Cloud detection and prediction for maximising solar PV utilisation in off-grid hybrid power systems

Final report: project results and lessons learnt

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Executive Summary

Development and Demonstration of CloudCAM PV Generation Forecasting

The project aimed to develop a product that would enable solar farm operators to accurately predict changes in photovoltaic (PV) output due to cloud coverage 1-20 minutes ahead of time. This hardware, along with the software that would enable the interpretation of images, was known as 'CloudCAM', with two systems proposed to be developed. 'CloudCAM Optical' uses a fisheye lens that takes images of the whole sky, while 'CloudCAM Advanced' envisages the development of novel technology to further analyse cloud systems moving over the solar PV power stations. This novel technology enables the identification of cloud height, which in turn would allow for an increase in accuracy of the prediction for short term PV output. The overall aim of the development of the CloudCAM technology was to provide sufficient accuracy to enable power generation control systems to respond ahead of time to upcoming drops in PV due to cloud shadow.

Over the last two years, Fulcrum 3D has developed the software and hardware for both the optical and Advanced CloudCAM systems. The optical system was successfully tested in Sydney, with results showing that it was accurate in its ability to detect all clouds in the full 180^{o} hemisphere of the sky. This CloudCAM was then trailed in the Northern Territory (NT) with similarly successful results in cloud detection. Two more CloudCAMs were then built and installed at two off-grid solar power stations in the NT, and then at the beginning of 2016 they were integrated into the solar control systems on the 2 sites. The integration of these CloudCAMs with the solar power stations resulted in an increase in revenue (normalised for variance in monthly irradiation) for the solar power stations due to a reduced reliance on the batteries that were previously used to manage solar variance and a greater solar power level due to the higher confidence in consistent short term PV output. These trials were undertaken using the 'NowCasting' software on the CloudCAM. This gave operators of the solar power station information on the real time cloud levels around the solar farm, with clouds ranked on their distance from the sun (and therefore how likely they were to create shadows in the short term). While operating in this mode, data was collected from these CloudCAM systems, allowing for prediction algorithms to be developed and then tested on historical data stored on Fulcrum3D's servers. CloudCAM prediction was then deployed remotely to the existing CloudCAMs in the NT. These successful trials for CloudCAM have resulted in the first commercial third-party sale of the CloudCAM system, which was installed in August 2016.

During the project CloudCAM Advanced was taken from a conceptual idea to testing at the Sydney site. The hardware and software developed during the project have shown the potential of the technology to recognise cloud heights and types and integrate with CloudCAM optical to create a solution that has a higher accuracy of prediction then just the optical system alone. The project has finished with CloudCAM Advanced still in its trial stages, with Fulcrum3D intending to further develop the technology into a commercial product.

Fulcrum3D has overcome a large number of obstacles and learnt a great deal about large scale solar power generation during the project. Through discussions with multiple utility networks it became apparent that in Australia's current market, predication of cloud movements for greater than 10 minutes using the CloudCAM was largely redundant and that in remote area hybrid grids a time frame of 2-5 minutes was ideal (Lessons Learnt Report: Time frame for forecasting cloud shadows). This changed the overall aims and focus of the project to this shorter time scale. The main issues encountered with the optical system included reducing the impact of sun flare on the image and cloud detection software, which were fixed during the project (Lessons Learnt Report: Solar Flare). The CloudCAM Advanced had problems with a lack of suitable sensors available on the commercial market that provided the high resolution sky imagery at cost effective prices (Lessons Learnt Report: Advanced technology -Issues with hardware and sensors). Multiple sensors were trialled in Sydney and at the Northern Territory before the ideal sensor was chosen. Problems persisted with the CloudCAM Advanced system resulting in it not reaching the expected outcomes of the project.

Overall the project has resulted in the commercial sale and installation of CloudCAM at multiple solar PV sites across Australia, ensuring the optimisation of these sites for PV output and management for cloud shadows. With this outcome the project has achieved its overarching goal of making remote off-grid high penetration solar sites more cost effective. Further, valuable lessons have been learnt and substantial progress made with the CloudCAM Advanced system.

Project Overview

Project summary

This project resulted in the development, successful trial and first commercial sale of the CloudCAM system (Figure 1). This system has been shown to increase the yield of off-grid solar power stations, allowing operators to increase photovoltaic (PV) output due to the knowledge that there will not be any short term drops due to cloud shadows. This confidence in the level of future PV output allows operators to reduce their reliance on expensive alternative options, such as batteries or ongoing spinning reserve from local diesel generators. As well as the upfront cost of these management strategies, they have inherent inefficiencies that can reduce overall yield, such as the power lost in the recharge/ discharge process when using batteries or the unused power that is created with running diesel generators for spinning reserve. In some cases when these backup solutions are not available, remote solar power stations have to reduce their overall output, regardless of the amount of solar resource, to ensure that there are no sudden solar power station output variances that may be detrimental to the local grid (Figure 2). With a CloudCAM installed, solar operators have an accurate understanding of the risk of sudden solar variance occurring in the next 2-5 minutes, meaning that even without battery backup or extra spinning reserve, off grid power stations can operate without curtailment and with confidence that a cloud shadow will not cause a sudden drop in PV output in the near future (Figure 3 & Figure 4).

Figure 1: The commercially available CloudCAM (right) with attached pyranometer (left) and met station (centre)

