

# Overview of Microgrids and Blockchain Technology

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**Abstract:** This paper addresses the vital role of microgrids in the efficient utilization of renewable energy within the context of the evolving energy internet and electricity market reforms. In this work, we review the fundamental concepts of microgrids, their historical progression, energy storage technologies, and advanced control and scheduling techniques. We focus on the benefits of flexible interconnection in hybrid AC/DC microgrids and propose a decentralized energy trading system utilizing blockchain technology. Our findings demonstrate that implementing blockchain not only enhances trading efficiency and reduces costs but also facilitates secure peer-to-peer transactions between consumers and producers. This innovative approach resolves prevalent issues in traditional energy trading frameworks and fosters greater market dynamics. The significance of this research lies in its potential to inform the commercialization and sustainable development of microgrids, ultimately promoting optimal allocation and utilization of energy resources. By providing actionable insights, this work contributes to advancing the field of energy management and supports the transition towards a more resilient and decentralized energy landscape.

**Keywords:** Microgrid, Smart grid, Renewable Energy, Blockchain.

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## 1. Introduction

With the development of energy internet, the advancement of electricity market reform, and the widespread adoption of distributed generation and demand-side responses, a large number of consumers are transforming into prosumers. To achieve the integration of renewable energy and reduce energy losses, the energy internet can offer effective solutions. For instance, a local microgrid system consisting of multiple microgrids is a typical subnet of the energy internet. At the same time, the integration of numerous independent decision-making producers and consumers creates new business models, providing users with more options but also introducing challenges in transaction management. The key issue lies in designing transaction models and methods to avoid inefficiencies, lack of trust, and security concerns. Blockchain technology, with its decentralized database characteristics such as decentralization, transparency, immutability, and anonymity, can effectively address these issues. This paper focuses on reviewing microgrids, their important technologies, and the application of blockchain technology in microgrids.

## 2. Overview of Microgrid Technology

A microgrid is a small-scale power supply network that achieves power balance between distributed energy sources and local loads through energy storage systems and control devices. As a crucial component of the smart grid, a microgrid consists of distributed generation units, electrical loads, distribution infrastructure, and monitoring and protection systems. It can operate connected to the external grid or independently in an isolated mode. A microgrid has complete generation and distribution capabilities and is an autonomous system capable of self-control, self-protection, and energy management.

### 2.1. Advancements in Microgrid Technology:

With the advancement of renewable energy technologies such as wind and solar power, microgrid systems have begun

integrating more distributed energy resources, becoming one of the solutions for sustainable energy management [1]. Moreover, advancements in energy storage technology have made microgrids more efficient in power storage and regulation. The development of information technology and computer control technologies has further enhanced the intelligence of microgrids. Advances in automation control, data collection, and communication technologies enable microgrids to achieve more precise load management and power scheduling. Additionally, the introduction of smart grid technology allows microgrids to perform more complex control and optimization tasks, including real-time monitoring, remote operation, and demand response.

### 2.2. Energy Storage Technologies and Renewable Energy Generation Technologies

Currently, smart microgrids primarily rely on various renewable energy sources, with power inputs including mature generation technologies such as photovoltaic, wind, hydrogen, natural gas, and biogas. Energy storage is an essential part of microgrids, playing a crucial role in balancing power loads and significantly improving the efficiency of intermittent energy use. With ongoing technological advancements, existing energy storage technologies include battery storage, flywheel storage, superconducting magnetic storage, and supercapacitor storage. Among these, lead-acid batteries are a relatively mature storage technology but suffer from shorter lifespans and lead contamination issues. In the future, graphene batteries, with their high energy storage, low cost, and excellent performance, are expected to become innovators in the storage industry. Although the cost of storage technology remains high, countries are actively pursuing solutions to achieve an ideal state of "low cost + high storage." However, the adoption of renewable energy faces various challenges, including legal and regulatory barriers, infrastructure deficiencies, and technological challenges in integrating renewable energy into the power grid [2].

### 2.3. Control and Dispatch Technologies in Microgrids

The smart microgrid scheduling system utilizes complementary optimization technologies across various energy sources, fully exploring and leveraging the substitutability between different types of energy. This approach not only allows for the output of heat, electricity, and cooling but also enables energy exchanges such as solar/electric, heat/cooling, wind/electric, and direct/AC. In the source-storage-load stages, different types of energy undergo layered and orderly hierarchical optimization scheduling to achieve optimal energy utilization efficiency. Meanwhile, smart grids generate various types of data during operation, which contain crucial information elements and provide reliable references for grid scheduling, energy allocation, and grid construction. In traditional grid systems, data flow is mainly concentrated in generation, transmission, transformation, distribution, and consumption, characterized by unidirectional flow, which can lead to waste of electrical resources. In contrast, smart grids can extract effective information from both structured and unstructured data, integrating data throughout generation, transmission, transformation, distribution, scheduling, and consumption. This results in characteristics such as scalability, diversity, high speed, high value, and low density. With the aid of big data technology, the construction and development of smart grids become more practical and meaningful.

