Automatic Electricity Bill Meter Reading and Billing System for smart farming

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Abstract

The Automatic Electricity Bill Meter Reading and Billing System introduces an inventive solution crafted to align with the specific demands of contemporary agriculture. Its primary objective is to automate the processes of electricity meter reading and billing, aiming to elevate efficiency and sustainability within the realm of smart farming. By harnessing latest technologies, including machine learning and Internet of Things (IoT), this system finely tunes the accuracy, accessibility, and management of electricity consumption data on farms. The strategic deployment of smart meters, equipped with IoT-enabled sensors, facilitates real-time data collection of electricity consumption in smart farming environments. By eliminating the reliance on manual readings, the system guarantees timely and precise data transmission to a centralized server. Employing machine learning algorithms, the collected data undergoes analysis and processing, enabling accurate billing even within the dynamic and intricate scenarios characteristic of farming operations. The billing process takes a significant leap toward automation, generating meticulous bills grounded in real-time consumption data. Smart farmers are granted access to an intuitive and user-friendly interface, furnishing comprehensive information on consumption patterns, billing details, and historical data. This transparent accessibility empowers farmers to make knowledgeable decisions regarding their electricity usage, fostering resource efficiency and cost-effectiveness in agricultural operations. Beyond the conventions of traditional billing systems, The Automatic Electricity Bill Meter Reading and Billing System for Smart Farming incorporates advanced features, including automated alerts for abnormal consumption patterns. This proactive approach empowers farmers to swiftly identify potential issues and implement preventive measures, contributing substantially to the overall reliability and resilience of smart farming practices. In harmony with the principles of precision agriculture and sustainable farming, this system stands as a noteworthy advancement in utility management for the agriculture sector. By embracing technological strides, it not only streamlines billing processes but also by empowers intelligent farmers to make decisions based on data, optimize the use of resources, improve overall productivity, and sustainability of contemporary agricultural practices.

Keywords---Automatic Electricity Bill Meter Reading, Billing System, Raspberry Pi board, Smart Agriculture, Smart faring environment.

1. Introduction

In the ever-evolving landscape of agriculture, the integration of advanced technologies is reshaping traditional farming practices into intelligent, data-driven systems. The Automatic Electricity Bill Meter Reading and Billing System tailored for Smart Farming represents a pioneering solution designed to address the distinctive needs of contemporary agriculture. This innovative system seeks to revolutionize the management of electricity meter readings and billing processes, ushering in a new era of efficiency and sustainability for smart farming practices. Traditional approach to electricity meter reading and billing in agriculture has been fraught with challenges, including inaccuracies, delays, and a lack of real-time insights. Recognizing these limitations, our system harnesses cutting-edge technologies such as the

Internet of Things (IoT) and machine learning to redefine how electricity consumption data is handled on farms. Its primary goal is to automate meter reading and billing processes, ensuring that smart farming operations benefit from heightened efficiency and streamlined utility management.

Smart meters, equipped with IoT-enabled sensors, are strategically deployed in smart farming environments to enable real-time data collection of electricity consumption. By eliminating the reliance on manual readings, the system guarantees timely and precise transmission of data to a centralized server. Leveraging machine learning algorithms, the collected data is analysed and processed, enabling accurate billing even in the dynamic and intricate scenarios typical of agricultural operations. Automation takes centre stage in the billing process, generating precise bills based on real-time consumption data. Smart farmers are equipped with an intuitive and user-friendly interface, providing comprehensive insights into consumption patterns, billing details, and historical data. This transparent accessibility empowers farmers to make informed decisions, fostering resource efficiency and cost-effectiveness in their agricultural endeavours. Beyond the conventional realm of billing systems, The Automatic Electricity Bill Meter Reading and Billing System for Smart Farming incorporates advanced features such as automated alerts for abnormal consumption patterns. This proactive approach empowers farmers to promptly identify potential issues and implement preventive measures, contributing significantly to the overall reliability and resilience of smart farming practices.

