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Water Supply Energy and Resilience for Whitsunday Water

Integration of Solar and Backup Generation to Adapt to Our Extremes

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ABSTRACT

Many regional water utilities face significant challenges due to the increasing intensity of tropical cyclones with stronger winds and heavier rainfall (Khan et al., 2006).

The 23,860km^2 Whitsunday Region is home to 35,500 residents and receives approximately 786,000 visitors to the region annually (Tourism Whitsunday, 2017).

In 2016, Whitsunday Water undertook a 6-month research study on climate change mitigation strategies, finalising the scope for a 12-month full scale solar power pilot project in February 2017.

On 28 March 2017, the Whitsunday region was impacted by Tropical Cyclone (TC) Debbie. TC Debbie made landfall near Airlie Beach, crossed the coast north of Proserpine and tracked over the Bowen Water Treatment Plant (BWTP) 12km inland on the Proserpine River (BOM, 2018).

In May 2017, Whitsunday Water reviewed the initial project deliverables, focusing on lessons learned from TC Debbie. The finalised scope consisted of the construction of a 400kW solar array, integration of 450kW standby generation, installation of a new Main Switchboard (MSB), consolidation of three pole mount transformers and a full upgrade of the BWTP's operating systems.

Since commissioning in 2018, electricity bills show a consistent 40% reduction, with solar energy generating an average of 36,240kWh per month, saving an average of $16,500 per month.

This paper presents the reasoning to initiate the project, the key learnings implemented as a result of TC Debbie, the early benefits, detailed information about the construction phase and the financial, resilience and operational results.

INTRODUCTION

Whitsunday Water faces obstacles from extreme weather events, necessitating additional investments in resilience that challenge the ability to deliver high quality, reliable water services.

In March 2017, TC Debbie crossed the Central Queensland coast approximately 10km north of Airlie Beach. TC Debbie, which was the most dangerous cyclone to impact Queensland since Yasi in 2011 (BOM, 2018) was different to previous cyclones in that it prevented access to water facilities for up to four days, contributing to potable water supply interruptions. Accumulated rainfall in the following 48 hours exceeded 1,000 mm, significantly higher than the average annual rainfall of 1,881mm (WRC, 2017).

Extensive power outages as a result of TC Debbie cut power to the BWTP which supplies the northern region's water network, impacting the towns of Bowen and Merinda and their 10,000 residents. The subsequent flooding that followed due to the heavy rainfall prevented access to the site for an additional four days, eliminating the ability to connect temporary generators to bring the network back online.

Due to widespread outages in the electricity network and extensive road flooding, vehicular access for electricity response personnel was prevented during this time. Once access was gained, there was an asset and personnel shortage, and Whitsunday Water was unable to source suitably sized generators and get them to site for two weeks following the day TC Debbie made landfall.

Figure 1: BWTP Access, 3 Days After Cyclone Debbie, 2017

The BWTP is located on the banks of the Proserpine River, from which it sources raw water using a series of horizontal spears located under the river bed. The BWTP location is sound from a resilience perspective as it is not susceptible to most hazard impacts, such as flooding, storm surge or the highest cyclonic wind speeds (Burby, Deyle, Godschalk, & Olshansky, 2000).

METHOD

Opportunity review and prioritisation

Whitsunday Water began investigating opportunities for behind the meter energy generation in November 2016 after a review on high grid usage assets as part of a research study on climate change mitigation strategies. To initiate the program, a desktop review and prioritisation of site suitability for permanent back up generation (resilience) and behind the meter solar generation (reduction in costs) was undertaken. The criteria used for site selection was:

- Hazard identification (cyclone, flooding, storm surge, bushfire, earthquake);
- Site criticality and vulnerability;
- Historical power demand;
- Available roof or cleared land area for solar arrays;
- Influence / control of site;
- Geotechnical investigation;
- Assessment of community support / objection to upgrade (potential for noise or visual amenity complaints); and
- Ability to control electricity demands.

The objective of the program was to identify one or more high quality sites to deliver a project that could be used as a pilot to deliver further resilience projects. Whitsunday Water approached project opportunities with a view to look for cost effective resilience projects that would achieve savings that could be reinvested into water and sewer networks.

The following shortlisted sites were identified based on the above criteria:

- Bore Fields / Intake Pumps;
- Water Treatment Plants (WTP);
- Water High Lift Pump Stations (HLPS); and
- Sewerage Pump Stations (SPS).

