DEVELOPMENT OF MICROCONTROLLER-BASED ENERGY MANAGEMENT SYSTEMS FOR MEDICAL FACILITY

BY

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CERTIFICATION

This is to certify that this thesis "Development of Microcontroller-Based Energy Management System for Medical Facility" was carried out by Ugwu Kenneth Ukachukwu (20174081168) in partial fulfilment for the award of M.Eng. in Power System Engineering, Department of Electrical and Electronic Engineering, School of Electrical Systems and Engineering Technology (SESET), Federal University of Technology Owerri.

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DEDICATION

This research project is dedicated to Almighty God, whose mercy and wisdom enabled it to come to fruition.

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ABSTRACT

To conserve energy and to prevent frequent power outages due to overload or partial loss of supply on medical facilities that require uninterrupted power, a microcontroller – based medical facility energy management system is developed. Smart energy management system (EMS) basically monitors and controls loads and energy supplies to connected facilities. In medical facilities, there are critical loads and non – critical loads depending on functionalities required. Critical loads should never be turned off or loose supply while non – critical loads may be turned on or off depending on the power consumption and supply pattern. In practice, various combinations of load management and conservation measures are targeted at energy efficiency such as power factor corrections, rescheduling and combination of energy storage mechanisms. The functionalities implemented for electrical load management in this work are load prioritization, load scheduling, load add, and load shed. In addition, an algorithm for the determination of system loading condition such as normal load, under load and overload as well as automated load adding, and load scheduling schemes based on the operating conditions and customer's priority are developed. A C++ program is developed to achieve this algorithm. Furthermore, this thesis explores the potential cost savings associated with integrating an Arduino, a current sensor, and an Automatic Transfer System (ATS) into energy management, as seen in Figure 3.3. This is one of the most reliable and economical ways to improve the reliability and quality of the power supply. The University of Nigeria Teaching Hospital, Enugu was used as a case study. The result of this practical experiment shows that this scheme can improve distributional load management by reducing power change over time, loss of lives and great saving in cost of operation.

Keywords: Automatic Transfer System (ATS), Energy Conservation, Energy Management Systems (EMS), Load Prioritization and Microcontroller

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Many critical shutdowns occur in power networks across a wide range of industries. The health-care sector is no different. However, the health effects of power disruptions are not well recognized. Greater awareness is required to prevent and/or reduce negative health effects. Numerous nations throughout the universe are recently experiencing a severe energy crisis characterized by load shedding of natural gas and electricity. This not only interferes with people's daily life but also seriously hinders the social and economic development of nations. This is in addition to a lack of institutional and political support for harnessing the vast renewable energy resources that are already available (Aziz et al., 2017)

Today, “Load shedding” of energy is now a routine occurrence across the most developing nations. The failure of the energy sector is primarily due to unsatisfactory installed capacity, old plants with ineffective transmission networks, and bad economic administration(Uddin et al., 2018). The difficulties are intertwined. The underperformance is partly due to a lack of significant savings and governmental unsteadiness, which have prohibited the construction of extra-large coal or hydropower projects, increasing dependency on expensive imported fuels, and depleting domestic natural gas supplies.

Policymakers' role is critical at this stage not only for evaluating and appraising current strategies to close the energy source and demand gap, but also for developing future strategies to ensure reasonably priced electricity with well-organized generation, transmission, and distribution to ensure the country's long-term development (Aziz et al., 2017).

According to a report issued in December 2003 through the United Nations Energy Commission (UNEC), 1.3 billion individuals all-inclusive do not have access to power. Global power claim is predicted to triple between 2000 and 2030, growing at a 2.4 percent yearly rate (United Nations Energy Policy, 2021). The disparity between demand and supply necessitates short- and long-term strategies from governments around the world to address the issue (Larik, 2019) .

Electricity generation from various sources, effective electricity monitoring, and Corporate Social Responsibility (CSR) practices can all help to close the gap between demand and supply.

One of the main problems of the energy availability is power outage. Loss and theft of electricity can be detected using software tools. Electricity management systems are software applications that manage and optimize electricity to reduce the danger of a power outage. Software tools for energy management could be crucial in addressing the issue of erratic electricity supply. This field of study has gotten a lot of attention from researchers all over the world in recent years. The growing interest in energy management systems demonstrates the necessity to progress in energy management systems that can be used worldwide. Most of the study in this topic is limited, partly since academics simply offer diverse ideas but fail to produce adequate solutions that may be applied to real-world issues. A small number of researchers presented software methods for electricity management, but these were not widely accepted.

As a result, a microcontroller-based medical facility energy management is built to handle this problem, which is the major purpose of this work, to conserve and prevent power failures due to overload or extra-load on the system during peak time. This entails employing an automated transfer system (ATS) to monitor and control energy flow activities such as lighting, heating, ventilation, and air conditioning, as well as electrical appliances, and/or defining time schedules for their operation.

Power outages can occur because of an upsurge in the quantity of domestic appliances, increased cooling and lighting demand, and customer overuse during peak hours. The linked network's peak load occurs when most facilities use electricity at the same time of day. Electricity companies are forced to expand generation by building new conventional power plants as a strategy to satisfy the increased power demand. However, because of poor power plant utilization factors, increasing carbon dioxide emissions that contribute to climate change, and expensive investment costs, this approach is unsustainable.

The Smart Home Electricity Management System (SHEMS) is a critical component of smart grid demand-side management success (Perez, 2014). It uses the human-machine interface in smart households to control and arrange various medical facilities in real-time, based on user preferences, to reduce electricity costs and enhance energy consumption efficiency. With increasing fears about global energy security and environmental discharges, supplementary distributed renewable power sources, such as wind turbines, solar panels, and Plug-in Electric Vehicles (PEVs), will be grid-integrated into active distribution networks. A key component of smart grid demand-side management success is the Smart SHEMS (Perez, 2014).

This skill will be useful for handling electricity consumption in addition to being convenient. It is not a good power management strategy to leave our security lights on during the daytime or to have the air conditioner on evening when we are gone. However, a microcontroller-based energy management system can help you plan when you want these appliances to switch on and off, which can save you a lot of energy.

1.2 Problem Statement

Medical facilities, such as hospitals and clinics, are essential for providing critical healthcare services. These facilities typically consume a significant amount of energy to power medical equipment, lighting systems, heating, ventilation, and air conditioning (HVAC) systems, and other operational requirements. However, energy management in medical facilities faces numerous challenges, including inefficient energy usage, lack of real-time monitoring and control systems, and escalating energy costs.

i. Inefficient Energy Usage: Medical facilities often exhibit suboptimal energy consumption patterns due to outdated equipment, improper scheduling, and inefficient usage practices. This inefficiency results in unnecessary energy waste, increased operational costs, and higher carbon emissions, negatively impacting both the environment and the facility's budget (Jain et al., 2020) and (Fathy et al., 2021).

ii. Lack of Real-time Monitoring and Control Systems: Many medical facilities lack comprehensive real-time energy monitoring and control systems. Without accurate and up-to-date data on energy consumption patterns, it becomes challenging to identify energy-saving opportunities, detect anomalies, and implement corrective measures promptly. This lack of monitoring and control hampers efficient energy management and prevents proactive decision-making. (Santos & Ferreira, 2019).

iii. Escalating Energy Costs: Energy costs represent a significant portion of a medical facility's operational expenses. With the increasing costs of energy, healthcare organizations face financial challenges in managing their energy consumption effectively. The absence of robust energy management systems and strategies results in a lack of visibility into energy consumption patterns, preventing cost-effective measures and budget optimization. (Modi, 2022).

iv. Limited Integration of Renewable Energy Sources: Medical facilities can benefit from integrating renewable energy sources, such as solar panels or wind turbines, into their energy systems. However, the adoption of renewable energy sources in medical facilities is often limited due to technological barriers, lack of proper integration mechanisms, and inadequate control systems. This limitation hinders the potential for reducing reliance on fossil fuels and achieving greater energy sustainability (De Franco et al., 2017).

1.3 Aim and Objectives

The aim of this work is to develop a microcontroller- based energy management system for medical facility. The specific objectives to realize this work are as follows:

1. Determine energy sources and capacities in hospitals.
2. Perform load enumeration.
3. Design Energy Management Scheme
    a. Load prioritization scheme.
    b. Automatic Transfer System Scheme.
4. Develop algorithms for implementation of the system developed.
5. Validation of Developed System
    a. Simulate developed model or system.
    b. Performance of Cost Benefit Analysis

1.4 Significance of Study

The importance of microcontroller-based energy management systems in medical institutions can be summed up as follows:

i. **Reliability and Patient Safety**: Critical equipment, such as life support systems, patient monitoring devices, and diagnostic tools, depend on a steady and dependable power supply to operate without interruption in medical facilities. Energy management systems can assist with power quality monitoring, backup power implementation, and power outages prevention. These technologies help to ensure patient safety by maintaining a steady power supply and averting any potential harm brought on by blackouts.

ii. **Efficient Energy Use**: Operating medical equipment, lighting, HVAC systems, and other necessary services require a significant amount of energy in medical institutions, such as hospitals and clinics. By tracking and managing energy-consuming devices, decreasing energy waste, and increasing energy efficiency, microcontroller-based energy management systems can optimize energy usage. Cost savings and environmental sustainability may result from this.

iii. **Demand Response and Load Management**: Medical facilities can take part in demand response programs, which include cutting back on energy use during periods of high demand, thanks to microcontroller-based energy management systems. Medical facilities can help the general stability of the power grid by using load management techniques, such as modifying the consumption of non-essential equipment or switching to alternate power sources. Participating in demand response initiatives may also offer financial rewards for the facility.

iv. **Remote Monitoring and Control**: In medical facilities, microcontrollers can enable remote monitoring and control of energy management systems. Facility managers can use this capacity to monitor patterns of energy use, spot inefficiencies, and take well-informed decisions to reduce energy consumption. Additionally, remote monitoring helps in the early detection of equipment failures or anomalies, which results in better maintenance procedures and less downtime.

v. **Compliance with legislation**: Energy efficiency, environmental effect, and power quality in healthcare facilities are subject to legislation and norms in many nations. Medical facilities can assure adherence to these rules and avoid fines by installing microcontroller-based energy management systems. These systems offer information and analytics that can be utilized for reporting and proving compliance with the established standards.

vi. **Future-proof**: The healthcare industry is always developing because of technological advancements. Medical facilities can use innovative technology like artificial intelligence and machine learning and adapt to future advancements in energy management by using microcontroller-based energy management systems. These systems offer an adaptable foundation for adding new gadgets, maximizing energy use, and keeping up with market trends.

In summary, the study of microcontroller-based energy management systems in healthcare facilities is very important because it enables effective energy utilization, ensures dependability and patient safety, supports demand response initiatives, makes remote monitoring and control possible, ensures regulatory compliance, and aids in future-proofing healthcare facilities in the dynamic world of energy management.

1.5 Scope of Study

The developed scheme will be designed for monitoring an AC load within a selected power range (not more than 500watts) that can efficiently and automatically examine the load current and cut off the load when overload is identified.

Because of the complex nature of the entire UNTH, this work will only focus on monitoring the medical facilities situated at cardio thoracic centre (CTU), intensive care unit (ICU), the theatre, X- Ray/ Radiology units, catheterization laboratory and the main laboratory using the designed smart system.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of Energy Management

To maintain competition, the quality/cost ratio of the items given to the customers must continue to improve. This necessitates, among other things, a tight control of production costs. A closer look at how these costs are incurred reveals that taking benefit of utility incentives and favourable pricing in order to encourage consumers to use energy in such a way and at such times as to allow the utility to manage load patterns and achieve significant cost savings without sacrificing efficiency can be fruitful (European Environment Agency, 2013).

In recent years, as the earth's resources have depleted quicker, various countries throughout the world have worked to find ways to save energy and limit the impact of carbon on the environment to avoid resource waste and seek a sustainable livelihood to extend the earth's resources. Energy monitoring has become an important undertaking for maximizing energy efficiency by taking cognizance of energy efficiency in the current trend of saving energy and reducing carbon emissions. Energy management and monitoring is a game-changing overall energy-saving solution. Previously, the most logical first step in implementing the concept of peak shaving would have been to encourage consumers to change their habits regarding electrical energy demand, or to go one step further, to use automatic load scheduling to optimize consumption; this application is also known as Demand Response (DR). It is regarded as a crucial tool in energy management since it allows utility companies to meet the electricity needs of additional customers with little or no increase in power generation (Eze et al., 2016). There are various research in this sector, such as (Noda, 2013), that address the load shifting issue by modelling a discrete time open-loop control system with the present state of charge of the storage as the beginning condition. When compared to the traditional case, in which the load starts when the consumer demands it, the calculated savings in this study are larger than 19 percent. The algorithm for stochastic energy consumption scheduling is created. The goal of microgrid control is to achieve a real-time balance between power generation and consumption. Variations in local weather settings may cause a big increase or decrease in renewable power generation when renewable energy sources are added to a microgrid. Microgrid stability may be jeopardized by the unpredictability of renewable energy output. To improve system stability, one idea is to integrate stochastic modelling and optimization techniques into microgrid control (Liang & Zhuang, 2014). The utility companies' time-varying pricing are used as inputs to this algorithm. The simulation results suggest that this methodology can achieve significant operational/economic benefits for the customer (Wamba-Taguimdje et al., 2020). It is observed that the system leads to considerable savings in consumers' invoices and encourages the significant deployment of smart meters. By performing short-time predictions, the burden of the algorithm is reduced.

It has been observed that the approach saves consumers money on their bills and stimulates the widespread use of smart meters. The algorithm's workload is lowered by making short-term forecasts.

To deal with the peak shaving problem, several authors choose to use the load curve of residential customers as the research's initial input, ignoring changes in consumers' preferences. It also emphasizes the importance of lowering battery costs and enacting supportive policies to make battery energy storage systems economical in load-shifting applications and ensure their viability. Peak shaving is also used, although it is paired with the principle of power demand management for several cases regarding medium voltage distribution networks.

Wamba-Taguimdje et al., (2020) present a profitable case study for a public structure in Italy. They compared net present values (NPV) in a variety of battery energy storage system (BESS) circumstances, but without considering the consumer's desire. The main conclusion is that if the difference between maximum and minimum electricity prices was large enough, some savings may be made. Additional energy storage within the grid, on the other hand, would be required to allow many more power plants to run closer to optimum capacity and minimize energy losses during electricity transmission. As a result, energy storage is an important part of diversifying energy sources and expanding renewable energy sources into the energy market (Zhang, et al., 2020).

According to a 2009 study, households in the United States can save up to 48 percent on an annual basis in the best-case scenario, emphasizing the need to decrease costs and improve technology once more (UNCTAD/TIR, 2021). Practically, in every example studied, the energy peaks are lowered by 42 percent to 49 percent. As a result, energy conservation leads to financial savings. In China, questionnaires were used to test the reliability and validity of the results on

January 1, 2018. Individual actions on energy consumption and conservation are influenced by external factors such as energy conservation legislation, other people's behaviour, and the provision of knowledge regarding energy practices, according to the findings. In the literature, the usage of a battery energy storage system (BESS) in conjunction with renewable energy systems, known as hybrid systems, has been investigated and developed. A case study employing lithium-ion batteries and photovoltaic modules is carried out. For one of the situations considered, the outcome is only profitable in the long run. As a result, battery costs and battery ageing, as well as the constraint of charging and discharging cycles, which is an essential issue in practice, are found to be significant elements that must be overcome in order for such projects to be profitable (Hesse, H. C., Schimpe, M., Kucevic, D., & Jossen, A., 2017)

In 2010, another ground-breaking study was conducted, combining the concept of Behind the Meter Energy Storage (BMES) with a battery energy storage system and on-site PV power. Demand charges are decreased by designing consistently valid algorithms for both small scale and big scale values of independent system peaks. This system is critical because it compensates for losses caused by PV system energy losses or fluctuations. If interconnected at a critical load panel, the energy storage system is technically capable of providing emergency backup power during a utility outage (Zidar et al., 2016).

Another motivating issue is the use of electric vehicles as flexible loads in the electric network, which has been discussed in the literature, because this application can provide many benefits to distribution networks. As a result, a precise algorithm is being developed to treat scattered loads as supply system nodes, which is accomplished by building an equivalent network with a smaller number of nodes. This enables the distribution system operator to determine with a high degree of accuracy which areas or times of the day require flexibility, as opposed to estimating individual customers' demand.(Madzharov, D., Delarue, E., & D’haeseleer, W., 2014)

In (Soares, 2011), the notion of flexible loads (such as electric vehicles) is also discussed, as well as a two-step control scheme. Its goal is to make use of existing flexibility to assist in the resolution of grid limit violations. The concept of fairness is also addressed in terms of customer demand flexibility, to reward individual consumers for engaging in the system as flexible loads to increase frequency stability. Finally, it is argued that, while a two-stage centralized and decentralized control scheme capable of fairly exploiting all consumers' flexibilities in a network may not be the best option in the near term, it is the best option in the long run. Despite the fact that the number of lines of research in energy storage applied to residential customers is steadily increasing, the primary goal in almost all cases is to reduce the price tag of electricity by reducing or changing energy demand, with a focus on developing more efficient, complex, and precise control algorithms (Hu, J., et al., 2014).

In addition to meeting projected demand variations, utilities must have backup plants available to handle unexpected demand spikes, plant and transmission line failures, and other eventualities.

Meeting frequency regulation (the ability to respond to small, random fluctuations around normal load), load-forecasting errors (the ability to respond to a greater or less than predicted change in demand), and contingencies (the ability to respond to a major eventuality such as an impromptu power plant or trident attack) are all examples of responsive reserves (REISHUS CONSULTING, 2017)

2.2 Energy Management Systems

According to Rockwell Automation's market research, it's difficult for businesses to remain unaware of energy usage in their facilities nowadays. Energy is a growing portion of operating costs, and extracting, manufacturing, or doing anything requires a lot of it. Energy is critical to produce riches and the advancement of social welfare. This means that energy is mostly required to ensure long-term development (Apeaning, 2012).

Energy is necessary for the creation of wealth and the improvement of social welfare; therefore, a sufficient and reliable supply of energy is required for long-term development. However, most of the time, the use and conversion of primary energy results in waste and emissions; they are derived from finite resources that are environmentally unsustainable. The growing number of environmental challenges associated to energy use has sparked interest in issues of sustainable development, posing the challenge of decoupling economic growth and energy consumption (environmental threats related to energy use). To do so, intelligent use of resources, technology, suitable incentives, and strategic policy planning are required (Diehl, 1985)

Energy management offers enterprises a substantial chance to minimize their energy consumption while maintaining or increasing productivity. Around 60% of global energy use is accounted for by the industrial and commercial sectors combined. By efficiently adopting an energy management system, organizations in these sectors can reduce their energy use by 10% to

40%. Systematic energy management is one of the most successful ways for businesses to increase their energy efficiency because it provides them with the techniques and measures, they need to keep improving and seizing new possibilities. An energy management system (Ems) is a collection of actions and procedures that ensures that energy use in industry is tracked, analysed, and planned in a systematic manner.

