EAI Endorsed Transactions
on Energy Web
Research Article EAI.EU

Research on the Mechanism of Power Quality in Renewable Energy Marketing Based on BMA Algorithm

Qinghua Fan[1*]

[1]School of Management, Lishui Vocational & Technical College, Lishui city Zhejiang Province, China, 323000

Abstract

INTRODUCTION: Based on the BMA (Bayesian Model Average) algorithm, this paper deeply studies the mechanism of power quality in renewable energy marketing. By collecting a large amount of renewable energy market data and utilising the BMA algorithm for model building and data analysis, this paper aims to reveal the internal relationship between power quality and renewable energy marketing and explore its impact on actual market operations.
OBJECTIVES: In the context of data analysis, this paper selects multidimensional information, including sales data, user feedback data, and power quality monitoring data, from the renewable energy market over recent years. By integrating and analysing these data with the BMA algorithm, we find that power quality has a significant positive impact on the marketing of renewable energy.
METHODS: Specifically, when power quality is improved by 10%, the sales of renewable energy products are expected to increase by approximately 6% on average, and customer satisfaction will rise by 7% accordingly. This data shows that improving power quality can effectively promote the expansion of the renewable energy market and enhance user loyalty. Our research, leveraging the BMA algorithm, reveals that improving power quality serves as a dual catalyst for promoting renewable energy.
RESULTS: Firstly, it directly bolsters consumer trust and purchase intention towards renewable energy products. Secondly, it indirectly enhances the market competitiveness of these products by optimising their performance and reducing failure rates. These insights provide renewable energy enterprises with a pivotal foundation for optimising their marketing strategies.
CONCLUSION: In conclusion, power quality emerges as a crucial factor in the marketing of renewable energy. By prioritising its improvement, enterprises can simultaneously enhance sales, customer satisfaction, and product competitiveness, thereby underscoring the importance of power quality as a core component of their marketing strategy.

Keywords: BMA algorithm; Power quality; Renewable energy; Marketing.

Received on 02 May 2025, accepted on 19 June 2025, published on 02 September 2025

doi: 10.4108/ew.9221

1. Introduction

In recent years, electricity has become widely used in many industries and has become a vital engine for economic growth and technological advancement. As a clean and controllable energy source, electricity is crucial to modern power systems and serves as a barometer of a country's level of progress. Maintaining good power quality is essential for ensuring system dependability, customer satisfaction, and market competitiveness as renewable energy sources, such as solar and wind, become increasingly integrated. Power quality evaluation and management are essential for the long-term growth of renewable energy. Application has gradually become one of the important indicators to measure the development level of a country's economy and science and technology. In the electricity market, electric energy is a specialised product provided by the power department to power users, and its quality is guaranteed by both parties [1]. Like other commodities, quality is the inherent characteristic of commodities, so electric energy must also

*Corresponding author. Email: 803165@lszjy.edu.cn, qinghua_29@outlook.com

pay attention to quality [2]. In the middle and later part of the last century, with the development of new primary energy sources and the continuous expansion of generator equipment capacity, the separation of power plants and networks, as well as the separation of supply and transmission, began to be implemented in China's power system, which made electric energy a special commodity. Naturally, it possesses the characteristics of commodities; namely, it is put into the market and bid for on the Internet in fierce competition, thus gradually realising the characteristics of high quality and high pricing according to quality. At the same time, the quality issue of electric energy commodities in transactions has become a major concern that both buyers and sellers pay special attention to. The existing problems have become prominent sharply and reached an unprecedented level. The solution to the problem of power quality is not only reflected at the technical level but also at a deeper level, which involves building a reasonable evaluation system to accurately and conveniently classify power quality [3, 4]. Improved power quality is vital for the long-term sustainability of the renewable energy sector. It enhances market growth by increasing customer satisfaction and loyalty. Better power quality fosters consumer trust through enhanced product reliability and reduced failures. It enables efficient resource use and reduces economic losses. High-quality power supports technological progress and environmental protection by facilitating the stable integration of renewable energy sources. Overall, it strengthens marketing strategies and policy development, promoting sustainable growth. The proposed standard for power quality evaluation can position the special commodity of power, enabling it to have sufficient competitiveness in the increasingly fierce market competition and ultimately achieve rational resource use and effective resource allocation. It enables the power supplier to provide users with accurate power quality standards, allowing them to assess their current situation according to their own needs and existing conditions and ultimately determine the required power quality level. Power quality is crucial in renewable energy marketing, as it directly enhances sales and customer satisfaction. Improved power quality enhances product performance and reliability, fostering consumer trust and loyalty. It enables electricity to be priced based on quality, allowing users to select power levels that fit their needs and reduce costs. Emphasising power quality helps optimise resource utilisation and eases technical challenges in power supply. In this way, it can reduce costs and prevent significant economic losses. Secondly, it provides a more relaxed platform for the power supply system under great pressure, which gives the power supply system more energy to solve the problems existing in the technical level of power quality and then better serve users, thus achieving a win-win situation. These measures have promoted the rapid development of social technology and the continuous improvement of power market mechanisms [5]. A modern power quality evaluation system primarily bases its standards on user requirements. Power users aim to ensure safe production, minimise economic losses, and maximise economic benefits, thereby placing higher and stricter standards on power quality. Power supply companies, in line with the principle of user convenience and the interest of users, are also making efforts to address the issue of power quality. The establishment of a more rigorous, reasonable, and appropriate power quality evaluation system is therefore imminent. The practical significance of power quality evaluation is as follows: (1) It is the basis for the imputation of power supply and power consumption; (2) It is the reference standard for power users to choose the power quality matching with their own needs; (3) It is a prerequisite to detect whether a certain power supply network needs troubleshooting; (4) It is the data basis for pricing electric energy according to quality as a commodity; (5) It is the basis for the power supply department to improve the power supply quality and service; (6) It is an urgent need for the development of China's electricity market.

