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Automated Remote Monitoring of Renewable Energy Installations

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Abstract

Renewable energy installations such as wind farms, photovoltaic installations or solar water heating (SWH) plants depend on continuous reliable operation to justify their capital investment. A common misconception is that this technology will not need any maintenance or monitoring following installation. Renewable energy generation equipment is installed where the resources usage and power output is optimised. These are often remote locations which may be difficult or costly to visit to check operation or performance. Automated remote monitoring of the equipment on a continuous basis can detect sub-optimal performance or conditions that may lead to future equipment failure. This paper will present case studies demonstrating the benefits of automated remote monitoring of renewable energy assets. This paper will be of interest to anyone currently using or contemplating specifying renewable energy generation.

Introduction

Renewable energy generation is being installed on an ever increasing basis due to a number of environmental, operational and economic benefits. Renewable energy sources, in particular solar and wind, are intermittent and the output is variable based on often unpredictable conditions. Consequently the economics of such installations can be marginal which will be exacerbated with equipment failure or sub-optimal output due to poor maintenance.

Automated remote monitoring equipment can be used in the early detection of problems in renewable energy installations so that the output is maintained at optimal levels. It is often assumed that renewable energy generation equipment does not require maintenance. However this is untrue and if unmonitored there is often no indication of how well or poorly the system is performing following installation. As will be shown below, small changes in parameters can have a significant impact on the generated output.

As an example wind energy output is proportional to the cube of the velocity [1]. Misalignment in yaw of the turbine rotor to the incident wind direction of 10 degrees leads to a 6% decline in power. An increase to 20 degrees increases this to 17%. A faulty steering mechanism, misaligned wind sensor or control system error could result in significant power loss and consequently reduce revenue from the installation.

There are a number of smaller installations that make use of solar power. The cost of electricity generated by solar photovoltaic systems can be as much as 5 times of grid power. Reductions in output due to shading, accumulation of dirt and dust and errors due to solar array orientation and tilt further increase the cost of generation. In a study conducted by Cano [2] it was found that an accumulation of dirt over a period of 17 days could reduce the output by 4%. The impact of solar output from solar thermal or photovoltaic systems due to inclination and orientation is even more dramatic as shown in figure 1 [3].

