Confidential

Energy Transition in Pacific Island Countries

~ Challenges and Solutions ~

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Kyoji FUJII
Deputy Director General
YACHIYO ENGINEERING CO., LTD.

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Why Smart Grid Now?

*"**Smart Grids** and **Digital Transformation** in Energy"*

Reliability

Smart Meters

Decentralized Energy Resources

Data-Driven Decision Making

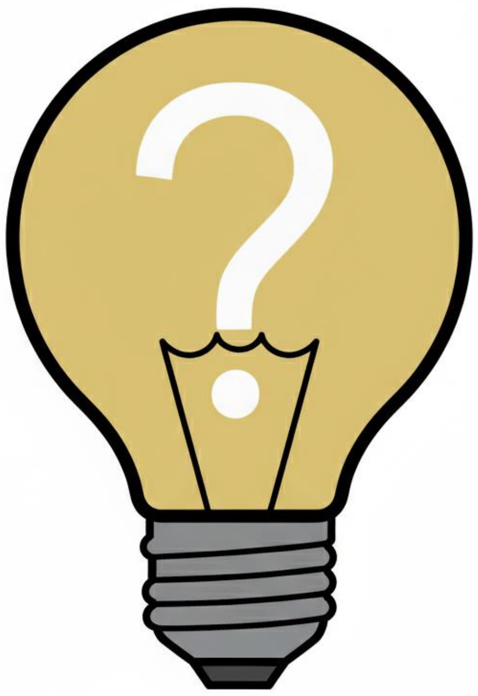
Predictive Maintenance

Communication Networks

Efficiency

Optimization

Automation



Big data analytics

AI-powered analytics

Global issues

Extreme weather, sea level rise, ecosystem destruction, food and water resource crises

Common challenges of pacific island countries

Resource Constraints and Economic Vulnerability: Risk of Rising Fuel Costs
Frontline of global warming: Risk of national survival due to sea level rise
Changes in the marine environment: Ecosystem impacts from El Niño and La Niña

The common challenges of island countries are directly related to global issues.
Introduction of renewable energy is essential to solve them.

But in fact, there are many challenges.

PROS

Expectations

- Contribute to a **sustainable society**
- Reduce **greenhouse gas** emissions
- Avoid risk of **volatile world oil price**

CONS

Concerns

- Output **fluctuations** of renewable energy threatening the stable supply of electricity
- **Reduced grid inertia** by renewable energy with DC origin may cause grid instability
- **Directions of power flow differ** from time to time (Day/ night)→Different bottlenecks

To massively introduce renewable energy, it is necessary to **develop a smart grid** to stabilize the grid.

“**Smart Grids and Digital Transformation in Energy**” to Solve Common Global issues

What is the Smart Grid?

- Integrating IT technology into the power grid
- Real-time monitoring of electricity usage and optimization of the supply-demand balance through interactive exchanges
- Digitizing grid status and information

⇒**The development of a smart grid is necessary** for the large scale introduction of renewable energy.

1. Why Smart Grid Now?

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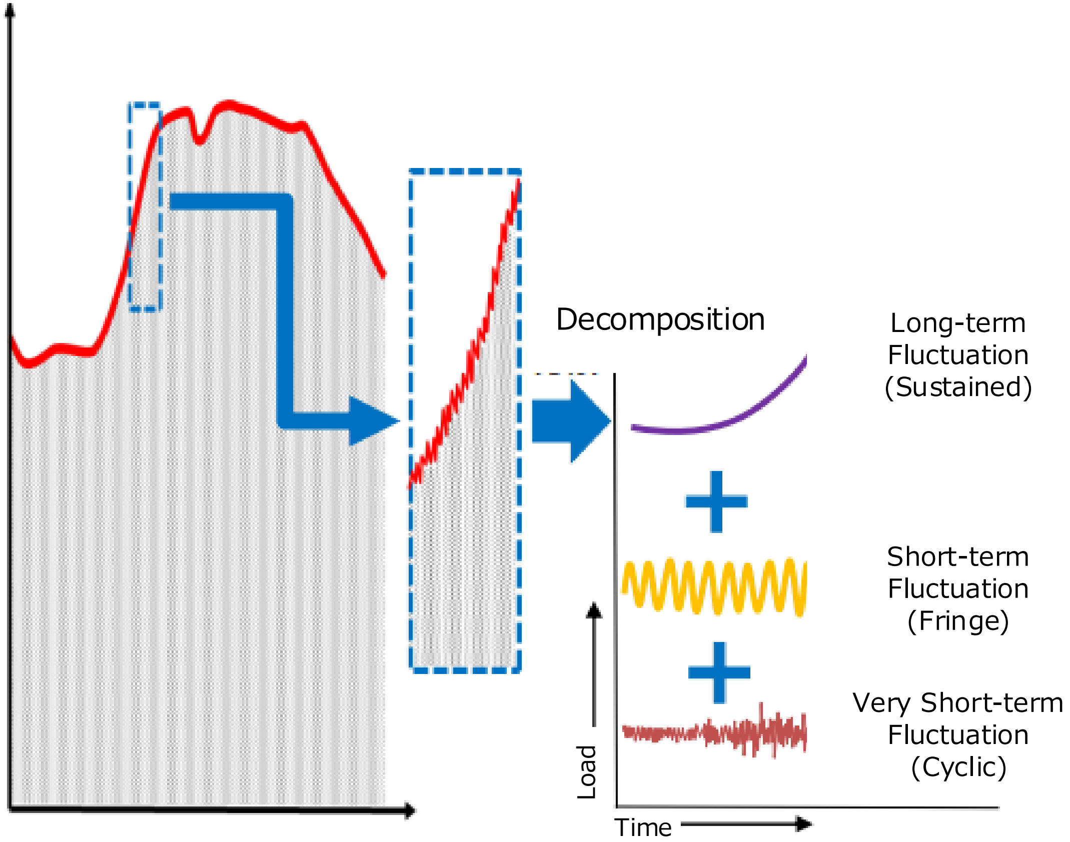
- Characteristics of Various of Storage Battery
- Virtual Synchronous Generator：VSG
- Static Var Compensator：SVC

Characteristics of Various of Storage Battery

Storage batteries Necessary to maintain the power quality of renewable energy sources.

