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Integrated application of cadmium telluride thin film components in curtain wall roofs

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Abstract

As an important venue for display and communication, the design of large exhibition halls should not only meet the requirements of aesthetics and functionality, but also take into account factors such as their subsequent use and green construction. This paper aims to deepen the photovoltaic design of large exhibition halls, taking into account their characteristics such as large footprint, low floor structure, and lighting projection area. It explores how to fully utilize renewable energy sources such as light and heat while ensuring aesthetic and functional requirements, and proposes a complete set of design and construction methods. These methods are verified and applied through practical cases

Keywords

Cadmium telluride film, large exhibition hall, curtain wall design, curtain wall roof, key technologies, application cases.

1. Introduction

With the intensification of global climate change, it has become particularly important to comprehensively and comprehensively promote green planning, green design, green investment, green construction, green production, green circulation, green life, and green consumption. Against the backdrop of intensified global climate change and depletion of renewable energy, how to establish development and construction on the basis of efficient resource utilization, strict protection of the ecological environment, and effective control of greenhouse gas emissions, and how to use technological means to promote green construction and green construction to a new level. To achieve the above goals, we explore exploring the potential of building construction while always adhering to the primary premise of green construction. Through building design methods, we start from the effective use of energy, ensuring the aesthetics and functionality of buildings, while ensuring cleanliness, safety, and inexhaustible resources Maximizing inexhaustible energy utilization. Ensure the implementation of green buildings to achieve carbon peak and carbon neutrality goals, and promote China's green development to a new level.

This paper aims to deepen the design and use of large exhibition hall skylights, deepen photovoltaic design of skylights, and explore how to fully utilize light and heat energy while ensuring aesthetic and functional requirements, in order to increase the proportion of green and renewable energy usage. Based on the characteristics of large-scale and floor to ceiling design of exhibition halls, a comprehensive design and construction method is proposed through analysis and research on photovoltaic materials, structural design, and construction technology, providing reference and guidance for the integrated design of renewable energy

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and curtain wall construction in large-scale exhibition halls. At the same time, we are further advancing towards the integration of photovoltaic buildings.

2. Project Overview

The Phase I project of Hangzhou Grand Exhibition Center is a large-scale comprehensive exhibition hall project, mainly composed of standard exhibition halls, conference centers, stand exhibition halls, and central corridor service spaces; The total construction area of the project is 1.22 million square meters. The first phase of the project consists of 8 exhibition halls and a central corridor, with a construction area of 64.32 square meters and an area of 215700 square meters. It has a single layer above ground (partially double layer), a top design elevation of 42.36 meters, a horizontal span of about 184 meters for the curtain wall, an aluminum panel system for the eaves of 12000 square meters, a cantilever structure height of 25.8 meters to 42.36 meters, a cantilever arc of 18-40 degrees, and a photovoltaic curtain wall area of 7841 square meters. The total installed capacity of photovoltaics is 771.88kWp, with 3356 pieces of 30% transparent cadmium telluride thin film photovoltaic glass installed and approximately 326 pieces of irregular non generating glass. After the completion of the project, it is expected that the annual power generation will reach 700000 kilowatt hours, and it will become a new highland for exhibition and business in China. Large exhibition buildings are the main supporting carriers for urban exhibition and exchange, and their green energy use and system are important components of curtain wall systems. Their performance and structural requirements are higher, and various structural parameters need to be comprehensively considered in the design process.

3. Key technology selection and integration integration

Under the dual carbon goal, there are various ways to utilize renewable energy. In order to promote the sustainable use of renewable energy, the landing process of photovoltaic facilities is accelerating. In order to achieve the dual carbon goal as soon as possible, integrated green energy building facilities have emerged. Given the wide area and low floor design characteristics of large-scale exhibition projects, the integration of photovoltaic building projects continues to advance, and it is particularly important to choose high-efficiency and high utilization regeneration systems.

