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DESIGN AND APPLICATION OF IoT BASED WEATHER STATION FOR HIGH VOLTAGE LABORATORIES

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Keywords

Internet of Things
Weather Station,
High Voltage Measurement,
Spherical Electrodes,
Raspberry Pi.

Abstract

This study presents the design and implementation of an internet of things (IoT) based weather station for high voltage laboratories using the Raspberry Pi 4 Model B and two BME680 sensors. The weather station calculates the relative air density and humidity correction coefficients using the temperature, pressure, and relative humidity data obtained from the sensors. The study investigates the effect of the constant and real-time calculation of these coefficients on the measurement of AC, DC and lightning breakdown voltage using spherical electrodes. Measurements were performed within a laboratory setting for a period of 12 hours, and the obtained results were subsequently compared. The findings reveal that the real time calculation of the correction coefficients leads to a reduction in measurement errors. The study also includes the development of a web-based user interface using HTML and CSS, which is hosted on the Raspberry Pi 4 using the Flask web framework. This interface allows users to access the weather station data from any device with a web browser and provides real-time monitoring of the current coefficients, as well as the capability to calculate actual parameters online.

YÜKSEK GERİLİM LABORATUVARLARI İÇİN IoT TABANLI HAVA İSTASYONU TASARIMI VE UYGULAMASI

Anahtar Kelimeler

Nesnelerin İnterneti,
Hava İstasyonu,
Yüksek Gerilimde Ölçme,
Küresel Elektrotlar,
Raspberry Pi.

Öz

Bu çalışma, Raspberry Pi 4 Model B ve iki adet BME680 sensör kullanılarak yüksek gerilim laboratuvarları için nesnelerin interneti (IoT) tabanlı bir hava istasyonunun tasarımını ve uygulamasını sunmaktadır. Hava istasyonu, sensörlerden elde edilen sıcaklık, basınç ve bağıl nem verilerini kullanarak bağıl hava yoğunluğunu ve nem düzeltme katsayılarını hesaplamaktadır. Çalışma, bu katsayıların sabit ve gerçek zamanlı hesaplanmasının, küresel elektrotlar kullanılarak ölçülen AC, DC ve yıldırım delinme gerilimi üzerindeki etkisini araştırmaktadır. Laboratuvar ortamında 12 saat boyunca ölçümler gerçekleştirilmiş ve sonrasında sonuçlar karşılaştırılmıştır. Bulgular, düzeltme katsayılarının anlık hesaplanmasının ölçme hatalarını önemli ölçüde azalttığını göstermektedir. Çalışma ayrıca Flask web çerçevesi kullanılarak Raspberry Pi 4 üzerinde barındırılan HTML ve CSS kullanılarak web tabanlı bir kullanıcı ara yüzünün geliştirilmesini de içermektedir. Bu ara yüz, kullanıcıların bir web tarayıcısı ile herhangi bir cihazdan hava istasyonu verilerine erişmesine olanak tanımakta ve mevcut katsayıların gerçek zamanlı izlenmesinin yanı sıra gerçek parametreleri çevrimiçi olarak hesaplama imkanı sağlamaktadır.

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Highlights

- IoT based weather station is an practical tool for real-time measurement of ambient conditions.
- Real time calculation of correction factors increase measurement accuracy in HV measurement.
- Designing a user interface enables real-time remote monitoring of ambient conditions.

Graphical Abstract

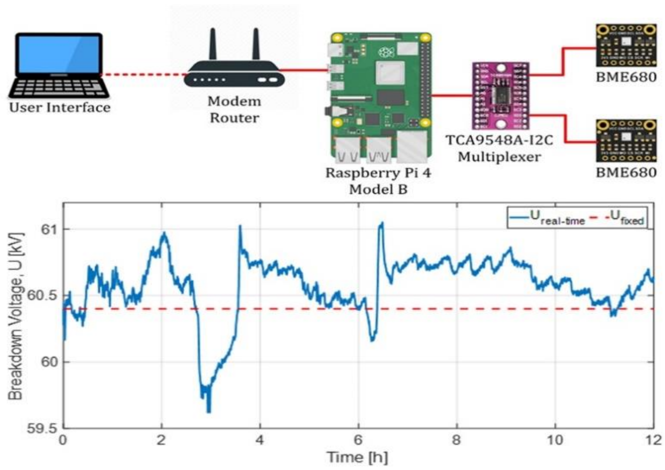

Figure. Graphical Abstract

Purpose and Scope

The objective of this study is to demonstrate that employing an IoT-based weather station to perform real-time calculation of correction coefficients used in HV measurements can effectively reduce measurement errors.

Design/methodology/approach

The weather station includes four hardware units which are one central control (Raspberry Pi 4) unit, one I2C multiplexer (TCA9548A) unit, and two sensor (BME680) units. A 12-hour duration measurement was carried out in the laboratory environment using the IoT-based weather station. The comparative analysis was conducted between real-time and constant correction coefficients. Additionally, a web-based user interface has been developed to enable access to weather station data over the internet, as well as provide real-time monitoring of existing coefficients and the ability to perform online calculation of actual parameters.

Findings

The correction coefficients calculated in real-time by the designed IoT-based weather station resulted in a significant reduction of the relative error observed in AC, DC, and lightning impulse voltage measurements utilizing spherical electrodes.

Practical implications

The weather station developed in this study aids in reducing the error rate in breakdown voltage measurements conducted in high voltage laboratories. Furthermore, the developed web interface facilitates real-time monitoring of ambient conditions and practical computation of correction coefficients.

