Construction of High Voltage Aging Chamber

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Declaration

We, hereby declare that this project neither as a whole nor as a part thereof has been copied out from any source. It is further declared that we have developed this project and the accompanying report entirely on the basis of our personal efforts made under the sincere guidance of our supervisor. No portion of the work presented in this report has been submitted in the support of any other degree or qualification of this or any other University or Institute of learning, if found we shall stand responsible.

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Certification

This is to certify that BILAL HAIDER 14-EE(P)-071, MUHAMMAD KAMIL 14-EE(P)-087, MUHAMMAD BASIL 14-EE(P)-114, ZEESHAN ASLAM14-EE(P)-123 have successfully completed the final project **Construction of High Voltage Aging Chamber,** at the HITEC University Taxila Cantt, Pakistan, to fulfill the partial requirement of the degree **BS. Electrical Engineering.**

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Construction of High Voltage Aging Chamber

Sustainable Development Goals

SDG No	Description of SDG	SDG No	Description of SDG
SDG 1	No Poverty	**SDG 9**	Industry, Innovation, and Infrastructure
SDG 2	Zero Hunger	SDG 10	Reduced Inequalities
SDG 3	Good Health and Well Being	SDG 11	Sustainable Cities and Communities
SDG 4	Quality Education	SDG 12	Responsible Consumption and Production
SDG 5	Gender Equality	SDG 13	Climate Change
SDG 6	Clean Water and Sanitation	SDG 14	Life Below Water
SDG 7	Affordable and Clean Energy	SDG 15	Life on Land
SDG 8	Decent Work and Economic Growth	SDG 16	Peace, Justice and Strong Institutions
		SDG 17	Partnerships for the Goals

Range of Complex Problem Solving			
	Attribute	**Complex Problem**	
1	Range of conflicting requirements	Involve wide-ranging or conflicting technical, engineering and other issues.	
2	Depth of analysis required	Have no obvious solution and require abstract thinking, originality in analysis to formulate suitable models.	
3	Depth of knowledge required	Requires research-based knowledge much of which is at, or informed by, the forefront of the professional discipline and which allows a fundamentals-based, first principles analytical approach.	
4	Familiarity of issues	Involve infrequently encountered issues	
5	Extent of applicable codes	Are outside problems encompassed by standards and codes of practice for professional engineering.	
6	Extent of stakeholder involvement and level of conflicting requirements	Involve diverse groups of stakeholders with widely varying needs.	
7	Consequences	Have significant consequences in a range of contexts.	
8	Interdependence	Are high level problems including many component parts or sub-problems	
Range of Complex Problem Activities			
	Attribute	**Complex Activities**	

1	Range of resources	Involve the use of diverse resources (and for this purpose, resources include people, money, equipment, materials, information and technologies).	
2	Level of interaction	Require resolution of significant problems arising from interactions between wide ranging and conflicting technical, engineering or other issues.	
3	Innovation	Involve creative use of engineering principles and research-based knowledge in novel ways.	
4	Consequences to society and the environment	Have significant consequences in a range of contexts, characterized by difficulty of prediction and mitigation.	
5	Familiarity	Can extend beyond previous experiences by applying principles-based approaches.	

Abstract

The construction of a high voltage aging chamber involves designing, fabricating, and assembling a specialized chamber for conducting accelerated aging tests on high voltage components. The chamber is built with materials that provide electrical insulation, prevent arcing, and ensure safety. It includes features such as high voltage interlocks, grounding systems, and shielding mechanisms. Construction of a high voltage aging chamber focuses on achieving precise temperature control, maintaining desired humidity levels, providing high voltage capabilities, and controlling UV intensity. These features collectively establish a controlled testing environment to conduct accelerated aging tests on high voltage components, enabling the assessment of their performance and durability under specific temperature, humidity, voltage, and UV exposure conditions.

The project's goal is to build a high voltage aging chamber that will allow for expedited aging studies on high voltage components. The chamber is meant to ensure electrical insulation, avoid arcing, and ensure testing safety. Various aspects are integrated into the chamber's architecture to achieve these goals. To begin, the materials utilized to construct the chamber are carefully selected for their electrical insulating qualities. These materials can resist high voltage settings without jeopardizing the testing environment's safety. Furthermore, precautions are made to prevent arcing, which could harm the components or impair the precision of the test results.

Second, high voltage interlocks, grounding systems, and shielding devices are included in the chamber. These characteristics are critical for guaranteeing operator safety and preventing potential risks during the testing procedure. The high voltage interlocks serve in the regulation of the supply of electricity in the chamber, but the grounding systems prevent static charges from accumulating. Shielding techniques are also used to keep any potential emissions or interferences contained during testing. Precision temperature control is one of the most important parts of building the high voltage aging chamber. This is critical for mimicking real-world situations and precisely analyzing the performance of high voltage components under diverse temperature scenarios. Maintaining proper humidity levels is also critical, since it can have a substantial impact on the aging process and component performance.

Also, the chamber is built to give high voltage capabilities in order to submit the components to the desired electrical stresses. The aging process is expedited by introducing the parts to higher voltages than they would ordinarily experience during normal operation, allowing researchers to assess their long-term endurance in a shorter time frame. Controlling UV intensity within the chamber is another crucial aspect. UV rays can have an impact on the aging process as well as the performance of some materials. Researchers can reproduce specific environmental conditions and study the impact of UV radiation on the aging behavior of components by varying the UV intensity. To summarize, the high voltage aging chamber is built with a well-thought-out design that integrates numerous characteristics for electrical insulation, arcing prevention, and safety.

The controlled testing environment enables researchers to evaluate the performance and durability of high voltage components under precise temperature, humidity, voltage, and UV exposure conditions. Finally, the goal of this project is to provide useful insights into the behavior of high voltage components, hence advancing their design and implementation in diverse industries.

Undertaking

I certify that the project **Construction of High Voltage Aging Chamber** is our own work. The work has not, in whole or in part, been presented elsewhere for assessment. Where material has been used from other sources it has been properly acknowledged/ referred.

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Table of Contents

List of Figures

List of Tables

List of Acronyms

RTV-SiR	Room temperature vulcanized silicone rubber
HV	High-voltage
ICU	Intensive care unit
UV	Ultraviolet
FEA	Finite element analysis
CFD	Computational fluid dynamics
RTDs	Resistance temperature detectors
SiR	Silicone rubber
FTIR	Fourier transform infrared
LC	Leakage current
HC	Hydrophobicity classification
RPC	Resistive plate chamber
BSO	Black seed oil
PV	Photovoltaic
TGA	Thermogravimetric analysis
XPS	X-ray photoelectron spectroscopy
GFRP	Glass fiber reinforced polymer
PD	Partial discharge
HVI	High voltage insulation
RGE	Rio grande energia
DSC	Differential scanning calorimetry
DMA	Dynamic-mechanic analysis
SEM	Scanning electronic microscopy
NEP	Neat epoxy
EPNC	Epoxy nanocomposite
EPDM	Ethylene propylene diene monomer
PDMS	Polydimethylsiloxane

Chapter One

1 INTRODUCTION

In order to build a high-voltage aging chamber, a specialized environment must be created. This environment is intended to subject electrical parts or devices to sustained high-voltage stress for an extended period of time. The goal is to test their performance under particular circumstances and simulate aging.

1.1 Background

High voltage aging chambers are specialized chambers with a controlled atmosphere for testing electrical equipment or components under accelerated aging conditions. This chamber simulates prolonged use and stress, enabling for the evaluation of the effectiveness and dependability of insulating systems. The chamber has safeguards to handle high voltage levels and reduce risks in order to assure safety. Power supplies, transformers, dividers, and measurement devices that generate and regulate high voltage are all included in the insulated enclosure, which has accurate temperature and humidity control. Components are held in place during testing by fixtures or mounting structures while maintaining insulating distances. The components are subjected to voltage levels greater than their rated values over a prolonged period of time as part of the aging procedure. Voltage, current, temperature, and humidity are just a few of the parameters that are meticulously monitored and managed during this process. Construction requires knowledge of insulation systems, electrical engineering, and adherence to safety regulations and industry standards. This guarantees accurate testing results in a secure setting.

1.2 Aims and Objectives

To establish a controlled testing environment for assessing and researching the performance, dependability, and safety of high-voltage electrical equipment, a high-voltage aging chamber is built. It is essential to the support of many activities in the field of high-voltage engineering, including research, development, quality control, and risk assessment. The following are the goals and objectives of this chamber:

1.2.1 Testing and Evaluation

High-voltage electrical equipment can be thoroughly tested and evaluated for performance and durability in a controlled environment. This guarantees accurate assessments of their durability and dependability.

1.2.2 Accelerated Aging studies

Studies Accelerated aging investigations are made possible by the chamber. Higher voltage, higher temperature, and more stress factors are appliedto the equipment in order to achieve this. This allows it to more quickly replicate long-term operation. With the help of this technique, performance can be predicted, failure mechanisms can be found, and design and dependability may be enhanced.

1.2.3 Performance Verification and Quality Control

It aids in verifying the effectiveness of newly created or updated equipment and carrying out quality control checks. This guarantees that the equipment complies with safety standards and requirements, enabling the identification and correction of flaws prior to deployment.

1.2.4 Research and Development

The aging chamber aids in the creation and research of high-voltage engineering. This enables the development of new materials and methodologies to increase the dependability of power systems as well as the investigation of equipment behavior and insulation performance.

1.2.5 Safety and Risk Assessment

It assesses the safety and risk factors associated with high-voltage equipment by determining potential failure modes and putting safety precautions in place. These initiatives support the development of safety regulations and security measures.

1.3 Motivation

Researchers and engineers build high-voltage aging chambers to study aging, detect degradation, and assess the performance and dependability of electrical systems. These chambers offer a controlled environment for this purpose and imitate and investigate the long-term consequences of electrical stress on machinery and components.

The aging chamber is a useful tool for spotting potential flaws and vulnerabilities that can appear over the course of high-voltage equipment's operational lifespan. This chamber aids in the creation of more durable designs and the application of preventative maintenance techniques by exposing parts like insulators, cables, and transformers to continuous exposure to high voltage. In turn, this improves the longevity and dependability of high-voltage systems.

