Southern Tablelands Electricity

Bulls Head Stand Alone Power Plant

This paper was presented to the ESEA Regional Conference held in Goulburn, NSW, April 27,1995.

by

Richard Chilko, Ass. Dip. E.E.
Engineering Officer / Technical Services, STE.

and

Tony Egan
Managing Director, New Generation Technologies

Table of Contents

Summary..........3

Background..........3

- Location
- Line History
- Service Charge
- Line Statistics
- STE Original Investigation for Stand Alone Supply

Why Substitute Stand Alone for Grid..........5

- Maintenance Costs
- True Cost per kWh
- Promotion of Renewable Energy

Stand Alone Investigation..........6

- Two Sites
- Amenities Site
- Communications Site
- Installed Equipment
- Equipment Selection

Customer Contribution..........9

Operation and Control..........10

- Amenities Site
- Main Site

Communications..........11

- Inverter
- Programmable Logic Controller
- Alarms and Response

Statistics..........13

- Present Load
- Demand
- Proportion of Generation
- Event Register

Future..........16

- Costs
- Addition of Solar
- Effect of Increased load

Acknowledgments..........17

Appendices..........18

Summary

This paper discusses the development of Southern Tablelands Electricity's stand alone power plant at Bulls Head. The plant was commissioned in January 1995 and in the main, supplies power to a communications facility. There are actually two STE stand alone power systems in operation at Bulls Head, one being a solar installation at an amenities facility and the other being a wind/diesel hybrid system supplying the actual Communications site. Both sites were supplied by an overhead 22kV distribution line which is still in place and operated in a fail safe mode to the communications site. A second stage to the project will be to add approximately 1.8kW of photovoltaic cells. At the completion of an evaluation period of approximately twelve months a decision will be made as to whether the ten kilometres of overhead line will be dismantled. In the meantime generation and load data is being logged and the system is being remotely monitored.

