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Short Paper

# Development of Uninterruptible Power Supply (UPS) with Power Saving Features

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**Special Issue on National Research Conference in Computer Engineering and Technology 2021. Guest Editor: Dr. Luisito Lolong Lacatan, PCpE* (Laguna University, Philippines)*. Associate Editors: Dr. Nelson C. Rodelas, PCpE* (University of the East-Caloocan City, Philippines)*, and Engr. Ana Antoniette C. Illahi, PCpE* (De La Salle University, Manila, Philippines)*.*

**Abstract**

*Purpose* - The general objective of the study is to develop an "Uninterruptible Power Supply with Power Saving Feature that can protect equipment in case of voltage sags and saves power.

*Method* - In the development of the project fabrication of UPS with power-saving this device aims to achieve the maintenance in voltage during voltage deviation and has power-saving benefits to the users. To check for the efficiency of UPS with power-saving features connect the loads (2 sets of a computer with a monitor) measure power consumption of the load without and with power saving features. The immediate result of discrepancies is evident in its functionality.

*Results* - The prototype UPS with power-saving features is functional when the discrepancies of results are immediately determined in the digital monitor when the load were connected. There is a significant reduction of power consumption with two computers using UPS with Power Saving Features.  The average savings is about 85.86

Watts and can be translated to about 309.10 kW in 30 working days. The power savings is attributed to the servo motors included in the design of UPS.

*Conclusions* -- Based on the results of the study, the following conclusions are: The efficiency of the UPS is 90% and is significantly attain 80 watts power savings. The develop UPS with Power Saving Features is evaluated to have a saving between 80 watts to 88 watts. This will translate to about 309.10 KW average savings in 30 days or 1 month.

*Recommendations* - The UPS with Power Saving Features is recommended to save power and protect the equipment.

*Research Implications* - This UPS is suggested to be used at home, offices, schools, enterprises and internet cafes for the utilization of power saving features.

*Keywords* – development, Uninterruptible Power Supply, power saving

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## INTRODUCTION

As the effects of climate change become understood and human-induced $CO_2$ concentrations in the atmosphere are globally accepted as the major cause, substantial reductions in $CO_2$ emissions from power production and other high $CO_2$ emitting industries will be required to manage the risks of climate change through a greater uptake of the near zero-emission technologies.

A changing climate will inevitably lead to increased vulnerability to, and severity and frequency of climate events which could lead to an increased risk of disasters occurring such as: heatwaves, species extinction, rising sea levels, and flood events. (Global CCS Institute, 2012).

Climate change is caused by human activity, as opposed to changes in climate that may have resulted as part of Earth's natural processes. In this sense, the term climate change has become synonymous with anthropogenic global warming. Global warming refers to surface temperature increases while climate change includes global warming and everything else that increasing Greenhouse gas levels will affect.

Greenhouse gases vary in their ability to absorb and hold heat in the atmosphere, a phenomenon known as the "greenhouse effect". HFCs (hydrofluorocarbons) and PFCs (perfluorocarbons) are the most heat-absorbent, but there are also wide differences between naturally occurring gases.

Greenhouse gases occur naturally and are needed to create the greenhouse effect that keeps the Earth warm enough to support life, human use of fossil fuel is the main source of excess greenhouse gases. By driving cars, using electricity from coal-fuel power plants, or heating our homes with oil or natural gas, the release of carbon dioxide and other heat-trapping gases into the atmosphere (Forest Carbon Projects, 2012).

The consequences of global warming, as the concentration of GHG (greenhouse gases), grows more heat is trapped in the atmosphere, and less escapes back into space. This increase in trapped heat changes the climate and alters weather patterns, which hasten species extinction, influence the length of seasons, cause coastal flooding and lead to more frequent and severe storms. Due to the inefficient consumption of energy, GHG is becoming a problem.

In recent years, significant advances in technology on power semiconductor device such as low-cost material, high-speed control processors, and matured PWM (Pulse Width Modulation) algorithms have led to several of modern ac-ac converter topologies. The trends for modern ac-ac voltage regulators have been greatly improving the utility interface with unity power factor. Such improvement reflects in the input current waveforms with minimized harmonics, compact-size converter implementation with low-volume and more integrating silicon structure of reduced passive components, and increased power handling capability with enhanced efficiency for high power applications.

