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PC-based control showcases Chinese heritage in modern museum installation

Movable walls open up a dialog between high-tech and history

Zhejiang Dafeng Industry is a leading solution provider from China serving the tourism and cultural sectors. When a branch for a national pavillion in Hangzhou was built, Dafeng was contracted to develop an intelligent folding wall system. With its greenish tile surface, the installation resembles a famous landscape painting. In the synchronized movement of the 251 walls weighing several tons each, PC- and EtherCAT-based control technology from Beckhoff ensures functional safety.

The museum installation plays with associations with the natural environment. The folding walls are made of celadon tiles, which were produced in a local ceramic tradition and are reminiscent of jade due to their greenish glaze.

The pavillion serves as a hub for preservation, exhibition, research and exchange. It combines the functions of a library, museum, art gallery, archive and exhibition hall. The newly constructed building complex is nestled among the mountains. The most eye-catching feature of the architecture is a folding screen consisting of movable wall elements that can open or close the exhibition space to the outside. To that end, the wall elements can be either folded like the panels of a traditional folding screen or positioned next to each other to form a flat surface like a painted partition wall. Following the design

concept, the installation resembles the famous Chinese painting "A Thousand Miles of Rivers and Mountains", which shows a blue-green landscape panorama over a width of more than 50 m. Therefore, the 251 folding screens of the entire installation were built using approximately 70,000 pieces of celadon tiles that were handcrafted to unique specifications in traditional kilns. Celadon is a form of ceramic typical of this region, which resembles jade with its greenish glazing and was very popular during the culturally significant Song dynasty (960 to 1279). The painting is also attributed to this period. The smooth open-
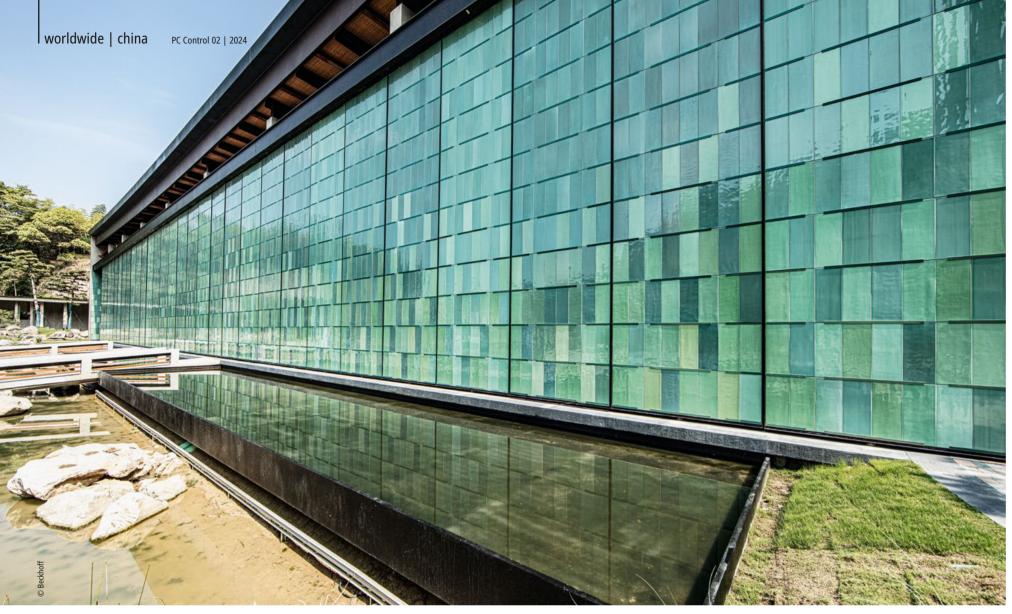
ing and closing of the high and heavy walls is ensured by a PC-based control system from Beckhoff, creating a visual link between cultural history and state-of-the-art automation.
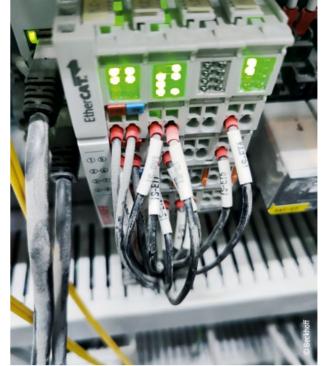
Stability, precision and safety

The construction phase of the pavillion began as early as 2020. However, the progress of realizing the celadon wall installation stagnated due to the high control requirements, as the largest wall type measures 2.1 m x 10.4 m, and

at a thickness of 22 cm, weighs four tons. The machinery not only had to be able to safely support these walls, but also ensure the jerk-free movement and translation along a track system designed for that purpose, as otherwise the walls would shatter due to their high inertia.

