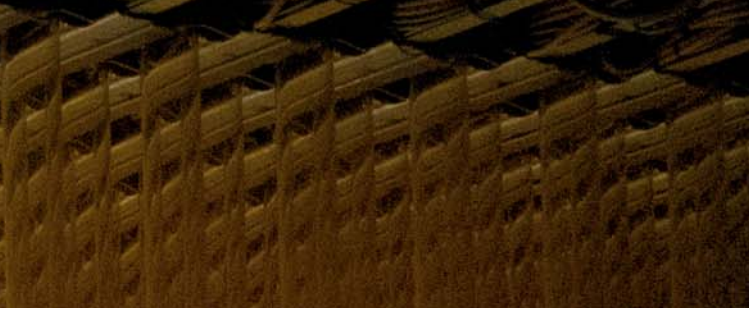
EtherCAT synchronizes 529 axes to automate kinetic art installation

“Breaking the Surface”:
Servo terminals move virtual ocean



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.

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."

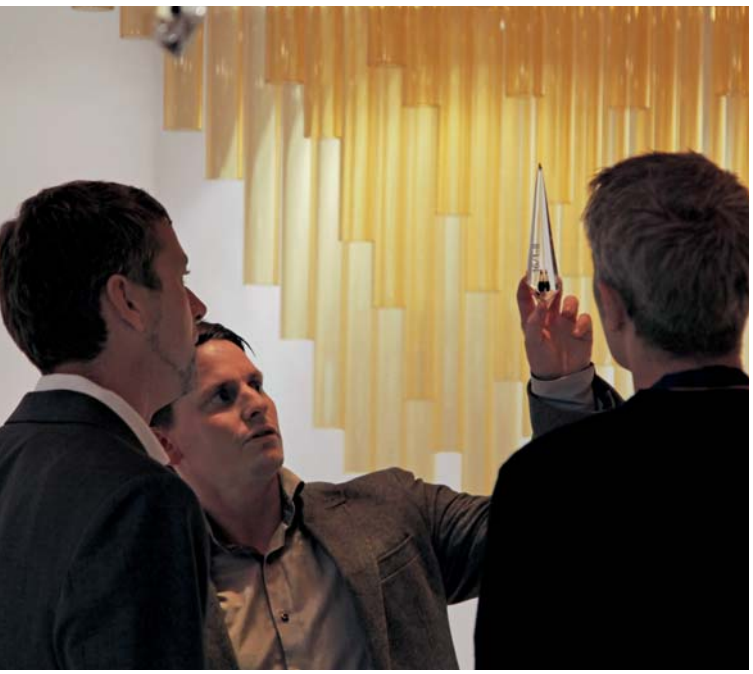
The control system architecture encompasses three main components:

- 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

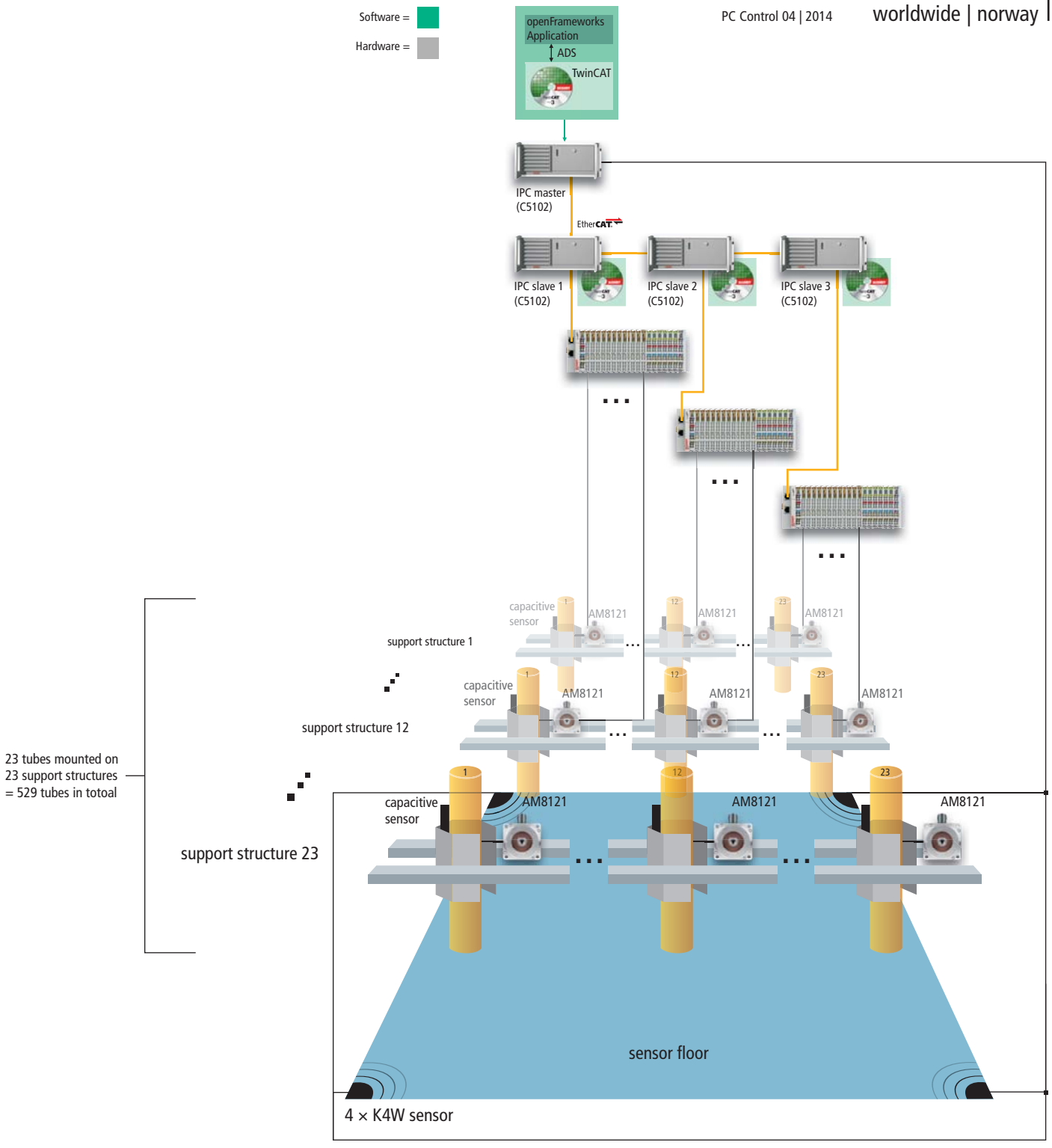
Lundin Norway, based in Oslo, is a subsidiary of Lundin Petroleum AB, a Swedish group of companies with a proven track record of finding, developing and producing oil and gas resources worldwide.

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