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CONVENIENCE OUTLET WITH LED LOAD-METER INDICATOR

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Abstract

Safety and reliability are some of the major concerns in the context of electricity consumption. With the possible threat it can cause, an individual's awareness is an essential aspect that everyone must consider in order to lessen such electrically inflicted accidents. This research study led to its purpose of developing a device that displays the total connected load current on branch circuit by means of embedding Light Emitting Diode (LED) display on the cover plate of convenience outlets in order to provide load monitoring as well as exemplifying electrical safety. Specifically, it mainly focused on the determination of the accuracy, precision level, and significant difference on the readings of different types of electrical load connected among residential units. Experimental method was employed and Philippine Electrical Code (PEC) and standardized materials were used as bases for the ethical foundation and whole-conduct of the said study. Arithmetic mean, percentage error, frequency count and One-Way Analysis of Variance (One-Way ANOVA) were the statistical tools used. Moreover, results showed that the average percentage error of the device is 6.82% that is interpreted as highly accurate while the result of the frequency count yielded to a 100% degree level of precision. Lastly, the device revealed that there is no significant difference on the readings of different types of electrical residential load connected.

Keywords: Convenience Outlet, LED, Load-Meter.

1. Introduction and Purpose

Electrical energy is essential in daily lives but could be very dangerous if not treated safely (Lesperance 1997). In addressing the situation on the safe use of electricity, an individual's knowledge regarding it is one essential aspect that everyone must consider in order to lessen electrically inflicted accidents like equipment damaged, electrical fire, electrical shock and in some serious cases, death (Saba et al. 2014, p. 1-2). These related problems do exist when electrical fault or short circuit happens on a specific area (McGrath 2019). Some of these causes include excessive load on electrical wires or too much electrical load on the circuit, which is generically termed as overload (Overload Protection n.d.). Basically, an overload occurs when a certain electrical circuit carries a load heavier than the limit it was designed for (Thiele 2018; Gladstone 1986, p.4). It can be due to increase in the number of electrical loads fed simultaneously or also to the increase in electrical power absorbed by one of more of these loads on a certain electrical circuit (Abdelmoumene&Bentarzi2016, p.2). In some studies, overload frequently happens because of consumers' malpractice of extending the number of spaces on a convenience outlet that is intended only for a specified number of connected appliances. This scheme of connecting too many appliances in one circuit affects mainly the cabling and wiring that causes the protective device to heat up and open circuit (Adams 1994, p.7). This implies that consumers have poor awareness pertaining on the allowable load of convenience outlet branch circuit, wherein it cause problems on electrical system leading to occurrence of fire(Cline, King & King, P.C. 2015). The Philippine Statistical Authority (PSA) articulated that there were over 40,696-recorded cases of fire incidents in the Philippines within years 2010 to 2013. The most common causes include faulty electrical wiring, LPG related, neglected cooking, cigarette butt, torch, candle, matchstick, neglected electrical devices, incendiary device, spontaneous combustion and others. Moreover, statistical record shows that a total of 29.6% and 3.9% of these were caused by faculty electrical wiring and neglected electrical appliances or devices (de Costo & Gumela 2014). In connection to this, the Bureau of Fire Protection (BFP) raises alarm on multiple wiring or what so called octopus-wiring connections as fire hazard (Chiu 2018).

As bases to ensure quality and standardized output in electrical works and implement the safe use of electricity, electrical practitioners within the country used the Philippine Electrical Code (PEC) as reference and technical guide. The said code mandates that for total cord-plug connected load where connected to a branch circuit supplying two or more receptacles or outlets, a receptacle shall supply a total cord-and-plug-connected load in excess of the maximum specified in Table 2.10.2.3(b)(2) wherein a 20-Ampere branch circuit rating shall have a receptacle rating of 20-Amperes with a maximum load of 16-Amperes (Institute of Integrated Electrical Engineers of the Phils. n.d.). With this standard, any scheme that exceeds the pre-set limit is classified as overload. Therefore, overloading will not occur if the total load connected does not exceed its maximum allowable load (Utility Products n.d.). Similarly, it can also be prevented through load monitoring for it serves as an essential tool to regulate and perceive the connected electrical load in a certain circuit, especially appliances. As expressed, load monitoring is essential for energy management solutions (Zoha et al. 2012). It provides an important means in understanding the load behaviour in the actual system. It may also be implemented randomly with different monitoring materials, measured materials and requirements for sampling rates and other applications. Moreover, the general purpose of load monitoring is to provide better load characterization and better load management (Huang et al. 2007).