3.1. Traditional monocrystalline silicon solar cell systems

Currently, crystalline silicon materials (including polycrystalline silicon and monocrystalline silicon) are the most important photovoltaic materials, with a market share of over 90%, and will continue to be the mainstream material for solar cells for a considerable period of time in the future.

Using high-purity single crystal silicon rods as raw materials, single crystal solar cells have high photovoltaic conversion efficiency (conversion rates ranging from 15.4% to 26.3%) and stand out in photovoltaic applications.

Fix the monocrystalline silicon solar panel onto an aluminum plate with a copper tube on the back to form a system. The group compared the photovoltaic thermal system with the photovoltaic solar thermal deposition system, and the analysis results showed that the overall energy efficiency of the photovoltaic thermal system is close to that of the solar thermal deposition system, and the photovoltaic thermal system has higher fire protection efficiency than the other two systems. In order to simulate and calculate various parameters of the system, the simulation results show that the electrical performance, thermal efficiency, total conversion efficiency, and thermal utilization efficiency of the system are 10.01%, 17.18%, 45.00%, and 10.75%, respectively.

3.2. Polycrystalline silicon solar cell system.

Polycrystalline silicon solar panels are usually made from discarded monocrystalline silicon tailings or metallurgical silicon materials, and their cost is lower than monocrystalline silicon. Monocrystalline silicon solar panels were developed based on solar panels, with the photovoltaic industry accounting for 70%. The photoelectric conversion efficiency of polycrystalline silicon solar cells is usually lower than that of monocrystalline silicon solar panels with the highest photovoltaic speed, with a conversion efficiency of about 20.89%. The temperature coefficient of crystalline silicon solar cells is relatively high; The photoelectric conversion efficiency of crystalline silicon solar cells decreases more significantly with the increase of their own temperature; How to effectively utilize the heat absorbing layer to timely remove the heat from crystalline silicon solar panels; The production cost of crystalline silicon solar cells is high, and their low light performance is poor. Therefore, the performance of crystalline silicon solar cells needs to be further improved.

3.3. Cadmium telluride thin film curtain wall system.

Compared with other solar cells, cadmium telluride thin film solar cells have a relatively simple structure, usually consisting of five layers, namely a glass substrate, transparent conductive oxide layer, cadmium sulfide (CdS) window layer, cadmium telluride absorption layer, back contact layer, and back electrode.

Cadmium telluride is a direct gap semiconductor with a gap width that matches the solar spectrum very well, and its gap width can operate normally at high ambient temperatures, with good radiation resistance. In addition, cadmium telluride solar cells are composed of polycrystalline thin films, and the preparation process is relatively simple. Therefore, the application of cadmium telluride solar cells is very promising, especially suitable for high-altitude and desert power plants, outer space and deep space energy, and as compression batteries.

Electrical performance parameters				
model	JC-RTN	JC-RTN	JC-RTN	JC-RTN
Pattern form	Treasure Blue	Treasure Blue	yellow	green
power	65wp	85wp	85wp	85wp
Power tolerance	±5%	±5%	±5%	±5%
short-circuit current	0.71A	1.13A	1.08A	1.06A
Open circuit voltage	117.2V	118.4V	118V	117.2V
Peak power current	0.52A	0.97A	0.91A	0.92A
Peak power voltage	72V	97.1V	94.7V	90.1V

Mechanical parameters			
Component dimensions	1200*600*9.34mm	Battery type	Cadmium telluride thin film (CdTe)
weight	16.8kg	area	0.72m2
Junction box	Back or side connection, cable2.5mm2, 650±10mm		
connector	MC4 or MC4 compatible		
structure	3.2mm CdTe+0.38mm PVB (color)+0.76mm PyB+5mm		

Fig. 1 Parameter diagram

4. Integrated Application of Cadmium Telluride Curtain Wall and Roof in Large Exhibition Halls

4.1. Key points of science and technology: Taking the photovoltaic roof of Hangzhou Grand Exhibition as an example.

In the construction of the photovoltaic curtain wall project for the daylighting roof, cadmium telluride film modules were first applied in the construction of building photovoltaic integration projects for the daylighting roof. While ensuring the primary requirement of structural transparency, cadmium telluride transparent modules with a transmittance of 30% were applied, generating over 700000 kilowatt hours of electricity annually, which is equivalent to the lighting electricity consumption of the basement and above ground office of the Hangzhou Convention and Exhibition Center, and more than 30000 trees were planted next to the building.

