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Pacific Power Association, Suva Fiji Islands. The PPA is an inter-governmental agency and member of the Council of Regional Organisations in the Pacific (CROP) established to promote the direct cooperation of the Pacific Island Power Utilities in technical training, exchange of information, sharing of senior managment and engineering expertise and other activities of benefit to the members.

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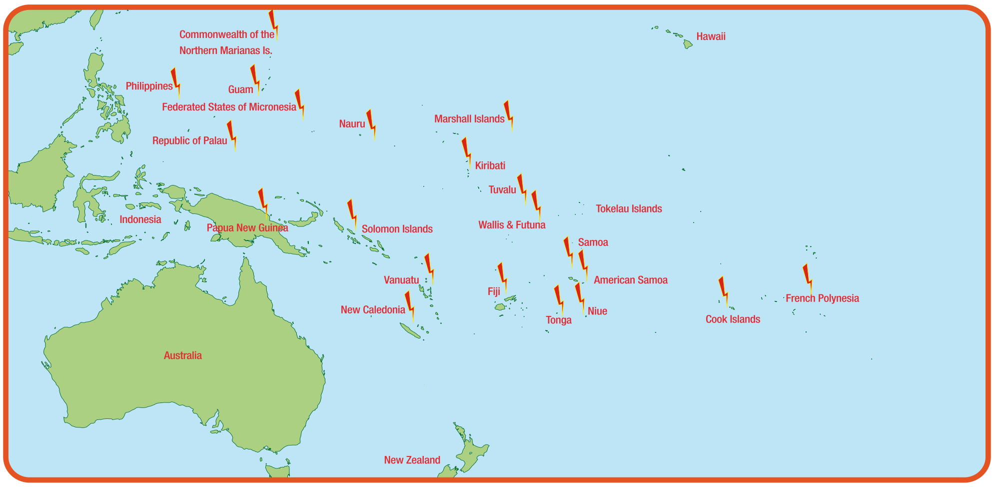

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Editor's Notes

Andrew D. Daka
Executive Director

Bula vinaka and Greetings from Suva.

Let me start by wishing all a belated Happy New Year and the Staff of the Secretariat do sincerely hope that the New Year has started well for all the readers. As we go to print, we are a couple of weeks before the end of the first quarter of 2017 and I believe that everyone is well into their respective work programs for the year.

The implementation of the World Bank financed Sustainable Energy Industry Development Project (SEIDP) has progressed significantly and the capacity training activities kicking-off with the first of the many training workshops scheduled to take place in Nadi, Fiji, from 27 – 31 March 2017. Whilst only the ten Pacific World Bank countries will benefit under the grant, the PPA Secretariat has and will continue to seek support to enable the rest of the utilities to also participate in the events.

This issue of the magazine continues with the series of technical papers presented at the Association's 25th Annual Conference in Nuku'alofa, Tonga.

While engine heat recovery has been around for a while and a number of utilities have ventured in that area, the challenge is to see a successful project in the islands. Heat recovery makes sense as a means to increasing the output of the engines and using energy that is normally lost to the surrounding.

A number of the Pacific Islands countries have set a 100% renewable energy target which they hope to achieve within a time period. The article "Age of Renewable Power Systems – Transformation of Island Power Systems" discusses the challenges that utilities will come across in the journey to achieving the target. It discusses the cost implications, staffing capabilities and some of the technology traps as well as the involvement of IPPs. The article also proposes a way for cooperative approach between stakeholders to achieve safe and reliable power.

Sustainable tariffs/rates are the lifeline of a utility to ensure sufficient financial resources to function. Solomon Power's article outlines the process it had undertaken in the review of its tariffs/rates.

Utilities are always striving to implement technology that will help in reducing fuel consumption and there is further added advantage where it is used in conjunction with renewable energy technology. A number of PPA member utilities have deployed fuel saver technology that is used in PV systems with storage. The SMA article provides more information on the technology and its application in the field which is helpful to utilities that might be looking for solutions to their fuel consumption.

We also pay tribute to Billy Roberts the former CEO of Marshalls Energy Company and former PPA Board Chairman who passed away on 31 January 2017. Billy together with the likes of Utu Abel Malae of ASPA and the then Chief Executives of PNG Electricity Commission (now PNG Power), Commonwealth Utilities Corporation, SIEA (now Solomon Power) and Tonga Electric Power Board (now Tonga Power Ltd) were instrumental in the formation of the Association. For those who have met and worked with Billy, he was an experienced professional with a witty sense of humour which was very useful in his role as the master of ceremonies at many of the closing dinners at the annual conference.

As we go to print, registrations for the 26th Annual Conference and Trade Exhibition to be hosted by the Electric Power Corporation (EPC) of Samoa in Apia has been open since the end of January 2017. This year's conference will be EPC's second time to host having been host to the 5th Annual Conference in 1996. Members should book early to take advantage of the discount rates.

It would be remiss of me to sign-off without welcoming to the Association our new Allied Members who have join since the last issue of the magazine; America's Best Electrical Mart, AVO New Zealand, EPC International Pty Ltd, Generator Rental Service Ltd and Indra Australia Pty Ltd. The Association values the support of all the Allied Members.

On that note and until the next edition,

Cheers.

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Baseload Renewable Energy using Diesel Engines

John Fox
Chief Executive Officer, ElectraTherm, Inc., USA.

Continuous duty gensets provide base load power generation in diverse applications around the globe. In the past, there were no proven commercial products for converting engine heat to power so operators had little choice but to accept the heat loss to the atmosphere. Today ElectraTherm has deployed more than 50 units worldwide with over 70 years of cumulative fleet experience with excellent availability. ElectraTherm is the leader in small-scale, distributed power generation from waste heat utilizing Organic Rankine Cycle (ORC) and proprietary technologies to generate power from low temperature heat ranging from 77-122°C.

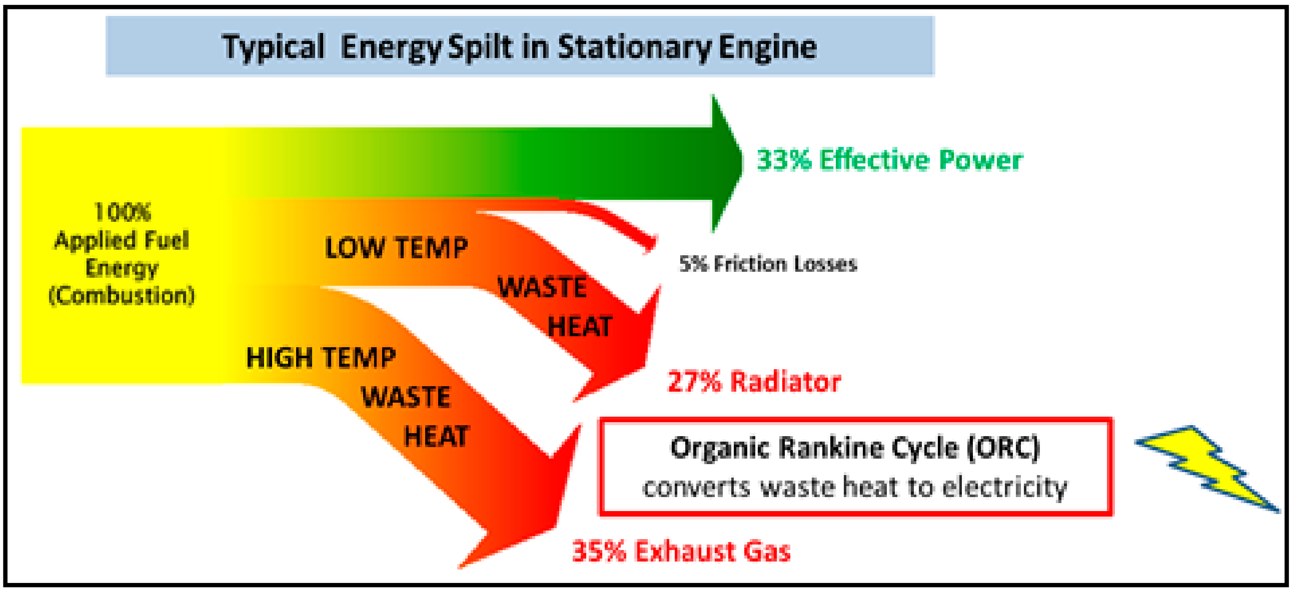
ElectraTherm's Waste Heat to Power (WHP) technology converts various sources of heat into power, including internal combustion engines, small scale geothermal, biomass, flare gas, and process heat. ElectraTherm's primary market is waste heat from stationary internal combustion engines. With the typical engine running at about 33% efficiency, there is considerable waste heat between the jacket water and the exhaust. Typical engine sites include: prime power production in remote areas, island and developing nations, biogas gensets including landfill and wastewater treatment plants, natural gas compression stations and renewable biofuels.

