ELECTRICAL ENGINEERING CONCEPTS AND APPLICATIONS

EDITED BY
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Contents

Preface

Electrical engineering is a branch of engineering that focuses on the research, development, and usage of machinery, gadgets, and systems that rely on electricity, electronics, and electromagnetic. Electrical engineering is the area of engineering that focuses on the real-world uses of electricity in all of its forms, including electronics. Electronics engineering works with wire and radio communication, the stored-program electronic computer, radar, and automated control systems whereas electrical engineering deals with electric light and power systems and apparatuses. In 1837, the telegraph became the first use of electricity that was really feasible. In 1864, James Clerk Maxwell presented the fundamental principles of electricity in mathematical form and predicted that electromagnetic energy would radiate in the form of radio waves. This was the beginning of the field of electrical engineering. It wasn't until the introduction of the telephone (1876) and the incandescent light that the necessity for electrical engineers became apparent. (1878).

Electrical engineering has many applications. Electrical has various uses that scientists have created. The primary source of power, electricity, is one such useful use. Electricity is the only kind of energy that can be converted. A century ago, people used oil lamps to light their homes. After the creation of electricity, several uses, including the development of the bulb, emerged. Electricity is used nowadays for a variety of purposes, including cooking, heating, traveling, and more. Electronics and Electrical Engineering-related education and research activities are combined to become Electrical Engineering. There is a good balance of young and seasoned faculty members in the department, and they are all very enthusiastic and committed. To foster an atmosphere that supports experiential learning, the faculties actively participate in planning technical workshops, camps, and visits to the Institute in addition to teaching and doing research there. The present PhD students' research focuses span the fields of image processing, optical sensors, VLSI, power electronics, and renewable energy. A large number of our B. Tech. PhD candidates also do summer internships at reputable academic institutions and businesses. Around 20% of these internships are at universities abroad. The Department is extremely well supported by knowledgeable personnel who aid in the efficient operation of labs and other administrative tasks.

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CHAPTER 1

INTRODUCTION TO A SMART BANK LOCKER SYSTEM

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In today's society, individuals are now more concerned with the security of their assets, expensive things, and accessories like jewellery, money, credentials, and other items. The suitable position to keep them secure is in the bank lockers, but increasingly, bank robberies have now been rising daily. The old techniques of protecting bank vaults and system failures are the major causes of traditional bank theft. The current BLSS is just not particularly effective, and a knowledgeable hacker could simply breach it if they had the key or PIN. With the recommended bank locker network security based on two-step verification, this form of deception may be defeated. The authentication mechanism technique is used for bank ATM withdrawals, and web-based login providers like Google, Facebook, MSN, and Yahoo all provide two-factor protection for their online customers. To guarantee the protection and mobility of the documents or assets, the concept of a two-step authentication mechanism for bank repositories is enabled [1].

For the aforementioned need, a one-time password and fingerprinting biometric-based two-step multifactor authentication will be able to address the inadequacies of the current system. This technique has the possibility of significantly increasing security. This solution will lessen fraud and abuse caused by fraudulent activity of keys, passwords, PINs, and IDs. Instead of a key, the locker in this construction has a simple, low-power electromagnet that locks and unlocked the locker. The suggested system would integrate two separate security mechanisms, a fingerprint biometric and a one-time password, to alleviate the shortcomings of the current technologies and offer excellent protection for bank lockers.

Consumers had to have their fingerprints scanned to get into a bank locker. If the fingerprinting match, the system uses your customer's registered contact details to deliver the one-time password that needs to be entered through into the locker system. The bank locker may be entered if the entered passcode is validated; else, the platform is locked. With the implementation of this financial locker system, there would be less time to waste, better use of equipment with double security, fewer employees, customer happiness, reduced frauds, simple accessibility, as well as overall improved service for bank clients [2].

In today's society, bank lockers are fundamental and are regarded as the safest location to preserve valuables like jewels, papers, due to improved, and other items. Most businesses still use outdated, improperly secure systems like manual gates and PIN codes or passwords. Whenever time a client uses a locker with a conventional lock, the bank personnel would help them. Both the customers and the employees can find themselves wasting time as a result of this. Such manual locker systems' biggest failing is a lack of security brought on by key duplicates which would lead to the stealing of all the precious items from the bank lockers. For personal identification, locker access requires a password, Personal Identification Number (PIN), or smart card. In any case, card readers may be stolen, and usernames and PINs can be misplaced or unintentionally guessed. Many banks continue to have difficulty with thwarting unauthorized, intrusions, and halting this same leak of classified info. All of these create issues with conventional financial lockers, which causes armed robberies. To prevent unwanted

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access, the security of these lockers must still be guaranteed and maintained by robust verification measures [3].

Need of the Bank Locker

- Creating a bank locker security system to take the same place as the manual lock, PIN code, and password now used.
- Using an autonomous locker system with two-step authorization to increase security.
- To avoid having to carry identity cards or keys and to do away with the need to memorize several PINs and passwords.
- To stop the thefts and manipulations.
- To provide banks with bank locker technologies that are simple, trustworthy, and easy to use.

BLSS based on RFID and GSM technology

Only users who have registered may reclaim anything from bank lockers, including money. The system's operation is built on RFID and GSM technology, which permits real-time authentication mechanism, validation, and door unlocking for bank locker access. The microprocessor AT89c51, GSM modem, LCD, keyboard, power supply, RFID tag, and RFID reader make up this system. The passivity tag contains a user's ID. The ID number is read by the RFID reader and communicated to the microcontroller for authentication. If the documentation is legitimate, the attachment to an organization would input the password on the keypad for the bank locker system. The system can send an SMS request to the authorized user's mobile phone number if the password proves to be genuine. The consumer then uses a GSM modem on something like a mobile phone to communicate the password to the microcontroller. For judgment call purposes, the microcontroller examines the password input through to the keyboard and received by the legitimate traffic cell phone [4]. The bank compartment will be unlocked if these passwords coincide; else, it will stay locked.

i. Strengths:

- The system is based on RFID and GSM technology, and it incorporates two different kinds of certification.
- For extra security, two passwords are preferred.
- Because RFID and GSM capabilities are being used, the solution is now more user-friendly. All individuals are familiar with these technologies because they employ ATM cards and smartphones in their regular lifestyles.

ii. Weakness:

- The system is based on RFID and GSM technology, and it combines two distinct kinds of certification.
- For extra security, two passwords are recommended. RFID and GSM equipment is being used, the method is now more user-friendly. All users are already familiar with these technologies as they utilize ATM cards and smartphones in their everyday routines [5].

