Advances in Intelligent Systems and Computing 1459

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New Trends in Disruptive Technologies, Tech Ethics, and Artificial Intelligence

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Advances in Intelligent Systems and Computing 1459

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Editors

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Preface

In recent years, we have witnessed significant advances in technologies such as artificial intelligence, big data, the Internet of Things, and bioinformatics. These advancements have made it evident that there is a need for a thorough review of current ethical patterns. One of the research fields that is rapidly growing and has a broad future is technology ethics or tech ethics. Until a few years ago, this type of research was a small part and did not involve many technology researchers. Currently, due to the proliferation of new applications of artificial intelligence, numerous initiatives, declarations, principles, guides, and analyses focused on measuring the social impact of these systems and the development of more ethical technology have flourished.

The International Conference on "Disruptive Technologies, Tech Ethics, and Artificial Intelligence" (DITTET 2024) provides a forum to present and discuss the latest scientific and technical advances and their implications in the field of ethics. It also offers an opportunity for experts to present their latest research on disruptive technologies, promoting knowledge transfer. This conference provides a unique platform for bringing together experts from various fields, academia, and professionals to exchange their experiences in the development and deployment of disruptive technologies, artificial intelligence, and their ethical problems.

The aim of DITTET is to gather researchers and developers from industry, humanities, and academia to report on the latest scientific advancements and the application of artificial intelligence, as well as its ethical implications in diverse fields such as climate change, politics, economy, or security in today's world.

Each paper submitted to DITTET underwent a rigorous peer review process by three members of each workshop's international committee. Of the proposals received from over 130 authors, 42 were selected for presentation at the conference.

We would like to express our deepest gratitude to all the contributing authors, as well as to the members of the Program Committees and the Organizing Committee, for their hard work and invaluable contributions. Their dedication and efforts were instrumental to the success of the DITTET 2024 event. Thank you for your support; DITTET 2024 would not have been possible without your contribution.

May 2024

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Disruptive Technologies Applied to Digital Education

Track on Artificial Intelligence

Integrating AI Techniques for Enhanced Management and Operation of Electric Vehicle Charging Stations

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Abstract. Managing Electric Vehicle (EV) charging stations poses challenges due to limited contracted power. To address this, we introduce the Intelligent Electric Vehicle Charging Controller (IEVCC) prototype. IEVCC optimizes power utilization without additional costs and can operate independently or in a network. A designated manager allocates power among chargers through load balancing and prioritization.

Our system incorporates predictive charging, using AI to anticipate users' needs based on historical data and preferences, ensuring availability. Additionally, AI-driven load balancing efficiently distributes power among chargers, preventing overload.

Dynamic pricing strategies incentivize efficient charging by adjusting tariffs based on demand and available power, promoting sustainability

In conclusion, the IEVCC offers a holistic solution for managing EV charging stations. By optimizing power usage, integrating predictive charging, load balancing, and dynamic pricing, it enhances efficiency and ensures prudent resource utilization in the transition towards sustainable transportation.

Keywords: Electric Vehicle (EV) · Charging Stations · Intelligent Charging Controller · Predictive Charging · Dynamic Pricing

1 Introduction

The surge in Electric Vehicle (EV) sales worldwide, driven by factors such as low Total Cost of Ownership (TCO), environmental concerns, and government incentives, underscores the increasing adoption of EVs [1,2]. Despite temporary setbacks due to the COVID-19 pandemic, EV sales witnessed a remarkable 108% increase last year compared to 2020 [3], with projections indicating continued

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growth albeit at a slightly slower pace [4–6]. These trends align with legislative initiatives like the European Commission's target of achieving climate neutrality by 2050 and a 55% reduction in greenhouse gas emissions by 2030 [2]. The urgency to reduce fossil fuel dependency has made the transition to EVs imperative, as evidenced by major automakers' commitments to become fully electric by 2030–2035 [13].

However, despite the increasing popularity of EVs, challenges persist, particularly regarding access to private charging facilities and the availability and affordability of public charging stations. Limited access to convenient charging infrastructure and inadequate residential electric infrastructure pose significant barriers. The standard 16A Schuko plug commonly found in residential buildings often fails to meet the charging demands of modern EVs, which require higher charging capacities.

