Assessment of The Developed Protective Device for Air Conditioning Units (ACUs)

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ABSTRACT

This study evaluated a protective device designed for air conditioning units (ACUs) to safeguard against power interruptions, intermittent power restoration, and voltage surges. The primary objective was to determine the device's performance in terms of sensing accuracy and operational consistency under controlled time intervals, using an experimental method. The device integrates electrical systems with sensing and electronic components, which are all governed by a microprocessor. Statistical tools, including percentage error, arithmetic mean, and a scoring method, were utilized to analyze the results. Findings revealed that the device demonstrated high accuracy in sensing current and voltage values and exhibited strong reliability in executing its time-delay function. These outcomes indicate the device’s effectiveness in protecting ACUs during unstable power conditions.

Keywords: Air conditioning unit (ACU), current, protection, voltage

INTRODUCTION

It is widely recognized among electrical practitioners that the electricity supplied to residential units is often unstable, resulting in fluctuations in current magnitude within electrical systems (IIEE, 2015). Such instability can cause significant damage to sensitive electrical equipment, particularly air conditioning units (ACUs), which are highly susceptible to these fluctuations (Kolifrath, 2019; Dahl, 2019).

ACUs are now commonly found in residential, commercial, and industrial settings, with widespread use particularly in institutional facilities (FSEC, 2014; USEPA, n.d.). These systems are designed to ensure thermal comfort and maintain indoor air quality (Yu et al., 2008). However, ACUs are highly vulnerable to electrical issues when not adequately protected. Two primary factors that pose risks to electrical appliances, including ACUs, are power interruptions with intermittent restoration and power surges (Papiewski, n.d.; Banda, 2009).

Power interruption refers to the complete loss of supply voltage and current due to various causes (Seymour, n.d.). During intermittent restoration, if equipment remains connected, a staggered restart may occur. Repeated exposure to such conditions can damage the compressor and internal components of the ACU, potentially leading to failure of the compressor or the entire unit (Neighbors A/C, 2018). Additionally, if an ACU lacks a delay timer and is restarted immediately after being turned off, the compressor is forced to start against high internal pressure, which can cause mechanical damage (High Performance HVAC, n.d.). On the other hand, a power surge is defined as a temporary spike in electrical voltage (Sweetwater, 2003). These surges often occur during the interruption and subsequent restoration of electricity, posing a significant threat to heating, ventilation and air conditioning (HVAC) systems, appliances, and electronic devices. The severity of the damage increases with the magnitude of the voltage spike (Lawber, 2017).

To protect sensitive equipment such as ACUs, modern systems typically incorporate a time-delay feature, ranging from 3 to 5 minutes, to prevent the compressor from short cycling. A delay of up to 5 minutes is particularly effective in protecting the compressor from high pressure resulting from changes in refrigerant flow at the reversing valve (Grantham, 2018). Electromechanical controls can be integrated with the circuit

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board to activate the time-delay function and prevent short cycling (Whitman et al., 2000). In simpler implementations, such controls are often governed by microprocessors—most notably Arduino microcontrollers—due to their affordability, ease of programming, and capability to facilitate real-time feedback control systems for accurate time-delay settings (Krauss, 2017).

With this understanding of protective mechanisms for ACUs, the present study was motivated to perform assessment of the currently developed protective device. This device features both load current and voltage value display and an automatic switch-on time-delay function integrated into the ACU outlet. The study focused solely on window-type air conditioning units operating on single-phase, 60Hz, 220V/230V systems.

RESEARCH PROBLEM

The study generally aimed to evaluate the performance of a currently developed protective device designed for air conditioning units (ACUs) to safeguard against power interruptions, intermittent power restoration.

METHODOLOGY

This study employed an experimental research design, which is considered the most scientifically rigorous method of investigation (Patidar, 2013).

Prototype Interface

Figure 1 presents the actual photo of the currently developed protective device for ACUs projected at front view.

Figure 1: Actual Photo of the Currently Developed Protective Device for ACUs

Assessment Procedures

The assessment of the device performance was conducted using two primary parameters: (a) the accuracy of the sensors in measuring current and voltage, and (b) the determination of the device's reliability level.

To evaluate sensor accuracy, the device underwent three (3) trial measurements. During each trial, the sensed values for current and voltage were recorded and compared against actual values obtained using calibrated reference instruments. The average percentage error was then calculated for each parameter. The results were descriptively analyzed and interpreted according to the classification criteria presented in Table 1.

Average Percentage Error	Descriptive Interpretation
0.1% to 20%	Highly Accurate
20.1% to 40%	Very Accurate
40.1% to 60%	Moderately Accurate

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60.1% to 80%	Slightly Accurate
80.1% to 100%	Not Accurate

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

To assess reliability, the device was tested under three (3) distinct time-delay settings, with three trials conducted for each setting. The recorded time-delay values were then evaluated to determine whether they fell within the acceptable range of average deviation. A trial was classified as successful if the measured delay remained within this specified range. The interpretation of the results was guided by the criteria outlined in Table 2.