Industry's sensible use of energy, as highlighted by Raphael WentemiApeaning (2012), is a critical lever for ensuring a sustainable industrial development. The cost-efficient implementation of energy management and efficiency techniques provides enterprises with a viable means of obtaining both economic and social dividends while also lowering the negative environmental effects of energy use.

Unfortunately, developing-country companies are falling behind in terms of adopting energy efficiency and management techniques, and as a result, they are missing out on the benefits of implementation (Apeaning, 2012).

Energy efficiency and energy management are two concepts that are firmly rooted in the prudent use of energy resources and technology to decrease the negative repercussions of energy use. Energy management is a method for changing and optimizing energy utilizing systems and procedures in order to reduce energy requirements per unit of output while keeping or lowering total costs of production from these systems (Parkinson, 1979).

Energy conservation has a positive economic impact because it lowers the cost of production. Steel, aluminum, cement, fertilizer, pulp and paper are all energy-intensive businesses. The cost of energy accounts for a major portion of the entire product cost. In the overall industrial sector, energy costs as a percentage of total product costs range from 0.36 percent to 65 percent. Using energy-efficient technologies reduces manufacturing costs, resulting in lower-cost, higher-quality products (Agency, 2012).

An energy audit should be considered to effectively and efficiently solve the problem of uneven energy supply. An energy audit identifies where, when, why, and how energy is used in a facility, as well as prospects for efficiency improvements. Energy audits are an effective tool for discovering operational and equipment improvements that save energy, lower energy costs, and increase efficiency. The term "energy audit" is also used to refer to "energy assessment." The purpose of this study is to examine the energy audit and efficiency of a complex structure, as well as to identify strategies to reduce energy waste in a complex building. This study gives an overview of energy auditing, including the energy audit team, types of energy phases, and energy audit categories, as well as the energy consumption index. The study also discusses previous energy audits conducted on hospital buildings, academic buildings, and other structures(Ya et al., 2018).

According to Shadil and Sinan, firms frequently employ experts to assess their energy usage and offer suggestions for improving energy efficiency. Only 14% of respondent companies have hired an energy consultant and done a full process assessment with a focus on energy usage, according to the research. Further examination reveals that most of these businesses have either established the process to minimize energy consumption expenses or to ensure that electricity is always available.These companies did not hire consultants to evaluate their energy usage because they wanted to become more energy efficient. (Shadil & Sinan, 2020)

It's also important to note that 33% of businesses that engaged consultants to keep track of their energy usage did not do so. These corporations rejected the experts' recommendations as being too expensive and non-firm-specific to implement. (Mabaso et al., 2021)

2.2.1 Industrial Energy Management

Energy is critical to achieving a country's desired economic growth. A successful energy plan is woven into the very fabric of developmental goals. To generate income and improve society welfare, energy is necessary, and a consistent supply is required for long-term, sustainable growth. However, using primary energy frequently results in waste because it comes from limited and unsustainable natural resources. Initiatives to disentangle energy use from economic growth have been spurred by the increasing environmental issues associated with energy use, which also emphasize the importance of sustainable development.

Two (2) concepts can be distinguished in the prudent use of energy to accomplish energy conservation, according the Legislative and Institutional Framework on Energy Efficiency in India. Energy efficiency and energy management are included in the EE Initiatives in Industry and Buildings National Mission for Enhanced Energy Efficiency (NMEEE) Voluntary Initiatives to Promote Energy Efficiency, 2016. The necessity to reduce emissions to acceptable levels and the rising cost of electricity have made energy conservation more crucial globally. According to Bawa & Selby, (2018), governments and energy regulators must implement a well-structured framework to regulate and address energy conservation.

2.2.2 The Medical Facility Energy Management

Grid-connected electricity is inconsistent in many parts of Nigeria (as it is in other developing nations), and it is frequently missing in the most remote rural areas (Ya et al., 2018). In many regions, alternative fossil fuel electricity generation is too expensive. Many hospitals in Nigeria are powered by alternative gasoline or diesel-fuelled power plants. As a result, energy makes for a large portion of hospital operating expenditures, as well as patient bills. Hence, most hospitals particularly those in rural regions, are severely restricted in delivering crucially efficient and effective healthcare.

According to recent research released on June 2,2021 by the International Renewable Energy Agency (IRENA), almost a billion people presently rely on health facilities that do not have access to electricity (IRENA, 2021). While most large hospitals have 24-hour power, rural clinics have substantially lower electrification rates. Without reliable power, many life-saving operations cannot be carried out safely or at all.

Furthermore, nearly 60% of health facilities in 46 poor and middle-income countries lacked consistent electricity, according to a recent assessment of over 121,000 facilities. Even institutions with access to electricity can endure outages, reducing medical personnel' capacity to provide modern health care in rural areas.

The best option for resolving this problem is renewable energy. Healthcare facilities can be electrified using off-grid (stand-alone and mini-grid) renewable energy options, which are affordable, quick to set up, and reliable. This will improve patient care and help the world achieve sustainable development goal (SDG 3) — excellent health and wellbeing — while also improving lives. (IRENA, 2019).

A lack of sufficient and consistent power threatens the lives of millions of people, particularly women and children. In fact, more than 289,000 women die each year around the world as a result of complications related to pregnancy and childbirth, many of which could be averted if better lighting and other electricity-dependent medical services were accessible (SEforALL, 2019).

The Nigerian Energy Support Programme (NESP), a technical assistance initiative co-funded by the European Union and the German government and carried out by the Deutsche Gesellschaft für Internationale Zusammenarbeit, carried out an expanded phase of the pilot Energy survey across seven (7) Local Government Areas (LGAs) in Kano state in August 2020. Reiner Lemoine Institute (RLI) and INTEGRATION Environment & Energy GmbH (INTee) of Germany provided geospatial data specialists for the project. The program seeks to encourage and enable investments in the Nigerian home market for energy efficiency, renewable energy, and rural electrification (Consortium GOPA Consultants – intec, 2014).

In addition, a remote interview method was employed to interview health facility in-charges in selected health facilities across 43 of Kano's 44 LGAs and 27 of Osun's 30 LGAs as part of the expanded study. The results of the previously completed pilot survey requested that the survey's scope be expanded to collect enough data to provide a better picture of energy needs, current situations, and support in planning the adoption of appropriate energy solutions for communities. A total of 291 health institutions were included in the expanded coverage, with 173 in Kano state and 118 in Ibadan. The primary aim is to assess energy gaps and identify the potentials for connection to an off-grid power source (renewable energy) and at the same time, determine the readiness for Covid-19 response at the Primary Health facility level. The result of the survey show that some health services required to be enhanced and that not all infrastructures fulfil the minimum standard set by NPHCDA. Additionally, the availability of many different types of equipment at the health centres across all assessed facilities is impacted by power shortages, which has an impact on the output and overall performance of the facilities in terms of service delivery.

2.2.3 Importance of the Industrial Energy Management and Its Social and Economic Benefits

Enhancing energy efficiency in the industrial sector is essential to separating economic progress from the damaging effects that industrial development has on the environment and the climate.

2.2.3.1 Energy and Economics

Improved industrial energy efficiency offers numerous potential benefits; yet, due to a variety of constraints, the optimal degree of savings in efficient technologies is rarely achieved.

Rather than installing new technologies, significant industrial energy efficiency can be achieved simply by changing how energy is controlled (Science et al., 2015). As a result, rather than installing new technologies, most industrial energy efficiency improvements are obtained through changes in how energy is used in the plant. As a result, it is clear why improving technology efficiency alone will not result in optimal savings, but when combined with operational and maintenance practices, as well as management systems, will result in large savings.

The adoption of an energy management system in a facility creates a conducive environment for identifying and realizing energy savings in a long-term manner (Sucic et al., 2019) as well as allowing industries to integrate energy efficiency practices into current management systems.

If the system is not effectively built and run, energy-efficiency components in industrial systems will not deliver the projected energy savings. Improving industrial energy efficiency is crucial for enabling supply-constrained developing markets to meet increasing demand while simultaneously decoupling economic growth from environmental degradation (Industrial Energy Efficiency for Sustainable Wealth Creation, Industrial Development Report, 2011).

To be profitable, a company must rely on the relationship between sales and input costs, the larger the gap, the higher the profit margin. Firms tend to be price takers in competitive market places (Cooney, 2012); as a result, they have little influence over the price of their goods on the market, which also means they have little control over their sales revenue assuming continuous production capacity. Firms, on the other hand, have more influence over the costs of their inputs. Utility costs (energy and water), labour costs, and raw material costs are primarily included in a firm's input cost. As a result, short-term input costs can be lowered by optimizing production methods, employing less expensive inputs, and improving material and energy use efficiency, while long-term input costs can be decreased by introducing new equipment (Cooney, 2012). When energy accounts for a considerable amount of a company's input cost, energy efficiency can result in huge profit margins. Companies that adopt energy-efficient technologies have a better chance of improving their long-term competitiveness and productivity, due to the volatility of global energy prices combined with the rise of energy prices. This is accomplished by reducing the company's energy dependency and increasing energy supply security. In most cases, investing in efficient technology saves a lot of money and improves product quality. Companies can decrease or avoid pollution fees and levies by employing energy efficiency measures.

2.2.3.2 Energy and its Social Benefits

Firms and industries that implement energy efficiency in a cost-effective manner boost productivity; productivity growth is the primary driver of both industrial and economic growth. As a result, better productivity leads to higher profit margins, which can be redistributed as higher pay or invested to raise output, benefiting both the supplier and the consumer (Bhattacharyya, 2019). Improving productivity (because of higher industrial energy efficiency) can lead to the development of new inventions, which can result in the creation of new jobs and the expansion of existing ones. Energy efficiency can also improve the working environment of businesses and society's overall quality of life.

2.2.4 Demand and Supply Gap

The electric power industry's restrictions, as well as ongoing demands related to global environmental challenges and rising consumption, have resulted in an increase in the installation of distributed generation (DG) and energy storage systems (ESS) (Duan & Liu, 2011).

Energy is essential for human survival and development, according to Irawati Naik and Himanshu Naik. The gap between demand and supply of electric energy is expanding day by day as demand for energy rises and power generation falls short. Bridging the supply-side gap is a much easier said than done and expensive issue. The cost of electrical energy is also rising due to a lack of energy funding, a lack of capital, and high lending rates for the addition of generation capacity. Apart from adding capacity, the only realistic approach to deal with this issue is to make optimal use of available energy, which can only be done by constantly monitoring and controlling the usage of electrical energy. As a result, an energy management program is a systematic and scientific approach for identifying the potential for energy efficiency improvements, recommending solutions to accomplish predicted energy and cost savings with or without financial investment. As a result, the need to preserve energy, particularly in industry and commerce, is acute, as energy costs account for a significant portion of the overall cost structure of the business (Oksman et al., 2021).

Despite massive outlays for the energy sector since independence, the gap between supply and demand for energy is always widening, according to Elias Nugusu Tulu(Galassa, 2011). Furthermore, fossil fuel combustion produces greenhouse gases, which are harmful to the environment. Energy conservation and management, which can be considered a new fountain of energy that is kind and environmentally friendly, can assist bridge the gap between supply and demand for energy. With a quick payback period and a low initial investment, energy conservation is financially advantageous. In numerous sectors, such as industry, agriculture, transportation, and household, there is a lot of room for energy conservation. The energy audit can help the industry make a lot of money. However, the results thus far have been disappointing. The development of energy conservation as a mass movement is critical (Yogananda, 2020)

2.2.5 Energy Efficiency

According to Price and Mc Kane, energy efficiency in 2009 is the most effective way to address climate change, rising energy prices, and supply security while maintaining economic growth. The industrial sector, which accounts for 33% of global final energy consumption and 38% of energy-related carbon dioxide (CO_2) emissions in 2005, offers the best investment opportunities (Global Alliance for Buildings and Construction, 2019)

On the other side, energy efficiency is defined as a ratio between a performance output, service, products, or energy input and a performance output, service, goods, or energy output (EU, 2013). As a result, improving energy efficiency primarily refers to lowering the energy intake for a given service, good, or output. These two notions advocate the use of energy resources in a way that conserves energy (natural resources) and ensures little waste, hence encouraging environmental sustainability.

For underdeveloped countries, the demand for industrial energy efficiency is considerably stronger. The industrialization process, according to the IEA, causes these shares in energy use and energy-related CO_2 emissions to be much greater than in industrialized countries in 2008. In

2005, industry in non-OECD (Organisation for Economic Co-operation and Development) nations accounted for 38% of total energy consumption, compared to 27% in OECD countries (and up to 50% in some situations) (Landsberg, 1980).

Secondly, and with a few exceptions, developing countries are more carbon intensive than their industrialized equivalents, owing to a higher proportion of polluting sources, such as coal, in their final energy mix (IEA 2008). For example, between 1990 and 2005, carbon intensity in OECD countries declined, allowing CO_2 emissions to climb at a pace of 15%. Carbon intensity continues to rise in non-OECD countries, contributing to a 39 percent increase in CO_2 emissions during the same period (IEA 2008). Furthermore, this trend is likely to continue, with developing and transition countries expected to account for the majority of growth in industrial energy use and CO_2 emissions (Price & Mckane, 2009).

According to Jayant, and Sathaye Lynn, the small-scale sector is vital to the economy's energy supply, as well as the need to improve the energy and environmental performance of units in the sector (Jayant et al., 2005). It is based on the findings of a significant program in the small-scale sector that TERI (Tata Energy Research Institute) launched in 1995 with the help of SDC (Swiss Agency for Development and Cooperation). The program attempts to identify solutions to the SSI's energy problems through technological advancements as well as human and institutional development in a few small-scale energy-intensive industries.

2.2.6 **Energy Management Strategies**

Energy management strategies are methods and actions used to maximize energy utilization, cut down on energy use, and boost energy effectiveness. These tactics seek to reduce energy waste, bring down energy prices, and lessen the effects on the environment. These are a few of the most widely utilized energy management techniques:

Conduct an energy survey.

The first step to effective energy management program is to learn how and when each piece of equipment uses energy. Calculate the demand and monthly energy consumption for the largest equipment. The rate at which energy is consumed will vary throughout the day, depending upon factors such as demand from the distribution system and time of the day. Note the largest equipment which can be operated off- peak. Examine all available rate schedules to determine which can provide the lowest cost in conjunction with appropriate operational changes.

Energy Efficiency Measures: One of the most effective ways to cut back on energy use is to adopt energy-efficient practices and technologies. This can involve switching to energy-efficient versions of old appliances and equipment, enhancing insulation and the building envelope, boosting lighting and HVAC efficiency, and implementing intelligent energy management systems. These actions can cut energy waste and expenditures by a significant amount.

Scheduling and profiling of hourly load

The load scheduling is based on the projected appliances that become essential to be used at a specific period throughout the 24 h cycle. The uncontrollable loads demand instant power and are consequently scheduled to operate all through the cycle. The remaining other controllable loads would be allocated different period of operation. This means that their periods of operation are deferrable and do not demand constant power. The uncontrollable loads are spread over the 24 h cycle of operation by allowing each of them to be operated only at the time it will be mostly needed in such a way that the peak load at any point in time is reduced (Ogunjuyigbe et al., 2015)

Reduce Peak Demand

During on-peak period, avoid large equipment to be operated simultaneously. Seek for the opportunities to improve the performance of equipment that must run during the peak period, such as improving plant efficiency or upgrading plant’s aeration system.

Shift Load to Off- Peak

Several large loads can be scheduled to –off peak operation. For example, plants can use system storage to ride out periods of maximum load rather than operating them. This energy storage enables a shift of utilization to off-peaks without impacting on the operation of the productive process. Also, avoid running large intermittent plants while operating the most important plants.

Improve power factor.

Low power factor is not only inefficient but can also be expensive over the life of an electrical system. This is frequently caused by motors that run less than fully loaded thereby wasting energy due to drop in the motor efficiency below full load.

Improved power factor will increase the distribution system's efficiency and reduce energy loss associated with power factor penalties.

2.2.7 Types of Electrical Loads

An **electrical load** is a device or an electrical component that consumes electrical energy and converts it into another form of energy. Electric lamps, air conditioners, motors, resistors etc. are some of the **examples of electrical loads**. They can be classified according to various factors. Some popular **classifications of electrical loads** are as follows.

Resistive, Capacitive, and Inductive Load

Electrical loads can be classified according to their nature as Resistive, Capacitive, Inductive and combinations of these.

Resistive Load

Two common examples of resistive loads are incandescent lamps and electric heaters.

Resistive loads consume electrical power in such a manner that the current wave remains in phase with the voltage wave. That means, power factor for a resistive load is unity.

Capacitive Load

A capacitive load causes the current wave to lead the voltage wave. Thus, power factor of a capacitive load is leading. Examples of capacitive loads are capacitor banks, buried cables, capacitors used in various circuits such as motor starters etc.

Inductive Load

An inductive load causes the current wave to lag the voltage wave. Thus, power factor of an inductive load is lagging. Examples of inductive load include transformers, motors, coils etc.

Combination Loads

Most of the loads are not purely resistive or purely capacitive or purely inductive. Many practical loads make use of various combinations of resistors, capacitors, and inductors. Power factor of such loads is less than unity and either lagging or leading.

Examples: Single phase motors often use capacitors to aid the motor during starting and running, tuning circuits or filter circuits etc.

Other Types of Loads in Power System

Energy usage dynamics in emerging countries is often conceptualized through the energy ladder model and assumes that with increasing income, householders will have a preference to cleaner energy (Adamu et al., 2020).

There is a great difference in the energy consumption patterns of different types of users, such as domestic, commercial, industrial, agricultural, etc. Even for the same type of users, their patterns of electricity usage may be different. Knowing the energy consumption patterns of different users help support the production planning and the provision of more personalized electric energy services for electricity producers. It also helps different energy users to know their energy consumption patterns. This will imply some behavioural modifications in the lifestyles. For example, the wishes in terms of comfort and the way electrical devices are used will evolve significantly. Hence, energy consumption is likely to increase but the residential load curve will also be strongly modified (Grandjean et al., 2011).

In that case, users can adjust their energy consumption strategies more economically and optimally based on the awareness discovered from load classification. Hence, the energy consumption costs will be reduced, and the energy use efficiency will be enhanced more appreciably (Grandjean A, Adnot J, Binet G. 2012)

Domestic Load / Residential Load

Domestic load consists of lights, fans, home electric appliances (including TV, AC, refrigerators, heaters etc.), small motors for pumping water etc. Most of the domestic loads are connected for only some hours during a day. For example, lighting load is connected for few hours during nighttime.