<Example of Daily Power Demand>



Source: Agency for Natural Resources and Energy

Feature	Redox Flow Battery	Lithium-ion Battery	Sodium-Sulfur (NAS) Battery
Image	 Source: Sumitomo Electric Industries, Ltd.	 Source: GS Yuasa	 Source : NGK Insulators, Ltd
Energy Density	Low (about 1/5th of lithium-ion batteries)	High	High (about 3 times that of lead-acid batteries)
Design Life	Over 20 years	Around 10 years	Around 15 years
Safety	High (low risk of fire)	Concerns exist (risk of fire and smoke)	Concerns exist (treated as hazardous material)
Initial Cost	High	Relatively low	Low
Applications	· Large-scale energy storage · Storage for renewable energy	· Electronic devices · Home battery storage · EVs	· Stable supply for renewable energy · Peak shaving · Emergency power supply
Environmental Impact	Low (materials are relatively harmless)	Caution required for disposal (contains hazardous substances)	Affected by high-temperature operation

VSG ：Virtual Synchronous Generator

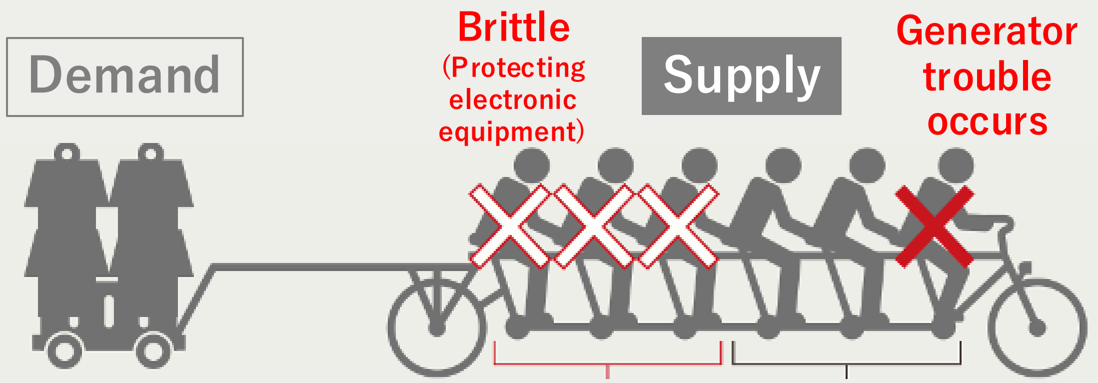
Inverter power sources, represented by solar power, wind power, and storage batteries, do not have the inertia to maintain the frequency of the power system.
Stable power supply is an issue.

Image of VSG
Source: Meidensha Corporation

VSG stands for **V**irtual **S**ynchronous **G**enerator and is one of the control methods for inverter power supplies.

VSG is expected to stabilize the grid by controlling the inverter power supply to behave as if it were a rotating generator (providing inertia).

Characteristics of Asynchronous Power Sources

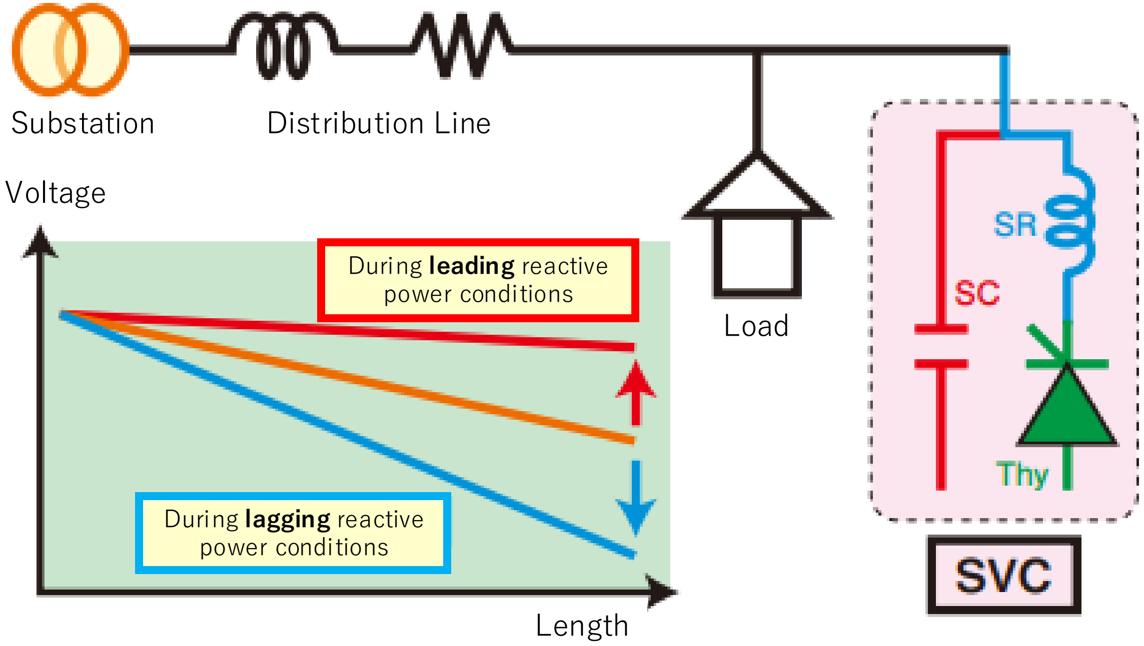


Synchronous power sources have the ability to restore frequency drops, but with asynchronous power sources, if frequency fluctuations exceed a certain range, there is a concern that they will trip offline in a chain reaction, disrupting the balance between demand and supply and causing a power outage.

