Carnarvon DER Trials 1&2 – ESCI-KSP Submission

Contact details

Principal Contact

Name: David Edwards

Organisation: Horizon Power

Position: Technical Visionary

Phone: (08) 6310 1793

Email: david.edwards@horizonpower.com.au

Physical Address

Street: 18 Brodie Hall Drive

Suburb: Bentley

State: Western Australia

Postcode: 6102

Mailing Address

Street: PO Box 1066

Suburb: Bentley DC

State: WA

Postcode: 6983

Introduction

The Carnarvon Distributed Energy Resource (DER) trials situated in the town of Carnarvon in Western Australia are investigating how Horizon Power can use existing infrastructure and new and emerging technology to gain visibility and control of DER. The project has received a funding contribution from the Australian Federal Government via the Australian Renewable Energy Agency (ARENA) as part of the Advancing Renewable's Fund.

The project web page including data visualisations and details of our customer participants can be found here: https://horizonpower.com.au/our-community/projects/carnarvon-distributed-energy-resources-der-trials/

The following sections describe the project in detail and should be read in conjunction with the attached PowerPoint presentation.

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Project context

Horizon Power

Horizon Power is one of the last remaining vertically integrated electricity utilities in Australia, responsible for each component of the electrical supply chain (generation, network and retail) in most of the systems it operates.

The Western Australian Government has a uniform tariff policy that ensures all retail customers in WA pay the same electricity tariffs. The uniform tariff is lower than Horizon Power's cost of providing electricity to its regional customers, so a subsidy is necessary to ensure Horizon Power's ongoing commercial viability. Reducing the subsidy is one of Horizon Power's key performance indicators.

Because Horizon Power is focused on lowering its cost to supply; and controls all aspects of the supply chain, it has a unique commercial framework and the opportunity to develop an efficient electricity supply, including the implementation of new technologies and methodologies based around a DER system.

Any benefits, regardless of where they are realised (generation, network or retail), will ultimately lower the subsidy Horizon Power receives. For example, sharing the deployment of DER system assets with customers, where this is economically efficient for the system overall, is a sensible outcome - despite it being incompatible with the traditional regulatory return model.

For a utility, the commercial objective to reduce costs creates a strategic response that is rare. In some circumstances, it will drive Horizon Power to reduce the funds it employs in the electrical system. This would usually be considered contrary to the prevailing utility business model and is therefore regarded as unique when contrasted to the approaches of most regulated utilities across the world. Despite this, the approach is compatible with the objective of lowering system costs overall and complementary to the implementation of high penetration DER supply models.

A strategic component of the existing infrastructure is the recently implemented Advanced Meter Infrastructure (AMI) project, which has seen advanced (smart) meters installed at all of Horizon Power's customer sites at a total cost over $30 million. The availability of electricity demand data at each of Horizon Power's customers, and the provision of the mesh radio network and back-end integration bring a vital foundation upon which to build, and significant value to the development of a DER management platform system.

Horizon Power's initial focus is in the town of Carnarvon, a medium-sized town with a high penetration rate of solar PV systems, where Horizon Power has an excellent relationship with its customers. Horizon Power will leverage off of its investments in the low voltage distribution network infrastructure, and its ownership of the new Mungallah power station to develop a DER system in Carnarvon that will allow Horizon Power to test new technologies and undertake several trials.

Industry transformation

The traditional energy business is undergoing an unprecedented period of disruption. New technology and changing consumer behaviour is presenting multiple opportunities and threats to the existing utility business model. One of these disruptions is the increasing demand and improving economics of Distributed Energy Resources (DER).

Horizon Power's economic analysis predicts that the delivery of energy into geographically isolated microgrid networks by high penetration DER will be more economical than the traditional centralised generation supply model across more than half of Australia's microgrid electricity systems by 2025.

Horizon Power is planning for a high penetration DER business future by investing in research and trials. The Carnarvon DER trials aim to resolve technical integration barriers and to find ways to reduce the cost of electricity by 25% when compared to the known costs of current DER supply models.

The DER trials in the town of Carnarvon has been specifically designed to push our current operational boundaries and test emerging technology. Using the latest DER products and testing new customer services, these trials will inform not only our business but the broader industry on critical issues relating to:

- Safety;
- Network protection;
- Power quality;
- Operational practices;
- Technical standards, and
- Business model evolution.

All of the experience and knowledge gained in these trials will support the ongoing evolution of our Microgrids throughout regional Western Australia. The first system other than Carnarvon to benefit from this evolution will be the town of Onslow, whose network and energy supply is about to undergo significant redevelopment.

Onslow is set to be the home of Australia's largest and most advanced distributed energy microgrid, targeting more than 50% of the energy needs to be supplied by renewable power. Horizon Power is preparing to deliver this contemporary energy solution by developing and integrating DER including rooftop solar and batteries at residential and commercial properties through an intelligent system control network.

Horizon Power believes that these resources are the key to a more sustainable energy future where individuals can service not only their own energy needs but can also contribute to their community's needs.

The Onslow Microgrid Project represents one of the largest and most comprehensive microgrid projects currently underway in the Asia Pacific region and will see customers enjoy improved reliability and greater control over their energy consumption.

