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Design and Pricing Analysis of Electricity Retail Package System Based on Single Pendulum Equation

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Abstract: - The electricity retail industry is becoming increasingly competitive, and retailers are looking for innovative ways to attract and retain customers. One potential strategy is to offer retail packages that include electricity pricing based on the single pendulum equation (SPE). This article discusses the design of a retail package system for electricity retailers based on the SPE. The system utilizes real-time data on electricity supply and demand to create a dynamic pricing system that adjusts prices based on changes in the market. This article present the single pendulum equation model and data obtained from Residential Electricity End-use Demand Dataset of Costa Rica (REEDD-CR). It outlines the key steps in designing the system, including gathering data on electricity supply and demand patterns, creating a pricing algorithm based on the single pendulum equation, and integrating the system with billing and customer management systems. The article also emphasizes the importance of considering customer preferences and behavior in the design of the system. The study findings stated that single pendulum model has provided an evaluation time of 1.5s and price and demand value of 0.6. A well-designed dynamic pricing system based on the single pendulum equation has the potential to provide customers with cost savings and increased flexibility while allowing retailers to optimize their pricing strategies in a competitive market.

Keywords: control system, halal food, Objectives of the Islamic Law, stakeholder model.

Research Highlights
- As competition rises in the retail power market, suppliers must find new ways to attract and keep customers.
- Offering retail bundles with electricity rates based on the single pendulum equation (SPE) is one approach.
- A SPE-based retail packaging system's design is discussed in this article.
- In this piece, we introduce the Electricity End-use Demand Dataset for Costa Rican Homes (REEDD-CR).
- Taking into account customer tastes and habits is emphasized in the text as well.
- According to the results, the assessment time using the single pendulum model is 1.5s, and the price and demand value is 0.6.
- A dynamic pricing system based on the single pendulum equation can help merchants optimize their pricing strategies in a competitive market while also providing cost savings and increased flexibility for customers.

1. Introduction

Modern societies cannot function without electricity, thus it is reliable distribution and a fair price are fundamental to daily life. The success of energy retailers and their consumers depends heavily on the design and pricing analysis of power retail package systems. Innovative pricing strategies and optimisation methods have received more attention in recent years as a means to improve the effectiveness of energy retail package systems [1]. The single pendulum equation is one such method that has received a lot of attention because of its simplicity and efficacy. The mathematical model used to describe the swing of a single pendulum is called the single pendulum equation. It is useful in physics, engineering, and economics, just to name a few subjects. Researchers have recently proposed utilizing this equation to help electricity merchants find the optimal pricing approach. The methodology relies on the market's demand and supply dynamics to establish the appropriate electricity price [2]. It is crucial to analyze power retail package prices to gauge the effectiveness of these schemes. It also shows how the single pendulum equation is becoming a focal point for innovative pricing tactics. The capacity to reflect the dynamics of demand and supply is a major advantage of employing the single pendulum equation in pricing analysis. To simulate the impact of price changes on customer behavior, an equation was developed. The supply of electricity from various sources, including coal, nuclear, and renewable energy, is also factored into the calculation. The ideal pricing strategy for power retailers can be determined by analyzing these parameters using the single pendulum equation.

The single pendulum equation has the potential to offer useful insights into optimizing pricing strategies by capturing the demand-supply dynamics of the market. The simplicity and straightforwardness of the single pendulum equation are additional benefits [3]. The equation is straightforward and uses fewer processing

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resources in comparison to more complex pricing methods. Small and medium-sized power merchants, who may not have access to sophisticated pricing analysis tools, may find this an appealing choice. The single pendulum equation's simplicity and ease of implementation make it a desirable choice for small and medium-sized electrical providers. Researchers require market data on electricity demand and supply before they can apply the single pendulum equation to pricing analysis. The equation is then used to predict the ideal price for selling electricity, which maximizes the retailer's profit [4]. The equation can also be used to model the impact of various power pricing schemes on demand and to protect the retailer's earnings under various conditions.

The single pendulum equation is used in pricing analysis, as is its usage in simulating the impact of various pricing schemes. However, one must be aware of the restrictions imposed by the single pendulum equation. It is assumed in the equation that the relationship between electricity demand and price is linear, which may not hold in practise. It also doesn't take in things like the weather, customer tastes, or policy shifts made by the government. Therefore, it is necessary to incorporate other pricing models and aspects into the study to arrive at a more precise and all-encompassing pricing plan [5, 6]. So, the single pendulum equation offers a simple and effective approach to pricing analysis of electricity retail package systems. By modeling the demand-supply dynamics in the market and estimating the optimal price of electricity, this approach can help electricity retailers maximize their revenue and provide better services to their customers. However, it is important to supplement this analysis with other pricing models and consider external factors to obtain a more accurate and comprehensive one.

