Application of Smart Energy Management Systems in Green Buildings

Yiqi Zhu

School of Thermal Engineering, Shandong Jianzhu University, Jinan, China

202203101133@stu.sdjzu.edu.cn

Abstract. Given the growing social demand for sustainable development and environmental protection, green buildings are attracting attention as an important means of reducing energy consumption and environmental impact. To comprehensively achieve the goal of sustainable development, it is particularly urgent to study the application of smart energy management systems in green buildings. The theme of this study is application of smart energy management system in green buildings. By exploring the integration of green buildings, smart buildings and smart energy management systems, the aim is to find effective solutions for building energy management. The study first delves into the detailed design principles and construction benefits of green buildings. Subsequently, it focuses on the application of smart building technologies and their developmental needs. Finally, the focus is on the integration of smart energy management systems. It is concluded that the application of smart energy management systems can improve the energy efficiency and environmental sustainability of green buildings. This study combines smart technology with energy management, offers an integrated and innovative solution in the green building domain, providing robust support for the future direction of the construction industry.

Keywords: Green building, smart building, smart energy management system.

1. Introduction

With the rapid development of the economy, the global demand for the use of energy resources is increasing. The increasing pollution caused by the use of energy resources has resulted in more and more serious environmental problems. In order to meet current needs without compromising the ability of future generations to meet their needs, research into and use of sustainable energy sources has become the trend of the future. According to data released by the Global Alliance for Buildings and Constructions, the global energy consumption of building operations accounts for 30% of the world's total energy consumption. To accomplish the goal of reducing pollution through the energy transition, the energy transition of buildings should be one of the primary goals. The use of sustainable energy in building systems is a major trend for the future. At the same time, with the rapid development of information science and technology, smart buildings and smart energy management systems are being constantly promoted for development. Depending on the technical support of the building equipment management system and the application of computerized intelligent control software, a smart building energy management system has been formed. Application of this system allows for higher levels of energy mobilization and less waste of resources. Therefore, it is possible to use smart energy management system in green buildings to meet the demand for energy resources while reducing the waste of resources and environmental pollution. This study mainly introduces the green building and smart building, the based on a case to investigate the application of smart energy management systems used in green buildings.

2. Green Building and Smart Building

As two important stages in the development of the building industry, green building and smart building collectively construct a vision of a sustainable future. Through in-depth study of green buildings and smart buildings, it is possible to understand the relationship between them and how they complement each other in terms of sustainability.

In the green building domain, energy-efficient design and the application of renewable energy provide a solid foundation for reducing the energy consumption and environmental effects of buildings. However, green buildings still have certain limitations in the process of energy management. Advances in technology have brought a higher level of intelligence to buildings, and the concept of smart buildings has emerged. Through advanced sensing technology, data analysis and automation system, smart buildings are able to more accurately capture changes in the environment and optimize energy use in a real-time responsive manner. This transformation not only improves the quality of the living and working environment, but also realizes the goal of sustainability in energy use.

2.1. Green Building

A reference in the World Cities Report 2022: Envisioning the Urban Future, published by UN-Habitat, points out that " Global city population share doubled from 25 percent in 1950 to about 50 percent in 2020; it is projected to slowly increase to 58 percent over the next50 years" [1]. The increase in urban population and the accelerated progress of urbanization globally have resulted in increased the pollution of the environment and the scarcity of energy resources. Therefore, it is necessary to promote the transformation of traditional buildings into green buildings and to achieve "green cities".

Green buildings maximize resource conservation, for example, energy, land, water and materials. The trend in green building is to utilize renewable energy in the construction sector as a way to address the energy needs of urban development. The popularization and promotion of renewable energy sources include photovoltaic power generation, solar thermal absorption, wind power, ground-source heat pumps, soil-source heat pumps, bioenergy, and etc. The development and utilization of renewable energy has become a priority for many Governments and is reflected in relevant public policies. The construction and utilization of green buildings is a demand of the construction industry and the stage of urban development.

Green building can also be referred to as a building that protects the environment and reduces pollution and lives in harmony with nature. Green buildings can be designed and constructed according to local geographic conditions, using local topography, soil and water environments, and vegetation conditions as resources for construction. Optimization of the design, construction and use of the environment by making full use of natural conditions. Buildings constructed based on these concepts will consume 30-50% less energy, 35% less carbon dioxide, 70% less waste, and 40% reduced water consumption, striving to achieve "zero energy consumption" and "zero emissions" [2].

