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ARDUINO-BASED LOAD CURRENT DISPLAY AND TIME-DELAY PROTECTIVE DEVICE FOR AIR CONDITIONING UNITS

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Abstract

The study aimed to design, develop and evaluate an Arduino-based load current display and time-delay protective device inclusively intended for air conditioning units (ACUs) during cases of power interruption with intermittent restoration and power surges. Specifically, it sought to determine the performance of the device in terms of reading and monitoring the current drawn by a certain ACU and the time elapse for the switch-on delay of the protective device with a given set of predetermined time. Thus, the device operates in the principle of a microprocessor and motor control and generally consists of two major components namely: a) load current reading display and b) adjustable switch-on time-delay outlet. The whole system was compacted inside a pull box and embedded with one ACU outlet. An Experimental method was employed and standardized materials were used as bases for the technical foundation and whole conduct of the said study. Arithmetic mean, average deviation, and percentage error were the statistical tools used. Results of the experiment showed that the load current display of the device in terms of average percentage error yielded to a value of 3.30% that is interpreted as highly accurate. Moreover, the precisions of time elapse for the switch-on delay on different predetermine time settings of 3 minutes, 4 minutes and 5 minutes are 3.0074±0.0934 minutes, 4.0179± 0.0614 minutes, and 5.0415± 0.0453 minutes respectively.

***Keywords*:** Air Conditioning Unit (ACU), Arduino, Load Current, Time-Delay.

1. Introduction and Purpose

It is a common knowledge for electrical practitioners that the electricity being supplied on residential units is unstable and that instability causes fluctuations on the magnitude of current to rise and fall on a certain electrical system (IIEE 2015, p.13). Due to this scenario, it can bring serious damages to electrical equipment that are barely sensitive to these fluctuations such as Air Conditioning Units or shortly called ACUs (Kolifrath 2019; Dahl 2019).

Nowadays, ACUs are common on residential, commercial and industrial establishments but mostly installed in institutions (Florida Solar Energy Center 2014; United States Environmental Protection Agency n.d.). The purpose of the system is to provide good indoor air quality and provide thermal comfort (Yu et al. 2008, p.4). However, this kind of equipment is vulnerable when not properly electrically protected. Two factors that affect most electrical appliances are the power interruption having intermittent restoration and power surges (Papiewskin.d.; Banda 2009). Power interruption is a complete loss of supply voltage or load current due to various reasons (Seymour n.d.). During the intermittent start of the restoration of power having the equipment sill being connected, it causes a staggered restarting of equipment. Having this scenario occurs repeatedly, the compressor and internal components of the ACU may be damaged which may further brought damages to the compressor part or in the whole unit as

well (Neighbors A/C 2018). If the system was not equipped with a delay timer and it was turned within 5 minutes of turning it off, the compressor inside the condenser must start against that higher pressure; which is not good for the compressor and could possible damage it (High Performance HVAC n.d.). On the other hand, power surge is a temporary increase or spike action in electrical voltage (Sweetwater 2003). They technically tend to occur when electricity is interrupted and restarts which may bring damage on Heating, Ventilation and Air Conditioning (HVAC) systems, appliances and electronic devices. The larger the spike, the more likely damage will occur (Lawber 2017).

Thus, to render protection on these sensitive equipments, modern air conditioners generally have a range of 3 to 5 minutes of time delay for the compressor to start to keep the compressor form short cycling. Considering the longest time delay of 5-minutes protects the compressor form high pressure caused by change in the flow of refrigerant at the reversing valve (Grantham 2018). The electromechanical controls can be connected to the circuit board in such a manner that the time-delay feature is used to keep the unit from short cycling (Whitman et al. 2000, p.271). In simple cases, electromechanical controls are governed by microprocessors such as Arduino microcontrollers that is the most popular of all due to its inexpensive cost and ease of programming. They are also capable on creating real-time feedback control system suitable for accurate setting of time delay (Krauss 2017).

