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PCcontrol

The New Automation Technology Magazine

Entertainment Industry Compendium 2022

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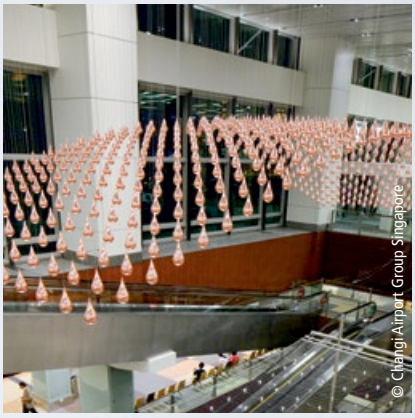
Success stories entertainment industry

The PC Control Entertainment Industry Compendium 2022, a special edition of our PC Control customer magazine, is a collection of selected application reports about entertainment industry and building automation projects which have been realized with Beckhoff technology. The wide range of applications with varying degrees of complexity will give you an idea of how versatile the solutions are that can be implemented with the open and universal PC- and Ethernet-based control technology from Beckhoff and the benefits it provides.



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PC-based control: The platform for creating maximum guest experience

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Michel Matuschke,
Market Manager
Entertainment Industry,
Beckhoff

Regardless of your position in the entertainment industry – as investor, planner, integrator or operator – you can benefit from the Beckhoff system. Maximum guest experience in theaters, at music festivals, at unique applications or in attractions require complex control technology that works reliably in the background: from the motion control of stage machinery that can change a stage in a matter of seconds, through magical lighting effects synchronized with music, the animation of figures in entertainment parks, and the effects in 4D and 5D cinemas – all the way to kinetic installations that interact with the audience. This is where we come in as automation specialists: In the various entertainment projects that our customers have successfully implemented around the world in recent years, it has become clear that our PC- and EtherCAT-based control system is an excellent fit for an industry that constantly needs to outdo itself – or the competition – in order to offer new attractions. With Beckhoff you have an experienced technology partner at your side and a control system that has been tried and tested in 24/7 industrial operation. It is the basis for translating your creative ideas into working technology and producing ultimate guest experiences.

Our interface diversity and the support of all relevant industry-specific protocols for the connection of lighting, audio and multimedia technology systems are likely unique in the industry. In this way, all technical systems can be run on a single control platform. The modularity of our PC controllers and the use of standards enable integration into almost any system. It is entirely up to your application whether you decide in favor of a centralized or decentralized control approach or whether you want to automate only a subarea or your complete application with Beckhoff technology. With us you can do both! The scalability of our software and hardware components with respect to performance, design and price also enables you to tailor the control system precisely to the application in question – and thus to find an economical solution. Should the requirements of your application grow, the controller can be flexibly expanded or scaled upwards.

At the same time, innovative strength and long-term availability are not a contradiction at Beckhoff: We think in terms of sustainable technology and not in terms of product cycles: all of the products we have developed over the past 40 years – from bus terminals to the fast EtherCAT fieldbus – are still available on the market and offer you economical and future-proof control solutions.

With this in mind, I hope you enjoy reading our latest compendium for the entertainment industry. Let yourself be inspired by the wealth of possible applications for PC-based control and the projects that have been successfully implemented in recent years in the stage and show industry and in the unique applications and attractions markets.

For more information, I recommend you to visit our website for the entertainment industry market www.beckhoff.com/entertainment-industry or simply contact us directly!

Stage industry references

Nishan Sacred Land Theatre, China

"Hamilton", Broadway Musical,
Hudson Scenic Studio, NY, USA

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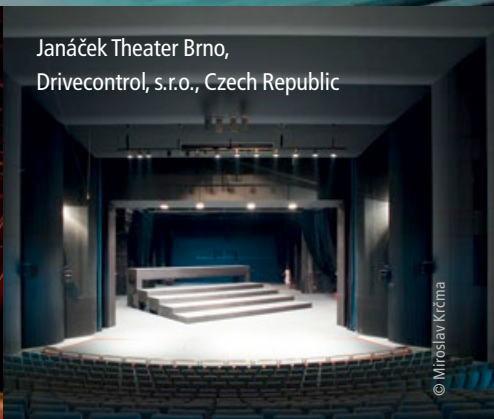

Janáček Theater Brno,
Drivecontrol, s.r.o., Czech Republic

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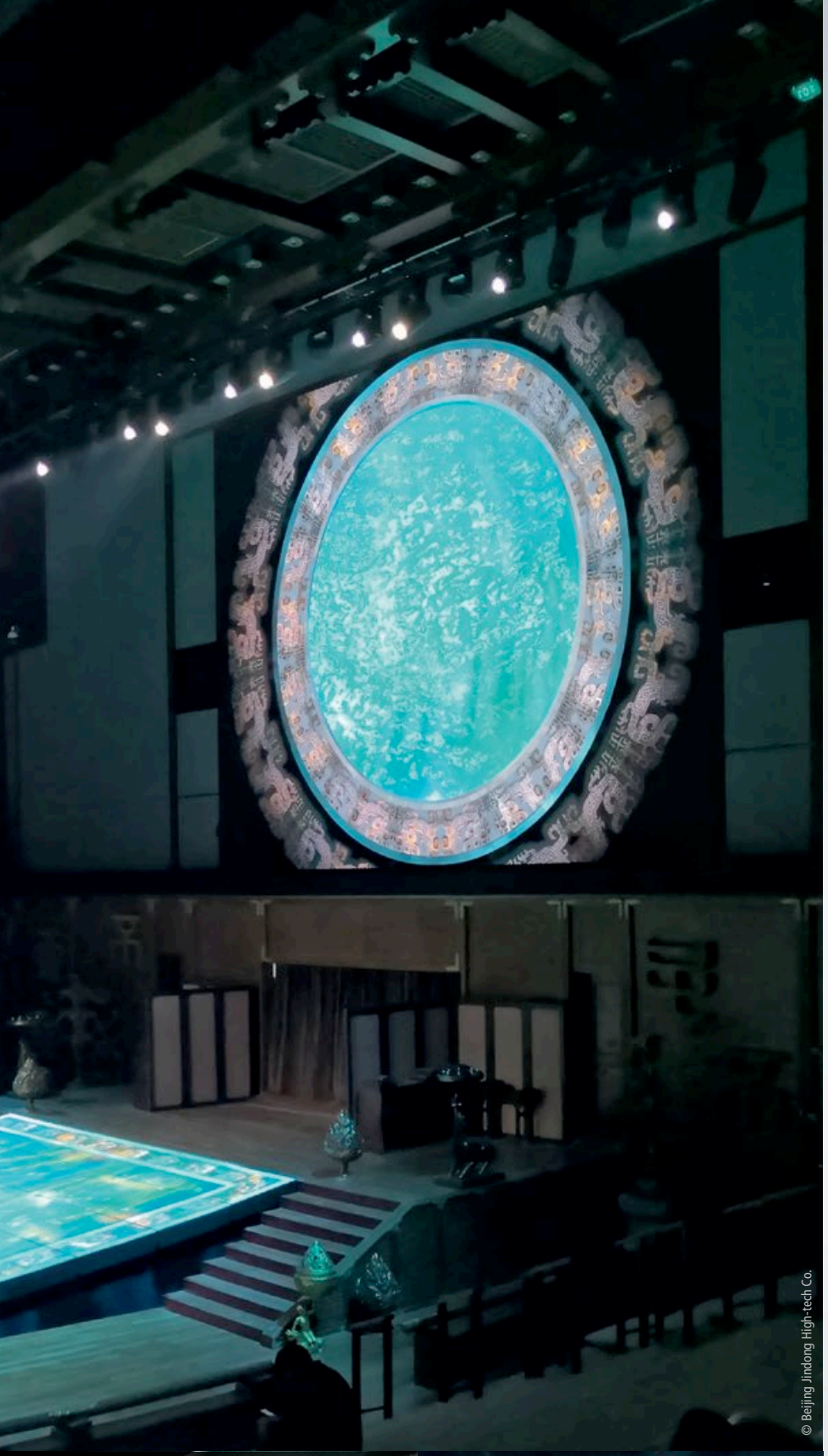

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"Das Wunder von Bern",
Stage Entertainment GmbH, Germany

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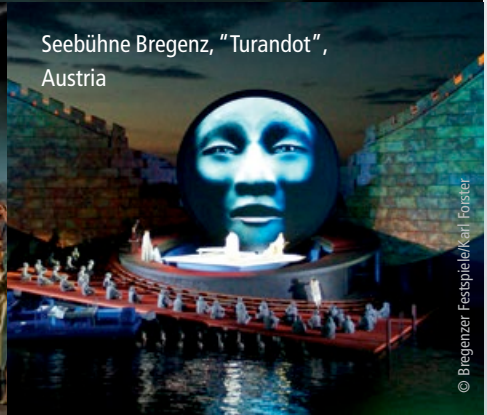
Seebühne Bregenz, "Turandot",
Austria



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Movable objects

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  - American Idiot, Broadway NY, USA
  - Billy Elliot, Broadway NY, USA
  - Mary Poppins, Broadway NY, USA
  - Spamalot, Broadway NY, USA
- Fülling & Partner Ing. GmbH, Germany:
  - "Das Wunder von Bern", Theater an der Elbe
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  - Rocky, Stage Palladium Theater, Germany
- Helsinki Music Center, Finland
- HOAC Schweisstechnik GmbH, Germany:
  - Royal Theater Copenhagen, Denmark
- Hudson Scenic Studio, NY, USA:
  - Hamilton, Broadway NY
- SALZBRENNER media, Germany:
  - 3D microphone winches, WDR Cologne
  - 3D microphone winches, Festspielhaus Baden-Baden
- Sibelius Hall, Lahti, Finland
- Stakebrand Technische Toneelinstallaties, NL:
  - Carré-Theater Amsterdam, Netherlands
- STB Steuerungstechnik Beck GmbH, Austria:
  - Seebühne Bregenz, "Rigoletto"
  - Seebühne Bregenz, "Turandot"
- Theatertechnische Systeme GmbH, Germany:
  - Schauspielhaus Nürnberg, Germany
  - Schauspielhaus Düsseldorf, Germany
  - Malmö Opera, Sweden

Lighting/multimedia

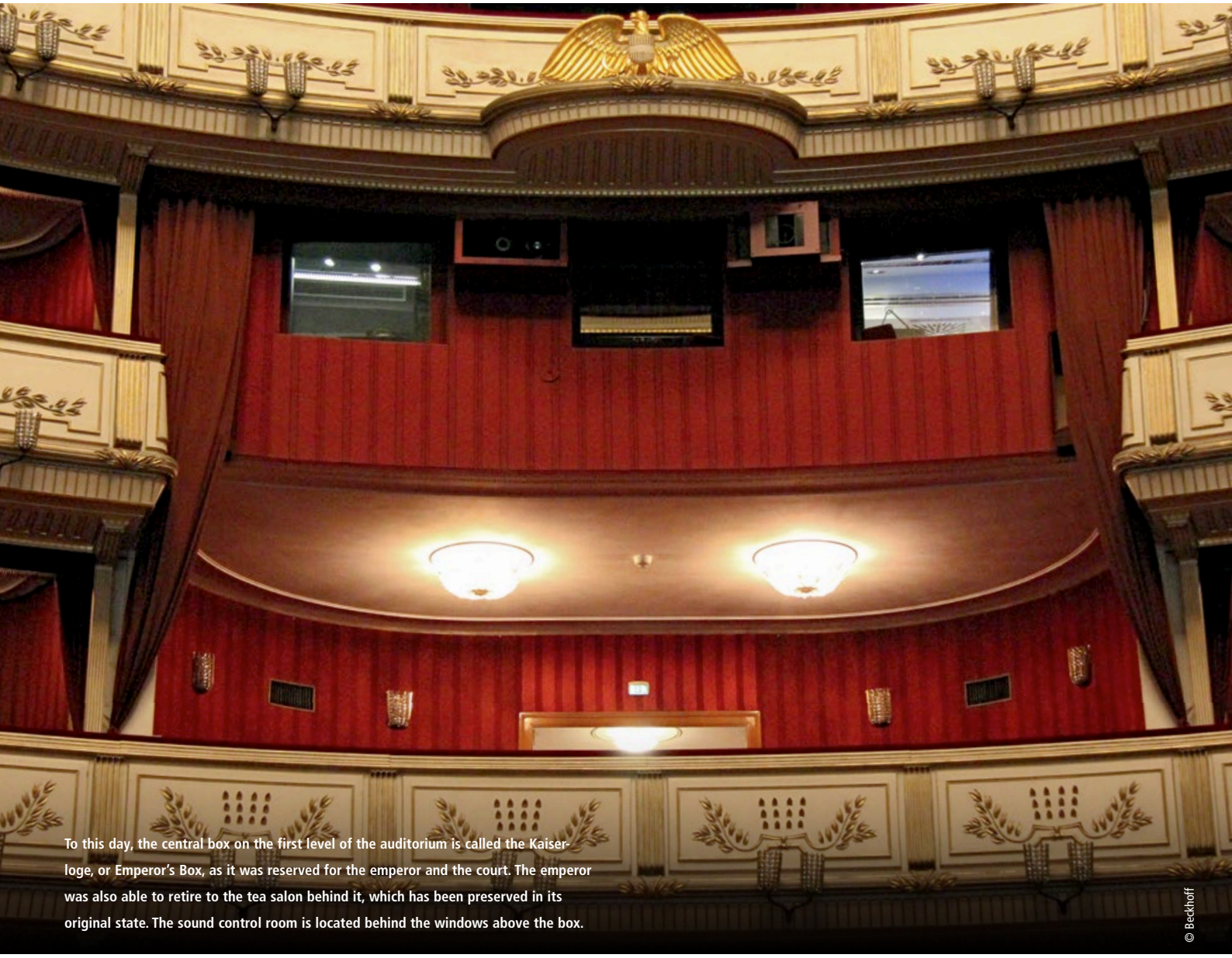
- Ferry Porsche Congress Center, Austria
- Helsinki City Theater, Finland
- Imatra Theater, Finland
- Kuopio City Theater, Finland
- Microsoft Deutschland GmbH, Cologne, Germany
- People's Grand Theater, Jilin City, China
- Rovaniemi Theater, Finland
- Salzgeber it revolutions, Austria:
  - Staatsoper Wien, Vienna, Austria
- Stage Entertainment GmbH, Germany:
  - "Das Wunder von Bern"
- Tampere Hall, Finland

Stage managers desk

- HFE professionelle Studiotechnik GmbH, Germany

University collaborations with Beckhoff

- Anton Bruckner Privatuniversität, Linz, Austria
- University of Wisconsin, USA
- University Shanghai, China:
  - Robots for Beijing Opera
- Yale School of Drama/Yale Repertory Theater, CT, USA



To this day, the central box on the first level of the auditorium is called the Kaiserloge, or Emperor's Box, as it was reserved for the emperor and the court. The emperor was also able to retire to the tea salon behind it, which has been preserved in its original state. The sound control room is located behind the windows above the box.

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TwinCAT TCP/IP from Beckhoff sets no limits when it comes to network communication

At the Wiener Staatsoper, high-tech supports the creative work of the audio and video department

The renowned Vienna State Opera is considered one of the world's leading opera houses. Around 300 performances with more than 60 different operas and ballets are scheduled each season. This is an enormous challenge for all the employees who work here in shifts, and for the stage technology, which has to function smoothly. To give visitors the best possible listening experience, the sound system has been upgraded using state-of-the-art audio technology and the audio control system has been entirely refurbished. The system requirements for the sound technology were high: in addition to perfect acoustics, it needed to provide optimized diagnostics options plus energy metering and the ability to visualize the system, especially the amplifiers. The system was brought to life by Viennese company Salzgeber GmbH, a specialist in planning and implementing high-tech audio and video systems, working closely with Beckhoff Austria.

On May 25, 1869, the Vienna State Opera was ceremoniously opened with a performance of Mozart's "Don Giovanni" in the presence of Emperor Franz Joseph and Empress Elisabeth (Sissi). Following serious damage sustained during the Second World War, the building was reopened on November 5, 1955 with a performance of Beethoven's opera "Fidelio".

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"The sound system that had been in continuous use at the Vienna State Opera for over 20 years could no longer keep up with the sound standards set by modern systems. Our situation involves typical audio signals such as opera vocals, acoustic instruments, a choir, an organ, and incidental music," explains Athanasios Rovakis, who is in charge of sound and video at the Vienna State Opera.

The choice of speakers was primarily determined by artistic requirements, such as organically embedding vocal and instrumental soloists or the choir in a given original sound from the orchestra. The speakers also needed to produce a certain sense of direction and distance for these sounds, as well as a certain sound character in general. "Today's systems, with their modelable coverage, can be used and tuned very differently than they were just a few years ago. This is particularly important in situations involving a lot of room acoustics, as is the case in this theater," explains Rovakis. "Due to its unique architecture, the Vienna State Opera house has very lively acoustics and there are sometimes long distances and different types of directivity to deal with. The auditory impression in the stalls is different from the one in the gallery, for example. Collectively, voices can be heard better further back in the "Stehparterre", a standing section of the hall, while the upper tiers receive a more balanced sound. The auditorium can accommodate almost 2,700 visitors, most of whom sit in the upper two tiers, so of course we have to take that into account when it comes to the sound system," explains Rovakis.

After several years of careful planning, the rebuild of the entire audio system was completed in November 2020. Tino Pfeifer, senior project engineer at Salzgeber GmbH – a specialist company with many years of experience in planning and implementing entertainment solutions – was involved from the very beginning. He planned and developed the monitored power supply, the amplifier monitoring, and the connection between the amplifiers and additional signals.

"I decided to go with an L-Acoustics speaker system – specifically, the ARCS W/F series sounded particularly good for the applications in this space. All the other integration steps then had to be based on the selected system, or be compatible with it," reports Athanasios Rovakis. The head sound engineer wanted a diagnostic

Group photo on the grand staircase of the Vienna State Opera, which has also been preserved in its original condition. (from left to right) Balazs Bezeczky, sales engineer at Beckhoff Automation Austria; David Salzgeber, managing director of Salzgeber GmbH; Tino Pfeifer, senior project engineer at Salzgeber GmbH; Athanasios Rovakis, head sound engineer at the Vienna State Opera; Michel Matuschke, manager for the entertainment industry at Beckhoff.

option based on collected and analyzed audio and power amplifier data. "This is a function that we had previously found to be very time-consuming to implement in an analog form, and which we definitely wanted to see brought up to date," explains Rovakis. "With the variety of audio channels we have to manage here, it's important that we can clearly see if a signal is actually getting to where it was intended for. We also have remote control abilities – for example, muting via physical hardware pushbuttons, which are also integrated into the automation of the audio mixing console." Other requirements were energy monitoring and fault diagnostics for the audio devices, as well as visualization of the audio system.

The next step was to find a solution that could combine these functions with the selected audio system. This is where Beckhoff came into play as a control equipment supplier. Since the audio devices from L-Acoustics can communicate with the control system via an SNMP (Simple Network Management Protocol V1.0) interface, Christian Henke from Beckhoff Austria worked closely with Salzgeber to develop a matching communication function block for TwinCAT 3.1. "Our TCP/IP server (TF6310) makes it possible to control an unlimited number of devices and functions. This is a unique selling point in the industry. And the response times that we offer are even faster than was required," comments Michel Matuschke, market manager for the entertainment industry at Beckhoff.

Energy metering for the audio system

Since the 1950s, the Vienna State Opera's sound technology has been repeatedly added to and, in some cases, replaced. "This means that layer after layer was laid on top of each other, and that gave us a rather confusing system of cables and individual components to deal with in the sound control room," explains Athanasios Rovakis. "With the help of Tino Pfeifer from Salzgeber, we completely redesigned the sound control room in a highly modular way, which hopefully means that we won't have to make any more fundamental changes to it in the next 25 years," he explains.

The power distribution in the control room, the point from which all the audio and video equipment is controlled, now consists of only three types of cable for incoming circuits, outgoing circuits, and the network. "The ultra-compact C6015 Beckhoff Industrial PC with an EK1100 EtherCAT Coupler and matching Bus Terminals is used for power distribution; it handles the process of switching the power supply on and off, and performs diagnostics on the fuses," explains Tino Pfeifer.

Instead of hard-wired devices, Salzgeber designed a flexible system consisting of eighteen 19-inch rack elements. Using the individual racks, all loads and each socket can now be assigned to groups, switched, and have their energy status read in. This configuration was created with the aim of switching interrelated functional units together flexibly and independently of their location. The modular bus design even allows entire racks to be separated and moved out of the room for servicing. "With such a vast number of performances and rehearsals to deal with, each with different technical requirements, this really helps us keep track of everything," says Athanasios Rovakis. "We have duplicates of every critical component in case something breaks. We analyze the three phases of the mains supply, which are equipped with their own residual-current device or circuit breaker. We can dynamically switch devices via six remotely controlled and monitored ports, which are in the form of socket arrays."

All the racks are based on the same structure, which includes a BK9100 Ethernet Bus Coupler with two KL3403 3-phase power measurement terminals, six current transformers, two KM2614 four-way relay terminals with 16 A wired to break contacts, and a KL1809 for monitoring the ground fault circuit interrupter switches. "In total, more than 100 switching channels as well as a wide range of monitoring options are available," explains Tino Pfeifer. The

Left: To enable the amplifiers from L-Acoustics to communicate with the conwtrol system, Christian Henke from Beckhoff Austria worked closely with Salzgeber to develop a matching communication function block for TwinCAT 3.1.

Right: One of a total of eighteen decentralized 19-inch racks for energy metering. Elements can be operated via pushbuttons (on one of the two central keypads at the bottom of the picture) or on the screen. When a new device is installed in the rack, individual sockets or groups can be assigned via the HMI.

Head Sound Engineer Athanasios Rovakis in the sound control room. He and his team of seven colleagues are responsible for everything involving sound engineering (including sound and image media productions, the sound in the auditorium, and monitor engineering for the performers on stage). They are also in charge of the video and image projections on the stage and handle the Vienna State Opera's Live at Home streaming.

A pleasant indirect light is created via LED strips. Blue indicates that the amplifiers are muted. Red and dimmed ambient lighting in the fully automated control room is an "on-air" signal.

power measurement terminal accurately displays the status of each load. Envelope curve analysis is used to monitor the current consumption of each outgoing circuit, with this data then able to be stored as a reference. The racks can be operated via two central keypads as well as on the PC. "But we can also operate all the functions downstairs from the auditorium – all we need is a network connection," adds Rovakis.

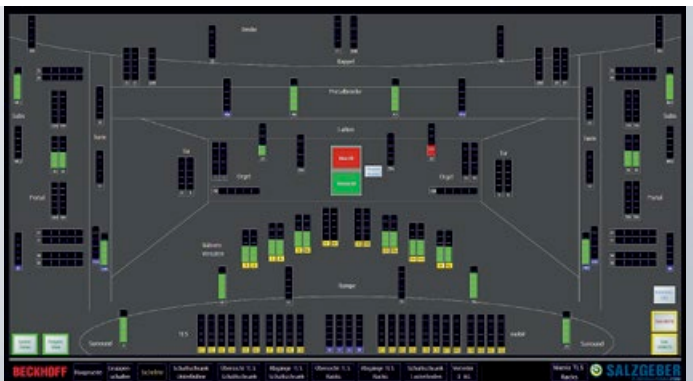
Visualization displays the status of all power amplifiers

The visualization element was implemented on the basis of the TwinCAT HMI server (TF2000) and runs on a C6515 control cabinet Industrial PC. The HMI, used for displaying the status of all audio devices, is made up of approximately 1000 PLC variables on one HMI page, with the variables updated every 50 ms. It includes various windows responsible for power distribution, status monitoring, and audio signals. "The development of the visualization or field of view was one of the most important aspects as far as we were concerned, and one of the main reasons for choosing to work with Beckhoff," states Athanasios Rovakis. "Now we can use the monitor to track where things are happening. When you play an audio signal in a case where the speakers are far away, you receive a diffuse noise whose origin you can't tell exactly when you're working at the mixer. This is where the 3D arrangement of speaker VU meters in the HMI comes in handy." The audio outputs can be muted individually or all together via physical buttons in the control room, via the audio consoles, and via the HMI. The current operating status of the amplifiers is also illuminated in the control room. A pleasant indirect light is created via LED strips. Blue indicates that speakers are muted. Red and dimmed ambient lighting in the fully automated control room is an "on-air" signal, which heightens the concentration of the operators.

"One major reason for choosing the Beckhoff control system was its openness and the long-term availability of the components. The Bus Terminals enable us to cover every function and we have even gained added value by implementing functions that we had not even considered before," states Athanasios Rovakis.

Further information:

www.it-revolutions.com
www.wiener-staatsoper.at
www.beckhoff.at



Visualization of the audio device statuses. The HMI is made up of approximately 1000 PLC variables on one page, updated every 50 ms.

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PC-based control runs the stage machinery for "Rigoletto"

Breathtaking spectacle on Bregenz's floating stage requires complex drive technology

The Bregenz Festival (Bregenzer Festspiele) on Lake Constance proved once again with an enthralling stage spectacle that audiences still love great opera, even in the 21st century. During the five-week 2019 season, roughly 180,000 spectators came to see Giuseppe Verdi's "Rigoletto." And the upcoming season, which will have its premiere on July 22, 2021, is almost completely sold out as well. An oversized clown figure – a kind of alter ego of Rigoletto – functions as the stage. To handle its complex movements, the Bregenz Festival depends on control technology from Beckhoff.

The main cabinet and the panel for controlling the hydraulics are each equipped with a built-in 15-inch CP6602 Panel PC from Beckhoff.

With a diameter of 22 meters (72 feet) and a total area of 338 square meters (3,638 square feet), the collar forms the central stage area. Mounted on a seesaw, the head can be moved across the entire stage.

© Bregenzer Festspiele/Anja Köhler/anderart.de

The "Seebühne Bregenz" (Bregenz floating stage) is famous for its spectacular productions, but Philipp Stölzl's staging exceeds all past performances in terms of aesthetics as well as technical feasibility. It is therefore no wonder that it was awarded the German Stage Award, the Opus, and that steelworking company Biedenkapp received the German Metalworking Award 2019 in the Special Designs category. All in all, 46 companies were involved in building the stage, which required three years of planning and 14 months of actual construction time before the spectacle had its premiere on July 17, 2019.

Moving scenery plays a role in itself

In Stölzl's production, the original location of the opera – the court of the Duke of Mantua – becomes a circus tent, and the court jester Rigoletto becomes a clown. The backdrop signifies that the protagonist is literally up to his neck in deep water. Only the head, encircled by a wide collar, and the hands of the gigantic clown protrude from the lake. He dominates the action and reflects the mental state of the opera's tragic character that gives the opera its name. When Rigoletto enters the stage, the head awakens and smiles over a glittering feast. The actors bustle about on the figure's collar, on its head, and in its mouth. The duke is a notorious seducer of women, and Rigoletto is his influential assistant. But when the duke seduces Rigoletto's daughter Gilda, the tables are turned, and the clown becomes himself the victim of intrigues. As a visible symbol of his breakdown, the stage comes apart: the collar sections drift apart, and the eyes and nose fall out of the head. Instead of the smiling clown face, a gruesome skull now dominates the scenery.

Each movement is programmed

All movements of the stage and actions of the singers, the choir, the stuntpeople and the extras were programmed in advance in a digital 3D model by splitting the production into single cues, each of which can be called up with a unique command. "After the scenery had been installed on the floating stage in May 2019, we began to program each cue in accordance with the previous model to test the settings of the axes and the hydraulic controllers, and to subject each of them to a safety analysis with regard to their drive force, load and speed," explains Wolfgang Urstadt, the technical director of the Bregenz Festival.

The stage, which was designed by Philipp Stölzl, allows the singers and actors to deliver spectacular performances.

Demanding motion control

With a diameter of 22 meters (72 feet) and a total area of 338 square meters (3,638 square feet), the collar forms the central stage area. It consists of one fixed and three movable parts, which run on a system of rails driven by electric cable winches when the stage breaks apart.

Five hydraulic cylinders and 14 electric motors alone handle the various movements of the head, which is 13.5 meters (44 feet) tall and weighs 35 tons (about 77,000 pounds). Mounted on a rotating seesaw that is 35 meters (115 feet) long, the head can be moved across the stage with a 94-degree angle. Driven by a central hydraulic cylinder, the seesaw also makes it possible to raise the head or submerge it in Lake Constance until the water reaches its upper lip. "This is no easy feat," says the stage technology manager: "Moving the head in only 27 seconds from 14.5 degrees above the horizon to 28 degrees below the horizon requires a hydraulic pressure of up to 160 bar." Nodding motions are executed with two hydraulic cylinders moving at 4.4 degrees per second. And opening the lower jaw takes another two hydraulic cylinders moving at a speed of 10 degrees per second. Four electric motors shake the head, and eight more roll its eyes and open and close its eyelids. "That's 19 axes for the head alone that must be controlled," explains Andreas Bechter, systems integrator at STB Steuerungstechnik Beck GmbH in Andelsbruch, Austria. "The power ratings range from 2 to 22 kilowatts for the electric drives and from 75 to 90 kilowatts for the hydraulic pumps."

The left hand, which reaches 11.5 meters (38 feet) out of the water and takes on various functions in the production, has a total of eight hydraulically driven axes. The biggest drive rotates the hand, while smaller drives connected in parallel tilt the hand. Small motors control the movements of the individual finger joints.

PC-based control technology speeds up complex implementation

"In terms of control technology, the challenge involved making the stage manageable because it was divided into so many individual moving parts. The complexity and the size of the stage and the absolute on-time delivery, which was a must considering the short season, were difficult to implement with traditional stage technology providers. That's why we looked for alternatives and ultimately found Beckhoff," says Wolfgang Urstadt. Each individual machine is equipped by its manufacturer with a simple commissioning controller. To communicate seamlessly with the higher-level Unican controller, a CAN-bus interface had been specified. The client also required various measurement systems for functions such as position feedback, encoder monitoring and pressure monitoring.

The redundant axis computers from Neuss-based stage technology specialist Unican control a total of 29 axes. Two control consoles are used to program and trigger the motion commands. From here, the axis movements are calculated and the commands issued to the underlying Beckhoff controller. Although the entire sequence is defined in detail, the performances do not run in automatic mode. As the stage manager issues the commands, one operator is responsible for controlling all head and collar movements and another operator controls the complex movements of the left hand. "Unforeseen events

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The stage consists of one fixed and three movable parts, which run on a system of rails driven by electric cable winches when the stage breaks apart.

such as a strong wind gust can cause individual cues to be interrupted. Safety comes first," says the technical director.

Unlike with stationary stages, the short season of the production and the predictability of any downtime that may occur require merely a project-based safety inspection. "The TÜV (note by translators: German technical inspection association) conducted the safety inspection as part of a prototype examination. This made it easier to keep to our tight schedule, because we could not begin rehearsals on the floating stage until the inspection had been completed," explains Stefan Fritschke, the control technician of the Bregenz floating stage.

Decentralized control architecture meets the special requirements of the floating stage

From Stefan Fritschke's point of view, the great advantage of the Beckhoff control system lies in its diversity of interfaces and its ability to operate with a decentralized control architecture. "The cramped space on the floating stage does not have room for a large control cabinet of the type you usually find in opera houses. That's why we needed a decentralized control concept for the many distributed axes. We now have a main cabinet, which is linked to one cabinet for controlling the collar and a second one for controlling the head. In addition, the emergency controls were not designed as a large secondary controller, as is common in large opera houses. If the Unican controller issues an emergency signal, the local Beckhoff controllers for the various stage components move the stage machinery into a safe position," says Andreas Bechter. "This was a special feature that we could only execute with Beckhoff. In case of a power failure, we perform a manual or emergency motion sequence."

The control platform in the main cabinet is a CX5120 Embedded PC in combination with a 15-inch CP6602 built-in Panel PC. The control functions are executed with TwinCAT 3 automation software. The algorithms for the precise control and positioning of the hydraulic axes come from the TwinCAT Hydraulic Positioning software library. The fast communication system is EtherCAT, which stands out with its excellent diagnostic capabilities and easy configurability. The hydraulics control console is equipped with another CP6602 Panel PC. "In view of the extremely limited space on the stage, the compact design of the HD (high density) EtherCAT Terminals comes in handy. They feature 8 or 16 connection points in the housing of a 12-millimeter terminal block," says STB general manager Alfred Beck.

Further information:

www.bregenzerfestspiele.com

www.steuerungstechnikbeck.at

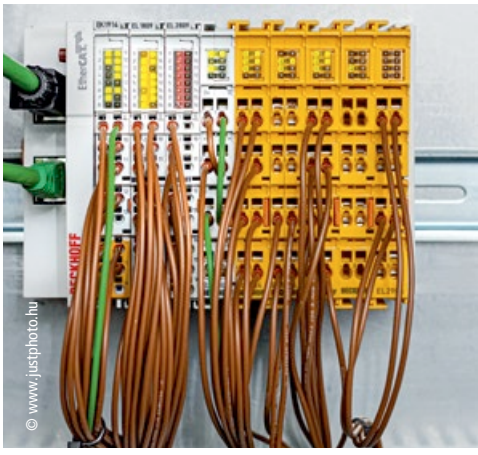
www.beckhoff.at

PC-based control technology at the Müpa Budapest festival hall

Festival theater modernized with advanced stage and acoustic technology

Müpa Budapest provides space for three expressive arts: music, fine art and theater. The festival hall boasts a multifunctional theater with what the operator claims to be one of the world's leading acoustic designs. Hungarian company Színpad Automatika Kft. was commissioned with modernizing and further developing the stage and acoustic technology in the festival theater in 2019 and relied on PC-based control technology from Beckhoff in the process.

Müpa uses over 250 mechanically operated stage and acoustic systems. Some of the systems have their own controllers and operating units. There are also smaller groups that share control systems. In the concert hall, approximately 150 systems can be moved from one control panel, and the main computer for the theater also controls more than 40 systems. Színpad Automatika has been looking after most of the systems since 2014. The Budapest-based specialist focuses on stage construction, maintenance and development of stage devices and new device installations. It also designs new mechanical systems together with the Müpa Main Engineering department.



EtherCAT and TwinSAFE Terminals in the control cabinet for controlling the orchestra pit

Upgrade with TwinSAFE integration

In 2019, work began on modernizing and optimizing the proscenium (front stage) control system. Some parts had already been in operation for almost 15 years, which was a reason for replacement in itself and provided a great opportunity for modernization. After evaluating systems from different suppliers, Színpad Automatika opted for PC-based control from Beckhoff, as Managing Director József Bálint explains: "When it came to general control technology requirements, we needed a deterministic system with a sufficiently high capacity to carry out synchronization tasks and more flexible programming compared to PLC devices. With its PC-based control technology, Beckhoff fulfills all these criteria and also offers a wide product range, comprehensive support, high levels of flexibility in terms of programming and connectivity as well as seamless integration of safety technology with TwinSAFE."

"In the festival theater, we operate eight stage systems using one user interface. The largest stage system is used to raise or lower the orchestra pit, which can be used as a cavity, forestage or auditorium. This lift comprises three motorized parapets to separate the area from the auditorium. Two stage lifts, a loudspeaker holder and an acoustic panel holder installed overhead cover this smaller stage area in front of the auditorium's safety curtain," explains Gyula Cseh, head of stage technology at Müpa.

With the previous system, only the orchestra pit itself could be controlled and positioned. This has now been extended to the four systems of the upper stage area, which could previously only be moved at one or two speeds and without an indication of the height or magnetic field control. Since the modernization, all five of these areas have been controlled via the ultra-fast EtherCAT real-time communication system. With this, it is possible to synchronize the existing island controllers and also transmit safety-relevant data between the controllers and the TwinSAFE EtherCAT Terminals. A CP6600 built-in Panel PC with touchscreen and the TwinCAT 3 PLC software runtime form the central control unit. "The biggest challenges in the project were the group operation of safety switches, pinch protection sensors and emergency stop keys, as well as the fact that the controllers are located in three different rooms. TwinSAFE from Beckhoff proved to be a good solution here. The EL1918 EtherCAT digital input terminal that provides TwinSAFE Logic is installed in the control panel, while the other TwinSAFE I/Os are located directly in the relevant control cabinets on-site," explains József Bálint.

Gyula Cseh adds: "One advantage of the new system is that we can now move and position these somewhat cumbersome stage systems at the same time and in any combination. This increases efficiency and accuracy significantly during

Theater at Müpa Budapest with the Beckhoff CP6600 built-in Panel PC integrated into a control panel

preparatory work. What's more, we can save nominal values with specific designations in the controller and call them up to reach the required target positions quickly and precisely. In line with the development strategy, the long-term goal from the outset was for the operators to be able to save all necessary information in the automated systems themselves during technical maintenance of the individual productions and then be able to call up the relevant data from here during recurring shows. Our expectations have been met in all areas."

During the development of the new proscenium control system, the four manual stage lifts in the backstage area were also automated. The operator now selects the required direction of movement on the touchscreen of the CP6600 Panel PC and can then move the lifts in groups at the touch of a button. What's more, all relevant information, e.g., to protect against overloading and to monitor the rope tension, is shown on the display.

PC-based control promotes flexibility

With a view to further developments, József Bálint summarizes: "We have had very successful experiences with Beckhoff technology up to now and have further developed our system so that it can be scaled up to several hundred axes if necessary. Depending on the number of axes, the synchronization tasks are carried out by a suitably powerful controller. We benefit particularly from the broad and finely scalable Beckhoff IPC range in this regard. In a typical configuration, the CP6600 (10.1") or CP6606 (7") built-in Panel PC with ARM Cortex™ A8 processor is used, both of which are ideal for controlling up to 10 axes. For a larger number of axes, the C6015 ultra-compact Industrial PC with Intel Atom® processor is the perfect choice. TwinCAT 3 is used consistently as the control software." Real-world examples of applications using the C6015 are the scalable 14-axis controller for the Szigliget theater in the city of Oradea and a scalable three-axis controller for the Csiky Gergely Hungarian state theater in Timişoara, both in Romania.

