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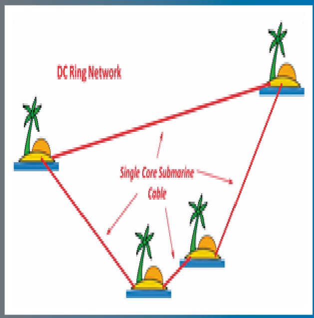

PPA

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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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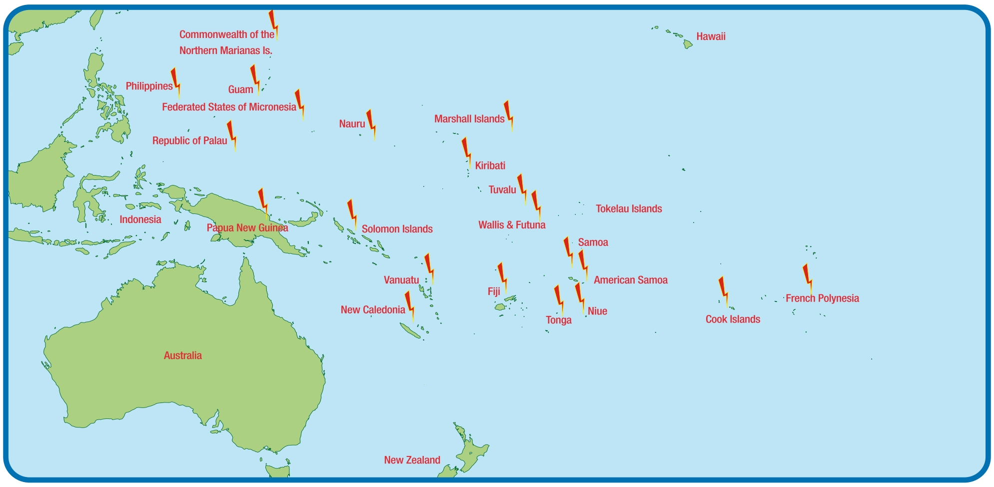

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Editor's Notes

Andrew D. Daka
Executive Director

Bula vinaka and Greetings from Suva.

It was not too long ago that we were ushering in 2017 and right now getting ready to farewell the year that will soon be. As we look forward towards celebrating the Festive Season that marks the end of 2017and welcomes 2018, we take time to reflect on our achievements and learn from the things that have not turned out as planned to better meet the new challenges.

Reflecting on 2017, the Pacific Power Association as an organization has had a successful year with growth in membership, finally getting some traction in the implementation of the Sustainable Energy Industry Development Project (SEIDP) and the success of its 26th Annual Conference held in Apia, Samoa. The success experience in 2017 owes much to the Board, Allied Members, Development Partners and the Staff of the Secretariat who have put a lot of effort and dedication in their tasks and supporting the organization.

Having mentioned that, the Association continues to pursue its submission to the host government for international organization status. The Secretariat is closely liaising with the Fiji Government with the assistance of the Management of the Fiji Electricity Authority to further process the application. Whilst doing so, the Association will also explore the Government of Samoa's offer to host the Association in Apia, Samoa.

The upcoming 12 months will be a very busy one for the Utility Members of the Association especially those from the World Bank beneficiary countries. A number of workshops funded under the project have taken place in 2017 and a lot more has been planned for the next 12 months. Utility Members will need to note the trainings and dates so as to be able to take advantage of these capacity building program. The renewable energy resource mapping component is also envisaged to commence early in 2018 as the procurement is now at the RFP stage.

The main articles in this issue of the magazine continues on with the series papers presented at the recent 26th Annual Conference and Trade Exhibition. The articles discuss loss reduction, a case study examining the feasibility and cost of using DC transmission in the place of AC network and PPUC's decision to replace its engine cooling towers with radiators and its benefits.

This time of the year is also the cyclone or typhoon season. As such, utilities will need to look at their own preparedness in the event that one comes their way. On this matter, the SEIDP has planned a number of activities to address disaster preparedness, response and resilient infrastructure plans.

At this point I would like to welcome our newest Allied Member; Greenbox Energy Pty Ltd of Kingsway West, Australia.

I would like to conclude by taking the opportunity to thank all the Active, Allied Members and Affiliated Members for their support to the work of the PPA this year and we look forward to your continued support in 2018.

Wishing all a Merry Christmas and a Prosperous 2018.

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Technical and Non-Technical Energy Losses Control: Making Electricity More Affordable and Accessible While Reducing Costs

Giovanni Polizzi
Manager Energy Solutions - Indra Australia Pty Ltd

Abstract:

The control of technical and non-technical losses is one of the challenges for utilities in many countries. The resulting savings for the entire organisation make the supply of commodities economically more viable and thus accessible to a larger customer base.

Addressing the issues behind the losses, requires a comprehensive approach at strategic and operational levels, and the development of a plan that includes the characterisation of the situation of metering of the border points, the internal control points and the network conditions.

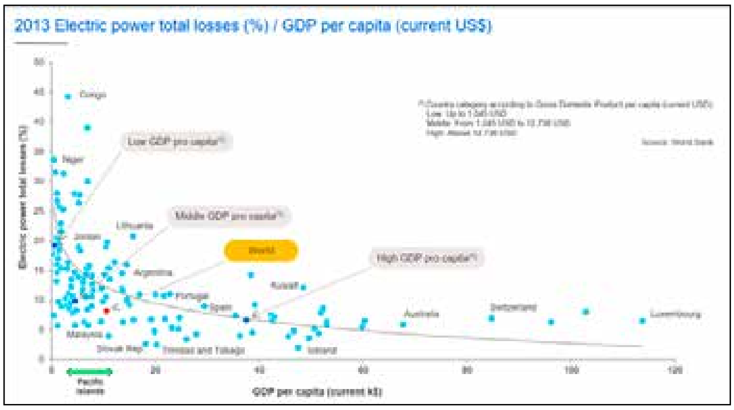
The reduction of technical and commercial losses translates into rapid economic benefits that can be passed on as tariffs reduction once the ROI for the losses reduction project is achieved.

A number of tools are available to perform a fine analysis and characterisation of losses, fraud and default behaviours and to determine their temporal and geographical evolution differentiated by customers' category.

The proposed paper goes through Indra's methodological approach, with some very successful cases of losses reduction, and includes a combined action of software solutions and consultancy services, to achieve the analysis of the factors underlying the losses, the identification of the main losses and where they occur, the process to focus on the causes of the most economically relevant effects, the implementation of the losses reduction measures, the post implementation follow-up to quantify the achieved results.

Introduction

The ever-present mismatch between generated/purchased/produced resources and the billed energy, has a detrimental effect on any utility's bottom line. In some geographies, this effect can be very substantial, as reported by the World bank in 2013.



There is a range of combinations of social, economic, technical and organisational factors behind the energy losses that significantly affect economic performance and efficiency in the supply of commodities: electricity, gas and water.

The control of technical losses and the management of fraud and default are two of the key challenges for Utilities in many countries, that result in economic benefits for the whole system, with a payback time of less than a year in some cases. The extra revenues can be passed on as a **reduction in tariffs** without any disadvantage to the balance between the system's costs and the revenues collected.

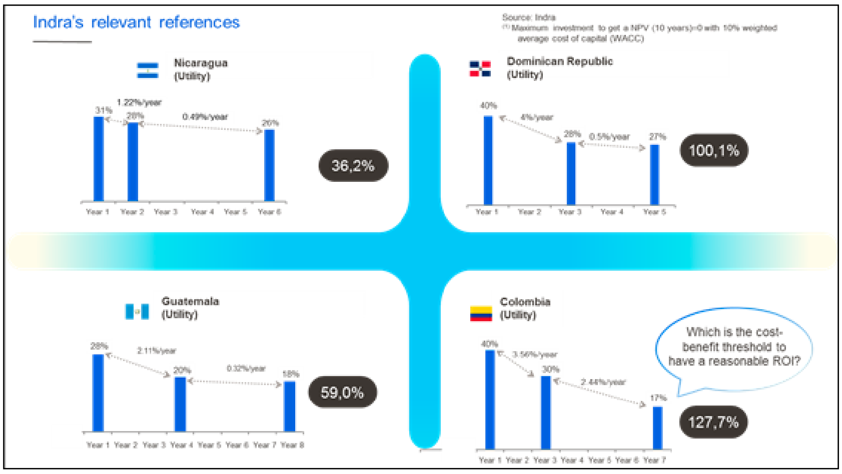
This paper wishes to describe a number of methods and technologies used by Indra in different countries around the world, to reduce **non-technical losses**, to increase revenues and to keep non-technical losses under control.

The situation across The Pacific islands

In 2012 non-technical losses across the utilities in the **Pacific Islands** had values between 20+% to just below 10%, as described in the report[i] commissioned by the PPA. The report indicated that there was a substantial margin for improvement

i Quantification of the Power System Energy Losses in Southern Pacific Utilities, prepared by: KEMA International B.V. May 25, 2012 – Consolidated Report and an urgency for action and thus proposed a number of tactical and strategic measures to be undertaken to reduce losses and improve revenues.