Underpinned by a modular, efficient, gas-fired power station and state-of-the-art solar farm the Onslow Microgrid will leverage off advances in digital communications infrastructure trialled in Carnarvon to integrate with intelligent devices and appliances as well as prepare for future technologies such as electric vehicles.

Importantly, the features of Horizon Power’s approach to managing high penetration DER aim to support the development of local communities through increased competition and greater participation which will lower electricity bills, as well as the subsidies that Government pays to support the provision of reliable energy across regional areas.

A Microgrid which optimises distributed energy resources can deliver more cost-effective and environmentally friendly energy, reducing the carbon emissions produced by conventional generation. Horizon Power’s vision is for a new era of energy competition and efficiency, where all customers have the opportunity to benefit from the overall lower cost of producing energy.

A high penetration, yet fully integrated DER system will drive in-depth interaction with consumers and strengthen the value of the local grid. This scenario ensures that microgrid utilisation is maintained while encouraging the highest level of electricity affordability.

By selecting plant and equipment based on complete life-cycle costing inclusive of operation and maintenance while meeting minimum technical requirements, Horizon Power's strategy through the comprehensive scope of activity within Highgarden is to:

- Integrate conventional assets with contemporary assets.
- Guide the business in the selection of equipment, asset planning and augmentation to transition to a DER system in the most economically sustainable way.
- Undertake specific trials designed to resolve technical, transition and economic barriers associated with a high penetration DER system.

The two trials detailed in the following sections have been devised to test specific technical and operational barriers, namely gaining visibility and control of distributed Solar PV and Energy storage. We aim to challenge our existing business model, with the objective of moving to a more sustainable, decentralised approach. These trials will assist us in assessing the commercial, technical and operational pathway to transition away from a centralised generation model, to a predominantly decentralised approach to the provision of energy capacity.

As one of the largest operators of microgrids in the world, Horizon Power sees significant value in the development of a cost-effective DER Microgrid Operating Platform that provides safe and reliable energy as a foundation to improved quality of life and economic development to the many remote, and often underprivileged, regions of the world.

Horizon Power’s future is founded in the ongoing development of cost-efficient DER microgrids. The cultural change required within the company as we evolve away from a traditional utility model in a monopoly landscape is substantial. The creation of new customer relationship models, incentivising their investment in their own energy future and transitioning them to engaged prosumers requires careful adaptation of our business model and planning activity.

Academic partnership

Recognising the value of educational partnerships, Horizon Power has engaged a team of seven researchers from the Engineering and Energy Discipline at Murdoch University in Perth Western Australia. Murdoch University has a long-standing research involvement in both renewable energy systems and their integration into electrical grids. Expertise specifically relevant to this project includes

- Energy system planning, modelling and control optimisation
- Distribution system planning
- Power system analysis (modelling, protection and stability)
- Renewable energy based electrification
- Power electronics
- PV and power system modelling and simulation
- PV systems integration and performance evaluation, and
- Balance of system components and particularly grid-connected inverter testing.

Murdoch University houses specific facilities for PV system component testing and has access to state-of-the-art network simulation tools such as DIGSILENT PowerFactory.

The project activities at Murdoch are managed by Dr Martina Calais and Dr Parisa Bahri who have extensive experience in attracting and managing collaborative research projects, and supervision of research staff and students.

Of particular interest to these DER trials is the working association that Murdoch University has with Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR) in Germany. DLR has developed capability in the use of multiple sky imaging devices and forecasting technology to provide accurate short term forecasting across a wide optical field that is of particular interest to this project.

Also, the prestigious German Hanse-Wissenschaftskolleg Fellowship in 2014-15 enabled Martina Calais to work on a research project on “Improving Photovoltaic Systems Integration in Remote Diesel Networks” with NEXT Energy also in Germany. The fellowship also enabled knowledge sharing with Horizon Power and the start of the collaboration with Solar Energy Meteorology group at Oldenburg University. Since 2014 these collaborative research activities have been supported by Murdoch University through several research grants enabling pilot simulation projects and infrastructure for validating short term solar forecasting using sky cameras. The experience gained through these projects lays a strong foundation for the assessment of forecasting techniques in the Carnarvon Der trials.

APPENDIX A contains a breakdown of the ‘DER Trails Project Deliverables and Outcomes’. Each of the infrastructure and research deliverables is detailed for a fuller understanding of the objectives of the trial and expected research outcomes.

The research team at Murdoch University are an integral part of the Carnarvon DER trials and have been engaged contractually for the full three-year term of the trials.

The Carnarvon DER Trials

Trial site location

The Western Australian town of Carnarvon situated on the mouth of the Gascoyne River, 900 km north of Perth, has a population of approx. 5500.

Horizon Power commissioned the new 13 MW gas-fired (with diesel peaking) Mungallah power station in 2014. Ownership of the power station offers control system access and integration planning as well as the possibility for optimisation recommendations that would not otherwise be afforded with an independent power producer operating under a commercial power purchase agreement.

With an economic base of predominantly primary producers, Horizon Power experienced rapid uptake of solar PV 2008 – 2011 with higher than an average system, typically 30 kW, used to offset cool room and water pumping power purchases.

