Tonga Energy Road Map
Tonga Power Limited.
The Kingdom of Tonga

PREPARATORY SURVEY REPORT ON THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP IN THE KINGDOM OF TONGA

MARCH 2013

JAPAN INTERNATIONAL COOPERATION AGENCY
YACHIYO ENGINEERING CO., LTD.
WEST JAPAN ENGINEERING CONSULTANTS, INC.

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PREFACE

Japan International Cooperation Agency (JICA) decided to conduct the preparatory survey on "the Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map in the Kingdom of Tonga" and entrusted the survey to Yachiyo Engineering Co., Ltd. and West Japan Engineering Consultants, Inc.

The survey team held a series of discussions with the officials concerned of the Government of Tonga, and conducted field investigations. As a result of further studies in Japan, the present report was finalized.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relations between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Tonga for their close cooperation extended to the survey team.

March 2013

Hidetoshi IRIGAKI

Director General,

Industrial Development and Public Policy Department

Japan International Cooperation Agency

SUMMARY

① Overview of the Country

The Kingdom of Tonga (hereinafter referred to as "Tonga") located in the South Pacific. Its territory is approximately 748 km^2, the population is 104,509 (2011, the World Bank), and GNI per person is USD 3,580 (2011, the World Bank). Tonga consists of 176 islands and the largest island is Tongatapu Island which is the residence for 71% of its population.

Major industries are agriculture, fishery and tourism. However, 31 % of GDP is occupied with remittance from overseas since the economy of Tonga largely depends on grant aid assistance from other countries and money transferred from migrant workers. 25% of whole import figures is import of petroleum-based fuel which is comparable to 10% of GDP because of geographical conditions as island country. Furthermore, more than 98% of electric power supply is covered by diesel engine generators operated using the imported diesel fuel. Tonga is easily affected by international fluctuation of crude oil price resulting in vulnerability from the aspect of energy security

② Background of the Project

The soaring of the global crude oil prices in 2008 obliged the Tongan authority to raise electricity charges to TOP 1.00/kWh (approx. USD 0.5/kWh), causing serious impact on economic activities and the peoples' lives in the country. Having learnt from this experience, the Cabinet of Tonga dissolved in 2009 a policy goal of "increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020" to deal with two crucial issues: greenhouse gas emissions reductions and improvement in energy security. The government also formulated a Tonga Energy Road Map 2010-20 (hereinafter called the "TERM") as an implementation policy to achieve the policy goal. Having made various efforts, Tonga still needs to adopt renewable energy systems further to achieve the target of "50% of electricity from renewable sources". But it is difficult to stably supply electricity and secure the quality of electricity if the proportion of wind and photovoltaic power generation is substantially increased since the output level of these renewables are fairly fluctuating. In these circumstances, Tonga's electricity sector needs to adopt renewable energy sources further and at the same time stably supply electricity and minimize the fluctuation in frequencies of the grid system by using microgrid systems.

On the basis of these circumstances, in April of 2012, Tonga made a request for the introduction of microgrid system to achieve the policy goal of TERM, as a Japanese grant aid project. In the response to this request, the government of Japan implemented the preliminary survey and the government of Japan decided to implement the Preparatory Survey pertaining to implementation as a grant aid undertaking.

③ Outline of the Study Findings and Project Contents

In response to the request, JICA dispatched the Study Team to Tonga from August 14 to September 1st, 2012 (the first field survey) and from September 18 to October 7, 2012 (the second field survey) in order to reconfirm the contents of the request and discuss the contents for implementation with related agencies on the Tongan side (responsible government agency: Tonga Energy Road Map Government Committee (TERM), and implementing agency: Tonga Power Limited (TPL)), survey the Project sites and gather related materials and data.

On returning to Japan, the Study Team examined the necessity, social and economic impacts and validity of the Project based on the field survey materials and compiled the findings into the draft preparatory study report. Furthermore, JICA dispatched the Study Team to Tonga for the third field survey from December 14 to December 22, 2012 in order to explain and discuss the draft preparatory study report and reach a basic agreement with the Tongan counterparts.

The Project plan compiled based on the survey findings targets procurement and installation of PV system of 1MWp, power storage system (lithium-ion Capacitors) of total 1MW and microgrid controllers, procurement of 11kV switch gears and construction of 2 buildings for inverters power storage systems.

Outline of the basic design is the list below.

Outline of the Basic Design

	Contents of the Plan	Quantity/Capacity
Procurement and installation of equipment	1. Microgrid system in Popua Power Station	
	1.1 Microgrid controller	1 set
	1.2 Power system stabilizing system	Capacity to cover 500kW x 1min x 1/2, according to SOC 50% =8.3kWh or more
	1.3 House electric facility board	1 board
	2. Microgrid system at the Vaini Project Site	
	2.1 Microgrid controller	1 set
	2.2 Power system stabilizing system	Capacity to cover 500kW x 1min x 1/2, according to SOC 50% =8.3kWh or more
	2.3 PV system	500 kW
	2.4 Grid-connected switch gear for 11kV system	7 boards
	2.5 House electric facility board	1 board
	3. Optical cable communication system	Approx. 15 km
Procurement	4. Grid-connected switch gear for 11kV system (Popua Power Station)	4 board
	5. Replacement parts	1 set
Construction	a. Building for inverters and power storage system at the Vaini Project Site	Total floor area: approx. 190 m^2
	b. PV array bases	1 set
	c. Building for inverters and power storage system at the Popua Power Station	Total floor area: approx. 100 m^2

④ Project Implementation schedule and Cost Estimation

In the event where the Project is implemented based on the Japan's Grant Aid scheme, the total cost of the Project will be (*confidential*). The contents and costs to be borne by the Tongan side will primarily be provision of remodeling work for the existing power generating facilities (approximately 7.2 million yen), expansion work for 11kV switch board room (approximately 4.2 million yen), and installation work for Grid-connected switch gear for 11kV system (approximately 1.4 million yen) at the Popua Power Stasion, and lease fee for the PV system site of approximately 3.2 ha (approximately 0.8 million yen), clearance of trees, and exterior wall and gate work for the PV system (approximately 3.7 million yen) and work to increase the size of the distribution wire of 11kV and connection of work (approximately 3.2 million yen) at the Vaini Project site. The implementation schedule for the Project will be approximately 23 months, consisting of detail design for 5.5 months and procurement of equipment and installation for 18.5 months (including the facility construction work for 8.0 months).

⑤ Project Evaluation

(1) Relevance

As detailed below, this project contributes to the realization of Tonga's development plan and energy policy goals, and the benefit of general citizens: the project is deemed relevant as a grant aid project.

1) Target population

If the project is implemented, electricity produced by the renewable energy source will be supplied to some 75,100 residents in Tongatapu Island, and the dependence on petroleum-based fuels and risks of price fluctuation reduced. The project covers some 12,800 general households and other 50 customers in its sites.

2) Urgency

In Tonga, electricity charges soared as a result of a global rise in crude oil prices in 2008, causing serious damage to the people's lives and national economy. This project is expected to urgently reduce dependency on petroleum-based fuel for energy consumption.

3) Contribution to stable management of public welfare facilities

Tonga relies on diesel power generation for 98% of its power supply and frequently suffers from rises in electricity charges due to a rise in fuel prices. High electricity bills weigh on the management of public welfare facilities.

The implementation of this project and a subsequent reduction in dependence on diesel power generation alleviates the risk of inflation of electricity charges and contributes to the stability of public welfare facility management.

4) Operational and maintenance capacity

The Power Generation Department of the TPL routinely operates and maintains diesel power generators and thus has a relatively high technical level. Though it is not used to microgrid controllers or Power storage devices, the TPL will be able to operate and maintain the equipment to be procured in this project, with initial operation guidance as on the job training implemented by the supplier, and with technological transfer through soft component implemented by the consultant.

5) Project contributing to Tonga's development plan

The Tonga Strategic Development Framework (TSDF), the country's development plan, sets one of its strategies to "maintain and where possible expanding the provision of reliable and cost efficient power supplies, using traditional and renewable options, to all communities" Since this project aims to expand the use of renewable energy sources, it is believed to contribute to the achievement of TSDF objectives. The TERM, Tonga's energy policy, sets its goal of "increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020", and thus this project contributes to the achievement of the goal of the TERM, too.

6) Environmental and social impact

The Survey Team has examined the project in accordance with environment-related laws and regulations in Tonga and the JICA Guidelines for Environmental and Social Considerations and concluded that the project has no particular impact on the environmental and social aspects of the country since it only has minor impact on the natural and social environments but contributes to a reduction in greenhouse gas emissions.

7) Japan's grant aid scheme

This project is feasible with no particular difficulty on the grounds that major equipment is to be procured in Japan, that it is completed within the term of the E/N, and thus that its plan and schedule have been drawn up in a realistic manner within the framework of the grant aid scheme.

(2) Effectiveness

The effects expected to be produced as a result of the implementation of this project are as follows.

1) Quantitative Effects

Output indicator	Present value (2011)	Target value (2018) 3 years after the completion of the project
Reduction in diesel fuel consumption [kℓ/year]	-	327
CO_2 emissions reduction* [t-CO_2/year]	-	886
The amount of annual power generation by 1MWp PV system [MWh/year]	0	1,308

Note:*The reduction attributable to the project only. No effect of the existing PV system is included.

2) Qualitative Effects

Present states and problems	Project countermeasures (grant aid project)	Extent of project effects and improvement
1. Tonga relies on diesel power generation for 98% of its power supply and thus is vulnerable to fluctuations in fuel prices.	A PV power plant is constructed.	The project reduces dependency on diesel power generation for the country's power supply and alleviates the risk of inflation of electricity charges.
2. Tonga promotes the introduction of renewable energy sources, but the introduction in the large volume undermines the stability of the power grid since the output of PV, wind-power and other renewable power generation fluctuates considerably.	Microgrid systems are introduced.	The power storage systems and microgrid controllers can make up for fluctuating output of renewable energy and stabilize the grid power generation.

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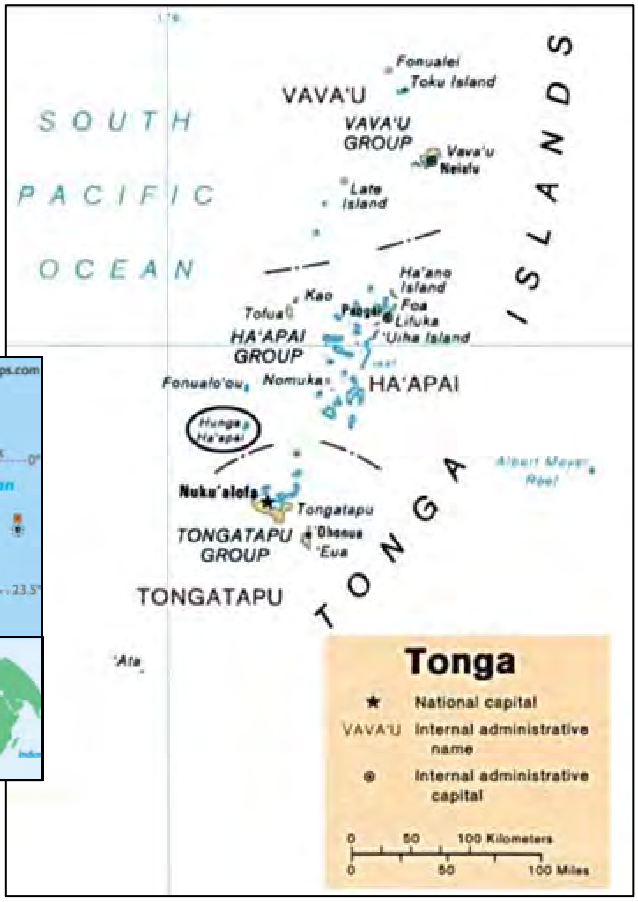

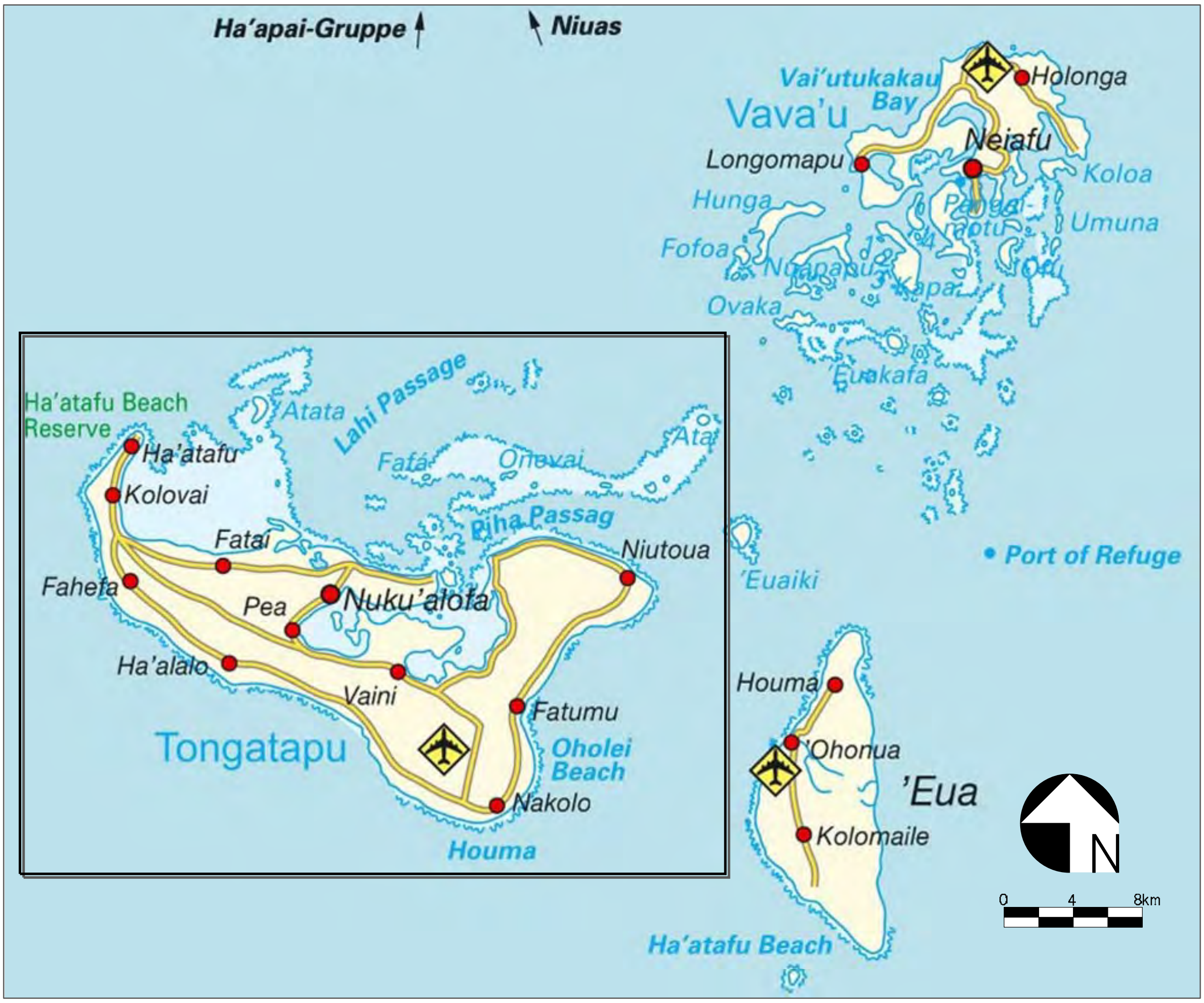

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ABBREVIATIONS

ADB	Asian Development Bank
AusAID	the Australian Agency for International Development
CA	Concession Agreement
CCCPIR	Coping with Climate Chang in the Pacific Island Region
DAC	Development Assistance Committee
DSM	Demand Side Management
EIB	European Investment Bank
GDP	Gross Domestic Product
GIZ	Deusche Gesellschaft fur Internationale Zusammenarbeit
GNI	Gross National Income
IPP	Independent Power Producer
IUCN	International Union for Conservation of Nature and Natural Resources
JICA	Japan International Cooperation Agency
MLECCNR	Ministry of Land, Environment, Climate Change and Natural Resources
NZAID	New Zealand Agency for International Development
NZMFAT	New Zealand Ministry of Foreign Affairs and Trade
PEC	Pacific Environment Community
PIFS	Pacific Islands Forum Secretariat
PILR	Policy, Institutional, Legal and Regulatory
PRIF	Pacific Region Infrastructure Facility
REEEP	Renewable Energy and Energy Efficiency Partnership
SCADA	Supervisory Control and DATA Acquisition
SHS	Solar Home System
SPC	South Pacific Commission
TERM	Tonga Energy Road Map
TERM-C	Tonga Energy Road Map Government Committee
TERM-IU	Tonga Energy Road Map-Implementation Unit
TGIF	Tonga Green Incentive Fund
TPL	Tonga Power Limited
TSDF	Tonga Strategic Development Framework
UNDP	United Nations Development Programme
WB	World Bank
WBG	World Bank Group

Chapter 1 Background of the Project

1-1 Background of the Request for a Grant Aid Project and the Outline

Because of the geological condition as an archipelago country, import of petroleum-based fuel accounts for 25% of total imports, equivalent to 10% of GDP. Moreover, Tonga relies on diesel power generation using imported fuel for 98% or more of electricity supply. In such situations, the country is susceptible to fluctuations in the global crude oil prices and thus fairly vulnerable from the energy security perspective. The soaring of the global crude oil prices in 2008 obliged the Tongan authority to raise electricity charges to TOP 1.00/kWh (approx. USD 0.5/kWh), causing serious impact on economic activities and the peoples' lives in the country. Having learnt from this experience, the Cabinet of Tonga dissolved in 2009 a policy goal of "increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020" to deal with two crucial issues: greenhouse gas emissions reductions and improvement in energy security. The government also formulated a Tonga Energy Road Map 2010-20 (hereinafter called the "TERM") as an implementation policy to achieve the policy goal. Having made various efforts, Tonga still needs to adopt renewable energy systems further to achieve the target of "50% of electricity from renewable sources". But it is difficult to stably supply electricity and secure the quality of electricity if the proportion of wind and photovoltaic power generation is substantially increased since the output level of these renewables are fairly fluctuating. In these circumstances, Tonga's electricity sector needs to adopt renewable energy sources further and at the same time stably supply electricity and minimize the fluctuation in frequencies of the grid system by using microgrid systems.

Under these circumstances, in April 2012, the Government of Tonga requested the Government of Japan to launch a grant aid project for the introduction of microgrid systems that can contribute to the achievement of the objectives of the TERM. The project aims to procure and install grid-connected photovoltaic system (output: 1,000 kWp) and microgrid systems to stabilize the power grid at the Vaini Project site and on the premises of the existing Popua Power Sation in Tongatapu on which the capital city of Nuku'alofa is located.

1-2 Natural Conditions

(1) Temperature

Monthly average, maximum and minimum temperatures of each month of 2011 measured at the Fua'amotu International Airport by the Tonga Meteorological Services are shown in Table 1-2.1 and Figure 1-2.1. The monthly average temperature is more or less stable throughout the year; from 21°C in July to 26.4°C in February. The monthly maximum temperature is also stable throughout the year from 31.5°C in December in winter and 28.4°C in July in winter. The minimum temperature recorded ranges between 11°C in September and 20.6°C in November. The gap between the maximum and minimum temperature is the largest, 20.1°C, in September when it is hot in daytime and chilly at night.

Table 1-2.1 Average, Maximum and Minimum Temperatures by Month

Unit:°C

Month	1	2	3	4	5	6	7	8	9	10	11	12	Annual ave.
Average	25.7	26.4	26.2	25	23.2	22.1	21	21.1	21.3	22.5	24	25.2	**23.7**
Maximum	30.6	31.6	32.5	31	30.1	29.2	28.4	28.7	31.1	28.5	29.8	31.5	**30.3**
Minimum	19	19.6	20.1	19.4	18.6	15.6	14	14.1	11	15.4	20.6	16.6	**17.0**

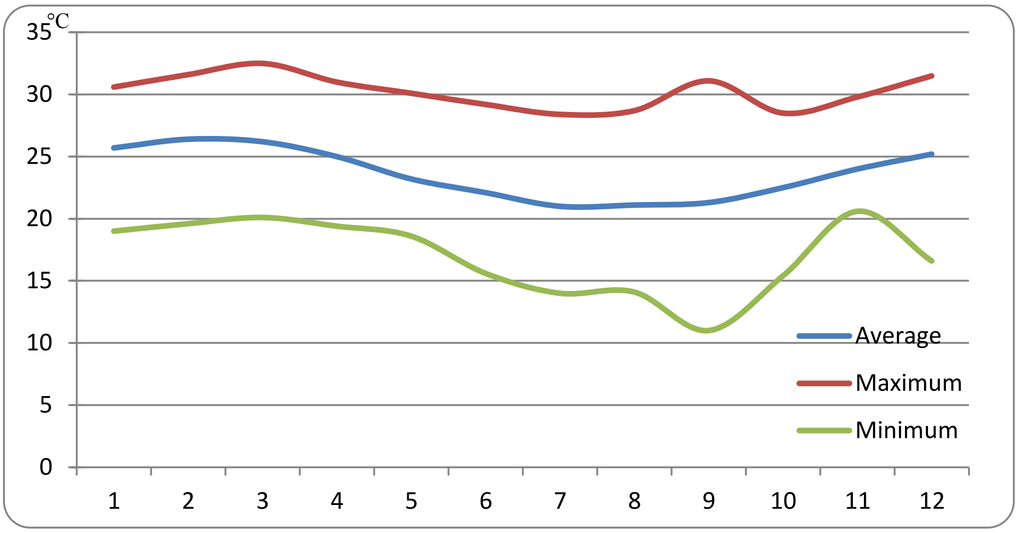


Figure 1-2.1 Average, Maximum and Minimum Temperatures by Month

(2) Rainfall

Data on and a graph of the monthly average rainfall in 2003 - 11 in Tonga are shown in Table 1-2.2 and Figure 1-2.2.

- The minimum annual rainfall is 1,546 mm recorded in 2003 and the maximum annual rainfall 2,383 mm recorded in 2008.
- As for a monthly average basis, the minimum rainfall is 105 mm in October and the maximum rainfall 252 mm in January.
- It rains every month, and it is considered appropriate for cleaning of PV modules.

Table 1-2.2 Monthly Average Rainfall

Unit: mm

Month \ Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total	Monthly ave.
1	413	85	259	194	19	304	570	163	261	2,268	252
2	30	98	15	153	240	420	144	269	239	1,608	179
3	321	253	144	137	180	279	77	191	140	1,721	191
4	78	36	313	357	287	92	249	605	172	2,189	243
5	38	127	161	34	572	344	206	209	244	1,933	215
6	16	211	172	359	48	94	73	10	167	1,149	128
7	116	164	165	70	228	97	69	56	208	1,172	130
8	221	355	193	90	126	35	105	21	89	1,235	137
9	76	245	125	101	158	285	323	32	201	1,545	172
10	62	30	318	99	133	42	48	158	58	947	105
11	42	38	179	43	149	285	40	136	210	1,122	125
12	135	108	49	293	163	108	189	185	304	1,533	170
Annual Total	1,546	1,751	2,092	1,927	2,303	2,383	2,093	2,035	2,293		

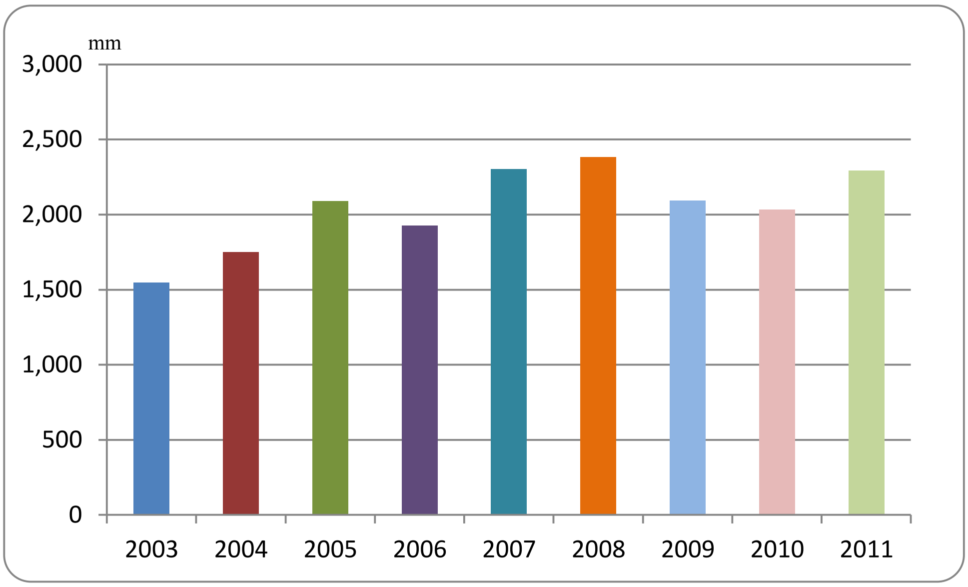


Figure 1-2.2 Annual Total

1-3 Environmental and Social Consideration

1-3-1 Outline of the Project Components affecting Environmental and Social Concerns

The Project's components include micro grid controller, storage system, solar PV system, and non-physical components such as preparation of operating and maintenance manuals. Regarding the renewable energy, the Government of Tonga (GOT) requested introduction of both solar PV system (0.5 MWp) and wind turbine (0.5 MWp) to the Government of Japan. However, the wind turbine was not accepted as one of the project components because of its environmental constraint described in 1-3-4. As to the storage system, the capacitor bank, which does not contain any hazardous heavy-metals, was introduced to the system due to the characteristics of photovoltaic power generation.

As a result, the physical components of the Project have been finalized through the series of discussions between the Tongan side and Japanese side. That is, micro grid controller and lithium ion capacitor (500 kWp) will be provided to Popua Power Station, while solar PV system (1.0 MWp) and lithium ion capacitor (500 kWp) will be provided to the project site for new power station at Vaini. The land use of the project site at Vaini will be converted from weedy vacant lot with some untended coconut trees and others to power station. Accordingly, the project site at Vaini shall be the subject of environmental and social consideration.

1-3-2 Basis of Environmental and Social Contexts

1-3-2-1 Physical Situation of the Project site

The project site for solar PV system is located at Vaini roughly in the center of Tongatapu Island, and bordered on the north by Taufa'ahau Road which is the arterial road cutting through east and west of the island. The land is owned by a noble and, as shown in the following figure, it is weedy vacant lot with some untended coconut trees and others.

Figure 1-3-2-1.1 Northwardly Scenery of the Project site for Solar PV System

In the above scenery, the backward land with scattering coconut trees and others is the project site for solar PV system, the road with the white pickup truck is the two-track arterial road, and the paved road in front is the access road to waste disposal site which is located approximately 500 m to the north of the project site. The opposite dirt road is 4 m wide farm road and bordering the east side of the project site. Vaini village is located approximately 1 km to the east and Veitongo village is located approximately 2 km to the west from the project site along the arterial road.

Figure 1-3-2-1.2 Southwardly Scenery of the Project site for Solar PV System

The above figure is the southwardly scenery of the project site along the farm road. The east side of the project site is bordered by the farm road. The backward whitish building at the other end of the farm road, which was vacant house until recently, is used as church by a Christian religious group.

The vicinity of the project site is a stretch of farm land occupied by a mixture of untended farmlands and well-organized farmlands. There are several farmhouses in the bordering land lots in addition to the church. All those buildings are more than 20 m away from the edge of the project site.

1-3-2-2 Non-necessity of Land Acquisition and Resettlement

As described later, land transaction in Tonga is prohibited by law, and consequently Tonga Power Limited (hereinafter called the "TPL") has to lease the land lot of the project site from the landowner. The project site is vacant lot owned by a noble who has already agreed on the lease to TPL. None of resettlement is expected because there is not any dwelling building or illegal occupation in the project site.

Apart from land acquisition and resettlement, cutting of trees is needed for the construction of the solar PV system. The compensation for those trees will be lump sum payment included in the lease contract of the project site.

1-3-2-3 Land System and Land Right of the Project site

The prime feature of land system in the Kingdom of Tonga is that "all the land of the Kingdom is the property of the Crown", as declared in the Land Act. The Minister of Land, Environment, Climate

Change and Natural Resources (hereinafter called the "MLECCNR") is responsible for the land administration of the Kingdom's land as the representative of the Crown. There are two types of landownership; one is the Crown Land and the other, estate so-called "Tofia". The Crown Lands include Royal Estates, Royal Family Estates, lands for public purposes such as road and cemetery, and so on, while the Tofias, which are entitled to privilege of hereditary transfer, have been given to only so many people such as nobles provided in the Land Act. People (or Commoner) can only lease the Crown Lands or Tofias with conditionality of less than 99 years' lease period because the Land Act places a ban on sale of the Kingdom's land.

The project site for the solar PV system at Vaini is owned by Lord Ma'afu who is the Minister for the MLECCNR. Lord Ma'afu has accepted TPL's request for the lease of the land, and sent the confirmation letter to TPL during the First Field Survey on August 2012. And then, the CEO of TPL and Lord Ma'afu put their names on the lease contract in October. After that, the signed lease contract was deliberated by the Cabinet for the registration and it was eventually booked in the land register on November 9^{th} 2012. Under the contract, TPL will rent a land area of approximately 3.2 ha for 50 years. The compensation for the trees within the project site is included in the rent as lump sum payment.

In general, the documents of the lease contract will be submitted to the MLECCNR for approval and registration. The submitted lease contract will be deliberated in the Cabinet and, if it is acceptable, the Minister of the MLECCNR will approve the lease contract with the Cabinet's consent. And then, the project site will be surveyed and registered by the MLECCNR. According to the Planning & Urban Management Agency of the MLECCNR, it generally takes one month from submission of the lease contract to the registration.

In this case, however, the MLECCNR conducted the survey of the project site and identified the boundary prior to conclusion of the lease contract, because of the urgent need of topographic survey of the project site.

1-3-2-4 Recycling of Used Lead-acid Batteries

Gio Recycling is the only recycling firm collecting used lead-acid batteries in Tongatapu. Under the Basel Convention, the collected batteries had been purchased by CMA Recycle who is one of recycling firm in New Zealand and, eventually, those used batteries had been exported to Korea for the reprocessing before the contract between those two firms expired at the beginning of year 2012. Although Gio Recycling had arranged the re-signing procedure prior to the expiration of the contract, the inability to re-signing had lasted for a period of time because the approval process by the Government of New Zealand had required considerable time. However, the exportation of used batteries has started again because the licenses were granted from the Government of New Zealand on September 2012 and from the Government of Tonga on October 2012

According to Gio Recycling, the purchasing price of used batteries in Tongatapu is 0.15 TOP/kg, while CMA Recycle purchases used batteries by 20 ft container and the price is in the range of 500 to 600

NZD/ton. In addition, expense of approximately NZD2,000 per container for shipping, insurance and others are burden to Gio Recycling.

In the Project, lithium-ion capacitor will be employed in the storage system in order to compliment unstable PV output caused by movement of clouds, therefore, it will not generate any used lead-acid batteries. However, introduction of industrial lead-acid batteries for storing of surplus electricity will be required for the storage system in cases where wind plant is introduced as a renewable energy source in future. In this case, TPL intends to entrust handling of used lead-acid batteries to Gio Recycling.

1-3-3 Environmental Legal Framework

1-3-3-1 Environmental Legislation relevant to the Project

Existing environmental legislation relevant to the Project is shown below.

Table 1-3-3-1.1 Existing Environmental Legislation relevant to the Project

Legislation	Year Passed	Last Amended	Objective
Environmental Impact Assessment Act 2003	2003	-	To provide for the application of environmental impact assessment to the planning of development in Tonga
Environmental Impact Assessment Regulations 2010	2010	-	To regulate major development projects and the applications of notification consistent with the EIA Act 2003)
Waste Management Act 2005	2005		To manage and oversee the function of the Waste Management Board
Parks and Reserves Act 1976	1976	1979 & 1988	To provide for the establishment of Parks and Reserves Authority and for the establishment, preservation and administration of Parks and Reserves
Hazardous Wastes and Chemicals Act 2010	2010		To provide for the regulation and proper management of hazardous wastes and chemicals in accordance with accepted international practices and the International Conventions applying to the use, transboundary movement and disposal of hazardous substances and for related purposes.
Renewal Energy Act 2008	2008	2010	To regulate the use of renewable energy in the Kingdom and related matters
Environmental Management Act 2010	2010		To establish the Ministry of Environment & Climate Change* to ensure the protection and proper management of the environment and the promotion of sustainable development

*The Ministry of Environment & Climate Change was incorporated into the MLECCNR as the Department of Environment & Climate Change due to the reorganization of government ministries in July 2012.

Source: Department of Environment & Climate Change

The Environmental Impact Assessment Act 2003 (EIA Act 2003) provides the power of the Ministry, the establishment and functions of the Environmental Assessment Committee, penalty, definition of major projects and so on. The major project is defined as a development activity which is likely to result in or increase pollution, or to have adverse impact on natural environment. A development activity which is classified as the major project is subject to conduct an appropriate environmental impact assessment. Development of electric generation station is defined as the major project even though renewal energy is used for the power generation. Therefore, the Project is subject to conduct an

EIA.

