Volume 1, Issue 3, Nov 2023 International Journal of Modern Science and Research Technology

GSM-based Automated over Voltage and under Voltage Monitoring System for Panel Boards using Arduino Uno

Mike G. Belarmino,
Krista Franchesca Mary B.
De Guzman, Ian Alain Dave C.
Lopez, and Ma. Patricia Beatriz P. Pascual
Department of Electrical Engineering, Pamantasan ng Lungsod ng ValenzuelaValenzuela, Philippines
Adviser: Engr. Jomel R. Cristobal, EE

Abstract:

In recent years, the need for efficient and reliable power supply management has become increasingly important. Power fluctuations, such as overvoltage and undervoltage conditions, can significantly impact the performance and lifespan of electrical appliances and equipment. To address this issue, this project proposes a GSM-based overvoltage and undervoltage monitoring system using Arduino Uno. The researchers analyze and examine the monitoring system in a panelboard and aim in the following (1) calculation of the accuracy level of the system readings compared to the multimeter reading of the panel board,
(2) assessment of the relationship between the connected loads and the voltage variation in the panelboard, (3) store locally of the data gathered in the panel board, (4) comparison of correlation of the GSM module and Data logger. The prototype has been installed in two settings mainly the College of Engineering and Information Technology Electrical Room and Electrical Engineering Laboratory, and observed the voltage and current of the panelboard for 7 days to acquire the necessary datato parameters. Based on the data gathered the researcher determine conduct a GSM test and set a value of

overvoltage to greater than 210 V and undervoltage with a value of 207 V and below to check if the GSM work properly. Furthermore, the accuracy level of the voltages and current by comparing the measured data of the prototype to manual measurements of the multimeter. Comparison between the stored data in theSD card and the SMS sent by the GSM were also assessed to examine the correlation between the two variables. Voltage and Current Variation were determined by using a system with a motor loadand with a neutral load. Lastly, advantages and disadvantages of the monitoring system compared to manual operation were tabulated to assess the costbenefit analysis.

Keywords: Arduino Uno, GSM, Overvoltage, Undervoltage, SMS, Data logger, Neutral load, Motor load.

I. Introduction:

Monitoring electrical parameters in a facility is crucial for maintaining equipment efficiency. Online monitoring, achieved by integrating electronic devices into the system, allows real-time tracking of these parameters and extends the equipment's economic life. Electrical equipment operates within voltage limits, and any voltage changes can result in damage. Overvoltage refers to a sudden increase or exceeding of voltage limitations, which can harm the equipment and connected loads [39][31].Loss of insulation and damage to electrical components may occur when voltages surpass standard values. Similarly, undervoltage, characterized by voltages below the standard value, can cause damage to electrical loads and equipment. Insufficient voltage requires extra current draw, impacting the equipment's normal operation and eventually leading to its deterioration [8]. To achieve efficient real-time monitoring, the study aims to integrate overvoltage and undervoltage monitoring systems with GSM and a data logger. This automated monitoring system will be developed for a balanced three-phase panel board, including current monitoring. The researchers will focus on monitoring phase voltages in a balanced three-phase system, where currents pass through three wires, and the neutral wire carries fault current to the Earth. The device will be powered directly from a convenience outlet and converted to DC using an ACto DC 12V Power Adapter for continuous operation [21].

The researchers sought and aim to answer the following questions:

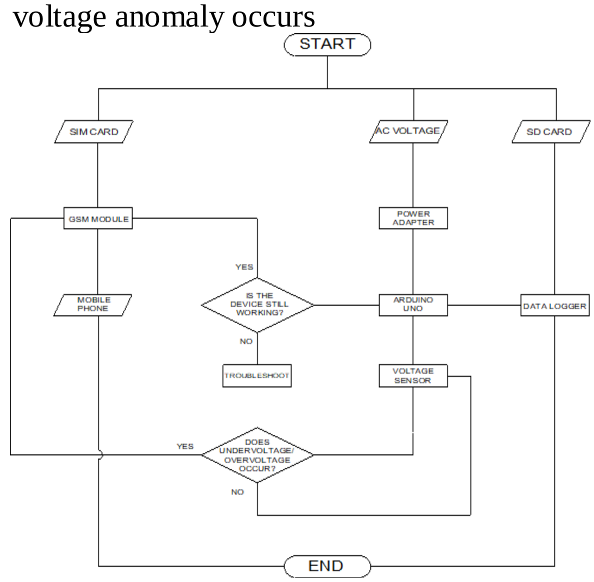
1. What is the accuracy level of the system readings compared to the multimeter reading of the panelboard?
2. How does connected loads affect the voltage and current output of the panelboard?