Loads- Critical and Non-Critical

Critical loads are those loads that need constant supply of energy regardless of circumstances. Energy supply to these loads should not ever be interrupted.

Usually, critical loads are present in plants, hospitals, financial institutions etc where certain processes cannot be stopped. The equipment is so critical that there is a greater demand for steady electric energy. Hence an auxiliary power supply is needed for times when the public supply goes down or when the power exceeds or below certain rated value.

Non –Critical loads are those which do not form part of a production or process plants and its disconnection is only minimal or nuisance value. These loads are automatically disconnected when maximum energy is needed for the operation of essential loads. For instance, leaving an outside light on in the daytime when the surgical operation is going on in a hospital might cause shortage of energy at that time, hence should be switched off.

Base Load And Peak Load: Understanding Both Concepts

Load, in electrical engineering, is the amount of power being consumed by all the components (appliances, motors, machines, etc.). It is categorised as base load and peak load depending upon the nature of the electrical components connected. Home appliances do not always run. For instance, a toaster or microwave oven may be used for a few minutes, a television or computer may be used for a few hours and Lighting in the house is only required during the evening and so on. Power demand typically follows a bell curve on a day-to-day basis with the peak demands changing based on the season.

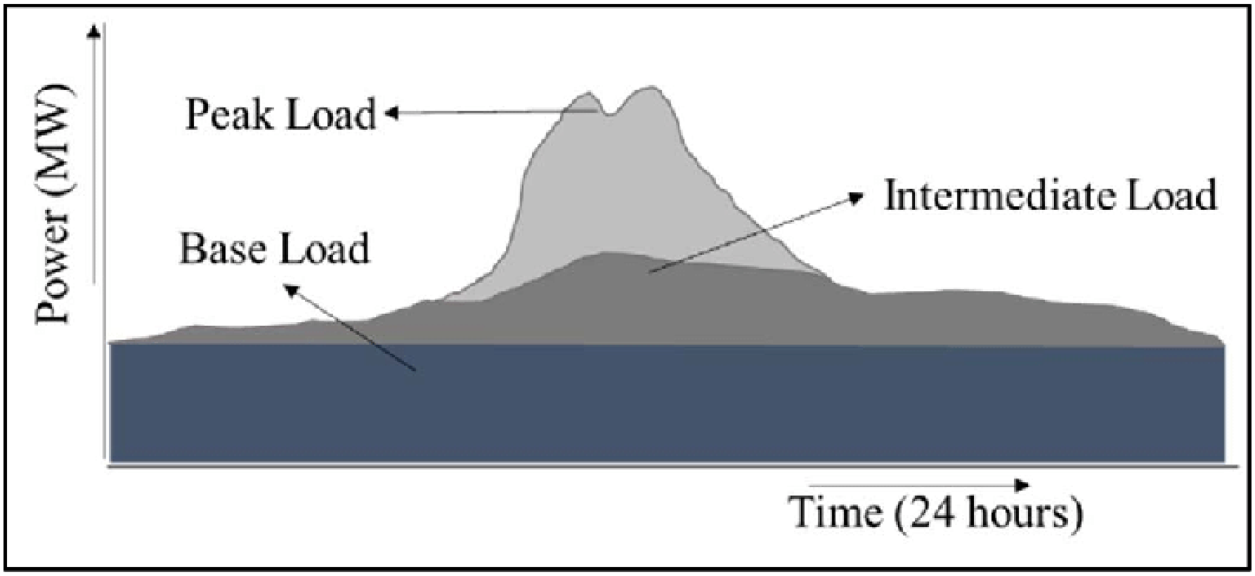

Plate I: Base Load and Peak load Shave (Rana et al., 2022)

Between 6am to 12pm demand for power is relatively low, but never below the certain base. This is the base load which must always be accounted for by grid operators. Between 12pm to 6pm is the peak period. Here additional generator must be provided to offset the electrical load on utility power. This is the peak load. Hence every electrical grid must have base load power plants, intermediate power plant and peak power plants for efficiency and reliable operation (Rana et al., 2022) .

Also, there are some electrical appliances that keep running at all the times, no matter what. The refrigerator, for example, must be plugged in at all the times. Another such examples are the heating, ventilation, and cooling systems in the house (**HVAC system**).

Base load is the minimum level of electricity demand required over a period of 24 hours. It is needed to provide power to components that keep always running (also referred to as **continuous load**).

Peak load is the time of high demand. These peaking demands are often for only shorter durations. In mathematical terms, peak demand could be understood as the difference between the base demand and the highest demand.

Now going back to the examples of **household loads**, microwave oven, toaster and television are examples of peak demand, whereas refrigerator and HVAC systems are examples of base demand.

On a broader perspective, it could be assumed that the electrical grid is a big household. Under normal circumstances, the power required by the electrical grid is constant during various period of the day.

This **constant power**, which is always required, is called the base loading. But during a special event, like the final match of World Cup, the demand will be more, as a lot of people will watch TV. This short, high demand period is a peak loading.

2.2.8 Base Load and Peak Load power plants

Power plants are also categorised as base load and peak load power plants.

Base Load Power plants

These are plants that are running continuously over extended periods of time. The power from these plants is used to provide the base demand of the grid. A power plant may run as a base load power plant due to various factors (long starting time requirement, fuel requirements, etc.). Examples of base load power plants are nuclear power plant, Coal power plant, hydroelectric plant, geothermal plant, Biogas plant, Biomass plant, Solar thermal with storage, Ocean thermal energy conversion.

Peak Load Power plants

To cater for the demand peaks, peak load power plants are used. They are started up whenever there is a spike in demand and stopped when the demand recedes. Examples of peak load power plants are Gas plant, solar power plants, Wind turbines and Diesel generators.

Power Plants Economics

Power plants are designated by *base load* with respect to their low-cost generation, efficiency, and safety at rated output power levels. Base load power plants do not change production to equal power consumption demands. Since it is Base load power plant, it is less cost to operate them at constant production levels. Use of higher cost combined-cycle plants or combustion turbines is thus minimized, and these plants can be cycled up and down to match more rapid fluctuations in consumption. Base load generators, such as nuclear and coal, often have very high fixed costs, high plant load factor and very low marginal costs. On the other hand, peak load generators, such as natural gas, have low fixed costs, low plant load factor and high marginal costs (Wikipedia, 2011)

In general, base load plants are large and provide most of the power used by a grid. Thus, they are more effective when used continuously to cover the power base load required by the grid.

Base Load Power Plant Usage

To actualize a constant power output, nuclear and coal power plants may take many hours, if not days. Because they need an extended period to warm up to its operating temperature, they handle large amount of base load demand. Dissimilar plants and technologies may have varying capacities to alter the output on demand. Nuclear plants are generally run at close to peak output continuously (apart from maintenance, refuelling and periodic restoration to its good condition), while coal-fired plants may cause to go through a recurring sequence of a day to meet up demand (Wikipedia, 2011).

Peak and Intermediate Sources

Electricity demand is not constant over the course of a day, all through the week, and seasonally. Demand is also dependent on location, population, and weather. Areas with towering population normally have higher demands and often have large public transportation systems which rely on electricity. To meet the shifting demand for power, peak and intermediate power plants are matched into the system.

Peak load power plants supply power for the period of peak system demand periods. They are highly responsive to changes in electrical demand and can be started up relatively quickly and vary the quantity of electrical output by the minute.

Barring undue stress on a grid system, peak load plants typically operate 10 to 15 percent of the time and are smaller than base load plants. Peaker plants are very costly to run in relation to the quantity of power they generate and the cost of fuel to operate them. Due to their dimension, however, they are less expensive and easier to build. Peaker plants are most often natural gas combustion turbine plants, but some do run on light oil.

Intermediate load plants fill the gap between base load and peak load power plants. From a cost and flexibility standpoint, they typically operate between 30 and 60 percent of the time.

Intermediate plants are larger than peak load power plants, so their construction costs are higher, but they also run more efficiently. Both wind and solar can be considered intermediate power sources. Both are intermittent by nature, as output fluctuates with weather patterns. Wind and solar cannot be relied upon to meet constant supply needs, nor can they be immediately called upon to meet peak demands. They are, however, effective as intermediate sources and can help to reduce the need for fossil fuel intermediate plants or overuse of Peaker plants during heavy demand days.

2.3 Microcontroller based smart systems.

Microcontroller based smart system, also known as Intelligent Automated Home, refers to the automation of our daily household electrical devices and appliances. Thanks to the advent of intelligent home systems, users can now enjoy the benefits of a convenient, comfortable, and safe automation experience within their homes. These systems integrate advanced technologies to automate and control various household functions such as lighting, temperature, security, and entertainment, enhancing overall convenience and efficiency. By leveraging smart home solutions, residents can manage their environments remotely through mobile devices, ensuring comfort and security even when away. This innovative approach not only simplifies daily routines but also promotes energy efficiency and enhances home safety, marking a significant advancement in modern living standards. Smart home systems combine hardware, software, communication networks, and electronic interfaces to allow a variety of electronic devices to communicate with one another.

Islam et al., (2021) developed a smart home system that allows users to operate (turn on/off) appliances using an Android app. It includes an extra circuit that improves the ATmega328 microcontroller-based Arduino UNO board's capacity to control appliances. Scientists and policymakers are embracing new energy sources and technology for power generation in response to the progressive increase in energy demand. Aside from electricity generation, the energy-saving trend is gaining traction among stakeholders, because saving energy is more manageable than generating it. Currently, around 20% of energy is consumed for artificial lighting in homes, offices, enterprises, laboratories, and agricultural institutions, with a considerable portion of this energy being squandered due to inefficient usage of these artificial light sources (Tang et al., 2017).

In Europe, over 40% of electrical power is used to light buildings, resulting in around 35% of greenhouse gas emissions (Dascalaki et al., 2010). In recent years, numerous studies have been conducted to monitor, manage, and save energy for lighting. As a result, implementing a smart light management system is a cost-effective energy-saving solution that includes an autonomous control system depending on room characteristics such as occupancy, light intensity, or daylight availability. Now, both wired and wireless smart light control systems are being employed to save energy. A wireless Zigbee communication system is one of them, and it includes LED lights with unique drivers to brighten the spaces (Islam et al., 2021). This system likewise uses motion and light sensors, but because of its implementation restrictions, it is not ideal for every location. Some cutting-edge bespoke wiring systems control light intensity by varying the resistance levels in the circuit. However, because of the high installation costs and the need for a more system-oriented approach, the control system is less successful.

Ahmed, (1980) came up with a fluorescent lighting control system that used an electronic ballast to manage the intensity of high-power fluorescent lamps. The system received control signals from the occupancy sensor and the light intensity sensor, which turned on or off the lighting and controlled the light intensity of each lamp. This control system was ineffectual because a single high-power fluorescent bulb, which was used at the time, was insufficient to uniformly illuminate the space. The light emitting diode (LED) is a more efficient lighting source than a fluorescent bulb because of its lower energy consumption, longer lifespan, and ecologically friendly constituent components. These LED lights and unique drivers are integrated into a variety of wireless sensor network (WSN) technology known as Zigbee communication to reduce power consumption while lighting in a variety of areas (Islam et al., 2021).

The motion sensors and light sensors are used in this cutting-edge Zigbee communication-based intelligent lighting control system (Magno et al., 2015).

Cho et al., (2013) described a smart lighting control system in which they used a controller with an optimized smart algorithm to generate control signals and alter the brightness of LED lights by using pulse width modulation (PWM) on a purpose-built LED driver. Magno et al. described a smart system that included motion and light sensors and communicated over Zigbee. Light sensors and wireless sensor network technology are used to control a distributed LED driver directly. However, the intelligent, Zigbee-based system's fundamental constraints are the implementation of failures and shortages. Another challenge in incorporating security measures is the Zigbee wireless network's limited resources. Furthermore, the system's nodes are primarily battery-powered, with limited processing power and memory.

Furthermore, occupancy sensor-based wired smart lighting systems are available on the market and in the literature (Magno et al., 2015), although most of these sensing systems have a lesser energy-saving capability. A smart control system based on embedded microcontrollers was recently reported (Binti Mohd Arifin & Thamrin, 2018).

The technology is tailored to the room's natural light, resulting in an efficient lighting control adjustment to tune the LED bulb to the required light level. The light in the room is dimmed by using the various resistance values in the circuit to manage its intensity. Dimming light technology, which necessitates a more systems-oriented approach, has had a less effective track record. The high expense of installation and maintenance, as well as the inability of retrofitting, are the key reasons behind this (Caicedo & Pandharipande, 2013).

2.3.1 Application of Arduino in fault detection, measurements and control

Many approaches have been used to measure, monitor, and detect faults in the electrical systems based on microcontroller. (Kaur, 2010) designed a training system that uses both electro-mechanical and microcontroller (Arduino) based relays simultaneously such a way that the electrical system could be switched to either electro-mechanical or microcontroller- based relay setup. This system also displays the current magnitude during the fault and the time required by the relay to clear the fault with the help of Arduino (Ali et al., 2020).

Arduino is an open-source microcontroller which can be easily programmed, erased, and reprogrammed at any instant of time. Built on simple microcontroller boards, it is an open-source computing platform that is used for constructing and programming electronic devices. It is also capable of acting as a minicomputer just like other microcontrollers by taking inputs and controlling the outputs for a variety of electronics devices. It is also capable of receiving and sending information over the internet with the help of various Arduino shields. It uses a hardware known as the Arduino development board and software for developing the code known as the Arduino IDE (Integrated Development Environment). Built up with the 8-bit Atmel AVR microcontroller's that are manufactured by Atmel or a 32-bit Atmel ARM, these microcontrollers can be programmed easily using the C or C++ language in the Arduino IDE (Louis, 2016).

Currently, digital electronics energy measurement is continuously replacing existing technology of electro-mechanical meters. A wireless digital power meter will offer greater convenience to the meter-reading task. Arduino is getting more and more attention in the field of measurement instruments and monitoring systems due to its flexible features and rich library functions. It is user robust, fast and at the same time user friendly.

In modern power systems, voltage quality is becoming increasingly important with their growth in power electronics and their high sensitivity of electronic equipment. Voltage quality covers a wide range of voltage disturbances and deviations in voltage magnitude or waveform from the optimum values. Disturbances related to voltage quality could occur because of the operation of the power grid and/or of units connected to the grid. On the other hand, voltage irregularities are the major issues the industry and home users are facing and are often responsible for damages in sensitive equipment due to overvoltage or undervoltage (Tung & Khoa, 2019)

Sarwar et al., (2019) focus on the design and implementation of an automatic synchronizing and protection relay to automate the synchronization process of a Distributed Energy Resource (DER) to the Main Grid. The proposed design utilizes a cost-effective data acquisition using Arduino in combination with LabVIEW software to implement the multi-purpose synchronizing relay. The proposed synchronizing relay can synchronize a Distributed Generator (DG) to the power grid from black-start and fulfils the requirements imposed by the utility. The synchronizing relay is implemented through voltage and frequency control of an actual lab-scale synchronous generator. In the synchronization process, frequency synchronization is done using speed control of the stepper motor as the prime mover and voltage synchronization is accomplished using Excitation Control module through Power-Hardware-in-the-Loop (PHIL) simulation.

2.3.2 Automatic Load Sharing

Electricity is an exceptionally one of the useful forms of energy. It plays an ever-increasing role in our contemporary modern society. The electrical power systems are highly non-linear, very huge and complex networks (Lawan et al., 2017).

Such electric energy is integrated for economic benefits, increased reliability, and operational advantages. They are one of the most significant elements of both national and global infrastructure, and when these systems go down, it affects the national economic security directly or indirectly (Study & Impact, 2022).   This enables one to understand that if load is rising fast and power generation is stable then it is not likely for the system to drive the future requirements (Denholm et al., 2020).

A power system is made up of components such asgenerators, lines, transformers, loads, switches, and compensators. Hence, a widely distributed power sources and loads are the general configuration of modern power systems. Electric power systems can be divided into three subsystem, namely, generation, transmission systems and distribution systems. The main process of a transmission system is to transfer electric power from electric generators to customer area, whereas a distribution system provides a connection between high voltage transmission systems and end user services. The generator can supply important domestic or industrial loads during power shortages. One setback facing generator usage is overloading by consumers which affects the efficiency of the generator. To improve the quality of power with adequate solutions, it is important to know the type of constraint that occurred. Moreover, if there is any lack in the protection, monitoring and controlof a power system, the system might happen to be unsteady.

The problems of overloading, voltage variation and heating effects are very common. It takes a lot of time for its repair and involves lot of costs. This work is all about shielding the generator from overload condition. Therefore, it requires a monitoring system that can automatically detect, monitor, typify and classify the existing constraints on the generator.

2.3.3 Synchronizing the Normal Supply and Generation

Power supply from the national grid can be coupled with that of the generator and PV-cell via extended parallel for continuity of operation through the automatic transfer switch (ATS). Automatic Transfer Switches (ATS) are primarily used in power transfer as a critical mechanism to backup power system. They are dependable, rugged, adaptable, and compressed assemblies for transferring essential loads and electrical distribution systems from one power source to another. They utilize simple electrical operators to provide high-speed, quick-break, quick-make preloaded transfers. The operators are connected to the switch mechanism through precision self-aligning, ball joints and heavy-duty linkage rods which prevent misalignment.

2.3.4 Automatic Transfer System (ATS).

A key element in the creation of microcontroller-based energy management systems in medical institutions is the Automatic Transfer System (ATS). It offers a smooth and dependable transition between various power sources, assuring a steady supply of electricity for crucial machinery and systems. Here are some significant ways that ATS helps medical facilities control their energy use:

Redundant power sources are frequently used by medical facilities, including the primary electrical grid, standby generators, and renewable energy sources. The quality and availability of these electricity sources are continuously monitored by the ATS. The ATS recognizes the problem and automatically switches the load to a backup power source if the primary source fails or becomes unstable, minimizing downtime and providing an uninterrupted power supply (ANDRE, B., 2017).

A microcontroller-based energy management system, which serves as the system's brain, is integrated with the ATS. The microprocessor monitors the status of the power sources, load requirements, and other pertinent characteristics using input from a variety of sensors. It then uses this data to process judgments about choosing a power source, reducing load, and maximizing energy (Anon, 2020).

Prioritizing loads: In a medical facility, some systems and facilities, including life support machines, emergency lighting, or vital monitoring equipment, need to be powered on constantly. These vital loads can be given priority by the microcontroller and ATS, ensuring they get power even during changes in power sources or situations with insufficient backup power. To save energy and increase the duration of backup power sources, non-critical loads can be selectively shed or momentarily turned off (Muhammad et al., 2018).

Energy Efficiency and Demand Management: To improve energy usage in healthcare facilities, microcontroller-based energy management systems can include cutting-edge algorithms and control strategies. The system may dynamically change power distribution, put in place energy-saving measures, and lessen overall energy waste by assessing real-time data on power consumption, load patterns, and patient care requirements. Cost savings and increased energy efficiency may arise from this (Abubakar et al., 2017).