In the integrated photovoltaic construction, a single 320Wp cadmium telluride photovoltaic module with a capacity of 320Wp is used, and 3356 single 320Wp modules are installed. The total photovoltaic capacity is 771.88kWp. The layout of photovoltaic modules adopts a rooftop tiling method, with each group consisting of 6/7 photovoltaic modules. Three groups are equipped with a set of photovoltaic return kits, and 1 * 6mm2 photovoltaic lines are led to the inverter in the distribution room through cable trays. The project is equipped with 10 inverters, and every 5 inverters are connected to 1 low-voltage cabinet grid connected cabinet. This project adopts 2 400V low-voltage grid connected cabinets, which are used for power consumption through 2 transformers. The power generation form is to spontaneously use surplus electricity for grid connection. While meeting the requirements of skylight transmission, combined with power generation, it can improve the efficiency of subsequent use and assist in the use of green energy for environmental protection. At the same time, the use of assembly components saves a lot of maintenance costs compared to traditional processes, reduces material waste and environmental pollution, and is in line with the development trend of green and low-carbon buildings in China.

4.2. Main construction and installation technical measures

The construction method for installing cadmium telluride thin film photovoltaic roofs mainly includes nine parts: measurement and retesting, installation of photovoltaic modules, system debugging, construction of grid lines, installation of combiner boxes, installation of photovoltaic inverters, installation of distribution panels and cabinets, cable laying, lightning protection and grounding construction, and trial operation.

4.2.1. Measurement and component installation

1. Construction surveying and layout

The basis for construction measurement includes the layout plan, construction drawings, and positioning control points on the construction site. The main content of construction surveying includes reviewing coordinate points, setting out fixed points based on coordinate points, and related openings.

2. Photovoltaic bracket and module installation plan

The photovoltaic modules are connected and fixed to the original roof truss using bolts; Retest the flatness of the original roof truss and the deflection of the supporting beams; Exceeding the specified scope requires the corresponding construction party to carry out rectification; Retest the reserved hole positions and compare whether the position of the pressure blocks, components, and small frame dimensions meet the installation requirements.

4) Installation of photovoltaic modules

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During transportation and storage, components should be handled with care, without strong impact or vibration, and should not be placed horizontally under heavy pressure. Prevent battery cracking and affect operational efficiency. The installation of components should be done from bottom to top, block by block. During the installation process, it must be handled gently to avoid damaging the surface of the components. The installation of components must be done horizontally and vertically, and the spacing between components within the same array must be consistent; Pay attention to the direction of the component's junction box. The connection between components and bracket systems can be installed using mounting holes on the frame, fixtures, or embedded systems. The installation of components must follow the examples and suggestions below.

