Smart-UPS with a priority-based load management system

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Abstract. In this paper, a cost-effective Smart-UPS has been developed which will perform load shedding on a priority basis. This smart UPS will include an accessory installed along with the conventional UPS. This paper relates to the field of managing power distribution. In particular, it pertains to a system and method for power distribution among devices, based on priority. The objective of the present disclosure is to efficient supply to distribute power among requirement of devices, to provide cost efficient power management and to enhance output of the devices with limited power back up.

The designed project will switch off lower priority loads according to Battery percentage to minimize the load suffered by the battery. The loads connected to supply load are divided into three sections, i.e. high priority (HP), medium priority (MP) and low priority (LP) loads. The project involves the development of a smart UPS system which will automatically switch off/on the high priority (HP) loads, medium priority (MP) and low priority (LP) loads (specified during installation of the UPS as specified by the user).

Keywords: UPS (Uninterrupted Power Supply), HP (High priority), MP (Medium priority), LP (Low priority), AC (Alternate current), DC (Direct current), IoT (Internet of things), etc.

1. INTRODUCTION

Electrical energy is very important, as electrical vitality is significant for each association Industries, instructive organizations, data innovation, horticulture, and business markets. The employments of vitality increment consistently and year increment in new ventures, homes, markets, and new tasks. As more nations emerge from destitution and build up their economies, vitality request rises correspondingly. For eliminating the energy shortage of electrical energy during load shedding period several backup measures are taken i.e. alternators, batteries, Backup UPS, etc.

The proposed project aims to minimize load suffered by the backup supply on the customer side during load shedding. The efficiency of UPS degrades as battery charging capacity degrades, a faulty battery consumes more power than its capacity and provide a minimum or small amount of energy than expected. If the mains power supply fails, the output inverter continues to operate, but now delivers power from the back-up power source (usually a battery) to the critical electrical load [1]. With the proposed model the switching from power supply to multiple loads can be done on a prioritized basis. The user will get an advantage to divide the respective loads on a priority basis according to their need. This does not only provides another IoT model but also helps in Electrical
energy conservation. Then present inventions related to system and methods for efficiently supplying power to a plurality of loads include controlled switching of circuits between a primary power source and at least one secondary power source. The method further includes categorizing the plurality of loads into one of a first group identified as non-delay able loads allocating power to each load in the second group of power supply source and allocating any remaining power to loads in the first group of loads. Dynamic allocation may include categorizing each load in terms of peak power and steady-state power. Categorizing the plurality of loads may include for each load identifying a load type and using a default setting to categorize each load based on load type. It includes allowing a user to choose a default load setting \[2\]. Some smart energy meters are also developed which use the principle of monitoring the usage of electrical energy and dividing the day into various time zones depending upon peak load and steady or low load hours. The monitoring provides suggestions for efficient use of electricity for the various time zones \[3\]. With the help of our model, monitoring of backup supply power can be done and the use of the remaining power can be done wisely by allocating power to important electrical loads so that necessary equipment may work for a longer duration than in the conventional UPS. This model can also be used as an electrical energy management tool for backup supplies.

This paper consists of five sections. Section I is introduction, in section II a brief review is done about the model, in section III proposed model is explained, in section IV components used in the model development are discussed and in section V hardware of the model and its working is discussed.

2. LITERATURE REVIEW

The UPS is responsible to provide backup power when mains power fails, either long enough for critical equipment to shut down gracefully to prevent data loss, or long enough to keep required loads in operating condition until a generator comes online. The UPS system provides two functions i.e. it provides a secure power source when the main AC power supply fails, then supported the load while the power source shifts from utility to a standby generator and it provides a clean, stable and regulated supply when the mains supply is present. Due to the given reasons, electric utility companies consider UPS to be the primary source of standby power protection. Different types of UPS have been designed to serve different purposes, such as Power failure, Sags, Brownouts, Spikes, Surges, Line noise, Frequency variation, switching transient, Harmonic distortion \[4\].