The data results for the minor water pump stations and SPSs were shown to be an ineffective choice under this screening assessment. This passed the logic test as these locations are often less critical, lower power demand sites with limited land or roof space available.

In the prioritisation phase, shortlisted sites were assessed for the best opportunity. This was undertaken by industry participants using the HOMER micro-grid design package. The aggregate daily demand for each site was assessed against a range of solar array sizes. To do this, smart meter data for the prospective sites was obtained to estimate the optimal size of a solar array both with and without battery backup. The advantage of battery backup is that utility dependency is eliminated during network outages, however the increase in cost and complexity to the network and control systems deemed it infeasible for a pilot project of this nature.

The standout opportunity was the BWTP and HLPS, located in the Mt Pluto District of Proserpine. In addition to being in a rural location, the 6ha site had three separate meters which collectively represented the Whitsunday region’s largest electricity demand and Whitsunday Water’s highest electricity expenditure. The securely fenced compound includes power supply to the Bowen Low Lift Pump Station, the conventional BWTP and the HLPS that pumps treated water to the Bowen Reservoirs, 70km north of the site with a single lift.

The key project objectives were to build a solar array capable of supporting the entire load of the BWTP during the day, integration of suitably sized generators capable of remote activation, a significant operational cost saving and a reduction in greenhouse gas emissions.

The final scope consisted of five interlocking components:

1. Construction of a 400kW solar array capable of generating over 620MWh of clean energy and annual savings of >$200,000;

2. Integration of 450kW of standby generation that could be remotely activated for emergency operation;

3. Installation of a new MSB for more efficient power distribution to the existing site facilities;

4. Consolidation of three pole mount transformers into a single highly efficient 1000kVA pad mount; and

5. Upgrade of the BWTP's operating systems to increase remote system control and operational visibility.

Whitsunday Water funded the initial research study, with the majority of the construction and operational phase commissioning coming from the Queensland Government’s ‘Works for Queensland’ grant funding.

Consolidation of Connections and Backup Generation

Whitsunday Water engaged the local energy grid operator in the initial concept phase regarding consolidating electricity supply, the export of solar energy, islanding the BWTP during peak periods and exporting from the site. Given the remoteness of the site and that the scale of generation selected was relatively small (450kW backup, 400kW solar), the local energy grid operator elected to not work with Whitsunday Water on export or local shedding options as they believed the network in that location was sufficiently secure.

Given the complexity of backup generation and that all three on-site electricity meters needed to be operational in order to deliver water to customers, the three site connections were consolidated into a single meter. By consolidating supply, larger generation plant could be used to provide energy to the entire facility while reducing complexity.

Figure 2: Existing 2 x 500kVA Pole Mount Transformers

The local energy grid provider opted to replace the existing three pole mount transformers as they were deemed to be oversized and outdated comparative to similar electrical infrastructure in the area. A Connection Establishment Contract (CEC) for the connection of metered loads was negotiated and an easement was executed to allow unrestricted access to a new 1000kVA pad mount transformer.

Figure 3: Installation of New 1000kVA Transformer

To supply potable water to the northern region, the network requires that the Proserpine River Intake, HLPS and Plant System are all operational, so the project incorporated 450kW permanent onsite backup generation. This was critical as the flood immunity of the local roads that access this site is poor, with one crossing regularly being cut for short durations after heavy rainfall events exceeding 50mm. The post-TC Debbie review highlighted that not only was backup generation needed, but that there was also a requirement for minimum 3-day onsite fuel storage until road access could be restored.

A variation to the scope was made in line with Australian Standards to allow for a secure onsite fuel storage area (Standards Australia, 2017). A generator maintenance area was also constructed, and a periodic testing and maintenance agreement established with local electrical contractors. As part of the revised operational service schedule, generator testing is increased from 6-monthly to monthly during the annual cyclone season of November to March.

Figure 4: 450kW Standby Generation

Supervisory Control and Data Acquisition (SCADA) and System Upgrade

The technology used in this project was able to be integrated into the BWTP's operating software, ClearSCADA. By upgrading the operating software, Whitsunday Water has full remote visibility and emergency control over the BWTP via remote access location. Additionally, all WTP staff have a cloud based mobile app which is used to track the solar inverters and monitor production performance and environmental offsets at any time.

