Diffuse Energy: Reliable and resilient wind energy for off-grid telecommunication towers

Diffuse Energy's November install: An WA DPIRD station managed by Connect Technologies and Pivotel using NBN VSAT

LESSONS LEARNT REPORT 4

Project Details:

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EXECUTIVE SUMMARY

We now have 5 Turbines installed as part of the project collecting data on both the local weather conditions and turbine output. This has allowed us to do real world comparisons of performance vs wind speed across a variety of location types. It has also allowed validation of our wind forecasting methodology

The Covid 19 pandemic has continued to make it difficult for both us and our customers to get to site. Also, the supply chain issues have become far worse for the electronic components used in our controller. This problem is having an impact globally with component lead times pushing out as far as 18 months. This has delayed our current production run of controllers, now due in Jan 2022, but more importantly has created significant uncertainty around future production runs.

Technical lessons learnt during the period are the need to modify the controller power curve to yield better power output and a modification of our wind forecasting method for areas with dense surrounding bushland.

KEY LEARNINGS

LESSON LEARNT NO.1

The Hyland 920 Controller is not getting the most power from the turbine

Category: Technical

Objective: Operation of wind turbine systems

Detail Learning:

The Hyland controller operates using a Maximum Power Point Tracking (MPPT) algorithm that uses a discrete power curve for the turbine. At present this power curve is based on the mechanical output of the turbine from our design calculations and wind tunnel testing.

A key output of this project was to validate the Hyland 920's performance against wind data collected at each site in parallel with turbine output. It has been found that there is a discrepancy in the expected performance where the turbine is not making as much power as expected across the range of wind speeds.

Although the controller is tracking the current power curve exceptionally well, the turbine is spinning slower than expected at each wind speed, which means it has a lower output Voltage as the two are directly coupled. This is likely because the controller is overloading the turbine which causes it to run at a lower RPM than expected. This is caused by small voltage drops in the system between the turbine and the internal DC bus in our controller. This problem is at its worst at low to mid wind speeds and the indicated voltage suggests that the turbine is operating at or very near its stall point. When the turbine is in stall it has a significant reduction in power and although it recovers very quickly (< 1 s) in gusty conditions this has a deleterious effect. In transient conditions typical in the real world, the turbine can operate in a semi-stalled state where the centre portion of the rotor is stalled with the tips still operating, with a significant negative impact on performance.

Early in the project we built and commissioned a test rig for us to refine the controller. Using this we have been able to develop a better understanding of the system losses and their effect on performance. As most of the component efficiencies change with both speed and load of the turbine this is a highly iterative process. Below is a comparison of the existing power curve and the new power curve to be deployed from learnings from testing and field data.

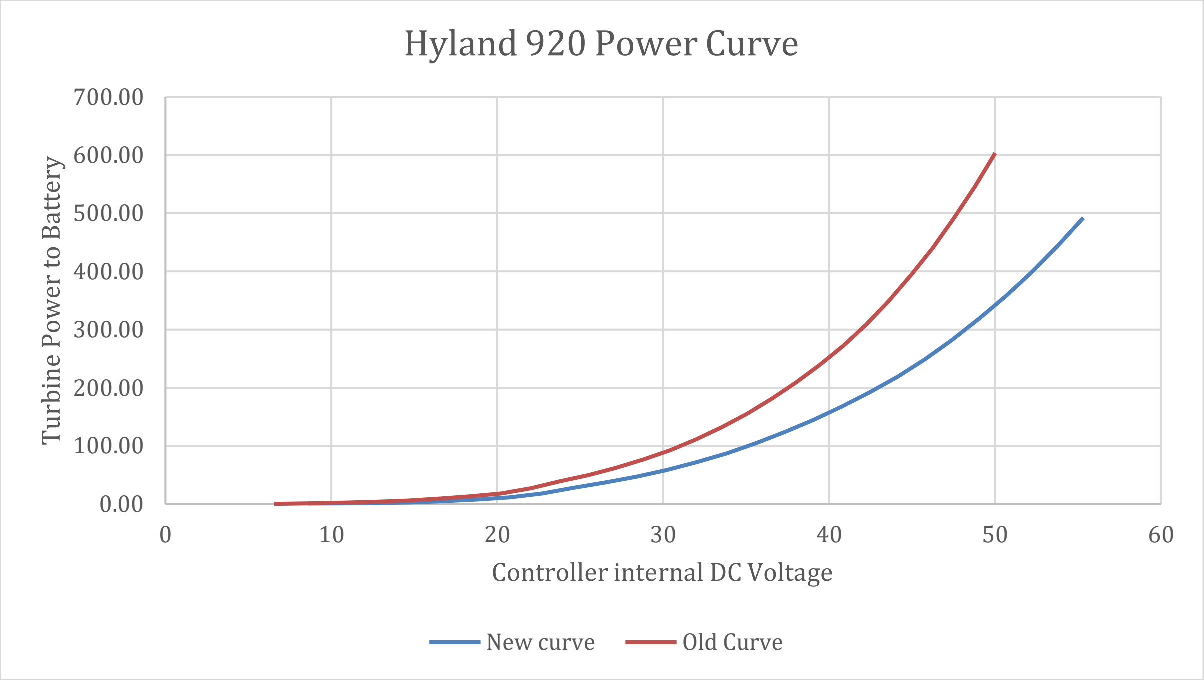

Figure 1. Modified power curve vs the original power curve to take into consideration system losses as installed.

