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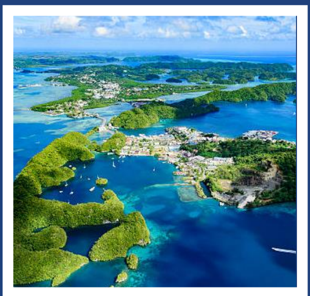

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Pacific Power Association, Suva, Fiji Islands. The PPA is an inter-governmental agency and member of the Council of Regional Organisations in the Pacific (CROP) established to promote the direct cooperation of the Pacific Island Power Utilities in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

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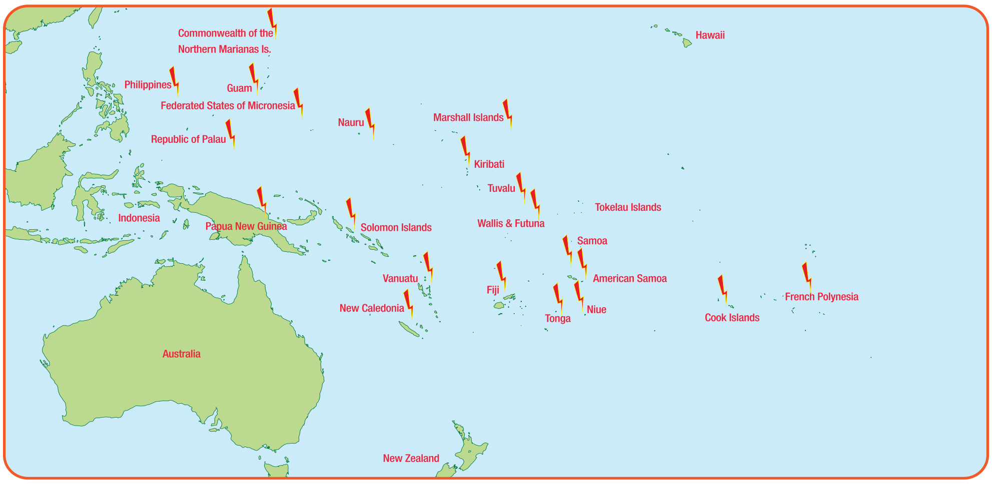

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Editor’s Note

Gordon Chang
Acting Executive Director

The 2021 year was accompanied by the same medical issue that we have had for the past two years – a year of continuous uncertainty.

The Pacific Power Association (PPA) would like to express its sincere appreciation to the World Bank, for their provision of funding to continue the ESMAP activity which is to increase the data availability and capacity of power utilities of the PICs countries. This World Bank project has been amended for a further one year due to the pandemic to February 2023.

With mixed emotions we viewed 2021 as one that will remain an emotionally experience with most of our business activities not being completed due to the COVID-19 pandemic not only to the PPA Secretariat but also to the PPA members. Our gratitude also needs to be extended to our Allied Members and Active Members for their continuous support to the PPA Secretariat by continuing their financial membership and support to the PPA budget. We also take this opportunity to welcome one new member NOJA Power who has rejoined PPA this quarter and wish the members who have withdrawn their membership all the best and that they may reconsider rejoining their membership with the PPA family again soon.

It is to be hoped and it is our wish that during this time of celebration of Christmas and the New Year, that we remember those that may have suffered so much with the COVID-19 pandemic to cope with their grief at the loss of friends and family and set about rebuilding their lives.

On that note, may we on behalf of the PPA Board, Executive Committee and Secretariat wish all the Members and readers a Merry Christmas and a Happy New Year 2022.

Vinaka Vakalevu

Project Delivery in the Age of Covid - an EPC Perspective - How Covid has necessitated a change in approach and learnings for the industry

Chris Service
Business Development Manager – Pacific – Infratec

In March 2020, the Covid-19 pandemic started to encroach on the Pacific. The situation evolved daily, with Pacific borders and travel corridors rapidly closing in a bid to shield Pacific nations from the worst of the pandemic.

Almost two years later, travel remains heavily restricted in the Pacific and renewable energy projects in the region have largely ground to a halt. The effects on the Pacific's renewable energy sector have been profound, but also present an opportunity to re-think how we respond as an industry moving forward.

As a Pacific focused EPC, the crisis challenged and pushed Infratec's 'NZ quality, locally delivered' model to new levels. This article highlights how Infratec has responded to the crisis and shares learnings and reflections for the industry to help build in resiliency to any future shocks.

Setting the scene

- As of March 2020, Infratec had active projects spanning 16 sites and 7 countries in the Indo-Pacific, representing 90% of our business activities. Projects ranged from utility scale solar farms, Battery Energy Storage Systems (BESS) to greenfield micro-grids, MV networks and long-term technical assistance programmes.

- At the time, Infratec staff were scattered across the region. In Indonesia, Infratec's MFAT funded NZMATES programme[1] with Mercy Corps Indonesia, had a permanent office with a mix of international and national staff. In Palau, the project team was in the final throws of commissioning a micro-grid in Kayangel with the Renewable Energy team within PPUC.

Initial response

- The first point of business was to get our people off site and back home while travel corridors remained open. With an international workforce that included routes from eastern Indonesia to Costa Rica, and Kayangel Atoll to New Zealand. Staff were instructed to down tools and evacuate as international travel became more are more limited.

- With staff secured, Infratec's focus turned to business continuity planning in an evolving landscape. How significant was the risk of Covid-19? How would local governments respond to this risk? How long would it be until we could get on-site again? How do we as a company manage contracts and cashflows with such uncertainty? Various scenarios were analysed, with a continuity strategy formulated and regularly reviewed.

- Relations with our utility customers were critical during this early stage. While contractual clauses provided some temporary relief, the full duration and extent of the pandemic's impact was unknown. The ability for Infratec and customers to come together, to appreciate each other's positions and respond accordingly, was critical to success. In some cases, hold points were agreed for site-specific work, while in others, detailed design and procurement were advanced and payment milestones adjusted to support cashflow requirements.

[1] https://www.nzmates.org/

Moving forward
Project Governance

- Infratec updated and operationalised its Health & Safety policy to include provisions for Covid-19. Examples included requiring all staff travelling internationally to have an exit strategy (MIQ booking) prior to departure and additional on-site Covid-19 protocols.

- Swapping handshakes for Zoom: Establishing local partners over Zoom was a lengthy but ultimately successful activity. Miscommunications were common during early stages and learnings included allowing sufficient time in project programmes to build relationships remotely.

- Contracting: The new risks and costs associated with the pandemic were rarely captured in traditional fix price lump sum contracts. Reconciling these issues with clients was both critical to ensuring project viability, and a significant administrative burden to navigate for all parties. Successful examples included de-scoping of fixed price contracts in favour of cost-plus contracts for high risk items; time extensions and cost recovery for quarantine costs.

Engineering

- Engineering was exclusively reliant on sourcing critical site information from local partners without on-site Infratec support, including geotechnical studies, surveys, documentation and site investigations. While largely successful, learnings were gained in terms of mutual alignment on scope, deliverables and expectation management.

Procurement

- Global supply chain shocks have rippled through the industry. Costs have increased, lead times have extended and in some instances, product lines have been discontinued. More restrictive terms from suppliers also created an additional price exposure gap due to longer BAU procurement approval processes than supplier validities would allow for.

- Infratec's response was a shift from 'just-in-time' to 'just-in-case' procurement, including an agreement with clients for the advance purchase of ~12MWh of BESS destined for projects in the Pacific, and temporarily stored and maintained in Auckland.

- International freight prices increased by more than 400% and now represent a major cost item for projects. Pacific freight routes have become less lucrative to global shipping companies, with freight reliability to the region falling below 20%. Strong relationships with our preferred freight forwarder have become critical to help forecast and de-risk projects.

Construction

- Remote delivery: Where scope and local capability allowed, Infratec pursued a remote delivery model as much as possible. Pre-Covid, Infratec operated with a dedicated layer of on-site management, supervision, specialists and largely recruited locally. With travel restricted, we sought out local partners and subcontractors who could provide the same level of supervision, quality control and trust to enable us to advance projects. While not all projects supported this, successful examples included:

– In Tonga, an all-local team is concurrently delivering two solar arrays on Vava'u and 'Eua, under the supervision of a locally based Infratec construction manager.

– In Palau, PPUC's team advanced the commissioning of the Kayangel solar/BESS micro-grid, with the remote support of Infratec engineers.

– In Indonesia, the Pūngao Pattimura Mini-grid Training Lab is now fully installed at Pattimura University and technical assistance continues with PLN to support the roll-out of sustainable solar and hybrid mini-grids in Maluku Province.

Learnings and reflections

- Relationships, relationships, relationships. Relationships are everything in the Pacific and a project's success can live or die on their strength. While Infratec prides itself on its local relationships and community engagement model, the pandemic has reinforced that more work can be done to strengthen local relationships across a range of stakeholders.

