Leveraging the Integration of IoT Devices for Energy Optimization in Office Blocks

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Abstract:- The integration of Internet of Things (IoT) devices in office buildings has emerged as a promising solution for enhancing energy efficiency and optimizing resource utilization. In the context of modern workplaces, the adoption of smart technologies offers a transformative approach towards achieving energy optimization goals. Internet connected smart devices are ubiquitous and hence opens new opportunities for optimising energy consumption within office blocks. This research paper explores the integration of IoT devices within an office improve energy efficiency environment to and sustainability. The research paper aims to review a simple and low-cost smart workplace model that employs IoT technology, cloud storage, and data analytics for real-time monitoring and analysis of energy consumption patterns within an office environment. The study examines the implementation of an integration of IoT sensors within an office environment enabling HVAC and lighting systems to dynamically adjust energy use based on real-time conditions such as occupancy levels, ambient temperature, and daylight availability. Through the identification of trends, anomalies, and opportunities for optimization, the study seeks to qualify adaptive control strategies that can effectually reduce energy waste and improve general operational productivity in office buildings. The findings from this research underwrite to the growing field of smart offices by demonstrating the potential of integrating IoT devices for energy optimization in modern office blocks.

Keywords:- IoT, Optimisation, Smart Workplace, Cloud Storage, Integration of IoT.

I. INTRODUCTION

Office buildings account for a significant portion of energy consumption. [1] changing the consumption behaviour of occupants in public buildings is considered a key factor that should be properly addressed. Apart from refurbishing and retrofitting older buildings to improve their energy efficiency, changing the consumption behaviour of occupants in public buildings is considered a key factor that should be properly addressed, because "buildings don't use energy, people do"[2]. Aspects such as heating, ventilation, air conditioning (HVAC), and office lighting jointly contribute to the energy footprint of several buildings. Identifying and subsequently addressing the energy efficiency challenges within office environments is important. The importance is not only for Chrispen Mafirabadza² Department of Information Technology Harare Institute of Technology Harare, Zimbabwe

reducing environmental impact but also for reducing operational costs thereby improving the overall sustainability of the workplace. Orthodox approaches to managing energy use in office blocks characteristically rely on manual adjustments and reactive responses to changing conditions. Resultantly, this ad-hoc approach often leads to suboptimal performance and energy expenditures which are unnecessarily high. The introduction of Internet of Things (IoT) technologies provides new prospects to enhance energy efficiency in office environments. Recently, the rapid improvement of technology has made way for the integration of smart Internet of Things (IoT) devices in different sectors. Optimization of energy consumption in office blocks is one of the sectors that can benefit from the technological revolution. With focus being increased on energy efficiency and sustainability, leveraging smart IoT devices in office blocks has become a promising approach to attain energy optimization, at the same time creating a smart workplace environment. Interconnected devices can monitor several building parameters in real-time and dynamically adjust energy consuming systems like HVAC and lighting to match actual needs. The integration of IoT sensors, control systems, and data analytics can lead to a smart workplace model that can be used to optimize resource utilization within the office. Through the deployment of a network of interconnected sensors and actuators, real-time data can be collected on various energy-related parameters, including occupancy patterns, lighting levels, temperature, and equipment usage. This data can then be leveraged to develop intelligent algorithms and decision-making frameworks that can then be used to optimize energy consumption, reduce waste, and improve the overall energy efficiency within the office.

II. RELATED WORKS

Energy consumption around the world is estimated to increase by 56% in 2040[1]. The new era of digitalization opens new possibilities to improve human health and productivity and enhance energy efficiency in the built environment. The Internet of Things (IoT) represents one of these opportunities to decrease energy demands and meet sustainable development goals[3]. Further studies stated that if buildings consider good communication between their systems for operation, a considerable amount of energy use could be lowered[4][5]. Therefore, the advancement in networking, computing and sensing technologies set IoT to be an important component in the design and the operation of any smart object in the built environment[6][7].

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There are a number of studies that have been conducted to promote energy efficiency in smart cities, though the impact of IoT on energy efficiency varies from sector to sector. Smart grid management and smart lighting systems, for example, are regarded as key players in energy optimization in smart cities [8][9]. In a recent study, [10] provided a comprehensive review of energy harvesting assisted IoT applications with the possibility of being used in smart environmental monitoring, smart transportation, smart homes and smart healthcare. The overall findings highlighted the potential of IoT powered cities in transitioning urban environments especially towards carbon neutrality. The studies also mentioned that the development of self-powered sensor nodes, self-sustainable wireless sensor nodes and selfcharging energy storage units may contribute to the reinforcement of the IoT concept by increasing 5G endpoints and accelerating digitalization in smart cities.

