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NEXT-GENERATION POWER SYSTEMS: INTEGRATING SUSTAINABLE ENERGY SOURCES WITH ADVANCED DISTRIBUTION AND COMPENSATION STRATEGIES

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Abstract:
Power systems of the next generation are a transformative advance in generating, distributing, and managing electric energy, with greater integration of sustainable resources into grid systems for improved reliability and efficiency. The current research investigates the building blocks, integration schemes, remuneration techniques, advantages, challenges, and applications of contemporary power systems. Global energy infrastructure is transitioning from centralized fossil-fuel-based grid systems to decentralized, intelligent, and renewable-based (DIW) systems. Some key enabling technologies are renewable energy resources (solar, wind, hydroelectric, and biomass), along with advanced energy storage systems coupled with the smart grid and hybrid energy design. They are the solution to harness all renewable energy intermittency while reducing system oscillation and increasing the flexibility of operations. According to the study, real-time monitoring enabled by Distributed Energy Resource Management Systems (DERMS), Advanced Distribution Management Systems (ADMS), and optimization tools based on artificial intelligence are critical in predicting maintenance and facilitating dispatch. Moreover, reactive power compensation, voltage regulation, and Flexible AC Transmission Systems (FACTS) are two needs of the day for better power quality and grid stability under high renewable penetration. Nevertheless, issues like high initial capital expenditure (CapEx), technological complexity, limited skilled workforce, and regulatory bottlenecks still obstruct scaling. Case studies from the industrial sector and pilot renewable energy projects show both promise and limits to current implementation efforts, underscoring the need for strong stakeholder engagement across scales and flexible policy adaptations.

Keywords: Enhances sustainable, reliable, and efficient energy systems by integrating renewables, improving grid stability, reducing emissions, and supporting future demand.

Introduction

The utilization of sustainable energy sources with advanced distribution and compensation strategies in next-generation power systems constitutes a dramatic change to the electricity generation, delivery, and management paradigms [1]. These systems function in order to boost operational efficiency, reliability, and sustainability while responding to the ever-increasing global demand for energy as well as the urgent need for greenhouse gas emissions reduction. This transition shares a crucial feature, namely the growing quantity of energy derived from renewable sources — solar, wind, and hydroelectric power — that increasingly contribute to electricity generation in the United States and other advanced market economies [2]. The world is moving in this direction, abandoning dependency on fossil fuels for cleaner and more resilient energy infrastructures. These new power systems will be important as they enable a more flexible and decentralized electricity grid. Centralized power is being challenged or replaced by distributed energy resources where generation takes place closer to the point of consumption [3]. Smart grid technologies, energy storage systems, and hybrid energy configurations for renewable variable control will empower this transformation. Meanwhile, new ideas like virtual power plants and microgrids have led to increased coordination of distributed systems where supply can better meet demand in real time [4]. The evolution of modern energy systems has a long and highly regulated history marked by key milestones in policies. Beginning with environmental regulations in the form of legislation such as the Clean Air Act in 1970 and preceded by energy-focused policy with disciplines in legislation, including the Energy Policy and Conservation Act of 1975, through to the publication and introduction (in 1988) of the Alternative Motor Fuels Act, governments worldwide have advanced an encouraging policy stance around energy efficiency (EE) across all spheres [5]. These initiatives were the starting point for modern-day renewable integration efforts and continue to impact energy decisions. While real strides have been made, there are still significant challenges to wean the grids from present sources to sustainable forms of energy. Renewables bequeath stability problems on an erratic basis, requiring advanced compensation techniques like reactive power control and voltage regulation [6]. Other adoption barriers include high initial investment costs, technical complexity, productivity, and a limited workforce and available technologies, which are also less prevalent in the institutions. Yet these limitations are continuously being addressed by innovation in energy storage, smart infrastructure, and grid optimization [7]. While modern developments are repeatedly centered around deploying enhanced distribution strategies and compensation mechanisms to uphold the stability and execution of the grid. New technologies, which are key for load balancing, frequency control, and voltage support to balance the typically variable nature of renewable energy inputs. Concurrently, government support and federal programs promoting distributed energy participation are hastening a shift towards more adaptable and robust energy systems.