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CHAPTER 2

TYPES OF BLSS

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Loop-Based BLSS

This system uses an Arduino and GSM module to behave as a loop-based bank locker network security. This device will function immediately to notify the security team through constant SMS alarms and alert notifications if there is a bank theft. Triac-BT136 and a Transistor BC547 are utilized to serve as the alarm for the soundtrack, and Proteus 8 software is used to mimic it [1].

IoT-based BLSS

An Automated Safety Vault with Double Layered Defense Mechanism is this system. Electronic lock with fingerprint security for users employing a biometric technology and sensing device, password verification, and encryption. Like fingerprints, the password throughout this system is pre-registered. Both a fingerprint and a password must have been supplied to open the locker. The locker may be accessible by legitimate personnel if the microcontroller matches the fingerprint and password; else, the locker stays closed [2].

3-Level Authentication for BLSS

A three-level bank locker security system is this one. Passwords, IRIS Recognition, and Voice Recognition may all be used to retrieve them. Similar to two-step verification, which incorporates both fingerprint and password scanning [3], [4]. Iris scanning is used to deliver the third degree of security. The password is authenticated first, then the fingerprint is authenticated. The iris is next scanned, and the container may be opened if all three protocols have been finished. The controller has complete responsibility for the operation [5].

Bank Locker System based on Two-factor Authentication

A user will be authenticated by a bank locker system using two-factor authentication. The two separate authentication methods fingerprint biometrics and a one-time password sent through the GSM module would be employed. The primary components of the project are the Arduino Mega 2560-R3, the GT-511C3 fingerprint scanner, the SIM900 Quad-band GSM module, the I2C LCD module, the lock type solenoid, and the PIR.

Strengths:

- The two-factor authentication applied by the system provides more security. Regarding the GSM module, fingerprint biometrics and speedy password transmission are necessary.
- The suggested system adheres to the requirements of three security problems, namely something you know (PIN), "something you are" (fingerprint biometric), and "something you have" (phone).
- The system is a customer since it makes use of well-known biometric identification and a cellphone to get the PIN for locker admittance.

Weakness:

- More sophisticated technologies may be utilized to provide versatility.
- Vibration and motion detection's accuracy and capacity may be further improved.

Planning Phase of BLSS

The first stages of the feasibility study's demands processing were analyzing the system's functionality, resolving user needs, resource optimization, and cost-effectiveness. The goal is to determine the degree to which the system can grow. The suggested bank locker system conception was made feasible and attainable by the literature research and software requirements. The following criteria were applied to determine the needs throughout this phase to move forward.

- Bank locker system users,
- How to use the bank's locker system,
- Bank locker system inputs and outputs of data.

A thorough review of the current bank locker system was conducted during the planning phase, which yielded the requirements for a new account locker system with further advancements. The following essential points will be covered in this analysis:

- The functions that the designed methodology must carry out and how they relate to each other.
- Identifying the present problems with the bank locker system and making workable recommendations for improving the newly proposed framework;
- A list of the properties from each entity in the whole financial locker system [6].

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CHAPTER 3
DESIGN OF BLSS (BANK LOCKER SECURITY SYSTEM)

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SYSTEM USER DESIGN PHASE OF BLSS (Bank Locker Security System)

The requirement collection that was covered in the first phase will be used to design the physical system. In addition to addressing user interface design, discussing the ease of access concerns, defining hardware and system requirements, and designing the overall system architecture. Work that involves computers will now be handled [1], [2]. The system's design becomes more controlled, and the deliverables for the financial institution locker system are of higher quality. The new bank locker platform's operating system, programming language, and hardware and software components are also chosen. This would reduce the uncertainty associated with purchasing a software platform [3].

Construction Phase

The bank locker system needs to first be designed, and then it should be transferred into computer language. With the aid of an open-source fully integrated development environment, the software generation procedure in this stage generates control instructions from locker system operations. The program created in a classified manner. As a result, programming would go quickly, and future changes would have been simple to implement should needs alter [4].

Cutover Phase

This covers system testing and implementation. To ensure that the created system is truly addressing and accumulating the demands that were received throughout the requirements planning phase, a test plan was prepared and will be carried out. The primary objective of this testing is to fix every system problem. This would permit the bank's locker system to offer products and services more effectively. After testing was done, implementation happens. All of the financial institution locker system's applications are loaded into a genuine environment without first being launched if everything proceeds without a hitch. This phase's activities here include the following:

- Before implementation, hardware and software components must be made completely operable.
- To use the old template of the bank locker system that employs two-factor authentication, the data from either the previous system has to be converted.
- User education.

Figure 1 depicts the two-step authentication implementation for the proposed bank locker security system that used an Arduino NANO. The 8051 controllers will respond to that same fingerprint scanner's input, as well as when it has been recognized, Arduino, transmits SMS instructions to the GSM module to send an OTP to the authenticated user's mobile phone. After

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entering the OTP on the keypad and confirming confirmation, Arduino sends open signals to the solenoid garage door to provide the access to the bank locker system.

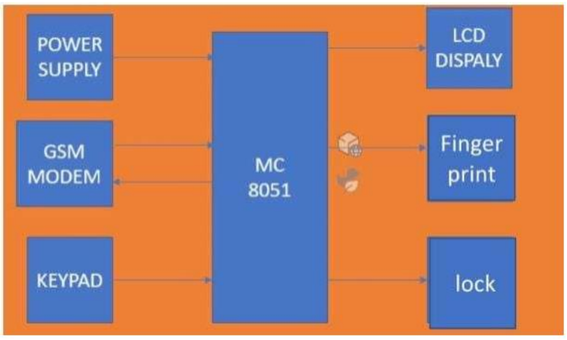

Figure 1: Represented the Block diagram of BLSS [5]**.**

Work Flow-chart for BLSS

Figure 2 shows the flowchart for the way the system operates and progresses automatically. The user must first contact their finger against a scanner. The system evaluates the fingerprint that is captured by the scanner to the fingerprint that is registered by the individual player. If they match, an OTP is created and sent through the GSM network to the registered cellphone number. The finger should have been scanned again if the fingerprint can sometimes be validated. On the keypad, input the OTP that was delivered to the phone. Cross-checking is accomplished between the input OTP and the obtained OTP. The bank locker would be accessible if the right password was entered; else, it would be blocked. To prevent password theft, the "one-time password" sent through the GSM network is created at random for each access and has a hard deadline. You need to go through each of the steps to open the bank locker.