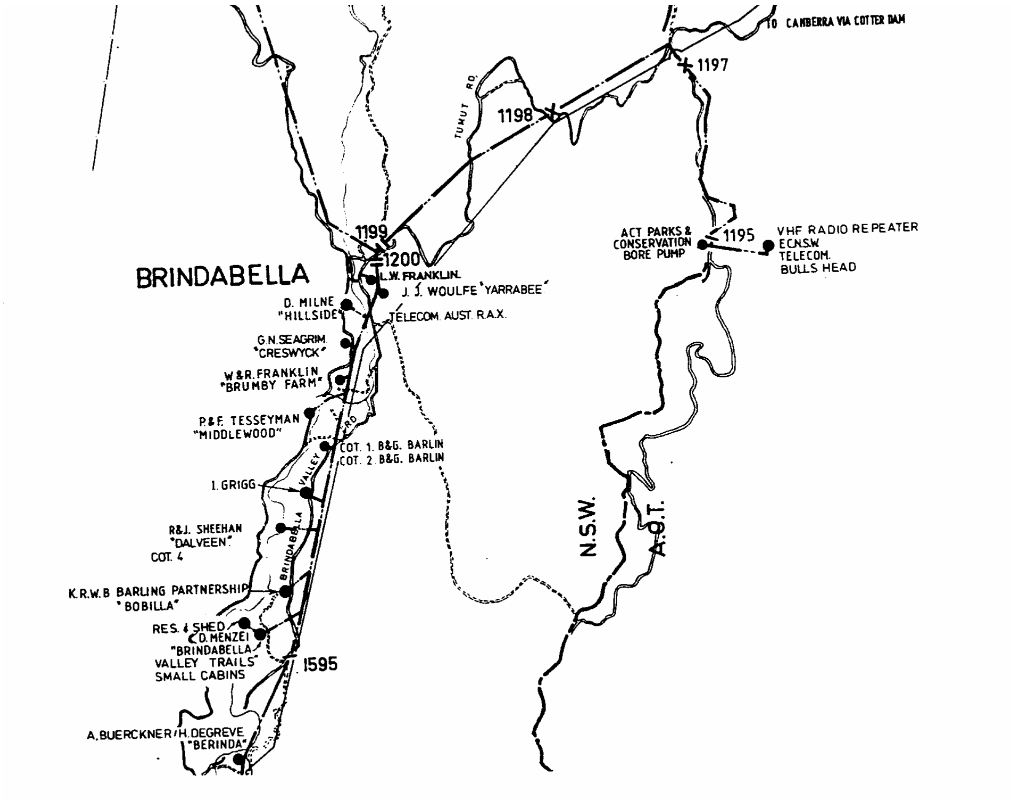
Background

Location

Bulls Head lies at an elevation of 1368 metres and is located on the ridge of the Brindabella Mountain Range which forms the water shed between the Goodradigbee River in NSW and the Cotter River in the ACT. The area is part of the Namadgi National Park which is located at the northern end of the Australian Alps, and to the western boundary of the ACT. It also lies within the Cotter catchment area, an area largely natural and undisturbed and managed to preserve the quality of Canberra's water supply. Although snow can fall over most areas of the park, it is most common on the Brindabella ranges.

Line History

The power line to the site was constructed in 1961 by the then ACTEA and supplied Bulls Head at 11kV. Southern Tablelands supplied customers in the Brindabella Valley and purchased electricity from the ACTEA via this line with the metering point and step-up transformer to 22kV located just beyond Bulls Head. As the supply line from Canberra rose through many sections of Pinus Radiata Plantation, the ACTEA were concerned at the fire hazard this presented and negotiations were put in place for Southern Tablelands to take over supply of Bulls Head and the Brindabella Valley with an extension of a distribution line from Yass.



<u>Brindabella /Bulls Head 22kV Power Line</u>

Service Charge

In actual fact STCC was informed by the ACTEA of their intentions to dismantle the section of line through the forest and advised that we would be required to make other arrangements for supplying the valley (this also included taking over three of their customers at Bulls Head).

By supplying the valley from Yass , Bulls Head was now served by an isolated spur line. The County Clerk of the time, Mr. F.M.Davies, faced with taking over a liability advised the two main customers, Telecom and the then Electricity Commission of NSW, that they would be required to contribute towards the maintenance cost of the line. A service charge was negotiated and was in addition to charges for electricity consumption. The basis of the service charge assessment was the cost of maintaining supply to the two main customers and was proportioned in relation to each customer's consumption. That was in 1983 and Telecom and ECNSW were requested to contribute $4,800 and $2,400 per annum respectively.

At the time both authorities decided to investigate a stand-alone option for the site in lieu of paying the proposed service charge. Apparently it was determined not to be a viable alternative.

Line Statistics

The spur feeding the Communications facility is some 10 kilometres in length with steel conductor and originates from the floor of the Brindabella Valley. It rises some 670 metres over the first 4.5 kilometres to Picadilly Circus and consists of 91 poles over its total length. The line traverses some extremely difficult country in terms of access for pole inspection and replacement and is susceptible to snow loading.

STE Original Investigation for Stand Alone Supply

In 1990 the on going costs associated with tree clearing and maintenance prompted STE to investigate a suitable Remote Area Power Scheme (RAPS) for the site. At the time the basic economics dictating the type of RAPS system that would be suitable, was as follows:-

- Solar up to 700watts
- DC Hybrid from 700 to 3000watts
- Diesel or Grid above 3000watts

Although consumption was only around 50 kWh per day demand could vary considerably with air conditioning, heating and rectifier load. Initial indications for equipment to supply this load and to provide storage capacity for seven days operation was of the order of $80,000. This did not include a building, civil works, installation or maintenance. The power source was only to be diesel and because of the logistics involved, the project was put on hold.

Why Substitute Stand Alone for Grid

The issue of a Stand Alone system again raised its head in 1994. Apart from the difficult access for line maintenance, the 10 kilometres of line continually requires extensive clearing at regular intervals and part of the line is within the Canberra water catchment, restricting the measures undertaken to control vegetation regrowth. The power line is in excess of 30 years old and will require substantial pole replacement in coming years. There is also the potential for extended interruptions to the Brindabella valley from line faults within the 10 km section to Bulls Head.