The burn-in chamber also provides a testing and validation ground for novel insulation materials, diagnostic procedures, and condition monitoring approaches. It backs initiatives in research and development aimed at enhancing the effectiveness, security, and sustainability of high-voltage systems.

Overall, the development of electrical engineering and the optimization of high-voltage machinery are greatly aided by the building of high-voltage aging chambers, which guarantee the dependable and effective functioning of applications like power transmission, distribution, and industrial processes.

1.4 Conclusion

The completion of a high-voltage aging chamber is a significant development in the discipline of electrical engineering. This feat is the culmination of a challenging engineering project that required meticulous planning, designing, and carrying out. The goal of the high voltage aging chamber is to establish a regulated environment where electrical materials and components can be stretched under high voltage for extended periods of time. This enables scientists and engineers to examine their effectiveness, toughness, and aging characteristics in realistic settings. Numerous benefits result from the construction of this facility, including improvements to dependable and efficient electrical systems, the identification of component weaknesses, the investigation of novel materials, and the advancement of electrical insulation and high voltage engineering. Researchers and engineers can boost technological advancements and improve reliability in a range of sectors by understanding how electrical components age and predicting their lifespan. This includes industries like power generation, transmission, electric vehicles, aerospace, and renewable energy systems. A major feat in this endeavor is the creation of a high voltage aging chamber, which allows for the enhancement of design practices, reduction of maintenance costs, and promotion of safety.

1.5 Report Organization

Chapter 1: This chapter emphasizes the value of a high-voltage aging chamber that is made to continuously subject electrical equipment to high voltage stress. The chamber streamlines testing, expedites aging studies, provides quality control, promotes research and development, and evaluates safety considerations. Its development advances electrical system safety, reliability, and technology.

Chapter 2: This chapter focuses on the benefits of polymeric insulators over ceramic ones, but it also recognizes that they can aging quickly outside owing to environmental factors. The study emphasizes the use of high-voltage aging chambers in comprehending the aging process and the significance of implementing environmentally acceptable insulation solutions for transformers. Researchers can increase the dependability and sustainability of electrical systems by researching and tackling these aging-related concerns.

Chapter 3: This chapter goes through the parts, characteristics, and temperature control system of a high voltage aging chamber. While the control system maintains a precise temperature for accurate testing, the high voltage power supply supplies the necessary voltage for component aging.

Chapter 4: This chapter present Construction of the high voltage aging chamber places a high priority on insulation, grounding, and safety. High voltage operations are reliable and staff safety is ensured through proper ventilation, monitoring, and testing.

Chapter 5: This chapter deals with Equipment is tested for dependability and safety in a high voltage aging chamber. Improvements in insulation, voltage capability, diagnostics, and automation increase precision and effectiveness.

Chapter 6: This chapter focuses on the Safety, voltage capacity, and environmental control issues must be taken into account while building high-voltage aging chambers. Integrating renewable energy promotes sustainability and advancement while standardization, diagnostics, and material development increase reliability.

Chapter 7: This chapter is a high voltage aging chamber project may have a large and varied influence on the environment and society. Responsible project management demands careful planning and the use of renewable energy sources.

Chapter Two

2 LITERATURE REVIEW

Polymeric insulators have seen rapid growth in their types, designs, and construction due to their many advantages over traditional ceramic insulators, including their light weight, flexibility, ease of installation, superior performance in contaminated environments, improved dielectric strength, and one-piece design. [1], [2]. Polymeric materials, however, have the problem of aging, particularly in outdoor conditions, because of their organic character. Environmental stresses include things like heat, humidity, acid rain, fog, ultraviolet (UV) radiation, and heat [3]. One of the biggest issues electrical insulations have to deal with is ultraviolet (UV) aging. The sun's total UV radiation is typically broken down into three components. Because its wavelength is smaller than 290 nm, UV C has the maximum energy of all ultraviolet light types. UV C is therefore undoubtedly bad for your health and even for other things like electrical insulators that are found on the ground. The current paper's goal is to investigate the UV C-exposed silicone rubber insulation's aging process. To achieve this, three distinct varieties of commercial silicone rubber insulators were aged using contaminated solution and UV C light. Then, using thermo-gravimetrical analysis, surface elements, and leakage current measurements, their electrical and thermal properties as well as changes on the surface were examined. It has been found that the influence of polluted solution has a greater impact on leakage current than the influence of UV light alone. Pollution and UV C rays together also greatly increase leakage current. The third harmonic component is particularly affected by pollution. UV C aging lowers the thermal decomposition temperature of insulations and deteriorates the surface of systems, particularly the polymers that surround the filler. [4]. These stresses have an impact on the mechanical, electrical, thermal, chemical, and physical characteristics of composite insulators. [5], [6].

Compared to other polymeric insulators, room temperature vulcanized silicone rubber (RTV-SiR) is usually suggested for outdoor high-voltage (HV) insulator coatings. This is because it has great weathering and heat resistance. RTV-SiR is an elastomeric organ siloxane polymer that mostly consists of silicon with carbon, oxygen, and hydrogen. RTV-SiR is an acceptable rubber because it contains hydrocarbon groups, whereas the Si-O bond gives it its inorganic characteristics [7]. RTV-SiR possesses exceptional insulating qualities and an unusual hydrophobic behavior as a result of its distinct hybrid nature [8]. RTV-SiR is used in a variety of industries and professions, including biomedical engineering, industrial rolls, and HV insulation [9], [10].

The basic ideas behind the water drop corona aging process for nonceramic insulators are presented. It is shown that water drops in the sheath regions strengthen the electric field and could produce corona, which could be crucial for long-term performance. Electric field calculations and small-scale experiments show how water drops at various points on the shed and sheath enhance the electric field. Two silicone rubber surfaces with varying hydrophobic qualities are given along with the threshold magnitude of the surface electric field for corona from water drops. Small-scale aging experiments are used to demonstrate the impact of water drop corona activity on the characteristics of the surface material [20]. As a consequence of different chamber design factors, the wire chamber aging issues. The chemistry perspective is emphasized, and numerous examples from the field of plasma chemistry are used as advice for potential efforts in the field of wire chambers. The paper highlights the relevance of variable tuning, the need for a pure wire chamber environment, and offers a useful rundown of currently accepted advice [21]. The output power of a photovoltaic (PV) system is strongly dependent on the DC cable system that connects the key PV system components, such as solar modules, inverters, batteries, and charge controllers. These cable systems are subjected to a wide range of harsh operating environments, including ultraviolet radiation, thermal, electrical, and mechanical stress. As a result, the insulation on the wire deteriorates and their performance suffers. DC PV cable samples were subjected to thermal and mechanical loads for 258, 396, 636, 876, 1000, and 1120 hours in this investigation. The cable sample was rolled into a 6 cm diameter mandrel in an air circulation oven set to 120 °C. The dielectric spectroscopic technique and the Shore D hardness test were used to investigate the impact of thermal-mechanical aging stresses on the insulation integrity of cables. With aging, the real and imaginary components of permittivity displayed non-monotonic behavior. Furthermore, at 396 and 636 age hours, the Shore D hardness increased. It dropped during the following age cycles, 876, 1000, and 1120 hours. The obtained results indicate that the XLPO might restore its mechanical properties after being exposed to high temperatures for a lengthy period of time [24]. Aging is the cumulative accumulation of changes over time that are connected with or responsible for the growing susceptibility to disease and death that comes with advancing age. These time-related alterations are attributed to the aging process. The nature of the aging process has long been debated. The accumulation of evidence presently indicates that the sum of the detrimental free radical reactions occurring continually throughout the cells and tissues represents the aging process or is a substantial contribution to it. In mammalian systems, free radical reactions involving oxygen predominate [30].

2.1 Importance of high voltage aging chamber

In high voltage transmission networks, silicone rubber (SiR) insulators are thought to offer a promising alternative to traditional ceramic insulators. When exposed to a combination of electrical, environmental, and solar pressures, SiR insulators age prematurely, which is a problem. On the multi-stress aging performance of silicone rubber with DC voltage, the impact of micro/nano-silica and micro-alumina trihydrate particles was examined. The hydrophobicity classification, leakage current, scanning electron microscopy, fourier transform infrared spectroscopy, mechanical testing, and visual inspection were used to analyze the SiR composites [11]. Composite insulators have been utilized extensively in transmission lines due to their outstanding anti-pollution performance. Composite insulators, however, exhibit a variety of problems after extended outdoor use under mechanical, electrical, and climatic stress. In order to understand the reasons and mechanisms of aging, this study compares the mechanical properties of samples before and after tests [12]. Effects of field aging were not considered to be crucial enough to require insulator replacement. For both insulators, the upper surface layer of the polymeric housing was the only place where field-ageing-induced morphological and material degradation occurred. Field aging had no effect on the housing material's ability to withstand erosion and tracking, [18]. Insulation using Silicon PU and thermoplastic Since the previous three decades, elastomeric materials have supplanted outdated ceramic insulators and are currently in use all over the world. As outside electrical insulation, they are also widely utilized. Since these materials are primarily organic, they age or degrade over time as a result of environmental factors including UVR, temperature, humidity, and rain, among others, so it is crucial to check their performance before using them in any setting. The best method at the present is accelerated multistress aging [8].

The radiology department has a lot of electrical equipment, X-ray machines, computerized tomography, and magnetic resonance imaging are some examples [5]. A sample is obtained under an electronic equipment for diagnostic purposes to gather biological markers such as complete blood count, urea and creatinine, antibodies, and microorganism culture [6]. It can be fatal to work near or with electrical equipment. The human body may be negatively affected by electrical current contact. In the human body, an underrun electric circuit can damage or destroy organs. Burns, punctured tympanic membranes, and various injuries can result from electrical equipment blast [7]. When a device has a flaw, such as a frayed electrical cable, damaged plug, damaged wires, or missing prong, the user comes into contact with the current [1]. Additionally, risky worker behaviors including gripping wire, using several extension cords, and revealing electrical wire all raise the chance for an electrical mishap. Additionally, the surgical smoke produced during diathermy has the potential to cause infection, cancer, and respiratory problems [8].