2. Analysis of Marketing Environment of Power Generation Company

The macro environment of the enterprise will be the main indirect factors affecting its development, including the political and legal factors, economic factors, social factors and technical factors of the country and industry, which form the four major elements of macro environment analysis, referred to as PEST analysis for short. These four elements are not controlled by enterprise behaviour [6]. Only by continuously analysing and studying these four elements can enterprises eliminate the backwards factors that hinder their development, identify the favourable factors that support their growth and expansion, and achieve stronger competitiveness in the market environment. The voltage stability index and frequency deviation are calculated as described in (2.1) and (2.2).

$$r_u = a_u B log_2\left(1 + \frac{pwh_u}{N_0}\right) \quad (2.1)$$

$$T_u = \sum_{i=1}^{N} \zeta_{ui}\, T_{ui} \quad (2.2)$$

2.1 Policy Environment Analysis

Before 2011, the total installed capacity of natural gas generating units in Zhejiang Province was 3.776 million kilowatts, all of which were used for peak shaving. Affected by the cost of natural gas and the annual power generation plan, the natural gas units in the province are operating at a limited capacity [7]. The policy of natural gas cogeneration is not implemented in the province. The management department only issues the annual power generation plan for natural gas generating units based on the peak shaving demand of the power grid, without considering whether the units meet the thermoelectric ratio stipulated in the National

Measures for the Administration of Cogeneration, and treats the units differently. Power quality plays a crucial role in renewable energy marketing, significantly enhancing consumer confidence, sales, and customer satisfaction. The market operates in a complex environment shaped by policy changes, economic growth, and the development of electricity market frameworks. Firms need to strategically oversee bids and agreements to enhance profits in both scheduled and spot markets. Sophisticated data analysis enhances power quality assessment and focused marketing approaches. Focusing on sustainability, operational effectiveness, and a robust organisational culture is essential for staying competitive in this rapidly evolving industry. In actual implementation, the annual power generation plan serves as a reference only, and the dispatching results take precedence. There is a big deviation between the final plan completion and the issued number. The provincial administrative department shall adjust the plan in the form of a document notification by the end of the year based on the actual completion of power generation. Since January 1, 2015, Zhejiang Province has implemented a two-part electricity price policy for natural gas generating units [8]. The two-part electricity price is divided into two parts: capacity electricity price and on-grid electricity price. Following the general idea of natural gas generator management in our province, the policy was strictly enforced at the beginning of formulation, and the annual capacity electricity price income of each gas turbine power plant only accounted for 60-75% of the fixed cost. The marginal contribution of on-grid electricity price is less than 0.1 yuan/kWh, which is far lower than that of coal-fired generating units in the same period. Since the implementation of the two-part electricity price, the capacity electricity price has remained unchanged. In contrast, the on-grid electricity price has been adjusted in sync with previous changes in natural gas prices, and the marginal contribution level has remained constant. From 2015 to 2019, power generation companies, through Tongxiang Municipal Government, Jiaxing Municipal Government, National People's Congress, or other power generation groups in the province, continuously reported the problems of enterprise production and operation, social stability and other aspects to the Provincial Energy Bureau, Price Bureau and the Secretariat of the Provincial Party Committee and Government, and put forward demands such as raising the level of capacity electricity price and trying out the policy of "determining electricity by heat", striving to improve the policy environment. The BMA estimates for model weight calculation and predicted values are shown in (2.3) and (2.4).

$$X(k) = \sum_{n=0}^{N-1} x(n) \cdot e^{-j\frac{2\pi}{N}kn} \quad (2.3)$$

$$BA = \frac{1}{L}\sum_{j=1}^{L} x(M'^{j} \otimes M^{j}) \quad (2.4)$$

In recent years, the focus of the Zhejiang provincial government's power operation and electricity price management has been on reducing electricity prices, but these efforts have not achieved the expected results. None of the price space has been vacated by the growth of social electricity consumption over the years, and previous natural gas price reductions have been used to improve the living conditions of natural gas-generating units. With the release of the No. 9 Document on New Electric Power Reform, Zhejiang has made numerous explorations and attempts to reform the electric power marketisation. In June 2017, the Zhejiang Provincial Government issued supporting documents, including the Comprehensive Pilot Program of Electric Power System Reform in Zhejiang Province and the Construction Program of Zhejiang Electric Power Market, which made top-level design and organisational arrangements for the design, implementation, and management of the Zhejiang electric power market [9]. At the same time, from the national level, Zhejiang Province has also been listed as one of the first batches of pilot areas for the construction of spot power markets. Finally, a relatively fair and healthy power market development model will be established. The increasing integration of renewable energy, facilitated by improvements in power quality, enhances sales and customer satisfaction. Market reforms and electricity trading mechanisms foster fair competition and optimise the utilisation of renewable energy. Advanced algorithms, such as BMA, improve system stability and increase consumer trust in renewables. Supportive policies promote the shift from traditional thermal power to cleaner energy sources. Renewables are expanding their role by providing both electricity and industrial heating solutions across various sectors.

2.2 Economic Environment Analysis

The rapid growth of electricity demand directly reflects the sustained growth of the social economy. With the deepening of the economic transformation across the entire society, a series of new measures, such as network business economy, information consumption, and 5G commercial operation, will further promote the growth of the tertiary industry and residents' electricity demand [10]. The power quality evaluation system is user-focused, addressing both safe production and economic benefits. It supports functions such as power supply imputation, quality-based pricing, and network issue detection. Multiple methods, including the analytic hierarchy process, full probability formulas, and evidence theory, are employed to evaluate various power quality indicators. The system handles uncertainty through probabilistic and evidence-based approaches to provide reliable assessments. It facilitates market-driven quality selection and competitive resource allocation. Integration with the Bayesian model averaging algorithm enhances model accuracy, especially for renewable energy marketing.

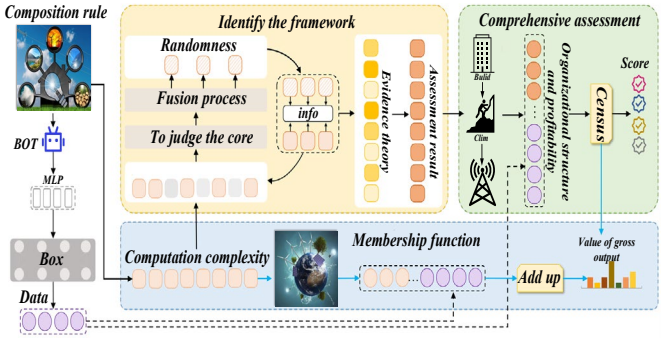

Figure 2.1. Flow Chart of Renewable Energy Power Quality Monitoring and Evaluation

Figure 2.1 shows flow chart of renewable energy power quality monitoring and evaluation. Power consumption will be a fundamental aspect of social and economic development [11]. The BMA algorithm integrates multiple models to analyze renewable energy data, including sales, user feedback, and power quality metrics. It accounts for uncertainties by weighting models based on their likelihood, improving prediction accuracy. Results indicate that improvements in power quality have a positive impact on sales and customer satisfaction. This highlights the critical role of power quality in driving market growth and fostering user loyalty. BMA insights enable companies to optimise their marketing strategies and enhance product reliability. With the reform of the Zhejiang power market, how to do a good job in power marketing under the new economic situation will become a new topic that power enterprises cannot avoid.

