Research on the Application of Green and Low-Carbon Technologies for Supporting Buildings of Power Transmission and Transformation Projects

Tianyou Yan[1,a*], Fulai Liu[1,b] and Nan Zhang[2,c]

*Corresponding author's e-mail: [a]yanty_gz@163.com, [b]lfl_gz@163.com, [c]zhangnan_gz@163.com

[1] Guangzhou Power Supply Bureau Guangdong Power Grid Co., Ltd, Guangzhou, Guangdong, 510635, China

[2] Guangzhou Electric Power Design Institute Ltd, Guangzhou, Guangdong, 510620, China

Abstract. To build a sustainable power network infrastructure and regulate the construction of green and low-carbon smart substations, the establishment of a construction standard system is one of the key tasks in the current power grid construction. This study analyzes the needs of the standard system for green and low-carbon smart substation construction by systematically sorting out the domestic and international technical standards for smart substations and the current situation of green substation standard construction; it designs a new hierarchical structure of the standard system and constructs a general framework of the standard system for green and low-carbon smart substations. For the first time, the study combines green, low-carbon, intelligent and digital concepts into standards, points out the urgent need to develop standards for the construction of the current standard system, and puts forward a focused action plan for standardization work.

Keywords: Supporting buildings for power transmission and transformation projects; green industrial buildings; building energy efficiency.

1. Introduction

Transmission and substation project is an important public infrastructure project in power grid engineering. With the development of urbanisation, the demand for electricity in urbans has increased substantially, and construction scale has been expanded, which has become an important way to ensure the safe and stable operation of power grids. In order to implement the national energy development goal of "carbon peak, carbon neutral" and to transform the power grid construction into a green construction mode, how to reduce the energy consumption and realise low-carbon energy saving of such buildings are receiving growing attention.

The application of green low-carbon technology, the integration of energy-saving and environmental protection concepts with intelligent technology, and the construction of supporting buildings for power transmission and substation projects into green and low-energy buildings are the current trend of development. In this regard, the power industry has carried out a series of codes to establish a perfect standard system for the construction of green low-carbon intelligent substations. Existing standards include the global information exchange

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specification IEC 61850 [1], GB 50059-2011 35kV ~110kV substation design specification to regulate the design, construction and other aspects of the construction [2], but did not substation green low-carbon energy saving field has not been formulated the relevant norms [3]. The current green building standard system is based on civil public buildings, therefore, it is necessary to combine the actual situation of substation construction, integration of relevant green building standards, improve the standard system.

This study analyses the application effect of green and low-carbon technologies in the supporting buildings of power transmission and substation projects by combining the low-carbon demonstration project of the 500 kV Kebei Power Transmission and Substation Project according to the characteristics of the supporting buildings of power transmission and substation projects, and explores the available green and low-carbon technological measures for this building to achieve the zero-energy-consumption standard.

Characteristics of supporting buildings for power transmission and transformation projects

According to HJ 2.4-2020 Technical Guidelines for Environmental Impact Assessment Transmission and Transformation issued by the Ministry of Environmental Protection [4], the supporting building of the transmission and transformation project, as a form of industrial building, the main construction requirements are based on the functional needs of the production of electrical equipment, to achieve the optimal configuration of the process, to ensure the safe and reliable operation of the power system.

The energy consumption of supporting building varies according to their functional requirements.[2] The main energy consumption of equipment rooms such as relay rooms, distribution device buildings (rooms) and auxiliary buildings is the energy consumption of electrical equipment operation, and the focus of energy saving is mainly on improving the efficiency of equipment operation. The energy consumption of buildings such as the main control and communication building and the inspection building is divided into building operation energy consumption and equipment operation energy consumption, it is also necessary to improve the building energy efficiency and reduce the energy demand of the indoor environment.