The microcontroller provides fault detection and alerts while continuously monitoring the power sources. It is capable of spotting anomalies such as voltage changes, frequency aberrations, and poor power quality. The microcontroller can produce alerts, notifications, or alarms in the case of a failure, enabling facility employees to take immediate action and guarantee continuous power supply to crucial sections.

Data logging and analysis: The microcontroller could record and store information on power, such as data on energy use, the efficiency of power sources, and load profiles. To find patterns, optimize energy use, create maintenance schedules, and come to wise conclusions about energy infrastructure or system changes, this data can be evaluated.

Medical facilities may guarantee a dependable and effective power supply, reduce disruptions during power outages, and optimize energy usage by integrating an ATS with a microcontroller-based energy management system (Okilly et al., 2023). This is essential for maintaining patient care, supporting life-saving machinery, and providing a secure and comfortable atmosphere for both patients and medical staff.

2.4 Review of Related Works

The power sharing and monitoring unit will protect the generator from overload by various consumers and will automatically disconnect the consumer when the load exceeds the maximum power demand for that consumer.

There have been numerous attempts to create a load sharing and control system for the power grid. Several similar works were examined. P. Biczel and colleagues worked on a power source and load control device (Lawan et al., 2017)

Similarly B. Enayati et al presented a model for control of power flow for autonomous micro grid operations (Thanh et al., 2017) .

Islam, S., et al., (2021)presented an energy-saving smart light control system that can automatically maintain the desired light intensity in a room. The 8-bit microcontroller chip PIC 16F876A is used in this suggested system to receive and process sensor data as well as make decisions for generating control signals. The occupancy sensor, light sensor, control unit, relay switch driving unit, display unit, and firmware make up the system. These six parts are controlled by the PIC microcontroller (PIC 16F876A), a CMOS FLASH 8-bit microcontroller IC with a 28-pin dual inline package (DIP) that has been utilized for data processing and decision making.(Islam et al., 2021).

To avoid overloading, Abhishek G. et al suggested an Automatic Transformer Distribution and Load Sharing Using Microcontroller, in which several transformers were operated in parallel. It is like parallel transformer operation, in which many transformers share the system load. When the load on the main transformer exceeds its rated capacity, slave transformers will share the load in the proposed way (Vani, 2017).

J. Liang and Q. Zhong have presented a control technique for voltage source inverters connected to a microgrid, although this requires impedance information, which reduces the reliability of the system (Guo & Mu, 2016).

The review of these works reveals their shortcomings in terms of functionality. It is yet to be built a standard device control system that does not require human intervention. This may be accomplished with a flexible Microcontroller and automated transfer switch (ATS), passive infrared (a motion detector), and minimal components since most of the work is software-based. The Microcontroller used in this project is Arduino due to its obvious advantages. The one inherent problem with standard power sharing and monitoring units is their broadcast strength.

It was noted that none of them considered up to three features of standard automated system. Therefore, this research will focus on integrating the following features in the hospital.

a. Current Sensor: none of the paper reviewed added this feature.
b. Passive Infrared (PIR) and LDR: this is a new technology that will be incorporated with the system to achieve maximum power saving.
c. None of them considered automatic transfer system for three sources.
d. The system is scalable: other works reviewed did not provide space for addition of feature loads.
e. This work will be capable of de-energizing any load once it exceeds or below the selected power range.

f. This work will be more of writing codes that will automatically compare loads from different sources. In this case one will not be afraid of plugging devices into the sockets

CHAPTER THREE

MATERIALS AND METHODS

3.1 Materials

The materials for this research work involve both software and hardware.

3.1.1 Software

The following software were deployed in the development of microcontroller-based energy management systems in medical facilities.

(a.) Arduino IDE
(b.) Proteus
(c.) C++ programming language

3.1.2 Hardware

The following hardware materials below were used to develop the design and construction of microcontroller-based energy management systems in medical facilities.

(a.) Arduino Microcontroller (Arduino ATmega 328p)
(b.) Current sensor (ACS 712)
(c.) Microcontroller (Arduino Nano)
(d.) ADC Converter
(e.) Display Screen (Liquid Crystal Display (LCD)
(f.) Signal Diode
(g.) Voltage Sensor
(h.) Energy Meter
(i.) Relay Drive Module
(j.) Transformer less Voltage Converter
(k.) Passive Infrared Sensor (PIR)
(l.) Light Dependent Resistor (LDR)
(m.) Diode
(n.) Resistors
(o.) Voltage regulators

(p.) Capacitors
(q.) Lamps
(r.) Switch Mode Power Supply (SMPS)
(s.) PC (Laptop)

3.2 Method

It is necessary to use a variety of techniques to efficiently monitor, regulate, and optimize energy use while developing microcontroller-based energy management systems for medical institutions. Following are a few typical techniques employed in this area.

3.2.1: Determination of Energy Sources and Capacities through Surveys

The chief engineer and the chief laboratory technologist were interviewed using questionaire. The interview method was used to gather the load capacity of the entire hospital.

The questions of the interview were shown in the templates in appendix A and B.

In addition, different energy supply sources and end users were revealed during a walk-through energy audit conducted. It was observed from the survey that the entire UNTH was fed by 750MVA transformer (six 500kVA sublet) and 500KVA, 100KVA, 1000KVA and 700KVA generators. Out of which 500KVA is feeding the Cardio Thoracic Centre (CTU & ICU) Units, Theatre, X-Ray/Radiology Units, Cardiac Catheterization Lab, and Main Laboratory. In the respective hospital, major energy services such as lighting, ventilation, communication, water pumping, and medical equipment operation were investigated.

According to the survey, there are some appliances that use a lot of electricity but cannot be turned off or moved to an off-peak period, such as lighting, medical equipment, and office equipment. Those categories are inextricably linked to the needs of end-users; as a result, they are classified as unmanageable loads because they should be available whenever needed. Air conditioners, refrigerators, and electric water heaters are examples of appliances that may be repaired and paused without having to restart the cycle. Thermoses and fans can be turned off and on as needed.

3.2.2 Perform Load Enumeration Using End-User Analysis Method

Experts in primary health care were interviewed in various departments and units at the University of Nigeria Teaching Hospital (UNTH). From the interview carried out, the energy usage of numerous facilities in different departments and units were carried out.

Table 3, 3.1, 3.2, 3.3 and 3.4 below show the power consumption of various equipment in Cardio Thoracic Centre (CTU & ICU) Units, Theatre, X-Ray/Radiology Units, Cardiac Catheterization Lab and Main Laboratory respectively. These units are fed by 500KVA transformer sublets and 500KVA Generator (back up)

Table 3.1 Power consumption of various equipment in Radiology (X-RAY) unit

Medical Equipment	Wattage(W)	Units	Total Wattage(W)
X-Ray Film Processor Tabletop	60000	2	120,000
X-Ray Film Viewer	60000	2	120,000
X-Ray Unit Universal	60000	2	120,000
X-Ray Mobile	2500	2	5,000
Ultrasound Scan (3 Probes)	2500	3	7,500
MRI Machine	3000	1	3000
Electrocardiograph 3 Channels	150	1	150
Hot Air Sterilizer	600	1	600
CT-Scanner	379	3	1137
Portable ultrasound Scanner	25	5	125
Mammography	750	1	750
Fan: Standing	70	2	140

Ceiling	85	2	170
Television	50	2	100
Air Condition	746	2	1492
Lighting bulb (Energy saving)	15	6	90
Computer	60	4	240
			TOTAL=380494W =380.494KW

Table 3.2 Power consumption of various equipment in the Main theatre

Medical Equipment	Wattage(W)	Units	Total Wattage(W)
Gastroscope (with halogen light source)	150	1	150
Colonoscope	150	1	150
Electrocardiograph 3 Channels	150	1	150
OperatingTable (Trauma/multifunction electric/hydraulic driven)	150	1	150
Anaesthesia Trolley (Anaesthesia Machine with Ventilator & monitor)	150	1	150
Syringe Pump	25	1	25
Electrosurgical Unit (Monopolar-Bipolar)	200	1	200

Suction Pump	84	2	168
Ventilator ICU	40	3	120
Pulsimeter	0.00006	1	0.00006
Patient monitor, anaesthesia	0.00006	1	0.00006
Oxygen Condenser	600	1	600
Examination lamp	40	1	40
Fatal Monitor	30	1	30
Microscope Binocular	60	1	60
Microscope Binocular	20	1	20
Analyzer Haematology	520	1	520
Defibrillator	2300	1	2300
Water Bath	1480	1	1480
Water Still	4000	1	4000
Centrifuge	110	1	120
Refrigerator	780	1	780
Hot Air Sterilizer	600	1	600
Bacteriological light	40	1	40
Incubator neonate	40	6	240
Surgical Light Mobile	50	1	50
Fibre Bronchoscope	150	1	150
Laparoscopy system with instrument	175	1	175

for general surgery			
Surgical	150	10	1500
Infant Reanimation Centre	40	1	40
Cardiotocograph	150	1	150
Nebulizer	150	1	150
Mammography	750	1	75
Coronarography Angiography System	600	1	600
Infant Warmer	750	1	750
Infusion Pump	85	2	170
Fan: Standing Ceiling	70 85	2 2	140 170
Television	50	1	50
Air Condition	746	2	1492
Lighting bulb (Energy saving)	15	5	75
Computer	60	2	120
			TOTAL =17962.00012W

Table 3.3 Power consumption of various equipment in Accident and Emergency Theatre

Medical Equipment	Wattage(W)	Units	Total Wattage(W)
Operating Table (Trauma/multifunction electric/hydraulic driven)	150	1	150
Anaesthesia Trolley (Anaesthesia Machine with Ventilator &6 monitor)	150	1	150
Syringe Pump	25	1	25
Suction Pump	84	2	164
Pulsimeter	0.00006	1	0.00006
Patient monitor, anaesthesia	0.00006	1	0.00006
Oxygen Condenser	600	1	600
Examination lamp	40	1	40
Fatal Monitor	30	1	30
Defibrillator	2300	1	2300
Infusion Pump	85	2	170
Fan: Standing Ceiling	70 85	2 2	140 170
Television	50	1	50

Air Condition	746	2	1492
Lighting bulb (Energy saving)	15	5	75
Computer	60	2	120
			TOTAL =17962.00012W

Table 3.4 Power consumption of various equipment in ICU/CTU unit

Medical Equipment	Wattage(W)	Unit	Total wattage(W)
ICU bed	-	4	
Baby cot	-	4	
Trolley, general purpose	-	1	
Trolley, instrument	1500	1	1500
Trolley, dressing	-	1	
Infusion stand	-	4	
ECG Monitor	150	2	300
Infant radiant warmer	750	1	750
Infusion pump	85	4	340
Syringe pump	-	4	

Refrigerator, general	780	1	780
Patient monitor	0.00006	2	0.00012
Spotlight	50	2	100
Mobile X -ray unit	60000	1	60000
Defibrillator	23000	1	23000
Suction machine, electric	84	2	168
Ventilator, adult	40	1	40
Ventilator, infant	40	1	40
	-		Total=87018W =8.7018kw

3.2.3: Design of Energy Management System

Several crucial elements and considerations must be made while designing an energy management system for a medical facility. The overview of the design process is as follows:

a. Load Prioritization Scheme

The first step in load prioritisation is to classify loads based on functionality and type.

I. **Functionality**: Depending on their level of care and specialization, medical institutions may have a variety of life-supporting tools. The following is a list of typical life-supporting devices in medical facilities: Mechanical Ventilator, Defibrillators, Haemodialysis Machine, Extracorporeal Oxygenation (ECMO) Machines, Infusion Pumps, Cardiopulmonary Bypass Machines, Continuous Positive Airway Pressure (CPAP) Machine, Intra – aortic Balloom Pump (IABP), Mechanical Ventilator, Cardiac monitors, infusion Pumps, intrauterine Devices, Electrocardiogram (ECG) Monitors, Continuous Glucose Monitoring (CGM) System. They are known as Essential loads.

II. **Types:** These includes Water Pumps, Lighting Systems, Air Conditioning Systems, X-Ray Machines, Computers, Printers, Office Equipment, and non-essential appliances. These are classified as non-essential loads.

Hence, to prioritize loads in the entire hospital, the chief electrical engineer and the chief medical technologists were interviewed to ascertain the load consumption strategies and the challenges they are facing to set up load priorities pattern which will guarantee that vital and necessary equipment gets power supply first, maximizing patient care and safety.

The results of the interview were used to organise the prioritization scheme as tabulated in Table 3.5 below. From the prioritization scheme shown in Table 3.5, facilities in load level 1 are taken preference to 2,3,4 and 5 since they are classified as life supports facilities. Consequently, they are slated to operate all through the 24hours cycle. Hence the other non- critical loads would be allocated different period of operation since they are not needed all the time.

Table 3.5: Key for Load Add Levels

Level	Facilities
1	Cardiac Monitor, Oxygen Condenser, Apnea monitor for infants, Kidney Dialysis, Respirator, Ventilator, Pressure Breathing Therapy, Infusion Pump, Defibrillators, Incubators (Infant)
2	Suction Pump, Peritoneal Dialysis Machine, Kidney Dialysis Machine, X-Ray Machines, Ultrasound Scan, MRI Machine, C-T Scanner, Electrocardiography, Mammography, Fatal Monitor, Pulsimeter, Gastroscope, Colonoscope, Patient Monitor anaesthesia
3	Centrifuge, Hot Air Sterilizer, Bacteriological Light, Nebulizer, Colonography Angiography, Fibre Bronchoscope, Laparoscopy System, Cardiotocography, Analyzer Haemoglobin, Oxygen Condenser, Trolly Instruments
4	Air Condition, Washing Machine, Refrigerators, Water Still, Water Bath
5	Lightening Bulb, Computer, Television, Fan, Photocopy Machines, Pumping Machines (SUMO)

Table 3.6: Load add and shed levels.

LEVEL	LOAD ADD	LEVEL	LOAD SHED
1		5	
2		4	
3		3	
4		2	
5		1	

Automatic Transfer System

An automated transfer system (ATS) is essential for maintaining a dependable and uninterrupted power supply in a medical facility's microcontroller-based energy management system. It facilitates power source management, status monitoring, and seamless switching between them as required. Here is an example of how an ATS might be used in such a system**:**

Monitoring of Power Sources: The ATS keeps a close eye on the reliability and condition of the available power sources. This often involves keeping an eye on the utility grid power supply as well as a backup power source, like a backup generator or an uninterruptible power supply (UPS), at a medical facility. From these sources, the microcontroller gathers information on variables including voltage, frequency, and power quality.

Power Source Selection: The microcontroller chooses the best power source for the medical facility's energy requirements based on the monitored data. To make an informed choice, it examines elements including each power source's availability, dependability, and quality.

Power Source Prioritization: In a medical facility, certain vital equipment and systems, such as life support systems, operating rooms, or emergency lighting, may need a continuous power source. varying loads or circuits are given varying priorities by the ATS, which is managed by the microcontroller, according to how vital they are. By doing this, electricity is always provided to crucial machinery even when it is being transferred.

Problem Detection and Transfer Initialization: The microcontroller activates the ATS to start a transfer to the backup power source if it detects a problem in the primary power source, such as a grid power outage or a large divergence in voltage or frequency. The transfer switch receives signals from the microcontroller telling it to unplug from the primary source and plug in to the backup supply.

Transfer Switch Operation: The microcontroller, which oversees the transfer switch, follows the commands it is given. It smoothly moves the load from the primary supply to the backup supply without interfering with or harming the delicate medical apparatus.

Synchronization of the transfer switch: The microcontroller makes sure that the backup power source and the load are in sync before carrying out the transfer. It confirms that the backup source's voltage, frequency, and phase angles meet the needs of the attached equipment. Any electrical disturbances during the transition are avoided by this synchronization.

The microprocessor instructs the transfer switch to handover the load to the backup energy source after synchronization has been achieved. To guarantee a steady power supply, it continuously monitors the power sources and load.

Automatic Restoration: After the main power source is stabilized and restored, the microcontroller checks on it and, if necessary, starts an automatic transfer back to the main source. The load is effortlessly reconnected to the primary source by the transfer switch.

The microcontroller-based energy management system makes sure that correct coordination, fault finding, and effective transfer across power sources are all achieved throughout the process. By maintaining the continued operation of vital equipment and lowering the possibility of disruptions that could have an influence on patient care, this helps maintain a consistent power supply at a medical institution.

3.2.4 Development of algorithm for the implementation of the system developed.

The sequence for the design and construction of the system is as follows:

a. **The existing load analysis of UNTH was carried out**: Having known that the load analysis procedure should be adjusted to the requirements and features of the medical facility. Hence, to achieve accurate and successful results, it is advised to engage with professionals or energy management specialists who have prior experience in conducting load evaluations for medical institutions.
b. **Selection of components:** When choosing components for the energy management system in medical institutions, regulatory compliance, dependability, and scalability were considered. In addition, to make sure the system complies with the precise specifications and safety regulations of the medical industry, the specialists in the field were contacted.
c. **Design of the system**: It is significant to note that the complexity of the energy management system and the specific needs may affect the design process. To guarantee a successful design and implementation, the chief electrical engineer and chief biomedical engineer were contacted for professional advice.

b. **Programming and simulation:** The firmware or software that runs on the microcontroller should be developed using an appropriate programming language. Install the Integrated Development Environment (IDE) required for the programming language of choice. The IDE offers a workspace for creating, assembling, and debugging code and ensuring the used microcontroller is supported by the IDE. The software for the microcontroller-based energy management system should now be put into development. This includes developing user interface functionalities, communication protocols, control algorithms, and data logging methods. For instructions, consult the datasheet, reference manuals, and programming manuals for the microcontroller. Use software or simulation tools to mimic the actions of the microcontroller-based energy management system. This enables testing various situations and validating the functionality of the code without the requirement for physical hardware.

c. **Testing on breadboard:** Before going to a more permanent implementation, the microcontroller-based energy management system can first be validated and verified of the hardware and software functionalities on a breadboard. The system can be further deployed and incorporated into the electrical infrastructure of the medical institution after being successfully tested on the breadboard.

d. **Fixing on main board/Veroboard soldering:** Using PCB design or Veroboard layout as a guide, put the components in the appropriate locations. Make sure you are facing the pads or tracks correctly and in alignment. Refer to the component's datasheets and pin diagrams to determine where it should go.

e. **Testing and troubleshooting:** This involves iterative cycles as you locate and resolve problems. A successful outcome will be influenced by persistence, focus on the details, and rigorous problem-solving techniques**.**

f. **Packaging:** Proper packaging is crucial for safeguarding system components and enhancing overall safety and reliability during installation. The selection of a suitable enclosure is paramount for meeting the specific requirements of the energy management system. Factors such as the size, material composition, durability, and environmental conditions of the medical facility are carefully considered during the packaging process. This ensures that the enclosure not only protects the components but also contributes to the system's efficiency and longevity. By standardizing these practices, the system can maintain consistent performance levels and mitigate risks associated with operational disruptions or damage. Effective packaging solutions are integral to maintaining the integrity and functionality of the energy management system within medical environments.

