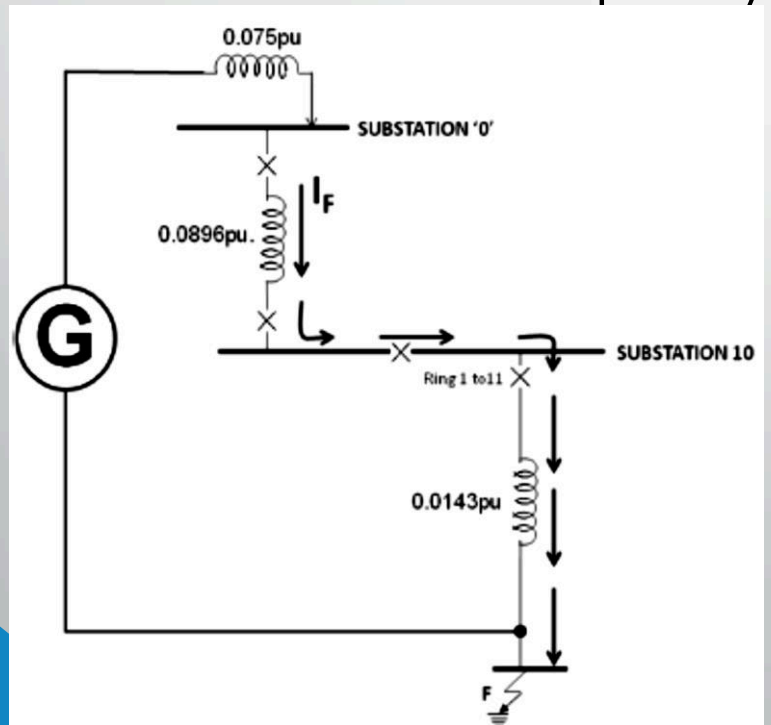
Figure (): Three-phase short-circuit protection