To address these challenges, this paper proposes an Intelligent Electric Vehicle Charger Controller that utilizes AI techniques to enhance EV charging station operation and management. The system integrates Predictive Charging, Load Balancing, and Dynamic Pricing to optimize charging schedules, maximize power utilization efficiency, and incentivize sustainable charging practices. Experimental evaluations demonstrate the effectiveness of this approach in enhancing charging infrastructure efficiency, availability, and sustainability.

In conclusion, the integration of AI-driven techniques offers a promising solution to the challenges faced in managing EV charging stations. By addressing limitations in charging infrastructure and promoting sustainable practices, this research contributes to the advancement of EV technology and supports the transition to a greener transportation system.

2 AI driven Electric Vehicle Charging Controller

In order to support the AI-driven Predictive Charging, Load Balancing, and Dynamic Pricing strategies, the hardware (Fig. 1) of the Intelligent Electric Vehicle Charger Controller (IEVCC) system is designed to accommodate these functionalities (Fig. 2).

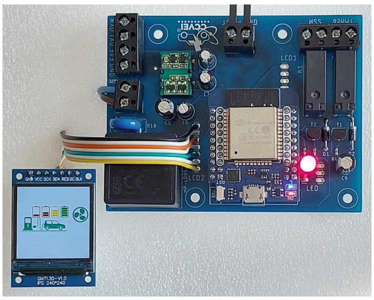

Fig. 1. IEVCC board

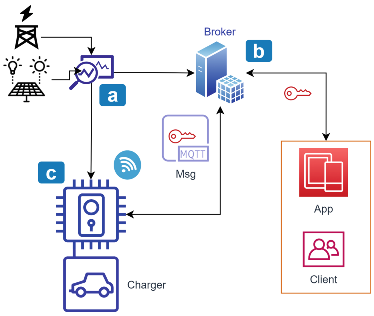

Fig. 2. Diagram of the Standalone Version.

Figure 2 shows a diagram of the system, which is composed by the:

– Consumption monitor hardware (a);
– Consumption monitor system - broker (b);
– Intelligent Electric Vehicle Charging Controller (c).

Firstly, the hardware incorporates advanced processing capabilities to enable predictive charging. The AI algorithms responsible for predicting the charging behavior of EV owners based on historical data and user preferences require computational power for analysis and decision-making. The hardware is equipped with a powerful processor or microcontroller, such as the expressif ESP32 board, which can handle complex calculations and perform real-time predictions. Using the processing capabilities of the hardware, the system can optimize charging schedules and ensure that charging stations are available when they are most needed.

Second, the hardware is designed to facilitate load balancing among multiple electric vehicle chargers. Load balancing techniques involve intelligent distribution of the available power among chargers within a building or parking lot. The hardware integrates communication interfaces and protocols to enable efficient data exchange between the chargers and the central controller. This allows the controller to monitor the power usage of individual chargers and dynamically allocate power resources based on demand and availability. By coordinating the charging activities of multiple EVs, the hardware ensures that the electrical infrastructure is not overloaded and maximizes the utilization of the available power.

Lastly, the hardware supports the implementation of dynamic pricing strategies. This involves the ability to adjust charging prices based on various factors, such as demand, time of day, and availability of renewable energy. The hardware is designed to facilitate communication with external systems or networks that provide information related to pricing and energy availability. When integrated with these systems, the hardware can receive real-time data and make pricing decisions accordingly. The hardware includes the necessary interfaces, such as Wi-Fi or cellular connectivity, to establish communication and receive pricing information. This enables the system to incentivize users to charge their vehicles during off-peak hours or when renewable energy sources are abundant, effectively managing the demand on the charging infrastructure.

Overall, the hardware of the IEVCC system is carefully designed to support AI-driven predictive charging, load balancing, and dynamic pricing functionalities. Its processing capabilities, communication interfaces, and connectivity options enable the system to optimize charging schedules, efficiently distribute power, and implement dynamic pricing strategies. By leveraging the hardware capabilities, the IEVCC system enhances the operation and management of EV charging stations, contributing to the availability, efficiency, and sustainability of the charging infrastructure.

2.1 Mesh Version

In the mesh version of the Intelligent Electric Vehicle Charger Controller (IEVCC) system, the integration of AI-driven Predictive Charging, Load Balancing, and Dynamic Pricing further enhances its functionality and addresses the challenges specific to condominium environments.