2.3 Microscopic Environment Analysis

Company resources primarily include organisational structure, profitability, and other key aspects. By the end of 19 years, the Power Generation Company had streamlined its original nine internal institutions into six functional departments: Office, Human Resources, Party Building Department, Finance and Budget Department, Marketing Department, Safety and Health Department, and Operation and Maintenance Department. The streamlining of departments and the division of functions have greatly improved the efficiency of the internal work of the company. The market demand function and the market supply function are shown in (2.5) and (2.6).

$$e^{+} = \mathbb{E}\left[max\left(0, \frac{a_n - c_n}{c_n}\right)\right] \tag{2.5}$$

$$M_c(x, y) = f_k(x, y) \tag{2.6}$$

After the project was put into production, affected by the provincial internal combustion engine policy and natural gas cogeneration policy, the power generation utilization hours of the unit were not high, and the average power generation utilization hours were only 1099 hours, which was always at a loss after the project was put into production. In 2019, 609 million kWh of electricity was generated, 596 million kWh of electricity was sold online, and 1,704,400 Ji Jiao were sold, resulting in a sales income of 494 million yuan (excluding tax), with a total profit of -23 million yuan. With the continuous efforts of the Power Generation Company, in 2020, 731 million kWh of electricity will be generated, 716 million kWh of electricity will be sold online, and 1,620,900 Ji Jiao will be sold, resulting in a sales income of 650 million yuan (excluding tax). The total profit will be 370,300 yuan [12]. The power grid dispatching relationship of the power generation company is managed by Zhejiang Electric Power Company (Provincial Electric Power Control Centre), and all its on-grid electricity is purchased and sold by Zhejiang Electric Power Company, which primarily supplies power users in the Hangzhou-Jiaxing-Huzhou area. In the past three years, the annual power generation has increased year by year. In 2019, the power generation was 600 million kWh, 105 hours ahead of the province's unified adjustment and rush to build gas turbines. The power generation ranked first in non-Hangzhou and Ningshao areas. At the same time, the Power Generation Company primarily undertakes the industrial heating task in the west of Tongxiang City, covering a total distance of more than 70 kilometres. There are large group enterprises, such as Tongkun Chemical Fibre, Xinfengming Chemical Fibre, Shuangjian Rubber, and Jingma Electric Machinery, in the heating area. In the region, there are 13 enterprises with sales income exceeding 100 million yuan, and the total industrial output value of the regulated enterprises is 32.35 billion yuan, accounting for 33.8% of the total industrial output value of the regulated enterprises in Tongxiang City. The total heating volume in 2019 is 630,000 tons [13]. In the next few years, Power Generation Company will continue to leverage its strengths in the two primary businesses of power and heat, fully utilise the efficiency advantages of gas-steam combined cycle units, and strive for greater economic benefits for its enterprises. With the deepening of power market reform in Zhejiang Province, Power Generation Company has made significant strides in public relations, emphasising its environmental friendliness and outstanding peak shaving capabilities, resulting in increased utilisation hours year after year [14]. In 2020, the unit utilisation hours will be 1,500 hours. Zhejiang Province, a province with significant energy consumption, must consider the sustainable development of its environment. Consequently, part of the power share of thermal power units in Zhejiang Province will be replaced by external power from the Ningdong Power Generation Base. 2020 marks the closing year of Zhejiang's energy dual control policy and the commencement of the power spot market settlement trial operation. The province has organised several power spot settlement trial operations with the participation of foreign power companies. During the long-term trial operation in July, the Power Generation Company utilised various methods to call and operate the unit, including clearing before the day and real-time opening before the day, and successfully generated 29.3371 million kWh of power, resulting in a power generation and heating income of

6.9741 million yuan. Under the planned mode, to achieve the same income as under the spot mode, it is necessary to complete 93.0625 million kWh of power generation. The economic benefit index is at the leading level in the whole province.

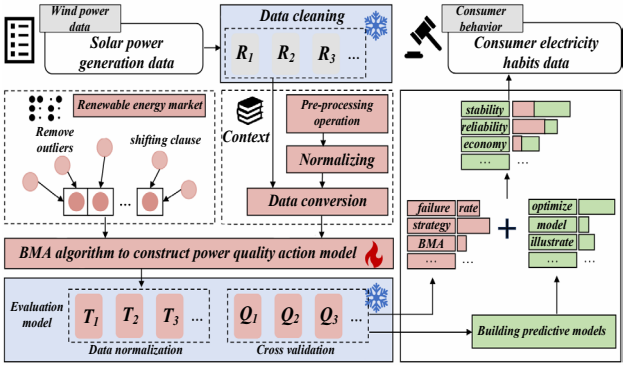

Figure 2.2. Flow Chart of Power Quality Optimization Processing Based on The BMA Algorithm

Figure 2.2 shows flow chart of power quality optimization processing based on the BMA algorithm. Brand and culture are the core competitiveness of enterprises. The Power Generation Company insists on playing a leading role in culture and guiding all cadres and employees to strengthen their confidence and work diligently. Under the guidance of Huaneng's "three colours" culture, based on the value orientation and the formed cultural atmosphere in the capital construction period, a unique sub-cultural system of "three firsts and three pleasures" has been created, that is, "taking the lead in creating the first, working in peace and contentment" [15]. The integration of Huaneng's "three colours" culture strengthens employee motivation by fostering shared values and a people-oriented approach. It promotes teamwork through collaboration and a resilient "wolf" spirit. This cultural alignment boosts productivity, innovation, and marketing effectiveness. Employees are united under a vision of green ecology and industry leadership. Ultimately, this drives sustainable growth and competitive advantage in the energy market.

At the same time, the corporate vision of "green ecology and gas turbine benchmark" has been put forward, "supporting the development of enterprises, contributing to the gas turbine industry, cultivating gas turbine talents and serving green water towns are the corporate mission, and forming" cultural integration, management integration, relationship and harmony ", that is, promoting the integration of technical culture and humanistic culture, realizing external coordination and management integration, and creating the harmony of external relations and interpersonal atmosphere. The culture of "Three Pioneers and Three Music" inherits the theme of "Three Colors" of the Group [16]. Taking the lead refers to the industry leading the way, while technology leading refers to the technology driving innovation. Creating first refers to the working state of keeping pace with the times and striving for the forefront. Leye is an important embodiment of the enterprise's "people-oriented" management concept, "Lequn" is an active advocacy for the cultivation of team spirit, the shaping of harmonious relations and the creation of a harmonious atmosphere, and "Lejia" is an important manifestation of the enterprise's inheritance of Chinese traditional "home" culture. "Three First and Three Music" is a fundamental portrayal of Power Generation Company's practice of Huaneng's "Three Colors" culture, and it also serves as the basic carrier and strong driving force of Huaneng's "Three Colors" culture.