The power generation industry across the Pacific Islands relies heavily on oil-refined products with quite a complex and lengthy supply chain, as indicated in 2012 by IRENA[ii] in the report on the Pacific Islands and Independent Territories (PICTs)[iii]. The price per kWh was found to be between USD 0.15–1.50 / kWh, depending on the islands, and as an average (a combination of residential, commercial and government tariffs) around USD 0.35 /kWh. However these prices are generally subsidised as the actual cost of electricity delivery varies widely from place to place exceeding USD 1.00 per kWh across the outer islands or the smaller grids.



Some islands are investing intensively to reduce their dependence on refined-oil products and switching to renewable energy generation, thus decreasing the cost per kWh in their generation energy mix.

Reasonable Investments

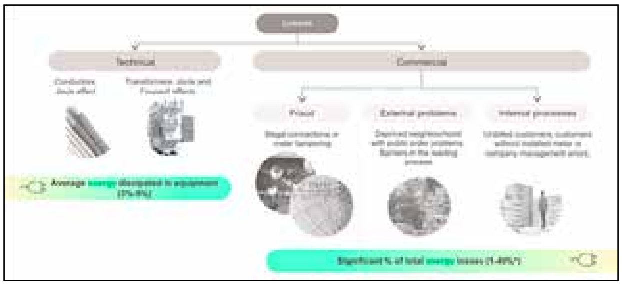
Independently of the market size and the price of the resources used to produce power, reducing losses has a significant impact on profitability. The investments in revenue assurance are generally profitable, with very short return of investment (ROI), as we will see in the coming paragraphs. As a general rule, the higher the cost of resources, the greater the beneficial effect of reducing non-technical losses, due to the combined effect of increasing revenues and decreasing expenditure.

Even in the case of an ongoing **investment on renewable energy**, which usually guarantees a low-cost resource for energy production, the reduction of non-technical losses results beneficial as an increment in revenues will surely achieve a shorter ROI.

Across a number of utilities in central America for example, the amount of savings and increased revenues has been outstanding, and has placed the non-technical losses reduction among the highest priorities in the agenda of the rest of utilities.

A strategy tailored on needs

In general terms reducing technical losses requires capital investment to act on asset design or modifying operation, as well as replacing major infrastructure. **Non-technical losses** however generally require lower investment as they normally address metering issues and customer behaviour. Leaving on one side the Technical Losses, the Commercial (or non-technical) losses can be associated to different factors as metering tampering and illegal connections, difficult access to metering instruments and therefore a delayed metering and billing process, and other factors generally associated to inefficiency of the internal procedures of each company.

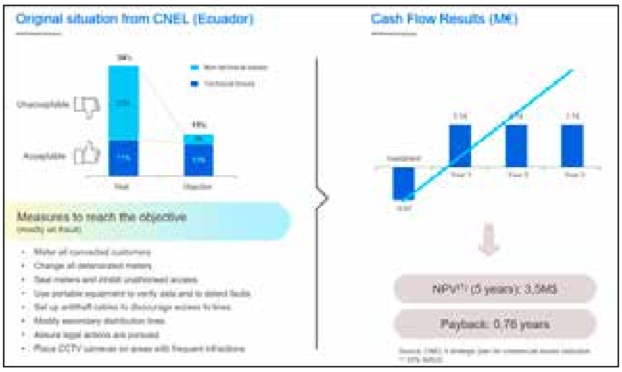


Each revenue assurance project therefore requires a specific approach, tailored to the company's needs. Defining the characteristics of the losses is of paramount importance, to implement effective losses reduction actions on the short term to

ii Pacific lighthouses – Renewable Energy Roadmapping for Islands, International Renewable Energy Agency (IRENA)

iii Pacific Island Countries and Territories (PICTs), The PICTs referred to are: Cook Islands, Federated States of Micronesia, Republic of Fiji, Kiribati, Republic of the Marshall Islands, Republic of Nauru, Niue, Republic of Palau, Papua New Guinea, Samoa, Solomon Islands, Kingdom of Tonga, Tokelau, Tuvalu and the Republic of Vanuatu.

achieve quick wins, and policies for the longer term. In the case of the Ecuadorian CNEL[iv], they had a clear strategy that required an initial limited investment but that once pursued, achieved a revenue stream for the following years and a very short payback time.

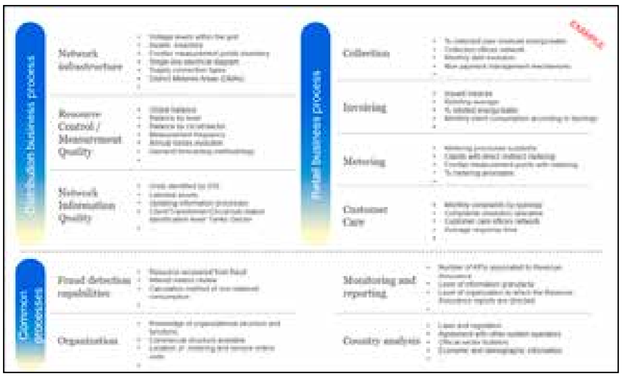


Non-technical losses decreased dramatically in less than a year and revenues started to increase very rapidly and kept coming during the next three years[v].

Defining a strategy

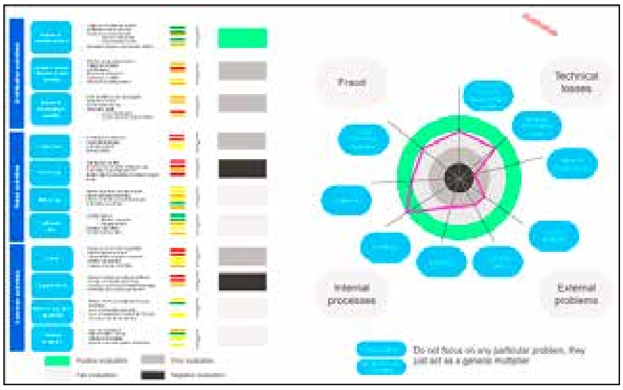
Before any decision or actions can be taken, it is important that the company defines the areas where interventions to recover revenues can be more successful and the necessary actions.

A preliminary **analysis checklist** that resumes a number of areas to be looked at, helps to describe the non-technical losses. This check-list is the input for a **Loss Reduction Plan**.



By performing the guided analysis with the check-list, the company is then able to calculate a balanced score card and thus to focus their actions in the short term and in the longer term, balancing between high impact returns and the medium to low impact ones, but also to evaluate the level of investment that each action requires.

The strategic plan for loss reduction defines the



necessary actions to achieve the targets within a specified time period.

- Analysis of the factors that may potentially cause commercial losses
- Identification of the points where losses occur and scoring them by magnitude
- Focus on the problems with the highest substantial impact which offer the highest economic return, thus providing the appropriate recommendations.

The outcome is a list of quantified recommendations that may include, process reengineering, process automation, implementation of software tools, rationalisation of the organisation, etc.

Implementing the strategy

As known a strategy is as good as its implementation plan, when it comes to bring results. So, the next step in the losses reduction path that the company has started, is the definition of the implementation plan.

iv Corporación Nacional de Electricidad, https://www.cnelep.gob.ec/,

v https://www.cnelep.gob.ec/servicio-indicadores-gestion-pec-comercial-energia/

The implementation plan must be based on the recommendations and must include an associated dashboard where the key performance indicators (**KPIs**) are periodically calculated and monitored. The choice of KPIs is a crucial factor as these must be shaped so to show the evolution of the results well ahead of the set deadlines, to allow the implementation of appropriate corrective actions, should the expected results lag in showing up.

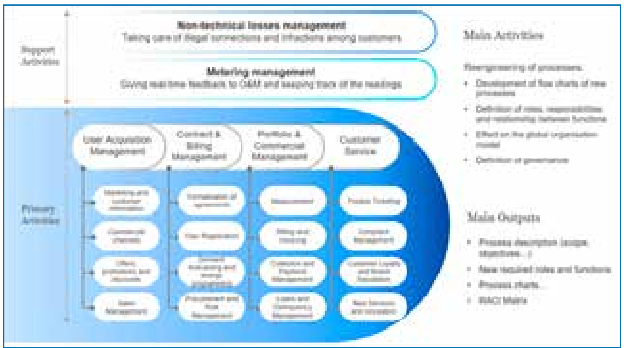
Supporting the execution of the Implementation Plan

One of the most important decisions to be taken is "where" to act first to achieve the highest loss reduction in the shortest time. "Where" has two sides, one being the areas of the networks and the other the internal process in the company.

A fine analysis of the internal processes and of the tools that employees rely upon to perform their daily jobs, is of paramount importance to spot inefficiencies, loops, gaps and fields of improvements.