Originality

The original contributions of this study are the utilization of an IoT-based weather station in high voltage laboratories, the implementation of real-time measurements and calculations to enhance measurement accuracy, and the development of a web interface designed specifically for high voltage laboratories.

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1. Introduction

Weather conditions play a crucial role in many fields of life, such as industry, agriculture, breeding, production, and health. Even small changes in ambient conditions like temperature, humidity, and pressure can have a direct impact on work and measurements. As a result, weather stations have been developed over the years to monitor and forecast weather conditions(Susmitha & Sowya Bala, 2014). These stations typically contain analog or digital sensors that measure temperature, humidity, pressure, wind speed, and solar radiation data. However, the type and number of sensors, as well as the data recording and monitoring methods, vary depending on the application area (Jayasuriya et al., 2018; Purnima & Reddy, 2012; Sulaiman et al., 2019). For example, a weather station design study conducted by (Savic & Radonjic, 2016) utilized Raspberry Pi 3 Model B as the programmable central control unit, DHT11 (temperature and humidity sensor) and BMP180 (pressure and humidity sensor) as sensors. They designed an Android application to monitor the measured temperature, humidity, and pressure information of the environment at the realized weather station via Android devices. In another low-cost Internet of Things (IoT)-enabled weather station design work by (Singh et al., 2020), NodeMCU firmware was used as a programmable central control unit, and Thingspeak Server was used to monitor the measured wind speed, wind direction, temperature, humidity, and pressure information of the environment.

Weather stations also have applications for specific areas or studies in literature such as agricultural activities by (Math & Dharwadkar, 2017), groundwater charge prediction carried out by (Holländer et al., 2016) and applied glaciology research carried out by (Citterio et al., 2015). Additionally, weather stations are extensively employed in laboratories, particularly those dedicated to education, research, and accreditation, as precise measurement accuracy is imperative in these areas (Iswanto et al., 2020). Variations in ambient conditions have the potential to compromise the measurement accuracy of physical quantities, leading to low sensitivity or erroneous measurements. Thus, to ensure high precision, real-time monitoring of ambient conditions is crucial. High voltage (HV) laboratories represent a domain where ambient conditions play a significant role in measurement accuracy(Bruce, 1947). The discharge principle in gases is utilized to measure alternative, direct, and impulse voltages using spherical electrode systems in HV laboratories. The sphere gap technique is considered to be the most dependable method for assessing HV and also serves as a calibration equipment. The measurement apparatus employs a gas-gap, commonly air, separating two metallic spheres, and the applied voltage is gradually increased until a breakdown occurs. The breakdown strength of the gas within the gap is reliant upon a multitude of factors, including the spheres' dimensions, polarity, surface condition and separation distance. In addition, breakdown voltage in a given gap configuration is influenced by the density of the air(Hauschild & Lemke, 2018). Ambient temperature, pressure and humidity directly affect air density and therefore, it is necessary to compensate for any change in the air density by using a weather station. However, utilizing commercial weather stations for collecting ambient condition data may not always be a viable option. While measurement data is typically transmitted to data loggers in such weather stations, such loggers are often not remotely accessible, and require the purchase of a separate communication unit that can transfer data via a GSM/GPRS channel to the manufacturer's website. While the collected data can be accessed via the internet, the option of on-line monitoring may not be available. Furthermore, additional costs may be incurred for GPRS communication and for accessing data through the manufacturer's website. Due to these aforementioned factors, the development of an affordable and open-source weather station that is tailored to meet the specific requirements of users is of significant importance. Moreover, the proposed weather station holds significance in terms of its measurement technique, as it possesses the potential to enhance the accuracy of measurements conducted within high voltage laboratories. The present study involves the development and implementation of an open-source weather station that utilizes Raspberry Pi to enable real-time monitoring of environmental conditions within HV laboratories. The system is equipped with the capability to calculate the relative air density and humidity correction coefficient in real-time. To evaluate the system's performance, measurements were conducted for a duration of 12 hours using the weather station, with the aim of assessing the impact of changes in ambient conditions on laboratory measurements. The findings indicate that measurement error rates are relatively higher when ambient conditions are not measured in real-time. Additionally, a web-based user interface has been developed as part of this study to enable access to weather station data over the internet, as well as provide real-time monitoring of existing coefficients and the ability to perform online calculation of actual parameters. The second section of this study provides a detailed overview of the developed weather station, as well as the measurement technique employed with spherical electrodes. Subsequently, the results obtained from laboratory measurements are presented and analyzed in the third section, while the fourth and final section highlights the key features and contributions of this study.

2. Methodology

In the study, a functional, reliable, and low-cost IoT based weather station design has been carried out using Raspberry Pi 4 Model B with two BME680 (temperature, humudity and pressure) sensors for using in HV laboratories. The Methodology section is organized into three subheadings, namely, weather station, correction coefficients, and user interface design.

2.1 Weather Station

Figure 1 illustrates the schematic diagram of the weather station that has been designed. The weather station includes two BME680 sensors to collect weather data such as temperature, pressure and relative humidity, a TCA9548A I2C multiplexer in order to connect two identical BME680 sensors to Raspberry Pi 4 using a single I2C bus without I2C address confliction and Raspberry Pi 4 to process the BME680 measurement data and host the web-based user interface. To enhance the measurement accuracy, the averaging of temperature, pressure, and humidity data collected from two sensors are presented.