Maintenance Costs

Maintenance costs for this spur are estimated to average $18,500 per annum over at least the next 10 years and are described below:-

Helicopter Inspection	$550	
I&P (inspection and preservation)	$2,000	
Clearing	$6,000	
Pole Replacement		$10,000
TOTAL	**$18,550**	

True Cost per kWh

In 1994 Telecom and Pacific Power were paying a service charge totalling $7,200 per annum, a charge that had never been indexed since its inception in 1984. The effect of this charge is to increase their cost per kWh from 18.4 cents under the General Supply tariff alone, to 58 cents.

Purchase costs from Pacific Power for energy sold at Bulls Head is about 6.5cents per kWh (the load factor is relatively good), compared to costs of wind generation at no better than 11 cents per kWh, diesel generation of at least 35cents per kWh and photovoltaic generation at some 20cents per kWh.

Annual consumption in 1994 was some 19,000 units with line maintenance cost for the same period being around $18,500. Couple this with electricity purchase costs, losses, depreciation and overheads, the true cost of supply was well in excess of $1 per unit.

Promotion of Renewable Energy

The use of a composite wind/diesel supply, supplemented at a later date by photovoltaic panels, will provide useful experience and information in the proportion of energy supplied from each source, as well as being a good public relations exercise in the promotion of renewable energy and the return of 20 hectares to its natural environment.

Stand Alone Investigation

Two Sites

The stand alone power system at Bulls Head consists of two separate installations. The main one is located at the Communications site, (the actual Bulls Head trig station), and a secondary at an amenities site, the distance between the two being too great for a cost effective single site supply. Both systems have operational characteristics that present no problems with grid connection, but can cause design and costing headaches for stand alone power installations. It was necessary therefore to employ strategies that utilised renewables to their best advantage while remaining cost effective.

Amenities Site

The biggest problem with the amenities site was the constant load of a small 12V DC fan powered by a Dick Smith AC-DC converter. The fan was used as part of a Clivus Multrum composting toilet and was required to run 24 hours a day. The way in which modern solid state inverters work is such that they are very efficient, around 90%, over the majority of their power output, but that they are very inefficient at low levels of demand. The inverter therefore would be consuming a great deal more power than it was delivering; the result being a larger and more costly system.

The solution :- get rid of the AC-DC converter; swap the 12V DC fan for a 24V DC unit and run directly from the stand alone battery bank. The inverter then would only be required to run a 1hp bore pump and an occasional lighting requirement, all using the high efficiency band of the inverter.

The power requirements at the amenities site were calculated at just under 1kWh a day, allowing for inefficiencies in battery charging and inverter losses. Due to the remoteness of the site and the need to at least equal the reliability of the grid, six MSX60W Solarex panels (twenty year warranty) were used in the design. The output of these panels even in the depths of winter, was in excess of the load requirements and together with a 370 Ah, 24 Volt battery bank holding the equivalent of ten times the daily discharge, the system had sufficient redundancy.

Communications Site

The transmitter site presented with a much larger load pattern over 24 hours somewhere between 1.5 and 2.5kW, the difficulty here being what size battery bank? If we were to go the traditional path we would end up with an extremely large battery bank at great cost to STE. The other option was to reduce the battery bank and use intelligent management systems that utilise the full capacity of the wind turbine.

