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# Remote Area Hybrid Solar-Diesel Power Systems in Tropical Australia

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**Abstract**

As of 2012 1.3 billion people, or 18.41% of the world's population, were without electricity. Many of these people live in remote areas where decentralized generation is the only method of electrification. Diesel generators power most mini-grids, but new hybrid power systems, incorporating renewable energy sources, are becoming a reliable method of reducing total system cost and diesel usage. This paper reviews the Ti Tree, Kalkarindji and Lake Nash (TKLN) hybrid solar-diesel power stations (1MW) with the proprietary Grid Stability System ("GSS") supplying electricity to three remote communities in central Australia.

The GSS is an innovative feature of this Epuron designed project. The GSS maximises solar energy input to the grid without interfering with the existing diesel generator control systems, thereby maximising fuel savings.

Data from the installed system were used to validate the GSS capabilities and performance. This study bridges the gap between design optimization studies that frequently lack subsequent validation and experimental hybrid system performance studies.


Selection and/or peer-review under responsibility of ISES.

*Keywords:* Grid Stability System; Hybrid Solar Diesel Power Systems; Higher Penetration Solar Systems.

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**Nomenclature**

TKLN Ti Tree, Kalkarindji and Lake Nash

GSS Grid Stability System

PPA Power Purchase Agreement

PPP Public Private Partnership

PWC Power and Water Corporation

PV Photovoltaic

SCADA Supervisory Control and Data Acquisition

## 1. History of TKLN Project

In late 2009, a request for proposal was released for solar power stations to be built in 3 remote locations in the Northern Territory of Australia. Each power station was to be integrated into the existing diesel power station mini-grid at the remote communities of Ti Tree, Kalkarindji and Alpurrurulam (Lake Nash). The main driver of this project was to reduce diesel consumption at each site. The proposal called for 'high penetration' solar systems but the choice of solar technology was left to the proponent.

Epuron (the developer) replied to the proposal and was subsequently chosen to build the project. Epuron partnered with Conergy Australia as an EPC contractor providing the solar power station and also Mpower who provided the battery grid stability system (GSS). This GSS would allow the solar power system to integrate with the existing power system while providing a high penetration (up to 80%) of generation. The client for the project was Power and Water Corporation (PWC), PWC owns and operates the existing diesel plant and power system for all three sites.

The solar project was funded through a 50/50 Public Private Partnership (PPP). Both Epuron and the Australian Government contributed $5M, where the public amount was provided through a grant from the Renewable Remote Power Generation Program under the then Australian Federal Government Department of the Environment, Water, Heritage and the Arts [1].

A Power Purchase Agreement (PPA) was later signed between TKLN Solar (a subsidiary company of Epuron) and Power and Water Corporation (PWC). A key part of the PPA was a clause that incentivised the solar power station to produce a smooth power output to the grid. Each of the sites has a negative ramp rate limit of 20-30 kW / minute. If the solar power system goes under this, a financial penalty is incurred. This price signal was given to ensure that load was not suddenly transferred to the diesel generators.

Each of the sites was commissioned in late 2012 and all have now been operating for several months. Each site is able to achieve over 75% penetration and it is believed this value could be increased in the future.

## 2. Integrated Solar-Diesel System Architecture

### *2.1 Main Components in the System*

The main components of the Ti Tree Solar Power Station include 324 kW of mono-crystalline solar modules, 19 distributed solar inverters and also a GSS that is located inside a shipping container adjacent to the solar array. The solar power station is connected to the adjacent existing diesel power station, where power is exported to a mini grid that includes a community load and farm load. The existing diesel power station contains three diesel generation sets of nominal capacity 450 kW, 520 kW and 700 kW [2].

The GSS receives a signal from the control system at the diesel power station so that it can place a limit on the solar system output. This is so that the diesel generators are not forced to run under their minimum power outputs nor above their spinning reserve power output limits. The GSS must also control the output of the solar power station during cloud events so that combined power output of the solar system and battery system is not less than a specified negative ramp rate.