Source: https://www.re100-denryoku.jp

SVC：Static Var Compensator

SVG (Static Var Generator) or STATCOM (STATic synchronous COMpensator)



Source: https://www.kyuhen.co.jp

Image of SVC

Source: Fuji Electric

SVC: Static Var Compensator has a fixed output of advance reactive power with an advance capacitor (SC), and by varying the output of the reactor (SR) with a thyristor, it generates **reactive power from leading to lagging at high speed and stepless.**
When a **voltage rise is required, the leading reactive power is sent out**, and when a **voltage drop is required, the lagging reactive power is sent out** to maintain the distribution line voltage constant.

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But how can we decide what is the best solution?

Inquiries from the Utility Companies

We want to formulate a least cost power development plan to achieve the renewable energy deployment goals.
How can we do it?

Can we maintain the fluctuation of voltage and frequency within allowable range even after the introduction of renewable energy?

We would like to find the bottlenecks and the priorities of counter measures to accommodate large-scale introduction of variable renewable energy into the grid.

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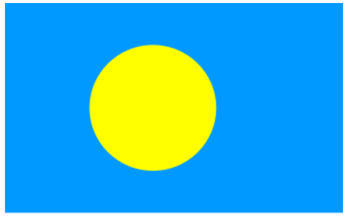
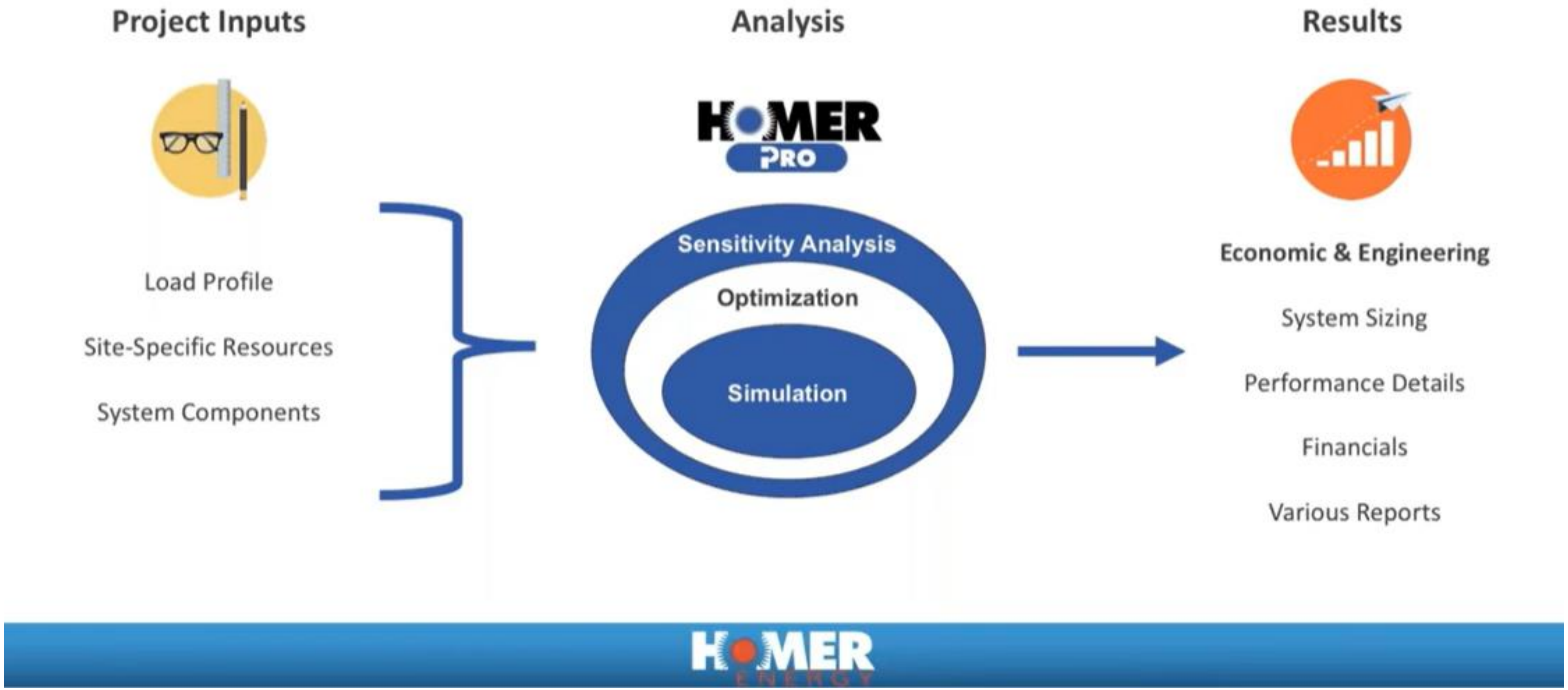
Capacity Building and Sector Reform for Renewable Energy Investments in the Pacific - Preparing Sustainable Investment Program



Country : Republic of Palau
Client : ADB
Scheme : Technical Assistance (TA)
Period : July 2021～March 2024
Outline : YEC provided capacity building and policy advice support to a series of ongoing and ensuing projects, comprising projects included in the indicative project pipeline under the Pacific Renewable Energy Investment Facility, and other investment projects in the energy sector.

Microgrid Analysis and Design: HOMER Pro



YEC formulated a **least cost power development plan** that would achieve the target of renewable energy share in generation by using Homer Pro.