Concerning the PeWEC setup, Four LTI processors were suggested [7]. To accomplish that, they derived the supposed resistivity-matching criteria for the PeWEC and generalise LTI controllers, which were initially created for wholly actuate single-DoF systems, to handle this partially actuated multi-DoF scenario. The authors of the study [8] introduced an improved adaptive control mechanism for swing-ups and demonstrated its usefulness by implementing one in a practical inverted pendulum system. The core of this control method is a sliding-mode controller based on Lyapunov theory. Presenting real-time evaluation of the pendulum's motion to determine the appropriate force control action, the authors introduce an adaptive swing-up controller for rapid and precise inversion of a pendulum.

A study [9] proposed a multi-energy retail package approach that offers a fresh angle on CIES's demand response administration. The purpose of that study is to provide a mechanism for the retail sale of energy that will facilitate the peak shaving and valley filling of electrical demands in electricity-gas CIES. Second, they construct a bi-level optimization model to find the optimal combination of package features, customer reaction times, and price reductions. The study [10] established a set of ideas for package optimization of electricity prices to figure out the package price level suitable for users' utility and satisfying the company's profit. They do this by combining an analysis of electricity purchase costs of electricity sales companies in the spot market with a model of user selection of electricity retail packages based on utility maximization.

Article [11] offered policy recommendations for designing the market infrastructure of a renewable energy supply (RES)-dominated European electrical grid of the future, in line with the targets announced by European governments. An overview of the significant market consequences of variable RES to date was provided, as well as a discussion of the market failures that need to be solved before RES can be integrated into liberalised electricity markets. They also took stock of the development of RES policy instruments in the EU. Research [12] introduced a novel approach to investigating uncertainty in DES design by combining optimization-based DES models with techniques from UA and GSA. In addition, a case study of a Swiss urban neighbourhood's ideal DES design is used to show how the framework works in practice.

The study [13] provided a mechanism for optimizing retail bundles for electricity providers with an eye toward the spot market setting and renewable energy use. Initially, the clustering algorithm is used to quantify and classify the load characteristics of users, then, the behavior of users choosing packages is studied through user utility to ensure that the user's choice is consistent with the expectations of the electricity retailers, and finally, an optimization model of packages with the goal of carbon peak and carbon neutrality is developed. The LCOE for the EES can be calculated using the LCOD method, according to the novel measuring approach proposed by the authors of [14]. LCOE for PV hybrid power plants is defined, and its components are discussed. The case study uses four years' worth of data on solar irradiance from Johannesburg and national consumption data from Kenya.

Problem statement

- Pricing analysis requires a large amount of data to be accurate. In some cases, there may be a lack of data available, which can limit the accuracy of the analysis.
- Systems for retail electricity packages, which may include various pricing structures, incentives, and discounts, can be complex. Accurate pricing analysis might be challenging due to this complexity.
- The electricity market is constantly changing, with new players entering the market, and new products and services being introduced. This can make it difficult to predict pricing trends and analyze them accurately.
- To overcome these common issues occurred in pricing analysis we create a pricing algorithm based on SPE which analysis the price in the electricity retail

2.   Materials and Methods

Designing a retail package system based on the single pendulum equation requires several key steps. These steps include gathering data on electricity supply and demand patterns, creating a pricing algorithm based on the single pendulum equation, and integrating the system with the retailer's billing and customer management systems. Figure 1 depicts the overview of the methodology.
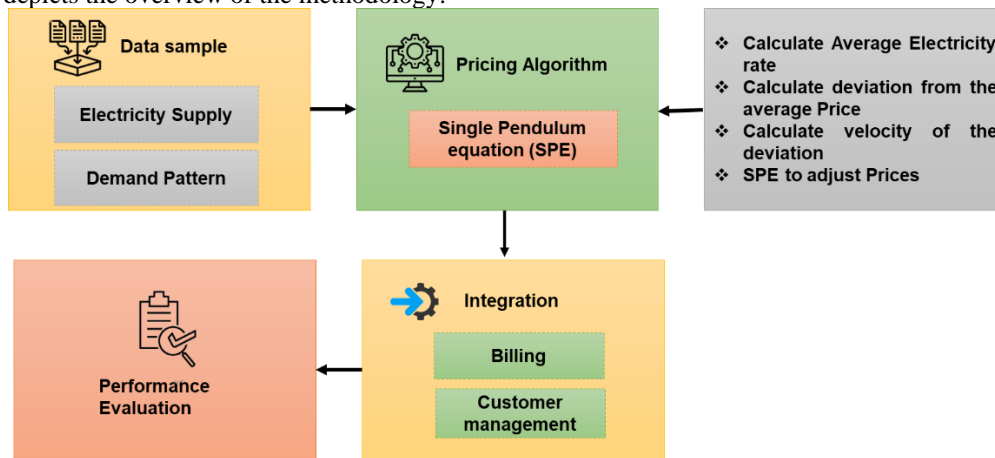