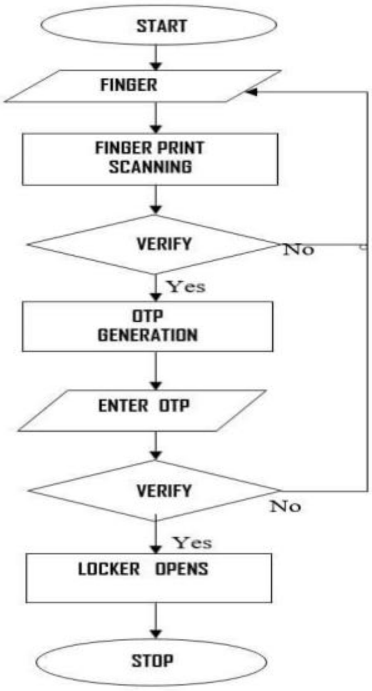

Figure 2: Represented the work-flow diagram for BLSS [6]**.**

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CHAPTER 4

KEY PHASES OF THE BANK LOCKER SYSTEM

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i. Data Acquisition:

The fingerprint scanner collects the users' data fingerprints at this stage. The fingerprint database stores the transmitted fingerprint picture as a template. Through the fingerprint GT511C3 optical scanner, the acquisition is possible [1].

ii. Feature Extraction:

The properties of fingerprints are determined and analyzed in the database together with their distinguishing characteristics. By using an extraction method for the fingerprint photograph, the acquired fingerprint images are helped by a background subtraction component, and its features have been saved to the database as prototypes. Image enhancement also called processing to sharpen ridge and extract minutiae, actually took place at this step [2], [3].

iii. Fingerprint Verification:

Participation in decision-making occurs. The user inserts his or her finger into the fingerprint-scanning equipment to open the bank locker. Once a fingerprint photograph has been captured, it is uploaded into a matching component that extracts the intricate details and compares them to the individual's fingerprint blueprint that was previously observed in the central database [4].

iv. One-time Password:

Each password created at randomized has an expiry date and can only be good for one login session. The user needs to input the password that is sent over the GSM module when the fingerprinting verification is accomplished. The user will be permitted access to the banking locker if the OTP matches; else, access will be restricted. You need to go through each step of the process to open the bank locker [5].

Hardware Design Requirements

Components used:

- Fingerprint module r307,
- GSM module SIM800A,
- matrix keypad,
- 12v solenoid door lock,
- Arduino nano,
- Transistor,

- LCD display,
- Adapter

Fingerprint Module R307

The fingerprint scanner shown in Figure 1 generally operates by exploiting optical rays, and there is an instrumentation amplifier circuit that records every small aspect of the fingerprint. Then, using an analogue to digital converter, this information is captured. Additionally, the ADC converter analyses it. Two procedures are necessary for using this fingerprint scanner: fingerprint matching and enrolling. Each module for this R307 scanner has to recognize the address. Each raw data is transmitted in the form of a data package comprising the address component when this module interfaces with the system. Only data packages whose value matched the scanner's address value will trigger a response from the scanner.

Figure 1: Represented the Fingerprint Module-R307 [6]**.**

GSM Module-SIM800A

It's a GSM module, as seen in Figure 2, and it works flawlessly with the Arduino nano. The SIM800A supports the quad-band frequencies of 850/900/1800/1900 MHz. It uses less power to transmit data, SMS, and voice information. To transmit the one-time password to the owner's phone while entering the bank locker, this GSM module was selected for the project. This GSM module is valuable since transmitting messages takes less time to process [7].

Figure 2: Represented the GSM module SIM800A.

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CHAPTER 5

EQUIPMENTS IN LOCKER SYSTEM DESIGN

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Matrix Keypad

The keypad features 16 matrix-style buttons. Any microcontroller may be easily interfaced with and is compatible with it. To scan through the keypad, just 8 microcontroller pins (4 columns and 4 rows) are required. This 4x4 Matrix keypad was selected for the project because it will serve as a helpful human interface element for those who utilize it to input data into the system.

Figure 1: Represented the 4*4 Matrix Keypad [1]**.**

12V Solenoid Door Lock

This solenoid is intended to open bank locker doors. It is constructed with a large coil of copper wire that has metal in the center. The slug is drawn towards the center of the coil as it heats up. This enables one-end pulling from the solenoid. The door may be opened by applying 9 to 12 VDC. For electronic access to open and shut bank locker doors, a solenoid is employed.

Figure 2: Represented the 12v Solenoid door Lock [2]**.**

LCD Display

Two rows of characters, each containing 16 characters, are shown on the LCD panel. This project uses this display to show the progress and condition of the locker.

Figure 3: Represented the LCD Display [3]**.**

ARDUINO NANO

The ATmega328p-based Arduino Nano is a compact, feature-rich, adaptable, and breadboard-friendly microcontroller board. There are 14 digital pins, 8 analogue pins, 2 reset pins, and 6 power pins in the Arduino Nano pinout. Although the operational voltage of this device is 5V, the input voltage ranges from 7 to 12V. It is programmed using the Arduino IDE, an offline and online integrated development environment. It is linked to the computer via a USB connection, or it may be powered by a battery, an AC-to-DC converter, or both. Due to its advantages of straightforward structure, high reliability, speed, an open source platform, flexibility, easy-to-use hardware and software, performance, and low power consumption this Arduino board has been selected for the Bank Locker Security System Project [4].

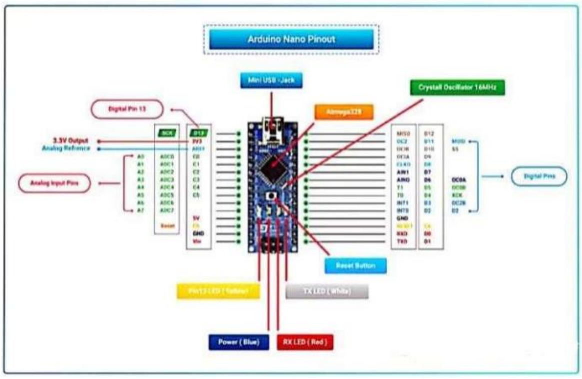

Figure 4: Illustrated the Arduino nano [5]**.**

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CHAPTER 6

DESIGN SPECIFICATIONS FOR SOFTWARE

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SOFTWARE USED:

- Proteus 8.0 for simulation,
- Arduino IDE for executing the project code.