The general objective of the study is to develop an uninterruptible power supply with a power -saving feature that can protect equipment in case of voltage sags and save power. The specific objectives of the study are as follows:

1. To develop a UPS with Power Saving Features to provide backup power in this disruption in the utility supplied power.
2. To determine the efficiency of UPS that saves power consumption.
3. To evaluate and test the developed Uninterruptible Power Supply with Power Saving Features.

The beneficiaries of this study are the computer users who use this UPS with power saving features. Among the computer users such as: offices, homes, schools, industrial plants, small, medium and large enterprises and internet cafés.

**CONCEPTUAL FRAMEWORK**

Considered the input variables such as: voltage and current, the process includes the AC voltage regulator/voltage switching (UPS) and servo motor while the output variables consist of: voltage regulation and power saving (Figure 1).

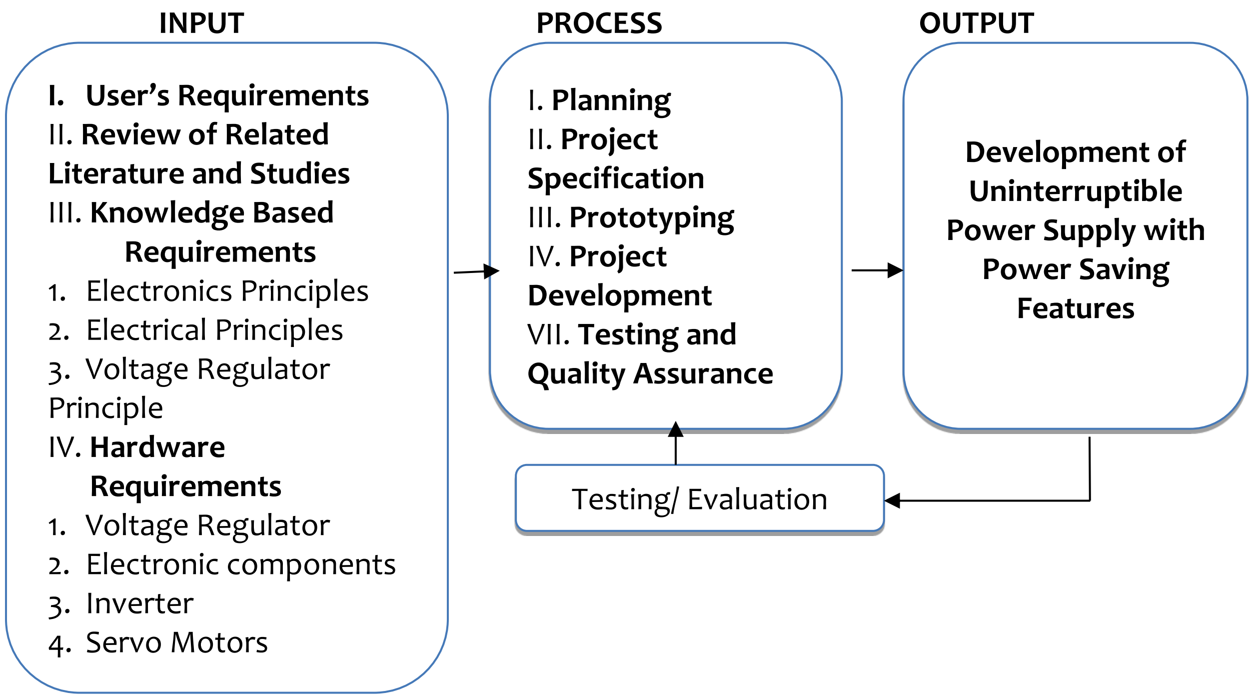


*Figure 1.* Conceptual Framework

## LITERATURE REVIEW

### *Uninterruptible Power Supply (UPS)*

Based on the description of Uninterruptible Power Supply taken from http://searchdatacenter.techtarget.com, it is a device that allows a computer to keep running for at least a short time when the primary power source is lost. It also provides protection from power surges. Another description of Uninterruptible Power Supply from https://www.cyberpowersystems.com states that it is also known as a battery backup, provides backup power when your regular power source fails or voltage drops to an unacceptable level. A UPS allows for the safe, orderly shutdown of a computer and connected equipment.

### *Main Components of a UPS System*

Through reading concepts about UPS, there are four (4) main components according to QPS Team (2014),

1. Static Bypass. In the event of a system failure, the static bypass automatically closes the circuit and allows the incoming power to divert around the rectifier, batteries and the inverter to supply utility-grade power (unconditioned) directly to the load. Although this is under unconditioned power, it allows the systems to continue functioning even if the UPS's internal components fail.

