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Design and Construction of an Energy Saving Control System for Rural Medical Facilities in Uganda

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***Abstract**: This study focuses on the design and construction of an energy-saving control system for rural medical facilities in Uganda. The aim is to address the energy challenges faced by these facilities through the implementation of a smart control mechanism and efficient technologies. The system is designed to optimize energy usage, reduce wastage, and improve energy efficiency. Key components of the system include advanced sensors, smart meters, and automated control algorithms. The study aims to contribute to the development of sustainable energy solutions for rural healthcare facilities, ultimately enhancing the quality of healt hcare services in remote areas of Uganda. Rural medical facilities in Uganda often struggle with inadequate and unreliable energy supply, which hampers the provision of quality healthcare services. Limited access to electricity and high energy costs imposes signi ficant limitations on these facilities, affecting critical operations, patient care, and the overall functioning of the healthcare system. To address these challenges, there is a need for innovative solutions that can improve energy efficiency and reduce energy costs in rural medical facilities. This study proposes the design and construction of an energy-saving control system tailored specifically for rural medical facilities in Uganda. The system aims to optimize energy usage by incorporating smart control mechanisms and efficien t technologies. By implementing advanced sensors, smart meters, and automated control algorithms, the system will intelligently monitor and regulate energy consumption, minimizing wastage and maximizing efficiency. The primary objective of this study is to develop a sustainable energy solution that can significantly reduce energy costs and enhance energy reliability for rural medical facilities. The implementation of this energy-saving control system has the potential to improve the overall quality of healthcare services in remote areas of Uganda. Additionally, it can contribute to the country's efforts in achieving sustainable development goals related to energy access and environmental conservation. Through the design and construction of this energy-saving control system, this study aims to address the unique energy challenges faced by rural medical facilities in Uganda. The subsequent sections will detail the methodology, proposed system components, and anticipated results and analysis, providing valuable insights in to the potential impact of this system on energy efficiency and healthcare service delivery in underserved areas.*

Keywords—Energy, saving, healthcare, control system, consumption, efficiency

1. INTRODUCTION

Energy savings in rural medical facilities are relevant in Uganda for several reasons. Firstly, Uganda, like many developing countries, faces a significant energy deficit. The country heavily relies on hydroelectric power, which accounts for approximately 86.4%, and solar energy, which accounts for 1.6% of the total energy consumed in the country [1] . This study focuses on addressing the energy challenges faced by rural medical facilities in Uganda by designing and constructing an energy-saving control system. The system aims to optimize energy usage by incorporating smart control mechanisms and efficient technologies. Statistical analysis will be conducted to evaluate the system's performance, and key performance indicators will be used to assess its impact on energy savings and facility operations [2].Powering medical facilities in Uganda can be a significant challenge, especially in rural areas where access to reliable electricity is limited. Fossil fuels have been used in health facilities to power the equipment, but their by-products, especially greenhouse gases [3], contribute to global warming, which results in climate change. Uganda, as a country, works towards creating an eco-friendly environment by eliminating carbon emissions into the atmosphere. In the fight to cut carbon emissions, fossil fuels have to be minimally used; however, in our current state, reducing the use of fossil fuels will put a very high demand on the remaining source of energy that is currently being used, thus the need for the design and construction of an energy-saving system for medical facilities in Uganda[4] . This will help reduce operating costs in medical facilities, mitigate the risk of power outages, especially during emergency situations, which can have a significant impact on the provision of medical services in rural areas, and also help medical facilities comply with the country's energy policies and regulations [1]. The Ugandan government has developed several policies aimed at promoting energy efficiency and renewable energy, such as the Uganda Energy Policy, which aims to increase access to affordable, reliable, and clean energy. Proper sizing of the loads, especially the diagnostic, therapeutic, treatment, and other peripheral equipment in the health facility using this design [5], will implement the Ugandan Energy Policy in all health facilities that adopt it, thus increasing the availability of energy to other sectors as well.

2. Methodology

The energy-saving control system is integrated with the advanced sensors and automated control algorithms to monitor and regulate energy consumption. The system design is considered be the specific requirements and energy profiles of rural medical facilities, allowing for efficient energy management [6].