Insulation using Silicon PU and thermoplastic Since the previous three decades, elastomeric materials have supplanted outdated ceramic insulators and are currently in use all over the world. As outside electrical insulation, they are also widely utilized. Since these materials are primarily organic, they age or degrade over time as a result of environmental factors including UVR, temperature, humidity, and rain, among others, so it is crucial to check their performance before using them in any setting. The best method at the present is accelerated multistress aging [9]. In electrical transformers, vegetable-based natural ester oil serves the twin purposes of insulating and cooling materials. It is regarded as a natural alternative to the conventional mineral insulating oil. Nano oils were created by dispersing a composite of aluminum oxide and zinc oxide (Al_2O_3+ZnO) nanoparticles into soy bean oil and a mixture of sunflower and olive oil with a concentration of 0.005g/L in order to preserve both improved electrical and thermal properties. This study compares the results of different tests on nano oil samples that were conducted before and after aging with those of mineral oil. These tests included those for breakdown voltage, tan delta, flash point, pour point, water content, viscosity, and FTIR [10].

For insulation and cooling purposes inside the transformer, liquid insulation media is used. Transformers currently use mineral oil made from petroleum, which is not renewable and does not degrade, posing a severe risk to the environment. However, there is a pressing need to adopt acceptable mineral oil substitutes that are environmentally benign and biodegradable due to the rising price and diminishing nature of mineral oil. For transformer insulation in high voltage systems, a variety of vegetable oils, including sunflower oil, soya bean oil, and a mixture of sunflower and olive (BSO) oil, are appropriate substitutes due to the limited supply of these materials. The aforementioned vegetable oils are put through multiple aging processes, and mineral oil is used as a comparison. Additionally, both before and after age, the dielectric and thermal characteristics of vegetable oils are examined. Fourier Transform Before and after aging, vegetable oils are subjected to testing for infrared spectroscopy, water content, breakdown voltage, viscosity, flash point, tan delta, and pour point. The effectiveness of the suggested vegetable oils is demonstrated by a comparison of vegetable oils with mineral oil [13]. In the field of high voltage outdoor insulation, there is a growing need for alternative materials, which is primarily driven by the need to reduce total costs while maintaining the necessary insulation properties. Due to their unpredictable reaction when exposed to environmental challenges, these insulators' aging is one of their most significant behaviors. From this angle, polymer hybrid composite materials could have a lot of advantages over polymer nano- and micro-composites [14]. Multiple stresses, including heat, UV rays, salt fog, and acid rain, are included in the design and construction of an environmental chamber. Leakage current values are noted following each cycle of weathering for the purpose of aging analysis. To track the structural alterations in all samples, Fourier Transform Infrared Spectroscopy (FTIR) was used. All of the hybrid composites demonstrated enhanced leakage current, hydrophobicity, and dielectric strength after being weathered in the lab [15]. After each cycle of weathering, leakage current (LC) and hydrophobicity classification (HC) measurements are made to examine the aging properties of these samples. Likewise, Fourier transform infrared (FTIR) spectroscopy is used to track significant structural alterations throughout the aging process. After 1000 hours of aging, the dielectric strength of AC is also tested. Mechanical qualities are also examined both before and after aging, as well as resistance to tracking and erosion. HSs have improved test scores across the board, according to the critical investigation. Over the course of aging, S2 has the lowest LC and HC values. At the conclusion of the accelerated aging, S6 similarly described the highest breakdown strength [16]. Predicting agings occurrence, speed, and circumstances as well as the average predicted lifespan of a composite insulator is crucial. This study outlines the procedures for artificial field testing (aging), natural testing, standards created for aging, analytical techniques, data obtained thus far regarding different metrics from various locations, handling instructions, and a conclusion on what is still required [17]. With a powerful gamma source, a resistive plate chamber (RPC) underwent a long-term aging test. The bakelite surface of the detector had been given linseed oil treatment while it was in avalanche mode of operation. Following the radiation treatment, the projected dose, charge, and fluence were roughly equivalent to the levels anticipated following ten years of operation in the CMS barrel region. Cosmic muon monitoring of the RPC performance during and after the irradiation revealed no discernible aging effects. Additionally, no change in bakelite resistance was seen [19]. The dependability of composite insulators used in transmission networks is a crucial aspect in ensuring uninterrupted power delivery to consumers. Because they are organic, these polymeric insulators age when subjected to electrical and environmental stress. UV is the primary cause of aging caused by surface degradation. Pollutants are accumulated on the surface of these insulators when they are employed in marine, industrial, and agricultural environments. As a result, its surface resistance decreases and leakage current begins to flow on the insulator surface, owing to changes in the chemical structure of the polymer chain. This causes flashover, which eventually leads to insulator failure. Leakage current is an important metric that indicates the surface state of an insulator. The UV chamber was designed and built in the current work. 11kV polymeric insulators were artificially aged for one and two years in this UV chamber. The studies were carried out to measure the leakage current on the insulator's surface under polluted conditions. The results reveal that leakage current increases as the insulators age [22]. The effect of electrical stress on glass fiber reinforced polymer in wet conditions was explored in this work. A specially developed and built test equipment was utilized to record the current flowing through the GFRP rod during the test. Based on the change in GFRP rod surface morphology and the current development trend, the degradation process of GFRP rod due to electrical stress was divided into four consecutive stages: degradation inception stage, hydrolysis stage, carbonization stage, and breakdown stage. The physical and chemical features of GFRP in different phases were revealed using SEM, Fourier transform infrared (FTIR), thermogravimetric analysis (TGA), and X-ray photoelectron spectroscopy (XPS). According to the findings, the GFRP degradation process caused by electrical stress in wet conditions occurred constantly in the form of flaw channels, in which the epoxy resin matrix was significantly deteriorated. During the test, the hydrolysis, oxidation, pyrolysis, and carbonization of the epoxy resin matrix can be measured successively. The percentage amount of highly oxidized carbon (C-O, C=O, and O-C=O) in the epoxy resin matrix on the GFRP surface increased prior to the carbonization process and then dropped during the carbonization process as the GFRP breakdown process advanced [23]. Due to its superior qualities, particularly its high hydrophobicity, silicone rubber (SiR) has seen a significant growth in use for high voltage electrical insulation in the outside environment over the last three decades, in addition to non-electrical uses. However, because its products are organic in nature, they are altered when subjected to various pressures, resulting in the loss of desired qualities that have a direct bearing on their longevity. This review article discusses the degradation of SiR composite insulators in outdoor working environments, which is caused by a variety of factors including ultraviolet (UV) radiation, biological contaminants, water concentration or moisture absorption, tracking/erosion, partial dissolution (PD), corona aging, and others. [25]. A multi-part study that looked at how high-voltage insulating (HVI) materials performed when exposed to electrified salt spray, UV light, and humidity. As the salt fog ages, a data collecting device continuously monitors the surface electrical activity. Dynamic water contact angle is utilized to monitor the effects of accelerated aging on the loss and recovery of hydrophobicity in silicone elastomers, while SEM and XPS are employed to examine surface structural impacts due to aging. Physical and electrical properties in aggregate are also presented [26]. A study was carried out to evaluate new and laboratory-aged samples of surge arresters and anchorage polymeric insulators for the Rio Grande Energia (RGE)'s 12 and 24 kV networks. Power Provider Differential Scanning Calorimetry (DSC), Thermogravimetric Analysis (TG), Dynamic-Mechanic Analysis (DMA), Fourier Transformed Infrared Spectroscopy (FTIR), and Scanning Electronic Microscopy (SEM) were used to examine polymeric compounds for changes in insulator properties caused by degradation during the experiments. The tests were carried out in laboratory apparatus (weatherometer, 120 °C, salt spray, and immersion in water) before and after 6 months of aging. Following the aging studies, high-voltage electrical tests were performed, including a radio interference voltage test and simultaneous measurements of total and internal leakage currents to confirm the surface degradation of the polymeric material employed in the housing. To force an internal degradation, the impulse current test was used with current values near to 5, 10, and 30 kA. Only surface degradation was identified at the polymer, according to the results. The aging had no effect on the major attributes of the pieces. It confirms the suitability of polymer insulators and surge arrestors for usage in energy distribution networks [27]. Environmental stress must damage the polymeric housing of distribution surge arresters, and moisture infiltration can disrupt the interface between the housing and the internal module. Moisture absorption at the contact should increase leakage current and produce tracking losses. UV, temperature, humidity, voltage, salt fog, and precipitation, as well as total and resistive leakage current from the arresters, can all be simulated by the suggested aging test equipment. In addition, in an outdoor test yard, we conducted field exposure tests with typical studies of field operated arresters. The electrical performance of the arresters was then compared, as well as the insulating quality of the housing material and the state of the housing surface [28].