2. Rectifier. The rectifier has two main functions: The first function of the rectifier is to charge the batteries (like an alternator in a car) so the batteries remain at the proper float voltage. The other function of the rectifier is to convert the incoming power from A/C to D/C.
3. Battery. The battery is the heart of the UPS system. The facility experienced a utility power failure; the mission critical equipment depends on the UPS's battery system to support the load.
4. Inverter. The final main component of a UPS system is the inverter. This device accepts the D/C from the D/C bus, which is supplied by the rectifier and the battery. Once the batteries wear down, the system is in jeopardy of dropping the load unless an external power source, typically either the utility or generator, once again begins to provide power to the UPS system.

In this paper, Standby UPS topology is used. Standby is the most basic UPS topology. A standby UPS resorts to battery backup power in the event of common power problems such as a blackout, voltage sag, or voltage surge. When incoming utility power drops below or surges above safe voltage levels, the UPS switches to DC battery power and then inverts it to AC power to run connected equipment. These models are designed for consumer electronics, entry-level computers, POS systems, security systems, and other basic electronic equipment.

When the utility power fails or performs poorly, the inverter and the battery step in to ensure continuous power supply to the load within less than 10ms transfer time (Figure 2). Standby UPS can be used only with low power ratings of less than 2kVA and is suited for powering devices not sensible to voltage variation like personal computers.

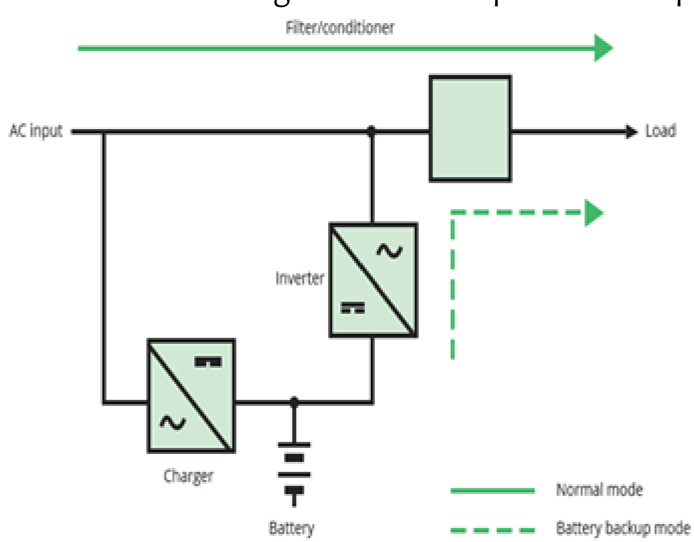


*Figure 2.* Standby UPS System

## *Servo Motor*

The researcher quotes the definition of servo motors to Electrical Dictionary, the principle of servo motors was also used in this project to decrease the amount of power consumption. As the term defines a Servo Motor is a power driven mechanism that supplements a primary control operated by comparatively feeble force (as in a servomechanism). A Servomechanism is an automatic device for controlling large amounts of power using very small amounts of power and automatically correcting the performance of a mechanism.

Petruzella (2010) illustrated that all servo motors operate in closed-loop mode. Closed-loop control compares speed or position feedback with the commanded speed or position and generates a modified command to make the error smaller. The error is the difference between the required speed or position and the actual speed or position. Keljik (2011) discussed that many manufacturing systems and robotic material handling systems use Servo motors to position controls for fast precision movement. Servo motors are small permanent-magnet (PM) motors that use lightweight armatures to provide quick start and stop operations without a lot of inertia to overcome.

At slow speeds of rotation, the standard PM servomotors tend to create cogging: that is they tend to ratchet through the rotation rather than have smooth rotation. This is a result of the iron in the armature being magnetized and reacting with the PM on the stator pole pieces.

## *Pulse Width Modulation*

A Pulse Width Modulation (PWM) Signal is a method for generating an analog signal using a digital source. A PWM signal consists of two main components that define its behavior: a duty cycle and a frequency. This principle was taken from IkikVC (2020), Pulse Width Modulation (PWM) is a digital technology that uses the amount of power delivered to a device that can be changed. It generates analog signals by using a digital source. A PWM signal is basically a square wave that is switched between on and off state. The duty cycle and frequency of a PWM signal determine its behavior. The duty cycle of the PWM signal refers to the ratio of the time that the signal is in a high (on) state over the total time it takes to complete one cycle. It is commonly expressed as a percentage or a ratio.