[11] described a gamified framework that aims to change occupants' energy-consumption behaviour and reduce energy wastage in public buildings. The authors developed a framework that leveraged low cost IoT devices, multi-channel smart meters and smart plugs, to improve prior energy disaggregation mechanisms and identify energy wastages at the device, area and end-user level[12].However, the approach depends, to a greater extend, on an individual's willingness to participate, energy awareness and conservation knowledge, willingness to change behaviour and successfully employing a comprehensive user engagement.

Currently, in these modern days, smart devices with the capacity for computation and communication are ubiquitous, ranging from simple sensors to household appliances and smartphones. Integrating these elements helps to develop diverse networks, leading to the consolidation of an IoT basis [13]. The integration of IoT technologies in smart buildings demonstrates effective solutions to lower energy consumption, reduce environmental impacts, assist in utilizing renewable energy resources and offer flexibility to users that all help in establishing smart and sustainable cities [14]. The advancement in networking infrastructure, wireless technologies and smart algorithms open new opportunities for intelligent buildings to achieve efficient communication and proper control between multiple systems and spatial spaces to reach optimal integration [15].[16] conducted a review on smart buildings to identify features and indicators. The study provided key aspects in designing smart buildings using four aspects which are, grid response, climate response, monitoring and supervision and user response.

However, on the other hand, there is a gap between conventional and advanced methods to develop and incorporate integrated building design to shape a smart built environment. Furthermore, a gap between building design and automation solutions[17][18][19] indicated that the integrated energy-efficient building design process (IEBDP) is still conventional and limited between the planning and the operational phase. For instance, [20] recorded the energy usage of a LEED-gold-certificated green office building for one year. The analysis of energy usage showed that the building may not be energy efficient when its real energy consumption was considered. [21] indicated that energy consumption in buildings is assessed by the pattern of energyappliances usage and power rating. The energy performance of buildings is affected by the dynamic interactions between the building spaces, the building systems, and the building occupants. Accurately estimating the energy required to maintain comfortable conditions inside a building is a challenging task, as it depends on several factors. Furthermore, built environment architectures usually have limited understanding of the capabilities and applications of Internet of Things (IoT) technologies when designing office buildings. These challenges must be considered carefully as cities and buildings increasingly integrate IoT solutions in pursuit of energy optimization goals.

Additionally, [3] clarifies that there are limitations to integrating IoT technologies at the early design stage of most buildings due to a lack of clear approaches by the experts in the built environment. They further explain that studies of IoT and energy efficiency mostly target devices, users and energy markets without considering the aspects of building design. IoT studies in the field of computer science and engineering are well established and defined, and yet studies of IoT by experts in the built environment are limited due to insufficient comprehension of technologies and their functional methods. It is therefore important that IoT be studied as a part of building services. In most buildings, the relationship between users and their energy use patterns is shown to be reduced when there is a lack of continuous or frequent feedback. Concerns are also found in regard to the storage capacity needed for data generated by IoT devices. The data often comes in different formats and structures, rendering its storage to be complex. Interoperability of the data received from various IoT devices within a building can be challenging, hence the eventual solution is to design a uniform network within an environment that connects physical objects together.

In this research paper, we basically explore the potential of IoT-enabled technologies to aid energy optimization in office blocks by employing a holistic smart workplace approach. The study examines the integration of IoT sensors and predictive analytics to dynamically manage energy consumption based on actual usage patterns and environmental conditions. Through modelling, the proposed framework is evaluated for its ability to achieve significant reductions in energy use and related costs in comparison to traditional energy management practices.

Findings from this research paper will provide valuable perceptions into the transformative impact of intelligent IoT systems on sustainable office power management. The research will positively impact the design of energy efficient office buildings and workplace productivity improvement through innovative automation. The developed techniques and lessons learned can guide building owners, office managers and policy makers in leveraging smart technologies to create self-regulating, resource optimized office spaces.

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III. PROPOSED SYSTEM

The research involves developing a simple, low cost but effective model that integrates IoT devices, storage and data analytics for power optimization. The settings within the office consists of HVAC and lighting.

The model design involves an optimized environment with energy optimization for HVAC and lighting. An open window within the office will not allow the HVAC unit to be switched on as this will lead to increased power consumption by the unit. Automatic power on and off of lighting will also be demonstrated to allow optimization when not in use. Remote switching is also possible in instances where the office user forgets to switch off the lights and leave them on. Wi-Fi connectivity acquires data from the office and sent it to a cloud database to enable remote controlling from a mobile device e.g. a smart phone. The unoptimized environment does not make use of IoT devices and hence there is no control in energy usage. On the model, the connections remain the same for both optimized and unoptimized environments. The current is measured over a defined period and results compared and analyzed for both environments in order to determine the difference between them.