The health problems caused by poor indoor quality in conventional buildings have led to the emergence of sustainable design and green building strategies. Building green buildings aims to create a healthier and more efficient built environment for users. Indoor air quality, thermal comfort, lighting, visual comfort and acoustic comfort of the built environment are the four key factors that define the quality of environment in green buildings [3]. The rapid development of modern science and technology combines smart energy management systems with green buildings. Through real-time monitoring of air quality, temperature, human activities, etc. in the building environment and intelligent adjustment of energy use in the building body, it can realize the goal of energy saving while controlling the above four key factors in a relatively comfortable range. It provides users with a healthy and efficient building environment and it solves the health problems caused by poor indoor quality in traditional buildings. This combination also forms a part of smart buildings.

2.2. Smart Building

Building Smart Alliance, a council of the National Institute of Building Sciences, define the smart building as follows: “smart building with its four components: systems, structures, services and management as well as their interactions, creates an efficient and low-cost environment” [4]. In more detail, a smart building is a holistic system that integrates the advanced aspects of computer networks and buildings. Compared to traditional buildings, smart buildings can achieve the purpose of building a positive built environment in a more efficient and less consumptive manner through the use of smart technologies. It is based on the building as the main body, the building intelligent system includes information facility system, building equipment management system, information technology application system, public security system, etc. Through the integration of systems, structures, services, management and their optimal combination, the ultimate goal is to provide people with a safe, efficient, convenient and healthy working and living environment, as well as to achieve both energy saving and environmental protection [5].

Smart building is an important trend in the modern construction industry, and the rapid development of science and technology provides new technologies for smart buildings. The technical scope of smart buildings covers computer communication technology, sensor technology, automatic control technology, and etc. Intelligent management and control systems for the building domain are developed through a high degree of integration and flexible application of various technologies. Smart building technology relies on sensors and other equipment for real-time monitoring of the building environment for intelligent dynamic adjustment of building equipment and facilities. At the same time as providing users with a comfortable and convenient living environment, the smart energy management system makes use of sustainable energy and improves the efficiency of energy use in the building environment. Satisfy the demand for a smarter, more sustainable building environment [6].

Smart buildings will integrate intelligent technologies to achieve a smarter, more adaptive building environment. This trend will encompass smarter air management systems, lighting systems and temperature control systems to enhance the quality of the building environment with the support of adaptive building design to meet various work and living needs. In the future, combined with machine learning and other technologies, smart building systems will be able to predict equipment failures and carry out preventive maintenance to enhance the reliability and longevity of use of equipment. In summary, smart buildings will evolve towards being smarter, more sustainable, and more concerned with the health and well-being of the users.

3. Smart Energy Management System

Smart energy management systems are integrated into building design as modern innovative technology, providing strong support for buildings to achieve energy efficiency and sustainability. Through the study of its application, significant improvements in energy efficiency and its positive impact on environmental sustainability can be seen.

Smart energy management system enables buildings to rationally plan and adjust energy use through real-time monitoring and data analysis. Energy wastage can be reduced through this system. This capability plays a key role in the process of achieving the goal of building sustainability. Through the optimal control of smart energy management systems, buildings can use different energy sources more flexibly. The system is able to intelligently switch and integrate multiple forms of energy, to maximize energy efficiency. Technological updates in smart energy management system have given the new generation of system the ability to learn and adapt to different conditions. Through continuous optimization of algorithms and integration of advanced technologies, the system can be more intelligently adapted to the demands of different building types and achieve more refined energy management.

3.1. Smart Energy Management System

Intelligent energy management system is a system that utilizes a combination of information technology, sensors, data analysis, automation, and other advanced tools. Designed to enable efficient management of energy in buildings, equipment or industrial processes. Smart energy management optimizes energy production, distribution and consumption through smart technologies. It can improve the efficiency, cost-effectiveness and sustainability of energy utilization. With the continuous growth of cities, the increase in energy demand has led to shortages in energy supplies.

The integration of smart technologies into energy management in smart cities facilitates the sustainable meeting of growing energy demand in urban areas [7].

The smart energy management system consists of several key components, including a sensor network, a data acquisition module, a real-time monitoring system, an intelligent analytics engine, an energy storage module, and a telecontrol platform. The sensor network is responsible for collecting energy usage data and environmental parameters in real time. The data acquisition module integrates the collected information. Real-time monitoring systems monitor the energy position of a building or equipment in real time. The intelligent analytics engine analyzes data through advanced algorithms and models to generate optimized schemes. Energy storage modules are used to collect, store and distribute the additional energy generated, increasing the sustainability and self-adaptability of the system. The telecontrol platform allows the user to supervise and customize the energy system remotely. These components collaborate with other components to enable intelligent, real-time management and optimization of energy. Smart energy management systems also have predictive capabilities that enable the system to anticipate future energy demand based on historical data and environmental changes, and to take measures to modify it accordingly.