Methodology

This study employs a comprehensive analytical and qualitative approach based on an extensive literature synthesis and systematic evaluation of contemporary power system architectures. The methodological framework analyzes the structural transition from centralized, fossil-fuel-based grid systems to decentralized, intelligent, and renewable-based (DIW) networks by examining core building blocks, integration schemes, and remuneration techniques. Furthermore, the operational performance of key enabling technologies—including Distributed Energy Resource Management Systems (DERMS), Advanced Distribution Management Systems (ADMS), hybrid energy storage, and Flexible AC Transmission Systems (FACTS)—is evaluated through comparative analysis and case study assessments of pilot renewable projects and industrial sector implementations.

Results

The findings demonstrate that real-time monitoring and artificial intelligence-driven optimization tools, integrated with DERMS and ADMS, significantly improve predictive maintenance and dispatch efficiency while successfully mitigating system oscillations and enhancing operational flexibility against renewable intermittency. Additionally, reactive power compensation and dynamic voltage regulation via FACTS technologies prove essential for maintaining grid stability and power quality under high renewable penetration. However, the study also reveals that widespread scaling remains severely constrained by high initial capital expenditures (CapEx), technological complexity, a shortage of skilled labor, and persistent regulatory bottlenecks, emphasizing the critical need for flexible policies and multi-stakeholder engagement.

Components of Next-Generation Power Systems

Next-generation power systems are designed for efficiency, reliability, and sustainability in the way electricity is generated and distributed. They are not structured around a single technology, but rather on an orchestrated collection of interconnected components that function collectively to manage disparate energy resources, regulate the grid, and optimize continuous energy flowing even under changing demand conditions [8]. Energy storage systems, which bring flexibility and stability to modern grids, are a large portion. These technologies hold excess electricity produced during high renewable output hours: lithium-ion batteries, pumped hydro storage, compressed air energy storage, and more. Consequently, this stored energy may be discharged at the time of minimum generation or peak demand and mitigates instability originating from the non-uniformity of renewable sources [9]. By decreasing the need for fossil-fuel backup systems, properly deployed energy storage also increases grid resiliency and reduces total carbon emissions. The diversity of energy sources is another keystone. The newer systems incorporate both renewable and conventional energy resources to maintain a steady, reliable supply. A Concise Study On Why Renewable Energy Is Important. These hold less environmental impact, hence the increasing focus on renewable resources like solar, wind, hydroelectric, and biomass [10]. Meanwhile, traditional providers such as natural gas or nuclear continue to help in stabilizing baseload. The contributions from each source are different; the renewables help our sustainability goals, whereas the traditional generation sources, such as coal or gas, provide a consistent output when renewable generation varies. Energy conversion technologies, which convert crude energy into usable electricity, are closely related to energy sources [11]. Steam turbines, on the other hand, gas turbines. Photovoltaic systems and combined power plants. The conversion is improved through advanced solar cell technologies and high-efficiency turbine systems, leading to higher efficiencies so that much of the energy available is actually made accessible to end users. These improvements have direct implications for better system performance and functional efficiencies by curtailing energy losses in generation [12]. Transmission systems are the electricity lifeline. These are also new as they use smart grid technologies to automatically monitor, control, and distribute electricity resources on demand in real time. This infrastructure is two-way, enabling distributed energy resources to return power into the grid [13]. When renewable generation fluctuates, it helps in further regulating frequency and voltage alongside storage integration, along with smart controllers. Underpinning these frameworks are balance-of-system parts, ensuring the safe and efficient operation of renewable and hybrid energy installations. Examples are power condition units, charge controllers, metering/monitoring meters, safety devices, and battery management systems. Together, these elements help to maximize system performance while ensuring both equipment safety and compliance with grid specifications [14]. The last, hybrid energy systems are an advanced integration model with the delivery of non-conventional and conventional energy sources. It is created to react on the fly to how energy requirements change from one timeframe to the next. Through the combination of energy management systems and smart grid technologies, hybrid configurations help to increase reliability, improve flexibility, and enable smoother integration with renewables into the existing power network [15].

