ABB grid integration technology connects world-first wave energy project

Carnegie Wave Energy adopts ABB microgrid solution for clean energy production

The onshore power plant takes advantage of ABB’s grid integration and process control equipment. It is the first demonstration of a complete grid-connected CETO system anywhere in the world, and the only wave project operating multiple wave units connected together.
Renewable wave energy is now supplying electricity to the Western Australian power grid, in a world-first project utilising grid integration and process control technology from ABB.

The Perth Wave Energy Project (PWE) – a $32 million undertaking developed by wave energy technology developer, Carnegie Wave Energy – is the world’s first commercial-scale wave energy array that is connected to the grid and has the ability to produce desalinated water.

The application relies on Carnegie’s patented CETO Wave Energy Technology – an underwater system utilising buoys and seabed pump units moving with the motion of the passing waves for electricity generation.

A decade in the making, CETO – now in its fifth incarnation as CETO 5 – offers the potential to revolutionise power and water production globally.

World-first project

Carnegie’s ground-breaking CETO technology harnesses the enormous renewable energy present in our ocean’s waves and converts it into two of the most valuable commodities underpinning the sustainable growth of the planet; zero-emission electricity and zero-emission desalinated water.

CETO – named after a Greek sea goddess – is the only ocean-tested wave energy technology in the world that is both fully-submerged, and generates power and/or desalinated water onshore.

The PWE is the first demonstration of a complete grid-connected CETO system anywhere in the world, and the only wave project operating multiple wave units connected together.

CETO was developed, tested and refined at Carnegie’s state-of-the-art Wave Energy Research Facility located at Rous Head in Fremantle, Western Australia. The facility consists of both onshore and offshore test sites for scale testing.

The PWE has allowed Carnegie to commercialise CETO, with the company’s first power revenues through the sale of its zero-emission electricity coming from the Department of Defence for its HMAS Stirling naval base, also located on Garden Island.

Carnegie required the application of proven technologies across all areas of the PWE, in order to ensure a robust system was employed. Following a rigorous tender process, ABB Australia was selected to design and construct the power generation and control system elements of the project and worked with Carnegie to devise a specialised ‘shaft-to-wire’ solution to convert wave energy to renewable, grid-quality electricity.

ABB technology

ABB and sub-contractor teams from Melbourne, Sydney, Darwin and Perth collaborated to develop the systems provided, which encompass process automation, electrical generation and grid integration.

The power and automation specialists were responsible for the design, manufacture, test, delivery, installation and commissioning of the solutions. ABB also provided all onshore process instrumentation, such as pressure and temperature sensors.
The shaft-to-wire solution interfaced PWEP’s hydraulic circuit to an 11 kV microgrid via standard 3-phase ABB induction generators, ACS800 variable speed drives and a ground-mounted 415/11000 V transformer. Low voltage switchgear and protection relays from ABB were also used in this system.

The Symphony Plus platform - a flagship ABB technology - was used for primary process control and monitoring. For the HMI, the team supplied Symphony Plus Operations. For scientific analysis purposes, high speed data acquisition was achieved with National Instruments (NI) cRIO hardware and Citadel database technology. The ABB and NI systems shared a considerable amount of data using Modbus communications. For convenience, all subsea control and data acquisition was implemented with the cRIO technology, as this is where the high speed measurements requirements were concentrated. Communications between subsea and onshore equipment (~ 3.2 km) was achieved with SHDSL modems over twisted pair.

The control system included two virtualised servers using VMware vSphere Hypervisor technologies on which one pair of redundant Symphony Plus Operations servers, a Remote Access Server and a NI LabVIEW server were implemented.

All the control logic was designed, implemented and tested by ABB and its subcontractors, based on functional requirements supplied by Carnegie.

**How it works**

The PWEP utilises submerged buoys, which move up and down with the passing waves. These buoys are connected to hydraulic cylinders by a flexible tether, thereby creating a pumping action. This is used to circulate a special environmentally-friendly hydraulic fluid between the onshore and offshore components of the plant.

The hydraulic pressure onshore is used to rotate a hydraulic motor, which in turn rotates an electrical motor. When the hydraulic motor rotates the electrical motor,

ABB drives configured in the ‘regeneration’ mode are able to generate electricity.

According to ABB control system engineer, Sam Bagherzadeh, the system relies on a brand-new philosophy invented by Carnegie and implemented by the ABB team.

“The main point to optimise the electricity generated is to optimise the differential pressure between the high-pressure and low-pressure sides of the hydraulic motor. This logic is quite sophisticated," Sam explained.

“During the commissioning, we slightly modified the logic that we had designed, and adjusted the parameters in the control loops. Our logic was able to satisfy all the tests that Carnegie conducted on site.”

An important specification for the ABB-designed portion of the PWEP was that it was able to provide fast data logging, meaning the control system needed to
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read and log the majority of analogue values at a 100 Hz sample rate.

*To conform to this requirement, ABB used four NI controllers – one based onshore, and the remaining three housed offshore in sub-sea pods. The offshore NI controllers are used to collect all the offshore digital and analogue data, with 100 Hz sample rates for majority of the signals, and stream the information to the onshore NI controller using three SHDSL links,* said Sam.