At present, most installed electric meters provide little information to their users (Hunter & Sandberg 2009). However with the advancement of technology, several multifunctional devices with monitoring capability for an electrical system were developed. Monitoring of these circuits allows the user to determine when circuits are approaching high loading levels (Lewis 2005). Some of these developed devices are the A-Series II branch circuit monitoring panel which enables the user to observe electrical parameters, deliver and stores data to a cloud-based system and the Multi-Mon, a 3-phase multifunction meter that provides efficient and monitoring capabilities on branch circuit monitoring applications (GE Industrial 2013; E-MON 2013). Despite the remarkable features and function of the said devices as well as the concerns of addressing electrical-related accidents, the provision of this technology and application on small-scale units will be somehow limited due to some constraints like the provision of 3-phase supply, fast-link internet connection and even data centers for up-to-date transmission and exchange of data. However, fine-grained load monitoring can also be achieved by deploying smart power outlets but it incurs extra material cost and installation complexity (Zoha et al. 2012). Through this phenomenon, the researcher was moved to conduct a study with the purpose of developing a device capable of monitoring the electrical load connected specifically designed branch circuits for convenience outlets. The technology aims to render electrical safety and come up with a functional and reliable device.

2. Research Problem

The study generally focused on the development of a device capable of load metering on branch circuit intended for convenience outlets to regulate and lessen the occurrence of electrical overload along residential area. With this, it was technically designed to set a visual display of load-meter indicator through the use of Light Emitting Diode (LED) embedded on the surface of the cover plate for each convenience outlet of a specified branch circuit. Specifically, it sought for the performance and reliability of the embedded LED load-meter indicator in terms of accuracy and precision. It also sought for the determination of any significant difference on the readings of different types of electrical residential load connected on a certain branch circuit.

3. Methodology

The study has utilized experimental method type of research. PEC was used as the basis for standards regarding technical and electrical parameters as well as standardized and fine quality materials for the fabrication and development of the device. It was considered as the most suitable process in gathering information and obtaining adequate results that will significantly address the stated problems in this study. Moreover, it used the manipulation and controlled testing to understand the relationship of the variables and parameters involved. Hence, the independent variable includes the ratings of connected load appliances among residential units while the dependent variable includes the performance of load-meter reading through the LED display in terms of accuracy and precision.

Research Procedures

Proper conduct of research procedures was taken into consideration to gain positive outputs. The framework was essentially composed of three stages namely: a) preliminary procedures, b) development process, and c) final output device.

Preliminary procedures

This stage essentially covers the conduct of gathering information and problem assessment in relation to the research problem. This includes the review of different literatures that significantly contributed as basis and guide during the whole-conduct of the study. Also, the conduct of electrical safety assessment in terms of technical reference for standards and procedures in dealing with electrical technology was also included in this stage.

Development Process

This stage comprises the core and organized procedures in the development of study such as planning, designing, preparation of materials needed, and fabrication. During this process, the study was subjected to its hardware development and undergone testing and evaluation as the last process on this stage. A couple of modifications and alterations were made to maximize the favourability of the results.

Final Output Device

This is the last stage of the framework where the final output is a finished functional and reliable prototype device for load monitoring of convenience outlets. Thus, the device was named 'Convenience Outlet with LED Load-Meter Indicator'.

Research Development

The development of the study has followed the process from the presented framework of procedures. In planning and designing, a computer-aided drafting software (SketchUp) was used in sketching the device's proposed layout as well as the device's circuitry components. This process has identified the necessary materials and components needed for development of the device. Then, preparation of needed materials took place after determining all the materials and components needed. The list of materials essentially includes convenience outlet set, utility box, bushing and locknuts, conduits, conductors, microprocessor (Arduino Uno), resistors, current sensor (ACS712 model) and LEDs. Also, several tools such as pliers, wire stripper, soldering iron and screwdrivers were also prepared in this stage. All materials used were standardized and high quality to ensure technical parameters such as durability and efficiency of results.