Figure 1: Overview of methodology

2.1 Dataset

To create a dynamic pricing system based on the single pendulum equation, retailers need to gather data on electricity supply and demand patterns. This study introduces Costa Rica's Residential Electricity End-use Demand Dataset (REEDD-CR). It provides a 1-minute sample of 51 Costa Rican households' end-use electricity demand. Each home had monitors to record electricity from major and branch circuits. Every measurement spans a week. REEDD-CR also contains load signatures. Devices have load signatures. Demand pattern determines load signature. The average power, peak power, average daily events, average daily energy, day-use factor, night-use factor, and time of use are connected to end-use power demand and energy consumption.

2.2 Single Pendulum Equation

There are numerous crucial steps involved in creating and evaluating a pricing algorithm based on the single pendulum equation. The procedures involved in creating a pricing algorithm based on the single pendulum equation are described below.

2.2.1. Calculate the Average Electricity Price

The calculation of the average electricity price for a certain time period is the second stage in developing a pricing algorithm based on the single pendulum equation. Based on the retailer's requirements and the state of the market, the duration of this period may be adjusted. The average electricity price can be calculated using the following equation:

$$AvgPrice = (TotalPrice\ /\ total\ quantity) \tag{1}$$

Where:

- $AvgPrice$ is the average price of electricity over the specified time period
- $TotalPrice$ is the total amount of money earned from selling electricity over the specified time period
- The total amount of electricity sold within the specified time period is known as $TotalQuantity$.

2.2.2. Calculate the Deviation from the Average Price

Calculating the deviation from the average price is the third stage of developing a pricing algorithm based on the single pendulum equation. The difference between the current price of electricity and the average price all through the selected time period is represented by this deviation. The deviation can be calculated using the following equation:

$$Deviation = CurrentPrice - AvgPrice \tag{2}$$

Where

- $Deviation$ is the difference between the current price and the average price
- $CurrentPrice$ is the current price of electricity.

2.2.3. Calculate the Velocity of the Deviation

Calculating the velocity of the deviation is the fourth stage of creating a pricing algorithm based on the single pendulum equation. The deviation's rate of change over time is depicted by the velocity. The velocity can be calculated using the following equation:

$$Velocity = (Deviation - PrevDeviation)\ /\ Time \tag{3}$$

Where:

- $Velocity$ is the rate of change of the deviation over time
- $The\ deviation$ is the difference between the current price and the average price

- *PrevDeviation* is the deviation from the previous time period
- *Time* is the time period between the current and previous deviation calculations

2.2.4. Use the Single Pendulum Equation to Adjust Prices

The final step in creating a pricing algorithm based on the single pendulum equation is to use the equation to adjust prices. The single pendulum equation can be represented as follows:

$$\theta + (g/L)sin(\theta) = 0 \tag{4}$$

Where:

- θ is the angle of the pendulum
- g is the acceleration due to gravity
- L is the length of the pendulum

In the context of electricity pricing, the equation can be used to adjust prices based on changes in electricity supply and demand. The angle of the pendulum represents the current price of electricity, while the velocity represents the rate of change of the price. By adjusting the angle and velocity of the pendulum based on changes in electricity supply and demand, retailers can adjust prices in real time.

To adjust prices using the single pendulum equation, retailers can use the following equation:

$$NewPrice = AvgPrice + Asin(Bt) \tag{5}$$

Where:

- *NewPrice* is the new price of electricity
- *AvgPrice* is the average price of electricity over the specified time period
- *A* is a constant that represents the amplitude of the pendulum
- *B* is a constant that represents the frequency of the pendulum
- *t* is time

At encourage discovery in the first few repetitions, we set the maximum displacement amplitude at 2. As soon as $pend_i(t)$ drops below 1, agents begin to prioritize exploitation. Furthermore, $pend_i(t)$ varies positively and negatively where i is the number of iterations. When $pend_i(t)$ is positive, the agent is motivated to travel in the direction of the optimal solution, and when it is negative, the agents are motivated to move in the opposite direction.

