AGRICULTURE VICTORIA

Automating Fixed Sprays to Maximise Solar Energy Utilisation

West Gippsland
Catchment Management Authority

Wilandra farms managed to automate 22ha of fixed irrigation sprays using pumps that were programmed to make the most of the solar energy being produced. This maximised the solar usage whilst providing enough water to meet irrigation demand, all automatically.

Wilandra farm owners, Wilco Droppert and Sandra Jefford.

Introduction

Over the last few decades, significant areas of irrigated land have been converted or developed for improved irrigation efficiency, with pressurised spray irrigation systems. While centre pivot and lateral move irrigation systems are the most common for pastures and hay production, fixed spray systems also have a significant role to play. In areas with trees and obstacles, or in oddly shaped paddocks, fixed sprays are one of the best options available.

Spray irrigation can be more water efficient than surface (flood) irrigation, particularly on free draining soils. Additional benefits also include ease of automation, rapid paddock trafficability, fertigation options, minimal runoff, and less earthworks.

Despite these benefits, spray irrigation systems do come with some challenges, which include high infrastructure and pumping energy costs. If renewable energy can effectively be utilised to cover the cost of pumping, it reduces the payoff period of a solar investment and may encourage more farmers to invest in renewable energy as a power source.

In August of 2022, Agriculture Victoria in partnership with Wilandra Farms and the West Gippsland Catchment Management Authority (WGCMA), set out to demonstrate the paired automation of a fixed spray irrigation system with an on farm solar array. The aim of this project was to maximise the utilisation of solar production and effectively irrigate 22 hectares of pasture.

Why use solar energy on farm?

The combination of high energy prices and increasing market pressure for industry to adopt ethical environmental practices has led to the increasing adoption of renewable energy on farms. Solar energy is one of the most common and affordable renewable options currently available.

'I was hesitant considering the infrastructure cost, but considering our electricity bill for irrigation used to be around $80,000 per year, there was a lot of upside potential.'

-Sandra Jefford

Maximising utilisation of the solar energy that is generated from an array on farm is imperative to making the cost benefit analysis of the infrastructure stack up. As grid feedback tariffs have continued to decline, they often do not offset the cost of the solar infrastructure so using as much of the electricity generated on farm is becoming a must.

The utilisation of solar production on farm can be difficult, however, due to the variable production curve throughout the day and across the seasons, as demonstrated in figure 1 below.

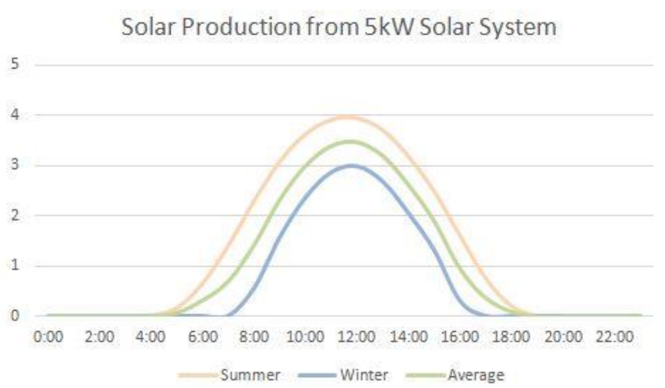

Figure 1, Average solar production curve (Solar Power Australia)

In contrast to the variable production of solar energy, the energy demands of irrigated farms are often large and fixed, at times of day that don't align with solar generation. For example, a 40kw irrigation pump would usually be run at night to capture off-peak power rates – this is not conducive to maximising solar utilisation.

To maximise solar utilisation, smaller loads and variable rate loads paired with automation are required. This allows switching between different size loads to maximise the utilisation of the solar energy being produced at any point in time.

'Solar is a variable energy source, we need multiple smaller loads, variable loads and automation to maximise utilisation.'

-Steve Soutar, Alternative Energy Innovations

Pre-existing irrigation at Willandra Farms

The project area for this study originally had a K-Line pod manual shift irrigation system. K-line pods are a relatively low-cost system, often installed to service oddly shaped paddocks or paddocks with lots of obstacles for an irrigation system to work around.