Next, fabrication process has taken place after the preparation of all the materials and components needed. It was considered as the most crucial and significant step in the development process of the device. Basically, the said process was technically divided into two areas based from their respective scope of works namely: installation of electrical foundation and components, and installation of electronic components with programming. The first scope pertaining on electrical works include the construction of a conventional branch circuit wiring basically composed of a pair of conductor for a set of convenience outlet attached on a utility box. Then, it was connected to a conduit and secured with bushing and locknut. Then, the other scope pertaining on electronic works include the embedment of LED on the plate cover and linking of current sensor on one of the conductor of the convenience outlet. Afterwards, the terminals of the LED with series-connected resistors and the current sensor were connected on the ports of the Arduino Uno as the system's microprocessor. And lastly, the said unit was programmed using the Arduino programming software.

Testing Procedures

The device was situated on residential units and was subjected for testing and evaluation. It contains the common residential appliances connected to the device that served as its electrical load. Moreover, each test was subjected to five (5) trials where it measured the overall average value of the percentage error. Then it was descriptively interpreted as reflected on Table 1 that shows the table of interpretation for the accuracy based from the obtained value of the said parameter. Additionally, each test was scored as the basis for reliability of the device where percentage (%)was anchored on the method of frequency count. These methods served as the bases for determining the functionality of the said device with the given parameters.

Table 1:Table of Interpretation for Accuracy based from Percentage Error

Percentage Error	Descriptive Interpretation
0.1% to 20%	Highly Accurate
20.1% to 40%	Very Accurate
40.1% to 60%	Moderately Accurate
60.1% to 80%	Slightly Accurate
80.1% to 100%	Not Accurate

Moreover, One-Way ANOVA was used to analyse the variance obtained on each test in determining any significance at a certain alpha level that comprised the different types of electrical residential loads connected to the device. With this, the study made use of the readily available statistic software on the Internet.

Statistical Tools Used

The following statistical tools were used during the conduction of the study.

Arithmetic Mean

Arithmetic mean refers to the average value of a certain parameter. In this study, it was used to compute the average percentage error for all the trials conducted.

Percentage Error

Percentage error refers to the measure the divergence of the values of actual and theoretical readings. In this study, the actual reading pertains on the reading value of the clamp-on ammeter and the theoretical reading pertains on the reading value of the LED load-meter with an increment step value of 4 Amperes per LED.

Frequency Count

Frequency count refers to the tabulation of quantity that meets a certain criteria. In this study, it was used to determine the level of reliability in terms of precision of the convenience outlet with LED load-meter.

One-Way Analysis of Variance (One-Way ANOVA)

One-Way ANOVA refers to a collection of statistical model and their relation procedures used to analyse the differences among group means in a sample. In this study, it was used to determine significant difference on the readings of different types of electrical residential load connected.

4. Data and Analysis

Table 2 shows the results obtained from different set of test and trials conducted in order to measure the accuracy of the device. Moreover, the computed overall average percentage error of the device is 6.82% that was interpreted as highly accurate. The obtained result favoured that the entire design and layout of the device has served its purpose constructively and efficiently.

Table 2: Result for Accuracy

Test No.	No of Trials	Clamp-on Ammeter Reading	LED Load-Meter Reading	Percentage Error
Test No. 1	1st Trial	6.52 A	6.05 A (2 LEDs)	7.21%
	2nd Trial	6.56 A	6.05 A (2LEDs)	7.77%
	3rd Trial	6.53 A	6.05 A (2LEDs)	7.35%
	4th Trial	6.42 A	6.05 A (2LEDs)	5.76%
	5th Trial	6.44 A	6.05A (2 LEDs)	6.06%
Test No. 2	1st Trial	12.86A	14.05 A (4 LEDs)	9.25%
	2nd Trial	13.34 A	14.05 A (4LEDs)	5.32%
	3rd Trial	13.04 A	14.05 A (4LEDs)	7.75%
	4th Trial	13.21 A	14.05 A (4LEDs)	6.36%
	5th Trial	13.33 A	14.05A (4 LEDs)	5.40%
			Average Percentage Error	6.82%

Then, the precision level was measured by means ofa percentage value that was anchored with frequency count on the adequate results.The tabulation was based on the correct number of LEDsthat lighted up and its consistency. Table 3 shows the summary of the results that yielded to a 100% degree level of precision. With this, it implied that the device is precisely functional.

Table 3: Summary of Result on Precision Level

Required Operation (Successful)	Frequency	Total	Percentage
The number of LED that lighted up in the load-meter matched its equivalent number in the current reading of the meter. Also it lighted up in a consistent manner	15	15	100%

And lastly, the summary of result forOne-Way ANOVA taking alpha value of 0.05 was shown in Table 4. The computed F value is 0.00082 which is lower than the tabulated F value (1,8)of5.32, so the null hypothesis ($\mu_1 = \mu_2$) was accepted. This implies that the result of the study was notsignificant at $\rho < 0.05$ among variables involved.