- Remote delivery is viable and needs more investment. Covid and the successes mentioned above have helped Infratec re-frame its risk appetite for delivering projects with limited on-site support. As an EPC, quality control, on-site HSE and specialist skills remain critical considerations for project delivery, but do not need to be exclusively managed by on-site foreign nationals. The last 18 months has taught us that the presence of just a few local experts – with remote support from specialists - can drive significant project progression. It raises the question whether it is time to evolve our mantra from 'NZ quality, locally delivered' towards 'locally delivered, remotely supported'? As an industry, how can we structurally invest in such skills to enable this across the region?

- Contracting models need to evolve. EPC and IPPs globally, are recognising the need to reconsider their contracting model in line with the new realities of risk. The traditional fixed price lump sum contract no longer adequately captures a contractor's risks in today's environment. Alternative risk-sharing models are becoming more common in international markets which effectively balance price transparency, risk and value for money.

- True partnerships = best fit for Pacific. Infratec believes that true partnerships are essential to structurally advance the renewable energy industry in the Pacific. To date, the industry has taken a project-based, transactional approach to a structural issue. Projects are tendered under price-based evaluation criteria, with little to no provision for partnering with, upskilling, and training local companies. Covid-19 has shown us the shortcomings of this approach, with projects grinding to a halt as soon as international travel is closed. A partnership-based approach is an opportunity to build-out renewable energy assets while also building-in in-country capacity in Pacific nations.

Harnessing Public Buildings for Solar Generation across the Pacific Region

Thèo Dumanchin
Business Development Manager – Pacific – Vergnet

About Vergnet
- Company Established: 1989
- Headquarters in France with permanent subsidiaries in Africa, Caribbean, Indian and Pacific Oceans
- A regional subsidiary Vergnet Pacific in New Caledonia
- Wind, Solar & Hybrid solutions provider
- Long-term track record in complex and isolated regions
- 365MW installed renewable energy plants in 40 countries
- Over 130 staff throughout the entire value chain of renewable energy project: from R&D to O&M expertise

Solar: a Natural Resource Fit for the Pacific

Why Targeting Public Buildings for Solar?
- Governments must take the lead in the Energy Transition: Ambitious NDCs through Renewable (up to 100% renewable by 2030)
- Taking advantage of the existing public facilities: Government Buildings, Schools, Health Centers, Military & Navy Facilities, Public Housing, Sports Complexes, etc.
- Existing synergy between Governments and Power Utilities
- Simple to replicate
- Creating local jobs and strengthening local expertise
- Raising the awareness of students through educational material

Energy Challenges faced by the Pacific Islands
- High reliance on imported fossil fuels: high cost, long supply chain, CO2 emission
- Energy demand is growing
- Challenging climatic conditions
- Scarcity of Land

Solar Energy as a matter of course
- Abundant and sustainable resource
- Cost-competitive energy
- Increasing energy independence and diversification of the electricity production mix as a degree of security
- Equipment and design are adapted for islands conditions ensuring durability and efficiency over time
- No land footprint: solar solutions suitable for buildings, easy and fast installation

Project Insight #1 – South Province
- Project Type: Grid-Connected Rooftop Solar PV Systems
- Location: South Province, New Caledonia
- Public Buildings: 4 Secondary Schools, 3 Health & Social Centers, 1 Territorial Building
- Client: South Province
- EPC Contractor: Vergnet Pacific
- Rated Power: 534 kWp

- Estimated Energy Output: 748,020 kWh/year
- Commissioning Date: June 2021

Project Insight #2 – Nursery School of Wepwe

- Project Type: Grid-Connected Rooftop Solar PV System
- Location: North Province, New Caledonia
- Public Building: Nursery School
- Client: Municipality of Pouembout
- EPC Contractor: Vergnet Pacific
- Rated Power: 33 kWp
- Estimated Energy Output: 46,200 kWh/year
- Commissioning Date: March 2021

The Mana Pacific Moana Pledge and Blue Planet Alliance

Samantha Frick
Business Development Director — Mana Pacific

PPA Allied Member, Mana Pacific, presented at the virtual Annual PPA Conference on 26 August, 2021 alongside their partner Blue Planet Alliance. As a social impact company that develops and finances resiliency projects, Mana Pacific teamed up with the Alliance and its founder Henk Rogers, the visionary of Tetris, to accelerate the transition to renewables in the Pacific.

John Miller and Henk Rogers signing partnership MOU at Blue Planet event at COP26 in Scotland.

At the PPA Conference, Mana Pacific and Blue Planet Alliance presented a strategy for how islands can achieve independence from fossil fuels and gain access to affordable and reliable clean energy. Called the Moana Pledge, this solution is a development "accelerator engine." By aggregating the demand of the Pacific Islands and providing an agreeable, standardized Master PPA framework, it unlocks funding, lowers costs, and speeds the delivery of renewable energy projects. The engine and its related platform includes an online "marketplace" to accelerate the contracting, sourcing, funding, and execution of projects. The Transpacific Master Power Purchase Agreement includes industry best practices, equipment standardization and interoperability, a vendor qualification process, a long-term operations and maintenance plan, as well as workforce development and capacity building to maximise local social and economic benefit. It was recently certified by the Global Solar Impulse Foundation as a scalable, efficient, and profitable approach to make a significant and lasting impact on the environment.

The formation of the Moana Pledge was and continues to be a collaborative effort. Critical contributions were made by Pacific Power Association utility members, Pacific Island governments, regional Pacific intergovernmental organizations, technology and financial institutions, and development partners. Mana Pacific hosted and participated in regional and international events and listening sessions to ensure the Pledge will address challenges facing PICT's. Alongside Pacific Island leaders, Mana Pacific carried the message it shared at the PPA Conference to COP26 in Glasgow. The momentum continues to build as the Moana Pledge signing event will take place at Our Oceans Conference taking place in Palau in February 2022. Visit ManaPacific.com and contact us at info@manapacific.com to inquire how to access the Moana Pledge resources and financing solutions.

Redefining 21st Century Engineering

Souranka Bhuniya
Manager - Sterling and Wilson Private Limited

Sterling and Wilson was incepted in the 1920's as Wilson Electric Works .It joined forces with Sterling Investments of the Shapoorji Pallonji Group in the year 1973, to form the engineering giant both in India and abroad .

Shapoorji Pallonji Group has a legacy of 156 Years, consists of 18 major companies, 6 business segments, present in 70 countries and has 70000 + employees. Sterling and Wilson is a 94 years old company with 7 major businesses, present in 40 + countries, 5000 employees.

The main business lines are Solar, Hybrid and Energy Storage, Cogeneration, Data Centers, Sterling Generators, MEP (Mechanical, Electrical and Public Health Engineering) and IEPC (industrial EPC), Transmission and Distribution.

Sterling and Wilson is instrumental in CSR activities .The number impacted lives counts at 6500 in 2018-2019 and its is growing every year.

Solar EPC, Hybrid and Energy Storage:
With 11.4 GWp EPC portfolio and 8.1 GWp O&M Portfolio, SW is present in 24 countries with operations in India, Asia, Middle East, Africa, Europe, Australia, United States and Latin America. SW provides Complete range of Turnkey and Balance of System (BoS) solutions for our utility-scale, rooftop, and floating solar power projects. We have the credential of World's single largest single site solar project, 1177 MWp in Abu Dhabi. Total order book in Australia now stands at about AUD 1.2 billion with a portfolio of more than 1.1 GW. Hybrid energy offerings, deals with a mix of solar, wind, gas, diesel and battery energy storage, Standalone turnkey battery energy storage solutions and Industrial, island and grid-connected systems /microgrids. Our 1st solar-diesel hybrid is Africa's largest battery energy storage at 37 MWh and is set to empower the future.

Diesel Generators:
Under the brand name of Sterling Generators, our manufacture facility boasts of being Asia's largest genset integrator. We are a large scale manufacture of power and control panels, motor control centers, APFC panels, Prefabricated enclosures , E-House and provider of balance of plant equipment. The plant in Silvassa, India has 45,000 Sq.M Plant area and technically advanced infrastructure for fabrication. The 14-tank pretreatment plant for surface treatment, a powder coating plant and a state-of-the-art PLC based testing facility (up to 3000 kVA) is the first of its kind in the country. Partnership with the global leaders in diesel engine manufacturing, namely Escorts-India, MTU-Germany, Perkins-UK, Volvo- Sweden and MHEPL-India has helped us set benchmarks in fuel efficiency, reliability, and strict adherence to global emission norms. The facility is ISO 9001, ISO 14001 and BS OHSAS certified by Germanischer Lloyd Gmbh, Germany. We proudly display 860 Happy Clients, 3000 Projects, 14377 DG/Panels installed.