ElectraTherm has demonstrated over a 10% increase in fuel efficiency along with simple installation, mobility and low maintenance. The Power+ can replace the engine's radiator entirely and deliver a payback of three years or less for diesel or heavy fuel oil-fired gensets such as those deployed all across Asia Pacific. In effect, the engine's waste heat becomes a source of cost savings by displacing the radiator's capital cost and parasitic load, i.e. more power with no incremental fuel costs and no added emissions.

How it Works

ElectraTherm's Power+ Generator operates using a closed loop ORC, where hot water is the fuel. Hot water from the engine enters a heat exchanger to pressurize the non-flammable, non-toxic working fluid, driving the twin-screw expander and generator to create electricity. ElectraTherm's patented twin-screw expander is unique in its configuration, lubrication and specifications, but the core technology is based on reliable, proven compressor technology that has been around for more than 20 years.

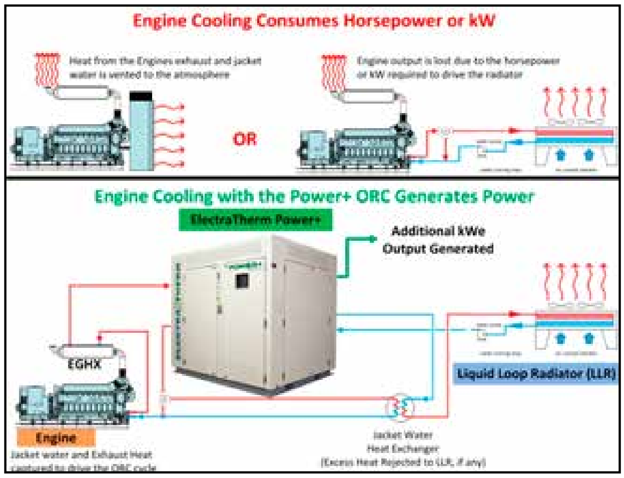
The twin screw expander has a rotational speed of 1800 - 4900 RPM, considerably less than turbo expanders. Unlike high speed turbo expanders, screw expanders are robust units that tolerate "wet" dual phase flow. This allows the Power+ Generator to utilize more cost effective and compact heat exchangers that tolerate perturbations in both temperature and flow with turn down ratios of 6:1 available on demand. This is particularly advantageous in low temperature waste heat streams such as engine jacket water. Through a patented lubrication scheme, the Power+ Generator design is simplified and eliminates lubrication reservoirs, oil coolers, pumps and land filters, creating a simple, robust, and efficient system with fewer parasitic loads and maintenance requirements. Engine gensets are a great match for ElectraTherm since a significant portion of the waste heat is at low temperatures and engine throttle positions can vary widely depending on the electrical load demand.



Because there are multiple waste heat streams from an engine there are correspondingly multiple ways to apply ORC technology to an engine.

1) JW only – single heat stream to ORC
2) JW boosted by exhaust – single heat stream to ORC
3) JW and exhaust utilized separately – dual heat streams to ORC
4) Exhaust only – single heat stream to ORC

Maximum electrical output is achieved when both JW and exhaust waste heat streams are utilized. Maximum parasitic load offset from engine cooling is achieved when all the JW energy can be consumed by sizing the ORC appropriately. The combined benefit by offsetting the cooling loads AND producing power can have a 10%+ effect on engine fuel consumption. With a new site, the engine radiator can be replaced (never purchased) by the Power+ Generator and its condenser, a liquid loop radiator. A secondary loop is configured between the engine and the condenser for the ORC, and this loop controls the return temperature of the jacket water to the engine. The ORC condenser is sized for 100% heat rejection for the engine, so the ORC and the engine cooling operate seamlessly whether the ORC is on or off.



Many Benefits of Heat-to-Power for Stationary Engines

There are multiple benefits to integrating an ORC heat to power generator with an engine genset. The first benefit is clear: the additional electrical output from the conversion of the waste heat to electricity with no additional fuel consumption or emissions. Second and less obvious is the reduction or elimination of the parasitic load from the engine cooling fans. The Power+ Generator acts as the radiator and, therefore, the engine-driven radiator fans can actually be disconnected, allowing more work to be performed by the engine to generate additional electricity. A third benefit can be achieved in hot climates or seasonally high ambient conditions, since the ORC's cooling requirements are much greater than the engine's cooling requirements – additional cooling capacity at high ambients may improve engine performance. The Power+ Generator electricity output combined with reduced parasitics account for more than 10% fuel efficiency gain depending on engine size and configuration. The additional benefit from decreasing the engine's de-rate period or the amount of de-rate will, of course, vary with ambient conditions.

ElectraTherm currently manufactures a 35 kW unit that fits well with ~500 kW gensets (4200 model), a 65 kW unit which fits well with ~800 kW engines (4400 model), and a 110 kW unit (6500 model), well suited for 1-2 MW engines.

ElectraTherm's experience to date with genset integration has been very successful. Applications include single engines and multiple engines utilizing jacket water heat alone as well as jacket water combined with exhaust heat. Engine models that have been integrated with the Power+ Generator include Jenbacher, Deutz and MWM engines in Europe as well as CAT and Waukashau engines in North America.

Collaboration with Chuuck Public Utility Corporation

ElectraTherm collaborated with the Chuuck Public Utility Corporation on a Power Station waste heat recovery feasibility study. The utility was seeking a waste heat recovery solution to their newly built power station. With the station already built and in operation, it was critical to find a solution that fit perfectly with their specific needs and could be seamlessly integrated with little to no downtime.

The study determined that ElectraTherm's Power+ 6500 was the optimal fit for a 900kW engine and a flue gas heat exchanger. The project was estimated between 3-5 years for return on investment based on all costs and labor. The study was favorable to the ORC integration, based on economics and the robust, proven technology of ElectraTherm and its international fleet.

Conclusion

Distributed WHP systems for stationary engines are not yet well known or mainstream in Asia Pacific, but the technology is field proven, and the economics are attractive. ElectraTherm's various packaged solutions are making it easier to economically capture waste heat and make emission-free and fuel-free power from sources that already exist.

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Cost of Service and Tariff Review of Solomon Power, Solomon Islands

Pradip Verma
Chief Executive Officer, Solomon Power.

The Government of Solomon Islands (SIG) and Solomon Power (SP) are committed to the importance of having dependable, accessible, and reliable electricity supply in Solomon Islands to promote sustainable economic development. Towards this end, SP with the assistance of World Bank, has conducted a Cost of Service and Tariff Review during 2015-2016. This study was carried out by Quantum, a Consultancy firm based in Argentina selected through a rigorous World Bank procurement process.

The current electricity tariffs charged by Solomon Power in Solomon Islands are set by a regulation gazetted in 2005. This is a simple calculation based upon CPI movements and Fuel Price Movements. This simple tariff has been running for nearly ten years and is overdue for a review.

The purpose of conducting a Cost of Service Study is to determine SP's full costs of providing electricity for various categories of customers. SP's full cost of service includes its efficient operating costs plus an appropriate return on the assets necessary to produce, deliver and sell electricity to its customers and meet growing demand through prudent investment.

The Cost of Service is being utilised by SP to determine and understand its internal cost structure so that it can better control its costs, manage its business on a commercial basis, improve customer service and its financial performance. A Cost of Service is used by the SIG to inform its policy decisions, develop SP's revenue requirements and set appropriate tariff levels that will enable SP to meet service levels and meet demand growth over time.

The purpose of this paper is to discuss the methodology utilised to determine the energy, maximum demand, non-fuel operating expenditure, capital investment, and the building block approach for revenue determination, Weighted Average Cost of Capital and a tiered tariff structure.