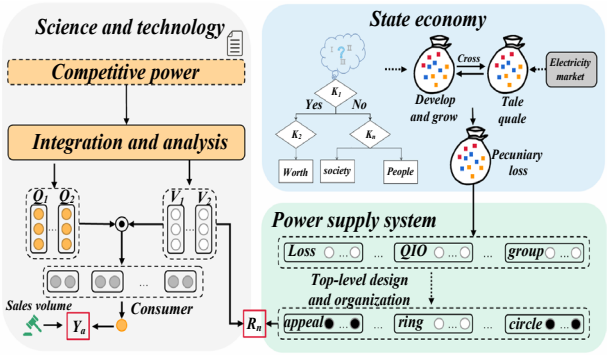

Figure 2.3. Application and Feedback Flow Chart of BMA Algorithm in Power Marketing

Figure 2.3 illustrates the application and feedback flow chart of the BMA algorithm in power marketing. Cultivating an excellent marketing team is crucial and necessary for the overall marketing situation of the enterprise. Renewable energy marketing relies on collecting detailed sales data, customer feedback, and power quality monitoring to inform its strategies. Sales data includes transaction records and market trading information segmented by customer and region. Customer feedback is gathered through surveys and usage behaviour analysis to assess satisfaction and loyalty. Power quality is monitored in real time using sensors that measure key electrical parameters. Advanced evaluation methods and algorithms analyze and integrate these data sources. This integrated data approach helps optimize marketing strategies, improve product reliability, and enhance customer trust. Currently, there is still considerable room for improvement in the construction of the marketing team and the training of marketing personnel in power. Generation companies [17]. Power quality is crucial for enhancing customer satisfaction and market competitiveness in the renewable energy sector. Improved power quality leads to more reliable and stable electricity, reducing equipment failures and building consumer trust. This increased trust boosts purchase intentions and encourage repeat business. Companies that focus on power quality differentiate themselves by offering superior product performance and reliability. Aligning marketing strategies with power quality improvements helps meet customer expectations and supports sustainable market growth. The company needs to

change its mindset: Electric power enterprises are no longer just a single industrial unit that requires science and engineering but also professional economic and financial talents to promote enterprise development. The model recommends that renewable energy enterprises focus on improving power quality as a key marketing strategy to enhance sales and customer satisfaction. Power quality should be used to differentiate products by emphasizing reliability and performance. Companies should adopt data-driven methods to optimize marketing strategies in line with customer needs. Building skilled marketing teams and maintaining proactive communication with regulators and grid operators are essential. A customer-centric approach that tailors solutions to specific needs will improve competitiveness and market share. Firstly, strengthen the training of marketing personnel. The company conducts open competitive exams for employees based on their job performance, professional abilities, and personal preferences and selects verified personnel to participate in marketing work. T Power Company should strengthen the introduction of professional marketing personnel and, through various channels such as campus and social recruitment, internal recommendations, etc., input more professional talents to inject fresh blood into the company's marketing. Hire external professional organizations to provide multi-dimensional and multi-level training on marketing personnel's market analysis skills, interpersonal communication skills, marketing skills, electricity market, and other aspects so that production personnel understand marketing and human marketing personnel understand production and cultivate composite marketing talents. Secondly, strengthen internal team building [18]. A good team does not depend on the outstanding individual abilities of its members but on the cohesion of the team. Marketing work is a job that requires long-term investment and mutual assistance; relying solely on one person to complete the entire marketing process work is unrealistic. Team members need to establish an atmosphere of mutual trust and assistance. Create a cohesive force within the team and encourage members to pursue their goals actively. Establish an internal "wolf" culture within the team, daring to fight and fight like a wolf while uniting and cooperating like a pack. Finally, set reasonable short-term goals. The ultimate goal of marketing work is to complete the marketing tasks set by superiors. Taking quick steps is an effective way to achieve long-term goals. Team leaders need to break down tasks in a planned manner based on marketing tasks and timelines. To achieve the ultimate goal by achieving short-term goals one by one. Short-term goals can provide team members with clearer objectives and execution strategies that are not empty. After completing small goals, providing certain incentives can better mobilize the enthusiasm of marketing personnel and maintain a high-quality work state at all times.

3. Comprehensive Evaluation of Power Quality

Currently, China is a major energy consumer. While people enjoy the convenience brought about by large-scale economic development, the impact on the ecological environment caused by excessive energy use is also increasing. The main reason for the frequent haze weather in the past two years is the excessive emission of automobile exhaust and factory pollutants. The destruction of the ecological environment has caused significant harm to human health, as evidenced by the increasing number of patients with respiratory tract infections, such as pneumonia [19]. At present, people are making great efforts to study clean energy, hoping to help people escape the predicament threatened by the ecological environment. As a clean energy source, electricity is being widely used. How to use clean energy reasonably and efficiently is of great significance, as evaluating power quality and pricing according to the level of power quality is crucial. Power quality comprehensive evaluation system, from the initial development of fuzzy mathematics evaluation method to the present probability and statistics eigenvalue method, fuzzy and probability and statistics method, matter-element analysis method, some literature according to the principle of "birds of a feather flock together" through fuzzy clustering method finally get a unified evaluation, each method has its advantages and disadvantages, and some methods have their limitations in the scope of application [20]. In this paper, several methods are adopted, and the characteristics of these evaluation methods are also explained, which likely have some shortcomings. It is expected to provide some new ideas for the comprehensive evaluation of power quality.

