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Design Performance of an Online Electricity billing network and Metering System in Nigeria

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Abstract

The Nigerian power sector faces significant challenges related to inadequate, disorganized electricity billing, and consumer relations management. Despite the adoption of prepaid billing meters, electricity tariff charges and collection remain major issues in major cities in Nigeria. The process of installment and payment is cumbersome and distressing for electricity consumers. They must physically visit banks to make payments and then take bank tellers to power control utility offices to confirm their power payment before they can recharge their meter cards. The primary motivation behind this research is to design and implement a convenient, cashless, automated, and transparent electricity metering, billing, and payment system. Leveraging the power of the internet of things (IoT), this proposed system enables power meters to communicate through SMS and email networks. Once fully implemented, it will allow electricity consumers to remotely recharge and pay their bills using their mobile phones and laptops seamlessly. The implementation of the Online Electricity Payment and Metering System in Nigeria aims to improve accountability, streamline processes, and facilitate payment for electricity across Nigeria. The proposed system was developed using HTML, CSS, PHP, and MySQL programming languages.

Keywords: Keywords: MySQL Programming Languages, Billing, Metering, HTML

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Introduction

Energy is very significant in every human activity in life for everyday living. An energy meter is a fundamental component of electricity supply. It is an instrument used to measure the consumption of electrical supply by electrical appliances in private homes or business areas [1, 13]. Energy meters are rated in kilowatt-hours (kWh). The kilowatt-hour represents the amount of electricity energy consumed by a heap of one kilowatt over a time of 60 minutes. Understanding and managing energy consumption is crucial for sustainable living. An energy meter fundamentally comprises voltage coils and current loops [2, 12]. The voltage loop

measures the instantaneous voltage (volts), while the current coils measure the instantaneous current (amperes). This electrical system enables both electricity consumers and the utility company to remotely monitor their electricity usage and consumption [3, 11, 18]. Additionally, it allows clients to remotely pay or "recharge" their meters. The system is efficient and effective against corruption since energy consumption can be estimated remotely by the electricity company and cross-checked with revenue earned over time. The electronic meter with a communication network, which in this case includes an SMS network and email network, is vital. The concept of remote electricity billing is unique. The Online Electricity Payment and Metering System aims to improve accountability, organization, and ease of payment for electricity in Nigeria. It enables the electricity management board to collect data on consumed units from energy consumers [7, 15], thereby enhancing how electricity is shared. Each consumer is provided with a unique energy meter equipped with a GSM modem, microcontroller unit, and display unit. Energy subscribers can conveniently pay through the online electricity system without queuing at banks. This system allows consumers to pay for what they can afford. The expansion in power consumption and the cost implications per kWh have driven the adoption of efficient energy appliances and monitoring. Metering is defined as a method for estimating and monitoring energy consumption and utilization [1, 16]. However, the Nigerian power sector faces challenges of inadequate and disorganized billing, as well as consumer relations. Despite the introduction of prepaid meters, energy tariff billing and collection remain problematic. [19] The payment process is cumbersome, requiring electricity buyers to visit banks and then take bank tellers to the power control utility office for capacity payment confirmation before recharging their meter cards. The primary goal of this work is to design and implement a convenient, cashless, computerized, and transparent electricity metering, billing, and payment system that eliminates the need to visit banks. SMS and email integration will notify users when payments are made and their meter cards are energized. A unique feature of this system is that once a consumer is disconnected or their allocated energy is exhausted, they can remotely pay from anywhere in the world using their mobile phones or laptops. Upon confirmation of the payment, they are automatically reconnected. Since this project operates on an internet network, the system can be accessed from any part of the country.

1. Concept of a Computerized Power Monitoring System

Primarily, a computerized system, or an automated system, is a collection of computer devices that collaborate to perform tasks or jobs within a company [6]. This system encompasses networks, hardware, software, and various connections. The pivotal role of the computer within this system is to collect, organize, store, display, and retrieve data/information [2]. The purpose of computerized systems is to address the most urgent office challenges and to organize data in a logically coherent manner, thereby assisting management in making informed decisions [3].

A computerized power monitoring system is composed of different components that oversee the distribution of electric power from one source to another. This system is

responsible for controlling the flow of power and calculating its relative value, whether in monetary, current, or voltage terms. It compiles and stores billing information, using data from various engineering sources, in a suitable format within a database that holds all the processed information [4, 5].

The computerized power monitoring system addresses the limitations of other remote monitoring techniques. The absence of a computer model can lead to complex and error-prone power distribution computations. In contrast, conventional storage methods like paper files not only take up substantial office space but also lack security. An automated system, on the other hand, manages information efficiently and ensures it is kept up-to-date. Such systems are usually managed by an Administrator proficient in computing.

2. Evaluation of Existing Systems

Manual electricity bill payments involve physically going to a utility office, bank, or authorized payment center to make payments in person [10, 14]. This traditional method remains common in areas with limited digital infrastructure or among customers uncomfortable with online payments. Manual payment offers direct interaction with service representatives, allowing customers to address concerns immediately. They also receive a physical receipt as proof of payment, [8. 12] which many find reassuring. However, manual bill payments can be time-consuming [5]. Customers must travel to payment locations, which may involve long waits, especially during peak times. This can be inconvenient for those with busy schedules or who live far from payment centers. Additionally, payment centers often have limited hours, adding to the inconvenience.