1-3-3-2 Environmental Policies in TERM

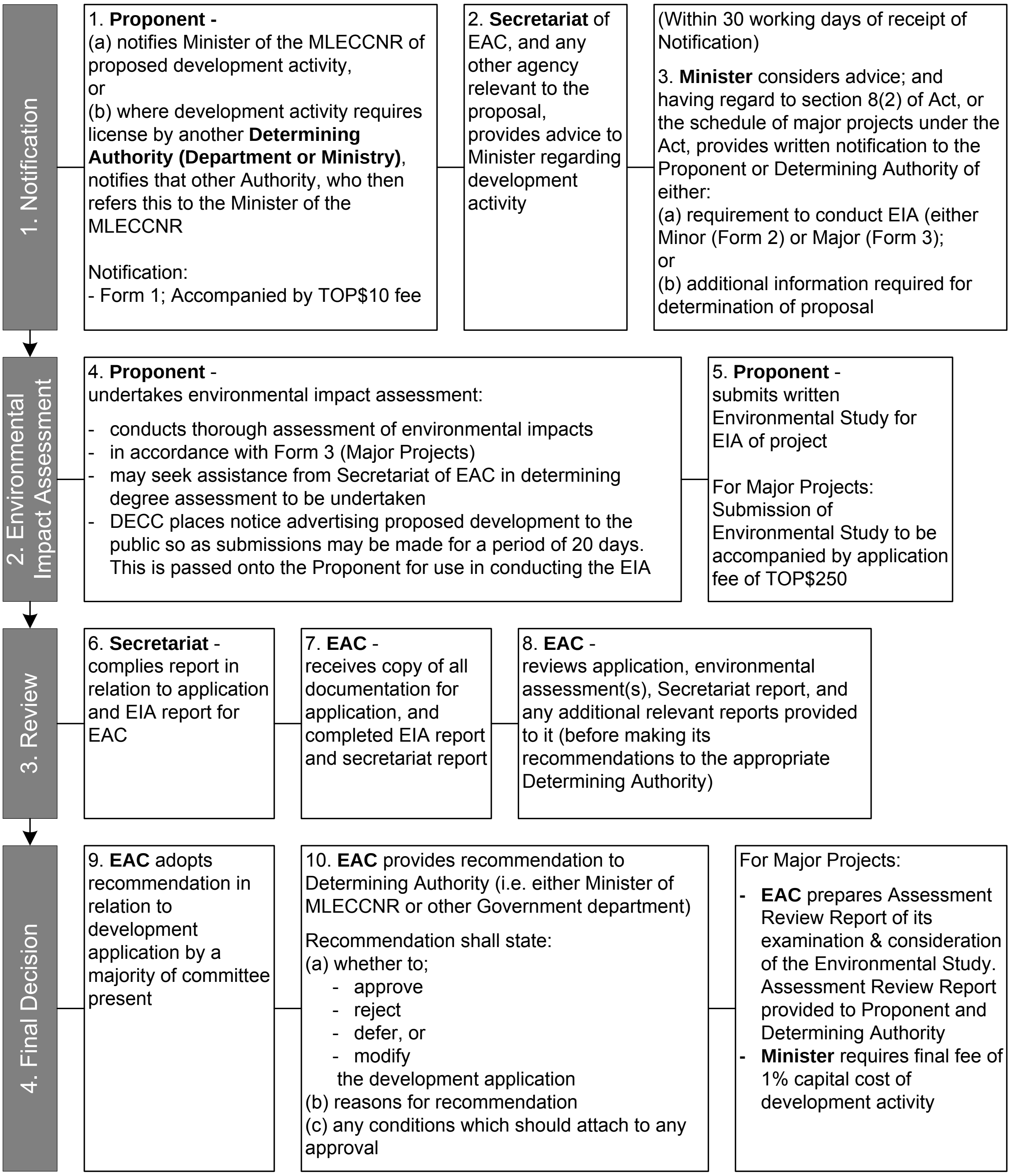
The objective of TERM is to reduce vulnerability to high and variable petroleum price with introduction of renewable energy. In order to achieve the objective, a set of key principles have been set out in TERM. Social and environmental sustainability is one of the key principles, and it is explained as follows. "Environmental and Social sustainability encompasses both minimizing local negative social and physical environmental impacts of the energy sector, as well as aligning with global goals with respect to minimizing impact on climate change where possible. New energy investments under the TERM would be subject to *Environmental and Social Impact Assessment and Mitigation Plans* as necessary, as per international practice. Special consideration will be given to those groups with specific needs including youth, women, religious groups and those with special needs. Investments that have major negative environmental or social impacts or constraints that cannot be mitigated or solved will be avoided."

As mentioned above, TERM requires environmental and social impact assessment and mitigation plans as per international practice in order for development of electric generation station. In this regard, the JICA Guidelines for Environmental and Social Considerations shall be observed as well as the World Bank's Safeguard Policies and other standards of international financial organizations related to the environmental and social considerations of the Project.

1-3-3-3 Environmental Management Administration and EIA Procedures

The Environmental Management Act 2010, which created the former Ministry of Environment and Climate Change (MECC), empowered the Minister and the Director for Environment and Climate Change as well as Environmental Officers on environmental management. In relation to the EIA procedure, the Minister determines whether the proposed development is a minor or major project, and receives an assessment report and issues the approval with or without conditions, a request for further information, or a rejection. Meanwhile, the Director, who is the head of the Secretariat of the Environmental Assessment Committee (EAC) and chairs the Committee, inspects or investigates any facility or activity deemed to be causing potential impact on the environment. The Secretariat which is staffed with Environmental Officers receives application documents related to environmental impact assessment of the proposed project and gives advice on implementation of environmental study under the Director's instructions. It is deemed that the power and authority of those key actors are the same as before, although the former MECC was incorporated into the MLECCNR in July 2012.

The EIA Act 2003 has been enforced under the Environmental Impact Assessment Regulations 2010 (EIA Regulations 2010). The EIA Regulations provides the procedures of EIA for major projects classified under the EIA Act 2003. The EIA procedures, as shown in the following figure, are divided into four steps; namely, notification, environmental impact assessment, review and final decision with or without conditions.



Source: Department of Environment & Climate Change

Figure 1-3-3-3.1 Procedures of EIA

All development activities must be notified to the Minister who determines whether the proposed development is a major project or not. However, according to the Department of Environment and Climate Change (DECC), this Project can skip the notification because it is obviously the major project, and the proponent can step into the study of EIA, complete the EIA report and submit it to the Secretariat with an application. The Secretariat compiles a report based on the application and the EIA report, and then submits those documents to the EAC for the review. The EAC reviews the submitted documents and prepares/submits a recommendation to the Minister for final decision. According to the

TPL, in case of the project of Popua 1 MW Solar Firm, it took less than 3 months from the notification to the final decision by the Minister.

1-3-4 Review of Alternatives

In order to optimize the environmental and social impacts by the Project, the following alternatives including zero option were reviewed.

Alternative 0: None of project implementation (zero option)
Alternative 1: Construction of 0.5 MWp PV plant and 0.5 MWp wind plant, and other needed facilities
Alternative 2: Construction of 1.0 MWp PV plant and other needed facilities

The Alternative 1 is the original plan that was requested by the Government of Tonga, and the Alternative 2 is the agreed plan by both the Tongan and Japanese sides during the First Field Survey. The results of review of those alternatives are shown in the following table.

Table 1-3-4.1 Comparison of Alternatives

Items to be reviewed	Alternative 0 (w/o Project)	Alternative 1 (0.5 MWp PV plant + 0.5 MWp wind plant)	Alternative 2 (1.0 MWp PV plant)
Benefit	None	• Reduction of fossil-fuel consumption and stabilization of electricity supply by development of renewal-energy-based electric generation along with introduction of micro-grid system	Same as on the left
Reduction of CO_2 Emission	None	1,268 ton/year	886 ton/year
Social Impacts	As-is (Social impacts due to the vulnerability to oil price will continue without any improvement)	• A certain decrease of agricultural product because of land use conversion from farm land to power station • Possible damage of tourism resources because of spoiling of landscape caused by existence of gigantic wind turbine	None
Environmental Impacts	As-is (Environmental impacts due to consumption of fossil-fuel in the existing diesel power plant will continue without any improvement)	• Minor changes of topography in the project sites are expected because of clearing and leveling of the sites • Possible soil erosion because of clearing and leveling of the sites • Possible impact of flora, fauna and biodiversity because of existence and operation of wind plant • Possible impact of landscape because of existence and operation of wind plant	• Minor changes of topography in the project sites are expected because of clearing and leveling of the sites • Possible soil erosion because of clearing and leveling of the sites
Possible Pollution	As-is	• Possible air pollution because of SPM and dust arising from operation of construction vehicles and machineries • Possible generation of construction wastes from construction activities • Possible generation of used lead-acid batteries approximately every 10 years • Possible pollution of noise arising from construction vehicles and machineries • Possible pollution of noise and low-frequency noise because of operation of wind turbine	• Possible air pollution because of SPM and dust arising from operation of construction vehicles and machineries • Possible generation of construction wastes from construction activities • Possible pollution of noise arising from construction vehicles and machineries

Source: JICA Study Team

The Alternative 0 (zero) means that the operation of existing power generating system (11.28 MW diesel generating along with the newly developed Popua 1.3 MWp Solar Farm) continues without any changes. Therefore, it brings neither benefit nor reduction of CO_2 emission in future.

In case of the Alternative 1, it is likely to bring the most reduction of CO_2 emission compared to the other alternatives. The GOT requested to the GOJ to introduce both solar PV system and wind turbine generator system as the renewal energy source of the Project. However, the wind turbine system is hardly adopted in the Project from the viewpoint of environmental and other constraint described below.

It is unlikely that the construction, existence and operation of solar PV system have serious impacts on social and natural environment. Meanwhile as for wind turbine generator system, the following environmental items should be appropriately evaluated prior to the construction because problems of those items might be caused by wind turbine due to its mechanism.

- Noise
- Low-frequency noise
- Radio disturbance
- Shadow flicker
- Disturbance of birds' migration routes
- Spoiling of landscape

As to disturbance of birds' migration routes especially, survey of existing conditions on the migration routes generally takes one year at minimum. Accordingly, it takes one and a half year or more to obtain environmental permission from both Japanese and Tongan authorities, taking into account the required time for data analysis, assessment of the environmental impacts, information disclosure, stakeholder meetings, review of the EIA and so on. The time required for the EIA procedures does not meet the time schedule of the Project.

Another reason is that TPL did not commence the collection of wind conditions throughout a year at the site, which shall not meet the schedule of the project.

In addition, road shall be prepared for extension work of the existing grid to the wind turbine system, and installation and maintenance work for the wind turbine system. This preparation of the road requires extension of existing agricultural road, which includes complicated negotiations with lessee and owner of the land along the road on division of lot, transfer of dominion and so on, and procedures for them. This preparation of the road makes it difficult to install wind turbine system as well.

1-3-5 Scoping

(1) Specification of Factors affecting Environment

Factors (or activities) which are accompanied by the project implementation and assumed to be affecting environment in/around the project site are examined in the cases of the Alternative 1 (0.5 MWp PV plant + 0.5 MWp wind plant) and the Alternative 2 (1.0 MWp PV plant) as mentioned in the preceding section. The specified factors are shown below.

Table 1-3-5.1 Factors Affecting Environment

Factors affecting environment		Assumed environmental impacts
Construction Phase	Land preparation	Loss of agricultural product, topographical change, soil erosion and generation of construction wastes due to land preparation work (clearing and leveling of the sites)
	Operation of construction machineries	Air pollution, noise and vibration due to operation of construction machineries at the sites
	Transportation of equipment and materials	Air pollution, noise and vibration due to transportation of equipment and construction materials to and from the sites
	Construction of power plant	Construction wastes due to construction work of facilities
Operation Phase	Existence of wind plant *	Loss of agricultural product, spoiling of landscape, impacts on flora, fauna and biodiversity due to existence of wind turbine
	Operation of wind plant *	Spoiling of landscape, impacts on flora, fauna and biodiversity, generation of used lead-acid batteries, noise and vibration due to operation of wind plant

Note: The marked item (*) is only applicable to the Alternative 1.

Source: JICA Study Team

(2) Review of Environmental Items

The environmental items to be examined are classified into three categories; social environment, natural environment and pollution, and 30 environmental items are specified based on the JICA Guidelines for Environmental and Social Considerations. The relationship between the environmental items and the factors affecting environment is shown in the following tables, in the both cases of the Alternative 1 and the Alternative 2.

Table 1-3-5.2 Scoping Matrix for Alternative 1 (0.5 MWp PV Plant + 0.5 MWp Wind Plant)

Category and environmental item \ Factor affecting environment			**OVERALL RATING**	Const. Phase: Land preparation	Const. Phase: Op. of const. machinery	Const. Phase: Transp. of equipment	Const. Phase: Const. of power plant	Op. Phase: Existence of wind plant	Op. Phase: Operation of wind plant	Description
Social Environment	1	Involuntary resettlement								There is no possibility of impact because no houses exist in the sites.
	2	Local economy such as employment and livelihood, etc.	B	B				B		Loss of agricultural product is expected in the site of wind plant.
	3	Land use and utilization of local resources								There is no possibility of impact because the construction and operation of power plants do not affect surrounding land use and utilization of local resources.
	4	Social institutions such as social infrastructure and local decision-making								There is no possibility of impact because there are not any social institutions in the sites.
	5	Existing social infrastructure and services								There is no possibility of impact because there are not any social infrastructure and services in the sites.
	6	The poor, indigenous and ethnic people								There is no possibility of impact because the sites have not any relationships with poor, indigenous and ethnic people.

Category and environmental item			OVERALL RATING	Const. Phase: Land preparation	Const. Phase: Op. of const. machinery	Const. Phase: Transp. of equipment	Const. Phase: Const. of power plant	Op. Phase: Existence of wind plant	Op. Phase: Operation of wind plant	Description
	7	Misdistribution of benefit and damage								There is no possibility of impact because the construction and operation of power plants do not result in any misdistribution of benefit and damage.
	8	Cultural heritage								There are not any cultural heritages in the sites and those vicinities.
	9	Local conflict on interests								There is no possibility of impact because the construction and operation of power plants do not create any local conflict on interests.
	10	Water usage or water rights and rights of common								There is no possibility of impact because the construction and operation of power plants do not affect water usage and water rights.
	11	Sanitation								There is no possibility of impact because the construction and operation of power plants do not affect sanitation.
	12	Hazards (Risk) of infectious diseases such as HIV/AIDS								There is no possibility of impact because the construction and operation of power plants do not lead to any hazards of infectious diseases. During construction phase, hiring of local workers is expected and workers' lodging is not necessary.
Natural Environment	13	Topography and geographical features	B	B						Minor changes of topography are expected because of clearing and leveling of the sites.
	14	Soil erosion	B	B						There is a possibility of impact because of clearing and leveling of the sites during construction phase.
	15	Groundwater								There is no possibility of impact because the construction and operation of power plants do not affect groundwater.
	16	Hydrological situation								There is no possibility of impact because the construction and operation of power plants do not affect hydrological situation.
	17	Coastal zone								There is no possibility of impact because the construction and operation of power plants do not affect coastal zone.
	18	Flora, fauna and biodiversity	C					C	C	There is a possibility of impact because of the existence and operation of wind plant.
	19	Meteorology								There is no possibility of impact because the construction and operation of power plants do not affect meteorology.
	20	Landscape	C					C	C	There is a possibility of impact because of the existence and operation of wind plant.
	21	Global warming								There is no possibility of impact because the construction and operation of power plants do not affect global warming.
Pollution	22	Air pollution	B		B	B				There is a possibility of impact because of SPM and dust arising from operation of construction vehicles and machineries.
	23	Water pollution								There is no possibility of impact because the construction and operation of power plants do not lead to water pollution.
	24	Soil contamination								There is no possibility of impact because the construction and operation of power plants do not lead to soil contamination.
	25	Waste	B	B			B		B	Construction wastes arise from construction activities. Replacement of lead-acid batteries arises periodically, say every 10 years.
	26	Noise and vibration	C		B	B			C	There is a possibility of impact because of noise and vibration arising from operation of construction vehicles and machineries. Operation of wind plant generates noise and low-frequency noise.

Factor affecting environment

Category and environmental item / Factor affecting environment			OVERALL RATING	Const. Phase				Op. Phase		Description
				Land preparation	Op. of const. machinery	Transp. of equipment	Const. of power plant	Existence of wind plant	Operation of wind plant	
	27	Ground subsidence								There is no possibility of impact because the construction and operation of power plants do not lead to ground subsidence.
	28	Offensive odor								There is no possibility of impact because the construction and operation of power plants do not lead to offensive odor.
	29	Bottom sediment								There is no possibility of impact because the construction and operation of power plants do not lead to bottom sediment.
	30	Accidents	B		B	B	B			There is a possibility of impact on traffic/construction safety because of the operation of construction vehicles and machineries and construction work.

Rating

A: Serious impact is expected.

B: Some impact is expected.

C: Extent of impact is unknown. (Examination is needed. Impacts may become clear as study progress.)

No mark: No impact is expected. IEE/EIA is not necessary.

Source: JICA Study Team

In the case of the Alternative 1, nine (9) environmental items shall be examined through the study of EIA. Of these items, three (3) items are rated as C that means the extent of impact is unknown and, accordingly, those impacts have to be carefully assessed through the study of EIA. As shown in the above table, those C ratings are, incidentally, attributed to the wind turbine plant.

Table 1-3-5.3 Scoping Matrix for Alternative 2 (1.0 MWp PV Plant)

Category and environmental item		Factor affecting environment	OVERALL RATING	Const. Phase: Land preparation	Const. Phase: Op. of const. machinery	Const. Phase: Transp. of equipment	Const. Phase: Const. of power plant	Description
Social Environment	1	Involuntary resettlement						There is no possibility of impact because no houses exist in the sites.
	2	Local economy such as employment and livelihood, etc.						There is no possibility of impact because the site is vacant lot and there are not any economic activities.
	3	Land use and utilization of local resources						There is no possibility of impact because the construction and operation of power plants do not affect surrounding land use and utilization of local resources.
	4	Social institutions such as social infrastructure and local decision-making						There is no possibility of impact because there are not any social institutions in the sites.
	5	Existing social infrastructure and services						There is no possibility of impact because there are not any social infrastructure and services in the sites.
	6	The poor, indigenous and ethnic people						There is no possibility of impact because the site has not any relationships with poor, indigenous and ethnic people.
	7	Misdistribution of benefit and damage						There is no possibility of impact because the construction and operation of PV plant do not result in any misdistribution of benefit and damage.
	8	Cultural heritage						There are not any cultural heritages in the site and its vicinities.
	9	Local conflict on interests						There is no possibility of impact because the construction and operation of PV plant do not create any local conflict on interests.
	10	Water usage or water rights and rights of common						There is no possibility of impact because the construction and operation of PV plant do not affect water usage and water rights.
	11	Sanitation						There is no possibility of impact because the construction and operation of power plants do not affect sanitation.
	12	Hazards (Risk) of infectious diseases such as HIV/AIDS						There is no possibility of impact because the construction and operation of PV plant do not lead to any hazards of infectious diseases. During construction phase, hiring of local workers is expected and workers' lodging is not necessary.
Natural Environment	13	Topography and geographical features	B	B				Minor changes of topography are expected because of clearing and leveling of the site.
	14	Soil erosion	B	B				There is a possibility of impact because of clearing and leveling of the site during construction phase.
	15	Groundwater						There is no possibility of impact because the construction and operation of PV plant do not affect groundwater.
	16	Hydrological situation						There is no possibility of impact because the construction and operation of PV plant do not affect hydrological situation.
	17	Coastal zone						There is no possibility of impact because the construction and operation of PV plant do not affect coastal zone.
	18	Flora, fauna and biodiversity						There is no possibility of impact because the construction and operation of PV plant do not affect flora, fauna and biodiversity.
	19	Meteorology						There is no possibility of impact because the construction and operation of PV plant do not affect meteorology.
	20	Landscape						There is no possibility of impact because the construction and operation of PV plant do not affect landscape.
	21	Global warming						There is no possibility of impact because the construction and operation of PV plant do not affect global warming.

Category and environmental item \ Factor affecting environment			OVERALL RATING	Const. Phase				Description
				Land preparation	Op. of const. machinery	Transp. of equipment	Const. of power plant	
Pollution	22	Air pollution	B		B	B		There is a possibility of impact because of SPM and dust arising from operation of construction vehicles and machineries.
	23	Water pollution						There is no possibility of impact because the construction and operation of power plants do not lead to water pollution.
	24	Soil contamination						There is no possibility of impact because the construction and operation of power plants do not lead to soil contamination.
	25	Waste	B	B			B	Construction wastes arise from construction activities.
	26	Noise and vibration	B		B	B		There is a possibility of impact because of noise and vibration arising from operation of construction vehicles and machineries.
	27	Ground subsidence						There is no possibility of impact because the construction and operation of power plants do not lead to ground subsidence.
	28	Offensive odor						There is no possibility of impact because the construction and operation of power plants do not lead to offensive odor.
	29	Bottom sediment						There is no possibility of impact because the construction and operation of power plants do not lead to bottom sediment.
	30	Accidents	B		B	B	B	There is a possibility of impact on traffic/construction safety because of the operation of construction vehicles and machineries and construction work.

Rating
A: Serious impact is expected.
B: Some impact is expected.
C: Extent of impact is unknown. (Examination is needed. Impacts may become clear as study progress.)
No mark: No impact is expected. IEE/EIA is not necessary.

Source: JICA Study Team

In the case of the Alternative 2, six (6) environmental items shall be examined through the study of EIA. Those 6 items are all rated as B that means some impact is expected. The degrees of those impacts are deemed to be very limited and, in fact, reliable mitigation measures can be done against those impacts.

1-3-6 Emission Reduction

The effect of emission reduction by both cases of the Alternative 1 and Alternative 2 can be estimated from the offset of diesel fuel with the electric generation by the renewal energy resource respectively. The results of the estimation are shown below.

Table 1-3-6.1 Emission Reduction in the cases of Alternative 1 and Alternative 2

	Alternative 1 (0.5 MWp PV plant + 0.5 MWp wind plant)	Alternative 2 (1.0 MWp PV plant)
Rated Capacity of System (MW)	1.0	1.0
Estimated Electricity Output (MWh/year)	1,750	1,308
Reduced Quantity of Diesel Oil (kl/year)	438	327
Reduction of CO_2 Emission (t-CO_2/year)	1,187	886

Source: JICA Study Team

In the case of Alternative 1, the reduction of CO_2 emission will be 1,185 tons. On the other hand, 886 tons of CO_2 reduction is expected in the case of Alternative 2. The effect of emission reduction in Alternative 2 is less than the case of Alternative 1 because solar PV plant does not generate electricity during nighttime. The detailed estimation of the emission reduction by both cases of the Alternative 1 and Alternative 2 is shown below and estimated annual electric energy of PV system is described in 2-2-2-3 (1) while that of Wind Turbine is in Annex 10.

(1) Case of the Alternative 1

The estimated electricity output in the case of the Alternative 1 is as follows.

Estimated Electricity Output by 0.5 MWp PV Plant: 654 MWh/year
Estimated Electricity Output by 0.5 MWp Wind Plant: 1,096 MWh/year
Total Output: 1,750 MWh/year

The estimated electricity output can be converted to reduced quantity of diesel oil based on the actual fuel consumption of the diesel power plant in Tongatapu as follows.

Reduced Quantity of Diesel Oil = 1,750 MWh/year ÷ 4 kWh/l = 438 kl/year

The reduction of CO_2 emission is calculated using the unit calorific value (39.1 GJ/kl) and the emission factor (0.0693 kg-CO_2/l) of diesel oil as follows.

Reduction of CO_2 Emission = 438 kl/year × 39.1 GJ/kl × 0.0693 kg-CO_2/l = 1,187 t-CO_2/year

(2) Case of the Alternative 2

The estimated electricity output in the case of the Alternative 2 is as follows.

Estimated Electricity Output by 1.0 MWp PV Plant: 1,308 MWh/year

In the same way, the estimated electricity output can be converted to reduced quantity of diesel oil based on the actual fuel consumption of the diesel power plant in Tongatapu as follows.

Reduced Quantity of Diesel Oil = 1,308 MWh/year ÷ 4 kWh/l = 327 kl/year

The reduction of CO_2 emission is calculated as follows.

Reduction of CO_2 Emission = 326.9 kl/year × 39.1 GJ/kl × 0.0693 kg-CO_2/l = 886 t-CO_2/year

1-3-7 Mitigation Measures

As shown in the following table, the mitigation measures are examined in the case of the Alternative 2 that is the agreed plan between the Tongan and Japanese sides.

Table 1-3-7.1 Assumed Mitigation Measures

Items	Rating	Possible Impact	Assumed Mitigation Measures
Topography and geographical features	B	Minor changes of topography are expected because of clearing and leveling of the site.	The degree of the topographic change is very small because the magnitude of land preparation work is very limited and soil transportation to/from the site is not expected. Impacts such as soil erosion resulting from topographic change can be avoided or mitigated with appropriate measures such as covering over turned soil by tarpaulin.
Soil erosion	B	There is a possibility of impact because of clearing and leveling of the site during construction phase.	During construction phase, soil erosion can be avoided or mitigated with appropriate measures such as covering over turned soil by tarpaulin.
Air pollution	B	There is a possibility of impact because of SPM and dust arising from operation of construction vehicles and machineries.	During construction phase, occurrence of dust will be avoided or mitigated by watering or dustproof covering on turned soil. As for SPM and dust arising from transportation of construction materials and equipment from wharf to the site, the impact will be mitigated with careful selection of transportation route and operation hour avoiding the center of town.
Waste	B	Construction wastes arise from construction activities.	Construction waste will be treated at the nearby landfill site located at approx. 500 meters on the north of the project site, in accordance with law.
Noise and vibration	B	There is a possibility of impact because of noise and vibration arising from operation of construction vehicles and machineries.	The noise and vibration caused by vehicle operation for transportation of construction materials and equipment from wharf to the site will be mitigated with careful selection of transportation route and operation hour avoiding the center of town. In addition, operation of construction vehicles and machineries will be limited during daytime hours in order to avoid impact of noise and vibration at night.
Accidents	B	There is a possibility of impact on traffic/construction safety because of the operation of construction vehicles and machineries and construction work.	The risk of traffic accidents will be decreased with careful selection of transportation route and operation hour. In addition, safety education (for traffic safety and safety control in the construction site) and safety patrol will be implemented regularly, in order to avoid/decrease the risk of construction accidents.

Source: JICA Study Team

1-3-8 Monitoring

As a whole, the impacts of the Project on the natural and social environment are not significant as mentioned in the previous section. The most of the impacts are deemed to occur during construction phase, and those impacts can be avoided or mitigated with daily construction management. Accordingly, there are not any environmental items to be monitored.

1-3-9 Preparation of Environmental Checklist

Through the consultation between TPL and the JICA study team, the environmental checklist for the Project (refer to ANNEX. 6) was prepared in order to confirm the situation of EIA procedures and the environmental items to be considered.

1-3-10 Perspective on EIA Report and Environmental Permit

In accordance with advice of the Secretariat of EAC in the Department of Environment & Climate Change, TPL has submitted a series of documents based on the results of the Second Field Survey to the Secretariat, in order to obtain a pre-approval for the Project and to shorten the time period required to the EIA procedure. In relation to the preparation of the EIA report, TPL will implement an environmental and social survey including stakeholder meetings. TPL submitted the EIA report for the formal application to the Secretariat based on the series of finalized drawings and specifications, provided by the JICA study team to TPL during the Third Field Survey in December 2012. TPL is waiting for the approval.

Chapter 2 The Contents of the Project

2-1 Project Summary

2-1-1 Overall Goal and Project Objective

To reduce the dependence on petroleum-based fuel for its energy supply and overcome the vulnerability to fluctuations in transaction prices in the global oil market, Tonga has promoted, as its energy policy goal, to introduce renewable energy and alleviate risk of fluctuations in petroleum product prices. It has also formulated a Tonga Energy Road Map (hereinafter called the "TERM") as an implementation policy to achieve the goal.

The TERM has set its goal of increasing the proportion of renewable energy to 50% of the entire electricity supply. This Project aims to contribute to the fulfillment of the goal of recyclable energy on one hand, and, on the other, to stabilize the frequency, electric voltage and other qualities of the electric supply system when Tonga has adopted a large amount of renewable energy whose power output is unstable.

2-1-2 Project Summary

To achieve the foregoing goal, this Project installs a grid-connected photovoltaic system (1.0 MWp), an power storage system and a power system stabilizer at the Vaini Project site, and an power storage system and a power system stabilizer on the premises of the existing Popua Power Station, and constructs related communications systems and facilities. This will increase the proportion of renewable energy sources to the electricity supply and stabilize the electricity quality in Tongatapu. In this Project, this cooperation project concerns the procurement and installation of the PV system, power storage systems and power system stabilizers, and construction of related facilities.

2-2 Outline Design of the Cooperation Project

2-2-1 Design Policy

2-2-1-1 Basic Policy

To stably introduce renewable energy to Tonga, this cooperation project procures and installs photovoltaic system modules of 1 MWp, power storage systems (lithium-ion capacitors) of 1 MW and micro-grid controllers; builds a system model in the Project area; simulates the model; and verifies the prerequisites of the plan. The objective year of this Project is 20 years' time after the commencement of the service.

2-2-1-2 Policy for Natural Conditions

(1) Policy for temperature and humidity conditions

The area concerned has a tropical marine climate, and the temperature is more or less stable throughout the year with the monthly average temperature ranging between 21 and 25°C. The annual average humidity is 79%. Power conditioners, micro-grid controllers, breaker boards and other devices to be procured under this project are installed indoors, so no special measure needs to be taken for the outside air temperature. As for ventilation of heat generated by the instruments, the room temperature is designed to be 35°C or lower for the efficient operation, and the outdoor systems are designed to function appropriately at the temperature of 40°C.

(2) Policy for seismic conditions

Tonga adopts the horizontal seismic coefficient of 0.1 G, but large earthquakes of magnitude 7 or higher have been observed 200-odd km away from Tongatapu Island once in several years. In this regard, and to avoid any damage to the instruments during transportation, the project adopts the horizontal seismic coefficient of 0.2 G, which is normally adopted in Japan.

(3) The ground

The ground surface of the construction site for the electricity room on the premises of the Popua Power Station consists of a silt layer with sand and a coral sand layer below. According to simplified cone penetration tests and soil tests, the allowable bearing capacity of the ground in the case of independent footing has been calculated at 50 kN/m^2, which is adopted as the bearing capacity of the basic study site for the buildings in the Popua Power Station.

The sites for photovoltaic array and the electricity rooms at the Vaini Project site are located some 13 m above sea level, where a raised coral layer exists 2-3 m below, and thus are free from unequal settlement even if the planned buildings are constructed. The simplified cone penetration tests and soil tests show that the allowable bearing capacity in the case of independent footing has been calculated at 150 kN/m^2, which is adopted as the bearing capacity of the basic study site for the electricity room at the Vaini Project site.

2-2-1-3 Policy for Socio-Economic Conditions

Most of Tongan people are Christian and have no particular social customs that may affect the construction schedule except the Christmas holidays. To begin construction of the PV modules, power storage systems, communication wires and other systems, announcements must be made in advance to local people to seek for their understanding of this project.

2-2-1-4 Policy for Matters Affecting Construction

Tonga has long relied on foreign aid from Japan, Australia, New Zealand and other countries for its economy. It has a limited number of educational institutions that can train engineers, and Tongans have to go abroad to receive professional education. In such circumstances, it is difficult to secure local engineers with a certain capacity, though manual laborers are locally available.

For marine transport involved in construction, transport ships with cranes must be prepared since the port of discharge has no crane facilities. On the other hand, the roads from the port to the Vaini Project site and the Popua Power Station are well developed, so there will be no problem with land transportation of materials and equipment.

2-2-1-5 Policy for Use of Local Contractors, and Material and Equipment

(1) Use of local contractors

In principle, this cooperation project uses construction equipment and manpower of local construction companies for the installation and construction work of facilities. However, Japanese specialist engineers need to be dispatched to the country for quality control, schedule management, safety control, and tests and adjustments.

(2) Use of local materials and equipment

Aggregates, cement, reinforcing bars and other materials for the foundation work are locally available, but these materials except aggregates are imports and thus their unit prices are high. Moreover, Tonga's construction market is sluggish at the moment, so it takes time to procure the necessary amount of materials for the project. Steel frames for construction, finishing materials, equipment materials, piping materials, cables, and other materials and equipment for the machine and electricity works are difficult to locally obtain; they will be procured in Japan or third countries.

(3) Procurement of materials and equipment in third countries

For materials and equipment to be procured in third countries, the prices, quality, delivery term, easiness to procure spare parts after the commencement of the operation, terms and conditions for after-purchase servicing, consistency with the existing systems and other conditions are carefully taken into account.

All the systems, materials and equipment related to the electricity in Tonga are imports, many from Australia, New Zealand and other countries. The possibility of procuring breaker boards and other equipment in third countries are carefully taken into account. It is desirable, however, to introduce a Japanese photovoltaic system, power storage systems and micro-grid controllers for these systems from the viewpoints of the actual performance, quality and durability of these systems, as well as excellent after-purchase servicing, and the operational, maintenance and management technologies of Japanese suppliers. The Tongan side also strongly wishes to have Japanese products.

(4) Construction

As stated in Section (2) above, Tonga's construction market is low at the moment. Even so, several foreign-capital local general construction companies and electric work companies are doing business in Tonga; it is relatively easy to procure simple laborers, transportation vehicles, and construction machines and materials in general. It is thus relatively easy to secure local workers to construct the buildings and conduct the civil engineering foundation work for this cooperation project.