Further information:

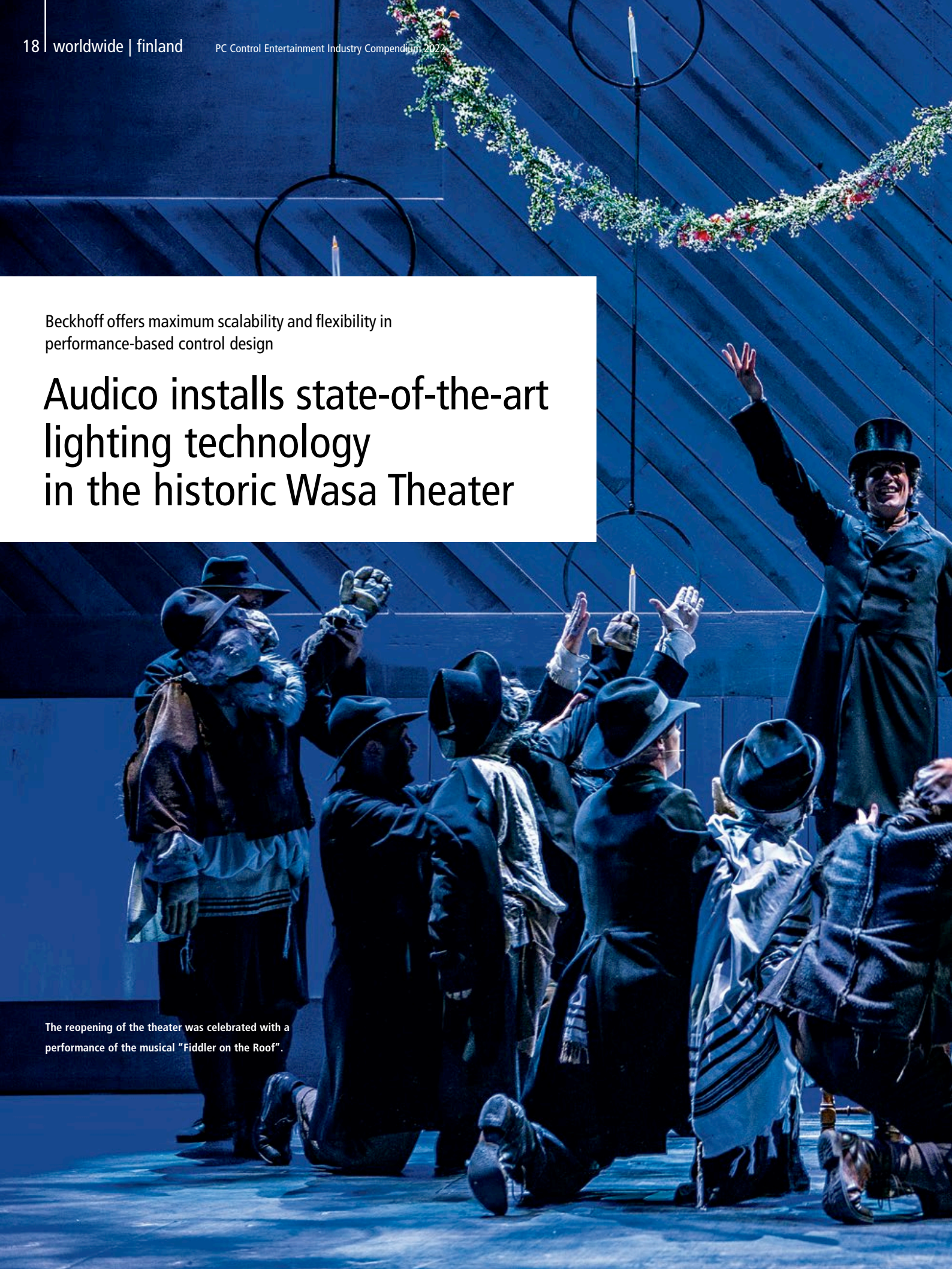
www.mupa.hu

www.szinpadautomatika.hu

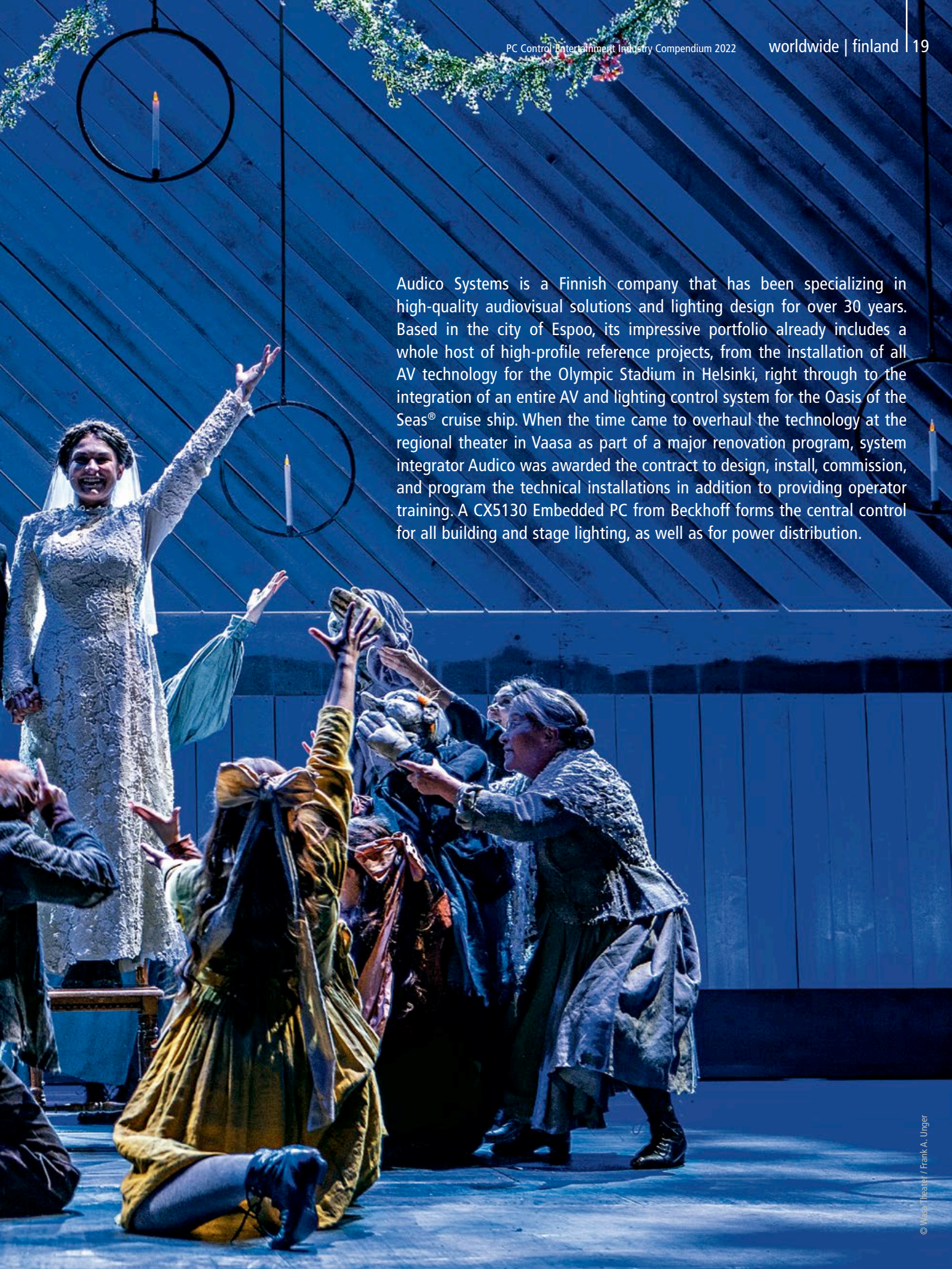
www.beckhoff.hu

Beckhoff offers maximum scalability and flexibility in performance-based control design

Audico installs state-of-the-art lighting technology in the historic Wasa Theater



The reopening of the theater was celebrated with a performance of the musical "Fiddler on the Roof".



Audico Systems is a Finnish company that has been specializing in high-quality audiovisual solutions and lighting design for over 30 years. Based in the city of Espoo, its impressive portfolio already includes a whole host of high-profile reference projects, from the installation of all AV technology for the Olympic Stadium in Helsinki, right through to the integration of an entire AV and lighting control system for the Oasis of the Seas® cruise ship. When the time came to overhaul the technology at the regional theater in Vaasa as part of a major renovation program, system integrator Audico was awarded the contract to design, install, commission, and program the technical installations in addition to providing operator training. A CX5130 Embedded PC from Beckhoff forms the central control for all building and stage lighting, as well as for power distribution.

© Wasa Theater / Frank A. Unger

The Wasa Theater is one of the oldest playhouses in Finland, having celebrated its 100th anniversary in November 2019 following extensive renovation work. While it may only appear to be a small, regional theater at face value, with seating for just 272 in the main auditorium, it now boasts some truly state-of-the-art technology. This includes not only an immersive sound experience afforded by the very latest in audio technology, but also a brand new lighting control system, which illuminates the stage with as many as twenty projectors and thirty moving heads.

Modular and scalable: Adapting to performance requirements with the Beckhoff controller

"The regional theater in Vaasa is an excellent example of the modularity and scalability of the Beckhoff control system, which applies right down to each individual component," explains Audico Project Manager, Tapio Järvinen. "This allows us to design and dimension the perfect control system to suit our customers' individual project requirements." The 240 relay channels in operation at the Wasa Theater represent a relatively small amount, as larger stages can easily accommodate many times that number. What's more, multiple end devices can be connected to a single relay output depending on the customer's requirements, ranging from classic sockets and on-stage control boxes through to 19-inch devices. This system makes it possible to control all typical devices associated with an entertainment application, such as lighting and lighting effects, or any kind of AV and multimedia devices. "Depending on the performance requirements of the project, all we have to do is scale the control up and add a few more I/O modules. The software tool always remains the same," observes Tapio Järvinen. "It doesn't even matter if plans change along the way, as this modular system is incredibly flexible." This scalability in terms of both performance and design mean it is also ideal for integration into existing systems and therefore any kind of retrofit. "Another major advantage from our point of view is that, with the Beckhoff controller, we are completely free to choose the method of control that suits us best. Whether we opt for a centralized or decentralized solution comes down entirely to the project, the structural conditions, and customer requirements," notes Tapio Järvinen.

Flexible lighting control via lighting control board, Panel PC, or push-button

Theaters often have separate systems to handle show lighting, backstage blue lighting, auditorium lighting, and working lighting outside of performances, which always means extra work when it comes to maintenance, servicing, and operation. "In the Wasa Theater, we implemented a lighting control system that can also be operated independently of the lighting control board via control panels and push-buttons for even greater flexibility," emphasizes the Audico Project Manager. The show and stage lighting, the building lighting, and the power distribution all run on a Beckhoff Embedded PC CX5010 with TwinCAT automation software. The CX controller functions more or less like a logic control center – that is, it receives the commands from the show lighting (which in this case was activated by means of an MA lighting console) via the EL6851-0010 DMX slave terminal, processes them in the control logic, and switches the respective outputs

The small, regional playhouse known as the Wasa Theater was equipped with state-of-the-art lighting and audio technology.

Following extensive renovation work, the Wasa Theater in Vaasa, Finland, celebrated its 100th birthday in November 2019.

Jonas Björkgren (left) and Mats Antell at the control desk. One of the CP3712s can be seen in the background.

as required by the lighting control board. In addition, the CX also controls the functional building lighting in the foyer, restaurant, halls, and side rooms of the theater via the EL6851 DMX master terminal and the relay terminals.

The lighting can be operated via the three Beckhoff multi-touch Panel PCs in the CP37xx series in addition to the lighting console. User levels are defined in the logic for the respective buttons in the HMI, which determine who has access to individual functions and when. This feature makes it possible for the various groups of people working at the theater to carry out operating functions of varying scope: These range from switching the lights on and off, dimming them, or selecting a specific lighting scene that the actors want to call up for a rehearsal, and more in-depth commands that the stage electrician can execute, right through to full access to all functions for the lighting technician or designer.

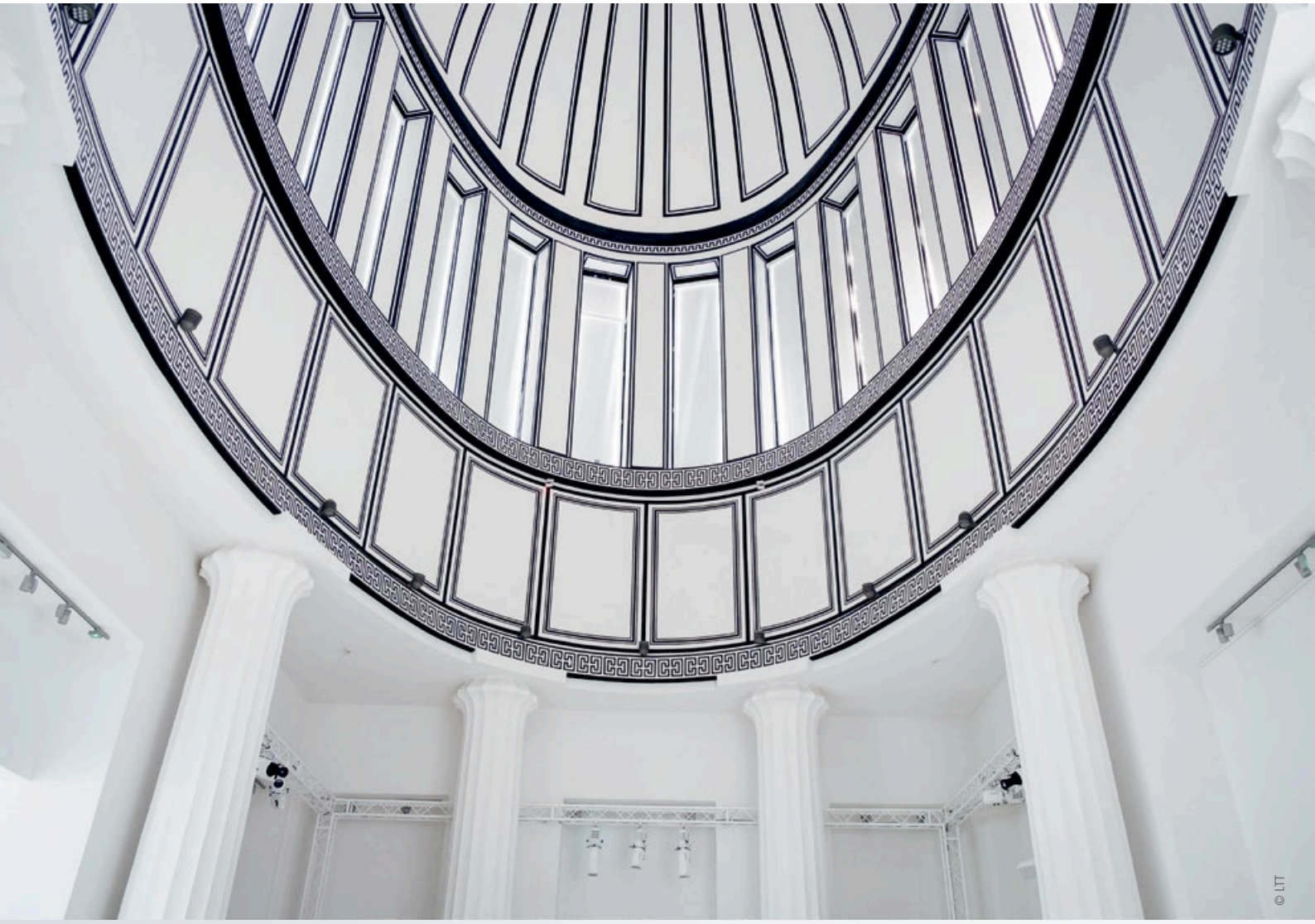
Visualization takes place on the three Panel PCs via TwinCAT HMI in the browser. The TwinCAT HMI server on the CX controller supplies the three multi-touch Panel PCs with data for the user interface. As for communication, this takes place via a separate VLAN in the theater network, with one VLAN configured for each technical system.

In addition to the lighting console and the Beckhoff Panel PCs with multi-touch screens, conventional light switches can also be integrated into the control logic. In show mode, these switches can be locked to prevent unwanted control commands. "The KL2641 digital relay output terminal is very popular in entertainment projects, as it is capable of controlling the mains voltage for the lighting and sockets directly," reveals Tapio Järvinen. The terminal offers yet another advantage by providing the option of manual operation, which can come in very useful in the start-up phase when power is needed but the control system is not yet fully powered up, or in the event of an emergency, for example.

Simple system integration, flexible retrofitting

"Further advantages of the Beckhoff controller include how easy it is to integrate into other systems and its flexible communication options," enthuses Audico Project Manager, Tapio Järvinen. "Even if the building automation system is from another supplier, for example, the Beckhoff controller can easily communicate with it via BacNet or Modbus TCP. We can also control the DALI lighting installation. On this project the choice of DMX channels was limited, which meant it was necessary to form lighting groups and switch the lighting in a certain section of the building all at the same time, for example. Incidentally, we did not carry out any energy measurements in the Wasa Theater; however, this is becoming increasingly important and requested by many customers. For us as a system integrator, it is a huge bonus to be able to retrofit the Beckhoff control system just the way we want."

Further information:
www.audico.fi/en
www.beckhoff.fi



Beckhoff C6670 multi-core Industrial PC integrates multimedia, building automation, and drive control on a single control platform

Cutting-edge exhibition technology in historic setting

Following extensive restoration, the historic Four Domes Pavilion in Wroclaw has found its purpose as a museum of contemporary Polish art. Specialist lighting and stage technology company LTT, based in Warsaw, was engaged in 2019 to create effective staging for the works of art. Sophisticated lighting and multimedia technology as well as an extensive system of winches combine to provide a contemporary museum presentation. LTT has been a Beckhoff customer for some ten years already and relied on the hardware and software components of the Verl-based automation manufacturer for this complex project too.

The integration of a truss system by LTT facilitated installation of modern exhibition technology, which does not impact on the listed architecture or disrupt the aesthetic overall impression.

Constructed between 1911 and 1913 based on the designs of architect Hans Poelzig using reinforced concrete techniques that were state-of-the-art at the time, the Four Domes Pavilion was used originally as an exhibition building during the Centenary Exhibition in 1913. In the decades that followed, the building was used for a variety of purposes until it was added to the list of UNESCO World Heritage sites in 2006. Consequently, it was decided to completely restore it to its original condition. Since opening its doors again in 2019, the renowned building with an area of around 10,000 square meters has been used as a museum.


© LTT

The building's domes are likewise accentuated by projections. The total of 190 blind controllers are operated by 17 EK1100 EtherCAT Couplers with 2-channel relay output terminals (KL2602).

Multimedia finds its way into exhibition life in the museum

Interactive digital systems have long since ceased to be a rarity in museums. Shaped by the pervasive presence of multimedia in everyday life, the modern museum visitor expects a diverse presentation of artworks that appeals to all the senses – not to say a show. The people in charge of the National Museum of Wroclaw picked up on this changing perception and opted for a comprehensive concept of media stagings: lighting, sound effects, and video projections are used effectively to capture the attention of the observer. In addition to spatial sounds, the artworks are brought to life using targeted and atmospheric sound effects. Projections are used, for example, to project a color detail in an abstract painting onto the floor, while other objects are superimposed with an enlarged projection of themselves, or change their appearance through alternating light colors. Motion sensors allow interaction between visitors and artworks, or rather the multimedia effects.

Beckhoff C6670 Industrial PC with 12 cores as a higher-level controller

All technical functions are executed in a coordinated manner centrally on the high-performance C6670 multi-core Industrial PC with the TwinCAT automation software and EtherCAT as a fast communication system: "The video projection

The AM8000 servomotors for controlling the winches are installed in the trusses in such a way that they are virtually invisible for museum visitors.


© LTT

17 EtherCAT Couplers of the type EK1100 are used here for darkening the rooms with a total of 190 2-channel relay output terminals for controlling the blinds.

© LTT

including visitor tracking was programmed in the Coolux controller and runs on the central Beckhoff PC," explains Emil Mączewski, Controls Design Engineer at LTT. "We define the positions here, or presets as they are known, which are traversed when the show starts. Because Coolux controls the video content, generating the positions using this tool makes most sense." In addition, the user interfaces of the Microsoft Surface Control Panels, which are positioned in each of the fifteen exhibition rooms for locally controlling darkening, light, or the show system, were likewise generated with Coolux. The control of the building light and illumination of artworks were programmed in various lighting scenarios using the MA Lighting on PC software, which likewise runs on the central Beckhoff PC. The audio installation was programmed in a Dante domain with QSC. Coolux Widget Designer software running on Beckhoff's Industrial PC coordinates the lighting and sound effects generated with the video projections and is integrated into the power distribution and blinding system, which is controlled with TwinCAT system using TCP/UDP connections via TwinCAT TCP/IP (TF6310).

Depending on the respective multimedia staging, the 12-core Industrial PC controls the blinds to allow complete or partial darkening of the rooms. 27 EtherCAT Couplers of the type EK1100 with a total of 190 2-channel relay output terminals (KL2602) are used here. The roof-mounted anometers for measuring the wind strength are integrated in the terminal system via seven KL1702 digital input terminals. This is necessary because the blinds, which are mounted on the outside of the dome, have to be raised in the event of a storm. Also executed on the central PC is the entire power distribution system for the expansive building, which is accommodated in nine control cabinets in the total of seven control rooms.

Ultra-compact C6015 Industrial PC as a distributed winch controller

As with many historic buildings, it was also a prerequisite with the Four Domes Pavilion that the technology would cause minimal disruption to the overall architectural impression and that there would be no interference in the fabric of the building. LTT achieved this by using a truss-based system for mounting the lights and projectors and by concealing the entire cabling almost completely. "The highlight of the system are the winches installed directly in the standard 4-point trusses, which can be traversed silently and precisely in order to move art objects along pre-programmed paths," explains Wojciech Baczyński, Chief Operating Officer at LTT. The short, single-meter long truss sections can be installed flexibly depending on the requirements of the exhibition. The drive technology in the winches consists of the AX8000 modular multi-axis servo system, the AM8043 servomotors, and the AG3210 planetary gear units. A C6015 ultra-compact Industrial PC with the TwinCAT NC I and TwinCAT NC Camming motion control software is used in each of the fifteen exhibition rooms of the Four Domes Pavilion for controlling the winches. Designed for weights of up to 50 kg, one object can be held by three winches and moved in a coordinated manner along a defined path. "The Hot Connect functionality of EtherCAT and its simple configuration in the TwinCAT software offers us a major advantage," underscores Wojciech Baczyński. "We use the EK1501 EtherCAT Coupler with DIP switch here, which allows us to regroup the winches easily, change their sequence, and switch them on and off flexibly." With TwinCAT NC and the TwinCAT PLC Logic, Beckhoff also offers the possibility using DMX master and slave terminals (EL6851 and EL6851-0010) to import and process motion commands via the lighting console and output them to the motors.

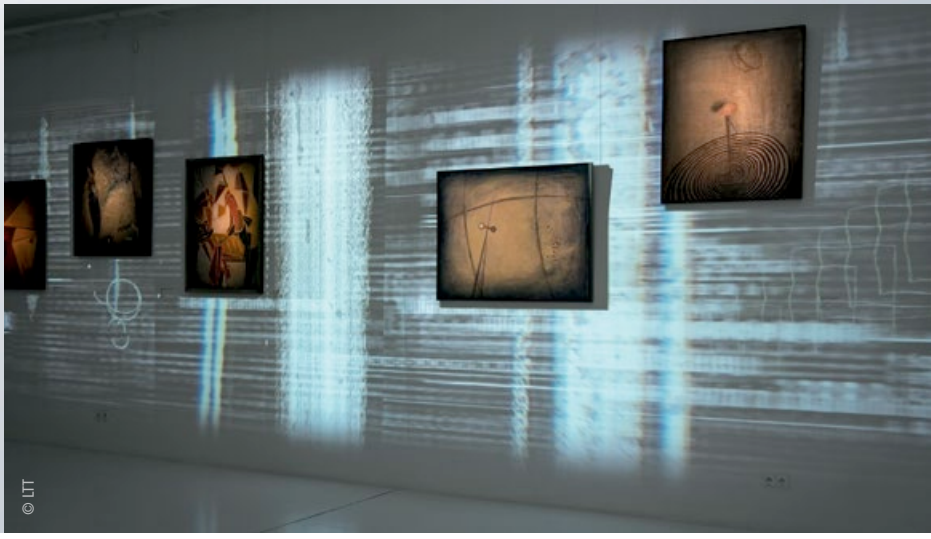
"Thanks to the high processing power of the multi-core Industrial PCs and TwinCAT as a multi-core-enabled software platform, which allows the different functional areas to run on the individual cores, we have every opportunity available to us to realize future installations. The imagination of the exhibition organizers knows no bounds," concludes Wojciech Baczyński.

Further information:

www.ltt.com.pl
www.beckhoff.pl

The Beckhoff C6670 multi-core Industrial PC is used as a central controller for the blinds, power distribution and winches, as well as for synchronizing all information in the museum..

Projections illustrate the historical context in which the paintings were created..



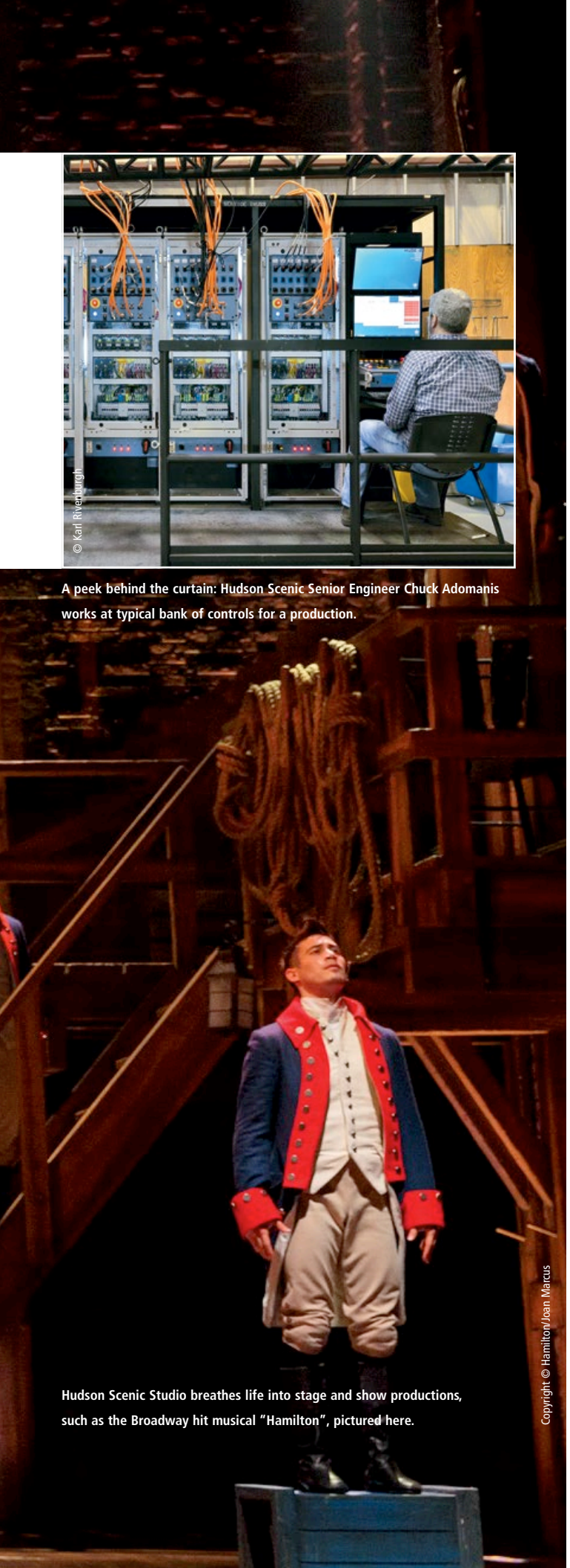
Hudson Scenic Studio sets the stage for show applications of all sizes with scalable control technology from Beckhoff

Blockbuster effects, automated for any theatrical production

In William Shakespeare's celebrated play, "As You Like It", the legendary playwright famously wrote that "all the world's a stage, and all the men and women, players". Perhaps this kinship to the theater experienced by audiences is what continues to drive the success of plays around the world. Making the storytelling and action seems effortless, enabling the viewer to naturally step into the lives of the characters on stage, takes a herculean effort behind the scenes. This is where Yonkers, NY-based Hudson Scenic Studio comes into play, providing scene fabrication and automation services to the entertainment industry since 1980.

© Karl Rivenburgh

A peek behind the curtain: Hudson Scenic Senior Engineer Chuck Adomanis works at typical bank of controls for a production.


Copyright © Hamilton/Joan Marcus

Hudson Scenic Studio breathes life into stage and show productions, such as the Broadway hit musical "Hamilton", pictured here.

Chuck Adomanis, Senior Engineer at Hudson Scenic Studio, explains: "Over the years, we have built a solid reputation as a full-service theatrical automation and production shop. Our extensive experience in the entertainment industry provides us with the ability to offer custom artwork and stage pieces, scenic construction and automation for nearly any stage or show application. We serve the Broadway theater market and provide solutions for other live events, TV and film, and for permanent installations such as theme parks and cruise ships."

Flexible and scalable control technology for projects of any size and budget

Hudson Scenic Studio serves some of the largest and most successful Broadway shows to ever hit the stage. Their impressive repertoire include productions such as Disney's "Aladdin", and "Hamilton", the smash hit musical about the life of American founding father Alexander Hamilton. However, Hudson Scenic offers support for stage and show technology to customers of all sizes, as Adomanis continues: "I think the biggest differentiator for Hudson Scenic is flexibility and our willingness to work with any customer, big or small, to help them discover the best solution for their needs. Whether the production is a multimillion dollar Broadway show or a play at a small regional theater, we have the flexibility to tailor systems and components that ideally fit the client's application."

Hudson provides the means for creative directors and their crews to bring their boldest stage and show ideas to life. From the ground up, the company offers planning services, project management, fabrication and commissioning to help nearly any stage and show application earn rave reviews. To accomplish this, Hudson builds incredibly intricate scenery and stage props, and then makes that scenery dynamically move, shift and change to enhance the visual direction of the show. In the Aladdin project, for example, buildings that form the marketplace of Agrabah move and rotate across the stage while turrets raise and lower. Every individual action, or effect, such as opening a trap door in the stage floor, lifting a section of scenery or helping an actor fly across the stage, requires complex control technology. There are virtually no limits to the imagination here; however, the prerequisite for staging such blockbuster effects is that the mechanical systems, the software and the automation work smoothly.

A peek behind the curtain

Behind the scenes, large control cabinets house the automation and control systems for the show. The HMI software developed by Hudson is used to operate the whole system. Controlling all the complex moving parts in a large-scale theatrical production such as the Broadway shows served by Hudson requires a robust control system in the background. Specifically, Hudson uses Beckhoff CX2030 Embedded PCs with 1.5 GHz Intel® Core™ i7 dual-core CPU, as well as several CX5100 Embedded PCs with Intel® Atom™ processors. Hudson also uses 7-inch CP6606 Panel PCs with ARM Cortex™-A8 processors for testing effects before implementing them in the field. Chuck Adomanis explains the need for a variety of controllers: "Each of these devices acts as a primary system controller, running PLC, NC and HMI software as the main control devices in our automation system. The highly scalable range of

Displaying the HMI programmed by Hudson is a series of 15-inch Beckhoff CP2916 multi-touch Control Panels.

Action and spectacular effects are the heart of any performance: for motion control, Hudson Scenic leverages AX5000 series EtherCAT servo drives and AM8000 series synchronous servomotors with OCT.

controllers allows us to choose the right performance level for the job, and it helps mitigate cost for the shows and for customers." When larger screens are required, the Hudson-programmed HMI is displayed on a series of 15-inch Beckhoff CP2916 multi-touch Control Panels.

TwinCAT 3 automation software provides the core underlying architecture for Hudson control systems. Adomanis continues: "We use a variety of TwinCAT 3 packages for PLC and motion control, given the varied nature of our projects, and we utilize the full range of available TwinCAT modules: TwinCAT PLC and NC for axis control, TwinCAT ADS, TwinCAT TCP/IP Server or TwinCAT OPC UA for horizontal and vertical communication. TwinCAT gives us remote access to show sites, ensuring that our customers receive timely service from our experts." Remote access enables Hudson to diagnose equipment issues anywhere in the world without engineering teams having to physically travel to the venues, providing significant cost savings which can be passed on to the customer.

Control-integrated safety solution meets complex requirements

As one can imagine, safety is paramount for stage and show applications. Hudson Scenic relies heavily on the TwinSAFE system from Beckhoff to integrate the wide range of necessary safety functions into the automation system, such as guard doors and e-stops. "Our previous e-stop solution was hard-wired to run a 24-volt signal, which required running additional cable," explains automation engineer Erik Nelson. "With TwinSAFE, we have a single cable and it connects everything, greatly simplifying our commissioning, increasing reliability, and allowing us to satisfy increasingly complex safety requirements."

Flexible, cost-effective and reliable: the high-speed EtherCAT system

Communication of the real-time relevant signals in the field takes place via EtherCAT. EtherCAT Terminals and EtherCAT Box Modules offer best-in-class speed, as well as a minimal footprint – essential in the space-constrained applications Hudson takes on every day. In addition, the low cost of the Beckhoff I/O terminals was especially appealing for Hudson Scenic, as Chuck Adomanis explains: "The EtherCAT I/O system offers a low price per point and with TwinCAT, we can quickly map and freely configure I/O, adding up to significant cost savings."

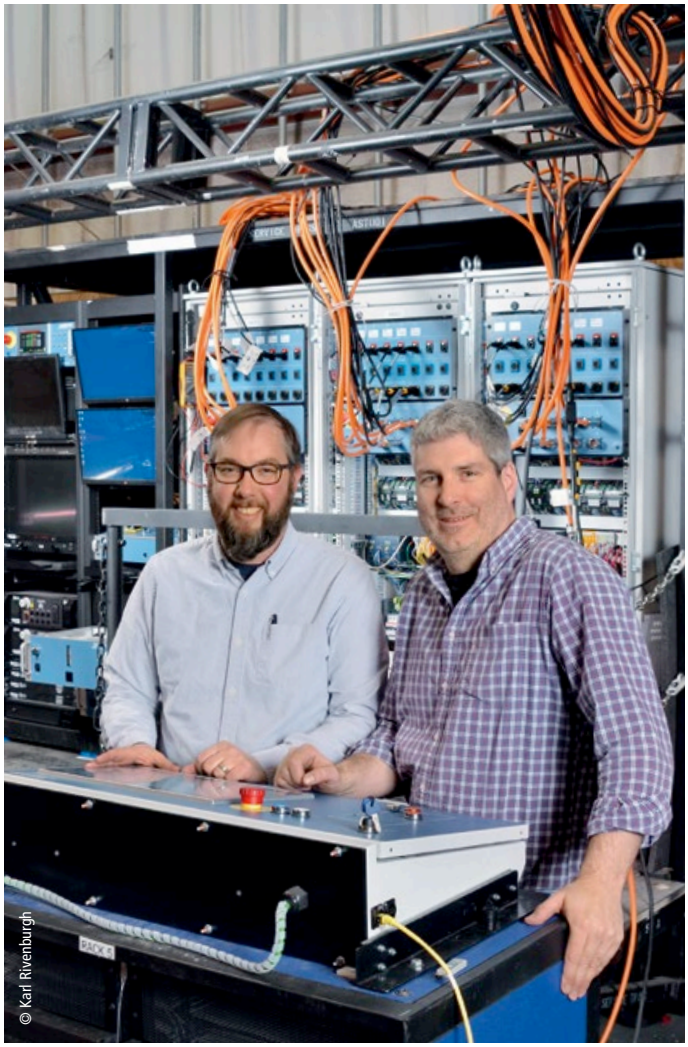
Beckhoff servo drive technology implemented as the standard

For motion tasks, Hudson relies on AX5000 series EtherCAT servo drives and AM8000 series synchronous servomotors from Beckhoff, a change from the three-phase induction motor systems used in the past. Beckhoff servo drive technology is now used as the standard motion system. "As the technical demands of our projects continue to grow and change, One Cable Technology (OCT) for the motors and drives, when coupled with absolute encoder technology, provides excellent value in our projects and will be our standard on new equipment," Adomanis said.

Increased performance and profitability earn critical acclaim

Beyond added flexibility in system design and maintenance, Hudson Scenic achieved impressive performance increases. Adomanis explains: "With our

A CX2030 Embedded PC serves as the master controller. This works in concert with additional CX5100 Embedded PCs to provide the necessary computing power across an entire production.



(left to right) Erik Nelson, Automation Engineer and Chuck Adomanis, Senior Engineer at Hudson Scenic Studio.

previous PLC and motion system, we were living in a world with scan times higher than 20 milliseconds for PLC commands and motion control. Now, our scan times are around 1 or 2 milliseconds, which could certainly be decreased further if necessary. When working with EtherCAT and TwinCAT, we can accomplish real-time, microsecond-level deterministic I/O communication, which was impossible in the past."

In addition, engineering costs have been greatly decreased while efficiency has increased. "Code written for one project is easily scaled from one effect to another without a lot of rework," said Erik Nelson. "We're no longer stuck manually addressing data registers and PLC memory." Adomanis also noted that though the specific cost savings are not easy to quantify, "we can say unequivocally that our margins have dramatically improved on projects and Hudson can go after applications large and small with PC-based control and EtherCAT technology and maintain high profitability."

"Beckhoff is able to go beyond the 'basic automation and controls' vendor with entertainment industry-specific technologies, such as I/O terminals with DMX communication and other standards used for lighting and multimedia equipment," Adomanis noted. "Working with an automation company like Beckhoff, with profound understanding of entertainment applications, provides considerable benefits to Hudson Scenic Studio and our clients."

As these projects grow in scope and technological complexity, the Hudson Scenic Studio team is ready to meet any entertainment engineering challenge that comes their way. With Beckhoff providing the controls foundation, these talented engineers have the necessary tools to keep bringing the artistic visions and dreams of stage and show professionals into reality.