2. Literature Survey

Huibin Sui et. al [2009] have introduced an adaptable and economical Advanced Metering Infrastructure (AMI) system. The system has utilized various communication channels, such as GSM and GPRS. This integration has resulted in decreased labor expenses, improved accuracy in meter reading, and the delivery of precise billing information, assisting customers in efficiently managing power usage. The decentralized architecture of the AMI system has ensured its adaptability across utility systems of different sizes. The proposed system’s effectiveness has been validated through its successful deployment in multiple utility scenarios across Shandong Province, China.

A. Vijayaraj et.al [2010] has utilized a central Electricity Board (EB) office equipped with an RF system to access all consumer homes within a locality. Each house's EB meter is wirelessly connected to the EB office via a network for enabling periodic meter updates. The EB office calculates the amount due based on the consumed units and subsequently transmits this information to user's mobile phone. This system will ensure connectivity to remote areas even during power outages, thanks to its reliance on wireless technology. Offering user-friendly accessibility, the new system surpasses the efficiency of the existing infrastructure.

Tanvir Ahmed et.al [2011] have unveiled a low-cost high-performance Automatic Meter Reading (AMR) having four main components specifically suited for Bangladesh to provide maximum data rate and widest coverage. The current analog energy meter does not need to be replaced because the reading unit is used to determine the number of rotations made by disk in the energy meter. To store data in a microcontroller, the existing energy meter is attached to an additional module. Wimax transceiver available in the communication unit is responsible for widest coverage area for wireless communication between the server and the meter. This unit is responsible for receiving and processing data gathered from meters.

Shraddha Male et.al [2014] have introduced an affordable and uncomplicated wireless GSM energy meter with remote access to the existing meter, eliminating the need for extensive human labour. The system has incorporated a GSM-based wireless module for communication, seamlessly integrating with the electronic energy meter to allow remote monitoring of electricity usage. To ensure secure access, authentication measures are implemented, enabling users to retrieve detailed information from the developed web pages worldwide. The use of a GSM-based wireless Automated Meter Reading (AMR) system proved to be a highly effective approach for modernizing billing systems. Moreover, this system grants electricity companies the authority to take actions against delinquent customers with outstanding dues, including the option to disconnect power supply and subsequently reconnect it upon settling the dues. Customers receive comprehensive monthly usage and billing details through messaging after the data processing is complete.

Milanpreet Kaur et.al [2017] have outlined energy consumption monitoring by the utilization of an Arduino Uno board and Ethernet and IoT concept. The presented design has minimized human involvement in electricity conservation. Consumers have utilized the IP address on their devices to access information about energy consumption. This proposed system provides Dependable and precise information on Electrical Energy Management System (EMS) via IoT is provided by this system.

Anirudh Kumar et. al [2018] have delineated a real-time approach using conventional meters to measure active power. They have integrated a Light-Dependent Resistor (LDR) in their system to monitor the blinking frequency of the LED on the meter. The active power registered by traditional meters is proportionally related to the blinking frequency and this value in an online data server.

Osmi Jaiswal et.al [2018] have suggested a wireless approach to design an Intelligent Energy Meter (IEM) reading and bill generation utilizing Arduino Mega and Ethernet Shield. SMS using GSM900 is sent to the consumer after generating bill for every month. They have also disconnected the power supply for the defaulters using a relay controlled wirelessly through the Internet of Things (IoT) concept.

M. Dhivya et.al [2019] have developed a smart meter capable of effortlessly identifying power consumption. Their system utilizes current and voltage sensors to calculate power, displaying the information on an LCD screen along with the associated cost. This allows users to easily monitor their accumulated power consumption costs. Additionally, their system is designed to automatically send SMS notifications to users at the end of each billing cycle.