On the other hand, few local engineers have experienced construction of steel structures such as buildings for inverters and power storage systems to be constructed under this project. Thus, local constructors are used as general workers only, and engineers need to be dispatched from Japan or other countries for quality control, technical guidance and supervision of construction work.

2-2-1-6 Policy for the Operation and Maintenance Capacity of the Implementing Organization

Tonga Power Ltd. (TPL) is in charge of the operation and maintenance (O&M) of the micro-grid system, as well as the existing systems, after the operation starts. The TPL currently operates and maintains a photovoltaic (PV) system (1.3 MWp) that was constructed with the aid of New Zealand, so seems to have the technology related to general grid-connected PV systems. However, the micro-grid system is a pioneering technology that is still under demonstration test operation even in Japan, so the contractor and consultant from Japan must transfer the relevant technologies through on-the-job training (OJT) during the construction period and soft component programs, while the implementing organization of Tonga must build a medium- and long-term O&M system under an O&M agreement with the consultant.

Moreover, there is a possibility that O&M personnel of the TPL are not well versed in the operational skill of the micro-grid system, and systematic and theoretical knowledge about routine inspections and preventive maintenance. Thus, Japanese engineers provide short-term intensive lectures as part of OJT during the construction period of this project. The lecture-style training programs are addressed to O&M personnel so that they can learn the basic theories of machine and electrical aspects of the micro-grid system. The training programs also offer recommended preventive maintenance methods after the commencement of the operation so that the TPL can effectively and efficiently operate the equipment and systems to be constructed.

2-2-1-7 Policy for Setting of the Scope of Facilities and Equipment, and Their Grades

Taking all the conditions above into account, the Basic Policy for the scope of procurement and installation of equipment and materials, and the relevant technological levels in this cooperation project is set out as follows.

(1) Policy for the scope of facilities and equipment

The capacities of the PV system and power storage systems (lithium-ion capacitors), and the micro-grid controllers comply with the standards good enough to maintain the quality (voltage and frequency fluctuations) of electricity as of 2012 in Tonga, and system components are formed so that the micro-grid systems can be efficiently and economically operated and maintained. The capacity of the power storage systems, in particular, are set at 1 MW in this cooperation project, but if the capacity is found to be excessive for maintenance of the current electricity quality after the commencement of the system operation, it will be reduced at the time the power storage systems are replaced later.

(2) Policy for grade setting

Since the TPL, the implementing organization of the project, is equipped with technologies of New Zealand, it is considered that it can operate and maintain the system if its technological capacity is enhanced through OJT and soft component. When deciding the specifications of each instrument, the current state of these affairs are fully taken into account so as not to divert them from the technical level of the TPL which is in charge of the O&M of the instruments after the commencement of the service.

(3) Policy for architecture

For appropriate designing from the technical and economically efficient perspectives, the specifications of materials conforming to BS, ACI, ASTM and other international standards are adopted, while the variety and specifications of materials, as well as the quantity, are minimized by improving the compatibility of materials.

2-2-1-8 Policy for Construction/Procurement Methods and Schedule

This cooperation project is carried out in accordance with Japan’s grant aid scheme, so the procurement and installation work must be completed within 24 months after conclusion of the Grant Agreement (G/A). To meet the schedule and produce expected effects, a schedule must be designed so that tasks carried out by the Japanese and Tongan sides are well coordinated, and care is taken for transport routes, methods, terms and procedures.

Materials and equipment procured are transported from Japan or third countries to Tonga chiefly by sea. The entire roads for transport of materials from the port of discharge in Nuku'alofa to the Popua Power Station and the Vaini Project site (approx. 15 km in length) are paved, relatively in good conditions and without any weight limit and have no particular problem. In addition, no particular problem apparently arose when the existing power generating systems were transported to the Popua Power Station. Traffic is somewhat heavy in the morning and evening so that it is necessary to consult the traffic police about the timing of transport using trailers and other large vehicles, and safety measures.

2-2-2 Basic Policy

2-2-2-1 Prerequisites for Planning

(1) Power demand

Where forecasts of power demand, the bases of the electric power development plan, are concerned, the power demand (kWh) and peak power (kW) in Tongatapu Island for 11 years from 2010 to 2020 were forecast with the support of the World Bank. The demand was forecast in the following five cases. Figure 2-2-2-1.1 shows forecasts of the peak power.

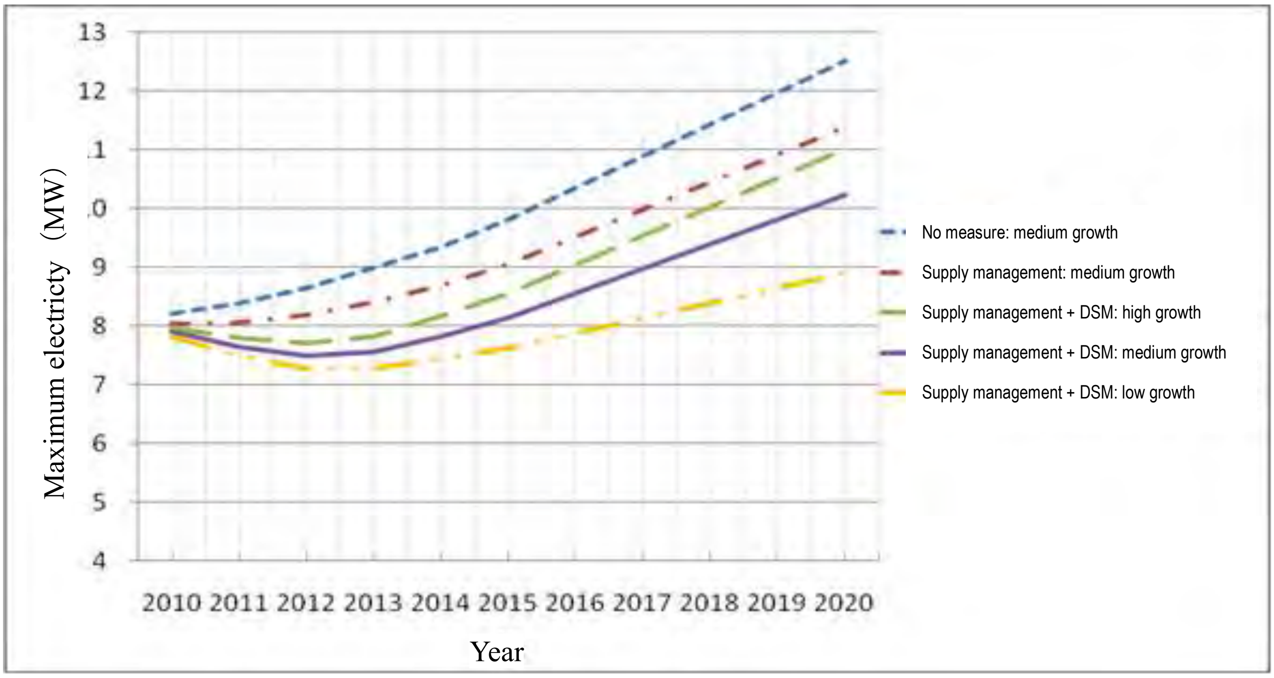
(a) Neither efficient supply management nor demand side management (DSM): medium growth (blue line)

(b) Efficient supply management: medium growth (red line)

(c) Both efficient supply management and demand side management: high growth (green line)

(d) Both efficient supply management and demand side management: medium growth (purple line)

(e) Both efficient supply management and demand side management: low growth (orange line)



Source: The World Bank（2010.1）"Report on the Tonga Electric Supply System - A Load Forecast"

Figure 2-2-2-1.1 Forecasts of Power Demand (Tongatapu Island)

Together with the forecasts above, it has been confirmed that Tonga has potentials for further energy efficiency: during the period between September 2008 and May 2011, the "Promoting Energy Efficiency in the Pacific" (PEEP-1) was carried out as a Demand Side Management (DSM) program with the support of the Asian Development Bank. Currently, PEEP-2, the second phase of the ADB-backed promotion, is in progress, aiming to cut the entire energy consumption in Tonga by 10% by March 2015. In light of this, this project draws up a grant aid program by adopting Case (iv) "Both efficient supply management and demand side management: medium growth" as the base power demand.

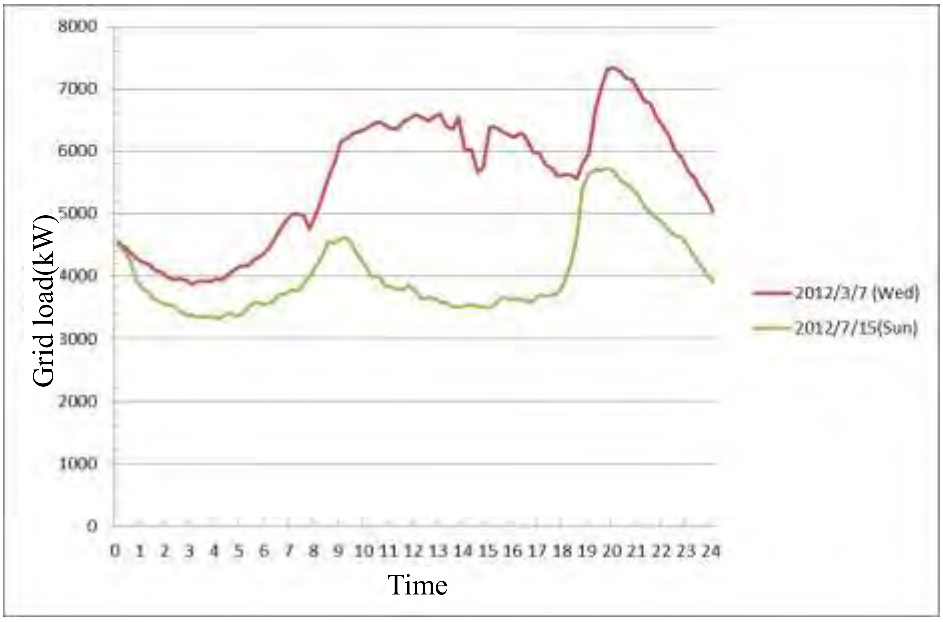
(2) Daily load curve

Quite a few Christians in Tonga are fairly pious and commercial activities are banned on Sundays. Because of this, power demand tends to be high on weekdays and low on weekends. It is also high at daytime in summer due to air-conditioning and low at daytime in winter.

The grid-connected renewable energy generator currently in operation is a PV system of 1.3 MWp, and a PV system to be supplied under this project has the capacity of 1.0 MWp, so that the proportion of renewable energy to the entire energy output is high at daytime. On winter Sundays when power demand is low, in particular, the proportion of photovoltaic power generation is the highest, and fluctuations in solar power output affect the grid system the most.

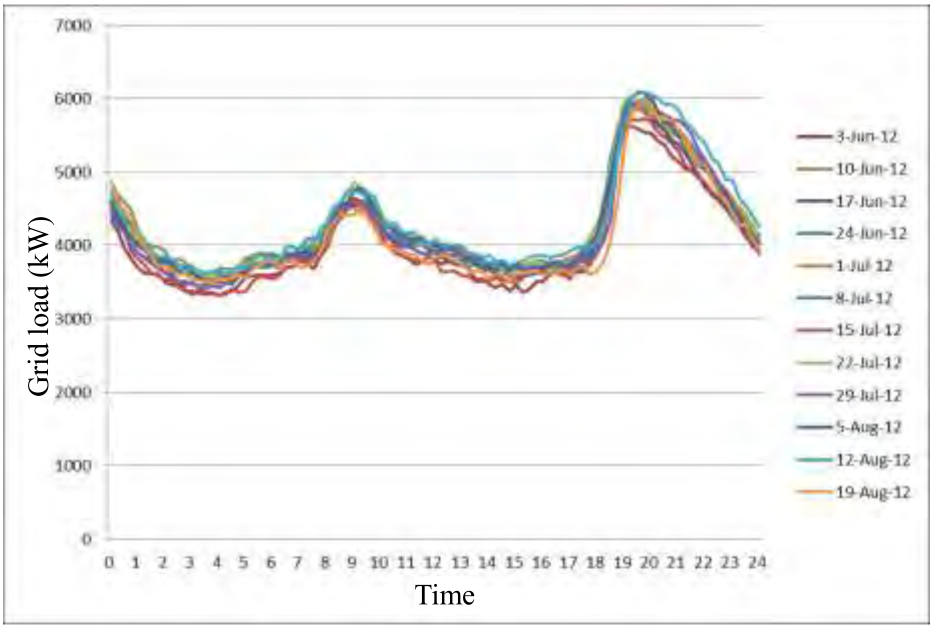
Figure 2-2-2-1.2 shows daily load curves of the grid system on a weekday (Wednesday, March 7, 2012) and a winter Sunday (July 15, 2012) in Tongatapu Island, and Figure 2-2-2-1.3 shows daily load curves on winter Sundays in 2012. These figures show that the daily load on winter Sundays falls to the level of midnight, and that the daily load is the lowest, some 3,500 kW, on July 15, 2012, in the past year.

In deciding the capacity of the power storage systems that will make up for fluctuations in the output of the PV system, this project adopts the strictest condition, the daily load curve on July 15, 2012, as a base condition.



Source: Created by the Survey Team based on data obtained from the TPL

Figure 2-2-2-1.2 Daily Load Curves in Tongatapu Island (Weekdays in Summer and Sundays in Winter)



Source: Created by the Survey Team based on data obtained from the TPL

Figure 2-2-2-1.3 Daily Load Curves in Tongatapu Island (Sundays in Winter)

(3) Electric Power Development Plan

In its Business Plan 2012-2023, the TPL intends to abolish high-speed diesel generators of the 1,400 kW capacity (Caterpillar 3516B) from 2014, but procure a medium-speed diesel generator of the 2,880 kW capacity (Mak6CM32C) in 2013, and a high-speed diesel generator of the 2,000 kW capacity (Caterpillar C175-16) each in 2015, 2017 and 2020. The power supply and demand balance to 2020, incorporating the TPL power development and abolishment plan, together with forecasts of power demand, is shown in Table 2-2-2-1.1 and Figure 2-2-2-1.4. The term "n-1 capacity" in the table and figure means the total power-generating capacity of the generators minus the capacity of a generator of the largest capacity. It represents the supply capacity in case the generator of the largest capacity stops due to any accident or inspection.

Table 2-2-2-1.1 Power Supply and Demand Balance of the Grid System in Tongatapu

	Installed Year	Capacity (MW)	Year 2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Peak Demand (MW)			**7.50**	**7.57**	**7.82**	**8.15**	**8.53**	**8.93**	**9.35**	**9.78**	**10.24**
Growth Rate (%)				0.87%	3.30%	4.31%	4.67%	4.67%	4.67%	4.67%	4.66%
2. Installed Capacity (MW)			**12.58**	**15.46**	**14.06**	**15.66**	**14.26**	**14.86**	**14.86**	**14.86**	**15.46**
2.1 Popua Diesel P/S			**11.28**	**14.16**	**12.76**	**13.36**	**11.96**	**12.56**	**12.56**	**12.56**	**13.16**
(1) Caterpillar(3516B)-1	1998	1.40	1.40	1.40	**Retire**						
(2) Caterpillar(3516B)-2	1998	1.40	1.40	1.40	1.40	**Retire**					
(3) Caterpillar(3516B)-3	1998	1.40	1.40	1.40	1.40	1.40	**Retire**				
(4) Caterpillar(3516B)-4	1998	1.40	1.40	1.40	1.40	1.40	1.40	**Retire**			
(5) Caterpillar(3516B)-5	1998	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	**Retire**
(6) Caterpillar(3516B)-6	1999	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
(7) Mak(6CM32C)-1	2005	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
(8) Mak(6CM32C)-2	2013	2.88		2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
(9) Caterpillar(C175-16)-1	2015	2.00				2.00	2.00	2.00	2.00	2.00	2.00
(10) Caterpillar(C175-16)-2	2017	2.00						2.00	2.00	2.00	2.00
(11) Caterpillar(C175-16)-3	2020	2.00									2.00
2.2 Renewable Energy			**1.30**	**1.30**	**1.30**	**2.30**	**2.30**	**2.30**	**2.30**	**2.30**	**2.30**
(1) Popua Solar	2012	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
(2) Vaini Solar-JICA	2015	1.00				1.00	1.00	1.00	1.00	1.00	1.00
3. Firm Generation Capacity (MW) (2.－2.2)			**11.28**	**14.16**	**12.76**	**13.36**	**11.96**	**12.56**	**12.56**	**12.56**	**13.16**
4. Power Balance(MW) (3.－1.)			**5.08**	**7.90**	**6.25**	**7.51**	**5.73**	**5.93**	**5.51**	**5.08**	**5.22**
5. Capacity of the largest generator (MW)			2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88	2.88
6. n-1 capacity (MW) (3.－5.)			8.40	11.28	9.88	10.48	9.08	9.68	9.68	9.68	10.28
7. Reserve margin (MW) (6.－1.)			**0.90**	**3.72**	**2.07**	**2.33**	**0.55**	**0.75**	**0.33**	**(0.10)**	**0.04**

Source: TPL Business Plan (2012-23) and the World Bank (2010.1) "Report on the Tonga Electric Supply System- A Load Forecast"

Figure 2-2-2-1.4 Electricity Supply and Demand Balance of the Grid System in Tongatapu

Tonga is developing a roadmap to shift its energy supply source to renewables and conducting an energy efficiency campaign as shown in Table 2-2-2-1.2. However, since its financial resources and the feasibility of these campaigns are uncertain at the moment, this project confines renewable energy resources for the micro-grid systems to the existing PV system of 1.3 MWp and the PV system of 1.0 MWp to be supplied under the project. If the TPL intends to connect renewable energy sources involving output fluctuations such as wind power generation to the grid system in future, it must analyze the power system and introduce power storage systems necessary to maintain the quality of electricity on its own accord.

Table 2-2-2-1.2 Renewable Energy and Energy Efficiency Campaigns

Project	Indicative commissioning date*	Nominal capacity	Cost (NZ$ M)	Cum. cost (NZ$ M)
Existing PV - Tongatapu	2012	1 MW	Done	-
Proposed PV - Tongatapu	2013	1 MW	JICA	-
Proposed PV - Vava'u	2013	1.4 MW	Masdar/ADB	-
Biomass Stage I - 'Eua	2013	288 kW	2.7	2.7
Biomass Stage I - Tongatapu	2013	940 kW	5.0	7.7
Biomass Stage II - fuel crop establishment	2013		4.0	11.7
New MAK genset to replace 2x 3516B	2013		TPL	11.7
Heat recovery ORC on MAK	2013	160 kW	2.0	13.7
Landfill biogas	2014	100 kW	1.0	14.7
Wind (including small scale on Ha'apai)	2014	1.9 MW	15.2	29.9
Network efficiency improvements	by 2015	2.5% of existing use	TPL?	29.9
Demand side improvements	on going	2.5% of existing use	TPL?	29.9
Biomass Stage II - 1 MW (completed by 2018)	2018	1 MW	5.0	34.9
Biomass Stage III - 1 MW (completed by 2021)	2021	1 MW	5.0	39.9

Source: The TPL

(4) Standards of the Quality of Electricity

The TPL adopts EN50160, European standards, as its standards for quality control of electricity supplied to customers. EN50160 prescribes the standards for quality control of fluctuations in frequencies and power voltages as shown in the following table. As prerequisites for adoption of the micro-grid systems, this project aims to avoid any deviation from the standards and maintain the current quality level even if it adopts the new PV system of 1 MWp.

Table 2-2-2-1.3 Standards for Quality Control of Frequencies and Power Voltages

Item	Standards for Quality Control
Fluctuations in frequencies	For low/medium voltage of interconnected supply systems over time intervals of 10 seconds: 50 Hz ± 1% (49.5－50.5 Hz) for 95% of the time, and 50 Hz + 4 - 6% for 100% of the time.
Fluctuations in power voltages	For low/medium voltage of interconnected supply systems: ±10% for 95% of the time.

Source: EN50160

(5) Type and capacity of power storage systems to be installed in this project

In the project area, Tongatapu Island, diesel generators have been used as main power supply, and load/frequency of each power system is controlled by the speed governors of diesel generators. If a large renewable power source with respect to the scale of power systems is introduced, the load following capability of the power systems is required to support compensation for demand fluctuation as well as power fluctuation of the renewable power source. To introduce a renewable power source of which power fluctuation is expected to exceed the load following capability, this project will utilize power storage systems to compensate for fluctuation for stabilization of power systems.

Introducing a renewable power source of such a large scale that requires power storage systems helps departure from dependence on oil from the viewpoint of expansion of domestically produced energy. Since power storage systems are very expensive, however, this project should be designed in consideration of their type, feature, capacity, and life expectancy so that we can ensure reduced diesel fuel cost through photovoltaic systems exceeds the replacement cost of power storage systems. Otherwise, energy security would not be achieved.

Assuming an introduction scale of a renewable power source, current situation of frequency fluctuation before this project, and the load following capability of existing diesel generators as prerequisite, the basic policy on the type and capacity of power storage systems is described below.

1) Compensation method for power fluctuation of renewable power sources

When power storage systems are used to compensate for power fluctuation of renewable power sources with unstable power such as photovoltaic (PV) systems and wind power generation systems, the short-period fluctuation compensation method and the long-period fluctuation compensation method are available.

(a) Short-period fluctuation compensation method

With the short-period fluctuation compensation method, power storage systems are used to decrease the power fluctuation speed of renewable power sources to the degree that speed governors of diesel generators and other main power facilities can follow, and compensate for short-period power fluctuation. As final fluctuation compensation, power of main power facilities is increased or decreased to keep an adequate frequency. For short-period load fluctuation, minor fluctuation of which period is some seconds to some minutes is called “cyclic component”, while that of which period is some minutes to some dozens of minutes called “fringe component.”

Recently, physical cells such as lithium-ion capacitors and electric double layer capacitors as well as other control techniques have been innovatively developed. Capacitor-type physical cells are more advantageous in instantaneous large power output than conventional chemical cells such as lead-acid batteries and sodium batteries. Thus micro-grid system focused on power fluctuation compensation of cyclic components with physical cells has been actively implemented in some remote islands of Japan.

Lead-acid batteries, typical chemical cells, have 3500 cycles of charge and discharge (under depth of discharge 60%, 25°C), while lithium-ion capacitors, typical physical cells, have 100,000 cycles or more. This means physical cells are more advantageous in life expectancy.

In the short-period fluctuation compensation method, main power supplies such as diesel generators are in charge of final compensation. For this reason, this method requires the speed governors of diesel generators have the sufficient high-speed load following capability.

(b) Long-period fluctuation compensation method

With the long-period fluctuation compensation method, high-capacity power storage systems are used to schedule the operation of renewable power sources. For example, power obtained from PV system of which power reaches the maximum in the daytime is stored in bulk, and output at the demand peak time in the evening. This method utilizes renewable power sources in the most stable way, and allows for fuel replacement of diesel generators as well as adjustment of their load, which leads to improved thermal efficiency of motors and further reduced fuel consumption.

Long-period fluctuation compensation requires power storage systems with MWh-scale capacity. Thus from the viewpoint of Wh unit price, available power storage systems are inevitably chemical cells including lead-acid batteries and sodium batteries. (Though nickel metal hydride batteries and lithium-ion batteries are also chemical cells, they have not been used for MWh-scale capacity power facilities on a commercial base so far.)

Since chemical cells have limitations on instantaneous charge-discharge current per cell, the number of batteries in parallel should be increased to secure necessary charge-discharge current. (In the case of lead-acid batteries, an allowable maximum charge-discharge current is around 0.2 C_{10} [A].) Consequently, if chemical cells are used for fluctuation compensation, regardless of whether it is long-period or short-period compensation, instantaneous capacity such as allowable charge-discharge current rather than storage energy capacity becomes a critical requirement in deciding the scale of systems. As shown in Table 2-2-2-1.4, chemical cells including lead-acid batteries and sodium batteries are much more advantageous in kWh unit price, but they are not so advantageous compared to the market prices of physical cells as of 2012 in kW unit price.

Table 2-2-2-1.4 Features of secondary cells to be commercially used as power storage systems for power system stabilization

			Lead-acid battery	Sodium battery	Nickel metal hydride battery	Lithium-ion battery
① High energy density		Current	40 to 80 Wh/L	140 to 170 Wh/L	40 to 100 Wh/L	140 to 210 Wh/L
		Potential	×	×	○	△
② Performance of high capacity		Current	MWh level	Some hundreds MWh level	Some hundreds kWh level	Some dozens kWh level
③-1 Cost down	kW unit price	Current ※	150 to 250 thousand yen/kW	240 thousand yen/kW	100 thousand yen/kW	50 to 1500 thousand yen/kW
	kWh unit price		50 thousand yen/kWh	25 thousand yen/kWh	100 thousand yen/kWh	100 to 2000 thousand yen/kWh
	Main body price	Potential	△	△	○	◎
③-2 High power support		Current	1 hour rate (Capacity of 50%)	6 to 7 hour rate	1 hour rate	0.5 hour rate
		Potential	△	△	◎	◎
③-3 Available SOC area		Current	Relatively small	Very large	Very large	Large
		Potential	△	―	―	△
④-1 Extended operating life		Current	3000 cycles	4500 cycles	2000 cycles	3500 cycles
		Potential	△ (Sulfation)	△	○	○
④-2 Reduced effect of low SOC on life expectancy		Current	×	○	○	○
		Potential	△	―	―	―
④-3 Overcharge / overdischarge resistance		Current	Overcharge ○・Overdischarge ×	△	○	×
		Potential	△	△	―	△
⑤-1 Charge-discharge energy efficiency		Current	75 to 85%	90%	80 to 90%	94 to 96%
		Potential	△	△	△	△
⑤-2 Easiness of SOC monitoring		Current	△	×	×	○
		Potential	△	△	△	―
⑤-3 High efficiency at low availability		Current	△ (Reset loss)	△ to × (Heater loss, reset loss)	○ to △ (Reset loss)	◎
		Potential	△	△	△	―

［Source］National Institute of Advanced Industrial Science and Technology (2006)

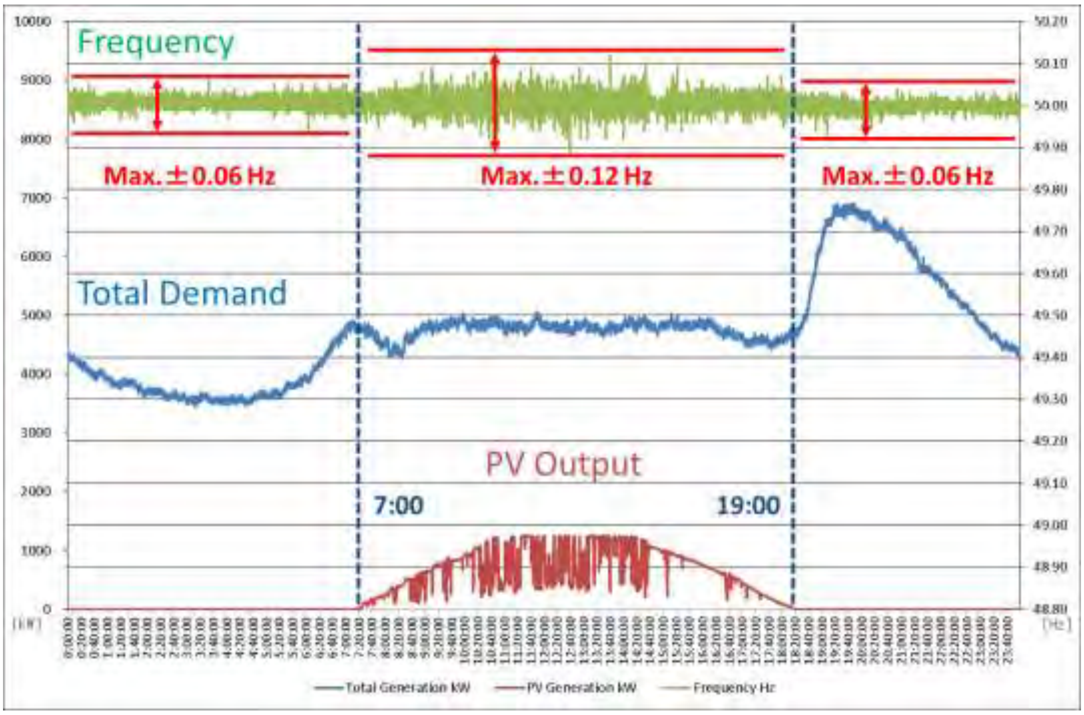
2) Prerequisites in considering the type and capacity of power storage systems

Given below are the prerequisites in considering the type and capacity of power storage systems to be installed under this project including the introduction scale of PV systems in the project, current situation of frequency fluctuation before start of this project, and the load following capability of existing diesel generators.

- Introduction scale of PV systems in this project: Installed capacity is 1,000 kWp
- Current situation of frequency fluctuation: Around 50 Hz ±0.12 Hz
  (The situation after PV system with an installed capacity of 1,300 kWp was provided by another donor.)
- Load sharing capability of existing diesel generators
  Diesel generators manufactured by CAT: Load sharing is available among six CAT diesel generators.
  Diesel generators manufactured by MaK: Load sharing is not available among six CAT diesel generators and one MaK diesel generator.
- Load following capability of existing diesel generators
  Diesel generators manufactured by CAT: Load following speed is 5% of the rated capacity per second
  Diesel generators manufactured by MaK: The load following capability is not available because the load sharing capability is not provided.

As for the power sector in Tonga, the primary energy's dependence on import fuels has reached 98%. From the viewpoints of departure from dependence on oil and achievement of energy security by domestically produced energy, introduction of large-scaled renewable power sources is expected in this project. As a result, PV system with an installed capacity of 1,000 kWp will be introduced.

The biggest power fluctuation occurs in the daytime when the power from PV system reaches the maximum. If power demand is low during that time period, the power fluctuation system of PV system is considerably affected. In case of Tonga, this condition is found on Sundays when economic activities are drastically decreased due to religious backgrounds. In Tongatapu Island, the PV system with an installed capacity of 1,300 kWp was built with the aid of New Zealand in August 2012 and has been commercially operated. As an example of the frequency state after the establishment of the PV system, Figure 2-2-2-1.5 shows the quality of frequency, power demand, and power of the PV system in August 29, 2012, Sunday. Since no power storage system has been installed yet, the quality of frequency is 50 Hz±0.06 Hz in the nighttime when the PV system provides no power, while it drops to as low as 50 Hz±0.12 Hz in the daytime when the PV system provides power, as shown in the figure. This figure also shows the power demand is kept at around 4,500 kW even in the daytime on Sunday. As described in (2), however, it has been lowered to around 3,500 kW in some cases.



［Source］ Tonga Power Ltd. SCADA system

Figure 2-2-2-1.5 Frequency state after the operation of the existing PV system (August 29, 2012)

The load sharing and load following capabilities of the existing diesel generators are described in the section “2-1-4 Existing facilities and equipment” in this report. As described below, the existing CAT diesel generators have the load following capability that supports high speed to some extent (load following speed is 5% of the rated capacity per second). This helps frequency fluctuation remain around 50 Hz±0.12 Hz in the daytime on Sunday, though dependence on the power of the PV system increases to 30% and the resultant power fluctuation occurs, as shown in Figure 2-2-2-1.5.

In Tongatapu power system, management of frequency is stipulated to keep within range of ± 1% (± 0.5 Hz) of the base frequency (50 Hz) based on EN50160 as shown in Table 3-2-2-1.3. In the meantime, as described above, frequency is maintained within the range of ± 0.1 to 0.2 Hz in actual operation.

For proper power system operation, the current frequency quality should be maintained. Further to expand management values, Tonga Power Ltd. should consult consumers and carefully proceed through verification during a certain period. Therefore, the objective of frequency management at the start of this project is to ensure that the power quality prior to the establishment of this project is not degraded and to keep within range of ± 0.1 to 0.2 Hz (in normal operation case).

3) Selection of power storage system type

The micro-grid system in the project is assumed to be commercially operated in Tongatapu Island, the main island covered by Tonga Power Ltd. If this project cannot realize departure from primary energy's dependence on oil as well as economical advantage of operation cost of the micro-grid system with renewable energy over that of diesel generators including fuel costs, sustainability of power business will be affected.

Further an electricity rate in Tonga has shifted over 40 yen/kWh (see the section "2-1-2 3 Electricity Rate"). Thus special attention should be paid so that the implementation of this project will not cause the raise of an electricity rate.

Prior to selection of power storage system type, a fluctuation compensation method of renewable power sources should be determined. Now, in the project area Tongatapu, the PV system with an installed capacity of 1,300 kWp has been already provided. Thus to install mega-scale solar system in this project, power storage systems should be able to provide some hundreds kW to MW instantaneous charge-discharge to keep the current frequency quality, regardless of whether the short-period fluctuation compensation method or the long-period fluctuation compensation method is applied for power system stabilization.

In design of micro-grid system, system integration and selection of control method shall be carried out carefully in consideration of characteristics of and daily output from power source of renewable energy in the Project area, characteristics of demand, and response capacity of main generators to load fluctuation. Under condition that the required technical specifications are satisfied, the financial issues shall also be considered not to hinder business operation of the power authority, for example, not require remarkable price rise of electricity in selection of type of power storage system.

If the long-period fluctuation compensation method is selected, power storage systems will inevitably employ chemical cells, as described above. When chemical cells are used for long-period fluctuation compensation that requires great depth of discharge, they will be given at least one cycle of charge and discharge every day. Since the life expectancy of chemical cells is around 3,500 cycles of charge and discharge, they will be replaced on a 100% basis at an interval of eight years, as found in past experiences.