Composite insulators are significantly used in power transmission networks. 371 composite insulation materials with operating lifetimes ranging from 3 to 22 years were collected from lines in hot and humid environments. These insulators' physical characteristics, mechanical properties, electrical properties, and interface properties were thoroughly examined. In addition, to describe insulator aging circumstances, 19 aging characteristic indices were developed. This study addressed the fundamental aging mechanism by investigating the association across aging index and working years. Meanwhile, based on the outcomes of the inquiry, we created life expectancy models based on physics and statistics, respectively. The thermal oxidation process of silicone rubber, according to the findings, determines the lifetime of the tested insulators. The composite insulator had an electrical life of 18.9 years, while the silicone rubber material had an electrical life of 14.6 years. Mechanical load and Fourier Translation Infrared Spectroscopy (FTIR) test results can be used to forecast the remaining life of insulators in high-temperature and high-humidity situations. Finally, we chose 20 insulators that had been running for 14 years and estimated their longevity using the method given in this paper. The forecast was off by one year [29]. The principal dangers to cable insulation are electrical stress, thermal stress, and mechanical stress. Electrical stress, whether from operation voltages or anomalous over voltages during transients, has a deleterious impact on power cable insulation. Excessive electrical stress will cause insulating materials to age, resulting in cable failures and power system outages. Polymeric power cable aging has been intensively examined during the last few decades. Although the aging mechanisms were researched on molded samples, little is known about the switching impulse aging of XLPE and EPR cables. 15 kV XLPE and EPR cable samples were aged for 10,000 switching impulses in this experiment [31]. A multistress environment using neat epoxy (NEP) was applied to an epoxy/silica nanocomposite loading in a specifically built chamber at 2.5 kV for 9000 hours. In order to study the aging of the samples, Fourier transform infrared (FTIR) spectroscopy, scanning electron microscopy (SEM), leakage current monitoring, and Swedish Transmission Research Institute hydrophobicity categorization were utilized in conjunction with continuous eye examination. After age, both samples were deemed acceptable and adequate for insulation. However, epoxy nanocomposite (EPNC) outperformed NEP. FTIR spectrographs revealed that the EPNC saw reduced decrease in key hydrocarbon groups. The tidy sample showed greater leakage current and so lost more hydrophobicity. Similarly, microscopic SEM evaluation of the nanocomposite indicated no substantial change in surface topography [32]. Time-dependent multistress aging of high voltage nanocomposites Insulators play an important role in electrical power transmission and distribution systems because they not only isolate supply lines from towers but also give mechanical support to conductors. As a result, insulators play a critical role in efficient and effective electricity transmission. For a long time, conventional porcelain and glass insulators were the sole insulators, until polymeric insulators were introduced and approved in most sophisticated countries. Polymeric insulators provide several advantages over ceramic insulators, including light weight, high dielectric strength, and low cost, among others. However, they are subject to aging as a result of electrical and environmental stressors. Some well-known polymeric insulating materials are silicone rubber (SiR), ethylene propylene diene monomer (EPDM), and epoxy. Advances in nanotechnology, on the other hand, aided in the development of polymeric insulators with superior properties. As a result, nanocomposites of polymeric insulating materials have been proposed to replace them. Polymeric nanocomposites, on the other hand, lack an extensive track record of performance. As a result, they should be examined for an acceptable period of time in comparison to neat polymeric materials to determine the effect of nano-fillers on their aging behavior. The criteria that influence the properties of any composite are the kind, size, and loading of nano/micro fillers. Because of its great thermal stability and electrical resistivity, silica is one of the top choices in wide range fillers. Multiple stresses exist in the natural environment. hence the insulators must be assessed in a multistress environment to achieve laboratory results that are near to the natural environment. Weathering cycles are periodic applications of various stresses in an environmental chamber. various stresses include ultraviolet (UV) radiation, warmth, acid rain, and so on. After a couple of weathering cycles or aging periods, several analysis techniques can be employed to examine the condition of the samples, or more precisely, to check the impacts of stresses on insulators, which may alter electrical, physical, and structural properties [33].

Polymer composite insulators, which are made up of fiber-reinforced polymer insulators wrapped in a polydimethylsiloxane (PDMS) cover, are currently replacing traditional ceramic insulators due to their distinct advantages. Polymers, unlike ceramics, have a relatively short life cycle. Outdoor insulators are subjected to a variety of electrical, mechanical, chemical, and temperature stresses while in use. Long-term performance and lifetime estimation of these insulators is critical, but challenging and time-consuming. The current investigation's goal is to establish the property's rate of deterioration during operation as well as its approximate useful life. Working insulators of varying ages were removed from service, and the mechanical, electrical, and hydrophobic properties of the PDMS cover were determined over time. The lifetime of a new chemical subjected to accelerated aging studies was compared to the lifetime estimated based on changes in mechanical characteristics and hydrophobicity of the surface (using MATLAB software). Predicting service life is useful for removing elderly insulators from service in order to avoid power outages [34].

Chapter Three

3 METHODOLOGY

3.1 Theoretical studies

The aging chamber is a two-walled, convection-heated and cooled machine. The aging chamber's outer body is built of thick PCRC, pre-coated with a corrosion-resistant GI sheet, primed and rust proofed before being painted with long-lasting stove enamel and attractive powder coated. The interior chamber is built of SS-304 grade thick gauge stainless steel sheet). The space between the walls is filled with high-quality mineral glass wool, ensuring optimal thermal efficiency in our chamber. The unit is available in single and double door versions, with a viewing window constructed of thick plexiglass/float glass to examine the specimens without affecting the chamber's temperature. This door includes a magnetic door closure. The unit is supported by a strong steel frame. The unit comes with a variety of customized shelves in numerous permutations and combinations to meet specific needs. Our aging chambers have a triple-walled back and two/four/six/eight (size specified) air circulation fans to keep the temperature uniform throughout the chamber.

3.1.1 Standard Future

The following are the main standard futures of high voltage aging chamber.

3.1.2 Humidity control

The combination of a variable speed motor with a thermostat allows for humidity control. To dry or "dehumidify" the chamber, we will require a mechanical mechanism. This is best accomplished with the help of a refrigeration system. In the chamber, a chilly cooling coil draws moisture in the air, producing it to condense into water, which may then be drained.

3.1.3 Open and Close Updates Through Mobile Network

Mobile technology has the potential to make operations more flexible by providing information anytime and anywhere via a mobile device, as well as setting up an alert system to determine whether or not the chamber is being used.

3.1.4 Heating

The chamber has an indirect heating system that consists of air heaters manufactured of high grade Kanthal A-1 wires of appropriate wattage. The heated air is spread evenly throughout the chamber by efficient motor fans, ensuring excellent temperature sensitivity.

3.1.5 Cooling (for below ambient conditions)

To conduct experiments at lower room temperatures, we placed an energy-efficient cooling unit in our aging test chambers. We use Kirloskar/Tecumseh/ Bitzer/ Denfos high-end CFC-free compressors that meet the most recent international regulations and guidelines. Air cooled refrigeration systems provide numerous advantages, including:

1. Low fan power usage.

2. Resistant to corrosion and freezing.

3. It requires relatively little upkeep.

4. Long-lasting operation

3.1.6 Corrosion Resistant Interior and Exteriors

Corrosion-resistant coatings, such as epoxy coatings, are applied both inside and outside the chamber to prevent degradation caused by moisture, salt spray, oxidation, or exposure to other environmental or industrial chemicals/corrosive agents.

3.1.7 Light Weight

The chamber is light weight due to its compact design and premium materials.

3.1.8 Control of UV intensity

Increasing the length of time, decreasing the distance between things and bulbs, and raising the number of lights are three methods for raising the intensity of UV radiation.

3.1.9 Temperature Control

The temperature within the aging chambers is controlled by an HMI and PLC controller based on Nanotechnology. Our aging Chamber has a temperature range of -10 C ambient to +100 C

3.1.10 Experimental Set Up

1. Gather all of the necessary knowledge for High Voltage Aging Chamber.

2. Learn C++ and Arduino app development.

3. Examine the High Voltage Aging Chamber settings.

4. Development of a 1kVA transformer,

5. Put the Model into Action and Construct It.

6. Test various materials in the aging chamber to identify their qualities, such as the lifespan of different materials and the effect of temperature, voltage, humidity, and ultraviolet radiations on their properties.

3.2 Method of Analysis

High Voltage aging is a sort of examination that uses accelerated conditions like as heat, oxygen, sunlight, vibration, and so on to speed up the aging processes of objects. It is used to investigate the long-term effects of expected levels of stress during a shorter period of time, often in a laboratory using controlled traditional test methods. It is used to estimate a product's useful lifespan or shelf life when actual lifetime data is unavailable. When a product hasn't been around long enough to reach the end of its useful life, something happens.

The following are the most important parts of an aging chamber:

3.2.1 Humidity

Humidity sensors detect changes in electrical currents and air temperature. There are three types of humidity sensors: capacitive, resistive, and thermal. All of these methods will detect minute changes in the atmosphere to compute the humidity in the air.

A capacitive humidity sensor estimates relative humidity by sandwiching a small strip of metal oxide in two electrodes. Metal oxide's electrical capacity varies with the relative humidity of the atmosphere. Weather, commercial, and industrial applications are the most common. In resistive humidity sensors, ions in salts are utilized to detect the electrical impedance of atoms. As humidity changes, the resistance of the electrodes on each side of the salt medium changes.

3.2.2 Temperature Sensors

Temperature sensors measure the amount of heat energy or coldness generated by a particular object or system It can detect any physical change in temperature and generate either an analog or digital output.

Thermisters are devices made from semiconductors whose resistance varies in response to temperature. They are suitable for very high sensitivity measurements in a limited temperature range of up to 100 degrees Celsius. Nonlinearity exists in the relationship between temperature and resistance. RTDs take advantage of the fact that the resistance of a metal vary with temperature. They offer higher precision and resolution than thermocouples and are linear over a wide range. As the sensory element in RTDs, precision wire, usually composed of platinum, is used.

3.2.3 UV Sensor

Illuminance is measured using a photo diode-type UV sensor. When light reaches a photo diode, it motivates the electrons, causing an electric current to flow In reaction to brighter light, the electric current will get stronger. After that, the electrical current can be measured and converted into a digital and analog output.

3.3 Technique

While constructing a high voltage aging chamber it required careful consideration of various factors. Some construction techniques and guidelines to follow:

3.3.1 Prioritize safety

High voltage chambers pose substantial risks, making safety a top priority. Ensured that the design conforms with all applicable safety standards and laws. To implement adequate safety measures, we worked with electrical engineers and high voltage system experts.

3.3.2 Insulation

Adequate insulating materials were used to prevent electrical leakage and to sustain high voltages. Ceramics, glass, and specific polymers intended for high voltage applications are popular materials.

3.3.3 Enclosure Design

Constructed a robust enclosure using non-conductive materials like fiberglass or reinforced plastics. This enclosure should safely contain high voltages and allow for easy maintenance and testing access.

3.3.4 Grounding

Established a reliable grounding system to ensure safety and protect against electrical faults. Adhere to electrical codes and standards when implementing grounding to mitigate electrical hazards.

3.3.5 Voltage Generation and Regulation

Employed a reliable high voltage generation system capable of producing the desired voltage levels. This typically involves transformers, capacitors, and voltage regulators. Consult electrical engineers to design a system suitable for your specific requirements.

3.3.6 Control and Monitoring Systems

Implemented an effective control and monitoring system to manage the high voltage chamber. This includes control panels, safety interlocks, voltage measurement devices, and automated systems for monitoring and adjusting voltage levels.

3.3.7 Ventilation and Cooling

Account for heat dissipation by providing proper ventilation and cooling systems. High voltage operations generate heat, so they employ fans, heat sinks, or air conditioning systems to maintain optimal operating temperatures.

