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:PRESENTED BY;

*** MIHI ABDERRAHMANE**
***NEDJAI MOHAMMED LAROUCI**

oltage Silicone V-Experimental Evaluation of High Insulator Chains under Laboratory Conditions

Board of Examiners

Dr.GUIA TALAL	SUPERVISOR	University of El-Oued
Dr. KHECHEKHOUCHE AL	Chairman of the committee	University of El-Oued
Dr. MERAZGA AZEDDINE	Discussant	University of El-Oued

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بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

DEDICATION00

،vement to my dear family and dear friendsI dedicate this achie

I dedicate this achievement to everyone who has enriched

،my life in one way or another

whether they are classmates, friends, acquaintances, or even people

،I have not met personally

m afar with their kind wordsbut have supported me fro

.and constant encouragement

،I dedicate this achievement to myself

،and I thank myself for the determination

،perseverance and dedication to hard work

of life and I wish myself success in a new stage

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I cannot express how grateful I am to everyone who stood by me during this long study period

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veryone who participated with me in this Thank you to e ،scientific journey

،and helped me achieve my goals and overcome challenges

and I wish everyone success in their professional and personal .lives

GENERAL SUMMARY

ملخص :

في هذا العمل قمنا بدراسة أنواع العوازل وتأثير التلوث عليها عند الجهد العالي ، وقمنا بإجراء سلسلة من الاختبارات على مستوى المختبر (جامعة الشهيد حمة لخضر) تم تسجيل البيانات ودراستها ومعرفة خصائص وقدرة هذه العوازل من أجل إدخالها في الاستخدام والعمل والاستفادة منها مستقبلا.

الكلمات المفتاحية:

التوتر الشديد، التلوث، تدفق الهواء، العوازل، المضادة

: SUMMARY

In this work, we studied the types of insulators and the impact of pollution on them at high voltage , we conducted a series of tests at the level of the laboratory the data were recorded and studied and to (University of Shahid Hama Lakhdar) know the characteristics and capacity of these insulators in order to enter them .into use and work and benefit from them in the future

Keywords

High voltage, Pollution, Leakage current, Insulators, Countermeasures

:Résumé

et de la pollution Dans ce travail, nous avons étudié les types d'isolants et l'eff ci à haute tension, et nous avons mené une série de tests au niveau du -sur ceux laboratoire (Université Shahid Hamma Lakhdar) Les données ont été enregistrées fin de et étudiées et les propriétés et la capacité de ces isolants ont été connues a .les introduire dans l'utilisation et de travailler et d'en bénéficier à l'avenir

Mots-clés

Haute tension , Pollution , Courant de fuite , Isoltors , contrenement

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GENERAL SUMMARY

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ductionGeneral intro

:General introduction

The field of electrical energy includes the design and operation of production, transmission and distribution systems. Since the late 1970s, electrical engineering has witnessed major s fieldand important developments in thi

High voltage equipment, such as cables, poles, and insulators...Etc., an essential part of aerial networks for transmitting electrical energy, and they are designed to operate efficiently s, although their cost represents and reliably in various environmental conditions. Insulator only a small percentage of the cost of overhead transmission lines, are a very important element in ensuring the good performance of these lines

lenges, the most Overhead lines and electrical power transmission stations face several chal prominent of which is the problem of insulator contamination, which is one of the basic factors that affect the quality and reliability of electrical transmission service. During periods insulating surfaces, leading to a of rain or fog, contaminated sediments accumulate on significant decrease in surface resistance, and this may sometimes cause a partial or .comprehensive electrical discharge

Insulators play a pivotal role in the design of overhead lines, as they connect electrical ors to support towers and provide electrical insulation between these parts. conduct Therefore, choosing the type of insulator, conducting acceptance tests, and continuous monitoring during operation all require special care to ensure optimal line performance

e electrical power transmission system is exposed to various environmental factors, and Th the problem of insulation pollution is one of the most influential of these factors on the ered as a efficiency and continuity of transmission . Insulator pollution can be consid continuous or intermittent accumulation of impurities from multiple sources; It may be the result of smoke from industries and cities (industrial or urban pollution), fine salt particles in (in desert areas (desert pollution coastal areas (marine pollution), or even sand particles

This research focuses on the study of conduction and electrical discharge phenomena that .occur in insulators under the influence of pollution

f insulators and the The first chapter of this work includes a presentation of the importance o purposes of their use, with an explanation of their different types, shapes, and materials from which they are made. The second chapter deals with the phenomenon of pollution and its h an explanation of the influencing impact on the transmission of electrical energy, wit .factors, measurement methods, and possible means of combating this pollution
The work concludes with an experimental application part that studies the effect of different f) on a model of a rectangular insulator types of pollutants (such as clay, sand, and tuf .Obenaus model [5]), in terms of discharge voltage and surface conductivity)

Chapter I
Overview of electrical insulators

I.1 Introduction

High voltage equipment in overhead power lines is made to work well in certain weather and environmental conditions. One important part of this equipment is the n though insulators don’t cost much compared to the total price of the insulator. Eve power line, they are very important for its safe and correct operation. Their main job .is to keep the high voltage parts separated from other parts

transport and distribution of electricity. They Insulators are necessary in both the help connect parts that have different electrical voltages, while also keeping them .safely apart

In this chapter, we will talk about high voltage insulators, the different types, and how .each one works

.sectional view of a rigid glass insulator-Cross **:Figure I.1**

I.2 Historical overview

based materials). -In the past, insulators were made of glass or ceramic (like steatite .Today, we also find them made from synthetic materials

voltage power lines usually have a disc -lass and ceramic insulators used in highG shape. These discs are joined together to make what’s called an insulator string. like surface to increase the -There are also insulators in a column shape, with a fin

this means the path along the surface of the insulator that —distance" leakage"
.electricity would have to follow to escape

Since the end of the 20th century, composite materials have been more commonly
re, covered with used to make insulators. These are made with a fiberglass co
.silicone or EPDM rubber

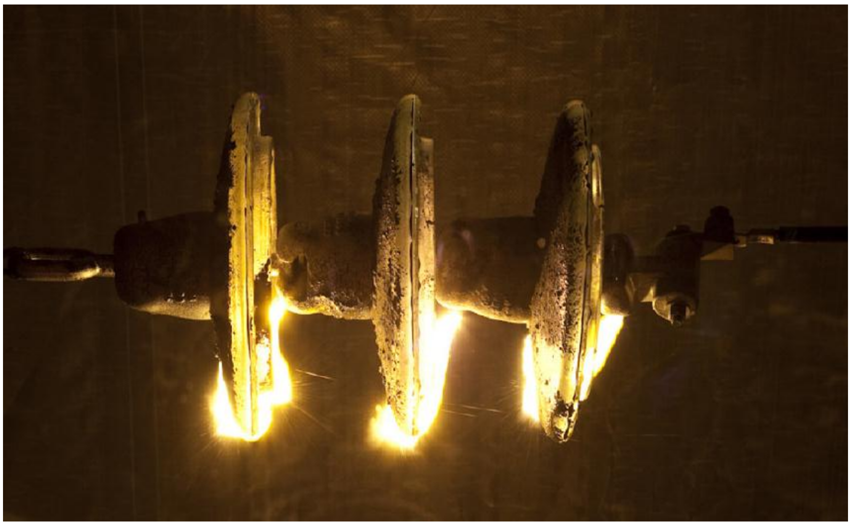
Composite insulators are lighter, usually cheaper, and have very good water
resistance (hydrophobicity). They are especially useful in polluted areas and in cities,
.where they are also more resistant to vandalism

I.3 Insulators: definition and basic concepts

I.3.1 Definitions

- An insulator is a solid material that does not let electric current **:Insulator** pass through easily. It has very high resistance and almost no conductivity. It rts and conductors to avoid short circuits, power is used to separate live pa .loss, or electric shock

- This happens on the surface of the insulator **:(Flashover (Surface Discharge** when an electric discharge jumps from one end of the insulator to the other, ead of through it. When this happens, it can cause going over the surface inst the circuit breaker to open, because it creates a short circuit between the see figure I.2). Flashover –conductor and the metal tower (a fault to ground .system usually causes a short interruption of power in the



Flashover (Surface Discharge) phenomenon on the surface of **:Figure I.2**
.the insulator

- This is the lowest voltage at which an electric arc **:Flashover Voltage**
:connects the two ends of the insulator. Flashover voltage depends on
  - ؛rage resistivity of the pollutionThe ave
  - ؛How the pollution is spread on the surface
  - ؛The length of the insulator
  - .The shape of the insulator
- This is the highest voltage the insulator can handle **:Withstand Voltage**
.without breaking down or causing a flashover
- This is a small current that flows along the dirty surface of **:Leakage Current**
the insulator. It becomes stronger as the voltage gets closer to the flashover voltage. It depends on many things like the type of pollution and the length of
.hthe leakage pat

In very humid conditions, salts in the pollution layer can dissolve, creating a thin
this increases the risk of —layer of liquid that helps electricity flow more easily
.flashover

- **:Shape Factor (F) of an Insulator**
ends on its size and dimensions. To The shape factor of an insulator dep estimate it using a graph, we draw a curve showing the inverse of the
.circumference (1/p) versus the length of the partial leakage path

ic The shape factor is found by calculating the area under this curve, using a specif
.formula

$$F = \int_0^1 \frac{dl}{p(l)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$

؛(is the partial length of the insulator (in meters **l**

.is the perimeter of the insulator depending on the partial leakage path length **(P(l**

:an Insulator I.4 Function and Structure of

Insulators are important components in the transport and distribution of electrical energy. Their main role is to create a mechanical connection between conductors on that have different electrical potentials. Insulators that are used to positi conductors in place are called alignment and anchoring insulators. They help transition from internal insulation (like oil or SF6) to external insulation. They also connect electrical equipment to the network, such as transformer connections and nds. Additionally, insulators form the outer part of certain devices, such as cable e .circuit breakers, surge protectors, and measuring devices

Insulators are designed and sized based on the environment they will be used in. nsulator is seen as two electrodes with a gap From an electrical point of view, an i between them, which has three areas made up of three different types of insulation :that work in parallel. These areas are

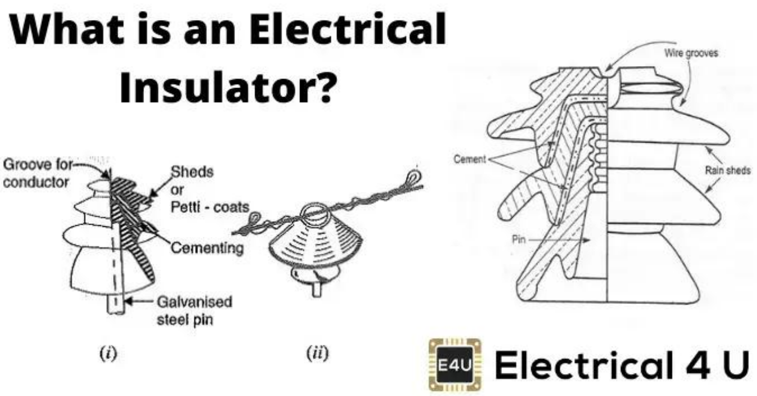
- .The air gap
- .The dielectric material
- c material (the length of this The interface between the air and the dielectri .(could flow interface is the leakage path, where leakage current

I.5 Characteristics of an Electrical Insulator

Electrical insulators are crucial components in power systems, ensuring the safe f electricity. Understanding their key characteristics transmission and distribution o .helps in designing systems that are both efficient and safe

1. This refers to the distance between two corresponding parts of **:(Step (P** s engineers consecutive insulators in a string. Determining this distance allow to calculate the total length of an insulator chain needed for a specific .[application[1
2. the creepage distance, it is the shortest Also known as **:(Leakage Path (Lf** distance along the surface of the insulator between two conductive parts. This path is vital in preventing surface leakage currents, which can occur due to .[contamination, moisture, or other environmental factors[2

3. This is the shortest distance through the air **:(Clearance Distance (Lc** between two conductive parts. It is essential for withstanding transient overvoltages and ensuring the insulator's ability to handle electrical stresses .[without breaking down[3