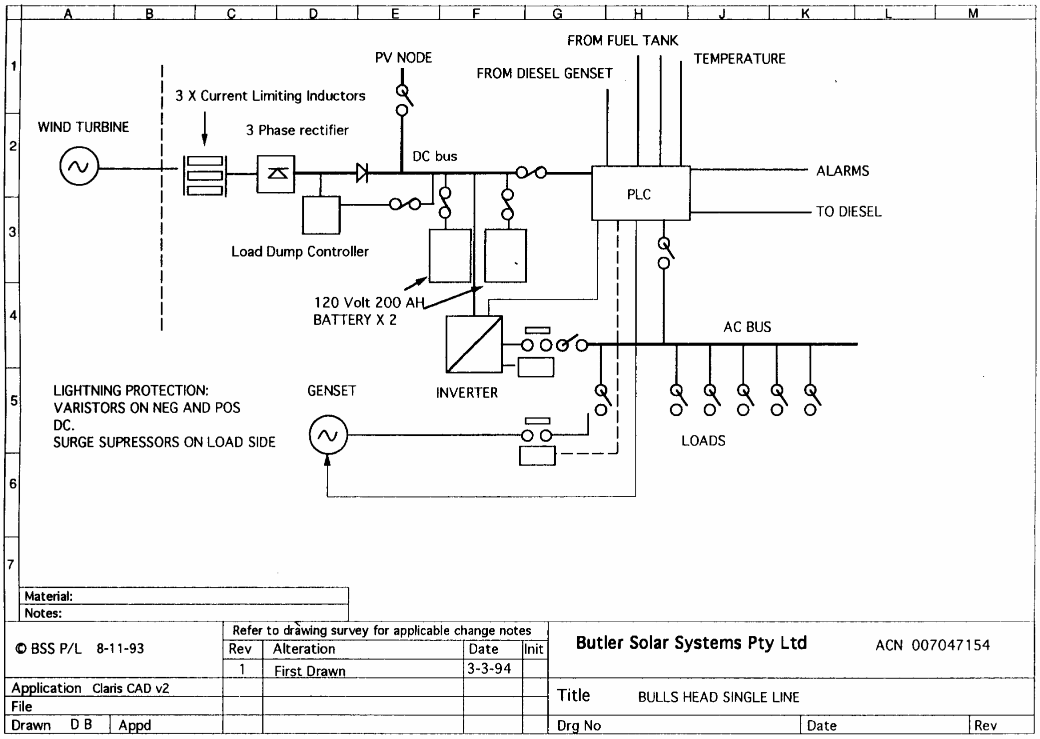
At this level of demand straight solar would have been a far too expensive an option and given its location on top of the Brindabellas where some of the highest inland wind regimes are recorded, the logical primary choice for renewable energy was wind.

In the original design we had allocated 30 MSX60W solar panels which would have complemented the wind turbine particularly during the summer months where data shows poorest wind conditions. This option is discussed later in the paper.

Installed Equipment

As indicated in the single line diagram, the stand alone plant at the Communications site consists of a 10kW wind turbine mounted atop a 24m steel support structure and a transportable building housing the following:-

- 6kVA diesel powered alternator
- 500 litre diesel fuel storage
- Interactive Inverter
- 400Ah battery
- Communications equipment for remote diagnostics and monitoring
- STE radio base station



Bulls Head RAPS System - Single Line Diagram

Equipment Selection

The location and logistics of the site required a wind turbine that was proven in the extreme weather conditions that can be experienced at Bulls Head, particularly ice and snow. The Bergey Westwind turbine is manufactured by Venco products in Western Australia and has proven performance in the United States, coupled with its autofurling and minimum maintenance requirements. Wind data that had been collected from two adjacent sites, namely Coree South and Picadilly Circus were used in determining the appropriate size turbine for the site. The 10kW turbine at a load factor of 30 percent, which was the extrapolated result from the known data, should be able to supply 100 percent of the load for most days of the year.

The battery storage and operation was sized simply to act as a buffer to smooth the short term fluctuations in the wind turbine input. The battery bank used was a 400Ah, 120volt Sonnenschein sealed gel type, again chosen because of its tested performance and minimum maintenance.

The inverter provided is a 5kW sinewave interactive, manufactured by Siemens with associated PLC control equipment for alarm monitoring and generator control. This equipment was designed and supplied by Butler Solar Systems.