What is the correlation of the GSM module and Data logger?

What are the advantages and disadvantages in terms of the monitoring system in panelboard compared to manual monitoring?

The step-by-step flow of the study shown in figure 1.1. Explained that the power source of the device will come directly to the convenience outlet to ensure the monitoring of the panelboard happens. These willbe converted into DC to satisfy the voltage needed of the Arduino. In the Arduino Uno, a sensor is connected. This sensor will be the one measuring the electrical parameters, specifically voltage. The device is programmed that whenever the measured voltage does not exceed or below the certain value coded to the Arduino, or basically if the voltage went under or over, the GSM module will automatically notify the building admin. To ensure that the device is working from 7 am to 8:30 pm, the building admin will be notified regarding the status of the parameters daily.

The input data shown in figure 1.1. will be the very basis of the study and will be processed by programming the device using Arduino IDE to make the other connected components work in a synchronized manner. Using the AC voltage sensor, the data will be measured and analyzed if an overvoltage and undervoltage occurs with respect to the Philippine Distribution Code specification. The result of the study will be acquired to the process which is to alert if a voltage anomaly occurs



Objective of the Study:

The purpose of the study is to develop an electrical parameter monitoring device that focuses monitoring voltage level at the panel board with a GSM module to inform the authorized personnel when an overvoltage or undervoltage occurs.

1. To calculate the accuracy level of the system readings compared to the multimeter reading of the panel board.
2. To assess the relationship between the connected loads and the voltage variation in the panelboard.
3. To locally store the data gathered in the panel board.
4. To test the correlation of the GSM module and Data logger.

Literature Review:

Overvoltage refers to prolonged voltage fluctuations where the RMS value exceeds or equals 110% of the nominal voltage [4]. This can cause severe damage to equipment due to overheating [2]. Undervoltage, on the other hand, involves long periods of voltage fluctuations where the RMS voltage is lower than or equal to 90% of the nominal voltage [4]. This can lead to operational breakdowns and issues such as inaccurate information and reduced effectiveness in motor systems [2].

The Philippine Distribution Code mandates that distributors have the responsibility to prevent the occurrence of undervoltage and overvoltage in consumer facilities during normal operation. These long-duration voltage variations can have detrimental effects on the equipment connected to the panelboard. Distributors must prioritize maintaining a stable voltage supply to ensure the safety and optimal performance of consumer equipment. Compliance with this code is crucial for mitigating potential damage and disruptions, highlighting the importance of effective voltage monitoring and regulation in power distribution systems [5].Automated monitoring systems are complex IT systems that collect, process, and analyze real-time signals and data. They help identify issues before they become problems, ensuring high availability and quality of service. Monitoring also aids in decision-making, infrastructure automation, and learning [32].

Monitoring systems are used in substations to determine the traction transformer's lifespan and improve monitoring by incorporating a real-time remaining life module [33]. Furthermore, these systems are applied in energy efficiency and power factor correction, where open-source energy monitoring libraries are used to automatically boost power factor and track energy usage [28].

In power systems, electrical automation involves collecting operational data, analyzing operating conditions, and performing control tasks to ensure effective analysis and control of power system data. Automation technology is utilized in information monitoring, protection systems, power generation control, and more [27].

Power monitoring systems are crucial for managing electrical equipment and ensuring optimal performance [45]. They detect internal factors and power disturbances that can disrupt operations and damage equipment [19]. These systems prevent motor failures by managing voltage irregularities during startup and identify long-term deterioration trends for energy optimization [19]. They also evaluate power quality, enabling predictive maintenance and identifying production defects caused by poor power quality [19]. Overall, power monitoring systems enhance productivity, prevent disruptions, and reduce costs [45][19].