Assuming PV system with an installed capacity of 1,000 kWp is introduced in this project, annually generated power of 1,300 MWh is estimated based on the solar radiation conditions in Tonga. (Refer to the section "2-2-3-1-6 Effects of CO_2 Emissions Reduction.") Among many renewable power sources, PV systems have a low capacity factor, which is around 15% in Tonga. According to calculation based on the fuel trading price by Tonga Power Ltd (1.7644 TOP/L as of 2012), annual fuel reduction cost will amount to 28 million yen. On the other hand, assuming the system supporting some hundreds kW to MW charge-discharge (with a capacity of 1,000 Ah, and lead-acid batteries with an output voltage of 2 V arranged in 240 serial×10 parallel) in the long-period fluctuation compensation method, annually required cost will amount to 30 million yen according to calculation based on the unit price of lead-acid batteries as shown in Table 2-2-2-1.4, which means it is difficult to achieve operation and maintenance of the system without raising an electricity rate.

Unlike physical cells, chemical cells have a long history, and there is little chance that future technological innovation will result in considerable drop of their prices. The long-period fluctuation compensation method is more effective in micro-grid system based on renewable power sources with a high capacity factor such as wind power generation systems rather than that based on PV systems with a low capacity factor.

In the light of these it is decided that this project employs micro-grid system with the short-period fluctuation compensation method. In the short-period fluctuation compensation method, the important points in selecting power storage systems include instantaneous large capacity power from the viewpoint of the compensation capability and the expected number of charge-discharge cycles from the viewpoint of replacement cost. Consequently, we adopt capacitor-type physical cells as power storage system type because of their advantages in the above points.

4) Micro-grid system introduced in the Project

In consideration of the above mentioned issues, the alternative of Micro-grid system introduced in the Project is shown in table 2-2-2-1.5. The Method for the Cyclic-Order Fluctuation is applied in the Project.

Table 2-2-2-1.5 Alternatives of Compensation Method for fluctuation of PV Output

	Compensation for Short-Period Fluctuation		Compensation for Long-Period Fluctuation
	Method for the Cyclic-Order Fluctuation	Method for the Fringe-Order Fluctuation	Method for the Sustained Order Fluctuation
Outline of Method	Power storage systems are used to decrease the power fluctuation speed of renewable power sources to the degree that speed governors of generators other can follow. Power storage compensates power fluctuation for short-period. Final compensation shall be carried out by increase and decrease of other generators. The method compensates cyclic-order fluctuation for a few seconds.	Power storage systems are used to decrease the power fluctuation speed of renewable power sources to the degree that speed governors of generators other can follow. Power storage compensates power fluctuation for short-period. Final compensation shall be carried out by increase and decrease of other generators. The method compensates fringe-order fluctuation for a few minutes.	High-capacity power storage systems are used to schedule the operation of renewable power sources. For example, power obtained from PV system of which power reaches the maximum in the daytime is stored in bulk, and output at the demand peak time in the evening. This method utilizes renewable power sources in the most stable way, and allows for fuel replacement of diesel generators as well as adjustment of their load.
Characteristic of Method	Capacitor-type physical cells are more advantageous in instantaneous large power output than conventional chemical cells such as lead-acid batteries and sodium batteries.	Though large capacity of power storage system is not required for the method, it is not possible to compensate fluctuation of output from photovoltaic system with energy capacitor system which continues fringe-order fluctuation for a few minutes. Power storage system of chemical cells is required.	Requires power storage systems with MWh-scale capacity. Thus from the viewpoint of Wh unit price, available power storage systems are inevitably chemical cells including lead-acid batteries and sodium batteries. Though nickel metal hydride batteries and lithium-ion batteries are also chemical cells, they have not been used for MWh-scale capacity power

	Compensation for Short-Period Fluctuation		Compensation for Long-Period Fluctuation
	Method for the Cyclic-Order Fluctuation	Method for the Fringe-Order Fluctuation	Method for the Sustained Order Fluctuation
			facilities on a commercial base so far.
Function required in Micro-grid Control System	High speed measurement and transducer devices of fluctuation of output from photovoltaic system are required. Micro-gird control device shall be able to calculate promptly control signals to bilateral inverters of power storage system in consistency with the fluctuation based on control block pre-set.	High speed measurement and transducer devices of fluctuation of output from photovoltaic system are required. Micro-gird control device shall be able to calculate promptly control signals to bilateral inverters of power storage system in consistency with the fluctuation based on control block pre-set.	Control sequences for schedule operation of renewable energy by utilizing power storage system are required. The control sequences shall be able to forecast output from renewable energy based on weather condition, analyze charging status of power storage system and load ratio of the generators, and control output of each equipment except for renewable energy. In addition, if instantaneous compensation is included, PID shall be set properly in consistency with characteristics of equipment.
Required Control System and Setting	Micro-grid control device shall be able to control output from power storage system promptly in consistency with the instantaneous fluctuation. Highly advanced sequence is not required, though high speed measurement and calculation system is required. PID shall be set properly in consistency with characteristics of governor of generators.	PID shall be set properly as same as cyclic-order compensation method. Fringe-order compensation method intends to compensate longer fluctuation by utilizing bigger capacity of power storage system than the cyclic-order method. Therefore, PID shall be set more properly to maximize efficiency of operation of the storage system.	Schedule operation of renewable energy is carried out with large capacity of power storage system. To maximize efficiency of operation of the storage system, micro-grid control system shall be able to forecast output from renewable energy based on weather condition. The set values for condition of the sequence actions shall be in consistency with the conditions in Tongatapu Island.
Compatibility with the Project	○ The Project is implemented as a project of the Japan's Grant Aid for the power authority in such severe condition as assistance is required. In consideration of such condition, cyclic-order method applying energy capacitor system, which can supply high instantaneous output in smaller storage capacity and maintain longer cycle life time, is suitable as the micro-grid control system of the Project.	× Larger capacity of power storage system is required for the method. It is superior from the viewpoint of stability of power frequency. However, chemical cells are required instead of energy capacitor system, as it compensates the fluctuation for longer period as a few minutes. Chemical cells require more capacity in viewpoint of storage to secure required instantaneous output from power storage system than energy capacitor system. It increases the cost for maintenance and replace.	× In the method, most stable operation of renewable energy is achieved. However, cost for maintenance hinder situation of business operation of the power authority, in case that applied type of renewable energy operated in lower utilization factor as photovoltaic system.

5) Consideration of capacity of power storage system using power system analysis

In this project, the purpose of power fluctuation compensation in PV systems by power storage systems is to stabilize power system frequency. As described above, power fluctuation in PV system has considerable effects on power system frequency when the power of the PV system covers power demand with a high percentage. This condition often occurs in the daytime when the power from PV system reaches the maximum and power demand is low. In case of Tongatapu Island, it occurs on Sundays when economical activities stagnate. The profile where the daytime load was the lowest in 2012 was July 15, 2012, Sunday, when the power demand was 3,521 kW, that is, about 3,500 kW. Taking this figure into consideration, power system analysis was conducted based on the following setting conditions. For the detailed results of the power system analysis, refer to Appendix 11 at the end of this report.

- Power demand at the profile to be analyzed: 3,521 kW
- Operating capacity of CAT diesel generators: 1,400 kW×3 units＝Total power 4,200 kW
- Load following capability of CAT diesel generators: 5% of the rated capacity per second

Though the total capacity of power storage systems can be selected freely to some extent by adjusting the number of batteries arranged in serial or parallel, the installed capacity of the entire power storage system is restricted by the standard single capacity of a bidirectional power conditioner.

In case that mega-solar system is procured and installed under the Project in addition to the existing system of 1.3 MWp, the total capacity of renewable energy exceeds 2 MWp. Therefore, mega-class capacity is required in power storage system to compensate fluctuation of output from power source of renewable energy. Three following scenarios on introduced capacity of power storage system are considered; total capacity of 1 MW (500 kW each for Popua Power Station and Vaini Project Site), total capacity of 500 kW which is half of the first scenario, and total capacity of 1.5 MW which is 1.5 time of the first scenario.

- Supposed installed capacity of power storage system
  (Note that capacities are indicated in kW rather than kWh because the short-period fluctuation compensation method is assumed.)

  Case 1： At the Popua Power Station side: 250 kW×1 min.×1/2
  At the Vaini Project site side: 250 kW×1 min. ×1/2

  Case 2： At the Popua Power Station side: 500 kW×1 min.×1/2
  At the Vaini Project site side: 500 kW×1 min.×1/2

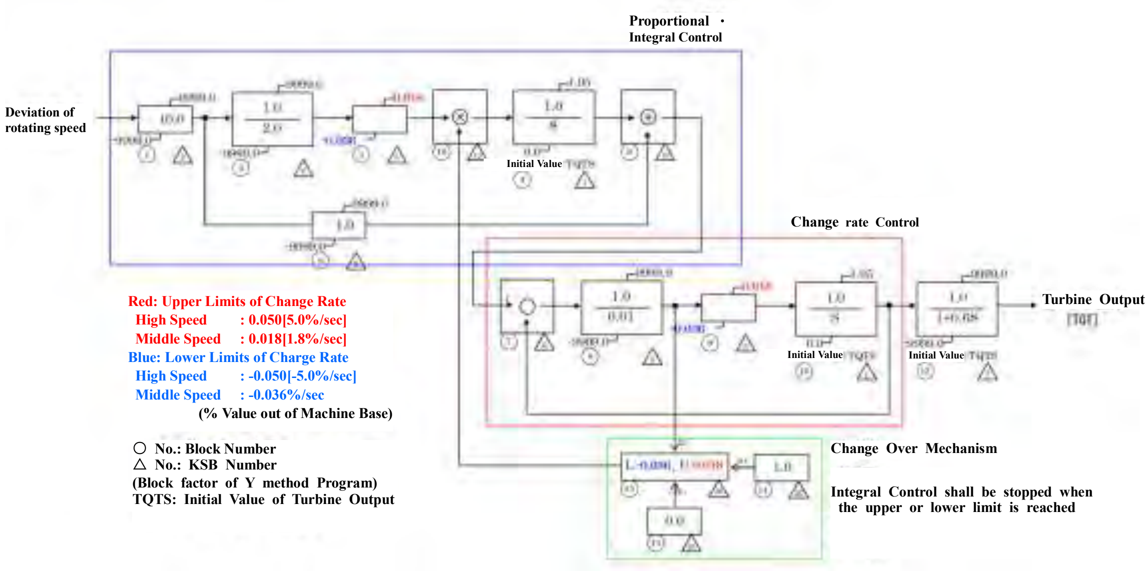
  Case 3： At the Popua Power Station side: 750 kW×1 min.×1/2
  At the Vaini Project site side: 750 kW×1 min.×1/2

Even if capacitor-type physical cells, especially lithium-ion capacitors with a relatively large storage capacity, are adopted as electrical power storage system, they should actually have the capacity enough to continue operation for several minutes, assuming some hundreds kW to MW level system. Since existing CAT diesel generators show good load following capability, one-minute continuing time is supposed here. Further capacities are divided by two because of the characteristic limitation of capacitor-type physical cells.

To study power fluctuation in PV system, we examined data obtained from the existing PV system with an installed capacity 1,300 kWp since its operation start (in August 2012), and identified high-speed power fluctuation in which power dropped by about 600 kW in ten seconds. In the light of this, the following power fluctuation of PV system is assumed in the power system analysis simulation.

- Power fluctuation of PV system: 50% of an installed capacity/10 seconds, ramp waveform

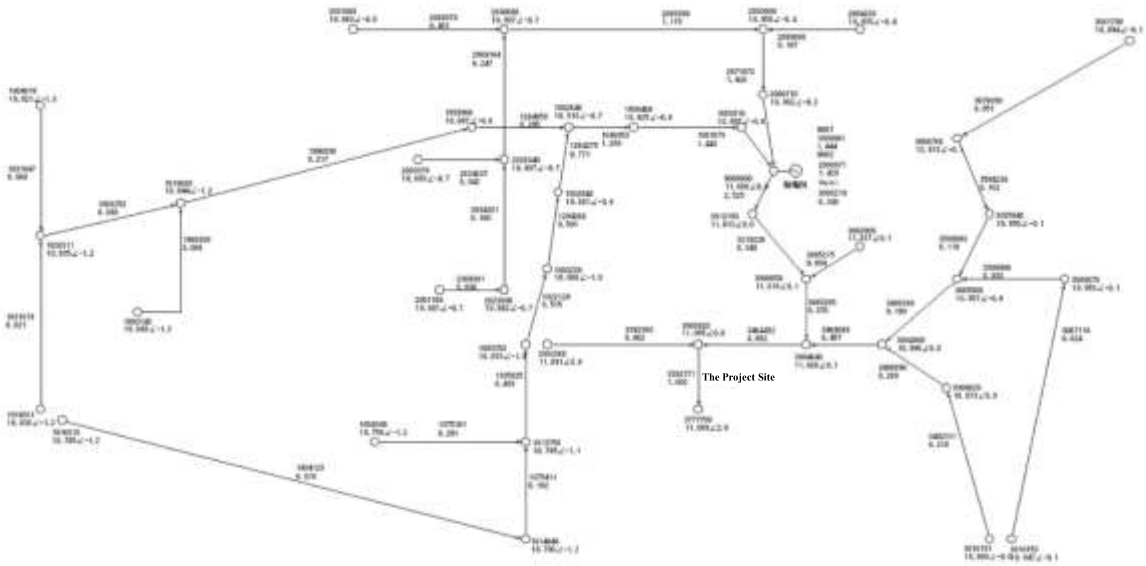
A governor block diagram was made based on the time constant and control gain that have been already applied to power systems with diesel generators used as main power supply in Japan, as shown in Figure 2-2-2-1.6. The upper and lower limits of a change rate are set at 0.05/0.05 because they are 5% of the rated capacity per second. Note that this figure also contains the setting values of middle-speed generators -0.018 (indicated in red)/0.036 (indicated in blue), which are used for analysis related to additional installation of a MaK diesel generator as described later.



[Source] Created by JICA Study Team

Figure 2-2-2-1.6 Governor control block diagram of the established diesel generators

The power system model created using the line constant and transformer information is shown in Figure 2-2-2-1.7. According to the existing power system operation by Tonga Power Ltd. the PV system with an installed capacity of 1,000 kWp to be introduced under this project will be connected to the Vaini feeder. After the PV system under this project starts its operation, however, Tonga Power Ltd. is going to change the opening position of the section switch so that it can connect to the NUK 1 feeder. This is because the priority order of distribution feeders in case of accidents at the electricity generation facility is NUK 2, NUK 1, and Vaini in order. Change of the opening position allows the PV system to be utilized with priority even if an accident occurs. Power system analysis was conducted each for the PV system connecting to the NUK 1 feeder and for that connecting to the Vaini feeder. Figure 2-2-2-1.7 illustrates the power system model when the PV system connects to the Vaini feeder.



Rated Output of PV System (Connected to Vaini Feeder)

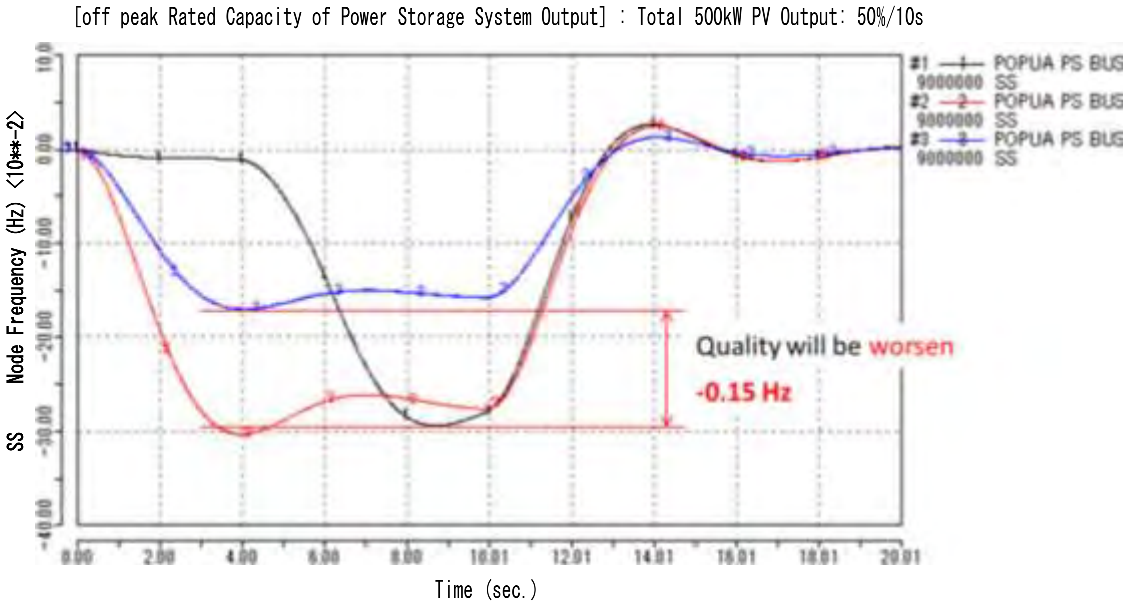
[Date] 2012 Jul. 15 14:00

[Load] 3521[kW]

[Source] Created by JICA Study Team

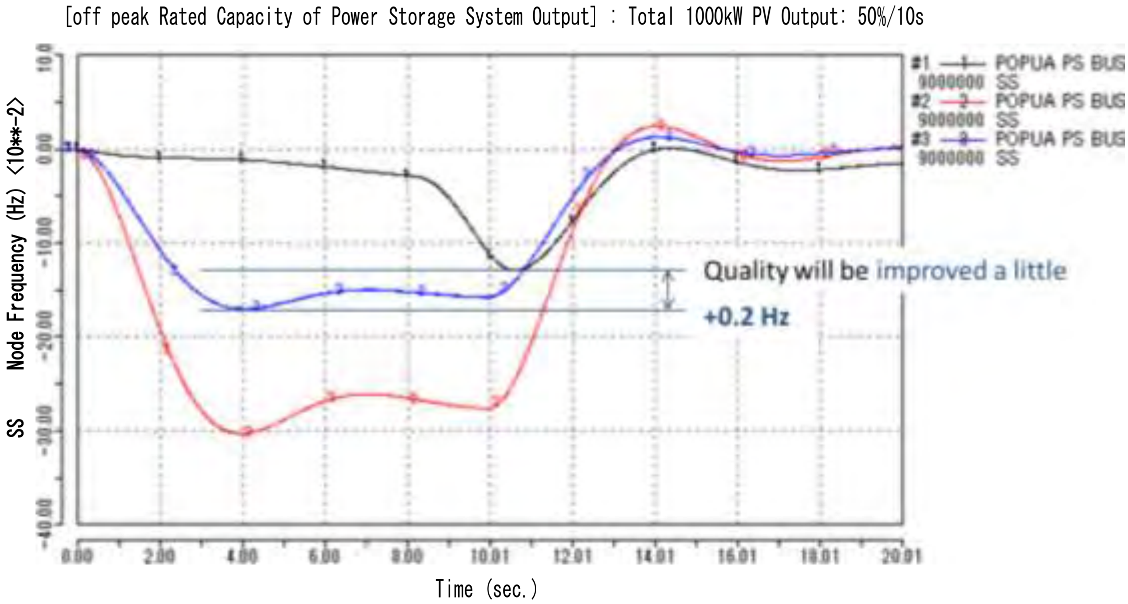
Figure 2-2-2-1.7 Power system model in Tongatapu

Figure 2-2-2-1.8, Figure 2-2-2-1.9, and Figure 2-2-2-1.10 show the simulation results of frequency fluctuation when the power fluctuation of PV system is applied to the established power system model. In each figure, the red line represents frequency fluctuation when PV system with an installed capacity 2,300 kWp (existing system + system under this project) is implemented without power storage system, and power fluctuation of 50% (1,150 kW) /10 sec occurs. The blue line, on the other hand, represents frequency fluctuation when PV system with an installed capacity 1,300 kWp (existing system only) is implemented without power storage system, and power fluctuation of 50% (650 kW)/10 sec occurs. The black line represents frequency fluctuation when power storage system is installed.



[Source] Created by JICA Study Team

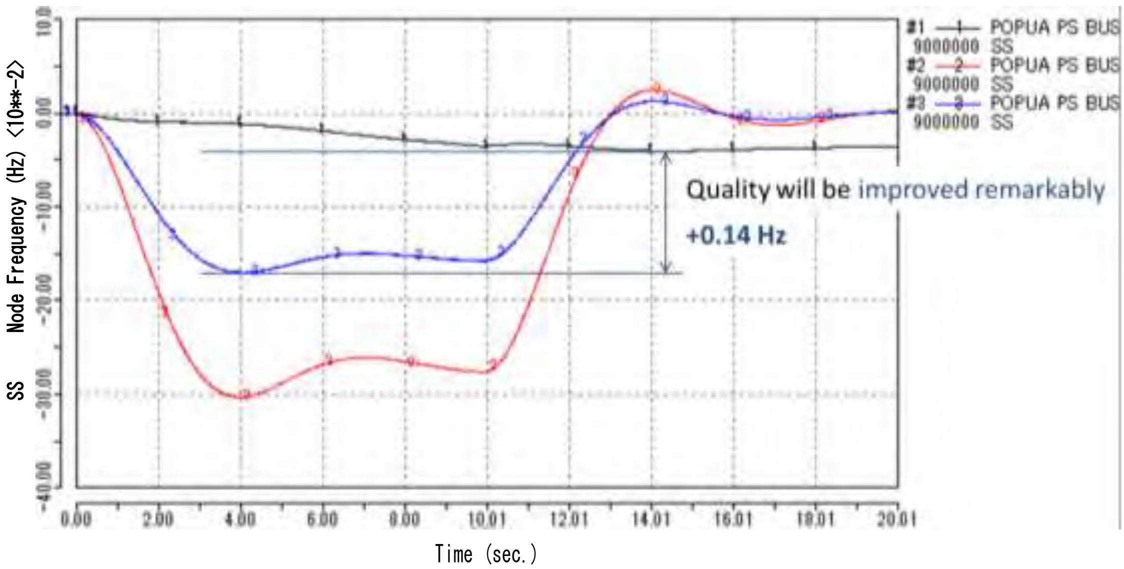
Figure 2-2-2-1.8 When 250 kW×1 min.×1/2 is implemented at two sites



[Source] Created by JICA Study Team

Figure 2-2-2-1.9 500 kW×1 min.×1/2 is implemented at two sites

[off peak Rated Capacity of Power Storage System Output] : Total 1500kW PV Output: 50%/10s



[Source] Created by JICA Study Team

Figure 2-2-2-1.10 750 kW×1 min.×1/2 is implemented at two sites

In each of the above three figures, the blue line represents the simulation of frequency fluctuation when PV system with an installed capacity of 1,300 kWp (existing system only) is implemented and power fluctuation of 50% (650 kW)/10 sec occurs, that is, the simulation of the current state. As shown in Figure 2-2-2-1.5, the actual measured value of the current frequency fluctuation is around 50 Hz±0.12 Hz as of August 29, 2012, Sunday. The simulation results show the peak value of the blue lines is －0.15 Hz. Considering that Figure 2-2-2-1.5 assumes power demand of about 4,500 kW while these simulations assume that of about 3,500 kW, the simulation results can be judged adequate.

In judgment of analysis results, if the peak value of the black lines is better than that of the blue lines, power storage systems are considered to be effectively operated.

If power storage system of 250 kW×1 min.×1/2 is installed each at the Popua Power Station and the Vaini Project site, the peak value of frequency fluctuation is improved compared to that when no power storage system is implemented (red line), but frequency quality is considerably degraded compared to the current one (blue line), as shown in Figure 2-2-2-1.8. This is because this electrical energy storage capacity is not enough to decrease fluctuation speed to such a degree that the speed governors of diesel generators can follow. As a result, we can say that power storage systems delay peak occurrence, but do not operate effectively in maintaining frequency quality.

If power storage system of 500 kW×1 min.×1/2 is installed each at the Popua Power Station and the Vaini Project site, frequency quality is slightly improved compared to the current one (blue line) (by around 0.02 Hz), as shown in Figure 2-2-2-1.9. Implementation of this electrical energy storage capacity allows the frequency quality of the micro-grid system to remain the current level. In the light of this, the objective of frequency management at the planning time of this project can be assured.

If power storage system of 750 kW×1 min.×1/2 is installed each at the Popua Power Station and the Vaini Project site, frequency quality is considerably improved compared to the current one (blue line) (by around 0.14 Hz), as shown in Figure 2-2-2-1.10. Implementation of this electrical energy storage capacity improves the frequency quality of the micro-grid system. However, power storage systems are high-cost facilities, and the objective of frequency management at the planning time of this project is to maintain the current frequency quality. In the light of these, this capacity is considered excessive.

From the results of study on the storage capacity of power storage systems using power system analysis, we decide to install capacitor-type 50%-charged power storage systems with a capacity of 500 kW×1 min×1/2 each at the Popua Power Station and the Vaini Project site under this project. To support increase or decrease of power from PV systems, power storage systems will be controlled in a 50% charged state.

Lithium-ion capacitor is superior to electric double layer capacitor, in case that large capacity of instantaneous output as hundreds kW for a few minutes is required in power storage system as the Project. Under condition of the same cost, for example, lithium-ion capacitor can keep the maximum output for a half to one minute order, though double layer capacitor can only keep for ten seconds order. Considering this characteristics and the recent experience in isolated power systems in Japanese islands, lithium-ion capacitor is applied for type of power storage system of the Project in consideration of the requires capacity as 500 kW×1 minute×1/2. we have selected lithium-ion capacitors as battery type in the light of the past.

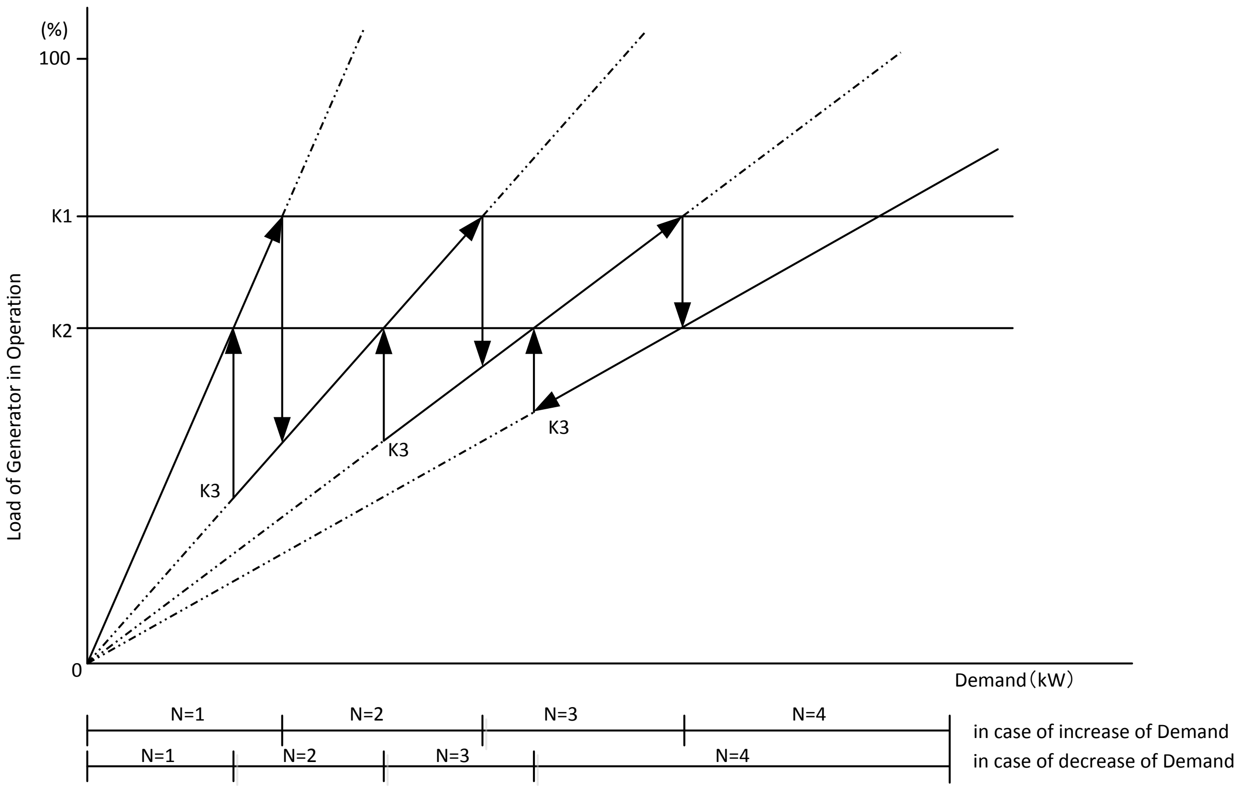
Maintenance within the range of ± 0.1 to 0.2 Hz (normal operation case) from the base frequency (50 Hz) is achieved by introduction of this scale of power storage system

(6) Operation of diesel generators after the start of the micro-grid system service

1) Operating method of existing diesel generators after the project start

Once power storage systems with the above described capacity are installed, power system stabilization will be achieved with the short-period fluctuation compensation method, provided that the spinning reserve of CAT diesel generators that have the load following capability is secured. If new PV system with an installed capacity of 1,000 kWp is additionally installed besides the existing PV system with an installed capacity 1,300 kWp under this project, the total capacity will amount to 2,300 kWp. To secure spinning reserve enough to support this capacity, at least three CAT diesel generators (each has a capacity of 1,400 kW) should be provided in the daytime when PV systems are operating (1,400 kW×3 units＝4,200 kW ＞ 2,300 kW). Further while PV systems are operating in the daytime, spinning reserve cannot be secured unless these diesel generators are running at a low load factor.

In the Popua Power Station, the setting values for controlling the number of active CAT diesel generators K1 and K2 are 85% and 65% respectively as shown in Figure 2-2-2-1.11. This figure also shows the total output power of diesel generators when a start signal is originated to standby generators and when a stop signal is originated to redundant generators in each of the cases for the number of active ones.



[Source] Created based on JIS F 9800 by JICA Study Team

(1) General of controlling the number of active generators

(2) Setting values for controlling the number of active generators in the Popua Power Station

Number of active generators	K3	When redundant generators are stopped Total output power of diesel generators	K1	When standby generators are started Total output power of diesel generators
N=1	0 %	0 kW	85 %	1,190 kW
N=2	33 %	910 kW	85 %	2,380 kW
N=3	43 %	1,820 kW	85 %	3,570 kW
N=4	49 %	2,730 kW	85 %	4,760 kW
N=5	52 %	3,640 kW	85 %	5,950 kW
N=6	54 %	4,550 kW	85 %	-

[Source] Created based on the Popua Power Station setting values by JICA Study Team

Figure 2-2-2-1.11 Setting values for controlling the number of active generators in the Popua Power Station

To secure three or more active generators, as shown in the figure, power demand of 1,820 kW to 3,570 kW is required. Since power demand of about 3,500 kW is expected even in the daytime on Sundays, which means the requirement of 1,820 kW or more power demand is satisfied, three active generators can be secured unless the distribution feeder is interrupted due to some reason such as an accident.

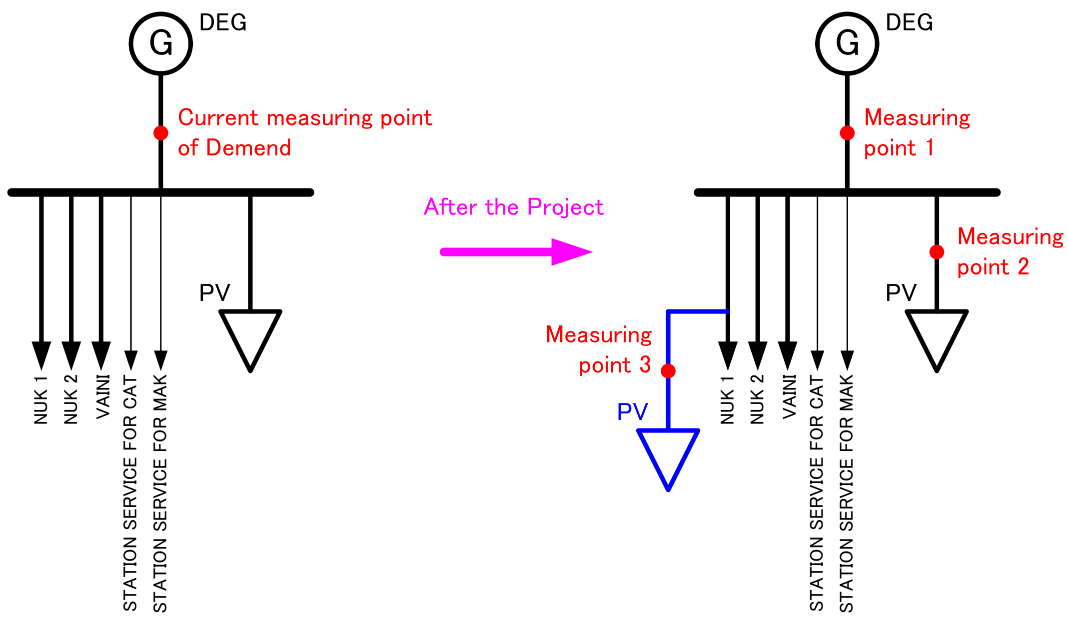
Further to operate the MaK diesel generator that is not provided with the load following capability for base load, CAT diesel generators and PV systems should share the load of about 3,570 kW. Assuming a single MaK diesel generator is operated for base load with a load factor of 80%, which leads to high thermal efficiency, it will output 2,200 kW because its single capacity is 2,750 kW. Therefore, to operate a MaK diesel generator for base load, power demand of about 6,000 kW (3,570 kW + 2,200 kW=5,770 kW) is required.