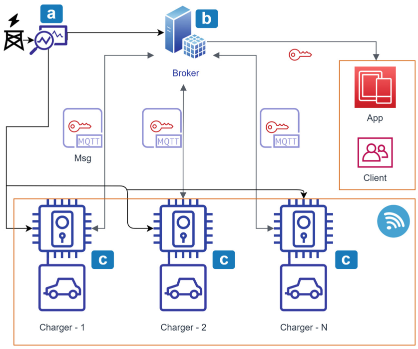

Fig. 3. Diagram of the Mesh Version.

To support Predictive Charging in the Mesh version (Fig. 3), AI algorithms are used to predict the charging behavior of EV owners residing in the condominium. By analyzing historical data and user preferences, the system can anticipate the charging patterns of individual users, even with multiple users having different needs or rights. The hardware includes a consumption monitor (a) that captures the charging data and communicates it to the central Broker/Manager (b). The AI algorithms running on the Broker/Manager analyze the data to optimize charging schedules, ensuring the availability of charging stations when they are most needed. This integration enables efficient charging management for multiple users within the condominium, addressing the unique infrastructure conditioning factors, such as cable thermal limits or the maximum available power from the energy provider.

Load Balancing in the Mesh version becomes more challenging due to the presence of multiple users with different charging needs. The hardware incorporates the Intelligent Electric Vehicle Charging Controller with energy meter (c), which facilitates load balancing among the chargers in the condominium. The central Broker/Manager receives information about the power usage and demands from individual chargers and dynamically allocates power resources based on the available power and user profiles. By utilizing AI-based load balancing techniques, the system ensures that the electrical infrastructure is not overloaded and maximizes power utilization among charging stations.

Dynamic Pricing is another essential aspect integrated into the Mesh version of the IEVCC system. Each user is provided with an NFC card that activates the charger and identifies them on the system. The card is linked to the user's account, which defines their access rights, such as the maximum power they can charge and priority over other users. Based on the user profile, the number of users charging at any given moment, and the available power, the system dynamically adjusts the charging rates and prioritizes charging based on predefined criteria. The chargers communicate all information about the charging sessions, including usage time and used energy, to the Broker/Manager. This information is then used to apply dynamic pricing strategies and charging fees. Through AI algorithms, the system optimizes pricing based on factors such as demand, time of day, and available power capacity, incentivizing users to charge their vehicles during periods of low demand and high renewable energy availability.

By integrating the AI-driven Predictive Charging, Load Balancing, and Dynamic Pricing functionalities, the Mesh version of the IEVCC system ensures efficient utilization of charging stations in condominium environments. It addresses the challenges of multiple users, varying infrastructure factors, and the need to make charging decisions based on user profiles and available power resources. With the hardware components, including the consumption monitor, Broker/Manager, and Intelligent Electric Vehicle Charging Controller, the system enables effective management of charging sessions, adjustments to charging rates, and accurate fee calculations based on AI-driven algorithms.

2.2 Consumption Monitor Hardware

The consumption monitor hardware (Fig. 4) is pivotal in overseeing power consumption within the house or building. Utilizing a PZEM-004T V3.0 board, based on the Vango V98xx IC, it measures critical parameters like Voltage, Current, and Active Power at regular intervals [11]. These values are then transmitted to the consumption monitor system, stored in a database for user access, providing insights into electricity costs associated with various home devices.

To augment system capabilities, artificial intelligence (AI) techniques are integrated into the consumption monitor system. AI algorithms analyze collected consumption data, predicting future energy usage patterns. This AI-driven Predictive Charging optimizes schedules, ensuring charging stations are available when needed, by anticipating charging patterns and adjusting schedules accordingly [14].

Fig. 4. Consumption Energy Monitor

Additionally, current consumption monitor data is communicated to a broker using the MQTTS protocol [12]. This facilitates the Intelligent Electric Vehicle Charging Controller (IEVCC) to not only adjust charging current based on contracted power information but also utilize AI-based Load Balancing techniques. These techniques intelligently distribute available power among multiple EV chargers, preventing overload and maximizing utilization [15].

Furthermore, the system integrates AI-driven Dynamic Pricing strategies, adjusting charging prices based on factors like demand and available power capacity [16]. This incentivizes users to charge during off-peak hours or when renewable energy is abundant, promoting efficiency and sustainability while managing infrastructure demand.