Customer Contribution

Following the investigation and a decision being made to go ahead with a RAPS system, consultation again took place with the STE customers concerned, regarding the cost of supplying the site. The service charge negotiated with Telecom and Pacific Power was discussed earlier, however the cost of installing a stand alone system was some $148,000. Two options were put forward for their individual consideration:-

OPTION 1 STE would contribute the total capital expenditure, with the service charge being increased to reflect CPI movement since 1983. This revised service charge would then be subject to annual CPI adjustments. For Telecom the charge would increase from the present $4,800 to $8,500 per annum and for Pacific Power, from $2,400 to $4,250 per annum. Energy consumption would continue to be charged at the General Supply tariff.

OPTION 2 A Capital contribution be made in proportion to the customers energy consumption that would permit STE to break even over a 30 year period. The individual contributions would be STE $85,000, Telecom $42,000 and Pacific Power $21,000. This option would require the present service charge to continue with annual CPI adjustments. Energy would continue to be charged at the General Supply tariff.

Telecom responded by selecting option 1, Pacific Power option 2.

Operation and Control

Amenities Site

The load at this site is by no means critical and now relies totally on stand alone operation. Unlike the Communications site, there is no remote interrogation or monitoring and any notification of supply failure is likely to come from the Ranger employed by the ACT Parks and Conservation. STE staff periodically check the plants operation during routine maintenance calls to the Communications site.

Main Site

In the normal mode of operation the inverter supplies AC power to the load drawing power from its DC input. The Inverter has a steady state capacity of 5kW and a surge capacity in excess of 10 kVA. This is sufficient to meet the average load of between 1.2kW and 2.7kW (March 1995) and to supply peak loads associated with starting air conditioners and other motor loads.

The DC supply to the inverter comes from a 400Ah, 120V battery and a rectified supply from the 10kW wind turbine. If the turbine is generating then DC power from the wind is used to supply the inverter (10 to 20 Amp at 120 Volt) and any excess is available to charge the battery.

As the battery state of charge rises and as the turbine output power rises the battery voltage will rise. At 145V DC, the load dump will come into action transferring the turbine output into the load dump resistor. The battery voltage will rapidly fall to 135 VDC, the load dump will disconnect and transfer power back to the battery and the inverter. The load dump will be periodically switched in and out controlling the maximum battery voltage and charging the battery. Under these conditions the battery will be close to the maximum state of charge and no more energy can be stored by the battery.

When the wind turbine output is insufficient to supply the inverter, the battery depth of discharge will increase. When it reaches a preset level the inverter will start the generator to recharge the battery, during this process the generator supplies the load directly and the inverter operates in the reverse to charge the battery. If the wind output rises during this process the load on the generator will fall, the generator will shut down, the load is reverted to the inverter and charging will be taken over by the wind turbine.

Communications

The system has been designed for remote monitoring and incorporates an auto dialler for notification of alarm or fault conditions that are activated via the PLC. The auto dialler utilises the same telephone line as the modem . The modem is dedicated to the inverter and is used for data transfer and remote diagnostics.

Inverter

The inverter includes an RS232 serial port which can be used to retrieve logged data and to diagnose operation of the inverter either using a local terminal or PC or remotely via a modem. The software was developed by Butler Solar during the course of the "Green Grid " trials and the same model inverter as used in that equipment, is in operation at Bulls Head.

Remote communications can be instigated through a standard terminal programme if operating under DOS or as in our case, through the Terminal Accessory from within Windows. Data is retrieved as ASCII format and then converted into text files that are suitable to copying into a spreadsheet. The output of the conversion programme results in the following files:-

A Detailed Log File containing 96 fifteen minute averages and peak values for each day.
A 24 hour Summary containing totalisations of energy and diesel running hours.
An Event File containing a record of up to 32 events per day.

Examples of these files in the form of Excel Spreadsheets have been included as Appendices.

Programmable Logic Controller

Although the generator starting and stopping is normally under the control of the inverter, the primary function of the PLC is to actually control the mechanics of the diesel powered generator and also as a means of monitoring alarm conditions. Under inverter failure conditions the PLC will override the inverter and take full control of the generator.