As described in the section “2-1-4 Existing facilities and equipment”, power demand of 6,000 kW or more is expected on weekdays even in winter where power demand is relatively low. Thus the MaK diesel generator may be operated for base load depending on the balance between demand and supply. If a load factor of 80% is assumed, in other words, no MaK diesel generator may be operated while PV systems are operating in the daytime on days when power demand is below 6,000 kW.

2) Reconstruction associated with the change of power demand measuring points for controlling the number of active generators

Since this project employs the short-period fluctuation compensation method, CAT diesel generators that support the load following capability, as perquisite, should secure the same capacity of spinning reserve as the output power from PV systems. It should be possible to satisfy power demand by increasing the loads of diesel generators without additionally starting standby generators if powers from PV systems are decreased.

Now, the total output power from the active CAT diesel generators among six is measured as power demand, as shown in the left figure of Figure 2-2-2-1.12, to control the number of active generators, as shown in Figure 2-2-2-1.11. For this reason, the output power from the existing PV system with an installed capacity of 1,300 kWp is judged less power demand with regard to CAT diesel generators, and the number of active CATV diesel generators is controlled accordingly.



[Source] Created by JICA Study Team

Figure 2-2-2-1.12 Change of the measuring points associated with controlling the number of active generators

When PV system is additionally installed under this project (the blue image in the right figure of Figure 2-2-2-1.12), assuming the current power demand calculation method, the total output power from PV systems are judged less power demand with regard to CAT diesel generators, and the number of active generators is controlled accordingly. As a result, the short-period fluctuation compensation method cannot be used to secure desired spinning reserve.

To secure adequate spinning reserve, the total value of power from CAT diesel generators, power from existing PV system with an installed capacity of 1,300 kWp, and power from new PV system with an installed capacity of 1,000 kWp to be additionally installed under this project should be entered as power demand to the number of active generators controller to secure enough number of active generators to satisfy the power demand. Tonga Power Ltd. is required to provide such a total power calculator at the input side of the load following controller in each of the existing CAT diesel generators.

3) Policy on restriction of PV system output

For operation of the micro-grid system, diesel generators should be operated at a low load to secure adequate spinning reserve. The number of active CAT diesel generators is controlled, as shown in Figure 2-2-2-1.11. The figure shows the minimum value of a load factor is 33% in the current operation. From the viewpoints of proper operation and maintenance of diesel generators, it will be adequate to keep this level even after the operation start of the micro-grid system under this project.

Nevertheless, there are some cases where power demand is below 3,500 kW, as described in

(2). In such cases, a load factor of CAT diesel generators drops below 30% even if three generators with a capacity of 1,400 kW are installed, assuming the PV systems provide output of 2,300 kW.

The project area Tongatapu is a remote island where its power system cannot expect any backup from a large-scaled commercial power system and diesel generators are only power facility that can provide the load following control. In the light of this, it is risky to presuppose operation and maintenance with severer conditions than the current ones at the planning time of the project.

Consequently, we decide to provide the micro-grid system under this project with a control feature that restricts power output from PV systems in cases where power demand is below 3,500 kW and a load factor of diesel generators drops below 30%, though such a situation will probably occur only a few times on Sundays in winter.

4) Consistency of this project with Tonga Power Ltd.'s future electric power development plan

Tonga Power Ltd. is planning to procure electric power generation system equal to the existing MaK diesel generator (with a single capacity of 2,750 kW) and additionally install it in the Popua Power Station in 2013.

The micro-grid system under this project does not actively control diesel generators. When power fluctuation of the PV systems is detected in a high-speed power meter to be supplied under this project, the micro-grid controller calculates it at high speed, and controls charge and discharge of power storage systems at high speed for power system stabilization with the short-period fluctuation compensation method.

As described above, with the short-period fluctuation compensation method, power storage systems decreases the power fluctuation speed of PV systems to a degree that speed governors of diesel generators or other main power facilities can follow, and compensate for short-period power fluctuation, while powers from main electric power systems are decreased or increased as final fluctuation compensation to keep frequency quality.

The first requirement for implementing the existing and additionally installed MaK diesel generators in the micro-grid system under this project is to secure spinning reserve enough to compensate for power fluctuation of the PV system with a total capacity of 2,300 kWp as before additional installation. If control system that allows for load sharing between the CAT diesel generators and the MaK diesel generators is established at the same time as additional installation, the micro-grid system under this project will not probably require large-scale reconstruction of its control system.

To secure sufficient spinning reserve, it is required to operate enough number of diesel generators to satisfy power demand without additionally starting standby generators, and to decrease a load factor to such a low level that the same capacity of spinning reserve as that of PV system power can be secured. To accomplish this, once an MaK diesel generator is additionally installed and the load sharing capability is provided, the total of power from the MaK diesel generators, power from the CAT diesel generators, power from the existing PV system with an installed capacity of 1,300 kWp, and power from the project PV system with an installed capacity of 1,000 kWp should be regarded as reference power for control of the number of active generators. Tonga Power Ltd. is required to install a total power calculator at the input side of the load following controller of a newly installed diesel generator.

The second requirement is to satisfy a condition that "the total capacity of the power storage systems to be installed at the Popua Power Station and the Vaini Project site under this project compensates for power fluctuation of PV systems so that the speed governors of MaK diesel generators show sufficiently high-speed load following capability, and frequency quality remains the current level." That is, an important issue is the load following capability of the speed governors of MaK diesel generators rather than the reconstruction of the control system in the micro-grid system.

Assuming a time constant and control gain based on the features of middle-speed diesel generators equivalent to MaK diesel generators (MaK diesel generators are also middle-speed diesel generators at 600[RPM]), JICA Study Team made evaluation using the power system analysis model as described in (5). The evaluation results show that this is a problem of the control setting of speed governors, and normal middle-speed speed governors can be used without the need to select any special speed governor. Nevertheless, since this is a very important issue associated with the frequency quality of power systems, Tonga Power Ltd. should make evaluation and verification regarding the load following speed of the speed governor of an actually installed MaK diesel generator.

Now, large-scale reconstruction of the control system of the micro-grid system is not planned. However, when reviewing the specifications of additional installation work including those of the considerable modification work for load sharing control among systems, the procurement agency of the micro-grid system of this project, Tonga Power Ltd., and the MaK diesel generator supplier should closely consult one another about control settings and establish a common awareness of the characteristics of each system to take proper adjustment and/or measures including change of control setting values.

5) Prospects of future development of renewable power sources in Tongatapu

The micro-grid system under this project employs capacitor-type physical cells and adopts the short-period fluctuation compensation method for stabilization of power systems in order to secure cost-effectiveness of the system and make full use of PV systems.

With the short-period fluctuation compensation method as adopted for this project, for fluctuation on the order of some seconds to some minutes (cyclic components), power storage systems are used to decrease the speed of power fluctuation from renewable power sources such as PV systems to a degree that power sources provided with the load following capability can support, and such power sources are responsible for final power compensation. As a result, power sources provided with the load following capability should be kept at a low load and sufficient spinning reserve should be secured.

The micro-grid system of this project assumes that a load factor of diesel generators provided with the load following capability is decreased to as low as 30% as prerequisite. If an attempt to further expand introduction of grid-connected renewable power sources with the short-period fluctuation compensation method is made in Tongatapu Island, it is difficult to achieve with the existing diesel generators because a much lower load factor is required for them.

In future, introduction of renewable power sources should be advanced mainly with the long-period fluctuation compensation method. Since PV systems have a low capacity factor as described before, introducing power storage systems for which the long-period fluctuation compensation method is supported is not reasonably cost-effective. Consequently, for further introduction of renewable power sources in Tongatapu, it is desirable to shift from PV systems to other renewable power sources with a higher capacity rate such as wind power generation systems while evaluating the potential of PV systems.

2-2-2-2 Overall Plan

(1) Design conditions

In deciding the size and specifications of this project, the Survey Team has examined various conditions stated above. Accordingly, the following design conditions are set out.

1) Climate and natural conditions

(a) Design temperature:	40^{o}C
(b) Design relative humidity (with no condensation):	a maximum of 85%
(c) Design wind speed:	57 m/sec (reference wind speed)
(d) Rainfall:	Annual average of 2,300 mm
(e) Salt deposit density:	0.5 mg/cm^2
(f) Seismic force:	0.2 G (horizontal)
(g) Bearing capacity:	50 kN/m^2 (The Popua Power Station) 150 kN/m^2 (The Vaini Project site)

2) Applicable standards

(a) Japanese Industrial Standards (JIS): Applicable to overall industrial products

(b) Standards of the Japanese Electrotechnical Committee of the Institute of Electrical

Engineers of Japan: Applicable to overall electrical products

(c) Standards of the Japan Electrical Manufacturers' Association (JEM): ditto

(d) Japanese Cable Makers' Association Standard (JCS): Applicable to electrical wires and cables

(e) Technical Standards for Electrical Equipment: Applicable to overall electrical work

(f) Standards of the International Electrotechnical Commission (IEC): Applicable to overall electrical products

(g) International Organization for Standardization (ISO): Applicable to overall electrical and machine products

3) Units to be used

The International System of Units (SI) is used in principle.

(2) Facility Layout Plan

The PV system of the capacity of 1MWp (hereinafter called the “PV system”) is installed on the project site at the Vaini Project site which is at the center of Tongatapu Island. The land owner, the noble, and the TPL have already concluded a lease agreement for the lease of 50 years, and the land concerned was officially recorded on the registry on November 9, 2012, after deliberations of the Cabinet. Therefore, there is no problem with site procurement.

Ground mounted PV arrays are installed after the Tongan side cuts down trees, develops the site and prepares the bases to mount PV modules. Due to the limited land area, crystalline silicon PV modules are adopted, which have high energy conversion efficiency. They require land of 24,000m^2 only, so that the PV system of the capacity of 1 MWp can be installed on the premises of the site at the Vaini Project site. Outdoor lights are installed around the site for security purposes.

Micro-grid controllers, power storage systems, PCS for the power storage systems, PCS for the PV system and other electric facilities are placed in a building to be newly built next to the existing PV building and in the other building to be built on the project site at the Vaini Project site.

The temperature inside the buildings must be appropriately controlled to secure expected operating lives of the power storage systems such as lithium-ion capacitors to be adopted in this project. Any loss of the functions of equipment and systems to be procured in this project results in a reduction in consumption of petroleum-based fuel, which is the objective of this project, and independence and sustainability of the business. Thus, air-conditioners are installed in the buildings for the electric facilities.

The power source for the building at the Vaini Project site is obtained from an incoming line from the commercial system, and that for the building in the Pupua Solar Farm from the neighboring PV building.

2-2-2-3 Summary of the Basic Plan

The Basic Plan of this project taking into account the Basic Design Policy, the Design Standards and the Facility Layout Plan stated in the previous section (See 2-2-2-2) is summarized in Table 2-2-2-3.1.

Table 2-2-2-3.1 Summary of the Basic Plan

	Contents of the Plan	Quantity/Capacity
Procurement and installation of equipment	1. Micro-grid system in the Popua Power Station	
	1.1 Micro-grid controller	
	(1) Micro-grid controlling board	1 board
	(2) PV system output stabilizing board	1 board
	(3) Data management system	1 set
	(4) Meteorological observation instruments (actinometers and thermometers)	1 set
	(5) PC for maintenance of PLC software	1 set
	1.2 Power system stabilizing system	
	(1) Power storage system	Capacity to cover 500kW x 1min x 1/2, according to SOC 50% =8.3kWh or more
	(2) Storage board for power storage system	1 set
	(3) Connecting board for power storage system	1 set
	(4) Interactive PCS	
	(5) Grid-connected transformer	500 kW
	(6) High voltage grid-connected transformer board	750 kVA
	(7) Low voltage grid-connected transformer board	The same number as interactive PCS
	1.3 House electric facility board	The same number as interactive PCS
	2. Micro-grid system at the Vaini Project site	1 board
	2.1 Micro-grid controller	
	(1) PV system output stabilizing board	1 board
	(2) Data management system	1 set
	(3) Meteorological observation instruments	1 set
	2.2 Power system stabilizing system	
	(1) Power storage system	Capacity to cover 500kW x 1min x 1/2, according to SOC 50% =8.3kWh or more
	(2) Storage board for power storage system	1 set
	(3) Connecting board for power storage system	1 set
	(4) Interactive PCS	500 kW
	(5) Grid-connected transformer	750 kVA
	(6) High voltage grid-connected transformer board	The same number as interactive PCS
	(7) Low voltage grid-connected transformer board	The same number as interactive PCS
	2.3 PV system	
	(1) PV modules	1,000 kWp
	(2) PCS	1,000 kW
	(3) Junction box	1 set
	(4) Collection box	1 set
	(5) Module mount	1 set
	(6) Grid-connected transformer	1250 kVA
	(7) High voltage grid-connected transformer board	The same number as PCS
	(8) Low voltage grid-connected transformer board	The same number as PCS
	2.4 Grid-connected switch gear for 11kV system	
	(1) Switch gear for 11kV system	7 boards
	(2) Grounding transformer (with reactor)	1 set
	(3) DC power-system	1 board
	2.5 House electric facility board	1 board
	3. Optical cable communication system	Approx. 15 km
Procurement	4. Grid-connected switch gear for 11kV system (the Popua Power Station)	
	(1) Switch gear for 11kV system	4 board
	(2) Grounding transformer (with reactor)	1 set
	(3) DC power-system	1 board
	5. Replacement parts	1 set

Contents of the Plan		Quantity/Capacity
Construction	a. Building for inverters and power storage system at the Vaini Project site	Total floor area: approx. 190 m^2
	b. PV panel bases	1 set
	c. Building for inverters and power storage system at the Popua Power Station	Total floor area: approx. 100 m^2

(1) Capacity of PV system to be introduced

The electricity sector of Tonga relies on import fuel for 98% of its primary energy supply. To break dependence on petroleum-based fuel and strengthen energy security by increasing the ratio of domestic energy sources, the country expects to introduce large-scale renewable energy sources through this cooperation project. In line with the requests from Tonga and discussions with the Tongan side, the project introduces a PV system of the capacity of 1.0 MWp.

The annual electric energy is estimated to be 1,308 MWh/year. Meteorological data used for the estimation and estimated monthly electric energy is listed in Table 2-2-2-3.2.

Table 2-2-2-3.2 Irradiation at Nuku'alofa and Estimation of Electric Energy of PV system

	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Irradiation(35°)	$kWh/m^2/day$	4.92	5.01	4.96	4.62	4.47	4.13	4.28	4.67	4.87	5.20	5.05	4.84	
Number of days	days	31	28	31	30	31	30	31	31	30	31	30	31	
Monthly Irradiation	kWh/m^2	152.52	140.28	153.76	138.6	138.57	123.9	132.68	144.77	146.1	161.2	151.5	150.04	1733.92
Average Temperature	℃	26.4	26.9	26.7	25.7	24.3	23.3	22.1	21.8	22.2	23.1	24.7	25.6	
Module Temperature Tm		44.8	45.3	45.1	44.1	42.7	41.7	40.5	40.2	40.6	41.5	43.1	44	
Temperature correction factor Kt		0.901	0.8985	0.8995	0.9045	0.9115	0.9165	0.9225	0.924	0.922	0.9175	0.9095	0.905	
Loss factor K=Kd*Kt*η		0.746028	0.743958	0.744786	0.748926	0.754722	0.758862	0.76383	0.765072	0.763416	0.75969	0.753066	0.74934	
PV Generation	kW	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	
Monthly Electric Energy	kWh/M	113,784	104,362	114,518	103,801	104,582	94,023	101,345	110,759	111,535	122,462	114,089	112,431	1,307,693

Source: Report of the Project for Introduction of Clean Energy by Solar Home System

Rating capacity of PV system, 1.0 MWp is the capacity at normal condition (AM:1.5, irradiation:1000W/m^2, temperature of PV cells:25°C). If irradiation Gs is assumed to be 1kW/m^2, annual electric energy is calculated from the formula below:

$E_P = \Sigma\ (H_A / G_S)* K * P$

(Σ stands for the integration of estimated monthly electric energy)

Variables and Coefficients are as below:

E_P: Estimated annual electric energy (kWh/year)

H_A: Monthly average irradiation (kWh/m^2/day)

G_S: Normal irradiation (1kW/m^2)

P: Rating capacity of PV module

K: Loss factor (Kd*Kt*η_{INV})

Kd: 0.9 is applied as Direct current correction factor for the conditions of surface, the fluctuation of solar irradiation and the characteristics of PV module

Kt: Temperature correction factor for the change of conversion efficiency by increase of the temperature of PV module

$Kt = 1 + \alpha\ (Tm - 25) / 100$

α: maximum output temperature coefficient (%^{o}C)= - 0.5 (%^{o}C^{-1}) [Crystalline]

Tm: module temperature (^{o}C)=Tav+ΔT

Tav: monthly average (^{o}C)

ΔT: increase of module temperature (^{o}C)

Backside open type	18.4
Roof mounting type	21.5

ΔT: 18.4 ^{o}C

ηINV: 0.92 is applied as conversion efficiency of inverter

Thus, estimated electric energy of PV system (1.0 MWp) is 1,308 MWh from the calculation above, if the system does not have any problem.

(2) Selection of materials of PV modules

Introduction of a large-scale PV system of the capacity exceeding 1.0 MWp requires vast land. The Tongan side has already secured a project site at the Vaini Project site near the central part of Tongatapu Island which is the subject of the project. Adoption of crystalline silicon PV modules makes it possible to install PV arrays of the capacity of 1.0 MWp on the site.

Crystalline silicon is adopted as a material of PV modules in this cooperation project.

(3) Selection of materials of PV module mounts

SC steel (SS 400) is used for PV module mounts of this cooperation project to secure a cheap but robust structure with high intensity and rigidity. It is coated with hot-dip galvanization (HDZ 55) since the project site is some 1-3 km away from the coastal line of Tongatapu Island.

(4) Selection of the type of power storage system

The type and capacity of the power storage system is determined with attention to the fact that the system affects the operation, maintenance and management cost to be borne by the TPL.

Lithium-ion and other batteries are used as power storage systems of electric and hybrid vehicles, but lithium-ion capacitors, electric double-layer capacitors, lead accumulators and NaS batteries, among other things, are normally used for power generation of a large capacity functionality-wise and cost-wise.

In the cases where energy storage systems are used to make up for short-period fluctuations in power demand as in this project, lead accumulators and NaS batteries, both of which are chiefly used for power storage (for peak shift, scheduled operation of renewable energy sources, etc.), need to have a considerably large capacity since they need to secure a large instantaneous charge-discharge capacity. Their dismantling and cycle length is 3,000 – 4,000 times only. Lithium-ion capacitors, electric double-layer capacitors and other physical cells can secure instantaneous output and their expected cycle length is expected to be 100,000 cycles or so, and thus their replacement cost is much better than chemical cells such as lead accumulators and NaS batteries.

Since this project uses power storage systems to make up for short-period fluctuations in, capacitor-type power storage systems are adopted.

(5) Capacity of power storage systems

The capacity of the power storage systems is determined in accordance with the dynamic power system analyses so that the batteries can maintain the current fluctuations in frequencies – that is the system with a 50% charge (State of Charge: SOC) can output electricity of 500 kW for 30 seconds (1 min x 1/2).

(6) Cable materials, etc.

The systems in this cooperation project are connected by cables. Since it is a connection of electric power systems, the electricity current is extremely large and thus the cable size is determined in consideration of voltage depression. Care must be taken, at the same time, to minimize the variety of cables to avoid an increase in transport freight.

(7) Outline specifications of the major instruments

The outline inspections of major equipment to be procured and installed under the cooperation project are shown in Table 2-2-2-3.3.

Table 2-2-2-3.3 Outline Specifications of Major Equipment

No	Name of major equipment	Rough specifications
1.	Micro-grid system in the Popua Power Station	
1.1	Micro-grid controller	
(1)	Micro-grid controlling board	Shape: metal enclosed switchboard for outdoor application Equipped with PLC for micro-grid control Equipped with PLC for the existing DEG control signal transmitter Equipped with PLC for the existing SCADA data transmitter
(2)	PV system output stabilizer	
(3)	Data management system	
(4)	Meteorological observation instruments (actinometers and thermometers)	Actinometers: Applicable standards: ISO9060 Second class or equivalent Sensitivity: 6~8 V/(kW/m^2) Thermometers: Type: measurement resistor Pt100 Ω 4 wire Shape: With basic shelter Temperature range of use: -40° ~+60-4 Converter: Output signal: 4-20 mA
(5)	PC for maintenance of PLC software	D300win (PLC developing tool shall be installed)
1.2	System stabilizing system	
(1)	Power storage system	Type: lithium-ion capacitor Use: for cycle use Capacity: 10 kWh or more Capacity to cover 500 kW x 1min x 1/2, according to SOC 50% Internal resistance: 19 mΩ or less

No	Name of major equipment	Rough specifications
(2)	Storage board for power storage system	Type: metal enclosed switchboard for outdoor application
(3)	Connecting board for power storage system	Type: metal enclosed switchboard for outdoor application Switchboard: MCCB
(4)	Interactive PCS	Total capacity: 500 kW or more Type: metal enclosed switchboard for outdoor application Main circuit system: self-exciting voltage Switching system: high frequency PWM Insulation system: commercial frequency insulation transformation Cooling system: forced air cooling AC output current distortion factor: General current 5% or less, each sub-wave 3% or less Power control system: Maximum output follow-up control Rated power conversion efficiency: 93% or higher Control functions: Automatic start/stop, soft start, automatic voltage adjustment, input/output over-current adjustment, and output adjustment Grid-connected protective functions: over voltage (OVR), under voltage (UVR), over frequency (OFR) and under frequency (UFR) Islanding operation detection function: active and passive types
(5)	Grid-connected transformer	Type: outdoor oil immersed self-cooled Voltage: 11/0.40-0.23 kV Capacity of transformer: 750 kVA Vector group: Dyn11
(6)	High voltage grid-connected transformer board	Type: metal enclosed switchboard for outdoor application Switchboard: vacuum circuit breaker (VCB) Rated voltage: 11 kV or more Rated interrupting capacity: 630 A or more Bus rated capacity: 1200 A or more Short-circuit capacity: 20 kA (1 sec) or more
(7)	Low voltage grid-connected transformer board	Type: metal enclosed switchboard for outdoor application Switchboard: MCCB or ACB Electrical mode: 3-phase 4-wire system, 400-230 V
1.3	House electric facility board	Type: metal enclosed switchboard for outdoor application Transformer voltage: 11/0.40-0.23 kV Transformer capacity: 50 kVA Vector group: Dyn11 Transformer method: dry system Switchboard: MCCB Electrical mode: 3-phase 4-wire system, 400-230 V
2.	Micro-grid system at the Vaini Project site	
2.1	Micro-grid controller	Transducer
(1)	PV system output stabilizer	
(2)	Data management system	
(3)	Meteorological observation instruments (actinometers and thermometers)	Actinometers: Applicable standards: ISO9060 Second class or equivalent Sensitivity: 6~8 μ V/(kW/m^2) Thermometers: Type: measurement resistor Pt100 Ω 4 wire Shape: With basic shelter Temperature range of use: -40° -+60-4 Converter: Output signal: 4-20 mA

No	Name of major equipment	Rough specifications
2.2	System stabilizing system	
(1)	Power storage system	Type: lithium-ion capacitor Use: for cycle use Capacity: 10 kWh or more Capacity to cover 500 kW x 1min x 1/2, according to SOC 50% Internal resistance: 19 mΩ or less
(2)	Storage board for power storage system	Type: metal enclosed switchboard for outdoor application
(3)	Connecting board for power storage system	Type: metal enclosed switchboard for outdoor application Switchboard: MCCB
(4)	Interactive PCS	Total capacity: 500 kW or more Type: metal enclosed switchboard for outdoor application Main circuit system: self-exciting voltage Switching system: high frequency PWM Insulation system: commercial frequency insulation transformation Cooling system: forced air cooling AC output current distortion factor: General current 5% or less, each sub-wave 3% or less Power control system: Maximum output follow-up control Rated power conversion efficiency: 93% or higher Control functions: Automatic start/stop, soft start, automatic voltage adjustment, input/output over-current adjustment, and output adjustment Grid-connected protective functions: over voltage (OVR), under voltage (UVR), over frequency (OFR) and under frequency (UFR) Islanding operation detection function: active and passive types
(5)	Grid-connected transformer	Type: outdoor oil immersed self-cooled Voltage: 11/0.40-0.23 kV Capacity of transformer: 750 kVA Vector group: Dyn11
(6)	High voltage grid-connected transformer board	Type: metal enclosed switchboard for outdoor application Switchboard: vacuum circuit breaker (VCB) Rated voltage: 11 kV or more Rated interrupting capacity: 630 A or more Bus rated capacity: 1200 A or more Short-circuit capacity: 20 kA (1 sec) or more
(7)	Low voltage grid-connected transformer board	Type: metal enclosed switchboard for outdoor application Switchboard: MCCB or ACB Electrical mode: 3-phase 4-wire system, 400-230 V
2.3	PV system	
(1)	PV modules	Total capacity: 1000 kWp or more Material: mono-crystalline or poly-crystalline silicone or tandem of crystalline silicone and amorphous Module efficiency: 12% or higher
(2)	PCS	Total capacity: 1,000kW or more Type: metal enclosed switchboard for outdoor application Main circuit system: self-exciting voltage Switching system: high frequency PWM Insulation system: commercial frequency insulation transformation Cooling system: forced air cooling AC output current distortion factor: General current 5% or less, each sub-wave 3% or less

No	Name of major equipment	Rough specifications
		Power control system: Maximum output follow-up control Rated power conversion efficiency: 93% or higher Control functions: Automatic start/stop, soft start, automatic voltage adjustment, input/output over-current adjustment, and output adjustment Grid-connected protective functions: over voltage (OVR), under voltage (UVR), over frequency (OFR) and under frequency (UFR) Islanding operation detection function: active and passive types
(3)	Junction box	Structure: outdoor, wall-mounted type Material: SPHC Coating: powder coating Switchboard: MCCB Internal devices: reverse flow prevention diode and induced lighting protector
(4)	Collection box	Structure: outdoor, wall-mounted type Material: SPHC Coating: powder coating Switchboard: MCCB Internal devices: reverse flow prevention diode and induced lighting protector
(5)	Module mount	Material: SS400 or SPHC Corrosion resistance: HDZ55 or more
(6)	Grid-connected transformer	Type: outdoor oil immersed self-cooled Voltage: 11/0.40-0.23 kV Capacity of transformer: 750 kVA Vector group: Dyn11
(7)	High voltage grid-connected transformer board	Type: metal enclosed switchboard for outdoor application Switchboard: vacuum circuit breaker (VCB) Rated voltage: 11 kV or more Rated interrupting capacity: 630 A or more Bus rated capacity: 1200 A or more Short-circuit capacity: 16 kA (3 sec) or more
(8)	Low voltage grid-connected transformer board	Type: metal enclosed switchboard for outdoor application Switchboard: MCCB or ACB Electrical mode: 3-phase 4-wire system, 400-230 V
2.4	Grid-connected switch gear for 11kV system	
(1)	Switch gear for 11kV system	Type: metal enclosed switchboard for outdoor application Switchboard: vacuum circuit breaker (VCB) Rated voltage: 11 kV or more Rated interrupting capacity: 630 A or more Bus rated capacity: 1200 A or more Short-circuit capacity: 20 kA (1 sec) or more
(2)	Grounding transformer (with reactor)	Type: outdoor oil immersed self-cooled Rated voltage: 11 kV or more Vector group: ZN Continuous rating: 200 A (10 secs) Reactor impedance:
(3)	DC power-system	Type: metal enclosed switchboard for outdoor application Power storage system: Sealed- lead acid battery Battery capacity: endurable for outage of 12 hours or longer Battery charger: equipped Supply voltage: 110 V DC voltage: 110 V
2.5	House electric facility board	Type: metal enclosed switchboard for outdoor application

No	Name of major equipment	Rough specifications
		Transformer voltage: 11/0.40-0.23 kV Transformer capacity: 50 kVA Vector group: Dyn11 Transformer method: dry system Switchboard: MCCB Electrical mode: 3-phase 4-wire system, 400-230 V
3.	Optical cable communication system	Communication wire: optical cable Size of optical cable: 12C, 1.25 mm^2 Length of optical cable: approx. 10 km Media converter: equipped Materials for joint use of electric poles: equipped with spring hangers and messenger wire
4.	Grid-connected switch gear for 11kV system (the Popua Power Station)	
(1)	Switch gear for 11kV system	Type: metal enclosed switchboard for outdoor application Switchboard: vacuum circuit breaker (VCB) Rated voltage: 11 kV or more Rated interrupting capacity: 630 A or more Bus rated capacity: 1200 A or more Short-circuit capacity: 20 kA (1 sec) or more
(2)	Grounding transformer (with reactor)	Type: outdoor oil immersed self-cooled Rated voltage: 11 kV or more Vector group: ZN Continuous rating: 200 A (10 secs) Reactor impedance:
(3)	DC power-system	Type: metal enclosed switchboard for outdoor application Power storage system: Sealed- lead acid battery Battery capacity: endurable for outage of 12 hours or longer Battery charger: equipped Supply voltage: 110 V DC voltage: 110 V

2-2-3 Outline Design Drawings

Outline design drawings for the Project are shown in Annex 11. These drawings include the single line diagram of the Vaini Project site and the Popua Power Station, diagram of control system connecting these sites, layout plans of the buildings to be constructed on the sites, and plan and sectional views.

2-2-4 Construction Plan / Procurement Plan

2-2-4-1 Construction Policy / Procurement Policy

This cooperation project is in accordance with Japan's grant aid scheme, and thus is carried out after approval of the Government of Japan, conclusion of the Exchange of Notes (E/N) between the relevant governments and conclusion of the Grant Agreement (G/A) between JICA and Tonga. The following are basic matters and matters requiring special consideration in respect of the implementation of this cooperation project.

(1) Implementing agency

The implementation agency at the Tongan side of this cooperation project is Tonga Power Ltd. (TPL). The relevant department of the TPL must execute this cooperation project and, after completion, operate, maintain and manage the systems and facilities to be developed under the project. For smooth implementation of the project, the TPL must closely communicate and consult with the Japanese consultant and contractor and determine staff members responsible.

Staff members of the TPL responsible for the project must give full account of the project to other TPL staff members and related organizations involved in the project, and local citizens concerned to obtain their understanding and cooperation.

(2) Consultant

For procurement and installation of equipment, a consultant of Japanese cooperation which JICA recommends to the Tongan Side concludes a contract for design, supervisory and consulting services with the TPL and engages in the design and supervisory work for procurement and installation. The consultant also draws up bidding documents and conducts bidding on behalf of the TPL, the implementing agency of the project.

(3) Contractor

A Japanese corporation appointed as the contractor by the Tongan side according to the open bidding in the framework of Japan's grant aid procures materials and equipment and conducts the installation work. The contractor is expected to continue to supply spare parts and provide services after completion of the project, and thus is required to carefully consider the contact system after the delivery of the said materials, equipment and systems.

(4) Necessity to dispatch engineers

This cooperation project is to procure and install a PV system of the maximum capacity of 1.0 MWp and related equipment, power storage systems (lithium-ion capacitors), and micro-grid controllers to operate these systems with the diesel power generators. A number of work groups engage in the procurement and installation work, so that they must mutually coordinate their works. Moreover, most of these works take place simultaneously, and thus it is essential to dispatch personnel from Japan who are capable of managing and supervising the entire work for the purposes of schedule, quality, output and safety management.

2-2-4-2 Points to Note for Construction and Procurement

(1) Points to note for procurement of materials and equipment

1) Countries where materials and equipment are procured

Materials and equipment to be procured in this project, including distribution wires, pipes and other secondary materials, are not manufactured in Tonga. The country imports these materials, which cannot be locally procured. Thus, all materials and equipment for the project are in principle procured in Japan or third countries except for aggregates for concrete.

2) Safety measures

The areas subject to the project have little security problems but still care must be taken for prevention of any loss of materials and equipment and the security of persons concerned. Therefore, not just calling on the Tongan side to take necessary security measures, the contractor on the Japanese side encloses the storage places with fences as part of temporary work, stations guards and takes other security measures.

3) Tax exemptions

Japan’s grant aid project in Tonga is subject to tax exemptions in accordance with the provisions of the E/N concluded by the two governments. To have materials and equipment for the project exempt from customs clearance and duties, the contractor must submit copies of bills of lading, a list of materials and equipment and other necessary documents to apply for exemptions from customs clearance and duties to the Aid Management Division (AMD) of the Ministry of Finance and National Planning (MFNP) through procurement officers of the TPL at the time such materials and equipment arrive at Port of Nuku Alofa. The contractor must also submit copies of these documents to the Ministry of Revenue to obtain the consent of the two ministries before the authorized representative of the MFNP subscribes his name. The contractor submits documents created and signed by the MFNP, together with a list of materials and equipment, to the customs house. The full tax-exemption method is adopted, rather than the refund method.

Where procurement of aggregates and other materials to be procured in Tonga is concerned, the contractor is eligible for refunds of the payments equivalent to the tax amount by paying the tax-inclusive prices first and submitting necessary documents including receipts to the AMD.