An outcome of the above study is the Draft Electricity Tariff Regulations 2016 which when gazetted will replace the current Tariff Regulations 2005. The draft tariff structure is also discussed in this paper.

Cost of Service and Tariff Review

Objectives

- Provide a safe, reliable, affordable and accessible supply of electricity to the Solomon Islands
- Long term sustainability of Solomon Power
- Meet Solomon Islands Government's commercialisation objective
- Increase economic growth in the Nation
- Building the Nation

Background

- Need to review and revise the existing tariff regulation
- Study funded by World Bank
- Consultant selected by a tender process
- Phase I (diesel only)
- Phase II (diesel and renewal sources of energy)

Challenges for Solomon Power

- Affordability
- Accessibility
- Delivery of a $1 billion capital infrastructure program
- Development and sustenance of human capital

1.0 Process adopted

To ascertain the cost of service and tariff a 9 step approach was adopted by Quantum. These are as follows:

Step 1: Identify customers

Step 2: Forecast Growth

Step 3: Energy Sales GWH

Step 4: Energy generation= Losses+ Energy Sales

Step 5: Demand requirements MW

Step 6: Capital requirements in terms of investment

Step 7: Operation and Maintenance Expenditure

Step 8: Revenue Requirements

Step 9: Translation into tariff

The census data, economic statistics and growth of the customer base over the last 5 years and other relevant parameters were utilised to identify the customers, the consumption and the future anticipated growth.

2.0 Phases

The assessment of cost of service, revenue requirements, and tariffs for Solomon Power over a 25 year time horizon (2014-2039), was carried under two broad scenarios:

Phase 1	Phase 2
Demand: projections	Demand: (as phase 1)
Cost of capital: 10.34%	Cost of capital: (as phase 1)
Initial RAB: SBD730 million	Initial RAB: (same as phase 1)
Fuel price : SBD 2.34/kWh sold (2015)	Fuel price: (same as phase 1)
Capex: Diesel only	Capex:
	Tina River as PPA (2022), Hybrids
	Solar Farms

3.0 Load growth scenarios considered

The Cost of Service and Tariff Review modelled the future tariff based on three scenarios, the Base Case, the Downside Case and the Upside Case The projected customer growth for the Base Case is 1.3%, the Downside Case is -2% per annum, whereas in the Upside case the projected customer growth per annum is 11%.

The cost of service and proposed tariff has been determined based on the Upside Case.

4.0 Building block approach

Maximum allowable revenue= Non-fuel expenditure + Fuel expenditure

Non-fuel expenditure= RAB*WACC+ Depreciation + Non-fuel operating expenditure

RAB= Regulated asset base

WACC= Weighted average cost of capital

WACC is based on cost of debt and cost of equity

Adopted capital structure: 60% debt and 40% equity

4.1 Calculation of WACC

The cost of equity was determined by utilising the Capital Asset Pricing Model and the cost of debt by adding a debt risk premium to the risk free rate.

WACC parameter/ calculation			
	Equity (40%)		Debt (60%)
Risk free rate (10 year commonwealth bond rate		5.68%	5.68%
Debt risk premium (BBB+ corporate)			1.77%
Market risk premium	6.5%	6.5%	
Equity Beta	0.8%	0.8%	
		5.2%	
Country risk premium		10.7%	
Return on equity		21.58%	
Cost of debt			7.45%
Proportion of funding		40%	60%
Equity and debt contribution		8.632%	4.47%
Weighted average cost of capital(nominal)		13.10	
Inflation		2.5%	
WACC Real		10.34%	

The capital structure of 40% equity and 60% debt is selected on the basis of the assumption that if Solomon Power was a operated like a private company the owners would choose to adopt this capital structure.

4.2 Non-fuel operating expenditure

These include wages, rents, taxes, insurance, repairs and maintenance, training and other expenses.These were determined by the utilisation of the Cobb Douglas methodology.

4.3 Fuel operating expenditure

This is an uncontrollable expenditure which is just a pass through to the customer.

4.4 Regulated Asset Base

The RAB for each year is calculated based on opening balance on 1 January less depreciation plus assets commissioned during the year. For example:

[1 January 2016 Opening balance of RAB]
\+ [$ value of commissioned assets during 2016]
\- [Depreciation during 2016]
= [Closing Balance of RAB on 31 December 2016]

The RAB for the 5 year period 2016-2021 has been calculated in SBD of 31December 2014 based on the estimated/projected capital works during this 5 year period.

5.0 Translation of revenue to tariff

The overall revenue is derived from the customers. There are three broad categories of customers: domestic, commercial and industrial. Under each of these categories there are tiers based on monthly consumption rate. These are shown in Table 1 below:

Table 1

Customer Category	Monthly consumption rate
Domestic	D1 <50kWh
	D2 50-200 kWh
	D3 200-500 kWh
	D4 >500 kWh
Commercial	C1 <250 kWh
	C2 250-600 kWh
	C3 600-1300 kWh
	C4 1300-2500 kWh
	C5 >2500 kWh
Industrial	I1 <1300 kWh
	I2 1300-6000 kWh
	I3 >6000 kWh

The tariff for each tier is so established such that it is attractive to the customer and lower than or as close as possible to the best alternative option. For example for a domestic customer who consumes less than 50kWh per month the best alternative option to electricity considered is kerosene lamps and candles.

5.1 Non-Fuel Base Tariff

The Non-Fuel expenditure component in the building block is recovered from the customers through a non-fuel base tariff.

A Non Fuel Base Tariff has been calculated for the next five-year tariff period beginning on 1 July 2016. This Non Fuel Base Tariff is stated in SBD of 31 December 2014 and therefore it needs to be indexed as explained in section 5.1.1.

The Non Fuel Base Tariff for each customer category consists of a Network Access Charge (NAC) and a Non-Fuel Variable Charge. The Network Access Charge (NAC) is a fixed charge per customer per month.

The Non-Fuel Variable charges are proportional to the kWh consumed. The NAC is converted to an equivalent variable charge for Cash Power (prepay) customers.

5.1.1 Adjustments to the Non-Fuel Variable Charge

The following adjustment mechanism will allow SP to incorporate changes in the input prices that are beyond its control.

Non-fuel charges (Base Tariffs), which contain costs for various activities performed by SP, shall be indexed every month. This adjustment index has the following formulation:

NFAI = NFAF ± X ± Z

Where:

- NFAI = Non-Fuel adjustment index
- X = X-factor for the next five-year period based on a total factor productivity study used in determining the appropriate level of the X-factor. Currently the X factor is zero.
- Z = the allowed rate of price adjustment for special reasons (cyclone, earthquake, floods, etc.) not captured by the other components of the formula. This will require a special application to and approval by the Minister.
- NFAF = Non-Fuel adjustment factor. This factor is a monthly adjustment to take into account the inflation and devaluation and is calculated as follows:

$$NFAF_m = \Delta CPI_{m-7} \times A + \frac{EXC_{m-7}}{EXC_0} \times \Delta PPI_{m-7} \times B$$

Where:

- *The NFAF index represents the monthly rate of change in non-fuel electricity prices.*
- *CPI_0=Base CPI rate. This is the December 2014 CPI index of 181.7 published on the CBSI web site in their Quarterly Reviews. The appropriate table is Table 1-30 "Honiara Retail Price Index" – All items*
- *ΔCPIm-7 = CPIm-7 / CPI0: Solomon inflation rate variation to be applied in month m. The CPIm-7 corresponds to the inflation which occurred seven months prior to the month for which the tariff is being adjusted.*
- *A: Incidence of costs affected by the local inflation. This was determined to be 39.1% by the Tariff Review.*
- *PPI_0= Base PPI rate. The December 2014 PPI is 110.8*
- *ΔPPIm-7 = PPIm-7 / PPI0: US inflation rate variation to be applied in month m. The PPIm-7 corresponds to US inflation which occurred seven months prior to the month in which the tariff is being adjusted.*
- *EXC_0= Base Exchange rate for SBD into USD. 7.59 for December 2014 as published by CBSI*

in their Monthly Economic Bulletin.

- *EXC_{m-7}= This exchange rate for SBD into USD corresponds to the exchange rate which occurred seven months prior to the month in which the tariff is being adjusted.*
- *B: Incidence of costs affected by the international inflation. This was determined to be 60.9% by the Tariff Review*
- *A+B=1*

The monthly adjustment formula of the non-fuel component of the tariff charges applies to each of the charges set for the different categories and consumption ranges. Parameters A and B shall be updated in each tariff review, which is expected to occur every five years.

