Development and Implementation of Power Saving Device for Inductive Load

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Abstract

This research study focuses on developing and implementing a power-saving device for inductive loads using the Power Factor Corrector (PFC) technique. Inductive loads often exhibit a low power factor, resulting in inefficient energy usage and the risk of equipment damage. The primary aim of this study was to explore and employ the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model as a systematic approach to create an effective PFC solution for improving power factor correction and enhancing energy efficiency. The research methodology involved a thorough investigation of various methods and techniques tailored to achieving accurate power factor correction specifically for inductive loads. Extensive analysis of the characteristics of inductive loads was conducted, identifying critical parameters and components necessary for an efficient PFC system. Through a series of carefully designed experiments, the researchers successfully demonstrated the exceptional performance of the developed PFC in achieving optimal power factor correction for inductive loads. The implementation yielded significant improvements in energy efficiency and substantial reduction in energy losses associated with inadequate power factor correction. The implications of this research extend not only to industries heavily reliant on inductive loads but also to household applications. This study makes a noteworthy contribution to the field by showcasing the development and successful implementation of a power-saving device customized for inductive loads. The findings have the potential to revolutionize energy utilization and power factor balancing, thereby advancing technology and promoting efficient energy usage in both household and industrial settings. The application of this device in household inductive load appliances holds promise for significant energy savings and improved power factor correction in everyday home electrical systems.

Keywords: *Power Factor Corrector, Inductive Load, ADDIE Model, Energy Utilization, Energy Loss Reduction, Household Appliances*.

1. Introduction

With the increasing demand for energy efficiency and sustainability, the development of power-saving devices has become a crucial area of research. Inductive loads, such as motors and transformers, are widely used in various industries and household appliances. However, these loads often exhibit low power factor and high reactive power consumption, leading to inefficient energy utilization and increased electricity costs. To address this issue, the design and implementation of a power-saving device specifically targeted at inductive loads have gained significant attention in recent years.

Inductive loads require reactive power to establish and maintain magnetic fields, which results in a phase difference between the voltage and current waveforms. This phase difference leads to increased power consumption and reduced power factor. Power-saving devices for inductive loads aim to compensate for reactive power, improve power factor, and reduce energy wastage. By optimizing the power factor and minimizing reactive power, these devices contribute to energy savings, lower electricity bills, and reduced environmental impact.

One approach to designing a power-saving device for inductive loads is the incorporation of power factor correction (PFC) techniques. PFC techniques actively control the power factor by adjusting the voltage and current waveforms, aligning them in phase and reducing reactive power. Various PFC topologies, such as boost converters, buck-boost converters, and bridgeless converters, have been explored in the literature (Datta, 2018;

Zhang, Yu, & Tang, 2019). These techniques aim to improve the power factor of inductive loads and enhance overall system efficiency.

Additionally, advanced control algorithms and intelligent optimization techniques have been investigated to further enhance the performance of power-saving devices for inductive loads. These techniques involve real-time monitoring of load conditions, adaptive control strategies, and feedback control loops to dynamically adjust the operation of the device (Kaur & Rana, 2020; Huang, Lin, & Tang, 2021). By intelligently analyzing load characteristics and adapting the device's operation, these techniques optimize energy consumption and achieve optimal power savings.

The design and implementation of a power-saving device for inductive loads have the potential to make a significant impact on energy efficiency, cost savings, and environmental sustainability. By addressing the power factor and reactive power issues associated with inductive loads, these devices contribute to a more efficient utilization of electrical power. Figure 1 shows the concept of the study.

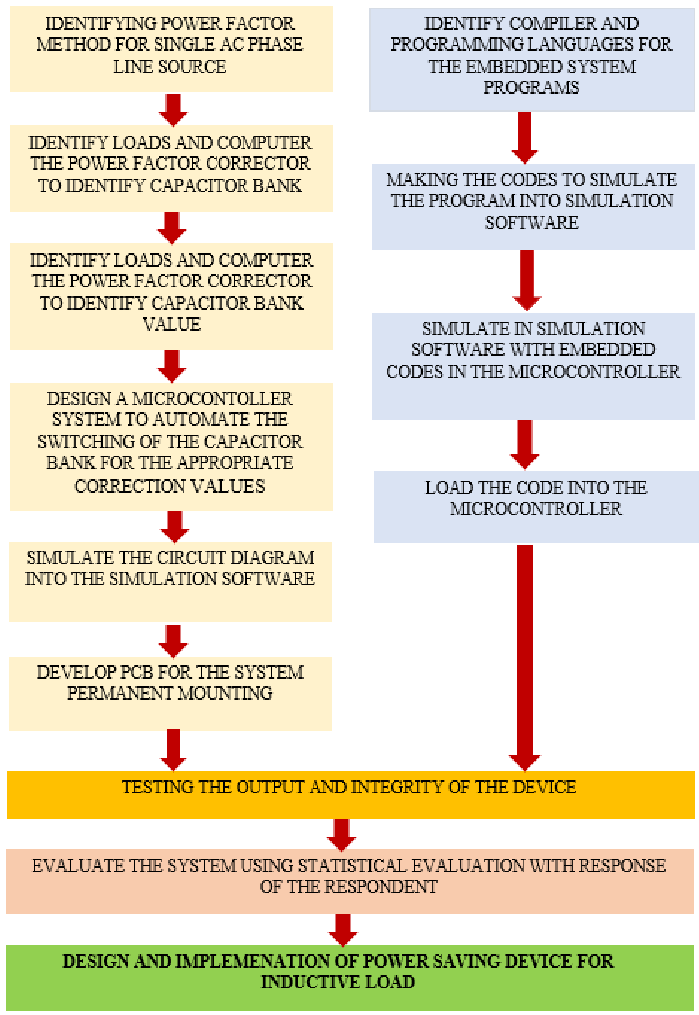

Fig. 1. Concept of the Study

2. Methods

The development of the power-saving device for inductive loads will follow the ADDIE model, a widely recognized instructional design framework consisting of five key stages: Analysis, Design, Development, Implementation, and Evaluation. This methodology ensures a systematic approach to the development process, enabling effective design, implementation, and evaluation of the device. Figure 2 deflects the ADDIE model scheme.