Manual payments may also incur higher costs compared to digital options [9, 17] including transportation expenses and potential fees for in-person transactions. Moreover, the manual entry of data during the payment process increases the risk of human error, such as incorrect account numbers or amounts, potentially causing delays or payment disputes. Limited payment methods at physical locations can also be a drawback for those who primarily use credit or debit cards [19, 14]. While manual electricity bill payments have certain advantages, such as accessibility and face-to-face customer support, they present significant limitations in convenience, efficiency, and cost. As utility companies and customers move towards digital payment solutions, the drawbacks of manual methods become more apparent [10, 12, 14], leading to a shift towards faster, more secure, and flexible payment alternatives.

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2.1 Challenges of the existing system

Human Error

- **Data Entry Mistakes:** Manual entry can cause errors, leading to inaccurate billing or incorrect customer info.[9, 16]
- **Calculation Errors:** Manual calculations can result in incorrect billing amounts, late fees, or discounts, causing customer dissatisfaction. [13, 20]

Time-Consuming

- **Slow Processing**: Manual billing takes longer than automated systems, causing delays in bill generation and payments.

- **Repetitive Tasks:** manually processing each bill, checking meter readings, and sending bills is labor-intensive and slows the process.
- **Higher Costs**
- **Labor Intensive:** Manual systems need more staff for data entry, billing, and customer service, increasing labor costs.
- **Physical Resources:** Printing, paper, and postage for manual billing add operational costs, especially when mailing bills.[13]

Lack of Real-Time Data

- **Delayed Billing**: Without real-time data, customers get outdated bills, making it hard to track actual usage and costs.
- **Slow Error Correction:** identifying and fixing errors is slower, leading to prolonged disputes and adjustments.

Limited Accessibility

- **Inconvenient for Customers:** Manual systems may lack online or mobile access, requiring customers to visit offices or contact support for billing details.[4]
- **Difficult to Scale:** Manual processes are harder to scale for large customer bases or expanding service areas.

Inefficient Record Keeping

- **Data Loss Risks:** Paper records can be lost, damaged, or misplaced, leading to incomplete customer histories.
- **Limited Data Analysis:** Analyzing usage patterns or customer behavior is challenging without digital records, limiting strategic decisions.

Security Issues

Data Vulnerability: Paper-based systems are more prone to unauthorized access, loss, or damage, risking customer privacy and data security

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Security Issues Data Vulnerability: Paper-based systems are more prone to unauthorized access, loss, or damage,

risking customer privacy and data security.
Fraud Potential: Manual systems may have weak controls, increasing the risk of fraud through record or bill manipulation

Requirements for the proposed system analysis
During the requirement analysis of the manual electricity payment system, functional requirements were identified. Face-to-face interviews and surveys were conducted with some staff members of PHCN Port Harcourt Discos to gather information about their daily operations. Additionally, their books and files were reviewed to extract details from their records. Other sources of information included textbooks, newspapers, magazines, the internet, and journals. The workflow of the existing system, including user registration and payments, was observed and analyzed. As a result, the need for a more efficient and automated system was recognized, featuring user management, meter management, billing and tariff calculation, payment processing, and consumption monitoring. Use-case diagrams were created to visualize the interactions between customers and the systems.
Design performance of Proposed System
A suggested online electricity billing system incorporates several fundamental components to simplify bill generation, improve customer access, and facilitate payments. Here's an overview of the crucial elements:
User Authentication and Profile Management
User accounts: Secure login for account access, bill viewing, and usage monitoring.
Profile Management: Users can update personal info, contact details, and account settings.

3. Billing and Payment System

Bill Generation: Creates monthly bills based on real-time consumption data.
Payment Gateway Integration: Secure options like credit cards, bank transfers, and e-wallets.
Automatic Billing & Reminders: Offers automatic deductions or email reminders to avoid missed payments.
3.3.2.3 Admin Portal
User Management: Admins can manage user accounts, billing adjustments, and handle complaints.

Data Security and Compliance

Data Encryption: Ensures secure transactions and data handling.
Compliance with Regulatory Standards: Adheres to energy and data privacy regulations.
Audit Trails: Logs system actions for accountability and transparency.

System Design; Logical Design

The logical design of the E-Billing System outlines how the system operates and interacts at an abstract level. It emphasizes the flow of information, essential components, and the interconnections between different parts of the system, without focusing on specific technologies or physical implementations.

Input Design for E-Billing System

The input design for the E-Billing System focuses on how administrators or authorized users enter billing information into the system to ensure efficient and accurate management of user payments. The system allows the addition of bills for specific users by gathering all relevant details.