PROTEUS 8.0:

A Windows program for parametric modelling, simulation, and PCB (Printed Circuit Board) layout design is referred to as the Proteus Design Suite. Depending on the scale of something like the designs being generated and the need for a microcontroller simulator, it may be acquired in a variety of configurations [1], [2]. An auto-router and foundational mixed-mode SPICE simulation capabilities are included in all PCB Design solutions. Both the simulation of prototypes and the design stage of a PCB-layout project leverage the Proteus Design Suite's schematic capture functionality. As a result, it is a basic component that comes with every product configuration. By adding a hex file or a debug packet to the microcontroller portion on the schematic, Proteus's microcontroller simulations function [3]. The associated analogue and digital equipment are then co-simulated with it. This allows one to utilize it for a variety of project prototypes in industries including user interface design, thermal management, and motor control. Furthermore used by ordinary hobbyists, it is straightforward to use as a training as well as a teaching tool since no infrastructure is needed.

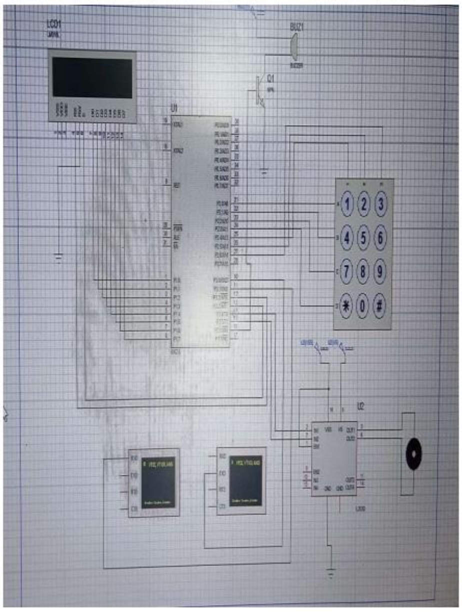

Figure 1: Represented the Simulation of Schematic in Proteus [4]**.**

i. **ARDUINO IDE:**

Sketches are a kind of software and these sketches will be constructed using the integrated software development environment for Arduino on a computer (IDE). The IDE tool enables editing, writing, and compilation of the code into rules that, following the programmed codes, the Arduino hardware will comprehend. For the Arduino board to execute well, the IDE also sends such instructions. Integrated Development Environment, or Arduino IDE, is software that resembled a notepad and allows us to generate code for the Arduino board. When working on projects, the IDE programmer code is recognized as the Arduino board's operating system. The file is known as a sketch in Arduino [5].

The prototype contains developed written codes. The PC compiler receives the created code from the Arduino IDE and validates it against a set of criteria before outputting a file that can be uploaded to the Arduino board. The Arduino IDE accepts the uploaded code and decides how the Arduino board employs the hardware and executes data. The Arduino programming language is a condensed version of C/C++ and uses simple development structures, variables, and functions. This is then converted into a legitimate C++ application. In contrast to other boards, the Arduino can manipulate electrical impulses and compared to another central processing unit, it can connect with it pretty easily. Even if it isn't managed by electrical impulses, it most likely uses electromagnets, propellers, and relays to communicate with it. Accordingly, the board choice is robust and able to function with the whole hardware of the bank vault system. Contrary to other text editors, the Arduino IDE makes it simpler to build programming for the Arduino board [6].

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CHAPTER 7

INTRODUCTION TO UNDER GROUND CABLING

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Electricity may be transmitted or delivered via subsurface wires or an overhead system. The benefits of underwater cables include lower maintenance costs, less fault probability, smaller voltage drops, and better overall aesthetics. They also reduce the likelihood to be damaged by storms or lightning. However, compared to a similar overhead connection, they have higher installation costs and create insulation issues at high voltages. Because of this, subterranean cables are deployed in situations where using utility poles is impractical. Such locales may include densely populated areas where overhead lines are outlawed by local authorities for safety precautions, areas near plants and switchgear, or areas where operating and maintenance costs forbid the use of overhead infrastructure [1], [2].

For many years, transporting electric power at relatively low or average voltages in crowded metropolitan regions has been the primary usage of subterranean cables. A cable encased in concrete consists of one or more components that are insulated properly and contained in a protective cover. Despite the variety of different kinds of cables, the choice of cable depends on the functioning voltage and service needs. In practice, a cable has to meet the following situations:

- High conductivity tinned unsupported copper or alumina should be utilised as the conductor in cables. The purpose of trapping is to make the conductor more flexible and capable of transmitting more current.
- The conductor size ought to be chosen such that the cable can carry the appropriate load current while overheating and with a voltage drop that doesn't go beyond that which is allowed.
- The cable's insulation should be of the right thickness to maintain a high level of safety and predictability at the voltage for which it is designated.
- The cable must be equipped with enough shock absorption so that it can resist the rigorous manipulation that comes with laying it.
- The materials that are made to produce cables should be chemically and physiologically stable throughout.

The Need for Underground Cables:

Electricity may be distributed or transported via subterranean wires or maybe an overhead system. The benefits of subsurface cables include fewer moving parts, fewer risks of failure, smaller voltage drops, and a better overall impression. They are also less likely to be damaged by storms or lightning. However, compared to an equivalent overhead system, they have higher installation costs and create encapsulation issues at high voltages. Because of this, subterranean cables are commonly used in situations where using overhead lines remains impractical. Such regions also include densely populated areas whereby overhead lines are prohibited through

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local authorities for safety precautions, areas near plants and switchgears, or areas where operating and maintenance costs forbid the use of rooftop construction. For many years, transporting electric power at relatively low or moderate energies in crowded metropolitan regions has been the primary usage of underwater cables [3].

However, more technological breakthroughs in manufacturing and design have resulted in the creation of connections that can be used at high voltages. As a consequence of this, it is now feasible to use subterranean cables to transport electric power across brief even modest distances. We'll emphasize subterranean cables' unique characteristics and growing role in the electricity network in this chapter [4], [5].

Manufacturing of Underground Cables:

The basic components of underground cables are a conductor, an encapsulating system, a wire screen, and even a sheath. An electric conductor, often comprised of copper as shown in Figure 1, is located at the heart of extra-high-voltage (EHV) lines.

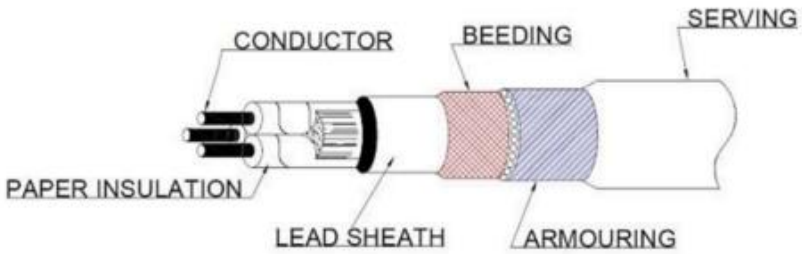

Figure 1: Illustrated the Structure of the Underground Cable.