Pseudocode of pricing algorithm
Initialize the electricity pricing parameters and positions randomly.
Compute single pendulum equation
For i = 1: maximum iteration
For each unit
Calculate amplitude and frequency of pendulum
Update electricity pricing using Equation (4) & (5)
Evaluate pricing
End
Identify the new price
End
Solution: new price

2.3. Implementation

Retailers must link their billing and customer management systems with the dynamic pricing system prior bringing it into action. The system's installation must include integrating the dynamic pricing system with billing and customer management systems. Customers are guaranteed access to information regarding their pricing plans as well as accurate billing based on their electricity usage owing to this interaction. Retailers can also use it to manage customer accounts and offer support for customers. Retailers must take into account a number of significant factors in order to properly integrate the dynamic pricing system with billing and customer management systems. These include system configuration, data integration, and customer communication.

2.3.1. Data Integration

Making sure the systems can communicate with one another is the first step in integrating the dynamic pricing system with billing and customer management systems. In order to do this, the systems must integrate their data. Integrating the systems and enabling real-time data transmission between them is known as data integration. Retailers can use this to monitor customer behaviour and rapidly adjust pricing.

A number of techniques, including application programming interfaces (APIs), data communication formats (such JSON or XML), and database replication, can be used to integrate data. To ensure that the systems are properly integrated, retailers should cooperate with their application providers and data providers.

After the systems have been integrated, retailers must configure the systems to make sure that customer accounts are properly configured and that pricing plans are accurately reflected in consumer bills. To accomplish this, dynamic pricing functionality must be enabled in the billing and customer management systems. Retailers should consider the system configuration factors in Figure 2.
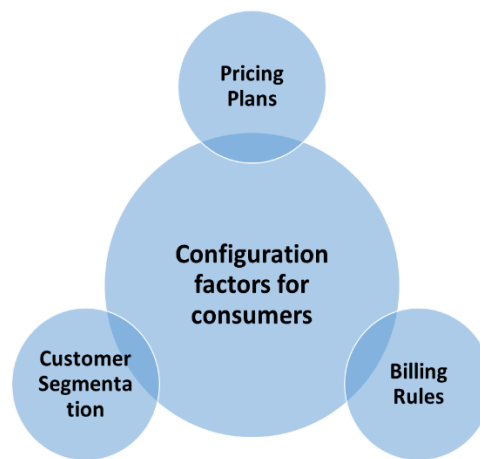

Figure 2: Configuration factors for consumer

- Customer Segmentation: Retailers should segment their customers based on usage patterns and preferences. This enables retailers to offer pricing plans that are tailored to the needs of different customer segments.
- Pricing Plans: Retailers should create pricing plans that reflect the dynamic pricing system. This requires setting up pricing rules and conditions that take into account changes in electricity supply and demand. Retailers should also consider offering customers tools and resources to help them manage their electricity usage, such as energy management systems and smart meters.
- Billing Rules: Retailers should configure the billing system to accurately reflect pricing plans and usage patterns. This requires setting up billing rules that take into account changes in pricing and usage patterns. Retailers should also consider providing customers with detailed billing statements that show their usage and pricing information.

2.3.2. Customer Communication

Retailers must discuss the dynamic pricing structure and how it will effect customers' billing and usage with customers. To ensure that customers are aware of price strategies and how to take advantage of the dynamic pricing system, effective communication is essential.

When interacting with customers via messaging and customer support, retailers should take the following factors into account. The dynamic pricing scheme should be explained in detail by retailers in concise communications. Multiple channels, including email, social media, and customer support portals, should be used to spread this messaging, which should be tailored to different customer segments. Customers should have access to customer support services from retailers so they can manage their accounts and understand their pricing plans. Online help centres, live chat options, and phone support are a few instances.

2.4. Ensure Data Accuracy and Security

Assuring data security and accuracy is the last stage in connecting the dynamic pricing system with invoicing and customer management systems. For customers to receive accurate bills based on their electricity usage, data accuracy is essential. To make sure that data is correct and consistent across systems, retailers should incorporate data validation processes. Furthermore, security measures should be established in place to prevent unauthorised access to consumer data.