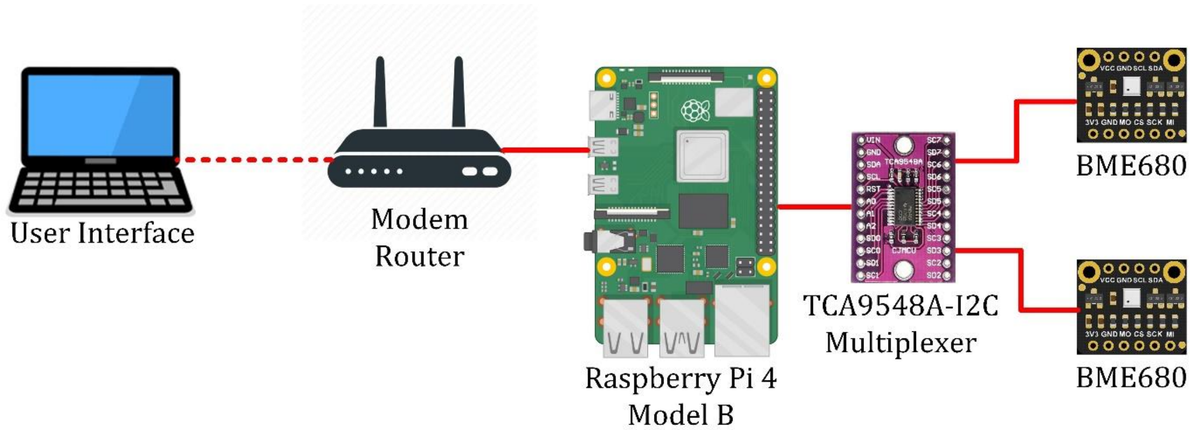


Figure 1. Schematic diagram of designed weather station

The BME680 sensor is a four-in-one digital environmental sensor that measures air quality, temperature, humidity, and barometric pressure. It features a high accuracy and low power consumption, making it suitable for various devices and applications. BME680 sensor incorporates a MEMS (Micro-Electro-Mechanical System) sensor that provides accurate temperature, humidity, and barometric pressure readings. The sensor communicates with microcontrollers and other host devices through the I2C and SPI interfaces, and it features a configurable interrupt system that allows for real-time alerts based on threshold values for any of the measured parameters. BME680 sensor also features a configurable oversampling rate for each of the measured parameters, allowing for a trade-off between accuracy and power consumption. Due to the cost-effectiveness and ease-of-use of the BME680 sensor, it was employed in this investigation for the purpose of monitoring the temperature, pressure and humidity levels within the laboratory environment. The BME sensor family represents a comprehensive set of sensors ideally suited for the targeted application, offering the capability to measure ambient temperature, relative humidity, and barometric pressure. Due to the technical limitations inherent in digital humidity and temperature (DHT) and barometric pressure (BMP) sensor families, employing a single sensor from either family alone is unfeasible for the current application. To fulfill the measurement requirements, it becomes necessary to incorporate an external sensor to supplement DHT or BMP sensor family. While this approach is disregarded in certain applications, it is deemed unfavorable in this study, as it entails an undesirable increase in the size of the sensor board design when multiple sensors are employed. Furthermore, the interaction between sensors, both thermally and electromagnetically, on the sensor board may give rise to measurement errors. Technical specifications of BME680 is given in Table 1 (Gas Sensor BME680, 2023).

Table 1. Technical Specifications of BME680 Sensor

Specifications	Temperature (°C)	Pressure [hPa]	Humidity (%RH)
Operating range	-40 – 85	300 – 1100	0 – 100
Accuracy	±0.5	±0.6	±3
Sensitivity	0.01	0.0018	0.008

In the study, the I2C communication protocol is chosen to connect BME680 sensors to the Raspberry Pi 4. However, in the I2C communication protocol, each device connected to the same I2C bus must have a unique I2C address. Since the two BME680 sensors are identical, both use the 0x77 I2C address by default. Therefore, a TCA9548A I2C multiplexer is used to avoid I2C address conflict. The weather station includes a total of four hardware units which are one central control (Raspberry Pi 4) unit, one I2C multiplexer (TCA9548A) unit, and two sensor (BME680) units. Upon completion of the design phases, the weather station was implemented, and the final version is depicted in Figure 2.