Integrated Strategies for Renewable Energy Incorporation and Grid Stability in Next-Generation Power Systems

Integration of sustainable energy sources within next-generation power systems requires a coordinated framework that combines advanced distribution methods, intelligent control systems, and adaptive compensation strategies [16]. The goal is not only to connect renewable energy to the grid but to ensure that it operates reliably, efficiently, and in harmony with existing infrastructure despite variability in generation and demand. A central element of this integration is Distributed Energy Resource (DER) management. Distributed energy resources include small-scale generation units such as rooftop solar, wind turbines, and local storage systems that are located close to end users [17]. Unlike traditional centralized power plants, DERs reduce transmission losses and improve system reliability by generating electricity near consumption points. However, their distributed nature introduces complexity in coordination and control. This is addressed through the use of Distributed Energy Resource Management Systems (DERMS), which work alongside Advanced Distribution Management Systems (ADMS) (Figure 1) [18]. Together, these systems enable real-time monitoring, optimized dispatch, and coordinated operation of distributed assets, improving grid stability while managing operational uncertainties. Another major strategy is renewable energy integration, which focuses on embedding solar, wind, hydroelectric, and other renewable sources into existing power networks. This process also includes the integration of energy storage systems and demand response mechanisms to balance supply and demand. Since renewable energy output is inherently variable, successful integration requires careful planning across technical, economic, regulatory, and institutional dimensions [19]. Standardized interconnection protocols, improved grid codes, and flexible market mechanisms are essential to ensure smooth operation. Advanced modeling and simulation tools are also increasingly used to assess system resilience under extreme weather conditions and fluctuating generation scenarios. Supporting these efforts is the development of hybrid energy solutions, which combine multiple storage technologies and energy sources to enhance system flexibility [20]. For example, hybrid storage systems may integrate lithium-ion batteries with flow batteries or hydrogen-based storage systems. This combination allows both short-term and long-duration energy storage, improving the ability of the grid to respond to rapid fluctuations as well as extended periods of low renewable generation. Hybrid configurations also enable cross-sector energy applications, further strengthening overall system resilience and efficiency [21]. A key structural shift enabling integration is decentralization and increased customer participation. In modern energy systems, consumers are no longer passive users but active participants in energy generation and distribution. Buildings equipped with renewable generation systems can operate as virtual power plants, supplying excess electricity back to the grid [22]. Large energy consumers, such as industrial facilities and data centers, can also adopt cogeneration and combined heat and power systems to improve efficiency. This decentralization enhances grid flexibility while requiring updated regulatory frameworks that support prosumer participation and distributed market structures. Finally, compensation strategies play a critical role in maintaining power quality and system stability. As renewable penetration increases, grid operators must manage challenges such as voltage fluctuations, frequency deviations, and reactive power imbalances [23]. Techniques such as reactive power compensation, voltage regulation, and frequency control are essential for ensuring stable operation. These strategies become even more important in systems with high levels of distributed and renewable generation, where traditional control methods are no longer sufficient. Together, these integration strategies create a cohesive framework that enables next-generation power systems to operate efficiently under increasing complexity [24]. They support the transition toward cleaner, more decentralized, and more resilient energy networks capable of meeting future global energy demands.