4) Transportation

The customs clearing procedure of materials and equipment to be transported to Tonga by sea is normally conducted at Port of Nuku Alofa (with 2 berths), the sole international port of the country. As stated above, customs duties are exempt, but the handling charges must be counted as part of the ocean transport cost of this cooperation project.

All the roads from the port to the project sites - that is, the Popua Power Station and the Vaini Project site - are well paved and thus there is no particular obstacle with inland transportation. For transport of heavy articles such as power conditioners and transformers, traffic congestions in the morning and evening and the safety of the surrounding areas must be taken into account.

Port of Nuku Alofa is not equipped with cranes that can lift heavy articles, so the contractor must secure by itself transport vessels with a crane, mobile crane facilities and other relevant facilities.

For transportation of materials and equipment from Japan, packing methods are adopted, which can bear long-term ocean transport, loading at the port, inland transport to the project sites and storage.

2-2-4-3 Scope of Construction, Procurement and Installation Work

The detail scopes of work to be borne by the Japanese and Tongan sides in this general grant aid project are as shown in Table 2-2-4-3.1.

Table 2-2-4-3.1 The Scope of Work to Be Borne by the Japanese and Tongan Sides

No.	Item to be borne	Country of parties responsible		Remark
		Japan	Tonga	
*1	(1) Securing of project sites		○	Already secured at the Vaini Project site
	(2) Cutting of trees, mowing and removal of obstructions on the project sites		○	Roots of trees must also be removed.
*2	Installation of fences and gates			
	(1) Temporary fences and gates	○		
	(2) Permanent fences and gates		○	
*3	Road work			
	(1) Roads within the project sites	○		
	(2) Roads access to the project sites		○	
*4	Supplementary facility work			
	(1) Electrical work			
	a) Connection work to existing distribution facilities	○		
	b) Indoor wiring work	○		
	c) Repair of existing distribution wires		○	The Vaini Project site
	(2) Drainage work			
	a) Outside the project sites		○	
	b) Inside the project sites	○		
*5	Transport of materials and equipment, customs clearance and handling of various taxes			
	(1) Transport to port and airport of delivery	○		
	(2) Tax exemption and customs clearance in Tonga		○	
	(3) Transport from port of delivery to the project sites	○		Delivery point: temporary storage secured on the premises of the Popua Power Station or the Vaini Project site

No.	Item to be borne	Country of parties responsible		Remark
		Japan	Tonga	
	(4) Exemption or payment of value added and other domestic taxes on locally procured materials and equipment		○	If necessary
*6	Measures necessary to obtain the following permits: - Permits for installation work - Permits to access to restricted areas		○	Acquired if necessary prior to the implementation of the project
*7	Appropriate operation, maintenance and management of facilities, and materials and equipment to be procured		○	Including the purchase of spare parts
*8	Payment of costs not included in grant aid		○	
*9	Payment of the following handling charges based on banking arrangement:			
	(1) Handling charges for authorized to pay (A/P)		○	Approx. 10,000 yen
	(2) Commission paid		○	Approx. 0.1% of the total project cost
*10	Securing and execution of budget for environmental and social considerations necessary for the project implementation		○	
11	Securing of site for temporary storage of materials and equipment		○	Site: the premises of the Popua Power Station
12	Securing of parking during the work		○	If necessary
13	Office for construction work	○		For Japanese consultant and contractor
14	Appropriate storage and safety control for materials and equipment at temporary storage	○		
15	Transfer of existing underground cables and pipes, and acquisition of related permits (electricity, telephone, water, sewerage, etc.)		○	If necessary
16	Acquisition of permits for trans-road work		○	
17	Provision of places to dispose of surplus soil and waste water		○	
18	Manufacturing and procurement of materials and equipment	○		Materials and equipment to be procured in this project
19	Installation, adjustment and tests of materials and equipment	○		The Tongan side lends maintenance tools included in the set of equipment procured to the Japanese contractor.
20	Temporary dead-line work during the work		○	
21	Procurement of materials necessary for the above final connection work	○		
22	Initial operation guidance and operational guidance for maintenance and management of equipment procured	○		
23	Securing of the safety of persons concerned with the project at the project sites		○	If necessary
24	Response to and compensation for users of electricity in relation to outages inevitable for the work		○	If necessary
25	Announcement of outage plans to users of electricity during the work		○	If necessary
26	Grid system at the Vaini Project site			
	Procurement	○		
	Installation		○	

Source: JICA Survey Team

Notes: Items with sign ○ indicate the country of parties responsible. Asterisk marks on figures are items stated in M/M of the primary survey.

2-2-4-4 Construction / Procurement Supervisory Plans

In accordance with Japan's grant aid scheme, the consultant takes the purpose of the outline design made in the cooperation preparatory survey into account, organizes a project team which can engage in the detail design work and construction supervisory work throughout the project, and smoothly carry out these tasks. It stations at least one engineer on the project site to manage the schedule, quality and safety. In addition, it dispatches a domestic expert to the factory inspections and pre-shipping inspections of materials and equipment procured in Japan to prevent any unnecessary trouble after the delivery to the site.

(1) Basic policy for construction supervision

The consultant makes it a basic policy to supervise the progress to have the work completed within the prescribed schedule, secure the quality, output and delivery period of materials and equipment as stated in the contract documents, and supervise and instruct the contractor for safe implementation of the work on site. Major points to note for construction supervision are as follows.

1) Schedule management

In order for the contractor to meet the delivery periods prescribed in the contract documents, the consultant compares the implementation schedule planned at the time the contract is signed with the actual progress each month or each week. If it foresees any delay, it provides the contractor with reminders and calls on it to submit remedies and put them into practice so that the work itself and the delivery of materials and equipment are completed within the contract term. It compares the planned schedule with the actual progress chiefly by means of the following methods.

(a) Confirmation of the value of work done (including the value of materials and equipment manufactured at factory)

(b) Confirmation of the amount of materials and equipment delivered (those for power generators)

(c) Confirmation of the status of the temporary work and preparation for construction machines

(d) Unit and actual values of engineers, skilled workers and other laborers

2) Safety control

The consultant discusses and cooperates with persons responsible of the contractor and engages in safety control to prevent any industrial accident on site and other accidents affecting any third parties. Points to note for safety control on site are as follows.

(a) Formulation of safety control regulations and appointment of administrators

(b) The holding of regular safety control meetings

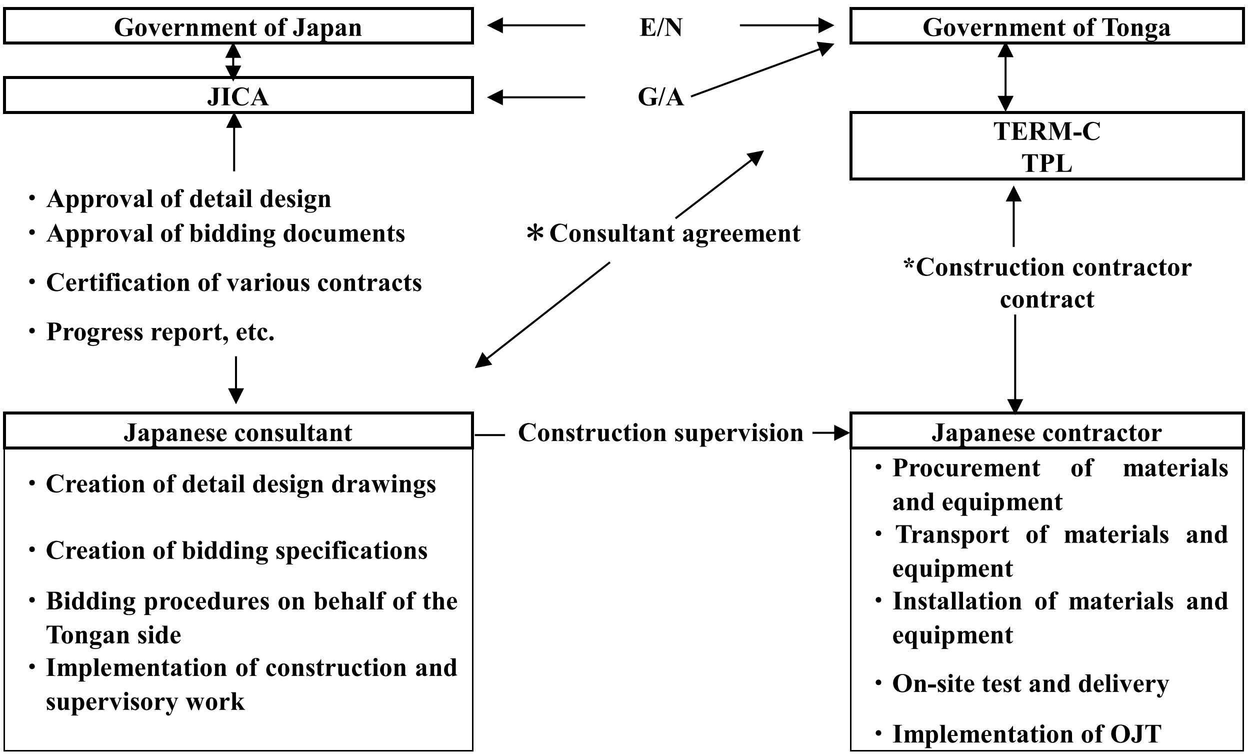
(c) Implementation of regular inspections of construction machines for disaster prevention

(d) Determination of operational routes of construction vehicles and machines, and observation of reduced speed

(e) Welfare measures for laborers and encouragement of taking days off

(2) Overall relationship for the implementation of the project

The interrelationship among parties implementing this cooperation project including the time of implementation and supervision is shown as Figure 2-2-4-4.1.



Note: *The consultancy agreement and construction contractor agreement need to be authenticated by JICA.

Figure 2-2-4-4.1 Interrelationships among Implementing Bodies

(3) Construction supervisor

The contractor concludes subcontracting agreements with local contractors of Tonga for implementation of the construction work of facilities and the installation work of equipment in accordance with the construction contractor agreement. To have such subcontractors fully observe the schedule, quality control and safety control during the construction period, the contractor must dispatch its engineers with similar experience abroad to the site to supervise such subcontractors.

2-2-4-5 Quality Control Plan

Staff members of the consultant responsible for supervision of construction supervise and examine, in accordance with the items listed below, if the contractor manages to secure the quality of materials and equipment to be procured in the project and the outputs of construction and installation as prescribed in contract documents (technical specifications, implementation design documents and other documents). If they have any concern about securing of the quality or outputs, they call on the contractor to make revisions, changes or corrections.

(a) Examination of manufacture drawings and specifications of materials and equipment

(b) Attendance at factory inspections of materials and equipment, or examination of report on the results of factory inspections

(c) Examination of methods of packing, transport and temporary storage on site

(d) Examination of construction drawings and instructions for installation of materials and equipment

(e) Examination of instructions for test operations, adjustment and inspections of materials and equipment at factories and on site

(f) Supervision of installation work of materials and equipment, and attendance at test operations, adjustment and inspections

(g) Examination of manufacture and construction drawings of equipment in reference to the outputs on site

(h) Examination of completion drawings

2-2-4-6 Procurement Plan for Materials and Equipment

Based on the points to note for procurement of materials and equipment in Section 2-2-4-2 (1) above, the countries of origin of these materials and equipment for the project have been determined as in Table 2-2-4-6-1. Since the micro-grid controllers, PV system and other instruments need to be designed and built for mutual system integration, they are procured in Japan. Even if Japan is specified as the country of origin, a number of makers manufacture the same systems so that the competitiveness is still secured. The Tongan side also strongly wishes to have Japanese products because of the performance in the past and excellent after-purchase services of Japanese suppliers.

As for the grid-connected switch gear for 11 kV system, since Japan does not adopt 11 kV as the rated voltage, it may be economically efficient to procure them in a third country: for securing the functions and quality, however, the project selects systems made in DAC member countries.

Moreover, most of construction materials and equipment are not manufactured in Tonga and thus are procured in Japan or third countries. Some of construction materials (stone, sand, etc.) are available in the market in Tonga and thus procured locally.

Table 2-2-4-6.1 Countries of Origin of Materials and Equipment for the Project

Materials and equipment	Country of Origin		
	Tonga	Japan	Third countries (see Note)
(Major equipment)			
(i) Micro-grid controller	–	○	–
(ii) Power system stabilizer (capacitors, etc.)	–	○	–
(iii) PV system	–	○	–
(iv) Switch gear for 11kV system	–	○	○
(v) Optical cable communication system	–	○	–
(vi) Materials for electric facilities (11kV cable, low-voltage cable, accessories, etc.)	–	○	○
(vii) Spare parts and maintenance and management tools	–	○	○
(Construction materials and equipment)			
(i) Sand and gravel	○	–	–
(ii) Cement	○	–	–
(iii) Fresh concrete	○	–	–
(iv) Steels	–	○	–
(v) Steel beams	–	○	–
(vi) Building equipment, interior or exterior materials and fittings	–	○	–
(Construction machines / transport vehicles)			
(i) General construction machines	○	–	–

Note: Third countries refer to DAC member countries.

2-2-4-7 Plan for Initial Operation Guidance and Operational Guidance

The PV systems (1.0 MWp), micro-grid controllers and power storage systems (LiC500 kW x 2) to be supplied under this cooperation project are relatively large systems. For the smooth operation of these systems after commencement of operation, it is proposed that the Japanese contractor conducts on-the-job-training (OJT) on the initial operation and operation during the installation and test operation periods as outlined below.

(1) OJT plan during the installation work and test operation

The O&M technologies for the systems, materials and equipment to be procured and installed under this cooperation project are transferred to the Tongan counterparts during the installation work and test operation.

The specifications and grades of the PV system to be supplied under the project are determined in accordance with the present technological level of the TPL, which engages in the O&M of the existing system constructed with the aid of New Zealand. The TPL has the O&M technologies for grid-connected PV systems since it is in fact operating and maintaining the PV system. Even so, the power storage systems and micro-grid systems to be supplied under the project are manufactured with the latest technology of Japan so that arrangements are made to have the manufacturers send their engineers to the site to conduct OJT on the relevant O&M technologies for the entire systems to be supplied in this project to engineers of the Tongan side. The training is conducted during the period of the installation work and test operation.

Training on the operational methods of various instruments which are essential for the O&M is also given to secure effective operation of the equipment to be procured.

1) OJT periods and sites

- Lectures: approx. 2 weeks (to be given during the construction period in Tonga)
- On-site practical training: approx. 6 weeks (to be given during the construction period in Tonga)

2) Instructors

Instructors of the OJT are installation, test operation and adjustment engineers dispatched by the manufacturers of the PV system, micro-grid controllers and power storage systems that the Japanese contractor delivers.

3) Trainees

OJT trainees of the Tongan side are O&M administrators of the TPL who directly engage in O&M tasks after the power generating systems start the operation as listed below. The TPL, the implementing organization of this project, must appoint specific staff members to OJT trainees before the installation work begins.

− General engineer:	1 person
− O&M staff members:	Electrical engineer: 1 person Mechanical engineer: 1 person Electrical technicians: 2 persons Mechanical technicians: 2 persons
	Subtotal: 6 persons
− Maintenance workers	Electrical engineer: 1 person Mechanical engineer: 1 person Electrical technicians: 2 persons Mechanical technicians: 3 persons
	Subtotal: 7 persons
	Total: 13 persons

4) Contents of the training

While lectures are given concerning the initial operation and operational guidance, the focus is placed on the OJT on site. Electrical engineers in the field must be well versed in the micro-grid system (PV and power storage systems) to install and operate them. The schedule of soft component for the micro-grid systems is shown in Figure 2-2-4-9.1.

5) Plan for the initial operational guidance

This type of the micro-grid systems chiefly consists of three systems: the PV system, micro-grid controllers and power storage systems. The initial operational guidance chiefly focuses on the role, system components and electrical properties of each system.

Operators of the grid-connected PV system have already mastered the basics of photovoltaic cells and grid-connected PV systems since they are operating the PV system of 1.3 MW from New Zealand. Since components of the power conditioner and other aspects of the current PV systems are much different from Japanese products, the OJT on the operation must begin with the very basics.

Operators will learn the following topics from the suppliers of the equipment.

(a) Pre-operation inspections, checkups and measurements

(b) Methods of test operations

(c) Routine checkups after the operation starts

Details of regular inspection items, safety measures, creation and storage of routine inspection logs and etc. are written in 2-4-3.

2-2-4-8 Soft Component Plan

To reduce the dependence on petroleum-based fuel for its energy supply and overcome the vulnerability to fluctuations in transaction prices in the global oil market, Tonga has promoted, as its energy policy goal, to introduce renewable energy and alleviate risk of fluctuations in petroleum product prices. It has also formulated a Tonga Energy Road Map (hereinafter called the “TERM”) as an implementation policy to achieve the goal.

The TERM has set its goal of increasing the proportion of renewable energy to 50% of the entire electricity supply. To achieve the foregoing goal, this Project installs a grid-connected photovoltaic system (1 MWp), an power storage system and a power system stabilizer at the Vaini Project site, and an power storage system and a power system stabilizer on the premises of the existing The Popua Power Station, and constructs related communications systems and facilities. This will increase the proportion of renewable energy sources to the electricity supply in Tongatapu and stabilize the frequency, electric voltage and other qualities of the electric supply system when Tonga has adopted a large amount of renewable energy whose power output is unstable.

The capacities of the PV system and power storage systems (lithium-ion capacitors), and the micro-grid controllers comply with the standards good enough to maintain the quality (voltage and frequency fluctuations) of electricity as of 2012 in Tonga, and system components are formed so that the micro-grid systems can be efficiently and economically operated and maintained. The micro-grid system is a pioneering technology that is still under demonstration test operation even in Japan, but the implementing organization of Tonga will be able to operate and maintain the systems if the OJT and soft component enhance their technical levels. In this regard, the implementation of soft component by the consultant with the following objectives is of significance.

The soft component aims at the following objectives. The fulfillment of these objectives is expected to produce sustainable effects of the grant aid project.

(a) After the completion of the project, the Tongan side smoothly starts to operate, maintain and manage the grid-connected PV system, power storage systems and charge/discharge control systems.

(b) The grid-connected PV system, power storage systems and charge/discharge control systems are sustainably operated, maintained and managed.

(c) The distribution system interconnected to the grid-connected PV system, power storage systems and charge/discharge control systems is stably operated.

Outputs that the soft component is required to achieve are listed in Table 2-2-4-8.1.

Table 2-2-4-8.1 Outputs of the Soft Component

Objective	Output of the soft component	Target party
1. After the completion of the project, the Tongan side smoothly starts to operate, maintain and manage the grid-connected PV system, power storage systems and charge/discharge control systems.	1-1 The target party establishes an operation and maintenance (O&M) organization for the grid-connected PV system, power storage systems and charge/discharge control systems. 1-2 The target party understands the outline and properties of the grid-connected PV system, power storage systems and charge/discharge control systems. 1-3 The target party understands the state of the systems and steps to be taken when the power output of the grid-connected PV system has fluctuated in the distribution system interconnected to the grid-connected PV system, power storage systems, charge/discharge control systems and diesel generators.	Power generation department of the TPL
2. The grid-connected PV system, power storage systems and charge/discharge control systems are sustainably operated, maintained and managed.	2-1 The target party prepares an O&M manual, including contents of troubleshooting, for the grid-connected PV system, power storage systems and charge/discharge control systems. 2-2 The target party prepares an operation manual, including contents of troubleshooting, for the existing diesel generators under the state where the grid-connected PV system, power storage systems and charge/discharge control systems are interconnected to the distribution system.	Power generation department of the TPL
3. The distribution system interconnected to the grid-connected PV system, power storage systems and charge/discharge control systems is stably operated.	3-1 The target parties understand the basic matters concerning the operation of the electricity system (the power supply and demand balance, and adjustments of frequencies and voltages). 3-2 The target parties understand the outline of power system analyses (load flow and stability analyses). 3-3 The target parties establish troubleshooting for the distribution system under the state where the grid-connected PV system, power storage systems and charge/discharge control systems are interconnected to the distribution system.	Power generation and distribution departments of the TPL

The soft component plan is attached as Annex 7.

2-2-4-9 Implementation Schedule

This cooperation project commences in accordance with Japan's grant aid scheme after the Government of Japan approves it and the governments of the two countries conclude the Exchange of Notes (E/N). The project consists of three stages: (i) detail design; (ii) selection of contractor (creation of bidding documents, announcement of bidding, bidding, evaluation of bidders and conclusion of contract); and (iii) procurement of materials and equipment, and installation work. The project implementation schedule is shown in Figure 2-2-4-9.1.

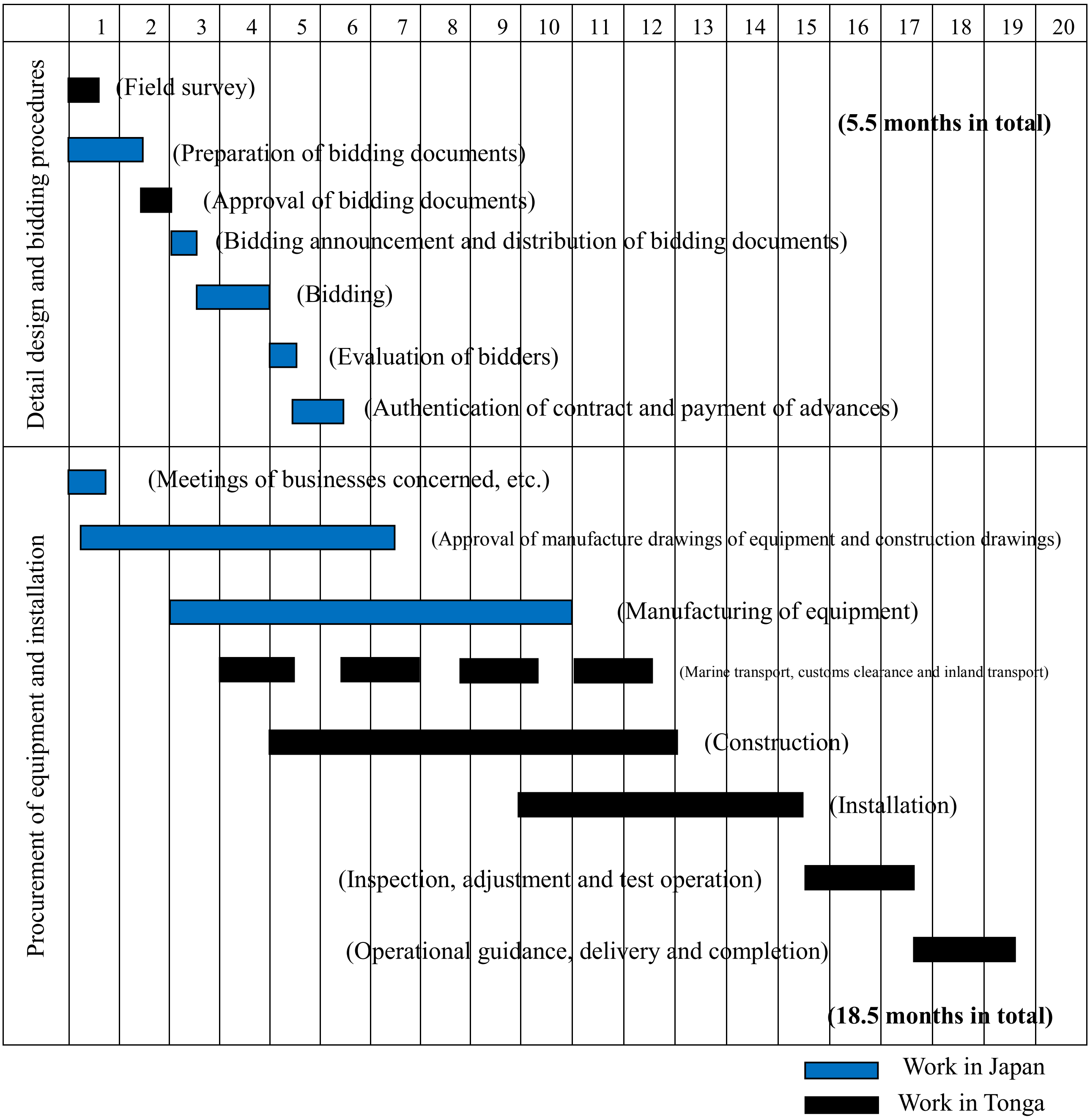


Figure 2-2-4-9.1 Project Implementation Schedule Sheet

2-3 Outline of Obligations of the Recipient Country

The Tongan side is responsible for the following items and assumes the cost involved, in addition to the scope of work indicated in Section 2-2-4-3 "The Scope of Work to Be Borne by the Japanese and Tongan Sides".

<u>Common items:</u>

(1) Provision of information and data necessary for the project.
(2) Measures for prompt unloading at the port in Tonga, customs clearance and tax exemption in relation to materials and equipment necessary for the project.
(3) Tax exemption and provision of facilities in relation to materials and, and Japanese citizens in Tonga necessary for the project.
(4) Exemption from business and other taxes in relation to materials and equipment, Japanese corporations and Japanese citizens necessary for the project.
(5) Payments of the cost of opening of accounts with Japan's certified foreign exchange banks and commissions paid.
(6) Payments of all costs that necessary for the implementation of the project but are not covered by Japan's grant aid.
(7) Appointment of specialized technicians for transfer of the O&M technologies in the project, confirmation of construction during the construction period, and attendance to quality inspections.
(8) Appropriate use, and O&M of facilities and equipment built and procured under Japan's grant aid.
(9) Environmental monitoring.
(10) Logging operation of trees on the premises at the Vaini Project site where the PV system is to be installed (including removal of roots).
(11) Installation of the room for the new breaker board of 11 kV on the premises of the Popua Power Station (including building of cable pits and installation of air-conditioners).
(12) Work to increase the size of the distribution wire of 11 kV from the site at the Vaini Project site to the connection point of the grid power of 11 kV.
(13) Free provision of temporary land for work office and material storage and for other temporary use.
(14) Remodeling work to add the load following capacity to the existing MAC power generating facilities and the existing CAT power generating facilities.
(15) Work to install and connect the breaker board of 11 kV (procured by the Japanese side) to the new room for the breaker board of 11 kV on the premises of the Pupua Solar Farm.
(16) Automatic unit control of the existing CAT power generating facilities and necessary corrections of set values of the operational output range on the operational mode in accordance with the load status.
(17) Conclusion of maintenance agreements with suppliers and payments of the cost of spare parts (from 1 year after completion).

2-4 Project Operation and Maintenance

2-4-1 Basic Policy

Systems that require the maintenance the most in the micro-grid systems are the PV system, and the micro-grid controllers and the power storage systems to stabilize the fluctuation of the PV system. The O&M and preservation of the system environment are essential to respond to daily change in power demand and stably supply electricity.

In order for the PV system, micro-grid systems and the power storage systems to maintain their performance and functions, and continuously supply electricity, the parties concerned are expected to take appropriate measures to prevent any troubles and conduct the O&M work, focusing on the improvement in reliability, safety and efficiency of the existing diesel power generating facilities.

The basic concept of the O&M is shown in Figure 2-4-1.1.

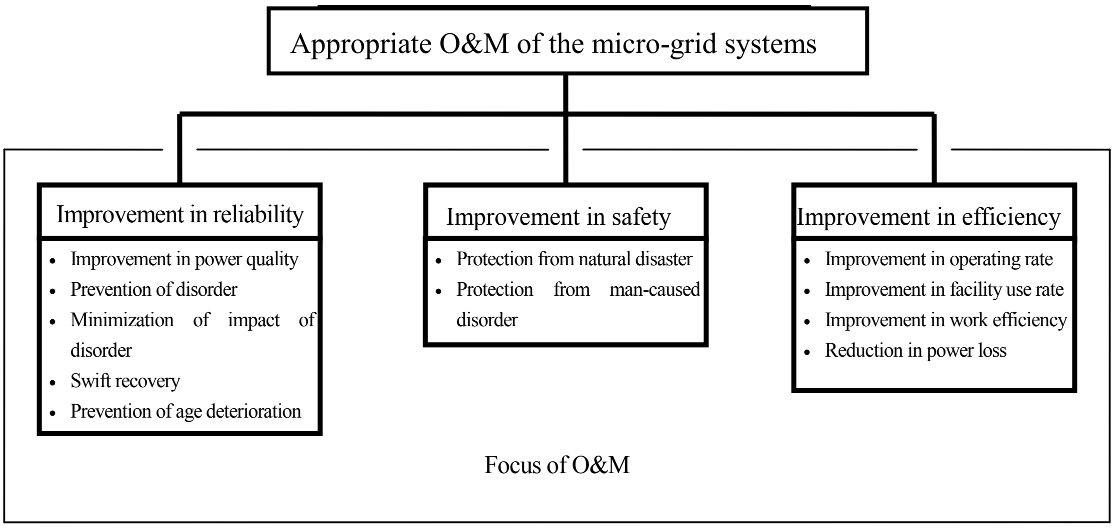


Figure 2-4-1.1 Basic Concept of O&M

In this project, the Japanese contractor dispatches specialist engineers to conduct the OJT and the consultant transfers the O&M technologies through soft component during the construction period. The Tonga side is required, bearing the basic concept above in mind, to operate and maintain the systems after completion of the project in accordance with the O&M manuals.

Since the micro-grid system to be introduced in this cooperation project is a pioneering technology that is still under demonstration test operation even in Japan, the Tongan side is required to conclude O&M agreements with the suppliers for several years after expiry of the guarantee period of this project (1 year after delivery of the systems) for appropriate maintenance and management.

2-4-2 Administrative, Maintenance and Management System

This project is carried out under the implementation system where the Tonga Energy Road Map - Implementation Unit (TERM-IU) serves as the contact point and Tonga Power Ltd. (TPL) is in charge of maintenance and management of the equipment and facilities to be supplied and constructed.

The Power Generation Department of the TPL is in charge of the operation, maintenance and management of the PV system, micro-grid controllers and other systems to be procured in this project. The department is staffed by engineers who have been graduated from universities in New Zealand and Australia; the technical is higher than that of other countries in Oceania. The department operates, maintains and manages the existing diesel power generators without any problems and has faced any serious troubles in the past. It complies strictly with the routine replacement of lubricants and routine overhauls of diesel engines, and systematically maintains and manages their facilities.

In July 2012, a PV system of 1.3 MWp started the operation on the premises of the Popua Power Station, and the Power Generation Department of the TPL is in charge of the operation, maintenance and management of the system. In such circumstances, staff members of the TPL will have certainly acquired the O&M skills for PV systems by the time the project is completed. Even so, the micro-grid system to be introduced under the project is quite new to the TPL. As for the above-mentioned PV system of 1.3 MWp, the TPL has concluded an asset management contract with Meridian Energy Ltd., the company having constructed the system, to extend the guarantee period to 2017. As in this case, it is recommended that the TPL and the Japanese suppliers conclude facility management agreements. Either way, since the the TPL has relatively high technical levels, it is considered to operate, maintain and manage the equipment to be procured in this project without any problem once the initial operation and operational guidance are provided through the OJT and the relevant technologies are transferred through the soft component.

2-4-3 Regular Inspection Items

2-4-3-1 Inspection Items

(1) General Items of Inspection for PV system

Regular maintenance and inspections are essential for sustainable operation of the electrical facilities including the micro-grid systems and the PV systems. Inspections to be made by operators are roughly classifiable into the following three categories. Since the TPL is to become the owner of these facilities and systems to be procured and installed under the project, it takes the initiative in the following routine inspections, regular inspections and purchase of spare parts. Standard regular inspection items for the facilities and systems are listed in Tables 2-4-3-1.1 and 2-4-3-1.2. Inspections of electrical facilities are, as shown in the tables, classifiable into the following three categories.

- "Inspection tours" that persons responsible make every day, checking abnormal noises, etc. of instruments with their five senses
- "Normal inspections" that persons responsible make on the electric charging parts that cannot be inspected during inspection tours, checking heat generation of bolts, fastening conditions, damage and dirt on the surface of insulators, etc.
- "Precise inspections" that persons responsible make to check the functions of interlock structures, etc. and maintain the precision of meters, etc.

Normal inspections are usually conducted once a year or every two years, and precise inspections once every four years. Persons responsible check deterioration in the performance of fuses, meters, relays and other devices in the micro-grid controllers, power storage systems, breaker boards, breaker boards and other equipment; deterioration in the performance of insulators; attrition of joints; and any abnormality of parts whose property changes over the period in normal and precise inspections. These parts should be desirably replaced with new ones from time to time after their properties and age of service are confirmed.