3.2.4.1 System flow chat

In this stage, a simple design of the system is created. It gives a brief idea of the system to the user. The quick design helps in developing the prototype.

The following is the simplified system algorithm of the entire system:

i. the system first turns on.
ii. the system initializes the input/output pins of the Arduino controller.
iii. the system scans for available load connected to the controller ports.
iv. now ready to respond to the current sensing from each of the loads.
v. responds to the loads according to the current drawn by each load.
vi. turns on the gadgets under control.
vii. toggles the state of the load if current exceeds the setpoint of current sensing unit.

The flowchart of the proposed Microcontroller-based Energy Management System in Medical Facility was designed from the algorithm as shown in Figure 3.1. The system consists of the following power sources which include the public power utility (EEDC), the generators and the PV system. Based on the proposed algorithm of the user's source priority according to the program commands in the microcontroller, the power from the public utility comes first in preference to the generators and the PV system in as much as the input power is within the required power range. Anything outside this voltage range(120V-240V), the system will automatically switch to the generator (G1, G2, G3) in that order. It is expected that the generators to be used are electronic chocked generator which can automatically switch ON/OFF.

The PV system was designed to operate at night only if there's no power from the public power utility. As shown in the flowchart below, the system also monitors the input voltage (V_i) and the current demanded (I_d). If the $Vi\ and\ Id$ are Ok it will switch on the load but if they are not ok, let it switch to the next available power source. At the same time there must be uninterrupted power supply (UPS) to hold on the power up to 10 sec for the switching to take place.

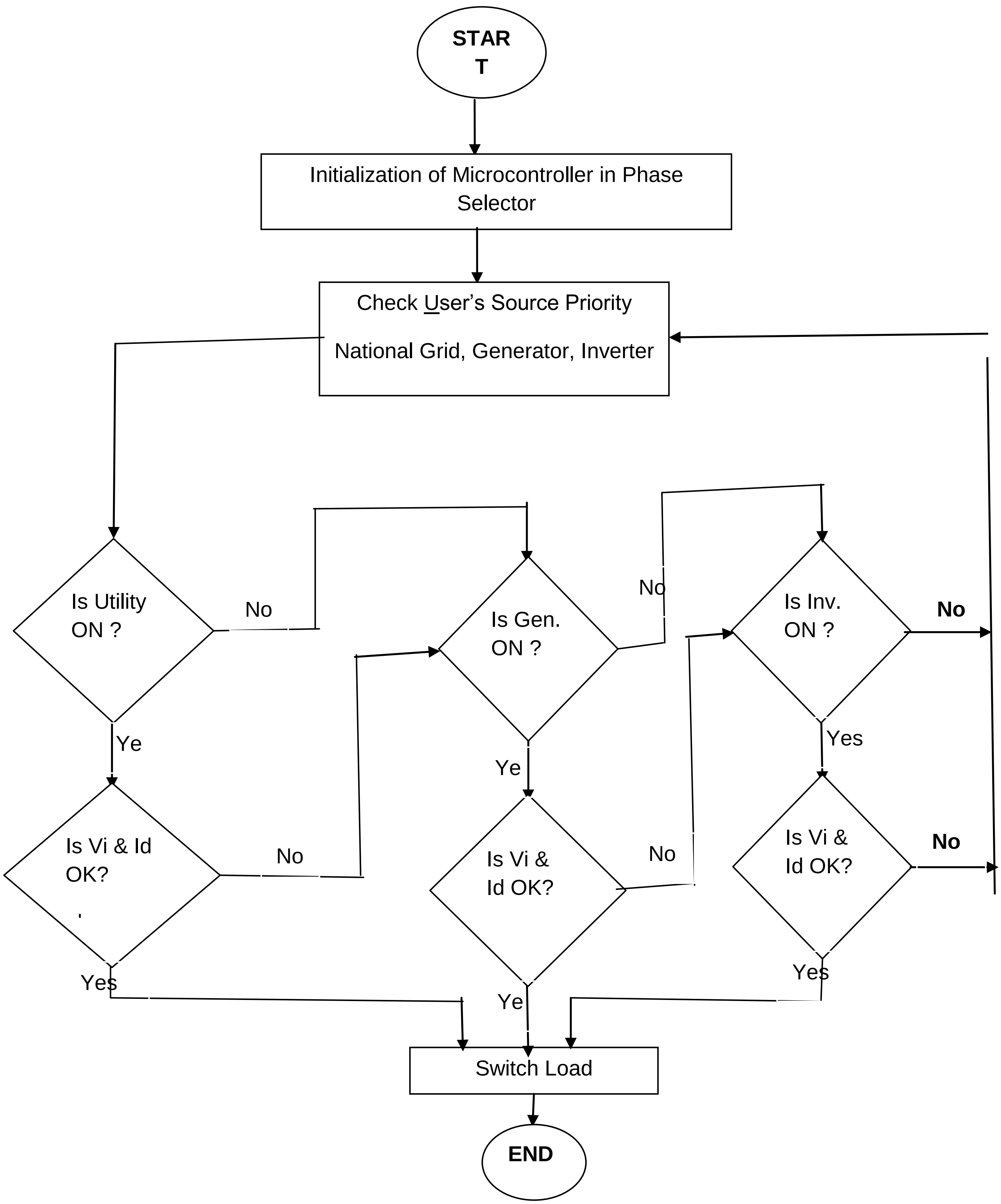
STAR
T
Initialization of Microcontroller in Phase Selector
Check User's Source Priority
National Grid, Generator, Inverter
Is Utility ON ?
No
Ye
Is Vi & Id OK?
No
Yes
Is Gen. ON ?
No
Ye
Is Vi & Id OK?
No
Ye
Is Inv. ON ?
No
Yes
Is Vi & Id OK?
No
Yes
Switch Load
END

Figure 3.1: The System Flowchart

Constructing of a prototype EMS for the Medical Facilities

3.2.4.2 Power Supply Design

This unit is responsible for power supply to the entire system. Figure 3.2 shows the block diagram of transformer-less power supply of 5V on Proteus Software. The values of the components used are 1N4007 Bridge Rectifier diode, 470μF/25V Filtering capacitor,Zener diode IN4733A and connectors.

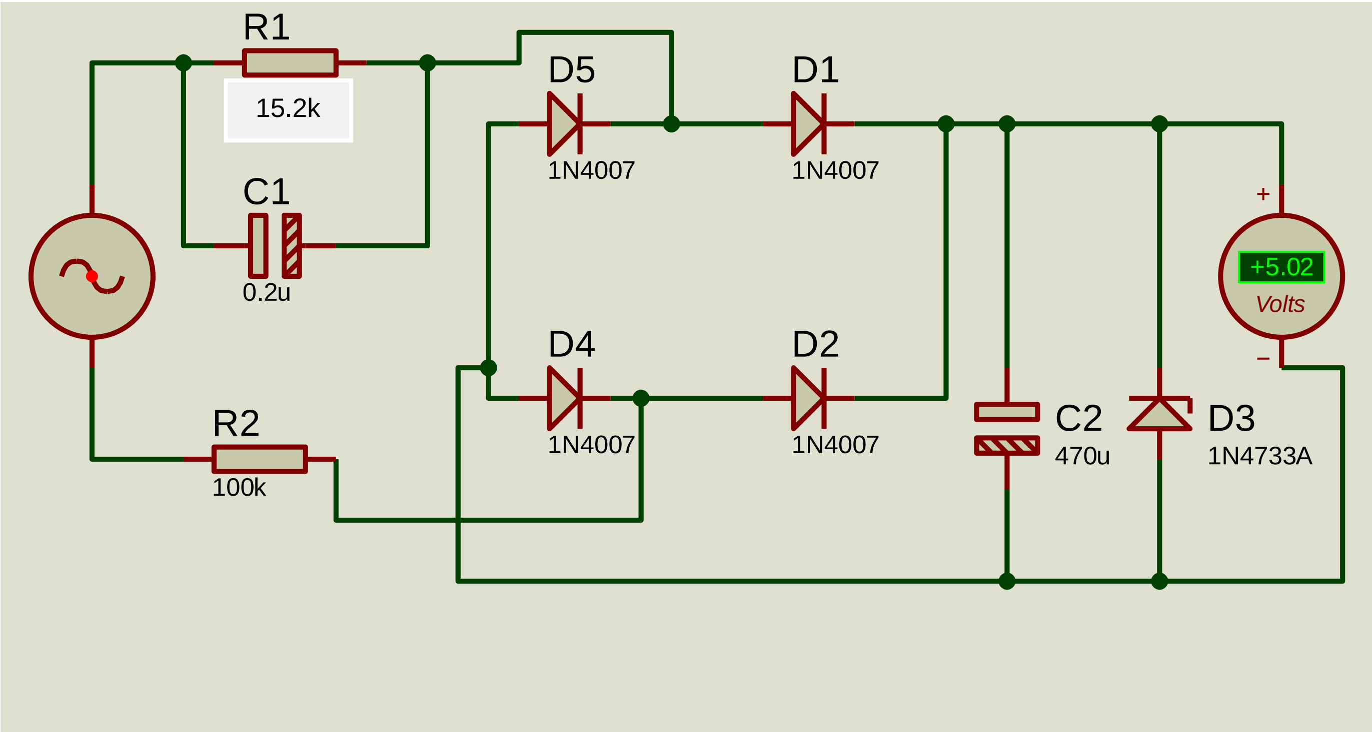

Figure 3.2: Power System Circuit Diagram

The following are the Power Supply component specifications.

i. Input AC voltage =220V
ii. Rectifier Diode DC Current Capacity=2A
iii. Filtering Capacitor voltage=470µF/25V
iv. Output DC voltage of Rectifier=5V
v. Output DC voltage of Rectifier=12V (for the Relay interface circuit)

Resistance (R_1); Capacitance C_1 can be calculated thus:

$$R_1 = \frac{V_{r.m.s} - V_o}{I} \qquad (1)$$

Where:

R_1 is the bleeder resistor which discharges a capacitor when the power is removed

$V_{r.m.s}$ = root mean square voltage (input voltage)

I = input current

Hence $R_1 and$ C_1 of Figure 3.2 are calculated thus:

$$R_1 = \frac{220\sqrt{2} - 7}{20mA},$$

$$= \frac{311-7}{0.02} \text{ ; hence } R_1 = 15.2\text{k}\Omega$$

$$C = \frac{1}{2\pi f X_c} \qquad (2)$$

$$= \frac{1}{2 \times 3.142 \times 50 \times 15200};$$

$$c = 0.2uf$$

Hence, $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$ (3)

$$R = \frac{R_1 R_2}{R_1 + R_2}$$

$$R = \frac{100 \times 15.2}{100 + 15.2} \quad ; R = 13.2\ k\Omega$$

3.2.4.3 System block diagram

In this phase, an actual prototype is designed based on the information gathered from quick design. It is a small working model of the required system.

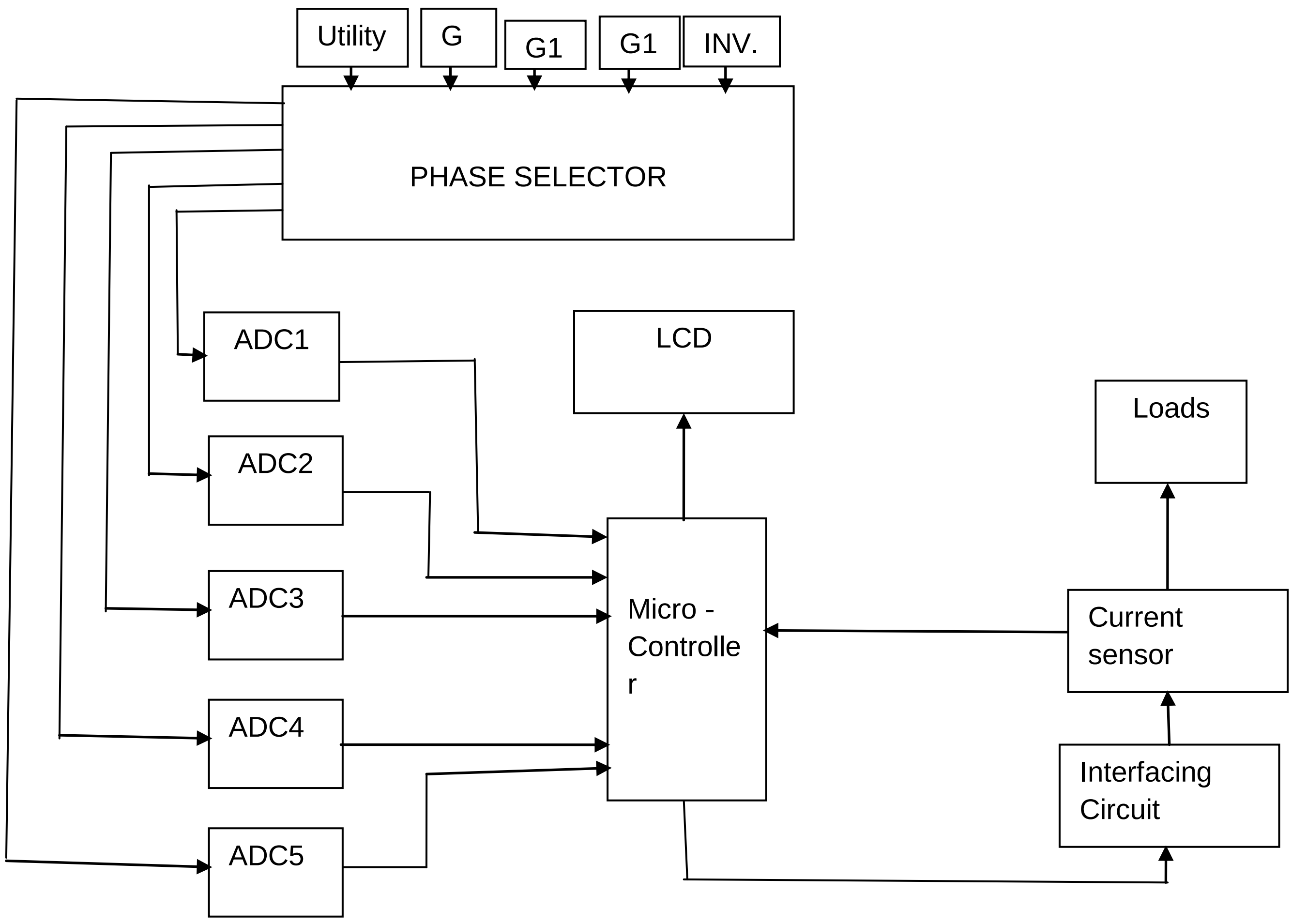

Figure 3.3: System block diagram

Figure 3.3 shows the block diagram of the Energy Management System and how each load connects to the Microcontroller. The entire system is powered by the AC main which could be the generator, the inverter, or the national grid. A rectifier circuit converts the AC to DC since the circuit needs only 5V. The DC output is also fed into other sensing unit connected to the system. The System is powered by an Arduino Switched Mode Powered Supply (SMPS). Arduino input or output pins get initialized and the loads connected at the Controller terminals are now ready for operation. Each load has a current sensor which calculates the amount of current drawn by each load in comparisons with the threshold value. If the current a load draws are higher than the threshold value, the controller automatically disengages the relay supplying power to that load. The UPS minimizes the down time and hold the current for some seconds before switching takes place. After 10 seconds, it checks again to ascertain the present current of the load, if another load relates to lower current capacity, it switches on the relay, connecting the load to the mains.

The passive infrared (PIR) monitors the motion around its vicinity and automatically switches on the inside light or fan when the motion of the enclosure is disturbed and switches off whenever there is no disturbance. Then the light intensity sensor takes care of the outside lights, by switching on and off during the night and day respectively. All these features are coordinated to achieve a better EMS in any hospital.

3.2.4.4 System Circuit Diagram

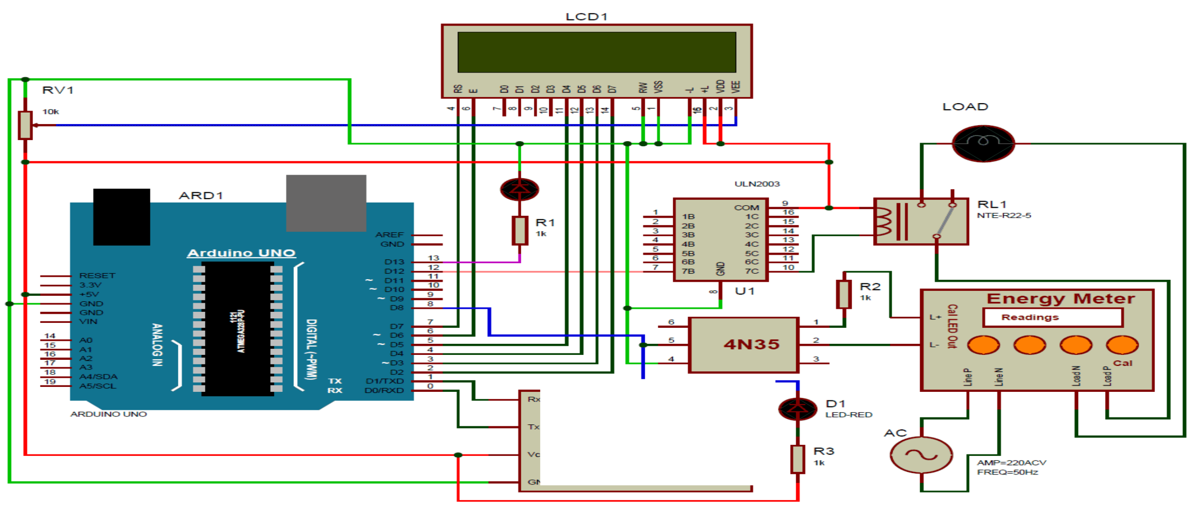

Figure 3.4: System Circuit Diagram

Figure 3.4 shows the the circuit diagram of the system where Arduino UNO has been interfaced with ACS712 current sensor, Autointensity unit and Liquid Crystal Display. It checks for the current of the connnected load and cuts off any load that draws more Current higher than the system rating. The Arduino UNO is a microcontroller board based on the AT mega 328. It supports the microcontroller simply by linking it to the computer with a USB cable or power it with an AC – to – DC adapter or battery to get started. It supplies different sensors through a 5V and a ground pin. The analogue pin of the Arduino is connected to different sensors to allow monitoring and control the appliance.

