SIEMENS

CASE STUDY

Ocean wave power – another sustainable energy source supported by advanced and reliable Siemens technology

Offshore Hawaii, Oscilla Power, Inc. will deploy its first 100 kW-rated, community-scale wave energy converter system incorporating a wide range of advanced Siemens technologies.

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Company: Oscilla Power, Inc., based in Seattle, WA

Challenge: Develop the most compact, capable, and reliable electrical controls and drive systems possible, given extreme space limits and remote operation in harsh conditions

Solution: Integrate a range of advanced Siemens technologies for remote automation, controls, data sampling, communications, and other operational tasks

Results: Oscilla Power now has highly functional and reliable systems capable of nearly autonomous, remote operation, all deployable much sooner to achieve a faster ROI

Engineering minds have dreamed of harnessing ocean wave power for hundreds of years, if not longer. After all, waves are constantly moving across ocean surfaces as dependably as twice-daily tides and the rising sun. One special attraction of ocean wave energy is its high power density. For example, wave power is 10 times denser than wind and 100 times denser than solar. In fact, the kinetic energy of waves is enormous: A four-foot, 10-second wave hitting one mile of coastline can power more than 9,000 homes.

Such potential has inspired many different approaches to capturing and using wave energy. One of the world leaders is Seattle-based Oscilla Power, Inc. "Ocean waves represent our planet's last untapped large-scale renewable energy resource," says Tim Mundon, Ph.D., the company's vice president of engineering. "Over 70 percent of the earth's surface is covered with water. The energy contained in waves can potentially generate up to 80,000 TWh of electricity per year, enough to meet our global energy demand five times over. In the U.S., wave power could potentially provide up to 10 percent of its energy needs."

Six degrees of energy capture. Oscilla Power's patented flagship technology is the Triton wave energy converter (WEC). It's a highly efficient, multi-mode point absorber consisting of a geometrically optimized surface float connected to a subsurface, ring-shaped, vertically asymmetric reactor ring by three taut but flexible tendons. Connected to those tendons and housed inside the float are three independent hydrostatic, hydraulic drivetrains with generators that provide a highly reliable, flexible, and high efficiency conversion of ocean waves oscillating mechanical energy to electricity. "The relative motion between the surface float and the reaction ring generates the power," Mundon explains.

Unlike most conventional wave energy devices, Triton's surface float can extract energy from ocean waves in all six degrees of free movement — heave, pitch, sway, surge, roll, and yaw. This enables the Triton WEC to capture energy over a wider range of ocean conditions than other approaches. In turn, this translates to a greater average annual energy production and a substantially lower levelized cost of electricity.

At this time, Oscilla Power is producing two WEC system models with this multi-mode architecture: the Triton-C and the Triton. The Triton-C is a 100 kW rated power system designed for remote or isolated communities, or small coastal facilities, while the Triton is a 1 MW rated power system that is designed to be installed in large arrays to provide utility-scale power at competitive costs of $0.10-0.15/kWh. Recently, the U.S. Navy installed a Triton-C offshore from its Marine Corps base in Kaneohe, Hawaii.

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The Triton-C's float is a tightly sealed, corrosion-resistant steel vessel – 10 meters x 7.5 meters by 2 meters in size – that houses the three drivetrain systems, electrical controls, battery banks, ballast, and other systems, including fire suppression.

Once deployed and properly anchored, the reaction ring is lowered on its three tendons to a depth of 20 meters. "We've optimized the shape of the float to take the best advantage of different types of surface wave action," Mundon says. "In addition, we've designed the Triton to survive the worst weather conditions with an integrated load-shedding mechanism. Its automated ballast system can submerge the float just below the surface in case of storms."

As the Triton-C floats offshore securely anchored to the sea floor, it's connected to the shore-based utility grid with an underwater umbilical cord of sorts. It consists of a shielded electrical power conduit – "basically a long extension cord," as Mundon describes it — that exports 720 volts DC to shore, where an inverter turns it into three-phase AC and a transformer steps it down to 240 volts to feed the local grid.

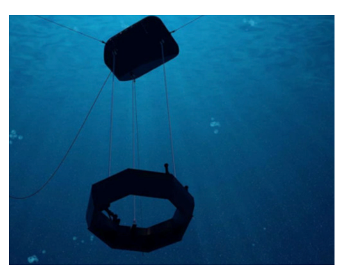
Also inside the cord to shore is a fiber optic cable to handle multiprotocol communications with a 4G wireless system as backup. "Our Triton WEC devices are completely unmanned, so their operations are completely remote," he says. "For the most part, we designed the Triton to operate autonomously offshore."

According to Mundon, the challenges the company faced in the Triton WEC's design, engineering, manufacturing, commissioning were extraordinary. Space and weight were key concerns. "Every ounce we can save in each Triton model we deploy means that much more electricity it can produce," he says. "So every component we used had to be as compact and lightweight as possible."

Triton components and systems had to be exceptionally reliable and capable of remote operation, too. Although the Triton vessel is designed to be water-tight, salty sea air can penetrate its seals, so its onboard systems must be corrosive resistant because maintenance is not readily accessible.

In addition, the instrumentation supporting remote operation required data sampling rates of 20 milliseconds — 50 data points a second. "We need such high-speed data collection and reliable communications between the float and shore, so we can closely monitor and record the onboard sensors in near real-time, keeping all the systems operating within tight parameters and watching out for any tell-tale anomalies," says Mundon.

Pictured is the 100 kW Oscilla Power Triton-C wave energy converter system's watertight floating vessel, to deploy in early 2022 off the shore of Hawaii to power a U.S. Navy Marine Corps base.



A subsurface reactor ring is suspended from the surface float by three taut tendons that connect to drivetrains onboard the surface float. The relative motion between the surface float and the reaction ring generates the electrical power that is transported via an underwater conduit to shore where an inverter converts it to AC power and connects to the local grid.