Considering the building function, the energy-saving design of buildings supporting power transmission and transformation projects has the following characteristics:

- Special building operating rules.The energy consumption of some functional areas is mainly generated by maintaining the normal operation of electrical equipment. Electrical equipment requires 24 hours of continuous operation, which increases the energy consumption of the building. Some devices in the equipment room dissipate more heat. Heat is transferred to the indoor air through convection and radiation, which increases the indoor air temperature. Most electrical equipment needs a constant temperature and humidity working environment, high requirements for the working environment, therefore, the supporting air conditioning system also needs 24h continuous operation, which increases the energy consumption of air conditioning.
- Thermal bridge effect in building shell.The hot and cold bridge is a part of the building envelope with strong heat transfer capacity and large heat flux. [5] Due to the process requirements, there are more cold and hot bridges in the supporting buildings of power

transmission and transformation projects, such as the cables that are introduced from the outside to the interior of the indoor building through the bottom cable duct.

- Complex influencing factors of building energy consumption.The air conditioning energy consumption of the building, in addition to the energy consumption generated by the temperature difference heat transfer inside and outside the outer envelope of the building itself, should also fully consider the influence of equipment heat dissipation on the indoor heat. However, the calorific value of most electrical equipment changes with the change of substation load and is unstable, so the factors affecting energy consumption are complex to quantify.
- At present, the energy-saving aspects of buildings supporting power transmission and distribution projects mainly refer to the design code for energy efficiency of public buildings. However, the transmission and distribution project supporting the building has its own architectural characteristics and equipment, such as rest and recreation characteristics. The design, construction and acceptance of the part can not be strictly enforced, resulting in the building's own energy consumption, poor comfort and other issues. [6] Therefore, there is an obvious lack of energy-saving design of power transmission and transformation. Determining the energy-saving technologies applicable to those buildings is of great significance to the development of the supporting buildings of low-energy power transmission and transformation projects.

2. Major green and low carbon technology measures and recommendations for substations

In order to reduce the energy consumption of the supporting building operation of the power transmission and transformation project, and to reduce the carbon emissions during the construction and operation of the building project, the green and low-carbon technologies that can be used mainly include high-performance enclosure systems, conservation of materials and resource utilization, high-efficiency building electrical equipment, and renewable energy applications.

2.1. High-performance envelope

2.1.1. Enclosure insulation

The energy-saving design of the building envelope is generally divided into: external walls, external windows and roofs.

The main body of the building enclosure system is the external wall and its roof, and the insulation layer of the external wall must reach the standard thickness, and the heat loss of the building through the external wall should be reduced to the design low point. In the case of green building projects, in order to ensure that the heat transfer coefficient of external walls and roofs reaches about $0.15W/(m^2 \cdot K)$, [7] it is necessary to increase the thickness of the roof insulation layer the thickness of the thermal insulation material is generally about 200mm. In this case, even in the cold winter, it can still maintain the temperature inside the building at about 20℃ through natural heat absorption. [8] In summer, the building envelope can block solar radiation to the room, and improve the thermal insulation performance to prevent outdoor heat into the room, avoiding excessive consumption of air conditioning system.

In the design of exterior wall insulation, in addition to the main control room, the outer wall as a whole to increase the exterior wall insulation layer insulation could be considered, coated with thermal insulation mortar, which can make the insulation performance is excellent and the price is economic. Compared with ordinary decoration works, thermal insulation mortar makes the project cost increased. However, the building with good thermal insulation performance of the envelope can reduce the cold and heat exchange of the house, and overall reduce the cost of cooling support.

External doors and windows are the weakest part of the building envelope in terms of thermal performance. The windows and doors of the building adopt vacuum glass passive windows and passive doors, and in the design stage, according to the characteristics of climatic conditions in Guangzhou, the direction of the building and the ratio of windows and walls in each direction are reasonably planned. Increased thickness of gas layer in vacuum glass and reflectivity of Low-E film, such as 6+19+6 built-in louver insulating glass and 6+12+6 Low-E insulating glass, effectively reduces the heat transfer coefficient of the external window, with the heat transfer coefficient of only 1.2 $W/(m^2 \cdot K)$, and the air-tightness level of 8. In addition to adding Low-E glass, the window frames are made of bridge-breaking heat-insulating aluminium alloy profiles in order to ensure that the external windows are airtight and free from hot and cold bridges. The south sunroom adopts colourful power generation film glass as the external sunshade, which aims to maintain the balance between heating and cooling needs in winter and summer seasons.