There are 16 inputs used on the PLC and if any of these result in an alarm condition the PLC activates the auto dialler which then rings three preprogrammed numbers in sequence. If the first call is successful and the person answering the phone acknowledges the alarm by depressing any key on a touch phone, the auto dialler will disconnect and take no further action. However if the first call is unanswered, the auto dialler will then progress to ringing the second number and so on.

At this stage remote interrogation of the PLC is not possible as the modem will answer for the inverter.

Some of the parameters the PLC monitors for are low fuel, inverter failure, generator failure, grid failure, wind but no generation and low battery condition for the main, auxiliary and generator batteries.

Alarms and Response

Four PLC outputs activate four separate alarms within the auto dialler. When contacted by the auto dialler the recipient will hear a synthesised message announce any of the following alarm conditions:-

1. BULLS HEAD - STE SUPPLY FAILURE
2. BULLS HEAD - SYSTEM FAULT URGENT
3. BULLS HEAD - SYSTEM MAINTENANCE REQUIRED
4. BULLS HEAD - LOW FUEL

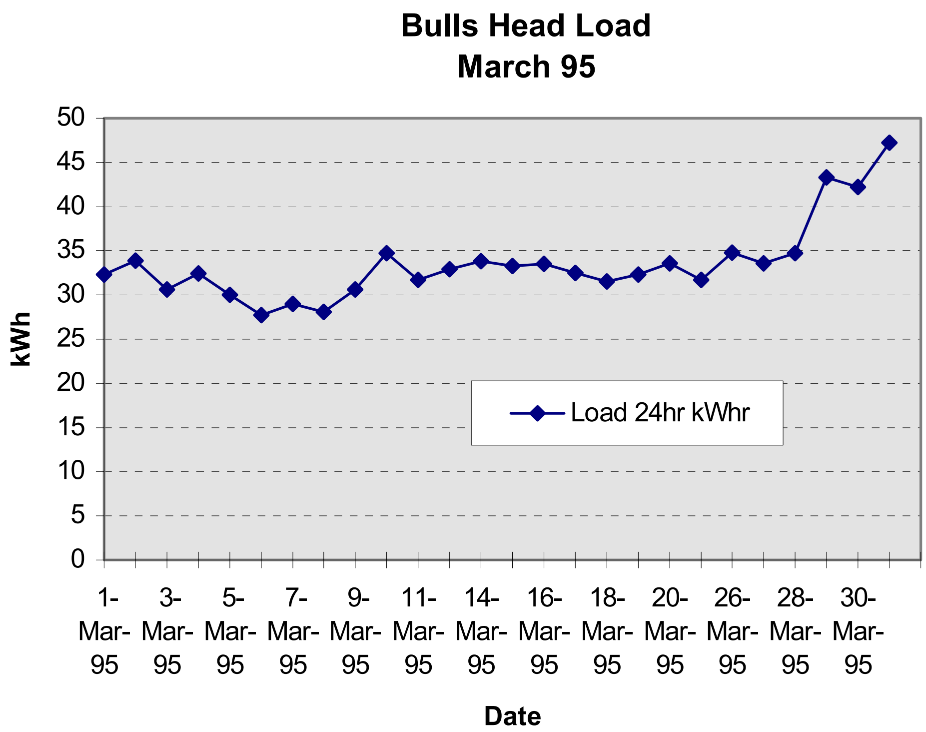
The STE supply from the Grid operates in fail safe mode; if the stand alone system fails completely the grid will automatically take up supply. Therefore under most conditions we can wait until the next working day before taking action. It would only be if we had a combination of conditions 1 and 2 that immediate action would be required. In regard to low fuel, when this point is reached we still have approximately 3 days supply (with no wind), before the diesel shuts down.

Statistics

Operating data is being collected and although it is early days at present, the information to date indicates that we may have to look further at storage capacity and or the size of any photovoltaic array.

