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RESEARCH ARTICLE

Impact of Dynamic Pricing with Smart Meters on Energy Consumption and Grid Load Stability in Electric Vehicle Usage

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Abstract

The increasing adoption of electric vehicles (EVs) in Indonesia offers both promising benefits and significant challenges to the country's power grid. This study investigates the effects of dynamic electricity pricing implemented through smart meter technology on energy usage patterns and grid load stability among EV users. Employing a quantitative descriptive method, data were gathered from 100 EV users at charging stations equipped with smart meters. The analysis focused on consumption behavior and costs during peak, off-peak, and super off-peak periods, as well as grid performance before and after the introduction of dynamic pricing. Findings reveal that while electricity consumption levels did not vary significantly across charging times, cost differences were substantial due to varying tariffs. Users who shifted charging to lower-rate periods achieved notable savings. Dynamic pricing also led to a 10% reduction in peak load and a more balanced nighttime demand, resulting in production cost efficiency of approximately 500 MW per hour. These outcomes underscore the effectiveness of dynamic pricing in encouraging energy-efficient behavior, enhancing grid resilience, and advancing Indonesia's energy sustainability targets.

Keywords: dynamic pricing, EV Charging, smart meter

I. Introduction

The global transition toward sustainable energy has accelerated the adoption of electric vehicles (EVs), which are increasingly recognized as a strategic solution to reduce dependence on fossil fuels and lower carbon emissions. In Indonesia, EV adoption has shown significant growth, with electric car sales reaching 10,327 units in 2022 primarily driven by government subsidies and popular models such as the Wuling Air EV. This trend aligns with the national commitment to reduce emissions and promote the use of clean energy.

However, the growing number of EVs presents new challenges to the electricity system, particularly in terms of increased pressure on grid infrastructure during peak load hours. The charging behavior of EV users contributes to uneven electricity demand patterns, necessitating smarter and more adaptive energy management strategies [1].

One promising solution is the implementation of dynamic electricity pricing supported by smart meter technology [2].This system allows electricity tariffs to vary based on time of use or grid load conditions, encouraging users to shift their energy consumption to off-peak hours. Smart meters play a crucial role in this system by providing real-time consumption data, enabling users to manage their energy usage more efficiently [3].

Recent studies indicate that dynamic pricing systems can optimize energy distribution, reduce electricity costs, and promote more environmentally friendly consumption behavior among EV users.[4] On the provider side, these systems also enhance grid stability and operational efficiency [5]. Nevertheless, several challenges remain, such as uneven infrastructure readiness, limited public awareness, and regulatory constraints [6].

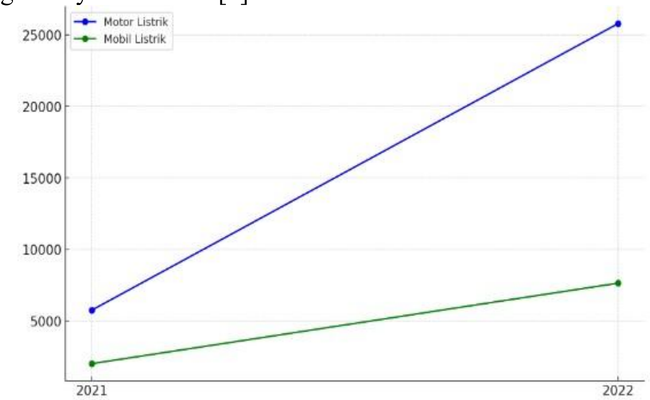

Figure 1. Electric Vehicle Adoption Data Source: Central Bureau of Statistics (BPS). (2023)

Given the rapid rise in EV adoption and the urgent need for energy efficiency, this study aims to analyze the impact of implementing dynamic electricity pricing using smart meters on energy consumption patterns and the stability of the electricity grid. This research is expected to provide strategic insights to support the development of a more resilient and sustainable power system.

Unlike previous studies Bonin et al, this research empirically measures behavioral changes and the electrical grid impact resulting from the implementation of dynamic pricing among Indonesian EV users.