Key characteristics of an electrical insulator **:Figure I.3**

I.6 Importance of These Characteristics

- Safety: Adequate step, leakage, and clearance distances prevent electrical .[4]breakdowns, short circuits, and other hazardous situations
- term reliability -Reliability: Properly designed insulators contribute to the long .and performance of electrical systems
- e: Adhering to recommended distances ensures that electrical Complianc .[systems meet various safety standards and regulations[5

I.7 Types of Electrical Insulators

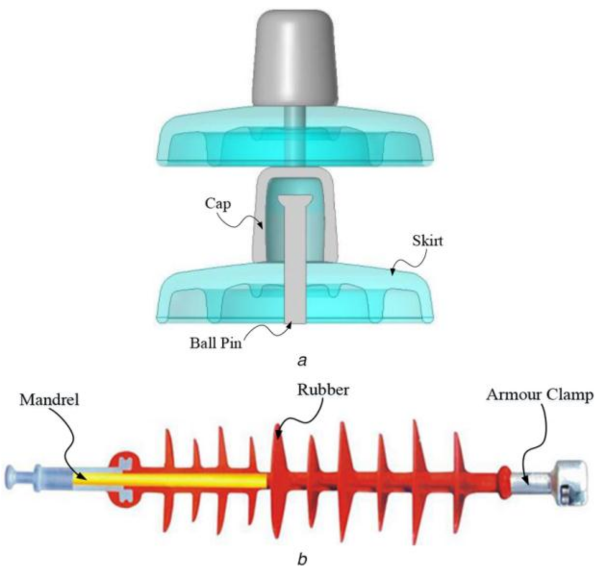
Electrical insulators are essential components in power transmission systems, used e, and secure electrical conductors. There are different types of to support, isolat :insulators, each designed for specific purposes. Below are the main types

1. **Support Insulators**
   These insulators are used to support the power lines, ensuring they stay in They provide a stable mechanical connection between the .place on the poles conductor and the support structure. Support insulators are typically used in .voltage lines-lower

voltage power lines to maintain -Support insulators used in low **:Figure I.4**
hanical connectionmec

2. **Crossing Insulators**

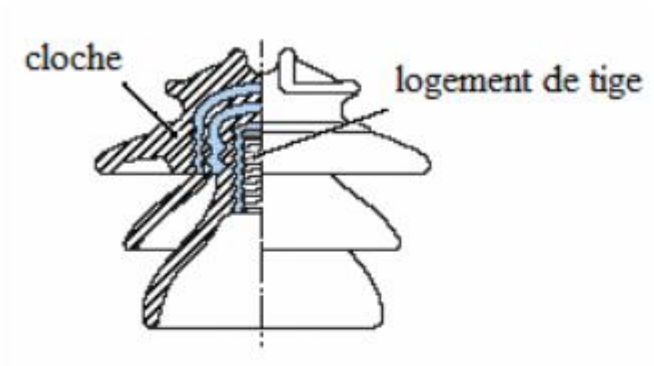
Crossing insulators are used where conductors cross over or under other lines, such as when lines pass over a road or railway. These insulators ng maintain the separation between conductors and other elements, preventi .any electrical contact or short circuits



Crossing Insulators used to maintain electrical separation where **:Figure I.5**
conductors cross over roads or railways

3. **Aerial Line Insulators**
   There are two main types .These insulators are used in overhead power lines
   :within this category

   ○ **Rigid Insulators**
   These are solid, fixed insulators used to support the conductor in place
   -without allowing movement. They are suitable for lower to medium
   .voltage transmission systems



sectional view of a rigid glass insulator-Cross **:Figure I.6**

   ○ **Suspended Insulators**
   Suspended insulators are made up of a series of discs or rings that
   voltage -are connected in a chain. These insulators are used for high
   the conductor to hang freely, which helps distribute the lines and allow
   .electrical stress evenly across the chain

   ○ **Chain Elements**
   These are components of suspended insulators that form the entire
   insulating chain. Each element in the chain contributes to the overall
   .voltage transmission-sulation, helping manage highin

These different types of insulators are chosen based on their specific function, voltage level, and environmental conditions. Proper selection and installation of [d efficiency of power distribution systems.[6insulators are crucial for the safety an

shaped -Suspended Glass Insulator Chain composed of multiple disc **:Figure I.7** voltage overhead lines-elements for high

I.8 Choosing the Right Insulators

voltage overhead -the cost of a medium Insulators may only represent about 7% of power line, but they are a very important part of the system. They help ensure safety, .service quality, and continuous operation

The best insulators for a certain environment are the ones that collect the least cleaning properties, especially -of pollution. This means they have good self amount when it rains. Even if the insulators are well chosen at the beginning, problems can .still happen later

:For example

- .Pollution in the area might increase
- .e built nearbyA new factory might b
- .A new road or a big weather event might affect the site

These changes can cause more pollution, which affects how well the insulators work. In that case, the original design may no longer be enough, and it may be necessary .steps to protect the system to take extra

Outdoor Insulators and Pollution –Source:Electrical Engineering Portal

I.9 Insulating Materials Used for High Voltage Insulators

High voltage insulators can be made from different solid materials like ceramic, etic (polymer) materials. In recent years, porcelain is used less glass, and synth because it is heavy and makes it hard to detect electrical problems. Today, many .companies prefer to use polymer insulators instead

Ceramic Insulators .1

for a long time because they work well and are Ceramic insulators have been used grain -strong. When the insulator needs to handle strong mechanical stress, fine for example, —ceramic is used. You can find ceramic insulators in electrical stations [ators.[7in switches, transformers, and support insul

Glass Insulators .2

In countries like Algeria, most medium and high voltage lines use glass insulators. .They are cheap and make it easy to see cracks or defects

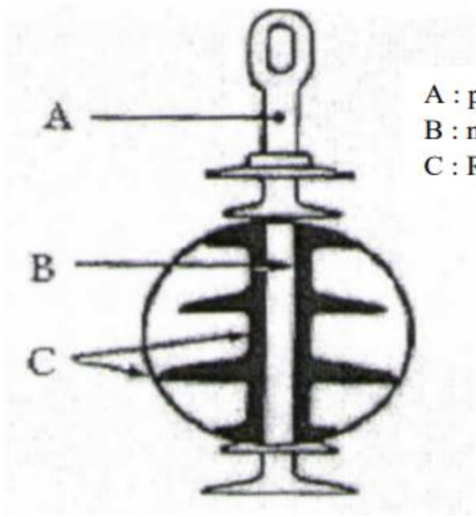
- Annealed Glass: This type is used for rigid insulators. However, it does not sudden temperature changes well and has weak mechanical strength. handle .So it is not used for suspension insulators

- about 5 to 6 —Toughened (Tempered) Glass: This type is much stronger times stronger than annealed glass. It can handle sudden temperature [s of up to 100°C, so it's better for outdoor and high voltage use.[8change

Synthetic (Polymer) Insulators .3

like material -Polymer insulators are made from fiberglass inside and a rubber ic, which outside. These are lightweight and very strong. They are also hydrophob means they do not let water stay on their surface. This makes them good for polluted .or wet environments

But they can get old and weak over time because of the sun, rain, and electrical [stress.[9



nents of Polymer InsulatorCompo **:Figure I.8**

I.10 Stresses on Electrical Insulators

Insulators are exposed to many types of stress during their use. These stresses can affect their performance and lifespan. We can group them .and electrical ‹into three main types: mechanical, environmental

Mechanical Stresses .1

Insulators are often used in chains that are connected together with a little .movement allowed. This design helps them work mainly under tension

- .They carry the weight of conductors and hardware all the time
- .must handle strong winds that can add extra force They
- The size of the insulator depends on how much force it needs to support. If [the force is high, the insulator must be larger and stronger.[10

Environmental and Weather Stresses .2

ed by pollution and weather. For example, in areas near the sea, Insulators are affect salt carried by wind slowly builds up on the surface of the insulator. Over time, the .salt covers the whole surface

which ،When this salt gets wet from fog, rain, or moisture, it becomes conductive allows a leakage current to pass. In bad conditions, electric arcs can appear and [cause full failure of the insulator.[11

Electrical Stresses .3

:This is one of the most important types of stress for insulators

- l voltage the insulator must handle during Service Voltage: This is the norma .normal operation
- Disruptive Discharge: This happens when the insulator fails under high .voltage, and a current passes through, permanently damaging the insulator
- tage that causes a spark or Flashover Voltage (Dry and Wet): The lowest vol .arc between the conductor and the ground
- Temporary Overvoltages: These can happen during storms or switching [events and last only a short time, but they can still cause damage.[12

igning and choosing insulators, These stresses must be considered when des .especially in areas with pollution, bad weather, or high mechanical load

I.11 Classification of High Voltage Insulators

high voltage ،**(IEC (International Electrotechnical Commission** According to the based on their shape and **two classes** lines are divided into insulators for overhead .design

Class A Insulators

where the shortest internal path for **solid insulation part** These insulators have a the shortest distance through the air (called "L") **at least half** isε") "electricity (called .around the outside of the insulator
are in this class. They provide good strength and are **long rod insulators** ،Usually .voltage lines-n used in highofte

Class B Insulators

the shortest air distance **less than half** isε" "In this class, the shortest internal path ."L"
are in this group. These are common and are **type insulators-post** or **Cap and pin** [easy to install or replace.[13

These classes help engineers choose the right type of insulator for different voltage .levels and environmental conditions

I.12 Conclusion

In this chapter, we learned about the definition, types, and main characteristics of se insulators play two important roles: mechanical high voltage insulators. The .support and electrical insulation

However, we also saw that pollution is a serious problem for insulators. When dirt, salt, or other pollutants build up on their surface, they can lose their dielectric rength. This means the insulator may no longer stop the flow of electricity properly, st .and in some cases, it can cause flashovers or complete failure

In the next chapter, we will focus more on the pollution of insulators and how it .eaffects their performanc

Chapter II

Pollution of Insulators

II.1 Introduction

Overhead power lines are essential for delivering electricity over long distances. These lines al currents from escaping and to keep the system safe. use insulators to prevent electric —such as coastal regions or industrial zones—However, in areas with high pollution insulators can become contaminated with substances like salt, dust, and industrial cumulate on the surface of insulators, they can form a pollutants. When these pollutants ac conductive layer, especially when combined with moisture from rain or fog. This conductive ‹*flashover* layer can lead to leakage currents and may cause a phenomenon known as s the insulator's surface, potentially leading to power outages and where electricity arcs acros .[equipment damage [1

To mitigate these risks, it's crucial to monitor the level of pollution on insulators and perform s. Selecting appropriate regular maintenance, such as cleaning or applying protective coating insulator materials and designs that are resistant to pollution can also enhance the reliability .[of power transmission systems [1

II.2 Origin of Pollution

ple, in coastal Pollution on power line insulators can come from natural sources. For exam areas, sea spray carried by the wind can deposit salt on the insulators. When this salt layer becomes wet due to fog or rain, it becomes conductive, which can reduce the insulation and .[cause electrical problems [2 h as near chemical or metallurgical plants, insulators can collect very In industrial areas, suc small solid particles. These particles are not very conductive when dry, but they can absorb ate a moisture. In humid weather, like fog or rain, the salts in these particles dissolve and cre .[conductive film, increasing the risk of flashover [3

These are typical examples of how pollution can severely affect insulators. But even areas .[far from the sea or factories are not completely free from pollution [2

minationNatural Anthropogenic Conta	Probable Pollution Source
□H	Atmosphere
،□SO ،□NH ،□□NO ،□CO ،□NO, NO □□NH	Atmosphere, Fertilization, Combustion
□Cl ،□□NH ،□□NO ،□□^{2}SO	Sea, Fog, Precipitation
□K ،□^{2}Ca ،□^{2}Mg ،□Na	Sea

[nants and Their Sources [4Contami :**Table II.1**

II.3 Definitions

- Pollution is a harmful change in the natural environment caused by human :**Pollution** activities. It can result from direct or indirect effects that alter the distribution of l and chemical makeup of the environment, and energy, radiation levels, the physica the abundance of living species. These changes can affect humans directly or through resources like agricultural products, water, and other biological products. onal belongings, limiting Pollution can also impact humans by damaging pers [environmental possibilities, or making nature less attractive.[5

- Salinity refers to the concentration of salt in water. It is calculated by :**Salinity** n dividing the mass of salt by the volume of the solution, typically expressed i [6].^{3}kg/m