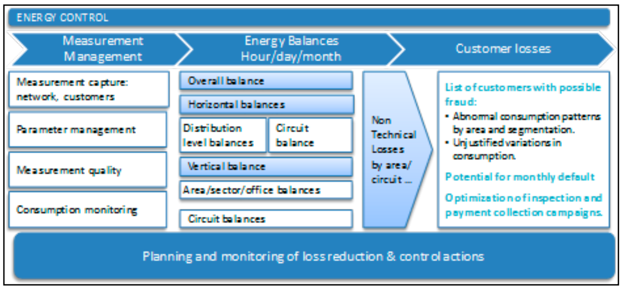
The quantification of losses and the definition of a grid-losses map is also a step to be taken with great care, as this will shape the revenue assurance strategy, the acceptable level of investments and the geographies in which the intervention must start from.

ECL system



An Energy Control and Losses (ECL) information system can be of great help to measure the magnitude of non-technical losses and the sections of the grid where these are most consistent. A ECL system is a complete energy control system that allows periodic monitoring and control of energy flows through the distribution grid.

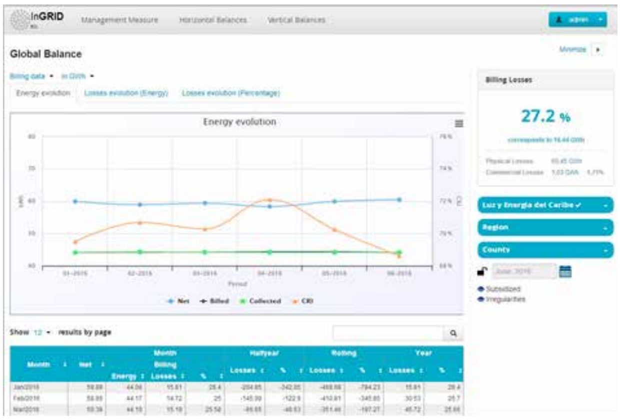
The ECL, by calculating energy balances in control areas, is able to identify the periodic evolution of energy losses in different areas and elements of the grid, identifying fraud (if it were the case) in each area or element of the monitored sections. Such a system can also greatly help in scheduling energy control strategies as it gives the possibility to monitor the real impact of the deployment of any revenue assurance strategy as this is being executed.

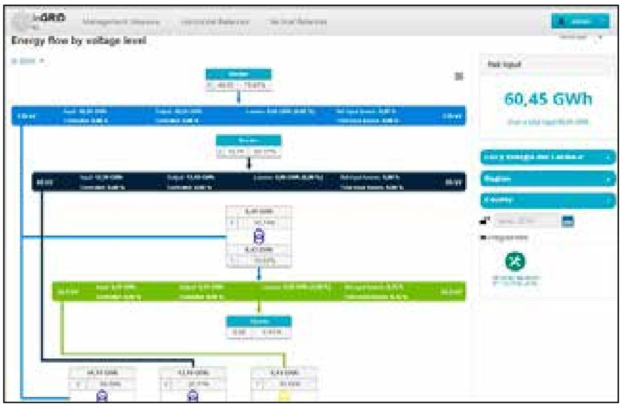


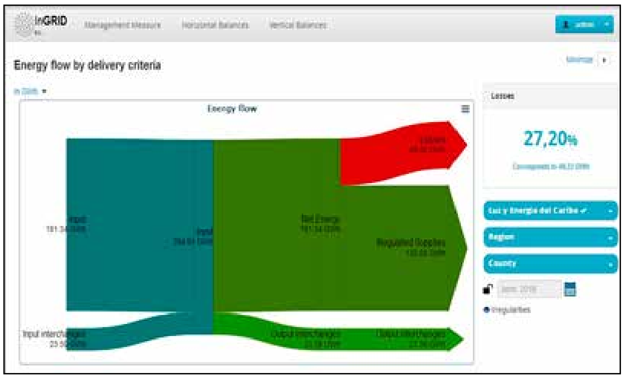
Some of the most profitable functionalities, can be summarised as follows:

- Daily monitoring of network consumption evolution, identifying deviations from expected values
- Detection and characterisation of areas, sectors, circuits and network elements by level of losses and their evolution over time
- Analysis of the potential fraud at the supply points, based on consumption patterns, supply characteristics, type of meter, etc.
- Planning and monitoring of the impact of actions for loss monitoring and reduction.

The following images show a user interface showing billing collection follow up, an energy flow analysis across different voltage levels, and a graphical representation of energy losses. These are tools that greatly help the monitoring and execution of any revenue assurance policy.







Fraud Detection tools

Non-technical losses, once found, have to be reduced but must also be monitored in the long term to stop as they start, new risks of fraud. Understanding the characteristics of the company's customer base and where new potential fraud can be building up, is essential to maintain under control non-technical losses.

A fraud detection tool, performs a fraud and default risk assessment based on metering analysis, and indicated the supply points with the greatest calculated risks. This information allows then the optimisation of the efforts as the inspection will be focused across the areas with the greatest potential of loss reduction. As a rule of thumb, a reduction of up to 70% of losses can be achieved by inspecting the customers with the highest 10% of fraud risk.

Supply points are also clustered by potential for fraud/default, and this allows the company to promote targeted activities of customer sign-up, metering, prevention, awareness and collection. Again, a great help to make these activities as efficient and effective as possible, to reduce costs of execution and to reduce the time for revenue collection.

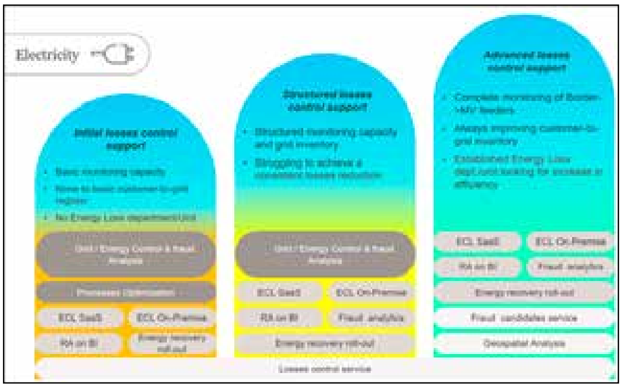
Having the knowledge of the fraud/default potential of the customer base, is also a strategic information for a cost/impact scenarios simulation based on the different behaviour of customers segments.

Finding the correct combination: Services vs Systems

As mentioned, each company needs a tailored solution that apart from being dependent on the amount and characteristics of the energy losses, also depends on the maturity of the energy losses control.

A company that just started to seek a reduction in losses, is more prone to go after the low hanging fruits, whereas a company with a track record of revenue assurance projects, will most probably have to go after a set of losses more difficult to detect and to turn into revenues.

Technology and experience always come into help, nevertheless the right choice for investment depends on the level of maturity of the energy losses reduction, as shown in the following image.



There are several possible combinations for example, if a company has recently started to pursue reduction in non-technical losses, it may want to make use of a SaaS kind of software platform to be able to limit the initial capital investment in infrastructure and to reduce the time to reach the first economic benefits. The company may also want to rely upon outsourcing to run business analytics (BA) and study the fraud grid map, before investing in a BA system and training its personnel.

A company with a longer experience in revenue assurance policies, may on the other hand be looking for an additional BA module (o data model) to its existing system to draw a finer non-technical losses map and trace new fraud hot-spots. Any fraud deterrent tool can be of help to a company that has a very low percentage of non/technical losses, as for example, CCTV cameras, satellite images, customer behaviour and installations inspection (night lights, swimming pools, garden maintenance, building types).

These chices come as a direct result of the initial analysis described at the beginning of this paper, and the cost-benefit analysis.

Indra Company

Indra is one of the main global consulting and technology companies and the technology partner for core business operations of its clients businesses throughout the world. It provides unique in-house solutions and advanced and high added value technology services that allow its customers to solve their most critical issues and enhance their processes, efficiency, profitability and differentiation.

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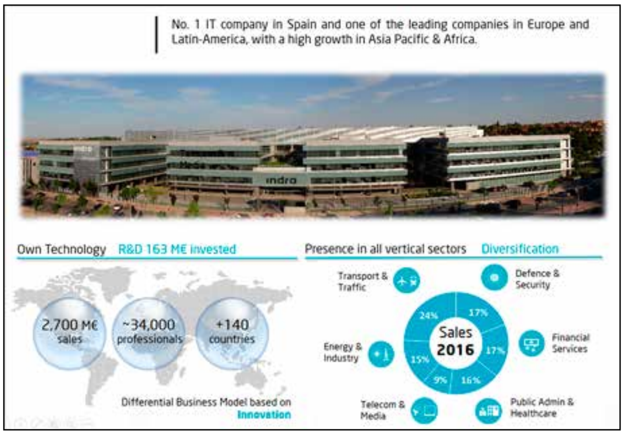

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Case Study: Low Cost Inter-Island DC Electric Power Transmission for Chuuk State

Mr. Craig Harrison
Managing Director, I S Systems Pty Limited, Australia

Abstract

Utilities seeking to electrify islands normally consider installing DE power plants, PV or wind with storage batteries or some form of hybrid RE power station with DE as the base generation. These solutions present large capital investment and/or high ongoing costs associated with fuel supply and maintenance.
Another option is to distribute electrical power to individual islands by subsea cables. Subsea cables also have high purchase and installation costs. In addition, subsea cables have a failure history. High system reliability requires redundancy that further increases the cost.