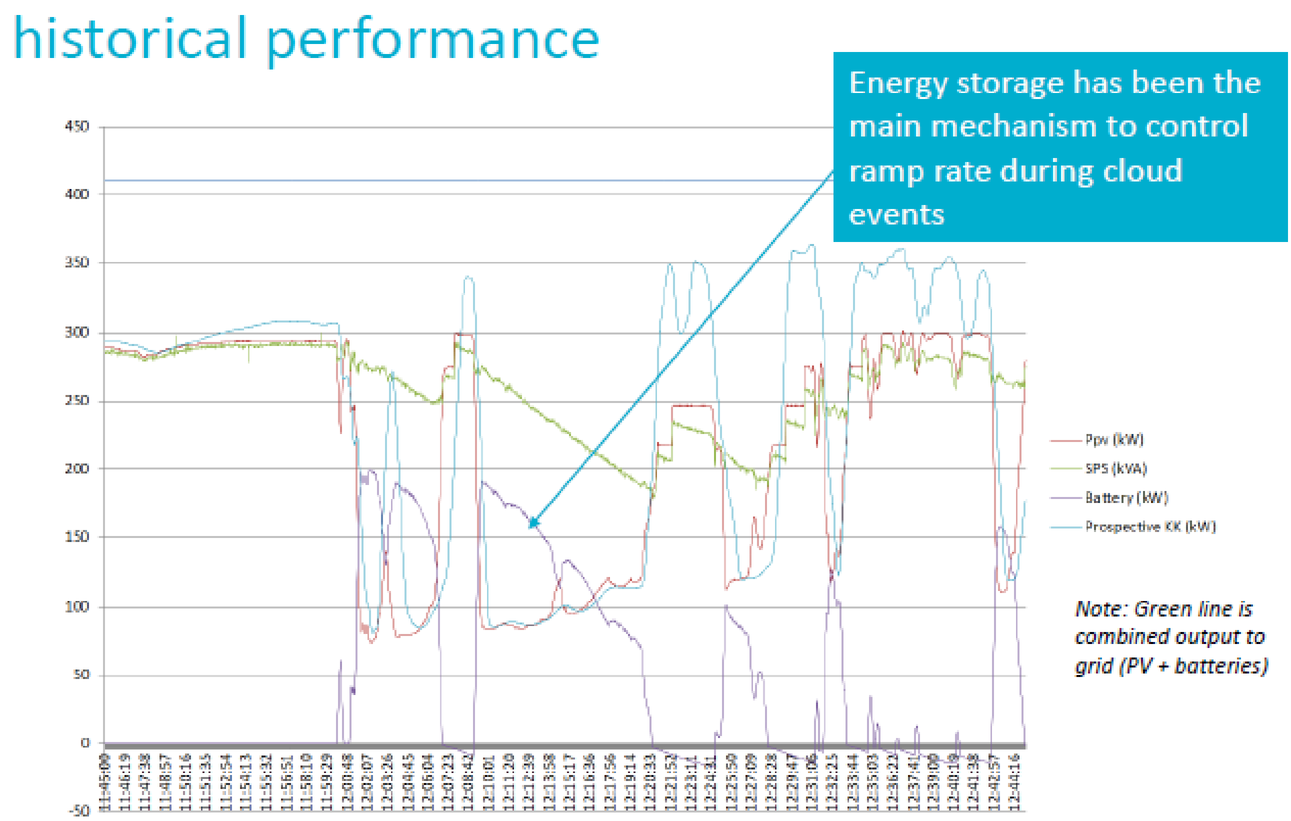

Figure 2: Historical performance of remote high penetration hybrid solar PV stations with battery systems used as grid stability systems.

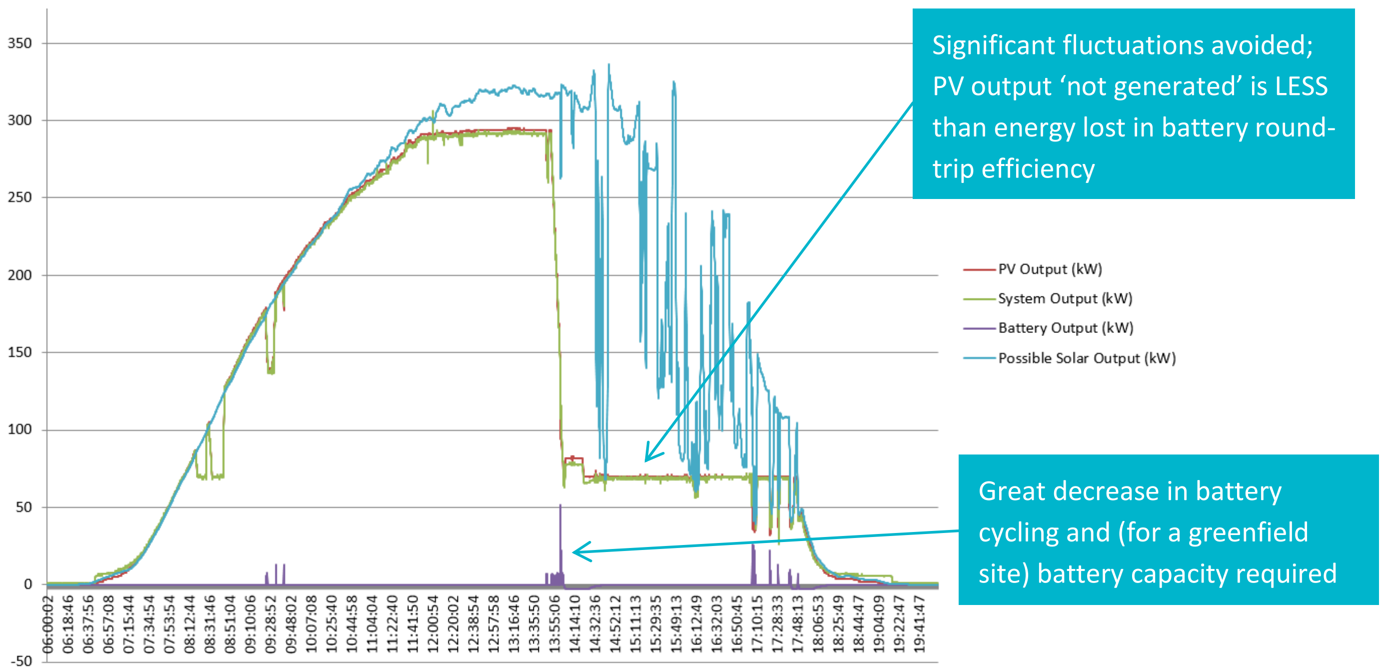

Figure 3: Operation of Kalkarindji solar PV power station after the installation and integration of CloudCAM. Increase in yield is experienced through the reduction of power lost from battery cycling as well as having a higher PV output when CloudCAM recognises there will not be cloud shadows in the short term future, allowing the power station to output closer to maximum possible solar PV output.