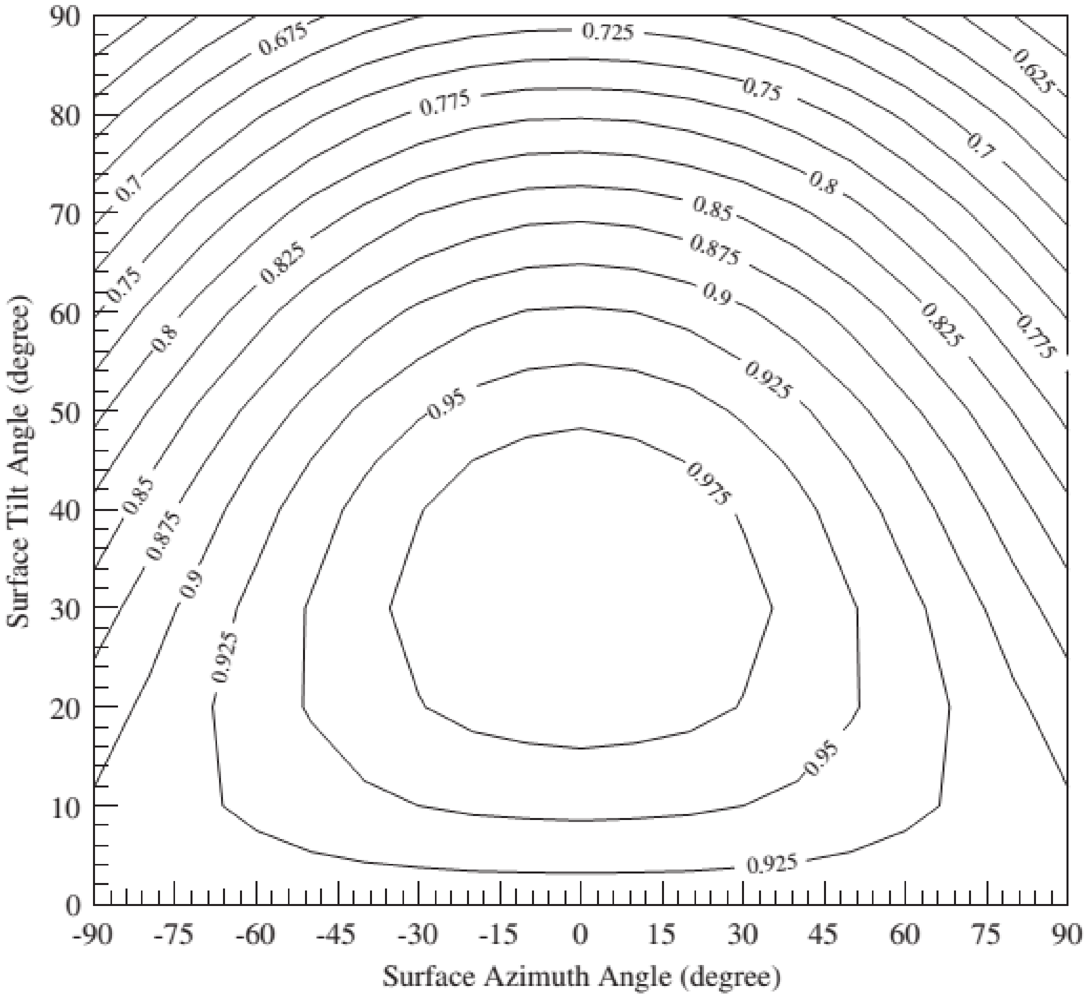

Fig. 1. Variation of Solar Output with Tilt and Azimuth for 54° N.

Tilt and azimuth errors can be introduced during installation or following maintenance at sites where these are fixed or due to sensor, drive or control system errors at tracked installations.

Monitoring systems can be readily deployed as part of the original installation or as a retro-fit kit on existing installations. The number of parameters and frequency of measurement (and consequently the monitoring cost) will depend on the scale of the installation and the performance requirements. The US National Renewable Energy Laboratory (NREL) monitor their PV installations as shown in figure 2.