User Selection/Input Form
Search or Drop-Down Menu:
Administrators can search for or select a user from a list of registered users.
Text Input Fields for User Details:
Name: Auto-filled based on user selection.
User ID: Automatically retrieved after user selection.
Bill Details Input
Bill Amount:
Numeric input field for entering the total amount due.
Validation to ensure no negative or invalid values are entered.
Submit and Reset Options
Submit Button:
To save the bill details and link it to the selected user.
This design ensures that bill entries are accurate, user-specific, and well-documented, minimizing errors and facilitating seamless payment tracking.
3.4.1.2 Output Design
The output design focuses on how the system delivers results and bill payment information. The system should clearly present payment information.
Payment Information Display:
Display of total bills: the system should be able to display the total bills paid by all the customers.
Display of paid bills: after payment of bill by customer, the system should be able to output or display bills paid by each customer to the administrator.
Display unpaid bills: for unpaid bills the system should also be able to display unsettled bills by customer to the admin.

3.4.2 Activity Diagram

An activity diagram for an electric billing system outlines the workflow of generating and managing electricity bills, ensuring efficient processing and accuracy. Figure 1 illustrates the activity diagram of the e-billing system.
Figure 1 shows the activity diagram of the system showing the various activities in the system from user authentication login to customer bill payment, bill viewing, and admin post bills. The Use cases diagram in figure 2 involve tasks such as View Bill (paid and unpaid), Pay Bill, post Bill. The system boundary defines what the billing system handles, such as bill calculation and payment processing

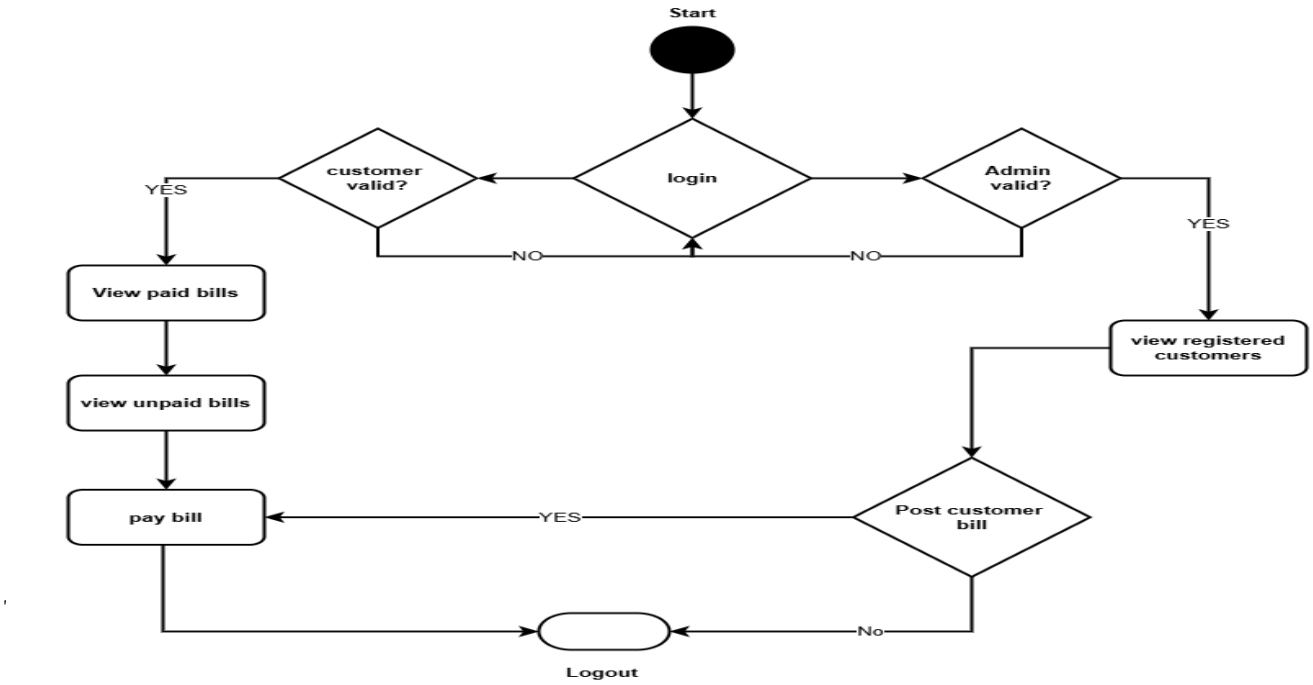

Figure 1 Activity flowchart of E-billing system

Figure 1 illustrates how customers and administrators use the system to manage billing processes effectively

3.1 Use Case network system

In an electric billing system, a Used Case pseudo-code visually represents how users interact with the system to manage electricity bills. Figure 2 shows the use-case pseudo-codes of the E-billing system. The class model for E-billing network System in figure 3 features classes such as Customer (which holds details like ID, name, and address), Bill (containing billing details like the amount due and payment status), and admin (which holds details like email and password). This diagram helps visualize the interactions between these entities to facilitate efficient system design.