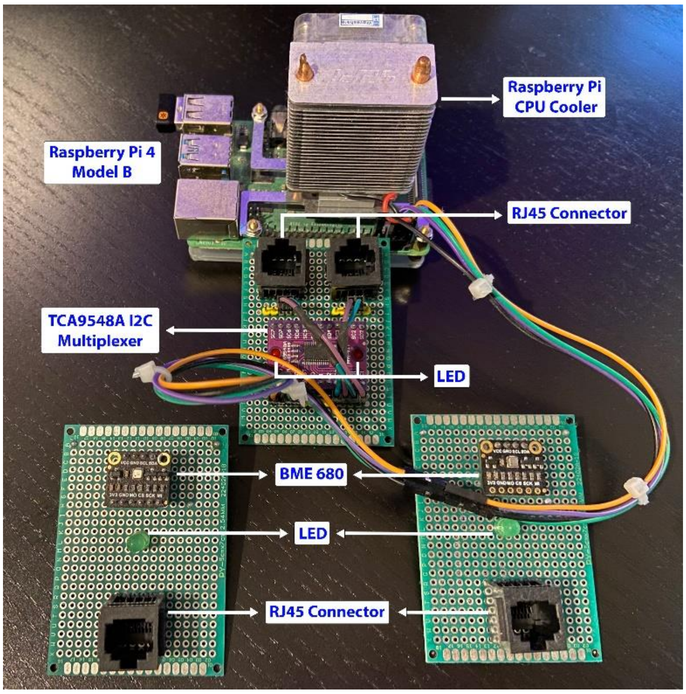


Figure 2. IoT based weather station designed for HV laboratories

2.2 Correction Coefficients

In high voltage engineering, the breakdown voltage of air is an important parameter to determine the performance of insulation systems. The measurement of breakdown voltage is usually performed by applying a gradually increasing voltage to a pair of electrodes until electrical breakdown occurs in the gap between them. The most commonly used electrode configuration for measurement of HVs is sphere-sphere configuration. A typical representation of sphere-sphere electrode in horizontal configuration is given in Figure 3.

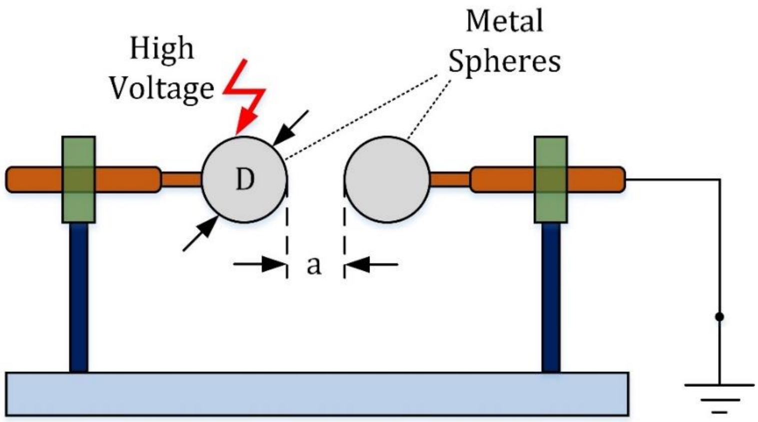


Figure 3. Sphere-sphere electrodes in horizontal configuration with one sphere grounded used for HV measurements

The sphere electrode is preferred over other shapes due to its ability to produce uniform electric fields and reduce surface effects. The measurement of breakdown voltage using a spherical electrode is often used in high voltage testing because it allows for accurate and reliable measurements. The breakdown voltage can be affected by various factors such as the humidity, pressure, and temperature of the air as well as diameter (D) and distance between the spheres (a). Therefore, it is important to measure these environmental parameters accurately and correct the measured values of breakdown voltage for their effects. Breakdown voltage of the gap is calculated as in Equation 1 (IEC, 2010).

$$U = \frac{\delta}{k} \cdot U_0 \tag{1}$$

Here, U represents the breakdown voltage under actual conditions, while U_0 denotes the breakdown voltage under reference ambient conditions. Furthermore, δ signifies the relative air density, and k represents the humidity correction coefficient. According to IEC60060-1, standard reference atmospheric conditions specified as follows:

- Temperature, T_0=20 °C (273 °K)
- Absolute air pressure, p_0=1.013 hPa (760 mmHg)
- Absolute humidity, h_0=11 g/m^3

Within the literature, tables have been presented detailing breakdown voltages (U_0) for various sphere diameters and electrode gaps under reference ambient conditions. These values have been incorporated into the Raspberry Pi system, thereby enabling users to perform calculations through the web interface. However, for non-standard ambient conditions, it is imperative to determine both the relative air density and humidity correction coefficient to obtain the actual breakdown voltage value. The relative air density is defined as the ratio of the ambient air density and the density of dry air at a standard temperature and pressure, as expressed in Equation 2.

$$\delta = \frac{p}{p_0} \cdot \frac{273 + T_0}{273 + T} \tag{2}$$

The weather station design initially computes the relative air density through the utilization of temperature and pressure measurements from the sensor array. Subsequently, the humidity correction coefficient is established through a two-step process, whereby the absolute humidity (h) is first calculated based on the ambient temperature and relative humidity (RH) data, after which the humidity correction coefficient is subsequently determined.

$$h = \frac{RH \cdot P_s}{R_w \cdot T \cdot 100} \tag{3}$$

In Equation 3, P_s is the saturation vapor pressure in Pa, R_w is specific gas constant for water vapor equals to 461.5 J/kg.K and T is the temperature measured in Kelvin. According to the equation proposed by Wagner and Pruss, the saturation vapor pressure of water at a given temperature T can be written as,

$$\begin{gathered} P_s = P_c \cdot exp\left[\frac{T_c}{T}(a_1 \cdot \tau + a_2 \cdot \tau^{1.5} + a_3 \cdot \tau^3 + a_4 \cdot \tau^{3.5} + a_5 \cdot \tau^4 + a_6 \cdot \tau^{7.5})\right] \\ \tau = 1 - \frac{T}{T_c} \end{gathered} \tag{4}$$

where P_c is critical vapor pressure for water equals to 22.064 MPa, T_c is critical temperature for water equals 647.096 °K, from a_1 to a_6 are empirical constants whose values are a_1=−7.85951783, a_2= 1.84408259, a_3= −11.7866497, a_4= 22.6807411, a_5= −15.9618719 and a_6= 1.80122502. Following the calculation of absolute humidity, humidity correction factor k can be obtained as a function of the ratio of absolute humidity to the relative air density, for different type of voltages as given in Equation 5 (IEC, 2010)..