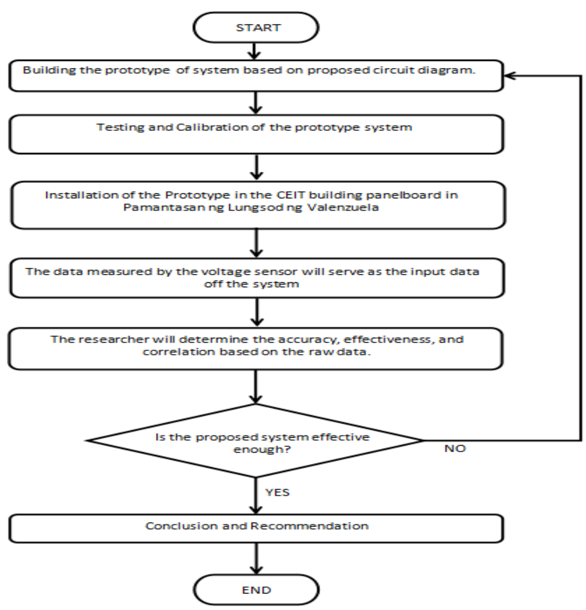
Throughout the completion of this paper, past related studies on overvoltage and undervoltage monitoring systems have been reviewed. However, limited studies have explored the use of GSM modules for sending SMS alerts, with some focusing on integrating them into panel boards. Most studies have primarily conducted simulations rather than practical implementations. Furthermore, many studies have utilized microcontrollers, such as Arduino Uno, to measure only the voltage in single-phase systems.

This study aims to address the research gap by monitoring under voltage and over voltage conditions in a balanced three-phase panel board. To achieve this, an Arduino Uno microcontroller will be utilized, along with an Arduino GSM shield for implementing an alert system and a data logger for data storage. In addition to voltage monitoring, the study will also measure current, another critical electrical parameter. The findings of this study will be supported by a comprehensive review of relevant literature and prior research, strengthening the rationale for the study. The ultimate goal of this research is to provide valuable insights and establish the significance of the research objectives.

II. Methodology:

This study discussed the design, setting, instruments and workflow applied in the study in a concise manner in this chapter. The study focused on the development of a voltage monitoring device in Pamantasan ng Lungsod ng Valenzuela(PLV) to manage the voltage output of a panelboard and provide timely data locally to inform qualified personnel about the condition of the panelboard. Alongside with the voltage, current was also monitored. The key components of the study are the system hardware and software setup. The system was implemented in an experimental condition toidentify the accuracy of the sensor in reading voltage and current parameters for calibration. Furthermore, the data was stored locally using a data logger and the researcher determined the correlation between the GSM module and the data logger based on the stored data. A test was conducted by the researchers that aims to compare voltages and current with motor load and with neutral load which determines if motor load affects voltage and current variation.

The proposed monitoring system was implemented in two of the panelboards in PLV. The prototype is installed in the lighting panel board of the Electrical room of the second floor for 4 days for neutral load and 3 days also at the panel board of the electrical laboratory of the College of Engineering and Information Technology (CEIT) building for the motor load. In addition, the system is tapped in the load side of the panel board, for actual reading and to gather data regarding the panelboard voltage and current output andcompare it to the multimeter readings of the panelboard system in order to calculate the accuracy and determine the percentage error of the device to the actual reading of the multimeter.



Data Gathering Procedure:

Phase1: Programming the System Software

The development of the system using the Arduino Integrated Development Environment (IDE) has the following steps:

1. Connect the Arduino Uno board to the device PC/Laptop and open the Arduino IDE software to start programming.
2. Select the specification of the Arduino board Tools

> Board > Arduino AVR Boards > Arduino Uno. In addition, select Tools > Port > Arduino Uno to determine if the PC/Laptop detects the Arduino board.

Insert the programmed codes in the Arduino IDE, the main components of the Arduino Uno were programmed based on its main purpose accordingly:

1. Voltage sensor to measure Three-phase AC System programmed with a threshold of 300 V maximum and send the data directly to the Arduino for other components.

2. Current sensor to measure Three-phase AC System programmed to automatically display RMS Current.GSM Module to automatically send SMS when overvoltage and undervoltage occur. In addition, it is also programmed to send an automated SMS to inform the authorized personnel that the device is working as well as the voltage condition at the same time.
3. Data Logger to store the measured data locally directly in an SD Card.

Phase 2: Gathering Inputs

The researchers will first seek permission to access the panelboard in PLV, CEIT building for the necessary data to be gathered. Furthermore, the schedule of loads of the selected panelboard should also be requested to record the connected loads in the panelboard.

1. Submit a request to the Dean of the CEIT to access the research setting.
2. Submit a request to the General Service Office (GSO) to acquire raw data from the schedule of loads in the selected panelboard.

Phase 3: System Testing and Calibration

After the installation of the hardware and software of the system, the researchers will conduct a test to determine if the proposed system is in good condition. The researchers will set a threshold of less than 207V for undervoltage and more than 210V for overvoltage to test the effectiveness of the electronic components in the system.