The introduction of automation technologies came into light in early 1900s with introduction of machineries which reduced manpower and enhanced efficiency of production in textile industries and in agriculture as well \[5\]. An automated device is able to replace human working force, since humans are more prone to errors and an automated device can work with almost zero error \[6\]. Since the concept of smart homes is recent, several studies are done in this context. One of them involves the work of Ehsan Kamel and Ali M. Memari in distribution of smart homes into three major categories based on the systems installed i.e. homes with energy monitoring systems, homes with systems equipped with controlling capabilities, and homes involving systems with advanced data processing capabilities \[7\]. The use of these technologies brings a reduction in direct human interactions which can improve the quality of living and facilitate daily life routine. The technologies such as home automation, remote access to appliances, monitoring of the health of the human body, tracing of activities, etc. bring ease to our lifestyle. In 2017 Pandiaraj R and Dr Rani Hemamalini R developed a device built with sensors and the Internet of Things (IoT), ZigBee wireless technology, and a mobile phone application for monitoring and controlling. IoT means things that are connected to the internet and capable of accessing from anywhere. The device monitors the house with the help of sensors connected to it and updates information to the owner's mobile phone through internet connection available in the house. The same way owner can control the home appliances and know its status from the mobile application \[8\].

A conventional UPS comes into action immediately after the Supply Mains has been cut off or the supply voltage drops to an unacceptable level, this may cause a sudden burden on the battery and quick draining of the battery can be seen due to the functioning of heavy or undesirable loads. This leads to wastage of the stored electrical energy which can't be afforded in today's era. Each country
tries to store a bulk energy supply to meet the increasing energy demands these days. In some situations, unnecessary electrical equipment are left in working condition unknowingly which also cause wastage of electrical energy and if these loads are turned off when not in use, important or useful electrical equipment tends to work for longer duration due to allocation of the remaining power to them but this requires some physical efforts too from the user's side. This leads to the proposed methodology of the development of a smart UPS system which will automatically switch off/on the High Priority (HP) loads, Low priority (LP) loads and Medium Priority loads (specified during installation of the UPS as specified by the user).

When the Supply Mains failure occurs the proposed UPS will sense the battery percentage or health of the battery and it will automatically act according to the predetermined algorithm. Since with the usage of power from the battery, the battery will tend to drain and with this decreasing battery health LP loads will start to turn off accordingly. Further the decrement in Battery health at a critical value the MP load will also shut down and beyond this point of operation only high priority loads will continue to work. In any emergency the user will have the privilege of turning on/off the HP, MP and LP loads with the provided App irrespective of the battery health.

3. PROPOSED METHODOLOGY

3.1 Study design

The components which are needed to design the proposed project are:

Arduino UNO which is an open-source microcontroller board developed by Arduino.cc. A USB cable for uploading the program onto the board. A 16x2 LCD panel that can display 16 characters in 2 rows each. A NodeMCU esp8266 Wi-Fi device which will act as an interconnection between the setup and the phone of the user. A battery that is to be used for testing. A laptop that is required for online simulation of the project and some other electronic components.

3.2 Study settings

The study of this project is done initially in an artificial or software-based arrangement because it uses a virtual battery rather than a conventional battery which is used for the storage of electrical energy in homes and industries. Further this simulation was implemented on hardware with conventional UPS.

3.3. Sampling

Systematic sampling is done during the development of this project. All necessary steps are taken for error correction and all the components used in this project are chosen in an appropriate manner to eliminate and minimize the errors.

3.4 Variables

From the point of view of the user, the Variables of this research are either Independent variables such as HP, MP and LP loads or Background variables i.e. the battery health.

3.5 Study method

We have included simulation-based laboratory experiments as the initial study method of this project. All the studies and assumptions are verified in an online simulator named Tinker cad prior to working on hardware. This study method has ensured the hardware setup is logically and reasonably correct and the analysis of the results based on online simulation led towards the right hardware arrangement. A sample screenshot of the sketch program is attached in Figure 1 and a flowchart of the proposed model is prepared and presented below along with the block diagram.
void loop()
{
    
    if(Serial.available() > 0) // Send data only when you receive data:
    {
        char data = Serial.read(); // Read the incoming data and store it into variable data
        Serial.print(data);
        Serial.print("\n");
        if(data == '1')
            digitalWrite(loadPin3, HIGH);
        else if(data == '0')
            digitalWrite(loadPin3, LOW);
    }
    int val = analogRead(batteryPin); // read the value from the sensor
    float volts = (val / 1023.0) * referenceVolts; // calculate the ratio
    Serial.print("Available Battery Voltage is: ");
    Serial.println(volts); // print the value in volts
    int BatteryPercentage = (volts/3.22)*100;
    Serial.print("Available Battery percentage is: ");
    Serial.println(BatteryPercentage);
    delay(5000);