- This is an electrolyte conductive layer placed on the surface of an :**Pollution Layer** [insulator. It consists of salt and inert materials.[7

- This term describes the amount of pollution present on an :**Pollution Degree** determined using methods like the Solid Layer Test, which insulator's surface. It is involves applying a salt and inert material mixture to the insulator and measuring the [resulting conductivity. [8

II.4 Formation and Distribution of the Pollution Layer

voltage insulators depend on -The formation and distribution of the pollution layer on high t, and the arrangement of the insulator several factors, including the insulator's profile, heigh strings relative to the ground. Generally, the pollution layer tends to concentrate on the parts -voltage conductor and in areas less exposed to self-of the insulator string closer to the high nd and heavy rain. As a result, the distribution of pollution along the cleaning factors like wi insulator strings is not uniform and becomes more pronounced as the length of the strings .increases

urfaces There is a noticeable difference between the layers formed on the upper and lower s uniformity of the pollution can be -of an insulator subjected to natural pollution. The non [categorized into three types: [9

1. This type is characterized by groups of **:Uniformity by Group-Longitudinal Non** ies of the pollution layer, with each group's insulators subjected to different conductivit value remaining constant. This pattern is observed temporarily during wet washing or [in insulator strings shaped like a 'T'.[10

2. This type features sectors or bands with varying **:Uniformity-Transversal Non** face conductivities of the pollution layer. These bands are distributed transversely sur around the surface of each insulator in the string. The conductivity within each sector remains the same along the leakage path. This form of pollution is primarily due to [prevailing wind and rain directions.[10

3. This is the most common type. It is **:Uniformity-Periodic Longitudinal Non** characterized by a periodic variation in the conductivity of the pollution layer along :specifications include the leakage path, maintaining circular symmetry. Key
    - The conductivity of the lower face of the insulator is greater than that of the .upper face
    - The pollution concentration increases from the peripheral area towards the .center
    - [The pollution is more pronounced between the ribs.[10

II.5 Sources of Pollution

Insulators used in electrical systems can become dirty due to various types of pollution. These pollutants can come from natural sources like the sea, deserts, or rain, as well as

mes, different types of pollution combine, from human activities such as factories. Someti
.making the problem worse

II.5.1 Natural Pollution

Natural pollution comes from the environment and happens without human activity. It
.d or rainincludes salt from the sea, dust from deserts, and pollution from win

II.5.1.1 Marine Pollution

In places near the sea, the wind carries salty water from the ocean, called sea spray. This spray sticks to the surface of insulators. When it becomes wet again (for example, with and in some ،**leakage current** This can cause .humidity or fog), it becomes conductive that damage the **flashovers** may appear. Over time, this may lead to **electrical arcs** ،cases **[11]** .insulator

II.5.1.2 Desert Pollution

insulators. During onto **sand and dust** In desert regions, strong winds blow fine particles like the day, the sun makes these particles dry. At night, moisture from condensation makes the dust conductive. This change in temperature and humidity increases the risk of electrical **[12]**.problems

Illustration of Desert Pollution and Its Effects on Insulators **:1.Figure II**

II.5.1.3 Heavy Rain

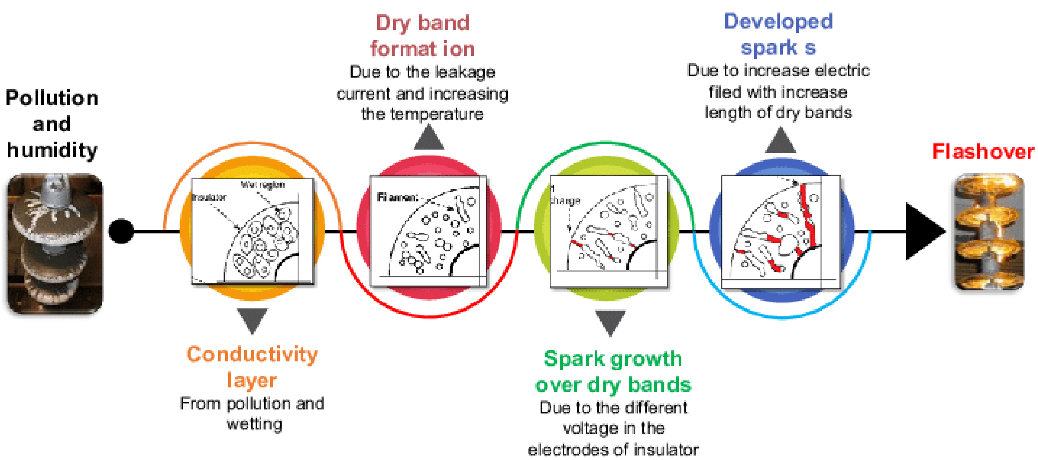
:Rain can help or hurt the insulators

- .Heavy rain can clean the surface of insulators and remove pollution :**Helpful rain**
- pollution sticky and conductive. In this Light rain or mist can make the :**Harmful rain** on the insulator, which allows electricity to **a continuous path** case, water can form **[13]**.especially during storms ،**flashover** flow through it. This causes a

e Impact of Harmful Rain on InsulatorsTh:**Figure II.2**

II.5.1.4 Inland Pollution

dust, Even far from the sea or deserts, pollution can occur. In farming areas, wind can carry from fields. This pollution settles on the insulator surface and **dry leaves, or plant waste** **[14]**.mes conductive with moisturebeco



Flashover Mechanism in Insulators Due to Pollution and Humidity **:Figure II.3**

II.5.2 Industrial Pollution

These .**chemical industries** or ،**factories, power plants** Industrial pollution comes from es and small particles into the air. These pollutants land on insulators and places release gas Some industrial dust, like .**highly conductive** often absorb moisture, which makes them **[15]**.can also cause corrosion ،**metal particles or chemical vapors**

cement factory may be covered with fine dust that attracts water Insulators near a :**Example** .and causes electrical leakage

II.5.3 Mixed Pollution

Mixed pollution happens when natural and industrial pollution occur at the same time. This is se it combines salt, dust, chemicals, and becau **worst type of pollution** usually the that is hard **thick, conductive layer** moisture. These mix on the insulator surface and form a **[16]**.to clean

In a coastal city with factories (like in South Asia), insulators may face both salty :**Example** .d industrial smoke, which greatly increases the risk of damagesea spray an

Illustration of Flashover Process

:Explanation

When an insulator is exposed to pollution and humidity, a thin conductive layer forms on its low, which heats the surface. Because of surface. This layer lets a small leakage current f this heat, some dry bands appear. These dry bands stop the current for a short time, but they also cause a high voltage difference across the bands. This high voltage creates e sparks appear, and they join together to make a sparks. As the dry bands get longer, mor full electric arc. This process is called a flashover, and it can damage the insulator or the power system. This picture shows all the steps of this process from the beginning to the final flashover

Effects of Pollution on Insulators .II.6

Pollution on insulators causes electrical problems. When dirt and water mix on the surface, they form a layer that can conduct electricity. This changes how voltage spreads across the this can lead to an electric arc that may short part of the ،insulator. In rainy or foggy weather .[insulator's surface [17

Localized Arc-II.6.1. Non

Sometimes, the electric arc appears in one place for a short time, then disappears and e current and a little energy is lost. comes back in another place. This creates a small leakag .[Usually, this does not cause damage to the system [17

II.6.2. Fixed Arc

In this case, the arc stays in one spot. If the current is direct (DC), it stays in place. If it is ack in the same spot. This arc makes heat that alternating current (AC), it keeps coming b .[can damage the insulator, and it may need to be replaced [17

II.6.3. Flashover on Polluted Insulators

Pollution builds up over time and is not fully removed by rain or wind. The top of the insulator ed better than the bottom, so more dirt collects underneath. The flashover process is clean :happens in four steps

Stage 1: Pollution Deposition

Pollution from the air sticks to the insulator, especially between the ridges. The amount :depends on

- articlesType and size of p
- Distance from pollution source or ground
- Wind speed
- cleaning by rain and wind -Shape and direction of the insulator, which affect self [19][18]

Stage 2: Moisture Absorption

the pollution dissolve in Fog or light rain makes the surface wet but doesn’t clean it. Salts in the water and create a film that conducts electricity. This leads to leakage current that .[increases over time if the surface stays wet [20

Stage 3: Dry Band Formation and Arc Initiation

surface. Water dries in some spots, creating dry When leakage current is high, it heats the areas that resist current. Voltage builds across these dry bands. If the voltage is too high, it .[causes an arc [20

Stage 4: Arc Behavior

rrent is low, the arc stops, The arc current is limited by the wet layer's resistance. If the cu and the cycle starts again. But if the current is too high, the arc continues and may cause a .[full flashover, damaging the insulator [20

II.6.4. Environmental Impact on Pollution Severity

have more pollution. This increases the chance of Places near factories or cities often insulator failure. It's important to use materials and designs that can handle tough .[environments [21

II.6.5. Solutions Using Silicone Coating

coating keeps water and dirt One solution is to use insulators with silicone coating. The away. This helps stop flashovers. Studies over 20 years show that silicone insulators work .[well even in polluted areas [22

II.7. Influence of Weather on Pollution Distribution

.ollution builds up and affects insulatorsDifferent weather conditions can change how p

Humidity.1

When the air is humid, pollution on the insulator becomes more conductive. This means electricity can pass through it more easily, which reduces the insulator's ability to hold .voltage safely

tureTempera.2

High temperatures dry out the pollution layer. When the pollution is dry, its resistance increases, and this helps the insulator work better. But, if the temperature changes a lot back and makes the between day and night, it can cause condensation. This brings moisture . pollution layer wet again

Wind.3

Wind carries dust and salt from the sea to the insulator surface. This adds more pollution. However, strong winds can also help clean the insulator by blowing away the dirt. So, wind .reduce pollution can both cause and

Rain.4

Light rain wets the dirty surface and increases the risk of flashover (electric current going through the pollution layer). On the other hand, heavy rain usually helps wash the pollution [away and makes the insulator cleaner. [23

II.8. Extreme Weather Phenomena

.Some special weather conditions can also affect insulators in serious ways

Frost .1

Frost is a layer of ice that forms when very small water droplets in fog or clouds freeze on the frost is light and not sticky. But near 0°C, ‹the surface. When the temperature is very low —water freezes inside small spaces in the frost, making it harder, heavier, and more sticky almost like solid ice

Freezing Rain .2

when they hit Freezing rain happens when small raindrops (100 to 500 micrometers) freeze a cold surface. This creates a hard and smooth ice layer that sticks well to the surface. It has (the same density as ice (0.9

Ice Rain .3

Ice rain forms when cold air near the ground cools the raindrops enough for them to become When they touch a surface, they freeze instantly and create a solid ice coating .supercooled

Wet Snow .4

Wet snow is a mix of ice, water vapor, and air. It comes in different forms. Sticky snow forms en they hit a surface, when snowflakes melt slightly during their fall and become wet. Wh they turn into ice crystals covered with water. This helps them stick. Sticky snow usually .[happens during heavy snow at temperatures above 0°C . [24

II.9. Pollution Severity of a Site

outdoor equipment, it's important to know To choose the right type of insulation for how polluted the location is. The pollution severity of a site is usually measured by how much rain falls there and how conductive the dirt on the insulators is

how the insulators will behave Knowing how polluted a place is helps us understand and how reliable the power lines and stations will be. It's also important to keep track of how pollution changes over time and in different areas. This helps engineers tect the system from choose the right kind of insulation and plan ways to pro flashovers caused by pollution

There are several methods used to check how severe the pollution is in a specific [area . [25

II.10. Methods to Measure Pollution Severity

ure how severe the To understand how pollution affects insulators, we need to meas pollution is at the site. This information helps engineers know how likely it is that an insulator will flash over (fail) because of pollution. It also helps them decide what size . and type of insulator to use

o measure pollution severity. Each method uses special There are different ways t tools to collect data about the dirt and salt on the insulator surface. These methods [help experts choose the right protection for the power system . [26

Measuring Device	**t MethodMeasuremen**
Portable probe conductivity meter	Electrical conductivity of pollution
Empirical formula	(Equivalent Salt Deposit Density (ESDD
Empirical formula	Surface conductance
Pulse counter connected to line insulator	Leakage current pulse counting
surement circuitMea	Highest leakage current