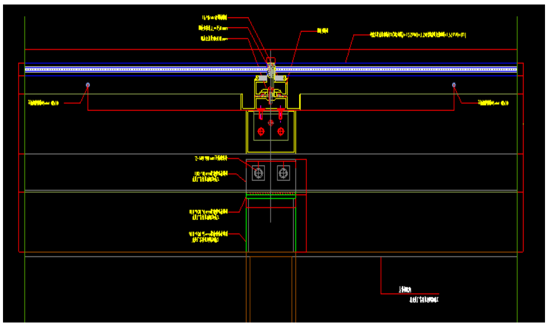

Fig. 2Photovoltaic Module Installation Diagram 1

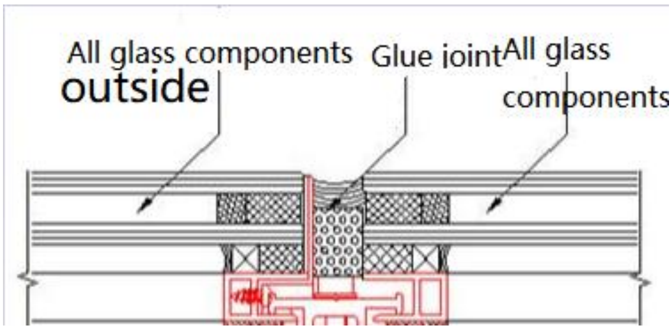

Fig. 3Photovoltaic Module Installation Diagram II

Fig. 4Roof truss span structure diagram

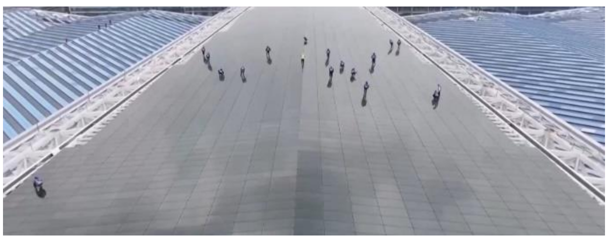

Fig. 5Photovoltaic roof installation rendering

3. General safety rules for the installation of solar photovoltaic modules

The installation of solar photovoltaic power generation systems requires specialized skills and knowledge, which must be completed by professionally qualified engineers.

When installing, operating, and maintaining photovoltaic modules, please ensure that you fully understand the information in this installation manual and understand the risks of injury that may occur during the installation process. Photovoltaic modules produce electricity when exposed to sufficient sunlight or other light sources. Please take corresponding protective measures when operating to avoid direct contact between personnel and 30VDC or higher voltage. When the component has current or external power supply, the component must not be connected or disconnected. The front of the solar photovoltaic module array is used to stop power generation. Do not wear metal accessories when installing solar photovoltaic modules.

4.The wiring of solar photovoltaic modules needs to be determined based on the power station design drawings. The component wiring should meet the requirements of the design drawings. The wiring connectors are connected using MC3/MC4 standard components and plugs, using specialized crimping tools. When wiring, be careful not to reverse the positive and negative poles to ensure correct wiring. After each component is connected, check whether the open circuit voltage of the string is correct. After the connection is correct, disconnect the wiring of one component and connect the string to the corresponding terminal of the combiner box.

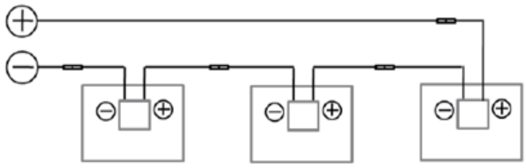

Fig. 6Component wiring diagram

5. Lightning protection grounding installation

The grounding wire should be insulated and must be made of whole wire without any joints in the middle. The grounding wire should meet the requirements of thermal stability during short circuits, and its cross-sectional area should not be less than 4mm2. The grounding wire of the lightning arrester should be selected at the closest position to the grounding body. The connection between the grounding body and the grounding wire should be welded; The grounding wire can be connected to the equipment with bolts.

The grounding flat iron shall be made of hot-dip galvanized flat steel not less than 40mm x 4mm, and each corner shall be made into an arc shape.

6. Overall convergence line

Before the overall assembly, consider the direction of the wiring first, and then lay it out to the inverter. The solar panel wiring should use double sheathed multi stranded copper flexible wires, and the wire conduit should be horizontal and vertical.

7. Cable laying

When cables pass through walls, galvanized protective pipes should be used. Before laying, the protective pipes should be visually inspected to ensure that the inner and outer surfaces are smooth. Wire pipes should be cut with a steel saw, and the ends should be treated with burrs. If any, according to the design drawings, the corresponding construction party should take pre embedded measures to avoid rework; The cable is laid along the main bridge to reach the distribution room. During the process, the bridge cover plate needs to be opened. After the cable is laid, it should be restored to its original state. Fire resistant mud and other sealing materials should be laid at the cable entrances and exits.