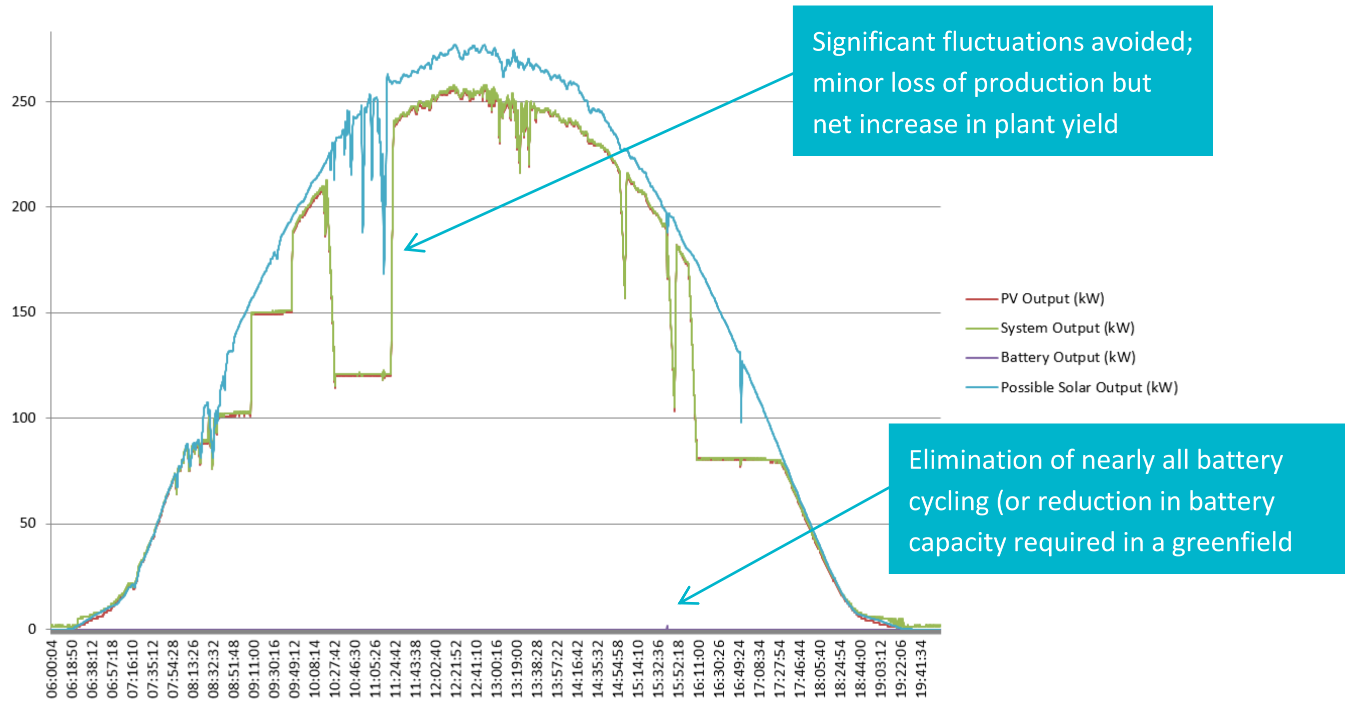

Figure 4: Operation of Ti Tree solar PV power station after the installation and integration of CloudCAM. Increase in yield is experienced through the reduction of power lost from battery cycling as well as having a higher PV output when CloudCAM recognises there will not be cloud shadows in the short term future, allowing the power station to output closer to maximum possible solar PV output.

CloudCAM Advanced will further refine this process by determining the height of clouds detected. During the project this new technology reached the testing stage in Sydney. Different sensors for CloudCAM Advanced were tested at solar power stations across Australia and hardware was developed and built to enable a full sky image to be taken. The prototype reached the testing stage in Sydney multiple times, with Fuclrum3D confident of testing integration of CloudCAM Advanced with solar power stations and the optical system in the future. With lessons learnt along the way, Fulcrum 3D is imminently poised to produce a commercially viable CloudCAM Advanced system for the wider solar PV market.

Project scope

CloudCAM was developed in response to the increase in medium and high penetration solar PV installations worldwide connected to island or weak grids. While solar PV technology has many benefits as a renewable energy source, short-term intermittency in high PV penetration systems due to clouds can lead to disruptions and grid instability from sudden drops in PV output. Current management strategies include limiting PV penetration, installing storage (battery or flywheel) for ramp-rate compensation, or running at a high spinning reserve capacity (Figure 2). These solutions increase project capex, increase opex from increased diesel usage and system maintenance, or underutilised infrastructure. This problem was apparent to Fulcrum3D when sister company Epuron was building high penetration solar sites in the NT and a part of the capital costs was for installation of batteries used for ramp-rate limiting and grid stability during cloud events. It was recognised that a system that could accurately detect clouds and predict cloud movements and cloud shadow locations would allow solar sites to pre-emptively ramp down and therefore reduce the need for these high costing alternative management strategies.

The ARENA/Fulcrum3D project started in September 2014 and encapsulated the development and demonstration of Fulcrum3D's CloudCAM, a system that was to monitor clouds in real-time and to provide accurate prediction of cloud shadows with the aim of reducing or completely eliminating the need for expensive energy storage or other management strategies. At a high level the goal of the CloudCAM project was to mitigate the large costs of these currently employed solutions, and enable cost effective, high penetration PV hybrid grids. The project was to take the PV output forecasting technology from the development stage through to a pilot scale demonstration.

The expected outcomes of the project were:

- Develop the hardware (camera and other sensors, housings and mountings) and software of the 'CloudCAM' system and use these systems to create images of the sky and collect other data;
- Interpret those images to detect clouds, their characteristics, and velocity and use this information to predict cloud movement and corresponding short term changes in incoming solar radiation and therefore PV output;
- Trial the CloudCAM PV output forecasting system at the Epuron Solar-owned Uterne site in the Northern Territory;
- Evaluate whether the CloudCAM PV output forecasting technology can adequately identify cloud height and separate out layered clouds – and thereby enable accurate, local, short term forecasting (10 – 20 minutes ahead) of solar irradiance and hence PV output;
- Assess whether the accuracy of the prediction from the combined sources (CloudCAM and CloudCAM Advanced) is greater than for either system alone; and
- Collaborate with CSIRO and ANU to compare the relative accuracy of CSIRO, ANU and CloudCAM's respective cloud detection algorithms.

Initially the project concentrated on the development of new technology that could provide the high resolution and robust prediction algorithms required to provide system operators with the high level of confidence required to impact on solar power station operations. This focus of the project was to assess whether utilising novel technology to identify cloud heights could increase the accuracy of short term irradiance forecasting and solar power station output prediction to a commercially useful level. It is important to note that at the time that this project was undertaken, and still at the present time, outside of CloudCAM, no system exists to predict the level and type of clouds and corresponding change in the short term PV output with sufficient accuracy to enable power generation control systems to respond effectively. The project was aiming to rectify this by providing insight into whether the CloudCAM PV output forecasting technology could be utilised in future to enable power generation control systems to respond effectively to short term changes in PV prospective output (10-20 minutes with the CloudCAM Advanced system).

The development of the CloudCAM Advanced was important to the project. However there was also a focus on the original CloudCAM system, with current overseas competitors inadequate for the Australian market, with low resolution and poor PV output prediction outcomes. Similarly at the time that the project started, no Australian company had a solution capable of cloud detection in the commercial space and, outside of Fulcrum3D, this remains the case today.