The town power system has a high feeder and transformer loading of PV and requires sufficient spinning reserve to cover renewable energy variability.

Carnarvon was the first WA town to reach its unmanaged hosting capacity limits in 2011, only 1000 kW of managed hosting capacity requiring batteries and solar smoothing remains available

The population of the town has always held great enthusiasm for solar PV with 121 customer connected systems as well as two commercial solar farms operated by Solex (40 kW) which was the first privately owned solar farm in Australia, and EMC (300 kW).

Trials Description

The two trials currently underway in the town of Carnarvon have been devised to develop a technical solution for operating and maintaining high penetration DER environments using open standard protocols (Sunspec Alliance Protocol) to gain visibility of, and control over customer connected DER.

The trials will test the use of Horizon Power's existing AMI mesh radio network as a comms channel to achieve the monitor and control of DER. Also, the trials will gather extensive system performance data; power station SCADA data; AMI data from selected points on the distribution network, and concise meteorological data to assess the impact of appropriately managed DER on our current hosting capacity calculation methodology. They will also improve our understanding of the effects of cloud events on system performance, where the predominant renewable energy resource is solar.

Ten Solar PV/Battery combo systems and six existing PV system upgrades, from varying brands that demonstrate strong support for Sunspec will be installed at selected customer premises to test, their remote control functionality (via Sunspec) and ability to contribute to grid stability. This will provide Horizon Power with an understanding the technology and features available to our customers for participation in reformed tariff environments; Microgrid operation or future trading mechanisms.

The Carnarvon DER trials comprise two areas for investigation:

- #1 Monitor & Control of PV
- #2 Monitor & Control of Energy Storage

These trials will investigate technology options for the monitor and control of DER leveraging available AMI assets, current technology choices, developments in other utility jurisdictions and product evolution in the consumer market. In doing so, they will:

- Assist the development of tariff flexibility;
- Establish a robust communications architecture to assist with:
  - (a) Future DER trading;
  - (b) Feed in management; and
  - (c) Development of self-supporting infrastructure.
- Enhance Horizon Power's published Renewable Energy Technical Requirements regarding the connection of DER;
- Improve understanding of the impact of transient two-way energy flow upon Horizon Power assets and infrastructure;
- Test the robustness of the Horizon Power Hosting Capacity calculation methodology;
- Contribute to the development of a platform for the management of high penetration renewables in remote islanded Microgrids;
- Optimise conventional power station operations as part of a DER management system;
- Advance development of the 'open standards' supporting the interoperability of distributed network connected energy sources.

The experiential learnings gained in these first two trials will contribute to the design and operation of subsequent trials, which will use the same DER infrastructure and are planned to run immediately after these trials.

The development of this living laboratory environment that uses actual network infrastructure, real customers with their diverse requirements, and the variability of real weather, will make a significant contribution to our learnings which can be applied broadly across Horizon Power's remote Microgrids.

Establishing the communications and computing architecture that allows for DER monitoring, data acquisition, performance analysis, and real-time control is a fundamental outcome from these DER trials. To achieve success in this area, we have chosen to work with an established third-party DER aggregator, Reposit Power of Canberra, who has experience with DER integration and sound knowledge in the creation and application of Virtual Power Plants (VPP) as a way to monitor and control DER.

We have commenced the trials using internet communications between Reposit Power's aggregator platform and the DER at the customer's premises. This choice was taken to gather sufficient understanding of data bandwidth requirements and the business objectives for the visibility and control of DER. In parallel, we are investigating the use of the Silver Springs IoT mesh network used for our smart meter infrastructure, as an alternative communications pathway for DER control.

In remote locations, where urban communications standards are often unavailable, a low-cost alternative communications architecture is required to ensure safety, commercial and technical outcomes are not compromised. A local Internet of Things (IoT) network is considered likely in these cases, with Horizon Power leveraging its existing AMI network as well as other communications platforms as appropriate.

These trials support the ongoing realisation of core objectives to:

- Lower the cost of energy in remote Microgrids by allowing for much higher levels of renewable energy, thereby delivering direct economic benefits to subsidy and tariff payers.
- Embrace technological and economic advantages of DER while also meeting customer demands for these products.
- Through improvements in service delivery and facilitating a shift to more localised resources, generate indirect benefits, including economic development and social outcomes.
- Embracing innovative technology shifts to advance the renewable energy market in remote locations.
- Remain future focussed through our System Blueprints work that defines the target supply, customer and operating models for each of our systems.
- Remain locally relevant by offering products and services appropriate for communities and consumers outside larger urban areas.

The program being undertaken by Horizon Power aligns with the four enabling action areas defined within the United Nations Sustainable Energy for All Global Action Agenda; being a defined pathway for sustainable energy for all. The four enabling action areas are:

- Energy planning and policies at all levels: Promoting direct public action and improving the legal and administrative context for successfully engaging the private sector and civil society.
- Business model and technology innovation: Developing new approaches to overcome barriers that have impeded the deployment of sustainable energy services and technologies in the past, deliver affordability and reliability, and develop incentives for innovation.
- Finance and risk management: Promoting instruments to reduce risk and increase private investment in sustainable energy through the targeted use of public and philanthropic capital.
- Capacity building and knowledge sharing: Developing human and institutional capacity and adopting successful strategies proven elsewhere for faster replication across the world.