Cable sealing should be carried out in accordance with the design requirements and regulations.

4.2.2. System debugging

Before system debugging, conduct a system check, which includes: detection of grounding resistance value, detection of line insulation resistance, performance testing of control cabinet, detection of photovoltaic array output voltage, and controller debugging.

According to the operation and debugging plan, prepare instruments, tools, and debugging record forms, check whether the solar photovoltaic wiring is correct, whether the wiring of the inverter and grid connected cabinet is correct, and whether the wiring of protective devices and electrical equipment meets the requirements of the drawings.

Among them: Before the inverter is connected to the grid, the following tests should be conducted first:

Conduct insulation testing on the solar power generation system, and only after passing the test can it be connected to the grid. Test the output voltage of the DC lightning protection box (or the input terminal of the inverter) to determine whether the solar cell output is normal. Measure the voltage at the grid connection point and whether the frequency is within the grid connection range of the inverter. After the above tests are completed and the grid connection conditions are met, grid connection debugging can be carried out. Close the input and output isolation switch of the inverter, close the corresponding circuit breaker of the grid connection cabinet, observe whether the grid connection voltage and current are normal, and check whether all parameters of the inverter are normal. Repeat this operation until the inverter works normally.

4.2.3. System debugging

The installation of photovoltaic modules and combiner boxes has been completed and inspected as qualified; The specifications and models of materials required for photovoltaic module wiring (cables, tie wires, conduit, etc.) should meet the requirements of the design drawings, and have material inspection certificates and product factory certificates.

Photovoltaic modules and photovoltaic arrays: A single photovoltaic module is connected in series to form a string, and the connected photovoltaic modules are connected in parallel to form a photovoltaic array.

4.2.4. Installation of combiner box

Using galvanized angle steel to make fixed brackets for the junction box; Fix the manifold box bracket onto the component bracket; Install the combiner box, and ensure that the grounding wire of the combiner box is reliably grounded in the correct position, the components are complete, and the box is firmly fixed; The paint is intact, the inside and outside of the box are clean, and the box door is flexible to open and close; The circuit numbers are complete, the wiring is neat, and there are no twisted wires; The installation of the ground wire is obvious and firm; The cross-sectional area and phase color of the wire comply with the specifications. The casing of the combiner box should have a clear and reliable protective ground wire (a yellow green dual color wire). The wiring of the junction box is arranged neatly and tied into bundles; Fixed at the moving parts; The wiring should have appropriate margin for easy maintenance. The switches and fuses inside the combiner box should be in an open circuit state.

4.2.5. Installation of photovoltaic inverters

According to the requirements of the construction drawings, the installation of the foundation of the power distribution device should first use qualified materials and determine the actual position of the foundation. At the same time, the pre embedded parts of the civil engineering should be cleaned, the elevation of the embedded parts should be measured, and the thickness of the pad iron between the channel steel and the embedded parts should be calculated based on the highest elevation of the embedded part. Then, the pad iron and channel steel should be placed in position, and the elevation and horizontal dimensions should be corrected. The pressure foot channel steel, pad iron, and embedded parts should be welded firmly and connected to the grounding grid using electric welding. The supervision party should be notified in advance for acceptance. After the installation of the basic steel for low-voltage panels and cabinets, the top should be 10mm higher than the ground level.

According to the predetermined order, the area near the branch station is transported and rolled into place by hydraulic carts or rollers. Correct and fix the cabinet body, use bolts to fix the cabinets, and use welding to fix the cabinet feet. After fixation, the acceptance is qualified. To avoid damaging the indoor floor, a layer of rubber should be placed on the dragging or rolling route, and then a suitable layer of boards should be laid. The installation of the switchgear must strictly comply with the requirements of the manufacturer and specifications, with its verticality and levelness meeting the requirements of the specifications, and self inspection records should be kept. After installation, regularly measure and record the insulation situation and take targeted measures.