Cogeneration:
The portfolio includes Open cycle, Combined Cycle, CHP, Gas and Liquid Fuel-based power plants and

Energy solutions around gas turbines, steam turbines & reciprocating engines.

In depth audit of site and plant load data, Conceptual design, sophisticated analysis of gas and electricity data, optimal plant configuration savings, payback and IRR, Incentive realization and robust EPC process makes Sterling and Wilson as a preferred choice. With the acquisition of Italy's power giant STC Power and Costell, we proudly portray 225 + projects and 2000 MW plus installed capacity.

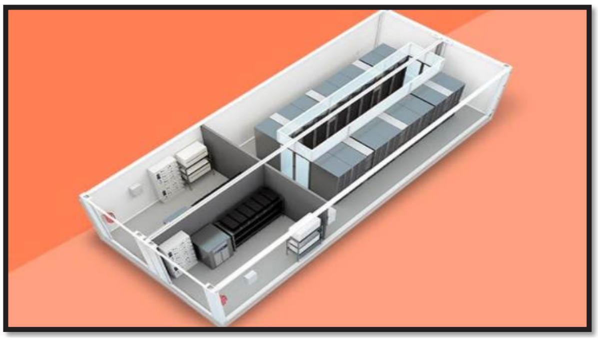
STC POWER

COSTELL CRESCE LA TUA ENERGIA

Data Centers:

The offerings are:

- Hyper Scale Data Centers – Conventional Brick and Mortar offerings.
- Modular Room-in-Room Data Center Systems
- Edge Data Centers – Containerized Data Centers (CDC)



Our customers are National Stock Exchange of India, National Security Depository Limited (India), Vodafone, Software Technology Parks of India, State Data Center and many more . The Containerized Data centers are highly efficient and convenient, and they are perfect solution for securing massive IT infrastructures, to be implemented outside the company building. They suit all requirements be it a permanent solution, a backup, or a temporary data center. These DCs are completely protected against fire, fire-fighting water, corrosive gases, vandalism, unauthorized access, eavesdropping/radiation, noise, dust, and debris.

How to Build Network Reliability: A Staged Approach

Martin van der Linde, *MIEAust, BE, BBus Mgt*
General Manager Marketing — NOJA Power

Cost effective and omnipresent, the overhead electricity network is here to stay. Despite the advent of grid scale distributed generation, rooftop solar and asynchronous sources, the distribution network's likely trajectory is the operation of an electricity marketplace, acting as a broker between generators and loads, electron manufacturers and consumers.

The previously feared obsolescence of trillions of dollars of infrastructure is now unlikely to come to fruition, giving engineers an existential liberty in knowing their work towards securing reliability of a distribution network of the future has value, and is very much worth pursuing.

Since the distribution network is here to stay, the key focus remains "how do we maintain network reliability". It's an age-old question, but our modern version includes the additional caveats of "how do we cater for distributed generation" and "how do we make our designs future proof with an upgrade path?".

Through this article we take a generalist approach to review the existing principles of network reliability, with consideration of zeitgeist challenges such as renewable integration and network future proofing. The recipe for reliability becomes a journey, from substation level network protection and automation only, evolving to a fully automated Smart Grid with bidirectional power flow.

We can use a model of Network Reliability Practice Maturity to help clarify the path from beginner, to best practice modelling, then through to experimental innovation for the grid of the future. Reliability rewards are commensurate with graduation through each stage. In our experience in delivering power reliability systems to 104 countries worldwide, we have devised a useful model for building distribution network reliability. We call it The Network Reliability Practice Maturity Model.

This model visualises how it is highly unlikely an organization can leap through from substation-based protection to a fully automated "smart grid", without passing the intermediate stages and learning these competences. Ironically, most utilities don't even have to – the Pareto Principle will yield most reliability rewards with well graded recloser implementation. Nonetheless, this model provides the rails necessary to plan a progressive improvement of your network reliability.

The Principle Concept of Overhead Network Reliability.

The electricity distribution network accounts for 80% of electricity delivery outages [1]–[5]. However, it is a symptom specifically of the challenges of distribution of electricity. For the electricity distribution network, centralized generation and transmission has a much smaller geographic exposure to risk. There are simply more distribution lines and assets than transmission lines or generators, spreading resources thinner over a larger volume of assets. Accordingly, it stands to reason that the majority of failures are assigned to the group with the largest exposure to the elements.

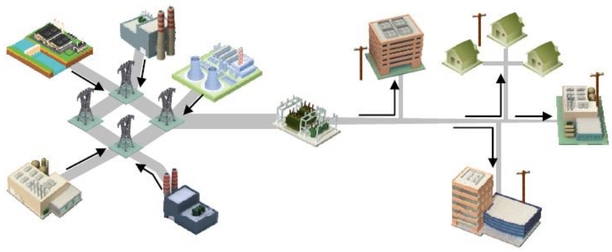


Figure 1 – 20th Century Electricity Network

However, industry experience has precipitated a few best practices for gaining optimum reliability on asset investment. The fundamental principle for overhead network reliability is to use switchgear to break the network up into smaller zones, and then decentralizing protection and implementing automation. By making a massive network into smaller manageable zones, it is possible to improve the reliability for each of the connected areas. Without this form of sectionalization, a single permanent fault would result in an entire feeder, or even substation, being turned off. By breaking the network up into smaller sections, faulted zones can be isolated.

A NOJA Power OSM Recloser used as the point of connection switchgear for a Grid Scale Solar Farm

Network Reliability Practice Maturity – A Staged Model

The journey towards network reliability requires a staged approach. Figure 2 provides a conceptual overview of this transition, starting from the baseline of substation circuit breakers carrying all protection responsibility, transitioning through to the communications-enabled wide area experimental/ innovation-centric protection schemes such as synchrophasors.

With 80% of delivery outages coming from overhead distribution lines, and of those 80%, a further 80% can be classified as momentary. Specifically, these are fault events which are temporary and will clear themselves, provided that the act of clearing the fault does not cause subsequent critical damage to assets leading to permanent faults. Practical examples of these faults include vegetation and fauna contact with overhead lines.

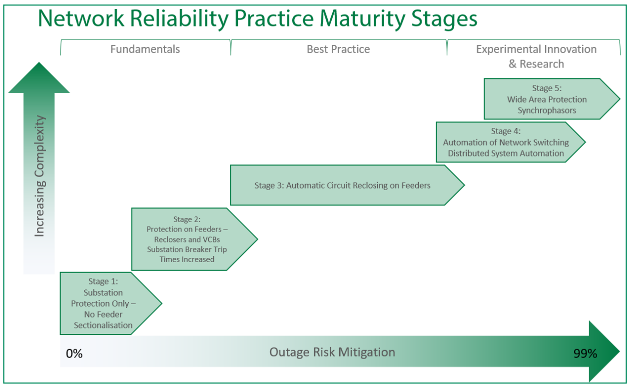


Figure 2- A staged Visualisation of Network Reliability Practices

As we work through each stage of improved network reliability practice, we build on the expertise built at the previous tier. It is highly unlikely that a Smart Grid automation project with DSA will correctly operate and grade if the utility has not yet mastered distributed grading of protection assets in tiers 2 and 3.

Not all scenarios call for comprehensive smart grid automation either. As with most engineering decisions, there is a cost/return calculation to be made. If you are facing major challenges with significant distributed generation assets, then aspirations to achieve wide area protection is reasonable. Worldwide however, most distribution networks would benefit greatly from moving from stage 1 to stage 3 or 4 protection, affording 80% of the reliability gains on offer at a fraction of the operational and implementation costs of a stage 5 wide area protection scheme.

Pragmatically, we can visualize the performance of the distribution grid under each of these stages of reliability design as in figure 3.

For the exact same fault scenario, the different stages of network reliability design maturity yield significantly different results. The stage 3 improvement from stage 1 is dramatic, with 80% of all faults being mitigated as temporary, combined with the region impact mitigation by sectionalization. This high-level tour also shows the diminishing returns of network automation investment. There are gains to be made at the higher stages of reliability practice, but these are unlikely to surpass the performance gains seen by deployment of modern Automatic Circuit Reclosers with remote control to ascertain fault location.

Ironically, complexity is the antithesis of reliability. Reaching stage 4 and 5 may actually have a converse reliability impact in the short term as utilities work to grapple with the operational realities of new technology implementations. Network innovation has its rewards, but it is best applied with clear communication and documentation of learnings throughout the aspiring utility organisation.

A NOJA Power OSM Recloser installed close to a Distribution Substation

Reclosers and Sectionalisers

When pursuing a network reliability strategy, protection engineers are armed with the knowledge that 80% of distribution network faults are transient. By implemented Automatic Circuit Reclosing, these 80% of faults are prevented from causing outages, leading to a significant improvement in network reliability. However, when permanent faults occur, their geographic impact is determined by the density of distribution of sectionalising switchgear throughout the network. The more granular the subdivision of the network, the smaller the geographic reach of any particular outage, especially when multiple network feed paths are possible.