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A. Dynamic Pricing of Electricity

Dynamic pricing is one of the electricity tariff setting mechanisms that adjusts prices based on time of use, consumer demand, and electricity system capacity. It has become a global concern in supporting energy efficiency and electricity demand management, especially with the increasing integration of renewable energy

Based on research conducted by [7], dynamic pricing aims to encourage more flexible consumption patterns, thereby helping to reduce peak loads and improve the stability of the electricity distribution system. This is in line with [8] view that dynamic tariff models can improve the operational efficiency of electricity providers while encouraging active consumer participation in energy management.

One of the most common forms of dynamic tariffs is Time-of-Use Pricing (TOU), where electricity rates differ based on certain time periods of the day. Peak load periods are assigned higher rates to reduce electricity usage, while lower rates are assigned during off-peak hours. According to [9], the application of TOU can minimize the operational costs of power plants and reduce carbon emissions because it allows optimizing the use of renewable energy. In addition to TOU, there is also the Real-Time Pricing (RTP) model, where electricity prices fluctuate based on market conditions and demand in real time.

In Indonesia, the issue of dynamic electricity tariffs is becoming more relevant as energy demand increases and pressure to reduce electricity subsidies increases. According to a report by [10], the uneven pattern of electricity consumption is a major challenge in the national electricity system.

Thus, dynamic pricing is one of the strategic innovations in the electricity tariff system that not only supports energy efficiency but also has a positive impact on environmental sustainability. Various studies show the great potential of this model in optimizing energy use, although implementation challenges require more attention, especially in the context of developing countries such as Indonesia.

B. Smart Meter

Smart meters are technological devices that enable automatic and real-time measurement of electrical energy consumption. This technology replaces conventional meter systems with more sophisticated capabilities to record electricity usage data, communicate directly with electricity providers, and provide detailed information to consumers. According [11], smart meters play an important role in building a *smart grid* that supports energy efficiency, electricity system stability, and the application of dynamic electricity tariffs such as *time-of-use pricing* or *real-time pricing*. The main advantage of smart meters is their ability to provide electricity consumption data transparently to consumers. Here is the ecosystem of Smart Meter.

Smart meters have great potential to revolutionize the way electrical energy is consumed and managed, especially in the transition to clean and sustainable energy. Although there are challenges in implementation, various studies show that the benefits of this technology, both in terms of energy efficiency and cost savings, far outweigh the obstacles. The following AMI development is running at PT PLN (Persero).

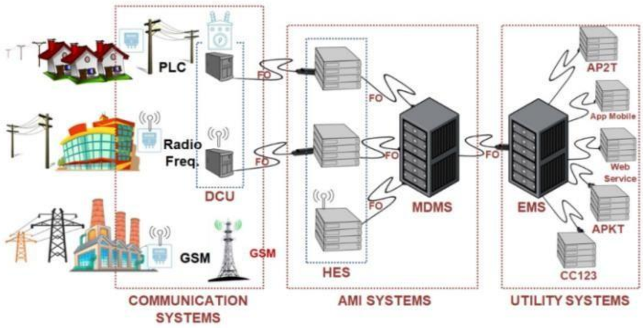

Figure 2. The ecosystem of Smart Meter

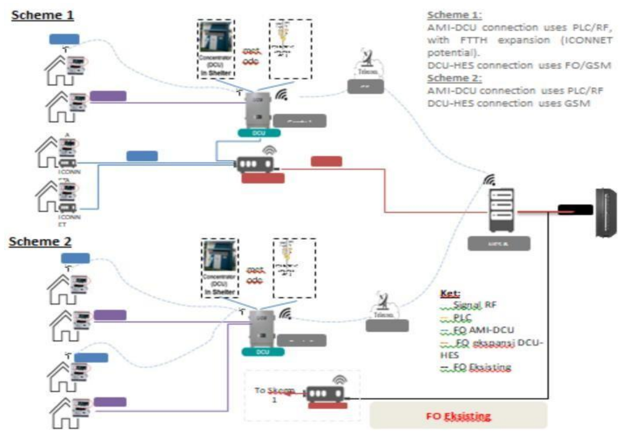

Figure 3. The following AMI development is running at PT PLN (Persero)

C. Electric Vehicle

Electric vehicles (EVs) are one of the main solutions to reduce carbon emissions and dependence on fossil fuels in the transportation sector. EVs utilize electrical energy as a power source, either fully in battery electric vehicles (BEVs) or in combination with hybrid electric vehicles (HEVs). This technology has gained global attention for its role in supporting environmental sustainability, energy efficiency, and air pollution reduction [12].

