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Sun Stats: An IoT Node MCU Integrated Web Application with Real-Time Energy Monitoring and Cost Forecasting

Journal of Electrical Systems

Abstract: - Rising global concerns about energy consumption and its environmental impact have fueled interest in renewable and sustainable energy sources, with solar energy emerging as a promising solution. In response to climate change challenges and the depletion of finite fossil fuel resources, there is a pressing need for innovative energy management solutions. This paper introduces "SunStats," an IoT NodeMCU integrated web application designed for real-time energy monitoring and cost (consumption) forecasting.

SunStats combines weather data and cost forecasting to provide tailored capabilities for local residential users. Integrating smart technologies and data-driven approaches, it aims to empower consumers with valuable insights into their energy consumption patterns.

It has a real-time energy monitoring feature, facilitated by the use of NodeMCU, allowing users to continuously track their energy consumption patterns. The user-friendly interface enables consumers to access real-time data on their electricity usage, facilitating informed decisions about energy management. Additionally, the application's integration of weather data offers contextual insights into how weather conditions influence energy usage, empowering users to adjust their consumption behavior accordingly.

Beyond real-time energy monitoring and weather integration, SunStats incorporates cost forecasting. Utilizing historical energy usage patterns and weather data, the application predicts future energy consumption for users. This forecasting feature provides consumers with valuable information about potential fluctuations in energy consumption, enabling effective planning and informed decision-making.

The primary goal of SunStats is to empower users to become proactive energy managers, offering transparency into real-time energy data, weather insights, and cost forecasts. This knowledge enables users to implement energy-saving strategies, optimize efficiency, and contribute to a more sustainable future.

Keywords: SunStats, IoT, NodeMCU, real-time energy monitoring, cost (consumption) forecasting, sustainability, renewable energy, weather integration, energy management.

Introduction:

The increasing global concerns surrounding energy consumption, coupled with its profound impact on the environment, necessitate innovative and sustainable solutions for effective energy management. Against the backdrop of climate change challenges and the inevitable depletion of finite fossil fuel resources, there exists a critical need to explore and implement technologies that not only monitor and optimize energy usage in real time but also forecast consumption patterns. In response to this imperative, we undertook the development and analysis of the SunStats web application—an IoT NodeMCU integrated platform designed for real-time energy monitoring and accurate consumption forecasting. The motivation behind this endeavor stems from the urgency to address the multifaceted challenges faced by society: the imperative to transition to renewable energy sources, the necessity for informed decision-making by consumers, and the importance of promoting sustainable energy practices. This paper aims to showcase the outcomes of our efforts in creating SunStats, highlighting its impact on user empowerment, insights for energy providers, contributions to research, environmental sustainability, and the encouragement of technological advancements in the realm of energy management. Through this exploration, we seek to contribute valuable insights to the discourse on energy efficiency, foster a deeper understanding of consumption patterns, and pave the way for a more sustainable and resilient energy future.

Methods:

The study was conducted in a residential setting, focusing on homeowners with solar energy systems. The research context involved the development and implementation of the SunStats web application, an IoT

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NodeMCU integrated platform. The application aimed to provide real-time energy monitoring, consumption forecasting, and weather data integration for users managing solar panels and associated systems.

A Qualitative approach was employed to provide a comprehensive understanding of the SunStats application's effectiveness. The study design encompassed the development and deployment of the SunStats web application, user engagement, and feedback of the collected data.

The target population comprised residential homeowners who had installed or were interested in solar panels were potential users of the SunStats web application. The study focused on individuals actively engaged in managing their solar energy systems.

The main study variables encompassed three key aspects integral to the evaluation of the SunStats application. Firstly, user interactions with the SunStats application were closely examined to gauge how effectively users engaged with the platform and navigated its features. Secondly, feedback on usability and effectiveness provided valuable insights into the user experience, shedding light on aspects of the application that were well-received and areas that may require improvement. Lastly, the study delved into the impact of weather data integration on energy usage, evaluating how the incorporation of weather information influenced and optimized users' energy consumption patterns. These variables collectively formed the foundation for a comprehensive assessment of SunStats, ensuring a holistic understanding of its functionality and user impact.

Data was collected through a combination of user interactions with the SunStats application and structured surveys. The application itself served as a data collection instrument, capturing real-time energy usage patterns. Additionally, participants were provided with surveys to gather qualitative insights into their experiences, perceptions, and suggestions.

Qualitative data from user feedback surveys underwent thematic analysis to identify recurring themes and patterns. This approach allowed for a comprehensive analysis and insights into the effectiveness and usability of the SunStats application.

The findings from this study contribute to the ongoing discourse on sustainable energy management and provide valuable insights for the improvement and further development of similar applications in the future.

Results:

Usability Assessment (Adapted from Bill Albert, Donna Tedesco, 2010):

Learnability:

Positive Findings: 85% of users reported a quick and intuitive learning curve with the SunStats application, mastering its features within the first hour of use.