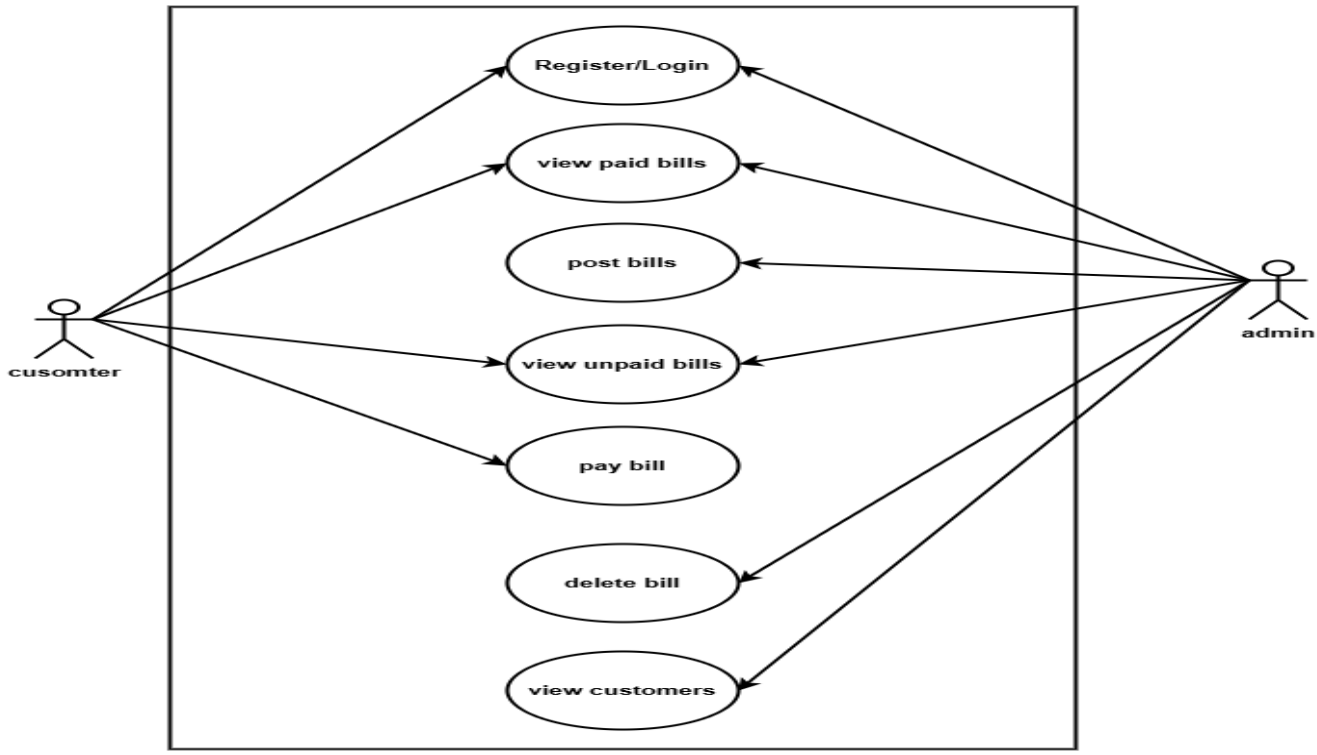

Figure 2 Use-case pseudo-codes of E-billing system

Design technique
The Waterfall Model is a structured, linear approach to software development, where each phase must be completed before the next phase begins. It is ideal for projects with well-defined requirements and stable environments, such as the development of an e-billing system using PHP.

Phases of Waterfall Model in E-Billing System:
Requirement Analysis: In this phase, detailed online findings were conducted with stakeholders (e.g., end-users) to understand the specific needs and functionalities required for the e-billing system. Requirements related to payment processing, user access, and reporting are gathered and documented

System Design: Based on the gathered requirements, the system's architecture is designed. This includes designing the database schema (using MySQL), the user interface (HTML and PHP), and the overall system flow.
Implementation (Coding): The actual development of the e-billing system takes place during this phase, using PHP for backend development. The system includes functionalities such as bill generating and payment processing.
Testing: After the implementation, the system undergoes rigorous testing to ensure all functionalities work correctly. Unit tests, integration tests, and system tests are conducted. Common issues like bugs, errors, and security vulnerabilities are identified and fixed.
Deployment: Once testing is complete, the e-billing system is deployed to a

production environment where it will be used by clients and internal users. Proper server configurations (using Laragon WAMP servers) are made to ensure smooth operations
Maintenance: Post-deployment, the system enters the maintenance phase, where regular updates, bug fixes, performance tuning, and adding new features are performed based on user feedback and evolving business requirements.

The Waterfall Model is highly useful for the e-billing system, as it provides a clear and sequential approach, ensuring that each phase is fully addressed before moving on to the next, minimizing confusion and rework. Figure 4 shows the waterfall approach.

This section provides an explanation of the system implementation process for the E-Billing System. It begins by discussing the features and the choice of implementation technology, highlighting the decision to use PHP and MySQL for their efficiency and suitability for dynamic web applications. The chapter outlines the system's key features, including user registration, bill generation, payment tracking, and administrative dashboards for managing billing records. It then elaborates on the system testing strategies employed during development, such as unit testing to verify the functionality of individual modules and integration testing to ensure seamless interactions between system components. Furthermore, the chapter specifies the target computer requirements for deploying the system, detailing the necessary hardware and software configurations for optimal performance. Finally, the chapter concludes by showcasing the results of the implemented system, demonstrating its functionality and success in meeting the project's objectives.