$$\begin{aligned} &k = 1 + 0.014\left(\frac{h}{\delta} - 11\right) - 0.00022\left(\frac{h}{\delta} - 11\right)^2, && 1\ g/m^3 < \frac{h}{\delta} < 15\ g/m^3, && \text{DC} \\ &k = 1 + 0.012\left(\frac{h}{\delta} - 11\right), && 1\ g/m^3 < \frac{h}{\delta} < 15\ g/m^3, && \text{AC} \\ &k = 1 + 0.010\left(\frac{h}{\delta} - 11\right), && 1\ g/m^3 < \frac{h}{\delta} < 20\ g/m^3, && \text{Lightning Impulse (LI)/Switching Impulse (SI)} \end{aligned} \tag{5}$$

2.3 User Interface Design

The obtained data, both measured and computed, are transmitted to the internet via a modem and can be accessed through the designated user interface. Figure 4 displays the web interface designed for real-time monitoring of the ambient conditions and the correction factors.

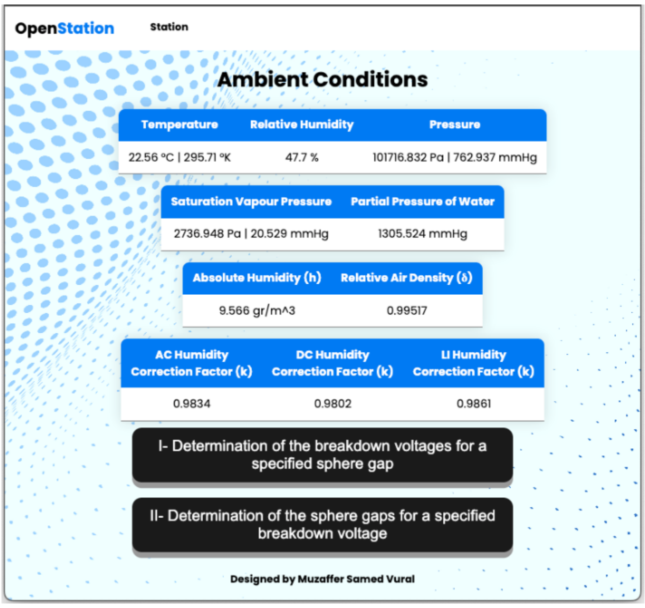


Figure 4. User interface designed for monitoring sensor data and correction coefficients

In addition to the interface for ambient conditions, the user has the capability to execute two distinct calculations as shown in Figure 4:

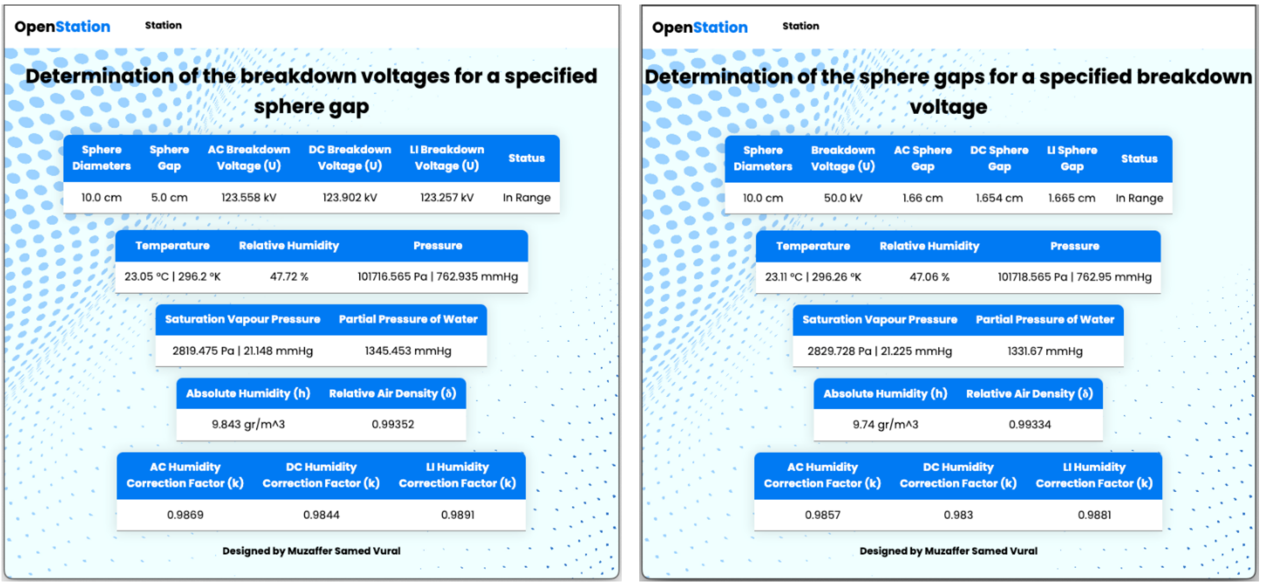
I. Determination of Breakdown Voltages for a Specific Sphere Gap: In this option, the user selects a specific gap between the spheres, and the corresponding AC, DC and LI/SI breakdown voltage values are then determined accordingly due to the ambient conditions.

II. Determination of Sphere Gap for a Specific Breakdown Voltage: The user specifies a particular breakdown voltage value and the distances between the spheres for AC, DC o LI/SI are then calculated to meet this value considering the ambient conditions.