How is a Sectionaliser different to a Recloser?

The key difference between a Sectionaliser and a Recloser is fault breaking capacity. Reclosers are protective devices, in they detect and interrupt fault current. Sectionalisers are not able to interrupt fault current, and instead rely on seeing a drop in voltage caused by an upstream device operating, before opening in this dead time to effectively "sectionalize" the fault. Both units succeed in breaking the network up into smaller segments, but Reclosers offer protection to the network, while sectionalisers rely on working with other protective devices.

In years gone by, a sectionaliser device was cheaper than a modern Automatic Circuit Recloser, but with the global scale adoption of ACR's the price has essentially converged. With the cost price differentiator cleared, the only viable reason for using Sectionalisers is for appropriate grading.
With over 30 years of experience in pole mounted equipment, NOJA Power's Group Managing Director Neil O'Sullivan said "If you have a requirement to install sectionalisers on your network today, it is probably because of grading limitations. By installing reclosers with sectionaliser capability you allow these devices to be re-configured as reclosers as other network protection devices particularly substations are upgraded to have digital protection to allow the entire feeder to be graded and protected with reclosers in a step by step approach. "

Grading

As seen in figure 3, to minimize the impact of permanent faults, the objective is to isolate the faulted section of the distribution network with as much precision as possible. Generally, this is achieved through the use of protection grading, a technique which uses either fault magnitude, coordinated protection operating time, or both, to ensure that the protective device closest to the fault is the fastest to open. This allows for predictable fault response. If a substation circuit breaker is set to a 1 second trip time, then devices which are closer to the fault will need to operate faster than 1 second to ensure that only the smallest faulted section is isolated.

When many of the electricity distribution networks of the world were built, engineers had to contend with mechanical relays and spring actuated switchgear, whose variance in time response necessitated significant grading margins between devices. When devices had unpredictable variances, these required larger grading margins to account for the possible deviations. Accordingly, a substation breaker setting of 1 second only allowed for 1 or 2 downstream protection devices, with a grading margin of 500ms or 333ms respectively. This drawback is being mitigated by the advent of microprocessor controlled switchgear.

Modern microcontroller based devices such as the NOJA Power OSM Recloser can be comfortably set with a 150ms margin, leaving room for up to 6 protective devices in series. However, if the replacement of a single unit is done within the context of older equipment, it might be necessary to have the new equipment operate as a sectionaliser until such time that the feeder grading is recalculated, or all legacy equipment is replaced.

To facilitate the piecewise upgrade of a network, NOJA Power's OSM Recloser system can also be used to fulfil the sectionaliser role. It is a standard function of the equipment, which is generally used when there is either insufficient grading to allow for determinant protective response, or simply to replace aging sectionaliser devices with ACRs. The OSM Recloser can be later programmed to act as a conventional recloser when the feeder protection is recalculated, offering an upgrade path for an individual installation without the investment commitment required to redesign an entire network.

For networks t hat are at stage 1 in our reliability maturity model, a common problem is that substation circuit breakers are set to trip too quickly to allow for protection devices closer to the fault to operate faster. In these scenarios, when the substation has a reclosing function, sectionalisers can be used along the network. In this scenario, these sectionalisers open when the substation does, and when the substation recloses, the faulted zone is minimized. This is better than no reclosing at all, but it performs worse than distributed reclosing as the momentary interruption is seen by the entire feeder.

In our experience, a pragmatic initial step to achieving a reliability improvement is to move the substation breaker response to match the short time current withstand capacity of the substation transformer. This generally provides sufficient grading headroom to include downstream reclosers, allowing for a network progression to stage 3 maturity and the rewards of 80% improved network reliability. Once a grading margin is present for downstream protective devices, the next question arises as to where exactly these units should be placed.

Choosing Recloser Installation Sites

Optimum placement of sectionalising devices such as reclosers or sectionalisers is a challenging problem. In mathematical terms, it is a "Combinatorial constrained problem with a nonlinear and nondifferential objective function"[1], [2], [5]. Essentially, the problem has too many variables to be simply solved, but there are technical ways to execute this optimization problem.

The overall goal is to divide up the distribution customer base into segments, balancing out the fault incidence rate with respect to customer volumes, all while considering voltage should be maintained within 10% of nominal value and load/generation balance should be maintained [6].

On a radial feeder, this is far easier, but for optimum reliability a ring feed is required. Ring network arrangements allow for alternative power sources in the event of a failure in any single section, providing a layer of additional mitigation for permanent faults. Whilst beyond the scope of this article, there are some good academic papers on this subject for further reading [2], [5].

From an asset management perspective, once your "sectionalization" devices are in service, a choice must be made between operational methods. The two primary options are "Run to Failure" and "Proactive replacement", of which the former is the older technique that has been proven to be more expensive [3], [7], [8]. Accordingly, in our experience we generally see distribution network service providers operating on a proactive replacement program, retiring aged technologies such as oil or SF6 based equipment with modern solid dielectric alternatives.

A Single Wire Earth Return network with a NOJA Power OSM Recloser

Conclusions & Designing for a Future Network

As the electricity distribution network transitions to greater levels of distributed generation, the simple reliability gains of achieving radial protective grading will no longer suffice to bring the reliability benefits that it once did. Distributed generation brings new challenges with differentiating load from generation and handling low inertia grids, and forward-looking utilities are experimenting with technologies such as Synchrophasors and wide area protection to provide options for reliability of the future distribution network. Nonetheless, for many utilities worldwide, the staged approach to network improvement allows for significant reliability and revenue rewards. These consistent results can be used to fund the research required to achieve the leading-edge technology goals that are being achieved in the modern distribution grid.

Reclosers which can operate as sectionalisers are an essential tool in providing a future proofed technology option that allows for the progressive upgrade of the network. They can be simply installed at the location of existing load break switches and sectionalisers without much consideration for grading. At the time that the feeder protection studies are reviewed, these devices can be easily reprogrammed to act as reclosers, providing significant reliability gains and mitigating the momentary outages of the distribution network.

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Building Total Underground Distribution System For Smart Cities And Urban Areas

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Abstract:
Traditional electrical reticulation includes various types of electrical distribution boxes and pillars installed above ground on footpaths and green spaces. They are functional but also present many issues:

- Reliability - exposed to weather, traffic, and vandalism
- Inherently unsafe with potentially exposed live parts
- Require regular and costly maintenance/ replacements
- Unsightly and obtrusive, taking valuable space in already overcrowded cities

If we are to create future-proof and sustainable cities, it requires much smarter infrastructure design. It is vital to provide reliable and safe, and yet unobtrusive electricity reticulation, and give back footpaths and green spaces in built-up areas to people.

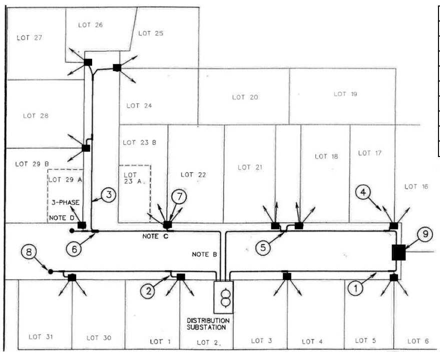
This case study discusses the Total Underground Distribution System that was developed and introduced in New Zealand 20 years ago. It can be worked on live as all fittings are completely touch-safe and fully submersible. It has increased the reliability and safety of low-voltage networks while providing environmental and aesthetic benefits with more space for the public. It has stood the test of time and has been adopted by power utilities and many private development projects in New Zealand.
It has the potential to significantly contribute to future-proof, sustainable, and smart cities.

Keywords: underground, distribution, infrastructure, system, LV

1. Background / Problem

Traditional electrical LV underground reticulation (Low Voltage Network) in urban areas consists of underground cables along the roads, and various types of electrical distribution pillars (pillar boxes) installed above ground on footpaths, pavements, and green spaces. At strategic points along the main underground cables (LV Feeder Mains), there are Link Pillars. The Link pillar has been designed purely for linking purposes i.e. to connect/disconnect or parallel LV feeders. It gives the LV network the ability to parallel or isolate low voltage mains cables and can also serve as a demarcation point for industrial customers.