The GSS achieves these functions with some key components, including nine strings of lead acid batteries, nine single-phase bidirectional inverters, a programmable logic controller and other control and communications equipment.

Fig. 1 - Ti Tree Solar Power Station. GSS and diesel power station in background.

Figure 2 - Ti Tree Grid Stability System.

*2.2 GSS Based Control System Philosophy*

Consistent with the intent of the project, the GSS system takes minimum input signals from the diesel primary power station control system, these being a start/stop signal, kW set point and a counter to monitor health of the communication link.

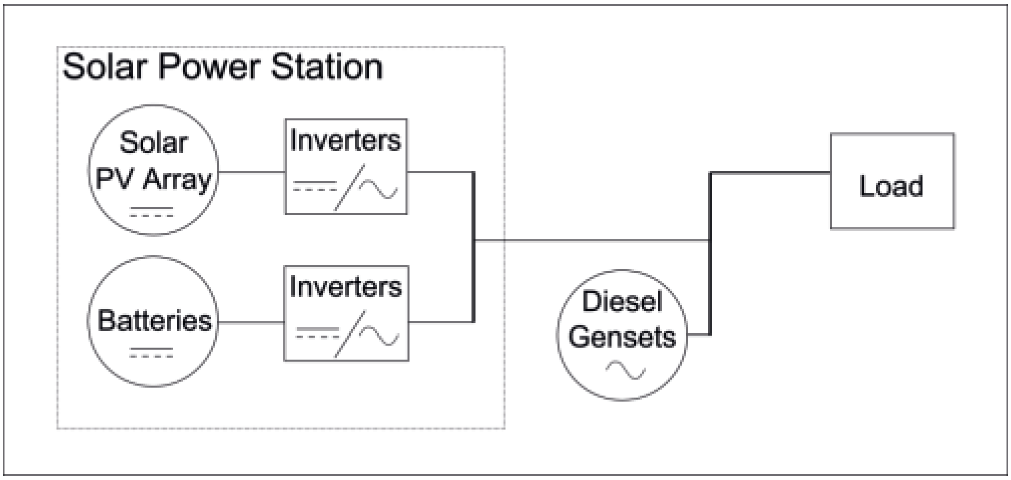


Fig. 3 - Ti Tree Solar Power Station and Grid Set up (simplified)

The GSS PLC uses the kW set point to limit the output of the solar system by sending a signal to each of the solar inverters. The main need for the set point is to make sure that none of the diesel generation sets are under loaded when the solar power station is being operated.

During a typical insolation loss event, a cloud will cast a shadow over the solar power station and solar output will drop sharply. Solar output is measured and forms an input to the GSS control system that controls output of the battery so that the combined output of the solar and battery system export power that does not fall below the rate of negative 30 kW / minute. This rate reduces the load transfer rate to the currently operating diesel generation set such that if there is a continued lack of solar resource, and the load exceeds what the current diesel generator can serve, there is enough time for a larger diesel generator to be started to take the load.

## 3. Ti Tree PV System Penetration Analysis

Figure 4 shows Ti Tree load profile between 1$^{st}$ of January 2013 and 31$^{st}$ of May 2013. The load data demonstrates that the maximum system load was 604 kW. The average load between January and May was 336 kW. The figure shows that few times solar system output dipped to 0 kW, which was due to the system outages. Birds on the power lines, generator mechanical/electrical issues, power system faults can generally cause system outages in the remote communities. In some cases under frequency load shedding does not react fast enough, generators' inability to pickup load quickly can cause generator trip and hence system black situations. These outages were not caused by the solar system integration.