Further information:
www.hudsonscenic.com
www.beckhoffautomation.com

 Published in PC Control 04 | 2016

Art, technology and nature come together to deliver a great stage experience

Advanced stage control technology produces magical moments on Bregenz's floating stage

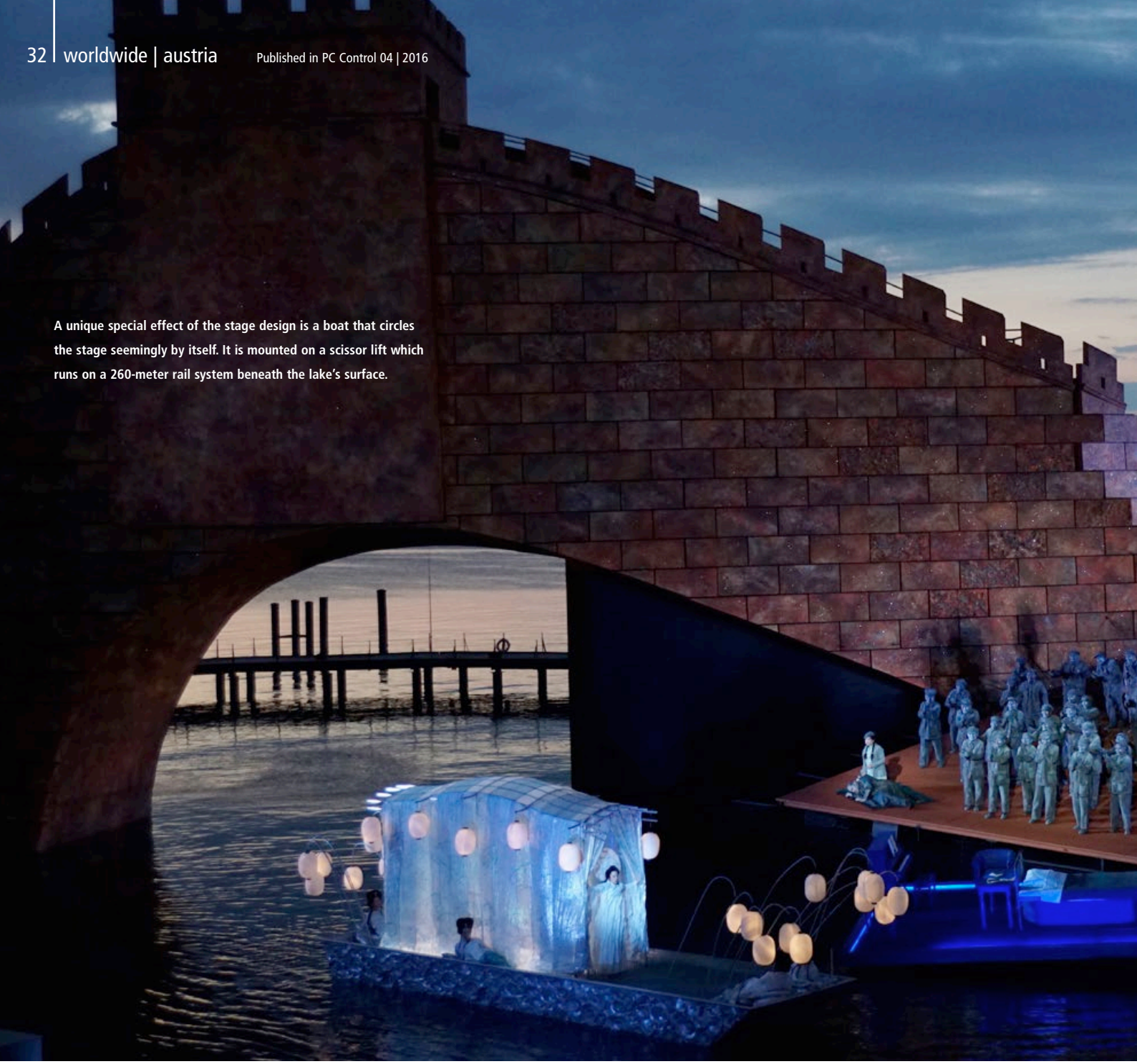
The seventy-year history of the Bregenz Festival in Austria has been accompanied by a series of technical masterpieces that make watching opera on Lake Constance a world-famous experience. From July to August, the floating stage on Lake Constance hosts spectacular opera performances that attract 7,000 spectators each night with their combination of music, singing, state-of-the-art stage technology and effective lighting against a spectacular natural backdrop. For Giacomo Puccini's "Turandot", which takes place in China, stage designer Marco Arturo Marelli built a "Chinese Wall" on the lake utilizing complex stage machinery controlled by Beckhoff technology.

© Bregenzer Festspiele/Karl Forster

The centerpiece of the floating stage is the round area at its center with an extendable rotating stage and two additional performance areas below it. The hinged floor features a video wall on its underside for special visual effects, projecting various stage setting images.

The tradition of the Bregenz Festival goes back to 1946, when the event started with a performance of Wolfgang Amadeus Mozart's musical comedy "Bastian and Bastienne" on two gravel barges anchored in the harbor. The space on the barges soon became too small, and the organizers decided to build a real stage on the lake, which became larger and more sophisticated as the years went by. Every two years, when the repertoire changes, the stage is completely torn down and rebuilt. This also applies to the 119 wood and steel poles that are driven up to 6 meters deep into the seabed and carry the huge weight of the performance space. This enables the organizers to be sure that the floating stage will hold up against the forces of wind, water and flooding.

The backdrop that Marco Arturo Marelli designed for "Turandot" consists of a 72-meter-long wall that snakes across the stage like a giant dragon. A sophisticated structure of steel, concrete and wood holds the 29,000 pieces in place. "Since the stage weighs 335 metric tons, the structural requirements are exceptionally demanding," says controls technician Stefan Frischke. "After all, the backdrop must be able to withstand extreme weather conditions such as thunderstorms." When the action calls for it, the wall must also be able to collapse very effectively, which happens at the beginning of the opera when more than 200 terracotta warriors become visible behind it, appearing to be marching from the heavens into the lake.



A unique special effect of the stage design is a boat that circles the stage seemingly by itself. It is mounted on a scissor lift which runs on a 260-meter rail system beneath the lake's surface.

The actual centerpiece of the floating stage is an extendable rotating portion with two additional performance areas below it. When its hinged floor opens up, it features a video wall on its underside for special visual effects using image projection.

PC-based control platform masters complex stage technology

The floating stage is also highly unique with regard to its control technology, as Stefan Frischke knows only too well: "In STB Steuerungstechnik Beck, we have found a great partner to help implement our stage control requirements, which are often very unusual." For Turandot, the Austrian systems integrator developed a Beckhoff-based control solution that includes the following functions:

- Control the rotating stage, which is 16 meters across, via a wire drive with various positions and end stops.
- Control various doors and hatches with position monitoring functionality.
- Collapse the "Chinese Wall" in a controlled manner.
- Control the hydraulics for the rotating stage "cover", which also functions as a video wall.
- Raise and submerge the hidden podium under the rotating stage.

The modularity of the Beckhoff terminal system allows subsequent changes and additions at any time and little cost.

The complex stage machinery is controlled via a Panel PC.

A unique special effect of the stage design is a seemingly autonomous boat that circles the stage. It may look magical, but does in fact require complex technology: The boat is mounted on a scissor lift that moves on a 260-meter rail system below the lake's surface. The scissor lift alone weighs 5 tons, and the boat adds another 2.5 tons.

The stage controller consists of a Panel PC as the central platform along with distributed EtherCAT I/O Terminals. "Since the floating stage involves some highly unusual requirements, the flexibility of Beckhoff control technology was of critical importance for us," says Alfred Beck, general manager of STB Steuerungstechnik GmbH. "It allows us to make changes and additions at any time and at little cost. Adding more terminals to the system is all it takes if we want to add more functionality. Another decisive factor during the selection process was the compact form factor of the Beckhoff control solution, because space is always limited on a performance stage."

Further information:

www.bregenzerfestspiele.com/en
www.steuerungstechnikbeck.at/en
www.beckhoff.at

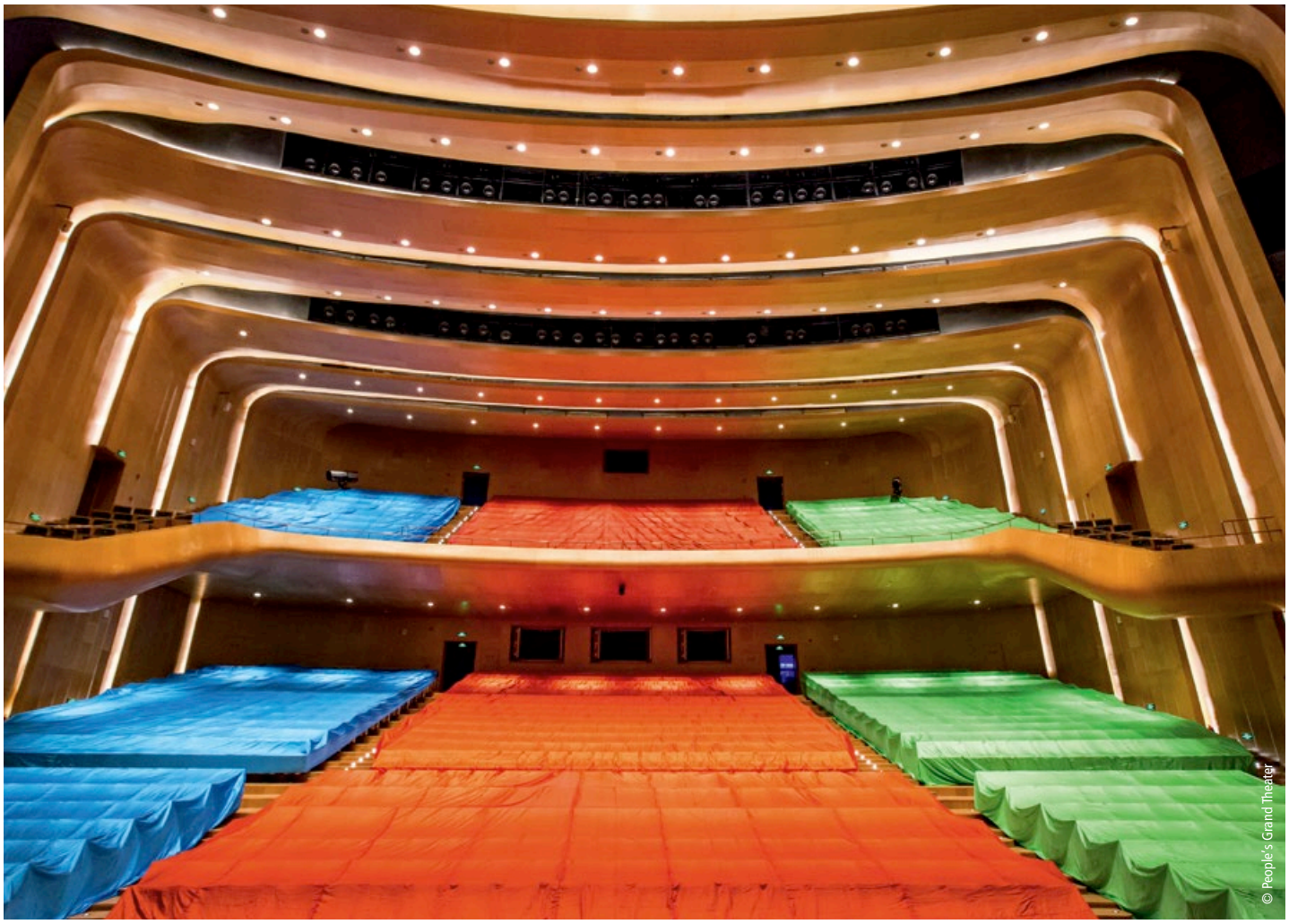
Integrated building automation with Beckhoff technology

Jilin City shines with People's Grand Theater

In September 2015, Jilin City in China inaugurated its People's Grand Theater with a film festival. In only two years, a complex was erected, consisting of two theaters, four movie auditoriums and various administrative wings in an area spanning roughly 37,000 square meters. All building automation systems, including the intelligent lighting controls, were realised on behalf of the construction contractor China Railway 17th Bureau Group Co., using Beckhoff technology.

The Jilin City People's Grand Theater at night

Interior views



As modern buildings become fancier and more complex, the scope of building automation systems increases as well, making simplification of the systems a new challenge. "The PC-based control platform from Beckhoff was totally new for us," explains Xinsheng Wu, project manager for the low-voltage system installed at the Jilin City People's Grand Theater. "The integrated building automation solution and the ability to control all devices from a single platform have greatly simplified the entire system. In the past, we needed different control components from two or even three manufacturers, which made the system much more complex."

Embedded PC, the integrated control platform for all functions

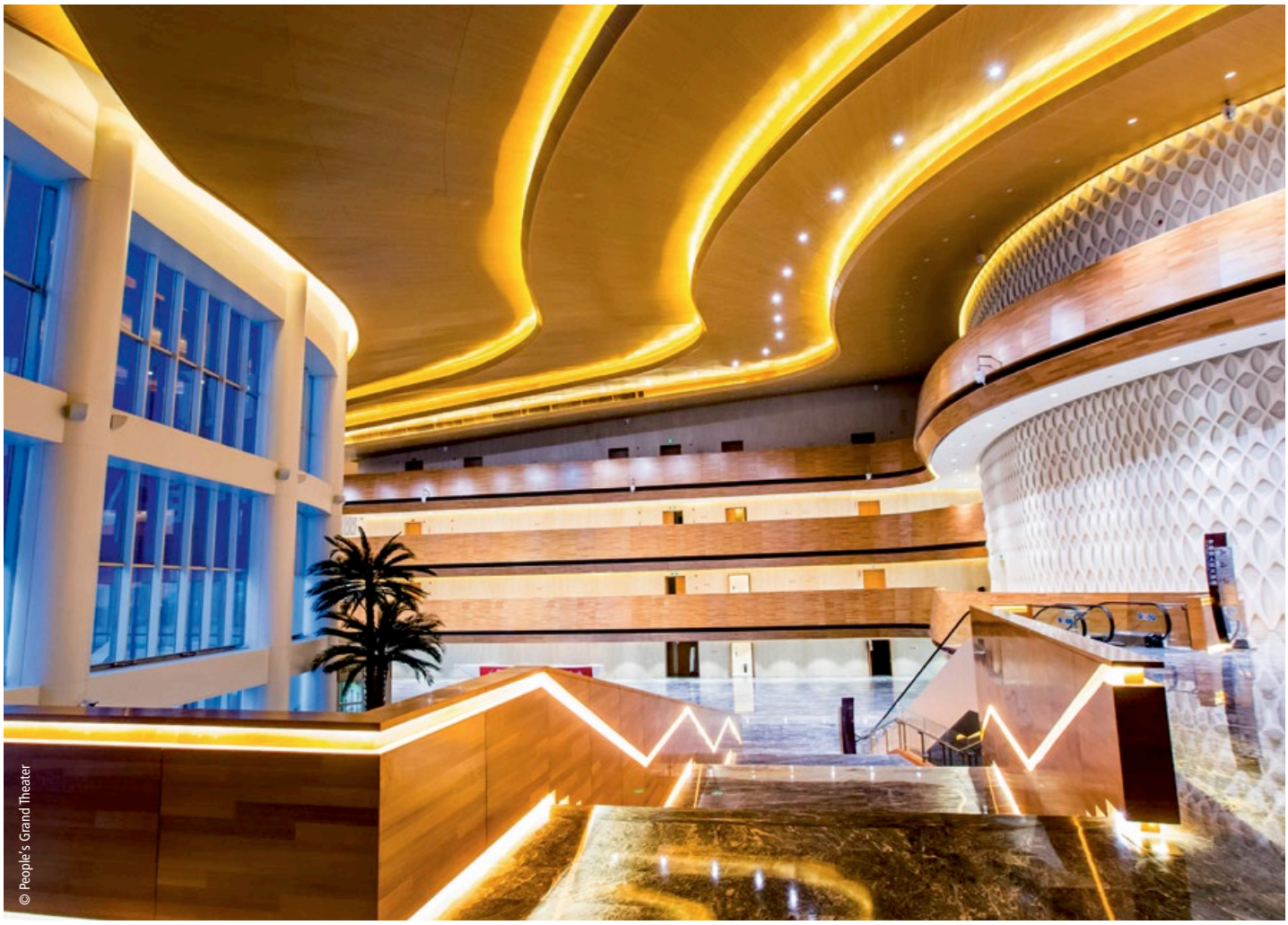
The PC-based control architecture is much more flexible than traditional systems, as Jun Han, the theater's technical director, notes: "To meet the requirements of this project, we only had to select the respective interfaces for the field devices and integrate them into the terminal string. The large selection of Beckhoff I/O terminals covers all building bus systems, including BACnet, EnOcean and DALI, among others. What impressed me most, however, was the fact that we needed only a single software tool for everything from planning to completion, helping us complete the entire project earlier than scheduled."

For the building automation, intelligent lighting controls, room controls and other subsystems, there are 18 CX8090 Embedded PCs, 74 BC9050 Ethernet Bus Terminal Controllers, 250 KM2614 4-channel relay modules and approximately 200 digital and analog terminals installed in the People's Grand Theater. "The entire building automation system is based on an integrated control platform, which simplified the project's execution as well as future maintenance activities," says Jun Han. "In addition, connecting the I/O terminals is easy; they are also very easy to replace, if necessary. As a result, the theater technicians don't have to worry about finding maintenance help, performing the work completely by themselves."

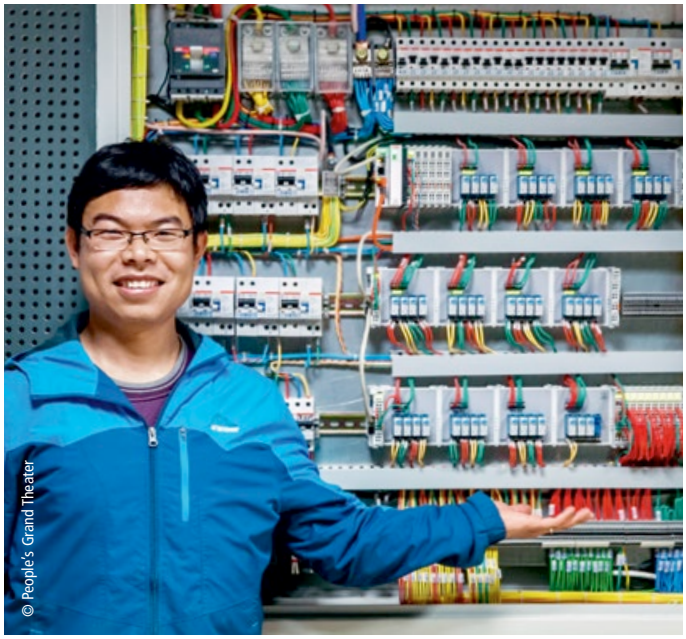
Further information:

www.cccme.org.cn/shop/cccme11693/index.aspx

www.beckhoff.cn



The KM2614 with four pluggable power relays in one fieldbus module makes it possible to control consumers with high power requirements directly on the supply network. Each relay can be switched on or off manually.



Jun Han, technical director of the "Grand People's Theater", in front of the control cabinet

 Published in PC Control 01 | 2015

Innovative light control in Hamburg's new musical theater

Beckhoff lighting control for the musical, "Das Wunder von Bern" (The Miracle of Bern)

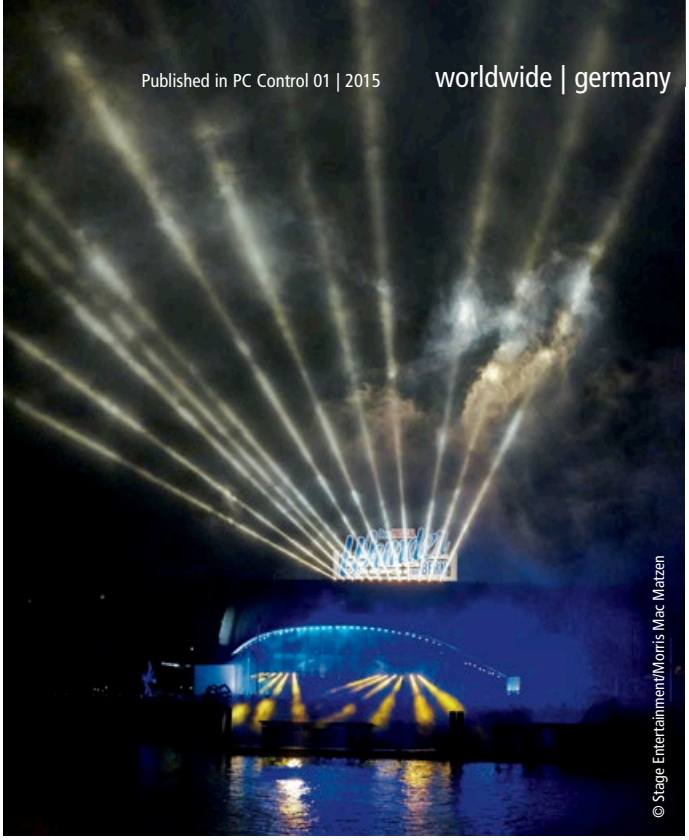
The new "Stage Theater an der Elbe" in Hamburg, Germany opened in November 2014 with the world premiere of the musical, "Das Wunder von Bern" (The Miracle of Bern). The facility is the first new theater built by musical production company Stage Entertainment, and sets new standards in the world of musicals for advanced stage equipment. The success story of Stage Entertainment – which operates 25 venues around the word, including eleven in Germany – began in 2001 with a performance of Disney's "The Lion King", which has delighted audiences to the tune of over 10 million attendees to date.

With "The Miracle of Bern" (which is based on the Sönke Wortmann film of the same name), Stage Entertainment producer and owner, Joop van den Ende deliberately decided on a production with a German theme. Set against the background of the German post-war era and featuring a touching father/son story, the musical tells the story of Germany's first World Cup soccer title in 1954. The "Stage Theater an der Elbe", with investment costs estimated at 65 million euros, was built in less than three years in the port area of Hamburg. The impressive building, with its high glass façade and domed roof with shimmering stainless steel shingles, was built on steel and concrete supports drilled into the Elbe River sand. Various foyers, the auditorium, with a capacity of 1,850; the main stage with an area of almost 350 m²; the two auxiliary stages; the service building with dressing rooms; as well as the workshops and plant rooms, cover an area of 10,200 m². The "Stage Theater an der Elbe" meets all the requirements of a modern musical theater and a global destination, designed with Stage Entertainment's very elaborate productions in mind.

Flexible lighting control via Embedded PC and DMX Terminals

Playing key roles in modern musicals – in addition to the music, songs, dance routines, stage design and costumes – are light, sound and special effects, much more so than in classical theater and opera performances. Lighting, in particular, is an important tool to grab the attention of viewers, create tension, and to rouse emotions. In addition to the stage lights, so-called non-dims (switchable power supplies), blue light, backstage way lighting, video streams, and architectural lighting installations must be controlled. Typically, this is accomplished with a lighting control console. "In addition to the main lighting control console, we have a second, independent lighting control system referred to as Scenestore, which we use for rehearsals or for backup lighting in the event of a fault," said Andy Peistrup, Stage Entertainment's lighting coordinator. "In lighting control systems, we often have the problem that, in principle, only one DMX transmitter feeds into the system. Even in constellations with a main desk and an emergency desk, the DMX output

Hamburg's new "Stage Theater an der Elbe" opened in November 2014 with the world premiere of the musical "Das Wunder von Bern" (The Miracle of Bern).



The "Stage Theater an der Elbe" in Hamburg, Germany is the first new theater building created by musical production company, Stage Entertainment on its own. It is equipped with state-of-the-art stage technology and breaks new ground in the world of musicals.

takes place at a single point. If this device fails, the lighting system, including the room light, is no longer controllable, and the auditorium and the stage are in the dark. The Scenestore, developed by Stage Entertainment, enables the room light to be activated in the event of a fault, and the data from the lighting control console to be suppressed. Power supplies that are switchable via DMX (non-dims), such as for moving lights or video cameras, can also be controlled with the Scenestore.

"If there is ever a problem at the lighting control console, for example a short-term DMX loss during saving, fixture cloning, or rebooting, the non-dims are de-energized and these consumers are switched off. Restarting and activating a rig with possibly 120 moving lights may take 15 to 20 minutes," said Andy Peistrup. Failure of the blue light could severely disrupt a show. "That's why it is important to be able to control these 'channels' independently," noted Stage Entertainment's lighting expert. "This is where our Scenestore control panel comes in, controlling the channels independently of the lighting control console. The channels remain at their set values – regardless of the state of the lighting control console and/or the operator." Scenestore is also used during rehearsals: the saved lighting scenes can simply be called up through the control panels on the stage or by the usher, thereby avoiding the need to start up the lighting control console. A specialized lighting technician is no longer required. The same goes for maintenance or cleaning operations, as Scenestore, or various flexible auxiliary control panels, enable the room light to be switched on without the need to power up the main lighting control panel. The auxiliary control panels are linked to the central controller in the control cabinet and can also be locked from there.

The Scenestore is controlled by a CX5010 Embedded PC with directly attached DMX terminals and further I/O modules for controlling distributed sensors

Scenestore is a secondary lighting control system developed by Stage Entertainment. The system is independent of the main lighting control console and used for rehearsals as well as for backup in the event of a fault.

and actuators. "We decided to use the PC-based control platform because it is designed for continuous industrial operation, and components can be supplied within 24 hours. With a total of nine performances running seven days a week, reliable technology is a must-have for us," Andy Peistrup added. "The operating system and programs are stored on a removable memory card, so that system troubleshooting and service are easier in the event of a fault. After our first positive experience with Beckhoff, we intend to use the technology in other shows."

Further information:
www.stage-entertainment.com

The new playhouse in Copenhagen has three stages and can accommodate an audience of around 1,000.

© HOAC® SchweißTechnik GmbH

Automated stage technology at the Royal Danish Theater in Copenhagen

Embedded PC controls movable stage turntable at historic Danish theater

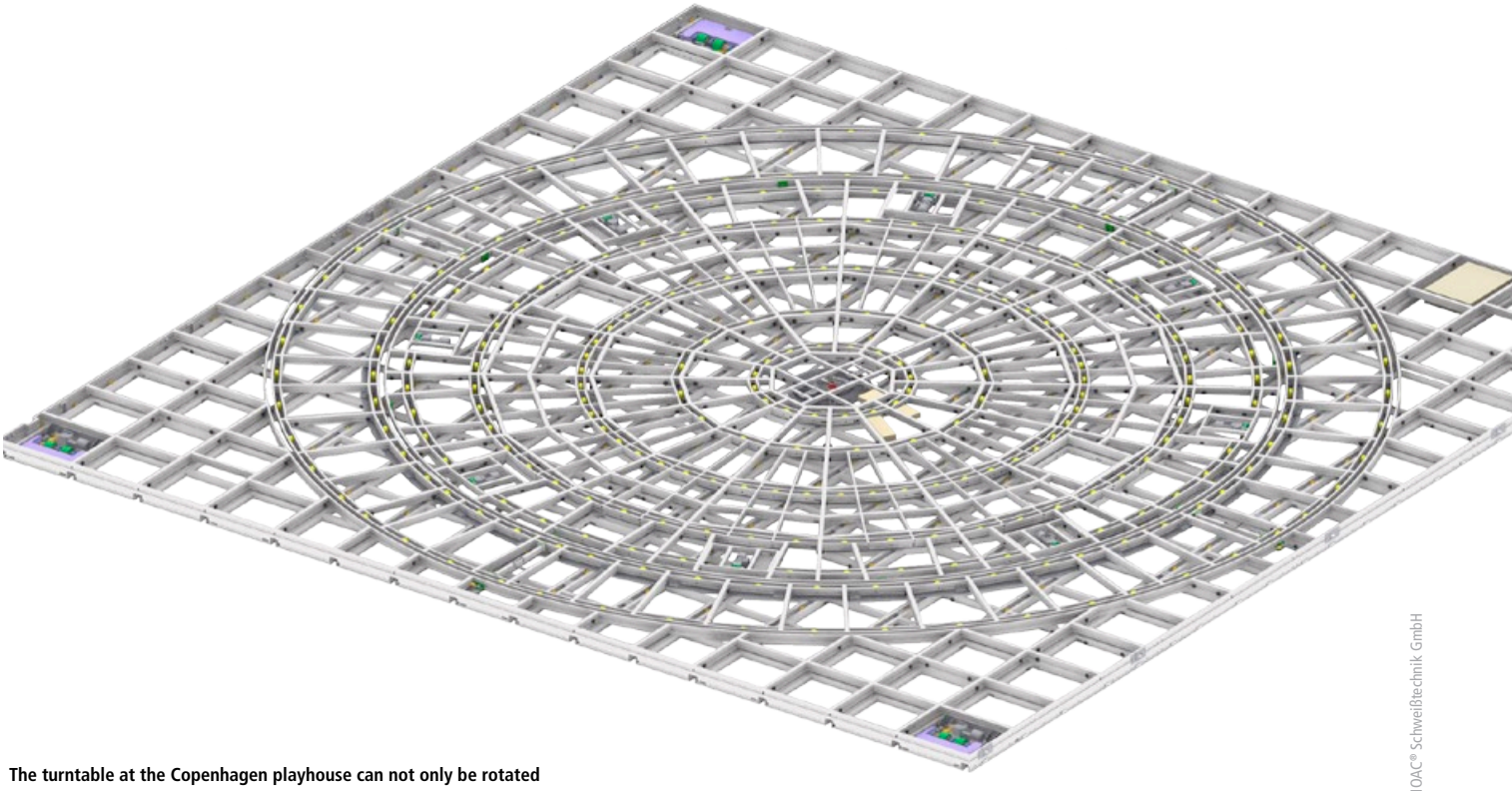
The playhouse at the Royal Danish Theater in Copenhagen serves as Denmark's center for dramatic arts programs. In addition to the actors' performances, advanced stage technology plays a key role in the production of the theater's impressive shows. A prime example is the movable stage turntable, produced by German manufacturer HOAC and intelligently controlled by a Beckhoff Embedded PC.

Established in 1985, HOAC Stage Technology GmbH, based in Moers, Germany, develops and manufactures aluminum-based systems and machine components for theater and stage technology. Supported by leading-edge PC-based control technology, the system-compatible structures offer a high degree of flexibility and functionality. The company is EN 1090 1-3 and ISO 3834 certified, represented in almost all European countries as well as the major theaters in North America and Asia and provides cross bars, stage and ballet carts, as well as stands and curtain pulley systems. HOAC also supplies stage turntables, which are available in various sizes, with internal or external drives, and with manual or programmable control.

Movable turntable for the new playhouse

The Royal Danish Theater – Det Kongelige Teater – in Copenhagen was established in 1874. The new Royal Opera was opened in 2005, and a new playhouse was built in 2008 to provide adequate space and advanced stage equipment for all performance types. At the time, the designs for the playhouse had to be scaled back to some degree, in order to meet budget and time constraints. For example, the turntable that had been proposed for the stage machinery was not realized, despite the fact that enough space would have been available.

In 2013, this deficiency was rectified using a movable turntable from HOAC, as managing director Dr. Gabriele Hogg explains: "We used a 16 x 16 meter scenery wagon, including a turntable with an integrated outer ring measuring 15 meters in diameter. The scenery wagon moves from backstage to the main stage by means of four integrated motors, guided linearly by lateral rollers in the recessed platforms and is lowered to a depth of 30 cm. This enables fast switching between shows utilizing the turntable and shows that take place on the podiums of the main stage, for example. The turntable can even be moved during the rotary motion."



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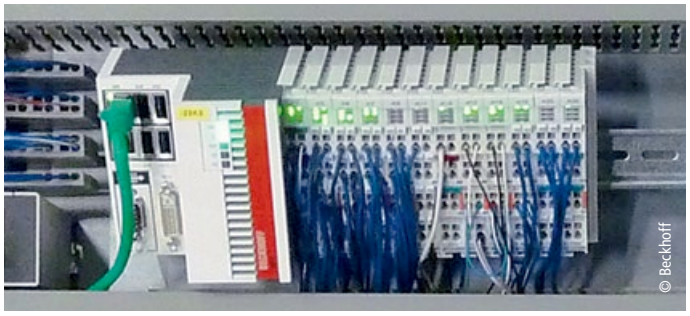
The turntable at the Copenhagen playhouse can not only be rotated but at the same time moved from the backstage to the main stage.



© Beckhoff

A high-performance and very compact control system was implemented using the CX5010 Embedded PC and EtherCAT Terminals.

Embedded PC controls all movements

Christian Leurs, who is responsible for design and process engineering at HOAC, describes one of the special design requirements necessary for the turntable: "For the Copenhagen project, a scenery wagon with integrated turntable had to be positioned using a bar code. Thanks to the flexibility of our system, we are able to move over a defined distance without actual data. Control is handled by a CX5010 Embedded PC with Intel® Atom™ processor, as the flexibility and openness offered by PC Control from Beckhoff were particularly important to us. For example, it enabled the I/O level to be implemented in a compact and modular manner via EtherCAT Terminals, in particular the EL1008, EL2008 and EL2004 digital terminals, and EL3051 and EL4032 analog terminals."

A further advantage of the openness of the system is simple and precise control of the asynchronous motor frequency converters via the EtherCAT Terminals, as well as point-to-point axis positioning with TwinCAT NC PTP software. Added to this is the use of established IT tools, as Dr. Gabriele Högg explained: "The turntable controller can store the programs for up to 10 different shows, with up to 50 scenes each. These can be easily transferred to a USB stick and edited in the form of an XML file. Another very important aspect for us is remote maintenance, which is also easy to implement with the corresponding option that is integrated in Beckhoff controllers."

Further information:

www.kglteater.dk
www.hoac.de/en
www.beckhoff.fi

EtherCAT controls DMX systems

Integrated lighting control at the Kuopio City Theater

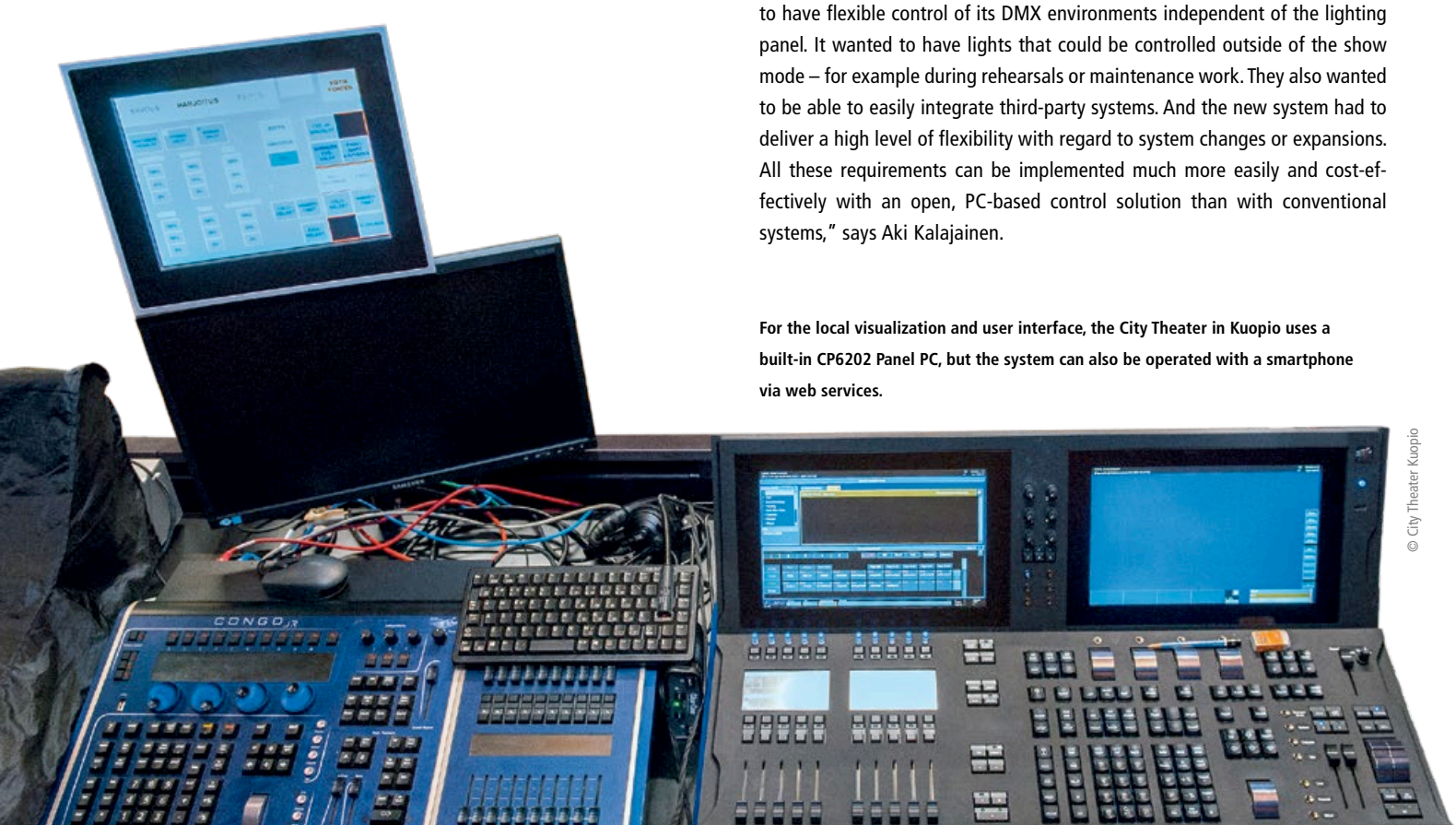
In the fall of 2014, the City Theater in Kuopio, Finland reopened its doors after a two-year renovation and conversion period. It is the largest theater in eastern Finland that offers sophisticated and diverse entertainment to people in the region. Roughly eight to ten premieres and about 300 performances are held each year. To bring the theater's operations up-to-date technologically, the city's government decided to expand the 1960s' building and renew its technical equipment. The concept of a central lighting panel that controls the local DMX systems via an Embedded PC turned out to be the best available solution in terms of user-friendliness, flexibility and cost.

The theater's expansion and conversion, which was handled by ALA Architects in Helsinki, incorporates the existing building's materials – glass and white concrete panels – without ignoring the originality of the previous design. With its "folds", the facade of fiber-reinforced concrete reminds the observer of a giant origami. To connect the old and new parts, the architects attached a bridge-like section that runs from the old building's lobby to the new auditorium while forming a protective canopy. In its new incarnation, the facility now features a main stage with 464 seats, a studio theater with flexible seating and state-of-the-art stage technology, and expanded technical areas. Also upgraded were all technical systems from HVAC and electrical systems to stage technology and lighting controls.

Embedded PC integrates all lighting controls

In the past, the stage lighting in Kuopio's City Theater was controlled via a DMX-based panel, but the auditorium lights, the blue backstage lighting, the work lighting and the power outlets were all controlled separately. "As a result, we had to maintain multiple systems, which meant multiple suppliers, different programmers, many subcontractors and lots of work when systems had to be changed," says Juha Westman, Technical Director of the Kuopio City Theater.