- **Cores or Conductors**

Depending on the type of service it is provided for, a cable may contain one or numerous cores (conductors). The 3-conductor wire in the illustration above, for example, is utilised for 3-phase service. To grant the cable flexibility, the filaments, which are typically stranded and comprised of tinned copper or aluminium,

- **Insulation**

Each core or conductor has layers of insulation that is a reasonable thickness, the thickness of which depends on the voltage that the cable must be capable of withstanding. Impregnated paper, varnished cambric, and rubber mineral combination are some of the materials that are frequently utilized as insulation.

- **Metallic Sheath**

A metallic coating constructed of lead or aluminium is inserted over the insulation to insulate the cable from moisture, conductor gases, and other harmful liquids (acids or alkalis) in the soil and surrounding environment as seen in the above image.

- **Bedding**

A layer of bedding made of something like a fibrous substance like jute or hessian tape is put well over a metallic sheath. Bedding serves to cushion the metallic sheath from corrosion damage and mechanical harm delivered on by armouring.

- **Armouring**

Armoring is put over the mattresses and consists of one or two additional of steel tape or galvanized wire. Its objective is to shield the cable from mechanical stress while it is being laid and handled. With certain cables, armouring may be necessary.

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- **Serving**

Armoring is blanketed with a serving, which is a layer of bamboo fibres like jute resembling bedding, to safeguard it from atmospheric pressure.

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CHAPTER 8

TYPES OF UNDERGROUND CABLES

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There are determined significant that may be used to characterize underground wires. When classifying, multiple factors will be considered, including [1].

Number of Conductors in the Cable

- Single core cable,
- Three core cable

A subsurface cable often contains one, three, or four cores, of course, these cables are designed following that.

To supply 3-phase electricity, transmission lines are often used. Up to 66 kV, a 3-cored connection is ideal. Beyond that, the number of cable insulation needed remains excessive. Even with certain restrictions, we use single-cored cables even though three-cored structures have become too large for higher voltages [2].

Voltage Rating of the Cable:

- Low-tension (L.T.) cables – up to 1000 V
- High-tension (H.T.) cables – up to 11,000 V
- Super-tension (S.T.) cables – from 22 kV to 33 kV
- Extra high-tension (E.H.T.) cables – from 33 kV to 66 kV
- Extra super voltage cables – beyond 132 kV

Depending on the service type it is developed for, a cable may comprise one core or more. It might be:

- Single core
- Two-core
- Three-core
- Four-core

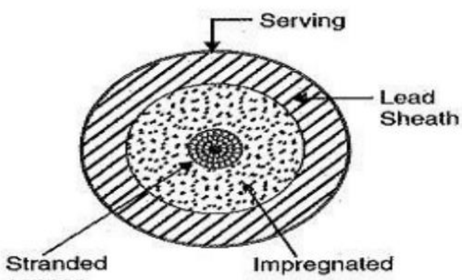

Figure 2: Represented the Constructional Details of a Single-Core Low Tension Cable.

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Depending on the operating energy and load requirement, either three-core cables or three-single-core cables may very well be utilized for three-phase service. Because the tensions that emerge in the cable at low voltages (up to 6600V) are often negligible, the cable has an ordinary structure. It has a single, spherical core manufactured of tinned stranded copper or aluminium that is surrounded by layers of moistened paper for insulation. A lead sheath covers the insulation and prevents moisture from penetrating everything inside. There is a general serving of chopped fibrous substance (jute, etc.) to prevent corrosion of the lead sheath. To safeguard against significant sheath losses, single-core cables frequently aren't armoured. Single-core cables' main benefits are their convenience of production and availability to bigger copper components [2].

- **Belted Cable:**

These cables have their electrons (often three) bundled together since being enclosed by an insulating paper "belt." Each conductor in these cables is isolated using paper that's been treated with the appropriate dielectric. A fibrous dielectric medium, such as Jute or Hessian, is used to fill the intervals between the electrodes and the insulating paper belt. This offers both flexibility and a round form [3], [4]. The copper sheath and armouring always are placed over the jute layer, as we previously mentioned (see Construction of Cables). This cable's unique aspect is that it could not be exactly round in form. To make more efficient use of the available area, it is maintained non-circular [5].

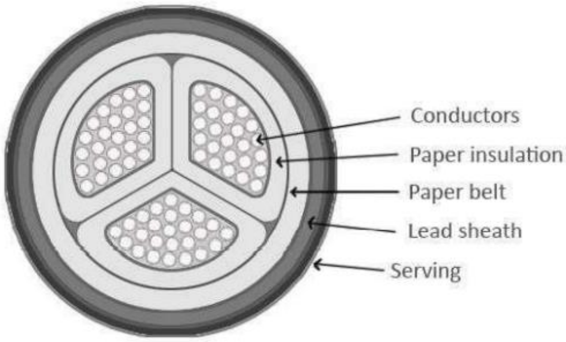

Figure 2: Represented the Structure of 1-belted cable.

Such a structure will have certain drawbacks. The insulation is strained because the electric field is tangential. The outcome is a continuous decrease in the dielectric strength. Therefore, such a design is not permitted for voltage concentrations that exceed 11 kV [6].

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CHAPTER 9

TYPES OF CABLING SYSTEMS

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SCREENED CABLE:

Further divided as H-type and S.L. - type cables:

- **H-Type Cables:**

M. Hochstadter developed the initial version. As seen in Figure 1, each of the three cores is separately insulated with paper without first being covered by a metallic screen cover. These metal coverings have openings in them. Because of this design, the three metallic displays can contact one another. Then, a metallic tape, often manufactured of copper, is used to link these three metallic surfaces together. This structure is enclosed by a lead sheath. Both the sheath and indeed the metallic coverings are connected. The fact that the electric pressures are radial rather than tangential and hence less with magnitude creates the necessity. The heat dissipation is also assisted by the metallic coatings [1].

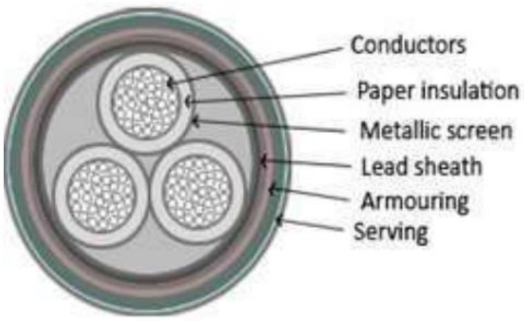

Figure 1: Illustrated the Construction of H-Types Cable.