Outcomes

The project resulted in the development of both CloudCAM optical and CloudCAM Advanced hardware, along with the creation of the supporting software. This software includes cloud detection algorithms to both detect and track the movement of clouds in the sky and map the corresponding shadows across the ground, as well as prediction software that can determine a clouds location ahead of time. This software has been developed so that it operated independently of the hardware which means it can be applied to Fulcrum3D's CloudCAM or third party hardware. It is also capable of running on site in remote areas and does not require access to large servers or databases. The Cloud detection for CloudCAM is higher than results seen in open literature. The CloudCAM system, consisting of a fish eye lens, capable of viewing the whole of the sky's hemisphere (Figure 5), was successfully trialled in Sydney, and has been installed in multiple solar power stations (Figure 6). These power stations are owned and operated by Epuron, with the results showing that CloudCAM enables an increase in solar yield and revenue (Figure 3 & Figure 4). This resulted in a commercial product that has since been sold to third-party solar power station operators, resulting in more efficient and cost effective solar generation within Australia.

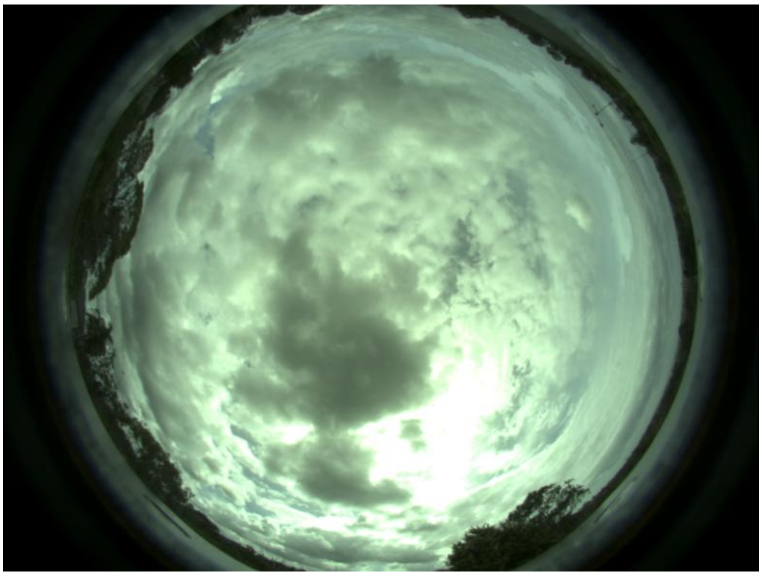

Figure 5: 360 degree fisheye view of a cloud field during the day, acquired using the CloudCAM optical camera.

Figure 6: The successful deployment of CloudCAM at Epuron's Uterne site, Alice Springs NT: (top) The CloudCAM system is housed inside a standard 7 x 4 box trailer containing a sky camera, pyranometer and Vaisala WXT520 for local meteorological measurements; (middle) the placement of the CloudCAM system adjacent to the Uterne solar arrays and (bottom) a close-up showing the optical camera assembly (right of centre) and calibrated Kipp & Zonen SMP11 pyranometer for irradiance validation (left of centre).

The development of the CloudCAM Advanced system was complex, and first required testing of multiple sensors and their ability to detect and determine cloud heights and densities. This took place in Sydney, as well as in solar power station sites in the NT. After testing multiple sensors, the most effective sensor suitable for cloud detection was determined. Unlike the optical system, which used a fisheye optical lens, the sensors commercially available for the CloudCAM Advanced system had limitations. This meant that Fulcrum3D had to design and build hardware to house the sensor and move it across the whole hemisphere of the sky, creating the first of its kind technology capable of producing whole sky monitoring at a cost effective price. This hardware with the fitted sensor was able to be tested in Sydney on multiple occasions, with further trials and development to occur in.

At the start of the project there was a focus on taking the CloudCAM Advanced system, with the novel technology and corresponding hardware, to the pilot scale demonstration stage. While this was not achieved during the last two years, significant progress was made on the development of this novel technology. Different sensors have gone through field tests, with the most accurate sensor for cloud detection identified. The hardware has been developed and built to enable full sky monitoring and the software for determining cloud heights and inputting that information into the PV output prediction algorithms has been developed. This project has showed that there is the potential for this CloudCAM Advanced system to determine different cloud heights and types and to provide extremely high level predication, capable of rendering other expensive battery or other management strategies for drops in PV output due to cloud shadows obsolete. The system that has been designed could potentially be commercially available at a fraction of the price of these currently utilised management options, and hence this project has not only shown that this new technology is capable of enabling power generation control systems to respond effectively to short term changes in PV prospective output, but once fully developed will significantly reduce the overall cost of remote off grid high penetration hybrid solar power stations.

As the project progressed, a greater focus was placed on the CloudCAM optical system. While the advantages of an operational CloudCAM Advanced system are understood, the lack of commercial success of currently available cloud cameras resulted in a possible underestimation of the potential impact that a well-developed, stand alone, CloudCAM optical system could have. The high resolution fisheye lens, along with Fulcrum3D's cloud detection software and prediction software has outperformed all other commercially available products on the market in not just cloud detection but in the task of determining solar PV outputs ahead of time. The trials, where CloudCAM was installed at solar farms in the NT, were extremely successful. With the solar power stations showing an increase of yield from the PV output and a decrease in the cycling of installed batteries for grid stability purposes. This increase in yield was due to the high penetration solar site being able to generate at full capacity, regardless of the state of charge of the batteries, with the high confidence provided by CloudCAM of no sudden drops in PV output to occur in the short term. Without CloudCAM, and when the batteries are not at full capacity, the solar site has to limit its generation so that any cloud events would not cause sudden PV output drops. The reduction of the cycling of batteries is also an important benefit and occurred because the solar site could pre-emptively ramp down before a cloud event, rather than using battery output to stabilise the grid while diesel generators caught up to the increase in required generation. This reduction in battery cycling allows for longer battery life, making this type of Grid Stability System more economically viable and also increases yield by decreasing the energy inherently lost in charging and discharging battery systems.

The success of the CloudCAM system developed during this project has shown that it is valuable to the solar industry in its own right, and does not require to be augmented by more advanced sensors to be of use to solar operators, especially for off grid high penetration solar sites. This was not clear before the project began, with similar overseas models on the market failing to provide solar operators with such a high level of confidence in cloud detection and prediction. The resulting commercial sales of CloudCAM and the continued interest in the product from corporations and utilities across Australia has exceeded the expectation for the optical system from the conception of the project. The CloudCAM optical system in its own right provides sufficient accuracy to enable power generation control systems to respond effectively to upcoming cloud events with a high level of confidence, and while it does not replace current management strategies in the way the CloudCAM Advanced system would, it can certainly supplement them, resulting in a much more cost effective solar site in high penetration off grid power stations.