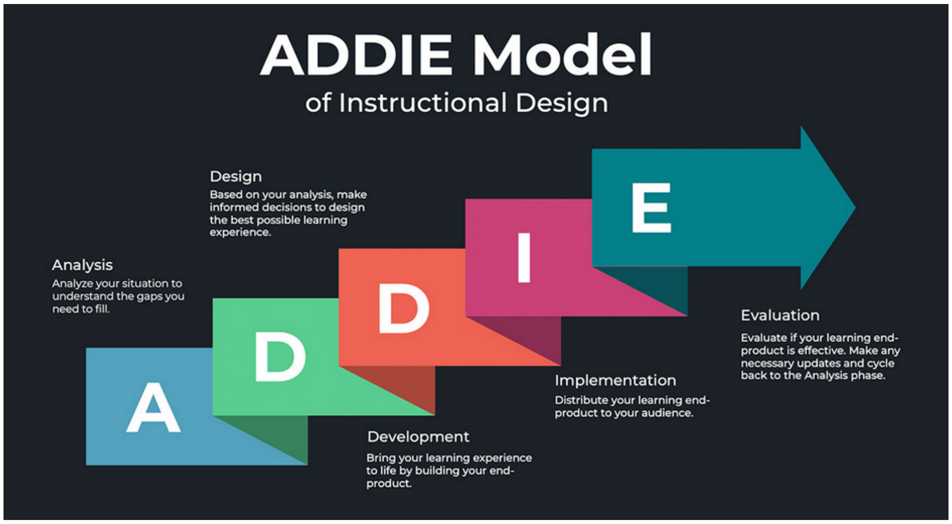

Fig 2. ADDIE Model

2.1 Analysis

A thorough understanding of the problem and requirements is gained. This involves conducting a comprehensive analysis of inductive loads, their power consumption patterns, and the impact of power factor on energy efficiency. Data collection methods such as literature review, interviews, and surveys may be employed to gather relevant information. The key outputs of this stage include a clear problem statement, defined objectives, and a detailed analysis of user requirements and constraints.

2.1.1 Related Literature

Power-saving devices for inductive loads have been the subject of extensive research and development in recent years. This section provides a review of relevant literature on the design, implementation, and performance of such devices.

One area of focus in the literature is the application of power factor correction (PFC) techniques to improve the power factor and efficiency of inductive loads. Zhang, Yu, and Tang (2019) investigated the implementation of PFC using a bridgeless boost converter. Their study demonstrated significant improvements in power factor and reduced reactive power consumption in inductive loads. Similarly, Datta (2018) conducted a review of different PFC circuit topologies, highlighting their advantages and limitations in achieving power factor correction.

Advanced control algorithms have also been explored in the literature to optimize the operation of power-saving devices for inductive loads. Kaur and Rana (2020) proposed the use of adaptive algorithms for controlling power-saving devices. Their research showed that adaptive control strategies can dynamically adjust the device operation based on load conditions, resulting in improved energy efficiency and power savings.

Furthermore, the integration of IoT (Internet of Things) and big data analysis has been investigated as a means to enhance the intelligence and performance of power-saving devices for inductive loads. Huang, Lin, and Tang (2021) developed an intelligent power-saving device based on IoT and big data analysis. Their study demonstrated the capability of real-time monitoring and data analysis to optimize energy consumption and achieve optimal power savings in inductive load applications.

In addition to PFC techniques and advanced control algorithms, the literature also discusses the design considerations and challenges associated with the implementation of power-saving devices for inductive loads. Factors such as system efficiency, reliability, cost-effectiveness, and compatibility with different load types are important considerations in the design process. Researchers have explored various circuit topologies, component selection, and protection mechanisms to address these design challenges (Datta, 2018; Huang et al., 2021).

Overall, the reviewed literature highlights the significance of power-saving devices for inductive loads and the potential benefits they offer in terms of improved power factor, reduced energy consumption, and cost savings. The studies emphasize the importance of employing PFC techniques, advanced control algorithms, and intelligent optimization methods to achieve efficient power savings in inductive load applications.

2.1.2 Objectives of the Study

This study aims to address the energy inefficiencies and excessive power consumption associated with inductive loads, focusing on the design, development, and implementation of a power-saving device that utilizes power factor correction techniques. The objective is to optimize energy utilization, enhance the efficiency of inductive load operations, and promote sustainable energy management practices.

2.1.2.1 Specific Objectives:

- 2.1.2.1.1 Design and Development of a Power-Saving Device
- 2.1.2.1.2 Prototype Construction and Testing
- 2.1.2.1.3 Implementation and Field Trials

The design, development, and implementation of the power-saving device with power factor correction capabilities will contribute to reducing energy wastage, optimizing energy utilization, and promoting sustainable practices in various industrial and residential applications.

An online website to calculate the power factor shown in Figure 2.2 that allows the researchers to easily identify the equivalent power factor of the given load.

Fig 3 Online Power Factor Calculator

2.2 Design

In the Design stage, the specifications and conceptual framework for the power-saving device are developed. This includes determining the optimal power factor correction techniques, selecting appropriate circuitry and components, and designing the control algorithms. The design phase will also consider factors such as load compatibility, ease of integration, and cost-effectiveness. The output of this stage is a comprehensive design document that serves as a blueprint for the development process.

During this stage of the study, the researcher focuses on designing a microcontroller system that can effectively control and automate the processes to align with the system requirements identified in the analysis phase. The researcher begins by creating a block diagram, as depicted in Figure 4, which serves as the foundation for the subsequent development of the system. The block diagram provides a visual representation of the system's components and their interconnections, guiding the researcher in the actual implementation of the system.

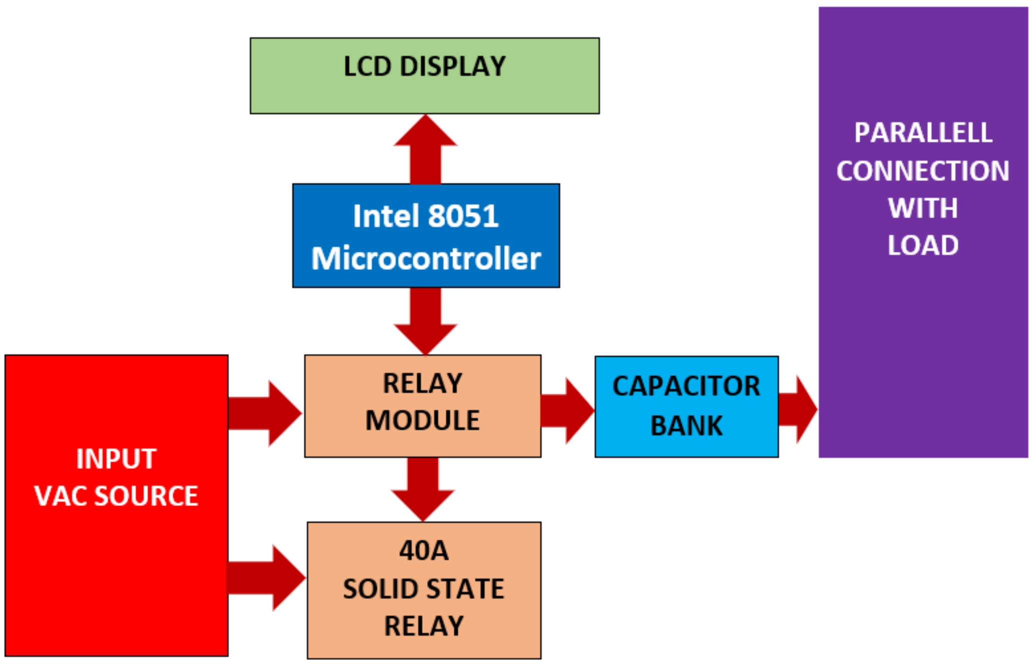

Fig 4. Block diagram of the system

Following the development of the block diagram, the next stage in the design process involves creating an equivalent circuit diagram. This diagram serves as a detailed representation of the system's components and their connections, enabling the researcher to test and simulate the system using available software tools. In this case, the simulation software chosen allows for a free download scheme, providing a cost-effective solution for evaluating the system's functionality.