There is a trend in society towards smart management solutions for energy use, in which a variety of communication technologies and interfaces are used to realize communication between the program side and the user side. Communication technologies are also used in area networks to enable monitoring and control of energy-using equipment. Desai and Singh [8] proposed a Smart Energy Management System as shown in Fig.1. The primary body of the system consists of a data collection engine, a device control gateway, and a data management engine. The data collection engine supports the collection of data from various metering systems. Device control gateways provide seamless control and automation capabilities for smart energy management system. The data management engine is a collection of internal program modules containing separate software modules. Provides external (API level) access, intelligent data analytics, and autonomous event management and scheduling capabilities, enabling secure interaction between user interface components and energy monitoring and control. It can be seen that smart energy management system is a solution that provides seamless integration and interoperability of various wired and wireless communication technologies. Combined with intelligent context-aware software, it provides a complete solution for the automation of energy measurement and device control. Smart energy management system provides proven integration technology in an intelligent solution to manage energy with low-cost consumption.

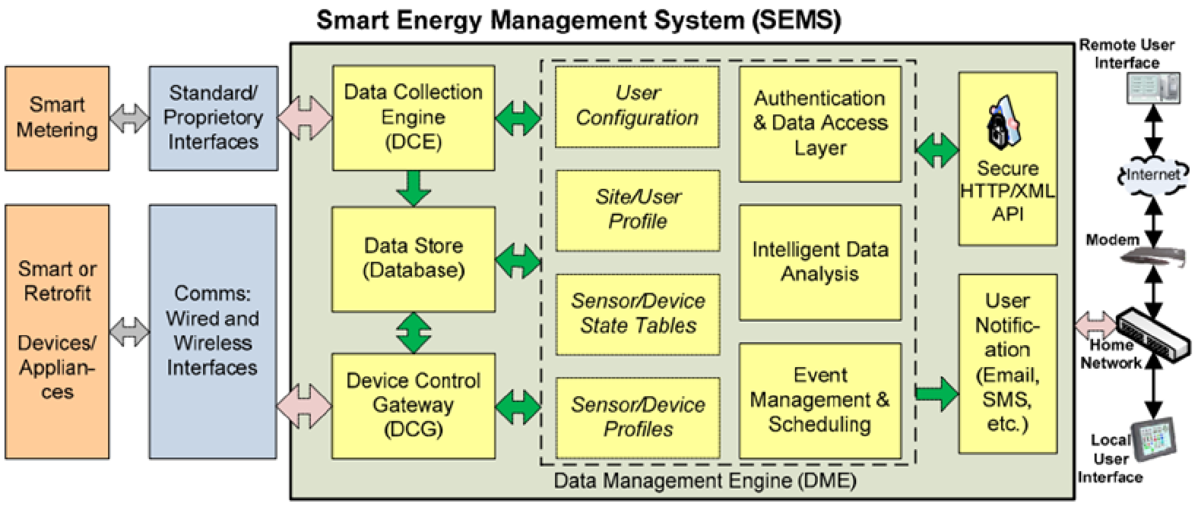

Figure 1. Smart Energy Management System architecture [8]

The importance of intelligent energy management systems in the building domain cannot be ignored. By monitoring, analyzing and adjusting energy use in real time, it improves energy efficiency, reduces energy costs and provides a strong response to environmental challenges. In the building domain, smart energy management system contributes to sustainable development by minimizing energy wastage through optimizing lighting, air conditioning and equipment operation, etc. As technology continues to advance, smart energy management system will become more intelligent and adaptive. Provide more accurate and efficient energy management programs for buildings and promote the development of green buildings. This trend will lead to more significant outcomes in the global level. It will lay a solid foundation for achieving the goals of sustainable energy utilization and environmental protection.