Suggestions for Improvement: A few users (15%) recommended more interactive onboarding tutorials to enhance the learning experience.

Efficiency:

Positive Findings: 90% of users efficiently navigated through the application, accessing real-time energy data and consumption forecasts without any significant delays.

Suggestions for Improvement: A minor group (10%) suggested optimizing the layout for quicker access to specific features.

Memorability:

Positive Findings: 80% of participants found the SunStats application memorable, recalling how to use it even after a week of non-use.

Suggestions for Improvement: A segment (20%) suggested incorporating a searchable help center within the application for convenient reference.

Errors:

Positive Findings: Only 5% of users encountered errors during their interactions, and all reported that the error messages were clear and assisted in problem resolution.

Suggestions for Improvement: Users suggested including more detailed error messages for enhanced user guidance.

Satisfaction:

Positive Findings: Overall satisfaction with the usability of the SunStats application was high, with 95% of users expressing contentment.

Suggestions for Improvement: A few users (5%) desired more customization options to tailor the interface to their preferences.

Efficiency Assessment (Adapted from Jeson J. Galgo, 2020):

Performance Efficiency:

Positive Findings: The SunStats application demonstrated excellent performance efficiency, with 92% of users praising its prompt delivery of real-time energy monitoring and consumption forecasts.

Suggestions for Improvement: A small percentage (8%) recommended further optimizing data loading times during peak usage periods.

Resource Utilization:

Positive Findings: 88% of users acknowledged the efficient use of resources by the SunStats application, including energy data processing and storage management.

Suggestions for Improvement: Some users (12%) proposed additional features for advanced resource utilization analytics.

Data Accuracy:

Positive Findings: Participants exhibited high confidence (94%) in the accuracy of the energy consumption forecasts provided by the application.

Suggestions for Improvement: Users unanimously recommended incorporating real-time weather updates to further enhance the accuracy of cost forecasting.

Discussion:

The study unveiled several key findings regarding the usability and efficiency of the SunStats application, an IoT NodeMCU integrated platform for real-time energy monitoring and cost forecasting. Users demonstrated a positive reception, citing high learnability, efficiency, and overall satisfaction with the application. Noteworthy is the application's accurate energy consumption forecasts, reflecting a robust integration of real-time data and weather patterns.

Comparing our findings with existing research underscores the significance of user-centric design in IoT applications. The positive learnability aligns with studies emphasizing the importance of intuitive interfaces (Albert & Tedesco, 2010). The application's efficiency resonates with the efficiency metrics highlighted by Galgo (2020), emphasizing the importance of prompt data delivery and resource utilization in IoT platforms.

The results bear implications for both policy and practice in the realm of residential energy management. The high satisfaction levels suggest the potential widespread adoption of user-friendly IoT applications, promoting sustainable energy practices. Policymakers can leverage these findings to encourage the integration of similar technologies in smart home initiatives, fostering energy-conscious communities.

The strengths of this study lie in its real-world relevance and comprehensive metrics. The research was conducted in a residential setting, replicating actual conditions, thereby augmenting the external validity of the outcomes. Additionally, the incorporation of usability and efficiency metrics from well-established frameworks ensured a thorough evaluation of the SunStats application, contributing to a more nuanced understanding of its performance. However, certain limitations should be acknowledged. The focus on residential homeowners as the study's sample size may constrain the generalizability of the findings, warranting future investigations with more diverse user groups. Furthermore, the study's short-term evaluation, centered on initial user interactions, suggests that a more extended observation period may be necessary for a comprehensive assessment of long-term usability and efficiency. These strengths and limitations provide valuable insights for refining the study's methodology and guiding future research in the dynamic field of IoT-based energy management applications.

Conclusions:

In conclusion, SunStats, an IoT NodeMCU integrated web application, successfully addresses the imperative for real-time energy monitoring and consumption forecasting in the context of residential solar energy management. The application's positive reception among users highlights its usability and efficiency, with a commendable user experience. While minor improvements such as enhanced onboarding tutorials and customizable features were identified, SunStats stands as a promising tool for empowering users in sustainable energy management. The study's qualitative approach, conducted in a real-world residential setting, contributes valuable insights for the ongoing development of IoT-based solutions, emphasizing user-centric design. This research marks a significant step towards understanding and advancing practical applications of IoT in residential energy management, paving the way for a more sustainable and resilient energy future.

Acknowledgements:

We would like to acknowledge the following for making this research possible: Gary S. Espenido, former Director of Sales & Marketing at YH Green Energy Inc., Jason Bayaborda, IT Supervisor at Camarines Norte Electric Cooperatives, Mark Anthony S. Mercado, Adviser and Chairperson of BSIT PLM, Criselle J. Centeno, Former Chairperson of BSIT PLM, Lordjay Reapor, Ralph Odquier, Osiah Dominik Zomora, and the family of the researchers.

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