- **S.L Type Cables:**

It is similar to H-type cables, except otherwise seen in Figure 2, each of the three cores has an independent lead sheath. This clause does dispense from the necessity for the preceding overall sheath. The benefit of such a design is that the likelihood of a core-to-core breakdown has been much reduced. The cable's elasticity has also been increased. The restrictions are rather strict. Only voltages up to 66kV are permitted in this kind of construction. Since the constituent sheaths are thinner, moisture may permeate the cable via manufacturing imperfections and lower its dielectric strength [2].

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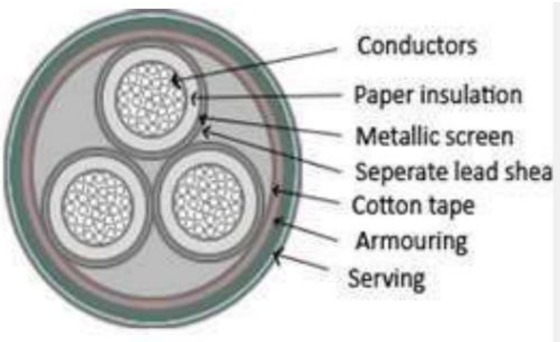

Figure 2: represented that the S.L Type Cable

- **H.S.L. Type Cables:**

This kind of cable is a hybrid of the H and S.L. types. These cables have individual lead sheaths and impregnated paper insulation around each core.

i. **Pressure Cables:**

Solid cables become unstable at voltages higher than 66 kV because electrostatic stresses in the cables are too high. This happens mostly because voltages greater than 66 kV induce voids to form [3], [4]. Therefore, we employ Pressure cables rather than solid cables. These wires are often loaded with either gas or oil [5].

- **Oil-Filled Cables:**

Through pipes made specifically for this purpose, oil is circulated at an appropriate pressure. Through reservoirs held at the appropriate distances, this oil supply and pressure are maintained. The oil used is the same one that is applied to paper insulators before impregnation.

- **Gas-Filled Cables:**

In an airtight steel conduit, pressurized gas typically dry nitrogen is circulated through wires. These cables have larger load current carrying capacities and higher operating voltages. However, the total cost is higher.

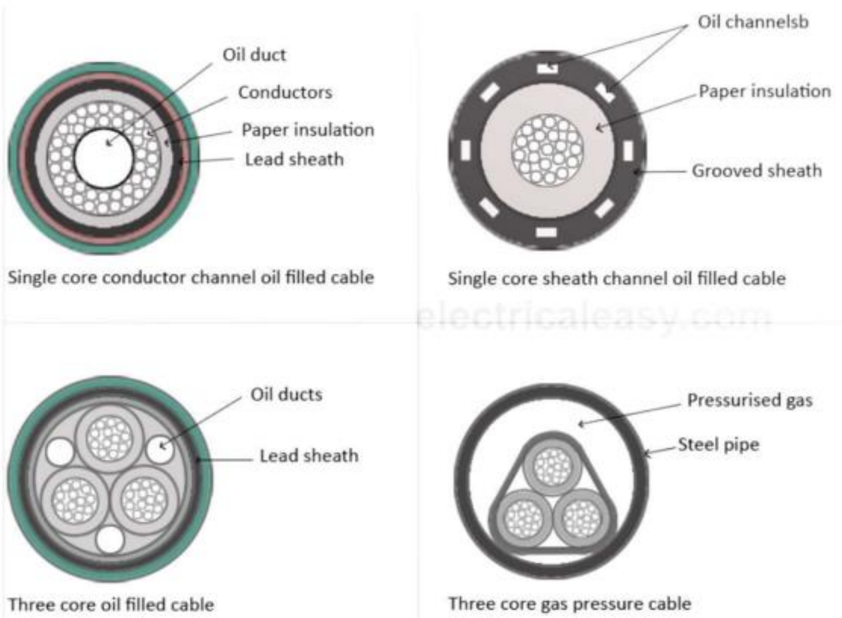

Figure 3: Represented the Different types of Pressure Cable [6]**.**

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CHAPTER 10

PROPORTIONAL METHOD OF MATHEMATICAL MODEL

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The core conductor and indeed the conducting sheath are tightly coupled in single-core as well as three-core cables. Additionally, there is also a conducting earth channel amongst the two neighbouring conductors enabling buried self-contained single-core cables. The steel pipe itself provides a dielectric medium in cables of the pipe type. As a result, a single-circuit personality three-phase cable is a multi-conductor system that is composed of the earth route, three cores, and three sheaths (a total of six conductors) [1].

The number of attached conductors for N three-phase cable circuitry is 6N for single-core or three-core core-sheath cables, and 9N for single-core core-sheath armour cables. The total number of interconnected conductors in core scabbard armour single-circuit three-core cables is seven. The self and mutual impedances of the conductors as well as the conductor shunt admittances are the electrical and structural characteristics of cables [2], [3]. The tiny conductivity of the shielding is often disregarded while still doing power frequency full employment analysis. Digital application software is used to calculate the specifications of multi-conductor cables with capacitors and inductors represented in per-unit length and shunt average variance extracted expressed in μS unit length [4].

Shunt Susceptance

The earth the screens are linked to provides an electrostatic shield in single-core screened cables because when phases are arranged parallel to each other and the earth's surface, inhibiting electrostatic coupling between the phases. This also remains good for cables with three phases and three cores that are properly screened. As a result, there is no mutual capacitance between the three phases, and the resistance of each cable is unaffected by the separation between the phases. The hollow core conductor, core insulator, sheath/screen conductor, sheath insulation, armour conductor, and a supplementary insulation layer, such as a plastic sheath, are all present in the cross-section of a typical cable (Figure 1).