## *Voltage Regulator*

In https://www.industrialcleanpower.com said that voltage and current constantly change in distribution systems. Your drives, boards and controls are constantly bombarded with voltage and amperage sags and surges. Voltage regulation maintains the voltage levels of a given utility or facility within acceptable ranges.

Voltage regulators in the traditional sense were in line with the incoming service to protect from line fluctuations. An effective voltage regulation solution controls the voltage of a system, so it remains within a practical and safe range of voltage tolerances under all design loads. A voltage at any utilization equipment should be within the guaranteed operative range of the equipment.

In addition, Csanji (2015) the goal of good voltage regulation is to control the voltage of the system so that it will stay within a practical and safe range of voltage tolerances under all design loads. A voltage at any utilization equipment should be within the guaranteed operative range of the equipment.

### *Power Factor Corrector*

As stated in https://www.industrialcleanpower.com, Power Factor Corrector is a technique that increases the power factor of a given power supply. Several negative issues can derive from a low power factor including penalties assessed from your utility provider, higher demand use charges, and decreased capacity in your electrical and breaker distribution system.

Furthermore, In the event a utility switches power supplies without power factor correction, it will draw the current in short, high-magnitude pulses. Many utility providers are paying attention, issuing guidance, and in many cases issuing fines for it. Moreover, Csanji (2015) mentioned that power factor correction and voltage regulation are closely related. In many cases, the desired voltage regulation is costly to obtain. Larger or paralleled conductors to reduce voltage drop under load are, in many cases, the proper solution.

### *Voltage Correction System*

In the discussion in https://www.industrialcleanpower.com, a voltage correction system (AVC) with power factor correction built in will provide an incredible amount of benefits to the facility beyond satisfying the utility provider requirements. While the correcting power factor with an AVC, can also stabilize the power internally to the facility and create many additional benefits along the way.

Additional benefits include the following:

- Reduced downtime
- Reduced or eliminated voltage/amperage fluctuation events wearing all computer components
- Reduced or eliminated voltage/amperage fluctuation events wearing all drives, PLC's, and control equipment
- Lowered maintenance and replacement parts cost
- Lowered peak demand from the utility provider (keeps in line kW vs. kVA ratio)
- Creates more electrical distribution capacity in the power distribution system

When the install equipment that will correct power and hold voltage, can also accommodate power factor issues. Halting wear and tear on other equipment in the facility by having stable voltage and power factors is the goal. The long-term positives are lowered operations and maintenance costs by limiting voltage and amperage anomalies inside the facility.

### *Related Studies*

CyberPower introduces Energy - Saving Green UPS this technology dramatically reduces the energy used heat generated by the transformer during normal mode. During normal power mode, the Green power UPS design bypasses the Automatic Voltage Regulation (AVR) and Transformer. The UPS Design is conventional online double-conversion, or line - interactive, and running under full load. CyberPower Systems has developed an uninterruptible power supply (UPS) technology design that reduces energy costs and consumption. (Shakopee, 2008)

## METHODOLOGY

This study used the Descriptive Method of Research. According to Catane (2000) in this type of research, a fact-finding study with adequate and accurate interpretation of the findings. It simply describes with emphasis what exists such as current conditions, practices, situations, or any phenomena. It describes the status of the system. In this method, the researchers were able to gather all the necessary findings and present them through narrative.

In this study, a switch-mode AC regulator is proposed to maintain voltage across a computer during voltage deviation. Such deviation may occur due to a change in load or change in input voltage due to a voltage sag of the system itself. In addition, from maintaining the voltage during voltage deviation incorporation of a power-saving device for power saving.

Build an accurate model that is reliable and significant for the use of the study, and to make the consecutive process that must be followed step by step procedure that lays down to the system. To design a project that prevents the wasting of time, and the redundancy of the procedure. The analyzing information with sufficient objectives and details to support the decision and all essentiality for the new system was dropdown to operate properly. The design shall instruct to ensure of implementation the system. The data collected for the system becomes the information needed in developing the system. The process of the system development life cycle in our study
Input

Input includes the users, knowledge, hardware requirements and review of related literature and studies. Understanding those requirements was very important in developing a project.