Activity Design and Methodology

These trials use 3/4G cellular networks, the public internet and Horizon Powers AMI Silver Springs Network (SSN) radio mesh to gain visibility and control of the DER performance and its effects on the operation of the distribution network and power station. Using the Sunspec protocol, an open standard specifically designed for the interoperability of DER increasingly adopted by a growing number of inverter and Microgrid controller manufacturers.

Individually metering the DER using Wattwatchers IoT devices on a 3/4 G network has unmasked real load which has been obscured for the past decade, yielding a clear picture of total renewable energy generated, local load and renewable energy total export.

The trial aims to prove that the AMI or the internet can provide a platform to implement Feed-in Management (FiM), the control of individual renewable energy generators and scheduling the discharge of network connected energy storage.

FiM is key enabler to increasing overall DER penetration through management to protect the quality of supply and system infrastructure.

During the trials, the switchboard wiring of 82 PV installations at residential and commercial premises have been modified to separately meter PV generation and load through dedicated Wattwatcher devices. This yields definitive PV production data for the trials as well as a benchmark for the development of algorithmic disaggregation of PV production.

Ten new solar PV/Battery combo systems have been installed in the town comprising systems from brands that have the strongest support for the Sunspec protocol. These PV/Battery systems have been equipped with energy storage products to test their suitability for our often extreme operational environment. The systems have been fitted with a (Reposit Box) node controller to provide communications back to the third-part DER aggregator.

The trials utilise sky camera forecasting system supplied by Fulcrum 3D to cover the geographic spread of renewable energy generation across the town's network. The sky camera is also fitted with a meteorological station that records temperature, humidity, barometric pressure, wind speed and direction and solar insolation.

A database captures the meteorological data, customer load, PV generation data and power station SCADA data to form an extensive co-incident data set supporting Murdoch’s Analysis and Horizon Power’s gateway to future machine learning.

Trial Context and Benchmarking

Horizon Power has a strong culture of innovation. In 2010 Horizon Power deployed two new power stations in Marble Bar and Nullagine in the Pilbara region. Utilising flywheel energy storage and advanced control systems in combination with tracking PV systems the stations achieved world record-breaking penetration of solar PV energy into the town’s distribution systems.

The experience of deploying, and then subsequently operating, these stations have had a substantial impact on the operations and culture within Horizon Power, which have irreversibly changed the company.

The experience gained in running isolated networks with energy storage to manage high penetration levels of renewable generation informed the development of the Horizon Power hosting capacity calculation methodology and the creation of the generation management technical requirements. Both of these pieces of work have been instrumental in the ongoing management of high numbers of customer connected PV system in our isolated networks. The introduction of solar smoothing and FiM (Feed-in Management) have been recognised as a beneficial means of both managing connected renewables and increasing the renewable energy hosting capacity of networks in general.

Horizon Power now faces the challenge of identifying new techniques of managing renewables in the face of increasing customer demand and the depletion of existing hosting capacity limits on its systems.

Long range modelling of each of Horizon Power’s 39 Microgrid systems over five, ten and fifteen-year horizons using the learning curves of PV and energy storage cost projections and the known fixed and variable costs associated with existing power purchase agreements have been used to develop a blueprint plan for each system. These System Blueprints show the point in the future at which a transition to decentralised generation is most cost-effective while informing current asset decision making.

Horizon Power seeks to be among the world’s best managers of high penetration DER microgrids by:

- Building on the knowledge gained from its system blueprinting exercise;
- Building on operational experience gained managing customer PV across our networks and
- Building on the knowledge gained in previously funded Australian projects.

Specifically the following reports within the Australian Renewable Energy Agency (ARENA) Knowledge Base, have been identified as contributory:

- AGL Energy Solar Project (Nyngan and Broken Hill Solar Plants) 6 off reports
- CAT Projects - Investigating the Impact of Solar Variability on Grid Stability
- ACIL Allen Consulting - Drivers of Domestic PV Uptake
- AECOM – Energy Storage Study
- Alice Springs - A Case Study of Increasing Levels of PV Penetration
- APVA – A Distributed Energy Market
- APVA – Magnetic Island & Townsville – Increasing PV Penetration
- CSIRO – Householder Participation in a Distributed Energy Market
- CSIRO – Integrated Solar Radiation Data Sources over Australia
- Moree Solar Farm – Lessons Learned
- Australian Solar Energy Forecasting Project (Ward 2016)
- Characterising and forecasting grid-connected solar energy (Kay 2015)
- Analysis of variations in instantaneous weather effects (CAT Projects 2015)
- DeGrussa solar project (ARENA 2016)
- Forecasting distributed solar energy production (ARENA 2016)
- Karratha Airport Solar Plant (ARENA 2015)
- Northern Territory Solar Energy Transformation Program (ARENA 2014)
- Real-time operational PV simulations for distribution network service providers (ARENA 2016)
- Solar and storage trial at Alkimos Beach residential development (ARENA 2014)
- Virtual Power Station 2 (ARENA 2014)
- Yulara solar project (ARENA 2015)

Creating an environment where our customers are incentivised to invest in DER technology and duly rewarded for doing so is key to reducing the levelised cost of electricity. In creating such an environment, competition for the lowest cost of supply is forced down to the consumer level of the network offering our customers choice and autonomy.