"The decision to install PC-based control technology from Beckhoff was made in accordance with the end user's requirements," explains Aki Kalajainen, Manager Building Automation at Beckhoff. "The Kuopio City Theater wanted to have flexible control of its DMX environments independent of the lighting panel. It wanted to have lights that could be controlled outside of the show mode – for example during rehearsals or maintenance work. They also wanted to be able to easily integrate third-party systems. And the new system had to deliver a high level of flexibility with regard to system changes or expansions. All these requirements can be implemented much more easily and cost-effectively with an open, PC-based control solution than with conventional systems," says Aki Kalajainen.



For the local visualization and user interface, the City Theater in Kuopio uses a built-in CP6202 Panel PC, but the system can also be operated with a smartphone via web services.

© City Theater Kuopio

The City Theater in Kuopio, Finland. The building's old and new sections are connected by a kind of bridge that runs from the lobby in the old part along its facade to the auditorium in the new part while forming a protective canopy.

Based on a PC- and EtherCAT-based control platform, the City Theater in Kuopio accommodates flexible and independent control of the DMX environments, integrated light switches and buttons, and the ability to integrate third-party systems.

The Beckhoff solution consists of a CX5010 Embedded PC as the central control unit, EL6851 and EL6851-0010 DMX master and slave terminals for controlling the local DMX environments, as well as various digital and analog I/Os and many KL2641 relays. All in all, roughly 550 terminals were installed. And with the BK1250 bus terminal, both EtherCAT and standard bus terminals could be mixed in the same bus station. The BK1250 recognizes the bus terminals and automatically assigns them on the EtherCAT system's process map. "For the local visualization and user interface we use the built-in CP6202 Panel PC, but the system can also be operated with a smartphone via web services," explains Jussi Piispanen of Beckhoff's Finnish subsidiary.

EtherCAT provides the backbone

The backbone of the new control platform is provided by EtherCAT, the high-performance, Ethernet-based fieldbus which was developed for industrial real-time communication. In connection with the EL6851 master terminal, it allows for the operation of an almost unlimited number of DMX environments simultaneously. With a cycle time of 10 ms and a single PLC task, 100 or more DMX environments can transmit the full protocol bandwidth of 512 channels. "Thanks to the option to integrate multiple DMX master or slave terminals into the system, the DMX environments can be distributed from the control panel to different switch cabinets and directly controlled via EtherCAT, which simplifies the DMX cabling and gives us more flexibility," explains Juha Westman.

"With the freely programmable TwinCAT automation software and the TwinCAT PLC DMX software library, we can create various lighting scenarios and assign them to buttons or graphical interface elements," adds Jussi Piispanen. "Even the relays are individually configurable as 'off relays', which switch off automatically at a specified time after the end of a performance."

In show mode, the input from the DMX slaves is copied to the outputs of the DMX master. Outside of show mode, when the control panel is not in use, such as during rehearsals or custodial work, certain control functions are available via buttons and the graphical interface. At these times, the Beckhoff platform controls all lighting and power control operations. The buttons for controlling the system in non-show mode are integrated via the digital KL2641 relay output terminal, which also controls the voltage of the DMX lights and the power outlets during shows. In show mode, these buttons can be locked to block unintended control commands. The manual operation option of this terminal has another benefit, for example during start-up phases when power is needed, but the controller has not yet completely powered up.

"The customer also wanted the ability to integrate additional components into the stage technology such as a fog machine, which exists in the DMX world. This requires a connection with the HVAC system so that the fog can be drawn in the right direction and the ventilation system adjusted accordingly. The serial KL6041 interface makes it possible. The communication between the central controller and the fog machine and the HVAC system runs over Modbus. This makes EtherCAT the powerful backbone, which covers all important interfaces such as DMX, sACN, Modbus and more," explains Jussi Piispanen, before adding that "EtherCAT has several more advantages, such as flexible topologies and easy cabling, which provide significant cost benefits."

"For everyday theater operations, PC- and EtherCAT lighting control has a series of benefits with regard to new usage options, increased flexibility and more user-friendliness," adds Juha Westman.

Further information:
www.beckhoff.fi

 Published in PC Control 01 | 2015

Modular, flexible, high-performance: PC-based control meets all requirements for modern stage management systems

EtherCAT and TwinCAT optimize stage processes

HFE Professional Studio Equipment, based in Leipzig, Germany, specializes in system solutions for theaters, opera houses and concert halls, as well as broadcasting corporations. The company's product range includes a state-of-the-art stage management system that can coordinate all technical operations of a theater performance. In view of the ever-increasing demands in the production of stage events, HFE developed a powerful and flexibly expandable solution that enables the connection of light signals, audio and video, call system and intercom. As an alternative to conventional versions of AV control systems for stage management, it combines ease of use with the performance and interface variety of the PC- and EtherCAT-based control platform from Beckhoff.

Stage managers are responsible for the trouble-free operation of theater performances. Using the stage management system, coordination of the whole performance and rehearsal sequences, including transformation of the stage settings for the next scene, light changes or timely use of tone sequences, sounds, and recordings, is all possible from a central location. The stage management console provides the communication platform for the stage operation, connected with all the rooms in the entire theater building via call and intercom systems, monitors, and cameras.

Industry-proven technology in the theater

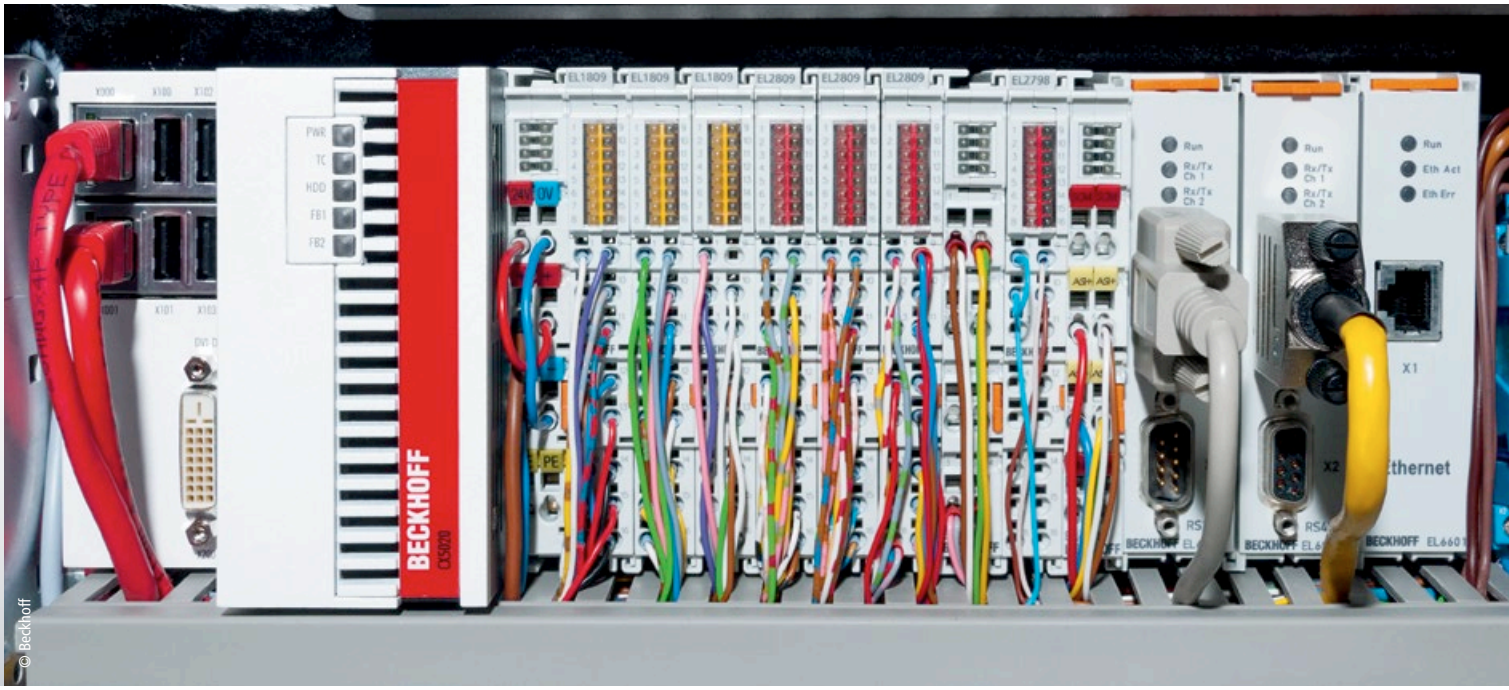
In order to meet the complex technical requirements of modern theater performances, HFE uses the PC-based control platform from Beckhoff as the foundation for its stage management systems. "Theaters place high demands on system reliability. Therefore, it made sense to use components that have been tried and tested continuously in industrial applications. Many customers also ask for long-term availability of controls products, in order to protect their investment. All of this is available with Beckhoff control technology," says Christian Just, IT and Development Engineer at HFE. According to the specialists from HFE, the central control platform with local I/O modules is ideal for enabling functions at distributed locations in theater applications.

EtherCAT, the real-time communication backbone of the control system

The central control platform of the HFE stage manager console is a CX5020 Embedded PC with TwinCAT 3.1 automation software and EtherCAT, the high-performance industrial Ethernet system. The local system components with digital and analog I/Os are also connected to the control unit via EtherCAT. A modular star hub can be created by using several EK1122 EtherCAT junctions (or EK1501 for optional fiber optic connections) in a station. Individual devices or complete EtherCAT segments can be connected at the junction ports. "The flexible bus topology offered by EtherCAT is a great advantage for theater applications. The Hot Connect function based on EtherCAT and enabled through defined bus segment groups is a big advantage compared to conventional solutions," noted Christian Just. "In this way, individual system groups, such as flexible operating points, can be exchanged during service operations. The short signal propagation and switching times, plus the high data throughput of EtherCAT are significant benefits: responses to user inputs occur in real-time, reducing latencies to a minimum." In addition to high performance, users also benefit from minimal cabling effort, as well as the full Ethernet compatibility of EtherCAT, i.e. support of external devices with Ethernet-based protocols.

Interface diversity sets no limits on creativity

Due to its wide range of interfaces, the PC platform allows the integration and control of all relevant components of a stage management system. "State-of-the-art performances require solutions that are versatile and expandable, in accordance with the requirements common to 'everyday life' in the events business," Christian Just states. "With our newly-developed stage management system, we are able to respond rapidly to user requirements. This applies to the integration of additional interfaces, as well as the functionality of the user interface and the control logic." The modularity and signal diversity of the Beckhoff I/O system are perfect for this purpose. Be it digital or analog I/Os, serial protocols (RS232/422/485), IP-based protocols, DMX or timecode: "The Beckhoff components, which are available centrally and locally, enable us to map virtually any application scenario," according to Christian Just. This makes it possible to integrate existing and external systems in the stage management system. For example, light control can be integrated via the EL6851 DMX terminal. Various Bus Couplers support the simple migration of data from existing bus systems to EtherCAT communication (e.g. EIB/KNX, M-BUS).



© Beckhoff

The central control platform of the HFE stage manager console is a CX5020 Embedded PC with the TwinCAT 3.1 automation software and EtherCAT, the high-performance industrial Ethernet system.

© HFE professionelle Studiotechnik GmbH

The stage manager console developed by HFE provides a powerful and flexibly expandable solution for connecting light signals, audio and video, as well as call and intercom systems.

The Adunas software developed by HFE runs on Windows, Linux and Android-based operating systems. This also allows implementation of distributed user interfaces, such as operation via smartphone, for example.

© HFE

The EL6001 (RS232) and EL6021 (RS422/485) EtherCAT Terminals enable the flexible connection of serial devices. EtherCAT Terminals with special functions deal with reading of the curtain status (EL5001 – SSI encoder interface) or the auditorium lighting level (EL3681 – multimeter terminal).

Customized solutions based on an open system

On the software side, HFE is excited about the flexibility and openness of the PC platform. With the integrated ADS interface in TwinCAT, the company is able to easily connect Adunas, its AV control software for stage management systems, with the Beckhoff control system.

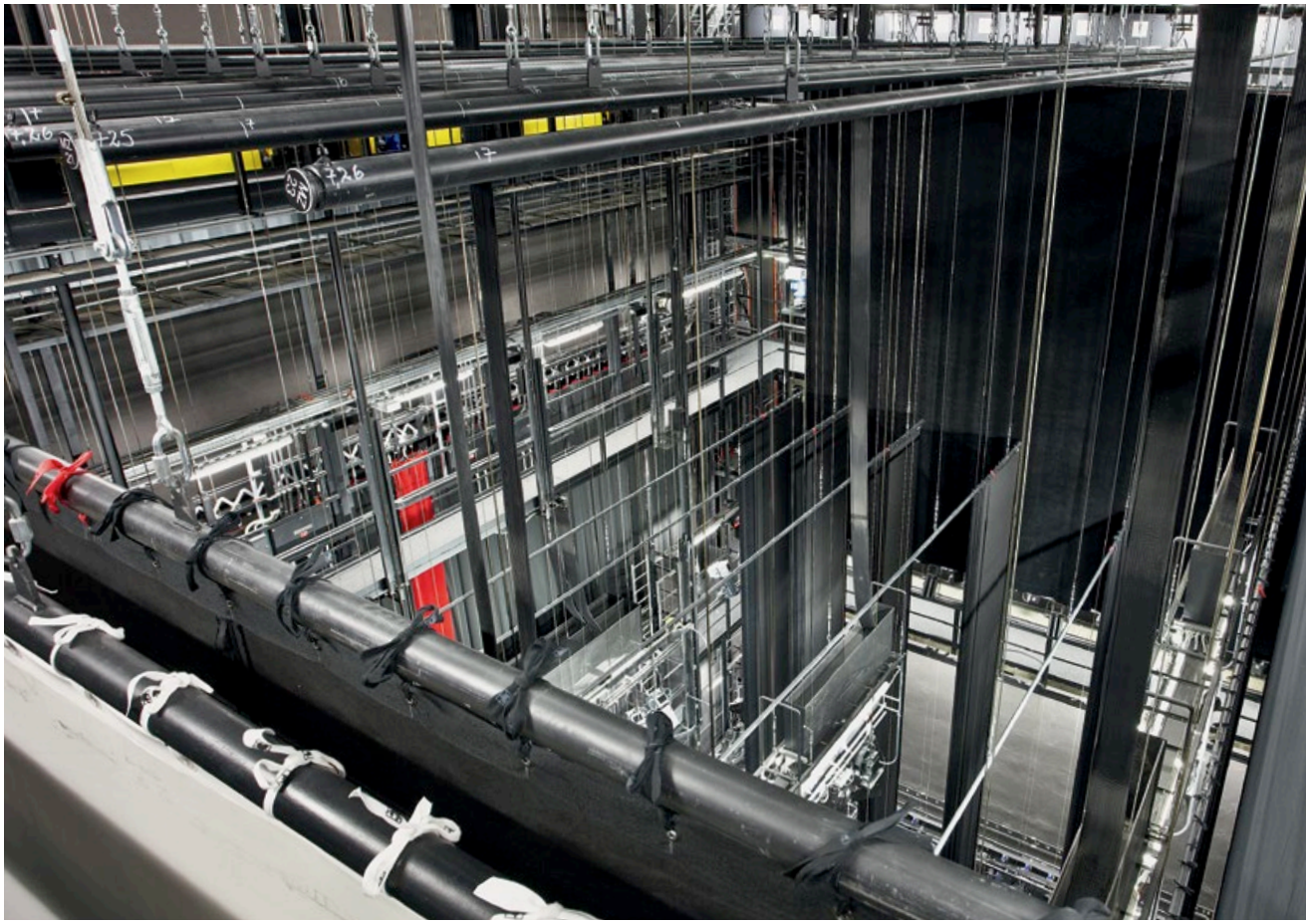
Conventional, physical controls, such as buttons or knobs are still popular with the theater industry. HFE complements these with touch-enabled Panel PCs running their Adunas software. "For the stage manager, this means comfortable operation without compromising on familiar processes and conventional input and output methods," says Christian Just. The Adunas AV control software extends the functionality and usability of the overall system.

Currently, the system runs on Windows, Linux, and Android-based operating systems. This makes it possible to realize distributed user interfaces that can be configured according to each application.

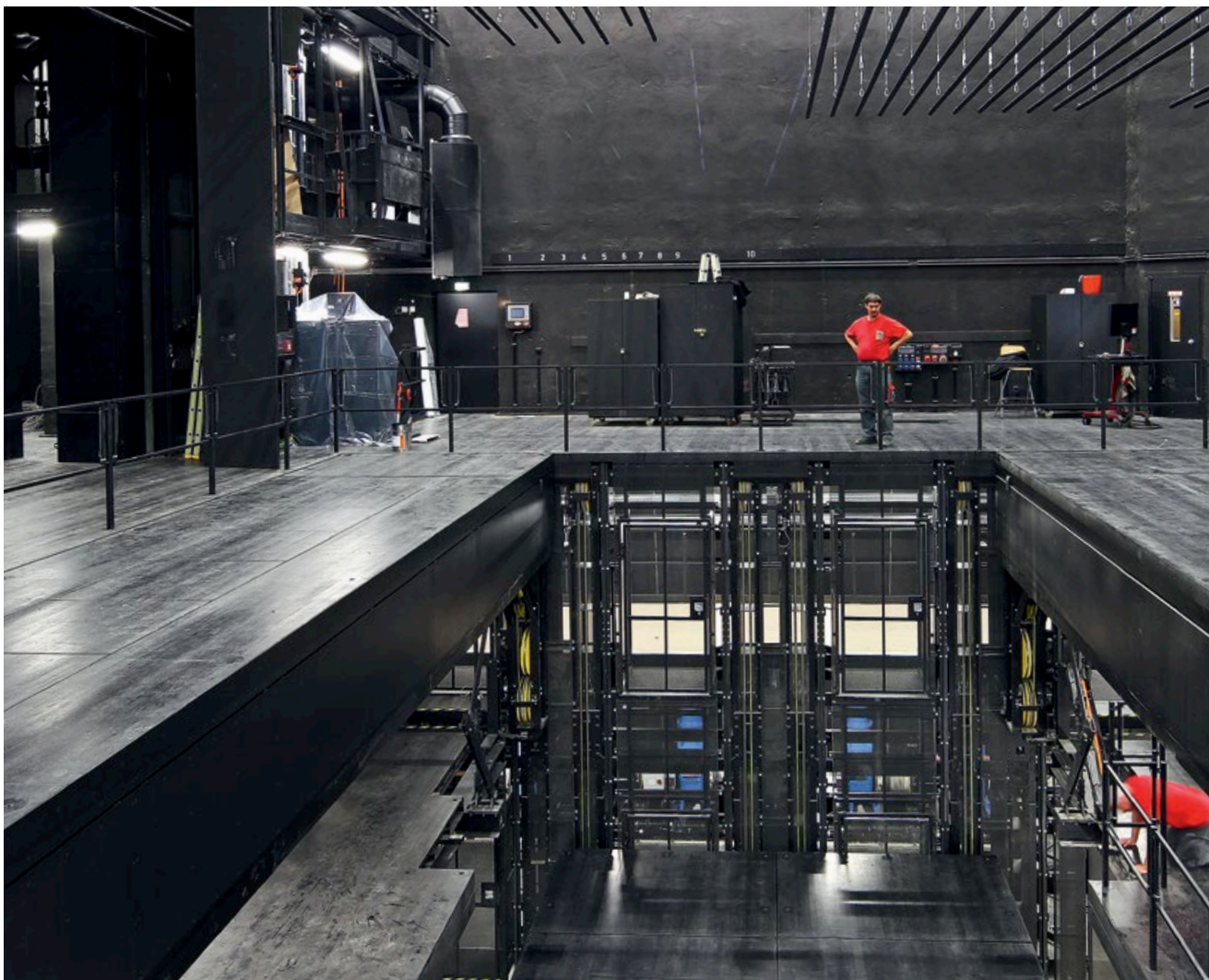
The specific versions that HFE offers its customers range from the design of the stage manager console and the configuration of the operating elements and displays, to the actual system functions. "We pursue an open concept. Together with our customers, we develop systems to suit their needs, at a price that is comparable to a standard solution," explains Christian Just.

In addition to the further development of the existing system, HFE also intends to use its technological potential for system solutions in other areas. Currently, the company is working on the design for a digital information system for broadcasters.

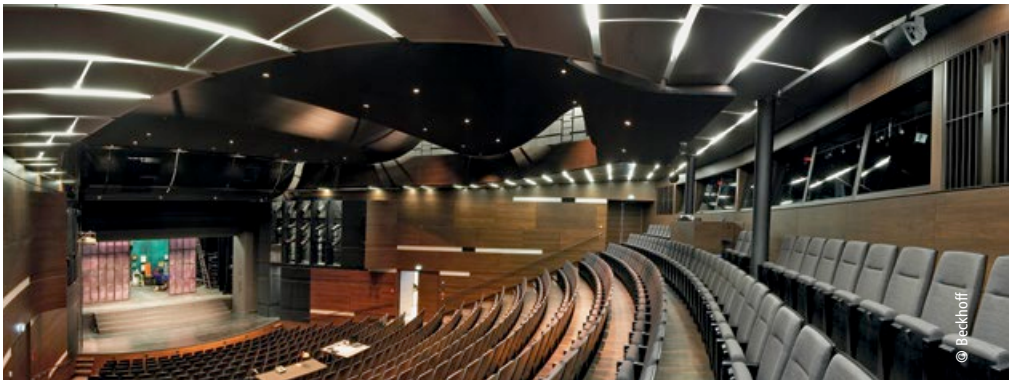
Further information:
www.hfe.de



View of the overstage machinery with the cable winches: following the complete rebuild of the stage, the Schauspielhaus in Nuremberg now has 47 machine hoists for the backdrop, panorama, portal, gallery lighting, overhead lighting, rear stage and forestage hoists, ten point hoists and four lowering devices for the stage podiums, which can be moved independently of one another.



The stage has a total area of 20 m x 35 m, wherein the main area, the four movable podiums, takes up a total area of 10.5 x 12 m.



In addition to the redesigned auditorium, the Schauspielhaus in Nuremberg now has ultra-modern stage equipment following the rebuild work, offering state-of-the-art working conditions and revitalized artistic/technical possibilities.

New control solution for Schauspielhaus renovation in Nuremberg

Complex stage and theatre technology with PC- and EtherCAT-based control

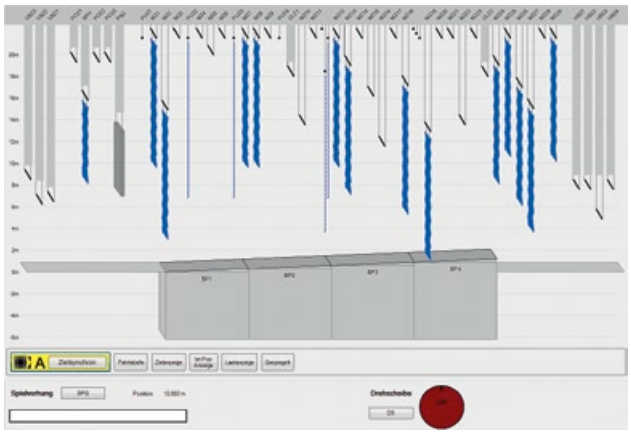
Flawless performances in opera houses and theatres require ultramodern and complex stage systems and technology. To meet these demands, the Schauspielhaus in Nuremberg, Germany has been completely renovated over a two-year construction period. The contract for the renovation of the entire stage equipment was awarded to TTS Theatertechnische Systeme, who, for the first time ever, relied entirely on PC-based control technology from Beckhoff with EtherCAT connectivity throughout for this complex project.

Up to 14 different performances take place each week in the Schauspielhaus of the State Theatre in Nuremberg. This is possible only with ultramodern stage technology, with lifting podiums, computer-controlled flies and turntable, as well as state-of-the-art lighting technology. For this reason the decision was made in favor of a general overhaul of the theatre: apart from the reception area, the renovation covered the seating and auditorium as well as the entire understage/overstage machinery. TTS GmbH was commissioned to carry out the entire renovation, from the steelwork through to the electrical and control installations. Specializing in technical theatre systems, TTS GmbH is based in Syke in north Germany and has been active in theatre and stage technology for 20 years and has used Beckhoff components since 2002.

EtherCAT – high-speed Ethernet as the higher-level bus system

The stage control is subdivided into different task areas and functional areas, for which various Beckhoff Industrial PCs and the EtherCAT bus system are used throughout. (see page. 31) The main controller is a TTS computer, which is implemented as a cable-redundant EtherCAT master. Safety functions are controlled via software specially developed for theatres. The back-up master computer is a Beckhoff C6340-0020 control cabinet Industrial PC running TwinCAT I/O software, which takes control of the cable-redundant EtherCAT network in the event of failure of the main computer.

Three Beckhoff C6920 control cabinet Industrial PCs with customized operating panels are in use on the main and auxiliary control consoles; four more Industrial PCs control the understage/overstage machinery.



© Theatertechnische Systeme GmbH

The stage area is visualized and operated via software specially developed by TTS.

© Beckhoff

TTS has been using Beckhoff components since 2002. "The use of local I/O peripherals from Beckhoff enables us to tailor our systems precisely to the needs of our customers. The successful introduction of the Bus Terminals was followed by a switch to Beckhoff Panel PCs and TwinCAT automation software," explains Frank Kremer. "In the last step, which was the search for a bus system to suit our purposes, we decided on EtherCAT, which encompasses the most important characteristics for us: real-time capability, high bandwidth, cable redundancy and impressive diagnostic properties."

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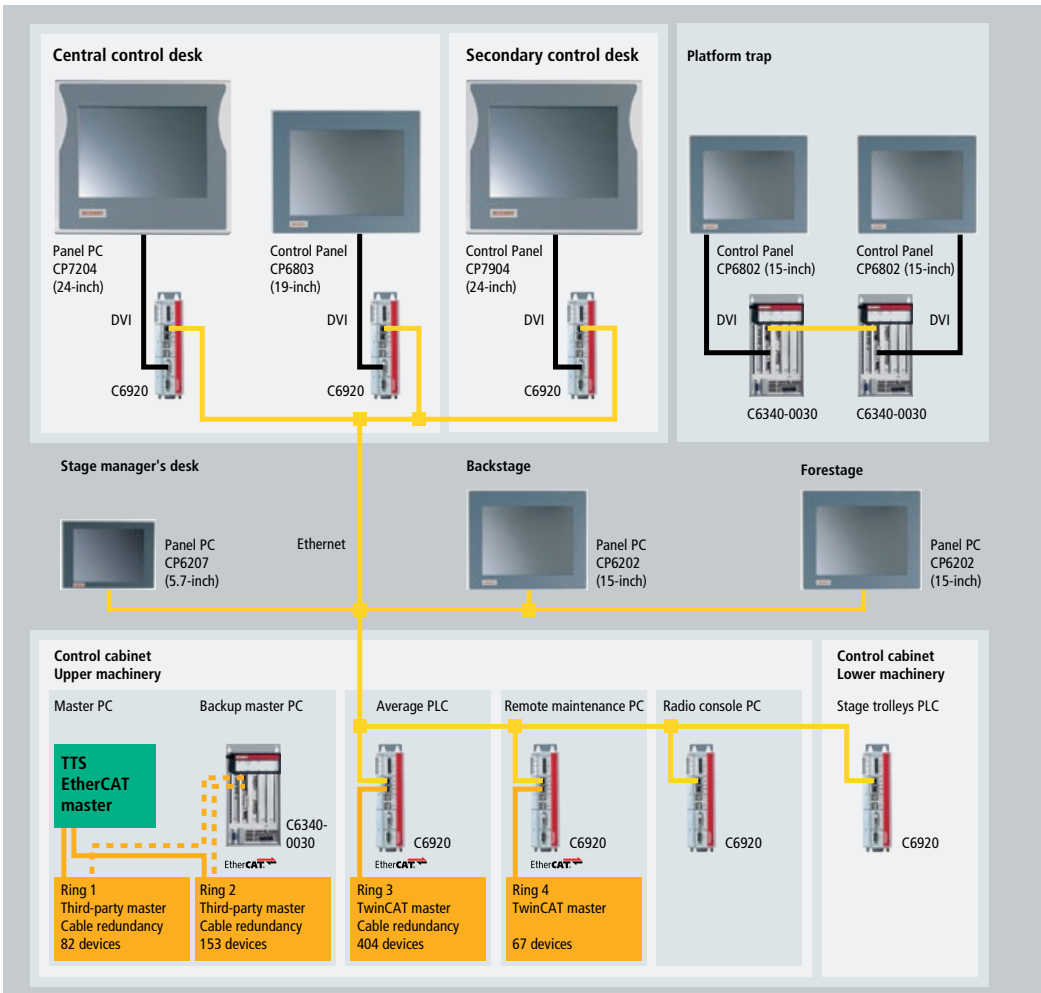
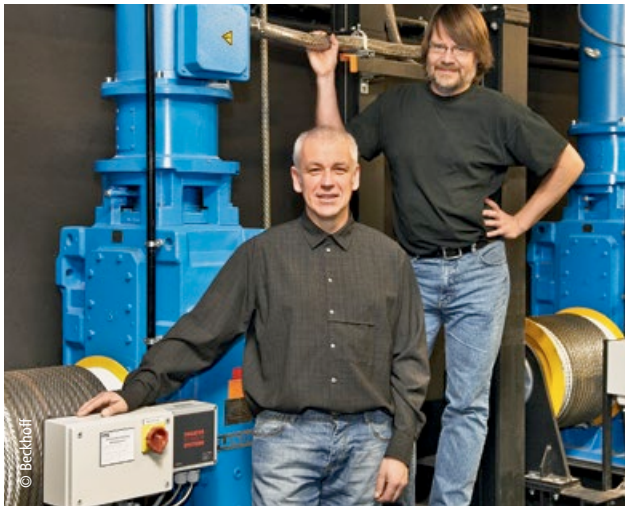


Customized Beckhoff control panel on the main control console. The 24-inch display provides the stage technician with an overview of the entire system without scrolling the screen.

Hans-Helmut Mandel, Beckhoff Hanover Sales, supervised the implementation of the project in close cooperation with TTS Theatertechnische Systeme: "One of the absolute highlights of this application is the EtherCAT redundancy, which guarantees maximum availability."



Frank Kremer, project manager at TTS Theatertechnische Systeme and Ole Sörensen, TTS software development

Three CP6202 and CP6207 Panel PCs are responsible for the control of the stage manager's console, the main stage and the forestage. The lowering of the platform is controlled by two C6340 control cabinet PCs with detached 15-inch panels.
More than 5000 I/O points are distributed around the stage area; these are monitored and controlled via 700 EtherCAT Terminals which are divided into four individual EtherCAT I/O strands or rings:

- Ring 1: TTS controller (C6340 Backup PC), cable redundancy: 82 devices
- Ring 2: TTS controller (C6340 Backup PC), cable redundancy: 153 devices
- Ring 3: Beckhoff C6340 IPC with TwinCAT master, cable redundancy: 404 devices
- Ring 4: Beckhoff C6920 IPC with TwinCAT master: 67 devices

The entire system can be controlled wirelessly from different control consoles, which are stationary, mobile or portable, depending upon the version. Eight customized control panels with touchscreen functionality are used, some with an integrated or a detached Industrial PC and display sizes ranging from 5.7 to 24 inches.

Scenery changes with the curtain open

Following the complete rebuild of the stage, the Schauspielhaus in Nuremberg now has 47 machine hoists, ten point hoists and four lowering devices (podiums), which can be moved independently of each other. The stage has a total area of 20 m x 35 m, wherein the main area, the four movable podiums, takes up a total area of 10.5 x 12 m. Each podium is equipped with a so-called tilting cover, which serves to tilt the entire podium surface by up to 10 degrees. In each tilting cover there are seven trap doors with electric drives, which enable the opening of the stage floor. Two lowering platforms can be placed on the lug subpodium of the podium under the trap doors. In addition, there is a foldable stage wagon with an integrated turntable of 10 m in diameter and a weight of 20 tons. If the turntable wagon is not in use, it is folded up at the rear of the stage and pulled upwards into a parking position. The lifting/folding movement is performed by a hydraulic cylinder that can pull up to 60 tons.
The technical functions of the stage offer a wide range of new possibilities for performances. One example of this is the open transformation of the stage, i.e. the scenery can be changed with the curtain open. To this end, the stage technician selects previously created movement sequences (so-called transformations) on the operator interface and subsequently executes them. Thus complex movements on the stage can be carried out at the push of a button. All driving modes are synchronized, so that synchronous movements between the understage and overstage machinery are easily possible. "Theatre operators place great importance on safety and very high availability of the controller. Redundant EtherCAT bus masters and EtherCAT with cable redundancy have been used in order to guarantee compliance with the SIL 3 safety requirements," explains TTS project manager Frank Kremer.

EtherCAT provides precisely synchronized movement sequences

There is an axis computer for each of the drives that need to be controlled, regardless of whether it is a backdrop hoist or a point hoist; a total of 70 EtherCAT drives were installed for this. The central computer from TTS controls the entire drive equipment. Each axis computer is responsible for the positioning and monitoring of the drive axis assigned to it, wherein it receives its drive commands and setpoint values from the master computer via a bus system. "With this latest controller generation we have used EtherCAT throughout as the bus system. EtherCAT combines the advantages of high bandwidth with real-time capability for the synchronization of the drives and with higher availability due to the cable redundancy characteristics," comments Frank Kremer.
The dual-channel master computer evaluates the input data from the various control consoles and the drive commands from the individual drive levers. It also relays the data to the axis computers and controls the entire data communication of the controller, adherence to specified movement sequences and the positioning of the axes. The axes of the overstage and understage machinery can be controlled simultaneously from the master computer so that, for example, a podium and a backdrop hoist resting on it can be driven synchronously.

Everything available at a glance

"In conclusion, it can be said that our requirements and functions have been entirely fulfilled by the new installation," confirms Florian Steinmann, stage inspector at the Schauspielhaus in Nuremberg: "Due to the elaborate decorations and the increasingly complex and numerous transformations of the stage area, we are well equipped for the future, too, with the new stage machinery. The 24-inch displays provide an overview of the entire stage without scrolling the screen. The operation and monitoring of the complex system has become much simpler and is more user-friendly as a result."

Further information:
www.ttssyke.de
www.staatstheater-nuernberg.de

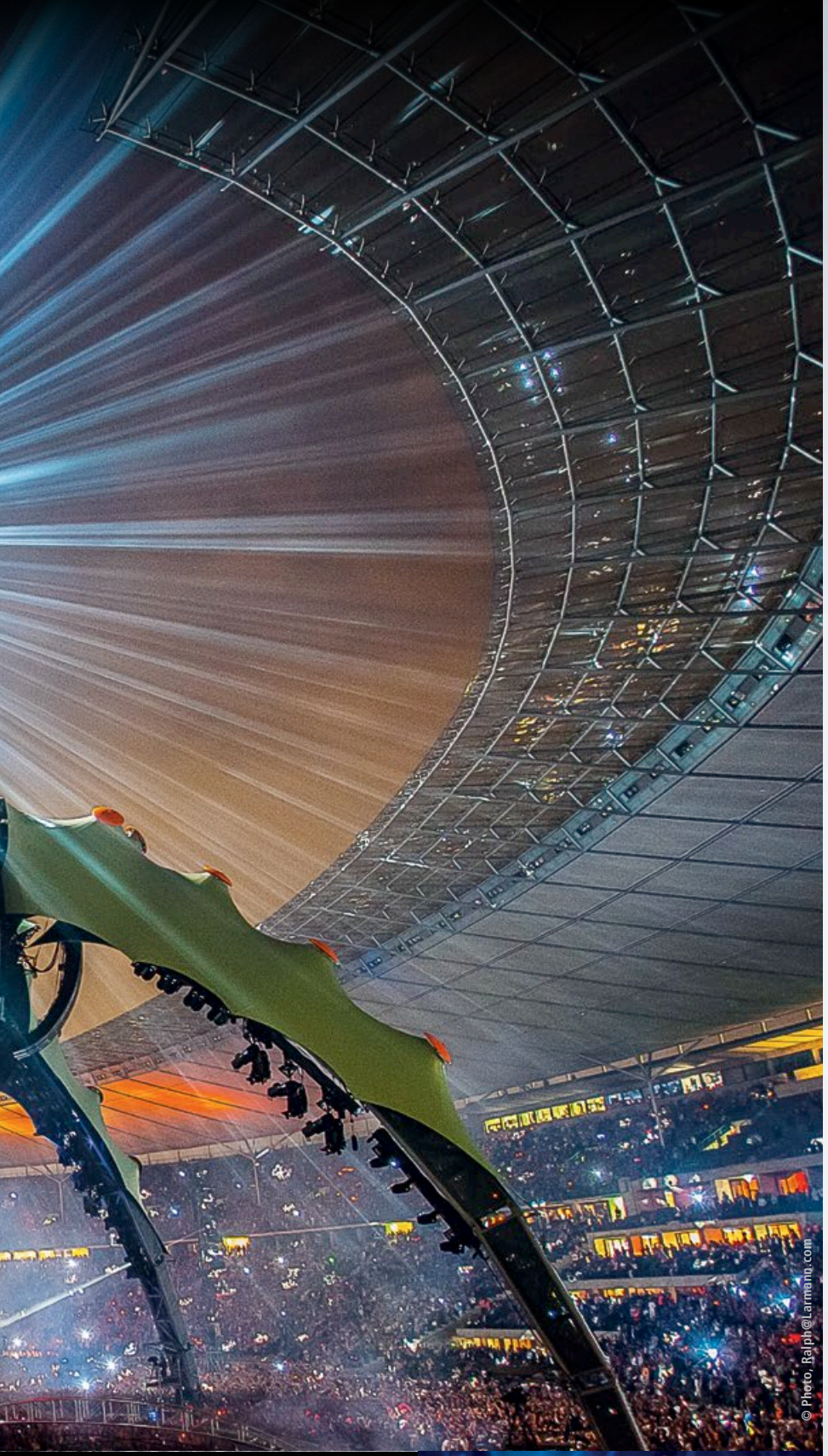
Show and concert industry references

U2 360° Tour

MetLife Stadium, NJ, Bockstiegel Automation/GTG GmbH, Germany

© Bockstiegel Automation/GTG

Aquagraphic® Aquatique Show, France



References for show and concert industry, selection

Concerts/tours

- SGPS/Show Rig, NV, USA:
  - Sir Paul McCartney
  - Justin Bieber
  - Miley Cyrus
  - Beyonce
  - Aerosmith
  - Justin Timberlake
  - Guns N' Roses
  - Rihanna
- Sigma Services Inc., FL, USA
- TAIT/Fisher Technical Services, NV, USA:
  - U2
  - Lady Gaga
  - Bon Jovi
  - Black Eyed Peas
  - Shakira

Music festivals/dance events

- SGPS/Show Rig, NV, USA:
  - Coachella Music Festival
  - EDC – Electric Daisy Carnival
- Statecore Innovative Entertainment Technology BV, NL:
  - "Sensation White", Amsterdam, Netherlands
- The Factory CVBA – VSO, Belgium:
  - "Pukkelpop" Festival, Hasselt, Belgium

Shows

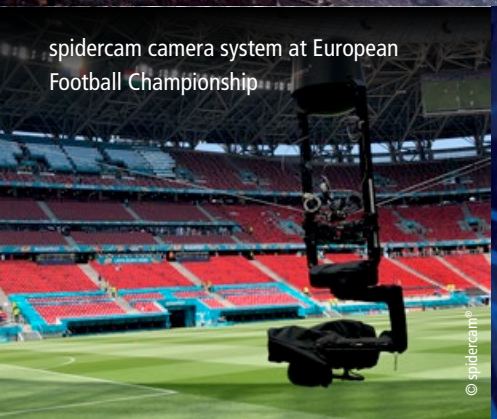
- Ehrlich Entertainment, Germany:
  - various magic shows with water effects, Germany
- Flying by Foy, NV, USA:
  - "A New Day", Caesar's Palace, Las Vegas, NV
- SGPS/Show Rig, NV, USA:
  - Cirque Arenaline, Hongkong, China
  - J-Lo, Las Vegas, NV, USA
  - Mariah Carey, Las Vegas, NV, USA
- Skjonberg Controls for Entertainment Industry, CA, USA:
  - various shows

Awards/contest shows

- SGPS/Show Rig, NV, USA:
  - Academy Awards/Oscars
  - Grammy Awards/Emmy Awards

Sporting events

- Böckstiegel Automation/GTG GmbH, Germany:
  - MetLife Stadium, NJ, Super Bowl
- SGPS/Show Rig, NV, USA:
  - NBA All-Star
- Sigma Services, FL, USA:
  - Cleveland Cavaliers
- spidercam GmbH, Austria:
  - mobile camera system spidercam®
- TAIT/Fisher Technical Services, NV, USA:
  - various sporting events



spidercam camera system at European Football Championship

"Sensation White", Eventions Products, NL

PC-based control of 1D/3D microphone winches delivers outstanding sound

High-precision microphone positioning for concerts and recordings

SALZBRENNER media is a system provider for professional audio, video and media technology used in applications worldwide. The company, which is headquartered in Buttenheim, Germany, has more than 60 years of experience in designing, planning, building, installing and maintaining sophisticated projects in the field of entertainment technology. For the development of its 1D and 3D microphone winches, SALZBRENNER media selected Beckhoff as its control supplier. Using TwinCAT 3 software and Embedded PCs, the company built a space- and cost-saving control solution for the PLC, drive and safety components.