With the acquired information on the means of equipment protection for ACUs, it may be used to address the problem brought during cases of power interruption having intermittent restoration and power surges. With this, the researcher was moved to develop an Arduino-based protective device that will render protection inclusively for ACUs by means of load current display and switch-on time delay function on the ACU outlet. The study was limited to air conditioning units running in 1-phase, 60Hz, operating voltage of 220V/230 Volts and of window-type only.

2. Research Problem

The study generally aimed to develop an Arduino-based protective device for ACUs during cases of power interruption with intermittent restoration and power surges. Specifically, it sought to determine the performance in terms of accuracy and precision of the load current reading display and the time elapse for switching-on delay of the device with a given set value of predetermined time.

3. Methodology

This study adopted the experimental type of research design. It is the most scientifically sophisticated research method for it is concerned with analysis of the effect of the independent variable to the dependent variable where the independent variable is manipulated through treatment or intervention and the effect of those interventions is observed on the dependent variable (Patidar 2013). In this study, the controlled and independent variable was the predetermined time-delay value for safe restarting of the equipment and the dependent variable was the actual measured time-elapse of the set of contactor circuit for the adjustable switch-on time-delay outlet.

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 consists mainly of gathering and assessing information based on what are the scopes of the study such as review of different literatures on problems encountered and technical data

for ACUs. They will serve as the primary inputs and significant foundation on the preparation of the study.

Development process

Development process is the most important and vital part of procedure because it is where the study will be technically developed that will lead to the output and evaluation to yield favourable results. This stage mainly composed the organized technical procedures in the development of the study such as circuit design, material preparation, fabrication and evaluation. Moreover, a couple of modification and alternations were made to maximize the favourability of results.

Final output device

This is the last stage of the procedure where the final output is a finished functional protective device for ACUs. Thus, the device was named 'Arduino-Based Load Current Display and Time-Delay Protective Device for Air Conditioning Units'.

Research Development

The development of the study has followed the process from the presented framework of procedures. In circuit design, a computer-aided drafting software (AutoCAD) was used on the schematic layout of the circuitry of the device. Then, preparation of needed materials took place after determining all the materials and components needed. The list of materials essentially includes current sensor (ACS712 model), ACU outlet, microprocessor (Arduino Uno), LCD Display, Contactor, Pilot Lamps, and Timer Relay. 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 favourable results.

Next, fabrication process takes place immediately after the preparation of all the materials and components needed. It was considered as the most crucial, but the most significant step in the development process of the device. The detailed design served as guide in the construction phase of the device. The device was constructed at Mercedes, Camarines Norte with the following activities conducted: lay outing, preparation of the case, assembly of electrical components, assembly of electronic components and programming. The whole activity was reflected on the work plan to facilitate the flow of development of the device.

Testing Procedures

After the device was fabricated, it has undergone evaluation to determine its performance during operation in terms of precision and accuracy. Moreover, in accuracy, the device subjected to three (3) trials where it measured the average percentage error of the load current reading display of the device as compared to the actual load current consumed. Then, it was descriptively interpreted as reflected on Table 1 that shows the interpretation for the accuracy based on the obtained value of the said parameter.

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, average deviation was used as a means of determining the level of precision of the time-delay switch on of the ACU outlet on the predetermined time setting of 3 minutes, 4 minutes and 5 minutes respectively. With this, the study made use of the readily available statistical software (Microsoft Excel) for ease of statistical calculation.

Statistical Tools Used

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

Arithmetic Mean

Arithmetic mean refers to the average quantity of a given set of values(Weissteinn.d.). In this study, it was used to compute the average percentage error for all the trials conducted as well as the base for the average deviation in determining the precision of the device.

Average Deviation

Average deviation is a more detailed measure of the precision of a group of measurements or experiment values (wikiHow 2019). In this study, it was used to determine the precision of the time-delay switch on of the outlet for a given predetermined time settings.