Recent Microgrid trials nationally as well as internationally have been focused on the use of one particular brand of DER system deployed en-mass and often tied together using propriety control protocols. Similarly, the trend in virtualisation of DER assets into Virtual Power Plants generally uses cloud-based control systems in closed and proprietary ecosystems that manage a single product brand. Our trials are different.

Horizon Power has studied the trials in Melbourne being carried out by AustNet/GreenSync using Selectronics and Fronius Inverters; the trials being conducted by AGL with Sunverge technology in South Australia; Vector's virtualisation of multiple Tesla Powerwalls; and SA Networks trial of Tesla Powerwalls and SMA SunnyBoy Storage inverters. What sets our trials within Highgarden apart from these trials is Horizon Power's support, and development of, open standard protocols (Sunspec) by creating open DER ecosystems comprising multiple product brands.

It is Horizon Power's strategy to offer customer choice and promote competition in the DER market while preserving the integrity and fidelity of the DER ecosystem from a system management perspective. Horizon Power believes that allowing the market to innovate to meet customer expectations is vital to sustain a healthy market place and to drive unprecedented levels of DER penetration; ultimately benefiting the consumer and lowering the overall levelised cost of electricity. Horizon Power's approach will see a DER market place where customers choose the products they buy and how those products will interface with the energy market.

Programme Outcomes & Knowledge Sharing

Horizon Powers programme of works

Western Australia is the largest market for off-grid renewables in Australia. Horizon Power is the state-owned utility servicing this market and is committed to a business future focused on high penetration DER through the digitisation, democratisation and decarbonisation of the energy supply chain. As the largest, long-term investor in renewable energy in Microgrids within Australia, Horizon Power is well qualified to deliver a high penetration DER outcome, with the requisite safety, operational and business frameworks supporting a cleaner and more efficient energy network.

As part of its commitment, Horizon Power is making a substantial investment to resolve technical, transition and economic barriers associated with high penetration DER, with strong governance and shareholder support underpinning these investments.

There is significant potential value available through the application of DER technology across more than 200 off-grid electrical systems within Australia. Horizon Power's DER program contains a strong emphasis on knowledge sharing.

Prior to the commencement of the Carnarvon DER trials, outside the budget and scope of works of the trials and in direct support of the work to be undertaken, Horizon Power has invested in the following projects and initiatives:

- **Engineering Partners:** Horizon Power has invested $120,000 via our engineering partners GHD who have developed all of the foundational documentation that describes the basis for and proposed design of the Highgarden trials (see attached documents).
- **FiM controller at HPCC:** Horizon Power is investing $191,000 in the deployment of a Feed-in Management control system into Horizon Power Control Centre Bentley to manage DER in multiple towns..
- **Carnarvon Energy Storage Trial:** Horizon Power is investing $3.5 M in a research and development joint venture with the TianJin Lishen Battery Co, China, to deploy a 2 MWh lithium Ion battery at the Mungallah Power station in Carnarvon. Principle investigations will be the provision of operational reserve capacity to replace that provided by spinning generation and the reduction in carbon emissions and OPEX through the optimisation of power station operation.
- **IMB Hindcasting and Forecasting model using Carnarvon Data:** Horizon Power has invested $250,000 into the joint development with IBM Think Labs of a weather forecasting model based on VELCO, IBM's work with the Vermont Electricity Corporation. A Watson based machine learning platform has ingested several years of Carnarvon power station and town network AMI data; the GIS data for all of the PV installations in the town, and their capacity, together with the corresponding period of Bureau of Meteorology (BOM) and TWC (The Weather Company) weather data. The resultant model drives a self-learning engine which takes the hindcast data and a 24 hr ahead TWC forecast to accurately predict customer load and renewable energy generation through a moving 6-hour window of 15-minute increments. Constant learning iteratively improves the accuracy of the estimates.
- **MRO Microgrid:** Horizon Power has completed construction of the solar/diesel hybrid - Murchison Radioastronomy Observatory Power Station in the Murchison region of Western Australia which will supply energy to the Australian Square Kilometre Array Pathfinder (ASKAP) telescope which forms part of the international Square Kilometre Array (SKA) project. This power station integrates with the CSIRO - Sustainable Energy for the SKA (SESKA) project which comprises 1.6 MW solar PV and 2.5 MWh of energy storage to provide very high levels of renewable energy penetration over 24 hours/day into a high energy content load. The integration of these to facilities has provided valuable input into Horizon Power's expertise in managing very high penetrations of Solar PV and Energy storage in Microgrids.
- **ANU:** Horizon Power is supporting the (ARENA funded) development of the Real-time Operational Distributed PV Simulations model for Distributed Network Service Providers (DNSPs) at the Australian National University (ANU) with the provision of network models and DER data from select regional towns including Carnarvon.
- **Internal Knowledge Sharing:** Horizon Power has implemented a companywide Ideas Hub platform and social network tools, to make data and information more widely available and encourage innovation and the dissemination of ideas. This has spawned thriving user and interest groups discussing amongst other things: Electric vehicle network integration, advanced renewable energy and microgrid modelling, big data management, home automation of DER and remote community business model development.