"In machine building, we mainly deal with materials like steel. Until then, I had never worked with ceramics," says Huafeng Yan, chief engineer for the development of the celadon folding wall at Dafeng. Furthermore, the enormous

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EtherCAT plays a central role in controlling the drive technology. The distributed clocks function enables system-wide synchronization of all wall panels in the installation

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A CX2040 Embedded PC with a quad-core Intel® Core™ i7 processor offers high computing power for controlling the many servo axes in the installation.

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When closing the walls, two axes for translation and one axis for rotation must be controlled with high precision so that the gaps between them do not exceed 1 cm.

weight of the celadon tiles resulting from the high density of the material, also means that the mechanical errors in positioning must be small. When the folding screens rotate to align in the same plane, the distance between them must be strictly controlled within 1 cm. Larger gaps between the screens would detract too much from the resemblance of the installation to the painting "Thousand Miles of Rivers and Mountains" after which it was named.

The system developed by Dafeng integrates motion control, logic control, safety monitoring, and real-time synchronization technologies. It embeds various algorithms implementing anti-vibration and acceleration functions including parabola overlay, which ensures that the celadon folding screens can run smoothly through 16 motion profiles. According to Dafeng, the safety control system of the system has achieved SIL 3 certification, the highest safety standard of the European Union. "We have reached a world-leading level for technical implementations in the cultural sector," says Hufeng Yan.

Powerful PC-based control system
At the core of the control system is the CX2040 Embedded PC with an Intel® Core™ i7 CPU, 4 GB of main memory, and Windows 10 operating system. This PC-based control platform offers excellent computing performance and,

with the TwinCAT 3 automation software, enables flexible engineering in compliance with IEC 61131-3. According to Huafeng Yan, the mixed use of the programming languages Structured Text (ST), Function Block Diagram (FBD) and Ladder Diagram (LD) greatly facilitated the development of customer-specific algorithm and logic programs. In addition, the motion functions could be developed rapidly using the TwinCAT 3 Motion Control library based on the PLCopen specifications.

Each celadon folding wall is controlled via up to three servo axes, with two axes controlling translation and one axis controlling rotation. With a total of 251 individual walls, each controller therefore needs to control the synchronization of more than 100 axes. To meet these requirements, Dafeng uses TwinCAT NC to specify corresponding slave positions through a complex cam table, and to plan suitable interpolation positions and speeds. A high-level monitoring software, developed using C#, enables the fast and efficient exchange of very large data volumes via the TwinCAT ADS protocol.

Precise servo control via EtherCAT
EtherCAT is established as the fastest Industrial Ethernet technology because compared to traditional fieldbus systems, it offers exceptionally high

data transfer rates. The celadon wall installation benefits from this with a correspondingly high level of precision. All servo axes are controlled via the distributed clocks function, to synchronize all nodes in the network, with a jitter well below 1 µs throughout the system. Three servo drives are required to control each celadon wall, which are connected via a network cable to one port of an 8-port EtherCAT junction CU1128. Furthermore, the system provides a hot-connect feature allowing for convenient insertion and removal as well as replacement in the event of a fault without interrupting operations.

For reliable and safe operation, the wall installation uses TwinCAT 3 EtherCAT Redundancy (TF6220). This EtherCAT cable redundancy integrates the entire system into a large closed control loop, where any physical or connection failure at one node does not affect the operation of the other devices in the network. This setup prevents the impact of transient electromagnetic interference on the system and greatly reduces the risk of downtime.

Integration of science, technology and culture
The celadon folding screens can be freely opened and closed at any angle to create an elegant visual experience in different scenarios. At the same time, the highlight of the national pavillion protects the public with its high level

of security. Huafeng Yan sees the success of the project above all in the deep integration of technology and culture: "The outside world generally regards stage machinery as part of the manufacturing industry. And in fact, the trend that digital technology and cultural innovation are empowering the traditional manufacturing industries is becoming more and more evident! The experience of participating in the construction of the national pavillion, will undoubtedly be a remarkable highlight in the history of our company."

More information:
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