Electric vehicle technology has continued to evolve rapidly in recent decades. One of the key components of EVs is the battery, which determines the efficiency, range, and production cost of the vehicle. According to research by [13], lithium-ion-based batteries are becoming the primary choice due to their high density and shorter charging duration compared to other battery technologies. Innovations in battery technology, such as solid-state batteries and fastcharging systems, continue to be developed to improve performance and reduce production costs of EVs [14].

In addition, the integration of electric vehicles with smart grids is also a significant area of research. EVs can serve as flexible energy storage through vehicle-to-grid (V2G) technology, where the energy stored in EV batteries can be returned to the grid during periods of high demand. This not only improves grid stability but also provides economic benefits to EV owners [15].

II. Methods

This study employs a quantitative descriptive approach to analyze the impact of dynamic electricity pricing based on smart meter technology on energy consumption and grid load stability in electric vehicle usage. Data were collected through direct observation at charging stations that have implemented smart meters, as well as from operational reports and energy monitoring systems. The research population includes all electric vehicle users charging their vehicles in the designated study area, with a purposive sample of 100 users selected based on specific criteria such as the type of electric vehicle, charging frequency, participation in dynamic pricing schemes, and geographic location.

The variables analyzed include dynamic electricity pricing, energy consumption patterns (including timing and amount of energy used), and the impact on grid load stability, especially during peak and off-peak hours. The collected data were analyzed using descriptive statistics to present average energy consumption and costs, and One- Way ANOVA was applied to examine differences in consumption and cost across different charging times (peak, off-peak, and super off-peak). This approach aims to provide empirical evidence regarding the effectiveness of dynamic pricing in managing energy loads and improving electricity system efficiency in the electric vehicle sector.

A. Data Collection Method

This study employs both primary and secondary data collection methods to obtain relevant and in-depth information regarding the implementation of dynamic electricity pricing and its impact on electric vehicle (EV) charging behavior using smart meters.

Primary data were obtained through direct observations at charging stations that have adopted smart meter technology. The researcher observed charging usage patterns, consumer behavior, and the implementation of the dynamic pricing system. The collected data were classified into several categories, as outlined below.

B. Questionnaire Data Report

Data collection was carried out through the distribution of questionnaires to electric vehicle users who had utilized charging services under a dynamic electricity pricing scheme. The questionnaire was designed using a quantitative approach, comprising closed-ended questions aimed at extracting information on energy consumption behavior, charging time preferences, user understanding of the dynamic pricing structure, and customer perceptions of the policy's effectiveness.

The questionnaire was distributed online via platforms such as [e.g., Google Form or Microsoft Form] during the period from [start date – end date]. Respondents were selected using a purposive sampling technique, with key criteria being residential or individual EV users who had actively engaged in EV charging for at least the past month. a total of [number of respondents] respondents completed the questionnaire with valid and complete answers. These responses were used as primary data for statistical analysis. Prior to deployment, the questionnaire instrument underwent validity and reliability testing to ensure that all items consistently and accurately measured the intended constructs.

Figure 4. Purposive Sampling of EV Charging Customers

C. Meter Data Report

Smart meter data were obtained directly from digital metering devices installed at the premises of EV users. Smart meters are advanced digital devices capable of automated, real-time recording of electricity consumption, including time-of-use (ToU)-based metering, making them highly suitable for analyzing the application of dynamic pricing schemes.

The data collected from the smart meters include total energy consumed (in kWh), charging times (timestamp and date), and the duration of each charging session. Data acquisition was conducted over the period of [e.g., May 1 to June 30, 2025] via backend systems or energy management dashboards provided by the service operator (e.g., PLN of third-party charging station providers).

Data were obtained from [number of customers or charging points], selected based on criteria such as active use of EV charging services under dynamic pricing schemes and availability of smart meters capable of accurate time- based logging. To maintain confidentiality, customer data were anonymized and used exclusively for research purposes.