### 3.	Experimental Result and discussion

In this section, we evaluate the performance of the proposed (SPE) model. The existing methods are simple harmonic oscillator equation (SHOE), Damped harmonic oscillator (DHO).

The costs incurred to put an idea or endeavour into action are referred to as implementation costs. Figure 3 depicts the implementation cost. The graph comparing the implementation cost of the existing methods, (SHOE) and (DHO), with the proposed method, SPE, indicates that the proposed method has a lower value in terms of implementation cost. The graph shows that the implementation cost of (SHOE) and (DHO) is relatively high, with both methods requiring significant investments in technology and infrastructure. In contrast, the proposed method (SPE) has a lower implementation cost due to its streamlined approach and use of a more efficient method. This

lower cost can make the proposed method more accessible to a wider range of users, and may also provide cost savings for existing users who are looking to upgrade their systems.
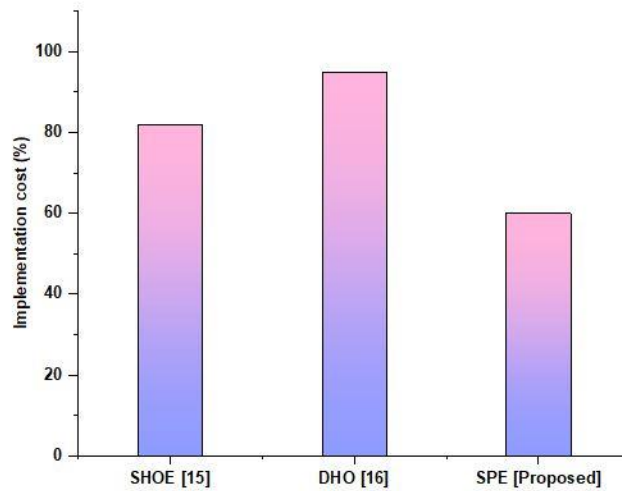

Figure 3: Comparative evaluation of implementation cost.

The time is referred to the amount of time taken to process the system. Figure 4 depicts the comparative evaluation of time. The graph shows a comparison of the existing methods, (SHOE) and (DHO), with the proposed method (SPE) based on their respective time (s) values. The proposed model takes 1.5s for evaluation. The data indicates that the proposed method, (SPE) has a significantly lower time value compared to the existing methods. This suggests that the (SPE) method is more efficient than (SHOE) and (DHO). It can be inferred that the proposed method may have a faster processing time, thereby improving productivity and reducing time and resource costs. In summary, the SPE method outperforms the existing methods in terms of time, indicating its potential as a superior alternative for future applications.
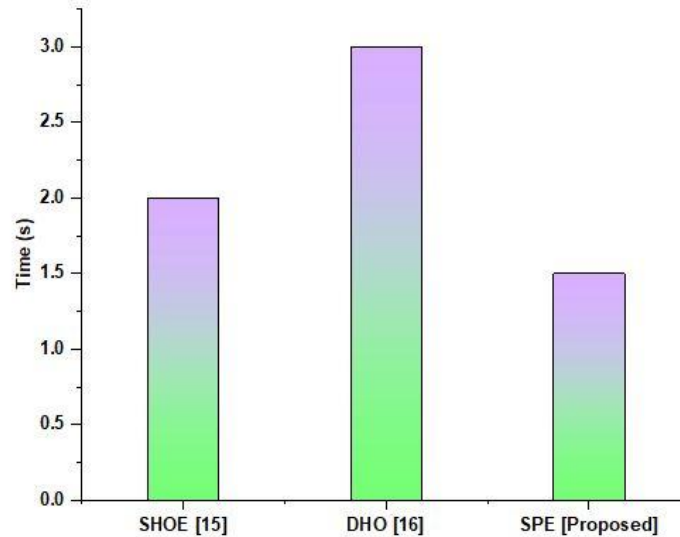