Across the nearly 2 years of the project there were some unexpected outcomes and learnings. One of the main outcomes that changed was the time frame required by solar farms to avoid unacceptable ramp down rates. On the outset of the ARENA project it was expected predication in the order of 10-20 minutes ahead of time would be required, however discussion with different utilities, as well as further analysis of Epuron's solar sites, it was found that prediction in the order of 2-5 minutes is more practical and enough time for PV output to pre-emptively ramp down if cloud shadows are imminent (Lessons Learnt Report: Time frame for forecasting cloud shadows).

The CloudCAM optical system also had issues with solar flare, with the binary (cloud/ not cloud) nature of the detection software sometimes picking up the white glare as cloud (Figure 7). This was a surprising result of the fish eye lens, and required tracking the sun and actively filtering out glare to ensure it was not creating false positives for cloud detection (Lessons Learnt Report: Solar Flare). As well as this, clouds within 5 degrees of the horizon were initially not accurately detected; in part due to the low spatial resolution towards the horizon combined with the whiter appearance of the sky at low angles (increased air mass near the horizon leads to scattered light from aerosols giving the sky a slightly whiter appearance compared with the rest of the sky). Increasing the resolution of the colour balance and creating a filter that revolved around the distance from the sun allowed for better detection of these clouds as well as continuing to account for sun glare on the lens (Figure 8).

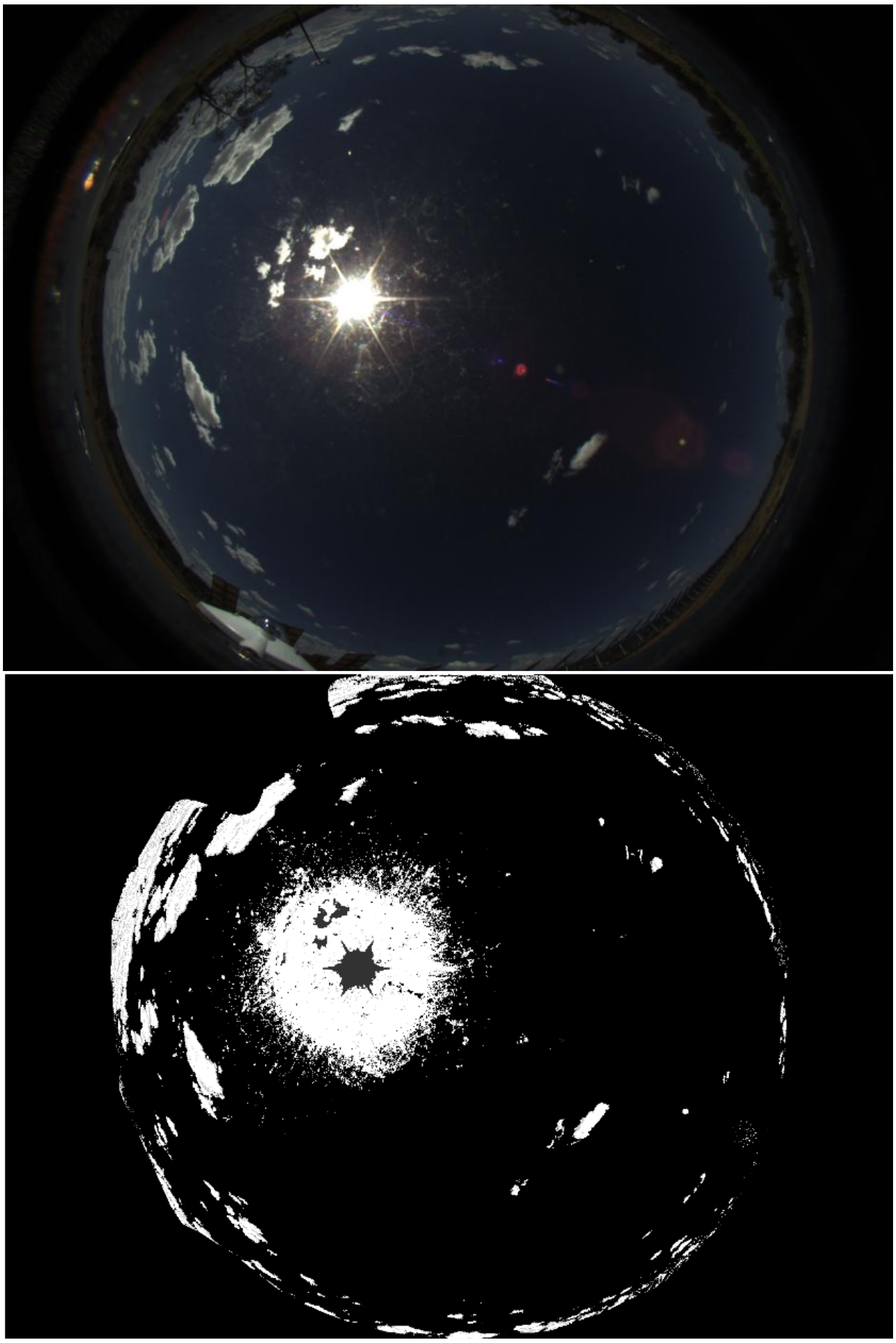

Figure 7: The top image shows the actual image of the sky dome acquired using CloudCAM Stage 1 (optical) taken from Uterne Solar Power Station, Alice Springs NT; the bottom image shows the CloudCAM binary cloud detection algorithm applied to the top image, on a pixel by pixel basis. Mainly cumulus cloud is contained in this image. This image shows the sky as it appeared above Alice Springs on 19th November 2014 at 04:06 (UTC). The solar glare is detected as cloud at this stage of the project.