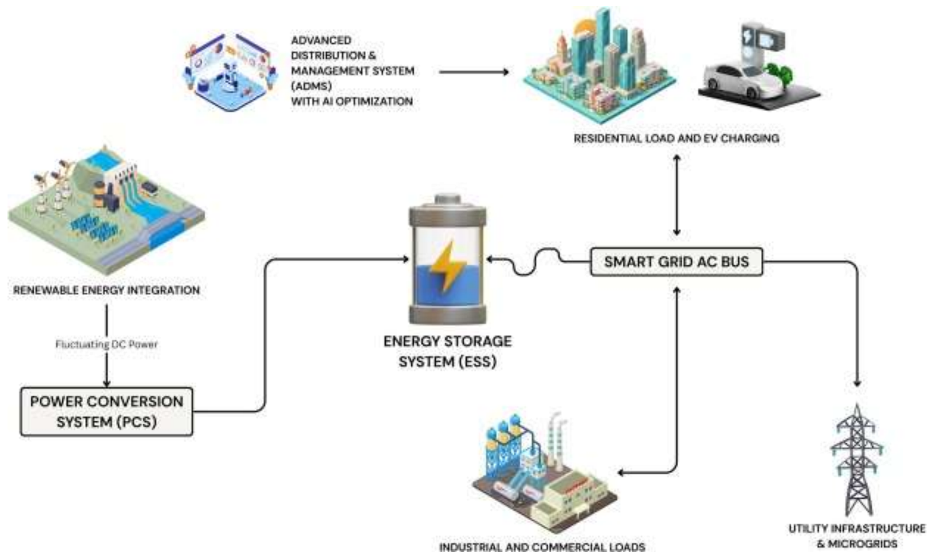

Figure 1. The next generation of energy storage for smart and sustainable power grids [55]

Compensation Methods and Benefits of Next-Generation Power Systems

Reactive power compensation and voltage regulation are two key control paradigms of next-generation power systems that assure stability, upgrade power quality, and support huge-scale integration of renewable energy sources [25]. Reactive power compensation is a process to help manage the balance of reactive power within electrical networks—devices that either supply (capacitors) or absorb (inductors) reactive power depending on what the system needs. Static VAR Compensators (SVCs) and Static Synchronous Compensators (STATCOMs) represent a more advanced technological option with dynamic and fast-action capabilities, making them particularly useful for voltage level stabilization in grids with a high share of intermittent renewable energy sources (Table 1) [26]. Flexible AC Transmission Systems (FACTS) are utilized for enhancing controllability and offering voltage support with real-time feedback. Insufficient compensation leads to energy losses and degraded power quality, requiring greater insight into the interrelationship between system parameters and control mechanisms. Compensation strategies looking across the year 2023 are certainly due to change with technology. These innovations will help renewables with a wider variety of control systems, optimal reactor management, and customized compensation solutions [27]. Ongoing research and development will be critical to meeting the challenges of modern power system complexity and sustainability in the future. Next-generation power systems provide tremendous economic and environmental benefits in addition to technical performance. Renewable energy also supports job creation at a higher rate than fossil fuel-based systems and stimulates local economies while creating indirect employment.

Table 1. Core Components and Integration Technologies of Next Generation Power Systems.

Component/Technology	Description	Key Benefits	References
Renewable energy resources	Integration of solar, wind, hydroelectric, and biomass into modern grids	Reduced greenhouse gas emissions, sustainable electricity generation	[2], [10], [19], [30]
Energy storage systems	Lithium ion batteries, pumped hydro, compressed air, hydrogen storage	Grid stability, renewable intermittency mitigation, peak load support	[9], [20], [21], [40]
Smart grids and digital infrastructure	Smart meters, DERMS, ADMS, real time monitoring	Improved operational efficiency, automated control, enhanced reliability	[13], [18], [28], [41], [44]
Hybrid energy systems	Integration of renewable and conventional energy with intelligent energy management	Increased flexibility, higher reliability, efficient resource utilization	[15], [20], [21]
Distributed Energy Resources (DERs)	Rooftop solar, local wind generation, battery storage, microgrids	Reduced transmission losses, decentralized energy production, improved resilience	[17], [18], [22], [45], [46]
Power quality and compensation technologies	Reactive power compensation, FACTS, SVC, STATCOM, voltage regulation	Voltage stability, frequency regulation, improved power quality	[23], [25], [26], [27], [42], [43]

Energy Reliability, Flexibility, Sustainability, and Key Challenges in Next-Generation Power Systems