Results of Study by Homer Pro

Table Comparison of the cases

Case	Item	Unit	2022	2023	2024	2025	2022-25 total
Scenrio-1 With Additional PV 30 MW	Investment	US$	0	0	50,120,000	0	50,120,000
	O&M cost*	US$	1,696,062	1,500,723	1,564,361	1,203,901	5,965,047
	Levelized cost of generation	US$/kWh	0.305	0.287	0.303	0.296	-
	PV excess generation	kWh	8,304	1,286,929	2,189,198	21,730,258	25,214,689
	CO_2 Emission	Ton/ year	55,784	47,394	49,305	37,194	189,677
	RE Fraction	%	5.6%	25.3%	23.6%	46.1%	
Scenario-2 Without Additional PV	Investment	US$	-	-	-	-	0
	O&M cost*	US$	1,696,062	1,499,323	1,562,961	1,573,646	6,331,993
	Levelized cost of generation	US$/kWh	0.305	0.287	0.303	0.316	-
	PV excess generation	kWh	8,304	1,286,929	2,189,198	212,178	3,696,609
	CO_2 Emission	Ton/ year	55,784	47,394	49,305	51,117	203,600
	RE Fraction	%	5.6%	25.3%	23.6%	24.9%	
Scenario-3 With Additional PV 30 MW, No PV excess	Investment	US$	0	0	102,900,000	0	102,900,000
	O&M cost*	US$	1,696,062	1,500,723	1,564,361	1,114,662	5,875,808
	Levelized cost of generation	US$/kWh	0.305	0.287	0.303	0.350	-
	PV excess generation	kWh	8,304	1,286,929	2,189,198	0	3,484,431
	CO_2 Emission	Ton/ year	55,784	47,394	49,305	34,938	187,420
	RE Fraction	%	5.6%	25.3%	23.6%	49.5%	-
Scenario-4 Without existing IPP nor Additional PV (Reference)	Investment	US$	-	-	-	-	0
	O&M cost*	US$	1,696,062	1,856,472	1,896,845	1,946,842	7,396,220
	Levelized cost of generation	US$/kWh	0.305	0.287	0.303	0.287	
	PV excess generation	kWh	488,010	487,058	496,891	16,593	1,488,552
	CO_2 Emission	Ton/ year	55,784	61,028	62,826	64,378	244,017
	RE Fraction	%	5.6%	5.6%	5.0%	4.9%	

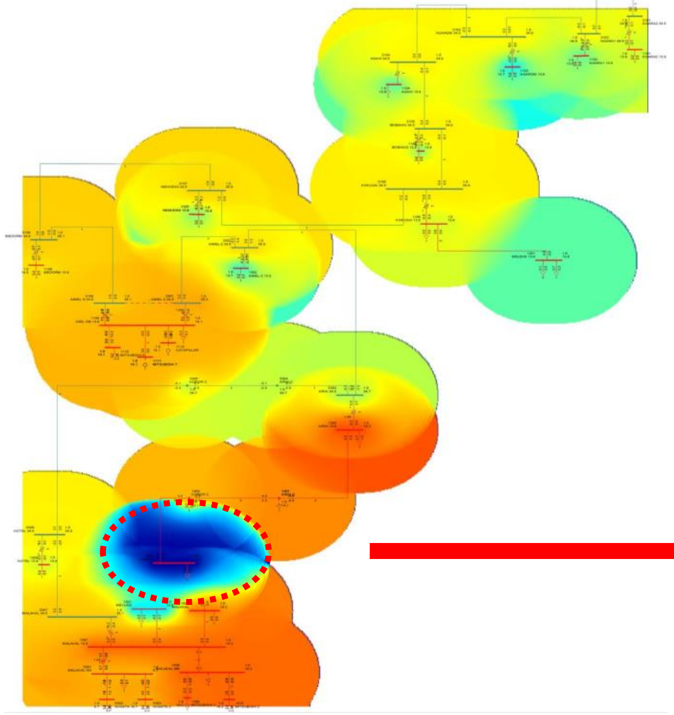
Least cost generation expansion plan

Source: Consultant

Results of power flow analysis

Generation:
- As of 2020

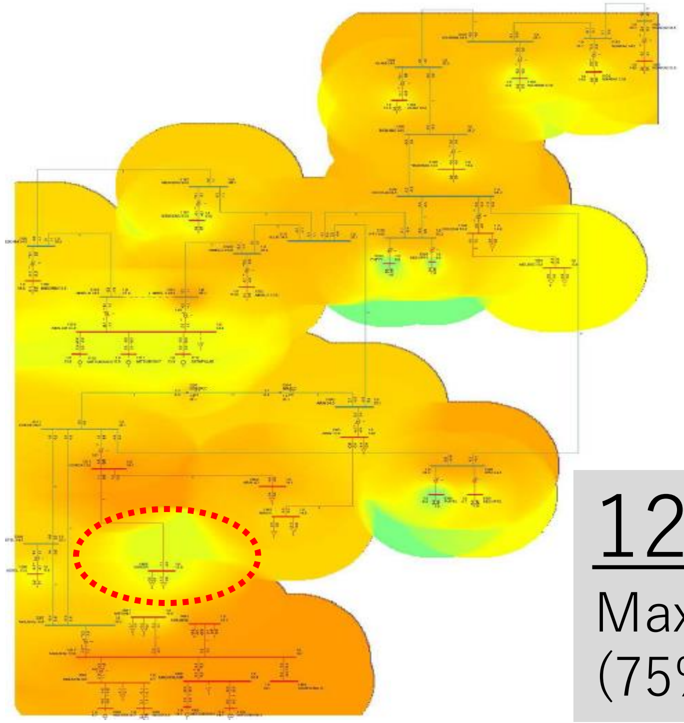
Power supply system:
- As of 2020



NG (<0.97PU)

Generation:
- Additional SHS and PV by 2025

Power supply system:
- Double-circuit of transmission lines
- New substation



OK

12:00 noon

Maximum Generation by PV (75% of Peak)

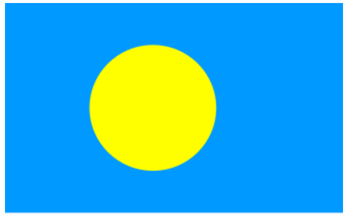
Indication of voltage in color

←High Low→

Source: ADB (Sep. 2022) "Capacity Building and Sector Reform for Renewable Energy Investments in the Pacific - Preparing Sustainable Investment Program (PAL)" Final Report

Examples of Achievements in Renewable Energy Projects (Case Study 2)

Project for the Development of Power Transmission Network



Country : Republic of Palau
Client : JICA and Government of Palau
Scheme : Grant Aid
Period : July 2021～January 2026 (ongoing)
Outline : YEC provided Consulting Services to improve the reliability and stability of electricity supply and to promote the introduction of renewable energy on the islands of Koror and Babeldaob, thereby contributing to the improvement of the quality of life of residents and the reduction of greenhouse gas emissions by upgrading transmission and substation facilities in PPUC's main power system of Koror – Babeldaob grid (KB Grid).