Rozeha A et. al [2019] have introduced a smart system to monitor energy involving household appliances by integrating Cellular Internet of Things (CIoT), Raspberry Pi-based smart plug. Google Colab functions as the training server and a dashboard built with the Matplotlib library Raspberry Pi-based smart plug acts as the gateway, capable of retrieving real-time data from individual home appliances. It is also equipped to load the trained model for validation using data. Google Colab is responsible for storing the training dataset and constructing a trained model based on recurrent neural network for predicting bills and alerts. This model predicts electricity bills and alerts from individual home appliances. Energy consumption in real-time is monitored by Dashboard designed using the functions of Matplotlib library.

R. Govindarajan et. al [2020] have leveraged cutting-edge wireless technologies to facilitate communication between the meters and consumers. They have integrated digital power meter into the main panel for connecting to a gateway. They have measured the different electrical parameters in real-time. These systems furnish consumers with detailed power consumption information and enable interaction by providing immediate access to energy usage and energy bills.

Shikha Prakash et. al[2020] have developed an energy meter designed to assist individuals with visual impairments or those unable to focus on meter readings due to a hectic schedule. The device is constructed to visually display power consumption and total monthly costs. This innovation provides consumers with valuable insights into peak loads, overall energy consumption, billing status, and more. The system has also featured voice alerts in English, conveying messages such as "Usage overload" and "Pay electricity bill." This system consists of a microcontroller, GSM modem, and Text-to-Speech module, the energy meter transmits readings to the microcontroller. Using calculations, it produces both auditory and visual alerts. The meter consistently logs readings in non-volatile memory and possesses the ability to send cost and usage information to consumers via the GSM modem.

Surabhi Naik et. al[2020] have created an intelligent electricity measurement system coupled with an Android-based payment platform. The research outlined in this article has comprised of three modules: a microcontroller-driven prepaid electricity measurement system for calculating power consumption, an Android application for meter reading and recharging, and a GSM circuit for Short Messaging Service (SMS) communication with the user. This integrated system has empowered users to monitor their electricity usage, fostering awareness and preventing unnecessary consumption. Additionally, users can check their balance, and if it is low, then recharge is required; otherwise, the supply will be disconnected. This approach has minimized manual efforts, automates the system, ensures timely payments, and mitigated revenue losses and theft.

A. I. R. Fernando et.al [2020] have implemented Smart Electricity Monitoring System a mobile application, utilizing Internet of Things (IoT) technology. The mobile app has provided users with a user-friendly interface to monitor their electricity consumption and automates the monthly electricity billing process. The smart electricity meter system comprises three components. Firstly, a hardware setup using Arduino measures home electricity consumption by capturing real-time Alternate current and Alternate voltage. These values are then used to generate real-time Alternate power. The system converts these real-time values into units (kW/h) and transmits them to a database via Wi-Fi. The second component involves a real-time database in Firebase, storing the data and enabling users to retrieve it through the mobile application. Lastly, the third component is a user-friendly Android application designed to enhance consumer engagement with their electricity consumption and contribute to reducing global energy consumption. With the mobile app displaying real-time results, users can gain insights into saving and reducing electricity usage compared to previous periods.

S. Allirani et. al [2023] have created and implemented a real-time smart meter. The total energy consumption is calculated by multiplying the measured voltage, current, and power factor every second, and this process is consistent across all consumers. The Data Concentrator Units (DCUs) contain information on the energy consumed in a specific area.

Bethi Manoj Reddy et. al [2023] have developed system for energy monitoring and environmental sensing functionalities using Arduino uno. They have created a power measurement circuit for precise assessment of electricity consumption, monitoring temperature and humidity levels. They have also ensured seamless data transmission to the ThingSpeak cloud platform, and designed an intuitive interface for data visualization.

P. Manikandan et. al [2023] have developed to enable both consumers and service providers to monitor power usage, calculate bills to promote responsible energy consumption, and facilitate remote bill payments to prevent potential issues. To track power usage, recharge, and settle bills, they used a dedicated Android app or web page.

Muhammad Sharir Fathullah Mohd Yunus et. al [2023] have suggested intelligent meter, constructed on an Internet of Things (IoT) platform, streamlines the entire procedure by utilizing IoT technology to transmit data to the utility provider, eliminating the necessity for in-person visits. Subsequently, the utility company can analyse the data to produce precise bills for individual users. The design has also incorporated additional features such as detecting meter tampering. This work has encompassed hardware development, programming, and circuit design. Utilizing Arduino Uno as the system's microprocessor ensures the efficient and reliable operation of the smart meter.