Figure 5 illustrates the circuit diagram of the main control system, specifically utilizing the Intel 8051 microcontroller. This microcontroller is a popular choice due to its versatility and widespread use in various applications. The circuit diagram showcases the specific connections, components, and interfaces associated with the microcontroller, providing a visual representation of the system's hardware configuration.

By creating the circuit diagram and utilizing simulation software, the researcher can evaluate the system's performance, test different scenarios, and identify any potential issues or improvements. This stage of the design process ensures that the system is thoroughly evaluated and optimized before proceeding to the next phase of implementation.

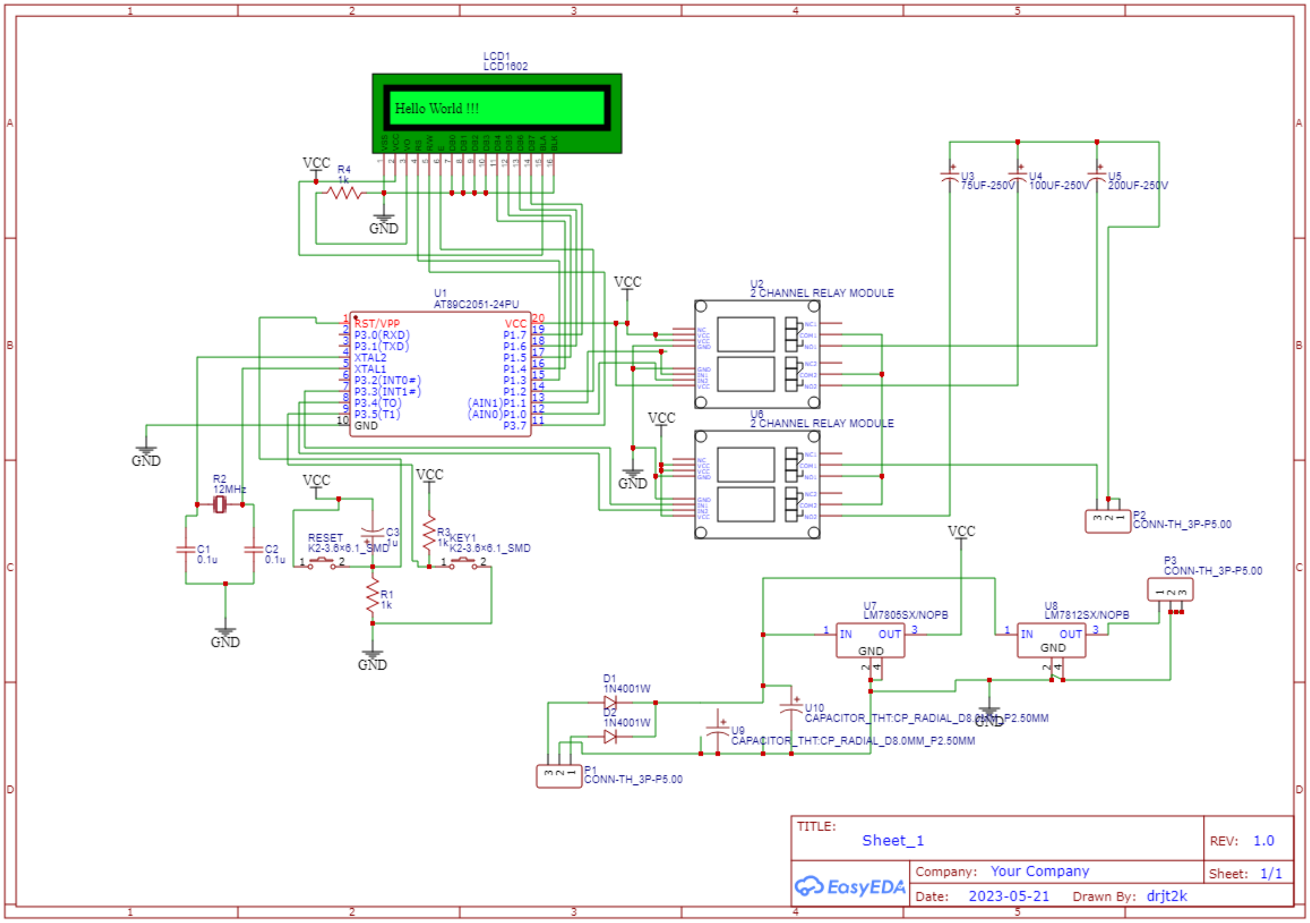

Fig 5. Schematic Diagram of the System

2.3. Development

The Development stage involves the actual construction of the power-saving device based on the design specifications. This includes procuring necessary components, assembling the circuitry, and programming the control algorithms. Prototyping techniques, such as breadboarding and 3D printing, may be used to create functional prototypes. Rigorous testing and iteration are performed to ensure the device meets the design requirements and functions as intended.

During this stage of the study, the researcher progresses from the circuit diagram to the actual layout of the circuit. The purpose is to ensure that all the required components are appropriately positioned on the permanent circuit board, facilitating the finalization of the system. Additionally, the researcher focuses on writing and embedding the necessary codes into the microcontroller, which plays a vital role in the device's operation.

Figure 6 provides a visual representation of the environment in which the researcher develops the code. It showcases the Integrated Development Environment (IDE) that includes a compiler specifically designed for working with the chosen microcontroller. Within this environment, the researcher utilizes assembly language to write and refine the code that will drive the functionality of the power-saving device.

By converting the circuit diagram into the circuit layout and programming the microcontroller, the researcher takes significant steps towards the completion of the system. This stage involves meticulous attention to detail to ensure the correct placement of components and the precise coding necessary for the device's operation.

The environment shown in Figure 6 serves as a workspace for the researcher to develop and fine-tune the code, leveraging the capabilities of the IDE and compiler to create an efficient and functional system.

Through this stage, the researcher moves closer to the realization of the power-saving device, combining the physical circuit layout with the embedded code to enable its intended operation.