Main Components of the Project

Installing New Power Lines

Approximately 35 km of new transmission lines will be constructed. This includes overhead lines that will be erected on poles, underground cables that will be buried in the ground, and cables that will run through Japan-Palau Friendship (JP) Bridge.

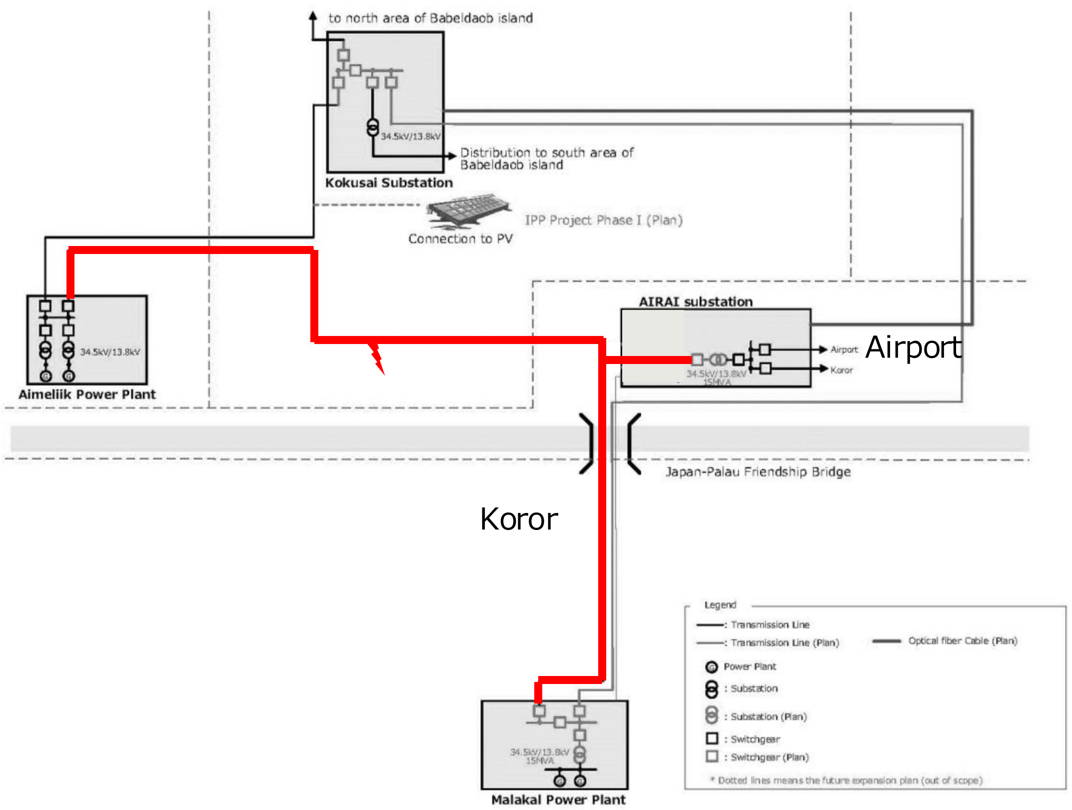
Upgrading Three Key Substations

The project will expand or update three main facilities of Malakal Power Station, Airai Substation, and Kokusai Substation. This involves installing new equipment, such as main transformers and switchgears (devices that control and protect the electrical system).

New transmission line by JICA Grant Aid Project

This project is a good example of the realization of one of the projects recommended by an ADB study supporting solar installation targets.

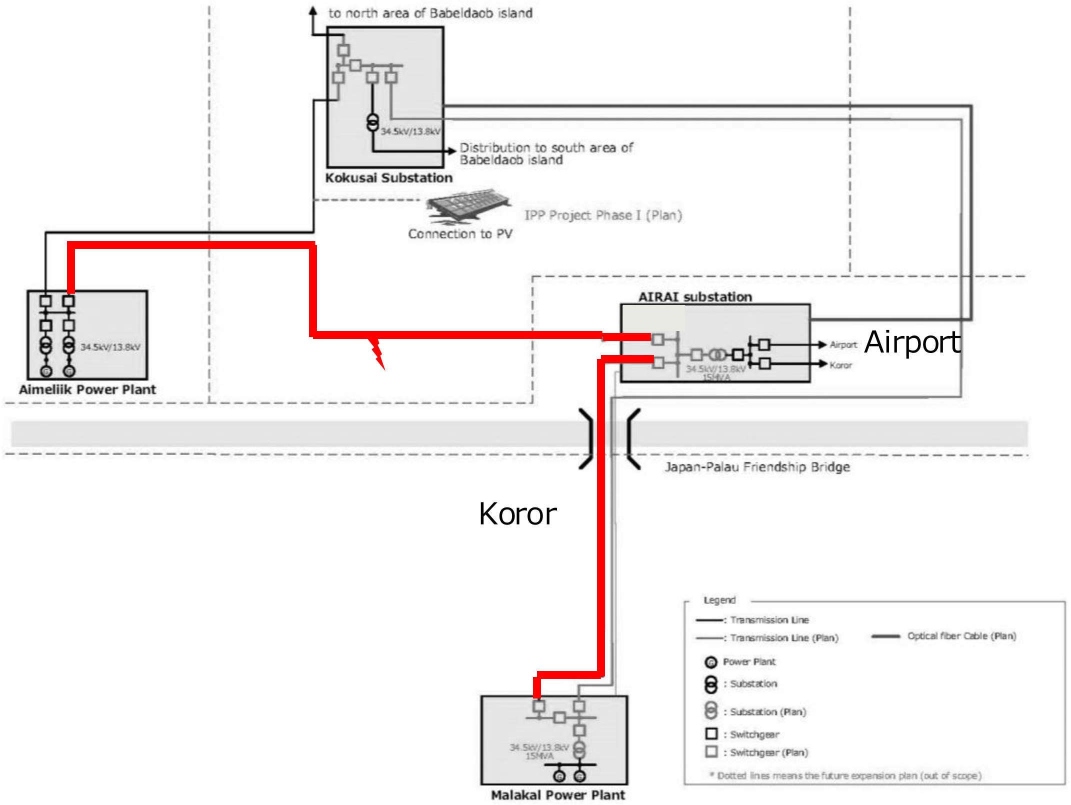
Need for grid reinforcement at Airai substation