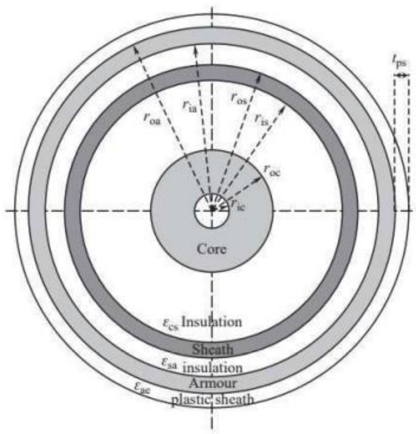

Figure 1: Illustrated the Cross Section of Cable [5]**.**

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Cables in Faulted Condition

An underground cable distribution system may encounter either a low-impedance failure or a high-impedance fault. Three-phase fault (3PF), single-line-to-ground fault (SLGF), line-to-line fault (LLF), and double-line-to-ground fault are the four forms of low-impedance faults (2LGF). The most frequent defect in an electrical network is the SLGF. In actuality, SLGF problems try to compensate for more than 85% of power system defects. A very frequent high-impedance defect of underwater cables in power systems is the water tree. Water tree is a fault situation that affects the wires' insulating material. It often happens when the soil's relative humidity is more than 65.0%. For the majority of the year, the soil saturation at a depth of one meter stays at 100%. Water tree was therefore likely to develop in subterranean cables. A water tree emerges from a few tiny gaps and develops by raising the voltage stress in its surrounding environment. Then, water-filled cracks start to appear. The high-impedance breakdown occurs when the water tree reaches the conducting layer of cables after forming and extending into a tree-like shape. Because of the water tree's high impedance, this kind of defect doesn't lead to a significant change in voltage or current. As a result, it is difficult to detect, however after a given amount of operation, it damages cables and even collapses them [6].

Locating Underground Cable Faults

It shouldn't be difficult to identify the nature of the project in subterranean wires using a millimetre. But certain techniques are necessary to locate the cable issue completely. The Murray and Varley loop tests are two methods that are used sometimes to find defects in vast underground cables. This page describes a few other widely accepted methods for identifying underground cable instabilities, including:

- Cable thumping,
- TDR,
- High-voltage radar methods

Cable Thumping For Locating Underground Cable Faults

In essence, a cable thumper is a mobile high-voltage surge generator. It is used to infuse the problematic cable with a high-voltage DC surge (about 25 kV). A high-current arc might form if you apply a high enough voltage to the damaged cable to remedy the open-circuit problem. The precise placement of the fault produces a characteristic pounding sound from any of these high current arc. The thumping approach involves setting a thumper to continually thump and then travelling along the cable path to hear the thundering sound. The ensuing thud will be harsher the greater the applied dc voltage. For comparatively shorter connections, this technique is helpful. This same thumping approach becomes unworkable for larger lines; just image having to walk along a wire that is numerous kilometres long to hear the thud [7].

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CHAPTER 11

ADVANTAGES AND DISADVANTAGES OF CABLE THUMPING

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The ability of cable hammering to pinpoint open circuit abnormalities with extreme precision is a significant benefit. This technique is very simple to understand and implement. Even if the pounding methodology locates faults quite precisely, it has limitations of its own. Applying this technique to longer wires takes a significant amount of time. To find the problem, you might be required to stroll along the cable for hours or even days. Additionally, the cable is exposed to substantial voltage spikes throughout the whole period [1], [2]. Therefore, excessive voltage surges may degrade the cable's insulation while the existing defect is just being discovered. If you are skilled in cable thumping, you may prevent damage to the cable insulation by just sending the bare minimum amount of current through the cable as during the test. While occasional pounding may not result in obvious damage, regular thumping may cause underlying cable insulation to deteriorate to an unsatisfactory level. Additionally, short circuit faults that do not arc over cannot be found using this approach [1].

Reflectometer in the time domain (TDR)

A short-duration, high resonant frequency, low energy signal of roughly 50 V is sent into the cable using a Time Domain Reflectometer (TDR). This signal returns from the region where the cable's impedance changes, such as a defect. TDR operates on a similar structure as a RADAR. A TDR calculates the amount of time it takes for the signal to return from the impedance change point or the point of fault. The amplitude of the rebounds and the amount of time that has lapsed are plotted on a graphic display, respectively (Figure 1). The proximity to the fault site and the elapsed time are directly proportional. An open circuit with high impedance causes the injected information to deflect upward on the trace with just a large amplitude. While a short-circuit failure will provide an increasing amplitude negative movement on the trace [3].

Figure 1: Illustrates the Megger Time Domain Reflectometer [4]**.**

A TDR does not degrade the cable shielding since it transmits a low-energy signal into the cable. This is a substantial benefit of employing TDR to locate a cable issue underground. A TDR is effective for both conductor-to-conductor shorts and constant current problems.

TDR's inability to specify the precise location of defects represents one of its weaknesses. It provides an approximate distance from the fault's placement. This knowledge might

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occasionally be adequate on its own, even though other times it just facilitates to allow for more accurate hammering. The user may not be able to see mirrors that may take place during the TDR's test pulse when it is being sent. This is often the result of blind spots or defects that are present at the end. Additionally, a TDR cannot recognize a ground fault with increased resistance (often above 200 Ohms). The TDR signal might be affected if there is nearby electrical noise [5].

- **Techniques for High Voltage Radar**

The low-voltage TDR's usefulness in locating underground distribution faults is limited since it cannot recognize high-resistance ground faults. The typical high-voltage radar solutions listed below may help TDR circumvent this drawback.

  - Arc reflection technique,
  - Surge-Pulse Reflection Technique,
  - Method of voltage decay reflection.

- Method of Arc Reflection

A TDR with a filter and thumper is employed for the arc reflection technique. For the TDR to adequately display a downward deflection, an arc spanning the shunt fault must also be created using the thumper (also known as a surge generator). The arc reflection filter provides the low-voltage signal down the wire while isolating the TDR from high-voltage surges caused by the thumper.

- **Method for Surge Pulse Reflection**

This technique utilizes the use of a storage oscilloscope, a scrapper, and a current coupler (analyzer). Long-run cables and faults that become difficult to arc across and do not show up that used the arc reflection approach are both applications for this methodology. In this procedure, a filter that may restrict the electricity and voltage supplied to the problem is not used; instead, a thumper is properly connected to the cable. A high voltage pulse from either the thumper causes an explosion to form at the defect in the cable, reflecting energy to the scrapper as a result. Until its batteries run out, the reflection alternates between the problem and the thumper. The surge reflections are recorded by the current coupler, and the stockpiling oscilloscope subsequently records and displays them [6].

- **Method of Voltage Decay Reflection**

This technique makes use of a voltage coupler, a storage oscilloscope, a high-voltage dc test set, and an insulating test set (analyzer). When the formation of an arc at the breakdown demands a breakdown voltage stronger than what a standard thumper or surge generator can give, this approach is employed for transmitting class cables. Here, the analyzer detects and shows the reflections caused by the explosion of dc voltage at the breakdown as sensed by the voltage coupler [7].

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CHAPTER 12

LAYING MECHANISM OF UNDERGROUND CABLE

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LAYING OF UNDERGROUND CABLES

Naturally, underground cables are supposed to be placed or buried underground. The quality of cable connectors, branch connectivity, and good cable laying are all critical factors that determine how reliable an underground cable network [1], [2]. There are three main approaches to deploying subsurface cables:

- Direct Laying,
- draw-in-System
- Solid System.