D S Naga Malleswara Rao et. al [2023] have proposed an envisioned system that elevated accuracy, minimized power consumption, and aims to connect consumers with energy providers by furnishing real-time energy consumption data, a web portal for billing information, and seamless integration with current energy meters. In essence, the proposal strives to enhance energy metering systems through the integration of Internet of Things (IoT) technology, addressing challenges like exorbitant costs, absence of bidirectional communication, electricity theft, and inefficient manual methodologies.

M Sentamilselvi et. al [2023] have presented an effective approach for detecting power theft, calculating user bills, and monitoring payload while upholding user privacy. To ensure personnel safety, the proposed system communicates with GPS, encrypting readings using functional encryption, and communicates with the operating system using encrypted texts. This allows for the computation of bills through a novel pricing method, load balance analysis, and the utilization of machine learning to identify instances of power theft. The primary objective of this project is to notify the electricity board of potential electric power theft occurrences, facilitated through embedded technology. The system is capable of measuring both the power transmitted over the load and the power utilized by the load over time, with IoT employed for parameter monitoring. Additionally, the system is designed to automatically trip if the user fails to pay the bill.

3. Proposed Methodology

The hardware setup used in the proposed methodology showing different components is shown in Figure 1.

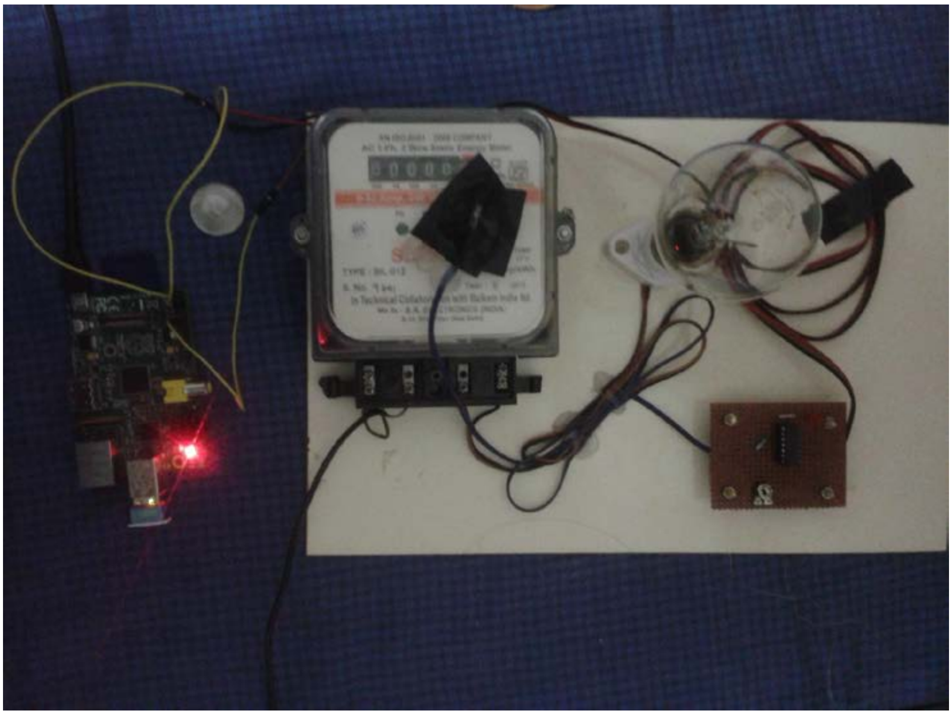

Figure 1 shows the hardware setup.