The GSM Module will be tested by setting a threshold of less than 207V for undervoltage and overvoltage as the sample load to be measured. The researchers will set up a threshold of which the GSM module will be activated if the voltage being measured exceeds the limit.

Phase 4: Correlation Assessment

The researcher will test the correlation of the GSM module and the Data logger by using the stored data and the data being recorded by the GSM module.

1. Record voltages stored in the data logger and the voltages in the GSM module.
2. The duration of time will be based upon consultinga statistician.
3. Calculate the difference ofthe voltages.

Phase 5: Accuracy Assessment

The researchers will first calculate the mean of the data and will be using the percent accuracy formula to determine the accuracy of the system based on the standard voltage supply of the panelboard.

Data Gathering Instrument:

Voltage and Current Data:

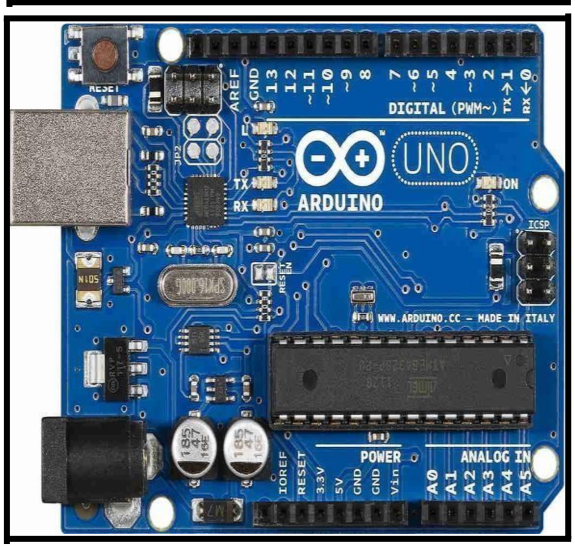
To ensure the accuracy of the prototype in measuring thevoltage and current of the EE Lab and EE room, the researchers utilized a multimeter and clamp meter. These instruments were used to determine the precise voltage and current values of the system. The data collection process was conducted hourly from 7 am to 8 pm, allowing for comprehensive monitoring throughout the day. By employing these measurement tools and implementing a consistent data collection schedule, the researchers were able to obtain reliable and accurate data for their analysis and evaluation.

A. Measuring Instruments

1) Multimeter

A. Processing Instruments

1) **Arduino Uno**



A. **Mean**

$$\bar{x} = \frac{\Sigma x}{n}$$

$\bar{x}$ = *mean of data*
x = *voltage measured by the system*
n = total number of data

B. **Standard Deviation**

$$\sigma = \sqrt{\frac{\Sigma(x_i - \bar{x})^2}{n-1}}$$

Where:
σ = standard deviation of the voltages value in the data set
$\bar{x}$ = mean of the data set
n = size of data points in the data

C. **Percent Accuracy**

Percent Error Formula $= \frac{(X-Y)}{Y}\ X\ 100\%$

Percent Accuracy Formula = 100% − *Percent Error*

Where:
X = Measured ValueY = Real Value

D. **Pearson Correlation**

$$r = \frac{\Sigma(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\Sigma(x_i - \bar{x})\Sigma(y_i - \bar{y})^2}}$$

Where:
r = correlation coefficient
x_i = raw data in the ≤GSM module
$\bar{x}$= mean of the raw data in the GSM module
y_i = raw data stored in the data logger
ȳ = mean of the raw data stored in the data logger

E. **Paired T-test**

$$\bar{x} = \frac{\Sigma x}{n}$$

$$\sqrt{\frac{n(\Sigma d^2) - (\Sigma d)^2}{n-1}}$$

Where:
$d = difference\ per\ paired\ value$
$n = number\ of\ values$

Experimentation:
Statistical Treatment:
The experimentation stage of this research primarily focused on data gathering, data processing, and system functionality. The researchers programmed the Arduino Uno microcontroller to record voltage and current measurements and send SMS alerts in the event of over or under voltage occurrences. If no voltage anomalies were detected, the measured data was sent periodically to the researchers and GSO Personnel. The electrical parameters of the prototype were recorded by the data logger every 5 minutes, while the researchers manually recorded the parameters at hourly intervals. The SMS alerts for the researchers were set to a five-minute interval, providing real-time updates on the status of the prototype. For the GSO personnel, SMS alerts were sent at three-hour intervals.