Electricity customers connected to an underground LV network in New Zealand are usually connected to the network with a fuse inside an LV enclosure on the boundary between the road corridor and the property e.g. inside a Service Pillar. Service pillars are typically connected to the LV Mains cable via so-called Tee-joints. From a Service Pillar to the customer switchboard there is usually an underground service cable. (Refer to Fig.1)



#	Description
1	LV distribution cable (mains)
2	Service branch cable
3	Distribution branch cable
4	Customer service cable
5	Service branch Tee-joint
6	Distribution branch Tee-joint
7	**Service pillar** (above ground)
8	Sealing end
9	**Link pillar** (above ground)

Figure 1 Typical layout of traditional LV "underground" reticulation in New Zealand urban areas

Underground cables are fully insulated, safe, and very reliable, however, it might not be true for the above-ground components - service pillars and link pillars. Although the traditional LV reticulation system is called the 'underground system', it is obvious there are some critical components that are not underground. The above- ground components, service pillars, and link pillars, are functional, but they also present many issues, as follows:

- Reliability - exposed to weather, traffic, vandalism, and other human activities
- Inherently unsafe with potentially exposed live parts and dangerous touch voltages
- Some of them even catch on fire due to internal component failures or other causes
- Require regular and costly maintenance/ replacements
- Unsightly and obtrusive, taking valuable space in already overcrowded cities

This Paper will discuss the traditional 'underground' LV reticulation system and compare it with the Total Underground Distribution System that was developed and used successfully in New Zealand for the last 20 years. The author will present the case study by comparing both systems in terms of reliability and safety, environment, sustainable development, and aesthetics of urban space in the future smart cities, and the total life-cycle cost.

2. Technical considerations – LV Insulation Coordination

When we talk about Insulation Coordination – we usually think of medium and high voltages (MV and HV). In that context, the low voltage (LV) insulation coordination is usually forgotten, ignored, or misunderstood.

However, the LV insulation coordination is also very important for many reasons, as follows:

- Reliability – LV is much more exposed to traffic, vandalism, and other human activities than MV/HV, and arguably to weather as well
- Safety - LV is much more accessible to the public than MV/HV (on the street, in a house, at workplace). Statistically, there are many more people (public) injured or killed by LV than from MV/HV.
- Environment – in addition to the LV's inherent higher energy losses per kWh delivered (compared with MV/HV), there are also significant energy losses due to millions of hot spots and overheating, which has an impact on environment.
- Also, a much higher number of incidents of property damage from LV e.g. house or business fires

The original purpose of the LV Insulation Coordination was to reduce the chance of equipment dielectric failure from voltage surges (overvoltages), to ensure the safety of people, protection of equipment, and, to a certain degree continuity of supply. For the same purposes, the LV Insulation Coordination should also include the following:

- Long-term voltages - rated voltage, rated insulation voltage, and working voltage
- Environmental conditions:
  - o The macro-environment of a location where equipment is installed or used
  - o The micro-environment inside an enclosure, quantified by pollution degree e.g. heating, ventilation, daily thermal cycle, presence of water vapour and condensation, dust
- Exposure to foreign interference – mechanical stress, vibration, traffic, and human activities including inadvertent or intentional intrusion and damage.

As per the international standards, the LV Insulation Coordination differs between several levels of insulation and categories of protection, subject to their purpose, and with hierarchically graded requirements [1][2], as follows:

- **Functional insulation**

Insulation between conductive parts is essential only for the proper functioning of the equipment, but not for safety. In other words – the equipment with only functional insulation is not touch-safe.

- **Basic insulation**

Insulation of live parts provides basic protection against electric shock. It separates the LV circuit from the earthed exposed parts. It is vital for safety. The equipment with the basic insulation is touch-safe.

- **Reinforced or double basic insulation**

Insulation that separates LV circuit from unearthed exposed parts. A breakdown of this insulation could be fatal because the full voltage can be transferred to the unearthed exposed parts.

- **Enclosures**

Enclosure provides additional protection. However, protection by enclosures does not necessarily improve the micro-environment regarding pollution [2].

3. Traditional LV 'underground' reticulation

3.1 Insulation Coordination of the traditional LV 'underground' reticulation

There is a significant inconsistency in insulation coordination between the various components of traditional LV 'underground' reticulation, which affect its reliability and safety, as follows:

The underground cables:

- Fully insulated (e.g. having basic insulation and sheath), thus satisfying requirements for both the Functional insulation and Basic insulation level.
- Furthermore, a combination of the basic insulation and the non-metallic sheath is deemed to comply with the requirements for both basic and fault protection (almost like double insulated) and hence doesn't need to be installed in an enclosure (except as required for mechanical protection) [3].
- Therefore - cables are touch-safe (see the note below)
- They are also fully sealed against moisture ingress, dust, and other pollutants (unless opened)
- In addition, cables are in the ground and normally

not accessible to the public

The internal components of the above-ground service/link pillars (e.g. fuses, fuse carriers, neutral/earth bars…)

- Not fully insulated – they satisfy only the Functional level of insulation.
- Not fully sealed against moisture ingress, dust, and other pollutants. For example, if there is moisture, condensation, or pollution inside such an enclosure, there could be surface tracking on internal parts
- Therefore - they are not touch-safe because of potential surface tracking (see the note below)
- The only barrier to these 'unsafe-to-touch' internal parts is the enclosure. However, once the enclosure is compromised (i.e. broken, pierced), such a service or link pillar is deemed unsafe. The same applies to metallic (conductive) and plastic (non-conductive) enclosures
- Even if the enclosure is not compromised, protection by enclosures does not necessarily improve the micro-environment regarding pollution [2]. E.g. surface tracking on fuse carriers inside a pillar may become dangerous for the maintenance staff or can be transferred to the outside of the enclosure.

Note: *The touch-safe design provides protection by eliminating finger contact with live parts. Nonetheless, only authorized personnel with appropriate PPE should open the enclosures and work on LV reticulation.*

3.2 Effects of the macro and micro-environments on the traditional LV 'underground' reticulation

The condition of Insulation Coordination of the above-ground components of traditional LV 'underground' reticulation is highly dependent on the macro and micro-environments [4].

The macro and micro-environments are constantly changing e.g. with more urbanization, denser population, more people and cars, more exposure to foreign interference, less urban space, more pollution (urban contamination), climate change effect, more flash floods, rising water table in cities at sea level, more daily temperature fluctuations… In other words, the macro and micro- environment is getting worse for LV reticulation in the urban environment, which directly affects the reliability and safety of LV networks.

It is becoming obvious that traditional enclosures that were designed decades ago for one type of environment cannot cope with the fast macro/microenvironment changes in super cities today and smart cities of the future.

3.3 Typical failures and failure modes of traditional LV 'underground' reticulation

Most failures of traditional LV 'underground' reticulation occur at above-ground pillar boxes and their internal components [4]. They are typically caused by inconsistency and deficiency of the Insulation Coordination i.e. the Functional insulation of components cannot cope with local macro- and micro-environment.

Typical failure modes of electrical pillar boxes – external and internal:

- A broken or damaged enclosure that allows for access to internal parts
- Deteriorated enclosure – damage from UV, rusty hinges, locks, and other parts
- Galvanic corrosion (rusty connections on Neutral-Earth bar and other metallic parts)
- Failure of fuses/fuse carriers - high contact resistance, overheating, etc.
- Bad Neutral (broken, lose, or rusty):
  - o can bring full potential inside the consumer property and cause electric shock or fire e.g. on appliance metal enclosures, kitchen sinks, etc (safety hazard)
  - o can cause reliability and power quality issues, and customer dissatisfaction e.g. flickering
- Fires caused by rusty connections due to increased contact resistance and overheating (Fig. 2)
- Floating fuses' - fuses detached from the carrier base due to corrosion or lose securing bolts
- Water ingress, condensation, and water droplets on metal parts causing surface tracking, operational, and safety issues including phase-to-phase and phase-to-earth tracking and faults

Typical root causes of the above failures:

- Exposure to various human activities (traffic, pedestrians, unintentional damage, vandalism, graffiti - resulting in damage and potentially access to live parts
- Exposure to local macroenvironment (rain, flood, elevated water table, UV, dust, and other pollutants)
- Exposure of internal parts to moisture, evaporation, and condensation - due to daily thermal cycle, or due to dew temperature at night, which can cause galvanic processes, corrosion, and deterioration
- Exposure to pollutants in an urban and industrial environment, salty sea-spray in coastal areas, etc

Fig. 2. *Burnt plastic service pillar and its internals. Root cause - increased contact resistance and overheating of fuse contact; condensation and corrosion of contacts, including on Neutral-Earth bar*

Fig. 3. *Rusty hinges and internal parts of metal service pillars, caused by moisture and daily thermal cycle*

Note: *Most manufacturers are now making stainless still versions of internal components to prevent corrosion, however, it will not stop the surface tracking due to condensation and loose contacts from daily thermal cycles.*

The Insulation Coordination in service pillars can be very unstable and unreliable (Fig. 4) This plastic pillar has fuse carrier that is secured to the back of the pillar with two coach bolts. The bolt heads are on the outside of the pillar and accessible to the public. The full voltage was measured on the coach bolt heads outside of pilar while the pillar was still in service. It was caused by surface tracking due to condensation. Note that this type of service pillar is not manufactured anymore. However, such a situation can happen on metal pillars as well (if not earthed properly), or other plastic pillars if they are damaged and the surface tracking makes its way outside the pillar.