Table 2-4-3-1.1 Regular Inspection Items of Electrical Facilities Related to the Micro-grid System

Item	Contents (method) of inspection	Inspection tour	Normal inspection	Precise inspection
External appearance of facilities	State of switch indicator and indicating light	○	○	
	Detection of abnormal noise and odor	○	○	
	Change in color of terminal area due to heat generation	○	○	
	Crack on, damage to and stain on bushing and porcelain tube	○	○	
	Rust on installation case, mount, etc.	○	○	
	Abnormality in temperature (thermometer)	○	○	
	Fastening of terminal area of bushing (mechanical checking)	○	○	
Operating devices and control boards	Displays of various maters	○	○	○
	Indicators of actual cycle meter		○	○
	Moist, rust and stain inside operation box and board		○	○
	State of lubrication feeding and cleaning		○	○
	Fastening of terminal area of cable	○	○	○
	State of switch indicator		○	○
	Leakage of air and oil		○	○
	Pressure before and after operation (air pressure, etc.)		○	○
	Movement of cycle meter		○	○
	Rust and deformation of, and damage to spring (care)	○	○	○
	Abnormality of pins, etc. at fastened area		○	○
	Inspection of backup switch and relay (care)		○	○
	Inspection of DC control power	○		
Measurement and test	Measurement of insulation resistance		○	○
	Measurement of contact resistance			○
	Inspection of heater burnout		○	○
	Operation test of relay		○	○

Table 2-4-3-1.2 Inspection Items and Judgment Criteria for PV System

Instrument, etc.	Inspection item		Item of inspection tour	Regular inspection and measurement	Judgment criteria
PV cells	Dirt on and damage to glass		○	○	Glass should not be dirty or damaged.
	Damage to, deformation of and rust on frame		○	○	Frames should not be damaged, deformed, or rusted.
	Dirt on and damage to external wiring		○	○	External wiring should not be dirty or damaged.
	Damage to earth wire and loosened terminal area			○	Earth wire should not be damaged, and terminal area should not be loose.
	Insulation resistance test			○	0.4 MΩ or higher if the working voltage is 300 V or higher.
	Measurement of open circuit voltage			○	The voltage of 1 series should be within the range of predetermined voltage.
Mount	Rust and scratching		○	○	No rust or scratching.
	Fixing of mounting structure		○	○	No bolt should be loose.
	Fixing of PV cells and mounting structure		○	○	No bolt should be loose.
	Grounding of mounting structure		○	○	The structure should be grounded.
	Attachment of structures		○	○	The structure should be firmly attached.
Operation / stoppage	Power conditioner	Grid-connected operation	○	○	It should be operated when the switch “Operation” is on.
		Stoppage	○	○	It should be stopped when the switch “Stop” is on.
	Commercial	Power outage	○	○	The power conditioner should stop

Instrument, etc.	Inspection item	Item of inspection tour	Regular inspection and measurement	Judgment criteria
	power supply			instantly.
	power supply – Power recovery	○	○	The power conditioner should automatically resume the operation after ( ) seconds on the recovery timer.
Junction and collection boxes	Loosened screw of terminal box	○	○	No screw should be loose.
	Wiring connections (polarity)	○	○	Wires are connected with correct electronodes.
	Damage to earth wire, loosened terminal area	○	○	Earth wire should be grounded.
	Rust and dirt	○	○	Boxes should not be rusted or dirt.
	Measurement of insulation resistance Voltage: DC1000V		○	Insulation resistance between the PV cells + (plus) and ground should be at least 1 MΩ.
			○	Insulation resistance between the PV cells – (minus) and ground should be at least 1 MΩ.
	Measurement of open circuit voltage of PV cells – Open voltage for ( ) series		○	This should be no more than DC (-) V. The range should be determined according to the system.
	Measurement of open circuit voltage of PV cells – Fluctuation in voltage		○	Voltage fluctuation between each series should be no more than ( ) V. (Decide according to the system).
Power Conditioner	Corrosion, rust, etc. of external box	○	○	External box should not be corroded or rusted.
	Loosened screw of terminal box	○	○	No screw should be loose.
	Wiring connections (polarity)	○	○	Wires are connected with correct electronodes.
		○	○	The AC output RST should be correctly wired.
	Damage to earth wire, loosened terminal area	○	○	Earth wire should not be damaged, and terminal area should not be loose.
	Configuration of protection relay		○	Configuration should remain as designed.
	Abnormal noise and odor at the time of operation	○	○	No abnormal noise or odor should be detected while it is in operation.
	Ventilation filter	○	○	Confirmation of clogging.
	Configuration environment	○	○	Temperature and humidity in the PC room.
	Measurement of grid power voltage		○	Voltage between RTs should be no more than AC( )V ± ( )V.
	Insulation resistance test		○	Check if the value is the set value or higher.
	Operation test of surface are		○	Confirmation of operation
	Test of protective function		○	Confirmation of prescribed protective function

Source: Created based on “Taiyoukouhatsudenshisutemu no sekkei to sekou” JICA Survey Team

Note: ( ) shall be filled with the value reasonable to the actual condition.

The PV system is inspected on routine (inspection tours) and regular basis. For the latter, the system is run for a certain period and stopped before each instrument is inspected and items listed in Table 2-4-3-1.2 are measured. The first-round regular inspection is desirably conducted in 3-5 years’ time after commencement of the operation.

(2) The outline of the maintenance conditions of existing 1.3MW PV system

As regards the maintenance of existing 1.3 MW PV system, the maintenance contract is made between TPL and Meridian Energy Ltd., which is a manufacturer of New Zealand. An overview with the check period and items of maintenance are mentioned in the contract. The extract of a portion related to PV system, and items of maintenance recommended by manufacturer of inverters are shown here for reference. The check period and items of maintenance are draft. Revision will be needed from now on based on actual maintenance activities to establish the final edition.

There are contents which are different from the method which is proposed in the Project in the following point. At a junction box (Array Guard Combiner Boxes), each string's current, voltage, and the temperature in a box are measured, and those values can be monitored with a monitor panel by a data communication system. Those contents are written down to the check sheet for maintenance. Each inverter can be measured in the temperature by the thermography for hot spots and can be checked whether there is an abnormal part. Taking into account of such situation, it is desirable for TPL to establish more rational maintenance method by taking a good portion from both maintenance methods through soft component.

In regard to monitoring, the PV system of New Zealand enables Meridian Energy to monitor condition of the inspection through the internet in addition to the values such as generating energy from PV system. It is recommended to install such system similar to the one of New Zealand at least during guarantee period.

1) Civil assets / General Site / Compliance

Daily tasks: General site inspection undertaken by security guards. Identification of any security issues, solar asset damage.

Weekly tasks: Site inspection by Tonga Power staff.

- ⇒ Identification of security issues, solar damage.
- ⇒ Assessment of vegetation growth.

Annual tasks: Compliance testing and inspections including:

- ⇒ Fire extinguishers (1 in Shelter and 5 across array at Array Guard boxes)
- ⇒ Fire Alarm (incorporate with overall alarm testing)
- ⇒ Ensure appropriate PPE (Personnel Protective Equipment) is available for O&M requirements at the solar facility including overall/long sleeves, rubber gloves, hard hats and protective eyewear.

As required: Vegetation control of solar site including grass mowing and weed spraying.

2) Racking

Monthly tasks: Array inspection by Tonga Power staff.

- ⇒ General inspection of racking structure and identification of damage.
- ⇒ Torque a portion of the facility each month (i.e. 16 strings)

Annual tasks: Array inspection by Tonga Power staff.

⇒ Inspection of racking structure, bolted connections and footings. Assess for damage, corrosion, etc. Execute each April after cyclone seasons.

⇒ Document this inspection.

3) Solar Modules

Monthly tasks: Site inspection by Tonga Power staff in conjunction with Racking inspection

⇒ Condition monitoring via PV Guard monitoring software.

⇒ Identification of damaged solar modules. Replace as required.

⇒ Assess soiling of solar modules across the array.

Annual tasks: Site inspection by Tonga Power staff.

⇒ Check condition of solar module connectors, junction boxes and cables.

⇒ Thorough visual inspection of the modules across the array, concentrating on structural corrosion, glass damage/discoloration, abrasion of module backing layer.

⇒ Document this inspection.

As required: Solar module cleaning (water only) if soiling is considered significant impact on output and is unlikely to be removed by next rain event.

4) Array Guards Combiner Boxes

Daily tasks: Undertaken activities defined by the Daily Check sheet. Specially review PV Guard monitoring system for;

⇒ anomalies in string output currents, voltages, total power, box temperatures.

⇒ confirm that each Array Guard has surge protection "ON".

Monthly tasks: Site inspection by Tonga Power staff.

⇒ Open each Array Guard and undertake a visual inspection, looking for any signs of moisture, corrosion, high temperature, circuit board damage, cable damage.

⇒ Check structural integrity of Array Guard and bracing to concrete pad.

⇒ Undertake a visual inspection of weather station on both Field A & B.

Annual tasks: Site inspection by Tonga Power staff.

⇒ In addition to the standard monthly inspection, undertake a thermal image review of each Array Guard using the Fluke Ti 32 camera and assess for hot spots and comparative anomalies.

⇒ Document this inspection.

5) DC Switches

Weekly tasks: Inspected by Tonga Power staff.

⇒ Inspection of DC Switch cabinet — assessing for damage to switches, cables and cable terminations — look for signs of arcing, heat or moisture within the cabinet.

Annual tasks: Site inspection by Tonga Power staff.

⇒ Undertake a thermal image review of the switches using the Fluke Ti 32 camera and assess for hot spots and comparative anomalies.

⇒ Document this inspection.

6) Inverter Shelter

Monthly tasks: Shelter inspection by Tonga Power staff.

⇒ Clean and tidy the shelter.

⇒ Inspect shelter for signs of vermin, reptiles or insects.

⇒ Lift floorboard and inspect cable gallery.

Annual tasks: Site inspection by Tonga Power staff.

⇒ Inspect shelter for signs of damage, defects, wear & tear.

⇒ Ensure door seals are in place and proving an adequate seal.

⇒ Lift floorboards out and inspect entire cable gallery.

⇒ Document this inspection.

As request: After significant rain events, inspect Inverter Shelter cable gallery for water ingress

7) Inverter

Daily tasks: Under activities defined by the Daily Check sheet.

Annual task: Site inspection by Tonga Power staff.

⇒ Undertake a thermal image review of inverter using the Fluke T32 camera and assess for hot spots and comparative anomalies.

⇒ Document this inspection.

Schedule Maintenance : Execute SPV Maintenance Program as defined by Emerson.

The outline of the maintenance which Emerson defined SPV Maintenance Program is shown below.

(a) Visual inspection and standard checks

a) Inspection of the SPV for general condition and soiling

A visual inspection of the SPV and all devices has to be performed. It has to be checked for soiling, corrosion and any abnormalities.

b) Inspection of the SPV for Thermal impact

A visual control of the system has to be performed in order to find any signs which hint hot spots in the system. Examples are: changed color of metal, blistering on coats of lacquer or deformation of plastic parts. It is highly recommended to scan the SPV using a IR camera (Fluke Ti10) for possible hotspots at periodic intervals.

c) Test of Emergency stop

The emergency stop has to be tested by pushing the emergency-Stop-button.

As soon as the button was pushed the inverters has to switch off immediately and without giving any error message. After the system shut down all inverter displays must show " trip UU ".

After the emergency stop button is brought back into healthy position the SPV has to reset automatically and then has to start up following the usual starting procedure.

d) Test for Frequency-Control-Relay

A system incident has to be simulated by using the simulation function of the Frequency-Control-Relay. The simulation function can simulate a value above or below the threshold and thus start the procedure for net-failure: the emergency-stop procedure as described above will be activated by the relay.

When the time for the simulated system incident is over, the Frequency-Control-Rely will go back to normal operating mode. Afterwards the SPV will first have to wait for the AC setting time before it should start up as usual.

e) Test of voltage-Control-Relay

A system incident has to be simulated by using the simulation function of the Voltage-Control-Relay. The simulation function can simulate a value above or below the threshold and thus start the procedure for net-failure: the emergency-stop procedure as described above will be activated by the relay.

When the time for the simulated system incident is over, the Voltage-Control-Relay will go back to normal operating mode. Afterwards the SPV will first have to wait for the AC setting time before it should start up as usual.

f) Checking the isolation-monitoring

The resistance value shown on the display is to be read off and has to be recorded on the maintenance protocol together with the weather determined state of the solar cells.

g) Checking the Shelter

The general cooling of the shelter has to be checked and ascertained. Maintenance procedures for the air conditioners installed have to be carried out as per manufacturer's recommendation. Check the air filter for soiling and damages. Check the doors for right closing. Sweep the inverter room for clean swept condition. Be aware that any source of soiling which could possibly harm the inverter must be recorded in the maintenance protocol and the responsible persons have to be informed.

h) Measuring the voltage of the UPS Battery

The capacity of the battery must be >85%.

(b) Spares Parts Management

a) For urgent repair, stock containing SPV spare parts have to be maintained at site.

b) If parts are available on stock, installation is recommended in a periodic cyclic replacement with parts of a SPV.

(c) Check for identifying Parts wear & tear

a) Checks of all parts mounted outside the shelter (Braking resistor) for corrosion

Parts mounted outside the shelter should be checked for corrosion and general condition. Especially the enclosure of the braking resistor should be opened and the resistor as well as their connections should be checked.

b) Checking the symmetry of each power module

The generated power should divide equally over the working power modules. The deviation between the modules should be no more than 5% up to below the average value. The measurement is to be taken for all three phase between the power connection and the Regen choke using a clamp ammeter.

c) Random inspection of contacts of the power contactors (AC)

AC power contactors have to be opened randomly and the connections have to be checked for loss of contact material. In case of advanced deterioration all connections respectively connectors have to be replaced. Please note that DC contactors cannot be opened and only a mere visual inspection can be carried out.

d) Inspection of all contacts of the power contactors (AC)

Power contactors have to be checked as described in point 3, but all contactors have to be opened and checked. Please note that DC contactors cannot be opened and a mere visual inspection can be carried out.

e) Replacement of all contactors according to maintenance schedule

All power contactors have to be replaced. Where it is possible the replacement is limited to the power connections. Only in case of downright good contact image the contactor can be left in place.

(d) Check for the Power Module Fan

In order to test the inverter heat sink fans a " checkbox " is needed which provides voltage via a potentiometer and a plug socket suitable for 24 DC supply of the heat sink fans.

The detailed check method is omitted.

(e) Wear test of the link-capacitors

The detailed check method is omitted.

(f) Extended functional testing and preventive measures

a) Check the 0-offset of all current measurement devices

The detailed check method is omitted.

b) Check and ensure that all electrical connection (screws) are tightened

The detailed check method is omitted.

c) Maintenance of all plug connections

The detailed check method is omitted.

d) Checking of voltage-displays

The DC voltage is to be measured with a multi meter at the DC-bus bar and then compared with array data.

e) Replacement of UPS battery

Replace the battery every 02 years.

2-4-3-2 Creation and Storage of Routine Inspection Logs

The operators inspect items listed in Tables 2-4-3-1.1 and 2-4-3-1.2 and keep inspection logs. Keeping inspection records leads to early detection of abnormality of instruments. When making inspection tours, the operators confirm and record the state of the operation of electrical facilities related to the PV system and micro-grid systems as shown below.

- The amount of solar radiation and the volume of PV power generated
- The state of the operation of the diesel power generators
- The state of the operation of the power storage systems
- Grid power voltage and frequency

The operators check the amount of solar radiation, the volume of PV power generated, the volume of power generated by the diesel power generators and others at every opportunity so that they can promptly detect any abnormality due to malfunction of PV modules, power conditioners, micro-grid systems or other systems.

2-4-3-3 Measurement and Safety Measures

The operators of the electric facilities for the micro-grid systems, and the PV system will have received guidance on safety control through the OJT and soft component by the time they actually engage in inspections, measurement and other duties. Before engaging in these duties, they take the following safety measures.

(1) Safety measures

The operators must observe the following safety measures (clothing and protection against electric shock) prior to the actual work.

1) Clothing

The operators must wear a helmet, working gear and protective footwear.

2) Anti-electric shock measures

The operators must:

(a) Wear insulating gloves.

(b) Use insulating tools.

(c) Not work when it is raining.

(2) Inspections of PV arrays: confirmation of voltage and polarity and measurement of open voltage

(a) Persons responsible confirm if each instrument is correctly built and the voltage is generated as prescribed in the specifications. They also confirm if the electronodes are correct with a voltmeter.

(b) Measurement of open circuit voltage
Persons responsible confirm if the voltage of 1 series is within the range of predetermined voltage with a voltmeter.

(3) Measurement of insulation resistance

Persons responsible conduct insulation resistance tests for each instrument. They measure insulation resistance before commencement of the operation after construction work; at the time of regular inspections; or after recovery from any accident to identify defects. They record resistance values measured.

(4) Measurement of earth resistance

Mesh earth wires are laid on the project sites at the Vaini Project site and at the Popua Power Station, which are connected to earth wires of the metal mount for the PV modules, the power conditioners and metal exterior boxes in which other electric instruments (including micro-grid controllers, breaker board of 11 kV and transformers) are placed. The earth resistance of the mesh earth wires should be equivalent to Type-C earth of the Japanese standards (10 Ω or lower of the earth resistance for low-voltage metal box with the working voltage of more than 300 V).

Persons responsible measure earth resistance at the time of regular inspections, using a measuring device to be supplied under the project, and confirm if it is 10 Ω or lower.

2-4-4 Plan for Purchase of Spare Parts

The PV system, micro-grid systems and other systems have no operating parts inside and thus are basically free from maintenance. They do not break due to wear and tear or friction. Since they use inverters, the related semiconductors may break. Defects of the semiconductors appear at an early stage of the operation. They are likely to operate appropriately if no initial defect is found. Still, they are not entirely free from breakdown, which may occur due to natural disaster, man-caused failure, aged deterioration or loss. In this respect, spare instruments critical to the operation must be purchased and kept in stock.

2-4-4-1 Cycle of Replacement of Equipment and Inspection Items

Equipment deteriorates over years and stops functioning in the end. The degree of deterioration of PV modules can be diagnosed to some extent by measuring output properties, whereas that of other equipment cannot be diagnosed so easily. To keep the reliability of the systems and from the preventative perspective, parts must be replaced by new ones before they break down while in operation. The cycle of replacement and inspection items for major instruments are listed in Table 2-4-4-1.1 for reference.

Table 2-4-4-1.1 Cycle of Replacement and Inspection Items for Major Equipment

Parts type	Recommended replacement cycle	Inspection item
PV module	20～30 years	Appearance and measurement of voltage
Connection box	20 years	Malfunction
Breaker	10～15 years	Malfunction
Collection box	10～15 years	Malfunction
Power conditioner	10～15 years	Malfunction
Transformer	20 years or more	Rise in temperature
Cooling fan	10 years or more	Change in air volume and rotational noise
Fuse	7 years or 50,000 hours	Melting
Air conditioner	10～15 years	Malfunction and drop in performance
Micro-grid controller	15～20 years	Malfunction and drop in performance
power storage systems	15～20 years	Malfunction and drop in performance
Pipes, wires and cables	10～15 years	Deterioration

2-4-4-2 Plan for Procurement of Spare Parts

Damage to or breakdown of major equipment of the Project is likely to stall the system itself. When a trouble occurs, the equipment in question should be promptly repaired or replaced by new one. The system can be recovered promptly if replacement parts are in stock, while it costs to have expensive parts or a large amount of parts in stock. The types and quantities of replacement parts to have in stock must be determined in accordance with the characteristics of equipment, economic efficiency, the time required for recovery and other factors. Table 2-4-4-2-1 lists replacement parts and their quantities to be procured in the Project .

Table 2-4-4-2.1 Replacement Parts and Their Quantities

Type of instrument	Quantity of replacement parts to be procured in the Project
Cooling fan for PCS	4 sets
Electromagnetic contactor for PCS	4 sets
Display panel for PCS	4 sets
Relay unit for PCS	4 sets
Electrolytic condenser for PCS	4 sets
Fuse for PCS	4 sets
Control source for PCS	4 sets
Small battery for micro-grid controlling board	3 sets
Display/operating panel for micro-grid controlling board	3 sets
Control source for micro-grid controlling board	3 sets
Cooling fun for micro-grid controlling board	4 sets
PV panel	1 series
Lithium ion capacitor	1 series

This project supplies replacement parts of the major instruments necessary for the maintenance of the equipment installed under the project and thus does not cause considerable financial burden on the implementing organization with regard to the O&M. However, it is recommended that the organization, the TPL, set aside funds for the repair cost of instruments from the money saved as a result of the operation of this micro-grid system to prepare for unexpected repair or replacement in future.

Test equipment and maintenance tools shall not be procured in the Project. However the equipment and the tools to be used during installation work shall be contributed to TPL.

2-5 Project Cost Estimation

2-5-1 Initial Cost Estimation

In the case of the actual implementation of the Project under the grant aid scheme of the Government of Japan, the Tongan Side is expected to pay the costs of its undertakings listed below. Cost to be borne by the recipient country: USD 696,000.- (approx. 56.0 million yen)

(1) The contents and costs to be borne by the Tongan side are as follows.

1) Payment for bank commission based on banking commission of an Authorization to Pay (A/P) and Payment commission:
   USD 20,000.- (approximately 1.6 million yen)
2) Clearance of trees, and exterior wall and gate work for the PV system site at the Vaini Project site:
   USD 46,000.- (approximately 3.7 million yen)
3) Work to increase the size of the distribution wire of 11 kV and connection work at the Vaini Project site:
   USD 40,000.- (approximately 3.2 million yen)
4) Expansion work for 11kV switch board room at the Popua Power Station:
   USD 52,000.- (approximately 4.2 million yen)
5) Installation work for Grid-connected switch gear for 11 kV system:
   USD 100,000.- (approximately 8.0 million yen)
6) Remodeling work for the existing power generating facilities at the Popua Power Station (Including Load Sharing of Generator 7 with other generators for maintaining fuel efficiency: USD70,000):
   USD 90,000.- (approximately 7.2 million yen)
7) Land lease/rental at the Vaini Project site for the first year (=TOP600,000+TOP10,000/year) :
   USD 348,000.- (approxmately 28.0 million yen)

(2) Estimation conditions

a) Estimation point: November 2012

b) Exchange rate: 1 USD = 80.40 JPY

(TTS mean value from April 2012 to September 2012)

1 TOP =45.80 JPY

(TTS mean value from April 2012 to September 2012)

c) Work and procurement period: The periods of detail design, and procurement and installation are as shown in the work schedule.

d) Others: This cooperation project will be implemented according to the Grant Aid Scheme of the Government of Japan.

2-5-2 Operation and Maintenance Cost

The Power Generation Department of the TPL will operate and maintain the equipment and facilities to be supplied under this project. It currently maintains and manages the existing power plants and distribution lines and thus will be in charge of the O&M of the PV, micro-grid and other systems to be built at the Vaini Project site to be newly supplied.

The PV system, micro-grid systems and other systems have no operating parts inside and thus are basically free from maintenance. Thus, the department does not have to urgently hire new staff members for the O&M of the new systems and intends to operate and maintain the systems with a total of current 22 staff members including the Director of the Popua Power Station.

The department must keep in stock spare parts (consumable goods and replacement parts) necessary for the sound operation of the power plant and facilities and thus the Power Transmission and Distribution Section of the Technical Department of the TPL must earmark a certain amount of budget (equivalent to approx. 3.5 million yen/year) for such spare parts. The TPL recorded sales of approx. 2.2 billion yen and operating profit of approx. 225 billion yen in 2012. This means that the O&M cost of the new power plant and facilities accounts for approx. 0.16% of the annual sales or 1.6% of the operating profit. It is considered that the section in charge will be able to secure the budget.

Chapter 3 Project Evaluation

3-1 Prerequisites for Project Implementation

The prerequisites for the project implementation are clearance of trees (including digging up and removal of roots) and other obstacles on the project site at the Vaini Project site and acquisition of environmental permits related to the implementation.

3-2 Inputs (Obligations) of the Recipient Country to Achieve the Overall Plan of the Project

(1) Prerequisites

To achieve the overall plan of the project, the Tongan side is required to undertake the following items.

1) To appropriately engage in routine maintenance and management so that the equipment the Japanese side procures and installs under the project is made the best use of;

2) To systematically allocate, and educate and train personnel necessary for the O&M of the equipment to be procured under the project so that the equipment can be smoothly put into operation;

3) To procure and replenish spare parts and consumable goods necessary for the O&M of the equipment to be procured under the project to guarantee the regular maintenance;

4) To conclude an O&M agreement with the makers of the instruments to enable continuous maintenance and management of the microgrid system; and

5) To set aside funds for the cost of upgrading power storage systems from the profit of the TPL.

3-3 External Conditions

To assume the obligations listed above, the TPL must make accounting procedures to record depreciation allowance and reserve some funds necessary to upgrade the facilities in future, rather than using the diesel fuel cost saved thanks to photovoltaic power generation for a reduction in the electricity charges, and, at the same time, seek for the understanding of the relevant organizations and the people that the reduction in charges in this manner will not necessarily lead to an ultimate reduction in the electricity charges.

3-4 Project Evaluation

3-4-1 Relevance

As detailed below, this project contributes to the realization of Tonga’s development plan and energy policy goals, and the benefit of general citizens: the project is deemed relevant as a grant aid project.

(1) Target population

If the project is implemented, electricity produced by the renewable energy source will be supplied to some 75,100 residents in Tongatapu Island, and the dependence on petroleum-based fuels and risks of price fluctuation reduced. The project covers some 12,800 general households and other 50 customers in its sites.

(2) Urgency

In Tonga, electricity charges soared as a result of a global rise in crude oil prices in 2008, causing serious damage to the people's lives and national economy. This project is expected to urgently reduce dependency on petroleum-based fuel for energy consumption.

(3) Contribution to stable management of public welfare facilities

Tonga relies on diesel power generation for 98% of its power supply and frequently suffers from rises in electricity charges due to a rise in fuel prices. High electricity bills weigh on the management of public welfare facilities.

The implementation of this project and a subsequent reduction in dependence on diesel power generation alleviates the risk of inflation of electricity charges and contributes to the stability of public welfare facility management.

(4) Operational and maintenance capacity

The Power Generation Department of the TPL routinely operates and maintains diesel power generators and thus has a relatively high technical level. The TPL will, though it is not used to microgrid controllers or Power storage devices, be able to operate and maintain the equipment to be procured in this project if the project provides them with initial operation guidance and technological transfer through soft component without problem.

(5) Project contributing to Tonga's development plan

The Tonga Strategic Development Framework (TSDF), the country's development plan, sets one of its strategies to "maintain and where possible expanding the provision of reliable and cost efficient power supplies, using traditional and renewable options, to all communities" Since this project aims to expand the use of renewable energy sources, it is believed to contribute to the achievement of TSDF objectives. The TERM, Tonga's energy policy, sets its goal of "increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020", and thus this project contributes to the achievement of the goal of the TERM, too.

(6) Environmental and social impact

The Survey Team has examined the project in accordance with environment-related laws and regulations in Tonga and the JICA Guidelines for Environmental and Social Considerations and concluded that the project has no particular impact on the environmental and social aspects of the country since it only has minor impact on the natural and social environments but contributes to a reduction in greenhouse gas emissions.

(7) Japan's grant aid scheme

This project is feasible with no particular difficulty on the grounds that major equipment is to be procured in Japan, that it is completed within the term of the E/N, and thus that its plan and schedule have been drawn up in a realistic manner within the framework of the grant aid scheme.

3-4-2 Effectiveness

The effects expected to be produced as a result of the implementation of this project are as follows.

(1) Quantitative effects

Output indicator	Present value (2011)	Target value (2018) 3 years after the completion of the project
Reduction in diesel fuel consumption [kℓ/year]	-	327
CO_2 emissions reduction* [t-CO_2/year]	-	886
The amount of annual power generation by 1MWp PV system [MWh/year]	0	1,308

Note:*The reduction attributable to the project only. No effect of the existing PV system is included.

(2) Qualitative effects (the entire project)

Present states and problems	Project countermeasures (grant aid project)	Extent of project effects and improvement
1. Tonga relies on diesel power generation for 98% of its power supply and thus is vulnerable to fluctuations in fuel prices.	A PV power plant is constructed.	The project reduces dependency on diesel power generation for the country's power supply and alleviates the risk of inflation of electricity charges.
2. Tonga promotes the introduction of renewable energy sources, but the introduction in the large volume undermines the stability of the power grid since the output of PV, wind-power and other renewable power generation fluctuates considerably.	Microgrid systems are introduced.	The power storage systems and microgrid controllers can make up for fluctuating output of renewable energy and stabilize the grid power generation.

[Annex]

A-1 Members of the Team

1. Members of the Team

(1) First Field Survey

Name	Assignment	Period	Organization
Hiroshi SUMIYOSHI	Team Leader	25Aug.'12～01Sep.'12	Japan International Corporation Agency
Yoshimasa SAKAMOTO	Planning Management	25Aug.'12～01Sep.'12	Japan International Corporation Agency
Mitsuhisa NISHIKAWA	Chief Consultant / Distribution System Design	14Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.
Kyoji FUJII	Deputy Chief Consultant/ Operation of Diesel Engine Generator	23Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.
Hidekazu SATO	Micro-Grid System-1 (Grid Control) / Battery Equipment Plan	14Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.
Shinya KONDO	Renewable Energy-2	14Aug.'12～28Aug.'12	West Japan Engineering Consultants, Inc.
Kazunari NOGAMI	Procurement Plan/ Cost Estimation-1	14Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.
Kenji OHARA	Natural Condition Survey/ Cost Estimation 2	14Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.
Shigeki TAKASHIMA	Social and Environmental Considerations	14Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.
Masao YAMAKAWA	Coordinator/Assistance for Micro-Grid Design	14Aug.'12～01Sep.'12	Yachiyo Engineering Co., Ltd.

(2) Second Field Survey

Name	Assignment	Period	Organization
Mitsuhisa NISHIKAWA	Chief Consultant / Distribution System Design	18Sep.'12～07Oct.'12	Yachiyo Engineering Co., Ltd.
Kyoji FUJII	Deputy Chief Consultant/ Operation of Diesel Engine Generator	18Sep.'12～07Oct.'12	Yachiyo Engineering Co., Ltd.
Hidekazu SATO	Micro-Grid System-1 (Grid Control) / Battery Equipment Plan	18Sep.'12～07Oct.'12	Yachiyo Engineering Co., Ltd.
Shozo KURASHIMA	Renewable Energy-1	18Sep.'12～07Oct.'12	Yachiyo Engineering Co., Ltd.
Shinya KONDO	Renewable Energy-2	18Sep.'12～30Sep.'12	West Japan Engineering Consultants, Inc.
Kazunari NOGAMI	Procurement Plan/ Cost Estimation-1	18Sep.'12～07Oct.'12	Yachiyo Engineering Co., Ltd.
Kenji OHARA	Natural Condition Survey/ Cost Estimation-2	18Sep.'12～07Oct.'12	Yachiyo Engineering Co., Ltd.
Shigeki TAKASHIMA	Social and Environmental Considerations	18Sep.'12～07Oct'12	Yachiyo Engineering Co., Ltd.
Yusuke KATSUTA	Economic and Financial Analysis	18Sep.'12～13Oct.'12	Yachiyo Engineering Co., Ltd.
Masao YAMAKAWA	Coordinator/Assistance for Micro-Grid Design	25Sep.'12～13Oct.'12	Yachiyo Engineering Co., Ltd.

(3) Third Field Survey

Name	Assignment	Period	Organization
Hiroo TANAKA	Team Leader	16Dec.'12～22Dec.'12	Japan International Corporation Agency
Yoshimasa SAKAMOTO	Planning Management	16Dec.'12～22Dec.'12	Japan International Corporation Agency
Mitsuhisa NISHIKAWA	Chief Consultant / Distribution System Design	14Dec.'12～22Dec.'12	Yachiyo Engineering Co., Ltd.
Shozo KURASHIMA	Renewable Energy-1	14Dec.'12～22Dec.'12	Yachiyo Engineering Co., Ltd.
Kazunari NOGAMI	Procurement Plan/ Cost Estimation-1	14Dec.'12～22Dec.'12	Yachiyo Engineering Co., Ltd.