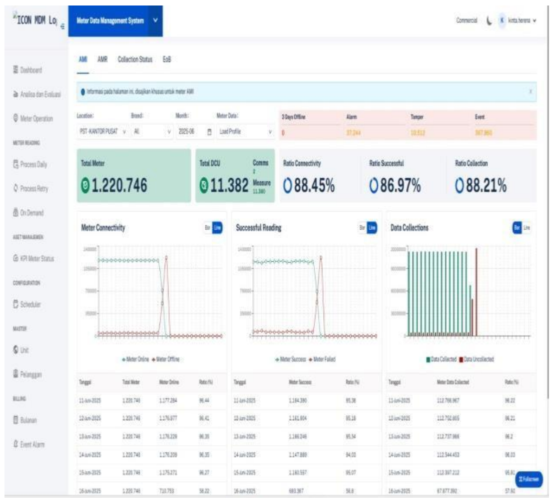

Figure 5. PLN MDMS Dashboard for Smart Meter Users

All retrieved data were extracted in [e.g., CSV or Excel] format and analyzed using statistical software for descriptive and inferential analysis. The analysis includes calculations of average daily consumption, identification of charging patterns based on time slots (Peak, Off-Peak, Super Off-Peak), and the calculation of electricity costs based on applicable dynamic tariffs.

Secondary data were obtained from documentation sources, including the questionnaire report, power plant operational data from utilities, electricity tariff policies, and load profile records from smart meter systems. Historical data comprising consumption volumes, charging times, and electricity costs before and after the implementation of dynamic pricing were analyzed to provide a quantitative overview. In addition, literature from academic journals, technical articles, and policy reports were reviewed to strengthen the analysis and to benchmark the findings of this study against previous research.

Technology-assisted data collection was conducted through the use of smart meters to record energy consumption (kWh), charging times and durations, and incurred costs. These data provide detailed insights into EV user behavior in response to dynamic pricing schemes, during both peak and off-peak hours. Analytical software tools were employed to ensure data accuracy and reliability throughout the data processing workflow.

The advancement of electric vehicle (EV) technology and the increasing load on power systems have prompted the need for more flexible and responsive electricity pricing schemes. One of the approaches adopted by energy providers, including PLN, is the implementation of dynamic electricity pricing. This scheme aims to influence customer consumption patterns, reduce peak demand, and optimize the efficiency of the power system.

Although dynamic pricing has been implemented, not all customers exhibit the expected changes in energy consumption behavior. Some users continue to charge their vehicles during high-tariff (peak) periods, despite the availability of price incentives during off-peak hours. This may be attributed to various factors, such as limited understanding of the tariff structure, inadequate infrastructure (e.g., smart meters), and variations in consumer behavior and preferences.

Furthermore, while electricity costs can potentially be reduced by shifting charging times, the total energy consumption (kWh) may not significantly change. Therefore, empirical analysis is required to assess the extent to which dynamic pricing influences both the cost and consumption behavior of electricity users, particularly among electric vehicle users.

D. *Descriptive Statistics*

Descriptive statistical analysis is conducted to provide a general overview of the collected data. Metrics such as mean, median, and standard deviation are used to understand patterns in energy consumption, charging duration, and electricity costs for electric vehicle charging. For instance, the average daily energy consumption and charging costs before and after the implementation of dynamic pricing are compared to identify overall behavioral differences.

The collected data were processed using data analysis applications, including Python and SPSS, to obtain more comprehensive and accurate insights.

III. Results and Discussion

A. *One-Way ANOVA Method*

In this study, the One-Way ANOVA method is employed to analyze differences in electricity consumption (kWh) and total electricity costs based on three time-of-use categories:

- Peak Hours (18:00-21:00)
- Off-Peak Hours (22:00-01:00)
- Super Off-Peak Hours (01:00-05:00)

This test aims to determine whether there are statistically significant differences in consumption patterns and electricity costs across the time categories under the dynamic pricing scheme.

Prior to the ANOVA test, assumptions of normality and homogeneity of variances are verified to ensure the data meet the requirements for applying One-Way ANOVA.

One-Way ANOVA compares the between-group variance with the within-group variance. If the between- group variance is statistically greater, it indicates that at least one group differs significantly from the others.

A significance level (alpha) of 0.05 is used in this analysis. If the resulting p-value ≤ 0.05, the null hypothesis (H_0), which states that there are no mean differences between groups, is rejected. This indicates that there is a statistically significant difference between at least two of the groups.

The ANOVA test is performed using statistical software such as SPSS, R, or Python. If significant differences are found, the analysis proceeds with post hoc testing using the Tukey HSD method to identify which specific groups differ from one another.