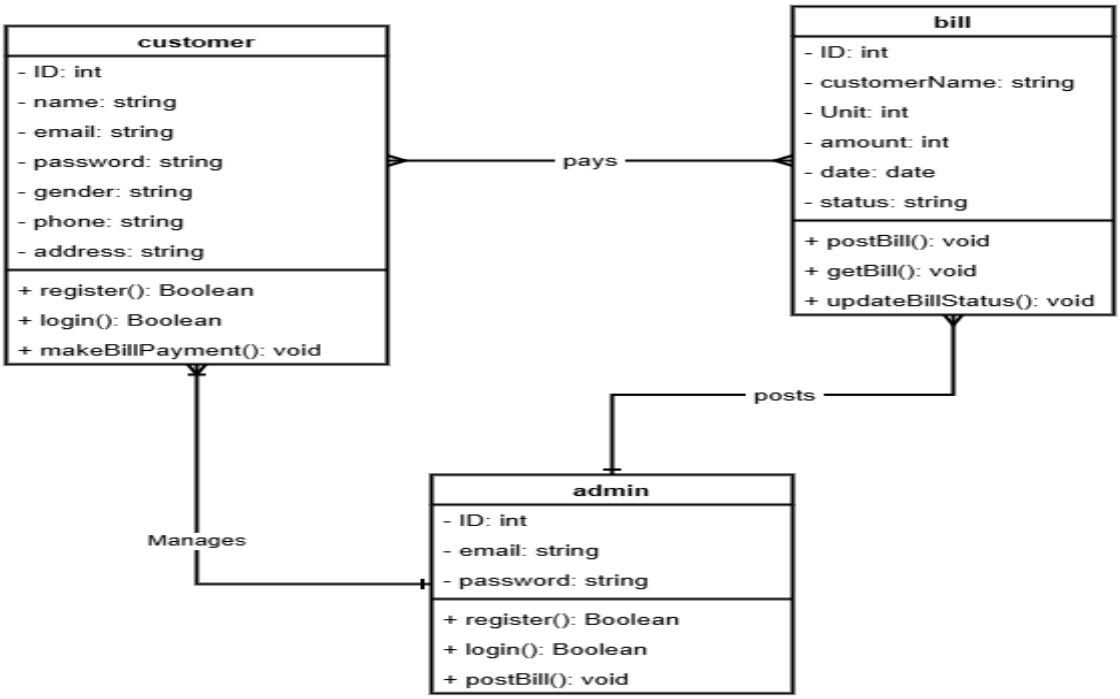

Figure 3 Class model for E-billing network System

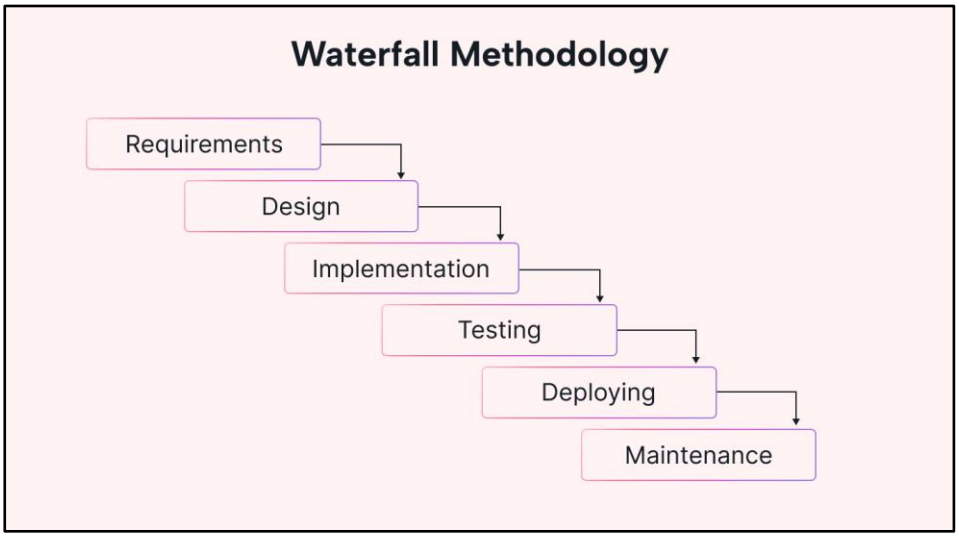

Figure 4 Waterfall

Features and Choice of Implementation Technology

The E-Billing System leverages PHP, HTML, and MySQL as its core technologies to deliver an efficient, user-friendly, and scalable solution. These technologies were chosen for their ability to work seamlessly together, providing a robust foundation for managing billing processes, user interactions, and data storage.

Choice of Implementation Technology

PHP (Hypertext Preprocessor)

PHP acts as the server-side scripting language to handle dynamic content and backend logic, facilitates secure data processing, bill generation, and integration with MySQL and provides a cost-effective, open-source solution with a strong developer community for support.

HTML (Hypertext Markup Language)

HTML builds a structural framework for the web pages, ensures a clean and organized interface for presenting billing information and user interactions and is also compatible with all major browsers and adaptable to responsive design requirements.