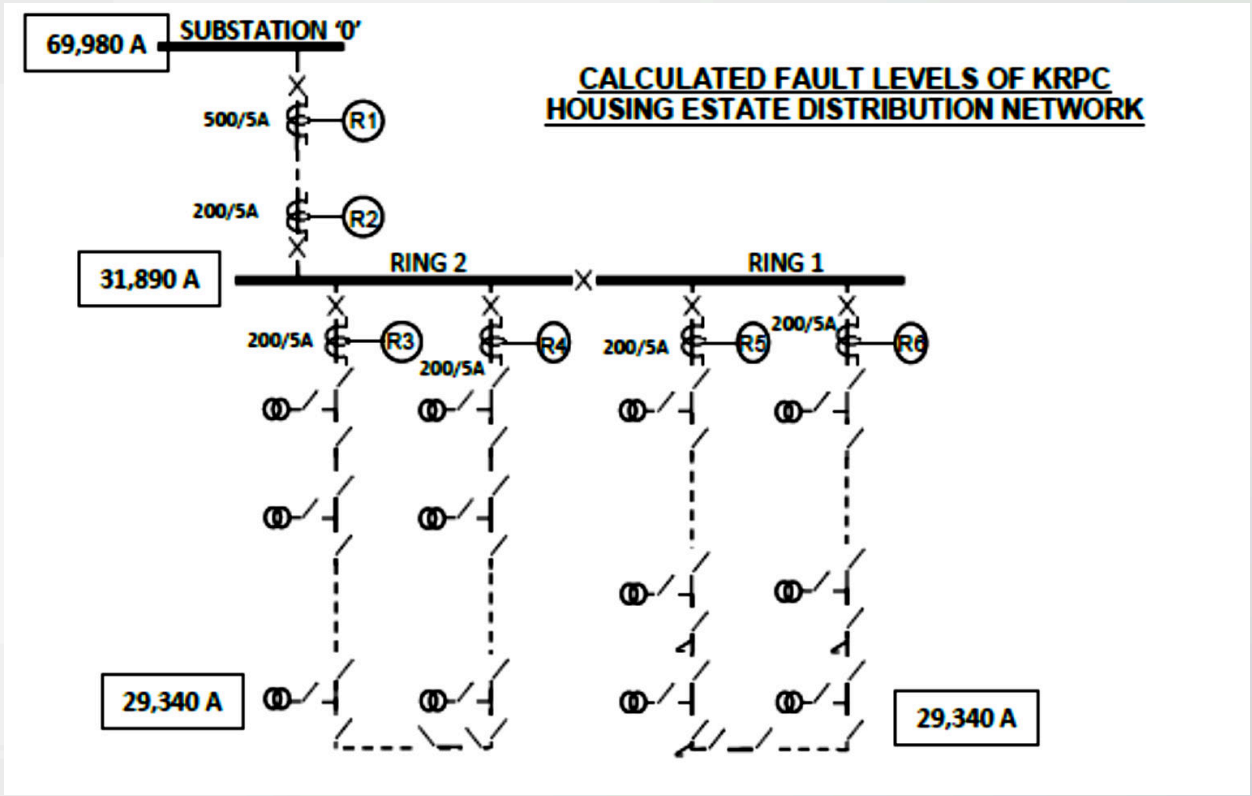


Time-current characteristic curve of combination IDMT Relay

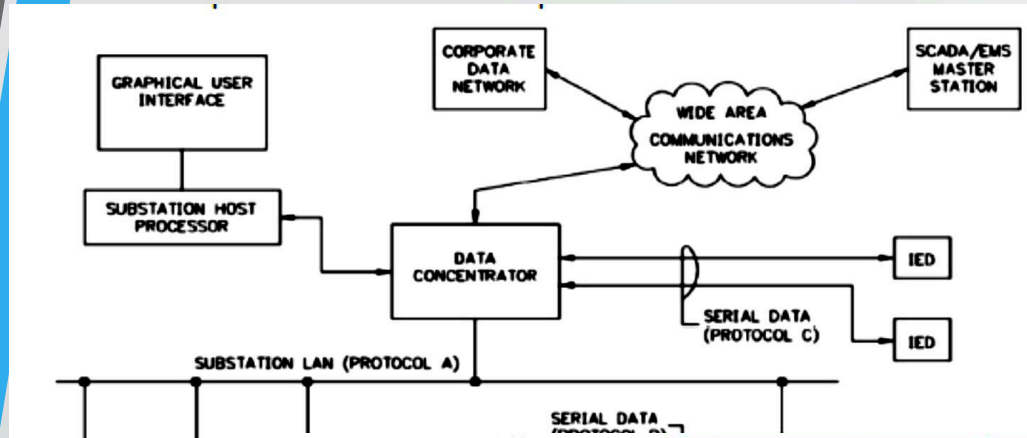
PROTECTION CO-ORDINATION EXAMPLE

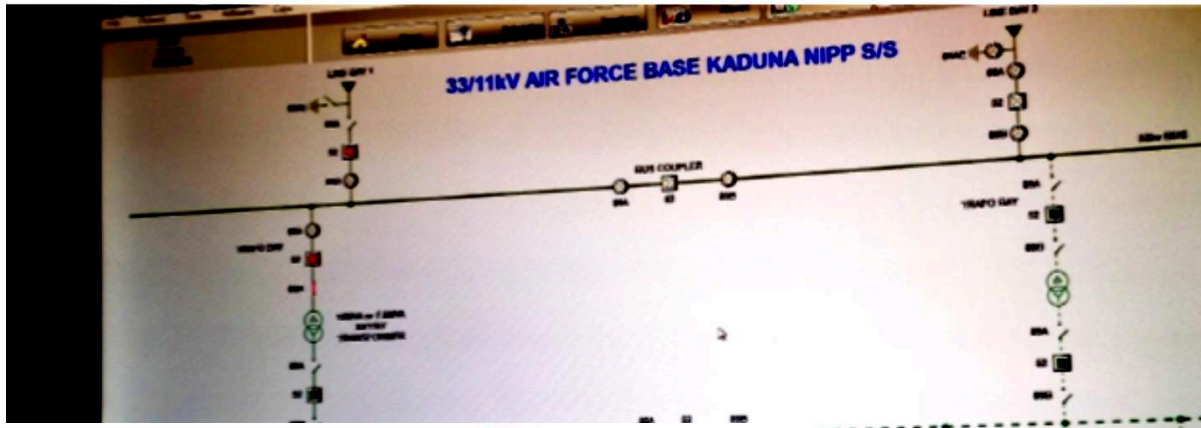
- Coordination involves selection of grading time and current of feeder.
- The selection of the proper *grading time and current* is essential for the selectivity of the protection.
- We start by evaluating the fault-level of the network, produce an impedance diagram and evaluate the fault/load currents as well as time-step delay.



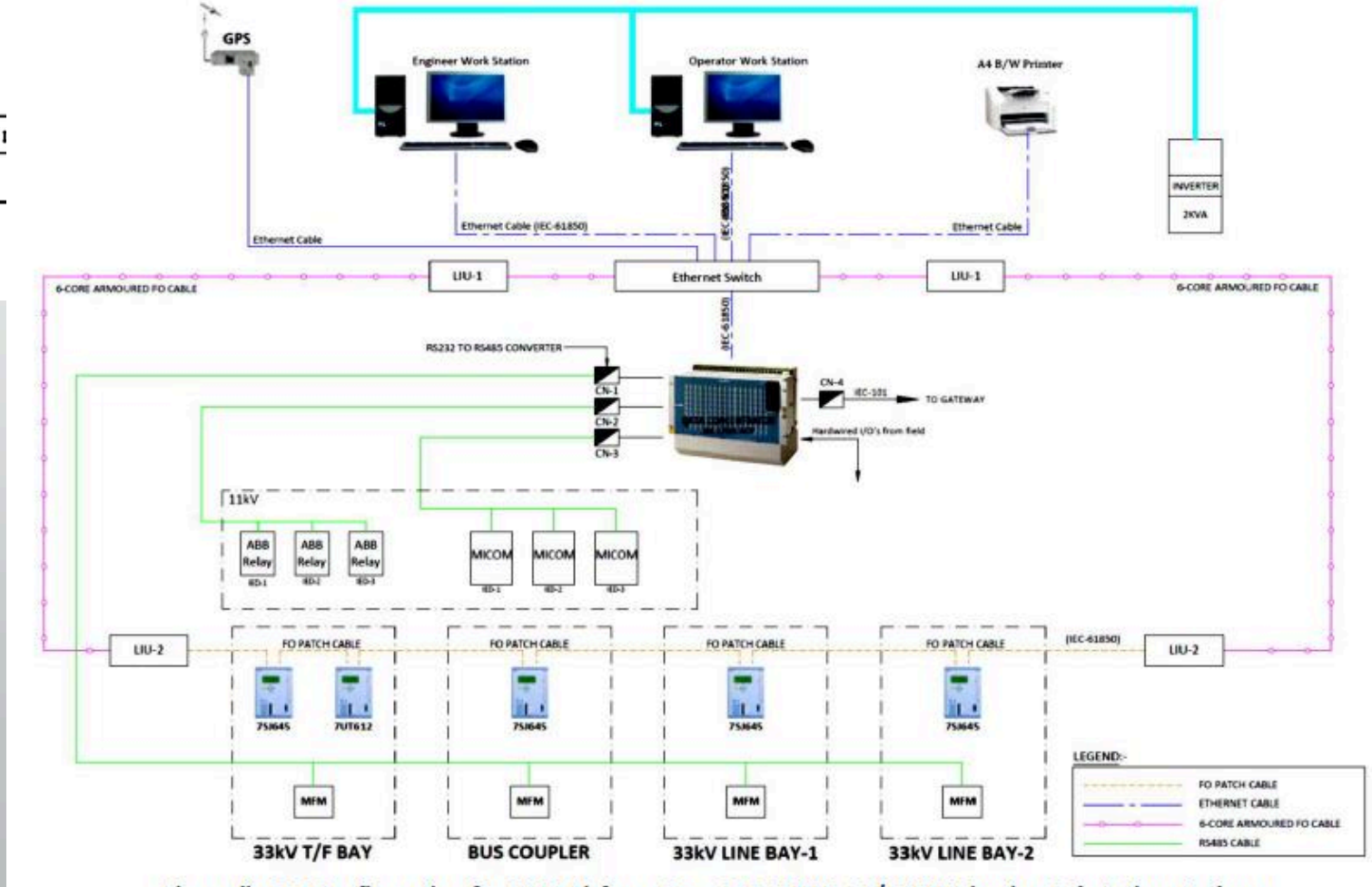


FEEDER ID	FULL-LOAD CURRENT	FAULT-LEVEL	CTR	PLUG SETTING	TIME DIAL SETTING	REMARKS
Substation '0' (Estate Feeder)	362.2A	69,980A	500/5A	5A	3.0(30%)	Back-up Fdr
Substation 10 (Incomer Fdr)	362.2A	31,890A	400/5A	5A	1.0 (100%)	-
Ring Feeder	173.2A	31,890A	200/5A	5A	1.0	Outgoing Feeder
	15.75A	29,340A	FUSE	32A	4msec	Load