3.1 Different Hardware components used in the proposed methodology.

3.1.1.Raspberry Pi

The central hardware component of the system for automatic electricity meter reading is the Raspberry Pi board, specifically the Raspberry Pi 4 model. It is accompanied by a MicroSD card containing the Raspbian operating system. This setup serves as the primary controller for the system. The Raspberry Pi features multiple serial ports designed for interfacing with both the electricity meter and GSM modem. To ensure smooth operation, all components are powered by dedicated power supplies.

3.1.2. AC 1 Phase 2 Wire Static Energy Meter

An electricity meter, compatible with the selected communication protocol such as RS-485, RS-232, or Modbus, is employed to interface with the Raspberry Pi. Cables and connectors are utilized to establish the connection between the electricity meter and the Raspberry Pi. The Static Wire Energy Meter represents a next-generation single-phase electronic meter specifically engineered for AC active energy measurement. Enhanced through the integration of customer requirements and feedback, its design and functionality have undergone significant improvements. This meter operates within a single-phase two-wire network, measuring active energy as a summation of forward and reverse energy flow. Notably, the meter's design ensures minimal maintenance intervention throughout its entire lifespan. Its measuring stability obviates the need for recalibration, while users can conduct accuracy tests using LEDs with pulse output. Moreover, the meter boasts impeccable magnetic immunity, with any magnetic influence below 500mT±10% resulting in an error margin within ±4%. Ensuring tamper resistance, the meter is effectively sealed, preventing unauthorized access without breaking the seal. Additionally, the terminal cover is constructed from transparent material and secured by a single sealing screw, enhancing visibility and security.

3.1.3. GSM Modem

A GSM modem, which includes a SIM card slot and active cellular service for sending SMS messages, is connected to the Raspberry Pi using either a USB or UART cable.

3.1.4. Power Supply, Cables and Connectors

Power adapters supply power to the Raspberry Pi, EB meter, and GSM modem. USB cables connect the GSM modem to the Raspberry Pi. Wiring connects the EB meter to the Raspberry Pi if necessary. Optionally, an Ethernet cable can provide network connectivity to the Raspberry Pi.

3.1.5. Optional Components

Sensors (e.g., temperature, humidity) are used for environmental monitoring. External antennas can be used for improving GSM signal reception. Power over Ethernet (PoE) adapter can be used for powering the Raspberry Pi through the Ethernet connection (if supported)

3.2 Different Software components used in the proposed methodology.

By utilizing these software tools and libraries, a comprehensive solution is developed for automatic EB meter reading using Raspberry Pi, an EB meter, and a GSM modem, integrating communication, data storage, and management functionalities.

1. The Raspberry Pi OS serves as the designated operating system for the Raspberry Pi board.
2. Python functions as the programming language predominantly employed for scripting and automating tasks on the Raspberry Pi.
3. Employing a Python library facilitates serial communication, enabling interaction with the EB meter and GSM modem through UART or USB connections.
4. Utilizing a Python library enables communication with devices supporting the Modbus protocol, frequently utilized for retrieving data from industrial devices like EB meters.
5. Minicom functions as the terminal emulation program utilized for serial communication with devices linked to the Raspberry Pi, aiding in testing and debugging processes.
6. The usb_modeswitch software tool is utilized to transition USB modems from storage mode to modem mode, thereby enabling their utilization for communication purposes.
7. AT Commands serve to govern GSM modems, allowing for direct communication with the modem via a serial connection through tools such as minicom or implementation within Python scripts.
8. SQL Databases serve as repositories for organizing and managing meter reading data in a structured manner. Popular options encompass SQLite or MySQL for local databases, while PostgreSQL is favoured for more extensive deployments.
9. A Web Server, such as Apache or NGINX, functions as software employed for hosting web applications capable of displaying meter reading data or providing a user interface for configuration and management purposes.

10. SMS Gateway Services represent online platforms or APIs permitting the transmission of SMS messages through the GSM modem. These services commonly offer HTTP or SMTP interfaces for seamless integration with custom applications.
11. SSH (Secure Shell) encompasses both a protocol and software utilized for secure remote access to the Raspberry Pi's command-line interface, facilitating remote system management and configuration.
12. Cron, a Unix-based scheduling utility, enables the execution of tasks at specified times or intervals. It finds utility in scheduling automatic meter reading tasks and data uploads to a centralized server.