5.2 Fuel Base Tariff

This is the mechanism to determine and adjust the fuel charge on a monthly basis. It allows SP to incorporate efficiency changes and/or changes in fuel prices that are beyond the control of SP.

The fuel cost to be passed through is expressed as fuel charge with efficiency modifications for heat rate and system losses. The efficiency factor to be applied to the fuel cost pass-through shall operate according to the following formula:

$$\mathrm{FPT} = \mathrm{AFC} \times \frac{\mathrm{THR}}{\mathrm{AHR}} \times \frac{1-\%\mathrm{AL}}{1-\%\mathrm{TL}} \qquad (1)$$

FPT: Fuel Pass-Through (SBD)
AFC: Actual Fuel Costs (SBD) plus PPA costs
THR: Targeted Heat Rate (litres/kWh) equal to 0.2700litres/kWh
AHR: Actual Heat Rate (litres/kWh)
%AL: Percentage of actual energy losses measured from the Power Station gate
%TL: Percentage of targeted energy losses equal to 23%
Then, the Fuel Charge is given by the following formula, applied on a monthly basis:

$$\mathrm{FC} = \frac{\mathrm{FPT}}{\mathrm{TS}} \qquad (2)$$

Where

FC: Fuel Charge (SBD/kWh)
FPT: Fuel Pass-Through (SBD)
TS: Total monthly sales (kWh)
Considering that SP must communicate in advance the tariff charges for each subsequent month, in order that users are informed and can take their decisions, the adjustment procedure and transfer to the users of the fuel cost is given in the following way:
Consider month m for which the Fuel Charge should be established.
SP is transiting month m-1.
The most recent month concluded for which the actual fuel costs incurred are known accurately is the month m-2.

SP should then proceed to calculate the fuel cost to be applied in month m, based on the cost incurred in month m-2.

$$\mathrm{FPT}_{m-2} = \mathrm{AFC}_{m-2} \times \frac{\mathrm{THR}}{\mathrm{AHR}_{m-2}} \times \frac{1-\%\mathrm{AL}_{m-2}}{1-\%\mathrm{TL}} \qquad (3)$$

For the Fuel Charge calculation, SP should consider the energy sales (TS) that occurred in month m-2. Thus the Fuel Charge to be applied during month m is as follows:

$$\mathrm{FC}_m = \frac{\mathrm{FPT}_{m-2}}{\mathrm{TS}_{m-2}} \qquad (4)$$

Actual energy sales for month m will differ from.

Therefore, SP will have recovered in more or less the fuel cost spent in the month m-2.

Hence, the formula to calculate the fuel cost to transfer to tariff requires a term that captures the deviations which have occurred during each month.

Therefore, the generic formula which calculates the fuel cost is the following:

$$\mathrm{FPT}_{m-2} = \mathrm{AFC}_{m-2} \times \frac{\mathrm{THR}}{\mathrm{AHR}_{m-2}} \times \frac{1-\%\mathrm{AL}_{m-2}}{1-\%\mathrm{TL}} + \Delta\mathrm{FPT}_{m-4} \qquad (5)$$

Where:

$$\Delta\mathrm{FPT}_{m-4} = \mathrm{FC}_{m-2} \times (\mathrm{TS}_{m-4} - \mathrm{TS}_{m-2}) \qquad (6)$$

About the author
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Currently he is the Chief Executive Officer of Solomon Islands Electricity Authority. Before taking over this position Pradip was employed with Transend Networks, Tasmania, Australia as Acting General Manager, Transmission Services. Pradip has extensive experience in the electricity generation, transmission, distribution and retails utilities in India, Algeria, Bahrain and Australia spanning over 38 years.

Pradip has a Bachelor's degree in Electrical and Electronics Engineering, Masters in Business Management, Diploma in Computer Programming and a Diploma in Company Directors Course, Australia.

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Age of Renewable Power Systems – Transformation of Island Power Systems

Dusan Nikolic, Brendon Bateman, Chris Blanksby
Entura, Hydro Tasmania

Abstract

There is a global trend of moving towards renewable power systems. With the hype that surrounds this, utilities have found themselves caught between public demands and government initiatives for change on one side, and responsibility for taking a measured approach and delivering safe, reliable, and quality electricity supply to the community on the other. Additionally, renewable energy systems have proven to be capital extensive, especially when additional enabling technologies such as battery energy storage are included. Finally, most of the technologies are still in their infancy and planning for the future, utilities could potentially be investing in problems, and not solutions.

This paper discusses common utility problems during transition to 100% renewable energy. It discusses the cost of implementing wide-scale renewable energy systems. It discusses utility staff capabilities and how they should transition, along with installed technologies. It presents technology traps and outlines how to avoid these. It also discusses involvement of Independent Power Producers in isolated power systems.

Finally, this paper proposes a methodology for cooperative approach between all stakeholders, which delivers a safe and reliable power system operation for the future.

1. Introduction

Twenty-first century kick off with a strong political will in Pacific nations for reaching high renewable penetration and reducing harmful gas emissions. This visionary step aligned multiple stakeholders – governments, global funding agencies, private investors and technology suppliers.

In the middle of the hype are island power system utilities which hold the responsibility for reliable power energy supply. Faced with firm political will on one side and responsibility to communities in which they operate, modern island power utilities found themselves navigating though complex landscape.

This paper discusses some of the challenges island power utilities might encounter. It discusses the need for planning and understanding renewable energy journey a power system is embarking on, presents and discusses some of the common technology traps on this journey, and proposes a framework for efficient project delivery and operational and maintenance teams.

2. Cost effectiveness of reaching 100% renewable energy penetration and need for strategic planning

One of the first hurdles to on a renewable energy (RE) journey is understanding how the cost of generating electric energy will change going from 0 to 100%. Since most of the decisions on this journey are impacted by economic factors, good planning is necessary at the very start.

Adding a small amount (typically less than 15%) of RE into a system is very cost effective. There is no spill or required enablers, so the cost of energy is at a minimum. However, with more generation, this situation unravels, and the cost of energy increases as shown in Fig 1. The initial trajectory of declining total cost of supply lasts only briefly, before the cost of enablers and spilt energy becomes critical.

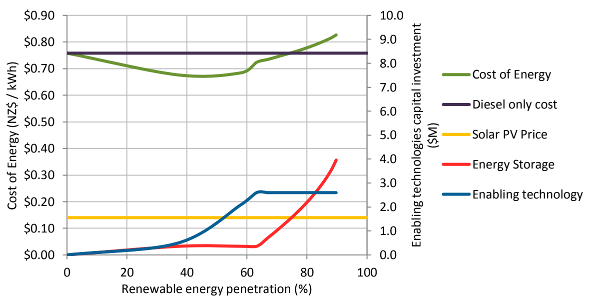

Fig 1. Example of impact of increasing renewable energy contribution on the cost of electricity supply (real case studies based on one of the scenarios for Aitutaki power system, Cook Islands)

The point at which the total cost of supply exceeds the levelized cost of electricity (LCOE) of diesel is typically the maximum portion of renewable energy that can be economically achieved in that system. This point is sensitive to factors such as LCOE of solar vs diesel, transport costs, the cost of planning and design, and available technology, each of which varies with the isolation and size of the island.

Navigating costs of implementing new technologies towards reaching political goals of very high renewable energy penetration requires complex strategic planning. The goal of such planning is identifying potential blockers early in the process, so the utility does not find itself paying for costly technologies which do not achieve intended results. Strategic planning process is also a very good stakeholder management tool, as it keeps utilities, governments and funding sources aligned towards a same goal.

3. Common technology traps

3.1. Medium vs high speed diesel engines

Most Island power systems around the world are primarily powered by diesel generators. As diesel generators consume costly diesel fuel, there was a clear incentive for selection of diesel generators with higher fuel efficiency. For last several decades, medium speed engines were favored against high speed diesel generators.

There was a good reason for favoring medium speed engines. These machines were made for marine applications, where an oil tanker had to run at rated capacity for weeks at time. Since they consume a lot of fuel, people made those machines quite fuel efficient. At the time, high speed engines were of poorer quality and could not compare with medium speed diesels in terms of fuel efficiency.