[Methods of Measuring Pollution Severity and Their Devices [27 : **Table II.2**

II.11 Pollution Levels and Environment Types

to know the types of pollution in To choose the right insulator for a power line, it is important the area. There are four levels of pollution. These levels and examples of typical environments [are shown in the table below.[28

Pollution Level	Examples of Typical Environments
Low	ow l htiw dna seirtsudni tuohtiw saerA • .density of homes using heating systems ro niar wol dna seirtsudni wef htiw saerA • .wind .snoiger gnimraF • .snoiger niatnuoM •
Medium	muidem dna ekoms gib on htiw saerA • .housing with heating dna seirtsudni ro sesuoh ynam htiw saerA • .ainsome wind or r .esolc oot ton tub ,aes eht raen saerA •
High	seitic gib ro seirtsudni ynam htiw saerA • .with heating pollution sdniw gnorts htiw aes eht ot esolc saerA •

	.from the sea
Very High	fo tol a htiw secalp ro saera ytsuD • .pollution .hick pollution layerst yrev htiw secalP • ytlas gnorts htiw aes eht ot esolc saerA • .winds dnas gniyrrac sdniw gnorts htiw streseD • .and salt

Classification of Pollution According to the Type of Environment **:Table II.3**

ctrical InsulatorsII.12. Methods to Reduce Pollution on Ele

II.12.1 Increasing the Creepage Distance

To handle higher pollution levels, it's important to increase the creepage distance :the surface path along the insulator). This can be done in two ways)

- which is effective but expensive ،with a longer one **Replacing the insulator** .and often not practical in substations

- made of polymer material to the existing insulator **Adding extensions** surface. These are glued on and help increase the creepage distance without .[replacing the whole insulator [29

II.12.2 Using Flat Insulators

Flat insulators, which have no ribs, collect less pollution and are easier to clean naturally by wind and rain. This design helps reduce the buildup of dirt and improves .[performance in polluted areas [30

licone GreaseII.12.3 Applying Si

In substations, silicone grease is applied to insulators to protect them. This grease is repellent, so it prevents moisture and dirt from sticking. However, it needs to -water .[be reapplied regularly to maintain its effectiveness [31

Silicone Coating II.12.4

A silicone rubber coating can be sprayed or brushed onto insulators. This coating repellent) surface. It -cures at room temperature and creates a hydrophobic (water irty helps protect insulators from pollution and improves their performance in d .[environments [32

II.12.5 Using Composite Insulators

Composite insulators are made with materials that naturally repel water, making them suitable for very polluted conditions. However, over time, exposure to sunlight, ade their surface, reducing their effectiveness. pollution, and weather can degr .[Regular inspections are necessary to ensure they are still functioning properly [33

II.12.6 Cleaning Insulators

Insulators can be cleaned manually or with water sprays. Cleaning without turning off line washing) is possible but requires special equipment and safety -er (livethe pow measures. In some countries, abrasive materials are used under pressure to clean stubborn pollution like cement. These methods help maintain insulator performance .[y and should be scheduled carefully [34but can be costl

Cleaning an insulator while the power is still on **: Figure II.4**

II.13 Consequences of Pollution on Insulators

II.13.1 Clean and Dry Insulators

or covered with dry pollution, only a very small current When an insulator is clean flows on its surface. This is because air, solid insulators, and dry pollution have very low conductivity. In this situation, the electric potential is distributed evenly across [ace. [35the insulator's surf

II.13.2 Wet and Polluted Insulators

If the pollution layer becomes wet due to rain, fog, or humidity, it turns into a conductive path. This allows a larger current to flow on the surface, changing the electric potential d to a breakdown of the air's insulating properties, causing an distribution. This can lea [circuits part of the insulator's surface. [35-electric arc that short

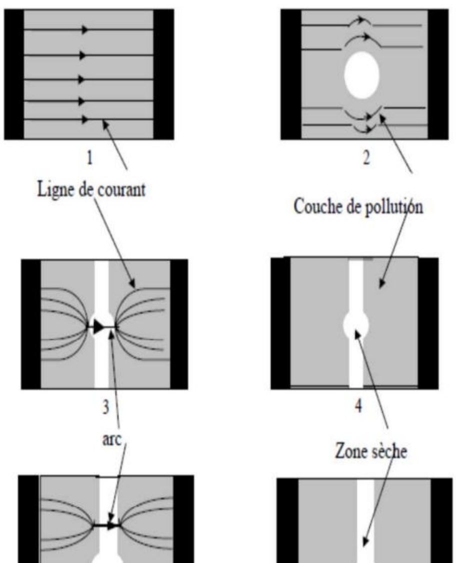
II.13.3 Types of Arcs on Polluted Insulators

:There are three main types of arcs that can occur on polluted insulators

- This arc appears briefly at one spot, then disappears and :**Localized Arc-nNo** reappears at another location. It usually doesn't damage the insulator but [indicates surface leakage currents. [36

- direct current) This arc stays in one place, either continuously (in :**Fixed Arc** or repeatedly at the same spot (in alternating current). The energy from the current causes heating, leading to dielectric losses. These losses are small at low voltages and frequencies but become significant at high voltages and [s, potentially damaging the insulator. [36frequencie

- This is a complete arc across the insulator's surface, leading to a :**Flashover** short circuit. It occurs when the wet pollution layer becomes conductive insulating enough to allow a continuous arc, bypassing the insulator's [properties. [37



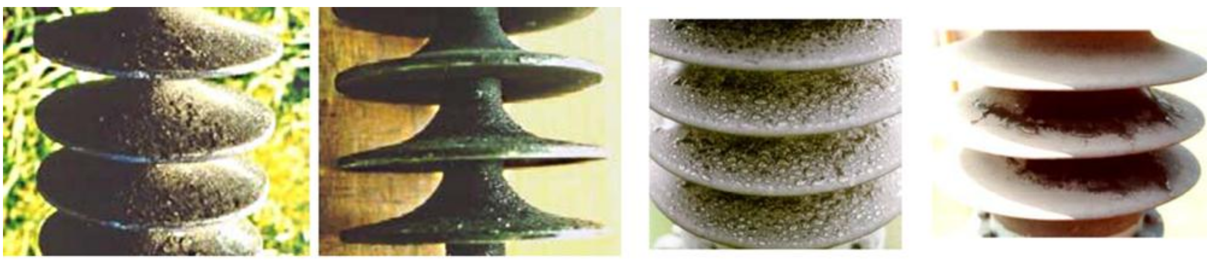
Stages of Bypassing a Polluted Layer on an Insulator **:Figure II.5**

II.13.4 Corrosion of Insulators

Corrosion happens when a wet, conductive pollution layer remains on the insulator's
me. This is more severe in direct current systems because the surface for a long ti
unidirectional current and electrostatic effects promote more pollution deposition.
pin -and-Corrosion can weaken the insulator's mechanical strength, especially in cap
[trical performance due to rust formation. [38types, and reduce its elec

II.14 Bypassing Polluted Insulators

1. **.Pollution deposits on insulators all the time**
   Polluted materials such as dust, smoke, and salt come from the environment
   lps move these particles, and and settle on the surface of insulators. Wind he
   the design of the insulator (especially if it is vertical) changes the air flow,
   which causes more deposits to form under the skirts of the insulator. Cleaning
   .[tier faster [39by rain and wind is better on the top side, so the bottom gets dir



Continuous Accumulation of Pollution on the Surface of Insulators :**Figure II.6**

2. **.Factors that affect how pollution builds up**
   Many things can affect how fast pollution collects on an insulator. These include the type, weight, and size of the pollution particles, the distance from the pollution source, the height of the insulator from the ground (where dust can rise), the wind speed, and the shape of the insulator. Some insulators can etter in rain or strong wind, especially if they are designed clean themselves b .[well [40
3. **.Moisture changes pollution into a conductor**
   When the weather is wet (fog, dew, or light rain), the pollution on the insulator dissolved salts, which becomes wet too. This creates a thin film of water with makes the surface conductive. Electricity can now leak along the surface of the insulator. This leaking current increases over time and depends on how much salt is in the pollution. Some types of dirt keep the surface wet longer, .[ich makes the situation worse [41wh
4. **.Dry bands form and can lead to electrical arcs**
   When the current flows along the surface, it creates heat (called the Joule effect). This heat makes some parts of the wet pollution dry out, especially s of the insulator. These dry parts are called “dry bands.” near the metal end They block the flow of electricity and cause a higher voltage to appear across them. If the dry band is not wide enough to hold this voltage, an electric arc .[42] can start and jump across the dry band
5. **.Arcs can become dangerous and cause a full flashover**
   The arc is affected by the resistance of the wet pollution layer. If the current is low, the arc can stop, and the cycle can begin again. But if the arc becomes d bypass the whole insulator. This is called a too strong, it can grow longer an flashover, and it can cause serious power problems. This is why it is very .[important to monitor and prevent pollution problems on insulators [43

II.15 Methods for Pollution Testing on Insulators

the performance of different types of insulators and select those that To compare perform best under polluted conditions, it is necessary to subject them to tests. site) or in a -These tests can be carried out either under natural conditions (on :two main categories of research on polluted insulators laboratory. There are

II.15.1 Natural Pollution Testing

Natural pollution testing involves setting up stations at various polluted sites **.1** where the behavior of insulator chains, of different lengths and profiles, can be observed. These insulators are all placed under the same voltage. Their performance is then evaluated based on the time they take to break down

under natural pollution and artificial pollution tests. The insulators are
t failed and those that survived after two or classified into two groups: those tha
three years of exposure. This method has the advantage of accounting for all
.[life environmental factors [44-the real

II.15.2 Artificial Pollution Testing

ural pollution conditions in a Artificial pollution testing involves replicating nat
laboratory. This method is widely used today due to its quick results. The
standardized testing methods include the solid layer method, the salt fog
.[method, and the liquid pollution method [45

II.15.2.1 Solid Layer Method

In the solid layer method, the insulator surface is covered with a solid pollution
layer consisting of sodium chloride and an inert binder. The conductivity of this
layer is adjusted by adding a specific amount of sodium chloride. If the
ified after the voltage is applied (known as the steam fog insulator is humid
method), the pollution severity is defined by the density of salt deposit,
If the insulator is humidified before the voltage is .^{2}measured in mg/cm
ity of the polluted layer. Some applied, the severity is defined by the conductiv
.[researchers have used a semiconductive layer as a pollution agent [46

II.15.2.2 Salt Fog Method

The salt fog method uses a saline solution that closely resembles marine
e matter. In this method, pollution, which contains a small amount of insolubl
the insulator is placed in a salt fog while under test voltage. The salinity level
of the fog defines the pollution severity. Based on the classification of polluted
.[47] ^{3}sites, the salinity values used range from 2.5 to 224 kg/m

II.15.2.3 Liquid Pollution Method

The liquid pollution method is similar to the clean fog method, in that a liquid
mixture is applied to the insulator before testing. However, in this case, the
of water, chalk, and pollution is not dried before testing. The mixture consists
either methyl cellulose or kaolin. As with the solid layer method, the
conductivity is adjusted by adding sodium chloride. After a few minutes of

drainage, the test voltage is applied to the insulator without further .[8humidification [4

:II.16 Conclusion

-Pollution of insulators is a very important factor to consider when designing high .voltage power lines

To choose the right size and type of insulator strings, it is necessary to know how standing this severity means studying the severe the pollution is at each site. Under different factors that show how much the insulation has degraded. However, it .usually takes at least three years to properly determine the pollution level of a site

cause it allows testing to be done on Using artificial pollution methods is helpful be just one type of insulator, and possibly even at a different voltage level than the one .planned. This makes the testing process faster and easier

e helpful to To give quick and useful information about insulation needs, it would b have a pollution severity map for the main polluted sites. These sites can be grouped into four levels of pollution severity. For each level, there is a minimum creepage o ensure distance (the length along the insulator surface) that must be followed t .good performance of insulators in those locations

Chapter III: Experimental Work and Discussion of Results

III.1. Introduction

In the high voltage laboratory at El Oued University, where our experimental study s conducted, there is an industrial frequency test transformer operating at 50 Hz wa .voltage equipment during testing-to ensure the proper performance of high