B. *Dynamic Electricity Consumption Patterns among Electric Vehicle Users When presenting and discussing results, give in depth analysis, not only reporting the results*

Table 1. Dynamic Pricing Electricity Consumption Patterns Applied to Electric Vehicle Users

Charging Time	**Consumption (kWh)**	**Tariff (Rp/kWh)**	**Total Cost (Rp)**
Peak Hours (18:00-21:00)	20.40	1,500	30,600.00
Off-Peak (22:00-01:00)	12.71	1,200	15,257.14
Super Off-Peak (01:00-05:00)	11.52	1000	11,523.33
Average (Mean)	14.88	1,233	19,126.82

In determining electricity tariffs, the calculation is based on the operating production cost (HPP) of power generation units, specifically those utilizing fossil fuels such as coal, gas, and oil.

By applying an average value derived from the upper and lower bounds within a 5% ratio margin, an assumed price is obtained as presented in the table above. However, this value is subject to change over time, in line with variations in load demand and the operational patterns of power plants.

As shown in Table 1, electricity consumption in kWh is relatively higher, as indicated by data obtained from both smart meters and questionnaire responses. This is primarily due to a larger proportion of electric vehicle users owning cars rather than motorcycles. This trend reflects the prevailing socio-economic conditions of the region, where a significant number of residents still rely on conventional motor vehicles. Furthermore, it suggests that users have not yet fully experienced or responded to the benefits of the dynamic electricity pricing scheme.

Table I the electricity consumption patterns and corresponding costs under a dynamic pricing model among electric vehicle (EV) users in Indonesia. Charging sessions are categorized into three time slots: Peak Hours (18:00–21:00), Off-Peak (22:00–01:00), and Super Off-Peak (01:00–05:00), with respective tariffs of Rp 1,500, Rp 1,200, and Rp 1,000 per kWh.

Despite the variation in tariffs, the electricity consumption levels remain relatively close ranging from 11.52 kWh to 20.40 kWh. However, the total cost incurred by users changes significantly, from Rp 30,600 during peak hours to Rp 11,523.33 during super off-peak hours. This contrast highlights the financial benefits of shifting charging behavior in response to pricing signals.This behavioral adjustment aligns with the economic theory of price elasticity of demand, which posits that consumers tend to reduce consumption or shift behavior when faced with higher prices, even for essential services like electricity.

Although electricity demand is typically price inelastic, the visible price difference per time slot, combined with informed users via smart meters, introduces a moderate elasticity that enables cost-optimization behavior. Moreover, this finding supports the demand response framework, in which dynamic pricing acts as a non-coercive control mechanism to smooth out electricity demand. By shifting EV charging to lower-tariff periods, the model not only benefits users financially but also contributes to grid efficiency and peak load reduction.

A comparison with Zhang et al. (2020) reveals similar behavioral patterns in Chinese EV users, who adapted their charging habits when dynamic tariffs were introduced, achieving both economic savings and grid stability. Similarity, Dobric et al. (2024) reported that in European urban areas, the application of time-of-use pricing and smart meter integration led to a 15% decrease in peak loads, emphasizing the global effectiveness of this approach. especially when supported by smart grid infrastructure and consumer awareness initiatives.

During the off-peak period (22:00 - 01:00), consumption decreases to 12.71 kWh with a tariff of Rp 1,200 per kWh, generating a cost of Rp 15,257.14. Meanwhile, during super off-peak hours (01:00 - 05:00), the lowest electricity consumption is 11.52 kWh with a tariff of Rp 1,000 per kWh, resulting in a total cost of Rp 11,523.33. Overall, the average electricity consumption of electric vehicle users is 14.88 kWh with an average tariff of Rp 1,233 per kWh and an average cost of approximately Rp 19,126.82. This pattern illustrates that charging during hours with lower tariffs can reduce the electricity costs incurred by electric vehicle users.