The 4N35 is a general purpose optocoupler which consists of LED and NPN phototransistors. It breaks the links between signal source and signal receiver to stop electrical interference. Pin 1 and 2 are connected to the energy meter. When the power comes into the circuit it emits infrared rays. To protect the energy meter from damage, usually a resistor (about 1K) is connected to pin 1. Hence the energy meter can be powered on when receiving signals. This can be done to control the loads connected to the phototransistors. Even when the loads short circuit occurs thus realizing good electrical isolation.

P4 of Arduino is connected via a resistor to the GND of the Arduino. This prevents any leakage in the 4N35 output transistor from pulling the Arduino input pin up. This Arduino calculates, measures, and collects the relative measurements and sets the state of the devices, sends them to our system that identifies and processes data. If these devises consume too much, the Arduino will automatically react and cut off region or underload or overload.

3.2.4.5 ACS712 Current Sensor Working and Applications

ACS 712 Current Sensor provides accurate measurement of AC/DC current. Different devices need a different amount of current based on their functional requirements. Some devices are so sensitive that they get damaged when a high amount of current is delivered to them. So, to save such a situation and monitor the amount of current required or being used in an application, measurement of current is necessary. This is where the Current Sensor comes into play. One such sensor is the ACS712 Current Sensor. Figure 3.5 elaborates more on the internal circuitry of ACS 712 current sensing unit.

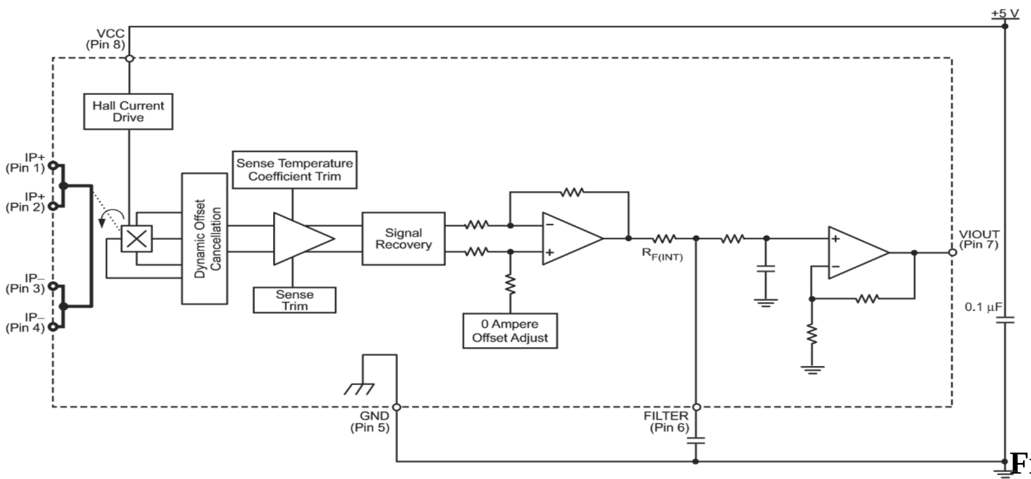

Figure 3.5: Circuit diagram of Current sensor module

3.2.4.6 Arduino UNO Microcontroller

Arduino Uno is a microcontroller board based on 8-bit ATmega328P microcontroller. Along with ATmega328P, it consists other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller. Arduino Uno has 14 digital input/output pins (out of which 6 can be used as PWM outputs), 6 analog input pins, a USB connection, a Power barrel jack, an ICSP header and a reset button.

For the Arduino environment, the following steps were deployed.

(a.) Connecting Arduino on the Breadboard

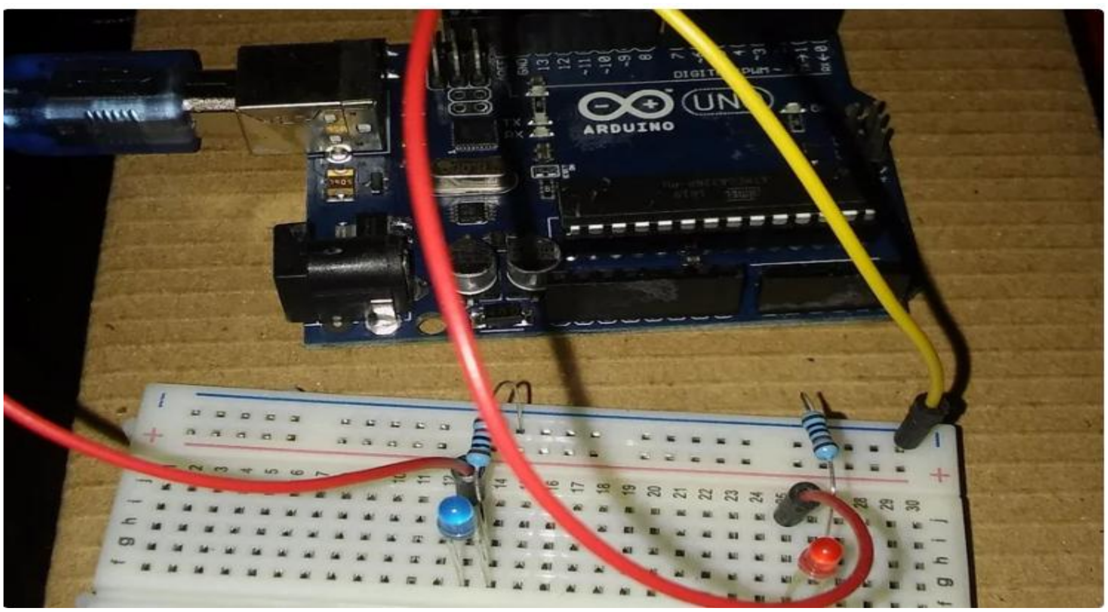

Plate II: Arduino on the Breadboard

Components Required: The components required for this project are listed below and all the parts were purchased at the local hardware store or on eBay. They are: Atmega328IC, 16Mhz Crystal, 22pf capacitor, L7805 voltage regulator, 10uf capacitor, LED, Breadboard, connecting wire, 6V or 9V or 12V power supply, Soldering Iron.

(b.)Atmega 328

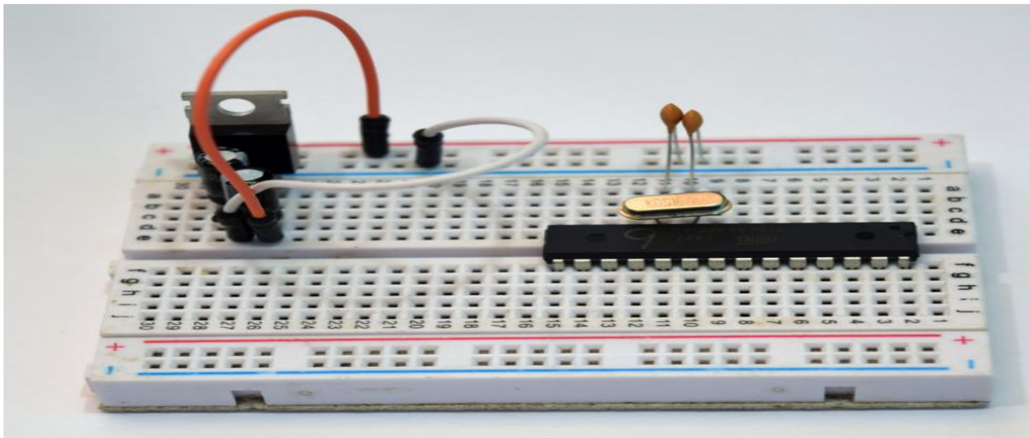

Plate III: Atmega328 on the Breadboard

The Arduino is based on the Atmega328IC and it is the brain of the circuit. All the processing is done by the IC. The Atmega328 has to have an Arduino boot loader flashed on to it to program it using Arduino IDE.

(c.) The voltage regulator

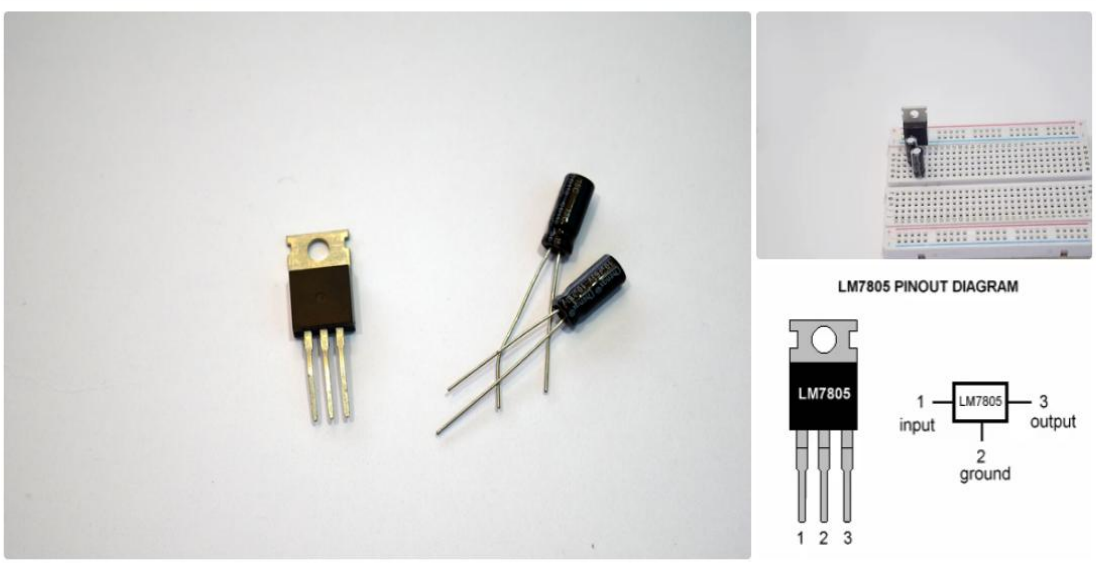

Plate IV: The voltage regulator on the Breadboard

The first step will involve connecting a voltage regulator, the atmega328 is a 5V microcontroller so is the Arduino Uno. So, we need a voltage regulator to supply steady voltage to atmega328IC. For this we will be using a L7805 voltage regulator. This chip is a popular voltage regulator and is cheap and serves the purpose of building an Arduino Uno. This voltage regulator gives a voltage of 5V and a maximum load of 1A.

(d.) The Circuit Configuration

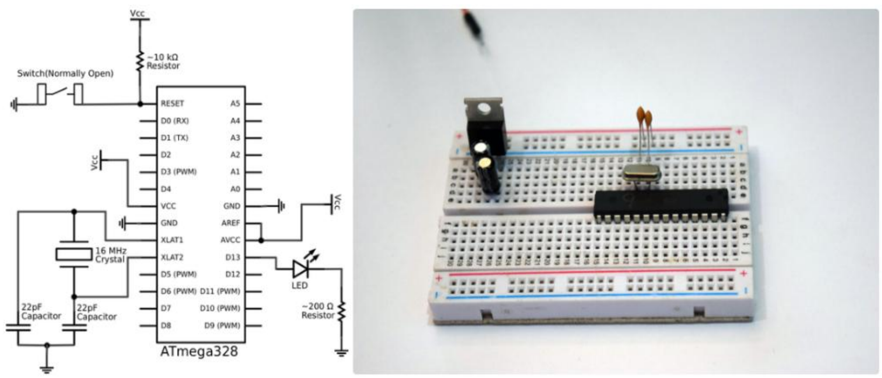

Plate V: Connection from Arduino to an external circuit configuration.

The connection of Arduino to an external circuit may vary depending on the circuit.

(d.)Serial Connection

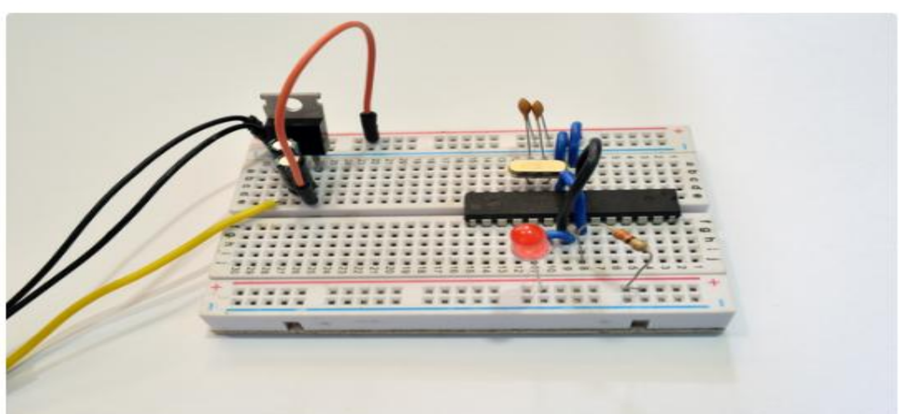

Plate VI: Serial Connection

In the Atmega 328IC the pins 2 and 3 act as a serial port and the board is programmed by connecting pins to the USB to the serial converter. After the connections, the USB end of the converter is plugged to the computer and install the necessary drivers (f.) **Uploading the code**

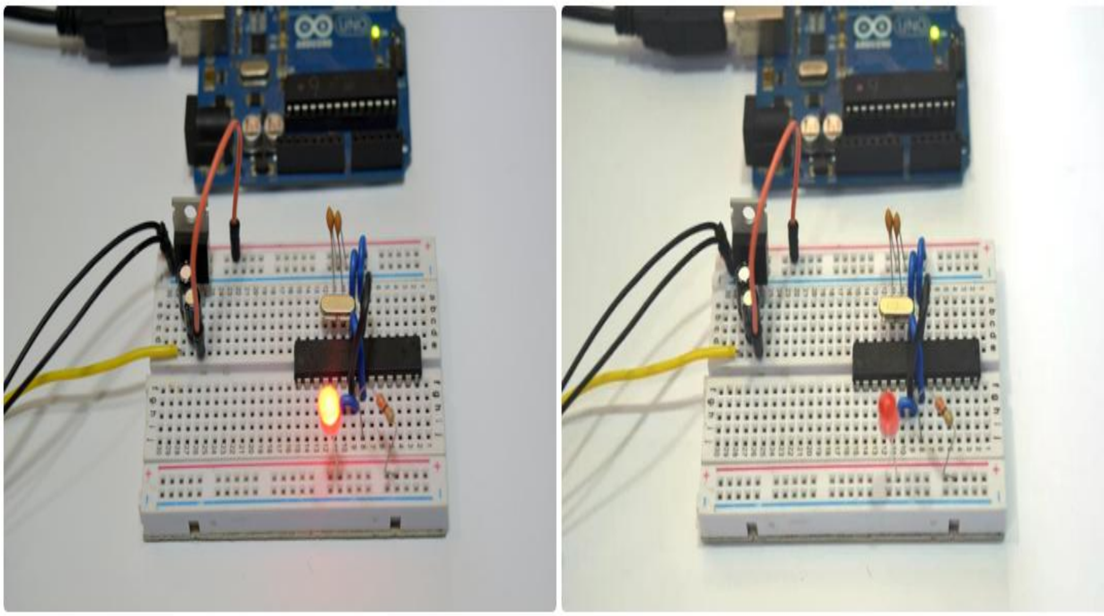

Plate VII: Uploading the code to the Arduino board.

The Arduino IDE is first downloaded and installed from the Arduino official website and thereafter the code is uploaded to the board. The suitable serial port, board are then selected. Hence the homemade Arduino is programmed, and the board is then tested as shown in plate viii

3.2.4.7 Analog to Digital Conversion on Arduino Microcontroller

Arduino Microcontroller has analog to digital conversions features on the analog pins. There are 6 pins designated for "Analog to digital" conversion labelled (A0 through A5). ADCs can vary greatly between Microcontrollers. The ADC on the Arduino is a 10-bit ADC meaning it could detect 1,024 (2^10) discrete analog levels. Some microcontrollers have 8-bit ADCs (2^8 = 256 discrete levels) and some have 16-bit ADCs (2^16 = 65,536 discrete levels).

The way an ADC works is complex. There are a few different ways to achieve this, but one of the most common techniques uses the analog voltage to charge up an internal capacitor and then measure the time it takes to discharge across an internal resistor. The microcontroller monitors the number of clock cycles that pass before the capacitor is discharged. This number of cycles is the number that is returned once the ADC is complete.

3.2.4.8 Relating ADC Calculation to a Smart Prepaid meter monitoring system.

This was used to calculate the incoming voltage to the prepaid meter monitoring system via an ADC terminal of the Arduino. The controller was connected to a voltage divider made of a Light Dependent Resistor (LDR) and a fixed resistor which calculates the amount of voltage to the ADC pin A0 in proportion to the light intensity. Whenever there is a difference in the expected ADC value and the threshold voltage, the system triggers the internet protocol (IP) Camera to capture the Power theft intruder and sends notification to the concerned authority against the suspected Power theft. The ADC reports a radiometric value. This means that the ADC assumes 5V is 1023 and anything less than 5V will be a ratio between 5V and 1023.

$$\frac{\text{Resolution of the ADC}}{\text{System Voltage}} = \frac{\text{ADC Reading}}{\text{Analog Voltage Measured}} \quad (4)$$

Analog to digital conversion is dependent on the system voltage. It predominantly uses the 10-bit ADC of the Arduino on a 5V system, the relation can be further simplified thus:

$$\frac{1023}{5} = \frac{\text{ADC Reading}}{\text{Analog Voltage Measured}}$$

3.2.4.9 Load Power Consumption and Analysis

For energy saving LED bulb power consumption:

Taking 10W LED bulb for example, consumes 10 Watts per hour. When the 10W LED bulb runs for 24 hours the total power consumption obtained from the energy meter was about 24 × 10 = 240Watts. This simply means that, in a year the total power consumption of the 10 Watt LED will be 10 × 24 × 365 = 86700 watts hour. This will act as a guide to generating values for Power consumption when the system is not controlled via Sensors as shown in the second column of Table 3.7. The third column was gotten by practically taking readings from the energy meter.

Table 3.7: Practical Comparison of Energy Consumption between Energy Saving Bulbs (without LDR & PIR sensors) and Energy Saving Bulbs (with LDR & PIR sensors)

Power ratings of the LED Bulbs	LED BULBS (Without PIR & LDR Sensors) kWh	LED BULBS (With PIR & LDR Sensors) kWh
Power consumed by 5W LED Bulb per day	120	14.2
Power consumed by 10W LED Bulb per day	240	28.4
Power consumed by 15W LED Bulb per day	360	42.6
Power consumed by 18W LED Bulb per day	240	51.12
Power consumed by 20W LED Bulb per day	240	56.8
Power consumed by 24W LED Bulb per day	576	68.16

3.2.4.10 Evaluation

In this stage, the proposed system is presented to the client for an initial evaluation. It helps to find out the strength and weakness of the working model. Comment and suggestion are collected from the customer and provided to the developer.