Insulators are essential components, and the tests conducted in the high voltage lab aluating various insulators of different sizes and properties to assess focused on ev their readiness and effectiveness in isolating electricity. This is crucial to prevent wire .damage and to evaluate their insulation capability in polluted environments

r, we present the test station equipment, describe the different types of In this chapte tests performed, the operating model used for high voltage insulator testing, the .testing procedures, and provide an explanation of the results

III.2. Experimental Setup

:(Test Circuit of the High Voltage Laboratory (University of El Oued III.2.1

The experiments were done in the High Voltage Laboratory at the University of El .Oued

:Our lab includes three types of voltage sources

- ،A 50Hz industrial frequency voltage source
- ،voltage generator A DC
- .An impulse voltage generator

:III.2.1.1 Equipment in the Test Station

:The test station in our laboratory is made of the following components

- ،A test transformer
- ،A regulating transformer
- ،Voltage dividers
- ،suring and protection devicesA control desk with mea
- .A digital oscilloscope

:III.2.1.2 Test Transformer

We used a test transformer that is designed and insulated for high voltage .generation

.Its transformation ratio is 250V / 100kV, with a power of 5 kVA

can vary the output high voltage from 0 up to the full value This transformer

:III.2.1.3 Regulating Transformer

.This transformer is used to change the voltage going into the test transformer

. Its ratio is 220V / 250V

:III.2.1.4 Digital Oscilloscope

.the waveform of the signal This device shows

It records the voltage wave shape during testing

:III.2.1.5 Control Desk

.The control desk runs on a 220V supply

It helps us change the test voltage automatically

e and digital oscilloscope in the Photograph of the control consol :**Figure III.1**
Oued-high voltage laboratory at the University of El

:III.2.1.6 Measuring and Protection Devices

The lab gets power from the control desk located outside the test area (Faraday .(cage

oltage transformer and its regulator are protected by a 250A fuse and a The high v .thermal relay

These protections are connected to the main contactor coil, providing safety against .transformer overload and short circuit currents

:For voltage measurements, we use

- ‹DSM: A digital voltmeter for AC voltage
- ‹DGM: A digital voltmeter for DC voltage
- A voltmeter and ammeter to measure primary voltage and current of the test transformer

:III.2.1.7 Voltage Dividers
:There are two types of voltage dividers in the lab

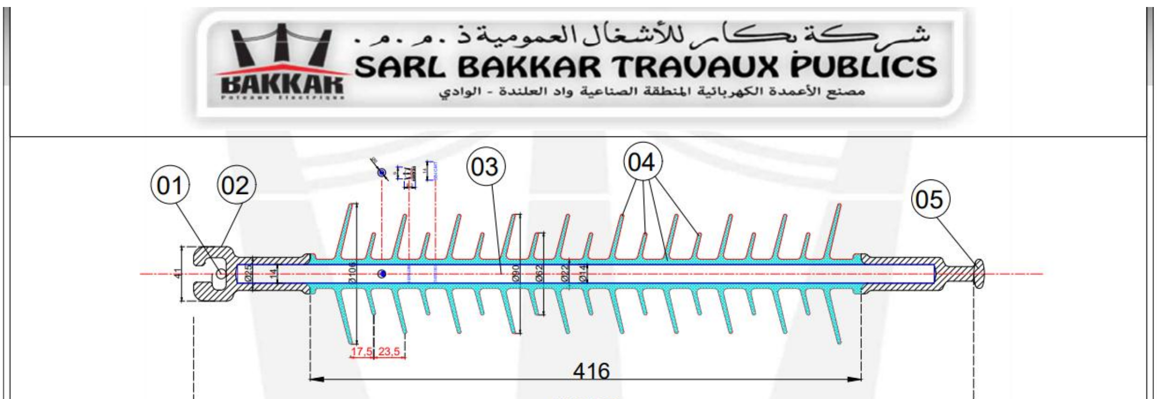
- ،(capacitive voltage divider for measuring AC voltage (industrial frequency A
- A resistive voltage divider for measuring DC voltage

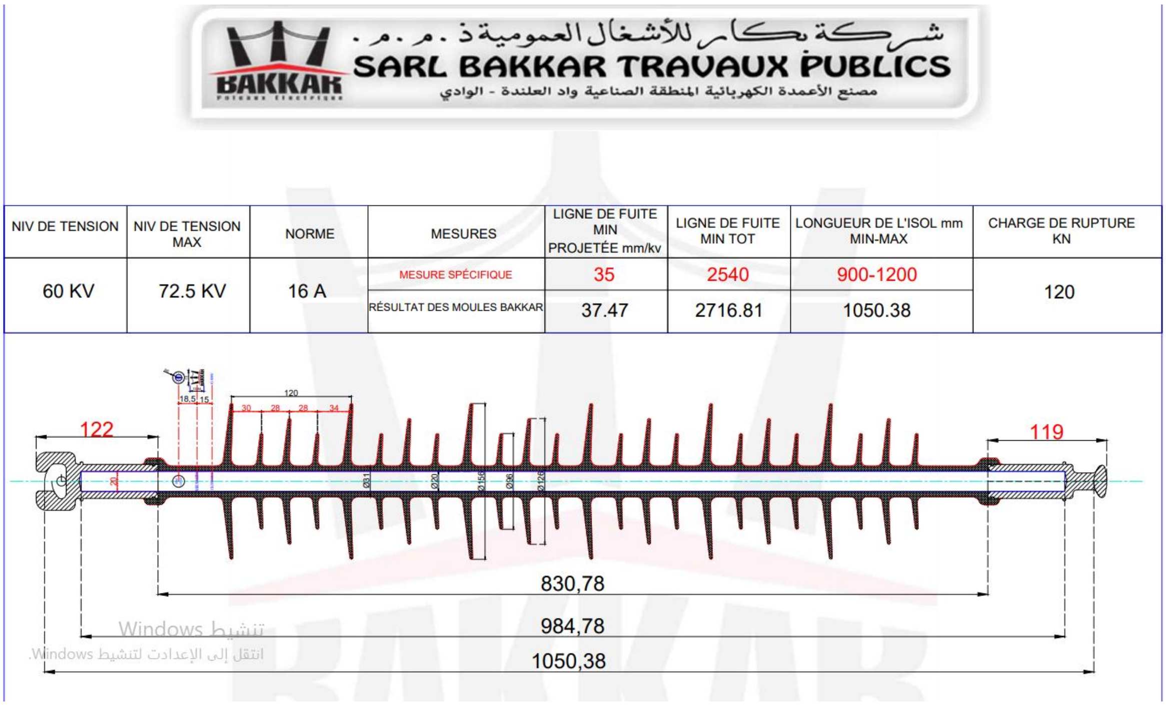
:III.2.1.8 AC Test Circuit
:voltage AC generators at industrial frequency are used for-The high

- ،power transformers voltage AC testing of-High
- voltage transformers for DC rectifiers, oscillating circuit -Supplying high .generators, and impulse generators

shows the AC test circuit made in the lab, and Figure III.3 shows the **:Figure III.2** age Laboratorysetup built in the High Volt

Prototype of the insulators used .3





NIV DE TENSION	NIV DE TENSION MAX	NORME	MESURES	LIGNE DE FUITE MIN PROJETÉE mm/kv	LIGNE DE FUITE MIN TOT	LONGUEUR DE L'ISOL mm MIN-MAX	CHARGE DE RUPTURE KN
60 KV	72.5 KV	16 A	MESURE SPÉCIFIQUE	35	2540	900-1200	120
			RÉSULTAT DES MOULES BAKKAR	37.47	2716.81	1050.38	

III.4. Experimental Study on Electrical Insulators

:III.4.1 Test Description

In this experiment, we tested two types of electrical insulators from many available in and the second one has a ،**kV 120** first insulator has a strength of the laboratory. The .The test was done to observe and compare the two insulators .**kV 60** strength of

:III.4.2 Insulator Images

Insulator with 120 kV **: Figure III.3**

Insulator with 60 kV **:Figure III.4**

III.5. Start of the Experiment: Type A and Type B Conditions

:Experimental Conditions 5.1

Type A :we used two different types of insulator setups ،At the beginning of the test .Each type was tested under specific environmental conditions .**Type B** and

- :**Type A**
  - C°27.4 = (**t**) Temperature
  - %43 = (**h**) Humidity
  - nPa 1001 = (**p**) Pressure
  - :**Dry condition**
    kV without flashover 140
  - :**condition Wet**
    kV without flashover 140

Appearance illustrating experiment A **:Figure III.5**

- :**Type B**
  - C°27.6 = (**t**) Temperature
  - %43 = (**h**) Humidity
  - nPa 1001 = (**p**) Pressure
  - :**Dry condition**
    verkV without flasho 140
  - :**Wet condition**
    kV with partial discharge 98.44
    kV without flashover 140
    Partial discharge started on the surface and continued

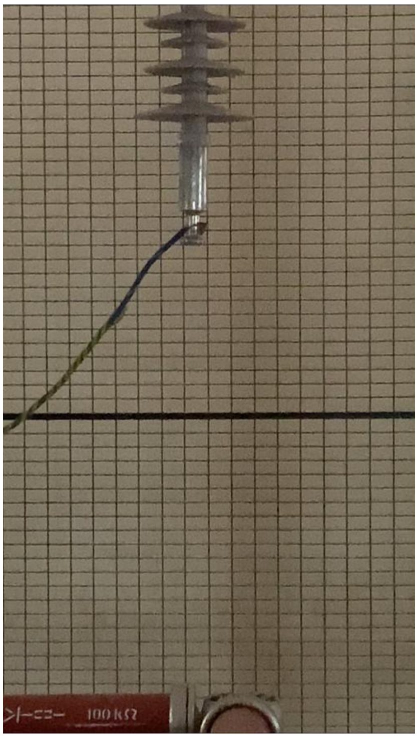


Illustration showing how to connect an electrical wire to an **:Figure III.6**
.insulator

Appearance illustrating experiment B **:Figure III.7**

III.6. Leakage Current Measurement

III.6.1 Observations on the Insulator Type 1

III.6.1.1 Clean and Dry Surface

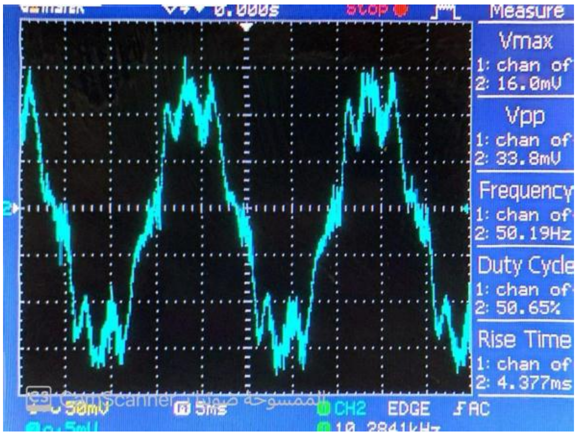
mpletely dry. The test was done to In this case, the insulator is clean and co
.measure leakage current

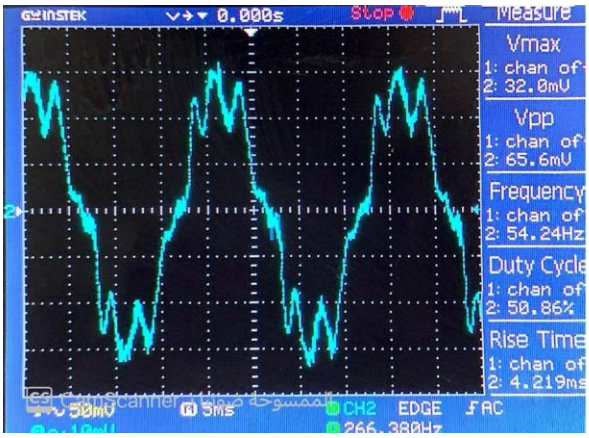
- **:Measurements**

Clean and Dry Surface	
→	
kv 5	μA 1.6
kv 10	μA 3.2
kv 15	μA 4.72
kv 20	μA 6.56
kv 25	μA 10
kv 30	μA 14