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The model designing will allow real time data collection and analysis in order to identify patterns, trends and anomalies in energy consumption within the office.

Model evaluation will also be done to determine whether the insights from data analysis can be used to implement further adaptive control strategies for energy optimization.

A. Architectural/Schematic Design

The diagram below shows the schematic design of the control circuitry, leveraging integration of different IoT devices.



Fig 1 Control Circuit Schematic Design

B. Materials and Methods

Below is a brief description of the major components used to design the circuit board as shown on Fig 1:

➢ Esp32 Micro Controller

At the heart of the proposed system model is the micro controller which acts as the brains (control) circuit from where input/output pins are connected for the purpose of data acquisition and control of output. It is a powerful, low-power dual-core Wi-Fi and Bluetooth combo SoC (System-on-Chip). It has multiple high-performance 12bit analog to digital converters (ADCs) for sensing the environment which basically includes temperature, office occupancy, window and lighting devices status. The ADCs can measure analog voltages in the range of 0 to 3.3V which is basically the operating voltage of the ESP32. The controller can connect to WI-FI network hence can be used to collect real time data and send it to the cloud. Fig 2 shows the ESP32 micro-controller.



Fig 2 ESP32 Micro-Controller

> 4 Channel Relay Module

The 4-channel relay module is a versatile electrical switching device that can be used to control high-voltage and high-current. It has four independent relay channels, hence allows for the control of four separate circuits. Its input signals i. e pins 3-6, can be connected to digital outputs of a microcontroller or other control system to boost the corresponding relay channels. The relay contacts normally open, common and normally closed (NO, COM, and NC) can

then be used to switch the high-voltage and high-current loads. On the proposed model, since the micro controller cannot switch different currents from HVAC, lights and office equipment, the micro controller energizes the relay which will resultantly turn the gadgets to on and off. The relay module hence isolates the micro controller from heavy current. Fig 3 shows how configurations to the relay module have been done on the proposed model.



Fig 3: 4 channel Relay Module

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➢ Voltage Sensor (ZMPT101B)

The ZMPT101B is a single-phase AC voltage sensor module designed for AC voltage sensing. This module typically includes a high-precision voltage transformer and a precision op-amp circuit, making it suitable for accurate and reliable measurements of AC voltage. It can measure AC voltages up to 250V and outputs a proportional analog signal. The ZMPT101 can be easily interfaced with a microcontroller or other data acquisition system to measure AC voltages. The analog output signal (pin 3) can be connected to an ADC (Analog-to-Digital Converter) input of the microcontroller. This is shown in Fig 4 below:

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Fig 4 Voltage Sensor Configurations

Current Sensor (SCT-013)

This is a non-invasive AC current sensor that uses a current transformer to sense the current flowing through a conductor. Resultantly, it provides an output voltage proportional to the measured current. On the model, the sensor's output voltage is connected to an ADC (Analog-to-Digital Converter) input of the ESP32 microcontroller measure the devices current.

The SCT-013 sensor is easily installed by clamping it around the conductor carrying the current needed to be measured. The sensor has a split core design, allowing for easy installation without disconnecting the conductor. The figure below shows how the sensor has been configured on the model board.



Fig 5 SCT013 Current Sensor

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> DHT22 Temperature Sensor

This is a commonly low-cost sensor used to measure digital temperature and humidity for various temperature and humidity monitoring applications. On the model, when the temperature is above or below the set optimum value, the HVAC unit will automatically switch on or off.

➤ Window Sensor

On the model circuit, there is a momentary switch (with a normal switch setup) that connects to the open window sensor. When switch contacts are open, the switch is connected to VCC and will sense 3.3V. When the contacts are closed, there is a 0-voltage change meaning the window is closed. The status determines whether the office window is open or closed when any HVAC device is switched on. If the window is open, the device will not switch on in order to optimize power. https://doi.org/10.38124/ijisrt/IJISRT24JUN2014

IV. RESULTS AND DISCUSSION

Model data acquired for analysis mainly centered on determining energy consumed by HVAC unit and lighting within an unoptimized office and an optimized office. In an unoptimized environment, the office user could switch on the HVAC unit when the office window was open. Office lights were also left in their ON state for a period of seven days, even when there was no one in the office. In an IoT optimized environment, the HVAC unit could not switch on when the window was open and remote switching off of lights was enabled as a way to optimize power. Collected data was captured using the ThingSpeak application, which was also used to store the data in the cloud and subsequently analyze it. A simple communication flow diagram is shown below:



Fig 6 Flow Diagram

C. Data Acquisition and Analysis

Data was acquired via the micro controller and stored to a cloud server which was accessed through the ThingSpeak application. The ThingSpeak application and API were used to store and retrieve data from the sensors on the model. ThingSpeak is a versatile platform for building IoT applications, collecting and analyzing sensor data and integrating with different IoT devices and systems. The application provides built-in data visualization tools like charts and graphs which assisted in data analysis. On data analysis, it integrates with MATLAB, which is a powerful mathematical computing software that allows advanced data analysis and visualization. ThingSpeak supports a wide range of IoT devices and sensors, which enabled easy integration with the ESP32 micro-controller. The application's capability to process and react to data in real time means feedback and control was easily achieved. Triggers and automation based on the incoming data (for example, sending notification to the user that lights were left ON) and hence remote controlling could be achieved.