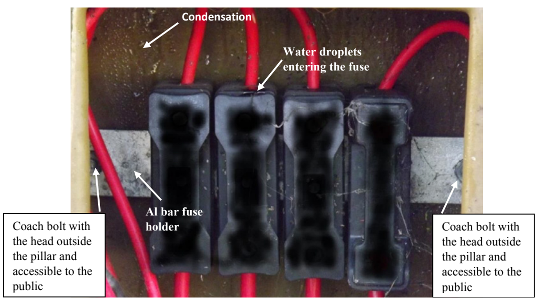


Fig. 4. *Condensation on fuse carriers causing a serious safety risk due to surface tracking.*
Full potential (voltage) is 'exported' to the coach bolt heads in the back of the pillar

3.4 Effects of the traditional LV 'underground' reticulation on urban living

- They are unsightly and obtrusive (Fig. 5, 6)
- Taking valuable space in already overcrowded cities on the footpaths and green spaces
- Inherently unsafe with potentially exposed live parts (if damaged or not installed properly)
- Require regular inspection and maintenance (or replacements) thus obstructing footpaths and traffic
- In addition, they present tripping hazards for people, especially the elderly, and children playing around

Many service/link pillars are partially buried or obstructed, so they cannot be inspected or maintained. It is a safety risk and operational constraint because the condition of internal parts is unknown e.g. is there any corrosion, broken neutrals, loose contacts, etc.

The only way to solve this problem is to reinstate (excavate, raise, remove barriers, or relocate) or replace which is a costly exercise keeping in mind the number of such installations.

Fig. 5 a) Buried and obstructed pillar b) damaged pillars

Fig. 6 a) b)

a) Unsightly Link Pillar taking valuable space on a busy and nicely paved pedestrian footpath in the city centre. Locals have tried to improve aesthetics with graffiti. However, it still obstructs the narrow pedestrian footpath and is subject to potential foreign interference. There are hundreds or thousands of similar pillar boxes in cities in New Zealand and around the world, many in much worse condition and 'not so nice' as this one.

b) Link pillar in the urban green space near a park with the bottom open and accessible to the public, creating a safety hazard, especially for children playing around.

If we are to create future-proof and sustainable cities, it requires much smarter infrastructure design. It is vital to provide reliable and safe, yet unobtrusive electricity reticulation, and give back footpaths and green spaces in built-up areas to people.

3.5 Total operational and life-cycle costs of traditional LV reticulation

All the above-ground components of the traditional LV 'underground' reticulation are exposed to micro-environment like moisture, condensation, daily thermal cycle, contaminants, and dust. In the presence of an electrolyte solution (moisture), a galvanic process takes place between the contact surfaces. Over time, it causes an increase in electrical resistance resulting in a reduction in overall performance and eventual contact failure. Also, the daily thermal cycle can loosen contacts, resulting in increased contact resistance and overheating. The contacts further degrade due to the inability to compensate for thermal cycling and moisture ingress.

The energy dissipated by connectors due to overheating (I2R losses) is a significant contributor to technical losses in distribution networks and increased costs. It also contributes to carbon emissions. While the energy loss in a single connection is relatively small, the total number of connectors in LV networks is typically hundreds of thousands or millions, and the aggregate cost of losses is significant.

In addition to the costs of technical losses, there are costs of regular inspection and maintenance:

- Most distribution companies inspect service and link pillars every year. It involves visual inspection of internal components for any defects e.g. corrosion, signs, overheating, vermin infestation... Considering a huge number of pillars, it is a costly and time-consuming exercise that also takes valuable resources.
- Costs due to increased monitoring and preventative maintenance, and
- Costs of repairs and replacement when the service/link pillar is damaged or when it fails.

The following should be considered when designing and selecting the LV reticulation system:

- The true cost of corroded or loose connections in service/link pillars extends far beyond its initial price
- Technical losses on LV are substantial due to large number of bad contacts that dissipate heat
- Energy losses should be included in the total operational cost
- The distribution company pays for these losses as their own energy consumption.

From the above considerations and failure modes - it is evident that internal components used in traditional LV reticulation were never designed nor intended to be installed in such a micro-environment.

4. Total Underground Distribution System

This system was developed and implemented in New Zealand 20 years ago as a direct response and solution to the problems of traditional LV reticulation in urban areas. A major distribution company was spending $1 mill per year on repairs and replacements of damaged above-ground pillar boxes e.g. about 6 pillar boxes damaged per day. They cooperated with an innovative local company to develop the Total Underground Distribution System. In contrast to traditional LV reticulation, this system doesn't have any above-ground components (Fig. 7).

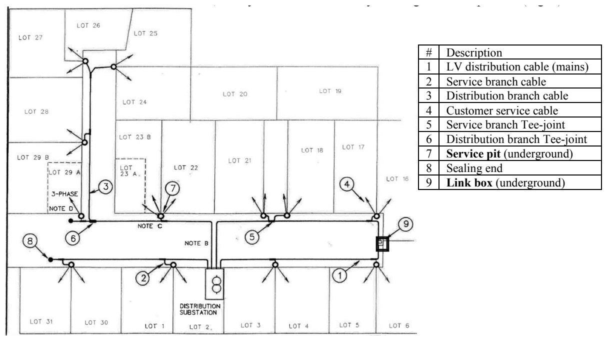


Fig. 7 – Typical layout of the Total Underground Distribution System in New Zealand urban areas

The Total Underground Distribution System incorporates a multitude of electrical fittings in a below-ground capsule (pit) with a vandal-resistant lid that sits flush with the ground. They are called Service Pits and Link Boxes. These components are unobtrusive, tough, environmentally friendly, and make cable installation easier than the units they replace. They are also often cheaper than their predecessor. They can be used to replace existing pillars or for new LV reticulation developments.

Note: The Total Underground Distribution System also includes a range of above ground mounted eco-friendly service pillars and link pillars that are superior to, and vastly outperform the existing ones. Some distribution companies in smaller cities and for specific reasons use them to replace the existing above-ground service/link pillars like-for-like. However, this is not a subject of this Paper. This Paper discusses only the underground components of the Total Underground Distribution System for LV reticulation in urban areas.

4.1 Insulation Coordination of the Total Underground Distribution System

All electrical boxes (service pits and link boxes) of this system are underground with the top cover flush with the ground level. Thus, they are not affected by the urban macro-environment.

All internal components (fuses and all connections, including the neutral and earth) are fully sealed and not exposed to moisture and condensation, so the chance of increased contact resistance due to galvanic processes is non-existent or minimal. Furthermore, since all components are underground, the contacts are not directly exposed to daily thermal cycling (heating and cooling) and therefore there is much less chance of increased contact resistance due to loose contacts. Thus, the internal components are not affected by the micro-environment.

Therefore, the Insulation Coordination of this System is consistent along the entire LV reticulation. Moreover, all inner parts are fully submersible and can be worked on live as all fittings are completely touch-safe.

4.2 Key components of the Total Underground Distribution System

The Service Pit (with its variations) and the Link Box are the backbones of this System.

Service Pit

It is used in New Zealand for the last 20 years in many domestic and business applications in high foot-traffic areas (usually in a driveway, footpath, or lawn). It can withstand a car driving over it. It is strong, versatile, made from black, UV stable plastic compounds [5]. Tested to AS3996:2006, and class B slip-test to AS/NZS 4663:2004.

Each service pit can supply several single-phase dwellings. It is safe and secure for the public, yet easily accessible. It is unobtrusive and gives back the space in urban areas to people.

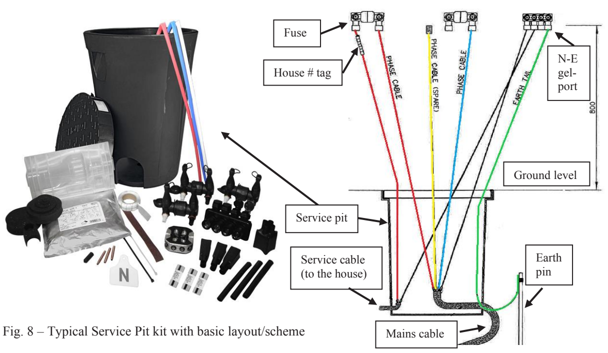


Fig. 8 – Typical Service Pit kit with basic layout/scheme

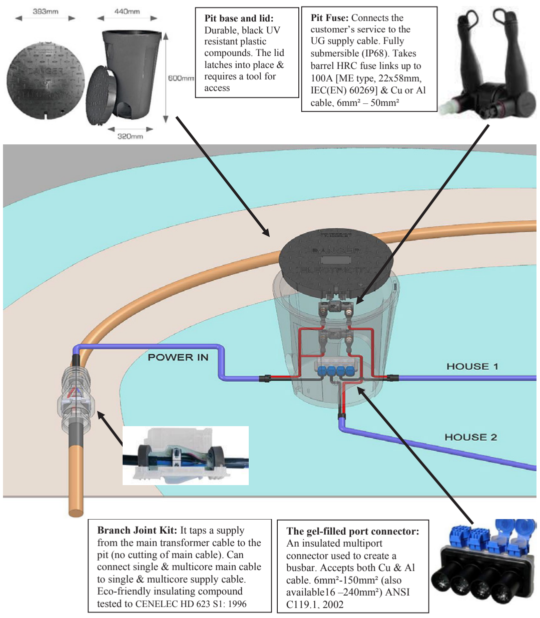


Fig. 9 – Service pit basic layout showing how does it work

Fig. 10 – Accessories: Opening tool; Cable lifting tool; Spare bolt with two O-rings; Multi gel-ports; etc…

Service Pit is fully submersible in the ground and protected from impact and vandalism. It is designed for residential and light commercial applications with up to 100A fusing. The lid can be latched and key locked, which increases security. The lid is sturdy, tested to withstand 80kN of force (Class B in NZ), and slip tested for pedestrian safety. Also, it is UV stable. It stood the test of the New Zealand sun with strong UV for 20 years.