During the experimentation phase, a mock experiment was conducted to ensure the overall system readiness for testing. This involved performing GSM tests to verify the successful transmission of SMS alerts during voltage anomalies, conducting correlation tests to validate the consistency of data sent via SMS and the data saved by the data logger, and gathering preliminary data. The accuracy of the Arduino measurements was also assessed through a comparison with readings obtained from a multimeter.

Following the completion of the mock experiment, the researchers proceeded with the actual testing period. Throughout this stage, all collected data were carefully tabulated, allowing for an evaluation of the prototype's efficiency and reliability. These findings are essential in assessing the overall performance of the developed monitoring system and its potential for practical implementation.

III. Result and Discussion:

Table 1.1 Actual Voltage Accuracy of May 08, 2023

Monday, May 8, 2023				
Time	Voltage (V)	Multimeter Measurements	Percent Error	Percent Accuracy
7:00 AM	235.25	234.00	0.534188034	99.46581197
8:00 AM	235.38	234.00	0.58974359	99.41025641
9:00 AM	233.42	232.00	0.612068966	99.38793103
10:00 AM	233.24	232.00	0.534482759	99.46551724
11:00 AM	240.03	239.00	0.430962343	99.56903766
12:00 PM	238.08	237.00	0.455696203	99.5443038
1:00 PM	236.28	235.00	0.544680851	99.45531915
2:00 PM	238.57	238.00	0.239495798	99.7605042
3:00 PM	235.52	234.00	0.64957265	99.35042735
4:00 PM	239.74	239.00	0.309623431	99.69037657
5:00 PM	238.57	238.00	0.239495798	99.7605042
6:00 PM	234.74	234.00	0.316239316	99.68376068
7:00 PM	240.46	239.00	0.610878661	99.38912134
8:00 PM	243.03	242.00	0.425619835	99.57438017
AVERAGE	237.31	236.21	0.46	**99.54**

Table 1.2 Actual Current Accuracy of May 08,

Monday, May 8, 2023				
Time	Current (A)	Multimeter Measurements	Percent Error	Percent Accuracy
7:00 AM	0.67	0.664	0.903614458	99.09638554
8:00 AM	1.17	1.167	0.257069409	99.74293059
9:00 AM	1.03	1.010	1.98019802	98.01980198
10:00 AM	1.25	1.248	0.16025641	99.83974359
11:00 AM	0.68	0.675	0.740740741	99.25925926
12:00 PM	0.65	0.643	1.088646967	98.91135303
1:00 PM	0.70	0.692	1.156069364	98.84393064
2:00 PM	0.70	0.689	1.596516691	98.40348331
3:00 PM	0.72	0.717	0.418410042	99.58158996
4:00 PM	0.67	0.666	0.600600601	99.3993994
5:00 PM	0.70	0.695	0.71942446	99.28057554
6:00 PM	0.66	0.654	0.917431193	99.08256881
7:00 PM	0.79	0.786	0.508905852	99.49109415
8:00 PM	0.65	0.643	1.088646967	98.91135303
AVERAGE	0.79	0.782	0.87	**99.13**

Table 1.3 Actual Voltage Accuracy of May 09, 2023

Tuesday, May 9, 2023				
Time	Voltage (V)	Multimeter Measurement	Percent Error	Percent Accuracy
7:00 AM	236.60	236.00	0.254237288	99.74576271
8:00 AM	236.40	235.00	0.595744681	99.40425532
9:00 AM	236.31	232.00	1.857758621	98.14224138
10:00 AM	233.34	232.00	0.577586207	99.42241379
11:00 AM	235.93	235.00	0.395744681	99.60425532
12:00 PM	234.92	234.00	0.393162393	99.60683761
1:00 PM	229.92	229.00	0.401746725	99.59825328
2:00 PM	232.38	231.00	0.597402597	99.4025974
3:00 PM	238.72	238.00	0.302521008	99.69747899
4:00 PM	235.77	235.00	0.327659574	99.67234043
5:00 PM	238.57	238.00	0.239495798	99.7605042
6:00 PM	234.74	234.00	0.316239316	99.68376068
7:00 PM	240.46	240.00	0.191666667	99.80833333
8:00 PM	243.03	242.00	0.425619835	99.57438017
AVERAGE	236.22	235.07	0.49	**99.51**