I S Systems undertook a voluntary case study investigating the feasibility and costs associated with a medium voltage DC power distribution system, rather than the traditional 3 phase AC distribution networks. The island state of Chuuk was selected as the basis for the case study. Chuuk has a large number of islands located in the lagoon that are without reliable electric power. Only one island in Chuuk State (Weno) has reliable electric power. Several previous studies undertaken by NREL, KEMA and IRENA provided basic technical information which allowed a detailed analysis to be undertaken.
The MVDC distribution scheme proposed in this study utilises a low cost single core DC subsea cable configured as a series loop. The loop passes from island to island and the DC power is converted to AC on each island by means of a DC to AC inverter.
The loop power delivery is configured as a constant current system rather than the traditional constant bus voltage source scheme that forms the basis of electrical distribution networks worldwide. There are important advantages associated with the controlled current source technique.
The case study demonstrates large costs savings associated with the single core DC cable constant current loop scheme. The scheme also inherently provides redundancy for cable and inverter faults thus dramatically increasing the power system reliability.

1-INTRODUCTION

1.1 Energy Supply Issues on the Pacific Islands

Several Pacific Island nations face the problem of supplying electrical energy to a group of nearby islands. Typically only one island, the 'main' island with the majority of the population, is electrified, while several nearby islands with lesser populations are not electrified at all or must run independent generating stations.
Extending the electricity network from the main island to the other islands via 3-phase AC submarine cables is costly. Running and maintaining separate power stations on each island is also costly and difficult for many reasons. Some of the main problems are:

1) Logistics of diesel fuel supply to a number of islands-wharves, storage facilities, etc.
2) Higher overall maintenance & fixed operating costs compared to one larger power station.
3) Higher running costs due to relative inefficiencies of smaller generating units.
4) Potential difficulties recruiting and training staff for each power station.
5) Potential for land disputes where land availability is limited.

1.2 DC Distribution

New technologies have now made DC distribution networks viable options and even advantageous over traditional AC distribution in certain situations. This report presents a case study for a DC electrical power distribution system to energise a group of islands. The proposed network would enable all islands in a group to be electrified and share the generating resources of a single (or multiple) islands. The required submarine cabling for the DC proposal only requires a single core and is thus much more economical than a 3-core AC approach, while loads and generating sources (existing and future) from any island in the network can be easily incorporated into without the need for communications and/or line synchronising. Additionally, the concept does not require a ground return path for operation – so there are no requirements for earthing electrodes in normal operation. Finally, the DC approach presented here allows for continued operation in the event of a damaged submarine cable- the DC distribution path can be routed around the damaged cable via earth until such time as the cable can be repaired. The proposed DC distribution topology uses well established and robust power electronic modules that are widely used in industry today for other applications, namely AC-DC converters (rectifiers) and DC-AC inverters. The basic concept of the proposed MV DC Series Distribution Network is shown in Figures 1&2. The DC network imports/ exports power at each island, while the power modules present a 3-phase AC interface for each island.

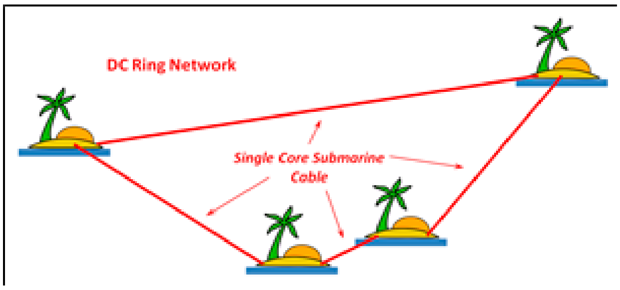


Figure 1- Series MV DC Ring Distribution Network.

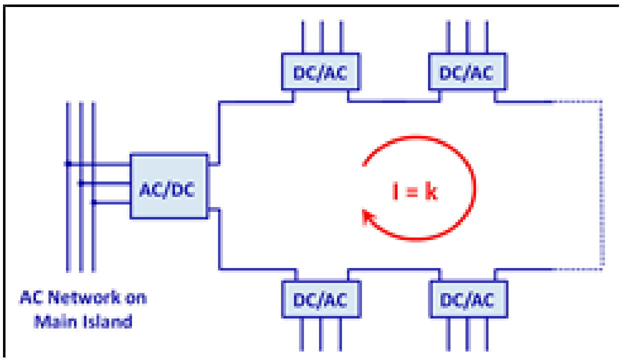


Figure 2- DC Series Ring Electrical Structure.

2-THE SERIES DC RING DISTRIBUTION APPROACH

The series DC Distribution network has several advantages over other topologies:

1) The system is completed unaffected by short circuit failures of loads or generating sources around the ring and there is no 'fault current' – the system continues to operate at normal ring current should a device in the ring fail.
2) HVDC circuit breakers are not required for fault clearing.
3) Generation sources can be easily added anywhere around the ring without the need for synchronisation, voltage matching, or communications.
4) Sources for the DC Series ring are easily interfaced to the existing Weno grid.
5) The resulting AC distribution voltages on each island remain constant irrespective of loading.
6) In the event of a submarine cable failure due to external forces, the fault can be bypassed by earthing both ends of the failed cable until the cable is repaired.

These characteristic advantages of the DC series ring system are discussed in more detail in the following sections.

2.1 No Fault Current Levels in the Event of a Failed Device

In a series circuit, the current is common to all loads and sources in the ring, while the voltage across each element varies according to the power it is supplying/absorbing. In normal operation, the source(s) act to maintain the ring current constant at some nominal value by raising or lowering the driving voltage around the ring as illustrated in Figure 3.

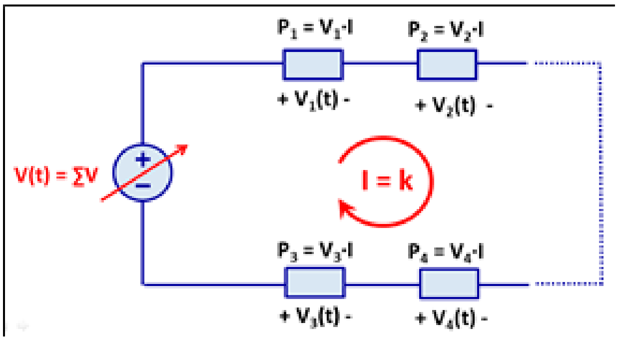
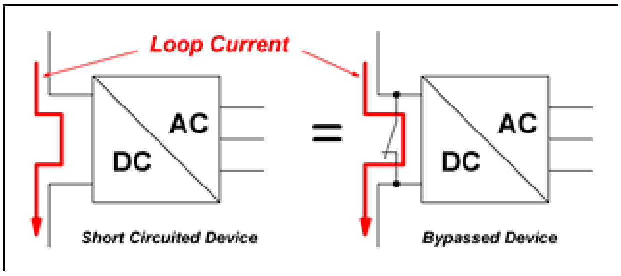


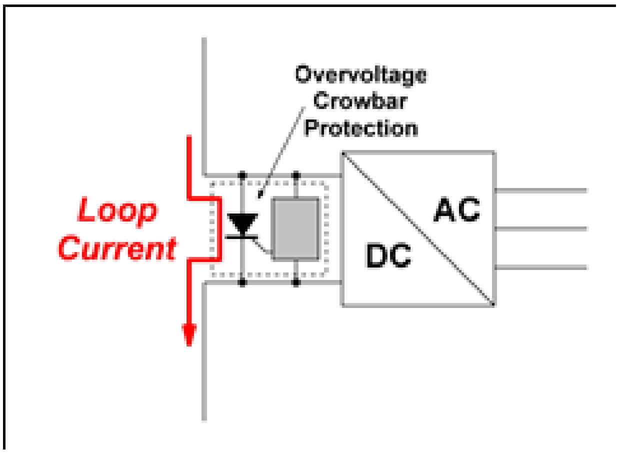
Figure 3- Ring Current Control via Variable Voltage.

Should an individual load (or source) fail to a short circuit state, the failed load is effectively 'self-bypassed' as illustrated in Figure 4(a), while the overall driving voltage around the ring would drop to maintain the original nominal ring current. Hence the ring current is unaffected by a short circuited device anywhere on the ring and there is no change in current magnitude-ie., there are no fault current levels to deal with on the DC Ring.