The integration of advanced technologies, such as artificial intelligence (AI), real-time monitoring, and predictive analytics into next-gen power systems significantly enhances the energy reliability and resilience capabilities within these systems [28]. These tools enhance operational efficiency through optimized energy generation, proactive fault detection, and predictive maintenance, which all contribute to increased uptime and improved system reliability. Also, mobile and dual-fuel power systems provide flexible, on-demand supply of electricity, guaranteeing a continuous service for essential infrastructures such as data centres, hospitals, and utility networks during peak demand or emergencies. Modern power systems are also characterized by flexibility and scalability [29]. Such systems are developed to respond swiftly to the fast-changing energy requirements in urban, industrial, and commercial sectors. It is achieved via matching generation capacity with demand forecasts; therefore, limiting resources will be wasted, and system performance is optimised. The flexibility is also improved by combining several energy sources and technologies in hybrid energy configurations, which enables systems to adapt to seasonal changes and intermittent renewable energy availability. Sustainability is still one of the main goals for the next generation of power systems (Figure 2). Integration of the lowest impact clean energy technologies contributes to the world's attempt to reduce greenhouse gases and mitigate climate change [30]. This research highlights how environmental impact assessments (EIAs) are integrated during project planning and development to safeguard ecosystems, biodiversity, and wildlife. It can be seen as a way to promote responsible energy development while remaining in sync with longer-term objectives of sustainability. A major hindrance is the capital cost of implementing infrastructure, such as solar panels, wind turbines, or energy storage systems, over other alternatives [31]. Such up-front expenditures, coupled with lengthy return on investment (ROI) periods, frequently cause organizations to shy away from making these kinds of financial commitments—especially those focused on the short-term ROI.

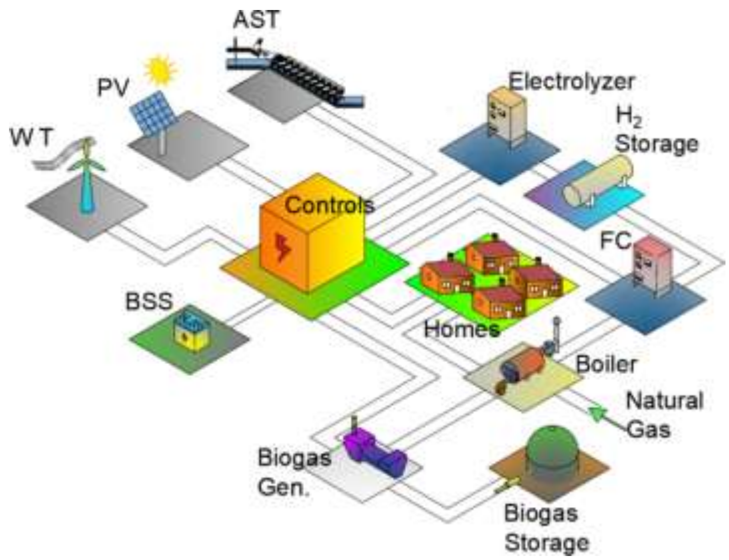

Figure 2. [Technical and economic analysis of a micro grid including various renewable energy technologies for rural areas [56]]

Case Studies on Sustainable Energy Integration and Advanced Power System Implementation

Case studies on sustainable energy integration provide practical insights into how next-generation power system concepts are being applied across industries and regions, revealing both progress and persistent challenges in real-world environments. In the manufacturing sector, multiple studies have examined the adoption of sustainable energy technologies across energy-intensive industries such as leather, pharmaceuticals, textiles, and cement production [32]. These sectors are known for high electricity consumption and significant environmental impacts. Research based on literature reviews and industry data identified multiple barriers to adopting sustainable energy solutions, including financial constraints, technical limitations, and organizational resistance. Despite these challenges, the studies highlight growing awareness and gradual movement toward cleaner energy practices within industrial operations. Another important area of implementation is the deployment of renewable energy projects in developing energy markets [33]. For example, pilot renewable energy projects conducted within electricity distribution networks in Nigeria under organizations such as Ibadan Electricity Distribution Company and Port Harcourt Electricity Distribution Company demonstrate early-stage efforts to integrate embedded renewable generation into existing grids. These projects focus on analyzing real operational data to guide large-scale implementation. In addition, supporting frameworks such as practical tools, technical guidelines, and standardized templates are being developed to help utilities and developers transition from planning to full-scale deployment, ensuring smoother integration of renewable systems into national grids (Table 2) [34]. Advanced Distribution Management Systems (ADMS) also play a key role in real-world case studies. These systems are used to optimize grid operations by enabling real-time monitoring, control, and decision-making based on localized energy data. Implementations of ADMS in renewable-integrated networks show improved reliability, better fault response, and more efficient energy distribution. By leveraging real-time analytics, these systems help utilities manage the complexity introduced by distributed renewable energy sources while maintaining grid stability and operational security [35]. Case studies show that such decentralized, intelligent systems significantly enhance both grid flexibility and sustainability outcomes. Finally, the successful implementation of sustainable energy systems depends heavily on collaboration and capacity building among stakeholders. Engineers, grid operators, technology providers, and equipment manufacturers must work together to manage the complexity of modern energy systems [36]. Continuous training and knowledge sharing are essential to keep pace with rapidly evolving technologies and integration strategies. Collaborative frameworks help ensure that technical expertise, operational planning, and innovation are effectively aligned, enabling more efficient and scalable renewable energy integration.