### 3. Microgrid Flexible Interconnection

The flexible interconnection technology for AC/DC hybrid microgrids allows for the connection of multiple AC or DC networks in various configurations—such as point-to-point, ring network, hand-in-hand, or parallel supply—based on the needs of different power sources and loads. This multi-terminal flexible interconnection fundamentally changes the original structure and connectivity of distribution networks, providing enhanced network connectivity and flexibility for integrating various AC and DC power sources and loads. Additionally, it improves the grid's ability to control random fluctuations. On the other hand, flexible interconnection devices enable coordination and control of power flows between different regional DC networks and AC systems, granting the system greater multi-regional interconnection and power balancing capabilities over time and space. This effectively unleashes the supply potential of the distribution network and enhances the capacity for accommodating distributed renewable energy. Based on the advancement of photovoltaic and energy storage construction, the integrated DC microgrid solution with PV-storage-direct-flexibility is adopted to build efficient PV-storage-direct-flexible microgrid clusters. By integrating distributed photovoltaics, energy storage, and adjustable loads in the DC microgrid, and utilizing ultra-high power density PV-storage-direct-flexible conversion equipment, this solution achieves integrated and efficient flexible control. It effectively addresses the challenges faced by industrial park power systems in large-scale renewable energy development, such as limited installation space for solar power and widespread, hard-to-regulate points. It also significantly improves system performance, enhances power supply quality and safety for users. Meanwhile, optimizing the microgrid structure and innovatively constructing AC-DC flexible interconnection networks further increases the flexibility and reliability of

grid regulation. By focusing on user microgrids and combining multi-voltage AC-DC interconnections, this approach connects user microgrid clusters, charging stations, centralized renewable energy, and centralized energy storage at various levels. Flexible AC-DC interconnection networks enable direct interconnection, real-time regulation, and mutual support of distributed renewable energy, distributed energy storage, and adjustable loads, balancing fluctuations in different types of distributed energy, loads, and microgrid demands over a larger spatial and temporal range. This facilitates broader and more balanced integration of renewable energy and accommodates fluctuations, achieving maximum local consumption of new energy power. Moreover, through the interconnection of multiple AC-DC microgrids, the system's reliability and transfer capacity during faults are significantly enhanced, improving the park's resilience in extreme events. Additionally, on the basis of advancing photovoltaic and energy storage construction, the integrated PV-storage-direct-flexible microgrid solution is applied to build efficient PV-storage-direct-flexible microgrid clusters. By integrating distributed photovoltaics, energy storage, and adjustable loads in the DC microgrid and utilizing ultra-high power density PV-storage-direct-flexible conversion equipment, this solution achieves integrated and efficient flexible control. It effectively addresses the challenges faced by industrial park power systems in large-scale renewable energy development, such as limited installation space for solar power and widespread, hard-to-regulate points. It also significantly improves system performance, enhancing power supply quality and safety for users. After connecting the microgrid to the grid, the traditional grid structure is transformed from a single-source radial distribution network to a new distribution network with multiple sources, posing significant challenges to system protection due to different fault characteristics. For example, in the event of an emergency in a cluster system, if a microgrid balance unit fails, other microgrids need to support that subnet. Without rapid interconnection communication, it is challenging to smoothly switch control modes to ensure system transient stability.

### 4. Decentralized Energy Trading System

Microgrids are typically located in different regions and operate independently. To achieve optimal resource allocation and sufficient flexibility, the Integrated Community Energy System (ICES) has been proposed as an effective approach to coordinate distributed energy resources and reorganize local energy systems. However, this method relies heavily on central management institutions, leading to lower efficiency in settlement and clearing. Blockchain technology, as an emerging distributed database technology with key features of decentralization and transparency, is well-suited for data analysis and decision-making in decentralized systems. Thus, blockchain technology can address issues such as high costs, low efficiency, and insecure storage in traditional distributed systems. In the energy sector, blockchain technology applications include distributed resource trading, reputation assessment, demand response, and power plant operation and maintenance. The use of blockchain technology can effectively ensure the security and privacy of energy transactions. This study highlights the benefits of implementing blockchain and smart contract technologies in

microgrid systems [3]. In this study, a blockchain trading framework was developed to enhance multi-agent collaboration and sharing in the energy market. The framework uses power system modeling and consensus technologies to model nodes in market transactions. A multi-agent collaboration and sharing platform, built on a private Ethereum blockchain, was employed to demonstrate sample transactions[4]. The various development technologies for P2P energy trading systems are analyzed, and an overview of actual P2P pilot projects is provided [5]. It emphasizes that successful implementation of P2P energy trading must consider adjustments to market regulation before commercializing the microgrid market. Yahaya and colleagues proposed a blockchain-based system for direct P2P energy trading. It includes a delay fee mechanism to optimize consumption, minimize prices, and incentivize load shifting. Simulation results indicate a significant reduction in electricity costs, and security analysis ensures the integrity of the energy trading smart contracts [6]. To establish a decentralized power trading model, a blockchain-based decentralized trading platform needs to be developed, aiming to find effective power trading management methods while balancing the interests of all parties. Constructing distributed energy and multi-microgrid market trading models and their solution algorithms holds significant meaning and practical value for the development of distribution networks and energy interconnection technologies.

As a crucial module in distributed systems, blockchain technology builds trust between trading parties through decentralization, enhancing its application potential in data analysis and final decision-making. However, to address complex multi-objective optimization problems, fair bidding rules and multi-objective dynamic programming models need to be established. This model should ensure fairness, transparency, and information effectiveness in multi-microgrid market transactions, while promoting the reduction of power production costs and the development of environmentally friendly electricity use. Therefore, the primary goal should be to minimize purchasing costs while prioritizing the electricity needs of centralized, intensive, and environmentally friendly industries, and to reasonably store the power of distributed aggregators. The mechanism for power distribution should be optimized to minimize

generation investment and energy waste.

## 5. Conclusion

Microgrids, through distributed generation, energy storage, and smart control technologies, can optimize power balance and enhance system intelligence. However, with the emergence of independent decision-makers and new business models, traditional power market trading methods face challenges. The decentralized, transparent, and tamper-proof nature of blockchain technology can effectively address these issues, enhancing the security and efficiency of transactions. Although current applications still face limitations, such as efficiency and cost concerns, future advancements in technology and regulatory improvements are expected to enable blockchain-based decentralized trading platforms to achieve a more efficient, fair, and transparent energy trading system, thereby promoting the development of microgrids and renewable energy.

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