11kV NIPP Substation Kaduna



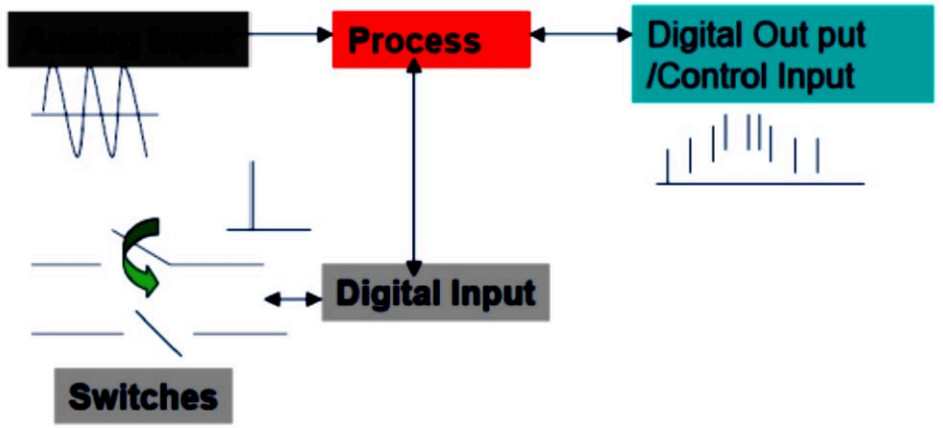


Figure (): THE SCADA PROCESS

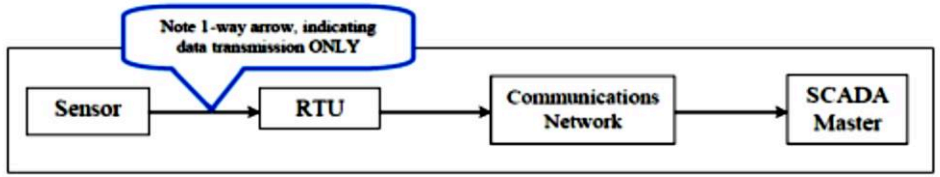


Figure (): Simplified Illustration of RTU one-way Function in a SCADA System

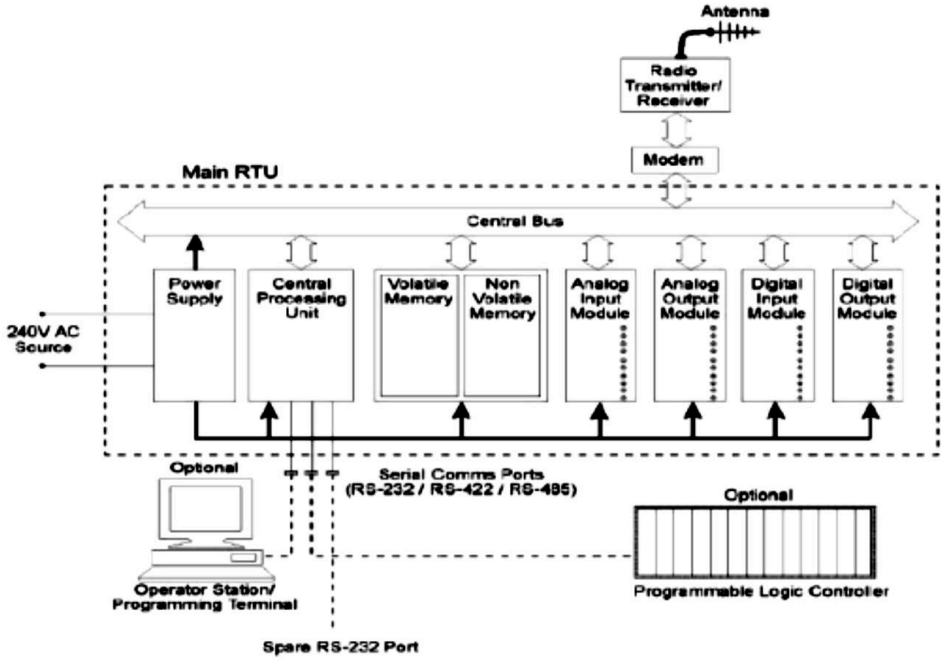


Figure (): RTU Architecture and Hardware Structure

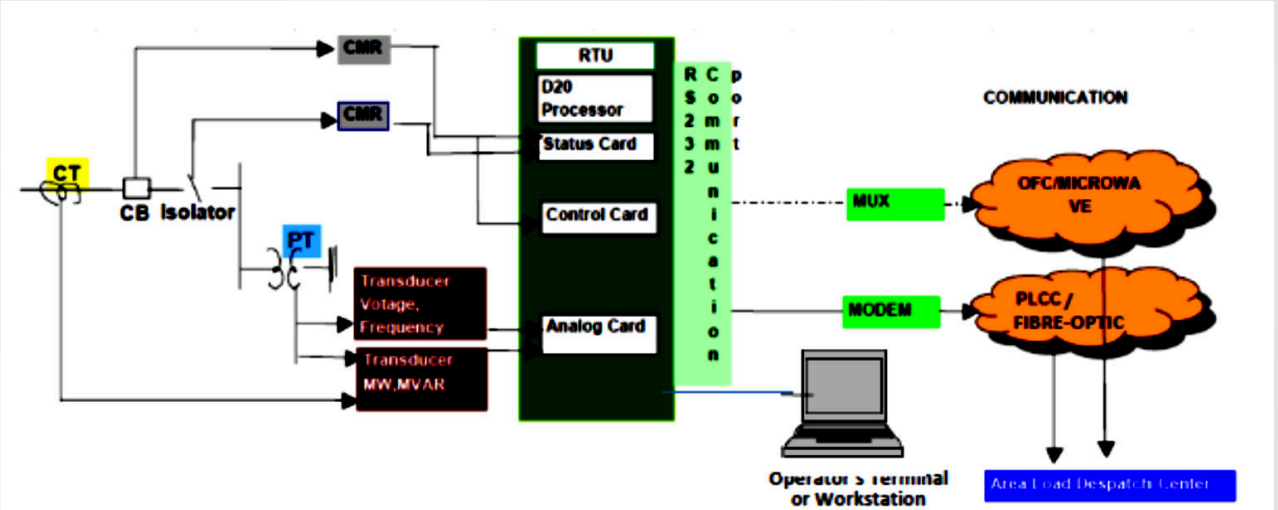


Figure (): THE SCADA LOCAL CONTROL