As highly efficient, medium speed engines were quickly accepted by power industry. While a power system demand changes over a day, it does it ever so slowly, so fuel efficient medium speed machines were a good choice. However, in recent decade, technological progress saw rapid increase of diesel fuel efficiency in high speed engines. Some diesel generator producers even claim high speed engines surpassed fuel efficiency of medium speed engines.

Compared to high speed engines, medium speed engines are twice the size, for similar power output, twice the weight, and most usually, twice the price.

Another thing to consider when selecting diesel generators for future systems is how they behave under quickly changing power system load. Since renewables are perceived as an offset in power system load, diesel generators see only the difference between the real load and renewable energy output. If renewables have highly variable output (as they usually do), diesel generators also see very variable load. This is the first problem with medium speed generators, as they do not respond very well to variable load. The second problem is their minimum loading threshold. The idea of high renewable integration is to push diesels as low as possible, so more renewable energy will be absorbed by the system. High speed engines can be pushed down to 30%, while medium speed engines should work above 50-60% at least. Finally, high speed engines are better responsive to power system dynamics of any kind.

So, for integration of renewables, high speed diesels are the best option. In terms of fuel efficiency, it seems that high speed engines have caught up with medium speed diesels. Economically wise, high speed diesels are at least half the price.

Even marine industry is changing its course – towards installing high speed engines instead of medium speed in ships as well – they are cheaper, have same fuel efficiency and are way smaller.

3.2. Power system services and enabling technologies

Diesel generators are a century-proven technology and are perfectly suited for provision of power in island systems across the globe. One single machine embodies all of the services a power system might need. The only down side of diesel engines is costly and environmentally unfriendly fuel burning, which turns attention to other, cleaner technologies.

When substituting diesel generators with different technologies, it is important to replace all the services diesel generators provide to a power system, and not only provision of real and reactive power. Those services are:

- Real (kW) power,
- Reactive (kVAR) power,
- Frequency control,
- Voltage control,
- Inertia,
- Fault currents, and
- Spinning reserve.

All of the above services need to be present in power system for it to have a stable and reliable operation. If a diesel generator is not present in the system suitable technology, or several technologies need to be present in the system. Only then can a system with high renewable penetration have reliable and stable operation. Since the technologies which substitute diesel generators can enable high renewable penetration in island power systems, they are simply referred to as enabling technologies.

When a variable renewable energy source is added to the diesel-only system, it usually provides only the real and reactive power components of the power system services. This lack of provision of other services can sometimes be detrimental to the system stability. Various enabling technologies are then added to the system for complementing renewable energy sources, and which can provide a number of power system services.

Battery energy systems are most usually added to a renewable energy system to provide spinning reserve. Some batteries can even provide voltage and most modern ones, frequency control. Other technologies such as flywheels are excellent in providing power system inertia. Technologies such as synchronous condensers are the best alternative for diesel generators when it comes to voltage control, inertia and fault currents.

It can be easily seen that diesel generators, machines which provide all of the necessary power system services are very hard to replace, and that no technology alone is yet ready to make that step. The best solution larger power systems can devise is using the strengths of several enabling technologies at once, with each one contributing power system services it is best at.

3.3. Battery energy storage systems (BESS)

Battery energy storage systems are currently the most widely known enabling technology, with a lot of research and development involved. This technology is marketed as the problem-solver for all renewable power system, however, what is interesting to note is that it does not provide all the power system services outlined in the previous section.

Batteries cannot effectively produce high fault currents or successfully emulate system inertia. Due to these limitations, use of batteries is recommended in two cases only:

- In small power systems, where power system stability and electric energy delivery reliability does not need to be high, or
- In larger power systems, where additional enabling technologies are functioning alongside batteries, and as a group are providing all of the power system services.

3.4. Other new technologies

Finally, what is important to note is that most of the technologies nowadays are not decades-proven and there are very few systems who reached high levels of renewable energy penetration, and which are yet to be economically and technologically assessed.
New technologies do not produce shortcuts to high renewable energy penetration and they most probably never will. The key to reaching high levels of renewable penetration usually lies in good compromises.

4. Independent power producers in Island power systems

On a road to 100% renewable power systems, some islands allow connection of independent power producers (IPPs) into an island power system. This is s convenient arrangement, as IPPs bring private capital into island power systems and usually contribute to increasing renewable generation.

It is important to realize opposing interests between island utilities and IPPs. Island utilities have a goal of increasing renewable penetration while providing reliable power supply. This goal is achieved by providing all the power system services described in section 3.2. On the other hand, IPPs have a goal of increasing profit, which is usually achieved by providing only one of the power system services, provision of real (kW) power. An island power system with too many generators which do not provide all the power system services might find itself very unstable.

One of the solutions to this conundrum can be an equal competition of the utility and IPP generation in a power system. If both parties provide all the necessary power system services, they can be easily integrated into the system.

To conclude, IPP can provide reliable generation in the system which will not cause power system issues. In such a case, a proposed solution should provide all the power system services, just like a diesel generation would. Systems which allow IPPs to generate without providing power system services will ultimately need to provide those services themselves, at a greater cost.

5. Operation and maintenance staff in renewable power systems

Operation and maintenance crews in conventional island power systems usually consisted of diesel fitters and electricians, with basic technical skills.

Renewable energy technologies are relatively new and very modern. All of the new technologies are also closed, and can only be assessed and queried by computers. This moving from traditional hands-on approach to investigations using software and computers implies new breed of operational and maintenance crews.

Renewable power system operational and maintenance crews need to be proficient in understanding several different technologies, such as battery and solar inverter technologies, wind turbines, communication technologies and complex control systems.

Renewable power systems are also more dynamic than conventional power systems. This means power system operators need to make decisions more quickly. It also means they need to stay informed about power system operation all the time, which is a functionality modern control systems and information technologies bring.

Resources invested in an island power system need to see optimal operation of renewable energy technologies for years to come. Adequate operational and maintenance crews are the work force which usually make this happen. Hence, training and ongoing development of operational and maintenance crews in understanding new technologies is the key.

While diesel-only power systems resemble each other, renewable energy power systems are different, due to the different and usually very unique renewable energy resource, its intensity or variability. Island power systems are leading the way in venturing into the age of renewable energy systems. This provides unique opportunities to Pacific utilities to develop and capture the knowledge and understanding of how these new renewable energy systems behave during their services life, and which new skills need to be developed that will allow these systems to meet the promise of clean energy over the future decades.

Just as it was essential for a diesel-only power system to have good operational and maintenance routines, it is essential for renewable energy power systems as well. With the uniqueness of renewable energy systems as a challenge, the new breed of technicians do not need to be equipped with procedures, but with deep understanding of renewable energy resources and new technologies, so the promise of renewable energy truly does benefit the communities they live in.

6. A Collaborative, Multi-disciplinary project approach

Delivery of high renewable energy integration in island power systems requires a comprehensive team approach, which cuts across a range of traditional boundaries. Delivery of a high contribution renewable energy system requires increased community energy literacy; buy-in from utilities, landowners, private capital, and various government agencies; and access to technical assistance and capacity building. An example of such a team is presented in Fig 2.

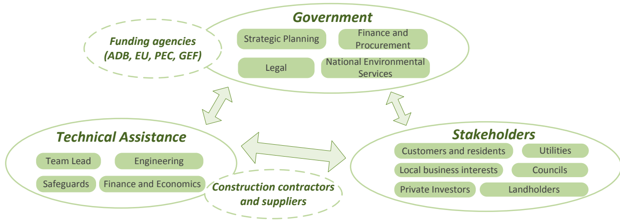

Fig 2. A Collaborative, Multi-disciplinary project team

7. Conclusions

There is a significant drive for island power systems to reach 100% renewable energy penetration. Most Pacific governments have set targets towards this goal, and power utilities found themselves between firm political will and technological, economic and stakeholder problems.

Solving a high renewable penetration conundrum is not a straightforward step, it is a multi-stage journey, which begins with adequate strategic planning. Accepting this approach provides an opportunity for adjusting decisions on size and type of renewable and enabling technologies. It also provides an opportunity to re-assess project economics along the way and utilities and power system operators to adjust to new technologies and power system dynamics.