These three methods are explained below with their advantages and drawbacks.

Direct Laying Of Underground Cables

Due to its ease of use and low cost, this methodology is the most common [3]–[5]. To protect the cabling being installed using this technology from corrosion and electrolysis, bituminized paper and covariance tape must be used (Figure 1). The steps that are required in direct laying:

Figure 1: Displayed the Direct Laying Procedure.

Laying Procedure

- A 45 cm wide by 1.5 m-deep trenches is constructed.
- The ditch is then resurfaced with a fine sand layer that seems to be 10 cm thick.
- Over the sand bed, another cable is placed. The cable is isolated from ground moisture by the desert substrate.
- The wire is subsequently once more buried with a layer of sand which is approximately 10 cm thick.
- To lessen the impact of mutual overheating, either a horizontal or vertical gap of roughly 30 cm is maintained when many cables are to be put in the same trench. The distance between the wires also ensures that a defect on one cable didn't damage the cable next to it.

- To shield the cable from accidental harm, the ditch is eventually filled with dirt as well as bricks.

Advantages

- Simpler and cheaper than the other two methods
- The heat generated in cables is easily dissipated in the ground.

Disadvantages

- To install new cables for fulfilling an increased load demand, completely new excavation has to be done which costs as much as the new installation.
- Alterations in the cable network are not easy.
- Maintenance cost is higher.
- Identifying the location of a fault is difficult.
- This method cannot be used in congested areas such as metro cities where excavation is too expensive.

Draw-In System

With this technique, manholes are deliberately positioned along the cable path along subterranean carbon steel or concrete pipelines or ducts. The wires are then drawn from either the manholes and placed inside these pipes. The three cable ducts are often joined by a fourth pipe or duct that carries the pilot wires and reactive power compensation connections. The gaps between the pumping stations ought to make it less difficult to draw the wires in. The radius of something like the corners must be larger at intersections or while holding up traffic. To protect yourself while being pulled, the cables that are going to be placed in this technique must be served with white cloth and jute rather than being coated (Figure 2).

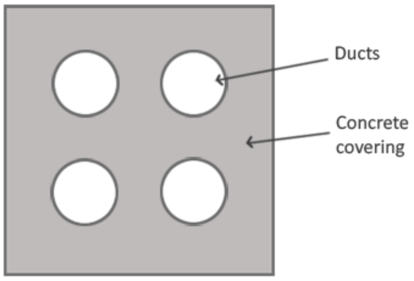

Figure 2: Displayed the Draw-In System

Advantages

- Manholes make it simple to make upgrades, expansions, or changes to the cable network without having to re-excavate the ground.
- This technology makes the cable jointing process easier since the cables do not need to be armoured.
- Maintenance costs are much cheaper.
- Lessening the likelihood of a problem because of the system's excellent mechanical protection.

Disadvantages

- The first commitment is fairly costly.
- Due to adverse heat dissipation temperatures, the cables' ability to transport electricity is compromised.

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CHAPTER 13

GRADING OF UNDERGROUND CABLES

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A cable's electrostatic stress isn't distributed equally. The potential gradient is positively associated with the cable's distance from the source. As a result, it will reach its maximum (gmax) at the conductor's surface gradually reducing until it reaches its minimum (gmin) at the sheath's surface. This indicates that electrostatic demand in a cable's dielectric is greatest somewhere at the conductor's surface and lightest at the sheath's surface. It is unquestionable that for a safety cable, the recommended insulation's dielectric strength must be greater than gmax, or the maximum value of potential gradient. The strength of the insulation needed isn't uniform to the concentration of electromagnetic stress in a connection [1].

Only at the surface of something like the core do we need the greatest dielectric strength. The resulting dielectric is excessively robust and is thus not appropriately used. The wire develops needlessly thick as a result of this as well. Electric hardware that is enormous is generally inappropriate. Furthermore, if the load capacity is not uniform, there is a greater danger of insulation failure. Grading of the cables needs to correct these issues [1]–[3].

Grading Of Underground Cables

The process of creating homogeneous electrostatic stress in a cable's dielectric is described as grading. The dielectric layer's level is made up is made uniform to facilitate this [4]. There are two main methods to do it:

- **Capacitance Grading**,
- **Inters Heath Grading.**

Capacitance Grading

Between the core and the sheath, several layers of different dielectric materials with varying permittivity are used to evaluate the capacitance. As a result, the offered hydrophobic insulation is composite then instead of homogenous. As shown in Figure 1, the different layers are designed such that the permittivity drops from either the conductor's surface to the cable's sheath, meaning that perhaps the permittivity of the dielectric is directly proportional to the distance from the source, precisely like the electrochemical gradient (Figure 1).

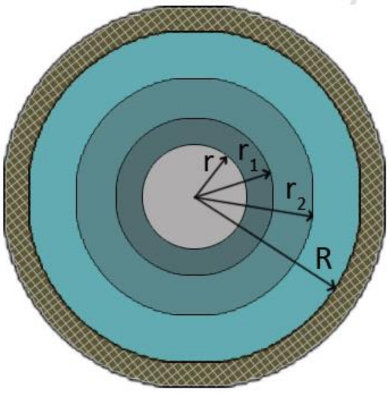

Figure 1: Represented the Capacitance Grading [5]**.**

Intersheath Grading

In this technique, we employ a homogeneous dielectric material rather than a composite dielectric made of several dielectrics. However, we add additional metallic sheaths in between the conductor and the central sheath to correctly disperse the stress. "Inters-heaths" are the term referring to these intermediary sheaths. The depending on voltage levels are then established in these inters-heaths. This technique promotes voltage propagation in the cable's dielectric, which results in a constant potential gradient (Figure 2).

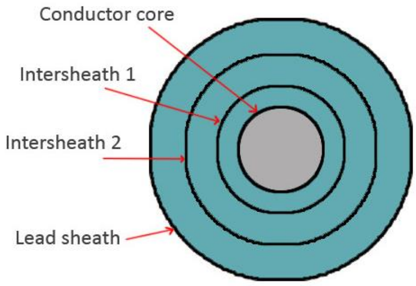

Figure 2: Represented the Intersheath Grading [6]**.**

There are certain drawbacks to interscholastic grading. The two main drawbacks are the losses experienced as a result of the higher charging currents of the multiple inters-heaths and the difficulty in precisely setting the inters-heath potentials. These factors make this procedure hardly used.

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