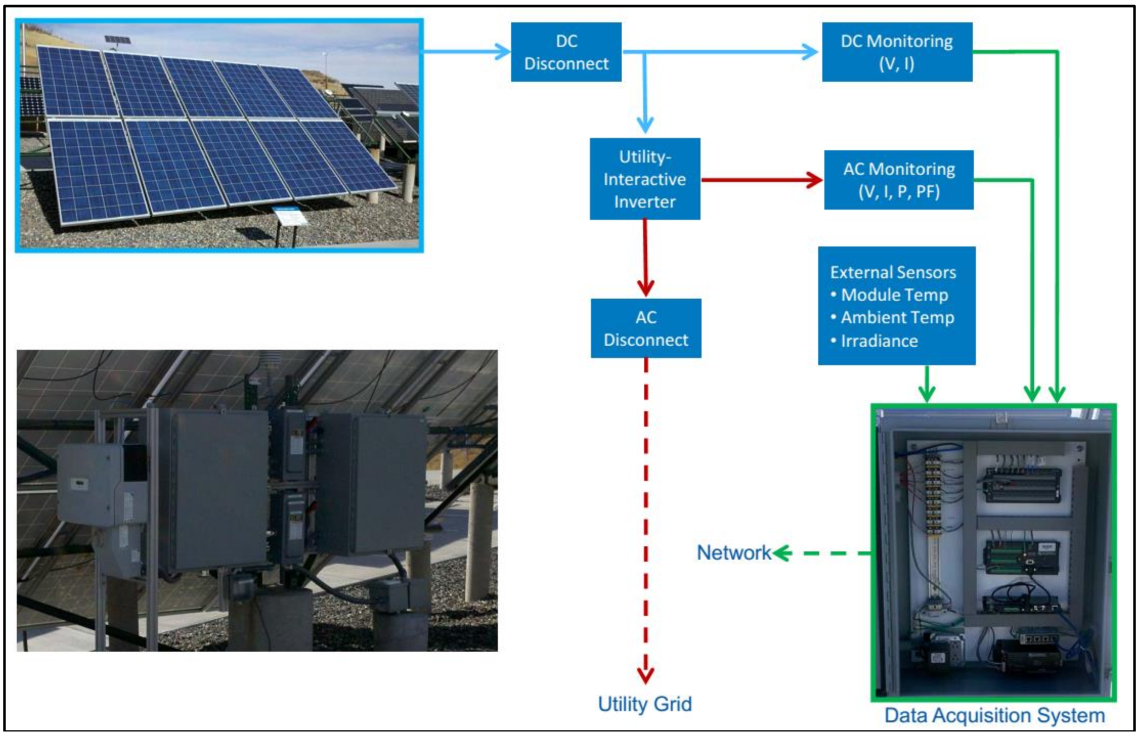

Fig. 2. Monitoring at a Typical NREL Installation.

There has been constant increase in the development of industrial automation through remote monitoring and diagnosis. Monitoring of key equipment has two main objectives:

- Prevent equipment failure
- Continuously monitor equipment performance to ensure operation is close to or at peak efficiency

Achieving these objectives increases revenue while reducing costs.

Remote monitoring uses sophisticated technologies and tools to assess equipment performance and condition which can be used to predict potential equipment malfunction or failure. Condition monitoring is a key element of predictive maintenance and enables intelligent scheduled maintenance. Imminent damages or failure is identified by a deviation from an established reference value.

While remote monitoring is not able to directly predict failure, it identifies machinery or equipment that is failing or imperfect; equipment with latent problems is at greater risk for failure. Further, it is typically more cost effective to address conditions that could cause failures, rather than repairing once a failure has occurred.

The bathtub curve is widely used in reliability engineering. It describes a particular form of the hazard function which comprises three parts:

- The first part is a decreasing failure rate, known as early failures.

- The second part is a constant failure rate, known as random failures.
- The third part is an increasing failure rate, known as wear-out failures

A graph of the bathtub curve is shown in figure 3 [5].

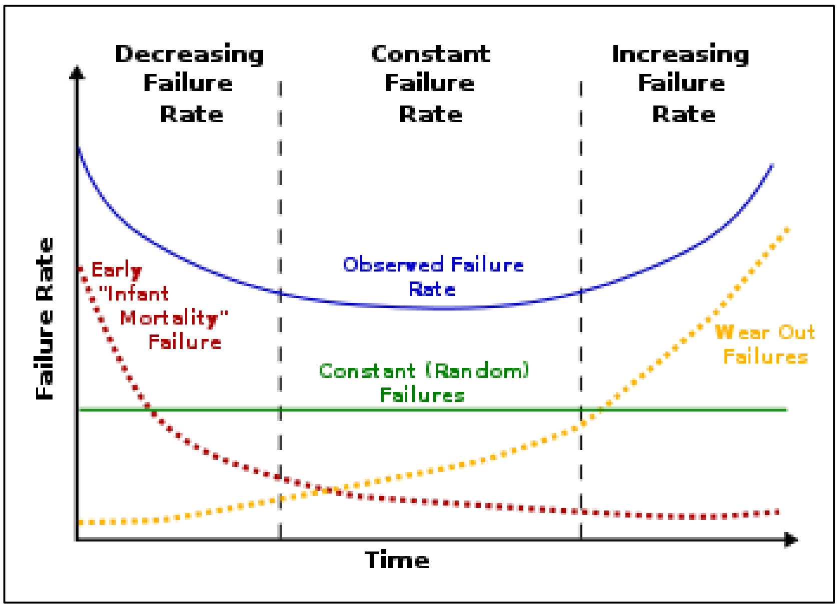

Fig. 3. The bathtub curve hazard function.