3.1 Comprehensive Evaluation of Power quality by Analytic Hierarchy Process

As a hierarchical and structured decision-making method, the Analytic Hierarchy Process (AHP) provides a concise and effective way of thinking for the rational evaluation of a multi-criteria system. Power quality ensures the dependable and effective functioning of electrical systems by maintaining constant voltage and frequency while minimising disruptions. It is evaluated using techniques such as the Analytic Hierarchy Process, probability theory, evidence theory, and Bayesian algorithms to ensure a thorough assessment and enhancement. In renewable energy, high Power quality enhances consumer trust and market competitiveness. It also enhances equipment reliability and facilitates the stable incorporation of renewable sources into the grid. Verifying power quality is important for the sustainable development and efficient operation of renewable energy systems. The core idea of the Analytic Hierarchy Process (AHP) is to describe the importance of two indicators in fuzzy terms and to express the relative importance of these indicators. This method combines qualitative and quantitative approaches, allowing for a comprehensive evaluation of multiple indices, and forms a single quantitative index to provide powerful results that support decision-making at a higher level. The

calculation formulas for the market equilibrium price and power quality on demand are shown in (3.1) and (3.2).

$$M_c(x) = \frac{1}{n}\sum_1^n M_c\left(x + N(0,\sigma^2)\right) \quad (3.1)$$

$$Te(\phi) = min_\phi \mathcal{L}_{MLT}(g(x^a, x^v; \phi), y) \quad (3.2)$$

The Analytic Hierarchy Process (AHP) is used to evaluate the multi-criteria problem of power quality [21]. The steps are as follows: firstly, the evaluation object system is defined, and the appropriate evaluation index system and hierarchical structure model are established. Secondly, the judgment matrix at each level is constructed, which is primarily composed of the relative importance of nine power quality indexes. Thirdly, the consistency of the judgment matrix is tested. Finally, the reasonable weights are determined, and the evaluation results are obtained. Analytic Hierarchy Process (AHP) must first establish a hierarchical model. According to the indexes listed in the power quality evaluation system presented in the first chapter, a hierarchical structure model for power quality evaluation is established. According to the block diagram of power quality evaluation presented in the first chapter, the voltage interruption index is classified as a component of the power supply reliability index. Bayesian Model Averaging (BMA) addresses model uncertainty by averaging predictions across multiple models weighted by their posterior probabilities. Unlike single-model methods, BMA improves prediction accuracy and robustness by accounting for uncertainty in model selection. It effectively integrates diverse data like sales, user feedback, and power quality measurements. Compared to methods like AHP or D-S evidence theory, BMA offers stronger statistical rigour and clearer uncertainty quantification. In this study, BMA demonstrated that improvements in power quality have a positive impact on sales and customer satisfaction. This makes BMA well-suited for optimizing renewable energy marketing strategies under uncertainty. The power quality evaluation model based on AHP is shown in Figure 3.1.

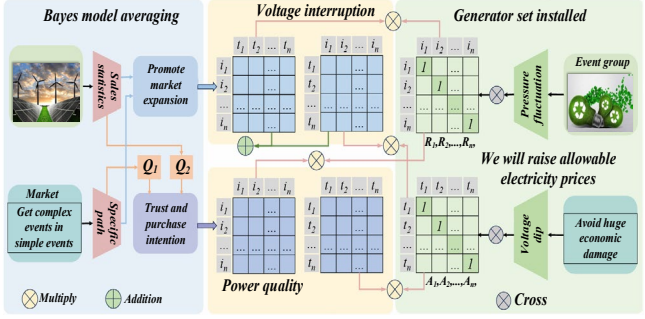

Figure 3.1. The Power Quality Evaluation Model Based on AHP

3.2 Comprehensive Evaluation of Power Quality by Full Probability Formula

Probability theory is a mathematical problem that we often encounter in real life. Scientific researchers have gradually established and summarized the related properties of events, probabilities and random variables from ordinary accidental events. Therefore, the knowledge of probability theory is slowly applied to many social and engineering technical problems. While solving issues such as population statistics, astronomical prediction, and product inspection, it also promotes the development and improvement of probability theory itself [22]. Therefore, probability theory, like many mathematical statistics disciplines, plays an irreplaceable role in all aspects of social life. Probability theory primarily determines the probability of complex events based on the known probabilities of simple events. Such a complex event can generally be decomposed into several simple events or a combination of several simple, independent events. The process of calculating the probability of complex events by using the probability of simple events involves the application of the full probability formula. To explain the total probability formula more clearly, suppose that there are n incompatible events, A_1, $A2$,..., A_n, A_1, A_2..., A_n can form a complete event group, and $P(A) > 0$, then for any event B, it always occurs simultaneously with one of A_1, A_2..., A_n, and the calculation formula is shown as (3.3).

$$P(B) = \sum_{i=1}^n P(A_i)P(B|A_i) \quad (3.3)$$

$$P(B) = \sum_{i=1}^n P(A_i)P(B|A_i)$$

The steps of evaluating power quality by using the full probability formula are as follows: Firstly, complete event groups A_1, A_2,..., and A_9 are established, which respectively represent nine indexes of power quality: voltage deviation, voltage fluctuation, three-term imbalance, total harmonic inclusion rate, voltage sag, voltage sags, frequency deviation, power supply reliability and demand side management. Power quality is essential in renewable energy marketing because it directly impacts sales, customer satisfaction, and product reliability. High power quality builds consumer trust and reduces product failures, making renewable energy products more competitive. It supports market expansion by increasing. Customer loyalty and encouraging repeat purchases. Accurate evaluation of power quality enables fair pricing and efficient resource allocation. Overall, improving power quality is key to aligning marketing strategies with consumer needs and driving sustainable growth in the renewable energy sector. Events B_1, B_2, B_3, B_4 and B_5 mean high power quality (level 1), good (level 2), medium (level 3), qualified (level 4) and unqualified (level 5), respectively. The quality of power is crucial for energy producers, sellers, and users. It ensures dependable and efficient energy distribution, helping producers minimise losses and enhance competitiveness. For marketers, high power quality enhances customer satisfaction and boosts sales. Customers gain from consistent electricity that safeguards devices and lowers

expenses. In general, power quality enhances market efficiency and energy consumption throughout the complete energy supply chain. The most important point here is to take the event into account, which means that the power quality level cannot be determined and can also be considered a virtual level. In the second step, the prior probability is determined based on the actual data, where the proportion of each index within the measurement period is used as the occurrence probability of that index [23, 24]. In the third step, the total probability formula is used to calculate and get the final evaluation result. Currently, the total probability evaluation method is utilised in all aspects of engineering. Using this method to evaluate the electric energy index still relies on obtaining the prior probability of each index first, accurately extracting its characteristics, and then determining the probability value through artificial statistical measurement. In this paper, the uncertain part is also considered as part of the results and has its corresponding probability value. Through calculation, we can know whether the power quality assessment based on the full probability method has its advantages in dealing with uncertain levels.