The platform is cloud-based meaning there was no need for any infrastructure or server installations. The storage, processing and management of IoT data were handled by the application, thereby ensuring easy maintenance and scalability of model applications.

D. Model Results

Voltage and current were measured in an office space for HVAC and lighting. The office window sensor sensed an open window when the HVAC unit was switched on by the user. The current measured by the SCT-013 sensor was 1 amp continuous. When the optimized environment was activated on the model, the HVAC unit could not be switched on since the window was open. After closing the window and switching on the HVAC unit, the current measured was averaging 0.7 amps over a period of 7 days meaning the energy consumed was less over the same period. Volume 9, Issue 6, June - 2024

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The temperature sensor on the model also ensured optimization by automatically switching off the HVAC unit when temperature within the room was above 26°, the maximum temperature set, and could switch it back ON when it was below 20°, the minimum temperature set. When the unit was being used without sensing room temperature, there was need for human intervention to switch it ON and OFF, and hence measured energy consumption over a period of 7 days was 1 amp continuous. With the automatic switching on and off of the unit, current consumption calculated was 0.6 amp over the same period. The reduction in energy consumption hence shows that there was power optimization achieved through the use of IoT window sensor device.

During the same period of seven days, the user left lights in the office in their ON state whilst there was no-one in the office. Voltage and current measured amounted to 20 watts

On the optimized environment, the user could switch off the lights remotely upon realization that the lights were ON from their mobile device. When energy consumption was measured for the period, the results show energy consumption of 15 watts, which was a reduction in power consumption, as compared to an unoptimized environment.

The results are a clear indication that IoT can be leveraged in an integrated approach to optimize power consumption from different devices.

V. CONCLUSION AND RECOMMENDATIONS

The development of an IoT-based energy optimization model for an office environment has demonstrated that IoT integration can significantly reduce energy consumption within office blocks. By leveraging smart sensors, automation, and data analysis capabilities, the model was able to show an average energy reduction of between 5% and 10% for HVAC and lighting units for an IoT optimized environment. The findings indicated that IoT-enabled energy optimization can yield substantial cost savings and enhance productivity. The smart workplace approach represented by the model offers a compelling solution to prioritize sustainability and operational efficiency within office environments.

The integration of IoT-enabled devices, such as smart lighting and HVAC systems, has allowed for real time data collection, analysis, and dynamic adjustment of energy-related parameters, leading to improved efficiency and reduced wastage. This adaptive approach presented substantial reductions in energy consumption, leading to cost savings and a more sustainable office environment. The model findings propose that a well-designed smart IoT infrastructure, combined with effective data management can empower office managers and building operators to make informed, data-driven decisions to optimize energy usage. The ability to monitor and control office systems such as HVAC and lighting provides a comprehensive view of energy consumption patterns, allowing for targeted interventions and the implementation of energy-saving strategies. Based on the research findings, the following recommendations are proposed for organizations looking to implement smart IoT solutions for energy optimization in their office buildings.

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- Develop a robust and scalable IoT architecture that integrates various sensors, actuators, and control devices throughout the office building. Ensure seamless communication and data exchange between the different components to enable real-time monitoring and control.
- Integrate smart, connected building systems and equipment like HVAC and lighting that can be automatically controlled based on the IoT data.
- Invest in data analytics capabilities to extract meaningful insights from the collected IoT data. Develop predictive models and optimization algorithms to anticipate energy consumption patterns and proactively adjust building systems for optimal performance.
- Ensure seamless integration between the smart IoT system and existing building management systems (BMS) to leverage the synergies and avoid data silos. This will enable a holistic approach to energy optimization and enhance the overall efficiency of the office building.
- Incorporate user preferences and behaviour into the energy optimization strategies to ensure occupant comfort and satisfaction. Leverage IoT-enabled user interfaces and feedback mechanisms to engage employees and foster a culture of energy-conscious behaviour.
- Investigate available government incentives, tax credits, or other financial schemes that can support the implementation and adoption of smart IoT technologies for energy optimization in office buildings. Advocate for policy frameworks that promote the use of energyefficient and sustainable building practices.

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