3.3.8 Access and Safety Interlocks

Installed safety interlocks that prevent access to the energized high voltage chamber. This prevents accidental entry during operation and safeguards personnel from potential electrical hazards.

3.3.9 Emergency Shutdown Procedures

Established clear emergency shutdown procedures and prominently display emergency stop buttons or switches near the chamber. This allows for immediate deactivation of the high voltage system in case of safety concerns or emergencies.

Chapter Four

4 KEY COMPONENTS OF HIGH VOLTAGE CHAMBER

4.1 High voltage power supply

It is essential to have a power source that can produce the necessary voltage in order to properly evaluate and age electrical components in a high voltage aging chamber. This power supply needs to be especially designed to manage high voltages in a reliable and safe way.

4.2 Temperature control system

A high voltage aging chamber's temperature control system is intended to regulate and maintain the temperature within a certain range so that aging tests on high voltage equipment can be carried out. The purpose of the aging chamber is to evaluate the performance and longevity of electrical components over an extended period of time by simulating harsh environmental conditions.

The following are the main elements and characteristics that are typically present in a temperature control system for a high voltage aging chamber:

4.2.1 Temperature Sensors

To precisely track the temperature at various areas within the chamber, a variety of temperature sensors, such as thermocouples or resistance temperature detectors (RTDs), are strategically positioned. We have used a DHT11 sensor inside our chamber. DHT11 sensors are used to detect temperature.

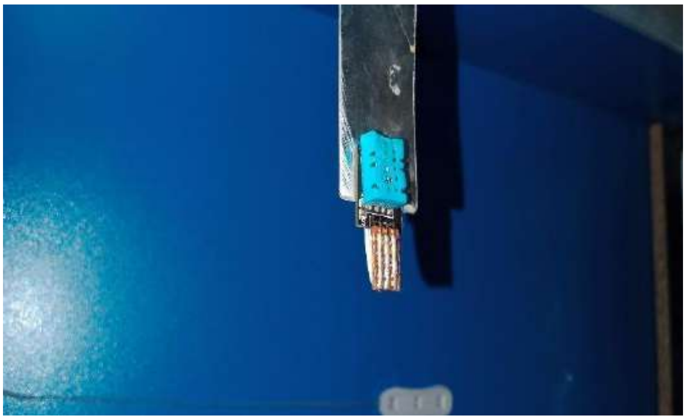

Figure 4- 1: DHT11 Sensor for Temperature

4.2.2 Control Unit

A central control unit here temperature control system is responsible for receiving data from the sensors and comparing it with the desired set point. It then adjusts the chamber's environmental conditions to achieve and maintain the desired temperature level. At the end LCD can show readings.

4.2.3 Heating and Cooling elements

In chamber heating and cooling elements are being located to detect temperature. Heating elements, such as electric resistive heaters, can be activated to increase the temperature upto 100 degree celsius, while on the other hand compressors are used to increase temperature upto minus (-) 10 degree celsius.

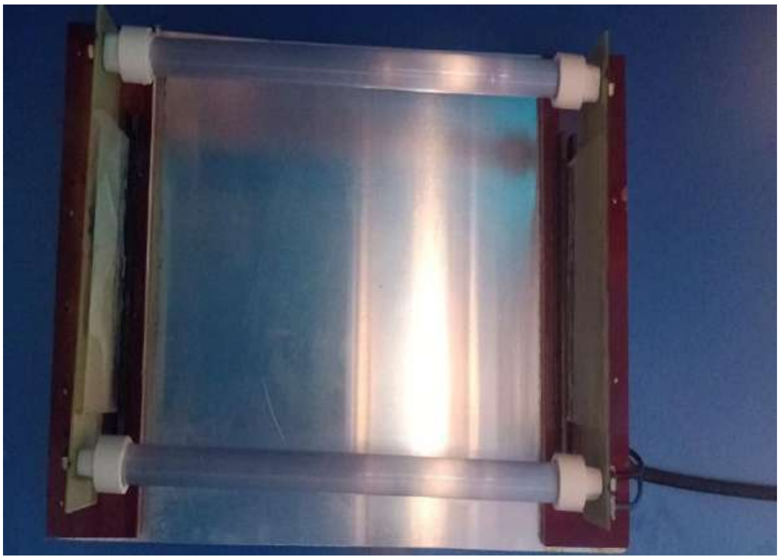

Figure 4- 2: Heating Rod

Figure 4- 3: Danfoss 6780 compressor for cooling

Figure 4- 4: Cooling condenser evaporator filter copper piper

4.2.4 Insulation

Insulation materials are employed to minimize heat transfer between the chamber and its surroundings in order to maintain a steady temperature within the chamber. This reduces the impact of external temperature variations on the inside environment.

Figure 4-5: Wooden Sheet and Aluminium Coil

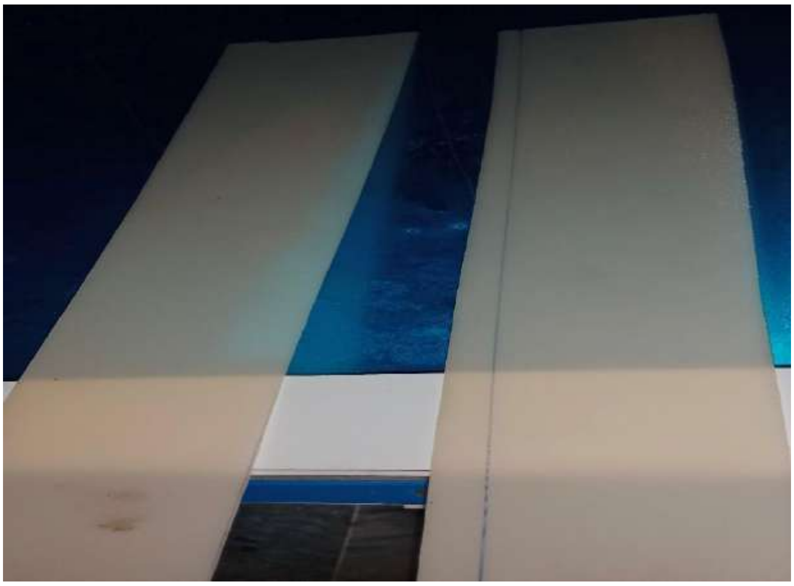

Figure 4-6: Plexiglass

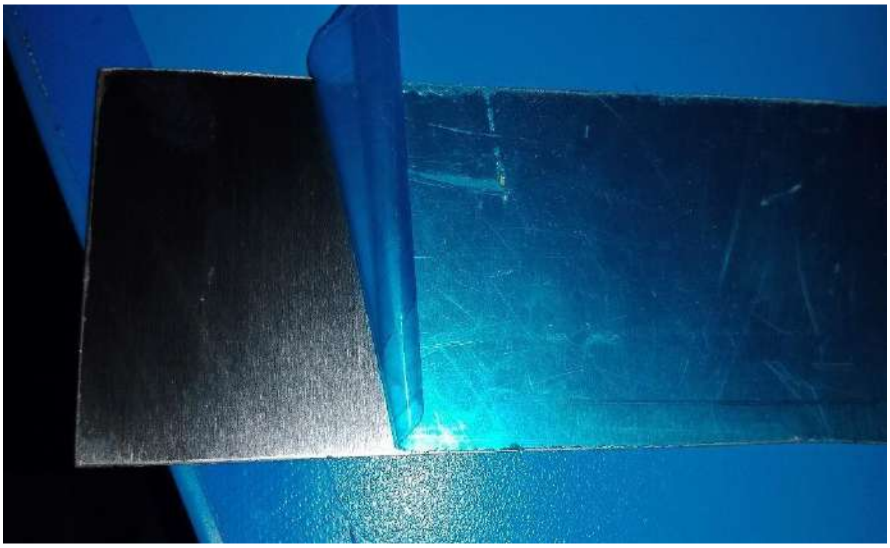

Figure 4-7: Multi-Layer Aluminum sheet

4.2.5 Air Circulation

An effective air circulation system ensures the temperature is evenly distributed throughout the chamber. Fans can be used to move the air and help to achieve consistent temperatures across different areas of the chamber. Fans are also used to provide cool air to the compressor so to achieve cool temperature more efficiently.

Figure 4- 8: Air Circulation Fan

4.2.6 Safety Mechanism

To prevent any overheating or temperature-related issues, safety mechanisms are being installed inside the chamber. These may include temperature limit switches, emergency shutdown systems, good insulation which can bear overheating, or alarms to alert operators if the temperature exceeds safe limits.

Figure 4- 9: Emergency Shutdown Breaker

4.2.7 User Interface

A user-friendly interface allows operators to set and monitor the desired temperature parameters, view real-time temperature data, and adjust settings as necessary. Chamber can be controlled manually or by App. The app used to control and monitor readings is the Blynk App.

Figure 4- 10: Blynk App

4.2.8 Data Logging and Monitoring

The temperature control system may include data logging and monitoring capabilities to record temperature profiles over time. This data can be analyzed later for performance evaluation or to ensure compliance with testing standards.

Figure 4- 11: Data Monitoring

Figure 4- 12: LCD

4.3 Humidity Control System

Controlling humidity is critical in a high voltage aging chamber to ensure optimal conditions for testing and aging electrical components. High humidity levels can cause corrosion and impair the performance of certain components. Here are some critical considerations for installing a humidity management system in a high voltage aging chamber:

4.3.1 Humidifier

Install a humidifier to bring moisture into the room. Humidifiers come in a variety of styles, including steam humidifiers, ultrasonic humidifiers, and evaporative humidifiers. Select a humidifier based on the size of the chamber and the level of humidity control desired.

4.3.2 Dehumidifier

When necessary, use a dehumidifier to remove excess moisture from the chamber. Dehumidifiers can assist keep humidity levels within a comfortable range and prevent condensation. Again, choose a dehumidifier that is appropriate for the size of the chamber and its humidity management requirements.

4.3.3 Humidity sensors

Install a humidity sensor or hygrometer to monitor the humidity levels inside the chamber. This sensor will provide real-time data on the humidity, allowing you to adjust the humidifier and dehumidifier settings accordingly. DHT11 sensors are being used to sense humidity inside the chamber.