If a source or load fails to an open circuit state, the ring current would quickly fall towards zero while the full ring voltage of the system would rapidly build up across the open circuited device. This would be a transient interruption (a few milliseconds) as all loads and sources would be equipped with overvoltage crowbar protection. When the crowbar protection senses an overvoltage condition, it's thyristor is triggered and so the faulty device is permanently bypassed. Crowbar protection in the event of an open circuit failure is shown in Figure (b).



a) Short Circuit Failure



b) Open Circuit Failure

Figure 4- Failure Modes in a Series Ring.

Short circuit faults on the AC side of any DC/AC power modules would still develop significant levels of fault current and are handled in the conventional way, with coordinated protection with AC circuit breakers and fuses. It is important to note that several per unit of fault current on the AC side of a load does not translate to any change in the DC distribution ring current.

2.2 No Requirement for HVDC Circuit Breakers

'On load' HVDC circuit breakers are not required for the protection of sources or loads in the series ring configuration. As discussed in the previous section, bypassing and protection is accomplished via on load short circuiting of the device, not via on load open circuit disconnection.

2.2.1 Sources

As shown in Figure 5, sources would be interrupted on the AC side with conventional AC switchgear, while the freewheeling diode across the DC output side of the source allows the ring current to continue flowing uninterrupted.

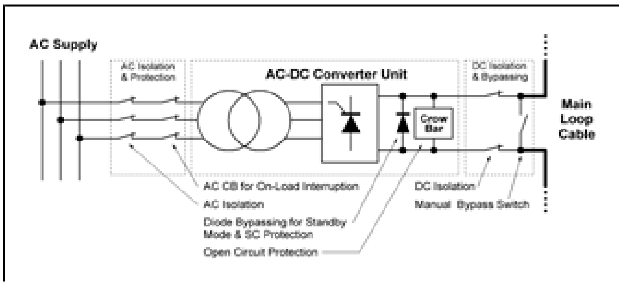


Figure 5- Basic Source Setup & Protection.

To service a faulted AC-DC unit, the manual bypass switch would be closed to take the full ring current. The DC isolation switches would then be opened under a zero current condition for safe disconnection of the unit once the manual bypass was completed.

2.2.2 Loads

Loads on the DC distribution network, which would be DC-AC inverters in most cases, would be similarly protected, with the main protection devices shown in Figure 6. The inverter output protection would be properly coordinated with the rest of the local AC distribution network and would be the last line of AC fault protection. The inverters would be capable of supplying several per unit current to help clear AC distribution faults in the usual coordinated manner.

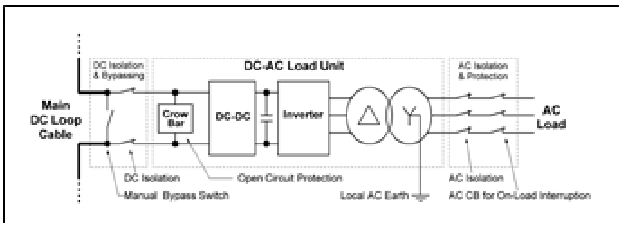


Figure 6- Basic Load Setup & Protection.

2.3 No Synchronising or Location Issues for Generation

There are no synchronisation requirements in a DC system. Standby AC diesel sets supply DC power via rectifiers and can operate at any frequency/speed and any voltage to optimise fuel consumption. Startup time for a dedicated genset

on the DC ring is absolutely minimal.
Renewable energy and energy storage subsystems can be easily integrated into the ring at any future time as they naturally produce DC power and are thus easily integrated.

2.4 DC Series Ring Easily Interfaced to Existing AC Network

For a group of islands with only one (or a few) of the islands electrified, the DC Series Ring network is easily interfaced to the existing AC infrastructure without any modifications whatsoever to the existing powerhouse(s), as long the capacity exists to meet the additional demand. This is illustrated in Figure 7 where a transformer hangs off an existing AC bus or transmission line to supply a controlled rectifier which energises the DC Ring Network.

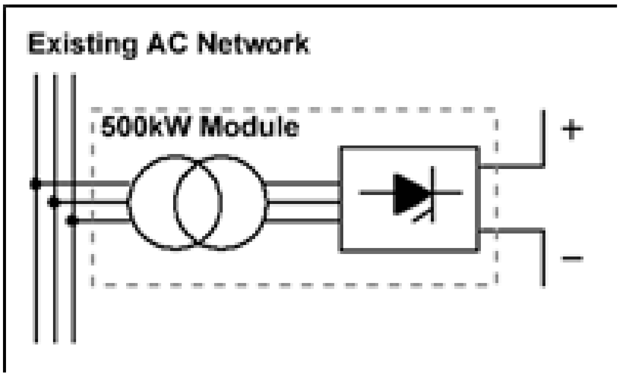


Figure 7- DC Ring Power from an Existing AC Network.

2.5 Modular Approach to Capacity Building

It is anticipated that electrification and demand would take time to develop. The DC series ring technology lends itself to a modular approach to capacity building for both generation and loading which minimises the initial capital expenditure to get up and running. This approach has been taken in the example below in Figure 8. The only item that would require initial installation based on the full projected system capacity would be the submarine cable. Arbitrary module sizes of 200kW and 500kW have been assumed as the standard module sizes.

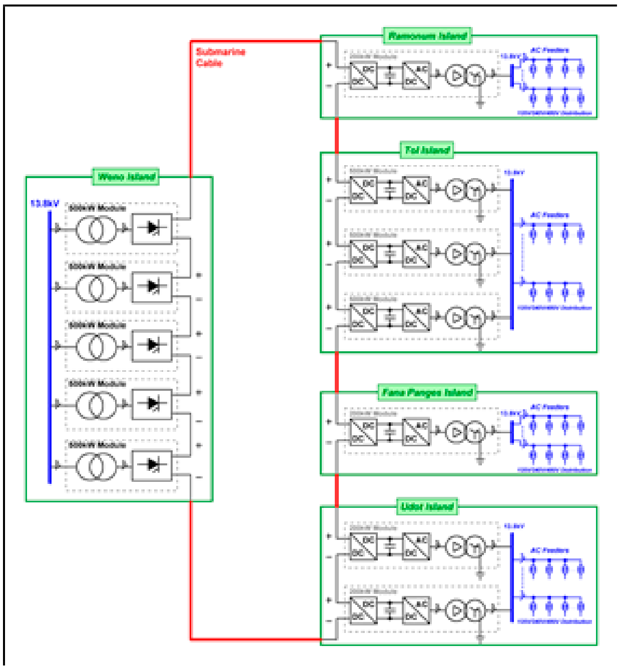


Figure 8- Modular Capacity Expansion.

2.6 No AC Voltage Regulation Issues at the End of Long Lines

In typical AC or DC constant voltage transmission & distribution networks, there are voltage drops along lines of reasonable distance, and the magnitude of these voltages drops varies with loading. Maintaining reasonable voltage regulation at all locations on the grid can be difficult as the load varies, especially in AC cases where some load centres are at the end of capacitive lines.
For the DC series ring network, the voltage at the AC bus on the DC-AC power module remains constant irrespective of the AC load level. The only voltage that varies with the AC kW load is the DC voltage across the input to the DC-DC converter as shown in Figure 9.

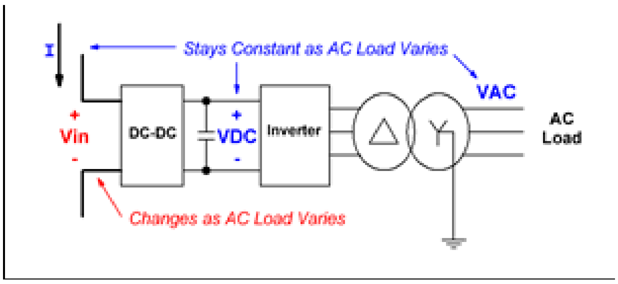


Figure 9- Parameter Variation vs AC Load.

2.7 Contingency Management of a Severed Submarine Cable

Submarine cables are at some risk of damage from fishing activities and tropical storm events. Burying the cable where possible on the sea floor reduces the risk but does not eliminate it. In a typical distribution system (AC or DC) a severed cable must be repaired before power can again be supplied to customers on the other end of the cable unless multiple cables or alternative supply routes are in already in place. Submarine cable repair is usually a lengthy process, possibly taking several weeks to get the necessary equipment to site, then locating and repairing the severed cable.
The DC Series Ring network can incorporate contingency switching to manage a severed cable situation easily and very quickly restore power to the network following a severed cable event by simply bypassing the severed cable and using an earth path (earth electrodes or submarine cable sheath) instead. If the switchgear has been preinstalled at either end of any submarine cable deemed to be at risk to damage, then the changeover to restore power is very quick indeed. The system can run in this mode indefinitely until the severed submarine cable is finally repaired. This concept is illustrated in Figure 10.