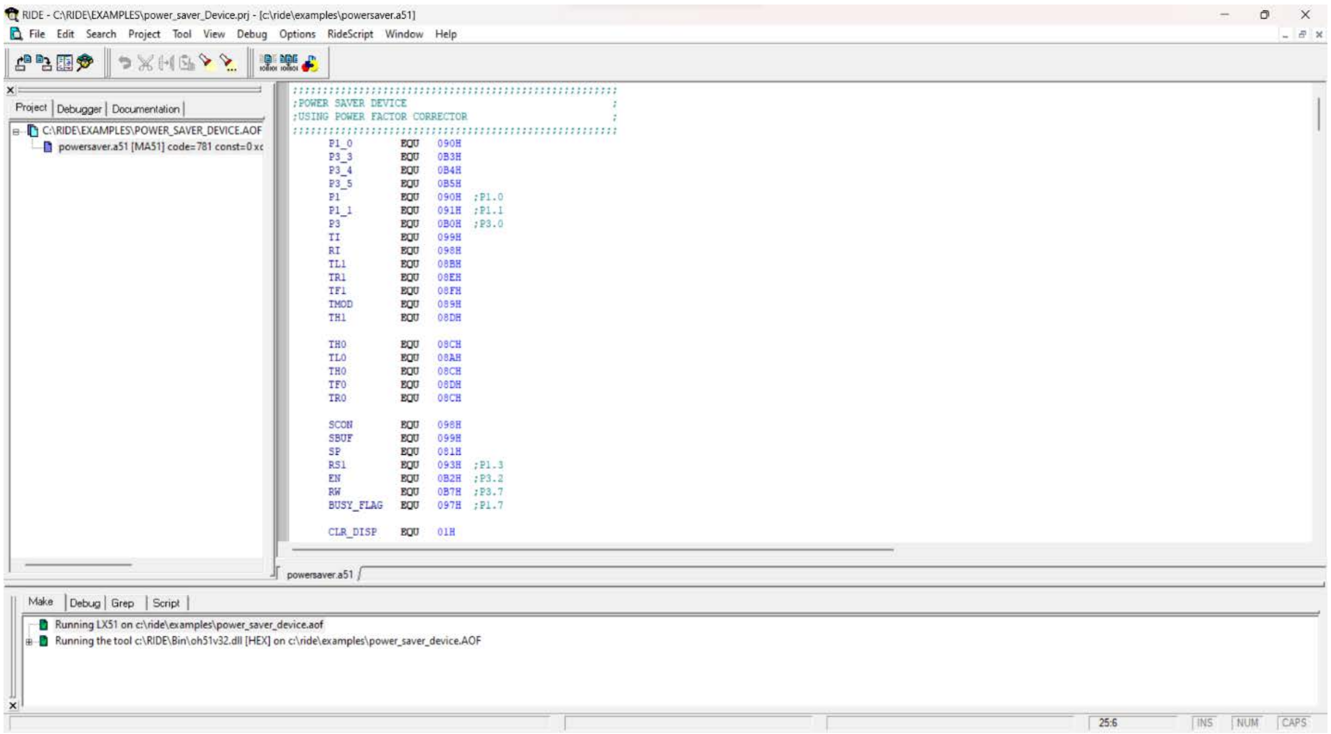

Fig 6. Compiler Environment

Additionally, once the system code has been developed for embedding into the microcontroller, a software and hardware emulator is employed to facilitate the integration of the code into the actual microcontroller chip. Figure 7 illustrates the software emulator, while Figure 8 depicts the hardware emulator.

In Figure 8, the microcontroller chip is placed securely in the Zero Insertion Force (ZIF) socket, ensuring a stable connection for the embedding process. The hardware emulator allows for testing and validating the functionality of the code in a realistic manner. On the other hand, Figure 7 showcases the software emulator, which serves as a virtual representation of the hardware emulator. Both emulators are crucial components of the development process, as they enable the assessment of the system's behavior and performance.

The software emulator provides a means to simulate the behavior of the hardware, allowing for the testing and debugging of the embedded code. It enables the researcher to evaluate the functionality of the system and make necessary adjustments before the final implementation.

The hardware emulator, on the other hand, provides a physical platform for testing the system. By placing the microcontroller in the ZIF socket and locking it securely, the researcher can observe the behavior of the embedded code on real hardware components.

Both the software and hardware emulators are indispensable tools in the development stage. Their presence ensures that the system can be thoroughly tested and refined before the final implementation. By utilizing these emulators, the researcher can assess the performance, functionality, and accuracy of the embedded code, ensuring that the power-saving device operates as intended.

The combination of the software and hardware emulators provides a comprehensive testing environment, allowing for a more realistic and reliable output during the system's development process.