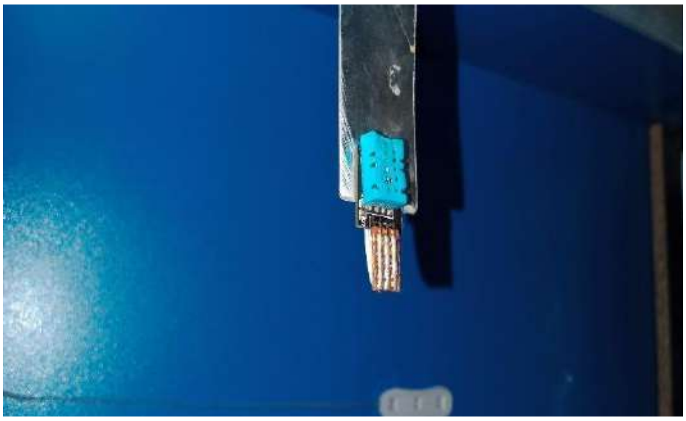

Figure 4- 13: DHT11 Sensor for Humidity

4.3.4 Control System

Implement a control system that incorporates the humidifier, dehumidifier, and humidity sensor. This technology will allow for automated humidity control based on preset settings. It can be configured to maintain a certain humidity range or to follow a predefined humidity profile for testing purposes.

4.3.5 Air Circulation

Maintain adequate air circulation within the chamber to ensure even humidity distribution. Proper air circulation keeps humidity levels consistent throughout the aging chamber and prevents localized humidity changes.

Figure 4- 14: Air Circulation Fan

4.3.6 Condensation Prevention

Prevent condensation on high voltage components or surfaces. To avoid condensation-related concerns, use insulation materials, adequate ventilation, and temperature and humidity management.

4.3.7 Maintenance and Calibration

Maintain and calibrate the humidity control system on a regular basis to ensure accurate readings and optimal performance. Follow the manufacturer's maintenance, filter replacement, and calibration instructions.

4.4 Control of UV intensity

In most cases, adjusting the UV light source or using a proper UV filter is required to manage the UV intensity in a high voltage aging chamber. Here are a few strategies for controlling UV intensity that are regularly used:

4.4.1 Adjustable UV light source

Install a UV lamp or light source with adjustable intensity. This could be accomplished with a variable-power bulb or a dimming system. You can change the intensity of the emitted UV light by adjusting the power supplied to the UV bulb.

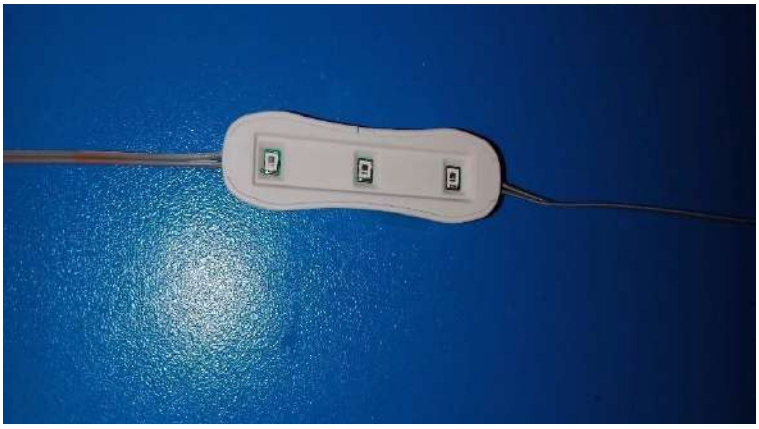

Figure 4- 15: UV light adjust the intensity

4.4.2 Distance and Exposure time

The strength of UV radiation reduces as you travel away from the UV source. You can indirectly alter the UV intensity by varying the distance between the UV light source and the thing being aged. You may also control the length of time the object is exposed to UV light. Longer exposure times result in greater cumulative UV intensity.

4.4.3 Light Modifiers

Use light modifiers such as diffusers or reflectors to evenly distribute UV light within the aging chamber. These modifiers can help to prevent isolated high-intensity zones, resulting in more uniform UV radiation exposure.

4.4.4 UV Sensors and Control system

UV sensors and controllers can be used to monitor and maintain the desired UV intensity levels. UV sensors can monitor the intensity of UV radiation, and controllers can change the power provided to the UV lamp based on the sensor data. This closed-loop technology aids in maintaining a steady UV intensity throughout the aging process.

Chapter Five

5 TESTING AND RESULTS

Before operational use, subject the high voltage aging chamber to rigorous testing and certification by qualified electrical engineers or testing organizations. This ensures compliance with safety requirements and verifies reliable performance under high voltage conditions.

5.1 Test Setup

Using thermal stress at 180C and 1000h, the accelerated aging of polymeric insulators is studied. After looking into how UV aging affects insulators, the experience is completed. The break down voltages are used to assess both during and after the accelerated thermal ageing test the polymeric insulator's electrical performance.

5.2 Results of Inclined Plane Test without Filler

Table 5-1: IPTWOF sample 1 breakdown voltages

S. No	Breakdown Voltages
1	10.87 KV
2	11.47 KV
3	13.89 KV

Average Value = 12.07 KV

Table 5-2: IPTWOF sample 2 breakdown voltages

S. No	Breakdown Voltages
1	14.01 KV
2	14.92 KV
3	15.82 KV

Average Value = 14.916 KV

Table 5-3: IPTWOF sample 3 breakdown voltages

S. No	Breakdown Voltages
1	16.467 KV
2	16.944 KV
3	17.243 KV

Average Value = 16.88 KV

Figure 5- 1:Insulator without filler

5.2.1 Results of Inclined Plane Test with Filler (Aluminum Oxide)

Table 5-4: IPTWF Al_2O_3 sample 1 breakdown voltages

S. No	**Breakdown Voltages**
1	13.560 KV
2	17.264 KV
3	12.755 KV

Average Value = 14.524 KV

Table 5-5: IPTWF Al_2O_3 sample 2 breakdown voltages

S. No	**Breakdown Voltages**
1	11.297 KV
2	13.627 KV
3	15.108 KV

Average Value = 13.344 KV

Table 5-6: IPTWF Al_2O_3 sample 3 breakdown voltages

S. No	**Breakdown Voltages**
1	12.270 KV
2	13.661 KV
3	13.027 KV

Average Value = 12.986 KV

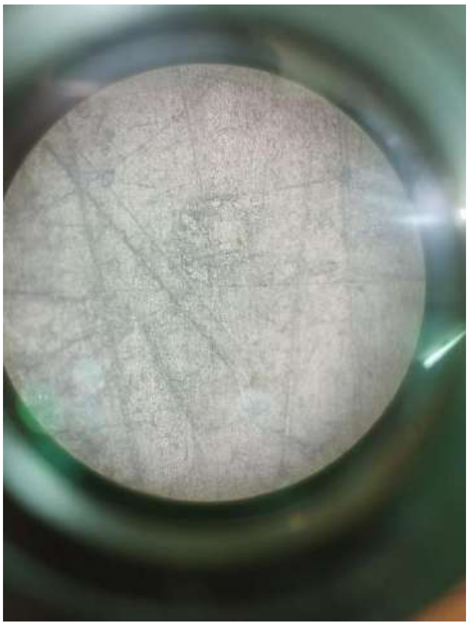

Figure 5- 2:Insulator with filler aluminum oxide

5.2.2 Results of Inclined Plane Test with Filler (Zinc Oxide)

Table 5-7: IPTWF ZnO sample 1 breakdown voltages

S. No	Breakdown Voltages
1	12.982 KV
2	14.054 KV
3	15.569 KV

Average Value = 14.201 KV

Table 5-8: IPTWF ZnO sample 2 breakdown voltages

S. No	Breakdown Voltages
1	14.884 KV
2	17.609 KV
3	16.435 KV

Average Value = 16.309 KV

Table 5-9: IPTWF ZnO sample 3 breakdown voltages

S. No	Breakdown Voltages
1	11.746 KV
2	13.150 KV
3	10.982 KV

Average Value = 11.959 KV

Figure 5- 3:Insulator with filler zinc oxide

Table 5-10: Comparison between average breakdown voltages of each sample

Sample No	**Average Value without Filler**	**Average Value with Filler (Al_2O_3)**	**Average Value with Filler (ZnO)**
Sample 1	12.07 KV	14.524 KV	14.201 KV
Sample 2	14.91 KV	13.344 KV	16.309 KV
Sample 3	16.88 KV	12.986 KV	11.959 KV

5.3 All Results of Thermal Ageing Test

5.3.1 Results of Thermal Ageing Test without Filler

Table 5-11: TATWOF sample 1 breakdown voltages

S. No	**Breakdown Voltages**
1	7.92 KV
2	8.45 KV
3	10.75 KV

Average Value = 9.04 KV

Table 5-12: TATWOF sample 2 breakdown voltages

S. No	**Breakdown Voltages**
1	11.13 KV
2	12.39 KV
3	13.95 KV

Average Value = 12.49 KV

Table 5-13: TATWOF sample 3 breakdown voltages

S. No	**Breakdown Voltages**
1	13.414 KV
2	13.941 KV
3	14.214 KV

Average Value = 13.856 KV

5.3.2 Results of Thermal Ageing Test with Filler (Aluminum Oxide)

Table 5-14: TATWF Al_2O_3 sample 1 breakdown voltages

S. No	**Breakdown Voltages**
1	12.460 KV
2	16.264 KV
3	11.431 KV

Average Value = 13.385 KV

Table 5-15: TATWF Al_2O_3 sample 2 breakdown voltages

S. No	**Breakdown Voltages**
1	10.292 KV
2	12.881 KV
3	14.191 KV

Average Value = 12.454 KV

Table 5-16: TATWF Al_2O_3 sample 3 breakdown voltages

S. No	Breakdown Voltages
1	11.240 KV
2	12.642 KV
3	11.029 KV

Average Value = 11.637 KV

4.13.3 Results of Thermal Ageing Test with Filler (Zinc Oxide)

Table 5-17: TATWF ZnO sample 1 breakdown voltages

S. No	Breakdown Voltages
1	11.891 KV
2	13.014 KV
3	14.529 KV

Average Value = 13.144 KV

Table 5-18: TATWF ZnO sample 2 breakdown voltages

S. No	Breakdown Voltages
1	13.541 KV
2	16.781 KV
3	15.419 KV

Average Value = 15.247 KV

Table 5-19: TAT WF ZnO sample 3 breakdown voltages

S. No	**Breakdown Voltages**
1	10.426 KV
2	12.149 KV
3	9.982 KV

Average Value = 10.852 KV

Table 5-20: Comparison between results of each sample after thermal ageing

Sample No	**Average Value without Filler**	**Average Value with Filler (Al_2O_3)**	**Average Value with Filler (ZnO)**
Sample 1	9.04 KV	13.385 KV	13.144 KV
Sample 2	12.49 KV	12.454 KV	15.247 KV
Sample 3	13.856 KV	11.637 KV	10.852 KV

Chapter Six

6 RECENT ADVANCEMENTS AND RESEARCH TRENDS

A high voltage aging chamber, also known as a high voltage test chamber or a high voltage laboratory, is a controlled environment used for testing and evaluating the performance and aging characteristics of high voltage equipment and components. These chambers are crucial for ensuring the reliability and safety of high voltage systems.