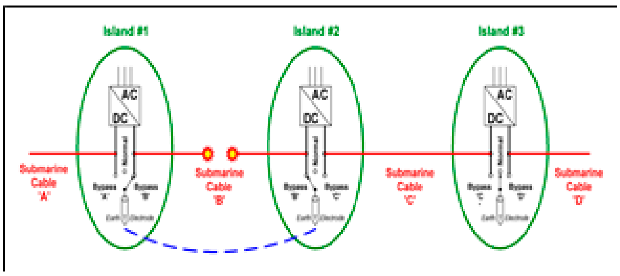


Figure 10- Bypassing a Severed Submarine Cable.

3 - CASE STUDY: CHUUK LAGOON

The DC distribution concept is now applied to the islands of Chuuk Lagoon to demonstrate the feasibility of the concept. The islands within Chuuk Lagoon are comparatively easy to electrify via submarine cable as the distances are short and the waters are relatively shallow. Chuuk Lagoon currently has one electrified island, Weno, with a population of 14,000, while an additional 20,000 residents on a dozen nearby islands are not electrified at all (excluding individual small scale PV systems on some of the islands). The DC Series distribution network utilises the power generation infrastructure already available on Weno and develops an economical distribution system for supplying power to the other islands in the lagoon.

3.1 The Islands of Chuuk Lagoon

The majority of the Chuukese population, about 35,000, live on the Faichuk and Nomoneas island groups in the relatively calm and shallow waters of Chuuk Lagoon, a large lagoon created by a 225km perimeter atoll as shown in Figure 11.

Figure 11- The Islands of Chuuk Lagoon.

3.2 Existing Electrification Infrastructure

Currently only one island, Weno, with a population of approximately 14,000, is electrified. It contains a power house with several diesel gensets and a 3-phase 13.8kV distribution system to provide electricity to the bulk of Weno Island's residents and industries. The power station on Weno Island has a firm capacity of 5.2MW while the network demand averages 2.6MW with a peak demand of 4.0MW [1].
The remaining 20,000 residents on the nearby Faichuk Islands and Southern Nomoneas Islands have no electricity generation or distribution other than small scale solar PV systems.

3.3 Estimating Potential Demands

To estimate the potential for electrical energy consumption on the other islands in Chuuk Lagoon, the latest census data (2010) was used as a starting point to estimate the populations of the various islands. The 2010 Census population data of the islands in the lagoon are shown in the red numbers of Figure 12.

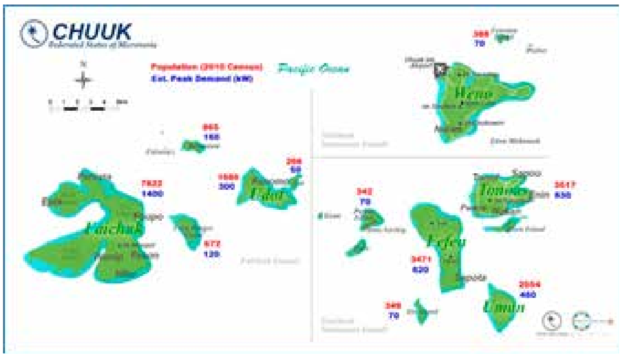


Figure 12- Population & Estimated Energy Demand.

A loading estimate for a given population size was developed from existing data for 12 Pacific Island Utilities from various KEMA, NREL, and PPA sources [2],[3],[4]. Across the 12 utilities investigated, a revenue paying customer averaged 4.8 residents, and the customer average demand was 0.62kW. On Chuuk itself (ie. Weno Island), the customer ratio was 3.8 while the average demand was slightly higher at 0.72kW per customer. Given that Weno Island houses all the government facilities and commercial industry, the lower 'residents per customer' and higher 'kW per customer' figures might be expected. The overall multi nation averages were used as the basis for estimating future load demands on the islands of Chuuk Lagoon, as it is assumed that the customer base on the remaining islands will be primarily domestic. Hence the scaling factor to convert population to average load is calculated as

Average Island Load (kW)=

$$Average\ Island\ Load\ (kW) =$$

$$Population \cdot \frac{1\ Customer}{4.8\ Residents} \cdot \frac{0.62kW}{1\ Customer} \approx \frac{Population}{8}\ (kW)$$

For peak loading, a loading factor of 70% was used, so the peak demand on a given island can be estimated by

$$Peak\ Island\ Load\ (kW) = \frac{Population}{8} \cdot \frac{1}{0.7} = \frac{Population}{5.6}$$

Given that the equipment on any island must be rated to service the peak demand, the peak demand calculations were used for the analysis in the following sections. The peak demand estimates for the remaining islands in Chuuk Lagoon are shown in Figure 12 (blue numbers).

3.4 Developing the DC Series Ring Design

This case study is primarily concerned with demonstrating the technical issues, feasibility and advantages of energising the islands in a DC Series Ring using single core submarine cable. Additional issues, not detailed in this report, which would need investigation for both AC and DC distribution networks include:

1) How the ocean floor topography will affect the exact routing of the submarine cable.
2) The actual cable landing locations on each of the islands. Assessments with respect to environmental impacts, land rights issues, proximity to load centres etc are beyond the scope of this study.
3) Whether or not the two landing locations on each island are best co-located or separated and linked via an overland cable. Again, a separate cost/benefit analysis study would be required to assess the better option for each island.

While all of these issues are important and need to be assessed prior to the commencement of any installation work, they do not impact on the technical considerations of the DC Ring design. For the islands of Chuuk Lagoon, there are probably two likely options for connecting the remaining islands to the Weno grid via a DC Series Ring interconnection. These would be:

1) Link all the major inhabited islands of the lagoon into one large series ring as shown in Figure13.
2) Run two separate DC rings, one for the Faichuk Islands, and one for the Nomoneas Islands as shown in Figure 14.

The physical requirements of the one and two ring options are summarised below in Table 1. Running two separate rings may be more practical depending on funding availability – ie., one group of islands could be energised initially, and a few years later when additional financing was available, the second ring could be installed. The dual ring option is likely to be the more cost effective solution overall as the slight increase in the length of submarine cables required is more than offset by the smaller cable size required for this approach. Both options are considered in the following sections.

Table 1 Requirements of Each Loop Option

Parameter	One Loop	Two Loops	
		Faichuk Islands	Nomoneas Islands
Length (km)	70	50	25
Estimated Peak Demand (MW)	3.9	2.0	1.9
Estimated Average Demand (MW)	2.7	1.4	1.3