While this type of manual shift irrigation system can be relatively effective if operated correctly, due to the high labour and skill requirement to operate, in practice they often result in very poor irrigation outcomes. K-Line systems are commonly left in the one location for a night set and moved the following day.

It is best practice to move the K-Line systems to several locations within the paddock within a given time period. In Wilandra's case, this would require moving the K-Line pods to at least six locations per set.

This leads to overwatering of a small area and the significant under watering of a large area. When operated like this, it is often that the pasture production underneath does not warrant the cost of running the pump.

'In 2019 I couldn't keep up with all the other jobs on farm and moving the pods, you could really see it in the pasture.'

-Wilco Droppert

On dairy farms where time and labour availability are at a premium, these smaller difficult irrigation systems are often run poorly. This was the case with Wilandra's system as can be seen below from satellite imagery taken in February of 2019 (Figure 2).

Figure 2, Project area outlined in orange while under K-line pod irrigation in February 2019.

The orange outline encases the K-Line pod irrigation system was being operated. Scattered green areas surrounded by dry ground can be seen as a result of the pods not being moved as designed to irrigate the area effectively.

Smarter irrigation

Wilandra Farms decided that fixed sprays, while expensive, would be the best option for an irrigation upgrade in this area. However, they wanted to integrate their existing solar array with the fixed sprays and automation so they could run the system easily and with renewable energy.

In irrigation, as with many other facets of agriculture, often technology and machinery from one manufacturer will not easily integrate or communicate with another manufacturer's equipment. Adding to this there were no available off the shelf systems from a single irrigation manufacturer that would be suitable for automating and programming all the aspects of this system.

To overcome the problems of integrating the various irrigation infrastructures / technology and the variable energy production of solar, Wilandra Farms looked to Steve Soutar at Alternative Energy Innovations (AEI) and their "SmartBox" technology, visualised in Figure 3 below.

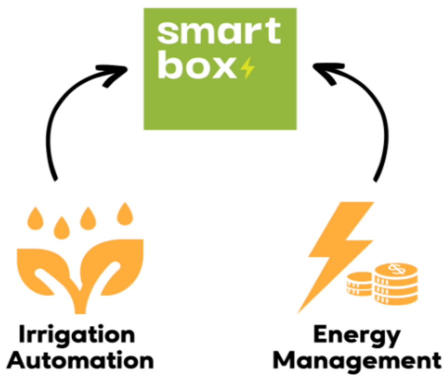

Figure 3, "SmartBox" integrates irrigation automation and energy management.

Steve Soutar's roots as an automation engineer with a history in process control, and a deep understanding of programable logic controllers (PLC's), enabled him to work with Wilandra Farms to design a system fit for their purpose.

Integration and automation

To effectively manage the various irrigation technologies, machinery and decision-making needed, AEI utilise industrial computers known as PLCs. PLCs are primarily used in the automation of factories and processing plants.

PLCs receive information from connected sensors, process the data and trigger outputs based on pre-programmed parameters. Essentially, they provide the 'brains' to control numerous pieces of machinery and technology.

> *'The system has a 'brain' constantly making clever decisions, ensuring our irrigation requirements are met while maximising solar usage.'*
>
> *-Sandra Jefford*

AEI have developed a "SmartBox" which packages PLC technology with proprietary pre-programming for efficient irrigation automation (Wilandra's SmartBox in situ in Figure 4). It focuses on irrigation automation, energy price optimisation and solar optimisation.

Figure 4, Wilandra's AEI SmartBox system paired with an AEI irrigation control box and variable speed drives for both bore and irrigation pumps.

Programmed logic is incorporated to determine how the system decides when to start and stop pumps and sprinklers based on the energy produced by the solar panels. This logic is implemented with the PLC, the system's 'brain'.

Basic elements of the programmed logic used in Wilandra's system include IF statements, and AND, OR, ELSE functions, that are used to combine conditions or specify alternative actions. An example programmed logic can then be: IF 15kW solar production, start one set of sprinklers; IF 25kW production, start two sets of sprinklers.

This means that if the solar panels generate 15kW of energy during the day, the PLC recognises this, and according to its programmed logic, it will start one set of sprinklers. Later in the day, if the solar production increases to 25 kW, the PLC detects this change, and based on the updated logic it will start two sets of sprinklers when the energy is available.