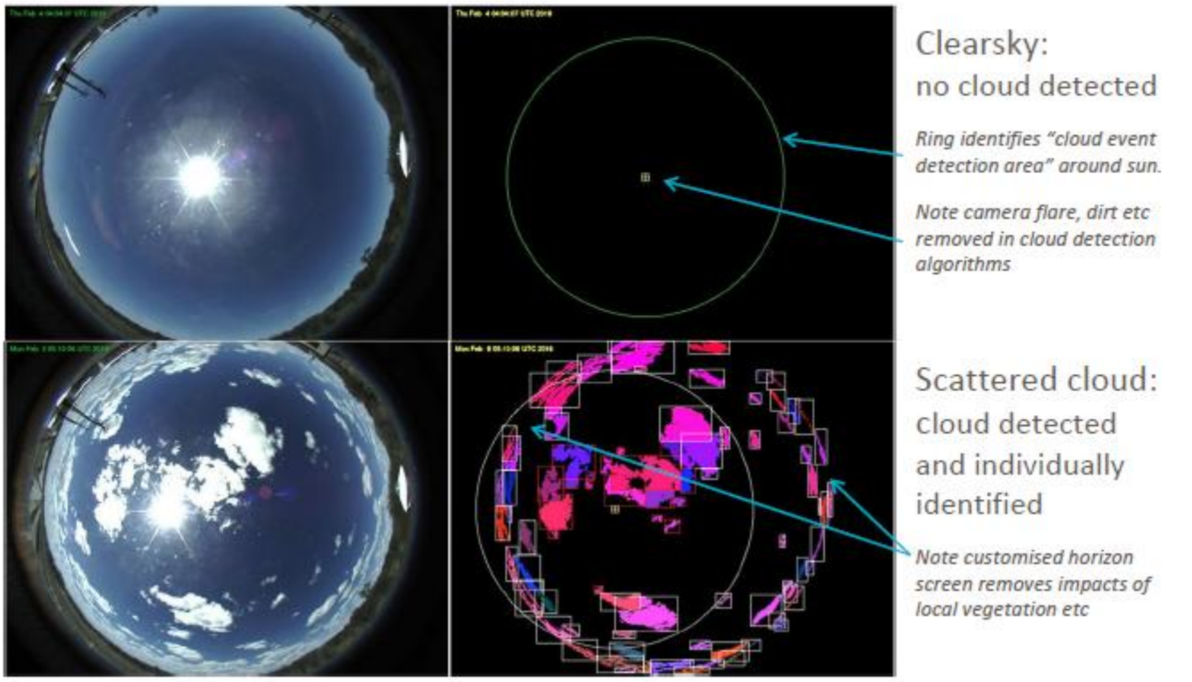

Figure 8: Optical CloudCAM visual output. The solar flare, dust and horizon all had intrinsic errors at the beginning of the project however as shown above have been accounted for and are no longer recognised as clouds.

The type of sensor required to analyse cloud to the resolution that was required for CloudCAM Advanced was also unknown at the start of the project, and multiple sensor types were trialled before finding a suitable sensor to progress forward with. The technical errors and mechanical faults that have halted the progress of the CloudCAM Advanced system were also unexpected and potentially underestimated in the planning and conceptualisation of the project (Lessons Learnt Report: Advanced technology. Issues with hardware and sensors).

Overall, with the progression in technology generated by the CloudCAM Advanced system as well as the commercial realisation of the CloudCAM optical system, the project can be attributed as a success. The installation of CloudCAM optical at multiple solar sites across Australia, along with the pipeline of sales that are expected for the next 12 months shows that the project has enabled CloudCAM to reach a stage where it is directly impacting the overall cost and efficiency for high penetration PV hybrid grids, allowing for them to be designed and managed in a more cost effective manner.

Transferability

The technology of CloudCAM is focused within the solar PV industry; however it also has potential benefits outside of this market. The Concentrating Solar Power (CSP) industry, is a similar but different industry where application of the CloudCAM could benefit. Interest in CloudCAM has been expressed, and discussions are continuing with a number of different developers of this emerging renewable energy technology. It was noted during the development of the project that there was also interest shown in the project outside of the renewable energy sector, with the Australian Army recognising that CloudCAM has potential uses in defence, while it is envisioned that CloudCAM may have uses in aviation and weather markets as well. While these horizons may offer more commercial opportunities for CloudCAM to continue to contribute to different Australian markets, they were not investigated during the project as the focus was on positively impacting the design and operation of solar PV power stations.

Within the solar energy market, network operators, utilities and solar farm designers have all been informed of the potential uses and benefits of the commercially available CloudCAM. The dissemination of knowledge gained throughout the project has occurred in a variety of ways. The most common and most effective has been through face-to-face meetings with interested parties. This includes network operators, solar farm developers and research teams (UNSW, ANU and CSIRO), as well as any other organisation that wanted to discuss CloudCAM in detail. Other methods of providing information on the knowledge gained from the project to the broader community were ARENA press releases and attendance and presentations at renewable energy conferences.

Conclusion and next steps

The commercially available CloudCAM system will have an immediate impact on off-grid solar power stations in Australia, reducing their reliance on batteries and spinning reserves, increasing overall PV yield (as was the case with the tested sites in the NT) and achieving the aim of making these solar station more economically viable. There are also implications for large scale, on grid solar power stations, as ARENA's CEO has stated "There is potential for this technology to be combined with the next wave of solar PV plants built in Australia, including those seeking funding through ARENA's $100 million large-scale solar competitive funding round". With CloudCAM to give operators of all sized solar plants prediction capabilities that will enable for better system management and improved efficiency.

While the successful trials and commercial sale of the CloudCAM optical systems showcases how far the project has come, as a whole CloudCAM is still in relative infancy. The product itself is well designed for on and off grid solar power stations; however minor changes in design and software could open CloudCAM up to a variety of other uses, such as defence, aviation or short term weather prediction. The CloudCAM Advanced system has come a long way to be on trial in Sydney and throughout the project has demonstrated its potential to take CloudCAM to another level of accuracy and prediction.

Fulcrum3D is committed to furthering both the commercial and Research and Development aspects of the overall project, and would certainly be willing and able to assist other companies that have an alternative application of the CloudCAM technology outside of the renewable energy sector.

Lessons Learnt

Lessons Learnt Report: Solar Flare

Project Name: *Cloud detection and prediction for maximising solar PV utilisation in off-grid hybrid power systems*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW/NT
Dissemination	Public

Key learning

Throughout the project, both the optical and advanced CloudCAM images showed small unwanted facets that were often produced resulting from solar glare under clear sky conditions within the vicinity of the Sun. These facets, if untreated, have the potential to be misinterpreted as cloud leading to inaccuracies in cloud detection and shadow placement prediction (Figure 9).