The system components are sourced and integrated according to the design specifications. Installations are carried out carefully to ensure seamless integration with existing electrical infrastructure and medical equipment.The circuit design was done using proteus and simulated to project the outcomes of the entire system when implemented

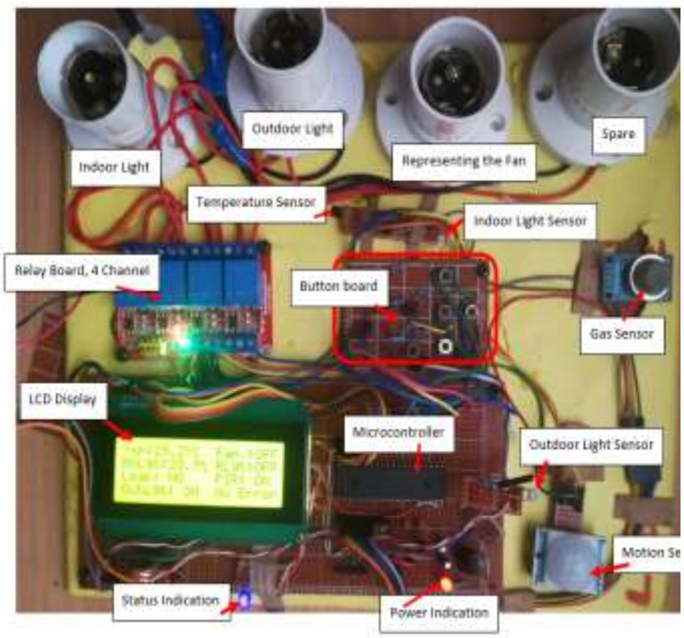

Figure 1: Circuit diagram of the entire system

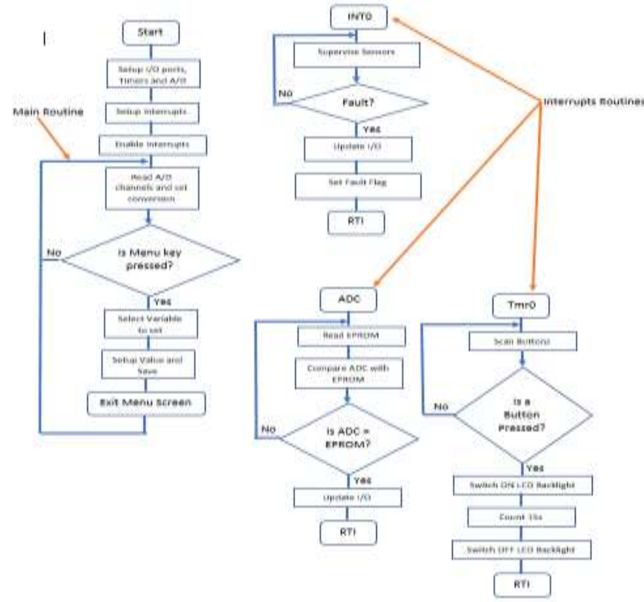

Figure 2: Flow chart diagram

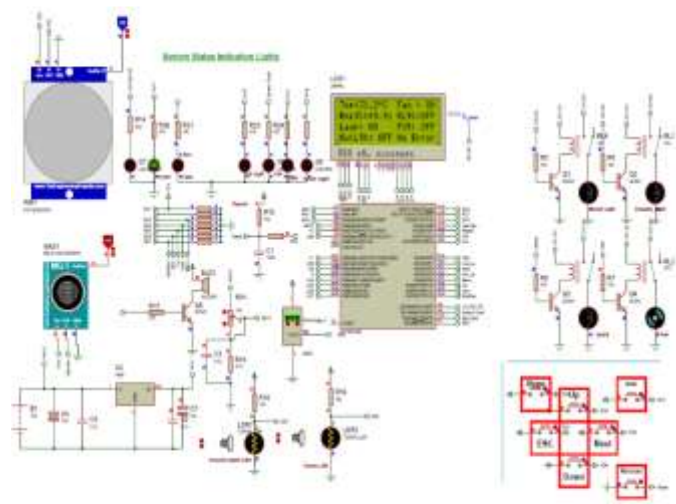

Figure 3: Implemented project of the entire circuit

3. Results and Analysis

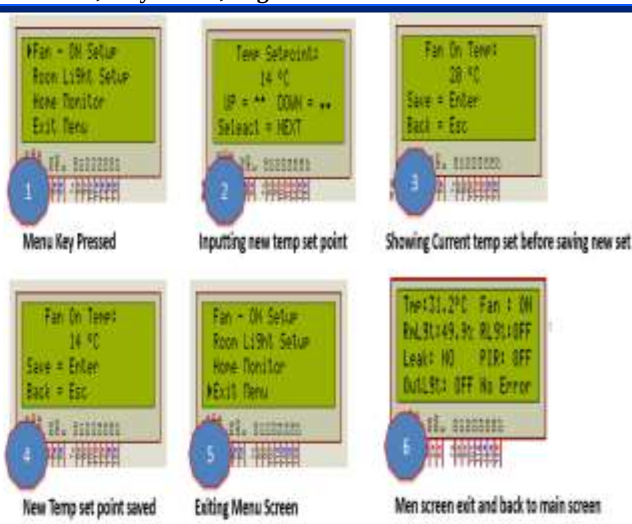

Figure 4: Simulation results

Testing parameter

<u>Case 1.</u> Proto type operation: Reading the Room Temperature and Tuning on the medical Room Fan

The fan, AC and refrigerators ON temperature set point was at 25°C, When the temperature is below the fan set point, the fan will remain off and when the recorded room temperature is above the set point, the room fan will be switched on to cool the room up to the desired temperature of 25°C. This routine shall continuously run as long as the MFESS is running. Pictorial representation of the process.

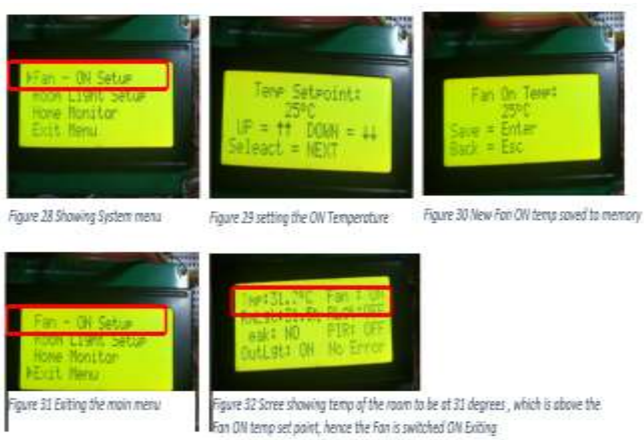

Figure 5: shows Setting the desired room temperature.

<u>Case 2.</u> Proto type operation: Reading the Medical Room Light Level and Tuning on the Medical Room Light

The process for setting the room light threshold is similar to that of the room temperature. The medical room light is read in terms of percentage level of darkness, the higher the percentage, the less the light intensity recorded in the room, hence the darker the room is and the reverse is true. In the below illustration, the percentage is set at 66%.