Compare the design schematic and wiring diagram of the grid connected inverter and recheck whether the wiring inside the grid connected inverter is correct. Is the wire number consistent with the drawing and is the wiring harness securely fastened. The contactor contacts should be tight, reliable, and operate flexibly. The fasteners and wiring terminals used for fixing and wiring should be intact and undamaged. The wiring of the grid connected inverter should be numbered and the terminal wiring should be clearly labeled. The grounding wire should be firmly connected and should not be grounded in series.

4.2.6. Installation of distribution panels and cabinets

The positioning of the cabinet should only be carried out after the concrete strength meets the requirements. After cleaning the installation site, start the installation work. First, mark the installation position of the cabinet according to the order specified in the installation drawings, manually move the entire row of panels and cabinets to the installation location, and then precisely adjust the first cabinet (or busbar bridge cabinet, intermediate cabinet). The verticality of all four sides should meet the requirements, and the position and size of other cabinets should be adjusted according to it as the standard.

4.2.7. Cable laying

Before cable laying, remove debris from the trench and lay 100mm bottom sand or fine soil. Cable laying can be done manually or mechanically. During laying, attention should be paid to not damaging the cable trench, and the bending radius of the cable should meet the specifications. The bending radius of multi-core cables should not be less than 6 times their outer diameter; The distance between the surface of the cable and the ground shall not be less than 0.7m. At the points where it is introduced into buildings, intersects with underground buildings, or bypasses underground buildings, it can be buried shallowly, but protective measures should be taken. There should be an appropriate amount of serpentine bends when laying cables in the trench, and appropriate margins should be left at both ends, middle joints, cable wells, and vertical differences of the cable.

After the cable laying is completed and self inspection is qualified, the quality inspection department of the construction unit and the supervision unit should be invited to jointly carry out concealed project acceptance. At the point where the cable passes through the floor slab, a sleeve should be installed. After laying, the gap between the sleeve and the floor slab should be sealed with fire-resistant materials. Hanging signage: The specifications of the signage should be consistent, and plastic signage should be used for this project. The hanging should be firm. The identification plate should indicate the circuit number, cable number, specification, model, and voltage level.

Direct buried cable construction should not be carried out too early. It is generally carried out after the completion of other outdoor projects to prevent cable damage during the construction of other underground projects.

4.2.8. Lightning protection and grounding construction

According to the quantity and material specifications required by the design, the material is generally cut using steel pipes and angle steels, and the length should not be less than 2.5m. If steel pipes are used to drive underground, they should be processed into a certain shape according to the soil quality. When encountering soft soil, they can be cut into an inclined plane shape. In order to avoid uneven force during driving and causing the pipe to tilt, it can also be processed into a flat pointed shape; When encountering hard soil, the tip can be processed into a cone shape. If angle steel is selected, angle steel of no less than 40 × 40 × 4mm should be used, and the cutting length should not be less than 2.5m. One end of the angle steel should be processed into a pointed shape.

The connection of the grounding body (wire) should be welded, and the welding must be firm without false welding. The welding surface should be treated with anti-corrosion. The grounding wire connected to electrical equipment should be connected with galvanized bolts. When non-ferrous metal grounding wires cannot be welded, they can be connected with bolts. The contact surface treatment at the bolt connection should be in accordance with the provisions of the "Construction and Acceptance Specification for Busbar Devices in Electrical Equipment Installation Engineering". The welding of grounding body (wire) should use lap welding, and the connection between the lap welding ground wire (excluding equipment grounding wire) and the grounding grid should not be less than two points. Electrical equipment installed on reinforced concrete supports shall not be naturally grounded using equipment supports, and embedded iron parts in cable trenches shall not be used as grounding wires.

4.2.9. Trial operation measures

The project department is responsible for organizing the establishment of a trial operation command group, coordinating the work of the participating units, and doing a good job in the organization and division of labor of each unit during the trial operation period. The project department is responsible for safety and environmental management during the debugging period.