Test Score	**Descriptive Interpretation**
9	Highly Reliable
7 to 8	Very Reliable
5 to 6	Moderately Reliable
4	Slightly Reliable
0 to 3	Not Reliable

Table 2: Table of Interpretation for Reliability

Statistical Tools Used

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

Arithmetic Mean. This refers to the average quantity of a given set of values (Weisstein n.d.). In this study, it was used to compute the average percentage error for all the trials conducted.

Percentage error. This 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 calibrated reference instruments and the theoretical reading pertains on the reading value of the reading display of the device.

Scoring Method. This refers to the proportion of successful outcomes relative to the total number of trials conducted. In the context of this study, it was utilized to quantify the frequency which the device successfully performed its intended function.

Data and Analysis

Table 3 presents the results from the three (3) trials conducted to evaluate the device's accuracy in measuring current. The computed overall average percentage error was 3.24%, which, based on the established interpretation scale, is classified as “Highly Accurate”.

No. of Trials	**Reading$_{\text{Clamp-on Meter}}$**	**Reading$_{\text{LCD Display}}$**	**Percentage Error**
1st Trial	4.60 Amperes	4.45 Amperes	3.26%
2nd Trial	4.71 Amperes	4.50 Amperes	4.46%

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3rd Trial	4.49 Amperes	4.40 Amperes	2.00%
	Average (Arithmetic Mean)		3.24%

Table 3: Result of Accuracy in terms of Current reading

Meanwhile, Table 4 presents the results of the three (3) trials conducted to assess the accuracy of the device in measuring voltage. The computed overall average percentage error was 2.23%, which is interpreted as "Highly Accurate" based on the predefined criteria. This result indicates that the overall design and configuration of the device effectively fulfilled its intended function with constructive and efficient performance.

No. of Trials	**Reading** $_{\text{Voltmeter}}$	**Reading**$_{\text{LCD Display}}$	**Percentage Error**
1st Trial	215.40 Volts	220.13 Volts	2.20%
2nd Trial	215.70 Volts	220.59 Volts	2.27%
3rd Trial	215.40 Volts	220.18 Volts	2.22%
	Average (Arithmetic Mean)		2.23%

Table 4: Result of Accuracy in terms of Voltage reading

These findings suggest that the sensor components functioned reliably across multiple trials and that the system design's and implementation were both effective and efficient. This is also consistent with those reported by Chooruang and Meekul (2018), who developed an energy monitoring system. Their research supports the accuracy of sensor-based systems for effective monitoring of energy-related data. Moreover, the consistently low error margins reflect the device's capability to deliver precise measurements, supporting its potential application in practical monitoring or control setting.

Table 5 presents the result of the trials conducted for each predetermine time setting. The data indicate that the device consistently operated within the acceptable time deviation established from its previous study, achieving a perfect score of 9 out of 9. This outcome is interpreted as indicative of a "Highly Reliable" performance.

Time	**Trials**	**Test Value**	**Deviated Time**	**Successful**	**Not-Successful**
3 Mins.	1st	3.001	3.007 mins.	✓	-
	2nd	3.013		✓	-
	3rd	3.008		✓	-
4 Mins.	1st	4.019	4.017 mins.	✓	-
	2nd	4.012		✓	-
	3rd	4.014		✓	-
5 Mins.	1st	5.025	5.033 mins.	✓	-
	2nd	5.041		✓	-

	3rd	5.038		✓	-
			Total	**9**	**0**

Table 5: Result for Reliability

These results jives with the studies conducted by Zhang and Han (2022) who explored time-delay systems and their applications and Shia and Druzhinin (2024) who developed a fault detection, protection and automation application.The data also reflects the device's high degree of temporal accuracy and functional reliability. This level of performance suggests that the device is well-calibrated and capable of maintaining stable operation under controlled conditions. The classification of the outcome as “Highly Reliable” further supports its potential for consistent performance in practical applications. These findings reinforce the validity of the device’s design and timing mechanism, and they provide a strong basis for its deployment in contexts where precise timing is critical.

CONCLUSION

The device demonstrated a high level of accuracy and reliability across all tested parameters—current measurement, voltage measurement, and timing functionality. The low average percentage errors of 3.24% and 2.23% for current and voltage, respectively, as well as the perfect reliability score in timing trials, confirm the effectiveness of the device’s design and calibration. These results are consistent with existing literature, underscoring the device’s potential in fault detection and automation applications. It is therefore recommended that the device be considered for integration to ACU operations. To further strengthen its practical viability, future studies should explore its performance under dynamic or variable field conditions and on varying models of ACUs.

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