In both options, the user is initially asked to provide sphere diameter and breakdown voltage (Option-I) or sphere gap (Option-II) information as input. These two parameters are then compared via Equation 6 to ensure that the sphere diameter is suitable for the specified breakdown voltage (I) or sphere gap (II). In the event that the sphere diameter is inadequate, the interface generates an error notification and prompts the user to enter new data that satisfies the conditions stipulated by Equation 6.

$$\begin{gathered} U(kV) = D(mm) \\ a(mm) \leq 0.5 \cdot D(mm) \end{gathered} \tag{6}$$

For instance, in the Option II, provided that the user has supplied suitable values considering Equation 6, the breakdown voltage (U_0) under reference ambient conditions can be computed by applying Equation 1, which incorporates real-time correction coefficients for air density and humidity. Subsequently, the corresponding sphere gap for U_0 value is identified from a reference table. Since the calculated U_0 value is typically a non-integer quantity that lacks an exact match in the reference table, a linear variation in the voltage-sphere gap over a given interval is assumed based on the two closest U_0 values, allowing for the actual sphere gap to be calculated via interpolation. The user interface developed for both options is depicted in Figure 5.



a) b)

Figure 5. User interface designed for the calculations in a) Option-I and b) Option-II

3. Result and Discussion

Following the design and implementation of the weather station, measurements were carried out in a laboratory setting over a 12-hour period (08:00 – 20:00) to assess its efficacy in high voltage measurement calculations. A comparison was made between the breakdown voltage values obtained through fixed and real-time calculation of correction factors. While Figure 6 displays the variations in ambient temperature and pressure, Figure 7 illustrates the changes in both absolute and relative humidity measured with the designed weather station in the laboratory setting.

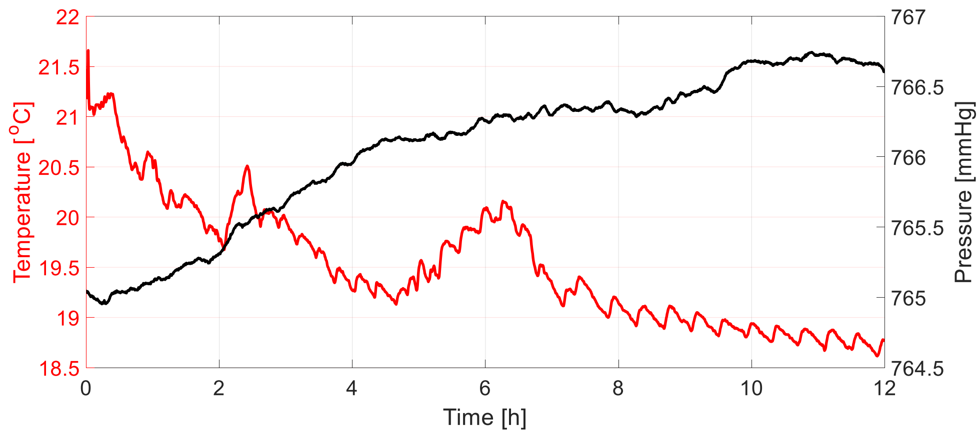


Figure 6. Temperature and pressure readings from the sensors during 12-hour period

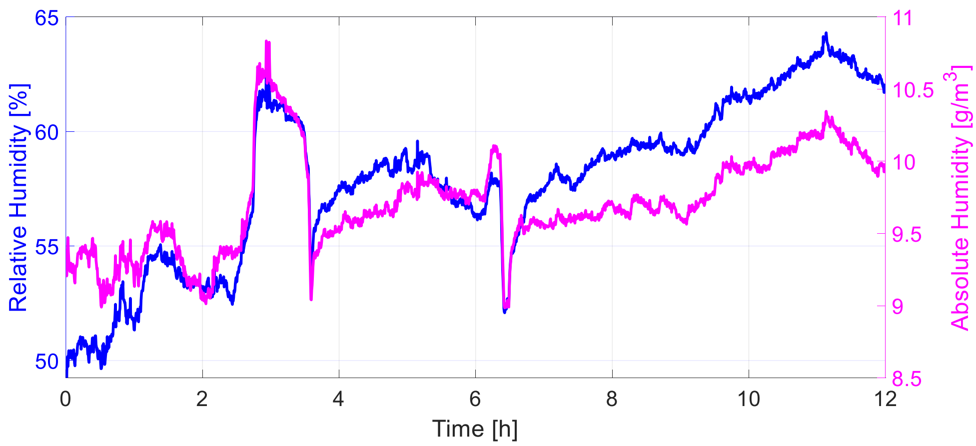


Figure 7. Relative readings from the sensors during 12-hour period

As observed from Figures 6 and 7, there was a minimal variation in ambient conditions throughout the 12-hour measurement period. Despite the use of HVAC systems to regulate ambient conditions in numerous laboratories, the ambient conditions may fluctuate within a specific range of tolerance due to various factors such as laboratory volume, HVAC capacity, thermal isolation etc. The particular sensor readings and the maximum relative change calculated over 12-hour period are presented in Table 2.

Table 2. Specific sensor readings and maximum relative changes

Sensor Readings	Minimum	Maximum	Mean	Max. Relative Change [%]
Temperature [°C]	18.615	21.66	19.517	16.36
Pressure [mmHg]	764.953	766.744	766.065	0.234
Relative humidity [%]	49.245	64.31	57.88	30.60
Absolute humidity [g/m^3]	8.9846	10.8383	9.7148	20.63

It can be inferred that the ambient temperature and humidity experienced considerable variations during the measurement period. Nevertheless, the maximum relative change in air pressure remained relatively low. The relative air density and humidity correction factors were computed based on the fluctuations in ambient conditions and are depicted in Figures 8 and 9, respectively.