The benefit of remote condition monitoring is its potential ability to extend the bathtub curve as is shown in figure 4 [6]. Remote condition monitoring and early diagnosis of impending failures can reduce the observed failure rates by shifting the failure curve downwards to reduce random failures as well as extending the curve to the right through constant preventative maintenance.

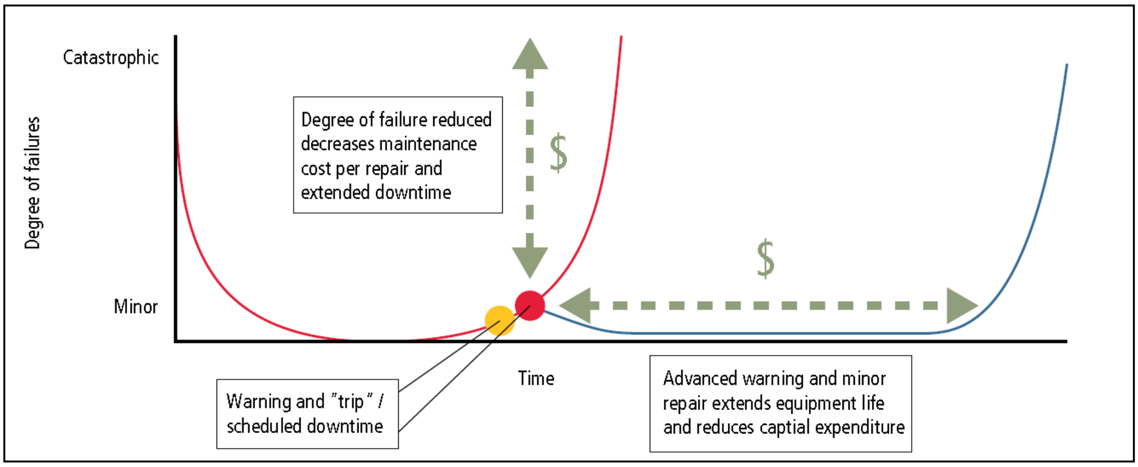

Fig. 4. Extending the bathtub curve with condition monitoring.

This paper examines two cases where automated remote monitoring is being used to monitor renewable energy installations. The first is the monitoring of a hybrid hot water installation that supplies hot water to a large commercial building. The second case is the remote measurement of an experimental building integrated PV installation in a new green building. This is highly promising technology that would provide significant benefits if the performance metrics can be determined.

Case 1: Solar Water Heater Installation

The system is a 200-kW hybrid system consisting of 100 solar water heater collectors, which will heat about 20 000 litres of water, while another 28 000 litres of water is heated using energy efficient heat pumps. This equipment will reduce the current building energy consumption by 5%. The installed cost is R2.3 million and the savings are expected to be just under R1 million with investment payback under 3 years. A schematic of the solar water system is shown in figure 5.