Knowledge Sharing

As part of the ARENA funding for the Carnarvon DER trails, Horizon Power has committed to an extensive knowledge sharing programme.

The Knowledge-sharing activities have included presentations at National and International industry relevant conferences, participation in national knowledge sharing events on Virtual Power Plants and IEEE 2030.5 Application Program Interface (API) development.

The data collected into the database will be made available through ARENAs knowledge sharing portal, as will several reports outlining the research by Murdoch University and Horizon Power's experiential learnings.

The combination of existing assets and opportunity in Carnarvon represents unique and significant value that Horizon Power will use as a platform to create new customer products, technical standards and operational templates that we can implement in the remaining 38 Microgrids within our operational footprint.

The dissemination of the project outcomes and gained experience through the company will be used to drive organisational and cultural change forming a vital part of the transformation of Horizon Power's business model in response to the existential imperative to innovate. The transition from a centralised generation business model to a decentralised generation business model is foundational to a Microgrid centric future based on enabling and rewarding customer investment in DER and the evolution of the network as a platform for the democratisation of the energy supply chain.

As part of the internal cultural change, the trials include funding allocations for training Horizon Power's staff in the agile project management framework and the development of new forms of contracts and product offerings to engage with our customer base.

Horizon Power has, during the development of Carnarvon Trials, executed confidentiality agreements with some of the most forward-thinking companies and utilities in the DER space, including ABB, Ergon, Enphase, Fulcrum 3D, Greensync, Green Energy Labs, IBM, Magellan, Murdoch University, PowerWater NT, Reposit, Sunspec, Selectronics, Sunverge, SolarCity, Telstra, Tesla, and Vector Energy.

We intend to treat our dealings with these organisations as a collaborative effort to further the development of open standards and shared understanding as we advance the interoperability of distributed energy resources.

In addition to the knowledge sharing obligations associated with the ARENA funding, Horizon Power and Murdoch University will disseminate the findings of these projects through industry and academic channels via research papers and conferences.

The following peer-reviewed journals and conferences will be targeted for these publications:

- Renewable Energy ("A" journal 2010 ranking, (IF 3.361)
- Renewable and Sustainable Energy Reviews (IF 5.51)
- IEEE Transactions on Sustainable Energy (IF 3.842)
- IET Renewable Power Generation (IF 2.28)
- Asia Pacific Solar Research Conference

- European PV Solar Energy Conference

The re-combinative approach to existing assets and the deployment of DER within Carnarvon creates a laboratory environment capable of generating extensive, rich and unique data sets of significant value to both academia and industry. The data derived from Carnarvon demonstrates a compelling model of high customer uptake of DER in a fossil-fuelled islanded network, in a region of Australia that is climactically relevant to some of the largest projected growth regions for microgrids of this century. This kind of high-quality energy-related data is immensely valuable at a time when large and comprehensive data sets are still rare.

Internally, Horizon Power is using big data and business intelligence to drive down the cost of supply through improved understanding of our cost to supply and the drive to a lean business model.

Horizon Power will continue its close association with academia and industry, using appropriate data sharing methods to unlock value in both the development of Microgrid management platforms and better-informed customer engagement.

Horizon Power's Capability and Capacity

Horizon Power is a State Government-owned, commercially-focused corporation that generates, distributes and retails high quality, safe and reliable electricity to about 100,000 residents and 10,000 businesses, including primary industry, across regional and remote Western Australia. Horizon Power's customers are dispersed across an area of approximately 2.3 million square kilometres - twice the area of UK, Germany and France combined.

Horizon Power has become a leader in managing the impact of generation variability and has introduced innovative measures to ensure the continued quality of supply to its customers and gained considerable experience in operating high levels of renewable energy generation on islanded grids. For example, the Marble Bar and Nullagine power stations both utilise flywheel energy storage to achieve high levels of renewable energy penetration into the town load. Experience gained with these two towns has led to the introduction of hosting capacity limits in each of Horizon Power's networks, and the development of the generation management technical requirements, solar smoothing and 'ramp rates' as techniques to manage the increasing demand for customer connected solar PV.

Horizon Power pioneered the use of distributed energy storage to manage fluctuations in renewable energy generation, with its network management capability for small to medium scale islanded and geographically isolated grids being world leading. The experience of Horizon Power's engineering staff to manage increasing levels of distributed generation and setting new technical standards to maintain power quality has caught the attention of utilities across Australia.

The Carnarvon DER Trials are managed by Horizon Power staff using Horizon Power's Project Management Methodology (PMM), supervised by our internal Project Management Office (PMO). Monthly project status reports submitted to the project sponsor (Horizon Power GM) and steering committee meeting comprising major stakeholders from Carnarvon Depot; System Planning and Capacity Support; Finance; Strategy, and PMO.

Project scheduling is conducted in Microsoft Project with project finance tracking in Ellipse. The project team use JIRA and Confluence (Atlassian) to manage workflow alignment with the Horizon Power gating process for project approval and funding allocation is managed by the project sponsor and the PMO.