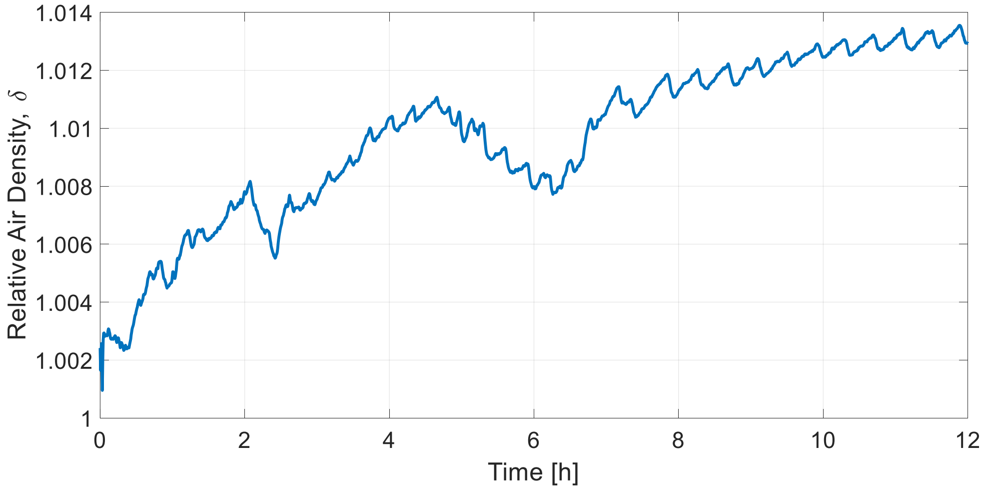


Figure 8. Calculated relative air density over a 12-hour period

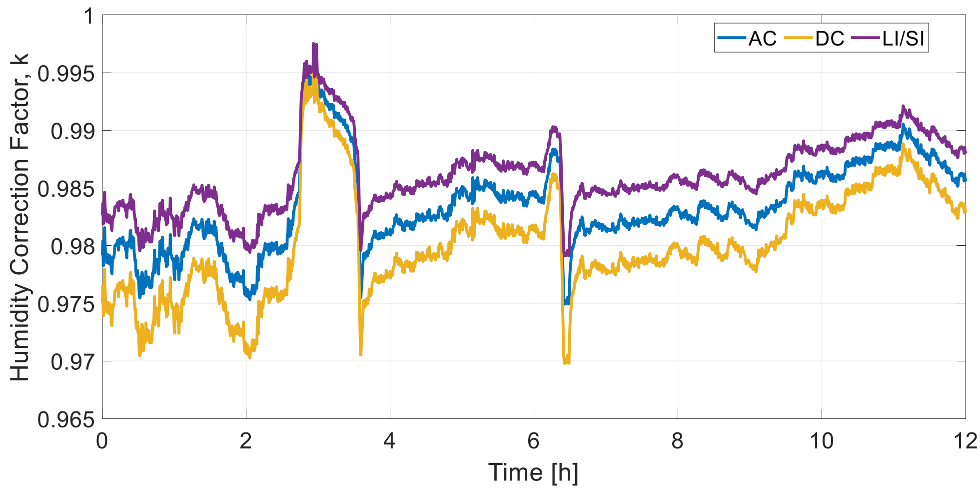


Figure 9. Calculated humidity correction factors over a 12-hour period

Relative air density is a variable that relies on both temperature and pressure. Hence, the pattern of relative air density over a 12-hour period differs from the temperature or pressure variation shown in Figure 6. However, a comparison of Figures 7 and 9 reveals a clear linear correlation between the humidity correction factor and absolute or relative humidity. These modifications to the coefficients will result in variations in the breakdown voltage value according to Equation 1. A sample calculation scenario has been performed to demonstrate the magnitude of this change clearly. Assuming a user intends to determine AC breakdown voltage employing spherical electrodes, they would measure the laboratory ambient conditions at t=0s.

Table 3. Ambient conditions and correction factors at t=0 s

Sensor Readings	Value
Temperature [°C]	21.23
Pressure [mmHg]	765.034
Relative humidity [%]	50
Absolute humidity [g/m^3]	9.2864
Relative air density, δ	1.00241
Humidity correction factor, k	0.97917

Subsequently, the user would calculate the correction coefficients with the acquired measurements and assume these coefficients remain constant for 12 hours. Table 3 outlines the values measured and calculated by the user at t=0s. The user intends to compute the breakdown voltage for the case where the sphere gap is 2 cm and the sphere diameter is 12.5 cm. The reference tables provide a breakdown voltage value (U_0) of 59 kV for this setup. Utilizing Equation 1, the user has calculated a laboratory breakdown voltage value (U) of 60.4 kV by considering the current ambient conditions. However, if the user were to perform this calculation over a period of time using fixed coefficients, a calculation error would occur due to the varying correction coefficients, which are dependent on environmental conditions. Figure 10 demonstrates the variation in breakdown voltage over time when using fixed and real-time computed correction coefficients (δ and k).