As Whitsunday Water assets, all project components are locked into a stringent maintenance schedule, ensuring immediate activation when necessary. When calculating the project's return on investment (ROI), the operational and maintenance costs were calculated and included in future Whitsunday Water OPEX budgets to fully capture project costs.

Solar Array

Whitsunday Water tendered a design and construct contract for the design and installation of the solar array, while opting to work with local contractors to deliver the generator facility. The basis of this was to let the solar energy market work directly with other vendors on complex integration matters.

Panels

A newly released Tier 1 polycrystalline solar panel was chosen, as in addition to being highly efficient, it meets all Australian product requirements, including for use in cyclonic zones (wind rating of 4000kPa) and tropical zones.

A ground mount array that includes framing adjustments while allowing near-perfect alignment and levelling of the rows of panels was selected. In addition to being significantly cheaper and requiring less maintenance than a tracking array, the finish of the components is a hot dipped, anti-corrosive galvanized steel which is compatible with the location's coastal proximity and high annual rainfall.

Figure 5: Solar arrays

The initial geotechnical investigations established that the ground conditions were a corrosive acid sulfate soil, so an epoxy spray was applied to the head of each post where the pile-driving process would compromise the galvanised finish.

Array Set Out

The accepted practice is to set spacing so that no shading occurs between 10am – 2pm during the winter solstice (Quaschning & Hanitsch, 1998). Because space is not an issue on site, the designers opted to eliminate shading between 9am – 3pm on the winter solstice, which required an additional 308mm between each row. This is now generating 10% higher yields than originally anticipated.

Sequence of Electrical Construction Works

Excavation of cable pits and under-road boring commenced as soon as the pile driving for the solar panel frames had been completed. This enabled ClearSCADA, DC, LAN network and fire system control cables to be run quickly, reducing disruptions to plant operations. In addition to inclement weather, installation of underground services was one of the most challenging aspects of the project. The BWTP is a brownfield site with a significant amount of underground infrastructure with inaccurate or missing as-constructed drawings, despite it being a 5-year-old site.

Figure 6: 25kms of DC Cable runs

Key learnings from this exercise were to extensively validate as-constructed data prior to commencing excavation. There is additional value in extensive hydrovacing as early as possible, as this had an impact on the civil design and delivery timeframe.

Whitsunday Water managed the design and construction of the MSB which required a new main incoming supply, three larger feeders to supply each of the existing site switchboards and a protected feed-in point for the seven inverters supplying power from the solar array.

Simultaneously to cable trenching, the MSB was installed and the feeds to the downstream electrical sub-boards were laid. The change-over of the consumer mains and sub-board feeders, and the commissioning of the new MSB was coordinated with the local energy grid operator and the existing consumer mains cables were removed.

Figure 7: New Main Switchboard

Inverters

Multiple string inverters were selected, rather than one, central inverter. The advantages being:

- Cost neutral choice;
- In the event of a string inverter failure, only a small percentage of the overall system capacity is lost versus the loss of the total system in the event of a central inverter failure; and
- The inverter selected offers the option of a range of DC and AC wiring boxes that incorporate string fuses, DC isolation switching and AC surge protection.

Figure 8: Inverter installation

RESULTS

Operation Optimisation

As of January 2019, Whitsunday Water are tracking a 40% energy saving, which is a satisfactory starting point as the learnings of how to operate with a high cost (grid) and a zero-marginal cost (solar) energy supply option are implemented.

The WTP Operators were engaged in the project throughout the planning, construction and commissioning phases as their knowledge of the operational constraints of the network and BWTP was extremely useful. Since commissioning, they have been actively involved in updating the BWTP Operations Manual and Maintenance Schedule in line with BWTP and solar performance.

Further optimisation is constrained as a result of a 3.5ML northern reservoir being offline for repairs, which are due to finish in March 2019. This limits the ability to shift water production to daytime and turn off at peak times.

Data modelling has been used to run scenarios with different level headspaces and demand to inform optimal operational strategies. The key learning from the post-commissioning analysis is that in order to maximise solar energy utilisation, BWTP operations must be shifted to times when both solar energy and sufficient headspace is available.

Despite this, the BWTP is being run to maximise day-time water production by setting the overnight target reservoir levels on a relatively conservative basis.

Figure 9 illustrates the need for effective operation at times of low demand in order to increase overall average solar energy use percentage.