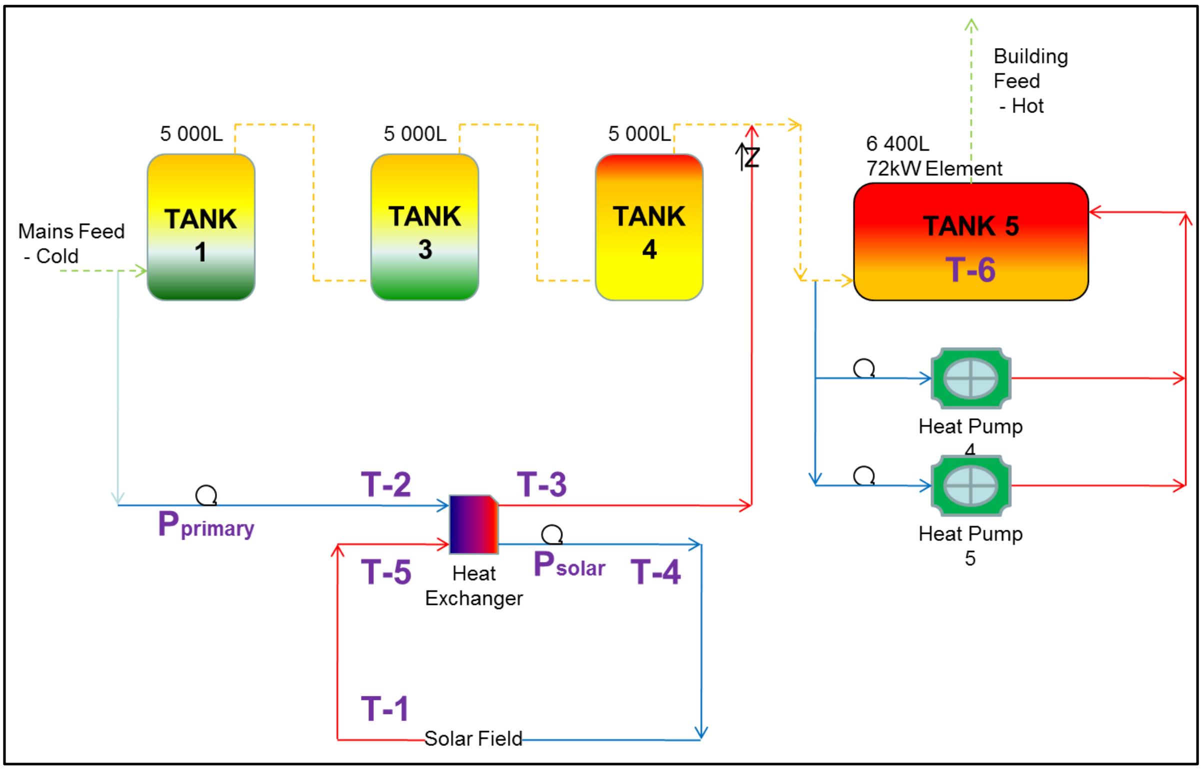

Fig. 5. Hybrid Hot Water System Process Flow.

As can be seen from figure 5 a heat exchanger is used to transfer the solar heat gain to the building hot water supply. A custom monitoring system was designed and manufactured that could automate the operation of the solar hot water component and provide the logic to switch the primary and solar pumps on and off based on various temperatures in the system. The specifications of the embedded control and monitoring equipment is as follows:

- Custom Monitoring and Control Unit with local display
- 32 Bit Processor with 512 kB Flash
- 6 RTD Temperature inputs (T1-T6)
- 6 Digital inputs for loop status
- 2 Relay outputs to control primary water and solar pumps
- GSM modem for alarms and reporting data every 10 minutes

Logic is provided for automated operation of the primary and solar pumps. The solar loop has to be switched off when the sun sets to prevent reverse heat transfer from the building water to the solar panels. A number of decision rules based on various temperatures are used to determine the states of the pumps. These are indicated in table 1.

	Solar Pump		**Hot Water Pump**	
STATE	P_S ON	P_S OFF	P_P ON	P_P OFF
T4-T2 < 20 °C				X
T4-T2 > 20 °C and T2 < 72°C			X	
T2 > 72°C				X
T1-T2 > 8 °C	X			
T1 < 45 °C		X		

Table 1. Pump State Logic

Similarly a number of temperature conditions will generate alarms. These relate to failure of bypass valves, pumps, leaks or blockages. The alarm conditions are shown in table 2.