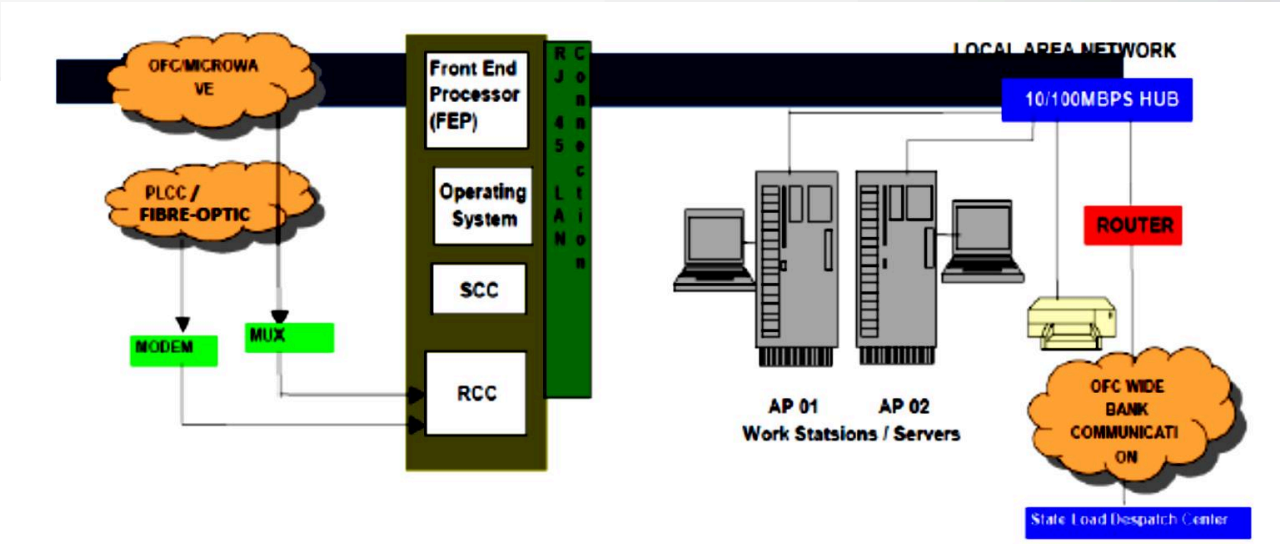


Figure (): THE REMOTE OR AREA CONTROL CENTRE

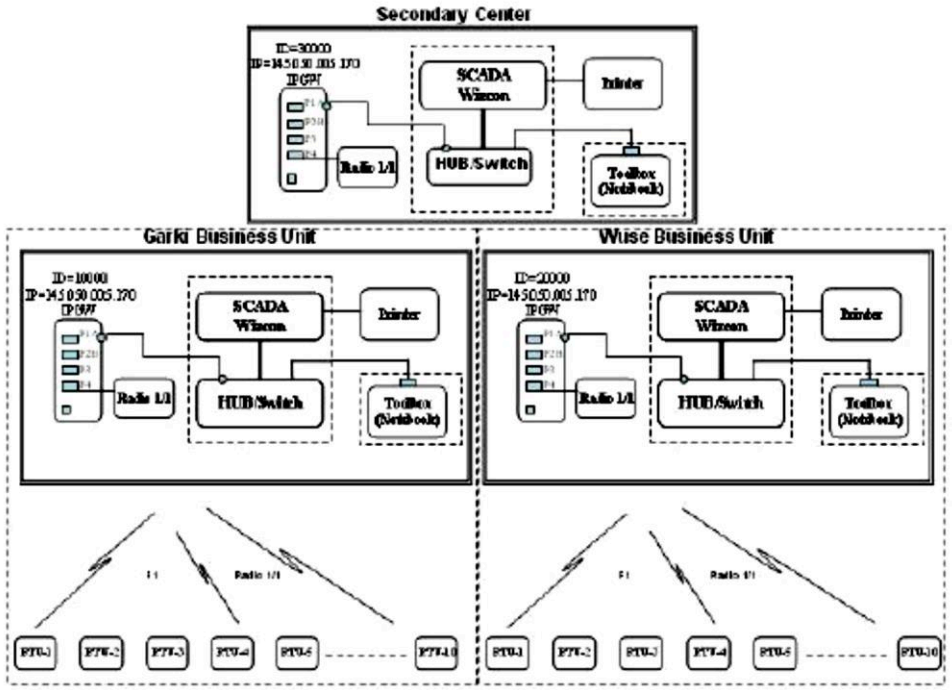


Figure (): Abuja Distribution SCADA System Architecture

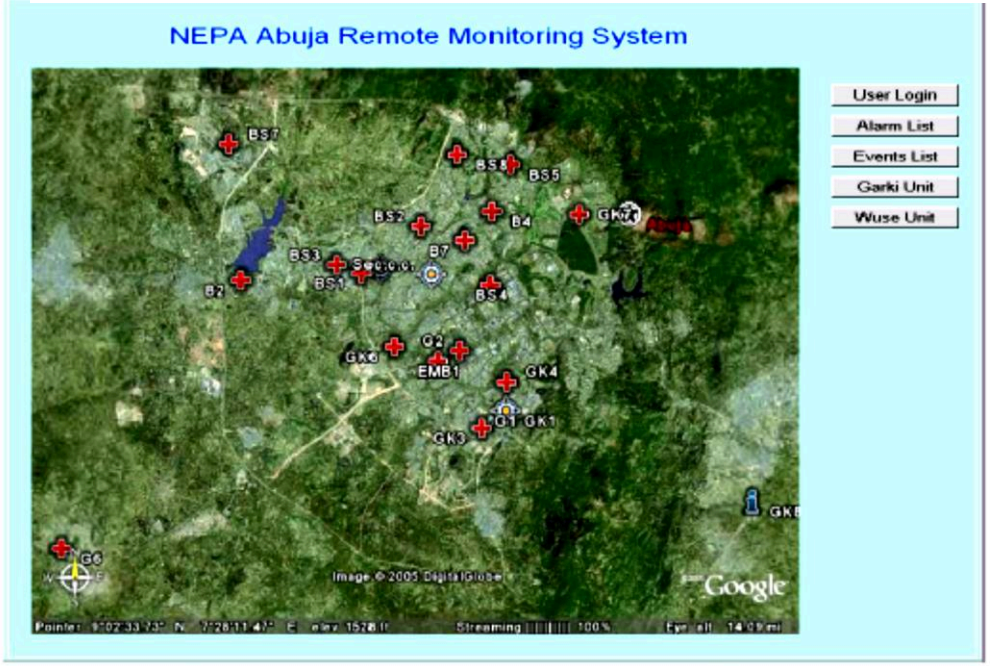


Figure (): Computer opening Screen with Google Map of Abuja

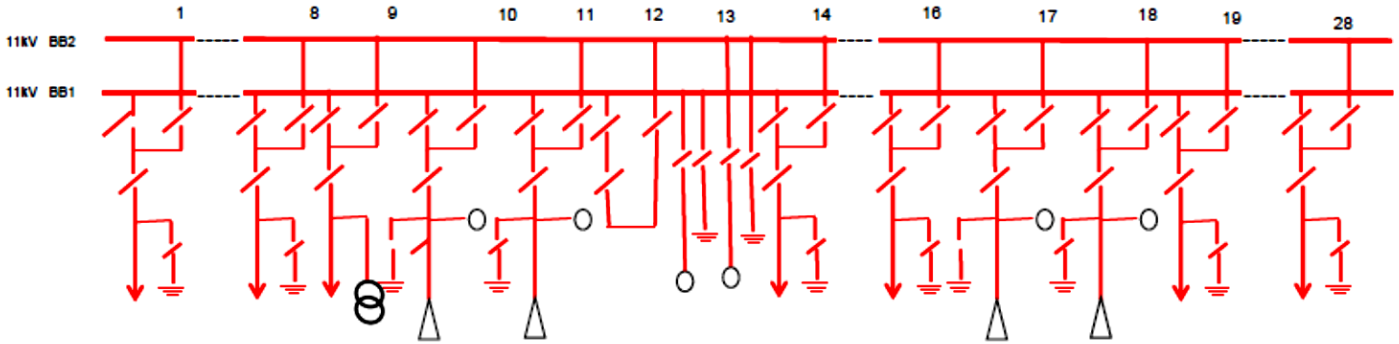


Figure (): 11kV SINGLE LINE EMBASSY 1 GARKI (Emba1)