The cable tail is typically left 800mm above the ground level. It allows a technician to work comfortably by seating in a foldable plastic low chair, without kneeling or bending over and straining the back. Once the job is finished, the cable tail is neatly coiled back at the bottom of the service pit.

The gel-filled port connector

This type of connector allows the Total Underground Distribution System to be equally suitable for fused and un-fused service mains at the boundary. It has been specifically developed for the electrical power industry. It is a submersible connector that provides a reliable moisture seal over a wide range of operating temperatures (-40°C to 95°C). It is corrosion-resistant, with an impact-resistant housing that can withstand rough installations.

Service Pit for the roads with heavy traffic

This variation of the Service Pit was developed for more demanding applications in industrial or commercial areas where it is exposed to heavy traffic and heavy loads. It comprises a standard Service Pit with a Class D Rated Cover Set installed above it [5]. It can withstand 210kN load (tested to AS3996:2006). It fits snugly over standard Service Pit enclosures to make them Class D rated when installed according to the manufacturer's instruction. It is made of marine-grade, corrosion-resistant materials, and complies with loading and slip resistance standards in Australia/NZ & Europe.

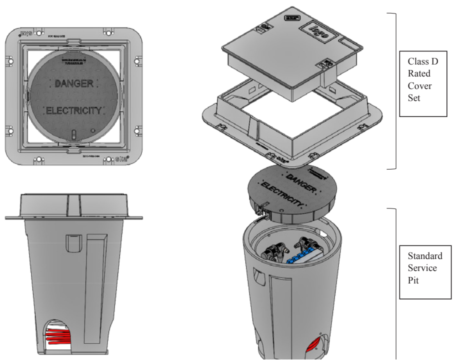


Fig. 11 - Service Pit with a Class D Rated Cover Set on top

Service Pit with underground Utility Vault 160A

This variation of the Service Pit is used as a solution for commercial sites and places where 100-amp fusing is not sufficient. It consists of a standard Service Pit with a 160A Disconnector inside. The disconnector has the same functionality as an above-ground solution but without the clutter. It is housed in an IP68 hinged electrical enclosure. The waterproof enclosure has glands on cable entry ports and is housed in a diving bell for added protection from moisture ingress [5].

Fig. 12 – Underground Utility Vault assembly (160amp in a standard Service Pit)

Link Box (2-way and 4-way, 600 Amps)

A Link Box solves the problems of above-ground Link Pillars (as discussed above). It is also used for the like-for-like replacement of existing bitumen-filled underground link boxes [5]. In addition, it is typically used in situations where New Zealand council by-laws stipulate underground installations only.

A Link Box maintains the integrity of the Insulation Coordination of the Total Underground Distribution System by using the diving-bell principle in a submersible pit. It allows the network to parallel or isolate LV mains cables. It is fully insulated without exposed live contacts or metal parts, and it is touch-safe. It complies with all applicable international standards: EN50393:2006, EC60439.5:2006, Ed2.0, C.81/3:1996, Pit & Lid meet B125 & EN124.

Fig. 13 – Link Box

Additional components of the Total Underground Distribution System [5] (Fig. 14 below)

- Large rectangular pits that accept multiple fuse ports, Earth-rod underground inspection pit, etc
- Full range of accessories that cover all needs and specific applications of modern LV reticulation

4.3 The life-cycle costs of the Total Underground Distribution System

The overall operational and life-cycle cost of the Total Underground Distribution System is much lower than the Traditional LV 'underground' reticulation:

- In most cases, the initial costs of purchasing and

installation are lower
- There is no need for regular annual inspections
- There is no need for monitoring and preventative maintenance
- Costs of repairs and replacements are minimal. It is extremely rare to find a damaged or failed component

Note: A sample inspection of numerous service pits was conducted after years in service. Many of them have been fully submerged, while some of them were exposed to seawater in the sandy coastal areas with daily raise & fall of water-table due to sea tides. When inspected, there were no signs of any deterioration. They retained full mechanical and electrical integrity and were still in full working and safe condition.

4.4 Effects of the Total Underground Distribution System on reliability and safety

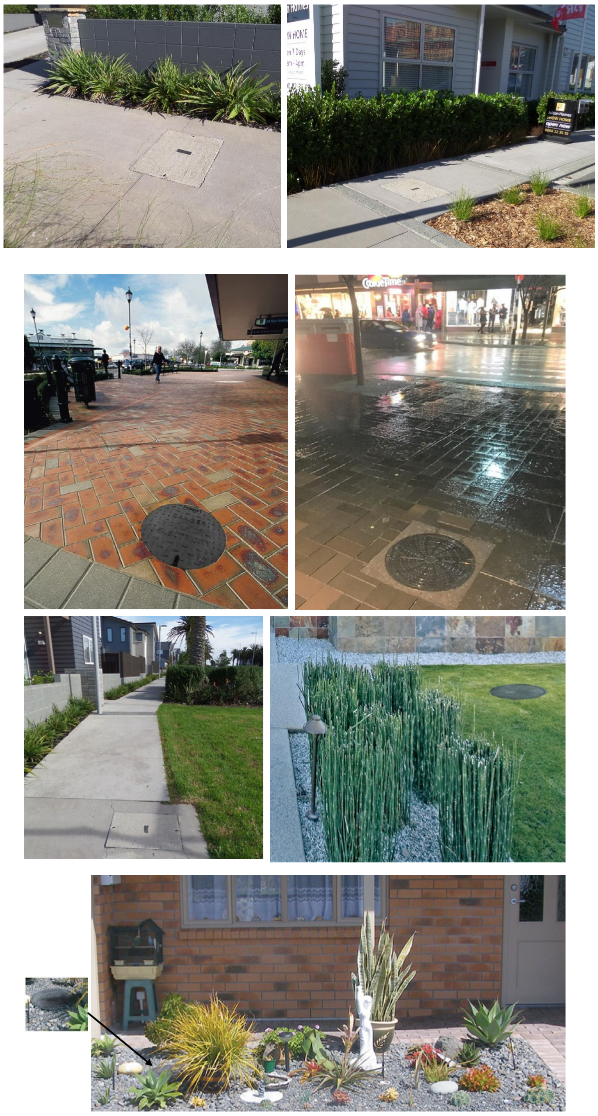
- This system maintains full Integrity of Insulation Coordination along the entire LV reticulation
- It eliminated or minimized the effects of macro & micro-environment, and human interference
- It is safe - every component is touch-safe

Note: The touch-safe design protects by eliminating finger contact with live parts of circuits. Nonetheless, only authorized personnel with appropriate PPE should open the enclosures and work on the LV reticulation.

- It is easy to install (with full training provided to the first-time users), with minimal or non-existent follow-up maintenance
- It is unobtrusive, almost invisible, and does not attract unwanted attention from potential vandals
- This system has dramatically increased the reliability & safety of LV reticulations across New Zealand

4.5 Effects of the Total Underground Distribution System on urban living

The following images are self-explanatory – Service Pits & Link Boxes shown in a real-life urban environment



5. Discussion

This Paper has discussed the reliability and safety of LV reticulation, and key factors that can have significant effects on it - the Insulation Coordination, and the macro and micro-environment. It then compared the traditional LV reticulation with the Total Underground Distribution System in terms of reliability and safety.

Traditional LV 'underground' reticulation has inconsistent Insulation Coordination. The integrity of its insulation coordination is further compromised by the local macro and micro-environments. It negatively affects its reliability and safety, thus making this system unsuitable for future sustainable urban developments and constantly changing macro and micro-environments. In contrast - the Insulation Coordination of the Total Underground Distribution System is consistent across all its components, which dramatically improves its reliability and safety. All its components are touch-safe e.g. if accessed by authorized staff with appropriate PPE.