© SALZBRENNER media

Eliminating the need for local winch controllers brings cost savings and keeps the winch housings small with dimensions of only 60 by 60 by 20 cm. This is particularly appreciated in theaters and event facilities, where space is usually at a premium.

29 1D winches and one 3D microphone winch system in the performance hall of the WDR in Cologne ensure high-quality, precisely targeted audio recordings. Beckhoff drive technology is used to control and move the freely positionable flying frame on which seven microphones are installed.

© WDR Köln; Ingo Lueck

At the 2019 Stage|Set|Scenery trade fair in Berlin, SALZBRENNER media presented with its MIC fly 1D/3D microphone winches, a newly developed system that ensures high-quality audio recordings through the precise use of microphone positioning technology in performance venues and studios. Its special feature is the cascading of the individual winches, which allows for 3D microphone travel in addition to simple up and down movements. "The first deployment of a four-point 3D winch was as part of a new audio system in the historic Klaus von Bismarck Hall in Cologne, the concert facility of the WDR broadcasting center," says Stefan List, project manager at SALZBRENNER media. The system comprises a group of four synchronously operated winches. They move a flying frame on which up to eight microphones (two per winch) can be installed above the three-dimensional workspace. In the WDR facility, this covered an area of 7 by 9 m (23 by 29.5 ft) horizontally and 3 m (10 ft) vertically. The 3D travel of the microphones makes it possible to place them precisely above the orchestra and/or the individual instruments. The entire system for the WDR's concert hall comprises 29 1D winches for individual microphones and one 3D winch with seven microphones.

Integrated concept for control, drive and safety technology

"We have been working with Beckhoff for roughly two years now," says Stefan List. "We first got in touch with Beckhoff at an entertainment industry fair when we were looking for a control solution for our winches. We were impressed by the PC-based control solution's high level of integration, which allowed us to combine sequential control, drive technology and safety technology in a single platform. As a specialist for custom-tailored solutions, we were looking for a control technology that would be scalable in terms of performance and design to give us the flexibility we needed to realize the individual requirements of our customers. For the 3D winch control, we only needed to adapt the software."

For the first time, the new audio system in the WDR's historic Klaus von Bismarck Hall in Cologne includes a four-point 3D microphone winch system from SALZBRENNER media.

With more than 2,500 seats, the Baden-Baden Festival Hall is Germany's largest opera and concert hall. As part of the renewal of the hall's roughly 20-year-old sound and video systems during the 2020 summer break, a MIC fly 3D microphone winch system was installed to ensure highly precise audio recordings.

A Beckhoff CX5130 Embedded PC is used as the central controller for up to five of the MIC fly 1D winches. For installations with more winches, SALZBRENNER media uses the more powerful CX5140 Embedded PC with an Intel® Atom™ CPU (1.91 GHz, 4 processor cores). TwinCAT 3 PLC, HMI Web and NC PTP software cover all necessary functions ranging from sequencing to visualization to motion control. The compact drive solution consists of an EL7221-9014 EtherCAT servo terminal with One Cable Technology (OCT) and integrated safety technology (STO) as well as an AM8100 servomotor that is specially designed for use with the servo I/O modules.

The 3D winches are centrally controlled via a CX5120 Embedded PC, which communicates with the four winches via the powerful EtherCAT industrial Ethernet fieldbus. The TwinCAT-based software tool, which SALZBRENNER media developed for controlling the individual winches, could be extended for the 3D winches simply by adding NC-I and kinematic functionalities. Only the input and output terminals are installed in the winches themselves. "Through the centralized control approach and the coordination of the axes with TwinCAT NC I, they can be positioned with a precision of less than 1 cm. The possibility to dispense with local controllers also brings cost savings, and the winch housings could be made quite small with dimensions of 60 by 60 by 20 centimeters," says the project manager. The small size is particularly appreciated in theaters and event facilities, where space is usually at a premium.

"For the first project in the WDR hall, we installed an AX5000 EtherCAT Servo Drive with integrated safety technology and the AM80xx servomotor with OCT for the 3D winches. For subsequent projects in the Baden-Baden Festival Hall and the broadcasting hall of Saarland Radio in Saarbrücken, we switched to the compact drive technology from Beckhoff for everything. This change was seamless because the same software can be used for all the different drive systems," explains Stefan List. The operation of the winches is web-based via touch panels with a user interface that is easy to use for the stage staff as well as the musicians. Up to 200 presets can be saved and called up. The control panel can be permanently installed or mobile; it connects to the local area network.

TwinCAT Kinematic Transformation handles complex cable pull calculations

Developed by Beckhoff and SALZBRENNER media, the software converts the space coordinates into specific rope lengths for the 3D winches to position the microphones based on the respective sound requirements. "We adjust the microphone positions based on the performance requirements or the instruments in the orchestra," explains Stefan List. The control challenge involves, among other things, making sure that the wires holding the frame with the microphones are kept taut. Since each wire must be kept at a different length, these calculations are highly complex. "With the cable pull kinematics that Beckhoff has developed and made part of the TwinCAT kinematics library, they no longer have to be calculated in the PLC but can be called up directly from TwinCAT NC. This simplifies programming considerably," explains Franz-Josef Klaus, engineer for motion control application software at Beckhoff.

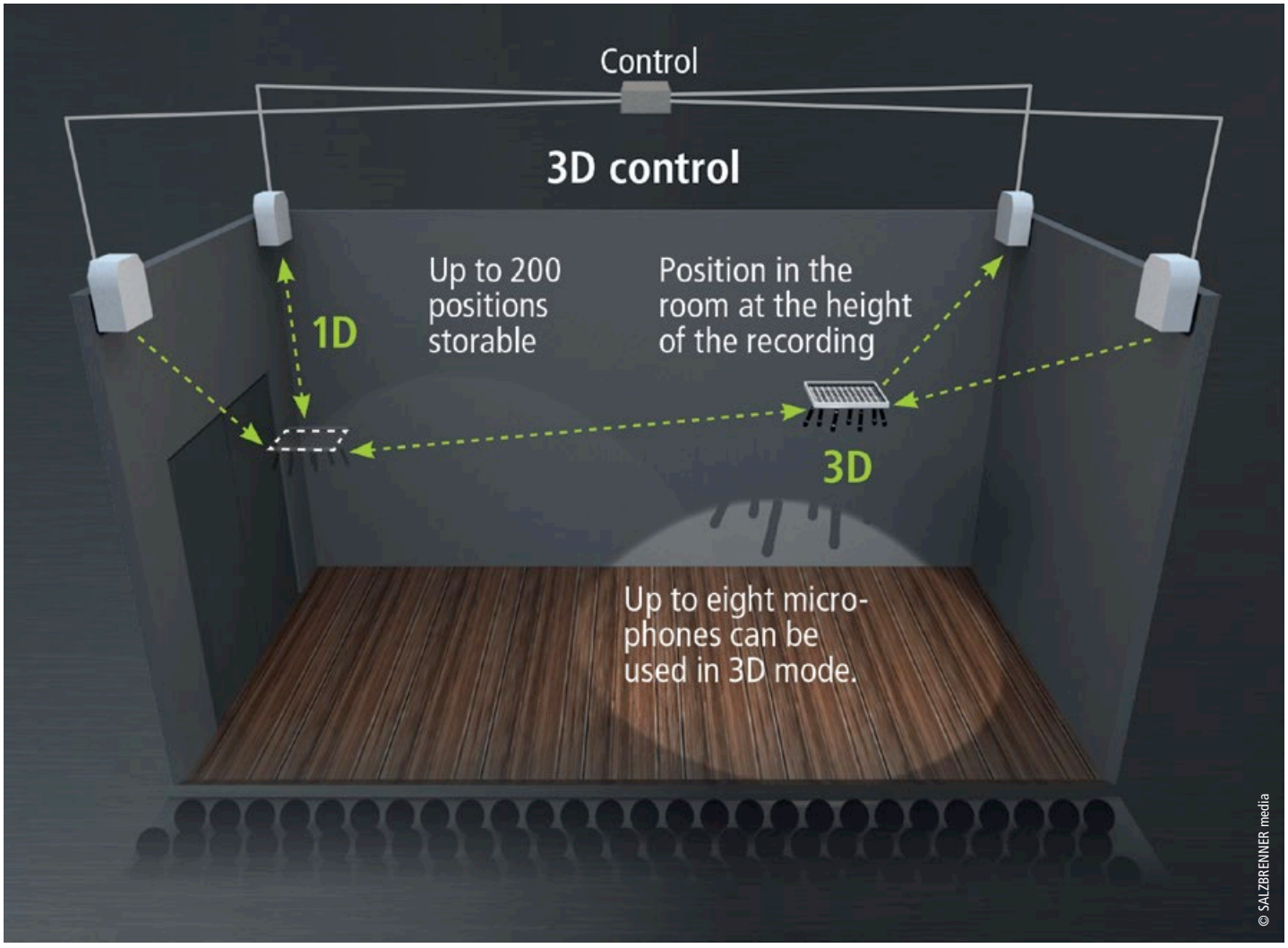


Diagram of the winch system for stage microphones

TwinSAFE answers demanding stage safety requirements

"A unique selling point of the MIC fly winch is its compliance with the demanding DEKRA safety standards that stage technology applications must meet," says Stefan List. Since the microphone winches are installed above the orchestra, they are equipped with a complex safety system consisting of programmable acceleration and deceleration ramps, slack-line protection, uncoiling and overload protection as well as electronic cable monitoring. "The integrated safety control from Beckhoff allowed us to implement a very compact solution," continues the project manager. "It consists of an integrated EL1918 8-channel TwinSAFE input terminal with TwinSAFE Logic and the EK1914 EtherCAT Coupler with integrated digital standard and safety I/Os. The cable tension measurement, which monitors the force minimum and force maximum directly on the line, is carried out by a force sensor that is analyzed by the EL3356-0090 TwinSAFE SC input terminal. The winch speed monitoring is carried out by an incremental encoder being read by the EL5151-0090 TwinSAFE SC incremental encoder interface. Comparing the results of the safe speed sensor with the actual drive rotation ensures a high level of safety. Since the safety signals are also transmitted over EtherCAT, only a single cable must be run to each winch.

With Beckhoff, we have a partner who is experienced in entertainment applications of all sizes and whose system toolbox offers many interfaces that are relevant for our industry. SALZBRENNER media implements a broad range of media and stage applications, and we will surely use Beckhoff technology for many more projects in the future," concludes Stefan List.

Further information:
www.salzbrenner.com

"Sensation 2012" – A mega dance event tours the world

Beckhoff technology ensures that show flows smoothly

40,000 visitors dressed entirely in white came to the premiere of the "Sensation 2012", which took place on 7th July 2012 in the Amsterdam Arena. – Apart from the music it is above all the special lighting and stage effects that make the "Sensation" a mega event of a special kind. Control technology from Beckhoff operating in the background ensures the smooth and safe technical flow of the show, for which the Dutch companies Statecore and Eventions Products are responsible.

The "Sensation" has developed within a decade into the world's largest dance event. The success story began in the year 2000 in Amsterdam; the dance party has been touring the world since 2008 and has in the meantime enthralled fans in 18 countries on four continents. Apart from the DJs there are additional acts and various special effects during the party. A further special feature of the "Sensation" is that the visitors must come in white clothing. This is intended to create a feeling of solidarity and equality in the audience; for the show the effect of this is that white can be optimally illuminated and coloured light is also perfectly reflected.

The sophisticated technology behind the show effects is the work of Eventions Products BV and Statecore BV, who are specialists for innovative entertainment technology. "In 2011 we were commissioned by Eventions Products to develop the show sequence for the 'Sensation 2012' ", says Erik Berends, founder of Statecore, relating how the cooperation began.

Beckhoff servo technology ensures a smooth show

According to Erik Berends, the Beckhoff technology is used mainly for the special effects, such as the six flying dancers, one of the highlights

Apart from the DJs there are additional acts and various special effects during the party, such as people "floating" through the air.

of the "Sensation 2012". The women are suspended in harnesses on steel ropes and float through the entire room via a rail attached to the ceiling. The movement takes place with the assistance of six carriages, on each of which a rope hoist with steel ropes is mounted. The carriages and rope hoists are driven by asynchronous motors and the Beckhoff AX5xxx EtherCAT Servo Drives. In order to realise movement in both the horizontal and vertical directions, a motion controller based on TwinCAT was developed. TwinCAT NC PTP runs on the Beckhoff CX5020 Embedded PC. In addition the controller is also used for the movement of props and lighting gear.

Safety plays a large role

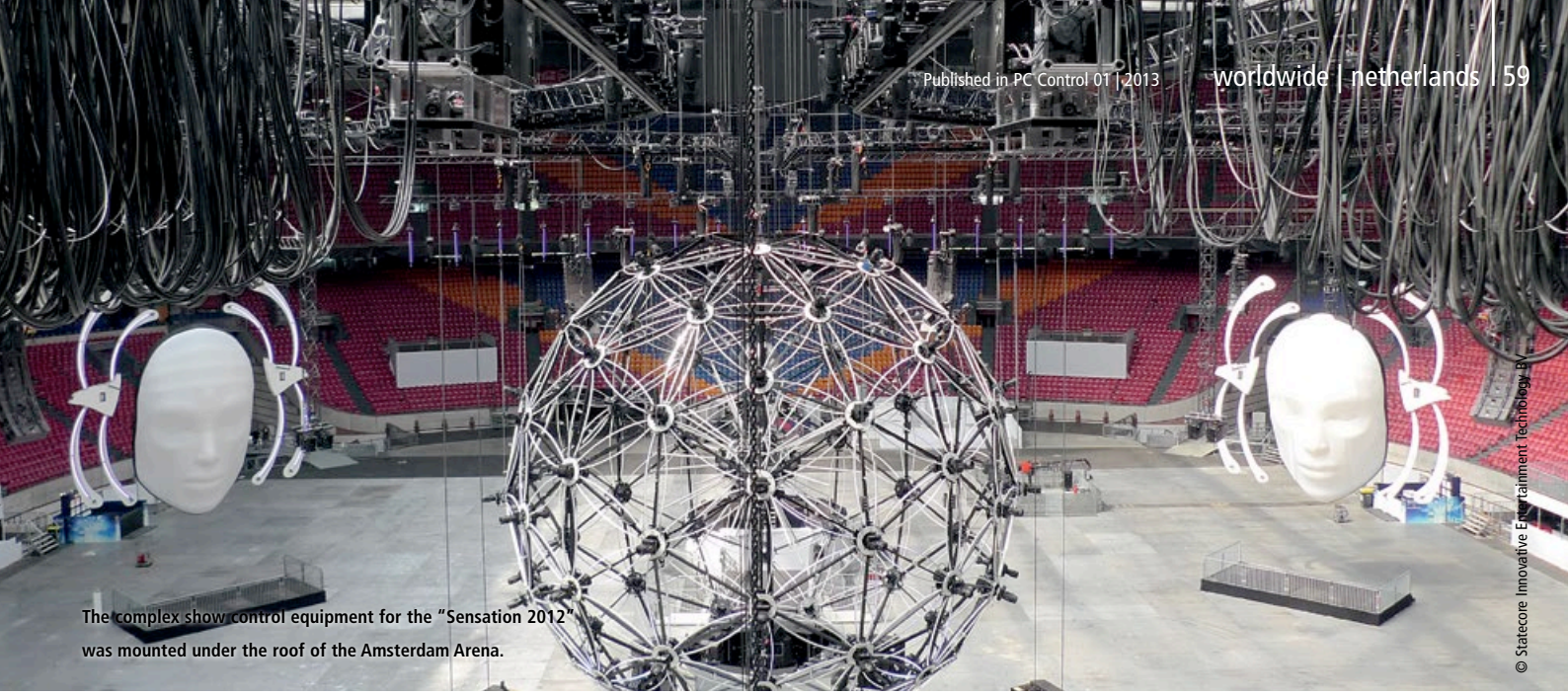
In the "Sensation" there is a large audience to be dealt with, while at the same time the safety of the artists must be guaranteed. "That demands correspondingly sophisticated safety technology", says Erik Berends. The safety-relevant components of the Beckhoff controller employed meet the specifications of the SIL3. The AX5805 safety option card is used in addition to the safety controller for the Servo Drives. The general safety controller is the EL6900 TwinSAFE PLC from Beckhoff; the safety-relevant signals are read-in and output via the EL1904 and EL2904 safety terminals. "All emergency stops must guarantee safety at several levels", explains the Statecore Managing Director. In the case of the drives the STO function (Safe Torque Off) is triggered via the AX5805; the brakes are activated via the EL2904 safety terminals, independent of the drive.

Outstanding communication

The complete HMI for the show runs on an iMac. "We have been using Apple for over ten years now, due to its user friendliness and stability", Erik Berends reports. The operating interface was written and designed in Xcode, the development environment for the Mac. Joysticks and pushbuttons are employed for the operation; they are connected to the control PC via Beckhoff terminals using the EtherCAT network. Communication between the Mac and the Beckhoff Industrial PC takes place over Ethernet using a specially written

The premiere of the Sensation dance party 2012 took place on 7th July 2012 in the Amsterdam Arena. 40,000 visitors dressed entirely in white participated in this gigantic dance event with special lighting and stage effects.


© Eventions Products BV



The complex show control equipment for the "Sensation 2012" was mounted under the roof of the Amsterdam Arena.

© Statecore Innovative Entertainment Technology BV

network protocol. Communication is handled by the Beckhoff controller on the basis of the TwinCAT Supplement TCP/IP Server.

Trouble-free sequence

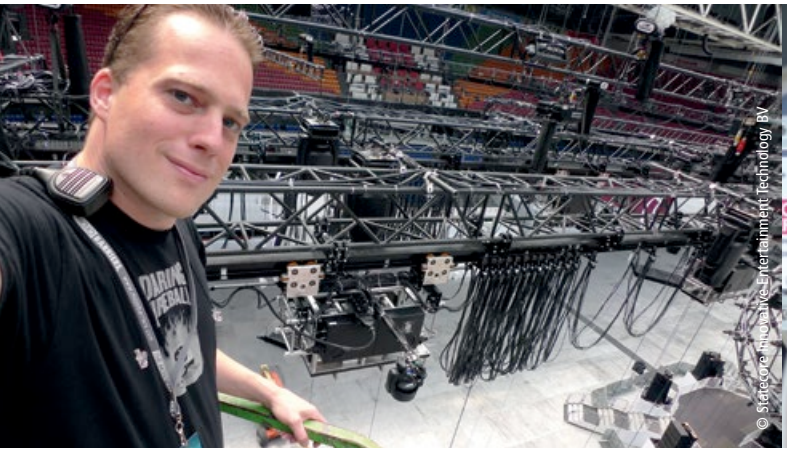
Statecore is very satisfied with the PC- and EtherCAT-based Control solution. "Due to its openness and universality it is extremely well suited to the tasks that we face with a show like the 'Sensation'. The Beckhoff product range is so versatile – even if you only consider the large number of I/O signals and fieldbus connections – that we can realise the most diverse solutions with it", emphasises Erik Berends. With TwinCAT both the dynamic movement controllers and the safety applications can be developed extremely well. Statecore also attaches great importance to the reliability of the controller. "The expectations of a large show, with expensive artists and a large audience, are very high nowadays and that means a great deal of stress. Malfunctions of the controller are the last thing we need. Therefore, everything that happens in front of and behind the stage must run absolutely smoothly", comments the Statecore Managing Director.

Simple, user-friendly operation

Erik Berends names a series of advantages which, in his view, have resulted from the use of the Beckhoff control platform: "The execution of difficult and complex motion sequences is now much simpler for the people who control the show. We control twelve axes at the same time with the Embedded PC. The control console encompasses all important pushbuttons and joysticks for the control of the mobile objects and the lighting. There is also an emergency stop button on the console for triggering a safe stop. The movements visualized on the iMac. However, the biggest advantage is the simplicity and user-friendliness of the solution as a whole: that is extremely important in show business – and in particular for an event that tours the whole world."

Further Information:

www.statecore.nl
www.eventions-products.com
www.ial.nl
www.beckhoff.nl



Erik Berends, Managing Director of Statecore, in the Amsterdam Arena during the construction of the "Sensation 2012"

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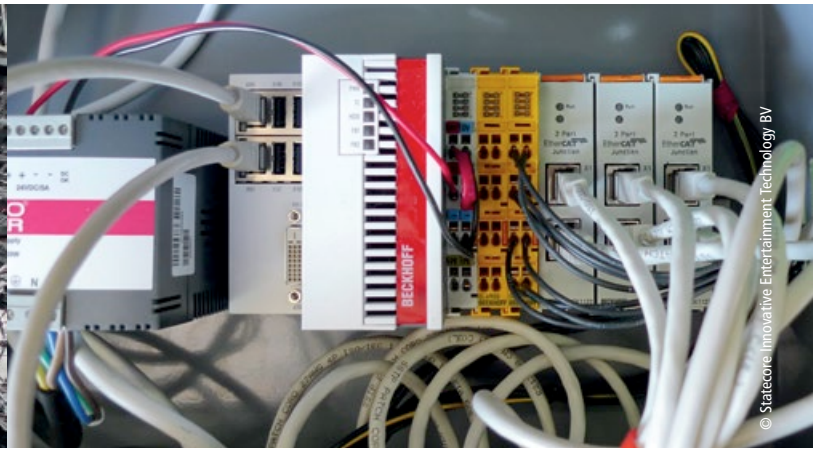


The Beckhoff control platform: a CX5020 Embedded PC with TwinSAFE safety terminals and EtherCAT Terminals

© Statecore Innovative Entertainment Technology BV

 Published in PC Control 04 | 2011

World class concert acoustics with Beckhoff automation technology

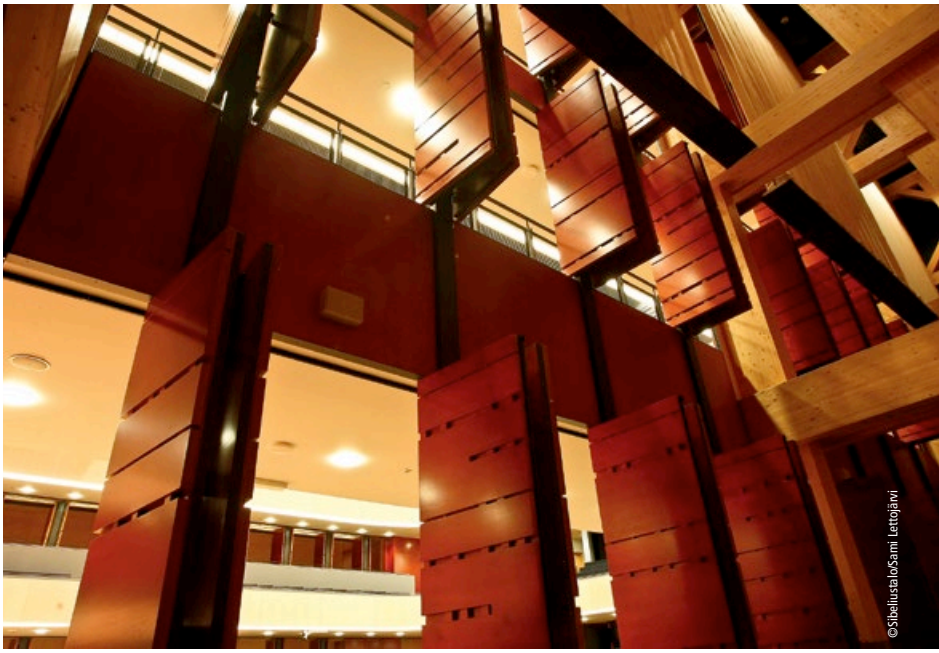
The Sibelius Hall in Lahti, Finland is renowned for its excellent acoustics, which were designed by the American acoustic designer Russell Johnson. It is the dynamics of the acoustics that are so special: mobile wall elements, so-called acoustic doors, make it possible to change and to dynamically adopt the room reverberation to suit the performance and the desired sound quality. As part of a controller relaunch on the basis of Beckhoff automation components, the adjustment of the acoustic doors has been optimized so that concert audiences can now enjoy perfect sound.

The Sibelius Hall was built with the ambitious goal of creating unique acoustics, despite a comparatively low budget. In the implementation of the building, the architects Hannu Tikka and Kimmo Lintula made particular use of a natural material: wood. The side walls of the cuboid 1,299-seat concert hall are made of veneered timber shells, which are filled with sand. Due to their solidity, the walls can also reflect low tones. In addition, the concert room is flanked by so-called echo chambers, which are as high as the building itself. They are equipped with 188 mobile wooden doors, with which the reverberation time of the sounds can be adjusted, depending on the effect desired by the musicians.

Beckhoff Embedded PC optimizes the hall acoustics

The American company Artec Consultants Inc., which was founded by Russell Johnson and whose name is synonymous worldwide with the realization of concert halls, was commissioned to design these extraordinary acoustics. However, during the use of the Sibelius Hall, which was

The acoustics of the Sibelius Hall in Lahti in Finland, which were designed by the legendary acoustic designer Russell Johnson, are world class. The side walls of the over 1,299-seat concert hall are made of veneered wooden shells filled with sand, which ensure optimum resonance.



The Sibelius Hall is flanked by wall-high echo chambers, which are equipped with 188 mobile acoustic doors. A Beckhoff Embedded PC from the CX series controls the positions of the acoustic doors via the KL2612 relay terminals. The reverberation time can be precisely adjusted according to the resonance effect desired by the musicians.

completed in 2004, it was determined that the solution for the automatic control of the acoustic doors was unsatisfactory. As a result, the Finnish company Keraplast Oy, based in Orimattila, Finland, was commissioned to relaunch the controller. Keraplast installed a Beckhoff Embedded PC from the CX series as the central controller, via which the 188 door elements are controlled. Relay Bus Terminals distributed to five PROFIBUS Bus Coupler stations control the asynchronous motors. Feedback is provided by digital input terminals, which detect the positions of the doors and pass them on to the controller – a solution that is as simple as it is inexpensive. "Beckhoff was chosen as control system provider because of really good pricing and industrial quality components. Now, the system has been proven to be really reliable in several events that have been held in the concert hall. Even though system layout is rather simple, the huge amount of controlled doors made an extra effort for the realization", says Keraplast Project Leader Toni Potinkara.

The sound experts at the Sibelius Hall are satisfied with the results: The doors can be positioned accurately and with high repeatability, individually or in groups, so that the room is widened or narrowed depending on the desired resonance. In this way the reverberation time can be increased up to "cathedral reverberation". In addition the CX has sufficient memory space to save a large number of door positions for different performances. A Beckhoff C5102 Industrial PC serves the musicians as a web server in order to access the position of each individual acoustic door.

Further information:

www.sibeliustalo.fi/en/sibelius-hall
www.keraplast.fi
www.beckhoff.fi

 Published in PC Control 02 | 2011

Pegasus: Precise flying effects for stage and show technology

Flying by Foy lets the stars fly

The entertainment industry is always growing, and with it the demand for surprising and ever newer special effects with which to astound the public. Flying sequences in film and live events are a main element in the director's bag of tricks. For over 50 years, Flying by Foy, a company based in Las Vegas, USA, has specialized in flight effects for performers. Even though the equipment is hidden behind the scenes as much as possible, automation of flight simulation requires a sophisticated control system, which Flying by Foy has implemented based on PC Control and EtherCAT from Beckhoff.

Over the years Flying by Foy has provided flight effects for over 50 Broadway shows, live events for the Smithsonian Museum in Washington D.C., for the Olympics in 2004 and other sporting events, as well as for numerous live entertainment events, theater, films etc. "We provide intuitive and easy to use controls so the operator can easily create dynamic and breathtaking flying performances without requiring knowledge of the automation's inner workings," explained Matt Bevacqua, Technical Designer at Flying by Foy.

EtherCAT sets no limits on Motion Control

In mid-2008, Flying by Foy decided to launch a major upgrade of their Pegasus Automation control products, to improve coordinated positioning and enhance the safety functionality. "In contrast to a crane moving containers at a shipyard where the system is continuously trying to avoid swinging, for example, Flying by Foy uses dramatic swinging and dynamic motion to produce exciting flying effects," Matt Bevacqua said. Free-form flying techniques require

Angel – Celine Dion "A New Day" – © Tomasz Rossa

considerable pendulum effects and significant swinging actions that cannot be easily duplicated by a gantry or a four point system with tight load control.

The new Motion Control and automation system for Pegasus must take this into account and provides the ability to safely implement dynamic, interpolated motion profiles. The previous generation of Pegasus Automation utilized a motion controller and inverter in one package, i.e. the drive with integrated intelligence, handled the positioning tasks and velocity control itself. "That worked fairly well, but we were limited by the legacy fieldbus infrastructure when communicating with the equipment," reported Matt Bevacqua. "This severely limited our applications since our systems often require multiple master controllers. It necessitated a level of coordination that was not possible with a standard fieldbus. We required a solution that would essentially allow us to write our own communication protocol."

Integrated control platform for all product lines

Flying by Foy currently offers three products lines: the DW-V3 performer flying winch, the IW-V winch that is built into a standard 12" box truss and is a useful solution for rock & roll touring productions and for quick load-in requirements at arenas, and the BR-X units with wireless control units that are pods which can traverse wirelessly along I-beams and can lift and rotate to maneuver. Windows-based Pegasus Automation Software acts as a traffic controller for all three controller platforms offering a user-friendly interface for writing, editing and saving data.

All three Flying by Foy product lines use a Beckhoff C6515 Industrial PC with Intel® Celeron® M processor, TwinCAT NC PTP Software and EtherCAT I/O Terminals. "The C6515 form factor works extremely well for fitting inside the rack while allowing internal heat to ventilate harmlessly out of the rack," said Matt Bevacqua. "A typical implementation may have five or six racks all together, so keeping the hardware well-ventilated is a must. Flying by Foy used the Industrial PC from Beckhoff in summer 2010 in an outdoor production of Tarzan located in the desert in Ivins, Utah where it was routinely well over 100° F (38° C).

Alternatively, Flying by Foy uses the CX9010 Embedded PC instead of the C6515. "Since TwinCAT is the integrated software platform for all Beckhoff controllers, all we need to do is transfer our control software from one Beckhoff hardware type to the other," explained Matt Bevacqua and continued: "Another benefit of using TwinCAT is that it allows us to write our own applications in the same Windows CE operating environment as many of our other system tools. We also take advantage of TwinCAT's impressive adaptability, I/O linking features and motion control function blocks."

Flying by Foy programs the majority of their drivers and user interfaces using Microsoft Visual Studio®. "We're looking forward to working with the newest software generation from Beckhoff, TwinCAT 3 which is integrated in Visual Studio®," said Matt Bevacqua. "TwinCAT already gives us limitless flexibility to implement our own custom drivers into the Beckhoff system and adapt to constantly changing project requirements. Today we're not locked into any specific hard-ware so we can easily change over time if needed. In

Celine Dion, "A New Day": Show at Caesars Palace in Las Vegas. Flying by Foy has been producing flight effects on the stage and screen for over 50 years and giving film and music stars their wings.

© Flying by Foy

"We deliver intuitive and easy to handle controls, with which the operators can produce dynamic and breath-taking flight scenes," Matt Bevacqua, Technical Designer, Flying by Foy.

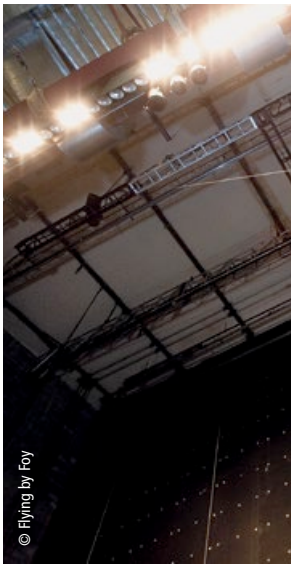
our business this is very important because our application demands are always evolving and lead times are usually extremely short."

EtherCAT – speaking the language of entertainment engineering

For the Pegasus Automation System's communication, Flying by Foy has taken a big step forward by using EtherCAT. "EtherCAT allows us to seamlessly communicate with nearly any available fieldbus," Bevacqua explained. "With the EL6751 CANopen Master Terminal, for example, we have a fully functioning CANopen master that's easily and cost-effectively implemented into the EtherCAT system. Even better, we can just as easily integrate other masters for PROFIBUS or DeviceNet, for example, to operate over EtherCAT."
Flying by Foy also utilizes the EL6851 DMX master/slave terminal for lighting control. "The ability to synchronize DMX lighting and Motion Control with EtherCAT greatly enhances our flexibility," explained Matt Bevacqua.

TwinSAFE ensures safety for operators and performers

Flying by Foy also guarantees operator and performer safety with the integration of TwinSAFE in the Pegasus system. "TwinSAFE has empowered us with an easy to implement safety solution by connecting the intelligent Safety I/O terminals on the same fieldbus and with the same cabling as our Motion Control," said Matt Bevacqua. "With TwinCAT, all motion limits are monitored. TwinSAFE is the safety controller that monitors all safety-relevant subsystems for our full line of hoists. As safety and motion data are transmitted over the same fieldbus, this eliminates additional cable runs. Also extending the safety controller is easily possible: With EtherCAT, if there is a need to add a safety function that wasn't originally planned, you only need to add a distributed TwinSAFE terminal and install an EL6900 Safety PLC terminal at the local control station."



XFC: Increased performance, decreased costs

XFC technology (eXtreme Fast Control), which is based on EtherCAT and PC Control, brings a further performance boost to Flying by Foy. With the ability to achieve I/O response times < 100 µs, EL1262 and EL2262 XFC terminals with oversampling from Beckhoff also play a role in the Pegasus Automation System. "XFC terminals are useful for replicating encoder signals for our flight simulation systems," explained Matt Bevacqua. With the Beckhoff standard encoder terminals it is possible to record positions in various different locations and to synchronize them using the distributed clock functionality. "Pegasus is able to read in an encoder position at one winch and, using XFC terminals, replicate that high frequency signal at a local station with an accuracy of about 10 µs and a delay of about 1 ms. XFC Terminals help us replicate these signals without having to run dedicated control lines, which results in considerable wiring and cabling savings."

Retrofitting made easy

"With one standard Ethernet cable run, we can bring essentially any type of data from any point in the venue back to our local Pegasus controllers," Bevacqua explained. "This simply wouldn't be possible with any other fieldbus system without a far more complicated wiring scheme and higher costs. With the EtherCAT bridge terminals, Flying by Foy can easily take I/O points from one system and transfer them over to another TwinCAT master so we can easily share motion

Flying by Foy's control solution is mounted in a 3.5" rack using a Beckhoff C6515 Industrial PC.

Test of a Pegasus automation system for simulating flight motion: Operator and performer safety are guaranteed by the integration of TwinSAFE in the controller.

© George Bodnar

Celine Dion "A New Day" – Piano Movers

axes with different masters. With TwinCAT, we have a completely software-based motion control platform, which means significant savings since we must constantly retool and change our equipment to suit our clients' wide range of artistic requirements."

Open for future developments

The 3rd generation of the Pegasus Automation System is flying to a great start, having been placed in over 100 axes of motion in the field. However, the Pegasus technology advancement to bring artistic concepts to life is by no means finished. Matt Bevacqua's upcoming plans for Flying by Foy include developments around the AX5000 EtherCAT Servo Drives. "Incorporating the AX5000 drives will give us a comprehensive, high performance solution that unifies the Pegasus controls under one advanced system architecture," Bevacqua explained. "With Beckhoff as our technology partner, Flying by Foy will continue to make creators' and directors' visions a reality – while ultimately, and most importantly, capturing the imaginations of their audiences."