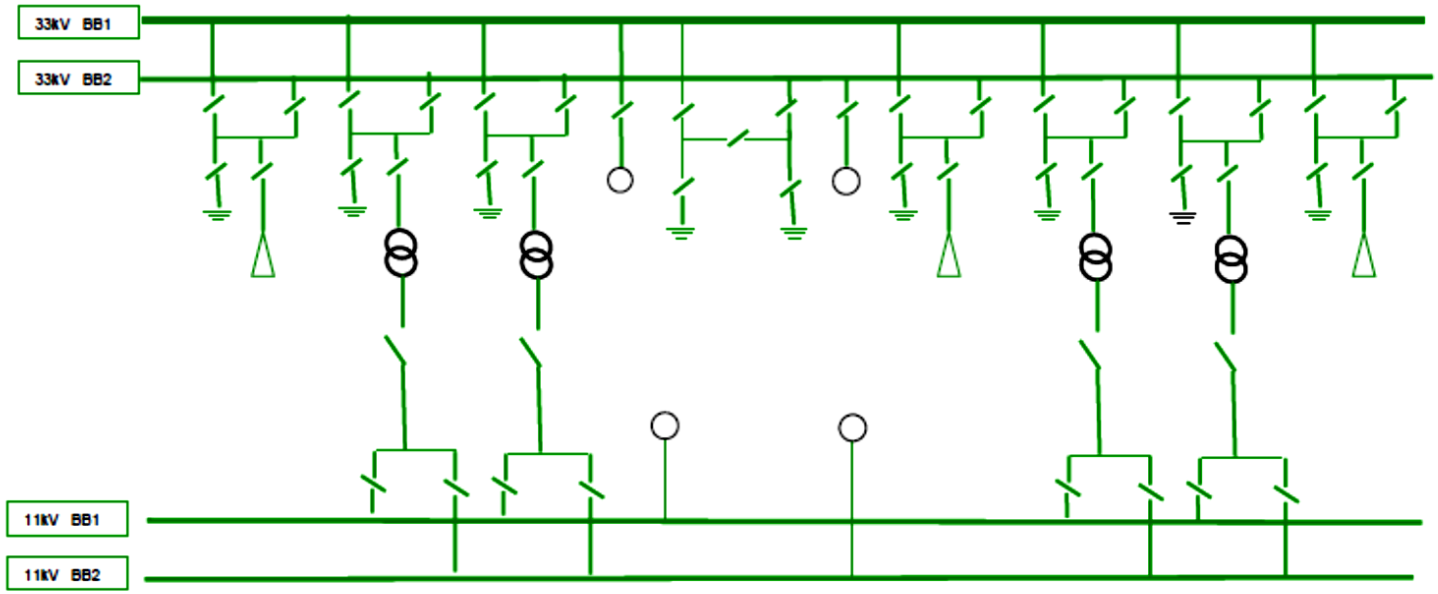
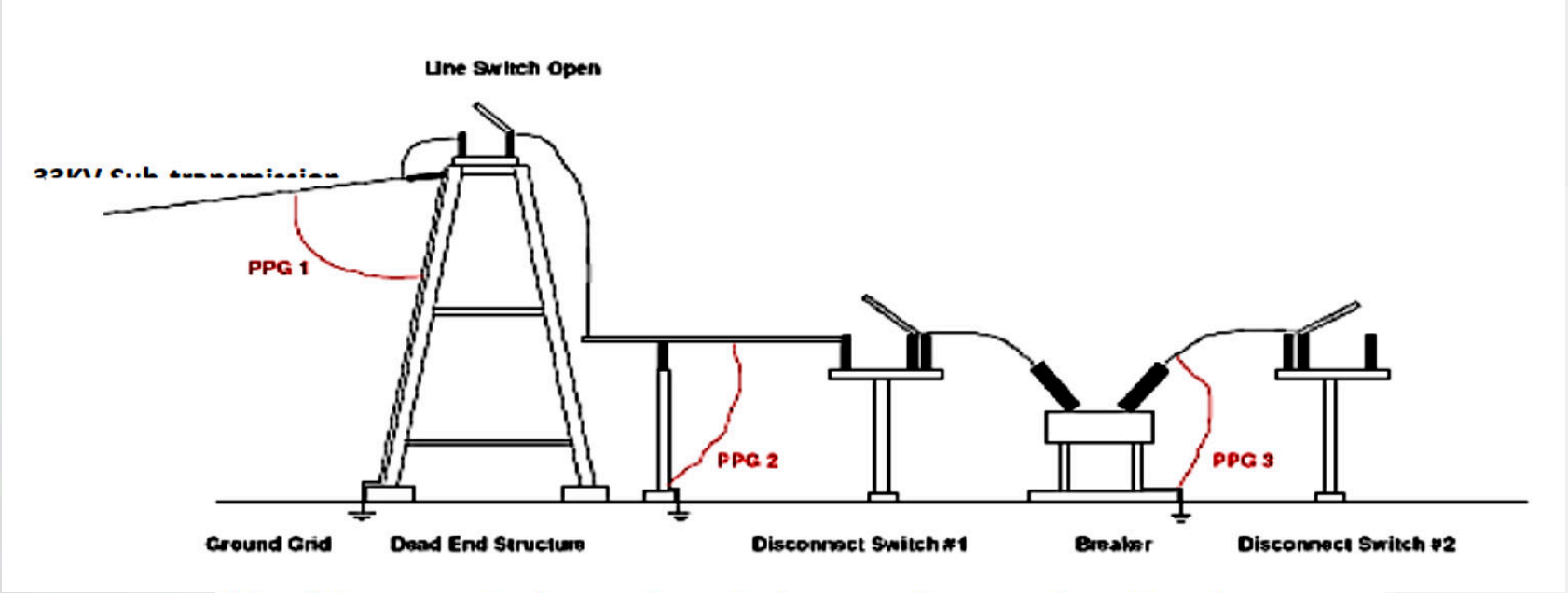


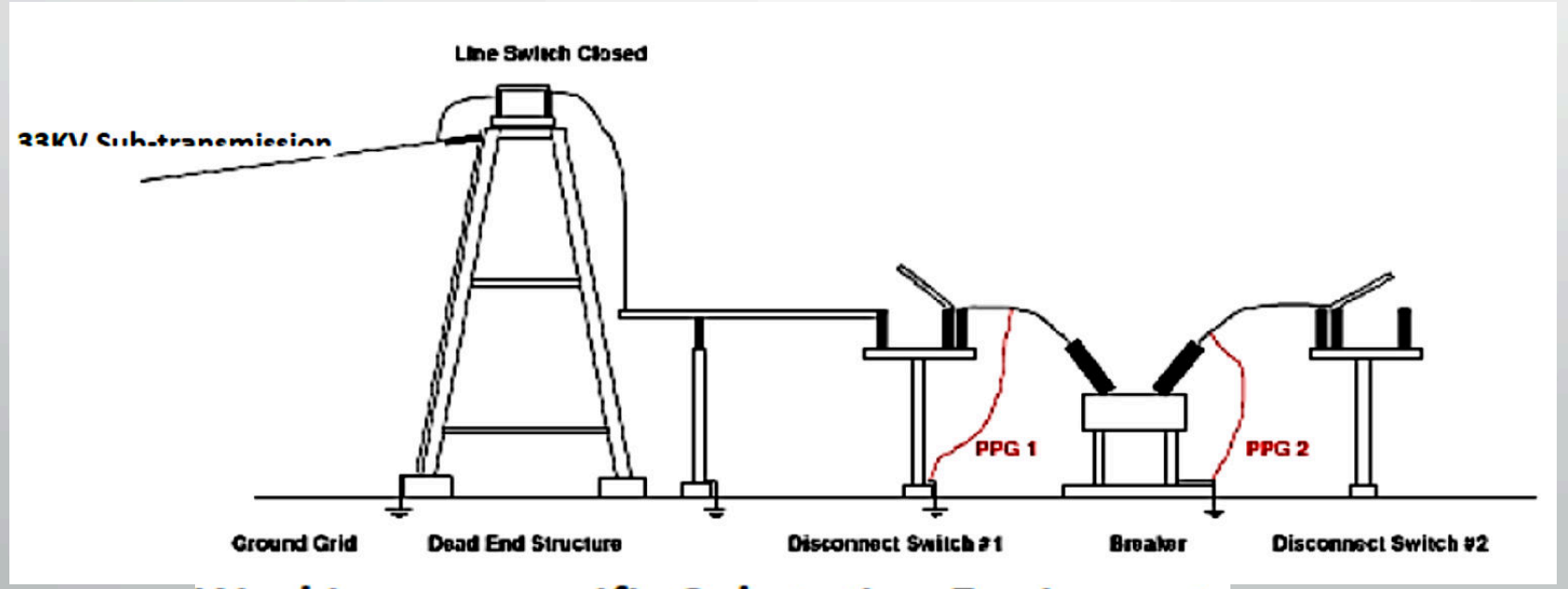
Figure (): 33kV SINGLE LINE DIAGRAM FOR REMOTE CONTROL PANEL EMBASSY ZONE (Emba1)