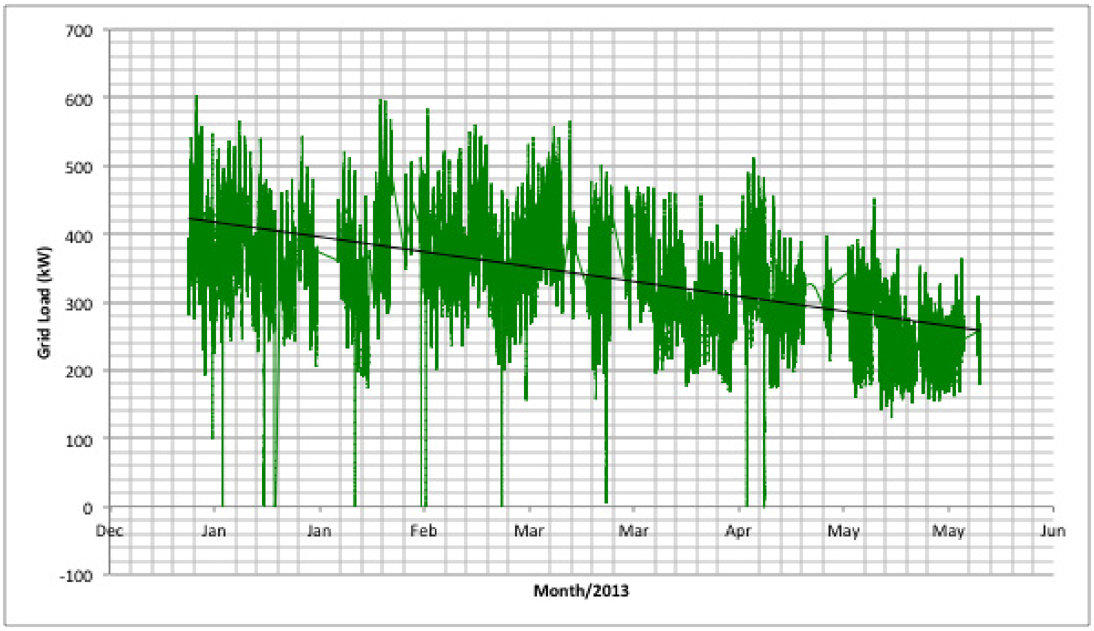


Fig. 4. Ti Tree total grid load profile between January 2013 and May 2013.

Figure 5 shows total solar system output during daylight hours (7:00 am – 6:30 pm) between 1st of January 2013 and 31st of May 2013. The black line in the graph shows average solar power output trend over the duration of five months. The PV output data shows that the maximum solar output was 304 kW. Five months data shows that the average solar output during daylight hours (between 7:00 am and 6:30 pm) was 139 kW.

The average solar system penetration during daylight hours on Ti Tree power system was 41 % of the system average load.