3.3 Sequence of different operations performed in reading automatic electricity meter

The energy meter features an LED that flashes periodically based on the load consumption. An LDR detects the LED flash, triggering another LED in the circuit to illuminate by comparing analog signals via an LM324 comparator, resulting in a digital output. When the output is 1, the LED illuminates.

To interface with the Raspberry Pi, three wires - red, black, and brown - from the LED circuit are utilized. The red wire, serving as the power supply, connects to GPIO pin 1, providing 3.3V. The black wire, representing ground (GND), links to pin 6. The brown wire acts as the input wire, supplying a 3.3V high signal to the GPIO pin, allowing for the counting of units. Each time the pin receives a high voltage, the count increments.

To configure the pin numbering to align with the breakout board, the 11th pin is designated as the input pin.

When the 11th pin detects a high voltage, the count increases. To retrieve the count from the pin, the following process is employed:

After obtaining the LED count over a specific duration, it is divided by 10 to determine the consumed units. Subsequently, the cost of the units is calculated based on the tariff. The user's ID, name, phone number, reading date, units, cost, and last payment date are stored in a database.

Additionally, details such as the user's phone number are retrieved from the database, and an SMS is sent to the user's number. Furthermore, after a designated interval, another SMS is dispatched to inquire about the payment status. If the bill remains unpaid within the specified timeframe, a notification SMS is sent, prompting the user to settle the payment; otherwise, it is disregarded. The snapshot shown in Figure 2 shows total units consumed and read by the system from the electricity meter followed by inserting these values into the database and also initiating the GSM modem for sending the SMS to the farmers.

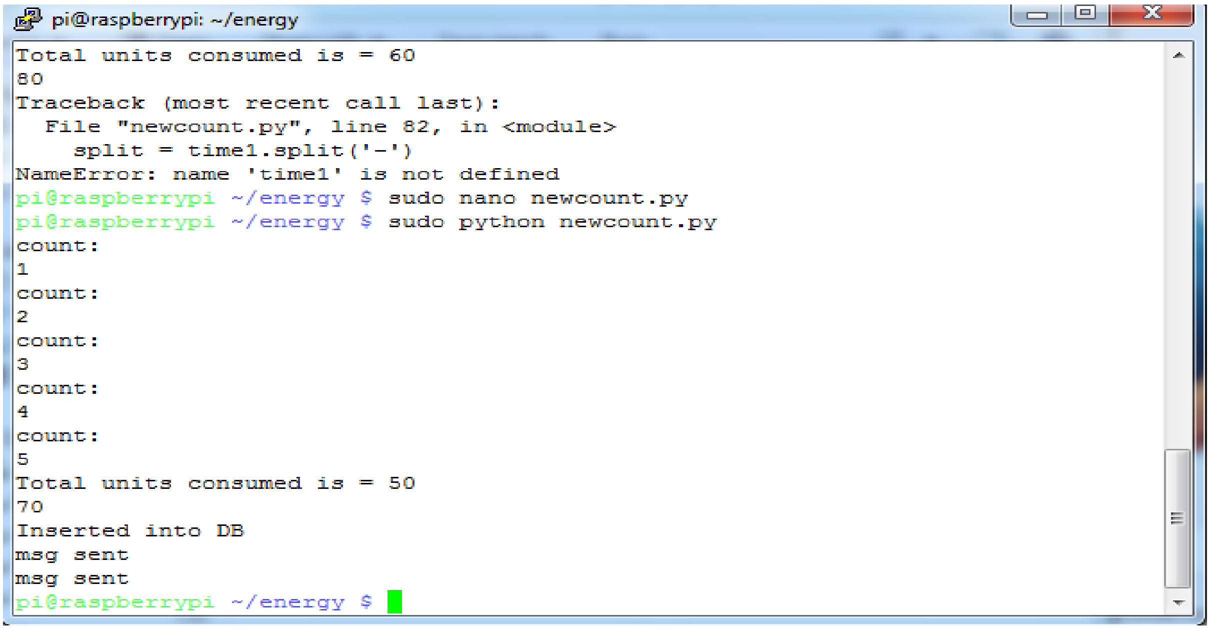

Figure 2 showing diff operations performed by the system

4. Results and Discussion

4.1 Accuracy of Meter Readings

The study assessed the accuracy of meter readings obtained from smart meters compared to traditional manual readings or conventional billing methods. Furthermore, it examined the system's reliability and consistency in collecting electricity consumption data over an extended period.