ELECTRICITY DISTRIBUTION SAFETY PRECAUTIONS MANUAL

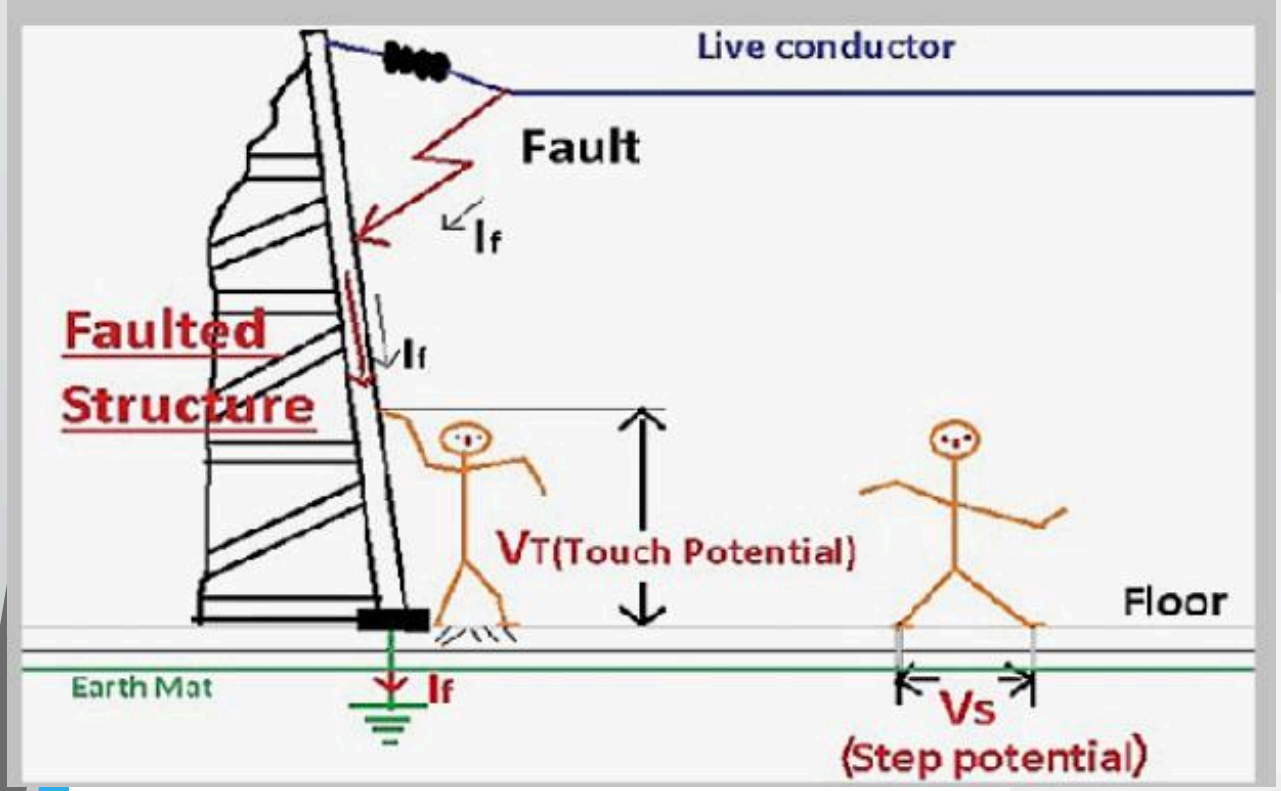
- Volume 5 is presented as Electricity Distribution Safety Manual. This Safety Manual is in two segments.
- The first segment relates to general and peculiar issues encountered in an electrical industry and the hazards associated with various segments of the Electric Power industry, including specific Electrical Equipment, Substation hazards, Power-line Hazards.
- Three key issues prevalent on the matter of Safety in electricity environment and workplaces are identified, and these include:
  - Protection of Life, involving site conditions, adequate equipment, tools and clothing, work rules or operational ethics
  - Protection of Equipment or property involves operating instructions, adequate system protection, Planned Inspection, testing and maintenance
  - Protection against interruption and Power Quality



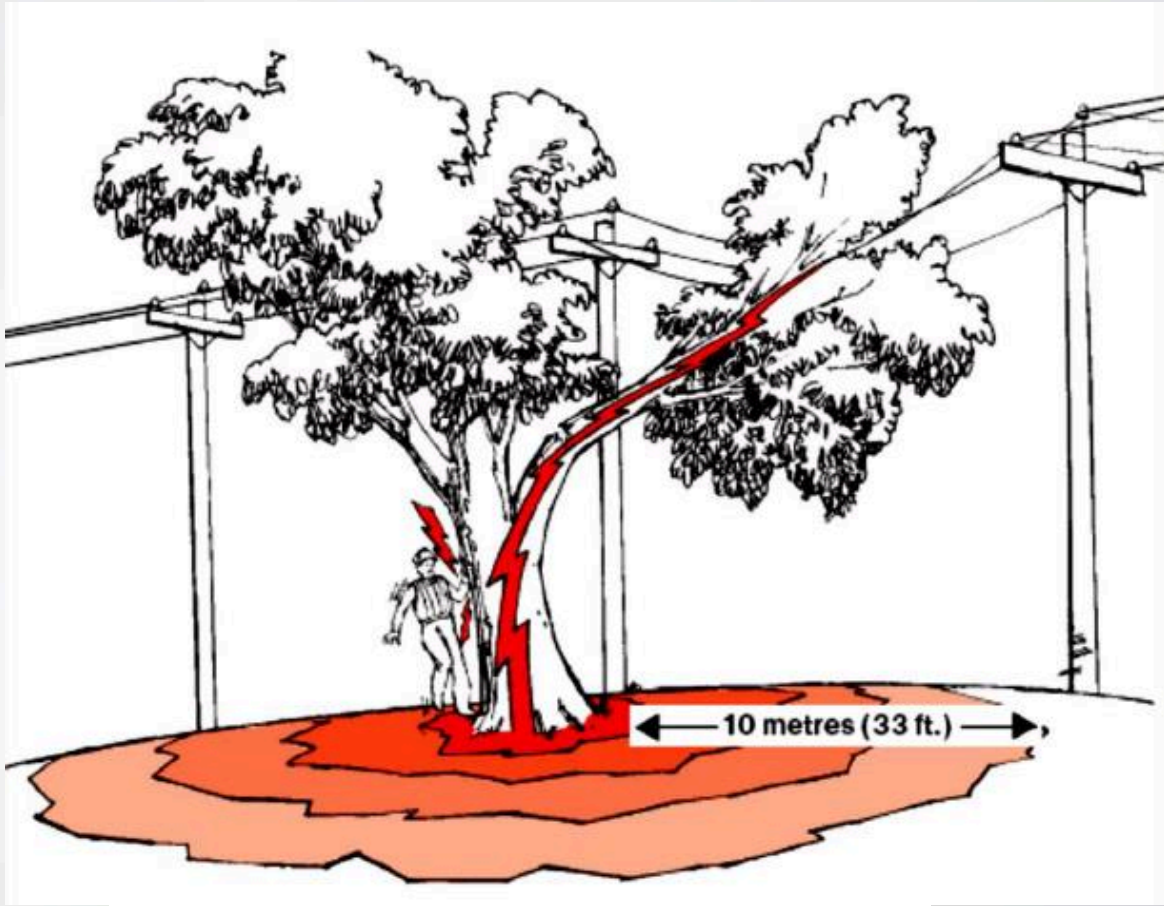
Working on Substation Primary incoming Equipment