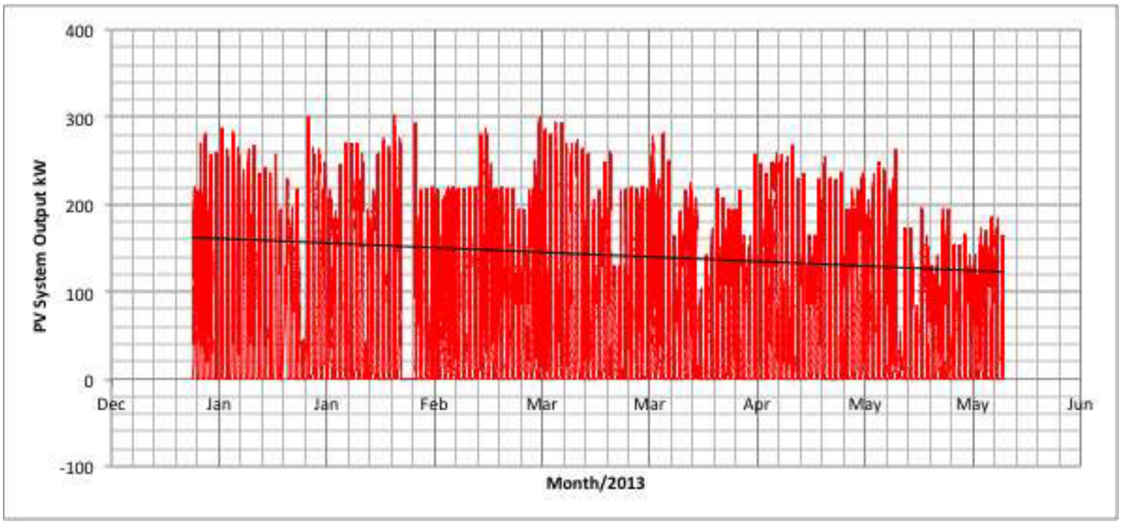


Fig. 5. Ti Tree solar PV system output between January 2013 and May 2013.

Figure 6 shows solar output on third of January 2013 from Ti Tree solar system. The figure 6 also shows that at 11:28 am solar system output dropped from 272 kW to 79 kW within 15 seconds. This demonstrates that solar system output can drop very quickly and design engineers should consider this carefully while designing high penetration solar systems. The GSS has been designed to compensate during these large drops in solar output.

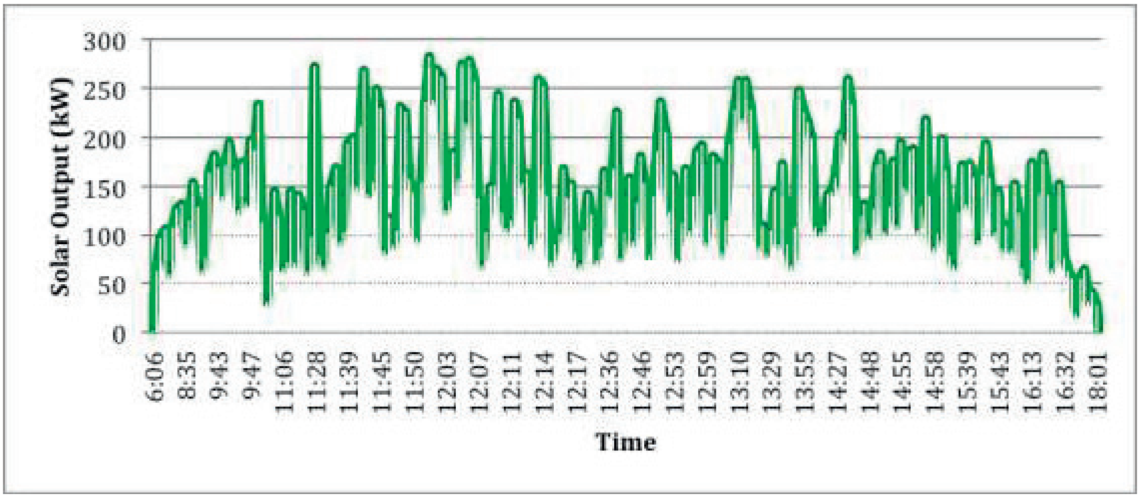


Fig. 6. Show solar power output on third of January 2013 from Ti Tree Solar System.

## 8. Conclusion

The integrated solar systems developed by Epuron in this TKLN project have been verified and can now offer utilities the ability to manage high penetration renewable energy systems in remote of off-grid locations. The automated site controller is capable of managing high penetration solar systems. 5 months data analysis demonstrates that GSS control system has achieved average penetration of 41% during daylight hours.

The following list summarizes the main features of GSS Technology:

- Control the output of the solar power station during cloud events so that combined power output of the solar system and battery system is not less than a specified negative ramp rate.
- Make sure that none of the diesel generation sets are under loaded.
- GSS PLC to limit the output of the solar system by sending a signal to each of the solar inverters.
- Set point and a counter to monitor the health of the communication links.

The new GSS approach will allow utilities to transition to higher penetration PV system without compromising system integrity.

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