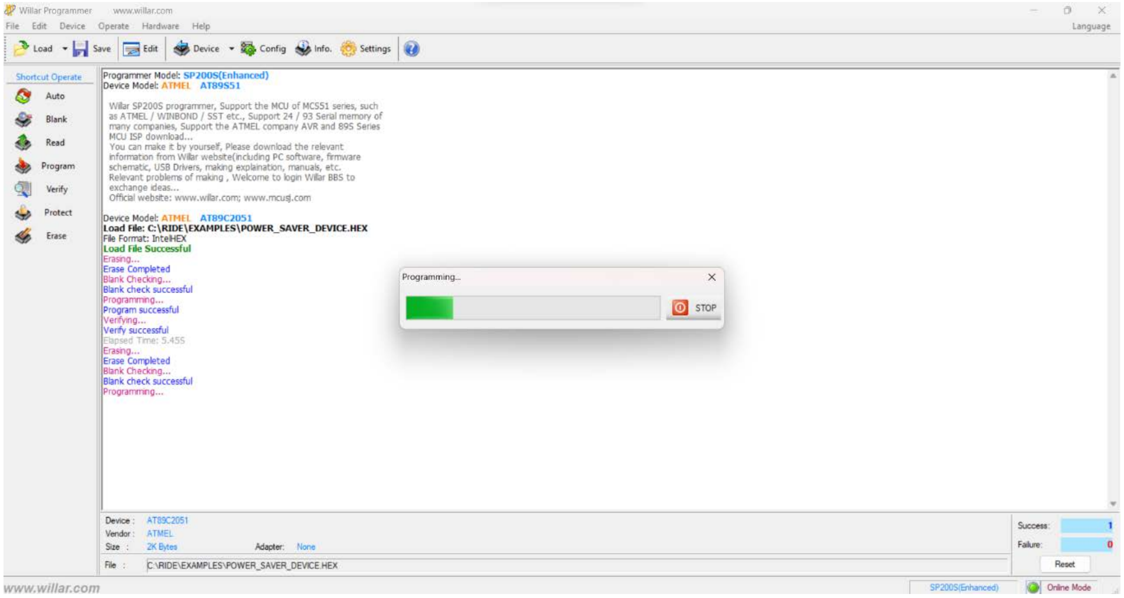

Fig7. Emulator Software for intel 8051 Microcontroller

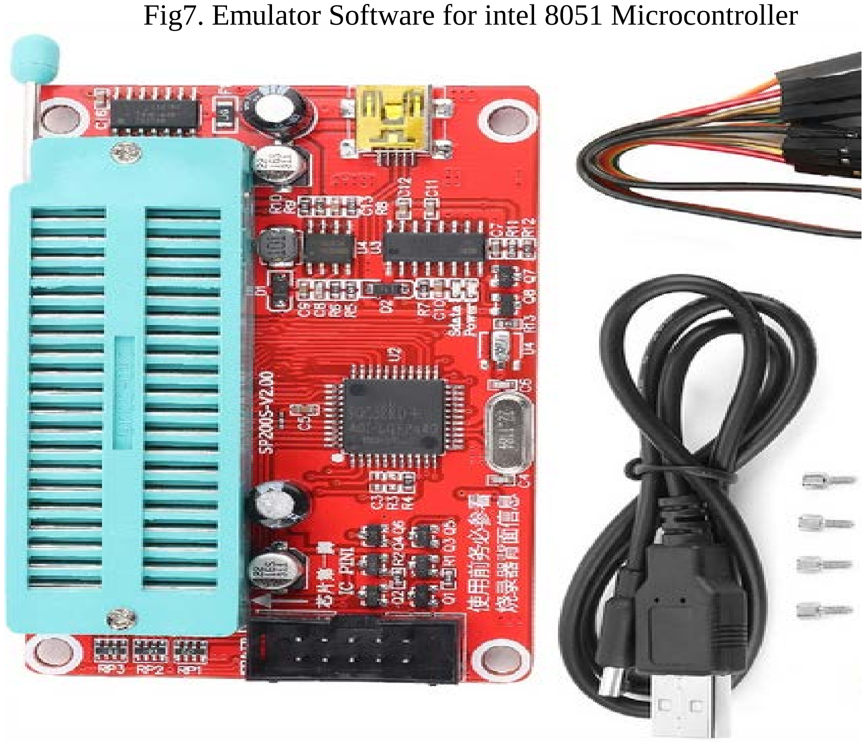

Fig. 8. Hardware Emulator

In addition, the researcher employed an online PCB designer to simplify the process of creating intricate circuit diagram layouts. This tool not only provides a user-friendly interface but also offers advanced features that greatly aid in the design and arrangement of complex circuit diagrams. The successful utilization of this online PCB designer is evident in Figure 9, which showcase the circuit diagram layouts accomplished by the researcher.

Figure 9 showcases the circuit diagram layout designed for the power-saving device, highlighting the intricate connections and placement of components. The online PCB designer allowed the researcher to visualize and optimize the layout, ensuring the efficient and effective implementation of the circuit.

The utilization of the online PCB designer greatly facilitated the development of the circuit diagram layouts, saving time and effort in the design phase. It offered a convenient platform for creating complex layouts, ensuring proper connections and efficient use of space. The evidence presented in Figure demonstrates the researcher's proficiency in utilizing the online PCB designer to create high-quality circuit diagram layouts for the power-saving device.

By employing the online PCB designer, the researcher was able to streamline the circuit design process, resulting in accurate and well-structured layouts. This contributed to the overall success of the design and implementation of the power-saving device for inductive loads. Figure 9 shows finished PCB board of the system ready for the production of the power saver device.

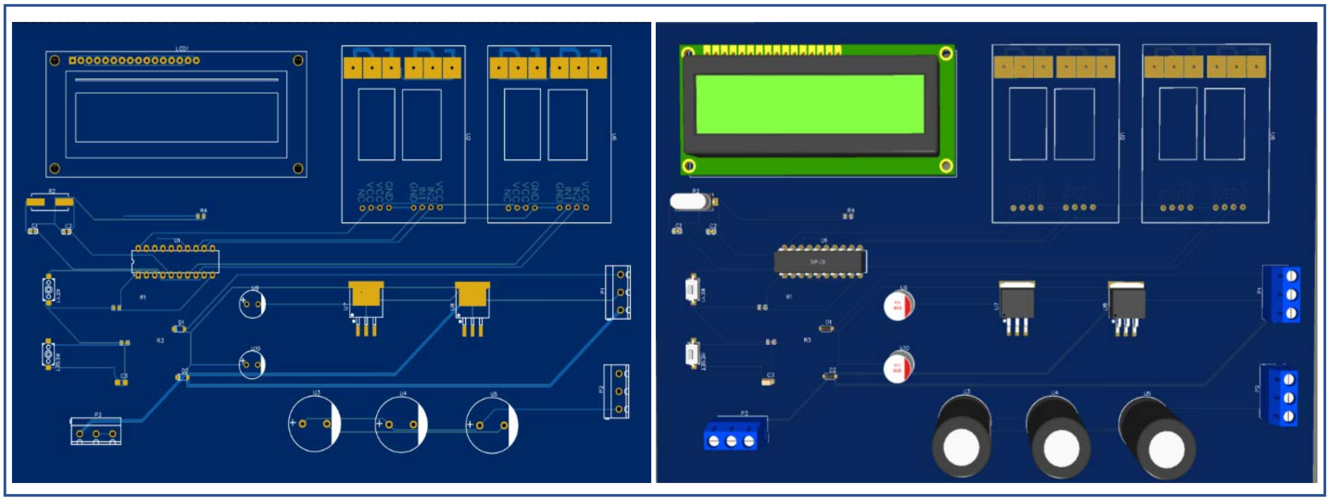

Fig. 9. PCB Board of the System

Fig. 10. Development of System

2.4 Implementation

In the Implementation stage, the power-saving device is integrated into practical settings with inductive loads. This may involve collaborating with industrial or residential partners to install the device in their systems. The implementation process includes configuring the device for specific load requirements, monitoring its performance, and providing necessary user training and support. Feedback from end-users is collected to identify any improvements or modifications needed.

During this stage of the study, the researcher proceeded with the implementation of the power-saving device in a designated area for testing purposes. This provided an opportunity to assess the functionality of the device and evaluate its power-saving efficiency. To ensure accurate comparisons and measurements, the setup involved subjecting two equal loads to different conditions: one with the power saver activated and the other without. Both loads were subjected to the same time frame and parameters.

Figure 11 presents a visual representation of the actual implementation of the system. The image showcases the physical setup where the power-saving device is installed and connected to the load. This setup allows for real-time monitoring and data collection to determine the effectiveness of the device in reducing power consumption.

By conducting the implementation in a controlled environment and comparing the power consumption of the load with and without the power-saving device, the researcher can gather empirical evidence on the device's efficiency. This practical evaluation provides valuable insights into the actual power-saving capabilities of the device and its impact on reducing energy consumption.

The implementation stage serves as a crucial step in validating the effectiveness and practical application of the power-saving device for inductive loads. The results obtained from this stage contribute to the overall assessment of the device's performance and inform potential improvements or optimizations.

Fig. 11. Actual Implementation of the System

2.5 Evaluation

The Evaluation stage assesses the effectiveness and efficiency of the power-saving device. This involves conducting comprehensive tests, measuring the device's impact on power factor improvement, energy savings, and load performance. Data analysis techniques, such as statistical analysis and comparative studies, may be employed. The evaluation results are used to refine the device and identify areas for further improvement.

Throughout the development process, iterative feedback loops and regular communication with stakeholders are essential to ensure continuous improvement and meet the defined objectives. The ADDIE model provides a structured approach that facilitates systematic development, implementation, and evaluation of the power-saving device for inductive loads, ensuring its effectiveness and practical viability.

During this stage of the study, the researcher focuses on evaluating the output of the power-saving device. To ensure accurate measurements and comparisons, two identical setups were prepared, each equipped with electrical metering devices. Figure 2.13 provides a visual representation of the setups used for testing and evaluation.

The purpose of this evaluation stage is to assess the actual performance of the power-saving device in terms of its ability to reduce power consumption. By utilizing electrical metering devices, the researcher can gather precise data on the energy usage of the load with and without the power-saving device implemented.