Risks (Current Situation)

- Airai substation is drawn by a T-branch, so if an accident occurs on the transmission line between Koror substation and Aimeliik power plant, the recovery time is long.
- In the event of an accident on the transmission line between Aimeliik power plant and Airai substation, it will not be able to supply power to Koror or to the airport.

Need for grid reinforcement at Airai substation



Effects

- The construction of the 34.5kV transmission line can realize minimizing the area of outages and minimizing the time of outages in the event of an accident.
- The outdoor switchgear at the Airai substation can be removed, reducing the number of types of switchgear to be managed and reducing maintenance labor.

Project Effectiveness

Baseline: 2020

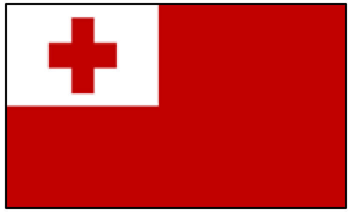
Target year: 2028-29 (3 years after the project completion)

SAIDI and SAIFI will be improved by 30%

SAIDI (Duration of power outage)
→ Annual power outage time reduced by 452 minutes/year/house

SAIFI (Frequency of power outage)
→ Annual power outage frequency reduced by 7 times/year/house

Project for Introduction of a Micro-grid System with renewable energy for the Tonga Energy Road Map

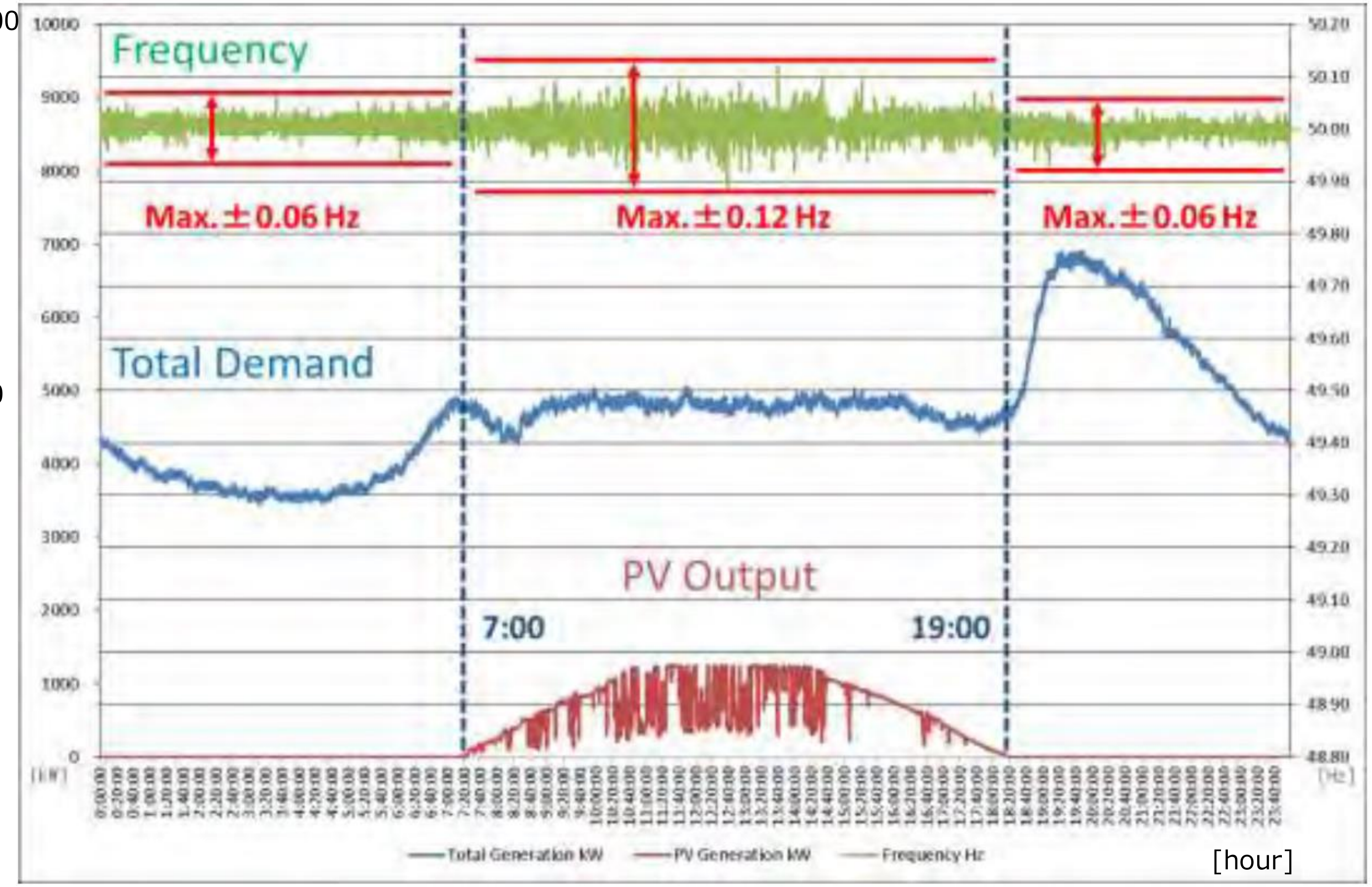


Country : Kingdom of Tonga
Client : JICA and Government of Tonga
Scheme : Grant Aid
Period : August 2012～March 2015
Outline : YEC provided Consulting Services for Introduction of Micro-grid system by introduction of PV system, Li-ion Capacitor, and Micro-grid controller. The service included feasibility study, support for tendering, and supervision.