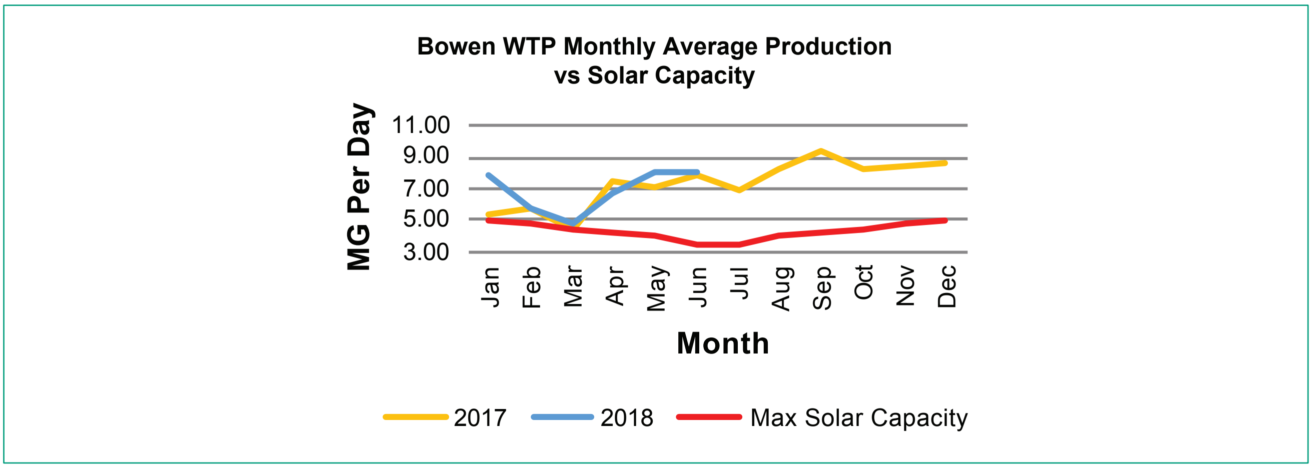

Figure 9: Historical water production vs theoretical production from solar

Figure 10 is from Whitsunday Water's solar energy management system that shows an example of sub optimal reservoir set points forcing curtailment of solar energy use in the mid-afternoon.

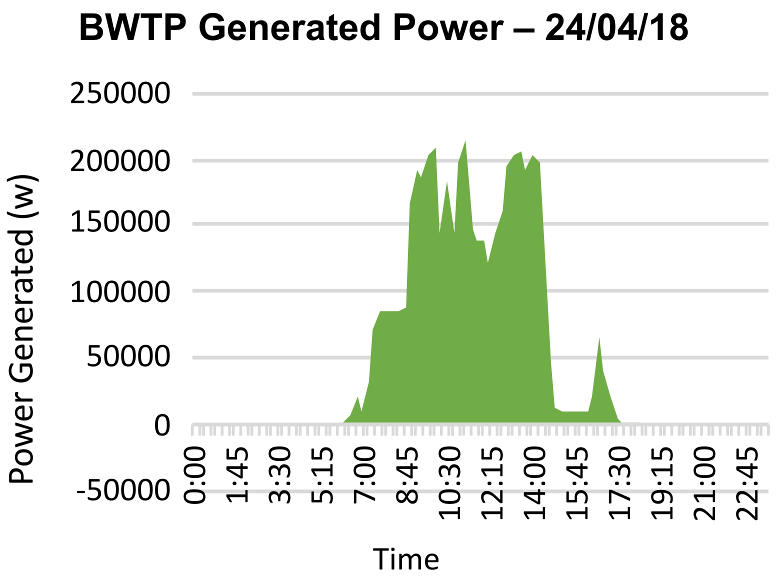

Figure 10: Typical daily solar output curtailed by reservoir capacity

NETWORK OPPORTUNITIES

Whitsunday Water has been using simplified data analysis from ClearSCADA and the Solar Data Manager to track performance in terms of maximising self-generated electricity. This data looks at a recent rolling average demand and average hours of generation per day, adjusted each month, and constrains the optimisation by the amount of reservoir and daytime demand of solar generation commitment by setting the reservoir to this level each morning.

Given the relatively simple analysis being run to allow for behavioural, climate and operational factors, the purpose of this data is to identify further resilience opportunities for later refinement.

PREPARATION FOR FUTURE PRICING OPPORTUNITIES

The project cost $1.1 million and to achieve a return on investment, the project needs to achieve at least 20% efficiency in cost through operationalising the learnings from the project by the end of the 2019/20 price period.