Figure 1: A sample sketch

Figure 2: Block diagram for the proposed smart UPS model.
4. **COMPONENTS REQUIRED**

4.1 **Arduino UNO**

Arduino UNO is a microcontroller having ATmega328p microprocessor. It has 14 digital input-output pins in which 6 pins are PWM output enabled and 6 analog input-output pins. It is programmed using Arduino IDE. It has an operating voltage of 5 Volts and a clock speed of 16 MHz
4.2 ESP8266 Wi-Fi module

It is a low-cost Wi-Fi microchip with microcontroller capability and equipped with L106 32 bit RISC microprocessor. It has 16 general purpose input-output pins and can handle up to 3.6 volts of operating voltage (generally +3.3 volts). In this project this is used for communication between the hardware and designed application. HC-05 Bluetooth module can also be used for connectivity purpose in the project, a separate Bluetooth connection feature is also added in the mobile application.

4.3 LCD display

A 16X2 LCD is an electronic module that uses liquid crystals to produce visible images. The term 16X2 refers to a display of 16 characters in 2 rows each i.e. 32 characters in total.
4.4 Breadboard

A breadboard is used as a constructional base for prototype electronic models and consists of a perforated block of plastic having several contact points under the perforations. There are metal stripes present inside the breadboard known as terminal stripes and bus stripes.

![Figure 7: Breadboard](image)

4.5 Relays

A relay is an electrically operated switching device consisting of various sets of input terminals for single or multiple input control signals. The relay is used to turn on/off a much larger electric current when operated by a relatively small electric current.

![Figure 8: A 4 channel relay](image)

4.6 UPS

A UPS is electrical equipment that supplies power to electrical loads in the condition of supply mains failure by the means of energy stored in batteries, super capacitors or flywheels. It can also be referred to as a continual power system.

![Figure 9: A backup UPS](image)
5. RESULTS

The circuit for the proposed model includes 5 LEDs that depict the Loads connected to the UPS and the power supply given to the Arduino board depicts the battery over which Load shedding is to be done. The green, White, Blue & Yellow bulb are connected in decreasing order of their priority in which Green has highest and yellow has lowest priority and Red bulb is defined as the emergency load in this case. During the operation of the UPS when battery health is above 80% all loads will work, when battery drops from the threshold value of 80% lowest priority load will shut off and the remaining loads will continue to work. Similarly, when battery health reaches 60%, 30%, and 10%, the system will automatically turn off the loads in order of their priorities.

![Smart UPS simulation model using LEDs as electrical loads](image)

**Figure 10**: Smart UPS simulation model using LEDs as electrical loads

![Android based GUI of smart UPS for manual switching of loads developed on blynk platform](image)

**Figure 11**: Android based GUI of smart UPS for manual switching of loads developed on blynk platform

When battery health reaches just below 10% the emergency load will automatically turn on and all other loads will be cut off from the battery supply. NodeMCU esp8266 is used for Wi-Fi communication with the mobile device and the model. Since the analysis of the loads shedding and battery health can be done over the internet too using the esp8266 module, this model is also IoT enabled.
6. CONCLUSION

Our proposed model of smart UPS is made for monitoring and allocation of stored electrical energy also known as a backup supply. This model is developed to retrofit existing UPS systems with an accessory which will enable them to perform load shedding on a priority basis. Most of the time the system will work on the given algorithm but in some cases when the user would require the switched offloads to work or working loads to shut off, the android application will help him out. With the provided application the user may switch on/off the loads at his will. This model not only reduces the physical efforts of the user by providing an automatic load shedding solution but also leads towards a better electrical energy management system. The model can be installed in offices, schools, colleges, factories, and even households, etc. basically at every place which is dependent upon stored backup energy for its operation after the cutoff of the mains power supply. So there will be a vast coverage of the proposed model in the current scenario.

The following points describe a small comparative analysis between the conventional UPS and the proposed model on the basis of the functionality and features:

A conventional UPS doesn’t provide a system for managing power distribution from the battery to the electrical loads but the proposed model does provide the above stated system.

Automatic and Prioritized load shedding feature which helps to provide power to important electrical loads for more amount of time is also not present in convention UPS whereas the proposed model is based on automatic and prioritized load shedding mechanism.

Conventional UPS also doesn’t provide remote switching of electrical loads but the proposed model comes with an android application which can be used for remote switching of loads whenever required.

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