Table 4: Summary of Result for ANOVA (ρ=0.05)

Source	SS	df	MS	
Between Treatments	0.0005	1	0.0005	F = 0.00082
Within Treatments	4.7943	8	0.5993	
Total	4.7948	9		

Source: https://www.socscistatistics.com/tests/anova/default2.aspx

Conclusion

The purpose of the study was to develop a device capable of load metering on branch circuit intended for convenience outlets that is functional and reliable. It utilized random suitable components such as ACS model of current sensor, Arduino Uno as a microprocessor and LED as load-meter indicator. The study has undergone experimental type of research leading to quantitative results. Results showed that the average percentage error of the device is 6.82% that is interpreted as highly accurate. Likewise, the result of the frequency count yielded to a 100% degree level of precision that is interpreted as highly reliable. Lastly, the study revealed that there is no significant difference on the readings of different types of electrical residential load connected.

The device was designed for residential units only operating around 220V to 230V and in single-phase condition. The branch circuit size considered was 20-Ampere rating that is principally intended for convenience loads. The restriction of the device assembly used is indoor type only and the loads considered are only termed as identified and listed as reflected from the definition of the PEC. Single branch circuit type equipment like electric range and air conditioners were not identified as test loads because they are required to be installed on a separate branch circuit. Lastly, the allowable connected electrical load shall be set to 80% as referred to the PEC.

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Appendix – Photo Documentation

Convenience Outlet Interface

Figure 1presents the layout and actual photo of convenience outlet interface with LED Load-Meter Indicator. Also, fore parts of the device were labeled on the presented layout.

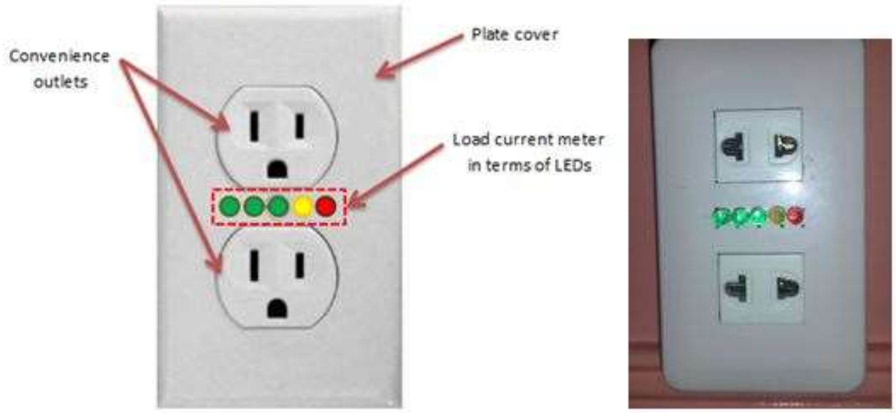

Figure 1: Layout Photo (left) and Actual Photo (right) of Convenience Outlet Interface with LED Load-Meter Indicator

Final Output Device

Figure 2 presents the layout and actual photo of the final output device.

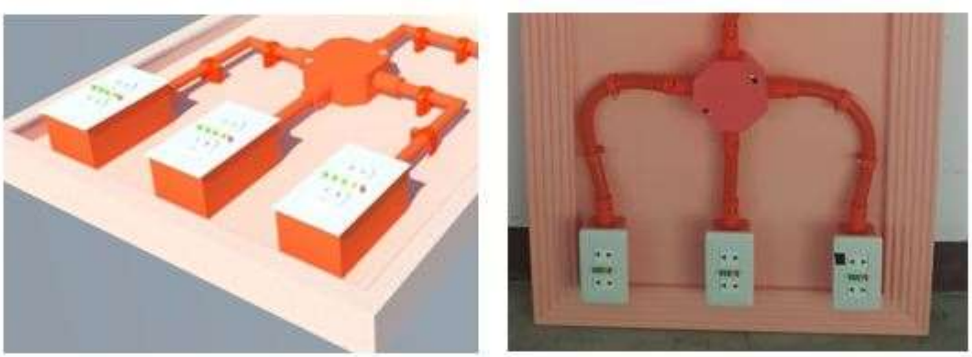

Figure 2: Layout Photo (left) and Actual Photo (right) of the Final Output Device