STATE	**ALARM**	**PROBLEM**
T1 > 100 °C	X	Panels Overheating Check Radiator Bypass if T2 > 75°C
T2 > 80 °C	X	Tanks Overheating Check if P_P Running
No Flow when P_S is running	X	Solar Circuit Leak or Pipe Blockage Check Pipes and Panels

Table 2. Alarm Logic

In order to prevent overheating of the solar pump loop, a radiator is provided to dump the solar heat gain under low or minimum flow conditions. This could be experienced on a weekend or public holiday when occupancy is low and consequently the hot water supply usage is low. The control system for the radiator bypass is independent of the monitoring system.

Data output from the monitoring system is sent to a remote server using GSM. The data format is a comma delimited text file which is time stamped. This allows the data to be imported into a number of tools such as a spreadsheet for analysis. An example of a sample graph from data loaded into MS Excel is shown in figure 6.

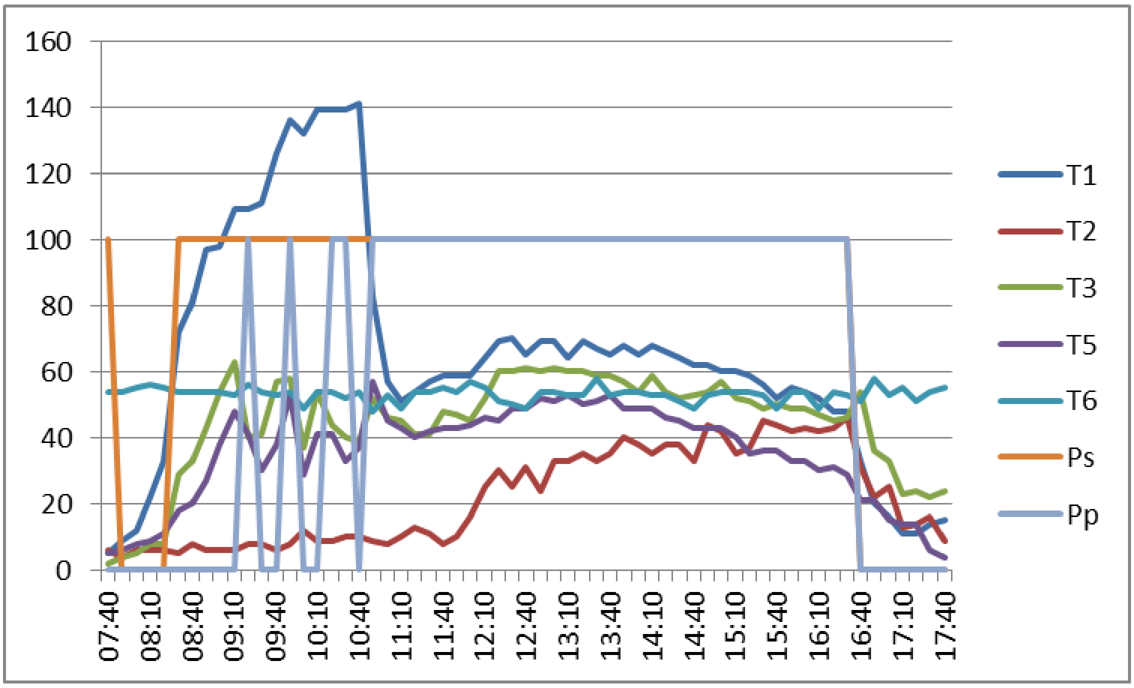

Figure 6. Sample Data from the SWH Monitoring System

The graph in figure 6 can be used to analyse operation by the supplier and maintenance department to determine if the equipment is operating correctly. The primary and solar pump operation is also overlaid on the graph.

This system was commissioned during 2011. It was intended to extend the remote monitoring and integrate the data into the building monitoring system (BMS). However due to budget constraints and changing project team this was never implemented. We were requested to stop monitoring after around 2 years. In early 2014 there was a failure of one of the peripheral systems which led to cold water in the showers. This highlighted the need for ongoing monitoring and a project scope has been provided for a live website and integration with the BMS.