Recent advancements and research trends in the construction of high voltage aging chambers have focused on several key considerations. This includes:

6.1 Insulation and shielding

High voltage chambers require robust insulation and shielding to prevent electrical breakdown and minimize electromagnetic interference. Some Recent advancements focus on the development of advanced insulating materials and techniques that offer improved performance and durability.

6.2 Voltage and current capabilities

High voltage aging chambers are designed to handle a wide range of voltages and currents. Recent trends involve increasing the maximum voltage and current capabilities to accommodate higher voltage systems and emerging technologies efficiently.

6.3 Environmental control

Maintaining a controlled environment is essential for accurate high voltage aging tests. Chambers are equipped with sophisticated temperature and humidity control systems to simulate real-world conditions. Advancements in this area include improved environmental control systems that offer higher precision and stability efficiently

6.4 Diagnostic and monitoring systems

High voltage aging chambers incorporate advanced diagnostic and monitoring systems to assess the performance and condition of test specimens. Recent research focuses on developing non-destructive testing techniques, such as partial discharge detection and ultrasonic testing, to evaluate insulation integrity and detect potential faults.

6.5 Safety features

Safety is a paramount concern in high voltage testing. Chambers are equipped with various safety features, such as interlocks, grounding systems, and emergency shutdown mechanisms. Ongoing research aims to enhance safety measures, including the development of advanced protective devices and automated safety protocols.

6.6 Automation and remote operation

To improve efficiency and convenience, there is a growing trend towards automation and remote operation of high voltage aging chambers. This allows for remote monitoring, control, and data acquisition, enabling researchers to conduct tests without the need for direct physical presence.

6.7 Integration with computer simulation models

High voltage aging chambers are increasingly integrated with computer simulation models, such as finite element analysis (FEA) and computational fluid dynamics (CFD), to enhance the understanding of electrical and thermal behavior. This integration enables more accurate predictions and optimized designs.

Robust insulation and shielding materials and techniques have been developed to prevent electrical breakdown and minimize electromagnetic interference. Chambers have been designed with increased maximum voltage and current capabilities to accommodate higher voltage systems. Sophisticated temperature and humidity control systems have improved environmental control. Advanced diagnostic and monitoring systems, such as partial discharge detection and ultrasonic testing, have been incorporated to evaluate insulation integrity and detect faults. Safety features, including interlocks, grounding systems, and emergency shutdown mechanisms, have been enhanced. Automation and remote operation enable researchers to conduct tests remotely. Integration with computer simulation models, such as finite element analysis (FEA) and computational fluid dynamics (CFD), allows for more accurate predictions and optimized designs.

Chapter Seven

7 IMPACT OF PROJECT ON ENVIRONMENT AND SOCIETY

The impact of a high voltage aging chamber project on the environment and society can vary depending on several factors, including the design, location, and management practices associated with the project. Here are some potential considerations:

7.1 Energy consumption

High voltage aging chambers often need a large amount of energy to operate, particularly when running constantly. Energy derived from nonrenewable sources, such as fossil fuels, can contribute to greenhouse gas emissions and climate change. However, by using renewable energy sources, the environmental effect may be lessened.

7.2 Emissions

High voltage aging chambers may emit pollutants, especially if they employ combustion processes or specific chemicals. These emissions may contribute to air pollution and have a severe impact on the health of local people, especially if effective emission control measures are not implemented.

7.3 Waste generation

The process within high voltage aging chambers may generate waste materials, such as byproducts of insulation breakdown or chemical residues. Proper waste management and disposal are critical for preventing environmental pollution and minimizing any possible threats to human health.

7.4 Noise and visual impact

During operation, high voltage aging chambers can emit noise, which can have an influence on the surrounding environment and local residents. Furthermore, if the project involves large-scale infrastructure, it may have aesthetic consequences, such as changing the landscape or vistas in the region.

7.5 Occupational health and safety

To safeguard personnel, the operation of high voltage aging chambers may need particular expertise and safety procedures. To protect the workforce's well-being, effective training, safety measures, and equipment maintenance are required.

7.6 Stakeholder engagement:

The presence of a high voltage aging chamber project may raise concerns among nearby communities, particularly regarding potential health impacts, noise pollution, or visual disturbances. Engaging with stakeholders through transparent communication and addressing their concerns can help build trust and minimize social conflicts.

7.7 Research and development

On the plus side, high voltage aging chamber projects can contribute to technical improvements and research in electrical engineering, insulation materials, and related sectors. These advancements may result in enhanced electrical equipment and systems, increasing efficiency, dependability, and safety in a variety of sectors.

To properly analyze the impact of a given high voltage aging chamber project, a detailed environmental impact study, community involvement, and adherence to applicable legislation and standards are required. Furthermore, implementing mitigating measures such as using renewable energy sources, deploying effective insulation systems, and ensuring adequate waste management can help limit negative effects on the environment and society.

Chapter Eight

8 CONCLUSION

The development of a high voltage aging chamber can have an influence on both the environment and society. It is critical to properly manage these repercussions in order to achieve a sustainable and responsible project. Environmental issues include effective energy consumption, emissions, and waste production management, with an emphasis on using renewable energy sources and adopting adequate waste management and emission control techniques. To create trust and avoid social tensions, community involvement is essential throughout the building process, incorporating local communities and stakeholders, resolving concerns, giving transparent information, and involving the community in decision-making. Occupational health and safety measures, such as sufficient training, safety standards, and equipment maintenance, must be in place to safeguard workers' well-being. High voltage aging chamber projects contribute to scientific developments in electrical engineering and associated sectors, resulting in enhanced electrical equipment and systems that help many industries in terms of efficiency, dependability, and safety. Conducting a full environmental impact assessment, following norms and standards, and applying mitigation measures throughout the building process are critical to optimizing good results and minimizing negative consequences. The building of a high voltage aging chamber may be done ethically and sustainably if these aspects are considered and suitable procedures are implemented.

8.1 FUTURE DIRECTIONS

The construction of a high-voltage aging chamber poses several challenges and opportunities for future work. Here are some key considerations:

8.2.1 Electrical Safety

High-voltage systems present significant safety risks. Ensuring proper insulation, grounding, and protection measures are in place is crucial to safeguard personnel and equipment. Future work could focus on enhancing safety features and developing advanced monitoring systems to detect potential faults or malfunctions.

8.2.2 Voltage and current capabilities

High voltage aging chambers are designed to handle a wide range of voltages and currents. Recent trends involve increasing the maximum voltage and current capabilities to accommodate higher voltage systems and emerging technologies efficiently.

8.2.3 Environmental Control

Aging experiments often require precise control of environmental conditions, including temperature, humidity, and atmospheric gasses. Designing chambers with efficient and reliable environmental control systems is essential for accurate and repeatable testing. Future works could focus on optimizing environmental control mechanisms, developing automated systems, and integrating sensors for real-time monitoring.

8.2.4 Sample Handling and Configuration

The arrangement and positioning of samples within the aging chamber can influence the results and reliability of the experiments. Future work may involve developing innovative sample holders, fixtures, and positioning systems to enable better control and manipulation of test specimens. Automation and robotics could also play a role in optimizing sample handling processes.

8.2.5 Data Acquisition and Analysis

High-voltage aging experiments generate a vast amount of data, including electrical measurements, environmental parameters, and sample characteristics. Efficient data acquisition, storage, and analysis techniques are necessary to extract meaningful insights from these experiments. Future works could explore advanced data acquisition systems, data fusion algorithms, and machine learning approaches to enhance data interpretation and decision-making.

8.2.6 Standardization and Collaboration

Establishing common standards and protocols for high-voltage aging experiments would promote comparability and reproducibility of results across different research groups and industries. Collaborative efforts could focus on developing standardized test procedures, benchmarking studies, and sharing best practices to advance the field collectively.

8.2.7 Advanced Diagnostics and Monitoring

Aging chambers could benefit from advanced diagnostic techniques to detect and assess degradation in electrical insulation and other components. Future work might involve integrating online monitoring systems, such as partial discharge detection, insulation resistance measurement, and gas analysis, to enable early fault detection and predictive maintenance.

8.2.8 Multi-Stress Aging

Real-world operating conditions often involve multiple stress factors, such as electrical, thermal, mechanical, and environmental stresses. Designing aging chambers that can simulate and apply multiple stressors simultaneously would provide more realistic aging conditions. Future research could explore the development of multi-stress aging chambers and investigate the synergistic effects of various stress factors on the aging process.

8.2.9 Materials and Insulation Research

High-voltage aging chambers rely on advanced insulation materials to ensure reliable performance. Future work may involve exploring new materials, such as nanocomposites, bio-based insulators, or eco-friendly alternatives, to improve insulation properties, reduce environmental impact, and enhance the overall efficiency and sustainability of aging chambers.

8.2.10 Integration of Renewable Energy Sources

With the increasing focus on sustainability, integrating renewable energy sources into high-voltage aging chambers could be a promising future direction. This could involve incorporating solar panels, wind turbines, or energy storage systems to reduce dependence on conventional power sources and minimize the environmental footprint of aging experiments.