2.1.2. Enclosure thermal and cold bridges and air-tightness

For green energy-saving transmission and distribution, the strength of the airtightness of the enclosure structure can not only affect the humidity of the indoor environment, but also reduce heat loss. In addition, the airtightness of the enclosure structure is one of the means of effective sound insulation and noise reduction, because for the problem of high operational noise of the substation equipment, the spread of sound is often diffused through the pipeline ducts.

Currently, power transmission and transformation projects widely use prefabricated construction products, which are prefabricated in factories and assembled on-site to achieve efficient and accurate batch construction. This prefabricated and assembled construction method leads to inevitable gaps between prefabricated components, which are prone to hot and cold bridges and have a detrimental effect on the airtightness of the house. [9] In order to solve these problems, the assembly building should comprehensively consider the heat preservation and insulation technical measures of the building envelope, and it is desirable to achieve integrated design. To build a continuous and complete airtight layer of the external enclosure structure of the external wall, PE film or a certain thickness of concrete layer and other materials with good densities should be used, and only a continuous and complete airtight layer can ensure that the airtightness of the external enclosure structure has good performance.

For the case of hot and cold bridges and reduced airtightness caused by cables and HVAC pipework through external walls, it is possible to reserve holes for HVAC equipment in advance of the masonry of the external wall [10], and seal the pipework with insulating material between the pipework and the wall structure after the installation of the ventilation ducts. [11]

2.2. Material conservation and resource utilisation

In order to reduce the implied carbon emissions of buildings supporting transmission and distribution projects, building materials should be selected with high strength and durability, and materials should be purchased and assembled as close to the site as possible.

The main structure of the building of power transmission and transformation project should use concrete pouring and steel reinforcement fixing to prolong the service life of the substation, strengthen the anti-hazard ability of the substation, and reduce the number of maintenances of the substation. [12] Measures should be in line with the current national standards, GB/T 50476Code for Durability Design of Concrete Structures , before the construction should be with GB 50107 Concrete Strength Inspection and Evaluation Standards and Standard for Long-Term Performance and Durability Test Methods for Ordinary Concrete GB/T 50082 and other relevant standards for the durability of concrete to do the assessment.

The surfaces of steel structural parts, metal accessories, metal panels and other components of buildings in the general environment should be treated with techniques such as paint or paint spraying. The surface of pre-buried iron and aluminium parts should be well treated against corrosion; insulating sheets should be added at the contact of different metal parts to prevent galvanic corrosion.

For the selection of steel bars, the amount of steel bars above HRB400 (or the design value of tensile strength is not less than 360MPa) is not less than 70% of the total number of stressed steel bars; in the main steel and secondary steel structure, high-strength steel dosage of Q345GJ, Q345GJZ and other (or the design value of tensile strength is not less than 295MPa) is not less than 70% of the proportion of total steel.

The auxiliary buildings of power transmission and distribution engineering often use prefabricated construction technology and prefabricated building products, which have the advantages of small construction cycle, small construction pollution and saving on-site labor. However, due to the characteristics of prefabricated building products, it is necessary to combine other green and low-carbon technologies, pay attention to the treatment of component connections, and the combination of thermal insulation and decoration.

During the construction process, materials that can be used locally can be selected according to local characteristics, saving transportation costs and reducing carbon emissions during transportation. The distance between the concrete main material site and the project should be within 400km, prefabricated construction products within 500km, steel within 1100km. In order to save materials, it is possible to communicate with the construction party to recycle materials that can continue to be used, and to recycle materials that cannot be used, and dispose of them in a pollution-free manner.

2.3. Energy-efficient building electrical equipment

In addition to the use of passive green low-carbon technologies to achieve energy savings and emission reductions, it is also possible to optimise the energy efficiency of building equipment systems.