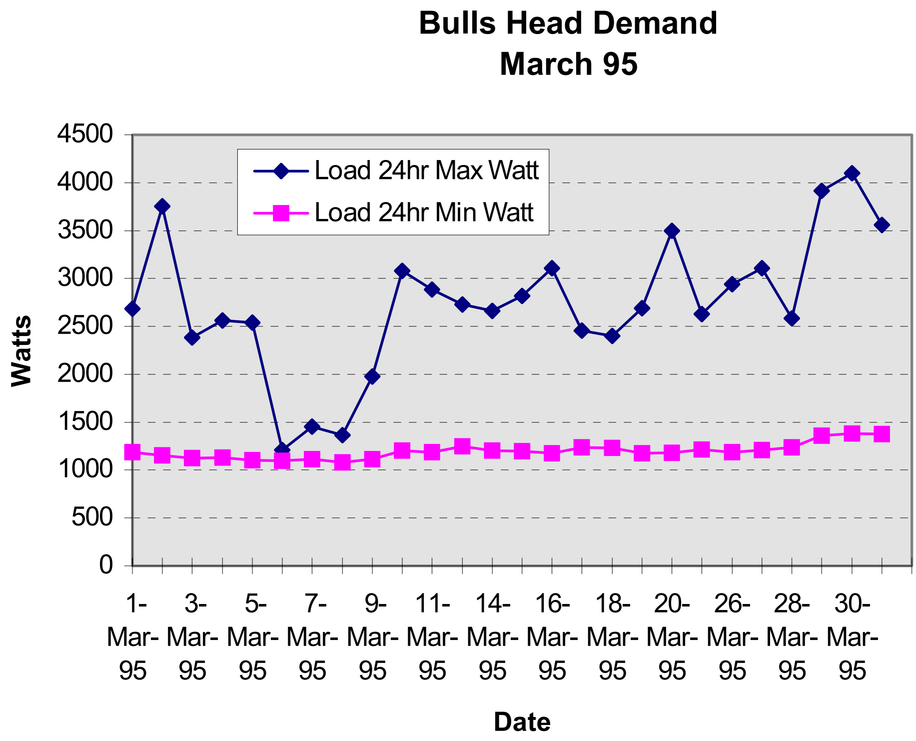
Present Load

The average Energy consumption for March was 34 kWh per day. This is slightly less than the history figure of around 50 kWh for which the system was originally designed. As indicated by the graph the load is increasing towards this figure and with continued monitoring an accurate profile will be obtained in due course.