3.2. Application of Smart Energy Management System in Green Buildings

3.2.1 Light-guide lighting technology

Light-guide lighting technology offers extremely high energy saving benefits. First, replacing artificial light sources with natural light sources can reduce the number of artificial light source lighting equipment, thereby reducing the energy consumption required for artificial lighting. Subsequently, the use of natural light sources brings less heat into the building environment than most artificial light sources when providing the same level of illumination. The use of natural light sources can effectively reduce the indoor warming caused by artificial light source lighting equipment to produce heat and reduce the air conditioning cooling load. Setting aside light-guide channels during the architectural design can combine the technology and beauty of the light-guide lighting system with the architectural space itself. Due to the variability in daily solar activity, passive concentrating modes may not be sufficient to meet the lighting needs of the building environment. The positive concentrator mode maximizes light harvesting efficiency by using a line of intelligent technology to manipulate the concentrator points in real time to track the sun's movements. The light-guide lighting system becomes an integral part of the entire green intelligent building lighting system.

The atrium of the Morgan Lewis Law Offices Building utilizes light-guided lighting technology as shown in Fig. 2. Due to a narrow atrium in the company's office building, lighting condition was unfavorable. Designer Matthew Kufferman placed a light-guide tube in it. It illuminates the entire long and narrow atrium while also serving as a large-scale luminous art installation in the building environment, creating a visual aesthetic for the users. The roof of the building has a light harvesting device that can be changed according to the changing state of the sun. The concentrator unit tracks the sunlight to ensure maximum reflection of sunlight into the light inlet and into the light- guide tube [9].

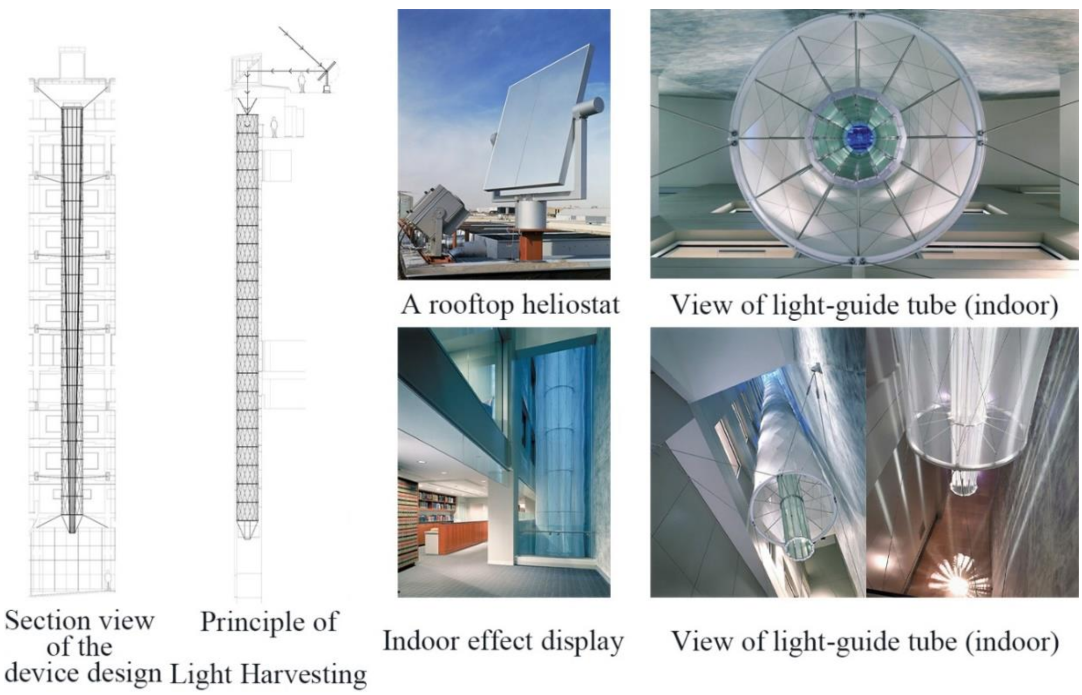

Figure 2. Light-guide tube design for Morgan Lewis Law Offices [10]

3.2.2 Light-heat balance shading

Traditional architecture often views the skin of a building as a barrier that separates the building's internal environment from the external environment. Green smart buildings with flexible structural skins prefer to use the skin as a medium for the exchange of substances and energy between the building's internal and external environments. Changing the characteristics of the building skin according to the needs to realize the exchange of substances and energy between the internal and external environments of the building can achieve the purpose of optimizing the conditions of the building environment.

The design of the light - heat balanced shading is based on variable units. Changing physical properties, chemical properties, or biological properties of the variable unit by manipulating the variable unit. This realizes the building's purpose of responding to changes in the wind, light, and heat environments and regulating them. Compared to traditional shading systems, the dynamic light-heat balanced shading intelligent system actively changes states to meet higher user demands. It minimizes energy consumption at the same time.