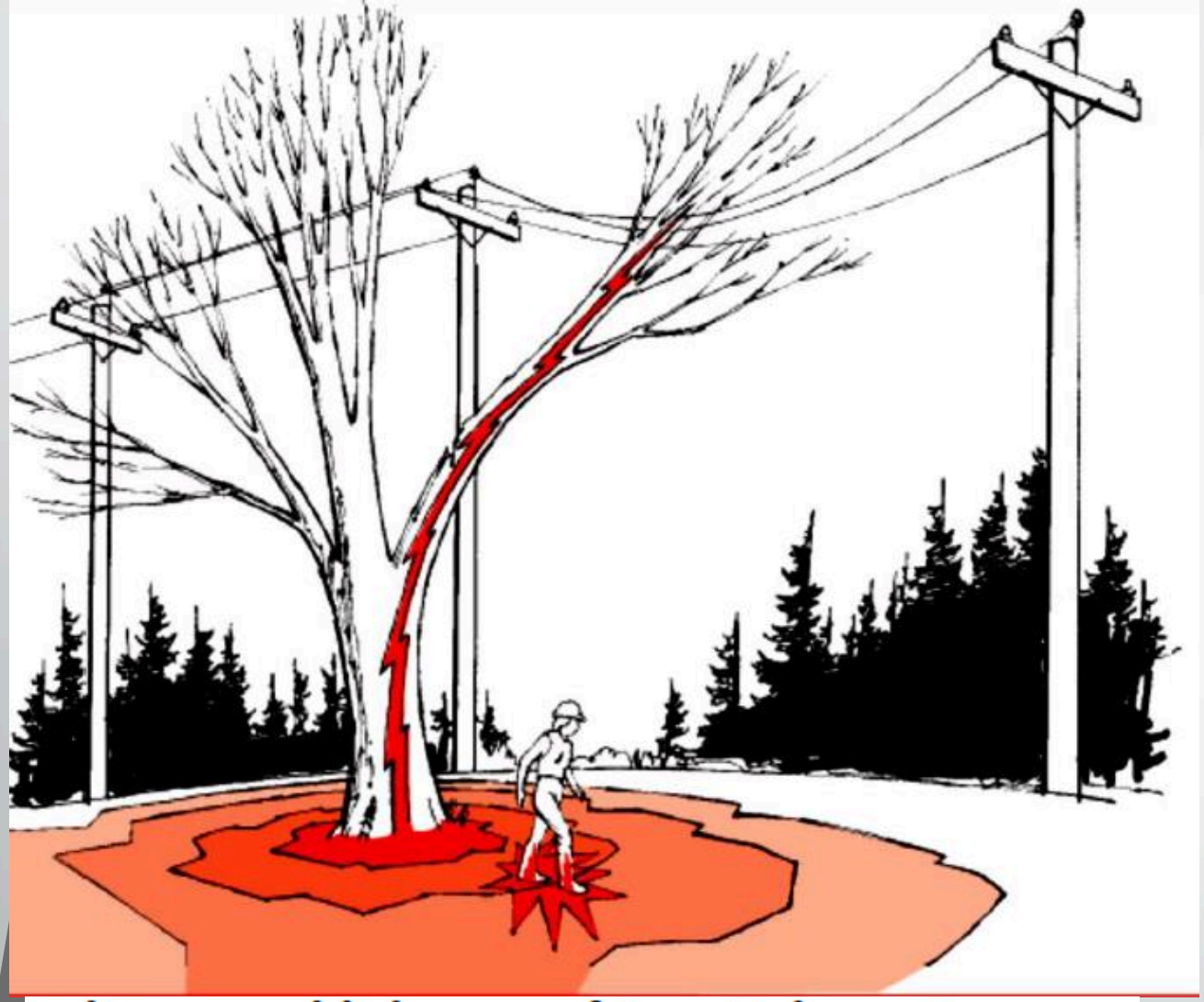
Working on specific Substation Equipment