Table 2. Benefits, Challenges, and Future Directions of Next Generation Power Systems

Discussion

Next-generation power systems are fundamentally reshaping how electricity is generated, distributed, and managed, mainly because they sit at the intersection of renewable energy expansion, digital intelligence, and grid modernization [37]. What this really means is that the power sector is no longer just about producing electricity efficiently, but about coordinating a highly dynamic system where supply and demand must constantly adapt in real time. The integration of renewable energy sources such as solar, wind, hydro, and biomass has introduced both opportunities and structural challenges that traditional power grids were never designed to handle [38]. One of the most important developments is the increasing penetration of renewable energy into national grids. While this transition is essential for reducing carbon emissions, it also introduces variability and uncertainty into power generation. Solar and wind energy, for example, are inherently intermittent, meaning their output fluctuates based on environmental conditions. This creates instability in voltage and frequency unless supported by advanced compensation mechanisms and intelligent control systems [39]. As a result, modern power systems are evolving toward hybrid and adaptive structures that combine renewable sources with energy storage, flexible transmission systems, and predictive management tools. Energy storage plays a central role in this transformation. Storage technologies such as lithium-ion batteries, pumped hydro, and compressed air systems act as buffers that absorb excess energy during periods of high generation and release it during peak demand or low production [40]. This balancing function is essential for maintaining grid stability, especially as renewable penetration increases. Beyond short-term balancing, emerging storage solutions like hydrogen-based systems are also enabling long-duration energy storage, which supports seasonal energy shifts and cross-sector energy applications. Alongside storage, smart grid technologies and digital monitoring systems are redefining how power networks operate. Real-time monitoring, artificial intelligence, and predictive analytics allow operators to anticipate demand fluctuations, detect faults early, and optimize energy flow dynamically [41]. These capabilities reduce system downtime and improve operational efficiency. In particular, AI-driven energy management systems are enabling distributed coordination of energy resources, where decisions are no longer centralized but shared across the network. This shift toward decentralized intelligence improves resilience but also increases system complexity, requiring robust communication and cybersecurity frameworks. Another critical aspect of next-generation power systems is reactive power compensation and voltage regulation [42]. As renewable energy sources are integrated at scale, voltage instability becomes more common due to fluctuating power injections from distributed generation units. Devices such as Static VAR Compensators (SVCs), Static Synchronous Compensators (STATCOMs), and Flexible AC Transmission Systems (FACTS) are essential in maintaining voltage stability and ensuring power quality [43]. These technologies provide dynamic reactive power support and enable real-time correction of voltage deviations. Without such systems, high renewable penetration would lead to frequent grid disturbances and reduced reliability.