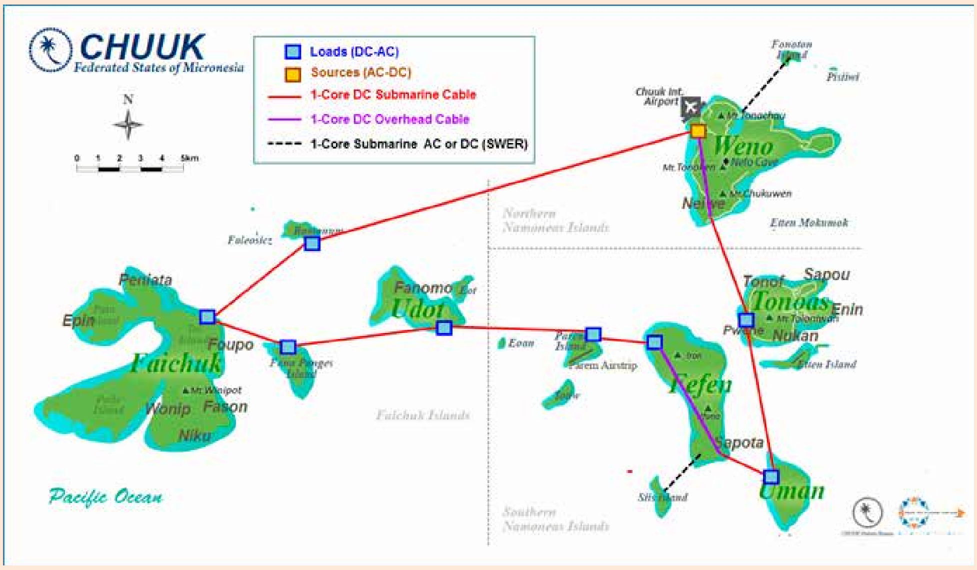


Figure 13- A Single DC Ring Linking All Major Islands

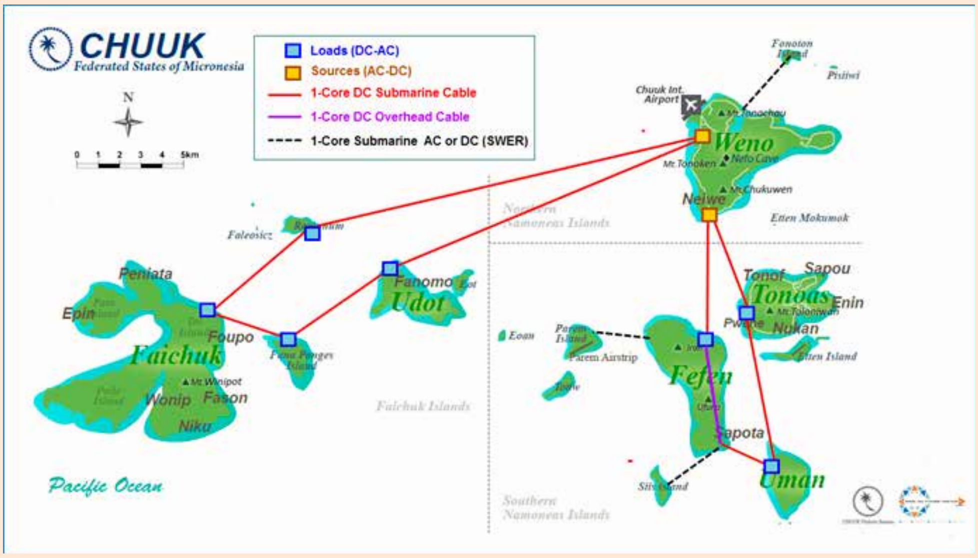


Figure 14- Two Separate DC Rings to Link the Major Islands

3.5 DC Submarine Cable Selection

3.5.1 Cable Voltage Rating vs Cable Size Trade Off

DC power delivery is simply the product of the voltage and the current, so an initial consideration of these two quantities is required to set the system operating boundaries. While it is desirable from the submarine cable point of view to operate the DC series loop at high voltage/ low current levels in order to reduce the conductor size required for the cable, this comes at the expense of the DC switchgear and subsystems needing to be rated for higher voltage operation. Hence there is a trade off to be made between the nominal operating voltage and current.

For the Chuuk Lagoon case study, a maximum voltage operating level of 20kV DC was chosen. This is similar to the peak voltage levels reached in a 13.8kV AC system and provides reasonable loop current requirements for the anticipated future load demands of the remaining islands in the lagoon.

The basic calculation steps are detailed in Appendix 4 and lead to the loop current and cable sizing requirements summarised in Table 2 below. These calculations were based on limiting the cable losses to around 5% during peak demand periods.

Table 2 Submarine Cable Size Requirements

Parameter	One Loop	Two Loops	
		Faichuk Islands	Nomoneas Islands
Length (km)	70	50	25
Peak Demand (MW)	3.9	2.0	1.9
Average Demand (MW)	2.7	1.4	1.3
Cable Size (mm2)	**240**	**95**	**50**
ILOOP for Peak Demand (A)	200	105	100
ILOOP for Average Demand (A)	150	75	70
Cable Losses @ Peak Demand (%)	5.4	5.3	5.1
Cable Losses @ Average Demand (%)	4.4	3.9	3.6

3.5.2Reducing the Required Cable Size through Load Profiling

Typically, the load profile (demand versus time of day) of any distribution is well known and the peak demand only occurs for a relatively short period of time each day. To reduce system losses during low demand periods the loop current set point can be adjusted (lowered) either by using pre-programmed values as a function of time of day, or by running the DC sources on Weno Island in a droop control manner.

Depending on the actual daily load profile, and the loop current setpoint control used during a daily cycle, it may be possible to further reduce cable sizing by sizing the cable based on energy losses (MWh) over the course of a day instead of power losses during the peak demand period.

4 - BUDGET ESTIMATES

4.1 Materials

The main system components comprise:

(i) Rectifier Station – AC to DC conversion – Weno Island.

(ii) Inverter Stations – DC to AC conversion – One unit for each island to be electrified.

(iii) DC Cable – Single Core – For interconnected island hopping loop

4.2 Rectifier & Inverter Stations

The rectifier substation and inverter substations are constructed as 40ft containerised switch room solutions. The electrical equipment is complete and includes switchgear, transformer, rectifiers, inverters and controls.

The footprint for the various size systems is:

- 4MW Rectifier 3 off 40ft containers.
- 1.4MW Inverter Station 2 off 40ft containers.
- 650kW Inverter Station 1 off 40ft container.
- 460kW Inverter Station 1 off 40ft container.
- 160kW Inverter Station 1 off 40ft container.
- 70kW Inverter Station 1 off 40ft container.

The switchgear provided permits connection to the local distribution network on each island and HV switchgear in the case of the 4MW Rectifier Station.

4.3 Cable & Cable Installation

The submarine cable is a single core copper cable (water proof & armoured) specifically designed and costed for the application by Nan Electrical Cables Australia Pty Limited.

4.4 Cost Estimates

The costing of the major components is presented in Table 3 along with cost estimates for a traditional AC installation. All costs are in US dollars. The estimates in Table 6.1 do not include the cost of the items common to both approaches – the AC distribution networks on each island and the HV connection to the power station on Weno Island.

The estimates also exclude overhead costs associated with land acquisition, sea or reef access, land titles, rent, government charges or taxes.

Table 3 Cost Estimates - DC Series Loop vs AC Reticulation

Equipment Required	DC Series Loop	13.8kV 3-Phase AC
Substations		
Weno	$ 950,000	$ 300,000
Faichuk	$ 475,000	$ 150,000
Fefen	$ 385,000	$ 150,000
Tonoas	$ 385,000	$ 150,000
Uman	$ 325,000	$ 125,000

Udot	$ 325,000	$ 125,000
Ramonum	$ 290,000	$ 100,000
Fana Panges	$ 290,000	$ 100,000
Parem	$ 270,000	$ 100,000
Siis	$ 270,000	$ 100,000
Subtotal	$ 3,965,000	$ 1,400,000
Submarine Cable		
75km of Cable	$ 2,925,000	$ 9,375,000
Transport	$ 235,000	$ 750,000
Installation Cost	$ 3,085,000	$ 9,900,000
Subtotal	$ 6,245,000	$ 20,025,000
Total	**$ 10,210,000**	**$ 21,425,000**

5- CONCLUSION

The MVDC distribution concept proposed challenges the common belief that MV/HV DC distribution systems are costly and not suitable for medium scale power distribution. The Chuuk study demonstrates the technical feasibility and cost effectiveness of the concept.

References

Title	Source	Date
Energy Snapshot – Federated States of Micronesia	NREL	2015
Quantification of Energy Efficiencies...... CPUC Final Report	KEMA/PPA	2010
Quantification of Energy Efficiencies...... CPUC Data Handbook	KEMA/PPA	2010
USA Insular Areas Energy Assessment Report	PPA/USA-DoI	2006
Pacific Lighthouses – RE Opportunities & Challenges...... FSM	IRENA	2013
About CPUC (webpage)	CPUC	2016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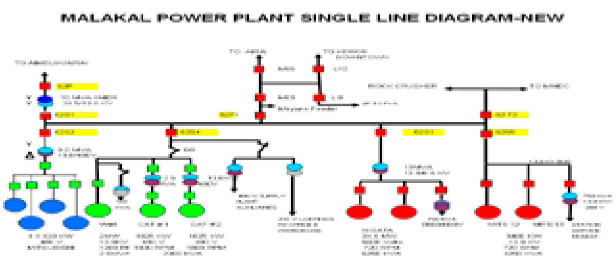
Conversion Of Cooling Tower System Of Niigata Engines to A Radiator System

Tito Cabunagan
PGD Manager, Palau Public Utilities Corporation

Background:

PPUC has a total installed capacity of 34.8 MW with 24.8 MW coming from Malakal Power Station and 10.0 MW from the newly constructed Aimeliik Power Station which was donated by the Japan Government.
The peak load of 12.0 MW for the main island of Koror and Babeldaob. The main Transmission line that links the two major power plants is rated at 34.5 KV while the main Distribution lines is rated at 13.8 KV.