Target Value of Frequency Control

On Tongatapu Island, the frequency control standard [EN50160] is ±1% (±0.5 Hz), but in actual operation, the frequency is maintained **around ±0.2 Hz**.

The design will be aimed to maintain this level after project implementation.



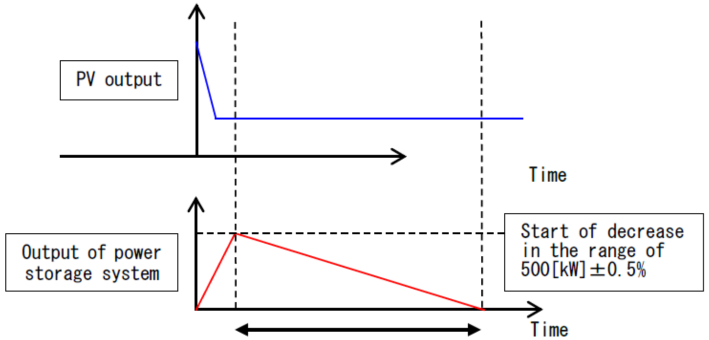
Current record of frequency and demand at Tongatapu Island

Simulation results of power system analysis

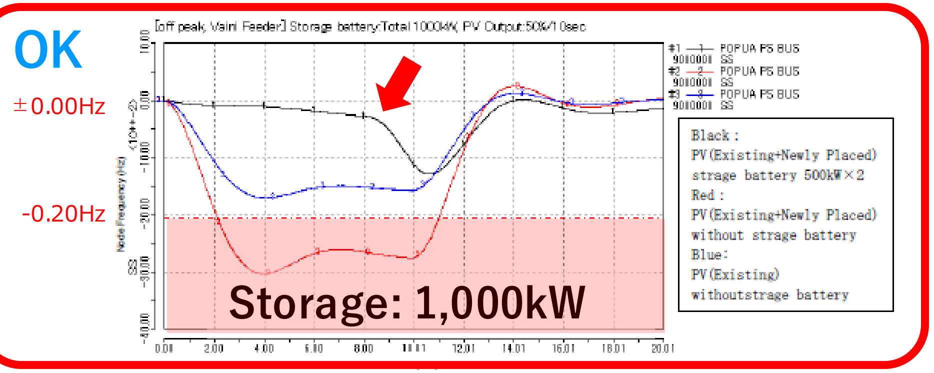
Through simulation of power system analysis,
the energy storage facility capacity is selected
to keep frequency fluctuations below an acceptable level.

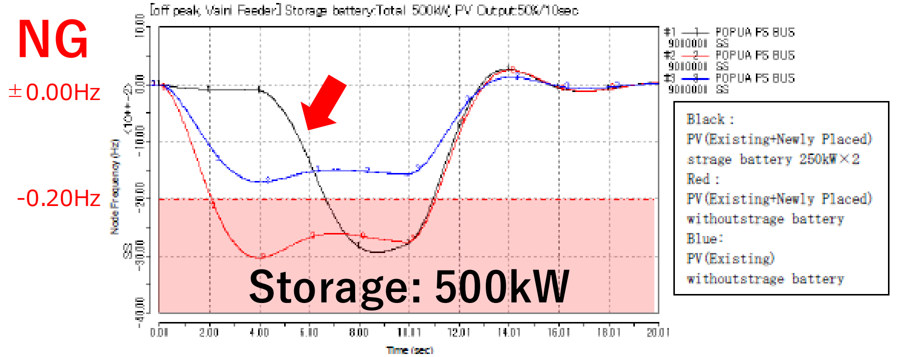
Simulation Model

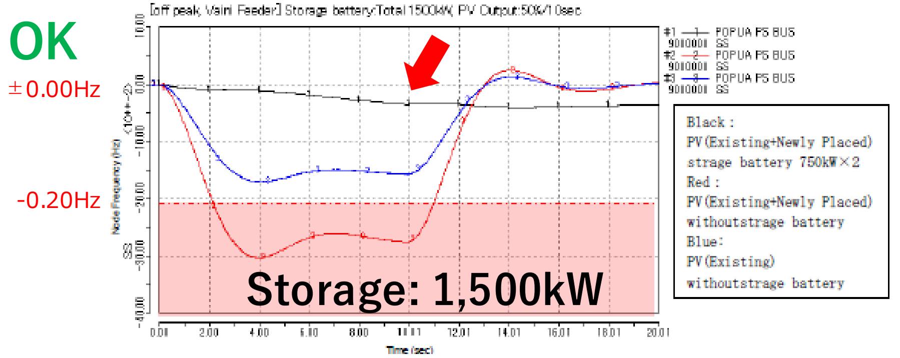
- Model in which PV output suddenly decreases by 50% in 10ms
- Compensated by storage battery output due to rapid PV output decrease



Storage capacity	Frequency drop	Evaluation
1,000 kW (selected)	**-0.13 Hz**	🎯 Target value is within acceptable range for practical use
500 kW (for comparison)	**-0.29 Hz**	NG Exceeds target value; power quality cannot be maintained
1,500kW (for comparison)	**-0.05 Hz**	✔ Meets target value substantially, but excessive in terms of cost







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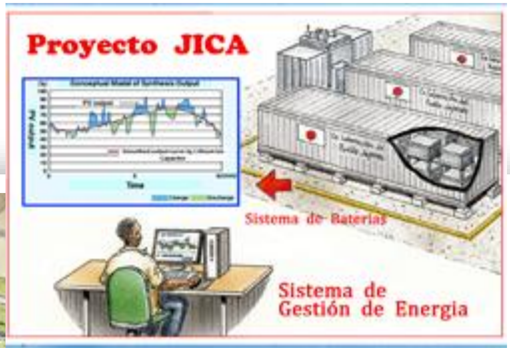
Project for the Improvement of Power Supply in the Isle of Youth

Country : Republic of Cuba
Client : JICA and Government of Cuba
Scheme : Grant Aid
Period : June 2018～June 2025
Outline : YEC provided Consulting Services for Introduction of Battery system with Energy Management System (EMS) by introduction of Batteries, Power Conditioning System (PCS) and EMS. The service included preparatory survey, support for tendering, and supervision.