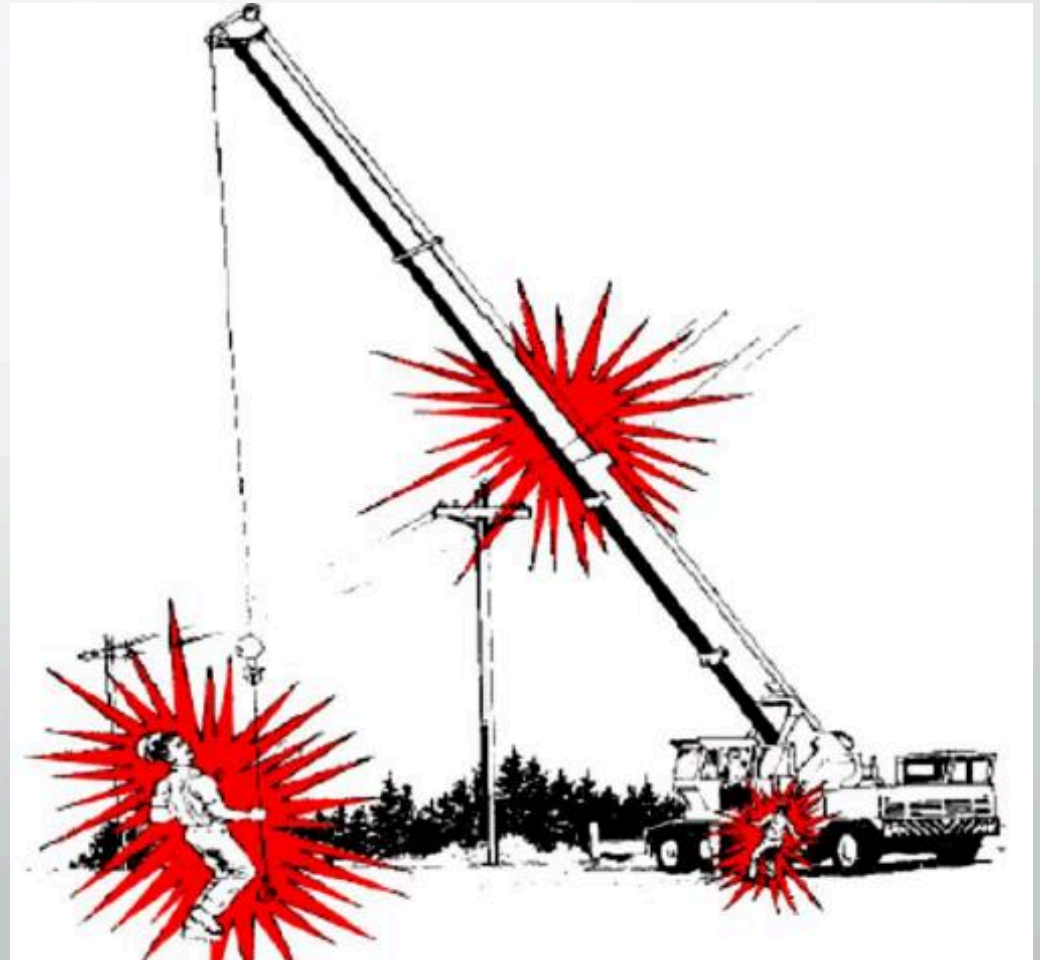
Step and Touch Voltage illustration



Tree in contact with HV line

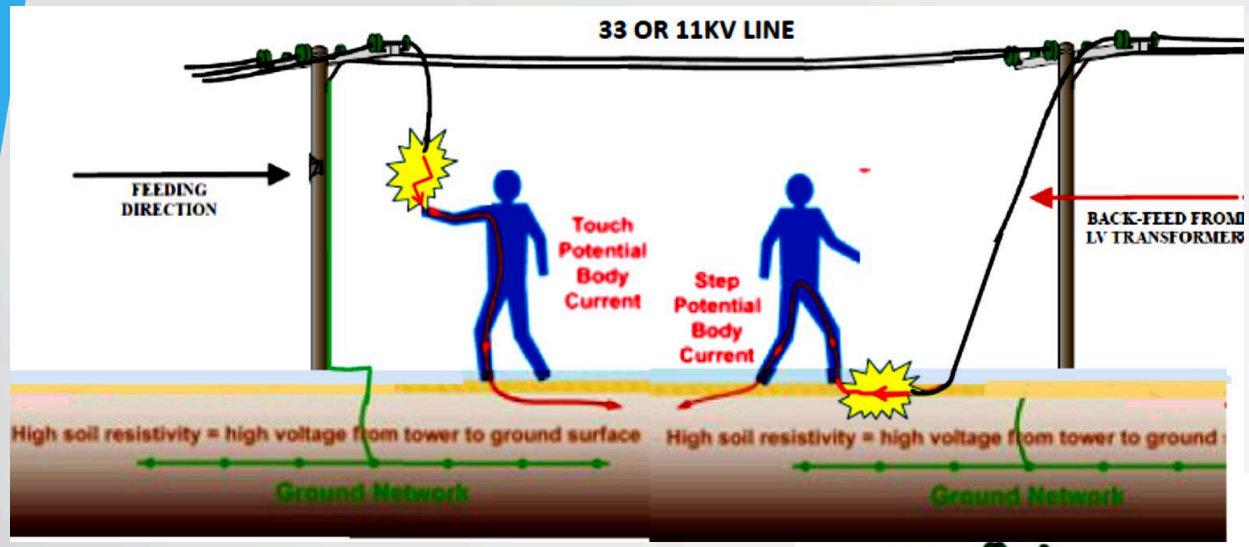


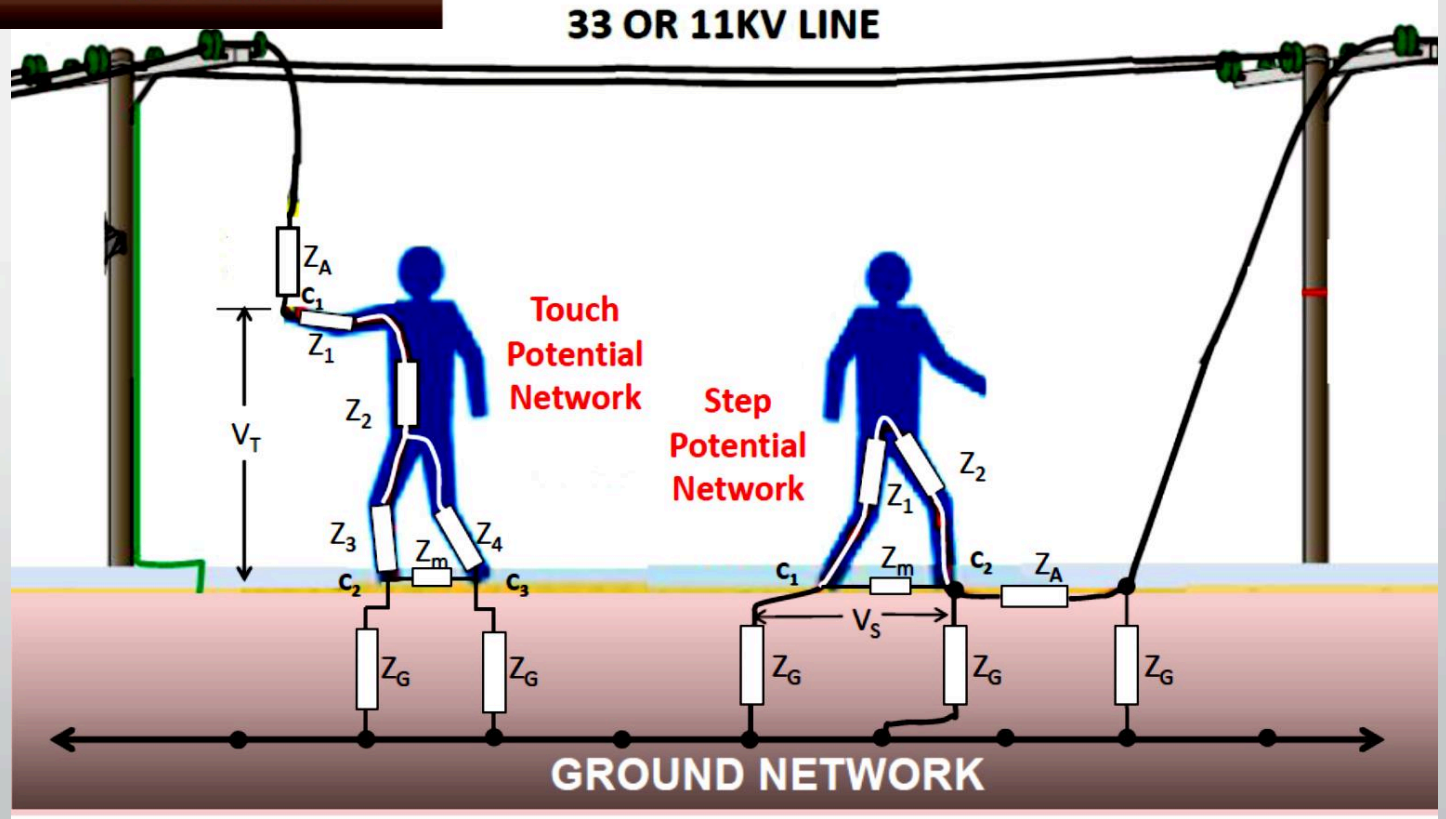
Indirect establishment of Step Voltage Contour



Power Line Hazards on heavy equipment operators

Step Voltage illustration on a charged ground





$Z_T = Z_1 + Z_2 + [Z_3 (Z_4 + Z_m)/ (Z_3 + Z_4 + Z_m)]$ $\quad Z_S = (Z_1 + Z_2)*Z_m / (Z_1 + Z_2 + Z_m)$

Z_A = Arc/Air Resistance, Z_G = Earth Resistance, Z_m = Mutual Resistance

ELECTRICITY DISTRIBUTION SAFETY PRECAUTIONS MANUAL

- This material is designed to provide the reader with an overview of hazards associated with exposure to electrical energy and safety measures based on International best practices as specified in various authorities in the Electrical Safety Field including ANSI/NFPA/NEC 70E, OSHA, IEC 61557, IEC 61558, IEC 62110 and (NESIS 2015) Regulation 3.6.2 – 3.6.5.
- The items considered in the first part also include Recognition of Electrical Hazards, Nature of Electrical Hazards and procedures for averting or containing Hazards.
- The second part of the Safety Precaution Manual deals with comprehensive Standard codes in The Electricity industry.
- These codes contain every perceive-able safety item that can be encountered in Electrical workplaces and the procedures required in actualizing them.


Thank You