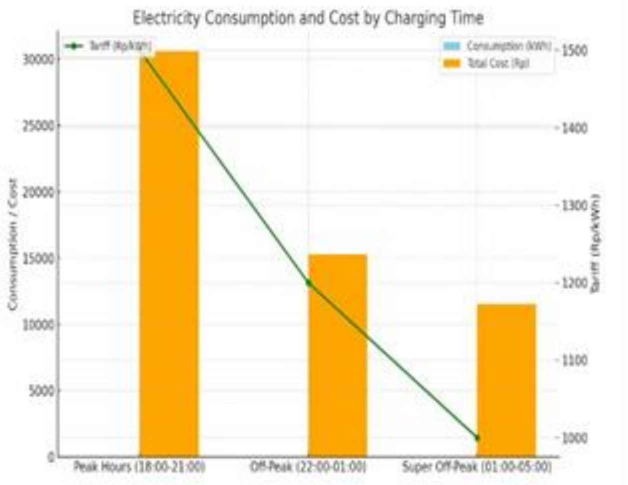

Figure 6. Electricity Consumption and Cost Charging Time

The graph titled "Electricity Consumption and Cost by Charging Time" demonstrates the relationship between energy usage (in kWh), total charging cost (in Rupiah), and dynamic pricing tariffs across three charging time intervals: Peak Hours (18:00–21:00), Off-Peak (22:00–01:00), and Super Off-Peak (01:00–05:00).

Prior to the implementation of dynamic pricing, most electric vehicle (EV) users conducted charging activities during peak hours, resulting in the highest electricity consumption (over 30,000 kWh) and maximum total cost due to elevated tariff rates (approximately Rp 1,500/kWh). This behavior contributed to higher operational stress on the grid during critical load periods.

Following the introduction of dynamic pricing :

- A significant behavioral shift was observed, with consumption during off-peak and super off-peak hours increasing, as reflected by the declining cost and tariff lines.
- Tariff differentiation incentivized users to shift charging from peak to lower-tariff periods. This is evident in the decreased consumption during peak hours and relatively higher utilization during super off-peak periods, where the tariff dropped below Rp 1,100/kWh.
- The green line illustrates the tariff gradient, while the orange bars reflect actual consumption and cost values.

This data confirms the effectiveness of dynamic pricing as a demand-side management strategy, optimizing load distribution while reducing user costs and overall system peak demand.

The electricity consumption pattern under a dynamic pricing system applied to electric vehicle users, as shown in Table 1, demonstrates variations in consumption and cost based on battery charging times. This aligns with the concept of dynamic pricing in energy economics theory, which states that electricity tariffs can be adjusted based on demand and time of use to optimize resource utilization and promote consumption efficiency [16]. During peak hours, electricity tariffs tend to be higher as an incentive for consumers to reduce usage or shift consumption to off-peak hours to avoid overloading the power grid [17].

A study by Wang et al. on electric vehicle charging patterns also shows that dynamic pricing systems can influence user behavior to charge during lower-tariff periods, thereby reducing energy costs and helping stabilize peak loads on the grid [18]. This supports the data in Table 1, where electricity consumption during super off-peak hours is lower but incurs the lowest cost, providing an economic incentive for users to utilize these hours.

Furthermore, the demand response theory highlights the importance of timing energy usage to relieve stress on the power system and enhance energy efficiency. [19] Therefore, the implementation of dynamic pricing not only offers financial benefits to consumers but also contributes positively to overall grid management.

In practical terms, this data indicates that education and dissemination of information regarding variable electricity tariffs need to be effectively communicated to electric vehicle users so they can optimize their charging schedules [20]. Research by Zhang et almalso emphasizes that the combination of smart charging technologies and dynamic pricing can enhance cost savings while supporting the integration of renewable energy into the power system [21].

Thus, the implementation of a dynamic pricing system for electric vehicle electricity consumption is an effective strategy to achieve cost and energy efficiency, while simultaneously supporting the stability and sustainability of the national power grid [22].

C. Comparison of Power Consumption (kWh) and Dynamic Electricity Pricing (Dynamic Pricing) Applied to Electric Vehicle Users During Peak Hours, Off-Peak, and Super Off-Peak Periods

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Table 2. ANOVA Test Results of Electricity Consumption and Cost Based on Charging Time

Variable	F Value	Significance (p)	Interpretation
Power (kWh)	1.657	0.198	Not Significant
Total Cost (Rp)	5.069	0.009	Significant

The ANOVA test results presented in Table 2 provide insight into the impact of charging time on electricity consumption and cost under a dynamic pricing system for electric vehicle (EV) users. The analysis shows that the power consumption (kWh) across different charging periods Peak Hours, Off-Peak, and Super Off-Peak does not differ significantly ($F = 1.657$, $p = 0.198$). This indicates that EV users tend to consume relatively similar amounts of electricity regardless of the charging time window.