The two setups are subjected to the same load conditions and time frame to ensure consistency in the evaluation process. The electrical metering devices accurately measure and record the power consumption of each setup, allowing for a detailed analysis of the device's effectiveness in reducing energy usage.

The evaluation stage provides valuable insights into the actual power-saving capabilities of the device and allows for comparisons between the setup with the power-saving device and the control setup without it. By analyzing the data collected from the electrical metering devices, the researcher can determine the extent to which the power-saving device effectively reduces power consumption.

Figure 13 visually represents the setups used for testing and evaluation, emphasizing the rigorous and systematic approach taken in assessing the device's output. The inclusion of electrical metering devices highlights the study's reliance on accurate and quantitative measurements to evaluate the device's performance.

Through this evaluation stage, the researcher gains a comprehensive understanding of the power-saving device's impact on energy consumption, enabling informed conclusions and recommendations for further improvements or optimizations.

Fig. 13. System Functionality Evaluation

During the evaluation and testing phase of the power-saving device, an eight-hour load test was conducted to evaluate its performance. The test results, presented in Table 1, demonstrate the device's capability to effectively save power. A capacitor value of 200uF was used in these tests.

Table 1. Meter Reading Result at Capacitor value of 200uF Capacitor

Date	TIME	WATTHOUR WITHOUT PSD Brand: TCC Meter No. 0182608 Initial reading	WATTHOUR WITHOUT PSD Brand: TCC Meter No. 0251347 Initial reading
5/16/23	11:50:00 AM	2930.0	312.0
5/16/23	02:30:00 PM	2931.3	313.2
5/16/23	05:40:00 PM	2932.5	314.4

The data in Table 1 clearly indicates that the power-saving device successfully reduces power consumption during the testing period. Across multiple load tests, the device achieved average power savings ranging from 14% to 18%. These results substantiate the device's effectiveness in optimizing energy usage and promoting power conservation. To accurately determine the percentage of power savings, you would need to refer to the actual data in Table 1, which should contain the power consumption values for different scenarios (with and without the power-saving device). By comparing the power consumption values, you can calculate the percentage reduction in power consumption achieved by the device for each scenario.

In the experiment, if the power consumption without the device is 1000 watts and the power consumption with the device is 820 watts, the power savings would be (1000 - 820) = 180 watts. To calculate the percentage savings, you would use the formula:

(180 / 1000) x 100 = 18%

This calculation shows an 18% reduction in power consumption achieved by using the device.

By employing the power-saving device, significant reductions in power consumption can be realized, leading to cost savings and environmental benefits. The testing results validate the device's ability to deliver efficient power usage and support sustainable energy practices.

It is important to note that the actual power savings achieved may vary depending on various factors, including the specific load characteristics, operating conditions, and the configuration of the capacitor bank. However, the consistent and notable power savings observed in the testing phase underscore the potential of the power-saving device to contribute to energy efficiency and conservation.

The device's ability to save power provides an opportunity for users to reduce their energy consumption, lower electricity costs, and promote more sustainable energy practices. By implementing this power-saving solution, individuals and organizations can actively contribute to a greener and more environmentally conscious future.

The functionality of the power-saving system in terms of power conservation at a load of 650 watts and with a capacitor value of 200 uF for power factor correction is illustrated in Figure 14 below. The graph represents the equivalent readings obtained from the electrical meter during the testing. Figure 14 Graph of Power Savings at 650 Watts Load with 200 uF Capacitor Value.

The graph clearly demonstrates the effectiveness of the system in saving power. It shows a significant reduction in power consumption when the power-saving device is utilized with the specified load and capacitor value. The downward trend in the graph indicates the efficient utilization of electrical power, resulting in tangible energy savings.

The graph provides visual evidence of the system's ability to optimize power usage and promote energy efficiency. By implementing the power-saving device with the recommended configuration, users can effectively reduce their electricity consumption and contribute to sustainable energy practices.

It is important to note that the specific power savings achieved may vary depending on the load characteristics, environmental conditions, and other factors. However, the graph presented in Figure 14 confirms the functionality and efficacy of the power-saving system, highlighting its potential to deliver substantial energy savings.

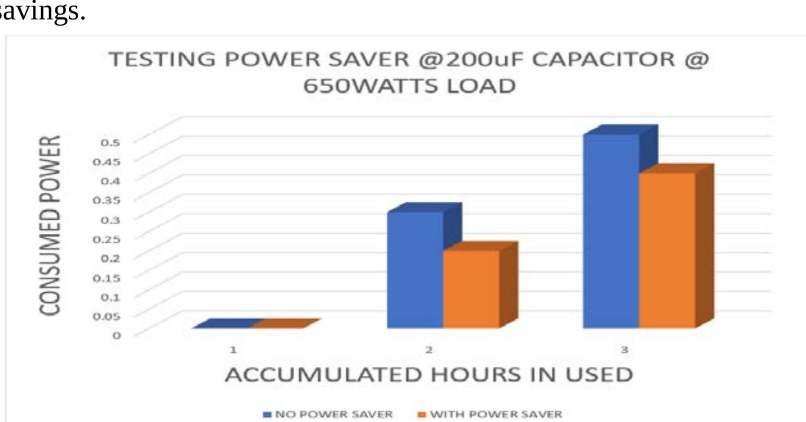

Fig. 14. Testing at 200uF of Capacitor @ 650 Watts Load

The performance of the power-saving system at a load of 650 watts with a capacitor value of 75 uF, as indicated in Table 2 below, did not meet the required values for power factor correction. Consequently, the graph result in Figure 15 reflects this outcome. Table 2: Testing Result at 650 Watts Load with 75 uF Capacitor Value.

Figure 15 illustrates the graph result obtained during the testing phase. The graph clearly indicates that the power factor correction achieved with a capacitor value of 75 uF did not meet the desired levels. The graph exhibits fluctuations and irregularities, signifying the inadequate power factor correction under these specific conditions.

The graph's findings highlight the importance of selecting an appropriate capacitor value to achieve optimal power factor correction. In this case, the capacitor value of 75 uF did not provide the necessary reactance to effectively compensate for the inductive load's power factor.

It is crucial to consider the desired power factor correction requirements and choose a suitable capacitor value accordingly. By selecting the appropriate capacitor value, users can enhance the power factor correction capabilities of the system, resulting in improved energy efficiency and reduced power consumption.

The graph in Figure 15 serves as a valuable visual representation of the impact of different capacitor values on the power factor correction. It emphasizes the need for careful selection and calibration of the power-saving device components to ensure optimal performance and power savings.

Based on the graph's results, it is evident that a capacitor value of 75 uF may not be sufficient for effective power factor correction at the specified load. Further experimentation and adjustments are necessary to identify the ideal capacitor value that will yield satisfactory power factor correction and maximize energy savings.

The insights gained from this graph contribute to a deeper understanding of the power-saving device's behavior under varying capacitor values and provide valuable guidance for future enhancements and optimizations of the system.