I. User's Requirements

The easiest way is to explain the user's requirements that detail how the user expects the design project to operate. Even though this sound was easy, probably the hardest requirement is to collect. The reason that researcher intends to explain is to satisfy the wants and needs of the users. As the user's it specifies the requirements that are needed in the UPS. Spending time in conceptualizing and designing the user's requirements it is important to specify scope, activities schedule, and cost.

II. Preliminary Interview / Survey

The researcher provides some details or information related to a certain project. Determining the user's requirements for the UPS with power-saving features helps the research to understand how this UPS should be developed.

III. Related Literature and Studies

Through research study in various references such as books, electronic resources and thesis writing, that is relevant to the project. It is composed of related literature and studies, both local and foreign, which contain facts and information on the research objectives. It also provides explanations and logical connections between previous researchers and the present studies.

IV. Knowledge Based Requirements

An approach is needed for certain requirements in developing a project by using the electronics principles, electrical principles, and voltage regulator principle through the development of the prototyping model. Knowledge in the electronics in developing the prototype of this UPS with power saving features such as: the specifications of electronic components, integrating the servo motors for power-saving. Aside from that, knowledge in the electrical principles in interpreting the results of this project design for the power-saving output.

Knowledge of voltage regulators helps to conceptualize this kind of project. A voltage regulator is an electrical regulator designed to automatically maintain a constant voltage level. It may use an electromechanical mechanism, or passive or active electronic components. Depending on the design, it may be used to regulate one or more AC or DC voltages.

The System Development Life Cycle (SDLC) process applies to project development. This ensures that all functional and customer requirements are met. The prototyping model requires that before carrying out the development of the actual project, a working prototype of the design project should be built (Figure 3).