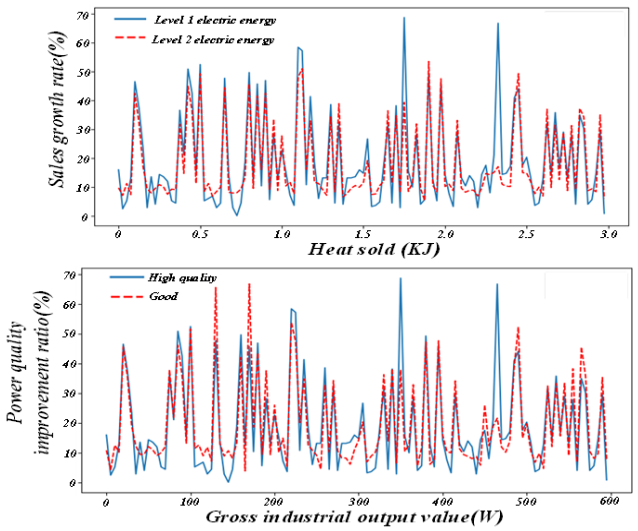

Figure 3.2. Comparison Diagram of Power Quality Fluctuation and BMA Algorithm Optimization Effect in Renewable Energy Market

Figure 3.2 illustrates a comparison diagram of power quality fluctuations and the BMA algorithm's optimisation effect in the renewable energy market. Planned electricity quantity is a concept introduced after the first round of electricity market reform [25, 26]. Bayesian Model Averaging (BMA) improves prediction by averaging multiple models weighted by their probabilities given the data. It combines prior beliefs and observed data to effectively handle model uncertainty. Instead of choosing one model, BMA uses all plausible models to make more reliable predictions. This reduces bias and overconfidence in complex problems. In renewable energy marketing, BMA reveals how better power quality boosts sales and customer satisfaction. The Provincial Development and Reform Commission, Energy Bureau, and Power Grid Company, based on the calculation of total social electricity consumption for the following year, combined with factors such as unit capacity and assessment, will implement government pricing for the rated electricity consumption of the units. Currently, Zhejiang Province implements different planned electricity distribution policies for various types of units. As the peak unit, gas turbine units obtain much less planned electricity than coal-fired and nuclear power units [27]. The research by Priyan Malarvizhi Kumar (2024) focuses on optimizing wind and solar energy systems while emphasizing environmental benefits. This approach is adopted in our work by applying the BMA algorithm to improve power quality in renewable energy marketing by balancing multiple performance factors [28]. Once the planned electricity is sufficient, it can exceed the marginal revenue and achieve profitability. In 2020, the power generation company achieved a total of 1,500 utilisation hours, equivalent to 688 million kilowatt-hours of electricity generation. In the current process of electricity market reform, a balance will be struck between planned electricity quantity and spot market electricity quantity. According to the reform plan for the electricity market in Zhejiang Province, the planned electricity quantity will play a crucial role in ensuring a smooth transition and a stable market. Electricity, as a real-time commodity, has the characteristic of not being stored for a long time [29]. The generation of planned electricity can ensure a balance between power supply and demand, ensuring that the power grid meets safety constraints. In terms of planned electricity marketing, power generation companies should strengthen communication with relevant departments, such as the Zhejiang Provincial Development and Reform Commission and the State Grid Corporation of China, before formulating their annual electricity consumption plans. Based on the current heating situation in the western region of Tongxiang, they should fully consider the guarantee of electricity demand in the heating market through rational arguments. In the process of issuing and implementing daily planned electricity, it is necessary to actively communicate with the dispatch and control centre to obtain information on grid power flow, network architecture and other aspects, and use important nodes such as the World Internet Conference and the NPC and CPPCC to strive for the start of unit dispatching [30]. If allowed by the rules, strive to achieve an early start and late stop with multiple transmissions. Marketing personnel should prioritize the completion of annual planned electricity consumption, and the entire factory should make this goal the core content of daily production and operation.

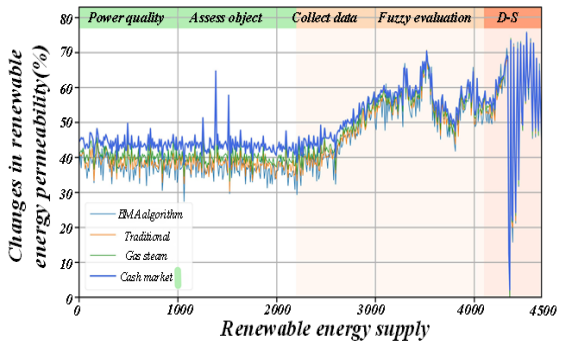

Figure 3.3. Power Quality Distribution Diagram of Renewable Energy Sources Based on The BMA Algorithm

Figure 3.3 illustrates the power quality distribution diagram of renewable energy sources using the BMA algorithm. The market electricity quantity is determined by the actual electricity demand in the electricity market, and human factors do not control the scale of electricity quantity. In the current electricity market, power generation Companies can engage in electricity trading with market users through bilateral negotiations, centralised bidding, and other means to obtain electricity beyond their planned capacity. In the 10 major industries that have been opened up, such as steel, non-ferrous metals, glass, and building materials, electricity users can sign bilateral price difference contracts with power generation companies. This portion of the market electricity is referred to as contracted electricity. In the operation of the electricity spot market, each power generation enterprise obtains the winning electricity through a reasonable bidding strategy in market competition and supplies electricity according to the obtained electricity, which is called spot electricity. The contract electricity quantity and spot electricity quantity together constitute the market electricity quantity. In terms of fuel cost and unit capacity for T Power Company, the main focus should be on spot electricity. By precisely calculating the marginal cost of each unit and providing reasonable quotations, opportunities can be created for unit clearance and operation, thereby increasing profits. In the spot market, due to current constraints on fuel costs, competition between gas and coal turbines generally favours coal turbines. However, the marketing strategy of power generation companies in the spot market can be based on power grid trends and network topology, combined with the maintenance and shutdown situation of various power generation companies, to analyze the power supply and demand relationship in Jiaxing and Huzhou regions, and quote based on marginal costs; When considering opportunity benefits such as auxiliary services, marginal balance can be used to lower the quotation to maximize the opportunity for unit operation [31]. In terms of contracts, firstly, a comprehensive understanding of the spot electricity prices during the early operation of the electricity market should be achieved. Based on the node electricity prices around important users, combined with the marginal cost of the unit itself, the contract price should be comprehensively considered. Secondly, conduct preliminary background checks on contracted users, select high-quality users, and reduce the difference in electricity consumption between day and night peaks and valleys. Avoid competing with the market for electricity during periods of tight supply and demand, characterised by large peak-to-valley differences, and discontinue electricity use when the supply and demand relationship is loose. These two methods will significantly reduce the return on the contract price difference.