Before the system joint debugging, the project department organizes the establishment of a trial operation command group, and formulates a trial operation plan with relevant units (including construction units, manufacturers, commissioning units, supervision companies, etc.). The trial operation command group is responsible for guiding the trial operation work of each unit and maintaining daily communication with relevant units. The commissioning unit shall organize personnel to prepare trial operation construction technical measures in accordance with the relevant provisions of the Construction Technical Measures Compilation and Execution Management Measures.

5. Quality control of photovoltaic curtain wall roof

The use of this technology is closely related to quality control during its use. During construction and use, attention should be paid to the quality of the technology and common quality issues should be comprehensively addressed.

Establish a quality reward and punishment system, and based on the implementation of the system, ensure that each person has a clear understanding of their respective quality responsibilities. Organize construction personnel to study the "Specification", "Inspection Standards", relevant technical documents and materials from the manufacturing plant, manuals, and design requirements of the design institute, so that construction personnel can clarify quality standards, master installation and commissioning processes, and ensure installation quality.

Before project construction, calculate the quantity of work and arrange the project schedule reasonably. Construction personnel must strictly follow the construction organization design and the content of quality, technology, and safety briefing, and do a good job in recording various original data.

When the bolt connection parts and bolt hole positions are inconsistent, flame welding cutting is not allowed, and only re drilling and adjustment can be carried out. Welding materials should be selected according to relevant regulations, and the welding materials used should have a supplier's quality assurance certificate.

When dealing with equipment defects, it is important to proactively collaborate with relevant technical and supervisory personnel to develop solutions suitable for on-site construction. Carefully inspect and record various equipment defects and non-conforming products, and handle them in accordance with regulatory requirements.

In addition to strict quality control and internal quality objectives, measures will also be taken to eliminate common quality problems, mainly from the following aspects of control, and relevant process operation manuals will be prepared: cable laying and cabinet wiring construction personnel must pass the assessment and training before taking up their positions, and be familiar with the regulations, specifications, and process requirements of cable installation. The cable tray should undergo secondary design, and technical personnel should consult with the supervisor and owner to determine the layout plan based on the drawings of the design institute and the actual situation on site, so as to make the direction, level, and cable layout of the tray more reasonable. The secondary design can only be implemented after going through the review and approval process. Technical personnel need to prepare work instructions for cable tray installation and cable laying, which will be reviewed and approved through relevant procedures. Before construction, technical personnel should conduct serious and detailed technical and process disclosures, and consider potential problems before construction. After the completion of the cabinet wiring work, quality acceptance should be carried out.

6. Conclusion and Outlook

The research on the integrated application of cadmium telluride film modules in curtain wall roofs, based on the Hangzhou Convention Center Phase I project, can be concluded that with the improvement of building energy efficiency requirements, new building energy-saving materials are also constantly developing. In order to significantly reduce building energy consumption, traditional photovoltaic roofing materials are mostly metal roofs and photovoltaic panel structures, which can no longer meet the requirements of large exhibition halls for energy conservation, transparency, and aesthetics. The new technology of building and energy integration has become an important direction for the development of green and low-carbon building energy conservation systems, and the technological development from energy conservation to green power generation has become the next journey that the construction industry needs to move forward. Reasonably analyzing the application of each node, comprehensively considering the economy, and implementing it after expert argumentation, the construction process is efficient and reliable, anticipating potential problems in advance, and solving them through technical means, saving construction costs, accelerating construction progress, and creating favorable conditions for the integrated construction of photovoltaic buildings, with broad application prospects.

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In order to implement the new technology of integrating building and energy conservation, the following three technical difficulties need to be solved: first, to ensure the original light transmittance requirements of the skylight; The second is to ensure the overall quality and durability of the curtain wall roof; The third is to enhance the flow of green energy in large exhibition halls and promote the continuous development of low-carbon green buildings.

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