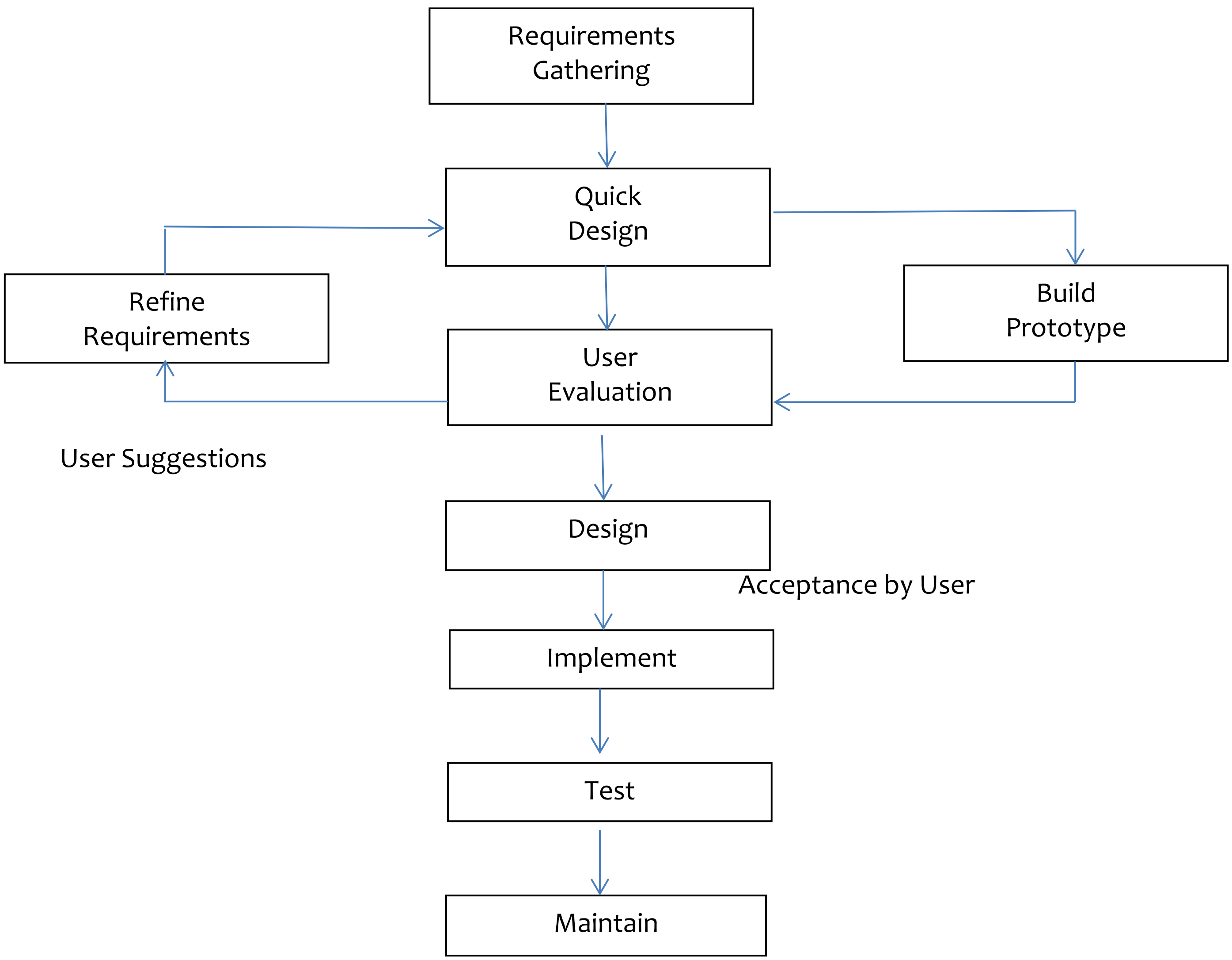


*Figure 3.* Prototyping Model

Requirements Gathering

A prototyping model begins with requirement analysis and the requirement of the project is defined in detail. The user is interviewed to know the requirements of the design.

Quick Design

When requirements are known, a preliminary design or quick design for the a project is created. It is not a detailed design. However, it includes the important aspects of the design project which gives an idea of the project to the customer.

Build Prototype

Information gathering from quick design is modified to form a prototype. It represents a rough design of the project.

User Evaluation of the Prototype

The proposed design is presented to the user for consideration as part of the development process.

Refine Requirement

Once the user evaluates the prototype, it is refined according to the requirements. When the user is satisfied with the developed prototype, a final system is developed based on the final prototype.

Design

Examines the hardware components defined in the design stage and produces a specification for how each component is implemented.

Implementation

The researcher takes the design documents, schematic diagram, circuit diagram, and starts the prototype model. This is usually the longest phase in the product life cycle. A researcher makes sure different components can interoperate with each other.

Testing

Determines whether the project meets the specified requirements and finds any errors in functioning.

Maintenance

Any updates in the development of the UPS, once it malfunctions, can be done as part of project maintenance work. Project development also does various enhancements in marketing campaigns to increase the visibility of customers that will use this UPS with power saving features.

In the development of UPS with power-saving this device aims to achieve the maintenance in voltage during voltage deviation and has a power-saving benefit to the users. In the testing procedure, the researcher connects this fabricated UPS with power-saving feature in two computers with a monitor as full-load then measures the power output. Compare the results obtained with the UPS alone. Note the difference between these devices and record the power saving obtained. These are the testing done using the power analyzer to get the measurements of power (in watts) using the UPS alone.

The study used the evaluation measurements:

1. In getting the measurements of power (in watts) using the UPS alone.
2. In measuring of power (in watts) using UPS with power-saving features.
3. In determining the power savings of the developed UPS with power-saving features were utilized.

AC Power Analyzer was used in determining the power reading measurements in watts.

*Figure 4.* AC Power Analyzer

Figure 4 shows an AC Power Analyzer a measuring module for AC power measurement. This device was used to determine the power reading measurements in terms of w (watts). The AC Power Analyzer is a front-end measuring module that can easily integrate into any circuit and system requiring AC power measurements functionalities. It can accurately measure RMS Voltage and Current, and with phase information, resolve these into data components essential for a comprehensive AC Power Analysis.

Measurement results are streamed out through a TTL UART compatible serial port. The data output format is available in CSV form, making data collection tasks easy for microcontrollers or PC. It can also be selected in formatted form for direct output to serial display devices, such as e-Gizmo 4x20 Serial LCD Display.

## RESULTS

To check for the efficiency of UPS with power saving features connect the loads (2 sets of a computer with a monitor) measure the power consumption of the load without and with power-saving features. The immediate result of discrepancies is evident in its functionality.