Due to the different functions of the supporting buildings, different forms of air-conditioning systems can be used, and the energy efficiency of the corresponding air-conditioning systems is controlled according to the requirements of General Code for Energy Efficiency and Renewable Energy Application in Buildings GB55015-2021 [13]. For the halls, equipment rooms and other rooms with multi-unit air conditioning systems, multi-unit air conditioning systems with an APF greater than 4.5 are used; for offices, lounges and other rooms with split air conditioning, Class 1 energy-efficient split air conditioning is used; hot water in the dining room and lounge is supplied by air source heat pumps with Class 1 energy-efficiency; for other equipment rooms that require heat dissipation, Class 1 energy-efficiency fans and pumps with variable frequency control can also be used .

A large number of equipment and servers in power transmission and transformation projects have heat dissipation demands, thus the heat dissipation load leads to high energy consumption of the air conditioning system. [14, 15] Studies have shown that when the heat recovery rate of the air conditioning system heat recovery device is 0.6~0.9 the energy saving is the highest, and the investment cost can be recovered in a shorter period of time. [16]

In addition, high efficiency lamps should be used in the lighting system of the supporting buildings, and the lighting power density should be reduced by 30% compared with the standard requirement value.

2.4. Renewable energy applications

In order to reduce carbon emissions caused by energy consumption, the supporting buildings should reasonably adopt renewable energy sources such as solar energy and wind energy according to the local climate and natural resources, and design them in an integrated manner with the buildings. The proportion of electricity supplied by renewable energy should be $0.5\% \leq Re < 1.0\%$. [7] Among them, photovoltaic power generation technology is now commonly used in power transmission and substation project, the main control and communication building, inspection building, etc. to provide energy. [17]

Taking the 500kV Kebei Transmission and Substation Project as an example, a photovoltaic system is constructed on the roof of the main control and communication building and the Inspection Building as the main means of energy supply for the buildings of the project, with priority given to the supply of energy to buildings other than the equipment rooms, such as the main control and inspection buildings, and the supply of lighting, air conditioning, and the operation of fans for the whole station. The annual power generation of the solar PV system of the project can exceed 280,000kWh.

3. The implementation effect of green and low-carbon technology application

The carbon emissions of the benchmark building of the 500 kV Kebei Power Transmission and Transformation Project Low Carbon Emission Demonstration Project (50 years) are estimated to be about 28370tCO_2. Through the application of green and low-carbon technologies, the carbon emissions of the supporting buildings of Kebei Power Transmission and Transformation Project are estimated to be 24270 tCO_2, carbon reduction is 4100tCO_2, and the carbon reduction rate is 14.5%; if it is built into a zero-energy building, the carbon emission is estimated to be 125tCO_2, the carbon reduction amount is 125tCO_2, and the carbon reduction rate can reach 96%, and the energy saving effect is remarkable.

4. Conclusion

This paper studies the application of green energy-saving technology in supporting buildings of power transmission and transformation projects, and analyzes the key points of building energy saving. In the low-carbon demonstration project of the 500 kV Kebei Power Transmission and Transformation Project, according to the estimate of the zero-energy building technology plan, the carbon reduction rate of the benchmark building can reach 96%, and the energy-saving effect is remarkable.

However, there are certain technical problems in the construction of photovoltaic roofs and low-energy buildings:

The photovoltaic module needs to have a reliable and firm connection with the main structure, and the roof and structure must be able to withstand the self-load and use load of the photovoltaic module to ensure the safety and durability of use; the connection between photovoltaic modules and roof structures should avoid the phenomenon of cold and hot bridges, and effectively play their characteristics of thermal insulation and heat insulation; the airtight film between the photovoltaic roof and the wall should form a closed loop to ensure the air-tightness of the building. How to solve these technical problems will become the focus of future technology improvement discussions.

In the process of construction of supporting buildings for new or reconstructed transmission and transformation projects, its impact on the natural landscape and environment can be reduced through the application of green and low-carbon technologies, in conjunction with the innovation of transmission and transformation project management. Maximum possible to reduce soil erosion, reduce the destruction of vegetation, reduce energy loss and reduce environmental pollution, to achieve land-saving, material-saving and energy-saving, help to achieve the grid industry, dual-carbon construction.

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