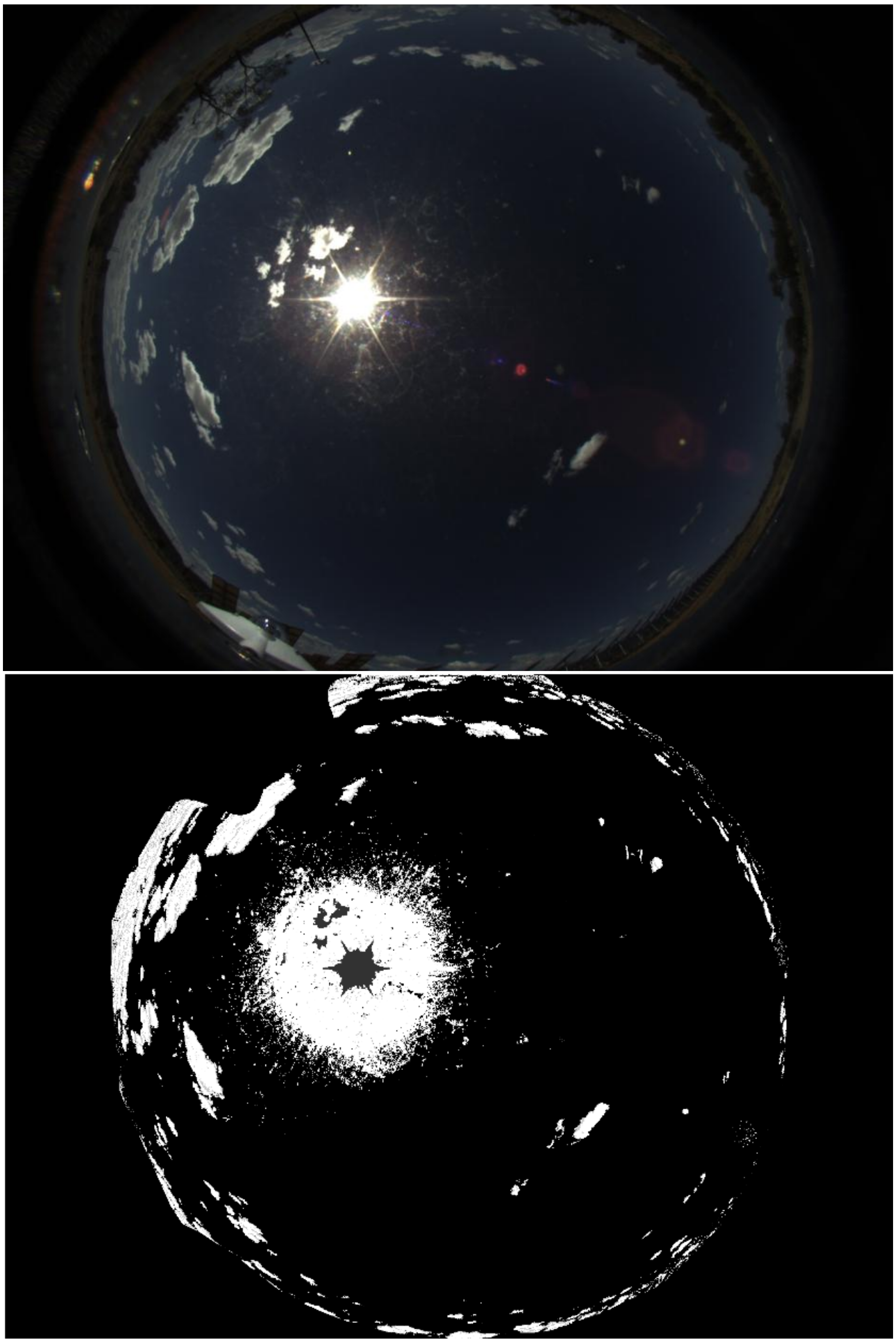

Figure 9: The top image shows the actual image of the sky dome acquired using CloudCAM Stage 1 (optical) taken from Uterne Solar Power Station, Alice Springs NT; the bottom image shows the CloudCAM binary cloud detection algorithm applied to the top image, on a pixel by pixel basis. Mainly cumulus cloud is contained in this image. This image shows the sky as it appeared above Alice Springs on 19th November 2014 at 04:06 (UTC). The solar glare is detected as cloud at this stage of the project.

Further trials have been conducted at site in the Northern Territory together with algorithm development leading to the creation of a solar flare filter for imaging. The filter is an algorithm applied to each image which annuls the unwanted effects of solar glare, leading to greater accuracy in cloud detection and shadow placement prediction.

The development of the solar flare filter algorithm during the project has enabled CloudCAM to accurately detect clouds under the full range of sky brightness conditions, leading to greater accuracy in cloud detection and subsequent cloud shadow placements (Figure 10).

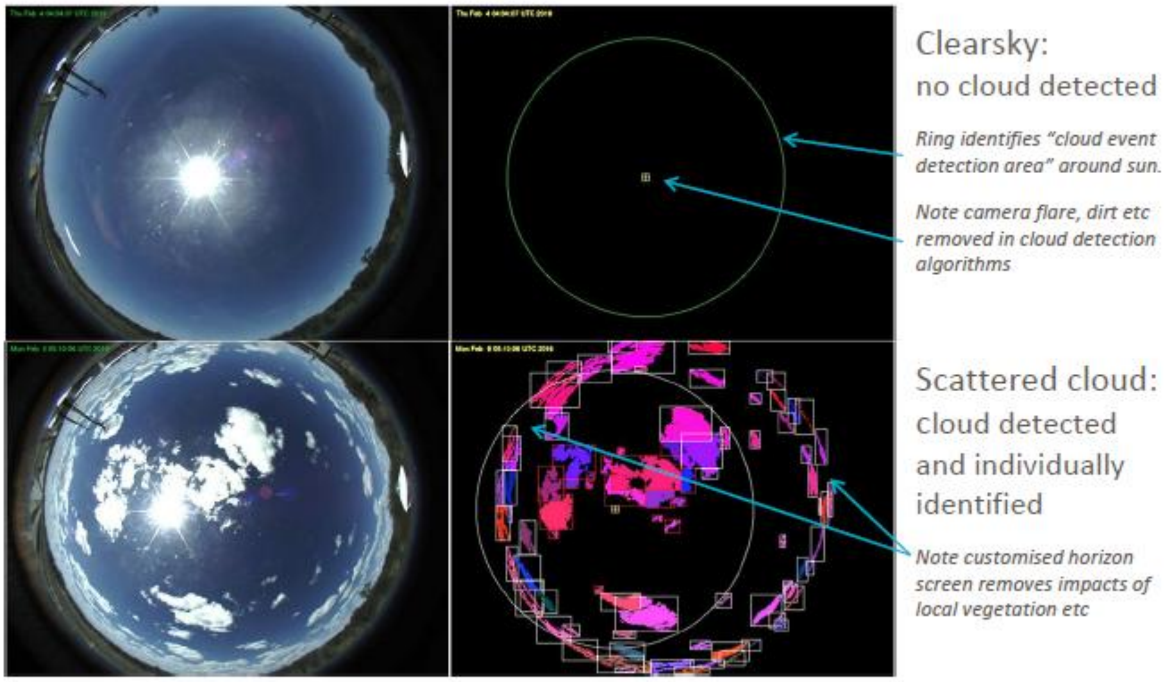

Figure 10: Optical CloudCAM visual output. The solar flare, dust and horizon all had intrinsic errors at the beginning of the project however as shown above have been accounted for and are no longer recognised as clouds.