Refining

A prototype is built and implemented according to the customer's (user's) specification and requirement before developing the final product.

Implementation and Maintenance

Implementation and maintenance are critical steps in the lifecycle of any system, software, or project. Here's a rundown of what each phase involves:

System Implementation

Plate VIII shows the state of the input voltage when it is too high. At this level, the system does not allow any of the devices connected to it to switch. The input voltage here is 502V and practically, this is not ideal for any electronic gadgets. The incorporation of this voltage monitors and controller becomes necessary to protect the electrical appliances under control.

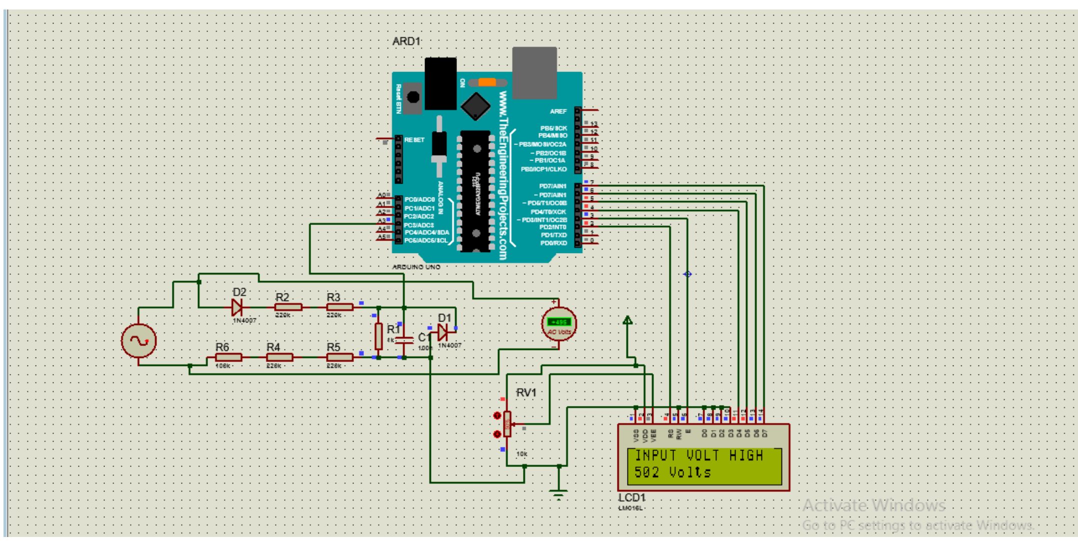

Plate VIII: Input voltage is too high (over voltage)

Plate IX depicts the state of the input voltage when it is too low. At this level, the system does not allow any of the devices connected to it to be controlled remotely. The input voltage here is 127V and practically, this is not ideal for any electronic gadgets. This causes some devices to draw more power than they should under normal circumstances. The incorporation of this voltage monitors and controller becomes necessary to protect the electrical appliances under control.

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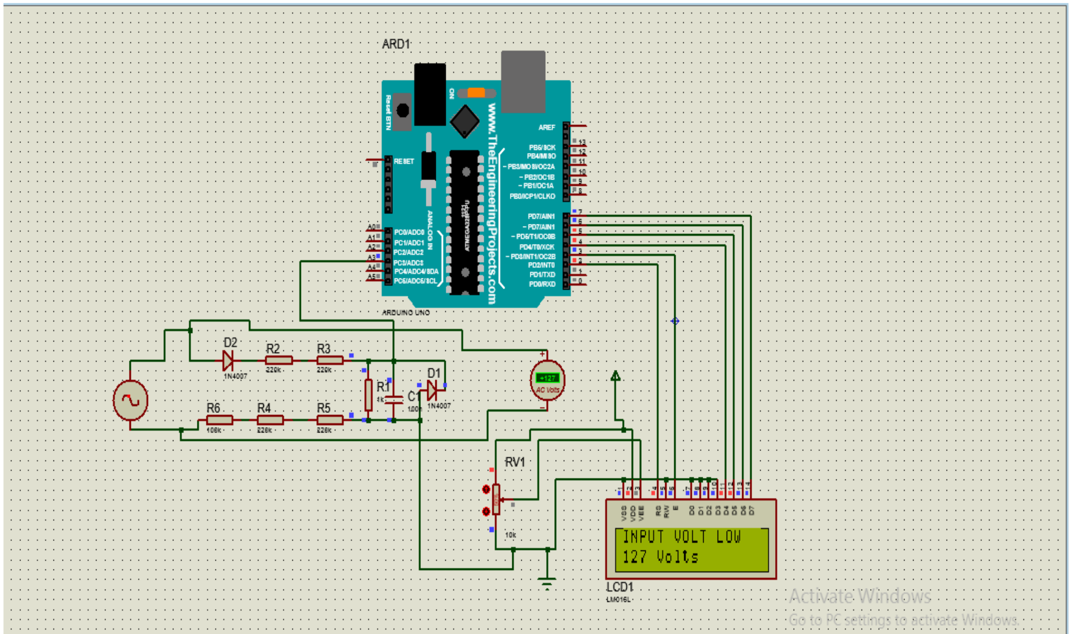

Plate IX: Input voltage is too low (under voltage)

3.2.5 Validation of Developed System

When a microcontroller-based energy management system is being validated at a medical facility, its performance, functionality, and dependability are evaluated to make sure it performs as planned and works well under real-world conditions.

Before the system, comes the unit test of each subunit to confirm the correct functionality of the system. Different materials selected were assembled in Proteus software to form the schematic setup for the design. All the components were tested one after the other and individually the subunit was built on the board and checked before it was finally transferred to main construction board. This was done to authenticate its functionalities. The entire circuit was arranged rationally according to design description. The project was executed using suitable component obtained from the design. The complete circuit diagram of the automatic load sharing and control system is shown in Figure 3.4. The written program was burned into the Arduino. Also, current transformer was wound of the required number of turns to suit the design. Power supply of 5V was also design for driving the circuit. The module was first tested on the breadboard before moving them to the Vero board for the soldering.

3.2.5.1 Simulate developed model.

The system was simulated using proteus simulation software as shown in Plate X

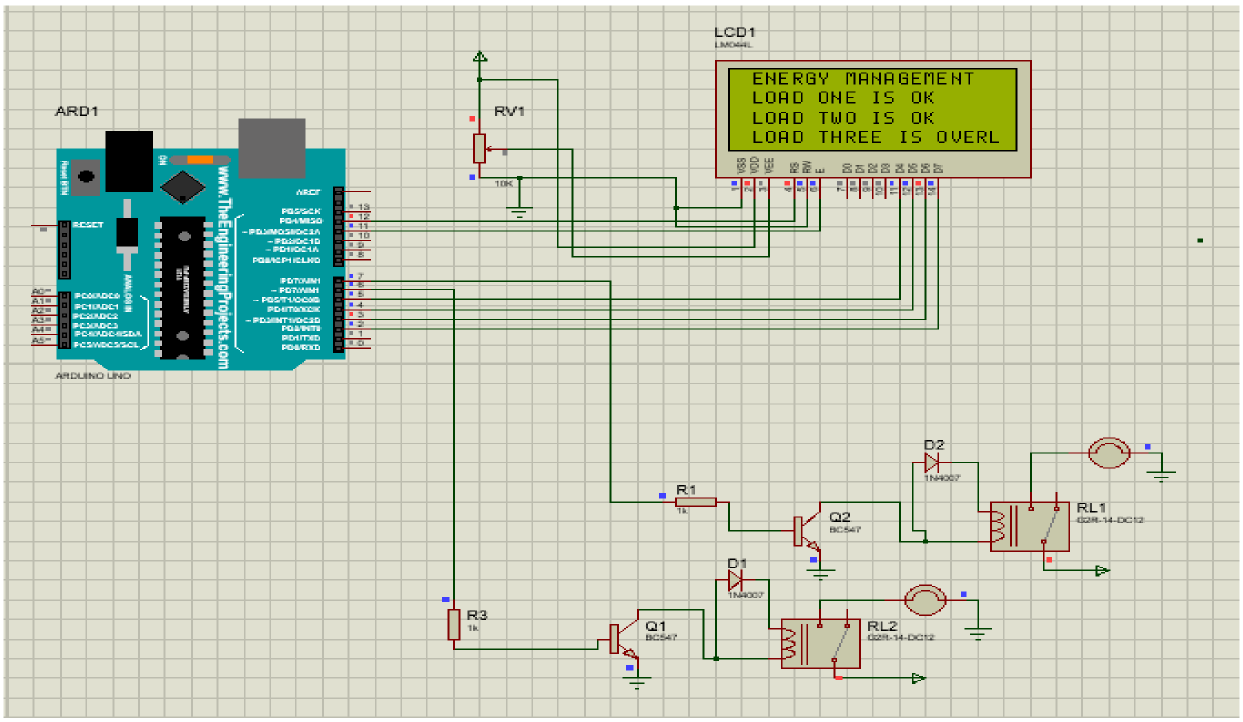

Plate X: Circuit diagram of proteus simulation

An Arduino Switched Mode Powered Supply provides electricity to the system (SMPS). The loads attached to the Controller terminals are now ready for operation after the Arduino input or output pins have been setup. A current sensor is installed on each load, which calculates the amount of current drawn by each load and compares it to the threshold value. The controller automatically disengages the relay delivering power to that load if the current drawn by the load exceeds the threshold value. The UPS cuts down on downtime by holding the current for a few seconds before switching. It checks the current of the load again after 10 seconds, and if another load with a lower current capacity is attached, it activates the relay, connecting the load to the mains. On the plate X above, you can see the final outcomes of the entire process.

3.2.5.2 Performance of Cost Benefit Analysis

Table 3.8 shows cost-benefit evaluation of installing an energy management system based on microcontrollers in medical institutions. It entails assessing the prospective costs and advantages of doing so. Hence, it is vital to keep in mind that the precise costs and advantages may change based on the medical facility's size, energy consumption habits, and extent of the energy management system. A microcontroller-based energy management system can provide medical institutions with several advantages. Here are some of the advantages:

Table 3.8: Bill of Engineering Measurements and materials evaluation

S/N	**Component**	**Quantity**	**Unit price**	**Total (₦)**
1	ATmega328p Controller (Arduino UNO chip)	**1**	**10,200**	**10,200**
2	Crystal oscillator (16MHz)	**2**	**200**	**400**
3	ULN2003 relay driver	**3**	**550**	**1650**
4	Fixed resistor(220Ω)	**10**	**5**	**50**
5	22pF non polarized capacitor (2 pcs)	**2**	**30**	**60**
6	Signal diode (4148)	**2**	**30**	**60**
7	Rectifier diode (1N4007)	**4**	**40**	**160**

8	5V DC Relay module	**1**	**1600**	**1600**
9	Voltage regulator	**2**	**150**	**300**
10	Micro USB cable	**1**	**600**	**600**
11	Liquid Crystal Display (LCD)	**1**	**1500**	**1500**
12	Jumper wires (yards)	**2**	**800**	**1600**
13	Soldering lead (yards)	**5**	**300**	**1500**
14	Vero board (dotted)	**1**	**300**	**300**
15	Electrolytic capacitor (1000µF)	**1**	**200**	**200**
16	IC Socket (28-pin)	**1**	**150**	**150**
18	6x9 adaptable box	**1**	**1300**	**1300**
19	A lamp-holder	**2**	**250**	**500**
20	Light Emitting Diode (LED)	**1**	**20**	**20**
21	Control switch (SPST)	**1**	**300**	**300**
22	Push to make button	**1**	**100**	**100**
23	Screws	**4**	**50**	**200**
24	Flexible wire (yards)	**4**	**150**	**600**
25	Energy saving bulbs (12V DC)	**1**	**450**	**450**

TOTAL AMOUNT = ₦23,800.00

(Twenty-three thousand eight hundred naira only)

Energy savings: An energy management system based on a microcontroller can help optimize energy use, track consumption trends, and spot potential improvement areas. Over time, this may lead to lower energy costs.

Cost reduction: By using energy more wisely, healthcare facilities can cut operational expenses and redirect funds to other crucial patient care areas.

Impact on the environment: Better energy management helps medical facilities adopt more sustainable practices and reduces their carbon footprint.

Increased Equipment Lifespan: Effective energy management can stop power surges and fluctuations, extending the life of medical equipment and lowering maintenance and replacement expenses.

CHAPTER FOUR

RESULTS AND DISCUSSION

The first test carried out was the system power consumption test. The total power of the device is the product of the voltage and current. The minimum and maximum voltage and current were recorded, and the power consumption calculated as follows:

4.1.1 Survey of energy sources

The results were used to develop the load profile of the entire hospital and how they are shared. From the results, the entire UNTH is fed by 750mVA transformer (six 500kVA sublet) and 500kVA, 100kVA, 1000kVA and 700kVA generators. Out of which 500kVA is feeding the Cardio Thoracic Centre (CTU & ICU) Units, Theatre, X-Ray/Radiology Units, Cardiac Catheterization Lab, and Main Laboratory

4.1.2: Load Enumeration Using End-User Analysis Method

From table 4.1 X-Ray Film Processor Tabletop, X-Ray Film Viewer and X-Ray Unit Universal consumed the highest amount of energy while the Lighting bulb (Energy saving) has the highest number of units.

Table 4.1 Power consumption of various equipment in Radiology (X-RAY) unit

Medical Equipment	Wattage(W)	Units	Total Wattage(W)
X-Ray Film Processor Tabletop	60000	2	120,000
X-Ray Film Viewer	60000	2	120,000
X-Ray Unit Universal	60000	2	120,000
X-Ray Mobile	2500	2	5,000
Ultrasound Scan (3 Probes)	2500	3	7,500

MRI Machine	3000	1	3000
Electrocardiograph 3 Channels	150	1	150
Hot Air Sterilizer	600	1	600
CT-Scanner	379	3	1137
Portable ultrasound Scanner	25	5	125
Mammography	750	1	750
Fan: Standing Ceiling	70 85	2 2	140 170
Television	50	2	100
Air Condition	746	2	1492
Lighting bulb (Energy saving)	15	6	90
Computer	60	4	240
			TOTAL=380494W =380.494KW

In addition, out of 20 lightening bulbs, 12 were selected for the outside light which can only be turned on automatically at night with the help of LDR and PIR. Hence the calculated saving is 1800watts per day. This amount of energy is being saved every day in addition to other medical equipment that are not being used unless a patient is admitted.

4.1.3 Load Prioritization Through Interview

Table 4.2 shows the outcomes of the interview. According to the findings, equipment in level 1 has the maximum rated capacity and, as a result, should be scheduled to run continuously throughout the cycle.

Table 4.2: Key for Load Add Levels

Level	Facilities
1	Cardiac Monitor, Oxygen Condenser, Apnea monitor for infants, Kidney Dialysis, Respirator, Ventilator, Pressure Breathing Therapy, Infusion Pump, Defibrillators, Incubators (Infant)
2	Suction Pump, Peritoneal Dialysis Machine, Kidney Dialysis Machine, X-Ray Machines, Ultrasound Scan, MRI Machine, C-T Scanner, Electrocardiography, Mammography, Fatal Monitor, Pulsimeter, Gastroscope, Colonoscope, Patient Monitor anaesthesia
3	Centrifuge, Hot Air Sterilizer, Bacteriological Light, Nebulizer, Colonography Angiography, Fibre Bronchoscope, Laparoscopy System, Cardiotocography, Analyzer Haemoglobin, Oxygen Condenser, Trolly Instruments
4	Air Condition, Washing Machine, Refrigerators, Water Still, Water Bath
5	Lightening Bulb, Computer, Television, Fan, Photocopy Machines, Pumping Machines (SUMO)

The light dependent resistor (LDR) with passive infrared control Load level 5 which is designed to optimize energy usage and functionality based on detected motion during nighttime hours. Ten of the total lighting units are set to work at night and can only be activated when motion is detected in the area.

4.1.4 Sequential Method

The result of the algorithm for the implementation of the system developed is shown in Figure 3.3 and Figure 3.4. According to the algorithm, Power from the public utility is taken preference to generator and inverter.