The second condition for turning on the room light is that the signal from the PIR must be detected, which implies that motion or a person is within the room. If these two conditions are met (i.e. darkness at 65% and Person detected), the light shall be switched on, if any of the conditions is not met, the light shall be switched off or remain off if it was off.

Figure 6: Reading the Medical Room Light Level and Tuning on the Medical Room Light

<u>Case 3.</u> Proto type operation: Tuning on the medical facility Outdoor Light

The outdoor light is turned ON and OFF without the need of setting the threshold through the main menu screen. Its threshold is set in the software in form of a variable. For the MFESS, it is set at 800 counts. This corresponds to the average light intensity during dusk and early morning hours of the day. Any count above the threshold will cause the Outdoor light to switched ON (dusk) and any count below the threshold, the Outdoor light shall be switched OFF (Morning).

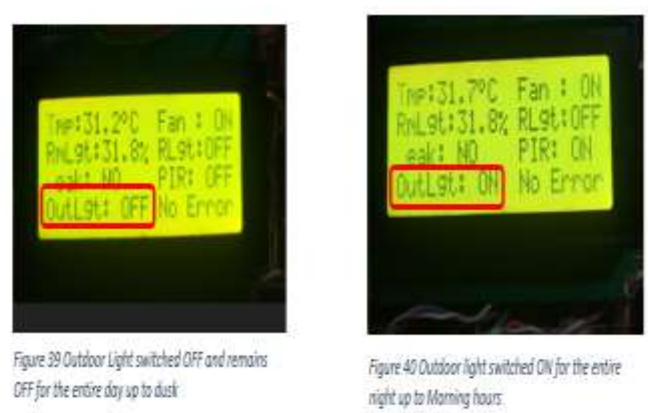

Figure 7: Tuning on the medical facility Outdoor Light

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Case 4. Proto type operation: Medical Gas Leakage Detection

The MFESS gas leak detection and monitoring is connected direct from the MQ-5 gas sensors. When gas is present within the oxygen cylinders and oxygen plants, a signal will be sent to the processor and a notices shall be issued to the user about the impeding danger and the necessary action taken to contain the hazard.