Table 1.4 Actual Current Accuracy of May 09, 2023

Tuesday, May 9, 2023				
Time	Current (A)	Multimeter Measurements	Percent Error	Percent Accuracy
7:00 AM	0.95	0.947	0.316789863	99.68321014
8:00 AM	1.17	1.166	0.343053173	99.65694683
9:00 AM	1.05	1.048	0.190839695	99.80916031
10:00 AM	1.12	1.115	0.448430493	99.55156951
11:00 AM	1.00	0.957	4.493207941	95.50679206
12:00 PM	1.60	1.595	0.313479624	99.68652038
1:00 PM	0.86	0.857	0.350058343	99.64994166
2:00 PM	1.11	1.108	0.180505415	99.81949458
3:00 PM	0.96	0.955	0.523560209	99.47643979
4:00 PM	1.01	1.007	0.297914598	99.7020854
5:00 PM	0.70	0.694	0.864553314	99.13544669
6:00 PM	0.66	0.657	0.456621005	99.543379
7:00 PM	0.79	0.786	0.508905852	99.49109415
8:00 PM	0.65	0.643	1.088646967	98.91135303
AVERAGE	0.97	0.967	0.74	**99.26**

Table 1.5 Actual Voltage Accuracy of May 10, 2023

Wednesday, May 10, 2023				
Time	Voltage (V)	Multimeter Measurement	Percent Error	Percent Accuracy
7:00 AM	234.14	233.00	0.489270386	99.51072961
8:00 AM	235.36	234.00	0.581196581	99.41880342
9:00 AM	236.31	235.00	0.557446809	99.44255319
10:00 AM	233.34	232.00	0.577586207	99.42241379
11:00 AM	234.25	233.00	0.536480687	99.46351931
12:00 PM	237.84	237.00	0.35443038	99.64556962
1:00 PM	235.60	235.00	0.255319149	99.74468085
2:00 PM	236.14	235.00	0.485106383	99.51489362
3:00 PM	238.33	237.00	0.561181435	99.43881857
4:00 PM	231.25	239.00	-3.242677824	103.2426778
5:00 PM	233.97	233.00	0.416309013	99.58369099
6:00 PM	239.33	238.00	0.558823529	99.44117647
7:00 PM	240.46	239.00	0.610878661	99.38912134
8:00 PM	243.03	242.00	0.425619835	99.57438017
AVERAGE	236.38	235.86	0.23	**99.77**

Table 1.6 Actual Current Accuracy of May 10, 2023

Wednesday, May 10, 2023				
Time	Current (A)	Multimeter Measurements	Percent Error	Percent Accuracy
7:00 AM	1.10	1.092	0.732600733	99.26739927
8:00 AM	1.16	1.143	1.487314086	98.51268591
9:00 AM	1.05	1.045	0.4784689	99.5215311
10:00 AM	1.12	1.111	0.810081008	99.18991899
11:00 AM	1.18	1.175	0.425531915	99.57446809
12:00 PM	0.82	0.816	0.490196078	99.50980392
1:00 PM	1.77	1.763	0.397050482	99.60294952
2:00 PM	1.52	1.515	0.330033003	99.669967
3:00 PM	1.58	1.578	0.126742712	99.87325729
4:00 PM	1.59	1.588	0.125944584	99.87405542
5:00 PM	1.72	1.705	0.879765396	99.1202346
6:00 PM	1.29	1.286	0.311041991	99.68895801
7:00 PM	0.79	0.789	0.126742712	99.87325729
8:00 PM	0.65	0.645	0.775193798	99.2248062
AVERAGE	1.24	1.232	0.54	**99.46**

Table 1.7 Actual Voltage Accuracy of May 11, 2023

Thursday, May 11, 2023				
Time	Voltage (V)	Multimeter Measurement	Percent Error	Percent Accuracy
7:00 AM	233.50	233.00	0.214592275	99.78540773
8:00 AM	237.76	237.00	0.320675105	99.67932489
9:00 AM	234.27	233.00	0.545064378	99.45493562
10:00 AM	236.94	236.00	0.398305085	99.60169492
11:00 AM	235.74	235.00	0.314893617	99.68510638
12:00 PM	236.78	236.00	0.330508475	99.66949153
1:00 PM	234.62	234.00	0.264957265	99.73504274
2:00 PM	234.15	233.00	0.493562232	99.50643777
3:00 PM	237.30	236.00	0.550847458	99.44915254
4:00 PM	234.26	233.00	0.540772532	99.45922747
5:00 PM	238.57	238.00	0.239495798	99.7605042
6:00 PM	241.84	241.00	0.348547718	99.65145228
7:00 PM	240.82	240.00	0.341666667	99.65833333
8:00 PM	241.66	241.00	0.273858921	99.72614108
AVERAGE	237.02	236.14	0.37	**99.63**