Table 1. Measurement of Power Savings for Two (2) Computers with Monitor

| Trials | Without Power Saving in Watt | With Power Saving in Watt | Computed Saving |
|---|---|---|---|
| 1 | 499 | 418.7 | 80.3 |
| 2 | 498.8 | 416.6 | 82.2 |
| 3 | 498.6 | 415.2 | 83.4 |
| 4 | 498.5 | 414.2 | 84.3 |
| 5 | 498.2 | 413.4 | 84.8 |
| 6 | 497.8 | 412.3 | 85.5 |
| 7 | 497.3 | 411.6 | 85.7 |
| 8 | 497.2 | 410.5 | 86.7 |
| 9 | 496.7 | 409.3 | 87.4 |
| 10 | 496.1 | 408.4 | 87.7 |
| 11 | 495.4 | 407.2 | 88.2 |
| 12 | 494.3 | 406.7 | 87.6 |
| 13 | 493.8 | 405.9 | 87.9 |
| 14 | 493.6 | 405.6 | 88.0 |
| 15 | 492.3 | 404.1 | 88.2 |
| **Mean** | ***496.51*** | ***410.65*** | ***85.86*** |

As presented, in Table 1 the power saving with two computers using the UPS without Power Saving Features and with Power Saving Features with an input voltage: 240 V to 245 V using the VARIAC and the Power Analyzer device to measure the power generated in watts. Results show that for trials 1 to 15, the mean power generated for UPS without power saving feature is 496.51 watts while for UPS with power-saving feature 410.65 watts and the mean power-saving 85.86 watts as shown in Table 1. Besides, this UPS developed used at home.

Table 2 illustrated the Electric Bill using UPS without and with Power Saving Features. Through the power usage based on the value presented there was a power saving of 5 KWh using this UPS with Power Saving Features using at least 3 hours a day.

Table 2. Electric Bill using UPS without and with Power Saving Features

| **Month Covered** | **Power Usage** (KWh) |
| --- | --- |
| **UPS without Power Saving Features** | |
| May to June | 27 KWh |
| **UPS with Power Saving Features** | |
| June to July | 23 KWh |
| July to August | 23 KWh |

Table 3. The efficiency of UPS with Power Saving Features

| **Trials** | **Power In (Pi)** | **Power Out (Po)** | **% UPS Efficiency** |
| --- | --- | --- | --- |
| 1 | 463.68 | 418.7 | 90.3 |
| 2 | 462.39 | 416.6 | 90.1 |
| 3 | 458.78 | 415.2 | 90.5 |
| 4 | 456.67 | 414.2 | 90.7 |
| 5 | 457.81 | 413.4 | 90.3 |
| 6 | 456.59 | 412.3 | 90.3 |
| 7 | 456.32 | 411.6 | 90.2 |
| 8 | 455.60 | 410.5 | 90.1 |
| 9 | 453.27 | 409.3 | 90.3 |
| 10 | 450.77 | 408.4 | 90.6 |
| 11 | 449.94 | 407.2 | 90.5 |
| 12 | 450.39 | 406.7 | 90.3 |
| 13 | 447.52 | 405.9 | 90.7 |
| 14 | 448.67 | 405.6 | 90.4 |
| 15 | 447.51 | 404.1 | 90.3 |

Table 3 shows that the efficiency of the UPS with Power Saving is 90%. Table 4 presented the comparison of the efficiency of UPS developed with the commercial.

Table 4. Comparison of Efficiency of UPS

| | |
| --- | --- |
| Commercially available UPS | 92 % |
| Developed UPS with power-saving features | 90% |

## DISCUSSION

The prototype UPS with power saving features is functional when the discrepancies of results are immediately determined in the digital monitor when the load were connected. There is a significant reduction of power consumption with two computers using UPS with Power Saving Features. The average savings is about 85.86 Watts and can be translated to about 309.10 kW in 30 working days.

The power savings is attributed to the servo motors included in the design of UPS. During a power outage, the supply is sustained due to battery power reserved during the charging period. The PWM tends to provide savings due to this result being the same as cited by the analysis.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the aforementioned summary of findings, the following conclusions are drawn:

1. The efficiency of the UPS is 90% and is significantly attain 80 watts power savings.
2. The developed UPS with Power Saving Features is evaluated to have a saving between 80 watts to 88 watts. This will translate to about 309.10 KW average savings in 30 days or 1 month.

The recommendation made is UPS with Power Saving Features is recommended to save power and protects the equipment.

## IMPLICATIONS

The research implications of the study, this UPS is suggested to be used at home, offices, schools, enterprises, and internet cafes for the utilization of power-saving features.

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