MySQL

MySQL serves as the database management system for storing user data, billing records, and transaction details, offers robust querying capabilities for efficient data retrieval and management and ensures data integrity and security while supporting scalability for future expansion.

By combining PHP, HTML, and MySQL, the E-Billing System achieves a seamless integration of front-end and back-end functionalities. These technologies enable the system to handle complex billing processes, provide a user-friendly interface, and ensure secure data management, making them ideal for the development and implementation of this application.

4..2 Features of the E-Billing System

User Registration and Authentication

Allow users to register and log in securely.

Role-based access control ensures that different user roles (e.g., admin, customer) have appropriate permissions.

Bill Generation and Management

Dynamically generates bills based on user inputs or system triggers.

Enables administrators to add, update, and delete billing records.

Payment Processing

Tracks payments made by users and updates billing statuses in real-time.

Supports integration with external payment gateways for seamless online payments.

Comprehensive Reporting

Provides detailed reports on user payments, outstanding bills, and system usage statistics.

Responsive and Intuitive User Interface

Ensures ease of use across devices, including desktops, tablets, and smartphones.

Features a clear layout with intuitive navigation for users to manage their bills effortlessly.

4.3 System Testing Strategies

System testing is a critical phase in the development of the E-Billing System, ensuring that all components function as intended and interact seamlessly to provide a reliable and efficient solution. The testing process encompasses two main strategies: Unit Testing and Integration Testing, each addressing specific aspects of the system's functionality.

4.3.1 Unit Testing

Unit testing focuses on verifying the functionality of individual components or modules of the E-Billing System.

Each unit, such as user registration, bill generation, payment processing, or notifications, is tested in isolation to ensure it performs its intended task correctly.
Implementation in the E-Billing System
Testing the user registration form to ensure data is validated correctly before being stored in the database.
Verifying the bill generation module to confirm it calculates amounts accurately based on user input.
Ensuring the payment processing function correctly updates payment statuses in the database.
4.3.3 Integration Testing
Integration testing evaluates how different modules of the E-Billing System work together. It ensures that data flows correctly between components and that the system functions as a cohesive whole.
4.3.4 Implementation in the E-Billing System
Verifying the connection between the user registration module and the database to ensure new users are correctly stored and retrieved.
Testing the interaction between the bill generation and payment processing modules to confirm payments update corresponding bills accurately.
Ensuring the notification system triggers correctly based on billing events, such as overdue payments or successful transactions.
Target Computer System Requirements
To ensure smooth performance of the E-billing system, it is essential that the user's computers meet certain hardware and software requirements.
Hardware Requirements
Memory (RAM):
At least 4 GB of RAM is required, with 8 GB or more being recommended. Adequate memory is crucial for running the web browser and any other applications simultaneously without performance degradation.
Processor:
A modern multi-core processor (e.g., Intel Core i7 or equivalent) is recommended. This ensures that the system can handle the processing demands of the web application, including database queries and user interactions, without lag.
Network Connection:
A stable broadband internet connection (minimum 3 Mbps download speed) is necessary for accessing the system efficiently. This ensures fast loading times and smooth interactions with the system.
Display:
A monitor with a minimum resolution of 1366x768 pixels is required to ensure that the web interface displays correctly and is fully usable. Higher resolutions are recommended for better clarity and more workspace.

4.4.2 Software Requirements
Operating System:
The system is compatible with most modern operating systems, including:
Windows 10 or 11.
MacOS 10.13 (High Sierra) or later
Linux distributions with a modern kernel (e.g., Ubuntu 18.04 or later)
Web Browser:
The system is designed to work optimally with the latest versions of major web browsers, such as:
Google Chrome (recommended)
Mozilla Firefox
Microsoft Edge
Safari (for macOS users)
The browser must support HTML5, CSS3, and JavaScript, which are essential for rendering the web interface

and ensuring full functionality of the system.

Software Dependencies:

While end-users typically do not need to install specific software, the server hosting the E-billing system should have the following software:

Web Server: Apache or Nginx

PHP: Version 7.4 or later

MySQL: Version 5.7 or later

This section shows a cross section of the implemented system, showing some features and unique functionalities on display.