Project Components

◆ Battery Storage System

Type: Lithium-ion battery
Capacity: 10 MW, 3.33 MWh

◆ Energy Management System (EMS)

EMS is a system that automatically controls the recharge and discharge of storage batteries and the output control of photovoltaic power generation to stabilize the balance between supply and demand and the frequency of the entire power grid.

◆ Power Conditioning System (PCS)

A device that converts the DC power of storage batteries and the AC power of the power system in both directions. A total of 20 units will be installed.

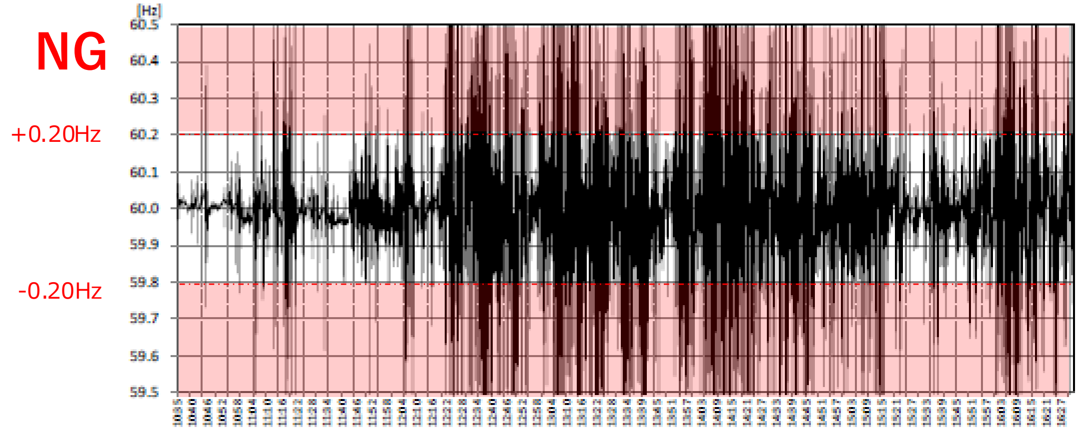
◆ Power Receiving and Transforming Equipment

Transformers and switchgear for connecting the storage battery system to the power system (34.5kV) are included.

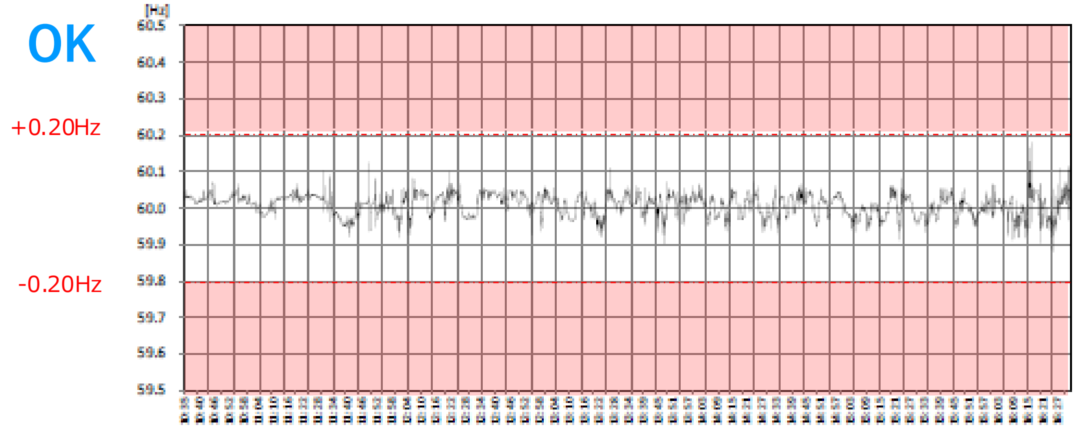
◆ Control and Communication Equipment

Control and Communication Equipment includes control panels, remote monitoring equipment, optical fiber cables, etc. to monitor and control the operational status of each power plant and storage battery system in real time.

Frequency fluctuation study by PSSE



Simulation before introduction (base case)



Simulation after introduction (verification case)

Simulation before introduction (base case):

- Even with the current solar power generation (4.2 MW), frequency sometimes deviates from the operational standard.
- If solar power generation is increased to 20.4 MW in the future, without a storage battery system, frequency fluctuations will increase and it will be **very difficult to maintain the stability of the power system**.

Simulation after introduction (verification case):

- The introduction of a 10 MW storage battery system and an EMS (Energy Management System) will **greatly reduce frequency fluctuations**.
- As a result, it will be possible to keep the frequency **within the operational standards**.

This comparative study provides technical proof

- ➢ The energy storage system to be installed in this project is **indispensable for future renewable energy expansion**.
- ➢ The energy storage system is **extremely effective in stabilizing the power system**.

Conclusion of the Case Studies

- Using Homer Pro, YEC developed a least-cost power development plan based on the introduction of renewable energy.

- The grid analysis software is effective not only for planning power system expansion, but also for planning measures when introducing renewable energy and selecting facility capacity, because it can confirm the power quality of the grid through simulation.

Tackling Global Challenges

- Pacific island countries face challenges in applying their solutions and know-how to other regions due to their geographical isolation and a scarcity of practical, nation-level examples.

- YEC has provided consulting services to many pacific island countries and is familiar with the trends in infrastructure growth and common challenges in each country.

- YEC will continue to provide effective solutions to global issues.

Feel free to contact us!

Kyoji FUJII

Deputy Director General
Yachiyo Engineering Co., Ltd.
+81-90-4450-8402
kj-fujii@yachiyo-eng.co.jp

YACHIYO
Engineering