4.1.5 Proteus Simulation of the Developed Model

The results of the simulation are as shown below in the following plates below:

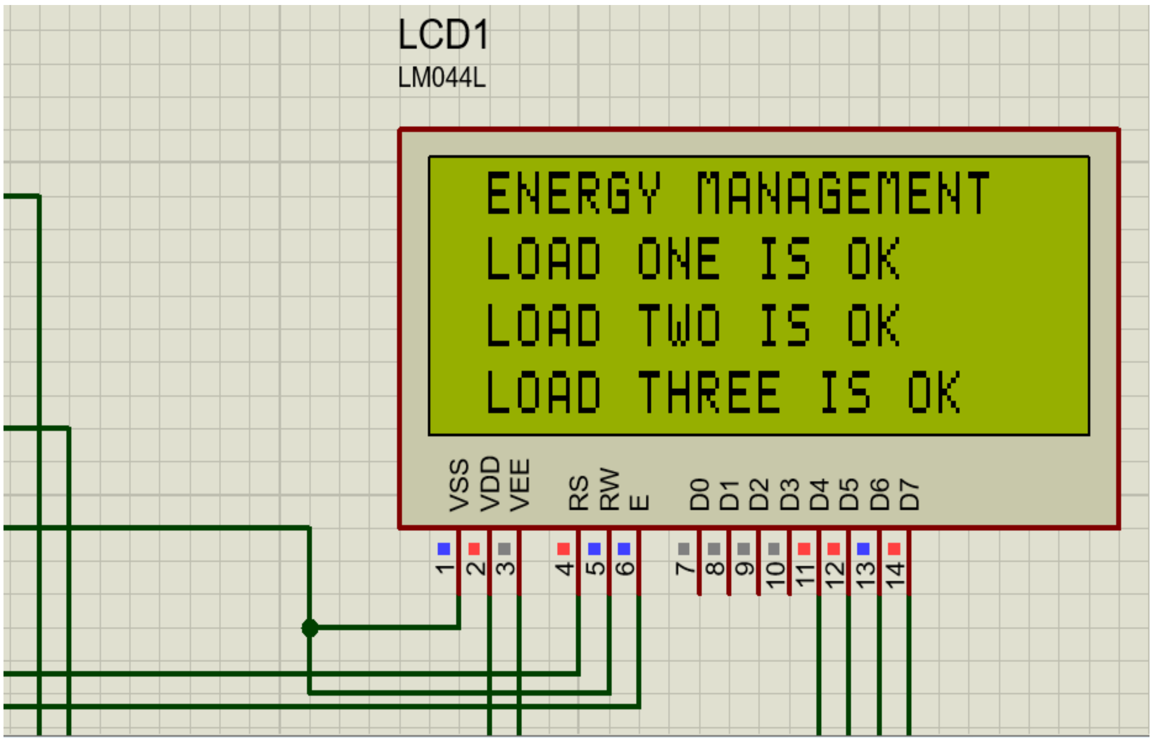

Plate XI: Load in three OK

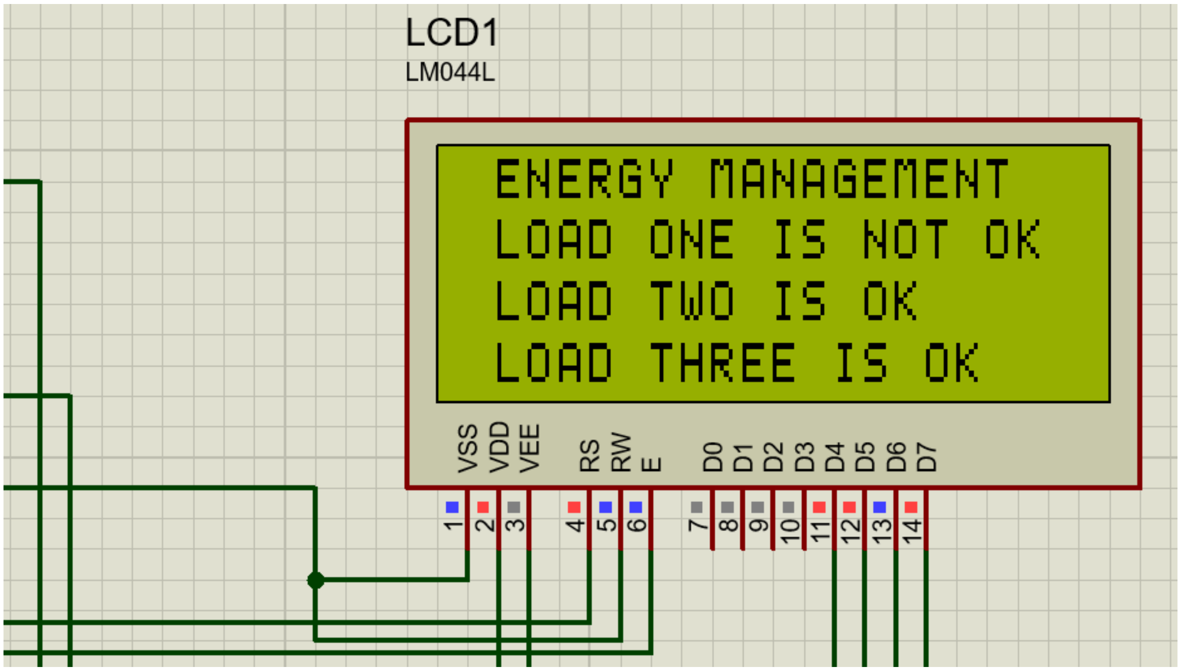

Plate XII: Load in one not OK

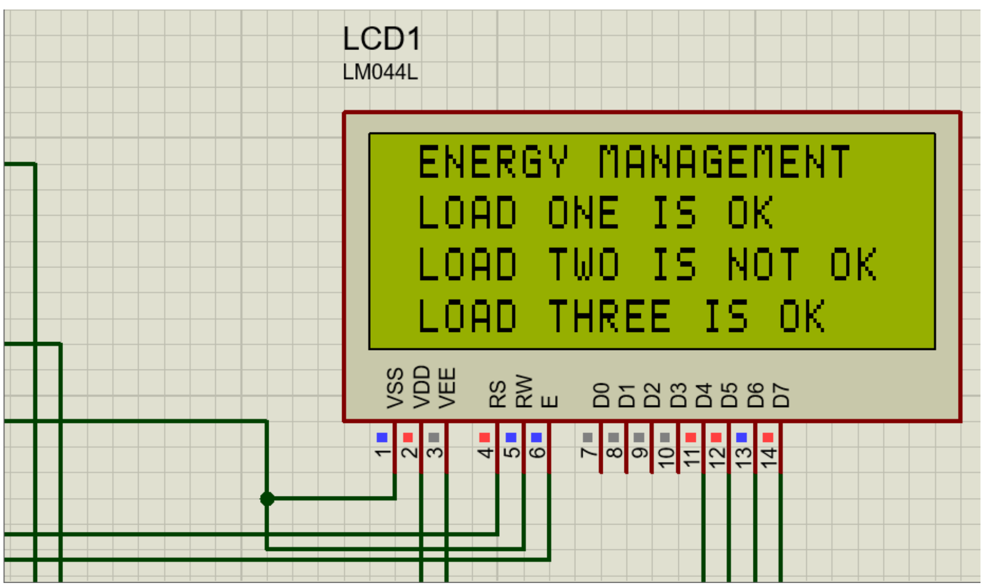

***Plate XIII*: Load in two not OK**

The state of the load in each line is depicted in Plates XII, XII, and XIII respectively. According to the program commands in the microcontroller, the system toggles the status of the load to verify if loads in each of the lines are ok or not, and it reacts to the recommended algorithm of the user's source of priority.

4.2.1 **System Power consumption test**

The voltage and current values from the digital multimeter are multiplied to get the device's total power consumption. Throughout the measurements, the lowest and highest values for voltage and current were noted. These measured data were then used to calculate the device's overall power usage.

Table 4.3: Measured values from the research conducted.

S/N	Voltage (V)	Current (mA)	Power (mW)
1	7	87	609
2	9	100	900
3	12	120	1440

The device was quite unstable and caused the microcontroller to restart when it was powered with the 7V power supply. The 9V power supply ran the device smoothly without any glitches. And the current at which the device operated was efficient. The 12V caused the arduino micro-controller to heat up. This was because the arduino has on it a 5V voltage regulator that operates at an optimum voltage of 7V. Although the technical specifications indicated that it could handle up to a maximum of 18V, heating will cause inefficient use of power. Therefore, after considering the voltage range, the 9V power supply was selected for its availability and less heating.

Table 4.4: Percentage gain in Energy Consumption between Energy Saving Bulbs with LDR & PIR Sensors

Power ratings of the LED Bulbs	LED BULBS (Without PIR & LDR Sensors) kWh	LED BULBS (With PIR & LDR Sensors) kWh	Percentage gain in power consumption with PIR and LDR
Power consumed by 5W LED Bulb per day	120	14.2	88.2%
Power consumed by 10W LED Bulb per day	240	28.4	88.2%
Power consumed by 15W LED Bulb per day	360	42.6	88.2%
Power consumed by 18W LED Bulb per day	240	51.12	78.9%
Power consumed by 20W LED Bulb per day	240	56.8	76.3%

Power consumed by 24W LED Bulb per day	576	68.16	88.2%

Percentage gain = $\frac{\text{Power without PIR \& } LDR\ Sensors\ -\ Power\ With\ PIR\ \&\ LDR\ Sensors\ )}{\text{Without PIR \& } LDR\ Sensors} \times 100\%$. On the average there is an 88.2% gain in power consumption when PIR and LDR are connected

4.2.2 Test Result for the Smart Street Light Control

Plate XIVshows the graphical representation of the analog and digital signal results obtained. When the light sensor was exposed to light, its output value changed from 100KΩ to about 3Ω on a digital ohmmeter. Analog to digital conversion technique was deployed to match the results based on a standard analog to digital metrics. Hence, 2.5 analog voltage is equivalent to 512 digital bits, 5 analog voltage is equivalent to 1024 digital bits in that order.

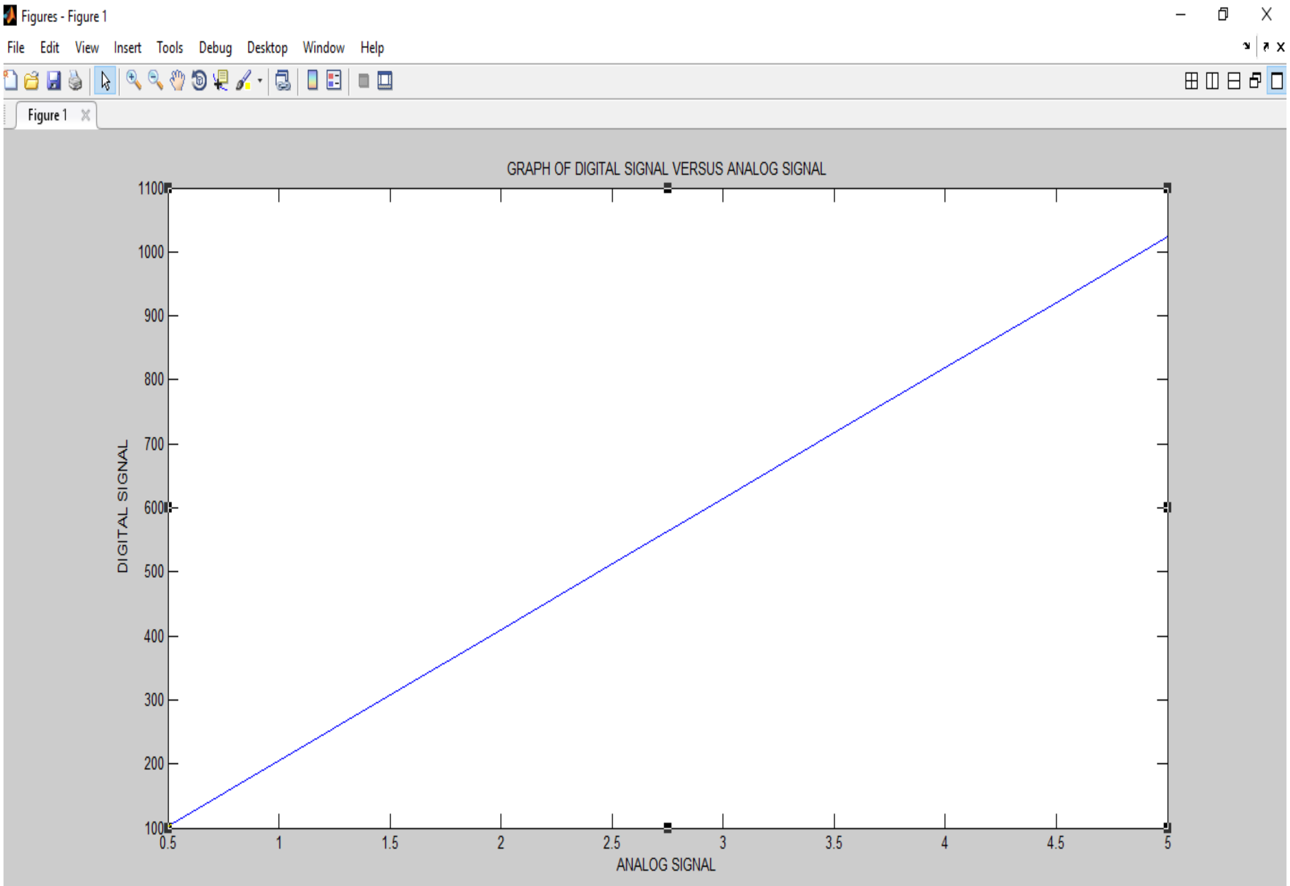

Plate XIV: Analog Signal versus Digital Signal

4.2.3The View Angle and Range Test

This test was to measure the view area of the device. The device was once again mounted on the ceiling of a room of dimensions $10\,m \times 5\,m \times 4.5\,m$. The device was able to detect the presence of a human being right at the entrance and at the end of the room. This made it possible for the device to keep the light on so far as the person was in the room and the fan was on.

4.2.4 Device Sensitivity Test

The sensitivity of the device is a measure of how fast it responds to a change in its state. The device was mounted in a room and three people engaged in an abstract activity in the room. The device maintained the on state of the lamp as far as the people were in the room. After exit of the three people, the device switched off the lamp.

Energy Saving and non-energy saving bulbs Power Consumption compared.

From the results obtained from the digital energy meter showed clearly that combining LDR and PIR sensors in designing an energy management system proved to be the most effective since the PIR sensor did not just come because motion disturbed rather it came on as result of sensing darkness in addition to the motion. This really made the choice of combining these two sensors an excellent combination. Plate XIV shows the graphical representation of the energy consumption of the LED Bulbs in two categories.

a. When LDR & PIR sensors were not incorporated into the Control system
b. When LDR & PIR sensors were incorporated into the Control system

From the table 4.4 and Plate XIV, it was clearly noted that if energy saving LED bulb rated 24W should be used for 24 hours without being controlled by sensors, then energy consumption per hour would be 576 KWh whereas if the bulbs are controlled by sensors, only 68.16 KWh of energy would be consumed. The difference in energy consumption becomes 507.84 KWh loss or gain of energy depending on either one uses sensor based or not.

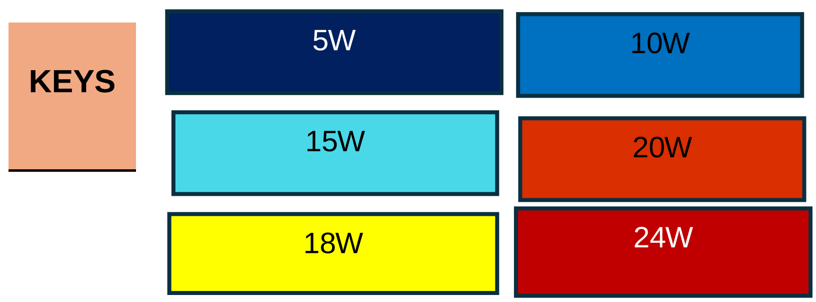

Plate XV: Energy of Sensor based and non-sensor-based LED Bulb energy Consumption

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This work presents a microcontroller-based energy management system for preserving energy sustainability in medical institutions. To test the proposed idea, a public power utility, generators, and PV panels are created and used. Generators and photovoltaic systems were added into the system to ensure an uninterrupted power supply because power from utility sources is not reliable and consistent. To move the load to the available power source, the proposed method is employed.

The suggested approach provides a practical method for real-time load sharing and control. The Micro Controller-based Energy Management System is a system that is specifically intended to monitor generator overload. The Arduino is used in conjunction with a relay and a transistor to create an energy management system for healthcare facilities. The Arduino is essentially designed as a controller to communicate with the relay, which is connected to a lamp and fan via a PIR sensor, as well as a thermostat via a temperature sensor. The results demonstrate that using Arduino can reduce the amount of energy consumed by electrical appliances. Furthermore, the system can be used on both small and large scales, such as office buildings, hospitals, banks, stadiums, houses, and hotels.

Nonetheless, this system was created for Energy Management, which takes light intensity into account and interfaces with Arduino Microcontrollers to manage the utilization of appliances such as light intensity rather than simply turning them on and off. In addition, the prototype system calculates the current drawn from each appliance depending on appliance usage and sends it to an Arduino Microcontroller, which calculates the total power spent by the appliances over time.

The appliances are turned on when there is a human in the proximity. The passive infrared, which serves as a motion sensor, accomplishes this. A greater quantity of energy can be saved by using appliances less frequently.

5.2 Recommendations

Following the importance of energy management in the power sector, I will make the following recommendations.

1. More enlightenments should be carried to improve the public especially those in rural areas and hospitals on the merits on energy management systems.
2. The proposed model should be adopted by hospital and by extension other public place to ensure that power wastage is minimised.
3. Future Studies: The sensor tends to turn on in the presence of both animate and inanimate items, which is one of the work's limitations.

More research can be done to ensure that a model is established that uses artificial intelligence (AI) to detect and classify items as they appear to the sensor, ensuring that only humans can activate the sensor.

5.3 Contribution to Knowledge

Medical facilities can create efficient energy management policies with the help of microcontroller-based energy management systems, which maximize energy efficiency through data analysis, control algorithms, and real-time monitoring. Demand response techniques and energy exchange programs are made possible by integration with smart grid technology, which improves overall energy management. Such systems facilitate the adoption of sustainable energy practices, supporting energy efficiency, smart grid technology, and regulatory compliance in healthcare facilities by giving facility managers the ability to make decisions.

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Appendix A

Template for the interview carried out

1. Designation Chief Electrical Engineer
2. Department Works
3. Age 40 to 50 years
4. Years of experience 5 – 15 years
5. Sources of power 750MVA transformer (six 500kvAsublets)

   Generators (250, 100|,1000,700) KVA

Appendix B

1. Designation Chief Biomedical Engineer
2. Department Biomedical
3. Age 40 to 50 years
4. Years of experience 5 – 10 years
5. Challenges Overloads
6. Equipment that needs constant power listed in Table 3.2 A

Appendix C

Programme code

```
int ldr=A0;//Set A0(Analog Input) for LDR.

int inputvoltage=A1;

int value1=0;

int value2=0;

float value3=0;

const int led=10;

int PIR=3;

const int transistorpin=6;

const int transistorpin1=7;


void setup() {

Serial.begin(9600);

pinMode(led,OUTPUT);

pinMode(PIR,INPUT);

pinMode(ldr,INPUT);

pinMode(inputvoltage,INPUT);

pinMode(transistorpin,OUTPUT);

pinMode(transistorpin1,OUTPUT);
```

```
}

void loop() {
  delay(10);
value1=analogRead(ldr);//Reads the Value of LDR(light).
//delay(10);
value2=digitalRead(PIR);//Reads the Value of LDR(light).
// delay(10);
Serial.println("LDR value is :");//Prints the value of LDR to Serial Monitor.
value3=analogRead(inputvoltage);
Serial.println(value1);
//delay(500);
Serial.println(value2);
delay(10);
Serial.println(value3);
delay(500);
int value3=analogRead(inputvoltage);
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
  float voltage=value3* (5.0 / 1023.0);
  // print out the value you read:
Serial.println(voltage);
```

```
//  if ((voltage>=1.64) && (voltage<=2.64)){

//    delay(1000);

//   // digitalWrite(transistorpin,LOW);

//    delay(1000);

//  // lcd.print("VOLTAGE IS OK");

//     delay(1000);

//  }

//

//

//else if (voltage>3.64){

//    //delay(1000);

//    digitalWrite(transistorpin1,LOW);

//    delay(1000);

//  // lcd.print("VOLTAGE IS HIGH");

//     //delay(1000);

//  }




if ((value1<=150) && (value2==HIGH))

  {

    //else if((value1<=600)&& (value2==HIGH))
```

```
   //delay(100);

   //digitalWrite(transistorpin,LOW);

   delay(1000);

digitalWrite(transistorpin,LOW);

    delay(100);

     //  delay(10000);

       //digitalWrite(transistorpin1,HIGH);

     }


//else if((value1<=200) && (value1>=10))

//  {

//    delay(100);

//    digitalWrite(transistorpin,LOW);

//    delay(50);

//   // digitalWrite(transistorpin1,HIGH);

//      //  delay(10000);

//        //digitalWrite(transistorpin1,HIGH);

//      }



  else
```

```
  {

    delay(10);
digitalWrite(transistorpin,HIGH);
digitalWrite(transistorpin1,HIGH);
    //digitalWrite(transistorpin1,HIGH);
     delay(10);
  }
  }
```