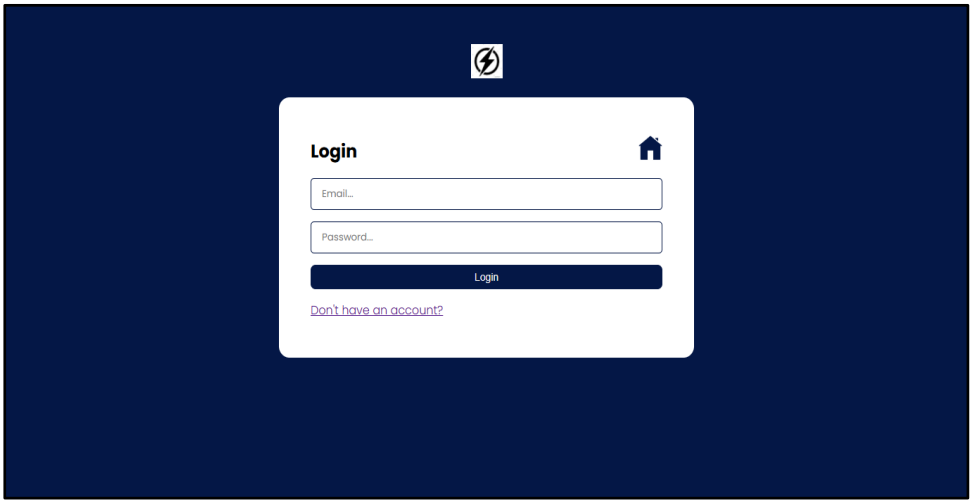

Figure 5 Customer Login page

Figure 5 shows the login page of the implemented system, allowing customers to provide their email and password to log into the system and proceed with paying bills and checking bill payments details.

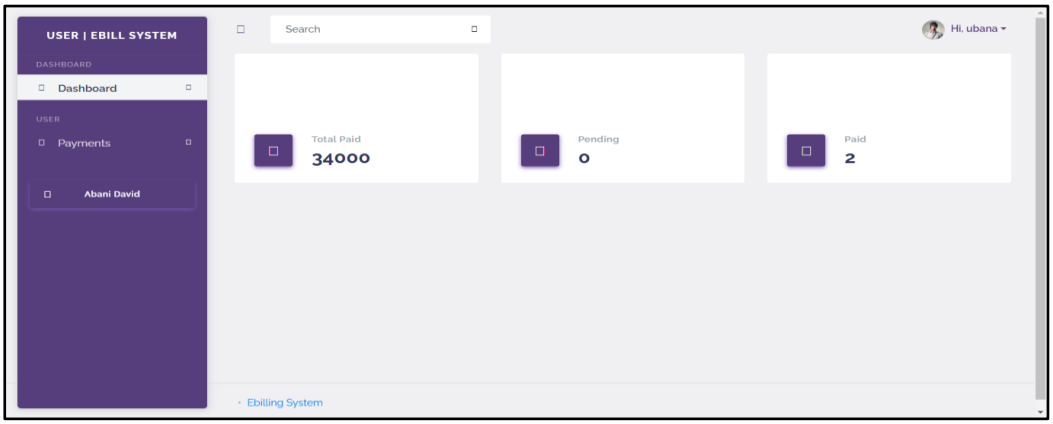

Figure 6 Customer dashboard page

Figure 6 shows customers' dashboard page, showing unique features like, total bill paid, view payment logs, links to logout.

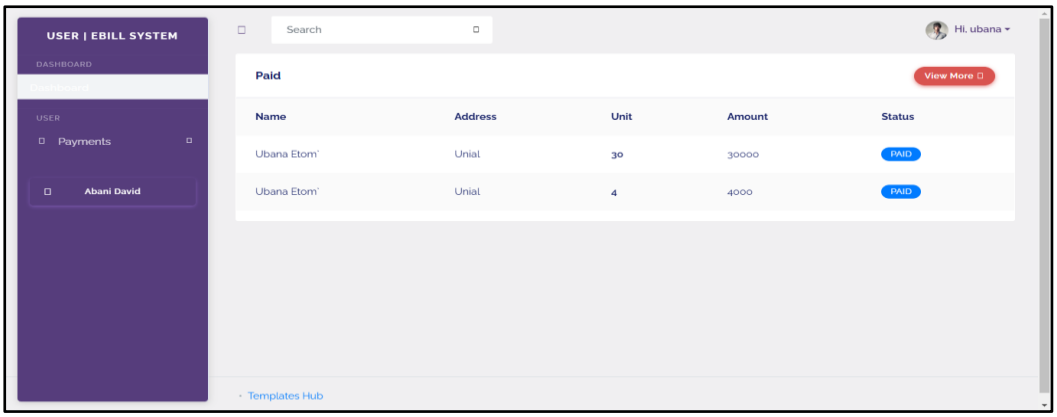

Figure 7: Bill payment page

Figure 7 shows the bill payment page, where the user can view all the bill payments made for overtime and see billing status accordingly. While Figure 8 shows the admin dashboard page, admin can view total bills paid, total customers and pending bills to be paid, Figure 9 shows the customer display page, here the admin can view all the available customers in the system and Figure 10 shows the add bill page where the admin can post electric bills to selected customer, then the customer can proceed to make payments for that bill.