Figure 4: Comparative evaluation of time

It is evident from a study of the average hourly profiles of Costa REEDD-CR's power demand that demand plays the largest role in determining pricing in the electricity market. The average profile is defined by regular basis and weekly workforce trends (working days, vacations, inter-holidays, vacation periods, etc.), which affect both price and demand. Temperature and humidity, which during warm seasons raises the heat temperature, also affect the need for power. In terms of temperature, a warm year continues the pattern of steadily rising average temperatures. More specifically, the period from August 2 to August 6 experienced the hottest temperatures in at least 20 years, with an average temperature. In addition to the demand's hourly profile, financial, commercial, and energy efficiency growth all have a mid-term impact on it. The growth in demand, which can be attributable to economic activity and energy efficiency, is roughly 0.6%, per REE statistics, once the effects of temperature and labour have been taken into account. Figure 5 depicts the representation of price and demand.
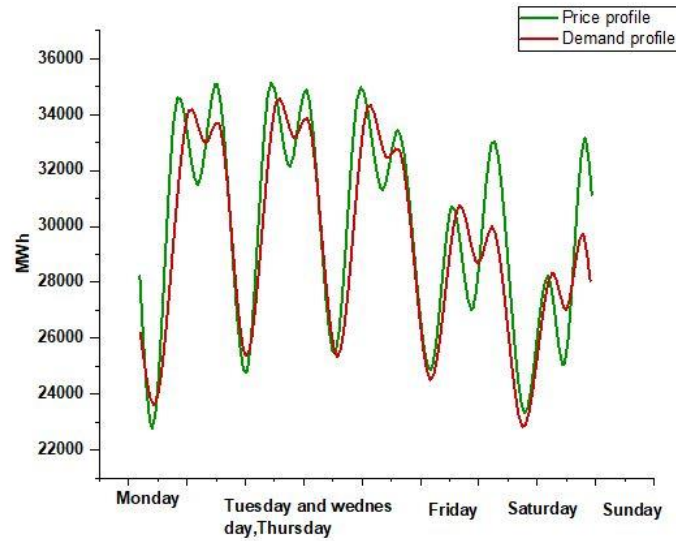
Figure 5: Representation of Price and demand

The quantity of electricity generated by renewable energy sources affects the price of electricity on the market. Due to their inability to manage their resources, non-manageable renewable sources like wind and solar offer their production on the power market at extremely low prices, which drives the price down. Production from renewable sources is viewed as a weather-dependent internal price factor. Figure 6 depicts the production and electricity price.
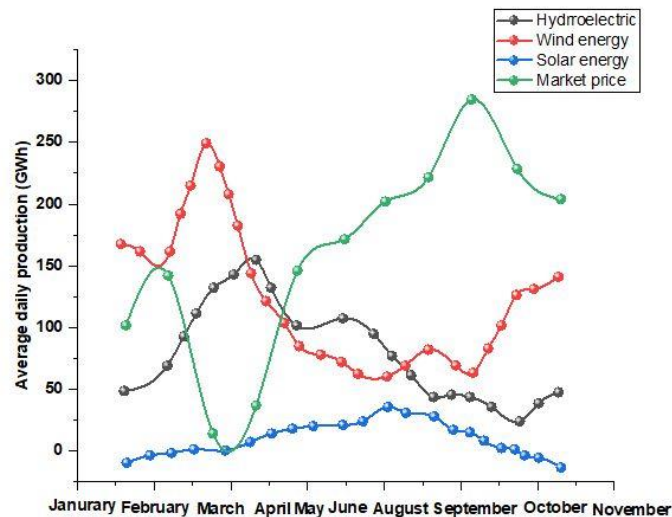

Figure 6: Result of production and electricity prices

4. Conclusion

To design a retail package system using the single pendulum equation, one must first conduct extensive research into electricity supply and demand patterns, as well as a thorough examination of consumer preferences and habits. Electricity supply and demand data can be used to inform a pricing algorithm based on the single pendulum equation, allowing merchants to implement a dynamic pricing system that responds in real-time to market fluctuations. It is essential that the system be integrated with billing and customer management systems so that customers may view their billing history and pricing details. Retailers may optimise their pricing strategies in a competitive market with the help of a well-designed dynamic pricing system based on the single pendulum equation, which benefits customers through lower prices and greater freedom of choice. A retail package system based on the single pendulum equation may not work in all markets or situations. The equation assumes idealized parameters that may not always be present in real-world scenarios, and some places may have trouble collecting correct data on electricity supply and demand. Technology and infrastructure investments may be needed to develop a dynamic pricing system based on the equation. Our result describe that our model has the potential to provide customers with cost savings and increased flexibility while allowing retailers to optimize their pricing strategies in a competitive market. The study findings indicate that the proposed model has provided 0.6% per REE in growth in demand. Future studies could employ mathematical models like the second order differential

equation to analyze electricity market prices. This could involve exploring equations or models that include renewable energy sources or energy storage technologies. More advanced algorithms for dynamic pricing and customer management could use machine learning or other advanced methods to improve accuracy and efficiency.

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