Solution: Integrate a range of advanced Siemens technologies for remote automation, controls, data sampling, communications, and other operational tasks.

For help in the complex system design and engineering that the Triton WEC concept requires to operate efficiently and reliably at sea, Mundon tapped the expertise of two Siemens Solution Partners, top system integrators in the fields of automation and controls as well as motion control respectively: Applied Control Engineering (ACE) and Applied Motion Systems (AMS).

These firms, in collaboration with Mundon and his engineering team, chose to standardize on hardware from the Siemens Totally Integrated Automation (TIA) portfolio, including SIMATIC, SINAMICS, and SCALANCE component families. Both companies have Siemens-certified engineers on their staff, plus they can call on Siemens expert resources any time engineering issues must be escalated. Additionally, standardization on Siemens hardware not only facilitates interoperability but also streamlines troubleshooting compared to the time and effort needed to diagnose operational problems in a multivendor architecture.

Mundon explains the choice of Siemens components involved several factors. One was their compact size, advanced features, easy interoperability, remote diagnostics, and proven reliability. Another was their programmability in the Siemens TIA Portal, which is much easier and faster than competitive alternatives.

A third consideration was the global service and support footprint of Siemens. “Our Triton wave-energy converters can generate power in just about any ocean environment, so knowing Siemens can support us just about anywhere on the globe and for decades to come is important to us and will also be a selling point to our customers,” he says.

Effective power generation and management. ACE developed the automation, control, and communications systems for the Triton-C. Among their hardware components are a Siemens SIMATIC S7-1500 PLC, ET200SP Remote I/O, and a fan- and maintenance-free SIMATIC IPC running SIMATIC WinCC Runtime Professional SCADA software. ACE engineers programmed the PLC and HMI using TIA Portal, which saved weeks of time and effort other vendor components would have required.

The SIMATIC IPC resides onboard the Triton-C to record high-speed OPC data from the S7-1500 PLC and provides historical visualization of the data for company engineers, whether safely onshore during commissioning or back at Seattle headquarters during ongoing operations. The IPC also records conditions on the float and subsurface equipment. The onboard historian IPC is backed up by a redundant one onshore, so if communications fail, engineers can still review historical data up to the failure point, which will facilitate troubleshooting.

Turning wave action to wave power efficiently. Working with AMS, Oscilla Power developed and engineered the three independent hydraulic drivetrains that reside inside the float to manage the highly variable power flows effectively and dissipate peak energy as needed. This way, the power variability of each drivetrain is significantly reduced for a more constant power output.

The electrical side of the Triton-C WEC drivetrains, provided by AMS, involves three subsystems: power generation using SINAMICS S120 drives and SIMOTICS torque motors; supercapacitors capable of storing approximately 3.7 megajoules of electrical energy; and a four-cell battery bank for critical control loads and black starts. As electrical power is generated, it is then aggregated and stored in the supercapacitor subsystem, further reducing power variability while boosting power quality. This design substantially mitigates one of the biggest challenges with wave energy devices.

Every WEC has an optimal force/displacement profile for maximum mechanical energy capture in each wave condition. Triton's drivetrain is fully controllable and permits arbitrary control profiles to be applied. "What's more, we can deploy various active control algorithms to significantly boost power capture in lower sea states," Mundon says.

Each drivetrain features a number of duplicated stages that the Triton control system can independently select and combine to precisely match the wave environment. "This provides improved redundancy and allows the components to work in their optimum power bands for any conditions, so they can provide maximum part-load efficiency," says Mundon.

> "With the Triton drivetrain architecture and various Siemens technologies, we've been able to demonstrate a mechanical to electrical conversion efficiency of more than 75 percent. And we're confident we can boost this even higher in future."
>
> **Tim Mundon**
> Vice President of Engineering

Results: Oscilla now has highly functional and reliable systems capable of nearly autonomous, remote operation, all deployable much sooner to achieve a faster ROI.

Mundon praises the technical competence and cooperation of ACE and AMS, the Triton WEC's systems integrators. "The complexities of making our many different systems work within extremely tight space limitations as well as remote, nearly autonomous, operation in corrosive ocean environments are mind-boggling, but both companies worked together to meet these challenges in the shortest time possible," he says. "The Siemens TIA portfolio and interoperable hardware components helped, too."

Engineers from ACE and AMS concur with Mundon about the value of using Siemens components and the TIA Portal for programming. "The interoperability that's designed and engineered into all the different Siemens components and their programmability via the TIA Portal as a common engineering software framework made their configuration much easier and saved weeks of time," says Chris Hudson, P.E., ACE's project manager. "Then, with the Siemens hardware having built-in web servers and remote diagnostics, the TIA Portal can be used for troubleshooting, fixing issues, and functional upgrades."

Carson Schlect, the project's AMS systems engineer, lauds the automation and control systems ACE designed and engineered, which made connecting to the drivetrain system much easier and faster. Together with Oscilla and ACE, we spent a total of about 12 hours to shakedown, test, and debug the connection between our systems using the TIA Portal," he says. "If it were a non-Siemens-based system or architecture on their end, we would have needed up to a month of combined engineering development, testing, and debugging time to make it happen."

Mundon sees a bright future ahead for wave power in general and Oscilla Power in particular. "Now that we've solved the Triton WEC's extraordinary engineering challenges and are operating a fully functional Triton-C, we're poised to ramp up production and more rapidly deploy and reliably operate our Triton-C model as we've done in Hawaii and scale up to offering arrays of our 1 MW utility-grade Triton model," he says. "With Siemens technology and the expertise of our systems integrators, we're confident we'll be able to achieve commercial viability and a return for our investors much sooner."

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