However, the total electricity cost shows a statistically significant difference based on charging time ($F = 5.069$, $p = 0.009$). This finding supports the effectiveness of dynamic pricing in influencing the financial impact of electricity use rather than the physical amount of consumption. Specifically, since the tariff rates vary across time periods (higher during peak hours and lower during super off-peak hours), users incur different total costs even when their energy usage is relatively stable.

This aligns with the principles of dynamic pricing in energy economics, which suggest that price signals can influence user behavior to optimize demand distribution (Joskow, 2008). Although consumption volume did not significantly change in this study, the significant variation in cost underscores the potential of dynamic pricing to provide economic incentives for shifting energy use to off-peak periods.

Furthermore, this finding is consistent with Albogamy et al. , who found that time-based pricing models can influence EV owners to schedule their charging during lower-rate periods, helping reduce peak load on the power grid.[23] It also echoes the concept of demand response which emphasizes the role of pricing strategies in managing energy demand and improving system efficiency.[24]

In conclusion, while the dynamic pricing strategy may not directly change the amount of electricity consumed by EV users, it significantly affects the cost-efficiency of their charging behavior. This demonstrates the potential of tariff structures to encourage more sustainable and economically sound electricity use patterns. Policymakers and utility companies may leverage this approach to reduce peak demand, lower energy costs for users, and enhance grid stability.

D. Electricity Grid Load Before and After the Implementation of Dynamic Pricing Due to Electric Vehicle Usage

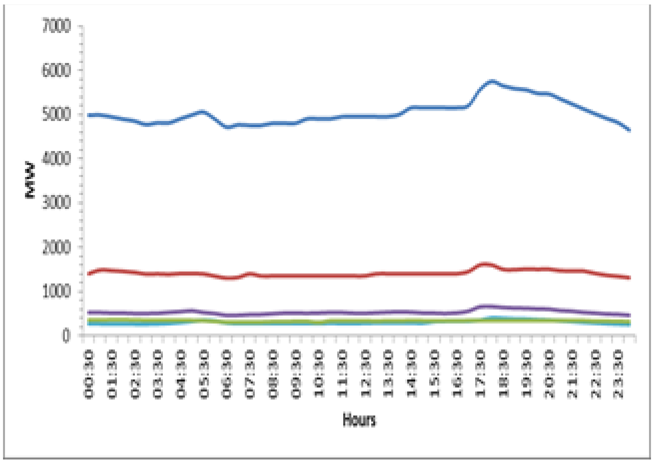

Figure 7. Electricity Network Load Before Dynamic Pricing Implementation Caused by Electric Vehicle Use

Based on the graphs produced, it appears that the implementation of dynamic pricing has a significant impact on the electricity load patterns resulting from the use of electric vehicles (EVs). Before the introduction of dynamic tariffs, the daily electricity load showed a very sharp pattern, with the peak load occurring at 6:00 PM, reaching up to 6000 MW. This peak load was caused by the convergence of household energy needs and EV charging activities, primarily because users tend to charge their vehicles upon arriving home after daily activities. This consumption pattern creates a high load that risks causing disturbances in the distribution network, especially in urban areas with high EV adoption rates. Additionally, the peak load concentrated in a short time requires additional power reserves and increases operational costs for energy providers.

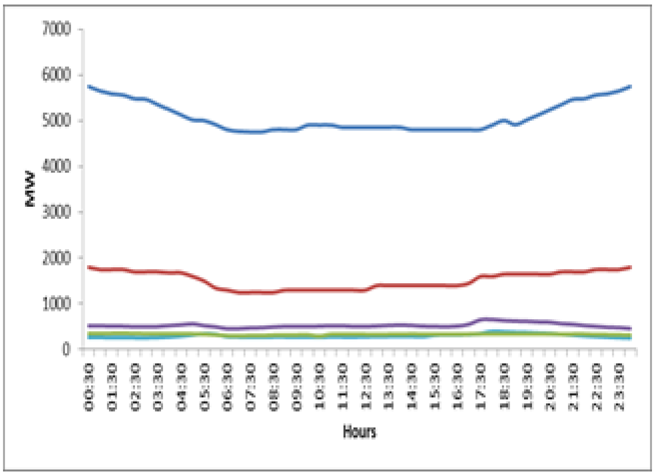

Figure 8. Electricity Network Load After Implementation of Dynamic Pricing Caused by the Use of Electric Vehicles