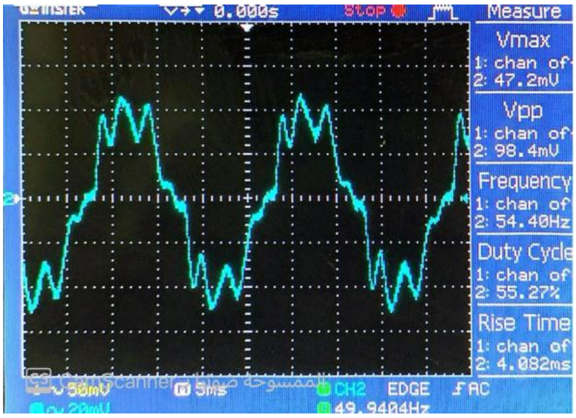
Measurements and results for a clean and dry surface **:Table III.1**

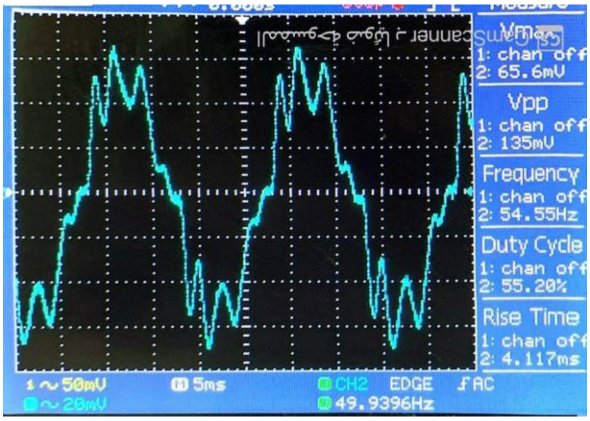
- **:Graph**





kv **10 kv 5**





kv **20 kv15**

Graph of clean and dry surface measurements on a digital oscilloscope **:Figure III.8**

III.6.1.2 Wet Surface Only

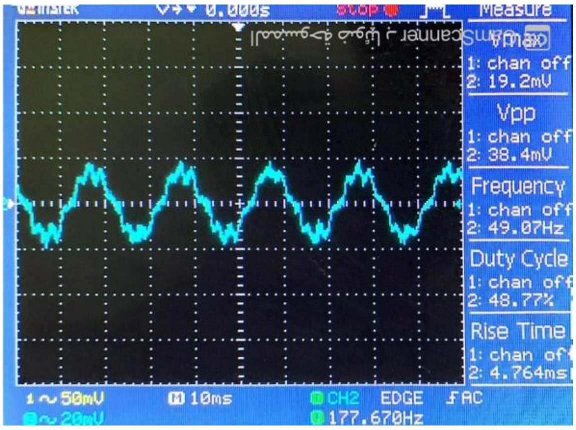
.The insulator surface was sprayed with water only, with no dust or mud

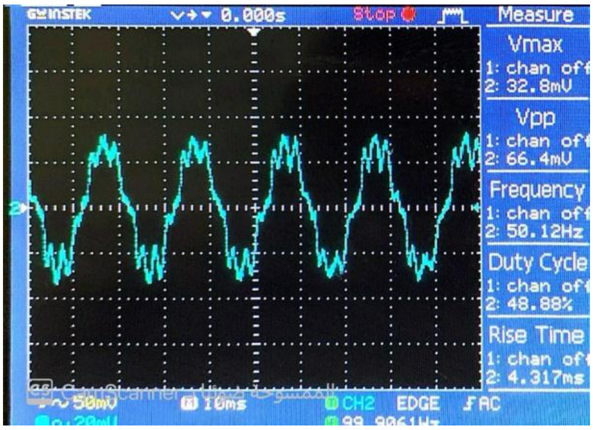
- **:Measurements**

Wet Surface Only	
→	
kv 5	μA 1.92
kv 10	μA 3.28
kv 15	μA 4.88
kv 20	μA 7.12
kv 25	μA 12
kv 30	μA 16

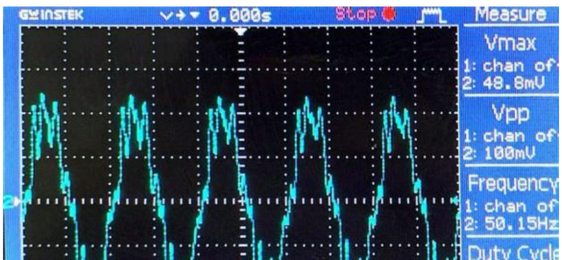
Measurements and results for a wet surface only **:Table III.2**

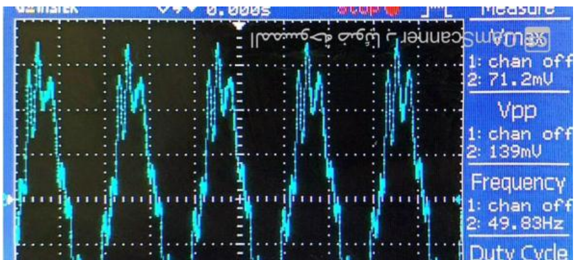
- **Graph**





kv 10 **kv 5**





kv **20 kv15**

Graph of wet surface only measurements on a digital oscilloscope **:Figure III.9**

III.6.1.3 Polluted with Mud Only

.ing waterThe surface was covered with dry mud, without add

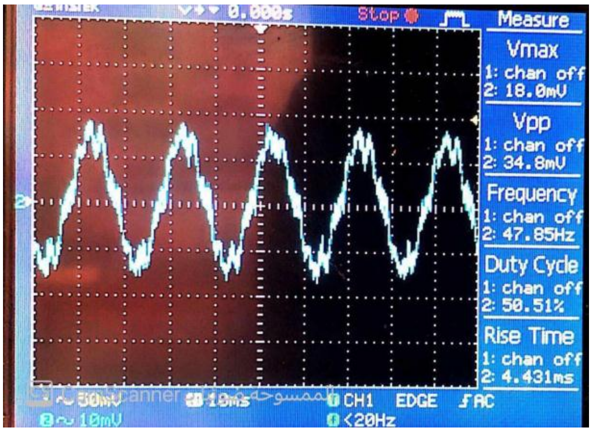
- **:Measurements**

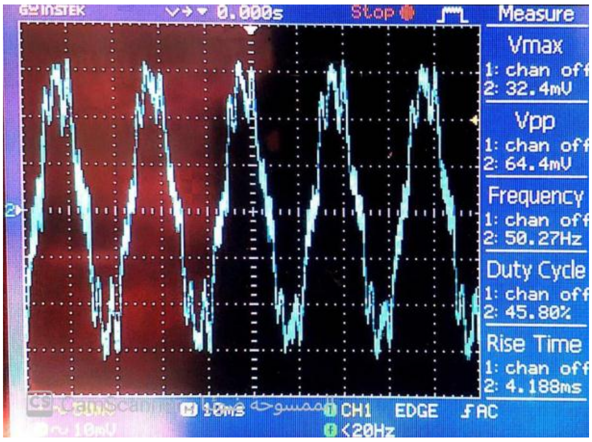
Polluted with Mud Only
→

kv 5	µA 1.8
kv 10	µA 3.24
kv 15	µA 5.12
kv 20	µA 8.8
kv 25	µA 10.4
kv 30	µA 12.8

Measurements and results for a Polluted with Mud Only **:Table III.3**

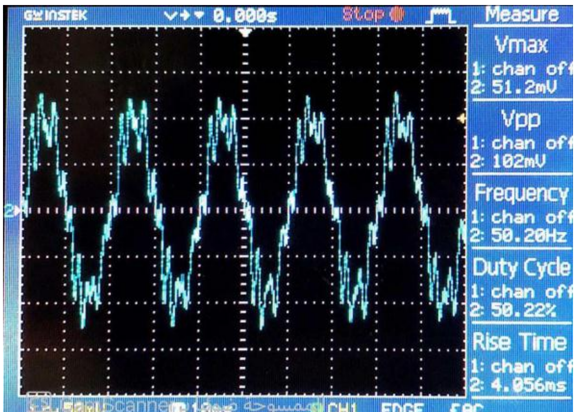
- **:Graph**

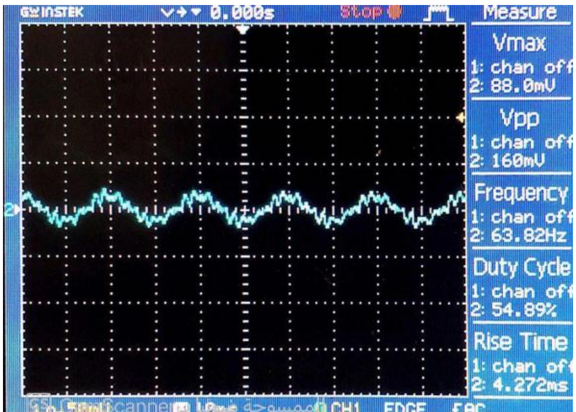




vkv

10 k 5





kv **20 kv15**

Graph of Polluted with Mud Only measurements on a digital **:Figure III.10**
oscilloscope

III.6.1.4 Polluted with Mud and Water

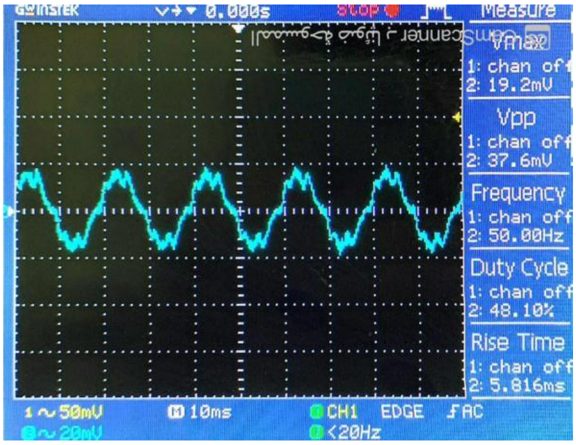
.water to simulate hard conditions In this case, the surface had a mix of mud and

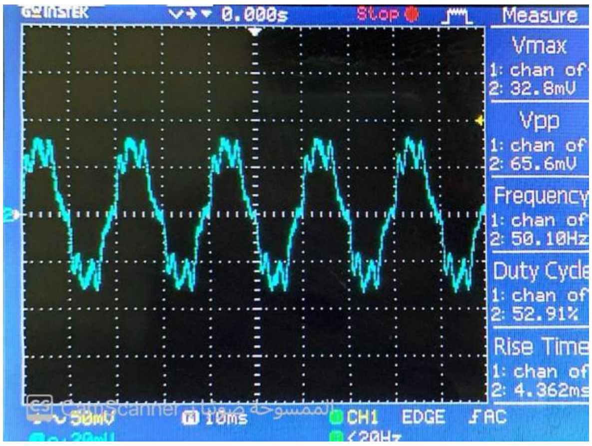
- **:Measurements**

Polluted with Mud and Water	
→	
kv 5	µA 1.92
kv 10	µA 3.28
kv 15	µA 5.12
kv 20	µA 8.9
kv 25	µA 10.6
kv 30	µA 13

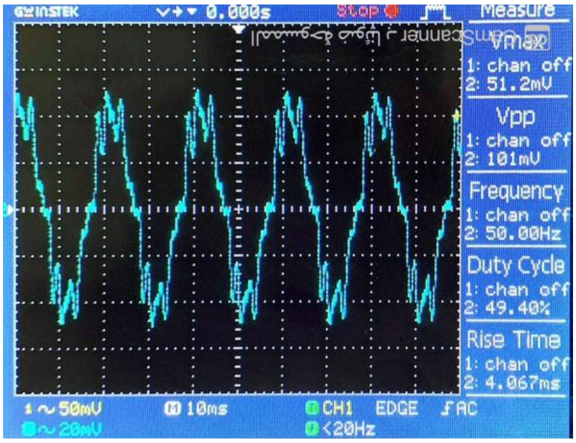
Measurements and results for a Polluted with Mud and Water **:Table III.4**