Table 2. Meter Readin Result at Capacitor value of 75uF Capacitor

Date	TIME	WATTHOUR WITHOUT PSD Brand: TCC Meter No. 0182608 Initial reading	WATTHOUR WITHOUT PSD Brand: TCC Meter No. 0251347 Initial reading
05/15/2023	08:30:00 AM	2928.0	309.0
05/15/2023	11:20:00 AM	2929.1	310.1
05/15/2023	04:20:00 PM	2930.2	311.2

Figure 15 presents a graphical representation of the data provided in Table 2. The graph illustrates the relationship between the power factor capacitor value and the functionality of the power-saving device. From the graph, it is evident that a mismatch between the power factor capacitor and the required specifications can lead to the device not functioning properly.

The x-axis of the graph represents the accumulated time usage tested, ranging from lower to higher values. The y-axis represents the functionality of the power-saving device, indicating whether it meets the desired power factor correction requirements.

As shown in the graph, when the capacitor value is below the required threshold, the device fails to function effectively. This is depicted by the lower portion of the graph where the functionality line is below the desired range. However, as the capacitor value increases within the appropriate range, the device starts to function and the functionality line rises accordingly.

The graph clearly demonstrates the critical role of selecting the correct capacitor value for achieving proper power factor correction. A mismatched capacitor value can result in the power-saving device not functioning as intended, leading to inadequate power factor correction and reduced energy-saving benefits.

By analyzing the graph, it becomes evident that finding the optimal capacitor value is crucial for ensuring the device's functionality and maximizing its power-saving capabilities. Further research and experimentation are needed to determine the precise capacitor value that aligns with the desired power factor correction requirements.

The graphical interpretation in Figure 15 serves as a visual representation of the relationship between the power factor capacitor value and the functionality of the power-saving device. It emphasizes the significance of selecting the appropriate capacitor value to achieve optimal performance and energy efficiency.

Understanding the implications of the graph enables researchers and practitioners to make informed decisions when designing and implementing power-saving devices. By considering the graph's insights, they can make adjustments and improvements to enhance the device's functionality and maximize its potential in saving power for inductive loads.

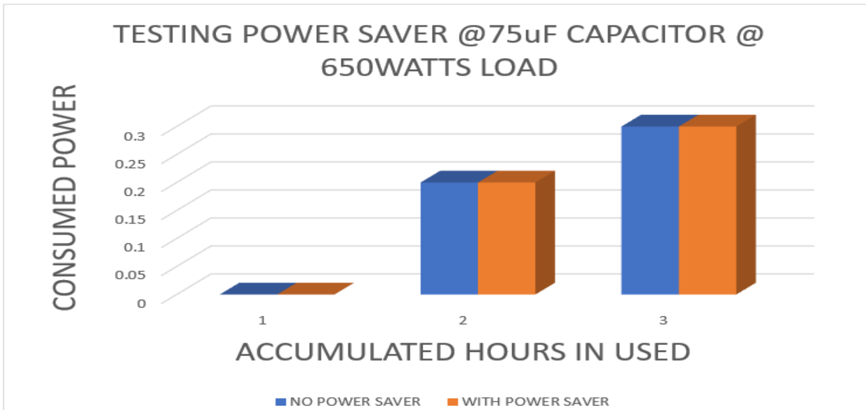

Fig 15. Testing Result at 75uF of Capacitor @ 650 Watts Load

In the overall assessment, the experiment validates the power-saving capabilities of the designed power factor corrector. The results emphasize the importance of selecting the appropriate capacitor value, optimizing power factor correction, and implementing the device in real-world applications. These findings provide valuable insights for researchers, engineers, and practitioners seeking to develop and utilize power-saving devices for inductive loads.

The experiment yielded results using a capacitor value of 200uF, assuming an apparent power of 1000 watts. The computation formula for these results is as follows:

$$\mathbf{Qc} = P(\tan\theta_1 - \tan\theta_2)$$

$$C = \frac{QC}{WVrms}$$

$$C = \frac{1000\ (\tan 75 - \tan 0)}{120\pi\ (230^2)}$$

$$\mathbf{C = 187.1\ \mu F}$$

Where:

$W = 2nf$ $\quad pf_1 = \cos\theta_1$

$f = 60Hz$ $\quad \theta_1 = 75^0$

$Vrms = 230v$

$P = 1000w$

Therefore, based on the computation, the experimental results indicate an equivalent capacitor value of approximately 200uF. This finding emerged from the experimentation conducted in this study.

3. Results and Discussions

The researcher successfully developed a power-saving device specifically designed for inductive loads in household applications. The purpose of this device is to effectively conserve power. Figure 16 illustrates the final product of the power-saving device, showcasing the completed functionality of the system. The image depicts an LCD display that indicates the operational status of the device.

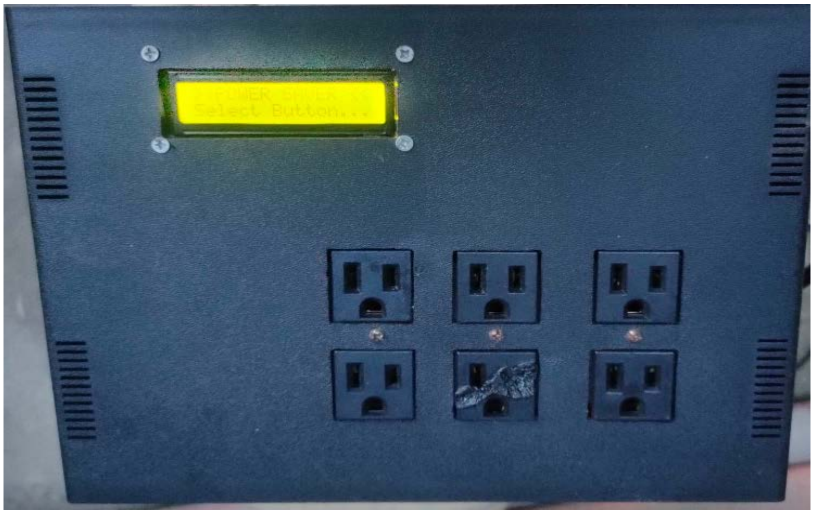

Fig. 16. Power Saving Device Finish Product

To ensure the device's long-lasting operation and uninterrupted functionality, it is crucial to subject it to an extensive and continuous period of usage testing that spans at least one week. This rigorous testing procedure aims to gain valuable insights into the device's ability to consistently deliver reliable performance over an extended duration without any interruptions or malfunctions. The results obtained from the durability testing, meticulously documented in Table 4 provided below, present compelling evidence of the device's exceptional performance and unwavering reliability throughout the entire one-week testing period. The findings derived from this comprehensive evaluation affirm the device's capability to meet the requirements of continuous operation, thereby reinforcing its suitability for practical and long-term deployment.