Table 1.8 Actual Current Accuracy of May 11, 2023

Thursday, May 11, 2023				
Time	Current (A)	Multimeter Measurements	Percent Error	Percent Accuracy
7:00 AM	1.19	1.183	0.591715976	99.40828402
8:00 AM	0.82	0.814	0.737100737	99.26289926
9:00 AM	1.65	1.647	0.182149362	99.81785064
10:00 AM	0.99	0.985	0.507614213	99.49238579
11:00 AM	1.66	1.653	0.423472474	99.57652753
12:00 PM	1.80	1.792	0.446428571	99.55357143
1:00 PM	1.73	1.725	0.289855072	99.71014493
2:00 PM	1.62	1.613	0.433973962	99.56602604
3:00 PM	1.61	1.608	0.124378109	99.87562189
4:00 PM	1.54	1.533	0.456621005	99.543379
5:00 PM	0.70	0.692	1.156069364	98.84393064
6:00 PM	0.71	0.704	0.852272727	99.14772727
7:00 PM	0.69	0.686	0.583090379	99.41690962
8:00 PM	0.72	0.713	0.981767181	99.01823282
AVERAGE	1.25	1.239	0.55	**99.45**

The researchers used International Business Machines Statistical Package for the Social Sciences or IBM SPSS statistical software to ensure the reliability and validity of the data. They proposed various statistical tools to address specific problems and achieve the study objectives. The firstproblem was to determine the accuracy of the gathered data, which was measured using percent accuracy. The comparison between multimeter readings and prototype readings showed a high accuracy of 99.54%, 99.51%, 99.77%, and 99.63% for voltages (Table 1.1, 1.3, 1.5, and 1.7) and 99.13%, 99.26%, 99.46%, and 99.45% for currents (Table 1.2, 1.4, 1.6, and 1.8). These results demonstrate the reliability of the monitoring system in storing and transmitting voltage and current data.

The second objective was to determine voltage variation using the paired t-test. Data from two different panel boards with neutral load and motor load were compared. The t-values calculated for voltages (Table 1.9) and currents (Table 1.10) exceeded the significance level of 0.05%, indicating a significant relationship between the variables in terms of variation. The researchers rejected the null hypothesis and accepted the alternative hypothesis, concluding that motor load has a more significant effect on voltage and current variation compared to neutral load.

Table 1.11 Actual Voltage Correlation DescriptiveStatistics of May 08, 2023

Statistics

		GSM	SDCARD
N	Valid	163	163
	Missing	0	0
Mean		237.4591	237.4591
Median		236.8400	236.8400
Std. Deviation		2.83277	2.83277
Range		11.94	11.94
Minimum		231.47	231.47
Maximum		243.41	243.41

Table 1.12 Actual Voltage Pearson Correlation of May08, 2023

Statistics

		GSM2	SDCARD2
N	Valid	163	163
	Missing	0	0
Mean		235.7326	235.7326
Median		235.2500	235.2500
Std. Deviation		3.06825	3.06825
Range		14.08	14.08
Minimum		229.33	229.33
Maximum		243.41	243.41

Table 1.13 Actual Voltage Correlation DescriptiveStatistics of May 10, 2023

Statistics

		GS3	SDCARD3
N	Valid	163	163
	Missing	0	0
Mean		236.2196	236.2196
Median		236.3000	236.3000
Std. Deviation		2.85063	2.85063
Range		13.06	13.06
Minimum		230.35	230.35
Maximum		243.41	243.41

Table 1.14 Actual Voltage Pearson Correlation of May 10, 2023

The third objective was to find the correlation between values sent by the GSM module and values stored in the SD card. Pearson correlation was used, and the results showed a strong correlation between the two. The calculated Pearson rcoefficient for voltage and current in the GSM and SD Card (Table 1.11, 1.12, 1.13, and 1.14) was equal to 1, indicating similar data and a correlation between the variables. The researchers rejected the null hypothesis and accepted the alternative hypothesis, affirming that the data stored in the data logger matches the data sent by the GSM module. This test confirmed the effectiveness of the prototype in monitoring and transmitting voltage readings.