APPENDIX A

The appendix contains a breakdown of the project deliverables and outcomes for the DER Monitor and Control of PV and the Monitor and Control of Energy Storage trials, both in Carnarvon.

Deliverables and outcomes

The project outcomes are a product of the ***Infrastructure*** deliverables and ***Research and Development*** deliverables.

The ***Infrastructure*** deliverables shall include:

A. Modify the meter wiring of Carnarvon project participants to separate the PV generation and load using dedicated meter coils (or install a dedicated AMI meter for PV installations where this is not feasible).

B. Ten new PV/Battery combo systems with a range of smart inverter and energy storage technologies installed in Carnarvon, equipped with remote monitoring and control of the PV generation and energy storage by leveraging existing AMI functionality where possible.

C. The infrastructure established and tested to control selected PV installations and energy storage systems in Carnarvon via Horizon Power's Control Centre (HPCC) or a local intelligence device.

D. The infrastructure established and tested to monitor the output and status of selected PV and energy storage systems in Carnarvon via Horizon Power's Control Centre (HPCC)

E. A recommendation for the implementation of the control and data storage architecture.

F. Gather and store operational data from distributed generation, weather station, and Horizon Power's SCADA system.

G. Gather and store selected 5-sec operational and weather data for limited periods (cloudy days) to assess the progression speed and impact of cloud events.

H. A data access or delivery system for the research partners.

The ***Research and Development*** deliverables shall include:

I. An assessment of the current conventional and PV generation, current spinning reserve policies, and load demand for Carnarvon, as well as Horizon Power's methodology used to determine the hosting capacity of distributed generation.

J. Statistical assessment of the impacts of high levels of distributed PV generation on the Carnarvon network, with a time of day and seasonal variation analysis.

K. Development of a PowerFactory simulation model for Carnarvon to evaluate power system's stability with cloud movements, given various PV penetration scenarios and spinning reserve control strategies.

L. Development of spinning reserve control strategies during cloud events, using generation management (solar smoothing), Feed-in management and short term solar forecasting tools. Testing of the control strategy through the PowerFactory simulation model.

M. Development, testing, implementation and analysis of Feed-in management control methodologies in Carnarvon.

N. Mapping of weather data, customer load data, power system SCADA data and distributed energy generation data to demonstrate the influence of renewable energy generation on the Carnarvon system operation.

O. A report recommending improved methodologies for determining the hosting capacity of distributed generation with and without management of PV and stored energy.

A description of each of these deliverables is provided in the following sections. The deliverables are reflected in the following knowledge sharing activities and the critical questions the project will answer:

Knowledge Sharing Activities Objectives:

- Improving understanding of the impacts of high levels of distributed PV generation on remote networks.
- Sharing of methodologies to determine hosting capacity in remote networks.
- Increasing understanding of control methodologies enabling high levels of distributed PV generation in remote networks.
- Increasing understanding of Feed-in management, control and communication infrastructure and its operation.

Critical questions the project will answer:

- What are the benefits and limitations of the proposed and investigated control methods and systems?
- How can Horizon Power's planning and operational strategies be adapted to increase the hosting capacity of distributed generation?
- How should standards and regulatory frameworks be adapted to enable a technically reliable transition to networks with distributed generation being a major electricity source?
- How can communication between network devices, power station and distributed generation equipment be modified to allow for increased PV generation in remote networks?

Infrastructure Deliverables

A. Modify the switchboard wiring of Carnarvon project participants to separate the PV generation and load using dedicated meter coils (or install a dedicated measurement device for PV installations where this is not feasible).

At least 80 solar PV installations in Carnarvon will be modified. Wiring of meter box installations to ensure PV production and load consumption can be metered separately on older PV installations. The activity allows for separating PV generation and load data. Control of the PV on older installations is expected to be limited to ON/OFF.

This part of the project requires considerable customer engagement, electrical contractors to rewire meter installations (Horizon Power bears the responsibility to rectify any safety issues or wiring defects discovered when the meter box panel is removed. Careful selection of participants through pre-screening will mitigate risk here).

Wiring of, and/or establish IoT Router comms link using the internet or Silver Springs Network (SSN) to newer PV inverters.

B. Ten new PV/Battery combo systems with a range of smart inverter and energy storage technologies installed in Carnarvon, providing remote monitoring and control of the new PV/Battery systems.

Equip ten houses with new PV/battery combo systems with feed-in management and the full range of smart inverter capabilities. Anticipated is a trial of up to four product types, to test various functionalities, performance characteristics and suitability for deployment in the various climate zones of the Horizon Power service area.

C. Control infrastructure established and tested to control selected PV installations and energy storage systems in Carnarvon via Horizon Power’s Control Centre (HPCC) or a local intelligence device.

The 10 new systems as well as the Carnarvon Police Station (50 kW, with smoothing and feed-in management) and the EMC solar farm (class 3 installation, 290 kW PV array, remote control for the system output from HP’s power station, SCADA provision, example of Generation Management active power set-point control (within 15 seconds), direct control over isolation circuit breaker, unrestricted access to live on site generation resource data (solar irradiance, wind speed and direction)) will be equipped with IoT Router devices allowing for set point variations, retrieving inverter data, as well as ON/OFF control.