However, after the implementation of the dynamic pricing system utilizing smart meter technology, a significant shift in consumption patterns is observed. The graph shows that although the peak load still occurs around 6:00 PM, the magnitude decreases to approximately 5450 MW. More notably, the load distribution becomes more even during nighttime to early morning hours, particularly between 10:00 PM and 4:00 AM. This indicates that consumers are beginning to be encouraged to take advantage of lower tariff periods for EV charging. This behavioral change is an indication that dynamic pricing is effective as a demand-side management tool within the electricity system.

These results are consistent with price elasticity theory in energy economics, where consumers tend to alter their energy consumption behavior in response to price changes. In this context, the application of lower tariffs at night encourages consumers to avoid peak load periods and choose lower-rate times to charge their EVs. The support of smart meters plays a crucial role in this process by providing consumers with real-time visibility of prices and electricity consumption. Smart meters also enable integration between the dynamic pricing system and home energy management systems (HEMS), allowing automatic optimization of energy consumption based on user preferences.

The study by Dobric et al supports these findings, revealing that the use of dynamic pricing in areas with dense EV populations can reduce peak loads by up to 15% and improve system efficiency by 12% [27]. Furthermore, Panday et al the shows that households equipped with smart meters exhibit faster and more significant changes in consumption patterns compared to households without these devices [28]. Features such as peak time notifications and mobile app integration make consumers more aware and educated in managing energy use. Regionally, similar findings were reported by Mahdi et al. who developed a two-level coordination model between energy systems and EV charging stations. They concluded that time-based charging management using dynamic pricing benefits energy operators in terms of grid stability and also provides cost efficiencies to EV users [29].

Besides technical and economic benefits, dynamic pricing also has a sustainability dimension. By encouraging charging outside peak hours, carbon emissions from power plants can be reduced by lowering the need for peak load plants, which generally use fossil fuels. This aligns with the energy transition direction that prioritizes efficiency and sustainability in power systems. Dynamic pricing can also be further integrated with renewable energy sources, where energy prices can be adjusted based on the availability of fluctuating solar or wind energy.

Overall, the study confirms that the implementation of dynamic pricing integrated with smart meters effectively shifts peak loads, evens out energy consumption distribution, and provides economic benefits to both users and energy providers. This policy is also supported by theory and empirical evidence over the past five years highlighting the importance of demand management strategies in addressing new challenges posed by EV penetration. The future implementation of this scheme will not only strengthen the reliability of the national energy system but also support sustainable development goals in the energy and transportation sectors.

IV. Conclusion

Electric vehicle (EV) users' electricity consumption shows significant cost variations depending on battery charging times due to the implementation of a dynamic pricing system. Although the electricity consumption volume does not differ significantly across peak, off-peak, and super off-peak periods, the total electricity cost varies significantly because of the varying tariffs. The implementation of dynamic pricing effectively shifts peak electricity loads by encouraging EV users to charge during lower-tariff periods, reducing peak load by up to 10 % and smoothing consumption distribution throughout the night. One of the key limitations of this study lies in its geographically constrained sample coverage, which may limit the extent to which the findings can be generalized to a broader national context. Since the data were collected from a specific region, the observed patterns of electricity consumption behavior and responsiveness to dynamic pricing schemes may not fully reflect the diversity of user behavior across different socio-economic and regional settings in Indonesia. Consequently, caution should be exercised when extrapolating the results beyond the study area. Future research is encouraged to incorporate a more geographically diverse sample to enhance the external validity and applicability of the findings at a national scale.

In the long term, the implementation of this approach is expected not only to provide economic benefits to end-users, but also to enhance the efficiency and stability of the national power grid, while supporting energy sustainability goals by reducing carbon emissions from fossil-fueled peak power plants. The application of dynamic pricing, supported by smart metering technology, serves as an effective demand- side management strategy in the context of increasing electric vehicle adoption.

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