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Fuel Saving Solution With Scalable Battery Storage Systems

Wendy Truong
Application Engineer, SMA Australia Pty Limited

Introduction

There has been an increasing number of renewable energy systems incorporated into the micro-grids in the Pacific Island Countries and Territories (PICTs) as Island Leaders steer their respective countries to meet renewable energy targets and reduce fossil-fuel dependence. Photovoltaic (PV) systems have been the most popular of renewable energy technologies due to its relatively low complexity in operation and maintenance whilst being cost effective when compared to the running of thermal generators.

For micro-grids with <20% penetration rate of renewable energy sources such as photovoltaics (PV), there are negligible effects on the utility grid and generally a control system is not required. (Isaka, 2013) However, the power provided from a PV system can be intermittent due to the nature of the technology, which means penetration rates of 20-80% within a micro-grid would require a system controller and accompanying generation or storage technology to maintain grid power quality and stability during fluctuations. By the same token, the load operation on a grid with PV penetration should be taken into account as abrupt changes in loads can have a similar effect to fluctuation in PV generation from weather changes. In systems where the penetration is higher than 80%, the use of battery storage becomes necessary to ensure spinning reserve is readily available to regulate voltage and frequency. The addition of battery storage is not limited to systems with penetrations rates above 80%; there are advantages of integrating storage at lower solar penetration rates as it offers ancillary services like power factor correction, load levelling and peak shaving.

The system controller with the integration of battery energy storage cannot be a rigid solution as there are over 3000 islands in the PICTs with various grid sizes and infrastructure. (IRENA, 2013) SMA Solar Technology AG is considering the use of a controller like the Fuel Save Controller with decentralised Power Conversion Equipment (PCE) like the Sunny Islands, which means that the battery storage system need not be large, and can be adapted to suit different micro-grid sizes. This paper explains conceptually how a decentralised system may look like compared to a larger centralised solution.

Technology

I. Fuel Save Controller

The Fuel Save Controller (FSC) is designed for diesel grids where PV penetration may affect the grid stability and power quality. It can limit the power from PV inverters and maintain the spinning reserve of secondary thermal generators by acting as a central point of information collection. It communicates directly to PV inverters, generator controllers and also has the ability to collect measurements from the grid. As shown in Figure 1, the communication hierarchy of the FSC provides a centralised communication platform to the utility SCADA system by collating the information from the equipment. This design avoids complex communication networks associated with sub-controllers and minimises the need for specialised technical knowledge across a range of devices.

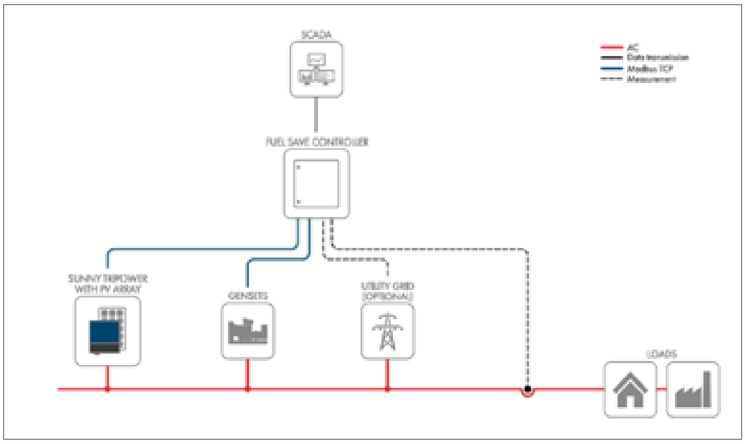

Figure 1 SMA Fuel Save Controller with Gensets & PV integrated

II. Fuel Save Controller with a Centralised Battery Storage System

For current FSC systems with integrated storage, it remains relatively simple in terms of operation and communication. Figure 2 shows the battery storage system is connected directly to the FSC, which maintains the batteries and provides dynamic grid support. An example of such a large scale storage system was installed and commissioned on a micro-grid in St Eustatius, Caribbean. (SMA Solar Technology AG, 2016) The 1.89MW PV system provided a penetration rate of 89% and is expected to provide 800 000 litres of diesel fuel savings per year. There are various sizes of the battery inverter, Sunny Central Storage, so it can work with systems that needs less than 500kW from the batteries. However, this may be larger than what some island micro-grids require and the associated costs involved with a centralised battery system may delay renewable energy integration due to the possible risks it poses to the grid.

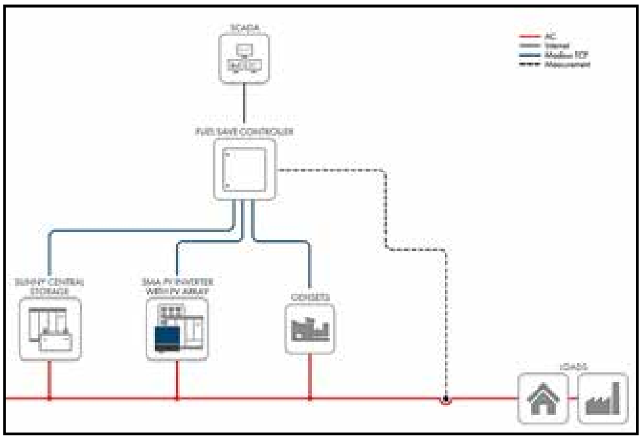

Figure 2 SMA Fuel Save Controller (FSC) with centralised battery storage system

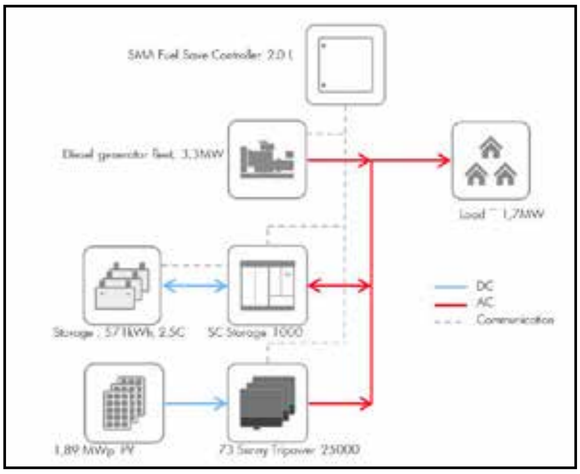

Figure 3 Technical overview of a PV hybrid system in St Eustatius, Caribbean (SMA, 2016)

III. Fuel Save Controller with Decentralised Battery Storage System

The concept of decentralised battery storage energy systems would incorporate FSC as the main controller with the PV inverters and battery storage system installed in parallel to the AC grid. With the previous centralised storage solution, there is one power conversion device or inverter for the entire battery pack. The solution proposed in Figure 3 is a modular solution based on individual battery banks with its own power conversion equipment that will also act as the controller to feed information of battery status and SOC to the FSC. With the battery banks operating as individual entities, this allows the systematic expansion of the storage system without changes to the rest of the control infrastructure. The PV system can also be expanded in the same manner where the communication link will be directly between the inverters to the FSC to minimise the introduction of additional hardware.

The FSC will determine when the batteries need to provide grid support based on the information collected from the loads and PV generation. This provides a streamlined interface for the user and allows simple integration into existing SCADA systems as opposed to a complex communication network with information feeds across different controllers.

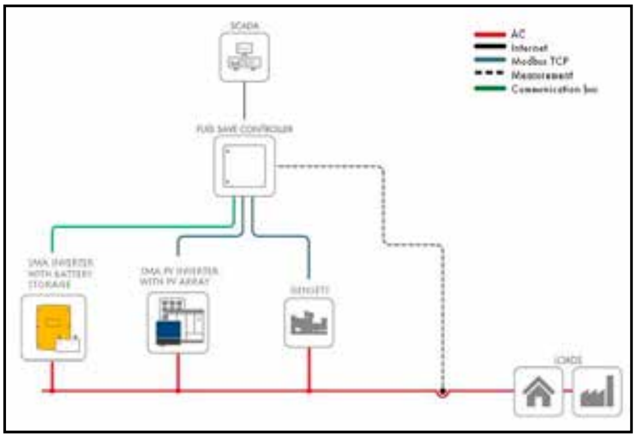

Figure 4 Fuel Save Controller (FSC) with decentralised battery storage system

Applications

A decentralised battery solution with the FSC is intended to provide micro-grid operators flexibility in choosing the size of the storage system to provide grid support requirements. The smallest battery inverter that is compatible with the FSC starts from 500kW, which may not necessary suit the needs of the grid operator. A scalable battery storage system would also provide the operator the opportunity to expand the system if more spinning reserve is required to increase the PV penetration rate on the grid. For island nations with a renewable energy target, there may be a pipeline for projects over several years that can complicate the simulation and design of the storage required. This solution will accommodate the renewable energy projects that will be completed in stages.