One line Diagram of Malakal Power Station:



10 MVA Malakal Substation:

Malakal Station

Malakal Power Station Composition:

A. Operational Units	–	11 Units
B. Control Room 1	–	4 Stations
C. Auxiliaries	–	20 +

Malakal Power Station has the following units installed with their corresponding present capacity:

Nigata 14	–	5.0 MW	–	2011
Nigata 15	–	5.0 MW	–	2011
Mitsubishi 12	–	3.4 MW	–	1997
Mitsubishi 13	–	3.4 MW	–	1997
Wartsila	–	2.0 MW	–	1996
CAT 1	–	2.0 MW	–	2007
CAT 2	–	2.0 MW	–	2007
Mitsubishi 16	–	0.5 MW	–	2013
Mitsubishi 17	–	0.5 MW	–	2013
Mitsubishi 18	–	0.5 MW	–	2013
Mitsubishi 19	–	0.5 MW	–	2013

Total		24.8 MW		

Malakal Power Station Derated Capacity:

Nigata 14	–	5.0 MW	–	2011
Nigata 15	–	5.0 MW	–	2011
Mitsubishi 12	–	2.5 MW	–	1997
Mitsubishi 13	–	2.8 MW	–	1997
Wartsila	–	1.2 MW	–	1996
CAT 1	–	1.2 MW	–	2007
CAT 2	–	1.2 MW	–	2007
Mitsubishi 16	–	0.5 MW	–	2013
Mitsubishi 17	–	0.5 MW	–	2013
Mitsubishi 18	–	0.5 MW	–	2013
Mitsubishi 19	–	0.5 MW	–	2013

Total		20.9 MW		

Niigata # 14 & 15

Cooling Tower Of Niigata #14 & 15

Technical Specifications: Cooling Tower

Made: Kuken Cooling Tower
Cooling Performance:
Inlet Temperature – 40.0 Deg C.
Outlet Temperature – 35.0 Deg C.
Volume Of Water Consumption;
Per Day – 35,000.00 Gals
Per Month – 1,050,000.00 Gals

Technical Specifications:

Radiator:
Capacity – Cw = 215 Cu.m./Hr; Jw=100 Cu.m/Hr
Lube Oil = 110 Cu.m./Hr
Cooling Performance – Cw= 48.8 – 45 Deg.c Jw= 92.5-77.6 Deg. C; Lo = 69.1-55 Deg C
Volume Of Water- Cw= 106 Gals/Bay; Jw=96 Gals/Bay; Lo = 111 Gals/Bay
Total Cost Of The Project:
New Radiator = $1,585,760.00

Project Concept:

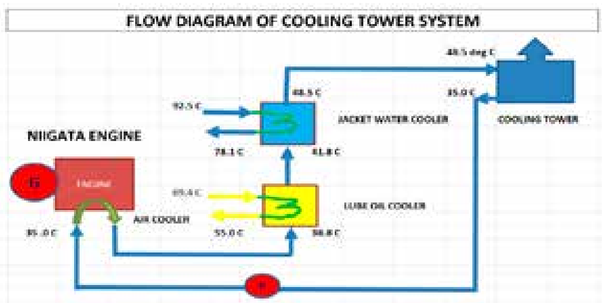
1. Minor Revision On The Piping Systems.
2. The Construction Will Be One At A Time Inorder Not To Affect The Plant Availability.

Auxiliaries Of Niigata # 14 & 15

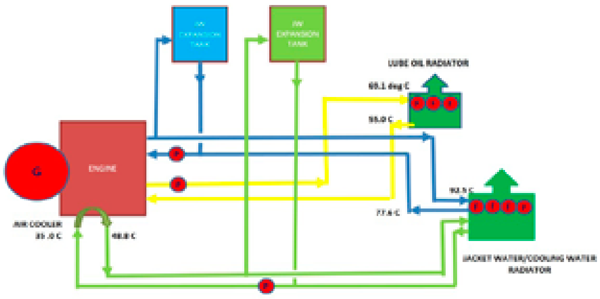
Maker Of Radiator For Niigata

ECODYNE
UET SWITZERLAND Inc.

Flow Diagram Of Cooling Tower System:



Flow Diagram Of Radiator System:



Benefits Of New Radiator For Niigata Engines:

1. Minimize Water Consumption
2. Niigata Operations Will Not Be Affected By Drought As Experienced In February – May 2016.
3. Less Maintenance As We Are Cleaning The Cooling Tower Every Month.

Background:

Malakal power station comprises of 11 operational units with two Niigatas rated at 5.0 MW each as the base load. These two Niigata units utilizes the cooling tower for its cooling water system. PPUC encountered a severe drought from February to May 2016 wherein the two Niigata engines were put to into an emergency/standby condition. With this kind of operation, the plant efficiency and reliability were affected as we are obliged to run the smaller and lower efficiency engines.

Approach:

First to be constructed is the new radiator foundation of Niigata # 15 engine followed by the demolition of its cooling tower system structures. The new radiator system will be constructed and assembled one at a time. This will allow the remaining unit to run in parallel with two Mitsubishi units in Aimeliik Power Station. The first cooling tower to be dismantled is the one serving the cooling system of Niigata # 15 and followed by Niigata # 14. Both units are expected to run on the new radiator system by the end of August 2017.

Findings or Results:

Radiator cooling system is most effective and ideal for Island countries especially Palau where water supply is a big problem during a period of dry spell.The radiator system made from Ecodyne guarantee's the efficient cooling and will never affect the capacity of both Niigata engines.

Conclusion:

Maintenance wise, the plant could save man hours from monthly servicing/cleaning of cooling towers and thus these man-hours will be diverted to other maintenance activities and improved as well as maintain the power station.

Isolated Power Systems (IPS) Connect Workshop – Rottnest Island, Western Australia

Pacific Power Association

The PPA's Sustainable Energy Industry Development Project (SEIDP) in collaboration with IRENA funded a number of Utility staff to attend the 3rd Isolated Power Systems (IPS) Connect event on Rottnest Island, Western Australia, from 13 – 17 November 2017. This year's event follows from similar events held previously on King Island and Flinders Island and is hosted by the University of Tasmania and Hydro Tasmania.

SEIDP funded participants from Kosrae Utilities Authority, Chuuk Public Utilities Corporation and Solomon Power whilst IRENA funded participants from EPC (Samoa), Tonga Power Ltd and Te Aponga Uira (Cook Islands).

The event comprised a two day professional development workshop on solar design, installation and maintenance followed by a two day conference on isolated power systems.

The conference focussed on the integration of renewable energy through hybrid models. The delegates at the conference represented developers and owners of renewable energy systems from Australia, USA and Europe. Presenters at this conference shared their experiences on project design, implementation and operation of renewable energy systems. Field visits to Carnegie Energy's Garden Island wave energy installation as well as the Rottnest Island's renewable energy installation and desalination plants were also organised for participants.

Photo: ISP Connect 2017 Participants (left to right) - Mark Waite (CPUC), Ann-Marie Daka (Solomon Power), Murray Shereen (TPL), Latuselu Posi (EPC), Fred Skilling (KUA), 'Apisake Soakai (IRENA), Teiiti Marita (TAU)

PPA hosts training workshop on Power System Modelling

Pacific Power Association

A training workshop hosted by the PPA on power system modelling was held in Nadi, Fiji. The workshop is one of the capacity building initiatives under World Bank funded Sustainable Energy Industry Development Project (SEIDP)[i] being implemented by the PPA.

One of the objectives of the SEIDP is to increase the capacity of the power utilities to enhance their ability to incorporate and manage renewable energy technologies. As part of the Technical Assistance of the project, the PPA had procured the power system modelling software Power Factory from DigSILENT and will carry out a series of workshops to build the capacity of utilities on how to utilise it. With most of the PPA member utilities embarking on renewable energy projects to displace fossil fuel generation, some utilities are not sufficiently equipped to carry out their own studies to determine the impacts of variable renewable energy technologies on the grid. The ultimate aim of the training workshop is to develop the capacity of PPA utility members to carry out their own power system planning and grid integration studies.

Representatives from 13 utilities across the Pacific were in attendance at this workshop which was facilitated by expert trainers from DigSILENT Pacific.

i The Sustainable Energy Industry Development Project (SEIDP) aims to increase the data availability and capacity of power utilities in PICs to enhance their ability to incorporate and manage renewable energy technologies and long -term disaster risk planning.

The project will provide support to the Pacific Power Association (PPA) to assist PIC utilities through a serie s of activities which will:

- Increase publicly available information on renewable energy resources.
- Increase available planning tools, and provide training to both the PPA and PIC power utilities in the use of these tools.
- Improve technical and institutional capacity within the PPA and PIC power utilities for planning and management, aimed at the successful integration and long-term management of power systems with higher levels of renewable energy.
- Strengthened planning capacity for disaster recovery and risk reduction within PIC power utilities.

The project will build on existing renewable energy policies and frameworks already implemented by governments and administrations in the region. Together with coordination from the PPA, the project will promote the implementation of shared renewable energy objectives.

Welcome!

To New Allied Members

One (1) new company has joined PPA as an Allied Member since our last PPA Magazine. The new member is:

GREENBOX ENERGY PTY LTD: Greenbox Energy Pty Ltd is based in Kingsway West, Australia. Their primary activity is Renewable Energy Systems and their secondary activity is Turnkey/Design Build.

PACIFIC BULK FUEL

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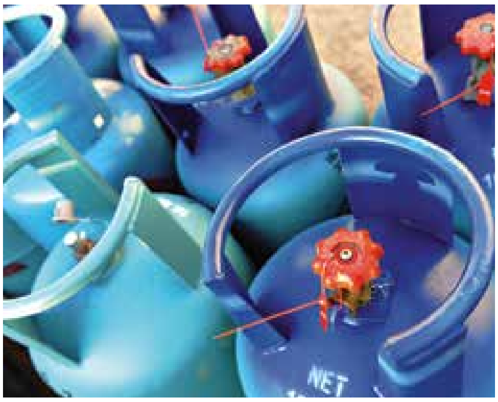

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