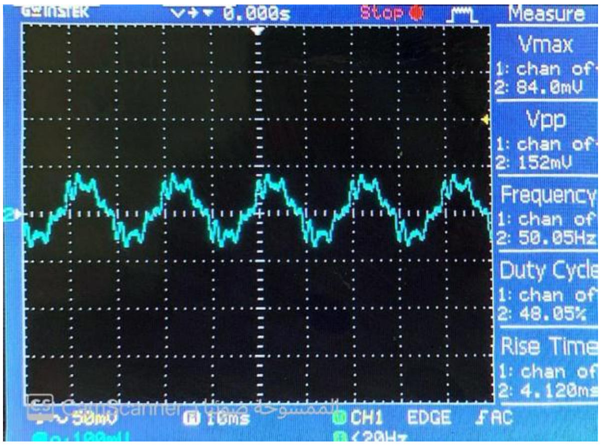
- **:Graph**





kv **10 kv 5**





kv **20 kv15**

Graph of Polluted with Mud and Water measurements on a digital **:Figure III.11** oscilloscope

III.6.2 Observations on the Insulator Type 2

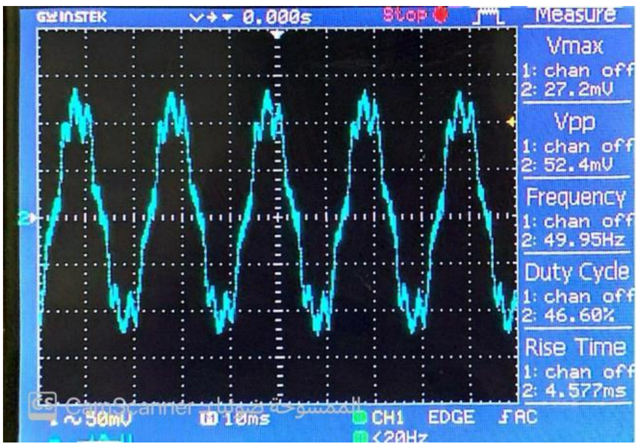
Clean and Dry Surface 6.2.1

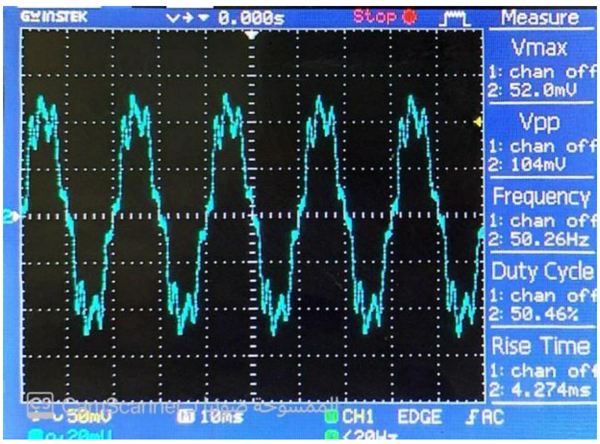
- **:Measurements**

Clean and Dry Surface	
→	
kv 5	µA 2.36
kv 10	µA 4.24
kv 15	µA 6.8
kv 20	µA 10.4
kv 25	µA 13
kv 30	µA 13

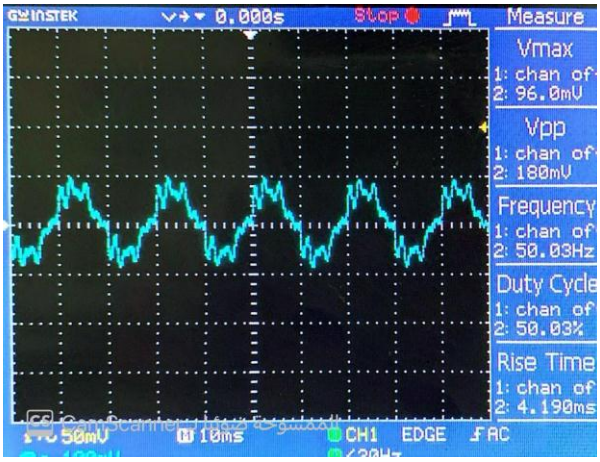
Measurements and results for a Clean and Dry Surface **:Table III.5**

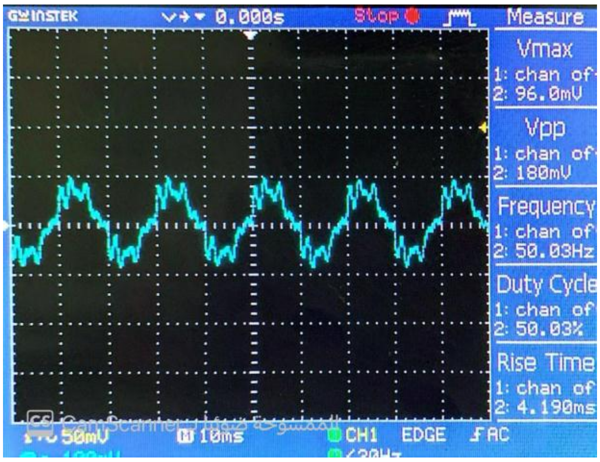
- **:Graph**





kv 10 **kv 5**





kv **20 kv15**

Graph of clean and dry surface measurements on a digital **:Figure III.12**
oscilloscope

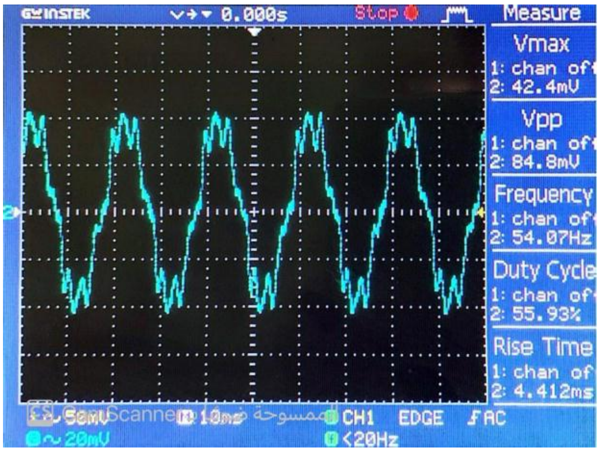
III.6.2.2 Wet Surface Only

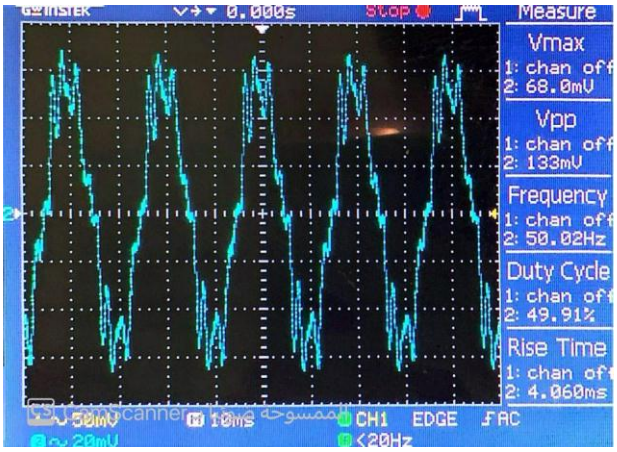
- **:Measurements**

Wet Surface Only	
→	
kv 5	μA 2.72
kv 10	μA 5.2
kv 15	μA 9.6
kv 20	μA 13.6
kv 25	μA 15.2
kv 30	μA 19.2

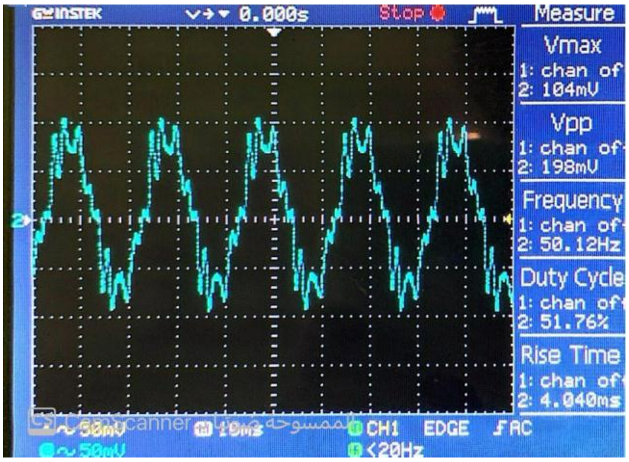
Measurements and results for a Wet Surface Only **:Table III.6**

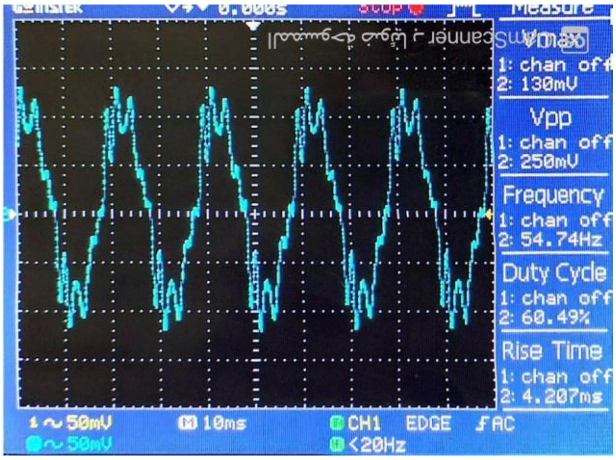
- **:Graph**





kv kv **10 5**





kv **20 kv15**

Graph of wet surface only measurements on a digital oscilloscope **:Figure III.13**

III.6.2.3 Polluted with Mud Only

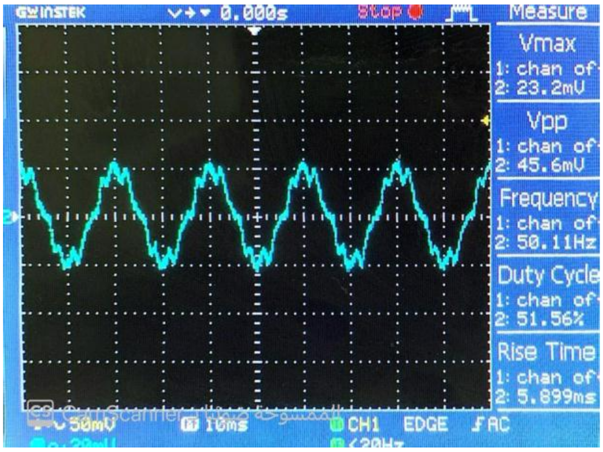
- **:Measurements**

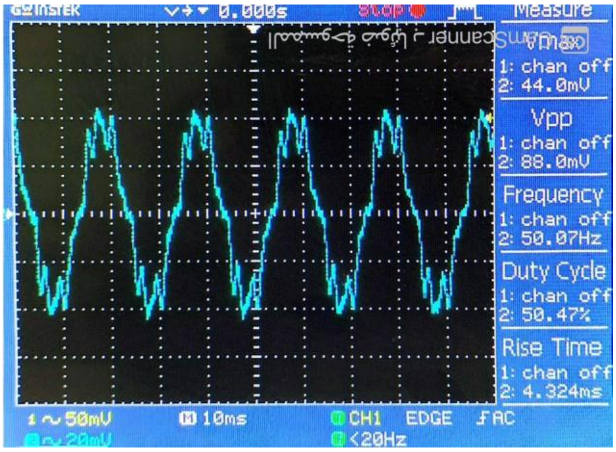
h Mud OnlyPolluted wit	
→	
kv 5	µA 2.32
kv 10	µA 4.4

kv 15	μA 6.72
kv 20	μA 11.2
kv 25	μA 19.6
kv 30	μA 16.8

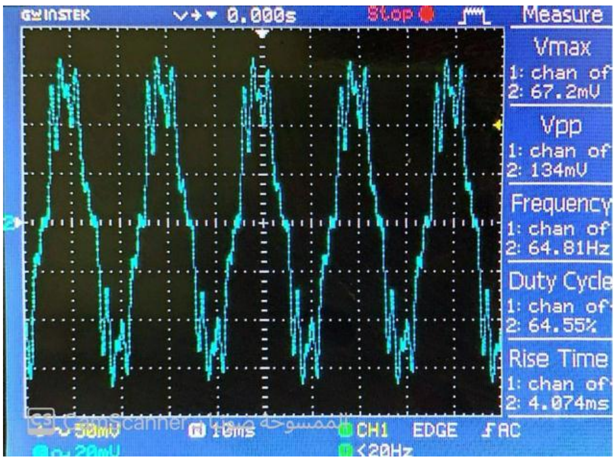
Measurements and results for a Polluted with Mud Only **:Table III.7**