Further information:
www.flybyfoy.com
www.beckhoffautomation.com

The housing design of the Beckhoff C6515 Industrial PC allows Flying by Foy to develop compact and, in regards to heat dissipation, efficient racks so that the heat is quickly dissipated when several of them are stacked on top of each other.

© Flying by Foy

The Pegasus automation software serves as the traffic controller for all platforms, in that it coordinates the functions of the various winches, hoists and wireless control units. TwinCAT NC PTP from Beckhoff controls the automation and motion requirements.

Unique applications references

"Kinetic Rain", Changi Airport, Singapore
MKT AG/ART+COM AG, Germany

"Time-dynamic model of Saxony",
SMAC, MKT AG, Germany

© Atelier Brückner/Michael Jungblut

"Breaking the Surface", Lundin Norway AS,
Scandinavian Design Group, Norway

© James Fox, Abida, Norwegen

References for unique applications, selection

Art installations

- MKT AG/ATELIER BRÜCKNER GmbH/TAMSCHIK MEDIA + SPACE GmbH, Germany:
  - State Museum of Archaeology in Chemnitz, Germany
- MKT AG/Art+Com AG, Germany:
  - "Kinetic Rain", Changi Airport, Singapore
- MKT AG/HB-Laserkomponenten GmbH, Germany:
  - 3D KineMatrix
- LightHive, London, U.K.

Media installations

- AquaDom, saltwater aquarium, Berlin, Germany
- Aquatique Show, Aquagraphic®, France
- as systems GmbH, Germany:
  - Waterdoor, Flimser Wasserwelten, Switzerland
- Ferry Porsche Congress Center, Austria
- GTG GmbH/Böckstiegel Automation, Germany:
  - Digital Tower, Changi Airport Singapore
  - Super Bowl, MetLife Stadium, NJ, USA
- Magical Production L.C.C., UAE:
  - Artificial waterfall, Dubai, UAE
- Microsoft Deutschland GmbH, Cologne, Germany
- MKT AG/HB-Laserkomponenten GmbH, Germany:
  - 3D KineMatrix
- Simtec Systems, Germany:
  - Digital Signage ScreenFlite®

Movable objects

- Frenckel clock tower, Tampere, Finland
- Milla & Partner GmbH, Germany:
  - Energy center, German Pavillon Expo 2010
- MKT – Fine Exhibition Engineering, Germany:
  - State Museum of Archaeology in Chemnitz, Germany
  - "Kinetic Rain", Changi Airport, Singapore
  - 3D KineMatrix
- Scandinavian Design Group, Norway:
  - "Breaking the Surface", Lundin Norway, Norway
- Simtec Systems, Germany:
  - Digital Signage ScreenFlite®
- spidercam GmbH, Austria:
  - mobile camera system spidercam®
- TAIT/Fisher Technical Services, NV, USA:
  - Lincoln Center, New York, NY, USA
  - Shanghai World Expo Sphere Array
- Utinam, monumental clock, Besançon, France

Corporate trade shows/corporate presentations

- Ehrlich Entertainment, Germany:
  - "Jules Verne & Porsche", Germany
  - "175 years railroad in Germany", Germany
- Scandinavian Design Group, Norway:
  - "Breaking the Surface", Lundin Norway
- SGPS/Show Rig, NV, USA:
  - CES

Digital Signage ScreenFlite®, Simtec Systems, Germany

Artifical waterfall, Dubai, Magical Production L.L.C., UAE

 Published in PC Control 03 | 2017

© Beckhoff

The 3D KineMatrix interactive kinetic sculpture, revealed for the first time in February 2017 at the ISE trade show in Amsterdam, creates a magical interplay of water and colored light.

Kinetic sculpture interacts with water and light

A fascinating play of water, light and movement

Development of sophisticated and technically challenging trick fountains that entertain and amaze has sparked the imagination of engineers for centuries. The interactive kinetic sculpture revealed for the first time in February 2017 at the ISE trade show in Amsterdam creates a magical interplay of water and colored light. The "3D KineMatrix" was developed by MKT Fine Exhibition Engineering, a proven expert in the design, development and implementation of interactive installations and kinetic sculptures. This project was completed in cooperation with HB-Laser, a world-renowned specialist in laser shows, multimedia and video mapping projects.

"We set a goal to combine our experience and create something unique out of the individual products, i.e. the '3D HydroMatrix' developed by HB-Laser and our kinetics expertise," explains Axel Haschkamp, member of the board at MKT. The result is a magical 3D sculpture using water, light and motion: a white ball appears to float weightlessly above the water matrix, moving in oscillating and circular motions. At times, it balances on the tips of the water fountains. At other times, it submerges below the water. The next moment it seems as though the ball itself were directing the dynamic upward and downward movement of the water matrix. The sophisticated choreography controlling the interaction between water, light and the kinetic sculpture is difficult to decipher, and viewers never tire of watching the interplay.

Modular and scalable: interactive sculpture flexibly adapts to individual locations

The sculpture is designed for indoor applications with limited space. These locations include hotel lobbies, malls, corporate foyers, airports, casinos and amusement parks. Essentially, it is ideal anywhere people want to create emotions, entertain or promote relaxation for spectators. The investment in a custom sculpture, which involves an enormous amount of planning and development, often exceeds the budget of the architects or clients. With the KineMatrix, MKT and HB-Laser have now created a modular solution that can be flexibly adapted to individual locations.

The product is based on the 3D HydroMatrix modules developed by HB-Laser. Equipped with 10 jets and 10 RGBW LEDs, they include all of the components required to create water and light installations. Depending on the location and scope of the application, multiple modules can be compiled in individual or serial configurations of any desired size as a star or square shape. According to Harald Bohlinger, Managing Director of HB-Laser, the flexible design and compact size are what make this interactive sculpture so unique: "There is currently no other system on the market that offers this 3D effect from such a short distance. In order to create this stunning effect, the system that we have implemented enables water jet spacing of only 50 mm, while conventional water fountains require a minimum spacing of 300 to 400 mm. Furthermore, the minimal spacing between the LED water fountains also enables the projection of videos or lettering onto the water with pixel-level resolution."

Both the water-light matrix and the kinetic assembly are flexibly scalable and can be adapted to the specific application scenario. Instead of a ball, any desired object can be moved three-dimensionally in the space above the 3D HydroMatrix in order to interact with water and light. The KineMatrix can also be flexibly combined with other media such as video, lasers, light, audio and fog.

Precision motion control makes a splash

A prerequisite for the modularity and scalability of the 3D KineMatrix is a compact control platform that can be scaled and adapted to individual project requirements in terms of dimensions and complexity. The three-dimensional movement of the ball, as used in the presentation at the ISE, is created by three winches. The motion control platform consists of a Beckhoff servomotor with an integrated holding brake, an EL7201-0010 servomotor I/O terminal with One Cable Technology (which integrates a complete servo amplifier, including encoder system in a 12 mm terminal housing), and a brake-chopper I/O terminal that provides brake resistance. A Beckhoff CX2030 Embedded PC serves as the central control unit. The control system contains the complete show procedure, with cable lengths and timings taken from an externally generated CSV file. TwinCAT NC PTP Motion Control software then carries out highly-precise position calculations. A TwinCAT Camming function block performs the linear or spline interpolation of the master support points and the corresponding slave

The interactive sculpture was designed for indoor applications. The modular design can be easily adapted to the specific architectural conditions of all kind of sites.

positions according to the position table. This creates a seemingly flowing motion for the observers. In order to synchronize the kinetics with the water matrix control sequence, which is saved on a circuit board, the control system sends the values to a higher-level master PC via ADS. This master PC also runs the application's visualization software.

Further information:
www.hb-laser.com
www.mkt-ag.de/home

Passengers check the time on the monumental clock in the Besançon train station while they wait for the TGV high-speed train.

Monumental clock in TGV train station in Besançon

Synchronized motion control: so perfect, you can set your watch to it

Monumental clocks have a long tradition in Europe. Many churches and city hall towers featured them as early as the Middle Ages to tell citizens the time of day. Admired as architectural and technological masterpieces, their elaborate designs reflected a city's wealth and importance. Following this ancient tradition, French clock manufacturer, Utinam has built a modern oversized clock for the TGV high-speed train station in Besançon, France. Its axis management system, which accurately synchronizes the movement of the pendulum with its escape wheel, is controlled using automation technology from Beckhoff.

What makes this clock so impressive – in addition to its sheer size – is the fact that it has no housing, making its mechanical workings fully visible. "The installation of this monumental clock demonstrates the region's expertise in the areas mechanical engineering, railways, and traditional clock-making," explains Philippe Lebru, who for 20 years has designed clocks and watches for Utinam. "The full complexity of such a clock lies in the scope and size of the parts used." For example, the escape wheel, which links the gears to the pendulum and ensures regularity of the clock's movements, has a diameter of 1.44 meters while the hour wheel measures 2.85 meters. The entire clock is six meters tall and weighs six tons. "Highly sophisticated techniques were required to machine the large parts with a precision of up to 1/100 millimeters," says the clock-making specialist. He adds: "A clock is essentially a machine that must never stop. The parts must therefore be engineered to require virtually no maintenance. Let's take a look at the pendulum, for example. It is four meters long, weighs 80 kilograms and swings 1,000 times an hour, i.e. 24,000 times a day or 9,125,000 times a year."

PC-based controller synchronizes pendulum movement with sound and light effects

The clock uses a CX1020 Embedded PC running TwinCAT NC PTP automation software as its control platform. Two AX5000 Servo Drives and two AM3500 servomotors control two processes. One maintains the pendulum's steady movement, which would otherwise decrease because of friction. As the pendulum passes the lowest point, the controller synchronizes the motor with the pendulum's oscillation frequency and restores its momentum via a system of cams. The other process involves synchronizing the escape wheel's movement with the pendulum's position by having the motor simulate the escape movement. The movement profile is designed in CAD before the system exports the data to the PLC in TwinCAT software and generates a rotary cam.

The PLC controls the application based on information delivered by two encoders. One is located on the pendulum, while the other is on the escape wheel. The first encoder indicates the pendulum's position so that the PLC knows whether or not the pendulum must be relaunched. It also makes it possible to determine the escape wheel's position based on the simulated movement profile. The second encoder is used for servo control of the escape wheel which advances forward more than it moves backward via discontinuous movement. The two axes are therefore mechanically separate and driven by motors which are linked via software. They operate in a master-slave arrangement, because the position of one is dependent on the other.

Whenever the pendulum changes direction, it plays a recorded sound: "tick" in one direction and "tock" in the other. In addition to the sound effects, LED lights mounted around the clock are synchronized with the movement of the pendulum. To do this, the Embedded PC has an audio output and a DALI interface. The real-time communication among PLC, drives, and motors is based on the EtherCAT industrial Ethernet system.

The application software was developed in the TwinCAT programming environment. "The solution is very user-friendly and made project development much easier. Combining the various elements is simple, as is the management of the axes," says Olivier Lehmann, the automation specialist from Utinam who supported the project.

The eye-catching clock which Utinam designed for the TGV station in Besançon has no housing, making its mechanisms fully visible. With its considerable height of six meters, it stretches over two floors. The escape wheel, which links the mechanisms to the pendulum, has a diameter of 1.44 meters while the hour wheel measures 2.85 meters.

Further information:

www.utinam.fr

www.beckhoff.fr

The projection surfaces are suspended on 30 steel cables. Their movement through the three exhibition levels with a height of around 15 meters is individually controlled by servomotors. A total of eight projectors are installed, five of which on the ceiling of the third floor and one each on the other three floors.

High-tech media technology in museum makes history a more interactive experience

PC-based control system adds life to kinetic landscape model

Presenting regional history in a scientific and, at the same time, exciting and eye-catching manner is a challenge for museum directors. At the State Museum of Archaeology in Chemnitz, Germany, this balance has been achieved rather successfully: history has become a multi-sensory experience, thanks to state-of-the-art multimedia technology. The kinetic landscape model depicting the Free State of Saxony, which hovers in the foyer of the building, is no doubt unique in the German museum landscape. As the model moves through three floor levels, a film is projected onto it, illustrating the development of Saxon cultural history. The implementation, production, and installation of the kinetic model took eight months before it was officially opened in August 2014. Scenography specialists, ATELIER BRÜCKNER came up with the idea and overall concept. The technical implementation was handled by MKT AG, leading experts for permanent kinetic installations. TAMSCHICK MEDIA+SPACE were responsible for the media design and production.

The State Museum of Archaeology Chemnitz, or 'smac' for short, opened in May 2014 and is based at the former Schocken department store, a building in the center of Chemnitz with origins stemming from the classical modernism period. In its permanent exhibition over three levels, and covering a total area of over 3,000 square meters, smac presents 300,000 years of Saxon history based on archaeological finds. The exhibition documents the changes from a natural landscape to a settlement landscape and to the modern cultivated landscape within the borders of today's Free State of Saxony, driven by people and against the background of changes in environmental and climatic conditions. "We show archaeology, as it really is – looking back in history and toward the future at the same time," explains curator Dr. Sabine Wolfram. "We answer universal questions with new methods; that's why our museum has something to offer for everyone."

High-tech in the museum: kinetic installation makes education an experience

"The 'time-dynamic model of Saxony' has an interactive and didactic function when it is operated from the ground floor, as well as an auto-active attraction as a linking, vertical timeline," notes Prof. Uwe R. Brückner, Creative Director of ATELIER BRÜCKNER, who designed this innovative media exhibition format for smac.

The kinetic model floats in the center of the building and connects the foyer with the three exhibition levels above – both visually and content-wise. The individual, translucent slabs move through the 15 meter high space, suspended on 30 steel cables. The film and sound effects are synchronized with the flowing, dynamic up and down movement of the slabs. "The media sculpture moves

Curator, Dr. Sabine Wolfram: "The spectacular show mode is no doubt a highlight in the museum experience for smac visitors. The most impressive view is from the third floor, with the landscape sculpture moving towards the observer."

© ATELIER BRÜCKNER/Michael Dürnagl

The "slabs", which represent a projection from above and below, move into the light cone, and dynamic projection mapping ensures that the sharpness of the image is precisely adjusted, according to the axial movement.

When the sculpture is not in show mode, it is positioned on the ground floor, so that visitors can interact with it and search for clues. Eight touchscreens can be used to call up information on the archaeology, as well as the cultural and economic history of the Free State of Saxony. The display can be transferred from the monitor to the Saxony model.

through the vertical air space of the museum once per hour. It forms a narrative bracket and a link for the exhibition content on the individual floors, a 'memory machine' that sends us on a poetic journey through 300,000 years of Saxon history," according to Charlotte Tamschick, Creative Director of TAMSCHICK MEDIA+SPACE, referring to the multimedia aspect of the kinetic installation.

When the sculpture is not in show mode, it is positioned on the ground floor, so that visitors can interact with it and search for clues. Eight touchscreens arranged around the sculpture can be used to call up information on the archaeology as well as the cultural and economic history of the Free State of Saxony. The display can be transferred from the monitor to the Saxony model, so that several queries can be superimposed, and visitors can interact with each other. "The result is a constantly changing topography – a 'tableau vivant' of Saxony," says Charlotte Tamschick.

Compact and scalable: tailored control technology

Peter Haschkamp, one of the two directors of MKT AG, the company commissioned to undertake the technical implementation of the kinetic sculpture, describes the technical characteristics of the installation. "A major challenge was the weight of the installation and the load distribution, taking into account the existing structural conditions. The total weight is around eight tons, including the slabs, the cable drums, the motors and the projectors, which had to be distributed across the ceiling in such a way that the structure of the historic building was not affected. This meant that the technical solution had to be very compact."

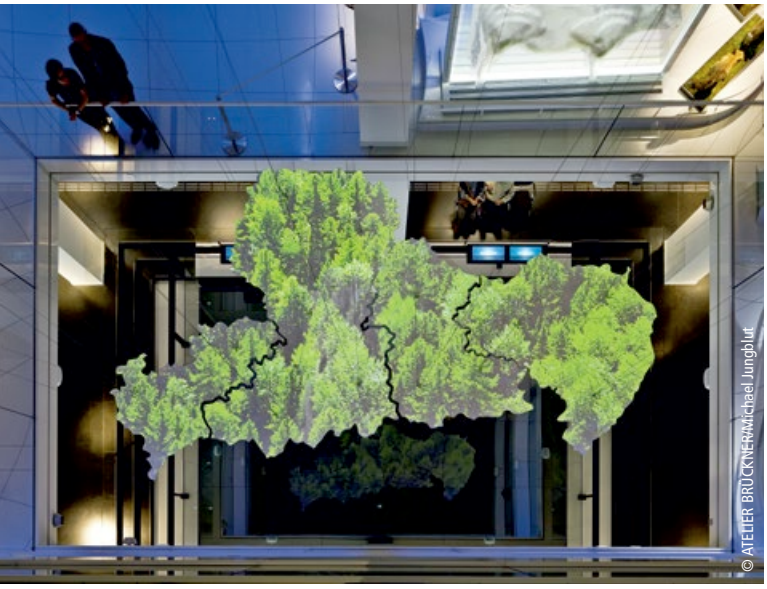
The axes and all the sensors, including the safety technology, are controlled separately via two built-in C6525 Industrial PCs from Beckhoff. TwinCAT NC PTP is used as automation software, which also calculates the high-precision movements.

MKT has a proven track record of a number of kinetic installations around the globe. One of the most prestigious projects is "Kinetic Rain" at Changi Airport in Singapore, where 1,216 axes are moved synchronously. However, the "Kinetic Rain" loads that must be coordinated are in the sub-kilo range, whereas the slabs of the Saxony model weigh of up to 42 kg, depending on their size. This results in significantly more stringent demands on the cables, cable drums and motors – for each slab, three cable drums with a diameter between 300 and 400 mm are used. "The 15 servo axes are driven by Beckhoff AX5x03 servo drives with integrated TwinSAFE option card and AM8043 servo motors with AG2300 planetary gear units," explained Michel Matuschke, Branch Manager for theater and entertainment technology at Beckhoff.

"MKT appreciated the fine scalability of our components, such as the servo drives, which are used in single- and two-channel versions at smac. In addition to the weight limits, the minimal installation space in the ceiling of the top floor presented a further technical challenge. The entirety of the equipment had to be accommodated within an area of 6 x 9 m. This task could only be accomplished through a distributed control architecture, such as the one offered by PC-based control technology," Peter Haschkamp added. "It enables us to distribute the control components evenly across the ceiling. We had already worked with Beckhoff on several previous projects and once again closely cooperated with them in the development of the technical solution for the Saxony model." Axel Haschkamp, co-director of MKT AG, mentions the "whisper-quiet" operation of the Beckhoff motors as a further advantage. It enables the slabs of Saxony model to float silently through the space.

EtherCAT: precise synchronization of multi-axis motion and projection mapping

Christian Lungershausen, Manager of Focus4 GmbH and responsible for the programming of interactive displays and the cinematic projections, describes



During its journey through the museum foyer, the time-dynamic Saxony model stops at each exhibition floor. The exhibition content of each floor is reflected in the images and sounds of the cinematic projection.

the special features of the project: "We installed a total of eight projectors – five on the third floor and one each on the other three floors – to display the film material onto the landscape model. A distinction is made between two modes: in interactive mode, visitors are able to project certain content onto the Saxony model while it is positioned on the ground floor. In show mode, the model moves through a space that is around 15 meters high, requiring coordinated interaction of all eight projectors. The "slabs", which represent a projection from above and below, move into the light cone. During the movement between the floors, the projection data are transferred between the projectors. Dynamic projection mapping ensures that the correct image is applied and the focus is adjusted."

"The task was solved simply and ingeniously by connecting the media control PCs with the slab movement controller via TwinCAT ADS (Automation Device Specification). It requires no additional hardware and is simply implemented via Ethernet by integrating the ADS communication DLL in the media control program," said Raphik Shahmirian, sales representative at the Beckhoff office in Munich. "Because of this open communication interface, the media controller knows the exact positions of the slabs at all times and can switch the focus and the media projectors accordingly."

The State Museum of Archaeology Chemnitz is based at the former Schocken department store in the center of Chemnitz, Germany. Erich Mendelsohn, a famous architect of the classical modernism period, designed and planned the building between 1927 and 1930 for the department store group owned and founded by the Jewish Schocken brothers.

Companies and institutions involved in the dynamic model of Saxony:

Scientific concept and data: Saxony Archaeological State Office
Idea and concept: ATELIER BRÜCKNER GmbH
Technical development and implementation: MKT AG
Media design and production: TAMSCHICK MEDIA+SPACE GmbH
Music and sound design: BLUWI Music and Sounddesign GbR
Programming of interactive displays and projections: Focus4 GmbH
Control system: Beckhoff Automation GmbH & Co. KG

Further information:

www.smac.sachsen.de
www.atelier-brueckner.com
www.mkt-ag.de
www.tamschick.com
www.focus4.de

At a glance:

Solutions for the stage and show technology
Control of a kinetic installation with dynamic projection mapping

Customer benefits
- Fast transfer and processing of large data quantities
- Compact and modular control and drive modules as a prerequisite for the technical implementation of the project

Applied PC Control
- Servo drives and servomotors for dynamic motion control
- EtherCAT Terminals
- Safety terminals
- TwinCAT NC PTP

 Published in PC Control 04 | 2014

EtherCAT synchronizes 529 axes to automate kinetic art installation

“Breaking the Surface”:
Servo terminals move virtual ocean

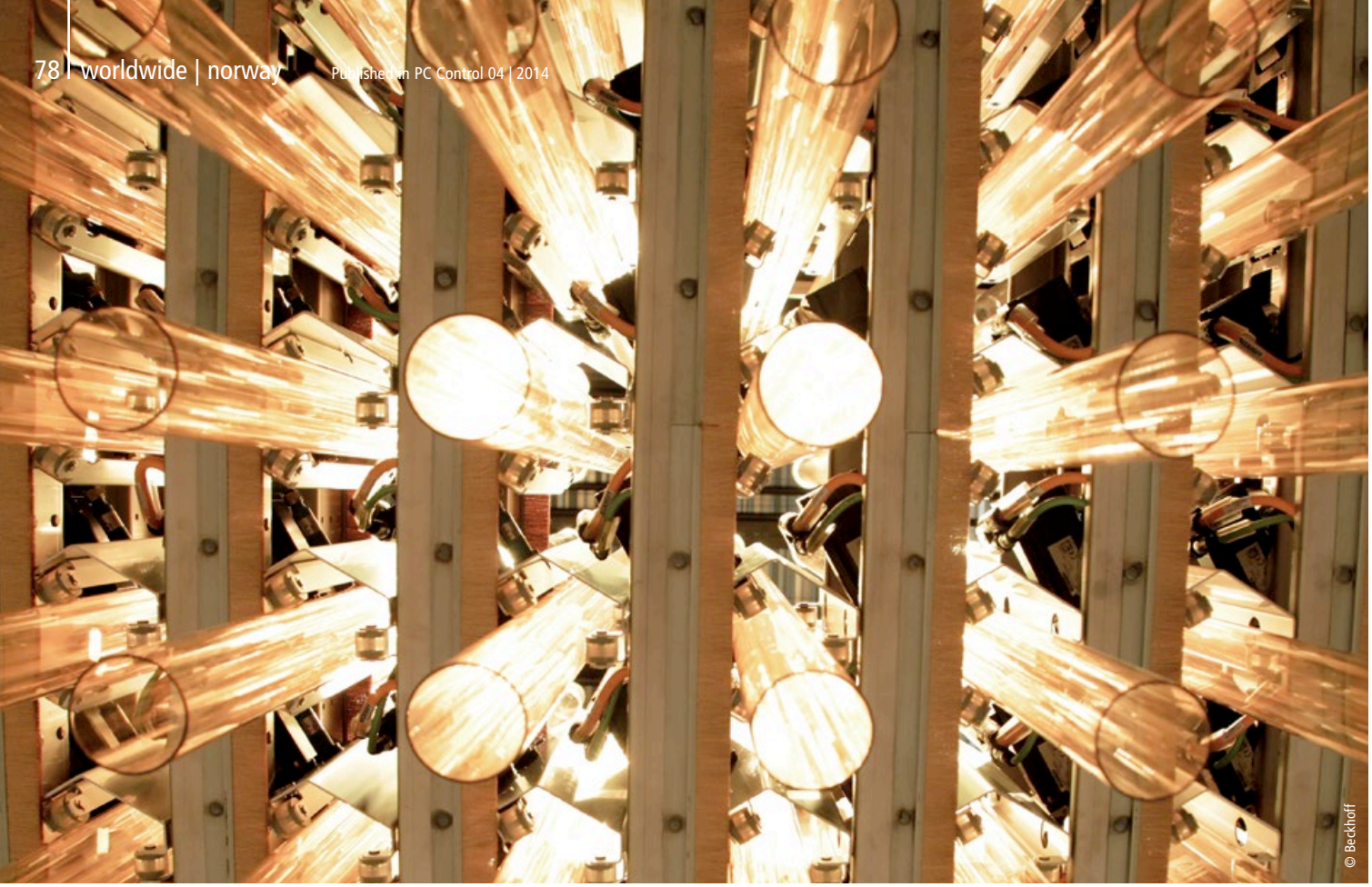
© James Fox, Abida, Norway

Norwegian oil company Lundin Norway envisioned something rather unique to mark the 10th anniversary of the company. Lundin caused quite a stir when they presented their kinetic art installation at the ONS Energy Convention, the world's largest offshore energy trade show, which took place in August 2014 in Stavanger, Norway. Visitors flocked to the Lundin trade show booth and HRH Norwegian Crown Prince Haakon from Norway, who visited the oil extraction company during his opening tour of the trade show, was visibly impressed by the presentation. 529 plexiglas tubes are moved continuously together in such a way that they simulate ocean waves, and at the same time symbolize the constant search for oil under water on the Norwegian continental shelf. In addition, visitors have the ability to interact with the installation. It is a markedly complex and sophisticated project, both artistically and mechanically, as well as in terms of the control technology. The project involved intensive cooperation between designers, architects, safety experts, and machine manufacturers, with Beckhoff as the control system supplier contributing to the success of this engineering marvel.

The kinetic installation "Breaking the Surface" consists of a field of 529 plexiglas tubes, constantly moved in such a way that they create a 3D image of undulation in the eye of the viewer.

The overall artistic concept of the "Breaking the Surface" installation, including the software engineering, originates from the Scandinavian Design Group (SDG). "The objective was to create a work of art that expresses the identity of Lundin Norway. Lundin's business is in the exploration and extraction of oil resources on the Norwegian Continental Shelf, so what is more fitting than to create an abstract representation of a sub-surface landscape?" said Bjørn Gunnar Staal, Senior Creative Technologist at the SDG, commenting on the design concept. The seismic recordings of the sea bed that geophysicists make in the search for oil reservoirs adopt a color scale between pale yellow and deep orange, depending on the density of the reservoir, in order to visualize the different layers of rock, gravel and sand in the stratigraphic models. This inspired the designers to color the Plexiglas tubes bright orange. The virtual ocean waves undulating before the eyes of the viewer are therefore not blue, but vary from bright to saturated orange depending on the viewpoint and the density of the tubes staggered one behind the other. While one single pipe represents a single exploration well, the multitude of overlapping translucent pipes create a moving landscape of organic, rock-like formations on the first floor. If a person approaches the installation, the virtual ocean landscape opens up. The tubes are driven to a safe position, allowing the viewer to "dive in", so to speak. With this interaction, the artists are deliberately alluding to the exploration of the sea bed for oil reservoirs.

Published in PC Control 04 | 2014



A total of 529 AM8121 servomotors and 529 EL7201 servo terminals were installed in order to move all the Plexiglas tubes.

Art and technology in harmony

The mechanics and supporting structure of the kinetic installation, which was supplied by the Norwegian engineering firm Intek Engineering, consists of a framework of 23 steel girders, located in the ceiling between two stories of the building. With approximately 5 tons distributed over an area of 25 square meters, the construction of the framework represented a great challenge – one that was accepted by architectural firm Ctrl+N.

Each steel girder is equipped with 23 honeycomb-shaped stainless steel housings, every one of which accommodates – in the tightest of spaces – a plexiglas tube, an AM8121 Beckhoff servomotor, a drive wheel, and six support wheels for guidance, as well as a capacitive sensor for position compensation. A 3D depiction of an undulating sea is created in the eye of the viewer, based on a cleverly devised relationship between speed, tube diameter, and the distance of the tubes from one another. These were implemented mechanically, with a total of 529 installed servomotors. The associated control electronics are located at both ends of the support structure and consist of an EK1100 EtherCAT Coupler, and a set of I/O components, including: digital input terminals, servo terminals for controlling the servomotors, and buffer capacitor terminals for stabilizing the supply voltage.

"A total of 10,200 connection points must be processed, representing a challenge both mechanically and with regards to the control electronics," emphasized Rune Nordby, Marketing Manager at Intek. "The compact design of the control and motion modules, above all the servo drives in a 12 mm terminal housing, was a prerequisite for the successful technical implementation of SDG's artistic concept."

The control system architecture encompasses three main components:

– the sensor and actuator level, consisting of EtherCAT Terminals and specific safety sensors
– the PLC level, based on four C5102 Industrial PCs
– the superordinate application level

In order to enable the interaction between people and the kinetic sculpture, two overlapping sensor data levels were installed: a 40 m² capacitive sensor floor installed under the parquet flooring and four K4W sensors (depth cameras) installed in each corner of the room. "We developed the higher-level control application in openFrameworks," Bjørn Gunnar Staal explained. Based on the data provided by the sensor floor and motion sensors, it encompasses a real-time model of the environment, for which a motion diagram is created to simulate the undulating movements.

Complex control technology simulates swell

The application communicates with the four IPC platforms, which also control the servomotors via TwinCAT ADS. "We used a whole bundle of openFrameworks add-ons for this application," explained Bjørn Gunnar Staal. In addition to that the team of developers from Scandinavian Design Group and Abida developed three new add-ons for "Breaking the Surface":

Fascinated visitors move through the virtual ocean waves. Motion sensors in the floor signal that someone has entered the installation and the tubes drive to a safe position.

Enclosed in a polyurethane crystal and labelled with the number of the exploration well, drilling samples from discovery sites in the Norwegian continental shelf are concealed in some of the tubes. They can be "discovered" by the visitor while interacting with the virtual ocean.

– ofxMultipleKinect, controlling the display and alignment of several Kinect point clouds in the same coordinate system
– ofxBeckhoffADS, facilitating the transmission of data between openFrameworks and the Beckhoff control platform
– ofxSensfloor, directing the communication and visualization of sensfloor data in openFrameworks

The set values of the motion diagram, which are programmed in C++, are imported into the TwinCAT NC PTP automation software via the ADS interface. In connection with the ultra-fast EtherCAT bus system and the servo terminals, the point-to-point axis positioning software calculates the position for each individual tube in a cycle time of 1 ms. An interpolating motion results, which the viewer perceives visually as natural undulation. If the sensors signal a movement, i. e. a person entering the "ocean", then the axis positions of the undulation are overwritten; the position of the pipes in close proximity is adjusted to form a protective dome around the person moving around in the space. "A thin metal ring, attached on the inside of each tube, gives us a reference signal every time it passes the capitative sensor inside the drive unit. This makes it easy and safe to double check and control our adjustment positioning algorithm which gives us the exact position of the tube at any time," explained James Fox, founder of Abida.

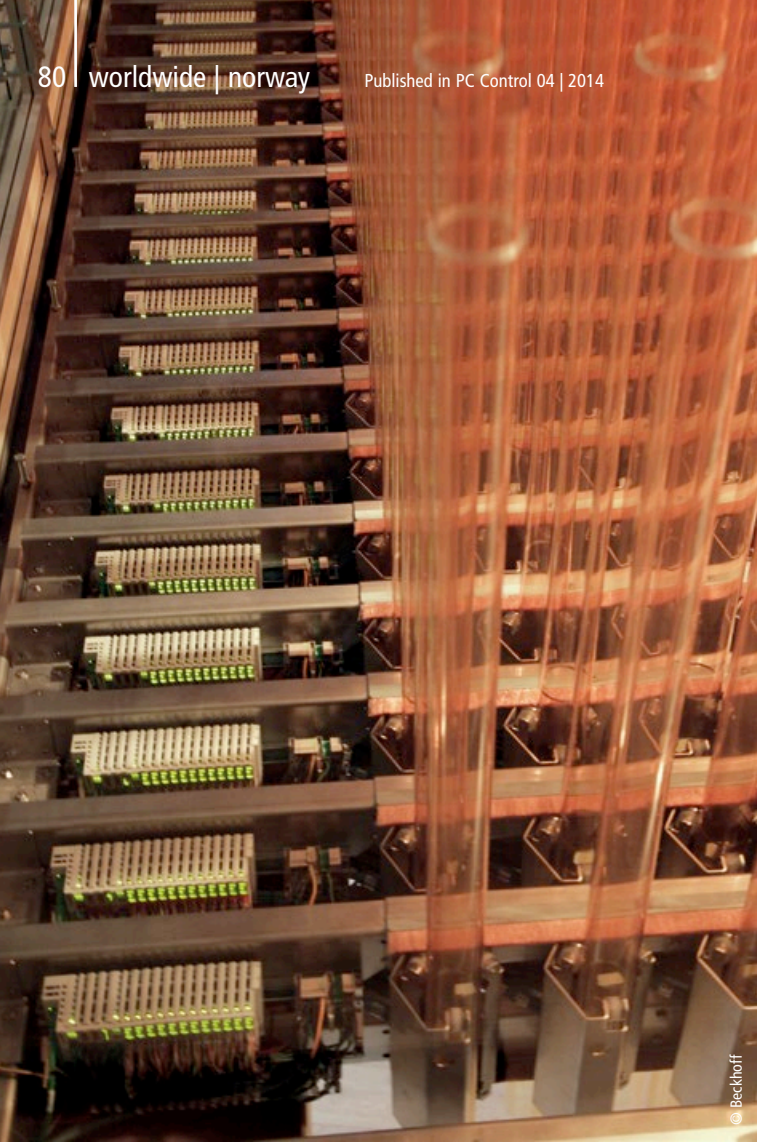
The higher PLC level consists of four C5102 Industrial PCs based on TwinCAT 3 and EtherCAT: one of the PLCs functions as the data communication and syn-

At a glance

Solutions for stage and show technology
Control platform for an interactive kinetic installation with 529 servo axes

Customer benefit
– Fast transfer and processing of high data volumes
– Compact design of control and drive modules as a prerequisite for the successful technical implementation of the project
– Integration of a customer-specific 3D application with TwinCAT via ADS communication

Applied PC control
– 529 servomotors and servomotor terminals for Motion Control
– EtherCAT Terminals: processing 10,200 connection points
– TwinCAT NC PTP: Point-to-point axis positioning software calculates the position for each individual tube in a cycle time of 1 ms, resulting in an interpolating motion which the viewer perceives as undulating ocean waves.



The compact electronics that control the 529 plexiglas tubes are installed at both ends of the support structure. The controls consist of an EK1100 EtherCAT Coupler, digital input terminals, servo terminals, and buffer capacitor terminals.

Scandinavian Design Group (SDG)

SDG is one of the leading design agencies in Scandinavia and is headquartered in Oslo. With almost 220 employees it represents the largest communications network in Norway and supports notable companies in branding and corporate identity development as well as in packaging design and end customer marketing. SDG is well-known for innovative solutions in the fields of digital and interactive design, as the kinetic installation for Lundin Norway impressively demonstrates.

Abida

Abida's broader mission is to integrate technology with design and architecture, but work in many additional fields. Our technologies are in most cases implemented through automation, custom software platforms and robotics with a background based on electrical-, systems-, and biomedical engineering.

Intek Engineering

The Norwegian engineering firm, Intek, headquartered in Raufoss and established in 1980, specializes in the automation of production machines, material handling systems, robot applications, and more.

Lundin Norway AS

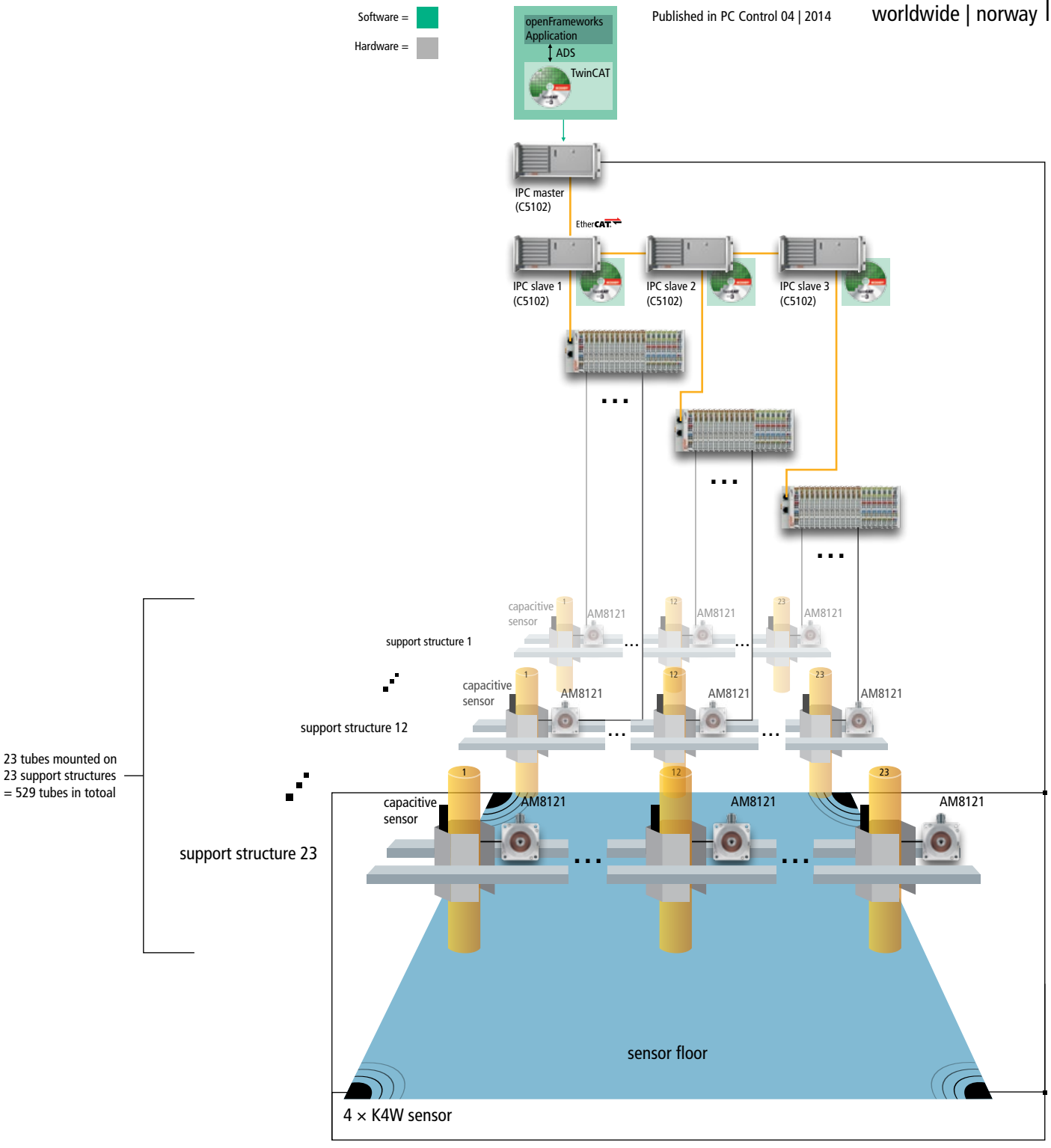
Lundin Norway, based in Oslo, is a subsidiary of Lundin Petroleum AB, a Swedish group of companies with a proven track record of finding, developing and producing oil and gas resources worldwide.

chronization level between the openFrameworks application App, and the three subordinated PLCs are each responsible for controlling one third of the servo axes. The PLCs accomplish the majority of the work by continuously adjusting the speed, acceleration, deceleration, and braking processes of each servo unit on the basis of the position specified by the higher-level application. Beyond that, these PLCs also manage calibration, position compensation, as well as speed and torque monitoring.