Moreover, the system supports renewable energy utilization, directing power from sources like solar panels directly to chargers. This AI-driven integration empowers users to monitor and optimize energy consumption, maximize renewable energy utilization, and make informed charging decisions.

3 Results

In this study, comprehensive tests were conducted in real-world parking spots connected directly to household power. Residents continued daily activities without disruption while the Intelligent Electric Vehicle Charging Controller (IEVCC), integrated with AI, autonomously adjusted charging power. This AI-driven adaptation ensured efficient charging operations, seamlessly accommodating electric vehicle needs alongside household activities.

3.1 Standalone Version

This paper examines how AI integration optimizes electric vehicle charging dynamics, focusing on the inaugural version of the standalone Intelligent Electric Vehicle Charging Controller (IEVCC). Through real-world charging sessions, the study demonstrates AI's role in adaptive power management, addressing household power constraints and responding promptly to energy demand fluctuations.

Our experiment utilized a 2015 Nissan Leaf 24 kWh with a user-contracted power of 5.75 kVA, allowing a maximum current of 25 A. The dwelling featured an intelligent meter, surpassing conventional overcurrent residual current breaker (RCBO) responsiveness. To ensure compatibility with the intelligent meter, an AI-driven buffer of 3 A was ingeniously implemented. This buffer serves as an intelligent safeguard, preventing household current from exceeding the meter's defined threshold and mitigating the risk of interruptions.

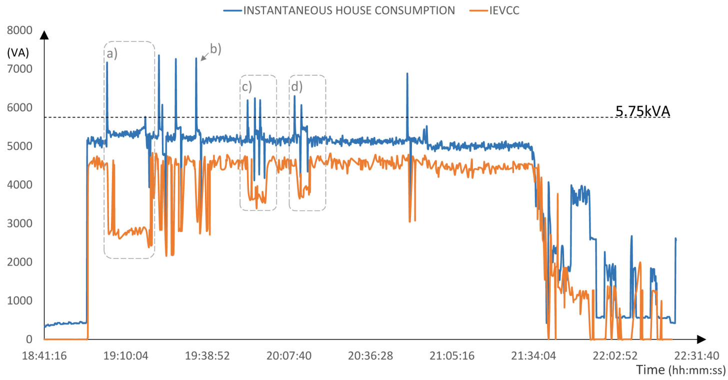

Fig. 5. Charging session data

The IEVCC, empowered by AI algorithms, orchestrates a dynamic dance between the charging requirements of the electric vehicle and the instantaneous power consumption of the home. Through continuous monitoring and analysis, the IEVCC effortlessly adapts the charging current to maintain a harmonious balance, ensuring that the sum of the current drawn by household appliances and the vehicle remains below the pre-defined maximum value. This seamless coordination is visible in Fig. 5, where the charging session unfolds.

Analyzing the details of Fig. 6, moments marked as a, b, c, and d reveal occasional peaks in power consumption. These spikes occur when household appliances activate, momentarily exceeding the maximum threshold. However, the AI-driven consumption monitor system, operating at a 10-s interval, detects these changes in real-time. Upon identification of a peak, the system promptly communicates with the IEVCC, triggering a rapid response. Leveraging its AI capabilities, the IEVCC swiftly adjusts the charging current available to the electric vehicle, bringing consumption back within defined limits.

In cases where available power cannot support household consumption and charging requirements simultaneously, the AI-powered IEVCC intelligently intervenes. It may temporarily suspend the charging process until the power supply becomes adequate to resume seamlessly. This AI-driven decision-making ensures optimal power utilization, mitigates the risk of power overload, and safeguards overall electrical system stability.