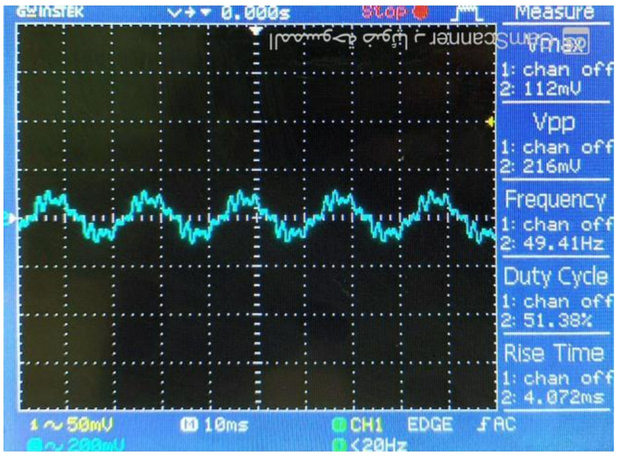
- **:Graph**





kv 10 **kv 5**





kv **20 kv15**

Graph of Polluted with Mud Only measurements on a digital **:Figure III.14** oscilloscope

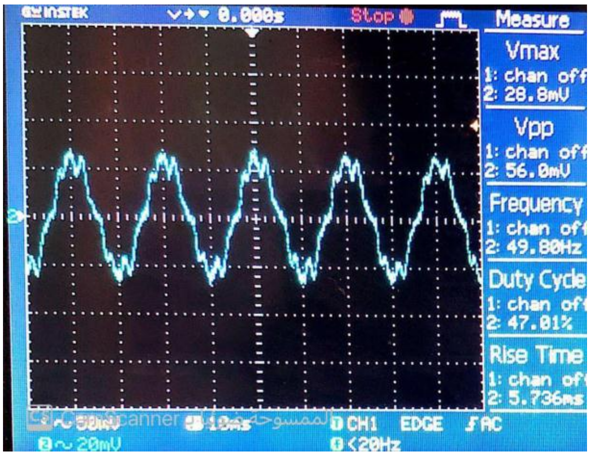
III.6.2.4 Polluted with Mud and Water

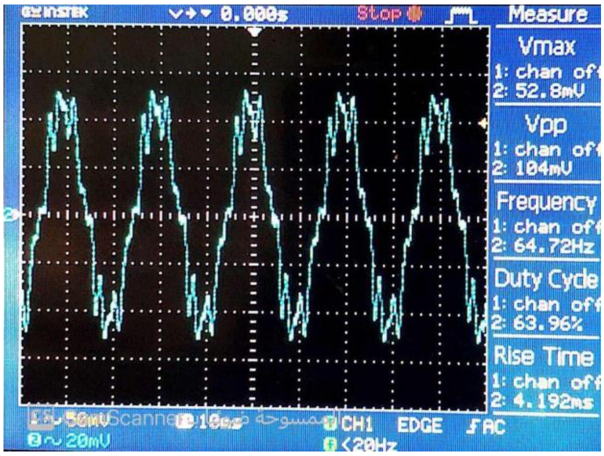
- **:Measurements**

lluted with Mud and WaterPo	
→	
kv 5	µA 2.88
kv 10	µA 5.28
kv 15	µA 9.6
kv 20	µA 13.6
kv 25	µA 17.2
kv 30	µA 20

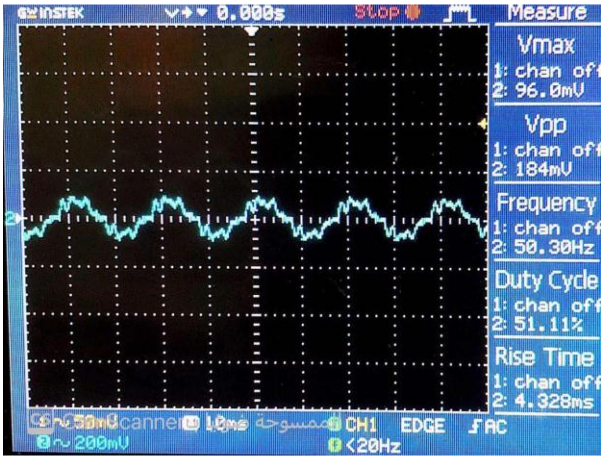
Measurements and results for a Polluted with Mud and Water **:Table III.8**

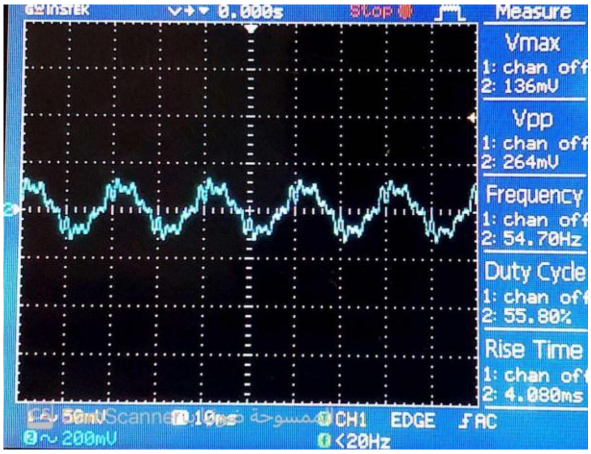
- :Graph





kv kv **10 5**





kv **20 kv15**

Graph of Polluted with Mud and Water measurements on a digital **:Figure III.15** oscilloscope

III.7. Leakage Current Calculation Formula

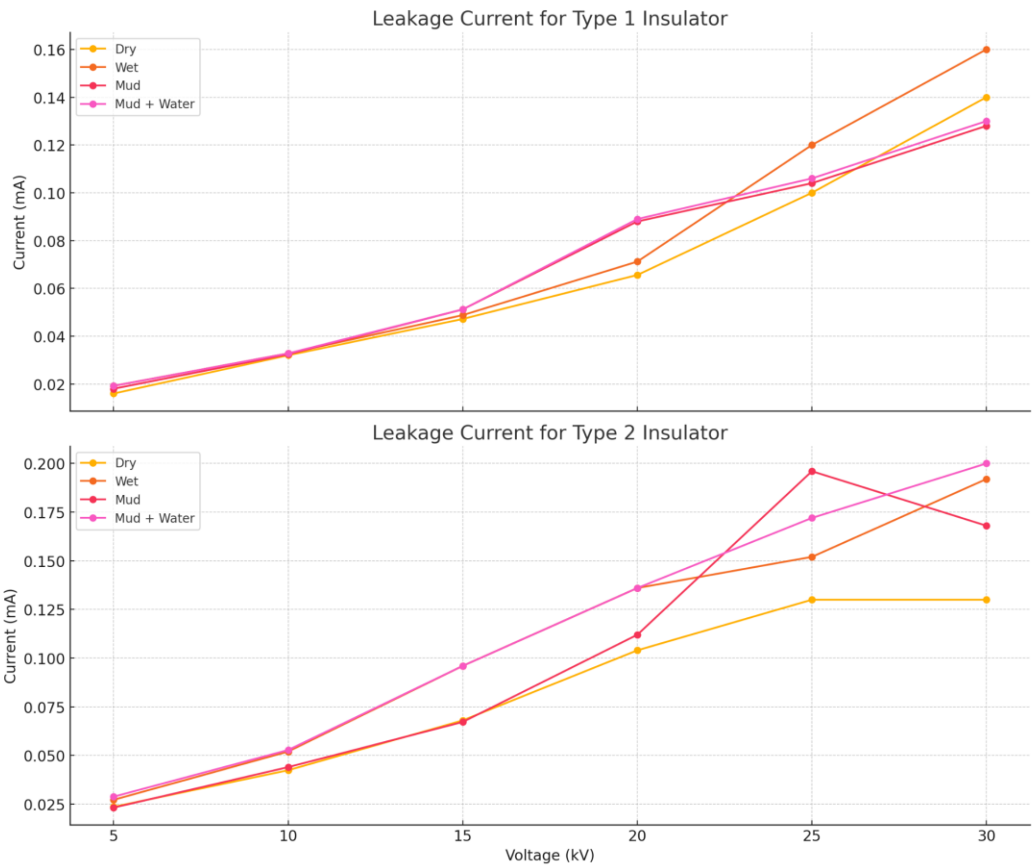
$$I = \frac{mV}{R}$$

:Where

- (Leakage current in milliamperes (mA :I
- (Measured voltage across the resistor in millivolts (mV :Vm
- (Ω)Resistance in ohms :R
- :so the formula becomesΩ , In our experiment, R=1000

$$I(mA) = \frac{Vm(mV)}{1000}$$

shows the variation of leakage current with applied voltage for both This graph insulator types (Type 1 and Type 2), under four surface conditions: clean and dry, .clean and wet, polluted with mud, and polluted with mud and water



rrent vs. Voltage for Type 1 and Type 2 Insulators under Leakage Cu **:Figure III.16**
Different Surface Conditions

III.8. Appendix: Insulator Surface Condition Images

This appendix shows all the images of the insulators used in the experiments. Each urface conditions applied to both Type A and Type image represents one of the four s :B insulators

- **Clean and Dry Surface**
- **Clean and Wet Surface**
- **Polluted with Mud Only**
- **rPolluted with Mud and Wate**

.These photos help to visually compare the condition of the insulator in each test

pe A Insulator ImagesIII.8.1 Ty

- Type A: Clean and Dry – **Figure III.17**
- Type A: Clean and Wet – **Figure III.18**
- Type A: Polluted with Mud – **Figure III.19**
- Type A: Polluted with Mud + Water – **Figure III.20**

III.8.2 Type B Insulator Images

- and Dry Type B: Clean – **Figure III.21**
- Type B: Clean and Wet – **Figure III.22**
- Type B: Polluted with Mud – **Figure III.23**
- Type B: Polluted with Mud + Water – **Figure III.24**

Figure III.18

Figure III.17

Figure III.20

Figure III.19

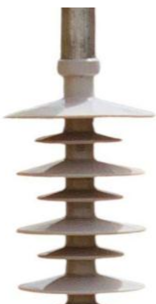


Figure III.22

Figure III.21

Figure III.23

Figure III.24

III.9.Conclusion

In this chapter, we referenced the experimental devices (test circuit, etc.) and presented the operating model used in the laboratory, as well as the experimental .each test setup and model configuration for

We also introduced different contamination models, such as water and mud. After that, we outlined the testing procedures used to measure the insulation voltage .withstand

tivities These contaminants were then applied in varying concentrations and conduc to our rectangular laboratory model. Through these tests, we aimed to determine the .voltage insulation-behavior of high

.Finally, we present the experimental results obtained and their interpretations

h type of contamination has its own From these results, it was concluded that eac degree of impact. In general, the voltage decreases for all types of contamination as though this variation is slight. On the other hand, —the contaminated area increases ffect, as this variation is sudden and the width of the contamination has a significant e .the material can no longer function as an insulator

According to the obtained results, we can say that mud and water contamination pose a greater risk under medium conditions, such as the concentration of different .(ypes of pollution and their surface distribution on the insulator (contamination widtht

General Conclusion

At the end of this project, we studied in detail the behavior and properties of especially in areas with ‹voltage networks-composite silicone insulators used in high industrial or natural pollution. This type of insulator is a modern development in the field of electrical insulation. It has many advantages compared to traditional eight, easy to install, insulators made of glass or porcelain, such as being light in w .and resistant to breaking or damage

One of the most important features of silicone insulators is their high resistance to pollution. This is because of their hydrophobic property, which means they can repel t the formation of conductive layers on the surface, and water. This helps preven reduces the leakage current. As a result, the chance of flashover or electrical arcs becomes lower. The tests also showed that silicone insulators work well even in both ns, which makes them a good choice for harsh dry and wet polluted conditio .environments

During this work, we did both experimental and numerical analysis to measure the leakage current and evaluate the insulator's performance under different conditions. cone composite insulators provide good safety and The results confirmed that sili voltage applications, especially in -reliability. This makes them very suitable for high .areas with heavy pollution or difficult weather

solution to Based on this study, we can say that silicone insulators are a strong problems caused by electrical pollution. They help improve the performance of power networks and reduce maintenance costs. We recommend continuing research and development in this area, especially to improve the materials and keep their .roperties over timegood p

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