3.3 Power Quality Evaluation Based on D-S Evidence Theory

Evidence theory is also known as the Dempster-Shafer reliability function theory. This theory was first proposed by Dempster in 1967, and the publication of A Mathematical Theory of Evidence by Shafer marked the birth of evidence theory. In the following 30 years, more and more scholars and researchers have continuously improved and perfected the evidence theory through decades of unremitting efforts. This information fusion provides a reliable method for achieving this goal. At the same time, it demonstrates an increasingly important role in addressing practical application problems. The D-S theory of evidence continues to gain traction, improving papers and solidifying the theoretical basis of evidence theory, making the algorithm more practical.

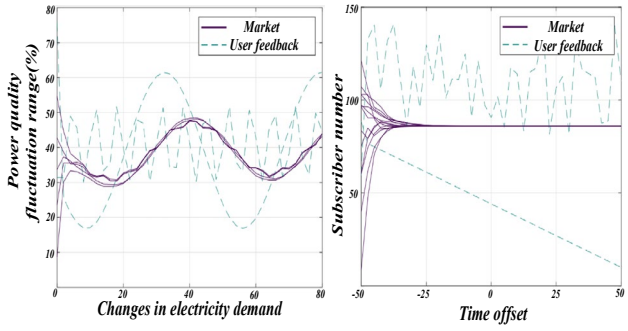

Figure 3.4. Effect Analysis Diagram of BMA Algorithm in Power Quality Improvement

Figure 3.4 shows the effect analysis diagram of the BMA algorithm in power quality improvement. Most things are uncertain. To describe objective things accurately, this description will vary widely according to the descriptor's knowledge reserve and the randomness of collected data. When dealing with information fusion involving uncertain factors, we must consider the impact of uncertainty on the

fusion results. Although much literature has proposed a comprehensive evaluation of power quality, these methods still have various limitations. When the analytic hierarchy process (AHP) encounters large-scale problems with numerous elements, it must continually verify whether the judgment matrix satisfies the consistency requirements, thereby increasing the computational complexity. At the same time, this method also has certain restrictions on the order of the matrix. The core of the fuzzy evaluation method is determining the membership function. If the membership function is selected improperly, the evaluation results may not achieve the expected outcomes and could even appear contrary to the intended results. Therefore, evidence theory has developed. At the beginning of its development, D-S evidence theory was mainly used in artificial intelligence and data fusion technology. In recent years, evidence theory has been widely used in the evaluation of various models. The market demand function, considering power quality, and the market equilibrium conditions, considering power quality, are shown in (3.4) and (3.5).

$$q(x_t \mid x_{t-1}) = \mathcal{N}\left(\sqrt{\bar{\alpha}_t}x_{t-1}, (1-\bar{\alpha}_t)I\right) \tag{3.4}$$

$$\mathcal{L}_{sup} = \mathbb{E}_{i\sim\mathcal{D}}H(\mathcal{G}_i, \mathcal{P}_i) \tag{3.5}$$

In D-S evidence theory, evidence is not real evidence but rather refers to observations and research results obtained based on existing experience and knowledge. Suppose there is a problem that needs to be evaluated, and a complete set represents all the elements contained in this problem. All the elements in it are mutually exclusive and must meet the requirement that there can only be one definite answer to the evaluation result at any time. Then, we refer to the complete set that satisfies the above conditions as the recognition framework. In this paper, a comprehensive power quality identification framework is constructed, utilising D-S evidence theory to evaluate power quality effectively. The collection of all possible power quality levels constitutes a recognition framework; that is, the recognition framework contains all the decision results. The calculation formula for the maximum profit function under power quality optimisation is shown in (3.6).

$$\mathcal{PL}_i^{k,t} = \beta\mathcal{PL}_i^{t-1} + (1-\beta)\widehat{\mathcal{PL}}_i^t \tag{3.6}$$

Every index of power quality constitutes evidence. The fusion process of evidence theory involves using the divided evidence set to judge the recognition framework independently and then applying synthesis rules to combine the judgment results of multiple pieces of evidence into a unified new evidence body, ultimately leading to the final judgment.

4. Conclusion

Through in-depth research on the mechanism of power quality in renewable energy marketing under the BMA algorithm, this paper draws the following conclusions. Firstly, data analysis reveals that power quality has a significant positive impact on renewable energy marketing. Specifically, when power quality is improved by 10%, the sales of renewable energy products increase by approximately 6% on average, and customer satisfaction also increases by 7% accordingly. The presented data not only underscores the paramount significance of power quality in marketing strategies but also offers concrete guidelines for enterprises to fine-tune their market approaches. The quality of power serves as a pivotal determinant in shaping the market competitiveness of renewable energy products. Electricity that exhibits superior quality can significantly enhance the performance and reliability of these products, thereby reducing the likelihood of malfunctions and fostering consumer confidence and loyalty towards them. This augmented trust not only contributes to an expansion of market share but also enhances the overall value of the product. But also serves to enhance the reputation of enterprises and fosters opportunities for repeat purchases. Our in- depth exploration has revealed a dynamic interplay between power quality and the marketing of renewable energy. As the quality of power continues to improve, it becomes increasingly imperative for marketing strategies to undergo commensurate adjustments and optimisations, thereby ensuring a more seamless alignment with the evolving needs and expectations of consumers.

Declarations

Funding
The authors declare that they did not receive any funding.

Conflicts of Interests
Authors do not have any conflicts.

Data Availability Statement
No datasets were generated or analyzed during the current study.

Code availability
Not applicable.

Authors' Contributions
Qinghua Fan is responsible for designing the framework, analyzing the performance, validating the results, and writing the article.

References

[1] Li, Z., Wang, Z., Yan, Y., & Ye, G. (2020). Research on Modeling Uncertainty of Load Modeling based on IMM Algorithm. 5th International Conference on Power and Renewable Energy (ICPRE).

[2] Ravi Kumar, B. N., & Suresh, Y. (2022). Effective ANN Model based on Neuro-Evolution Mechanism for Realistic Software Estimates in the Early Phase of Software Development. International Journal of Advanced Computer Science and Applications, 13(2). https://doi.org/10.14569/IJACSA.2022.0130223

[3] Xiang, F., Di, M. A., Weihong, H., Zhiqing, S., Xuan, Y., & Jian, L. (2019). Research on the blockchain consensus mechanism for distributed renewable energy access. Zhejiang Electric Power.

