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Sun (master)stroke

Solar trigeneration in action.

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COVER FEATURE

Sun(master)

Images: Jeremy Osborne, M.AIRAH

Atop the University of Technology Sydney's Faculty of Engineering and Information Technology building is a micro-urban power station that provides students and researchers with a glimpse into the future of distributed renewable energy generation. Sean McGowan reports on what is achieved with the click of a button.

So often, much of the debate surrounding renewable energy gets bogged down into the difficulties of reducing Australia's dependency on brown and black coal electricity generation.

But what if the solution is a multi-faceted one? What if a combination of renewables is actually the key? And what if they are combined into one urbanised plant?

These are some of the questions being answered by the University of Technology, Sydney (UTS), where a micro-urban power station is demonstrating that the innovative generation and use of solar

stroke

energy can provide energy for building services, chilled water and hot water.

Installed on the rooftop of the university's Faculty of Engineering and Information Technology (FEIT) building (as featured in the November 2014 issue of Ecolibrium) this micro power station is made up of three key pieces of equipment: solar-thermal collectors (STC), an Organic Rankin Cycle (ORC) turbine, and an absorption chiller.

The building also features a solar photovoltaic (PV) array and a wind turbine.

These are all tied together with 100kWh flow-technology batteries that supply an isolated mini-grid that runs throughout the building.

"The students get to see, touch and engage with real, working, renewable energy systems," says Jeremy Osborne, M.AIRAH, of Energy Analysis & Engineering (Energy AE), which designed elements of the system in consultation with NEP Solar.

"It is a glimpse into the future of distributed energy generation."

DEMONSTRATING TECHNOLOGY

FEIT research laboratories manager Ray Clout first approached NEP Solar for preliminary information on a solar thermal system in 2010, around the same time as the design phase of the new FEIT building commenced.

During this process, FEIT researchers were consulted on their future research goals and what equipment they would require to achieve these.

> ‘The students get to see, touch and engage with real, working, renewable energy systems’

"With the continued worldwide interest in energy re-use and conservation, FEIT decided that it should elevate its current research levels on this technology," Clout told Ecolibrium last year.

In 2011, NEP Solar was invited to quote on the supply of the solar thermal system by companies tendering for the electrical package of the building. However, with insufficient detail in tender documents, NEP Solar approached the university and secured a contract the following year to perform the conceptual design and detailed design of the system.

"Following successful design, we secured the contract through Lend Lease to supply, install and commission the complete system," says NEP Solar's managing director, Johan Dreyer.

Heading up the Australian SOLEM office at the time, Osborne was approached by NEP Solar to help develop the project.

The two then commenced work on turning the project into a reality, which included consultation with SOLEM staff in Europe who had specialist knowledge of such systems.

According to both Dreyer and Osborne, the open-minded attitude of Waterman,

The vertical-axis wind turbine charging a flow battery.

as the project's mechanical, BMCS, electrical and ESD engineer, was also critical to the project's success.

"We worked together with Waterman and the architect, Denton Corker Marshall, on the alternate configurations for and positioning of the solar collectors on the roof, and the size and position of the plant room," says Dreyer.

The teams also worked closely to incorporate the solar-thermal system into the building's interfaces.

"The system was intended, firstly, as a technology demonstrator and secondly, as a learning tool for research," says Dreyer of the university's objectives.

Importantly, the university required that the system was to only contain commercially available components. All equipment was also required to have product guarantees.

The faculty initially proposed a system in which the thermal power could be cascaded from one piece of equipment to the next.

> It is a glimpse into the future of distributed energy generation

The plant room during commissioning. The ORC (Organic Rankin Cycle) is front and centre.

This fully cascaded use of the concentrated solar energy would have offered a combined solar efficiency of up to 90 per cent.

However, a number of factors influenced the final design, including the availability of products and equipment of suitable size and temperature level. There were also budgetary and spatial constraints.

"Unfortunately, there were very few ORC turbines available on the Australian market, or even internationally, at the 5 to 10kW size we required," says Osborne.

The interconnected pipework connects building chilled water, hot water, and the cooling tower network. Although it looks a mess, the short routes lose less heat, take less time to pump and cost less.

The final design by NEP Solar and SOLEM (and later Energy AE) is effectively a solar thermal tri-generation system that delivers electricity or chilled water – or both – for short periods of time.

Domestic hot water is supplied either directly from the solar-thermal collectors via a heat exchanger, or through the heat rejection of the ORC and absorption chiller.

THE SOLAR FIELD

Sitting on the FEIT building's rooftop space, the micro-urban power station features a solar field consisting of four parabolic trough solar collectors that each has an aperture area of 29 sq m.

Manufactured by NEP Solar in Sydney, these 1.2m wide, 24m long collectors feature 12 composite reflector panels and are designed for rooftop mounting.

According to Dreyer, the total solar field is 115 sq m in area, and provides maximum power of 65kWth with nominal power of 50kWth.

Solar radiation is tracked and concentrated onto a receiver pipe containing the heat-transfer liquid (treated water). This converts about

The fluid thermal expansion system is suitable for high temperatures. A nitrogen blanket is used.

50 per cent of the available solar energy to useful heat in the form of 170°C pressurised hot water.

This heat is then stored in a 2,000L thermal storage buffer tank and distributed to either the ORC, absorption chiller or to the hot water network to produce electricity or hot water.