As the devices are designed to work harmoniously, the communication interface would be made backward compatible thus reducing communication issues in the future. This also lends itself to streamlined operation and maintenance of the system as the support for such devices would be from a central location of technical experience and expertise. So it is to the advantage of operators to have one controller that can intelligently control all components in a PV hybrid system.

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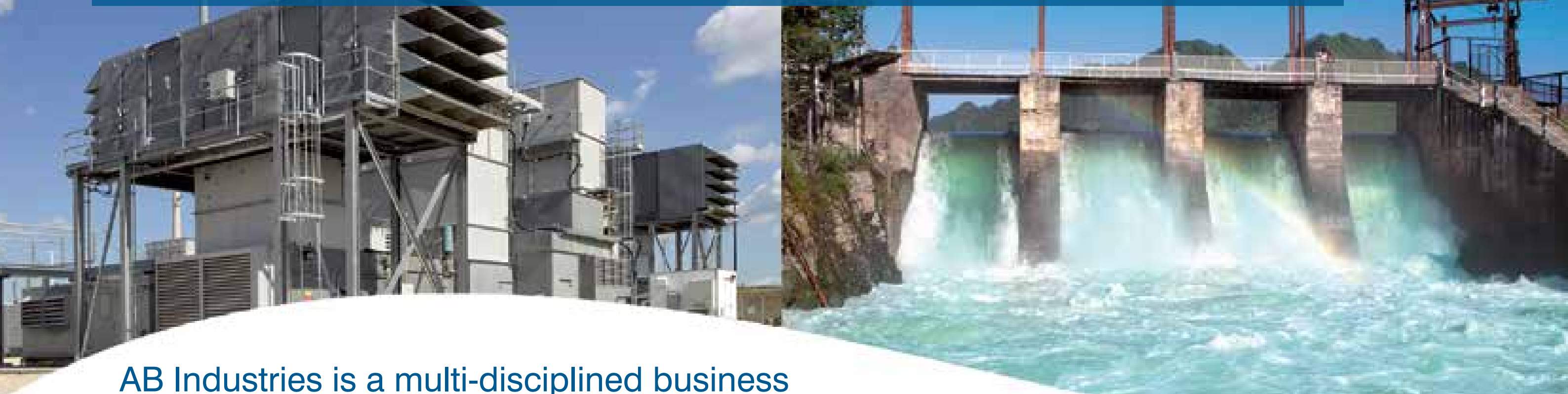

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Isolated Power Systems (IPS) Connect 2016

Pacific Power Association

IPS Connect 2016 was held in Whitemark, Flinders Island, Tasmania, Australia from 28 November to 2 December 2016. The event was hosted by Hydro Tasmania and University of Tasmania and supported through sponsorship by Goana Energy Consulting Pty Ltd and Entura.

The event was attended by delegates from Australia, New Zealand, USA, UAE as well as PPA Utility representatives. The participation of the PPA Utility delegates was made possible through funding from the World Bank funded Sustainable Energy Industry Development Project implemented by the Pacific Power Association, IRENA, World Bank's ESMAP Project and utility self-funding.

The participating PPA Utilities included TAU (Cook Islands), TEC (Tuvalu), PUB (Kiribati), Solomon Power, FEA (Fiji), PUC (Pohnpei State, FSM), CPUC (Chuuk State, FSM), TPL (Tonga), EPC (Samoa) and UNELCO (Vanuatu).

The IPS 2016 program had two components; a 2 days Professional Development course and a 2 days Technical Workshop with a one day island tour sandwiched between the two events.

Professional Development–28/29 November 2016

A two day professional development course was hosted and facilitated by Entura Clean Energy and Water Institute and covered the planning and implementing off-grid hybrid projects. Each island power system project is unique in the energy resources available, load profile, goals of the proponent, specifications of the power system and the logistical challenges presented by the remote location.

The two day course uses the extensive knowledge and experience within Entura and Hydro Tasmania to bring a pragmatic approach to project planning and implementation of renewable hybrid projects. Participants gained insights into issues specific to these kinds of projects and had the unique opportunity to observe Hydro Tasmania's Flinders Island Hybrid Energy Hub which was being commissioned.

Technical Workshop – 1/2 December 2016

The technical workshop brought together practitioners, financiers and owners of renewable energy projects from a number of countries including USA, UAE, Australia and New Zealand. This workshop provided an opportunity for project developers to share their experiences in developing and implementing renewable energy projects.

Presentations during the 2 day workshop looked at the Australian renewable energy market and projects, a number of international projects including those funded by UAE in the Pacific Islands and emerging renewable energy technologies in energy storage and low load diesel generators.

A specific panel session was for the Pacific delegates where the panellist included the World Bank, PPA, TAU, TEC and TPL.

Summary

The PPA Utility delegates found the professional development course to be very useful as this is usually not covered in the previous capacity building programs that have been delivered in the Pacific region. The majority of the capacity development programs in renewable energy tended to concentrate on the technical aspects of renewable energy technology, installation, operation and maintenance.

The technical workshop provided an opportunity for the PPA Utility delegates to learn from others experience; the successes, failures and any pitfalls in the planning and implementation of renewable energy projects.

The Pacific Power Association on behalf of the participating utilities expresses its gratitude to IRENA, the World Banks ESMAP Project and SEIDP for funding the delegates and looks forward to the next IPS event.

The Pacific Power Association also would like to thank the hosts and sponsors for the invitation to be part of the event.

PACIFIC POWER ASSOCIATION

Pacific Power Association

26TH Annual PPA Conference and Trade Exhibition

SHERATON AGGIE GREY'S HOTEL & BUNGALOWS
APIA, SAMOA
31st JULY - 4th AUGUST, 2017

HOSTED BY:

EPC

Samoa's first Wind Energy Project - Vailoa Aleipata

CEOs' Conference Theme:
"Affordable Electricity for All"

The PPA Secretariat is pleased to provide you with the summary information on this year's 26th Annual PPA Conference and Trade Exhibition which will be hosted by Electric Power Corporation, in Apia, Samoa.

The PPA Conference will offer delegates a combination of speeches, donor presentations, technical presentations, Utility Board Members workshop and the Trade Exhibition of products and services by our Allied Members.

Each year the conference gains more participants and it is the largest energy conference in the region, focusing on all aspects of electricity in the Pacific Islands. The 25th Conference held in Nukua'lofa, Kingdom of Tonga was attended by 223 delegates with 41 trade booth displays.

DATE AND VENUE

This year's conference will be held at the Sheraton Aggie Grey's Hotel and Bungalows in Apia, Samoa from 31st July – 4th August, 2017. It will be the second time EPC will be hosting the annual conference.

More details about the conference can be viewed in the official PPA Secretariat website: www.ppa.org.fj

Vale Bill Roberts

Tony Neil
Former Executive Director, Pacific Power Association

I am honoured to have this opportunity to provide this eulogy for Billy Roberts for the PPA magazine.

There is so much that comes to mind that could be set down here that best describes all of Billy's talents. Just some obvious ones that apply were his managerial expertise; his power utility knowledge; his loyalty to RMI, MEC and staff; his love of the Pacific Islands and their people.

One could not forget to mention his well-known sense of humour, which was much appreciated and will always be remembered in the Islands.

Bill Roberts enthusiastically supported the Pacific Islands power utilities association - the Pacific Power Association (PPA) - from the formal start of the PPA in 1992, until his retirement from MEC in 2009; and his clear support during his tenure as CEO of MEC for the Allied Members of the PPA.

I was witness to Billy's character and talents, as I was privileged to be invited to attend the first formal meeting of the PPA held in Saipan in 1992. From 1992 until 1998 I was on the PPA Board as the Chairman of the Allied Members, and from 1998 through to the end of 2010 as the Executive Director of the PPA. So I was associated with Billy Roberts for 18 years.