Case 2: Monitoring Experimental Building Integrated PV

Commercial buildings are a large energy user. A large number of commercial buildings only operate between 6am and 6pm. Sunlight is mostly available during these hours so it is feasible to generate electric power with photovoltaics (PV). However depending on the geometry of the building there is usually insufficient surface area on the roof of the building to provide for more than around 20% of the total energy requirement. This has led to the development of building integrated photovoltaics (BIPV) where the facade of the building is covered with PV panels. Traditional PV panels are opaque so light is blocked by these panels on the side of the building where they are used. An Australian company, Tropiglas Technologies Ltd [7] has developed a window material with integrated PV. This high performance glass harvests the infra-red and ultraviolet wavelengths to power integrated PV cells, while letting through the visible light. The principle is indicated in figure 7 [8].

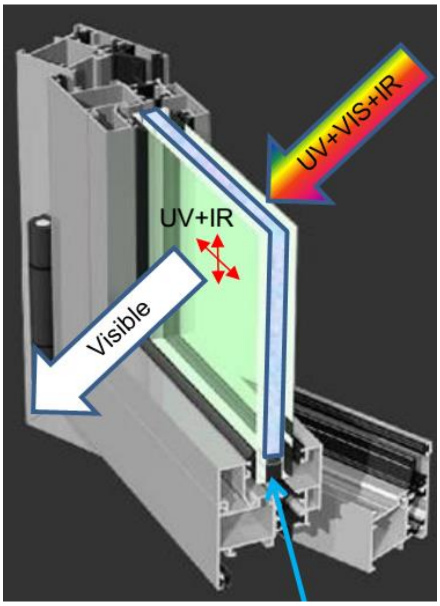

Figure 7. Tropiglas Energy Harvesting Principle

In order to evaluate the performance of this novel concept, a new energy efficient building was equipped with three panels. A data logging system is being used to automatically measure key performance parameters which are then integrated with the building management system. The data can be accessed remotely and downloaded for further analysis. The data logger collects the PV output data directly and the environmental data from sensors.

- Solar Radiation
- PV Output (Voltage and Current)
- Incident light
- Outside, Inside and Frame Temperatures

The installation of the Tropiglas panels and sensors is shown in Figure 8.

Figure 8. Installation of Panels and Monitoring Sensors

The data logger used to collect the sensor and PV data is house in a wall mount enclosure shown in figure 9. The data is collected in real-time and save in a Modbus data table for interrogation by the BMS.