D. Infrastructure established and tested to monitor the output and status of selected PV and energy storage systems in Carnarvon via Horizon Power’s Control Centre (HPCC).

Apart from the physical meters at the PV installations and customer loads, a system is required that communicates and logs data from the PV installations and loads. This deliverable is concerned with providing the infrastructure for collecting this data, i.e. a back end infrastructure and database that can be integrated with HP corporate SCADA historian.

E. A recommendation for the implementation of the control and data storage architecture.

A technical solution of the control and data storage architecture may already be found once the project commences, if not research has to be performed prior to implementation.

F. Gather and store 5-min operational data from distributed generation, weather stations, and Horizon Power’s SCADA system.

This is to be a Single Source of Reporting, consistent with Horizon Power’s AMI strategic development document describing the Intelligent Network Roadmap.

5 minute monitoring data to include:

- PV array status (curtailed – uncurtailed)
- PV array output (A, kW, kVAr)
- Load demand (A, kW, kVAr)
- Voltage
- Frequency

Weather station monitoring data to include (and may not be limited to):

- Solar irradiance (Diffuse and global horizontal irradiance)
- Wind speed & direction
- Ambient temperature

G. Gather and store selected 1-sec operational and weather data for limited periods (cloudy days) to assess the progression speed and impact of cloud events.

Note that the Installation of high-speed data recorders may be required at some points on the system to assess the system impacts of the cloud disturbance.

1-second monitoring data to be limited to specific cloud event periods, and to include:

- PV array status,
- PV array output (A, kW, kVAr)
- Load demand (A, kW, kVAr)
- Voltage
- Frequency
- Solar irradiance (Diffuse and global horizontal irradiance, possibly at a higher recording interval)
- Sky images (possibly at a higher recording interval)

H. A data access portal or means of delivery for research partners

Infrastructure will be put in place so that data access can be provided for all project participants.

Research and Development Deliverables

I. An assessment of the current conventional generation, current spinning reserve policies, load demand, as well as Horizon Power's methodology used to determine the hosting capacity of distributed generation.

This assessment forms the basis for deliverable K.

J. Statistical assessment of the impacts of high levels of distributed PV generation on remote networks with a time of day and seasonal variation analysis.

This work forms the basis for deliverable L. The studies contributing to this report will build on the ARENA funded work performed by CAT Projects in Alice Springs (CAT Projects 2015). The studies will analyse both weather (irradiance) and PV systems output data. The effect of spatial diversity of PV plants on in Carnarvon can then be assessed and validated. The studies will provide the foundation to determine and understand renewable energy diversity and fluctuation factors.

K. Development of a PowerFactory simulation model to evaluate power systems' stability with cloud movements, given various PV penetration scenarios and spinning reserve control strategies.

The development of the simulation model is necessary to deliver L. The development of the simulation model will initially be based on the assessment of Carnarvon's conventional generation, current spinning reserve policies, and load demand. The model will then become the platform to investigate higher PV penetration scenarios and different spinning reserve control strategies (e.g. using feed-in management). Of particular interest is system performance on intermittent cloudy days.

L. Development of spinning reserve control strategies during cloud events, using generation management (solar smoothing), Feed-in management and short term solar forecasting tools. Testing of the control strategy through the PowerFactory simulation model.

These studies are associated with the development of the new control strategies and include:

- System modelling and control details
- System performance analysis based on simulation studies
- System performance analysis using existing control strategies based on system data and simulation studies.
- Comparison of system performance using new and existing control strategies.

Of particular interest is system performance on intermittent cloudy days.

M. Development, testing, implementation and analysis of Feed-in management control methodologies in Carnarvon

These studies are associated with the customised PV/Battery combo systems equipped with a range of inverters. The studies will investigate the effectiveness of feed-in management control methodologies (ramp rate control, real and reactive power set points or functions P(V), Q(V)) in a weak section of the Carnarvon network, and their impact on power system operation (e.g. reactive power provisions). The experience gained will be particularly beneficial as standards undergo review.

A report will also summarise the experience gained during the project with respect to:

- Communication technologies for control and monitoring, pros and cons for each technology
- Inverter technologies

N. Mapping of weather data, customer load data, power system SCADA data and distributed energy generation data to demonstrate the influence of renewable energy generation on the Carnarvon system operation.

This study forms the basis for deliverable O. A report associated with this study will present aggregated load and feeder data that can be made available publicly. The study will present the real-time effect of cloud events on spinning reserve requirements, system loading, frequency and voltage at various points in the system.

O. A report recommending improved methodologies for determining the hosting capacity of distributed generation with and without management of PV and stored energy.

Studies for deliverables J, L, M and N form the basis for/enable the review and improvement of HP's Hosting Capacity criteria. The collection and analysis of high resolution operational and weather data for Carnarvon as well as the study of existing control algorithms will allow us to determine the renewable energy 'diversity factors', 'fluctuation factors', and 'peak PV generation' in Carnarvon. The will enable us to provide recommendations to increase hosting capacity and develop improved methodologies to determine hosting capacity in other towns.

- **References**

CAT Projects (2015). Investigating the Impact of Solar Variability on Grid Stability, ARENA.