Table 1.15 Cost Analysis

Cost for automatedmonitoring system	**Cost of manualmonitoring**
₱3667 overall cost of theprototype	₱399 for Ingco digitalmultimeter
₱14.28 load/day for the sim card of the GSM module	₱590 per daysalary ofelectrician (based on minimum wage)
₱100 - ₱1,500 maintenance cost	₱0 to ₱399 for replacinga broken digital multimeter
Total: ₱5181	Total: ₱1388

Table 1.16 Advantages and Disadvantages Assessment

Advantages	**Disadvantages**
Full list of the parameter readings for every 5 minutes	One monitoring system device per panel board
Real-time monitoring	
Cost of the load perday is cheaper than the salary per day of anelectrician	

The fourth objective was to compare the advantages and disadvantages of the prototype with manual monitoring. The system offers advantages such as a history of parameter readings for maintenance purposes, real-time monitoring via text messages, and cost savings compared to employing an electrician (Table 1.16). However, the disadvantage is that one monitoring system device can only monitor one panel board at a time, unlike manual monitoring (Table 1.16). The maintenance cost for the automated monitoring system shown in Table 1.15 is higher than for manual monitoring, ranging from ₱100 to ₱1,500 compared to ₱0 to ₱399 for replacing a broken digital multimeter.

IV. Conclusion:

In conclusion, Arduino, when combined with an SD card, a GSM module, and appropriate sensors, presents a versatile platform for data storage, SMS communication, and voltage/current measurement. This study has demonstrated the effectiveness and reliability of Arduino in these functionalities. Integrating an SD card enables efficient data logging and retrieval, while the GSM module facilitates remote communication and notification systems. Additionally, the ability of the Arduino to measure voltage and current in panel boards enables effective monitoring and control of electrical systems. The combination of these functionalities' positions Arduino as a robust tool for diverse applications, including data logging, remote monitoring, andautomation in fields.

The findings of this study provide compelling evidence regarding the dependability, accuracy, and responsiveness of the GSM-based monitoring system in detecting and responding to voltage fluctuations. The prototype strongly correlated with reference measurements, demonstrated accurate data transmission, and achieved precise calibration for reliable voltage readings. From 6 pm onwards, the supply voltage exhibits an increase, while the demand experiences a decrease, owing to the limited number of students present at the Pamantasan ng Lungsod ng Valenzuela. The system holds significant potential for various applications that require trustworthy voltage monitoring, ensuring the efficient and safe operation of electrical systems while minimizing potential disruptions or damages. It establishes its long-term viability in voltage monitoring and management applications.

Further research and development in this area hold promise for expanding the capabilities of Arduino and enhancing its functionality in data storage, remote communication, and electrical monitoring. Future investigations could explore additional sensor integration for expanded measurement capabilities, investigate optimizationtechniques for data storage and retrieval, and explore advanced communication protocols for enhanced remote monitoring and control. Overall, Arduino is a valuable platform with immense potential for innovation and application in various industries and domains.

Acknowledgment:

First and foremost, we express our deepest gratitude to God Almighty for granting us the wisdom, strength, robust health, blessings, and invaluable support system that enabled the realization of this research paper.

We want to take this esteemed opportunity to extend our profound appreciation and immeasurable gratitude to all individuals who selflessly extended their assistance, guidance, and unwavering support throughout this study.

We extend our heartfelt gratitude to Engr. Jomel S. Cristobal, our esteemed technical adviser, for his invaluable guidance, profound insights, significant suggestions, and comprehensive knowledge, which played a pivotal role in shaping the trajectory of our study.
Furthermore, we sincerely appreciate the invaluable contributions of our research adviser, Engr. Alex J. Monsanto, for his unwavering dedication, tireless efforts in teaching, thorough review, and insightful inputs have greatlyenriched the content and rigor of our research paper.

We would also like to express our profound thankfulness to Engr. Sarah Jane B. Cortez, her tireless support and unwavering guidance during the placement of our prototype were instrumental in its successful implementation. Additionally, we extend our heartfelt appreciation to our dean, Engr. Jordan N. Velasco, for approving the integration of our prototype within our educational institution and providing valuable suggestions to enhance the overall quality and structure of our thesis paper. Our gratitude also extends to our families, whose unwavering moral support, understanding, and financial provision have been indispensable throughout our academic journey. We thank our friends for their unwavering support and invaluable feedback on our study. Finally, we owe our most profound appreciation to the members of our group, whose unwavering dedication, relentless commitment, and resilience were instrumental in overcoming the myriad of challenges, sleepless nights, and adversities that accompanied this arduous journey.
The completion of this research represents not only a significant milestone for the researchers but also for all individuals who have been part of this study. Therefore, we offer our heartfelt appreciation and sincere gratitude to all of them for their invaluable contributions and unwavering support.

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