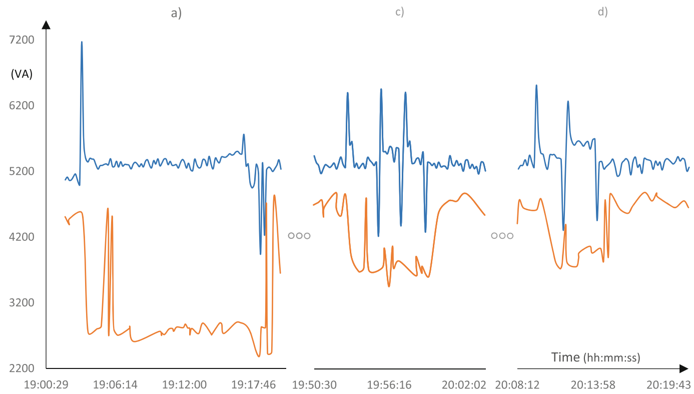

Fig. 6. Charging session data details of Fig. 5

The integration of AI in the standalone IEVCC not only enables efficient power management but also heralds a future of intelligent charging. Through machine learning algorithms, the system learns from past charging patterns, user preferences, and energy demand forecasts to dynamically optimize charging schedules. This AI-driven Predictive Charging maximizes charging station availability during peak demand periods, enhancing user convenience and alleviating strain on charging infrastructure.

In conclusion, our real-world experiments demonstrate the tangible benefits of integrating AI technologies into the standalone IEVCC. The seamless coordination between the intelligent meter, consumption monitor system, and AI-driven charging controller ensures optimal charging experiences while maintaining harmonious power balance within the household. This research lays the groundwork for intelligent, efficient, and sustainable charging systems, advancing us towards a future powered by smart energy management.

3.2 Optimizing Multiple EV Charging Scenarios

In the quest for efficient electric vehicle (EV) charging infrastructure, load balancing techniques integrated with AI algorithms have emerged as a promising solution. In this phase of our research, we conducted experimental simulations to evaluate the performance of load balancing in a multi-charger scenario. The simulation environment consisted of three chargers operating alongside the charging manager, showcasing the adaptability and intelligence of the system.

The ability to dynamically adjust the charging power based on global consumption patterns remains a key feature of our AI-driven load balancing approach. Unlike traditional systems, our solution does not require aggressive update intervals of less than 10 s, enabling smoother operation with minimal computational overhead.

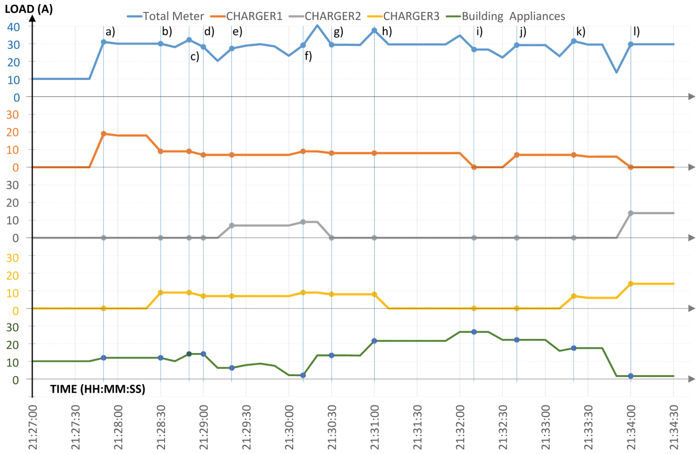

Fig. 7. Mesh Charger Network session sample

Figure 7 provides a snapshot of a sample interval illustrating load balancing dynamics among three connected chargers. Changes in overall consumption, unrelated to EV charging, trigger swift adjustments in the allocation of available energy to each charger, ensuring that the maximum load threshold (30 A) is not surpassed. Several situations depicted in Fig. 7 are described below, shedding light on the system's operation:

Charger 1: Initially requested to charge at 19.9 A, Charger 1 adjusted to 19 A due to limitations in integer values. As household appliance consumption increased to 12 A, only 18 A remained available for charging, prompting a reduction in charging current to 18 A in the next cycle.

Charger 3: Charger 3 registered and requested to start charging, with available power equally divided between both chargers, allowing them to charge at 9 A each.

Consumption Limit Exceeded: Building consumption exceeded contracted power, necessitating a reduction in available power for charging.

Reduced Charging Power: Following the previous power limit violation, charging power for both chargers was further reduced.

Charger 2: Charger 2, having registered earlier, initiated the charging process as available power allowed all chargers to operate simultaneously.

Increased Available Power: A reduction in building consumption increased available power for each charger, allowing them to increase charging current to 9 A.

Standby Mode: Rising building consumption led to insufficient power for all chargers to operate at the minimum power level of 6 A, placing charger 2 in standby mode.

Single Charger Operation: With rising building consumption, only one charger could operate, with charger 1 continuing charging.

Power Shortage: Increased building consumption led to insufficient power for both chargers, resulting in charger 1 being instructed to stop charging until power became available again.