Whitsunday Water is carefully adjusting operational processes and identifying the extent to which electricity demand can be shifted from this and other sites readily in order to leverage a different electricity tariff or open market electricity contract.

DISCUSSION

Lessons Learned from TC Debbie

The post-disaster assessment held after TC Debbie clearly showed how unprepared and vulnerable the BWTP was due to lack of site access and generators. As a result, critical water supplies were lost for an extended period of time which highlighted the need for local, resilience-based planning arrangements to enable self-reliance in a natural disaster situation.

Key learning actions from the post-disaster assessment are:

- Lack of Power – Generators, connection points, location of and accessible fuel supply;
- Critical Assets – Not clearly identifiable on regional maps, scale of vulnerability, spares and fittings, both required and on hand;
- Access – Alternate routes to critical assets in case of flooding or trees down, staff location map;
- Communication – Set coordinator required, direct communication to Local Disaster Co-ordination Center and dissemination to public; and
- Fatigue – Management of fatigue.

In addition to the installation of remotely activated generators, Whitsunday Water Operations staff have undertaken training as part of emergency preparedness procedures on how to activate and operate the generators and interpret SCADA data for reporting to the Disaster Management Team.

Planning

In addition to unseasonal wet weather constraints and a contractor and plant shortage as a result of TC Debbie, one of the most significant challenges of this project was the planning and development approvals. This project set a North Queensland precedent as the first of its size and kind. As a result, significant delays were experienced in-house due to a lack of existing process, knowledge or documentation relating to approvals of this nature.

New Infrastructure

The 23,860km^2 footprint covered by the Whitsunday region is significant and access to critical assets is often limited in severe weather situations. With tropical cyclone intensity predicted to increase in occurrence and severity (Emmanuel, 2005), it is imperative that practical and innovative measures are taken to ensure that the community has reliable water access and security.

Results

When TC Iris threatened to hit the coast near the Whitsunday Region in April 2018, the BWTP was successfully put into "standby" mode, allowing us to run off the generators during the night if necessary while running off the onsite generated solar during the day.

This exercise was repeated in December 2018 when TC Owen threatened the Whitsunday Region. As a result of the post-TC Debbie review, within 12 months all WTPs, STPs and major Pump Stations have generator plug-in points installed. When the TC Owen threat was active, by using the data collected from the BWTP regarding predicted demand and electricity network loads, Whitsunday Water was able to source and connect appropriately-sized generators at all other WTPs prior to losing road access, reducing the amount of generators that needed to be sourced.

Since its completion, the use of solar energy at the BWTP has resulted in a reduction of over 550,000kg of carbon dioxide (CO_2), 250kg of nitrogen oxide (NOx), 75kg of sulphur dioxide (SO_2), and has saved over 250 metric tons of carbon (C) going into the atmosphere which is the equivalent of over 30 hectares of deforestation (Aurora Vision, 2018).

Actual monthly electricity bills show a consistent 40% reduction compared to the previous two years which is expected to improve with further network optimisation and operational changes. Whitsunday Water expect to see a 15% increase in this figure in 2019 with opportunities for further improvements through additional network optimisation and operational changes.

Operation

Post commissioning data modelling of the BWTP solar array indicates 42% self-generated electricity should be achieved, where the actual data shows 40%. This is a sound relationship based on the input of 3ML reservoir capacity and daytime demand relative to solar generation. With both reservoirs online and the full 6.5ML available, the model returns an annual average of 64% self-generated electricity. Importantly, the key difference in ability to use self-generated energy is successful operational strategies during low demand periods.

Energy is being left in the solar panels as a result of not starting the reservoir at a low enough starting point during lower demand periods. Lowering the reservoir water start level will increase capacity and will allow for additional savings due to higher usage of self-generated electricity.

CONCLUSION

The impacts of TC Debbie coupled with increasing research pointing towards a correlation between greenhouse gas output and the severity of tropical cyclones (Geng & Sugi, 2003) demonstrate the importance of investing in water infrastructure facilities that are resilient and sustainable.

After natural disasters, the opportunity to address resilience and utilise it to maximise the overall network benefit is often neglected. Through careful staged analysis it is possible to identify sites where resilience can be improved and costs reduced through integrating generator delivery with solar energy deployment while delivering important resilience upgrades at no net cost to the community.

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Figure 11: Bowen WTP Locality Map

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