[4] Rui, & Gu. (2018). Research on Matching Mechanism of Resource Based on Genetic Algorithm.

[5] Yang, D., Ji, M., Lv, Y., Zhao, F., Geng, Q., & Bhola, J. (2022). Research on zoning, optimization, stability, and nonlinear control of wireless network in power grid communication. Journal of Interconnection Networks, 22(Supp06).

[6] Wang, G., Jia, R., Liu, J., & Zhang, H. (2020). A hybrid wind power forecasting approach based on Bayesian model averaging and ensemble learning. Renewable Energy, 145, 2426–2434. https://doi.org/10.1016/j.renene.2019.07.166

[7] Rajack, B. M. A., Ganesh, S., Mary, S. S., & Jimreeves, J. R. (2021). Determination of switching angle from inductance profile of converter fed switched reluctance generator in wind energy conversion system. IOP Conference Series: Materials Science and Engineering, 1084(1), 012063.

[8] Akintande, O. J., Olubusoye, O. E., Adenikinju, A. F., & Olanrewaju, B. T. (2020). Modeling the determinants of renewable energy consumption: Evidence from the five most populous nations in Africa. Energy, 206, 117992.

[9] Zjavka, L. (2022). Power quality statistical predictions based on differential, deep and probabilistic learning using off-grid and meteo data in 24-hour horizon. International Journal of Energy Research, **(8)**, 46.

[10] Zhang, Z., & Shang, M. (2024). Research on hydrogen leakage and diffusion mechanism in hydrogenation station. Scientific Reports, 14(1).

[11] Chen, G., G.-N., C., & Sun, L. L. P. (2022). Study on the mechanism of wrinkle flattening under internal pressure and the critical condition of dead wrinkle. Journal of Manufacturing Processes, 76(4), 740–751.

[12] Wang, L., Zhang, R., Zhang, L., Yi, T., Zhang, D., & Zhu, A., et al. (2024). Research on Individual Tree Canopy Segmentation of Camellia oleifera Based on a UAV-LiDAR System.

[13] Zhang, M., Guo, J., Yao, S., Ren, G., Guo, Z., & Yan, G., et al. (2024). The influence mechanism of ionic liquids on the ash melting and combustion characteristics of Zhundong high-alkali coal.

[14] Wensi, C., Shuo, W., Chao, M., & Mingming, X. (2022). Research on optimal scheduling of VPP based on Latin hypercube sampling and k-means clustering.

[15] Wang, L., Zhao, H., & Li, Y. (2019). Research on the multi-scale network crowd density estimation algorithm based on the attention mechanism. 2019 4th International Conference on Intelligent Informatics and Biomedical Sciences (ICIIBMS). IEEE.

[16] Wen, B., Tian, N., Feng, X., Lu, E., & Guo, Q. (2019). Research on the Privacy-Preserving Energy Management in Power Grid Based on Information Masking. 2019 IEEE 3rd Conference on Energy Internet and Energy System Integration (EI²). IEEE.

[17] Mingcai, C. (2018). Research on energy storage mechanism of renewable energy grid based on power balance strategy. Computer & Digital Engineering.

[18] Qiao, H., & Long, Z. (2021). Research on application of BP neural network based on genetic algorithm in heartbeat mechanism. IEEE.

[19] Hijazi, O., Abdelsalam, E., Samer, M., Attia, Y. A., Amer, B. M. A., & Amer, M. A., et al. (2020). Life cycle assessment of the use of nanomaterials in biogas production from anaerobic digestion of manure. Renewable Energy, 148.

[20] B, B. M. A., A, E. W., C, U. P., B, L. G., & B, D. C. (2018). Heat roadmap Europe: Identifying local heat demand and supply areas with a European thermal atlas. Energy, 158, 281–292.

[21] Li, J., Qiao, X., Zheng, L., & Li, Y. (2022). Research on adaptive cruise control based on driver characteristics.

[22] Da, S., Gang, L., Haoran, H., & Zengyao, L. (2020). Analysis and Research on the Mechanism of Grid Connected Sub / Super Synchronous Oscillation of Direct Drive Wind Farm via AC Series Compensation. 2020 5th International Conference on Power and Renewable Energy (ICPRE).

[23] He, Y. K., Liu, R. F., Ding, T., & Li, G. F. (2020). Research on Renewable Energy Accommodation Power Market Mechanism in Energy Internet Environment. 2020 IEEE Sustainable Power and Energy Conference (iSPEC). IEEE.

[24] Jianyun, Z. (2018). Research on the mechanism of subsynchronous oscillations of wind farms in Hami. Proceedings of the CSEE.

[25] Wu, B., Li, H., Meng, G., Xu, S., Zhang, J., & Cui, Y. (2021). Research on the seam formation mechanism of elliptical bipolar linear directional blasting based on the SPH-FEM coupling method. Shock and Vibration.

[26] Sun, R., Shu, Y., Lv, Z., Chen, B., & Wei, Z. (2020). Research on the Multiple Timescale Reactive Power Optimization of Receiving Power Grid Based on Model Predictive Control. 2020 12th IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC). IEEE.

[27] Weiyang, L., Bing, W., Min, W., & Guiru, C. (2019). Research on electric vehicles participating in bidding mechanism of power grid based on smart contract technology. Power System Technology.

[28] Kumar, P. M., Kamruzzaman, M. M., Alfurhood, B. S., Hossain, B., Nagarajan, H., & Sitaraman, S. R. (2024). Balanced performance merit on wind and solar energy contact with clean environment enrichment. IEEE Journal of the Electron Devices Society, 2024; 12: 808-823

[29] Chao, G., Nan, X., & Ning, L. (2018). Research on the mechanism of partial discharge in 35 kV GIL and improvement scheme based on finite element modeling. Sichuan Electric Power Technology.

[30] Qian, Z., Guo, P., Wang, Y., & Xiao, F. (2023). Ethical and moral decision-making for self-driving cars based on deep reinforcement learning. Journal of Intelligent & Fuzzy Systems: Applications in Engineering and Technology, (4), 45.

[31] Gemechu, D. N., Mohammed, A. M., Redi, M., Bessarabov, D., Mekonnen, Y. S., & Obodo, K. O. (2023). First principles-based approaches for catalytic activity on the dehydrogenation of liquid organic hydrogen carriers: A review. International Journal of Hydrogen Energy, (85), 48.