While the concept is relatively simple, many layers of logic programming are required for the multitude of decisions that are involved in integrated automation of a solar array and fixed spray irrigation system. Another exceedingly complicated aspect of this is ensuring that these decisions occur in the right order and interact with one another in the way intended.

Variable energy production

To allow for, and to maximise the use of variable generation of solar throughout the day, several alterations or additions to a conventional fixed spray system were included in Wilandra's system design.

A storage dam with a level sensor was constructed by the bore that feeds the irrigation system, which allows for solar electricity utilisation by pumping to fill the dam when irrigation is not required. This effectively acts as a battery for the irrigation system, as running the sprays when pumped from the dam uses significantly less energy than pumping up water from the bottom of the bore well. The level sensor feeds an input into the "SmartBox" ensuring that the dam does not overfill and does not empty while the sprays are on, safeguarding the system from running the pump dry.

A variable speed drive (VSD) was installed on the bore pump, allowing the bore pump to operate at a variable range from approximately 5-40kW. This enables capture of low levels of solar generation from the 50kW array and utilisation of excess energy production above what the sprays may be using.

Lastly, the sets of sprays were reduced in size from the maximum 12 sprays the pump can run, down to sets of 4. This allows for smaller chunks of available solar energy production to be utilised with 4, 8 or 12 sprinklers able to be run at a time.

The combinations of these alterations and additions to a conventional fixed spray irrigation system is paramount to ensuring the maximisation of solar energy when it is being produced.

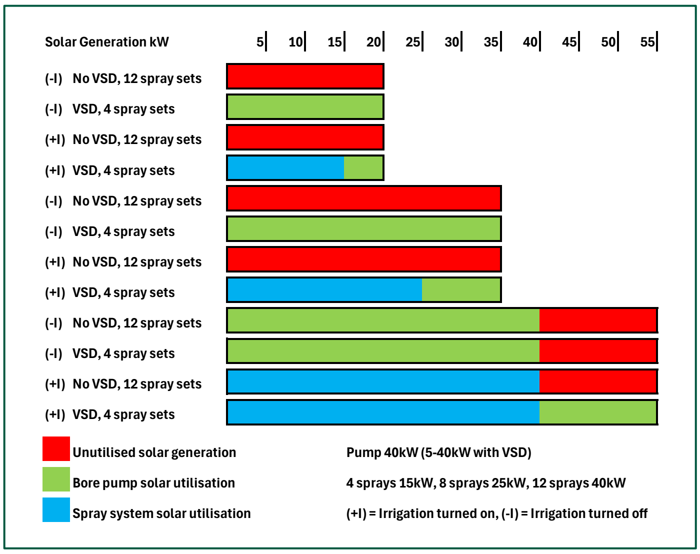

Figure 5, Comparison of solar utilisation at 20, 35 and 55 kW production with VSD and 4 spray sets vs no VSD and 12 spray sets.

Figure 5 above demonstrates that below 40kW of solar generation, no solar energy can be utilised without a VSD and smaller sets of sprays, while with this technology included, solar generation can generally be fully utilised. It is important to note that the "SmartBox" is required to intelligently manage the operation of all the irrigation components to achieve this optimised solar utilisation.

"SmartBox" decision making (process logic)

In Wilandra's system, the bore pump is programmed to switch on at approximately 5kw of solar generation and increase the speed of the pump up to around 40kw as more solar is generated. If an irrigation is programmed to occur on a given day, the bore pump speed will be reduced or switched off depending on requirements of the irrigation pump.

As solar production increases, more sets of sprinklers can be turned on with priority to run sprinklers over the bore pump. The sets of sprinklers are run sequentially with each set of sprinklers having its own timer in the AEI irrigation control box. This allows the system to alter what is running depending on solar generation and pick back up where it left off.

The system can also be set to switch over to mains electricity if the system will not be able to finish an irrigation operation within the desired timeframe. The level sensor on the dam also stops the dam overtopping and will prioritize filling the dam over irrigation to ensure the irrigation pump does not run dry.