This Paper also discussed the environmental and visual impact of LV reticulation systems on modern urban living and the future development of sustainable Smart Cities. Traditional LV 'underground' reticulation has many above-ground components that are highly obtrusive, unsightly, and susceptible to human activities and interference. Moreover, they take valuable space. It is evident that this old design of the traditional LV reticulation cannot cope with urban development. In contrast, all components of the Total Underground Distribution System presented here are underground, thus unobtrusive, and almost invisible. They gave valuable space back to people and made it more aesthetically pleasing.

6. Conclusion

If we are to create future-proof and sustainable cities, it requires much smarter infrastructure design. It is vital to provide reliable and safe, yet unobtrusive electricity reticulation, and give back footpaths and green spaces in built-up areas to people.

Since introduced in New Zealand 20 years ago - the Total Underground Distribution System has dramatically increased the reliability and safety of LV reticulation while providing environmental and aesthetic benefits with more space for the public. It has been adopted by distribution companies and many private development projects in New Zealand. New Zealand climate and environment can be harsh on electrical networks. This system has stood the test of time and constant changes in the urban environment.

Many New Zealand distribution companies regard the Total Underground Distribution System as the industry game-changer for LV reticulation. It became a superior and cost-effective alternative to traditional LV reticulations. It also has the potential to significantly contribute to future-proof, sustainable, and smart cities.

The final thoughts:

The concept of a Total Underground Distribution System for LV reticulation could be also regarded as a new technology platform for future smart developments and technologies. It opens many new possibilities and opportunities. For example, there is enough space inside of a Service Pit to put more sensors and devices (like the Utility Vault 160A, as presented above), or other innovative technologies e.g. LV monitoring.

This system has worked successfully in New Zealand for the last 20 years. It could work equally well in other countries for their smart Cities and smart grid planning and development.

References:

1. Insulation Coordination for Equipment within Low-Voltage Systems, IEC 60664-1 (2002)
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Tonga’s progress towards 50% Renewable Energy

Nikolasi Fonua, Acting Chief Executive Officer
Andrew Kautoke, Marketing & Communication Officer
Tonga Power Limited

Tonga’s transition towards 50% Renewable Energy remains on track although late with 7 out of the 14 Projects completed. Similar to neighboring Pacific Island countries the COVID-19 outbreak has heavily impacted projects causing major delays in project progress. The main causes of the delays are impacts on resources, specialized personnel from overseas for projects not being able to enter Tonga and supply chain lead times etc. The remaining RE projects include one of the most important enabling technologies for this transition to RE, which is the Battery Energy Storage Systems part of the Tonga Renewable Energy Project which will enable more integration of RE into the grid.

Figure 1 Grid Stabilizing BESS at the main Diesel Power Plant on Tongatapu

There has been noticeable progress on Tonga’s current on-grid electricity situation in comparison to the year 2010 when the Tonga Energy Roadmap was launched. There has been an overall 8,999 MWh of RE produced in 2020, totaling 12.27% of the overall electricity generated for the year 2020. A considerable achievement considering that there has been 44% growth in the demand for electricity based on 2010 figures, exemplified in the increase from 20,480 (2010) to 24,043 (2020) electricity customers. Alongside the energy generation transition, network upgrade projects also continue to progress, visible through the reduction in our total system losses from 17.5% in 2010 to 9.95% for the year 2020.

Figure 2 Load Shifting Bess installed behind TPLs headquarters on Tongatapu

2010	2020
52,582 MWh produced in total	76,016 MWh produced in total
13,086,288 liters of diesel burn	16,014,805 liters of diesel burn
0 MWh of RE produced	8,999 MWh of RE produced
0% RE	12.27% RE
17.5% total system losses	9.95% total system losses
20,480 Customers	24,043 Customers
SAIDI- 1,021 mins	SAIDI- 625.4 mins

As shown in the table below, currently, TPL has a total of 7 projects remaining that are required to take us to the 50% target. This consists of 3 solar projects, 2 wind projects and a BESS Load Shifting and stabilizing batteries. There have been added delays particularly with the wind projects since the preparation of the table above. There has been steady progress on these projects even during the pandemic, but with continued optimism, Tonga aims to achieve 50% RE target by 2025.

Preparation and efforts towards achieving 70% RE by 2030 are also underway with key learnings from the last 10 years being taken into consideration. Growth in demand for electricity continues to be a major challenge particularly with the global movement towards electric vehicles. Grid readiness and grid re-enforcement to cater to decentralized generation sources and intermittent power generation also continues to present challenges. There is also an increasing call for added focus on essential enabling projects. Projects aimed and preparing TPL for significant digitization and decentralization of the business. This includes the finalizing of institutional and regulatory reform which rides on the new national Energy Law. Centralizing Control and implementation of a national Grid Code. Finally, resource planning improvements will be required as the asset profiles of TPL become more complex.

	Project No	RE Projects	Project Status	Target Completion Date (Pre-COVID 19)	Latest Completion Target	Accumulated RE%
	8	Sunergise NZ IPP 6MW Solar - Tongatapu, Liukava, Fualu, Masilamea	CONSTRUCTION PHASE	2020	3 different plans (Sept, Oct 2021)	23.44%
SOLAR PROJECTS	9	Green Energy Technology (GET) IPP 6MW	AGREEMENT SIGNED	July 2020	March 2023	34.77%
	10	'Eua & Vava'u Island Solar 650KW	DETAILED DESIGN PHASE	End of June 2021	March 2022	35.71%
WIND PROJECTS	11	Niutoua Wind IPP 4.5MW	AGREEMENT NEGOTIATION	Dec, 2020	Sept, 2023	50.64%
	12	China Wind IPP 2.8MW	SITE MOBILIZATION	Dec, 2020	Sept, 2022	57.34%
	13	Tongatapu Load Shifting Battery Energy Storage Project	CONSTRUCTION PHASE	Nov, 2020	Sept, 2021	All RE above curren RE level not possible without this storage component
BATTERY ENERGY STORAGE PROJECTS	14	Tongatapu Stabilizing Battery Energy Storage Project	CONSTRUCTION PHASE	Dec, 2020	Sept, 2021	All RE above curren RE level uneconomic without this storage component

Eco-Friendly, Sustainable Guam Power Authority (GPA) Electric Vehicle leased to University of Guam — Centre for Island Sustainablility

Guam Power Authority

"We're a partner-in-sustainability with the University of Guam and today furnished one (1) Nissan Leaf all-electric vehicle to the University of Guam (UOG) Center for Island Sustainability (CIS)," stated GPA General Manager John M. Benavente, P.E.

"GPA initiated its electric vehicle trial fleet expansion in 2017. We are pleased that UOG will showcase GPA's all-electric vehicle to help educate and engage the island community on the benefits of vehicle electrification," added Benavente.

A two-year, Memorandum of Agreement (MOA) for Demand Side Management Electric Vehicle Lease, was signed both GPA and UOG. GPA shall maintain ownership of the vehicle throughout the lease period, which may be renewed annually by GPA. The electric vehicle shall be used for public outreach, educational, and professional business use only.

"GPA's Demand Side Management program(s) share similar objectives to include energy conservation, equipment/fuel efficiency, and reducing negative impacts on the environment; and we fully support UOG's use of this EV will to encourage and increase its visibility, as well as serve to bolster market penetration on island," stated Consolidated Commission on Utilities Chairman Joey T. Duenas.

The benefits through this partnership include:

- Educating and engaging the community on the benefits of vehicle electrification
- Encouraging the use of electric vehicles through UOG's and its showcase during event
- Providing additional data to support GPA's electrical fleet expansion and charging infrastructure development.

Present at the GPA Electric Vehicle turnover to the University of Guam Center for Island Sustainability presentation on April 14, 2021 were:
Shown (L-R) at back: Pedro Roy Martinez, Consolidated Commission on Utilities Commissioner; GPA General Manager John M. Benavente, P.E.; GPA Assistant General Manager Engineering & Technical Services John J. Cruz, Jr., P.E.; and Victor Torres, GPA Engineer II.
Front: Consolidated Commission on Utilities Chairman Joey T. Duenas; University of Guam President Dr. Thomas W. Krise; Dr. Austin Shelton, Director of the UOG Center for Island Sustainability and SEA Grant; Dr. Anita Borja Enriquez, UOG Senior Vice President and Provost; and Dr. Rachael Leon Guerrero, UOG Director for Office of Research and Vice Provost.

Welcome!

New Allied Member

One new Company has joined PPA as an Allied Member since our last PPA Magazine. The new member is:

NOJA POWER SWITCHGEAR PTY LTD: Noja Power Switchgear Pty Ltd is based in Queensland, Australia. Their primary activity is manufacture and supply of medium voltage (11kV – 38kV) switchgear.


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