Distributed Energy Resource Management Systems (DERMS) and Advanced Distribution Management Systems (ADMS) are increasingly being used together to manage these complexities. DERMS focuses on optimizing the performance of distributed assets such as rooftop solar and battery systems, while ADMS handles broader grid-level coordination, fault detection, and system restoration [44]. Their combined use allows for more efficient integration of decentralized energy systems, but it also requires high-quality data exchange and interoperable communication standards. A key trend shaping modern power systems is decentralization. Instead of relying solely on large centralized power plants, energy generation is increasingly distributed across smaller local units [45]. This includes residential solar systems, industrial cogeneration plants, and community microgrids. Microgrids are particularly important because they can operate independently or in coordination with the main grid, improving resilience during outages or extreme weather events. In this model, consumers also become producers, often referred to as prosumers, contributing excess energy back into the system [46]. This fundamentally changes market dynamics and requires updated regulatory frameworks to manage energy exchange fairly and efficiently. Despite these advancements, several barriers continue to limit the widespread adoption of next-generation power systems. High initial capital costs remain one of the most significant challenges. Renewable energy infrastructure, energy storage systems, and smart grid technologies require substantial upfront investment [47]. Although operational costs are lower over time, many organizations hesitate due to long payback periods and financial uncertainty. This issue is especially pronounced in developing economies where access to financing is limited, and risk perception is high. Technical complexity is another major constraint. Modern energy systems require integration across multiple domains, including power electronics, communication systems, artificial intelligence, and cybersecurity [48]. Managing this level of complexity demands a highly skilled workforce, which is not yet widely available. The shortage of trained professionals slows down deployment and increases dependence on external expertise, which can further increase project costs and implementation delays. Social acceptance and institutional readiness also influence the pace of adoption. In many regions, there is still skepticism toward new energy technologies due to a lack of awareness or perceived risks [49]. Additionally, regulatory frameworks often lag behind technological development, creating uncertainty for investors and utilities. Without supportive policies, standardized interconnection rules, and clear market incentives, the transition to sustainable energy systems remains uneven. Environmental and sustainability considerations remain central to this transition. One of the most significant benefits of renewable integration is the reduction of greenhouse gas emissions [50]. Wind and solar energy, for example, produce significantly lower emissions compared to fossil fuel-based generation. This contributes not only to climate mitigation but also to improved air quality and public health outcomes. However, sustainability must also be evaluated across the entire lifecycle of energy systems, including manufacturing, installation, and disposal of components such as batteries and solar panels [51]. A truly sustainable system must minimize environmental impact at every stage. Economic impacts further strengthen the case for next-generation power systems. Renewable energy industries generate more employment per unit of energy produced compared to fossil fuels, contributing to job creation and economic diversification. Additionally, advancements in energy efficiency and system optimization are expected to reduce long-term electricity costs for both consumers and industries [52]. Investments in clean energy infrastructure also stimulate innovation, attracting capital and accelerating technological development across related sectors. Case studies from manufacturing industries, distribution utilities, and renewable pilot projects demonstrate that successful integration depends on both technological and organizational readiness. Industrial sectors such as cement, textiles, pharmaceuticals, and leather manufacturing show that energy-intensive industries face the greatest barriers but also stand to gain the most from efficiency improvements [53]. Similarly, pilot renewable energy projects in developing regions highlight the importance of real-world data, adaptive planning, and phased implementation strategies. These examples reinforce the idea that energy transition is not a single-step process but a gradual transformation requiring continuous adaptation.

Advanced control systems such as AI-driven energy management platforms and multi-dimensional optimization models further illustrate the direction of future power systems [54]. These systems can dynamically adjust energy flows based on real-time conditions, prioritizing low-carbon energy sources and improving system-wide efficiency. However, their reliance on centralized computing infrastructure also introduces new risks, including cybersecurity vulnerabilities and system-level failure points. This highlights the need for decentralized intelligence and distributed computing architectures in future designs. Overall, the transition to next-generation power systems represents a fundamental shift in energy philosophy. It moves the focus from centralized generation to distributed intelligence, from static infrastructure to adaptive systems, and from fossil dependency to renewable integration. While the technical progress is significant, the success of this transition ultimately depends on solving financial, institutional, and social barriers alongside technological challenges.

Conclusion

Next-generation power systems represent a major shift toward cleaner, more intelligent, and more resilient energy infrastructure. By integrating renewable energy sources, advanced storage systems, smart grids, and real-time control technologies, these systems improve efficiency while reducing environmental impact. However, their success depends on overcoming challenges such as high costs, technical complexity, and regulatory limitations. The combined use of distributed energy resources, AI-based management, and advanced compensation techniques strengthens grid stability and flexibility. Overall, these systems offer a sustainable pathway for meeting future energy demands while supporting economic growth, energy security, and global climate goals.

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