Safe control of a virtual ocean

During the conception of the installation and its technical implementation, a great deal of attention was paid to safety requirements from the outset, in terms of both mechanical construction and the electrical system and sensors. After all, the installation was designed for interaction and should not pose any danger to people. James Fox who has been responsible for the safety and security concepts, was involved in the Scandinavian Design Group's project from the very start. "Even the decision to use Plexiglas tubes was based on a well thought out concept intended to exclude any danger of injury. Plexiglas is light and the edges of the pipe openings can be rounded. Apart from that, the installation was designed in such a way that it functions with a low speed of movement. The sensor level in the floor enables sophisticated scanning of even the tightest spaces, and uses redundant scanning to ensure that no blind spots are possible. The objective of our security concept was to make it safe enough to avoid the use of safety precautions according to Safety Integrity Level, category 3, which would have seriously impaired free access to this installation and its aesthetis" said James Fox and added: "We have been part of this team consisting of so many different people and companies, and yet still have been able to work together as a tight and homogenous group. I think we are all proud, client (Lundin Norway) and providers, to have been able to deliver an installation with a very high quality finish of this complexity and magnitude. The interdisciplinary collaboration from everyone involved in this project, has enabled us to firmly stand behind "Breaking the Surface" and happily say that it has been easy to proclaim that the installation is safe for human interaction!"

The impressive installation, which will soon be permanently on display at Lundin Norway's headquarters in Oslo, is rounded off by oil-filled crystals, which are concealed in some of the Plexiglas tubes. As the visitor moves through the virtual oil repository, he or she can "discover" these crude oil samples from Lundin Norway's six most significant oil discoveries, including the giant "Johan Sverdrup" discovery.



Bjørn Gunnar Staal from SDG can imagine further project implementations on the basis of TwinCAT and EtherCAT. "I worked with Beckhoff for the first time on this project, but it will certainly not be the last time. In this installation large amounts of data are collected via sensors and must be transferred to the controller and processed very quickly. PC- and EtherCAT-based control provides the perfect solution for these requirements."

Further information:

www.sdg.no
www.abida.no
www.intek.no
www.ctrln.no
www.lundin-norway.no
www.beckhoff.no

 Published in PC Control 03 | 2014

Embedded PC is the key that opens the "Waterdoor"

Magical water feature enabled by PC-based control

The "Waterdoor", created by engineering firm as-systems, highlights the World of Water exhibit in the Swiss town of Flims. Visitors watch, amazed at the dense curtain of water drops that magically opens when they approach. The one question on everyone's mind: Will the waterfall really stop when you walk through it? A Beckhoff CX8090 Embedded PC with integrated EtherCAT Terminals and TwinSAFE safety technology ensure that it does and that no one gets wet.

© Photo by Matthias Nutt

The "World of Water" in Flims, which was renamed "Sinfonia d'aua" when it opened in September 2013, demonstrates how natural resources can be used in an efficient, environmentally-responsible manner. Triggered by the accidental tapping of an underground lake during tunnel construction, the project took shape over quite a few years to remedy the situation. The complete water supply was restructured in an environmentally-minded manner, facilitating use for drinking water, power generation, and to cover the ski slopes with artificial snow. In the Punt Gronda station, interested visitors can learn about the complex ecological relationships between the water sources in the mountainous Flims region and the technical implementation of the project. "The Sinfonia d'aua presents the broad subject of water from various perspectives. We believe that nature is the most valuable asset in our tourism-oriented region. We don't just want to explain how our valuable natural resources should be treated, we want to demonstrate it using examples," says Martin Maron, director of Flims Electric, the company that was instrumental in bringing the project to life. To develop a unique water attraction that utilizes natural surroundings, as-systems was hired to install a curtain of water, which ultimately materialized as the Waterdoor.

Notably active in international light, sound, and stage projects for over 20 years, as-systems has a long history of designing amazing water features and displays. From complete landscapes with waterfalls, cascades, and fountains, to water screens showing projected images combined with complex lighting designs, the projects inspire the kind of awe and wonder that visitors experience when encountering water indoors.

Working technological wonders with a CX8090 Embedded PC

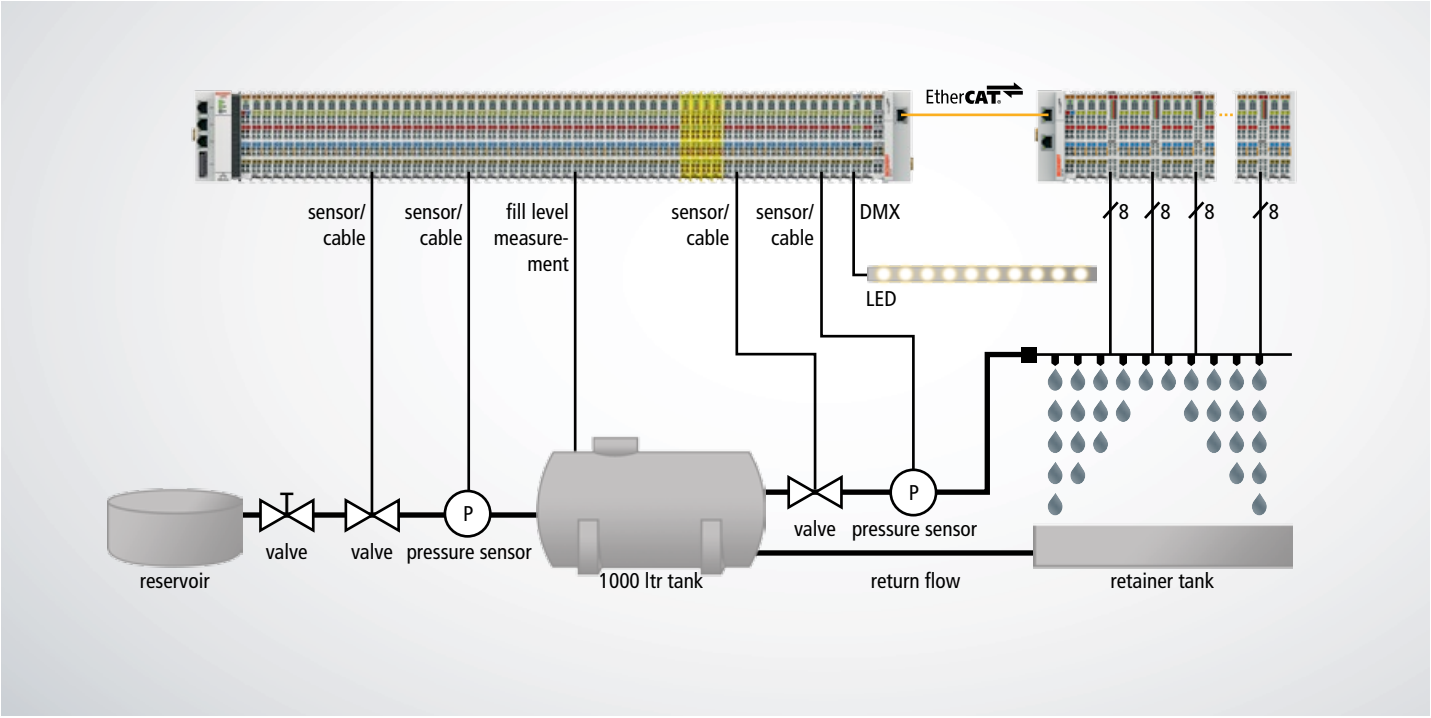
What looks at first glance like a miracle is enabled by advanced automation technology. The interactive water exhibit consists of a rail containing hundreds of jets mounted over a door lintel. A compact CX8090 Embedded PC and EL2798 EtherCAT relay terminals provide control for the jet assembly. Each of the digital terminals has eight switches that function like relay contacts for AC/DC voltages. The electronic switch connects with powerful MOSFET transistors, offering low start-up resistance to prevent high voltage peaks and electromagnetic interference. In addition, the CX8090 controls a total of 144 data points.

When the door radar detects a visitor, the water curtain opens from the center outward – similar to a curtain in a theater – and closes again after the visitor has walked through. A DMX terminal controls an LED bar in the door lintel, signaling green for "Go" and red for "Stop". Another function of the LED rail is to illuminate the water drops, which refract the light and thus become much more clearly visible to the visitors.

The Embedded PC regulates water levels and flow speeds, as well as valve settings. The water for the door is initially routed from a reservoir into a 1,000-liter holding tank via a magnetically-controlled valve. The system monitors this valve,

© Photo by Matthias Nutt

Surprised faces: triggered by motion sensors, the Waterdoor opens to let visitors pass through without getting wet.



as well as a manual valve, to completely isolate the system and prevent any backflow. The fill level and the refill logic are also monitored, i.e. the refill flow is limited and controlled to prevent any water from being refilled, in case of a leak. After performing all these checks, the system pumps the water to the door lintel. The system monitors the water's flow speed and pressure, as well as internal sensors, to detect any cable breaks. Since the pump turns itself off when the curtain has been open for a certain period of time, it also has special algorithms to prevent misinterpretations. Water tank safety is controlled using Beckhoff TwinSAFE Terminals that differentiate between rising water levels caused by the curtain being open for a long time or drainage problems. The system also uses a KNX interface to report events, such as a critical fill level, via SMS.

"The PC-based controller is ideal for our applications, not only because of its small size, its modularity, and ability to handle many types of signals. It also can be integrated into our remote control network to ensure trouble-free operation at all times," says Andreas Staphan, Managing Director of as-systems. "We also use the high-precision EtherCAT controller for our 'magical waterfalls', where individual valves are opened and closed to create pictures and messages in the form of falling water. In addition, we have decided to equip our future special exhibits with Beckhoff components. This allows us to standardize modules, taking advantage of the worldwide support and distribution network provided by Beckhoff to service our worldwide exhibits."

A DMX terminal controls the LEDs above the opening. Red indicates "Stop", while Green means "Go".

Further information:

www.as-systems.com
www.flimselectric.ch

| ST1 -04E |

Create ultimate guest experiences:

PC-based control for the entertainment industry

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PC and EtherCAT-based control technology for the entertainment industry:

- integrated and highly scalable automation system
- control of all entertainment applications: stage, theater, and concert technology, film studios, theme parks, 4D/5D cinemas, special effects, building automation
- comprehensive AV multimedia interfaces
- integration of DMX, Art-Net™, sACN, PosiStageNet, SMPTE timecode, and audio
- enables the implementation of professional show ideas with proven control technology

Scan to experience PC-based control for the entertainment industry live

New Automation Technology **BECKHOFF**

Published in PC Control 01 | 2013

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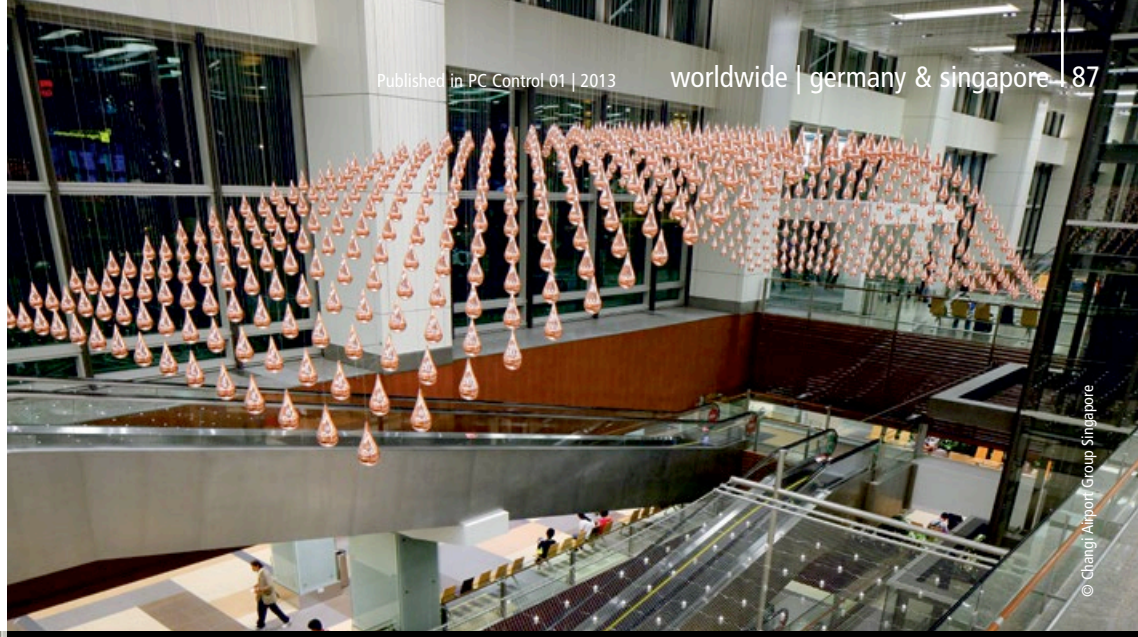

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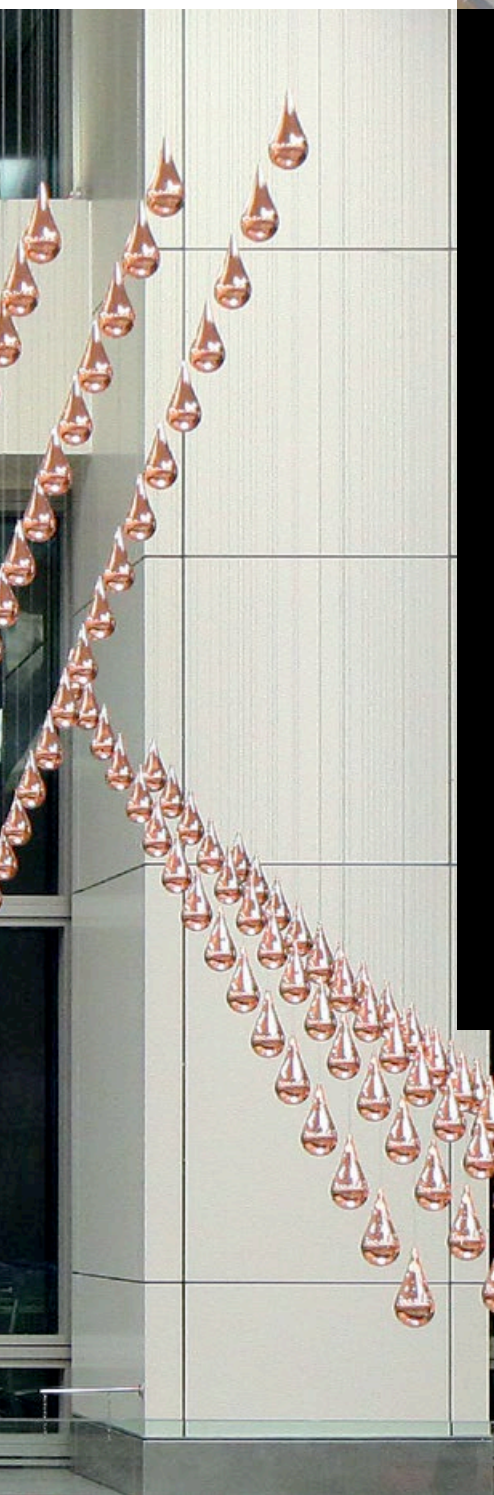
The installation, which consists of two contiguous fields of 608 droplets each, extends over a total area of more than 75 square meters and plays over a room height of over 7.3 meters.

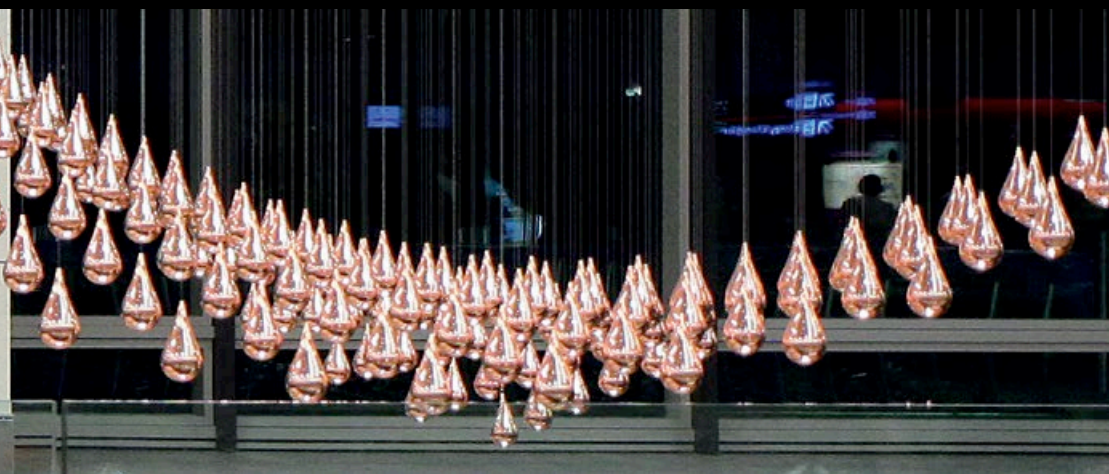
Changi Airport, Singapore: EtherCAT synchronizes the movement of 1,216 servo axes

"Kinetic Rain"

A perfect symbiosis of technology and art

What is probably the world's largest kinetic sculpture was realized in "Kinetic Rain" at Changi Airport in Singapore. The artistic concept of the installation and the calculatory design of the choreography originate from the Berlin-based Art+Com AG. In allusion to the tropical rain, the installation consists of 1,216 brilliantly sparkling, copper-plated aluminium droplets. These are suspended from the ceiling on thin steel wires and each one is moved by a small servomotor. During a 15-minute show, the droplets are formed into different pictures connected with the subject of flying. MKT AG, experts in kinetic installations, took care of the complete technical implementation of "Kinetic Rain", including the software. The challenge of moving 1,216 servo axes synchronously was solved on the basis of EtherCAT, TwinCAT and the compact Servo Drives in Bus Terminal format.

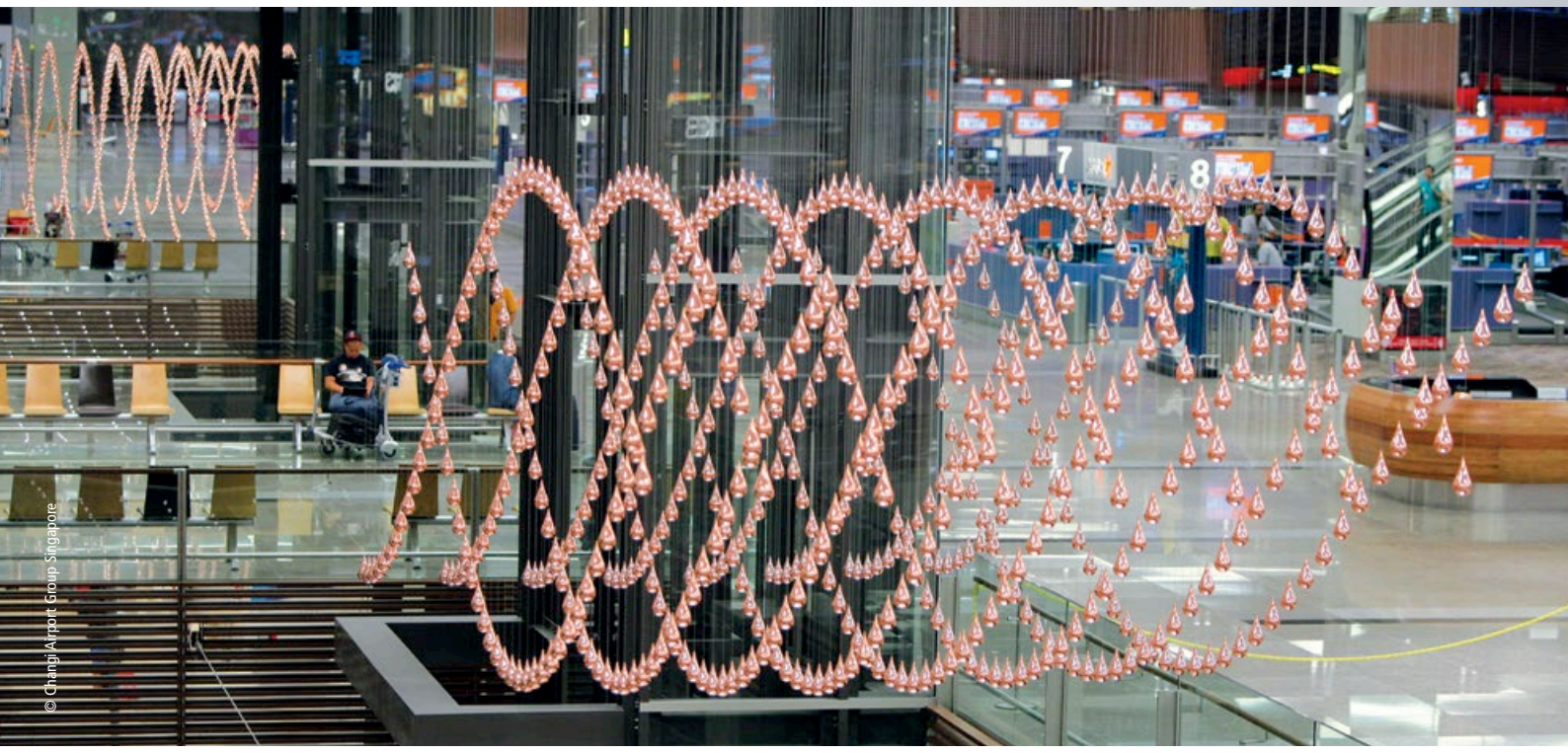




Changi Airport Group Pte Ltd.

The Changi Airport Group (CAG) Singapore was founded on 16 June 2009. As the administrative company of Changi Airport it is essentially responsible for the operation and management of the airport, its development as an air traffic hub, commercial activities and airport emergency services. The airport registered over 46 million passenger movements in 2011. As part of the modernization of the check-in hall, the CAG invested in a kinetic sculpture: with its allusion to the tropical rain, "Kinetic Rain" is an homage to the tropical city of Singapore.

During a 15-minute show, the 1,216 droplets are formed into sixteen different pictures connected with the subject of flying.



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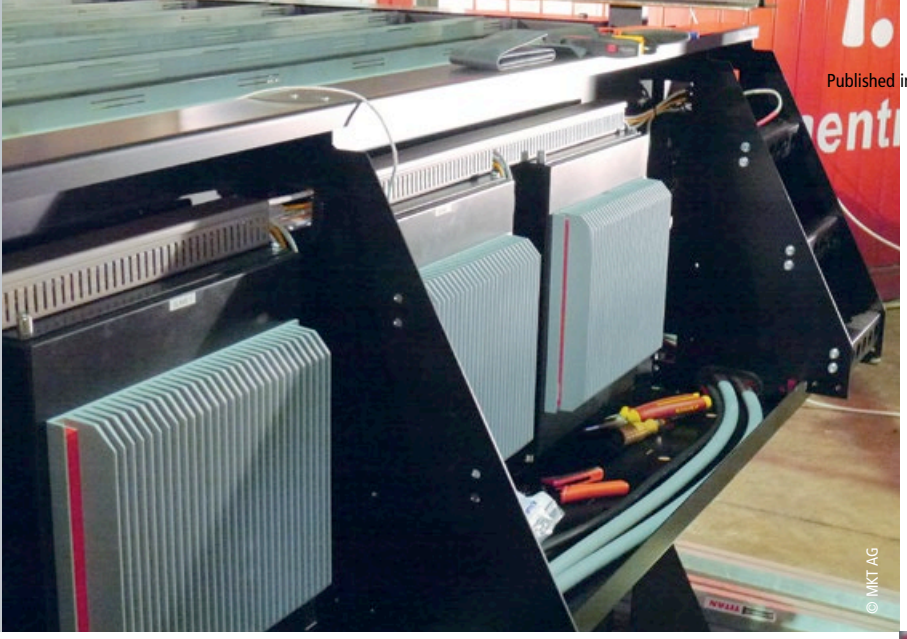
Air passengers and airport visitors who enter Terminal One at Changi Airport in Singapore are stopped in their tracks by a kinetic sculpture, "Kinetic Rain", as they make their way through the modernized check-in hall. "The harmonious interaction of more than a thousand droplets also symbolizes the many people at the airport who ensure day after day that passengers and visitors to Changi Airport are positively surprised and have fond memories of it," says Yeo Kia Thye, Vice-Director of Airport Operations at the Changi Airport Group.

The installation, which consists of two contiguous fields of 608 droplets each, extends over a total area of more than 75 square meters and plays over a room height of over 7.3 meters. The artistic concept for this unusual space installation comes from the Berlin agency Art+Com. The technical implementation of the overall project and the programming was accomplished by MKT AG from Olching, near Munich, Germany. The company, which specializes in kinetic installations, received support from Beckhoff during the programming and implementation of the control system. "In 'Kinetic Rain' we have realized the most sophisticated project of this type to date," says Axel Haschkamp, Director of MKT AG: "More than 2,000 engineer hours flowed into this project. Particularly challenging was not least the transport of the fully pre-assembled installation weighing 30 tonnes to Singapore."

The demands on the control of "Kinetic Rain" are extraordinarily high, with the precise movement of 1,216 axes. In addition to that, the project demanded high availability, compact design of the components and the replacement of components without addressing. "One of the paramount specifications of our customer, Changi Airport, was that the system must run 24 hours a day. Even if an individual axis were to fail, the show must go on," adds Peter Haschkamp, likewise director of MKT.



Due to its very flat design, the C6525 Industrial PC is ideally suited to installation in cramped spatial conditions. Thanks to an optional SSD storage medium and passive cooling technology, the C6525 does not contain any rotary components.

In the Beckhoff servo terminals, which fit seamlessly into the EtherCAT terminal row, and the AM3121 compact servomotors, MKT found a compact drive solution that fits perfectly into the tight installation space in the ceiling of the airport terminal building.

How do you control 1,216 axes synchronously?

"The synchronous movement of 1,216 axes is one of the absolute highlights of this project," stresses Raphik Shahmirian from Sales at the Beckhoff office in Munich, who attended to the technical implementation of "Kinetic Rain" in close co-operation with MKT. Beyond that, high requirements had to be met where the dynamics, precision and speed of the motion sequences were concerned. The droplets move with a speed of 1.5 m/s and an acceleration of 1.4 m/s². The movement must be dynamic, but at the same time flowing and absolutely free of jerks. MKT found the solution to this task in the PC- and EtherCAT-based Beckhoff control platform with compact Servo Drive Technology.

A central C6525 Industrial PC is responsible for the control. It communicates by TwinCAT ADS with the special GUI computer from MKT. At the same time, the PC centrally controls the 1,216 axes via TwinCAT NC PTP and acts as the master. Via the TwinCAT cam table function the master PC coordinates the distribution of the position data to the six slave PCs, to each of which 192 or 208 axes are assigned, and ensures the synchronicity of all axes according to a master axis as reference (see diagram page 20). Communication takes place in real-time over EtherCAT up to the drives.

The GUI computer from MKT serves for visualization, but also contains the show in the form of a table containing the position data for each droplet at time intervals of 200 ms. This corresponds to five pictures per second. A flowing movement perceptible by the human eye without jerks is possible only through the interpolation in TwinCAT NC PTP. Here, 100 intermediate positions are calculated for each droplet using a spline algorithm in a 2 ms NC task. These calculations take place on each slave PC for the local axes assigned to it.

The artistic intention to have the synchronous movements of the droplets run like a kind of 3-D film is possible only through the use of EtherCAT and TwinCAT NC PTP. While the master keeps all the axes synchronous to one other, the slave PCs calculate the positions of the axes assigned to them every 2 ms and communicate them over EtherCAT in real-time to the Servo Drives.

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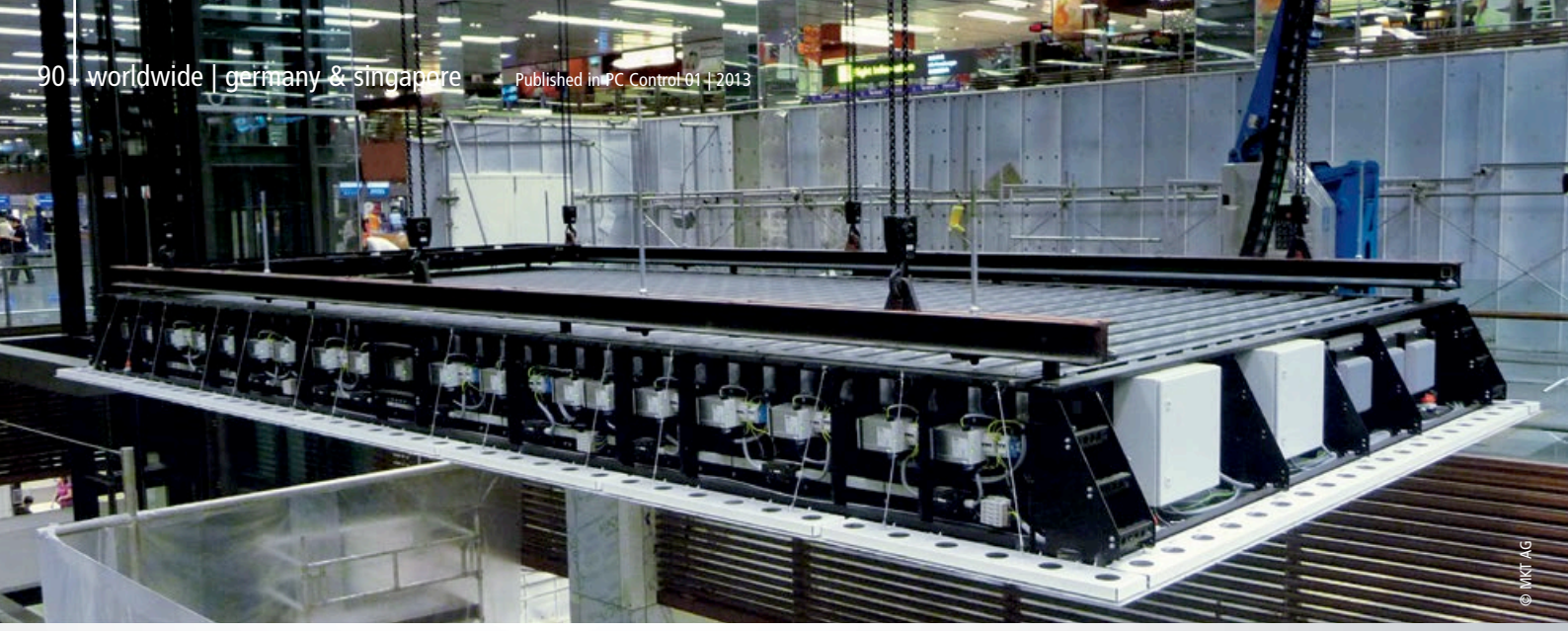
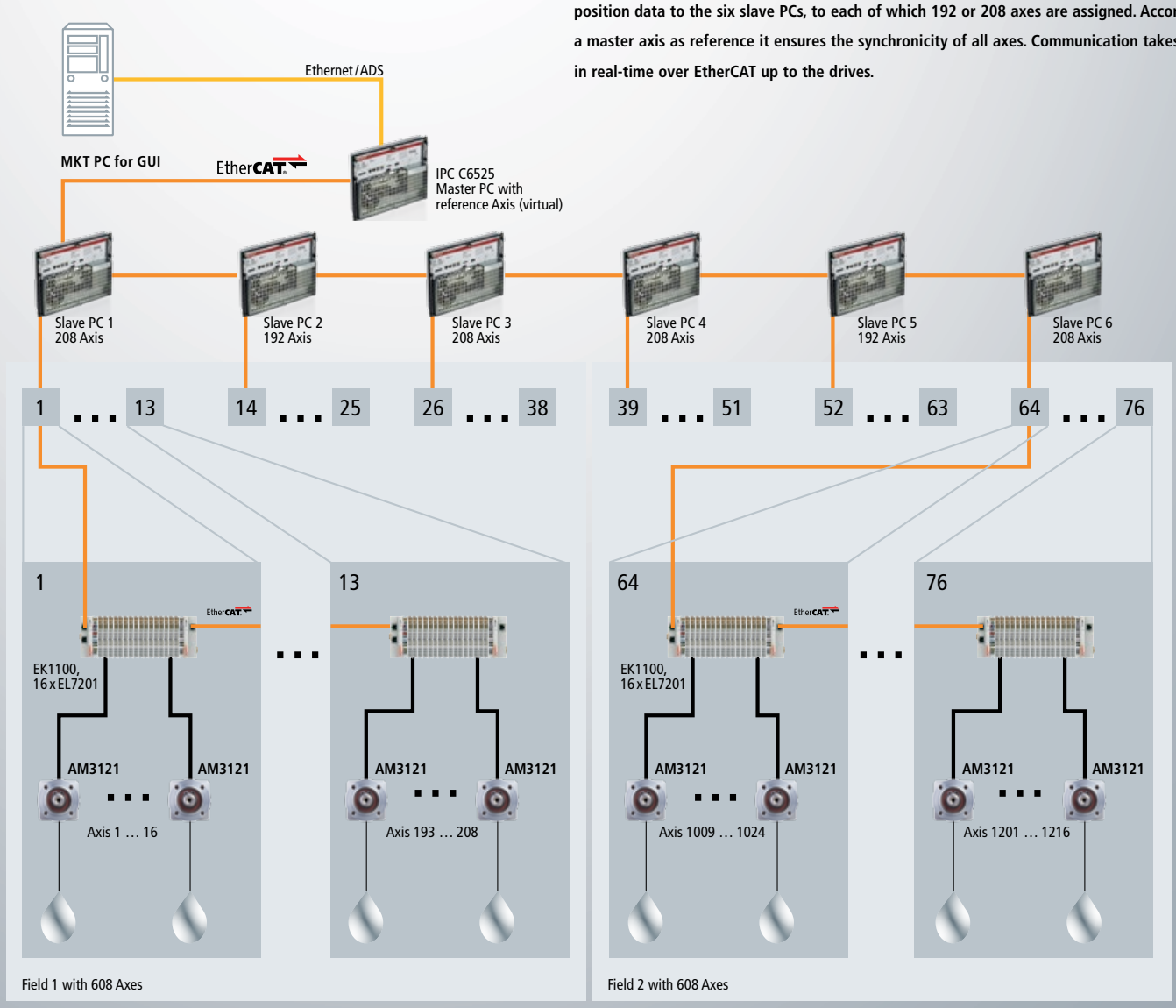

© MKT AG

A Beckhoff C6525 Industrial PC with the TwinCAT NC PTP automation software is responsible for the central control of the 1,216 axes. Communication with the GUI computer from MKT takes place via ADS. The C6525 acts as the master and coordinates the distribution of the position data to the six slave PCs, to each of which 192 or 208 axes are assigned. According to a master axis as reference it ensures the synchronicity of all axes. Communication takes place in real-time over EtherCAT up to the drives.



Field 1 with 608 Axes

Field 2 with 608 Axes

A particular challenge was not least to install the completely pre-assembled installation weighing 30 tonnes into the existing building.

Compact servo drive in a 12 mm terminal

The movement of the individual axes is extremely precise and lies in the range of 1 mm for an overall length of 7.6 m. The maximum offset between two droplets is 0.25 mm. Each droplet is controlled via an EL7201 EtherCAT servomotor terminal and a servomotor of the type AM3121. "In the servo terminals, which fit seamlessly into the EtherCAT terminal row, we found an extremely compact solution that fits the structural conditions perfectly, with limited installation space in the ceiling of the building," stresses Peter Haschkamp. In addition, servo drive technology offers dynamic advantages and allows flowing transitions.

Modularity of the controller simplifies commissioning

"Important for us was also the modularity of the control solution and the fact that an individual axis can be exchanged without addressing. That made partial commissioning possible, for example; i.e. we were able to work in parallel on software, hardware and the mechanism, allowing us to keep within the narrow timeframe that we had for this project," emphasizes Peter Haschkamp. With TwinCAT NC PTP it is additionally possible to "jog" the whole show, i.e. one can fast forward and rewind like a film. That very much simplified the commissioning for MKT. If an individual passage of the sequence was not yet 100 % satisfactory, the engineers from MKT could repeat it continuously. A big advantage, as Peter Haschkamp stresses: "With other solutions this is not possible and you are forced to continually start the show from the beginning each time until you reach the desired position, which is very time consuming."

In contrast to comparable kinetic sculptures realized by MKT in the past over decentralized hardware controllers, "Kinetic Rain" is controlled via a central PC and software and transmitted over EtherCAT. The cam table function, which MKT accommodated locally in the drive amplifier in earlier control solutions, is now executed by the software. In this way, the position data can be managed centrally and distributed in real-time to the axes over EtherCAT.

Important for MKT in choosing Beckhoff as partner was also the global positioning of the company. This way, Beckhoff was able not only to accompany and support the project with experts from the company's headquarters in Verl, Germany. The end customer is also assured of on-site support and service by the Beckhoff subsidiary in Singapore.

MKT AG

Based in Olching, Germany, MKT AG has been conceiving, developing and realizing unique exhibits and kinetic installations for trade shows, events, museums and showrooms for over 30 years. Its clients include not only artistic and cultural institutions, but also renowned industrial companies and service providers. MKT focuses on state-of-the-art technologies, interaction and stringent design.