Resumption of Charging: A subsequent reduction in building consumption allowed charger 1 to resume charging.

Charger 2 Rejoins: Another reduction in building consumption enabled charger 2 to resume charging, with charging current adjusted from 7 A to 6 A in the next time step as building consumption slightly increased.

Charging Progression: Charger 1 completed its charging session, coinciding with a decrease in building consumption, leading charger 3 to increase charging power and charger 2 to resume its charging session.

These simulation scenarios demonstrate the efficiency and adaptability of our AI-driven load balancing system in a multi-charger environment. Dynamic allocation of available power ensures optimal charging experiences, minimizing power limitations, and maximizing charging resource utilization. This research underscores the potential of AI in load balancing and its pivotal role in shaping a smarter and more sustainable future for EV charging infrastructure.

4 Conclusion

In this groundbreaking study, we unveil the Intelligent Electric Vehicle Charging Controller (IEVCC) as a game-changing solution propelled by Artificial Intelligence (AI) to transform the landscape of electric vehicle (EV) charging. The IEVCC not only dynamically optimizes charging power but also taps into AI capabilities to deliver unparalleled benefits.

With its AI-driven intelligence, the IEVCC seamlessly adjusts charging power for one or multiple electric vehicles based on a comprehensive range of conditions, ensuring that contracted power limits are never exceeded and averting potential disruptions like RCBO tripping. Through continual real-time data monitoring and analysis, the IEVCC fine-tunes the charging process for maximum efficiency and performance.

The IEVCC offers a spectrum of operation modes, blending AI automation with manual control options, granting users flexibility while upholding AI-driven safeguards. This amalgamation of AI intelligence and user adaptability sets the IEVCC apart as a truly versatile and user-centric charging solution.

One of the standout advantages of the IEVCC lies in its adaptive nature, effortlessly responding to changing conditions and external factors. By dynamically redistributing available power among chargers to achieve optimal load balance without surpassing pre-defined maximum load limits, the IEVCC ensures efficient energy utilization while preventing overloading scenarios.

Moreover, the IEVCC presents substantial cost-saving opportunities by intelligently managing the charging process, negating the necessity for users to increase their contracted power and optimizing charging efficiency to reduce charging times and minimize energy wastage.

Operating within a mesh network, the IEVCC efficiently shares resources and manages loads, offering particular value in settings with limited energy supply or within public parking buildings.

Integration with renewable energy sources further enhances sustainability, channeling solar energy toward EV charging and diminishing reliance on non-renewable sources, thereby aligning electric mobility with green energy practices.

Through AI-driven data analytics, the IEVCC not only provides crucial insights into user behavior and system performance but also empowers manufacturers and service providers to make data-informed decisions and refine future iterations.

In conclusion, the Intelligent Electric Vehicle Charging Controller (IEVCC) heralds a new era in EV charging, blending AI for dynamic power adjustment, load balancing, cost savings, mesh networking, renewable energy integration, and data-driven insights. This innovative approach accelerates the global transition toward sustainable transportation systems.

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Ensemble Learning Models for Wind Power Forecasting

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Abstract. Wind power, a clean and sustainable energy source, has experienced substantial growth in Brazil's energy capacity over recent decades. Accurate wind power forecasting is crucial for effectively harnessing wind energy and ensuring the reliable operation of power systems. However, due to the unique characteristics of wind power generation time series, developing statistical models for forecasting can be a challenging endeavor. This paper introduces a comprehensive approach by proposing forty-two ensemble learning models designed for forecasting wind power time series. These ensembles are created by combining various machine learning models and utilizing different aggregation methods, which incorporate various statistical measures such as the arithmetic average, harmonic average, median, and weighted average, with weights determined through metrics like mean absolute percentage error (MAPE), mean absolute error, and root mean squared error, was employed to evaluate its performance in forecasting wind power time series. This evaluation was conducted at time intervals of 10, 30, 60, and 120 min for two wind farms situated in Bahia, Brazil. The findings suggest that the ensemble method, which combines forecasts from individual models using weighted averages based on MAPE-derived weights, proved to be effective achieving the lowest percentage error in 87.5% of the evaluated cases. Conversely, the ensemble utilizing the harmonic average exhibited a higher error rate compared to the alternatives in 75% of the cases.

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