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 to the reading value of the clamp-on ammeter and the theoretical reading pertains on the reading value of the load current reading display of the device.

4. Data and Analysis

Table 2 shows the results obtained from the three trials conducted in order to measure the accuracy of the device. Moreover, the computed overall average percentage error of the device is 3.30% 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

No. of Trials	$\text{Reading}_{\text{Clamp-on Meter}}$	$\text{Reading}_{\text{LCD Display}}$	Percentage Error
1st Trial	4.60 Amperes	4.447 Amperes	3.33%
2nd Trial	4.71 Amperes	4.500 Amperes	4.46%
3rd Trial	4.49 Amperes	4.395 Amperes	2.12%
		Average (Arithmetic Mean)	3.30%

Then, the precision in terms of average deviation was measured by computing the mean and the absolute deviation. Table 3 shows that the precision of the device in terms of predetermined time settings of 3 minutes, 4 minutes and 5 minutes are 3.0074 ± 0.0934 minutes, 4.0179 ± 0.0614 minutes, and 5.0415 ± 0.0453 minutes respectively. It was observed that there is a significant increase in the value of absolute deviation as the time considered increases. This might be due to the systematic error that deviates by a fixed amount form the true value of measurement (Kallan.d.).

Table 3: Summary of Result for Precision

Test No.	Time Setting	Mean	Absolute Deviation	Average Deviation (Precision)
1	3 mins.	3.0074 mins.	0.0934	3.0074 ± 0.0934 mins.
2	4 mins.	4.0179 mins.	0.0614	4.0179 ± 0.0614 mins.
3	5 mins.	5.0415 mins.	0.0453	5.0415 ± 0.0453 mins.

Conclusions

The purpose of the study was to design and develop an Arduino-based protective device for ACUs capable of reading the load current consumed and has a switch on time-delay outlet that is functional in terms of accuracy and precision. The overall conduct of the study has utilized random components such as ACS model of current sensor and LCD display for the load current reading display; Arduino Uno as the microprocessor; and ACU outlet connected to a set of contactor circuit for the adjustable switch-on time-delay outlet. The study has undergone an experimental type of research leading to quantitative data. Results showed that the accuracy of the load current reading display of the device by means of average percentage error is 3.30% that is interpreted as highly accurate. Moreover, the precision of time elapse for the switch-on delay on different predetermined time settings of 3 minutes, 4 minutes and 5 minutes are 3.0074 ± 0.0934 minutes, 4.0179 ± 0.0614 minutes, and 5.0415 ± 0.0453 minutes respectively.

The device was designed for ACUs inclusively used in residential and small-scale commercial establishment units only. The values of electrical parameters considered are operating voltage of 220V to 230V, 60 Hertz and single-phase type of electrical system. Moreover, the study was limited to window-type of ACU only and its specified time-delay value for safe restarting. Other implications machine elements under the principles of HVAC and its thermodynamic implications were not included on the scope of the study.

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Appendix – Photo Documentation

Prototype Interface

Figure 1 presents the layout of the Arduino-Based Load Current Display and Time-Delay Protective Device for Air Conditioning Units. The said layout was projected at front view.

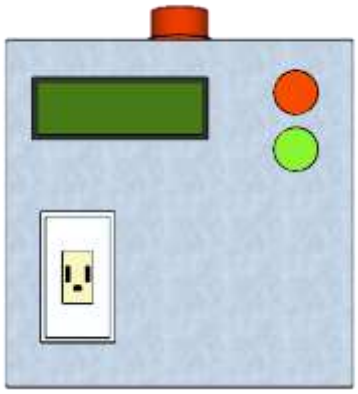

Figure 1: Layout Photo of the Arduino-Based Load Current Display and Time-Delay Protective Device for ACUs

Figure 2 presents the actual photo of the finished prototype model as the final output. The perspective was projected at front view.

Figure 2: Actual Photo of the Arduino-Based Load Current Display and Time-Delay Protective Device for ACUs