WHERE IN THE WORLD?

Due to a lack of availability in Australia, both the ORC turbine and absorption chiller were sourced from Europe.

The ORC selected for the project is of Swiss origin and uses a scroll turbine driven by the expansion of an organic fluid (a refrigerant) when heated from solar energy. In this case, the ORC operates at a nominal temperature of 135°C.

Dryer says this organic fluid boils at a much lower temperature than water and is similar to the fluid used in vapour compression air conditioners.

“The hot fluid expands over a turbine,” he says. “And the heat and pressure is used to turn the turbine, which in turn, turns an electrical generator.”

The fluid is then condensed before being heated again.

There are our new energy technologies on the roof: solar parabolic collectors, flat-plate collectors, PV, and wind turbines.

WORTHY OF AN AWARD

NEP Solar earned the highly coveted Denis Joseph Award for Innovative Use of Solar Energy in HVAC&R in last year's AIRAH Awards.

The 2015 AIRAH Award nominations are due to close soon. For more information, go to www.airah.org.au/Awards

"It is uncommon to use an ORC with parabolic troughs in Australia, and it is especially novel at this size," says Dreyer.

Similarly, NEP Solar was unable to locate an absorption chiller produced in Australia in the size range of 15 to 30kW required for this project. It therefore began a worldwide search.

The result is a small and compact Austrian-made chiller described as "the bull" due to its indestructible nature – perfect for students to get their hands dirty on.

This single-stage absorption chiller is used to generate 19kW of solar cooling through the evaporation of a refrigerant – in this case ammonia.

And as it can operate with water up to 95°C, it is able to operate after the sun has set by using the heat stored in the thermal buffer tank.

LINKING SOURCES

As well as the solar energy being generated by the solar parabolic troughs, additional energy is generated for the UTS FEIT building through the provision of a 24kWp solar PV array and a 12kWp wind turbine.

DC electricity from both systems feeds directly to two 50kWh flow-technology batteries. These then supply an isolated mini-grid in the building. This eliminates the need for an inverter on the PV system.

"Enabling all the separate equipment to work together has been a major challenge," says Osborne.

"Each is designed to operate on a standard electricity grid – not together, and not on an isolated mini-grid. We've certainly had our fair share of learnings already."

According to Dreyer, the major challenges have been the limited, commercially available components used on the project, and the spatial limitations of the plant room, which made the physical layout difficult.

> "The system was intended, firstly, as a technology demonstrator and secondly, as a learning tool for research"

He also says designing a system to operate automatically – yet be able to be used for research purposes – has presented its own challenges.

"Designing a very complicated system operating in a highly transient environment required careful design of the control system," says Dreyer.

Concentrating solar collectors.

Temperature sensors accurately monitor performance.

Significant investment and effort went into the selection of a full controls and monitoring system, which allows the UTS community to see all aspects of the micro-urban power station.

The outcome is one where all components can be studied together, or individually.

"There are no other systems known at present that can deliver as much continued learning to a university and the academic community widely as this," says Osborne.

"At a push of a button, students can run a concentrating solar power station using an Organic Rankin Cycle turbine, a solar cooling system, or commercial solar hot-water system."

"It gives complete flexibility to students, allowing them to validate their theoretical models against a real system, and provides an opportunity to learn how to control the interactions between each source, their storage mediums, and their loads to produce the most optimally economic outcomes for a commercial operation."

> "The commercial nature of the project demonstrates a future where a diverse, distributed and interconnected energy system is possible"

More significantly perhaps, the commercial nature of the project demonstrates a future where a diverse, distributed and interconnected energy system is possible.

To this end, the system might be used to foster research collaboration or to validate the renewable energy aspirations of cities (such as Sydney's 2030 plan).

It might also be used to develop new standards, with UTS offering to use the system to validate a new potential Australian Standard on industrial solar-thermal performance validation.

"By monitoring the system in detail, it can contribute to a better understanding of efficient plant room design, understanding the performance of ORCs and absorption chillers under part loads, and transient behaviour," says Osborne.

UTS is in the throes of completing an upgrade of the power control system and battery storage associated with the power station.

Although all systems are reportedly operating as intended, ongoing performance is still to be monitored; performance data has therefore not been published. ■

COVER WORTHY

The UTS Faculty of Engineering and IT building, on top of which sits the micro-urban power station, was the cover story for last November's Ecolibrium. To check it out, go to www.airah.org.au/ecolibrium

UTS MICRO-URBAN POWER STATION (UPS) AT A GLANCE

The personnel

- **Builder (building):** Lend Lease
- **Client:** University of Technology, Sydney (UTS)
- **Controls (UPS):** Yokogawa
- **Solar system design:** NEP Solar, Energy AE and SOLEM
- **Electrical contractor (UPS):** King and Martin Electrical
- **Mechanical engineer (building):** Waterman
- **Plumbing (UPS):** Paragon Plumbing
- **Solar thermal tri-generation:** NEP Solar

HVAC and UPS equipment

- **Absorption chiller:** Pink GmbH (Austria)
- **Battery storage:** ZBB
- **BMS:** Alerton
- **Heat exchangers:** Teralba
- **Organic Rankin Cycle turbine:** Eneftech (Switzerland)
- **Solar hot water system:** Rheem Australia
- **Solar parabolic collectors:** NEP Solar
- **Thermal storage tank:** Automatic Heating