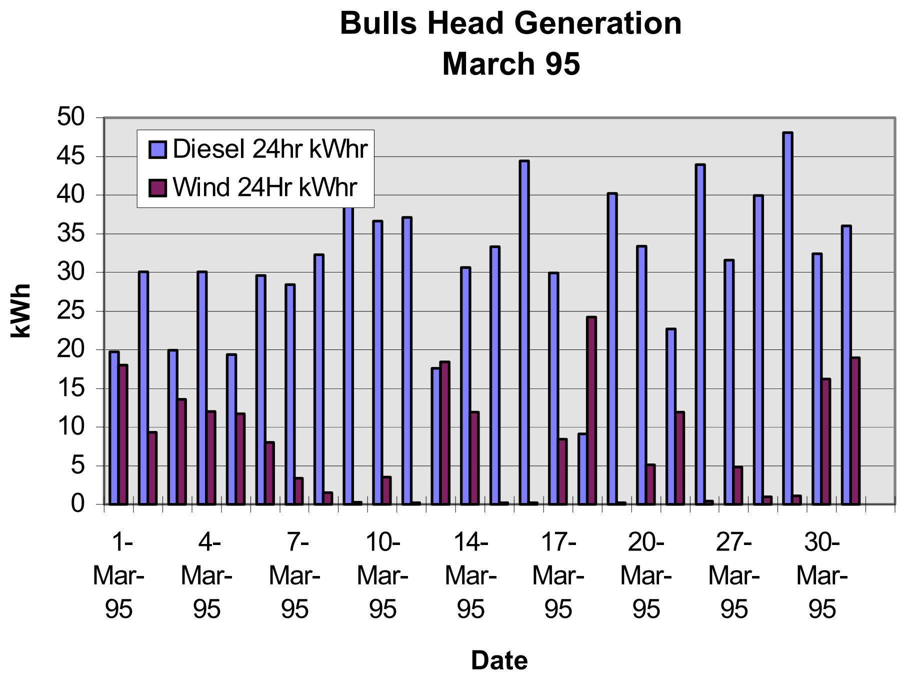
Demand

Maximum demand as indicated in the graph, has been averaged over 15 minute intervals. The actual Peak Demand during March 1995, (not shown), was as high as 11kW and would probably be attributed to the starting of an air conditioner.



Proportion of Generation

The proportion of energy supplied to the load from wind and also from diesel has been graphed for the month of March and is shown below. However to make any accurate assessment of system performance we need to determine the amount of energy the wind turbine sends to "dump" resistors, mounted externally on the building. To this end we are now logging the output of the turbine to extrapolate this quantity. Consideration must also be given to the wind conditions for March which historically appear less prevalent at this time of the year.



Another parameter that we intend to log is wind velocity. Although we have an anemometer on site, its purpose is for alarm monitoring in the event of wind being available and there being no turbine output. Until we have this data we will be unable to confirm our initial feasibility studies in which the indication was that the wind turbine should be able to be the primary generator at this site.

From the data used to compile the above graph, the wind turbine supplied 25 percent of the energy for March with the diesel operating an average of 10 hours per day.

Event Register

The event file records changes to the inverter state and is useful to track the sequence of events during normal and abnormal operation. There is a text explanation attached to each event which lists the nature of the event. For example, when the battery has been discharged by 20 percent and requests a generator start, two events in close proximity will be registered to firstly indicate the request and secondly to indicate when the generator is running. An example is detailed below:-

"Date Time=xxxx:xx Ev=50 ln=12 Sh=2 Gn=0 E50 Schedular Gen start on std discharge"

"Date Time =xxxx:xx Ev= 0 ln=10 Sh=3 Gn=4 Normal entry to synchronised operation"

Future

Addition of Solar

Stage two of this project was to install thirty 60 watt photovoltaic modules at an estimated capital cost of $25,000. Based on Solar data and temperature information for Canberra for the month of March we could expect to generate a net value of 9 kWh per day from an array of this size. Looking at the March consumption figures for the site, this would have been able to supply 75 percent of the base load through the day.

The size of any Solar component is now under evaluation as ACTEW is in the process of upgrading their communications facility and it is anticipated that their energy requirement will increase from the present 0.5kW to approximately 2.8kW in June.

At this stage it is still early days in the project, and it will take 12 months of data collection to make an informed evaluation as to the optimum size of any solar array or any increase in storage capacity that may be required. However, it is probable that we will implement the the second stage of the project as planned in the coming months and supplement as necessary, if and when the collected data proves we can optimise efficiency.

Effect of Increased Load

With the June increase in load the installed equipment has the capacity to meet the increased requirements even without considering the wind contribution. However there are three points to consider; that of increased fuel consumption, the increase in routine maintenance of the diesel engine and the faster deterioration of the diesel plant. Without added input from renewables, generation costs will rise significantly.

As mentioned earlier, to date we haven't experienced the contribution from the wind as initially expected and performance will be reviewed as operating data is accumulated over the ensuing 12 months.

An important consideration will be the benefit of increasing storage capacity which must be weighed closely against the capital cost and the life of the storage medium. There may be a negative cost benefit in providing storage for energy generated from high velocity winds that become available for say days on end.

Acknowledgments

The authors wish to acknowledge the contribution of Butler Solar in the design and supply of the main stand alone plant and in particular for the intelligence of the data logging and remote communications used therein. Some of the content of his paper including the single line diagram has been produced from Butler Solar documentation with their permission.