Figure 41 No gas leakage detected

Figure 43 Gas Leakage detected

Figure 8: Medical Gas Leakage Detection

Case 5. Proto type operation: Sensor ERROOR medical equipment Detection (Fault detection)

The system is equipped with a self-supervision system that is set within the code to detect any impeding system errors or faults. These faults are associated with the hardware, i.e. all sensors are monitored for any faults within their circuitry. A warning light is lit and the source of the error is displayed on the screen.

Figure 44 No Sensor fault

Figure 45 Sensor 2 fault (Outdoor light sensor error)

Figure 46 Sensor 1 fault (Indoor light sensor Error)

Figure 47 Sensor 3 Fault (Room Temperature sensor

Figure 9: Sensor ERROOR medical equipment Detection (Fault detection)

Figure 10: Testing the entire prototype

The table below will demonstrate the estimated benefits and savings if the MFESS is implemented in the case study medical facility. The table illustrates the savings in terms of running hours and costs benefits in terms of monetary value and amount of Energy saved.

Table 1 Showing the cost benefits of implementation the MFESS

Attributes			Before Implementation		After Implantation of the MFESS		
Appliance	Power Rating a	No. b	Running hrs/day (avg.) c	Kwh/day = aXbXc/1000	Running hrs/day (avg.) d	(kwh/day) = aXbXd/1000	Saving Kwh/day = c - d
Fan, ac and refrigerators	[illegible] w	10	8hrs	2580	2hrs	640	1920
TV	1000w	10	15hrs	150	4hrs	40	110
Theatre and Security Lights	1000w	5	16hrs	80	10hrs	50	30
Medical equipment devices	40000 w	5	16hrs	3200	8hrs	1600	1600
Total				5990kwh		2330	3660

How much energy is saved?

Before implementation of the MFESS, the average energy consumption for the day is 5990kWh which amounts to 63kwh per month (599kwh X 30days)

After the implementation of the MFESS, energy consumption per day is 3660kwh

Energy saved per day = 5990kwh – 3660kwh = 2330kwh per day.

Energy saving for a month = 2330kwh X 30days = 69900kwh

How much Money is saved?

Before Implantation: Money spent on energy per month, at 780shs per kwh

$$= \mathbf{179700}\boldsymbol{kWh} \times \mathbf{780}\boldsymbol{shs} = \mathbf{140,166,000}\ \boldsymbol{shs}$$

After MFESS implementation:

$$= \mathbf{109800}\boldsymbol{kWh} \times \mathbf{780}\boldsymbol{shs} = \mathbf{85,644,000}\boldsymbol{shs}$$

Therefore, total savings of energy in terms of money are

Per day: $= 4{,}672{,}200shs - 2{,}854{,}800shs = 1{,}817{,}400shs$

Per month: $= 140{,}166{,}000shs - 85{,}644{,}000shs = 54{,}522{,}000shs$

With the above analysis, it is seen that there is over a 50% saving on both energy and costs if the MFESS is implemented. Thus, this analysis meets the objectives of the project.

4. Conclusion

In conclusion, by implementing these energy-saving mechanisms at any rural medical facilities, administrators and medical directors can reduce energy consumption and save money on their energy bills. Additionally, reducing energy consumption also contributes to a more sustainable and environmentally friendly future hence this in turn reduces the medication bills and saves lives since it makes power consistently available for medical surgeries and any emergency conditions. The design and construction of an energy-saving control system for rural medical facilities in Uganda offer a promising solution to address energy challenges and enhance healthcare services. By leveraging smart control mechanisms and efficient technologies, this system aims to optimize energy consumption, resulting in cost savings and improved facility operations.

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