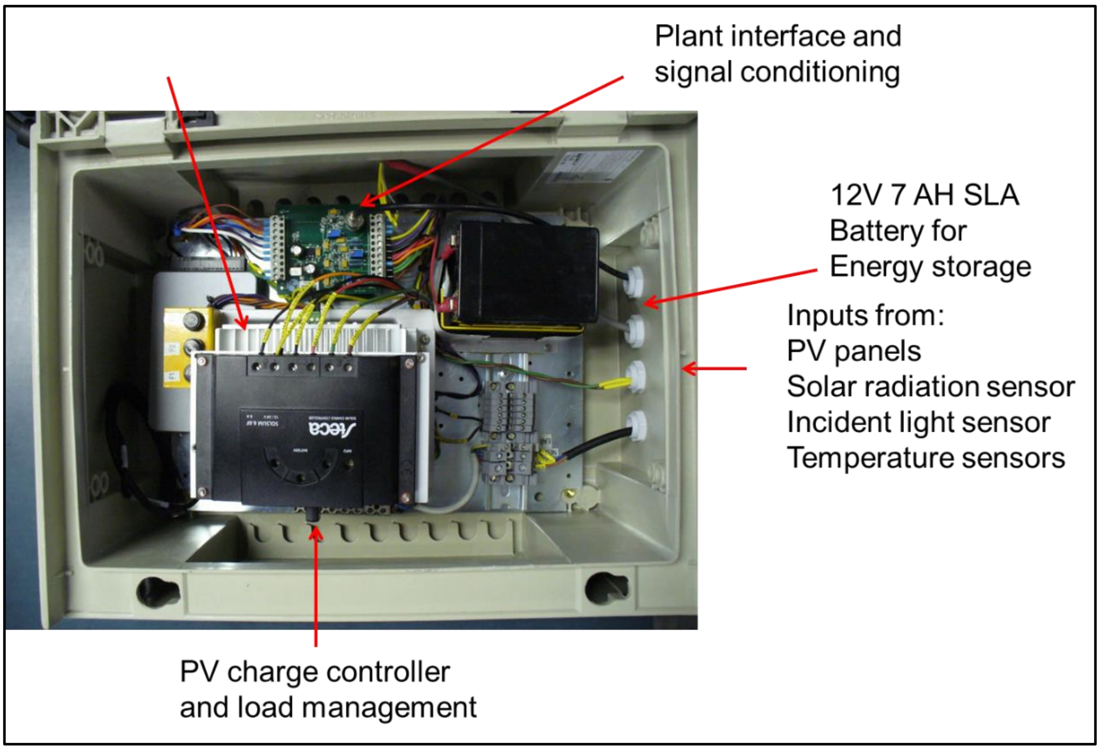

Figure 9. Data Logger Layout

Data is available as a real-time graph display from the data logger (figure 10), a dashboard on the BMS (figure 11) and as a data download.

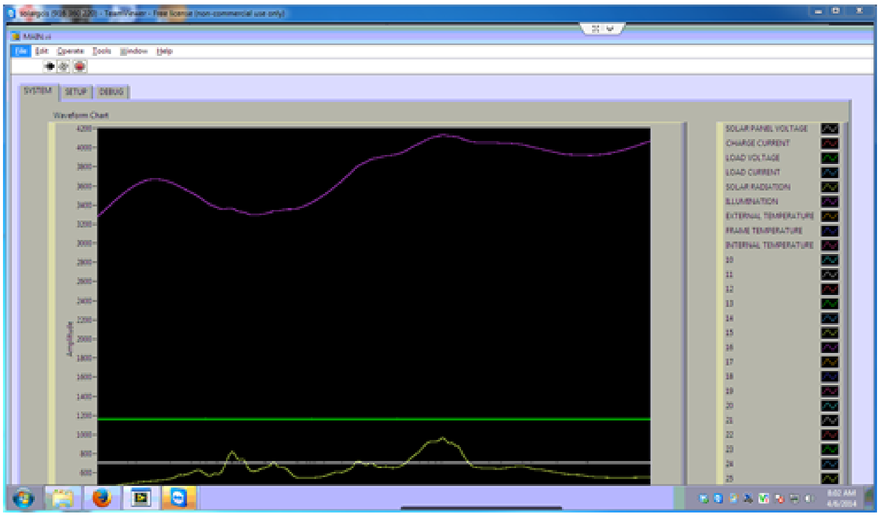

Figure 10. Raw Real-Time Data Display

Figure 11. BMS Data Display

The system was installed in February 2014 and the data has shown that the panels are not installed in the optimal location due to shading. However valuable data is being collected which will be used to improve the design of the glass and the location in the building.

Conclusions

The high capital cost and often marginal economics of renewable energy installations requires prompt intervention to maintain peak performance in the event of equipment failures or maintenance requirements.

Automated real-time remote monitoring can improve the availability and reduce the downtime of renewable energy installations. This can be achieved by using a range of technologies and communication systems.

Remote monitoring technology is readily available and is easily deployed without impact on the current infrastructure. It can be installed without using sensors or equipment from the automation systems and hence will operate independently and without any interference should it become faulty.

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