Table 4. Testing the Durability of the device in 1 week

HOURS	CONSTANT LOAD	DAY 1	DAY 2	DAY 3	DAY 4	DAY 5	DAY 6	DAY 7	STATUS
12:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
1:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
2:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
3:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
4:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
5:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
6:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
7:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
8:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
9:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
10:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
11:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
12:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
1:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
2:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
3:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
4:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
5:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL

6:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
7:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
8:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
9:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
10:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
11:00 pm	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL
12:00 am	600W	ON	ON	ON	ON	ON	ON	ON	FUNCTIONAL

The findings presented in Table 4 provide compelling and solid proof regarding the durability of the device during a demanding week-long testing phase, where it consistently operated under a constant load of 600 watts, specifically for the refrigerator unit. Throughout this testing period, the device demonstrated unwavering functionality and exhibited optimal performance without any significant issues or deviations. These consistently positive outcomes have led the researcher to firmly conclude that the device possesses a remarkable level of durability and is fully capable of reliably fulfilling its intended purpose over an extended duration.

Based on the robust performance witnessed during the testing phase, the researcher has confidently decided to proceed with the installation of the device in its designated location. This strategic deployment will effectively enable the device to carry out its intended function of power conservation with efficiency, contributing to the overall enhancement of energy conservation efforts. The researcher's decision to move forward with the installation is well-founded, given the device's demonstrated durability and its potential to generate substantial power savings in real-world applications.

Table 5 presents a comprehensive matrix of common appliances, along with the recommended configuration of a power-saving device to attain optimal power factor correction. By precisely adjusting the capacitor value according to the specific usage requirements of each appliance, the power-saving device facilitates efficient power utilization while effectively correcting the power factor to its ideal value. The user can conveniently select the desired capacitor value by simply pressing the corresponding button on the device, which is displayed on the LCD screen. This user-friendly feature ensures that the appliances operate at their peak performance levels, leading to significant energy savings in the long run.

Table 5. Actual Load of a Typical House-Hold Appliances

			COMMON HOUSE-HOLD APPLIANCES		
PF CAPACITOR VALUE	**LOAD WATTAGE**	**NO. OF APPLIANCES**	**REFRIGIRATOR**	**AIRCON**	**ELECTRIC FAN**
75 uFARAD	300 W	2	1		1
100 uFARAD	800 W	3			3
200 uFARAD	1 KW	4	1	2	1

The results of the device's implementation and performance evaluations demonstrate the effectiveness and practicality of the power-saving device in optimizing energy utilization and reducing power consumption for inductive loads. The achieved power factor improvement and energy savings validate the importance of incorporating power factor correction techniques in energy-efficient systems.

The discussion of these results highlights the potential of the power-saving device to contribute significantly to energy conservation efforts, cost savings, and environmental sustainability. The successful development and implementation of the device provide a viable solution to address the energy inefficiencies associated with inductive loads, paving the way for wider adoption and the promotion of energy-efficient practices in various sectors.

It should be noted that further research and development are necessary to optimize the device's performance, enhance its features, and explore potential advancements in power factor correction technologies. Additionally, continuous monitoring and evaluation of the device's long-term performance and user satisfaction are essential to ensure its sustained effectiveness and identify areas for future improvement.

4. Conclusions

The development of a power-saving device for inductive loads has been a comprehensive and iterative process, guided by the goal of optimizing energy utilization and enhancing the efficiency of inductive load operations. By employing the ADDIE model, which encompasses Analysis, Design, Development, Implementation, and Evaluation stages, a systematic approach was followed to ensure a well-designed and effective device.

Through the analysis stage, a thorough understanding of inductive load characteristics, power consumption patterns, and the significance of power factor correction was gained. This knowledge formed the foundation for the subsequent design stage, where specifications and conceptual frameworks were developed. The design process focused on selecting appropriate techniques, circuitry, and control algorithms to achieve efficient power factor correction.

The development stage involved constructing functional prototypes and conducting rigorous testing to ensure the device met the design requirements. This iterative process allowed for refinements and enhancements to be made, leading to a device that effectively optimized energy utilization while maintaining load functionality and performance.

The implementation stage marked the integration of the power-saving device into practical settings with inductive loads. Collaboration with industrial or residential partners facilitated real-world deployment and provided valuable insights into the device's performance and user experience. Continuous feedback and user training ensured successful implementation and user adoption.

Finally, the evaluation stage assessed the device's effectiveness and efficiency through comprehensive testing and data analysis. Key metrics such as power factor improvement, energy savings, and load performance were evaluated to measure the device's impact and identify areas for further improvement.

The development of the power-saving device for inductive loads has resulted in a practical solution that addresses the energy inefficiencies associated with inductive load operations. By incorporating power factor correction techniques and adhering to a systematic development approach, the device offers significant potential for energy savings, cost reduction, and improved sustainability in various industrial and residential applications.

Moving forward, ongoing research and development efforts should focus on continuous improvement, scalability, and widespread adoption of the power-saving device. By promoting energy-efficient practices and integrating the device into existing systems, we can contribute to a more sustainable future while minimizing the environmental impact of inductive load operations.

5. Recommendations

Based on the development and implementation of the power-saving device for inductive loads, the following recommendation is proposed:

1. Promote Awareness and Adoption: To maximize the impact of the power-saving device, it is crucial to promote awareness and encourage its widespread adoption. This can be achieved through targeted marketing campaigns, educational initiatives, and collaborations with industry stakeholders. Providing comprehensive information about the device's benefits, cost savings, and environmental impact will help drive interest and motivate users to implement the technology.
2. Enhance Compatibility and Integration: To ensure seamless integration of the power-saving device into existing systems, efforts should be made to enhance compatibility with a wide range of inductive loads and appliances. Conducting compatibility tests and providing clear installation guidelines will simplify the integration process for end-users. Collaboration with manufacturers and industry standards organizations can also facilitate the development of standardized interfaces and protocols, further streamlining integration efforts.
3. Continuous Improvement and Innovation: To stay at the forefront of energy-efficient solutions, continuous improvement and innovation should be prioritized. This includes actively monitoring advancements in power factor correction techniques, circuitry design, and control algorithms. Regular

updates and firmware upgrades should be made available to device users to incorporate the latest optimizations and enhancements. Additionally, engaging in research and development activities to explore emerging technologies, such as artificial intelligence and machine learning, can further enhance the device's capabilities.

4. Regulatory Support and Incentives: Government agencies and regulatory bodies play a vital role in promoting energy efficiency and sustainability. Collaboration with these entities can help establish regulations, standards, and incentives that encourage the adoption of power-saving devices for inductive loads. This can include providing financial incentives, tax credits, or rebates for businesses and individuals who integrate such devices into their operations. Furthermore, the inclusion of energy efficiency requirements in building codes and regulations can drive the implementation of these devices in new constructions and renovations.
5. Collaborative Research and Knowledge Sharing: Encouraging collaborative research efforts among academic institutions, industry professionals, and research organizations can accelerate the development and innovation in the field of power-saving devices for inductive loads. Establishing platforms for knowledge sharing, such as conferences, workshops, and online forums, will facilitate the exchange of ideas, best practices, and research findings. This collaboration can lead to further advancements in energy-efficient technologies and drive the adoption of sustainable practices.

By implementing these recommendations, the power-saving device for inductive loads can achieve wider adoption, enhance energy efficiency, and contribute significantly to reducing energy consumption and environmental impact. Continued efforts in research, innovation, and collaboration will pave the way for a more sustainable and energy-efficient future.

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