The outcome

Wilandra Farms have been overwhelmingly happy with the outcomes of this project. They have effectively irrigated approximately 22ha of pasture with zero pumping cost and zero labour requirements other than telling the system when they want to irrigate. Table 1 details the extent to which Wilco and Sandra have optimised their solar energy usage.

Table 1, Solar optimisation data for fixed sprays and dam for 23/02/2024 to 03/05/2025.

	Solar optimised fixed sprays	**Solar optimised local dam refill**
Operating time	177 hours	69 hours
Pumping	4, 167 kWh	1,229 kWh
Supplied by solar	93.7%	95.5%
Supplied by grid	6.3%	4.5%

Any excess energy that does end up feeding back into the grid offsets the small amount of grid energy that is used.

'It is amazing, there is no labour required and it irrigates the area flawlessly at effectively zero running cost.'

-Sandra Jefford

Figure 6 indicates the bore pump picking up the small amount of solar generation until around 7:30 am where the first set of sprinklers turns on. As more solar is generated the system turns on more sprays and switches on and off the bore pump where required to maximise utilisation. Once the irrigation is finished at around 2 pm the system ramps up the bore pump to ensure the buffering dam is refilled, utilising the remainder of solar generation out to around 6:30 pm.

The data in figure 6 was collected on an ideal solar day, however AEI are confident that the system will be able to keep up with irrigation and filling the buffering storage year-round with similar solar utilisation and mains requirements.

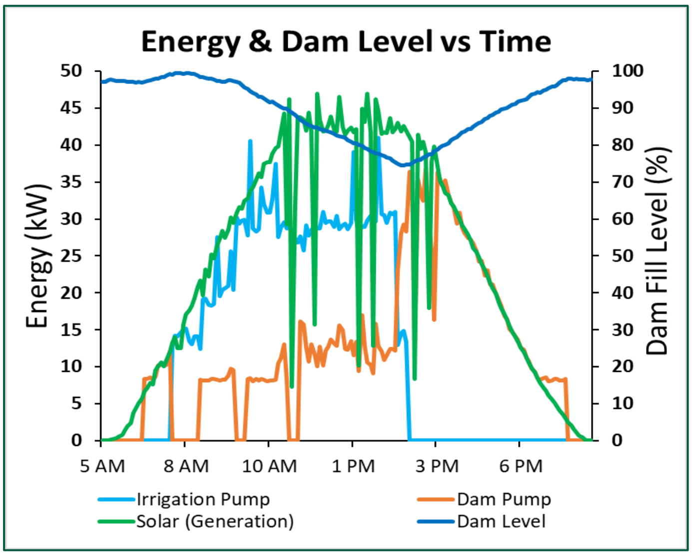

Figure 6, Fixed spray and buffering dam solar utilisation for one solar day period at Willandra Farms.

Irrigation intervals in summer may be as short as 1-2 days, however in the cooler months, intervals could stretch out to 8-10 days without factoring in rainfall. Considering the irrigation requirements, the system could support more sprays and still work effectively.

Soil moisture data has confirmed that the system was able to effectively manage the irrigation requirements of the area. The soil profile was very dry prior to the commissioning of the sprays, which is indicated by the red area in figure 7.

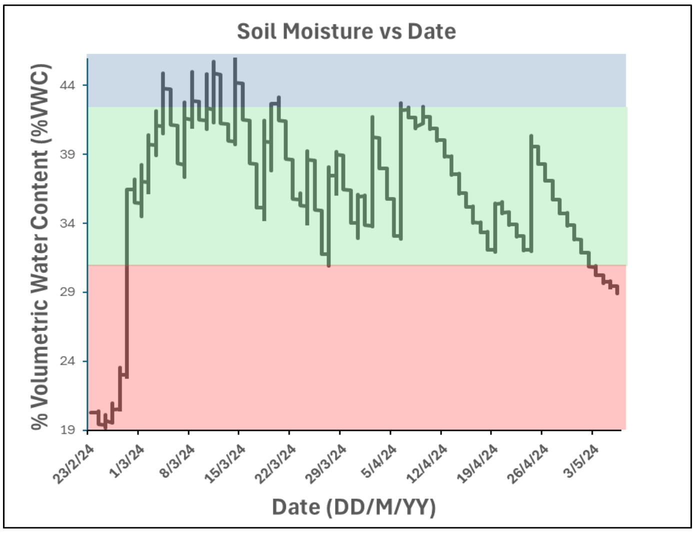

Figure 7, soil volumetric water content at 10cm – blue = waterlogging, green = readily available water, red = dry/stress

Once the sprays were commissioned, the system was run daily over a period to increase the soil moisture levels up to the range for readily available water, indicated by the green area.