From our modelling and observations this change is expected to improve the turbine yield by approximately 20%, depending on the site conditions. This will be tested and validated at our Stanhope microgrid test site prior to wide-scale deployment.

LESSON LEARNT NO.2

Controller manufacture heavily impacted by components shortages

Category: Commercial

Objective: Milestone 3b – installation of wind turbines and associated systems

Detail Learning:

The global semiconductor shortage previously highlighted as a challenge has devolved further and has now become a serious issue for future production of our controller. The previously reported shortages were largely around the microprocessors used in the controller. However, shortages have extended to a multitude of components, with prices of some components increasing by up to 45x. This has resulted in the doubling of the manufacturing cost of our controller in the last 6 months and has necessitated us to forward order components. The problem has extended to all semiconductor components and even some passive components.

This is a rapidly evolving problem affecting electronics manufacturers both big and small on a global scale. Large manufacturers at the front of the queue are stockpiling components where they are able to do so, further exacerbating the problem. Unfortunately, there is no clarity at this point as to how long this problem will last but it seems highly unlikely it will improve in any meaningful way before mid- 2022.

LESSON LEARNT NO.3

In locations that are surrounded by typical Australian bushland, even when the turbine is well above it, our wind prediction method has overestimated the average wind speed.

Category: Technical

Objective: Operation of wind turbine systems

Detail Learning:

When assessing candidate sites for a wind turbine installation, we conduct a desktop analysis to forecast wind speeds for the site and hence make a prediction of power output. It is important for both us and our customers that these predictions are as accurate as possible. Our predictions are formed (in Australia) using data from: https://nationalmap.gov.au/.

This website is an excellent resource put together by CSIRO’s Data61 and is publicly available. We also use data from NASA and the BOM as required. The raw wind data is coupled with local topography and topology as well as tower height to make a prediction on annual wind speeds and turbine energy production.

Part of this project was for us to gather data at each site and compare to our forecasts over time. For sites with dense surrounding bushland, our forecasts have been higher than measured, with both Mt Wondurrigah and Mt Hyland being approximately 2m/s lower than expected. The sites near Walcha and Stanhope, which are surrounded by open farmland, are very close to estimated average windspeeds.

A likely cause of the discrepancy for the Mt Wondurrigah and Mt Hyland sites, is due to a parameter we have been using when estimating average windspeed. In our calculations, we use a terrain roughness length (z_0) to modify the average windspeed to account for the surrounding landscape. We had previously been using a value of 0.25 for bushland, sourced from commonly used research.

However, if we modify this to 0.4 we get predictions that are in line with measured data. This corresponds with z_0 values published by the Danish Wind Energy Association, which are set out below.

Table 2. Roughness lengths for a variety of surfaces.

Description	**Roughness Length, z_0 (m)**
Water Surface	0.0002
Completely open ground with a smooth surface, e.g. concrete runways at the airports, mowed grassland, etc.	0.0024
Open farming areas fitted with no fences and hedgerows and very scattered buildings. Only softly rounded hills.	0.03
Farming land dotted with some houses and 8 m tall sheltering hedgerows within a distance of some 1,250 metres.	0.055
Farming land dotted with some houses and 8 m tall sheltering hedgerows within a distance of some 500 metres.	0.1
Farming land dotted with many houses, shrubs and plants, or with 8 m tall sheltering hedgerows of some 250 metres.	0.2
Villages, hamlets and small towns, farming land with many or tall sheltering hedgerows, forest areas and very rough and uneven terrain	0.4
Large cities dotted with high rise buildings.	0.8
Very large cities dotted with high rise buildings and skyscrapers.	1.6

We will use these values when estimating average windspeeds for sites in the future.

It should be noted that the local BOM station in Coffs Harbour, close to Hyland and Wondurrigah, has reported wind speeds in line with long term averages so it is unlikely this anomaly is caused by an unusually low wind season.

CONCLUSION

The technical lessons learnt, as detailed in this report, will allow us to improve the performance of our turbines and more accurately estimate wind resources at sites.

From our modelling and observations, we expect to be able to improve the turbine yield by approximately 20% by modifying the power curve that our control system tracks. The next step is to update the power curve in the controller at our Stanhope test site to validate this expectation.

We still have 6 sites to install our systems on for the project and when assessing candidate sites, we will use the updated roughness length value discussed in this report to estimate the wind resources of the site more accurately. We will comparethe estimation to the actual wind resources once the turbines and weather stationshave been installed and data has been collected over a number of months.

The global semiconductor (and associated components) shortage has become moresignificant since we reported in the last Lessons Learnt Report. We have ordered a batch of 30 controllers, due in January 2022, and will continue to source componentsas they become available.