Implications for future projects

Accounting for solar flare is important for any sky imaging project, especially for projects such as CloudCAM where its misinterpretation as clouds could lead to poor results. The methods and algorithms created for CloudCAM are transferable to other projects and an important step for making cloud detection, in the solar PV industry and in other industries, as accurate as possible.

Knowledge gap

At the conception of the project, Fulcrum3D had underestimated the impact that solar flare would have on accurate cloud detection, however has worked to successfully fill this previous knowledge gap.

Background

Process undertaken

Algorithms were developed and applied to raw images to remove unwanted attributes appearing such as sun flare. The corrected images were subsequently analysed allowing robust cloud detection, tracking and placement prediction to be achieved. The software that stopped solar flare being detected as cloud accurately tracks the sun position using predetermined calibration data and applies a filter that has more precise detection algorithm, taking into account that ‘clear sky’ is not blue, but rather sharp white, with similar technique to recognise the sun as separate from cloud used for the advanced system as well.

Lessons Learnt Report: Time frame for forecasting cloud shadows

Project Name: *Cloud detection and prediction for maximising solar PV utilisation in off-grid hybrid power systems*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW/NT
Dissemination	Public

Key learning

The project's original expectation was that prediction 15 minutes ahead and longer would be required by the solar industry. However, after talking to many potential users of the technology we now think that a few minutes ahead is the target.

Solar power stations on the Horizon network have a ramp rate limit of 12 minutes and this has been the driver for most, if not all, Australian industry interest for greater than 10 minutes. However, most remote area hybrid grids seem focused on 2 to 5 minutes which is enough time to start a classical diesel generator.

For the Epuron-owned solar power generation sites in the Northern Territory, operators require near-time forecasting (2 minutes) and nowcasting as they wish to use the results to control the behaviour of PV caps/set points and to anticipate the need to use batteries. Both uses are highly variable and have a near instantaneous response, so a shorter forecasting time is more suitable and gives a stronger chance of increasing yield.

Concentrating on this shorter time frame allowed for more accurate prediction from CloudCAM, with the optical system geared towards 2-5 minute accurate predictions, however finding larger errors occurring as the time frame for prediction increased past this point. With the information gained about the required smaller than expected lead time required for accurate cloud prediction to impact on solar power station operations, the project progressed from trying to reduce the errors for forecasting in the range of 15-20 minutes ahead of time and instead refined the software to create an even more accurate short-term prediction in the order of 2-5 minutes.

For this short time frame satellite imagery has little, if any, benefit for short-term forecasting of cloud. Once the decision was made to focus on forecasting in the range of 2 minutes the project stopped looking to incorporate satellite images for this short time frame.

Implications for future projects

This information is critical for any PV output prediction project centring around remote area hybrid grids. Understanding the needs of these grids is crucial for having the most efficient solar PV power station with supporting systems such as CloudCAM.

We note that Australia has very few grid connected large-scale plants (e.g. Broken Hill, Moree and Nyngan) and as such the 30 minute prediction for informing scheduling / bidding is not a market in Australia at present. However over the coming few years, such a demand is expected to emerge and as such CloudCAM will need to evolve to adapt to this longer time frame of required prediction. The continuation of the CloudCAM Advanced project alongside the commercially available optical system will be instrumental for creating a product that is relevant to these future projects.

Knowledge gap

The knowledge gap is no longer about what current solar PV power stations require in terms of cloud prediction but rather what future projects require. Fulcrum3D is well positioned to analyse market trends and understand the direction that the solar PV industry is taking, however changes to the operation of large scale grids, with the rising technology of battery storage and home installation solar PV could cause the utilities to require different outputs and ramp rates for PV solar stations into the future. Accurately predicating these changes to the industry ahead of time will enable CloudCAM to better service solar PV stations, updating to be as relevant as possible with cloud shadow predication and remaining an industry leader.

Background

Process undertaken

Various knowledge sharing activities were undertaken throughout the project to ensure that the final product fit the requirements of the solar PV industry. This included meetings with utilities and project developers, which helped shape the changed time frame for cloud forecasting from 15 minutes and longer to 2-5 minutes ahead of time.

Lessons Learnt Report: Advanced technology. Issues with hardware and sensors

Project Name: *Cloud detection and prediction for maximising solar PV utilisation in off-grid hybrid power systems*

Knowledge Category:	Technical
Knowledge Type:	Technology
Technology Type:	Solar PV
State/Territory:	NSW/NT
Dissemination	Public

Key learning

Setbacks were experienced during early stages of the project for the CloudCAM Advanced system in sourcing hardware sufficient for the purposes of accurate advanced sky sensing. Whilst many good detection devices are readily available for a variety of industrial and commercial applications, much innovation has been required to create a system suited to high resolution cloud sensing. Nevertheless, the hardware developed during the project has been sufficient to provide a successful proof of concept, highlighting the advantage of using Fulcrum3D's advanced imaging technique for the purpose of cloud detection and tracking. Further hardware development during the project showed the potential for full sky sensing capabilities, however further technical issues resulted in this hardware not progressing to a commercial product during the time period of the project.

Implications for future projects

The acquisition and assembly of advanced detection hardware for the purposes of cloud detection and sky sensing requires innovation in the development of specific equipment. Many commercially available advanced sensing systems are unable to meet the needs of high resolution sky sensing at a reasonable price. This project has shown the potential of this technology, and has succeeded in creating a prototype that will be the basis for a commercial model however further R&D is required for the project to reach this stage.

Knowledge gap

It is not the problems that are known that have caused the halt in the development of the advanced imaging technique, but the realisation that fixing these problems may uncover further unknown problems during trials. Being a novel technology, this is always a risk and while progress was certainly made, the continual technical difficulties encountered towards the end of the project resulted in the conclusion of the project with the advanced technology not at its fullest potential. Time constraints and other commercial aspects of Fulcrum3D played a part in this decision as much as the difficulties of the project itself. Further information on the technology and the functionality of the novel hardware developed by Fulcrum3D to enable full sky imaging will see the project progress into a commercial product in future.

Background

Process undertaken

Fulcrum3D sourced hardware to build the CloudCAM Advanced system; following construction the system was trialled in Sydney using parts that had been separately trialled at Uterne Solar Power Station in the Northern Territory.