Also present at this first Annual CEOs' Conference were quite a number of utility CEOs and about 12 private enterprise companies that had been doing business with the utilities were invited.

At this Conference there was a great deal of constructive networking, and importantly there was an agreement within the PPA structure, to permit companies doing business with the Pacific Islands to become Allied Members. The utilities were the Active Members.

During my time as Chairman, I had many dealings with Billy including a number of visits to MEC at Majuro, and attending the Annual Conferences through to 1998. In Majuro, Billy always made one to feel most welcome and helpful and Billy and his staff went out of their way to provide as much information as we needed to improve our opportunities to conduct business with MEC.

During those 6 years all the Allied Members remarked how Billy was so supportive of them in their dealings with him and they were very satisfied that at each Conference he would make time to spend with those Allied that had booths at the Trade Exhibition.

It was noted and appreciated that after hours, Billy usually had many utility CEOs and Allied Members join him at various watering holes where much networking and business was conducted.

At all times I observed that he was always professional and happy to advise and assist his fellow CEOs and the Allied Members during these Conferences.

In my role as the Executive Director of the PPA, I found Billy always supportive of the Association and on numerous times during these 12 years I was able to confer with Billy on issues ranging from MEC hosting Annual Conferences to energy losses, power plant issues and staff training programmes.

This support by Billy extended to raising the profile with the Government of RMI at every opportunity he had, and at one stage, when I was in Majuro, Billy organised for me to attend the RMI Nitijela and make a presentation to the RMI Senators and Ministers on a major Pacific Islands' utility issue which was communicated live nationwide. This was an example of his public support of the PPA by raising the PPA profile with the RMI Government.

In his approach to assisting fellow utilities he took opportunity, where welcome and invited, to send his staff to their utility to provide help on a particular issue. Billy would also accept staff from these utilities to spend time in MEC in a particular section and take this knowledge back to their utility.

Preparing this eulogy has raised many good memories for me and a touch of sadness with Billy passing away.

In my years of involvement with the people of the Pacific Islands, a good attitude to work and a great sense of humour creates for an efficient work environment are major characteristics of the Pacific Islands.

I feel that Bill exhibited these characteristics and talents described above, and I will go as far as to say that Billy was an icon in the formation of the MEC and PPA with his professionalism, sense of humour and fortunately at most times, his lack of what is now called 'Political Correctness.'

Those of us that have dealt with Billy Roberts these past many years will have a sense loss at his passing away, but he has left many of us with a better understanding and love of the Pacific Islands and their people.

Farewell Bill Roberts.

I am sure that we all extend our sympathy and condolences to Billy's wife Diane, his two children Ben and Kelly and three grandchildren.

P.S.
In respect to the formation of the PPA, I need to give credit to Utu Abe Malae, CEO of ASPA, Patrick Amini of ELCOM of PNG (now retired), John Pirie, CEO of the FEA (Now retired), and Billy Roberts, who saw the value of having an Association of Pacific Islands power utilities, with the aim of sharing knowledge and experience and in particular, assisting each other when there were critical times like equipment failures, typhoons and cyclones. I believe there were three separate annual meetings, 1989, 1990 and 1991 of these key CEOs that resulted in the PPA starting off in 1992.

Also here is a link of an article that ran in the Marshall Islands Journal on the late Billy Robert's.

http://marshallislandsjournal.com/Journal_WP/?p=4106

Welcome! *To New Allied Members*

Five (5) new companies have joined PPA as Allied Members since our last PPA Magazine. The new members are:

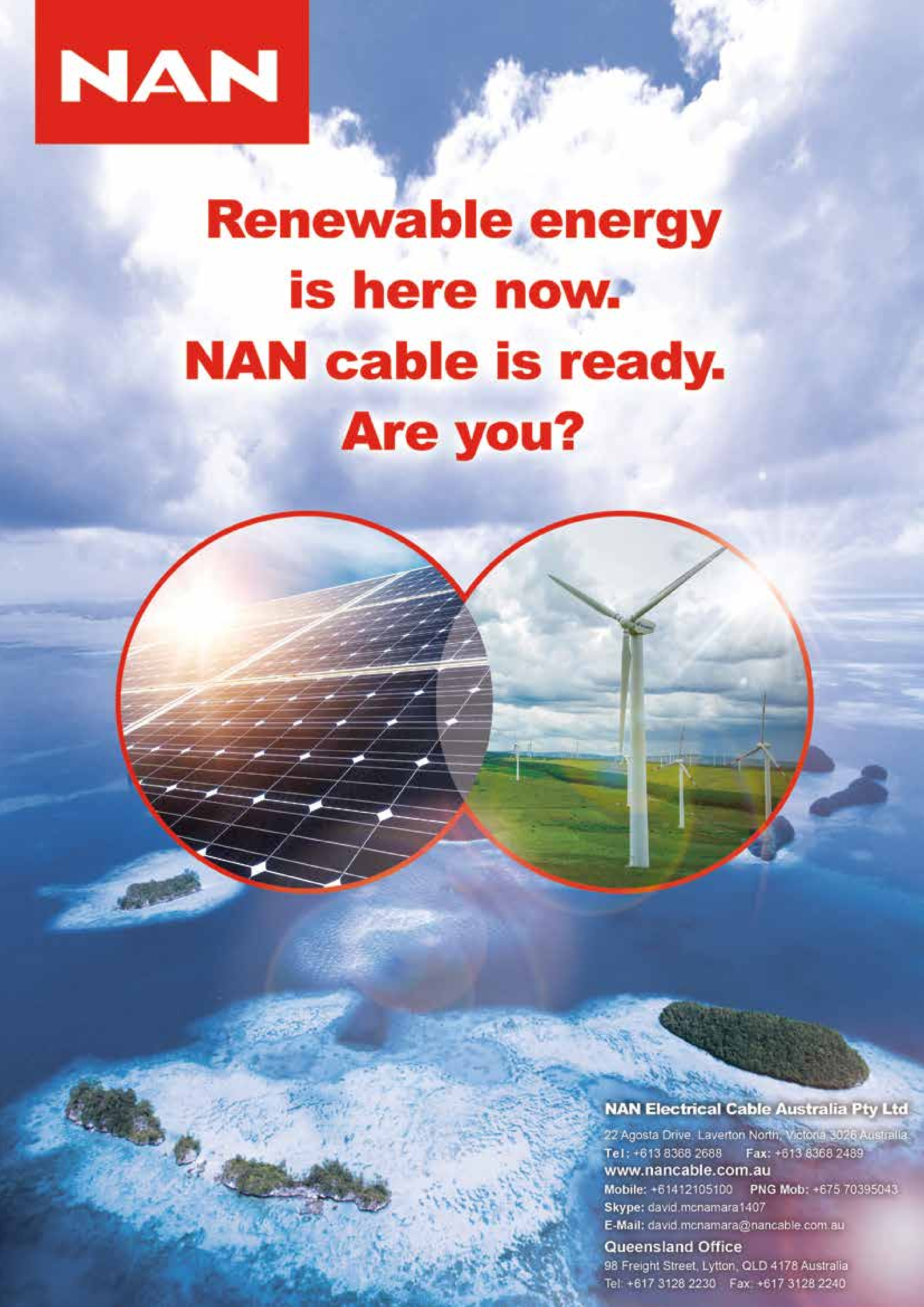
AMERICA'S BEST ELECTRICAL MART: America's Best Electrical Mart is based in Guam, United States of America. Their primary activity is stocking electrical material distributor. Their secondary activity is Electrical Contractor.

AVO NZ: AVO NZ is based in Canterbury, New Zealand. Their primary activity is Test & Measurement Tools.

EPC INTERNATIONAL PTY LTD: EPC International Pty Ltd is based in Melbourne, Australia.

GENERATOR RENTAL SERVICE LIMITED: Generator Rental Services Limited is based in Auckland, New Zealand. Their primary activity is generator rental and sales transformer rental. Their secondary activity is services to generators and transformers.

INDRA AUSTRALIA PTY LTD: Indra Australia Pty Limited is based in Homebush West, NSW, Australia. Their primary activity is Information Technology Products and Solutions. Their secondary activity is IT Systems and Solutions for the Energy Industry.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