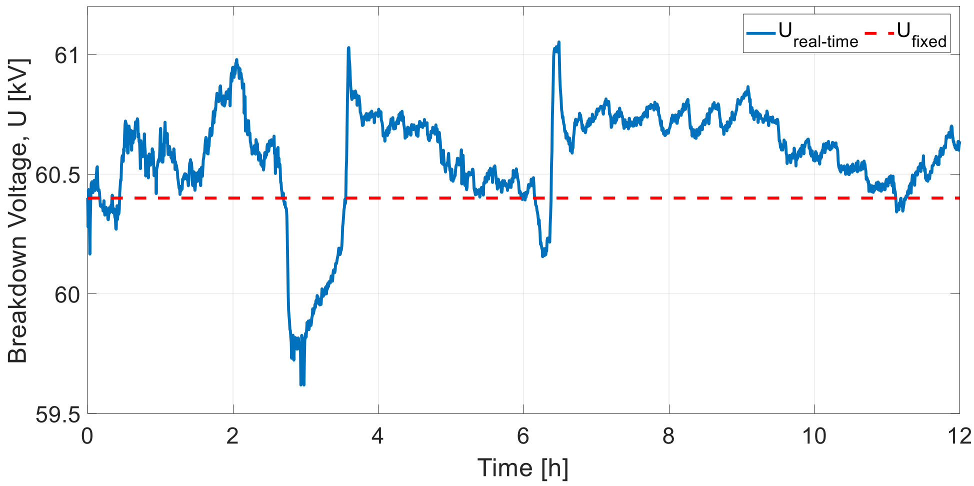


Figure 10. Variation in breakdown voltage using fixed and real-time computed correction coefficients

Based on the results presented in Figure 10, assuming the correction coefficients δ and k as constant by calculating them at the initial moment, leads to errors in the breakdown voltage calculations. After about three hours from the initial moment, the breakdown voltage value was found to be 59.619 kV due to the changing ambient conditions. If the changes in ambient conditions are not considered, the absolute relative error value within the specified time interval reaches a maximum of 1.31%. According to Equation 5, it is evident that the correction factor for humidity is also impacted by the waveform of the voltage to be measured. Consequently, breakdown voltage and the relative error rates will differ based on the type of voltage waveform. Relative error values for AC, DC, and LI/SI voltage waveforms, given the specified conditions, have been calculated and presented in Figure 11.

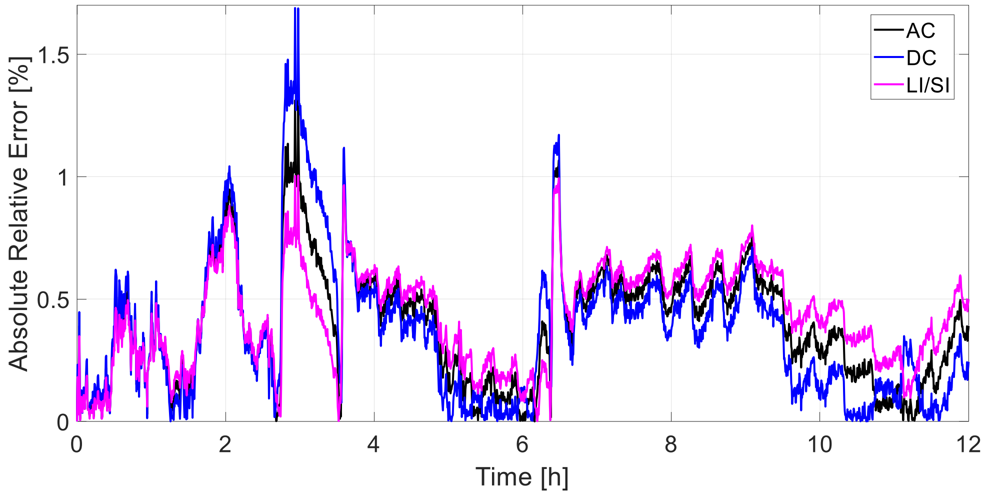


Figure 11. Variation in absolute relative error for breakdown voltage

When comparing the relative error rates of various waveforms under the same conditions, it is observed that DC voltage measurements exhibit the highest relative error. In contrast, impulse voltage measurements have the lowest relative error rate. While the relative error rates obtained in this study are relatively low, they have the potential to reach significant levels. Considerable changes in the environmental conditions of the laboratory can increase measurement errors. Additionally, the magnitude of the voltage to be measured, the sphere diameter, and the distance between the spheres are parameters that directly impact measurement errors. For this reason, inaccurate measurements or calculations of ambient conditions and correction factors can result in significant errors in the measurement of the breakdown voltage, leading to incorrect results and conclusions.

4. Conclusion

This study describes the development and deployment of an open-source weather station that employs Raspberry Pi to enable the real-time monitoring of environmental conditions within HV laboratories. The system is equipped with real-time calculation capabilities for the relative air density and humidity correction factor. To assess the performance of the system, a series of measurements were conducted over a 12-hour duration using the weather station. Furthermore, a web-based interface has been constructed to grant access to weather station data through the internet. This interface allows for real-time observation of current coefficients and permits online computation of actual parameters. The findings revealed that the real-time monitoring and calculation of environmental conditions and correction coefficients significantly mitigates the relative error rate in the measurement of breakdown voltage with spherical electrodes. Moreover, the measurements were carried out utilizing the designed weather station across multiple days and distinct time intervals, revealing the consistent repeatability of the recorded measurements. It is equally important to utilize weather stations with similar characteristics to minimize the measurement errors in all discharge-related measurements that occur in gaseous medium, such as surface discharge, internal discharge, corona, and others. Particularly, the utilization of a weather station that provides real-time correction coefficients in long-term measurements such as artificial ageing will enhance the precision of the results.

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Conflict of Interest

No conflict of interest was declared by the authors.

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