Peter Haschkamp and Axel Haschkamp (right) of the management board of the MKT AG Fine Exhibition Engineering

ART+COM

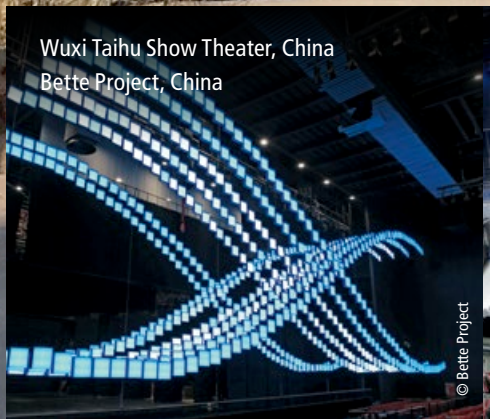
ART+COM AG, based in Berlin, Germany, takes new paths in spatial design. In cooperation with media designers, media artists, IT developers, technologists, programmers, communication and product designers, scientists, engineers and project managers, the creative and technological possibilities of the computer medium are researched and put into practice in artistic installations. In the course of the renovation of Terminal 1 at Singapore Airport, ART+COM was commissioned by the Changi Airport Group Singapore to design an expansive installation. The goal was to develop an identity-defining and contemplative moment for the check-in hall that would contrast the hectic travel atmosphere.

Further Information:

www.changiairportgroup.com
www.mkt-ag.de
www.artcom.de

Attractions industry references

Wuhu Fantawild Culture-tech Inc.
Hytechnology Inc., Shenzhen, China



Wuxi Taihu Show Theater, China
Bette Project, China

© Bette Project

Hexaflite® Flying Theater, China,
Simtec Systems, Germany

© Simtec Systems


© Hytechnology Inc.

References for attractions industry, selection

Entertainment parks

- Walt Disney Imagineering (WDI), Burbank, USA
- Alterface Projects S.A., Wavre, Belgium:
  - Interactive cinema with 4/5D special effects
- Bette Project, China:
  - Romantic Show of Tanhe, China
  - Wuxi Taihu Show Theater, China
- Boren Culture and Technology Co. Ltd., Jiangsu, China:
  - Zhejiang Yueqing Tieding Yo-Yo Park
  - Dalian Fu Cube Super Park
  - Shandong Jinan Movie Town
  - Suzhou H. Brothers Movie World
- Hytechnology Inc., Shenzhen, China:
  - Songs of birds, Wuhu Fantawild Culture-tech Inc.
  - Nuwa patches up the sky, Jinan Fantawild Culture-tech Inc.
- K. D. Decoratives Ltd., Huddersfield, U.K.:
  - "The Night before Christmas" (Sundown Adventure Land)
- La ProPoint Inc., CA, USA:
  - Movie theater attraction for Great Wolf Lodge Resorts
- Sigma Services Inc., FL, USA:
  - Paramount Wonderland, Canada
- Simtec Systems, Germany:
  - Hexaflite® Flying Theater, China
- Steel Construction and Robotic Machinery (S.Co.R.E), Lebanon:
  - Race simulator "Real-Motion"
- Xesa Systems – Full Motion Technology, Italy:
  - Full-motion simulator

Entertainment districts

- City of Dreams Casino, Macau, China:
  - diverse Entertainment-Districts

Motion picture studios/TV studios

- SGPS/Show Rig, NV, USA:
  - Fast & Furious 7
  - Transformers: Age of Extinction
  - Ironman 3
  - The Muppets

TV shows

- SGPS/Show Rig, NV, USA:
  - Big Brother
  - Biggest Looser
  - The Voice

Full-motion simulator
Xesa Systems, Italy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Movie theater attraction for Great Wolf Lodge Resorts, La ProPoint Inc., CA, USA


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Published in PC Control 01 | 2020

PC-based technology controls entertainment applications and kinetic digital signage

Highly precise motion control and synchronization

Simtec Group specializes in custom-tailored motion simulator systems. Founder and Managing Director Bernd Kaugmann used his extensive flight simulator expertise to enter the market for automobile component testing systems and entertainment applications. Today, simulator systems from Simtec can be found in entertainment parks, 4D theaters and museums around the world. With its development of Screenflite®, Simtec has entered the digital signage field as well. Resembling a kinetic piece of art, the media information system catches people's attention in airport terminals, train stations or shopping malls – precisely automated with PC-based control from Beckhoff.

To control the smaller motors that rotate the screens, Simtec uses compact drive technology from Beckhoff, the EL7201 servo terminals with One Cable Technology.

© Simtec Systems

The Screenflite® digital signage system developed by Simtec is an effective marketing tool. The dynamic movements of the panels capture the attention of passers-by and convey the advertising message kinetically.

© Simtec Systems

The modular digital signage system consists of three circular rotating levels and weighs 5.3 tons. Each ring holds four LED screens that can be moved in and out by approximately 1.1 meters and rotated with or against each other as desired.

The LED screens can be dynamically combined and separated again to form a wide range of shapes with two, three, four and six displays.

Over time, the development and manufacture of custom-tailored simulator systems for the entertainment industry has become Simtex Systems' core business segment with the highest sales, with about 80% going to China. "The Expo 2010 in Shanghai was our entry into the Chinese market," says Andreas Stickel, Director Business Development at Simtec Systems GmbH. "As a result of our strong international growth, we expanded our production site in Braunschweig, Germany and set up a subsidiary in China in 2016," he adds.

New generation of the "Flying Theater"

Adding to the classic attractions of its Funride™ family of products which deliver a perfect simulation experience by combining visual and mechanical effects, Simtec has developed the next generation of indoor attractions with its Hexaflite® Flying Theater. The moving platform featuring six degrees of freedom is surrounded by a spherical projection screen with a diameter of up to 23 meters. After the spectators have taken their seats on the platform, it tilts into a vertical position so that the audience sits directly in front of the giant screen. "Each spectator's centered position in front of the screen ensures that they enjoy the same experience from every seat," says Andreas Stickel. Linear acceleration ranging from ±0.7 g and ±1 g and rotations of ±15 to 20 degrees around all axes and the perfect synchronization with the projected images and special effects generate a spectacular, highly dynamic flight-like experience that fully immerses the audience in the screen action.

The moving platform is controlled by a Beckhoff CX5140 Embedded PC with a multi-touch Control Panel and TwinCAT 3 automation software. EtherCAT is leveraged as a powerful communication system. "The nearly unlimited network expandability of EtherCAT and the high data transmission rate make it the ideal fieldbus system for such a large-scale project. EtherCAT branching makes any network topology possible. Simtec also takes advantage of the redundancy supported by EtherCAT," explains Christian Spoer, Team Leader Software Engineering. The complex safety solution for the motion system is based on approximately 100 digital TwinSAFE terminals in IP20 and local TwinSAFE I/O modules in IP65. Also in use are four EL6910 TwinSAFE Logic terminals that communicate with each other as well as with the higher-level CX5140. "The signal and interface diversity of the Beckhoff I/O modules also allows us to easily integrate the stage lighting control via DMX terminals and the compressed air measurement with appropriate measurement modules," explains Christian Spoer.

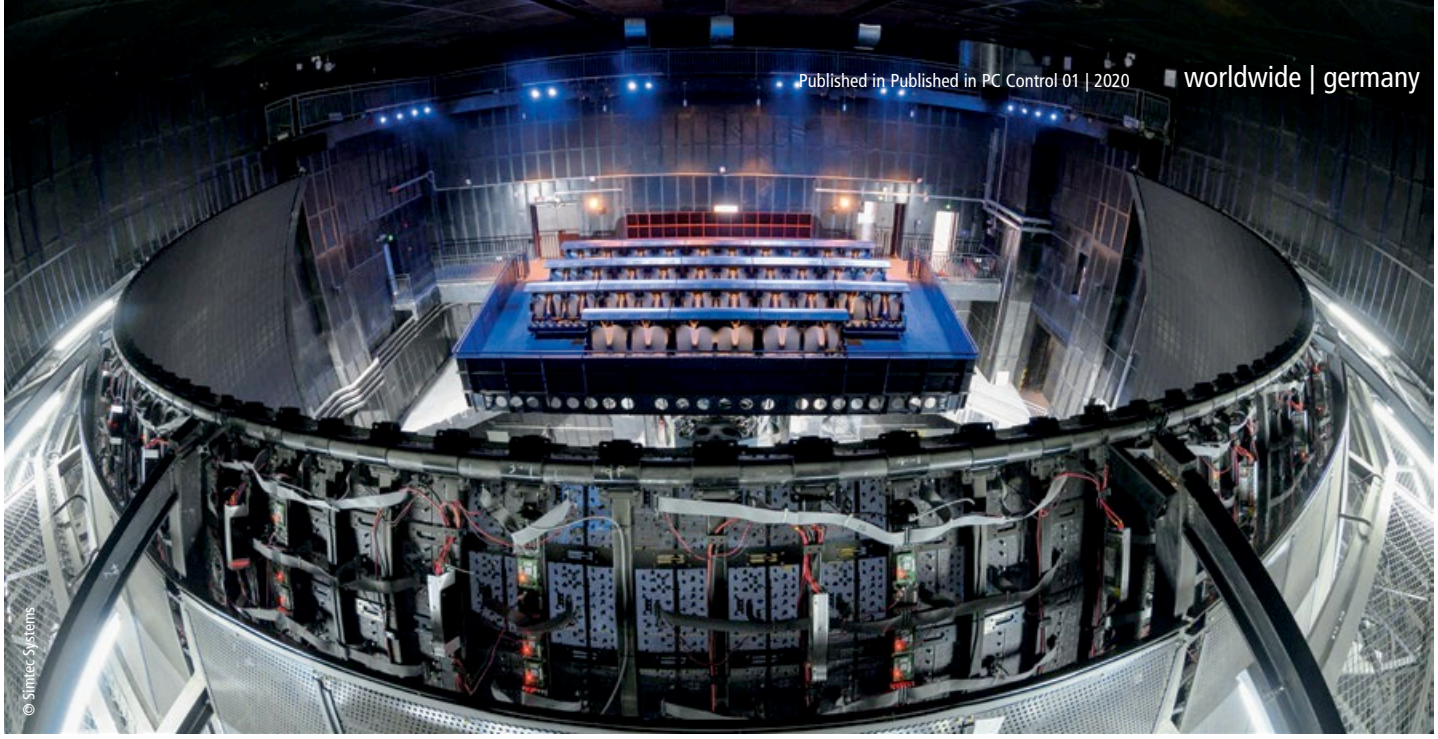
TwinCAT integrates customer-specific motion control expertise

Simtec has developed the closed-loop control technology for this application in-house in C++. The fact that TwinCAT 3 supports the C++ programming language was an additional plus. As a result, Simtec's entire motion control programming can be easily integrated into the TwinCAT 3 automation software and run in real time. The user interface of the Hexaflite® system is another proprietary Simtec solution developed in C++. "One of the great advantages of the Beckhoff technology is the ability of our visualization system to communicate easily with TwinCAT over ADS," emphasizes Andreas Stickel.

Digital signage interpreted kinetically

With its Screenflite® system, Simtec is now entering a new market. The modular media information system, which weighs 5.3 tons, consists of three circular rotating levels. Each ring holds four LED screens, each with a surface of 2 square meters, that can be moved approx. 1.1 meters in and out with scissor arms and rotated with or against each other. "Based on highly dynamic choreography, the LED screens move toward each other and separate again to form various combinations or shapes consisting of two, three, four or six screens in rapid order," is how Andres Stickel describes the kinetic system. "In addition, the flat screens on the upper and lower rings can tilt vertically. The mechanical design ensures that the screens don't collide with each other."

On each of the 12 screens, media content can be played in sync with the screens' motion. Since the motion sequences are determined through program-



The Hexaflite® Flying Theater consists of a platform that is movable with six degrees of freedom and surrounded by a circular screen, resulting in a viewing angle that's 180 degrees horizontally and 110 degrees vertically.

ming, sequences in line with the system's 20 degrees of freedom are possible. "We have created nine different motion cycles for the Screenflite®," adds Andreas Stickel, "but the kinetics are freely programmable and can be adapted by the operator's content designer."

Kinetics require exceptionally precise drive control and perfect synchronization

"From a control perspective, the digital signage system is our most complex product," says Christian Spoer. The challenge lies in the precision of the different motion control speeds and the perfect synchronization. The three rings that move the LED screens via their scissor arms are not linked mechanically but communicate via Wi-Fi using TCP/IP (via ADS). Only the power and the emergency OFF signals are transmitted via slip rings.

Each ring uses an ultra-compact C6015 Industrial PC with an Intel Atom® quad-core processor that functions as an EtherCAT master to control the movements of the four LED screens. Because of their high performance, one of these IPCs is able to handle the synchronization of all three rings over Wi-Fi. "The ultra-compact design of the C6015, which measures only 82 x 82 x 40 millimeters, is ideal for the small amount of space we have in the rotating shapes," explains Christian Spoer.

The motion control runs in a C++ module with a linked PLC project. "We programmed the axis control algorithms and the synchronization of the motion sequences in a C++ module that integrates seamlessly into TwinCAT 3. The TwinCAT NC library provides the closed-loop controller and profile generator," adds Christian Spoer.

To control all 27 PTP axes on the digital signage system's three levels, one- and two-channel EtherCAT servo drives from the AX5000 series with integrated safety functionality are used. And to control the smaller motors for rotating the monitors, Simtec uses EL7201 servo terminals with One Cable Technology (OCT) connection because their compact design works perfectly in the limited space available.

Conclusion

Simtec has used control technology from Beckhoff in many of its projects. "We use the complete spectrum of Beckhoff control components in our media information system, from the Control Panel and Industrial PCs to I/O terminals and TwinCAT software. The option to employ both centralized and decentralized PC-based control technologies works great for our needs and is an important prerequisite for our applications. We also benefit from the broad range of terminals that Beckhoff offers. For example, by simply inserting a pressure measurement terminal into the I/O segment you can recognize a pressure drop in the system and take appropriate corrective action. And in addition to the high communication speed of EtherCAT, which is a prerequisite for the perfect synchronization of the screens, we also benefit from its diagnostic functions. Other benefits include the direct integration of C++ modules into TwinCAT 3 as well as the ability to run it on top of Visual Studio, which allows us to easily integrate Git for the version management," says Andreas Stickel, summarizing the many advantages of PC-based control.

Further Information:
www.simtec.de/en

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LA ProPoint combines cartoons with animatronics in innovative attraction

Setting the scene effectively for Great Wolf Lodge resorts in small spaces

LA ProPoint, a specialist in entertainment technology, has implemented a new movie theater attraction for the American resort chain Great Wolf Lodge. A frame surrounding the screen is animated with integrated animatronic elements and video projection. For the integration of AV, animatronic and automation equipment, LA ProPoint utilizes the universal Beckhoff technology, which supports entertainment industry standards and enables space-saving installation in the lobby.

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Above: A scene from one of the Northwoods Friends cartoons
Left: The Great Wolf Lodge Resort in Bloomington, Minnesota, features the innovative Northwoods Friends Show theater developed and implemented by LA ProPoint.

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A CP6706 Panel PC running TwinCAT 3 software automates the entire Northwoods Friends Show.

Spellbinding entertainment can now be experienced in unusual places. Take, for example, the lobby at multiple locations of Great Wolf Lodge Resorts, a well-known chain of indoor water parks with hotel operations in the USA, where guests of all ages are welcomed by an innovative movie theater attraction. Here, the cartoon characters in the Northwoods Friends Show act in a special frame. Animatronic elements integrated into the frame move in precise synchronization with the action sequences and become part of what is happening on the screen. Video projections make the figures integrated into the frame even more lifelike. Following initial installations in four Great Wolf Lodge locations, more are already planned.

To successfully implement the new lobby theaters, an impressive amount of automation and networking technology needed to be installed into very small spaces. The entertainment engineering experts at LA ProPoint, based in Sun Valley, California, handled the design and installation of the project. The company specializes in entertainment and AV installations across North America. High-profile LA ProPoint clients include theme park and theatrical powerhouses like, for example, Cirque du Soleil as well as major sporting venues such as the AT&T Stadium, home of the Dallas Cowboys, and museum installations like the California Science Center.


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Bird's eye view of the water park at the Great Wolf Lodge in Bloomington

Leading the convergence of AV and entertainment technologies

"Productions like the animatronic Northwoods Friends Show are so exciting because they demonstrate how AV and entertainment technology continue to overlap," said Richard Adams, Automation Engineer at LA ProPoint. To implement the demanding theater installation for Great Wolf Lodge, LA ProPoint first had to find a control system that would combine the AV and animatronic functions seamlessly and cost-effectively. LA ProPoint was able to leverage expertise developed from a wide range of applications, including automation.

Showtime for automation with Beckhoff

At the end of the development process, the team decided on universal automation with a PC-based control platform and TwinCAT 3 software from Beckhoff. A CP6706 Panel PC handles the real-time control of all functions, including the stepper motor-driven animatronic elements and the AV equipment with TwinCAT. Using Ethernet TCP/IP, the TwinCAT control system connects to three different projectors from two different manufacturers, a Blu-Ray player, a high-end sound mixer and three BrightSign media players. "The most

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Figures integrated in the animatronic theater frame are moved by stepper motors and further animated by having video projected over them.

In this action sequence, part of the animatronic frame is lowered and video is projected onto another moving screen component to make it resemble a ladder.

© Beckhoff Automation LLC

important aspect backing our decision to use TwinCAT is the ability to program everything in one universal software platform," Richard Adams added.

To establish communication specific to AV and entertainment applications, the TwinCAT SMPTE timecode interface can extract timing information sent by a SMPTE master in order to provide an absolute time reference in the application. "That says a great deal about the suitability of TwinCAT in entertainment applications, and this is significant from a controls engineering perspective because traditional PLC platforms just don't go there," explained Adams.

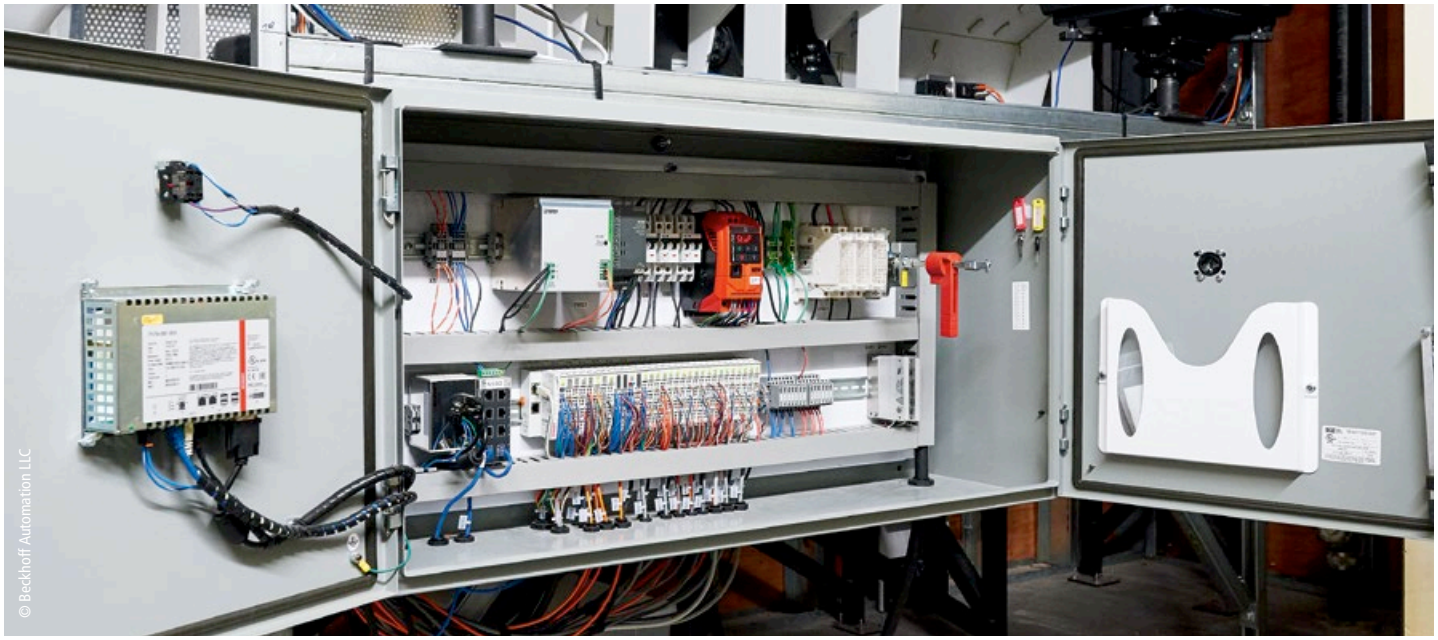
EtherCAT Terminals handle the system communication and enable a space-saving installation in a small control cabinet. For example, the EL3702 EtherCAT oversampling terminal acquires the signals from an SMPTE master, while the EL7041 EtherCAT Terminal operates as a compact drive amplifier for the stepper motors. Richard Adams commented: "The EL7041 stepper motor terminal was very easy to connect with the stepper motors for control. Instead of programming, mounting and wiring eight different motor controllers, everything is programmed centrally in TwinCAT and motors are cleanly wired back to DIN rail-mounted I/O."

The CP-Link 4 one-cable solution connects the Beckhoff controller installed in a small space behind the scenes to a CP2907 Control Panel, which serves as a convenient user interface at the reception desk. The intuitive HMI developed in TwinCAT by LA ProPoint offers easy operation for all resort staff – from front desk personnel to AV and maintenance staff.

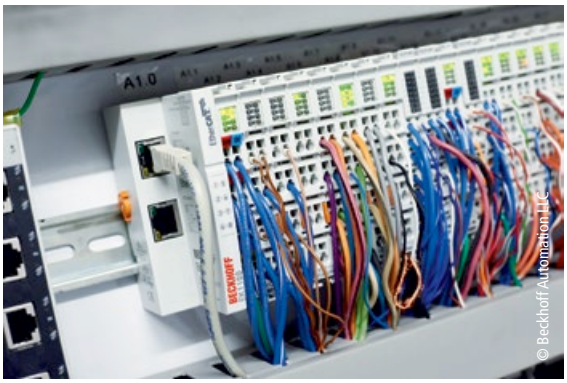
Reduction in development and installation time

Overall, LA ProPoint viewed its first ever PC-based control application as a success and is already planning further installations. "Programming the stepper motor control centrally in TwinCAT saved about a week in programming and troubleshooting time when compared with alternative approaches," Adams reported.

"In addition to our software development savings, PC-based control from Beckhoff also saved significant time in panel design and installation. We are certain it saved several weeks of design and development time in this regard."



View inside the compact control cabinet installation of the Northwoods Friends Show



Left: The controller in a small space behind the scenes connects to the CP2907 7 inch Control Panel at the reception desk of the Great Wolf Lodge via the CP-Link 4 one-cable solution.

Right: EtherCAT offers seamless support for typical standards in entertainment and AV technology, such as SMPTE timecode.

At a glance

Solutions for the entertainment industry
Innovative leisure park attraction combines animatronic elements and video projection in lobby movie theater

Customer benefit
- PC-based control supports communication standards of the entertainment industry and all control functions.
- TwinCAT considerably reduces the programming time.
- EtherCAT Terminals and compact drive technology enable space-saving installation.
- The affordable and easy-to-handle implementation is to be installed at further locations.

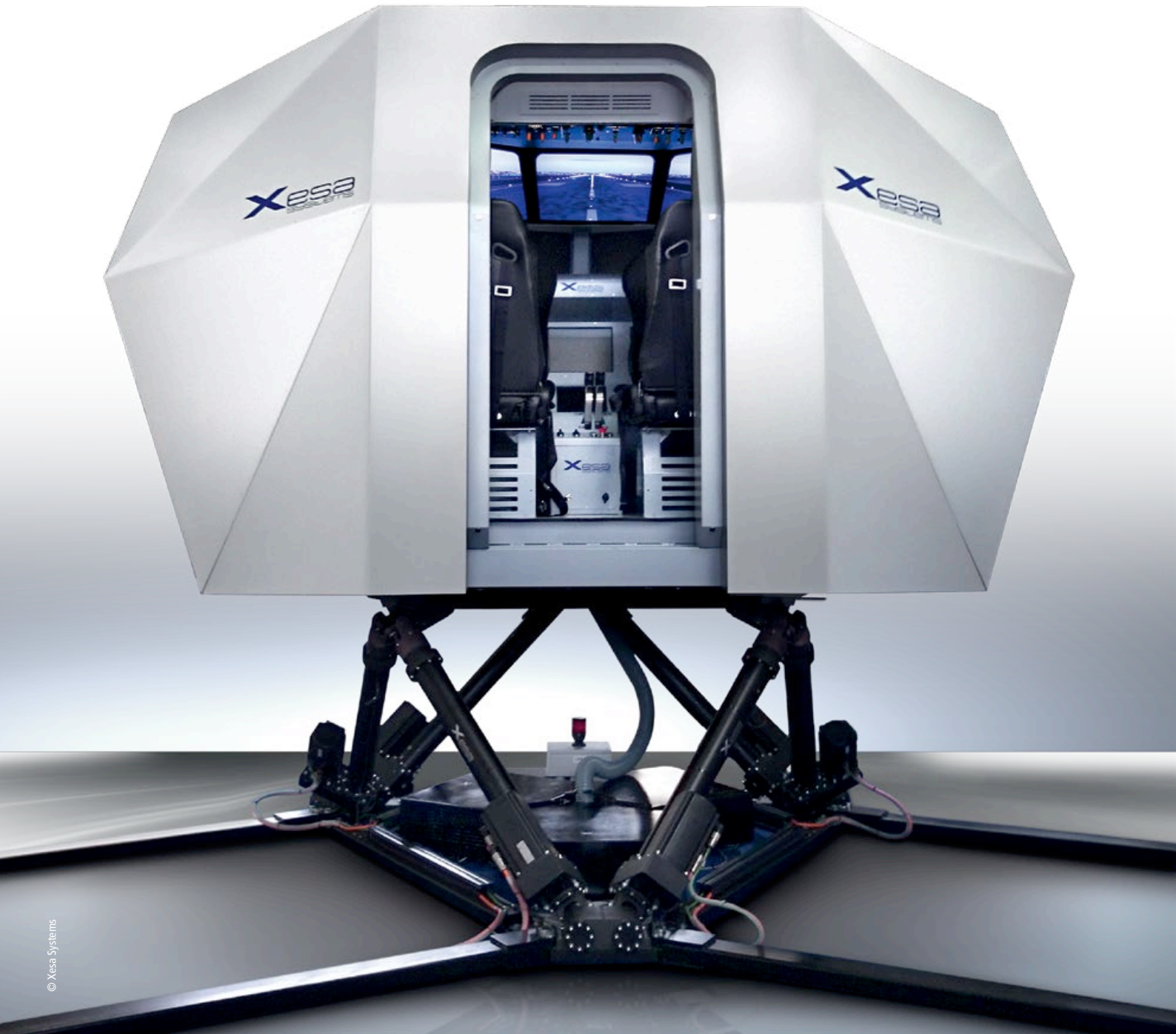
Applied PC Control
- TwinCAT 3 for programming with Structured Text, TwinCAT NC PTP for animatronics control, TwinCAT PLC HMI for the user interface, TwinCAT TCP/IP for vendor-neutral communication and TwinCAT SMPTE Timecode for AV device synchronization
- CP6706 Panel PC connected via CP-Link 4 to CP2907 7-inch Control Panel
- EL3702 EtherCAT oversampling terminal and EL7041 for controlling the AV systems and stepper motors respectively

Further information:
www.greatwolf.com
www.lapropoint.com
www.beckhoffautomation.com

Full-motion simulator for ultra-realistic driving simulation

PC- and EtherCAT-based controller provides highly dynamic, precise axis control in advanced vehicle simulations

Modern driving simulators are capable of replicating the sensations of motion, such as in the cockpit of an aircraft, in a car, on a train or on the bridge of a ship. These simulations are so realistic that they are often indistinguishable from the actual driving or flying experience. Full-motion simulation systems are used, for example, in professional pilot training as well as in "edutainment" and entertainment applications. The Italian brand Xesa Systems owned by GIEI s.r.l. specializes in this market segment, leveraging automation products from Beckhoff to bring simulations to life.



© Xesa Systems

The core of the Xesa motion simulator is a parallel kinematic machine built on a hexapod or Stewart platform. It has up to six degrees of freedom (three translatory and three rotary), enabling the generation of realistic motion sequences that are highly dynamic and accurately-positioned. The software produces a dynamically changing virtual environment that is in sync with real physical movements, completing the simulation. The physical drive of the motion platform is located at the lowest level of the system and uses linear or rotary actuators. Each axis is equipped with at least three sensors, and in some cases up to five. Feedback from these sensors – in conjunction with the feedback from an encoder mounted on the motor – enables absolutely precise movements to each of the individual positions. The axes are moved using Beckhoff AM8052 servomotors which are connected to AX5000 Servo Drives via One Cable Technology (OCT). A DIN rail mounted CX5020 Embedded PC serves as the central control platform.

The controller communicates with the drives after receiving data from the so-called washout filters (high-pass and low-pass software modules). This comes from the application software, where the simulation system and the inverse kinematics are located. After the physical model in the upper software layer has calculated the behavior of the system, and the inverse kinematics has performed the respective conversions, the information is transmitted to the automation system in the form of points where the simulator must drive to. This simulates a highly realistic driving experience for the driver.

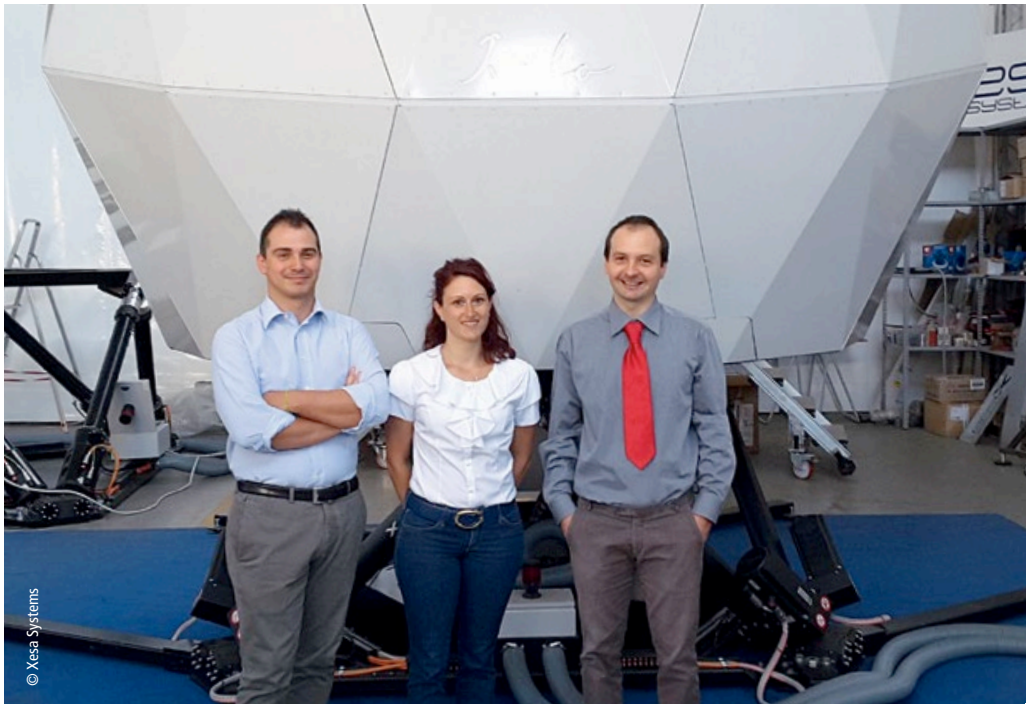
PC- and EtherCAT-based controller as a universal platform

"Xesa Systems and Beckhoff have collaborated closely for many years," explains Lorenzo Vicini, who is the engineering manager responsible for automation at Xesa Systems. "Our engineering successes certainly rely on the high degree of innovation offered by automation solutions from Beckhoff. One of the most substantial reasons why we chose a PC-based controller was that it enabled us to streamline our systems. We now only need a single CPU, TwinCAT as a universal software platform, and EtherCAT as the high-performance communication system for the entire application. Our software developers are far more flexible and gain a familiar, universal development environment with Visual Studio® embedded into TwinCAT 3. Additional benefits include the ability to link MATLAB®/Simulink® projects and the option to use C++ as a programming language. Further, the scalability of the Beckhoff components – from the PCs and drive components to the software – offers us a system with which we can create very precise controller designs that ideally fit the respective application."

"EtherCAT also plays an important role for us," continues Lorenzo Vicini. "On the basis of this fieldbus, we can achieve a controller accuracy that is higher than what is possible with any other system. A further advantage is the possibility of remote control as enabled by TwinCAT. We can fully access all devices: even if our simulator is located on the other side of the world, we can easily access it anytime via smartphone or tablet."

Controller-integrated safety solution

Xesa has also solved the issue of safety controllers in a simple manner with the integrated Beckhoff control architecture. The safety functions are implemented easily by adding safety option cards to the AX5000 drives. Even if safety requirements are not critical in the testing industry, extremely high precision is required. In order to connect the velocity and current controller to the AX5206 drive via the built-in encoder on the AM8052 servomotor, Xesa Systems uses a second external encoder to control the outer controller. "The performance that we achieve is impressive in this case, too," says Lorenzo Vicini. He emphasizes that: "With the integrated system from Beckhoff, we can achieve an individual axis precision of 10-5 m. Further advantages include the availability of a dual-axis drive and the OCT technology. This has made our machine designs and cabling much leaner. Connecting through OCT also allows us to start up one axis quickly and validate the system with the help of the TwinCAT NC PTP software library," concludes Lorenzo Vicini.



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From right to left: Lorenzo Vicini, Engineering Manager for automation at Xesa Systems, Elena Briganti, Marketing Communications from Beckhoff Italy and Gabriele Vercesi, Area Sales Engineer from Beckhoff Italy.

Further information:

www.xesasystems.com

www.beckhoff.it

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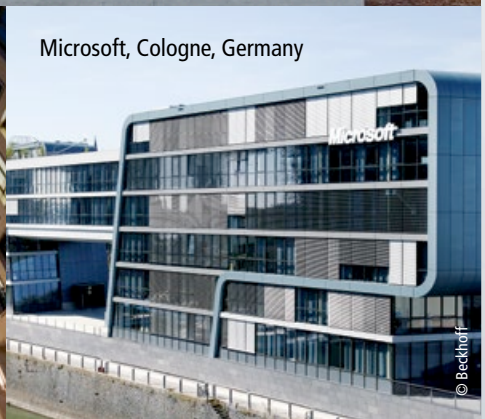

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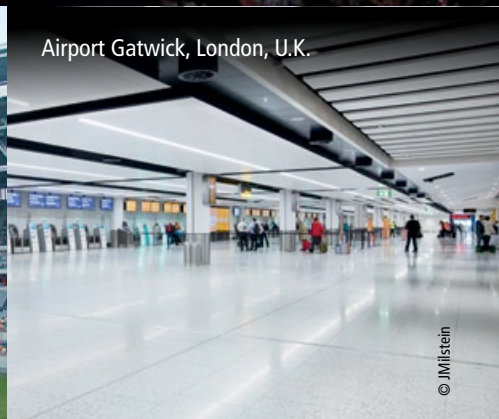

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Kaisermühlen Tunnel, Vienna, Austria
Ecoexperts Automation GmbH


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Marmaray rail tunnel, Istanbul, Turkey
Wico de Coprel

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- Unipark Nonntal, University of Salzburg, Austria
- University of Antwerp, Belgium
- UOW Malaysia KDU University College, Malaysia
- Zayed University, Abu Dhabi, UAE

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- Ali Bin Hamad Al Attiya Arena in Qatar
- Allianz Arena, Munich, Germany
- Anima Care retirement homes, Belgium
- Armonea retirement home, Belgium
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- Fuwai Hospital, Yunnan, China
- Grundfos Kollegiet, Aarhus, Denmark
- Merkur Spiel-Arena,, Düsseldorf, Germany
- Messe Basel, Hall 2, Basel, Switzerland
- Nürnberg Messe, Hall 3A, Nuremberg, Germany
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- Oslo City Hall, Norway
- Serlachius Museum, Mänttä, Finland
- Staatliches Museum für Archäologie Chemnitz, Germany
- Therme Wien, Vienna, Austria

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- Acciona S.A., Spain
- Aparcaments i Mercats de Reus, Reus, Spain
- e2watch, Regio IT, Aachen, Germany
- ECOexperts Automation GmbH, Kaisermühlentunnel Vienna, Austria
- Frankfurt Airport, Germany
- Gatwick Airport, London, U.K.
- HST Hydro-Systemtechnik, Germany
- KLIA 2 Control Tower, Sepang, Malaysia
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- Metro M2, Lausanne, Switzerland
- Nordtangente, Basel, Switzerland
- Offis, Institut für Informatik, University of Oldenburg, Germany
- Stadtwerke Konstanz/Cegelec, Germany
- Stadtwerke Lingen, Germany
- Vitrociset, Rome, Italy:
  - Brenner motor way, Italy
  - ENAV, air traffic control, Rome, Italy
  - Italian Ministry of Interior, unmanned remote control of radio site
  - SNAM, electric grid security, Milan, Italy
  - Terna, electric grid security, Rome, Italy
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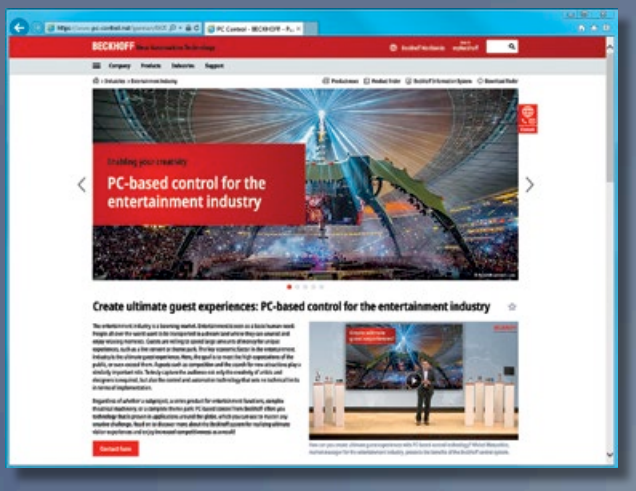

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