Soil moisture was then monitored to aid decision making around when to irrigate and the system was easily able to maintain ideal soil moisture levels, optimising pasture growth. Towards the end of the monitoring period, Wilandra Farms decided to delay an irrigation based on forecasted rainfall, which can be seen with the moisture levels moving into the dryer red zone on the chart in figure 7.

Wilandra Farms are exceptionally happy with the pasture production under the fixed sprays, indicating that it has been excellent, on par if not better than that under their centre pivots. However, pasture plate metering and forage sampling needs to be completed to provide data for comparison.

'We have grown as much or more high-quality pasture under the sprays as under our pivots.'

-Wilco Droppert

Reflections

As with many innovative projects, there were several learnings that Willandra Farms picked up along the way.

The biggest change they have made to their system is to the actual layout of the sprays. A 32m x 32m square grid was installed as designed by their irrigation supplier. A spray system assessment with catch cans in a 3.2m grid was conducted with a total of 100 catch cans placed. It found a relatively low distribution uniformity of 67%. Up to around 75% can be expected from an ideal setup. Plotting the catch can data on a bell curve (figure 8) shows that at a system setting of 8mm, around 60% of the area received within 1mm of the target amount and around 80% of the area received within 2mm.

If Wilco and Sandra were to begin this project again or increase the spray footprint in the future, they have said a 32m triangle grid would absolutely be used. According to the data sheets for the sprays, a triangle grid achieves a higher irrigation uniformity than an equivalent spacing square grid.

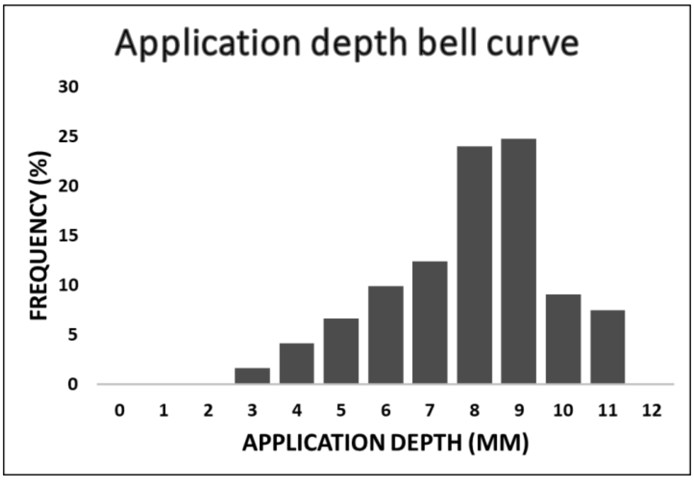

Figure 8, Spray system assessment of Willandra Farm's fixed sprays plotted on a bell curve.

Further to this, Steve from AEI suggested that the addition of a flow meter to the system would be a good idea. This would provide accurate water use data while also acting as a tool to aid in the detection of malfunctions in the system. If the system has a benchmark for expected flow rates for a range of activities, it can detect any deviations from expected rate ranges. This system can then be programmed to send a warning message to Wilco and Sandra's mobile devices.

Wilandra noted that the high price of the system could be a barrier to entry for farmers. A system like theirs, including the solar array and all other components, is worth more than half a million dollars. However, they hope that demonstrations of cases like theirs can catalyse other farmers to consider innovative ideas around irrigation and renewable energies.

'It is a dream to use, it has been so effective we are already looking to expand the footprint of the spray system.'

-Wilco Droppert

Furthermore, Wilandra believe increased incentive from banks, milk manufacturers, governments and consumers will increasingly make projects like this, with a positive environmental impact, viable for more farmers in the future.