Overall, the construction of high-voltage aging chambers requires interdisciplinary efforts, combining expertise from electrical engineering, materials science, environmental control, and data analysis. Addressing these challenges and exploring future directions can contribute to the advancement of aging research and facilitate the development of more reliable and efficient high-voltage systems.

Chapter Nine

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APPENDICES

```
#define BLYNK_TEMPLATE_ID "TMPL6t9HKmew6"

#define BLYNK_TEMPLATE_NAME "myproject"

#define BLYNK_AUTH_TOKEN "4gDXPhJKMsDOxv3e9Ak5YWikocoQVO6K"

#define BLYNK_PRINT Serial

#include <ESP8266WiFi.h>

#include <BlynkSimpleEsp8266.h>



#include <DHT.h>

#include <LiquidCrystal_I2C.h>

char auth[] = BLYNK_AUTH_TOKEN;

char ssid[] = "Myproject";

char pass[] = "myproject1234";

//int relay1_state = 0;

int relay2_state = 0;

int relay3_state = 0;

int relay4_state = 0;

unsigned long firstaction=millis();

#define temp1 D8
```

```
#define temp2 3

//#define button1_pin D5

#define button2_pin D3

#define button3_pin D4

#define button4_pin 10

//#define relay1_pin D5

#define relay2_pin D6

#define relay3_pin D7

#define relay4_pin 1

#define dht1on 9

#define dht2on D5

DHT dht1(temp1, DHT11);

DHT dht2(temp2, DHT11);

LiquidCrystal_I2C lcd(0x27, 20, 4);



BlynkTimer timer;



// Change the virtual pins according the rooms

//#define button1_vpin    V3

#define button2_vpin    V4

#define button3_vpin    V5
```

```
#define button4_vpin    V6


//----------------------------------------------------------------------------------------------------------
// This function is called every time the device is connected to the Blynk.Cloud
// Request the latest state from the server
BLYNK_CONNECTED() {
 // Blynk.syncVirtual(button1_vpin);
  Blynk.syncVirtual(button2_vpin);
  Blynk.syncVirtual(button3_vpin);
  Blynk.syncVirtual(button4_vpin);
}


//----------------------------------------------------------------------------------------------------
// This function is called every time the Virtual Pin state change
/*i.e when web push switch from Blynk App or Web Dashboard
BLYNK_WRITE(button1_vpin) {
  relay1_state = param.asInt();
  digitalWrite(relay1_pin, relay1_state);
  if (relay1_state == 0) {
      lcd.setCursor(0, 2);
  lcd.print("HR---OFF");
  } else {
```

```
        lcd.setCursor(0, 2);
  lcd.print("HR--- ONN");
  }
}
*/
//----------------------------------------------------------------------------------------------------------------
BLYNK_WRITE(button2_vpin) {
  relay2_state = param.asInt();
  digitalWrite(relay2_pin, relay2_state);
  if (relay2_state == 0) {
       lcd.setCursor(12, 2);
  lcd.print("CR--- OFF");
  } else {

        lcd.setCursor(12, 2);
  lcd.print("CR--- ONN");
  }
}
//----------------------------------------------------------------------------------------------------------------
BLYNK_WRITE(button3_vpin) {
  relay3_state = param.asInt();
  digitalWrite(relay3_pin, relay3_state);
  if (relay3_state == 0) {
```

```
      lcd.setCursor(0, 3);
  lcd.print("UV LIGHT OFF");
  } else {


       lcd.setCursor(0, 3);
  lcd.print("UV LIGHT ONN");
  }


}
//------------------------------------------------------------------------------------------------------
BLYNK_WRITE(button4_vpin) {
  relay4_state = param.asInt();
  digitalWrite(relay4_pin, relay4_state);
  if (relay4_state == 0) {
      lcd.setCursor(0, 2);
  lcd.print("HR--- OFF");
  } else {


       lcd.setCursor(0, 2);
  lcd.print("HR--- ONN");
  }


}
```

```
void setup()
{
  // Debug console
  Serial.begin(115200);
  lcd.begin();
  lcd.backlight();
  dht1.begin();
  dht2.begin();
  //------------------------------------------------------------------------------------
 // pinMode(button1_pin, INPUT_PULLUP);
  pinMode(button2_pin, INPUT_PULLUP);
  pinMode(button3_pin, INPUT_PULLUP);
  pinMode(button4_pin, INPUT_PULLUP);

  //------------------------------------------------------------------------------------
 // pinMode(relay1_pin, OUTPUT);
  pinMode(relay2_pin,  OUTPUT);
  pinMode(relay3_pin,  OUTPUT);
  pinMode(relay4_pin,  OUTPUT);
  pinMode(dht1on,  OUTPUT);
  pinMode(dht2on,  OUTPUT);
  digitalWrite(dht1on,  LOW);
```

```
   digitalWrite(dht2on, LOW);
 //-----------------------------------------------------------------------------------
 // During Starting all Relays should TURN OFF
 //digitalWrite(relay1_pin, HIGH);
digitalWrite(relay2_pin, HIGH);
digitalWrite(relay3_pin, HIGH);
digitalWrite(relay4_pin, HIGH);
lcd.setCursor(0, 2);
 lcd.print("HR--- OFF");
 lcd.setCursor(12, 2);
 lcd.print("CR--- OFF");
 lcd.setCursor(0, 3);
 lcd.print("UV LIGHT OFF");



 //-----------------------------------------------------------------------------------
 Blynk.begin(auth, ssid, pass);
 // You can also specify server:
 //Blynk.begin(auth, ssid, pass, "blynk.cloud", 80);
 //Blynk.begin(auth, ssid, pass, IPAddress(192,168,1,100), 8080);
 //-----------------------------------------------------------------------------------
 //Blynk.virtualWrite(button1_vpin, relay1_state);
 //Blynk.virtualWrite(button2_vpin, relay2_state);
```

```
  //Blynk.virtualWrite(button3_vpin, relay3_state);
  //Blynk.virtualWrite(button4_vpin, relay4_state);
  //---------------------------------------------------------------------------
}

void loop()
{
  Blynk.run();
  timer.run();
   listen_push_buttons();
  float h1 = dht1.readHumidity();
 delay(100);
  float t1 = dht1.readTemperature();

unsigned long currentMillis = millis();
if (currentMillis-firstaction >= (5000))
{
  digitalWrite(dht1on, HIGH);
  digitalWrite(dht2on, HIGH);
  }



  lcd.setCursor(0, 0);
```

```
 lcd.print("HT: ");
lcd.print(t1);
lcd.setCursor(7, 0);
lcd.print("'C");



 lcd.setCursor(11, 0);
lcd.print("Hum: ");
lcd.print(h1);
lcd.setCursor(19, 0);
lcd.print("%");



float h2 = dht2.readHumidity();
delay(100);
 float t2 = dht2.readTemperature();
 lcd.setCursor(0, 1);
 lcd.print("CT: ");
 lcd.print(t2);
lcd.setCursor(7, 1);
lcd.print("'C");
```

```
Blynk.virtualWrite(V0, t1);

Blynk.virtualWrite(V1, t2);

Blynk.virtualWrite(V2, h1);


if (t1 >= 100) {

digitalWrite(relay4_pin, LOW);

Blynk.virtualWrite(V3, relay4_pin);



         lcd.setCursor(0, 2);

  lcd.print("HR---ONN");

 }

if (t2 <= -10) {

digitalWrite(relay2_pin, LOW);

Blynk.virtualWrite(V4, relay2_pin);

        lcd.setCursor(12, 2);

  lcd.print("CR---ONN");

 }
```

```
}


void listen_push_buttons(){


  /*if(digitalRead(button1_pin) == LOW){

    delay(200);

    control_relay(1);

    Blynk.virtualWrite(button1_vpin, relay1_state); //update button state


   }

   */

   //-------------------------------------------------------------------------------------------------------

    if (digitalRead(button2_pin) == LOW){

    delay(200);

    control_relay(2);

    Blynk.virtualWrite(button2_vpin, relay2_state); //update button state


   }

   //-------------------------------------------------------------------------------------------------------

   else if (digitalRead(button3_pin) == LOW){

    delay(200);

    control_relay(3);
```

```
      Blynk.virtualWrite(button3_vpin, relay3_state); //update button state




    }
    //-----------------------------------------------------------------------
     else if (digitalRead(button4_pin) == LOW){
      delay(200);
      control_relay(4);
      Blynk.virtualWrite(button4_vpin, relay4_state); //update button state




    }
    //-----------------------------------------------------------------------
}
// MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
MMMMMMMM
```

```
// MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
MMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMMM
MMMMMMMMM

void control_relay(int relay){


  /*

  if(relay == 1){

    relay1_state = !relay1_state;

    digitalWrite(relay1_pin, relay1_state);

    if (relay1_state == 0) {

        lcd.setCursor(0, 2);

  lcd.print("HR---OFF");

  } else {



         lcd.setCursor(0, 2);

  lcd.print("HR---ONN");

  }

    delay(50);

  }

  */

  //------------------------------------------------------------------------

  if(relay == 2){

    relay2_state = !relay2_state;
```

```
  digitalWrite(relay2_pin, relay2_state);
  if (relay2_state == 0) {
      lcd.setCursor(12, 2);
lcd.print("CR--- OFF");
} else {

       lcd.setCursor(12, 2);
lcd.print("CR--- ONN");
}

  delay(50);
}
//--------------------------------------------------------------------------
else if(relay == 3){
  relay3_state =!relay3_state;
  digitalWrite(relay3_pin, relay3_state);
  if (relay3_state == 0) {
      lcd.setCursor(0, 3);
lcd.print("UV LIGHT OFF");
} else {

       lcd.setCursor(0, 3);
lcd.print("UV LIGHT ONN");
```

```
  }


    delay(50);

  }

  //--------------------------------------------------------------------

  else if(relay == 4){

    relay4_state =!relay4_state;

    digitalWrite(relay4_pin, relay4_state);

   if (relay4_state == 0) {

        lcd.setCursor(0, 2);

  lcd.print("HR---OFF");

  } else {


         lcd.setCursor(0, 2);

  lcd.print("HR---ONN");

  }


    delay(50);

  }

  //--------------------------------------------------------------------

}
```