4.2 Billing Accuracy and Timeliness

In addition, this research evaluated the precision of billing calculations and invoicing procedures carried out by the system. Furthermore, we assessed the promptness of invoice generation and distribution to farmers, including compliance with billing schedules and deadlines.

4.3 Reduction in Administrative Overhead

Additionally, we have quantified the decrease in administrative duties linked to manual meter reading, data entry, and billing reconciliation. Moreover, we have evaluated the time and cost efficiencies attained through the automation of billing procedures.

4.4 Energy Consumption Insights

Furthermore, we have examined electricity consumption data gathered by the system to detect usage patterns, trends, and potential optimization opportunities. Additionally, we have emphasized insights derived from the system that can guide energy management decisions and foster efficiency enhancements in agricultural operations.

4.5 User Satisfaction and Adoption:

We intend to collect feedback from farmers, farm managers, and administrative personnel regarding their interactions with the system. Additionally, we aim to evaluate user satisfaction with system functionality, ease of use, and overall effectiveness in fulfilling their requirements.

5. Future Work

The incorporation of renewable energy sources, such as solar panels or wind turbines, within the billing system may be explored in subsequent phases in the future. Algorithms could be developed to precisely track energy generation and consumption from renewable sources in the future. This would enable farmers to optimize energy utilization and potentially mitigate electricity expenses. In future we must examine the potential application of predictive analytics and machine learning algorithms to predict electricity consumption trends on agricultural properties. We need to create models capable of forecasting energy requirements by leveraging historical data, weather predictions, crop cycles, and other pertinent variables. These models would facilitate the implementation of proactive energy management approaches. In future, we must explore the implementation of advanced metering infrastructure (AMI) to enable finer-grained and immediate monitoring of electricity usage by integrating smart grid technologies like smart meters, sensors, and communication networks to augment capabilities in data gathering, analysis, and control. We must investigate how blockchain technology could improve transparency, security, and efficiency within billing and transaction procedures by developing solutions based on blockchain for recording meter readings, generating invoices, and facilitating peer-to-peer energy trading among farmers or with utility providers. We must create user-friendly interfaces and mobile apps offering immediate access to electricity usage data, billing details, and energy management resources by integrating interactive elements like energy consumption dashboards, personalized suggestions, and alerts to enable farmers to make informed decisions while on the move.

6. Conclusion

The introduction of an Automatic Electricity Bill Meter Reading and Billing System signifies a notable advancement in the domain of smart farming, offering a multitude of advantages for agricultural operations. By amalgamating smart meters, data management systems, and billing software, this system has fundamentally altered the approach to monitoring, invoicing, and managing electricity consumption in farm settings. The outcomes derived from implementing the system have unequivocally showcased its efficacy and efficiency across various crucial domains. Firstly, there has been a marked enhancement in the accuracy of meter readings in contrast to conventional manual methods, ensuring dependable data acquisition for billing purposes. This heightened accuracy has translated into precise billing calculations, resulting in more transparent and equitable invoicing processes for farmers. Additionally, the automation of meter reading and billing procedures has alleviated administrative burdens, affording farmers more time and resources to dedicate to core agricultural endeavors. By pinpointing inefficiencies and opportunities for optimization, farmers can enact targeted measures to bolster energy efficiency, curtail costs, and mitigate environmental impact. This not only bolsters the financial sustainability of farming operations but also aligns with broader objectives of resource preservation and environmental stewardship.

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