The Kiefer Technic Showroom in Austria, designed by Ernst Giselbrecht Architects, is a typical example of a variable skin as shown in Fig. 3. The building facade is fitted with 112 large motorized porous aluminum shading panels, which are controlled by 56 motors to open and close upwards or downwards. The result is a dynamically adjustable facade shading system on the building skin [9].

Figure 3. Variable skin for Kiefer Technic Showroom [9]

3.3. Shortcomings and Perspectives

Although the application of smart energy management system in green buildings has achieved a series of remarkable results, it is necessary to face some shortcomings to put forward an outlook for the next development. Some of the key aspects are explored below:

The collection, storage and analysis of data become more frequent while using intelligent systems. Designers must face the challenges of data security and privacy protection. Designers are required to ensure data security in smart energy management systems. For future research and development, there is a demand for enhanced data encryption techniques, authentication methods, and more robust privacy policies. Different smart energy management systems may use different standards. This leads to limited interoperability between systems. Future research should establish integrated solutions across platforms and standards. This ensures that the various systems work together to improve overall system effectiveness and achieve a higher level of intelligence. Current smart energy management systems may have limitations in coping with growing building sizes and energy demands. The future research should enable the system to adapt to green building projects of different sizes and complexities through more flexible architectures and technological tools.

Integrate artificial intelligence technology into smart energy management systems. The system will better be able to learn and adapt to the demands of the building and its inhabitants. The application of intelligence-based technologies enables systems to more intelligently predict, optimize and adjust energy use. Deepen the integration of smart energy management systems and renewable energy sources to improve the efficiency of renewable energy use through intelligent ways to achieve sustainable energy management. As urbanization accelerates, smart energy management systems will no longer be confined to single buildings, but applied to communities. This will provide more holistic solutions for building and energy management, enabling smart energy use and energy sustainability on a city scale.

4. Conclusion

Green building is supposed to move towards the direction of smart building, adding advanced technology into the design of the building structure and realizing the transformation from passive energy saving to positive intelligence. This transformation will reduce energy waste and enhance the overall efficiency of the building, leading to more sustainable solutions for future urban development and the lives of its inhabitants. Create a more intelligent, efficient and environmentally friendly building environment and contribute to sustainable urban development.

The application of smart energy management system opens a new chapter for the building industry to achieve energy efficiency and sustainability. Its efficiency in energy utilization and reduction of carbon footprint is significant. It ensures the reliability of energy supply for buildings while pursuing green and low-carbon goals. It has become one of the key technologies for future building development. Through the integration of smart energy management system with green building, a more intelligent, efficient and environmentally friendly built environment can be established, contributing to sustainable urban development.

References

[1] United Nations Human Settlements Programme. World cities report 2022: Envisaging the future of cities. June 29, 2022. Retrieved on December 25, 2023. Retrieved from: https://unhabitat.org/wcr/.

[2] Shi Yu, Jiahua Qi. Humanistic Interpretation for Green Building. Advanced Materials Research, 2013, 671-674: 2203-2207.

[3] Hirou Karimi, Mohammad Anvar Adibhesami, Hassan Bazazzadeh and Sahar Movafagh. Green Buildings: Human-Centered and Energy Efficiency Optimization Strategies. Energies, 2023. 16 (9): 3681.

[4] Ghorbanzadeh, M and Nezami, A. Smart architecture contribution to achieving sustainable architecture realization. Eco-architecture III: Harmonization Between Architecture and Nature, 2010, 128: 483-492.

[5] Shaowei Wang. Research on the integration of intelligent building and internet of things. Chang' an University, 2013.

[6] Zeze Y U. The Application of intelligent building technology in green buildings. 2023. Intelligent Building & Smart City (09): 124-126.

[7] Pitchai Pandiyan, Subramanian Saravanan, Kothandaraman Usha, Raju Kannadasan, Mohammed H. Alsharif, Mun-Kyeom Kim. Technological advancements toward smart energy management in smart cities. Energy Reports. 2023. 10: 648-677.

[8] Aniruddha Desai and Jugdutt Singh. Smart energy management system. Nanosensors, Biosensors, and Info-tech Sensors and Systems. 2010. 7646: DOI: 10.1117/12.848730.

[9] Shiran Cai. The natural dimension and sustainable design strategies of green intelligent building. School of Architecture, Southeast University, 2019.

[10] Raimund Koch. Carpenter lowings solar light pipe. Retrieved on December 25, 2023. Retrieved from https://carpenterlowings.com/portfolio_page/solar-light-pipe/.