*The data collected by the onshore NI controller is then logged with 100 Hz speed to a NI database called LabVIEW. LabVIEW is used both to program the NI controllers, and to record all the fast data in a way that is usable for scientific analysis.*

The team used Harmony Gateway Software (HGS) to establish the Modbus link between the main HPC800 Symphony Plus controller and the NI controllers, facilitating the transfer of information between the NI control system and the HPC800 controller, and vice versa. This allowed the team to implement all the control logics in the main HPC800 controller, send appropriate commands to the offshore pods, and collect all the information in the Symphony Plus Operations HMI portal.

*ABB also supplied an historian for this project – this is configured on the main Symphony Plus Operations serve, and is used to collect the historical data for all the digital and analogue values required in the project. This information is used by the plant operators to ‘fault find’, allowing them to browse all the trends recorded at any time,* said Sam.

Consolidated effort

ABB’s offering of efficient and advanced products is crucial to the day-to-day running of the Carnegie plant and was pivotal in allowing the wave energy technology provider to commercialise its CETO system.

ABB Australia project manager, Nirupa Chandler, says the ABB team deployed control and electrical technologies that have been proven across multiple industry sectors.

Designing the control logics used in the project and connecting the NI system to the Symphony Plus system, however, was a first for ABB, and the entire control system for the PWEP was a world-first application.

*Our control system is the nerve centre for the operation of the plant. Our understanding of complex processes like power station controls was crucial in imple-

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menting the control functionality for the project,” Nirupa explained.

“The team was challenged to deliver a project which in some ways was still being conceptualised as it was a new technology and application. It required input from various experts within ABB and Carnegie to finalise the design.

“As with any project, managing the schedule to achieve the customer’s target dates was crucial which made the commissioning period stressful at times as both ABB and the customer were working in parallel on the mechanical and electrical commissioning.

“But what is important to note is that – even at such stressful times – we did not lose our focus on ABB’s core values in safety, and we did not have any safety-related incidents on site. The project team was focused on overcoming any challenges along the way, and final testing and commissioning was completed in January this year.”

The project has been a success for both ABB and Carnegie, with the trial plant winning a Clean Energy Council (CEC) Innovation award in July – as well as garnering much attention on the world stage.

“ABB’s technology was obviously crucial to achieve this and we’re glad to have played a part in their success,” Chander said.

Customer benefits

For the customer, the ABB solution offers a number of benefits, including the delivery of a reliable grid integration and process control system from a single supplier, along with smooth grid integration of renewable energy.

Carnegie Wave Energy chief operating officer, Greg Allen, said the company was pleased to have collaborated with ABB on this world-first application.

“We chose ABB, confident they have the expertise required to cover the range of disciplines for the success of our development,” Allen said.

“During the tender phase ABB demonstrated that it had the products and expertise to meet the PWEP control and power generation system specification at a competitive price.

“ABB’s technology and past experience integrating renewables into microgrids, along with their knowledge of process control and communication systems, made ABB the perfect partner for this important project.”

The ABB system provides supervisory control and data acquisition for the entire plant including conversion of the fluid energy into electrical energy.

“The ABB system also provides the majority of the electrical protection functions for the plant to ensure that it complies with the technical rules related to grid connection,” said Allen.

Though the PWEP was the first time
“The size of the global wave resource is estimated to be large enough to meet between 20 percent and 200 percent of the world’s electricity demand. Human population and load centres tend to be located near coastlines, making grid connection relatively easy. Carnegie is focused on developing projects in commercially-attractive markets such as remote islands,” Allen said.

Carnegie had worked with ABB, Allen says the organisation would happily deploy ABB technology again in the future.

“The products and services that ABB has delivered for the PWEP are meeting the requirements of the project and Carnegie would certainly consider incorporating ABB products in future projects,” Allen said.

**PWEP Implications**

The PWEP reached a significant milestone in June this year, with cumulative operating hours of the three installed CETO 5 units exceeding 10,000 hours.

This milestone was not only significant for Carnegie and the PWEP, but also addressed the industry challenge of survivability and reliability in harsh ocean environments.

“Carnegie was also able to validate its deployment and maintenance philosophy by successfully retrieving a CETO 5 unit in less than a day, and demonstrating the viability of its ‘hot swap’ methodology – where the system has been designed to allow for units to be removed and reinstalled without having to halt plant operations,” Allen said.

The success of this project has led to Carnegie beginning work on a commercial-scale project with larger buoys and a new generation of the technology. This new CETO 6 project is currently in the design phase and will also be located on Garden Island.

According to Allen, CETO 6 has seen a significant design evolution that has the potential to further increase the market in which CETO can be utilised.

“In the case of the PWEP, using the CETO 5 generation, the electricity generation is occurring onshore, the CETO 6 design houses the power generation inside the buoy, allowing power to be generated offshore,” Allen explained.

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Axel Kuhr, General Manager of ABB Australia – who was among the guests invited to watch the Minister for Industry and Science, Ian Macfarlane, officially ‘switch on’ the onshore power station in February, said: “ABB is proud its grid integration know-how and technology helped Carnegie in achieving this important milestone. Wave energy holds potential in the clean energy space and we are delighted that our electrical and control solution facilitated the first grid-connected wave energy plant of its kind in the world.”

Contact us for more information