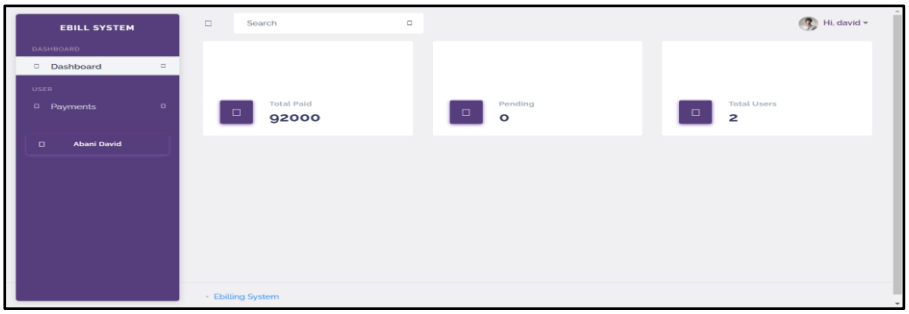

Figure 8: Admin Dashboard page

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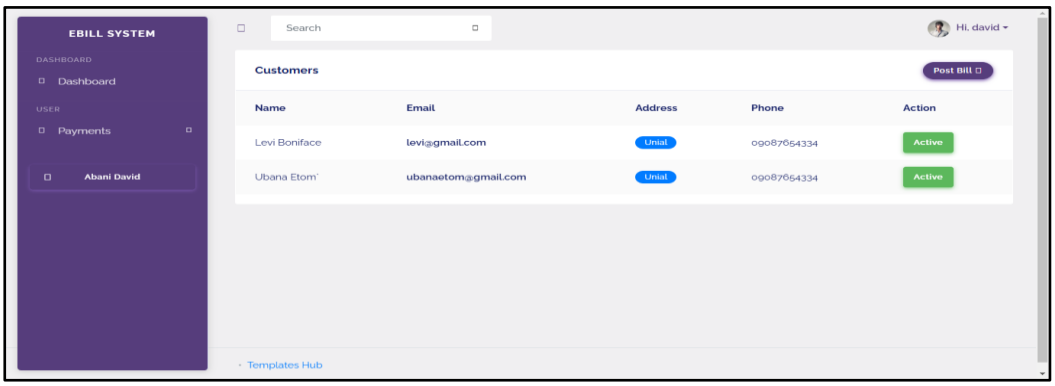

Figure 9 customer display page

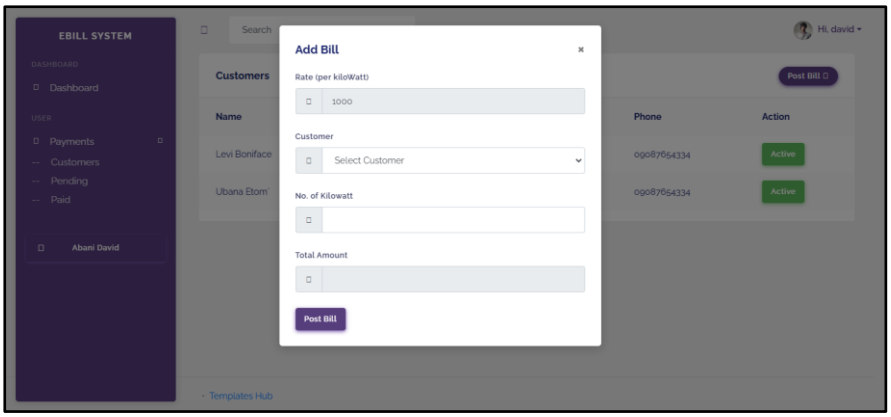

Figure 10 add bill page

Discussion

- **Login page**: the login page of the implemented system, allowing customers to provide their email and password to log into the system and proceed with paying bills and checking bill payments details.
- **Customer Dashboard page**: customer dashboard page, showing unique features like, total bill paid, view payment logs, links to logout.
- **Bill payment page:** the bill payment page, where user can view all the bills he/she has made payment for over time and also see billing status.
- **Admin dashboard page:** the admin dashboard page, her admin can view total bills paid, total customers and pending bills to be paid.
- **Customer display page:** the customer display page, here the admin can view all the available customers in the system.
- **Add bill page:** the add bill page where the admin can post electric bills to selected customer, then the customer can proceed to make payments for that bill.

Conclusion

The primary goal of this research was to design and develop an online E-Billing System that would streamline the billing process, enhance user access to billing services, and improve overall operational efficiency. By utilizing the Waterfall methodology and implementing the system with PHP, MySQL, and HTML, the Paper aimed to deliver a robust and user-friendly solution to address key challenges faced in traditional billing processes.

The developed system efficiently handles core billing functions such as user authentication, bill generation, payment processing, and receipt issuance. It has proven to be a reliable tool for managing daily billing operations, offering seamless experience for both administrators and users. While there are opportunities for further enhancement, particularly in scalability, security, and user experience, the research has established a solid foundation that meets its initial objectives and makes a significant contribution to modernizing billing management systems.

Recommendation and Feature Research

The development of the E-Billing System successfully addressed the core challenges of traditional billing processes, such as inefficiencies, delays, and data inaccuracies. However, there are several areas where the system can be improved or expanded to enhance its functionality, scalability, and security. Based on the findings of this research, the following recommendations and directions for future research are proposed

Scalability Enhancements

Integration with External Systems

Advanced Security Features

Mobile Application Development

Enhanced Analytics and Reporting

User Experience Improvements

Support for Multi-Currency and Localization

By addressing these areas, future researchers and developers can build on the foundation of this E-Billing System, ensuring it remains a robust, secure, and user-centric solution for modern billing needs.

Conflict of Interest:

The authors hereby declare no conflicts of interest. No financial or personal relationships with other people or organizations could inappropriately influence the content of this paper.

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