A-2 Field Survey Schedule

2 Field Survey Schedule

(1) First Field Survey

No.	Date(Day)	Contents of Survey			Stay at
		JICA members		Consultant members	
		Mr .SUMIYOSHI (Team Leader)	Mr. SAKAMOTO (Planning Management)	Mr. NISHIKAWA, Mr. FUJII, Mr. SATO, Mr. KONDOU, Mr.NOGAMI, Mr. TAKASHIMA, Mr. OHARA, Mr. YAMAKAWA (Mr. Fujii will join the survey team from 21st Aug.'12)	
1.	14 Aug.(Tue)			①Trip by air {Tokyo (19:00) – Auckland (08:45+1) by NZ-090}	Flight
2.	15 Aug.(Wed)			①Arrive at Auckland (08:45) by NZ-090 ②Trip by air {Auckland (11:00) – Nuku'alofa (14:50) by NZ-272}	Nuku'alofa
3.	16 Aug.(Thu)			① Courtesy call (Embassy of Japan in Tonga, JICA Tonga Office, TPL (Tonga Power Limited), TERM-C) ② Submission and explanation of Inception Report (IC/R) and Questionnaire ③ Courtesy call and survey on the existing power stations (Collection of Technical data & Specification and Operation records) ④ Confirmation of Candidate site (Solar generation, Wind generation, Micro-grid system, Battery system, etc.)	Nuku'alofa
4.	17 Aug.(Fri)			① Explanation of IC/R, Confirmation of the Requested Component and Explanation of Japan's Grant Aid scheme ② Survey on the existing solar generating system (Collection of Technical Specification, connection point to Grid and operation record), ③ Confirmation of Distribution system, Operation and Maintenance System of Tongatap grid ④ Confirmation of Organization, Budget, etc. of TPL ⑤ Confirmation of Environment Regulations and standard and EIA procedure	Nuku'alofa
5.	18 Aug.(Sat)			① Request to local subcontractor for Quotations (Facility construction, Installation) ② Data Analysis of Solar Irrigation and Wind conditions ③ Confirmation of Operation & control system of the Existing diesel engine generators. ④ Confirmation of Power System Standards, Interconnecting points, Distribution System and Power Demand Forecast.	Nuku'alofa
6.	19 Aug.(Sun)			① Internal meeting ② Arrangement of collected data ③ Consumers' Research ④ Data Analysis of Solar Irrigation and Wind conditions ⑤ Preparation of the Outline design (draft) such as Capacities and Layout of PV generating system and Wind generating system, Batteries, Micro-Grid System etc.)	Nuku'alofa
7.	20 Aug.(Mon)			① Site survey (System Standards, Interconnecting system, Distribution System and Load forecasting) ② Survey of Sites for the Solar generation, Wind generation, Micro-grid system, Battery system, etc.	Nuku'alofa
8.	21 Aug.(Tue)			① Survey of Sites for the Solar generation, Wind generation, Micro-grid system, Battery system ② Preparation of the Outline design (draft) such as Capacities and Layout of PV generating system and Wind generating system, Batteries, Micro-Grid System etc.	Nuku'alofa
9.	22 Aug.(Wed)			① Detailed site survey for Micro-grid system and batteries ② Preparation of Outline design (draft) such as Capacities and Layout of PV generating system and Wind generating system, Batteries, Micro-Grid System etc	Nuku'alofa
10.	23 Aug.(Thu)			① Site Survey and Discussion with TPL for Interconnection Point, Capacity of the batteries and Micro-grid system ② Preparation of Outline design (draft) and Field Report ③ Confirmation and Discussion of the Candidate site with Subcontractor (Topographic survey and Soil investigation works)	Nuku'alofa
11.	24 Aug.(Fri)			① Supplementary Site Survey for the Solar generation, Wind generation, Micro-grid system, Battery system ② Preparation of Facility Basic Planning (draft)	Nuku'alofa
12.	25 Aug.(Sat)	①Trip by air { Tokyo (19:00) – Auckland (08:45+1) by NZ-090}		①Supplementary Site Survey for the Solar generation, Wind generation, Micro-grid system, Battery system ②Preparation of Field Report	Nuku'alofa

No.	Date(Day)	Contents of Survey			Stay at
		JICA members		Consultant members	
		Mr .SUMIYOSHI (Team Leader)	Mr. SAKAMOTO (Planning Management)	Mr. NISHIKAWA, Mr. FUJII, Mr. SATO, Mr. KONDOU, Mr.NOGAMI, Mr. TAKASHIMA, Mr. OHARA, Mr. YAMAKAWA (Mr. Fujii will join the survey team from 21st Aug.'12)	
13.	26 Aug.(Sun)	①Arrive at Auckland (08:45) by NZ-090		①Supplementary Site Survey for the Solar generation, Wind generation, Micro-grid system, Battery system ②Preparation of Field Report	Nuku'alofa (Officials: Auckland)
14.	27 Aug.(Mon)	①Trip by air｛Auckland (07:20) – Nuku'alofa (11:10) by NZ-970｝ ②Internal meeting among the Team and JICA Tonga Office ③Courtesy call (Embassy of Japan in Tonga)		① Preparation of Field Report ② Internal meeting among the Team and JICA Tonga Office ③ Supplementary site survey ④ Courtesy call (Embassy of Japan in Tonga)	Nuku'alofa
15.	28 Aug.(Tue)	①Courtesy call on and Discussion with TERM-C and TPL ②Site Survey		① Courtesy call on and Discussion with TERM-C and TPL ② Preparation of Field Report ③ Site survey	Nuku'alofa
16.	29 Aug.(Wed)	①Site Survey ②Discussion on the MD with TERM-C and TPL ③Modification (if any) of M/D		① Discussion on the MD with TERM-C and TPL ② Modification (if any) of M/D ③ Preparation of Field Report ④ Submission and explanation of Field Report to TPL ⑤ Mr. Takashima; Trip to Auckland (15:50-17:50 by NZ275)	Nuku'alofa (Takashima: Auckland)
17.	30 Aug.(Thu)	①Signing of MD with TERM-C and TPL ②Report to Embassy of Japan in Tonga (EOJ), JICA Tonga Office		①Signing of MD with TERM-C and TPL ②Explanation of Field Report to TPL and obtaining the confirmation from TPL ③ Report to Embassy of Japan in Tonga (EOJ), JICA Tonga Office ④ Mr. Takashima: Survey of Battery Recycling factory (Auckland)	Nuku'alofa (Takashima: Auckland)
18.	31 Aug.(Fri)	① Trip by air {Nuku'alofa (12:10) – Auckland (14:10) by NZ-973}			Auckland
19.	01 Sep.(Sat)	① Trip by air {Auckland (08:25) – Narita (16:50) by NZ099}			Japan

(2) Second Field Survey

No.	Date	Consultant members	Stay at
		Nishikawa, Fujii, Satoh, Kurashima, Kondo, Nogami, Takashima, Ohara, Wada, Yamakawa	
1.	18 Sep.(Tue)	① Trip from Tokyo (19:00) to Auckland (09:00+1) by NZ-090	On flight
2.	19 Sep.(Wed)	① Trip from Auckland (15:30) to Nuku'alofa (19:00) by NZ-974 ② Concluding the Contract with Soil investigation company and coordinating the actual schedule(during transit time at the airport)	Nuku'alofa
3.	20 Sep.(Thu)	① Courtesy call and explanation of planned survey schedule, Contents of survey, etc. 1) JICA Tonga Office at 9:00 a.m.（Mr. Tsujimoto, Mr. Ishigaki） 2) TERM (Tonga Energy Road Map) at 11:00 a.m. (Mr. Inoke) 3) TPL (Tonga Power Limited) at 14:00 p.m.(Mr. John van Brink) ② Survey of Popua Power Station (P/S) (Specifications of Equipment/machineries, Operation records, etc.) ③ Concluding the Contract with Topographic survey company and coordinating the actual schedule, site location, etc.	Nuku'alofa
4.	21 Sep.(Fri)	① Technical discussions with TPL 1) Explanation of the analysis results for battery capacities, wind turbine potentials, etc. 2) Explanation of the Environmental comparisons such as Zero option, etc. 3) Discussions for Organization of O & M section and financial planning/records, etc. ② Survey of Popua P/S (Specifications of Equipment/machineries, Operation records, etc.) ③ Confirmation of Vaini PV site (Clearing situation of the site, Topographic survey points, etc.)	Nuku'alofa
5.	22 Sep.(Sat)	① Technical discussions with TPL 1) Explanation of the analysis results for battery, grid control system, etc. 2) Explanation of the Environmental comparisons such as Zero option, etc. 3) Discussions for Organization of O & M section and financial planning/records, etc. ② Survey of Popua P/S (Specifications of Equipment/machineries, Operation records, etc.) ③ Collection of amount of isolation data ④ Confirmation of Topographic survey points at Popua PS. ⑤ Collection of Local construction cost	Nuku'alofa
6.	23 Sep.(Sun)	① Internal meeting ② Arranging the data and information collecting ③ Local market survey	Nuku'alofa

No.	Date	Consultant members Nishikawa, Fujii, Satoh, Kurashima, Kondo, Nogami, Takashima, Ohara, Wada, Yamakawa	Stay at
7.	24 Sep.(Mon)	① Technical discussions with TPL 1) Explanation of the analysis results for grid control system, battery capacities, etc. 2) Explanation of the Environment and social consideration (scoping plan, etc.) 3) Discussions for Organization of O & M section and financial planning/records, etc. ② Survey of Popua P/S (Specifications of Equipment/machineries, Operation records, etc.) ③ Collection of amount of isolation data ④ Confirmation of Topographic survey and soil investigation works at Vaini PV site.. ⑤ Collection of Local construction cost	Nuku’alofa
8.	25 Sep.(Tue)	① Report to TERM about Progress of 2nd field survey, and discussion for Organization and budget of Term. ② Technical discussions with TPL 1) Micro grid controller, capacity of Batteries etc. 2) Explanation of the Environment and social consideration (scoping plan, etc.) 3) Discussions for Organization of O & M section and financial planning/records, etc. ③ Report to JICA about Progress of 2nd field survey. ④ Distribution lines survey ⑤ Survey of Local contractor situations	Nuku’alofa
9.	26 Sep.(Wed)	① Continuing discussions with TPL ② Continuing survey of Popua P/S ③ Continuing discussions with TPL and MLECCNR for Environment and social consideration ④ Continuing the progress of Topographic survey and Soil investigation.	Nuku’alofa
10.	27 Sep.(Thu)	① Continuing discussions with TPL ② Continuing survey of Popua P/S ③ Continuing discussions with TPL and MLECCNR for Environment and social consideration ④ Continuing confirmation of Topographic survey and Soil investigation.	Nuku’alofa
11.	28 Sep.(Fri)	① Continuing discussions with TPL ② Continuing survey of Popua P/S ③ Collecting the data and information for Maps, Weather information, Activities of other donors ④ Continuing discussions with TPL and MLECCNR for Environment and social consideration ⑤ Continuing the progress of Topographic survey and Soil investigation.	Nuku’alofa
12.	29 Sep.(Sat)	① Continuing survey of Popua P/S ② Collecting the data and information for Maps, Weather information, Activities of other donors, Local contractor, Local market, etc. ③ Preparation of Field Report	Nuku’alofa
13.	30 Sep.(Sun)	① Internal meeting ② Arranging the data and information collecting ③ Preparation of Field Report	Nuku’alofa
14.	01 Oct.(Mon)	① Supplementary survey for each assignment ② Preparation of Field Report	Nuku’alofa
15.	02 Oct.(Tue)	① Supplementary survey for each assignment ② Preparation of Field Report	Nuku’alofa
16.	03 Oct.(Wed)	① Supplementary survey for each assignment ② Preparation of Field Report	Nuku’alofa
17.	04 Oct.(Thu)	① Explanation of Field Report to TPL and TERM ② Correction of Field Report (If any) ③ Supplementary survey	Nuku’alofa
18.	05 Oct.(Fri)	① Obtaining the Confirmation of Field Report from TERM & TPL ② Report to JICA Tonga Office ③ Report to the Embassy of Japan to Tonga	Nuku’alofa
19.	06 Oct.(Sat)	① Trip from Nuku’alofa (10:20) to Auckland (12:20) by NZ-273}	Auckland
20.	07 Oct.(Sun)	① Trip from Auckland (09:25) to Tokyo (16:50) by NZ-099	Japan

(3) Third Field Survey

No	Date	JICA members	Consultant members	Stay at
		Tanaka, Sakamoto	Nishikawa, Kurashima, Nogami	
1.	14 Dec.(Fri)		① Trip from Tokyo (18:25) to Auckland (09:15+1) by NZ-090	On flight
2.	15 Dec.(Sat)		① Trip from Auckland (14:30) to Nuku'alofa (18:30) by NZ-974	Nuku'alofa
3.	16 Dec.(Sun)	① Trip from Tokyo (18:25) to Auckland (09:05+1) by NZ-090	① Visit the Popua Power station and Vaini site ② Internal meeting	Nuku'alofa
4.	17Dec.(Mon)	① Arrival at Auckland (09:05) by NZ-090 *Stay at Auckland	① Courtesy call to JICA Tonga Office ② Explanation on discussion of Draft Final Report (DFR) and Equipment specifications	Nuku'alofa
5.	18 Dec.(Tue)	① Trip from Auckland (09:40) to Nuku'alofa (12:30) by NZ-970 ② Meeting with TPL ③ Internal Meeting ④ Site visit (Popua)	① Technical discussions with TERM and TPL ② Meeting with TPL ③ Internal Meeting ④ Site visit (Popua)	Nuku'alofa
6.	19 Dec.(Wed)	① Discussion of Draft Minute of Meetings (M/M) with TERM and TPL ② Collection of M/M ③ Site visit (Vaini, Wind Turbine Candidate Sites)		Nuku'alofa
7.	20 Dec.(Thu)	① Signing of M/M with TERM, TPL and Ministry of Finance & National Planning ② Report to the Embassy of Japan and JICA Tonga Office		Nuku'alofa
8.	21 Dec.(Fri)	① Trip from Nuku'alofa (11:00) to Auckland (14:00) by NZ- 973		Auckland
9.	22 Dec.(Sat)	① Trip from Auckland(09:45) to Tokyo (16:55) by NZ - 099		

A-3 List of Parties Concerned

3. List of Parties Concerned

Tonga Energy Road Map (TERM)

Mr. 'Inoke Finau Vala	Director
Mr. 'Akau' Ola	Term-C Advisor
Mr. Ofa Sefana	Acting Energy Planning Specialist
Mr. Slua Aatu	Environmental Information Officer
Mr. Moleni Tuuholoaki	Acting Director of Meteorology
Ms. Katherine Bakes	Operations Officer (World Bank)
Mr. Shreejan Pandey	M.E. Research Scholar (EPE Entre)
Mr. Feleti ka Wolfgramm	Statistician

Ministry of Finance and National Planning

Aid Management Division

Ms. Natalia Palu Latu	Principal Economist

Ministry of Land, Environment, Climate Change and Natural Resources (MLECCNR)

Resources Department of Energy Section

*[1]Mr. Ofa Sefana	Acting Energy Planning Specialist

Department of Environment and Climate Change

Ms. Mafile'o Masi	Acting Deputy Director
Ms. Kate Mcpherson	Environment Legislation Policy Officer
Ms. Lesieli Tuivai	Ecologist, Environmentalist

Planning & Urban Management Agency

Mr. 'Atunaisa. M. Fetokai	Deputy Physical Planner
Mr. Tevita L. Fotu	Urban Planner

LGIS Unit

Mr. Richard Atelea Kautoke	Sen. GIS Specialist

Ministry of Infrastructure

Laboratory, Civil Engineering Department

Mr. Ringo K Fa'oliu	CEO for Infrastructure
Mr. 'Isileli. V. Tu'itupou	Director for Building Services & Control Division
Mr. Ken Robinson	Material Engineer

Tonga Meteorological Service

*[1]Mr. Moleni Tuuholoaki	Acting Director of Meteorology

Tonga Power Limited (TPL)

Mr. John Van Brink	Chief Executive
Mr. Lano Fonua	Strategic Initiatives Manager
Mr.Michael Lani 'Ahokava	Power Generation Manager

Mr. Murray Sheerin	Power Station Superintendent
Mr. Ian Skelton	Planning and Design Manager
Mr. Nikolasi Fonua	Business Development Engineer

Tonga Institute of Science and Technology

Mr. Samuela Matakaiongo	Deputy Principal

School of Engineering and Construction

Mr. Nonga Soakai	Principal of School
Mr. Tevita Tali Vakalahi	Acting Deputy Principal

Embassy of Japan

Mr. Yasuo Takase	Ambassador of Japan
Mr. Yoshimitsu Kawata	Counsellor
Ms. HanakoMasuhara	Researcher/Adviser

JICA Tonga Office

Mr. Makoto Tsujimoto	Resident Representative
Mr. Shigeki Ishigaki	Project Formulation Advisor (Program Support)
Mr. Kaname Ishiguro	Project Formulation Advisor

Geo Recycling

Mr. Fillimone Tu'ikolovato	Auto Mechanic Specialist & Owner
Ms. 'Ofa Tu'ikolovatu	Managing Director

CMA Corporation Limited, New Zealand

Mr. Mr. Brett Howlett	General Manager

Meridian Energy Limited

Mr. Murray Hill	Solar Project Development Manager

A & S Limited

Mr. Tukio Afeaki	Contracts Manager

A-4 Minutes of Meetings

THE MINUTES OF MEETINGS

ON

THE MISSION FOR THE PREPARATORY SURVEY

ON

THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

IN

THE KINGDOM OF TONGA

AGREED UPON BETWEEN

THE GOVENMENT OF THE KINGDOM OF TONGA

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Nuku'alofa, 30th August, 2012

Mr. 'Inoke Finau Vala
TERM-IU Director
Tonga Energy Road Map Agency
the Kingdom of Tonga

Mr. Hiroshi SUMIYOSHI
Leader
Preparatory Survey Team
Japan International Cooperation Agency

Witness

Ms. Lesieli Tufui Faletau
Acting Secretary
Ministry of Finance and National Planning

Witness

Mr. John Van Brink
Chief Executive
Tonga Power Limited

The government of The Kingdom of Tonga (hereinafter referred to as "GoT") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") have made several preliminary discussions in order to identify priority projects in the field of power sector, and agreed to make preparation for the Project for Introduction of a Micro-Grid System with Renewable Energy (hereinafter referred to as "the Project"). Accordingly, JICA dispatched a mission on the Project (hereinafter referred to as "the JICA Mission") to The Kingdom of Tonga from 14th August, 2012 to 1st September, 2012 in order to develop scope and implementing arrangements of a further survey which will study outline design of the Project (hereinafter referred to as "the Preparatory Survey"). The scope and implementing arrangements of the Preparatory Survey are described in the Appendix 1. The main points discussed during its visit are described in the Appendix 2.

It should be noted that implementation of the Preparatory Survey does not imply any decision or commitment by JICA to extend its grant for the project at this stage.

Appendix 1: Scope and Implementing Arrangements of the Preparatory Survey
Appendix 2: Main Points Discussed
Appendix 3: List of Attendants

Appendix 1

SCOPE AND IMPLEMENTING ARRANGEMENTS OF THE PREPARATORY SURVEY

I. BACKGROUND AND OBJECTIVES OF THE PREPARATORY SURVERY

In April of 2012, GoT made a request for Grant Aid for the Project to the Government of Japan (GoJ). GoJ decided to conduct the Preparatory Survey and entrusted JICA to examine the viability of the Project and sent the Survey team, headed by Mr. Hiroshi SUMIYOSHI, Director, Energy and Mining Division, Natural Resources and Energy Group, Industrial Development and Public Policy Department, JICA.

II. OBJECTIVES OF THE PROJECT

The project aims to develop and introduce a Micro-Grid System with large scale of renewable energy in order to reduce consumption of fossil fuel for generating electricity, and to stabilize electricity.

The project will be conducted under the Japanese Grant Aid Program aiming at promoting "Green Growth", which the GoJ puts stress on, by introducing Japanese Technology.

The project will also contribute to achievement of Tonga Energy Road Map (TERM)-objective.

III. ITEMS REQUESTED BY GoT

1. Project Site
   Vaini, and Popua Power Station, Popua, in Tongatapu Island
   (shown in Annex 1 and 2)

2. Responsible Organization
   Tonga Energy Road Map Agency (TERM-A)

3. Executing Agency
   Tonga Power Limited (The organization chart is shown in Annex 3.) as owner of the affected and new assets.
   *TERM Implementation Unit (TERM-IU) will have oversight of the Project.

4. Materials and services
   GoT finally requested to GoJ the following components to achieve TERM.

Outline of the final Request

Item	Components
Micro grid controller	• Generation and network control system integrated into TPL's SCADA at Popua power station • IP broadband and/or mesh type communications network that overlies TPL's Tongatapu network, connecting remote generation to the Popua SCADA system and micro grid controllers. • Integration of battery or capacitive storage and load flow "smoothing" algorithms to monitor and control field assets and enable future demand side management
Storage System (Batteries)	• Batteries and controller located at either Popua or at Vaini PV Site, controlling energy flows and quality, and optimizing efficiency of the diesel generators • Conversion of the TPL 2.88 MW MAK diesel generator governor to load following capability (requires manufacturer's involvement to modify governors, TPL has discussed requirements and scope with the manufacturer)
Solar PV system (1MWp)	• A single solar PV array at Vaini, in central Tongatapu, injecting into the TPL 11kV network, including spares • Network voltage management (regulator or other dynamic support)
Operation & Maintenance of the equipment	• Training TERM-IU staff and TPL staff • Operating and maintenance manuals and process documentation • O & M support

IV. SURVEY AREA

Tongatapu Island, the Kingdom of Tonga

V. SCOPE OF THE PREPARATORY SURVEY

1. Terms of Reference

The Team will formulate the Project so as to contribute to achievement of TERM.

The Team will examine carefully potential of wind power and photovoltaic generation in Tongatapu, and control method of the micro-grid system and capacity of power storage system introduced under the Project.

Based on the results of the Survey and discussion with the Tongan side, the Team will design the micro-grid system to reduce consumption of fossil fuel in power generation effectively.

The Preparatory Survey shall cover the following items:

(1) Implementation framework
(2) Requested components of the Project and their Priority
(3) Securement of lands for the Project
(4) Environmental and social considerations
(5) Positive impact of the Project and objectively verifiable indicators of the Project
(6) Technical Conditions for the Project
(7) General Information of Electric Power Sector
(8) Major Undertaking, including Tax and levy system
(9) Local conditions and capability for procurement, construction, installation and transportation
(10) Activities of other donors

(11)Soft Component

(12)Maintenance Contract

2. Desirable specialists for the Preparatory Survey

JICA will select and dispatch a survey team to carry out the Preparatory Survey. The team will include the specialists of the following field;.

(1) Distribution System Design

(2) Operation of Diesel Engine Generator

(3) Micro-Grid System (Grid Control, and Grid Stability Analysis)

(4) Renewable Energy

(5) Battery Equipment Plan

(6) Natural Condition Survey

(7) Social and Environmental Considerations

(8) Procurement Plan and Cost Estimation

(9) Economic and Financial Analysis

VI. SCHEDULE OF THE PREPARATORY SURVEY

The Preparatory Survey will be carried out in accordance with the tentative schedule attached in the Annex 4. The schedule may be subject to change during the preparation and the course of the survey.

VII. REPORTS

JICA will prepare and submit following reports in English to GoT.

1. Inception Report:

3 copies will be submitted at the commencement of the first work period in the Kingdom of Tonga.

2. Draft Final Report:

3 hard copies and soft copy (1copy is for TERM, another copy is for TPL and the other copy is for GoT) will be submitted 4 months after the commencement of the Preparatory Survey.

This report will cover:

(1) Outline of the Project,

(2) Basic Design of the Project,

(3) Outline of the undertakings of Tongan side,

(4) Operation and maintenance plan for the Project, and

(5) Cost estimation.

GoT shall submit its comments within one month after the receipt of the Draft Final Report.

3. Final Report:

3 hard copies and soft copy (1copy is for TERM, another copy is for TPL and the other copy is for GoT) will be submitted within one month after the receipt of the comments on the Draft Final Report.

VIII. JAPAN'S GRANT AID SCHEME

GoT understands the Japan's Grant Aid Scheme explained by the JICA Mission as described in Annex 5,6 and 7.

IX. UNDERTAKINGS OF THE GOVERNMENT OF THE KINGDOM OF TONGA

GoT shall act as a counterpart agency to the survey team and also as a coordinating body with other organizations concerned for the smooth implementation of the Preparatory Survey.

GoT shall, at its own expense, provide the survey team with the following items in cooperation with other organizations concerned:

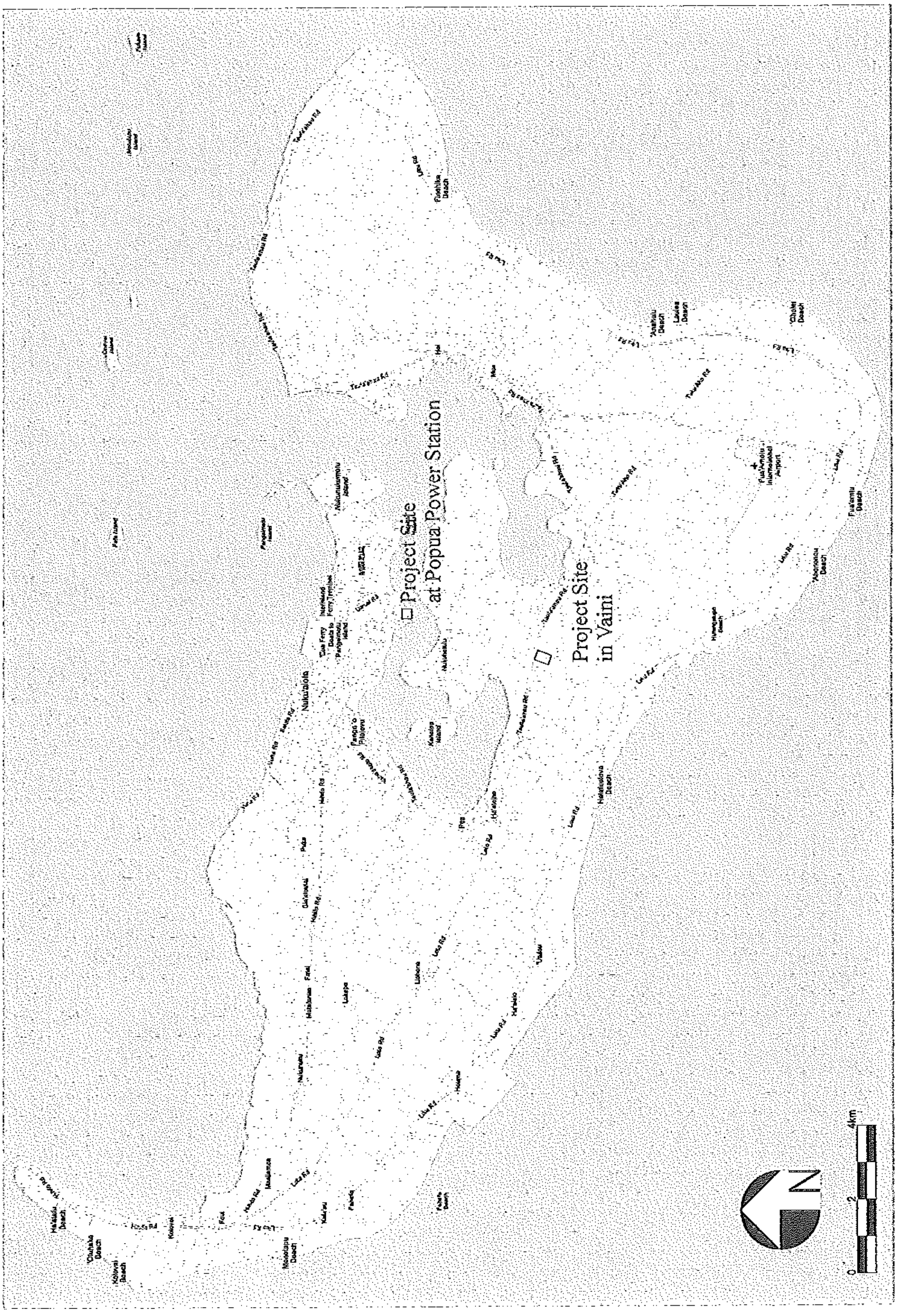
(1) security-related information as well as measures to ensure the safety of the survey team;
(2) information as well as support in obtaining medical service;
(3) data and information related to the Preparatory Survey;
(4) counterpart personnel;
(5) suitable office space with necessary equipment and secretarial service;
(6) credentials or identification cards;
(7) entry permits necessary for the survey team members to conduct field surveys;
(8) support in making transportation arrangements;
(9) support in obtaining other privileges and benefits if necessary;
(10)assist the team in custom clearance, exempt from any duties with respect to equipment, instruments, tools and other articles to be brought into and out of Tonga in connection with the implementation of the survey; and
(11) GoT shall bear claims, if any arises, against the members of the survey team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in implementation of the Preparatory Survey, except when such claim arise from gross negligence or willful misconduct on the part of the member of the survey team.

X. CONSULTATION

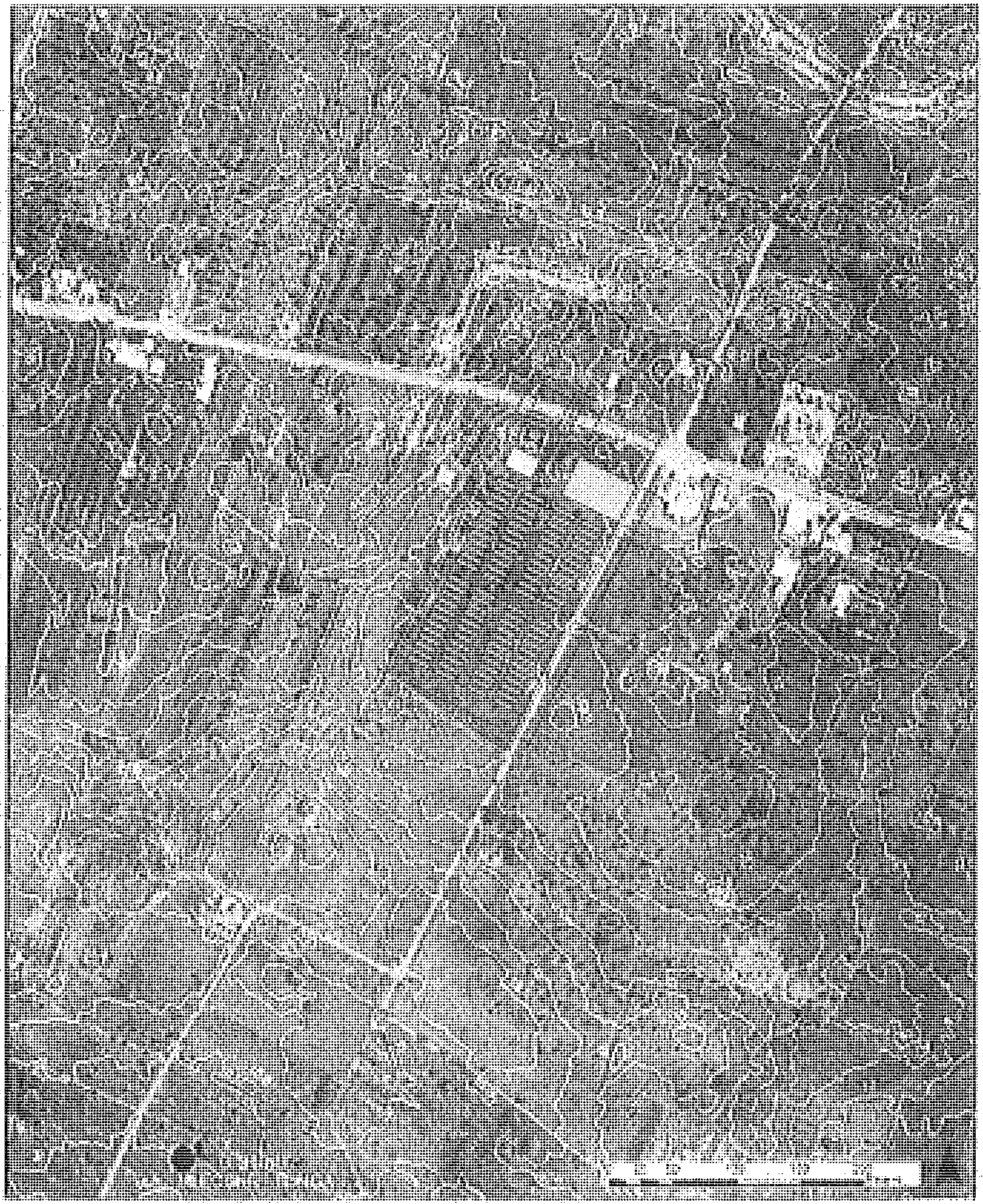
JICA and the GoT shall consult with each other in respect of any matter that may arise from or in connection with the Preparatory Survey.

END

Annex 1: Project Site
Annex 2: Vaini PV Site
Annex 3: Organization Chart of TPL
Annex 4: Schedule of the Preparatory Survey
Annex 5 Japan's Grant AID Scheme
Annex 6: Flow Chart of Japan's Grant AID Procedures
Annex 7: Major undertakings to be taken by each Government



Project Site



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CANDIDATE PHOTOVOLTAIC SITE

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Senior Management – Chart 1

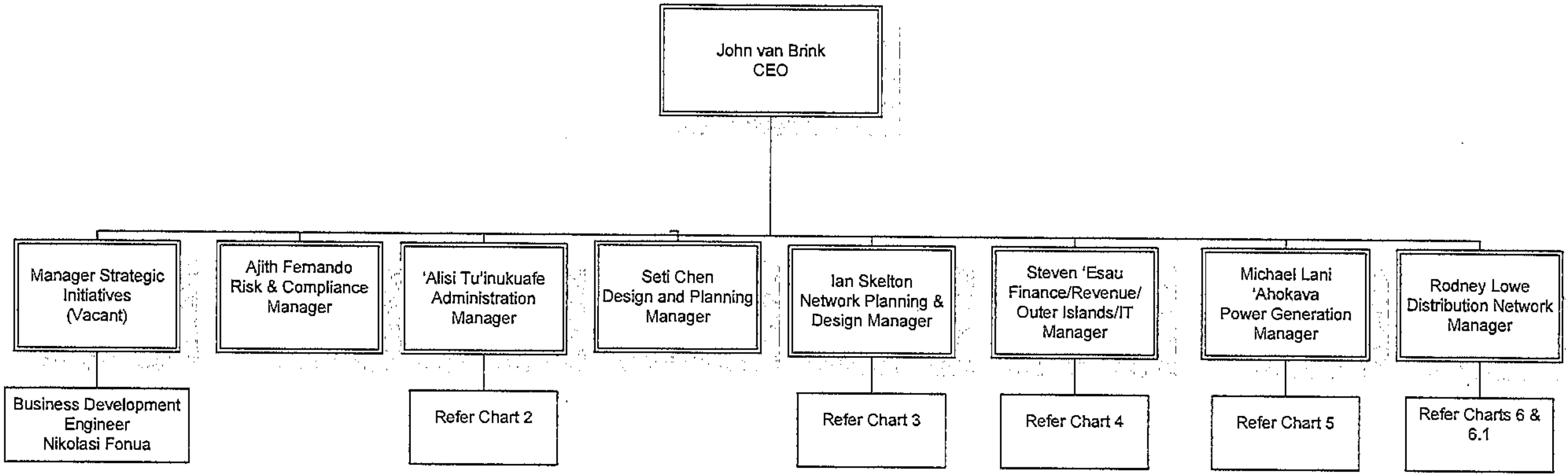
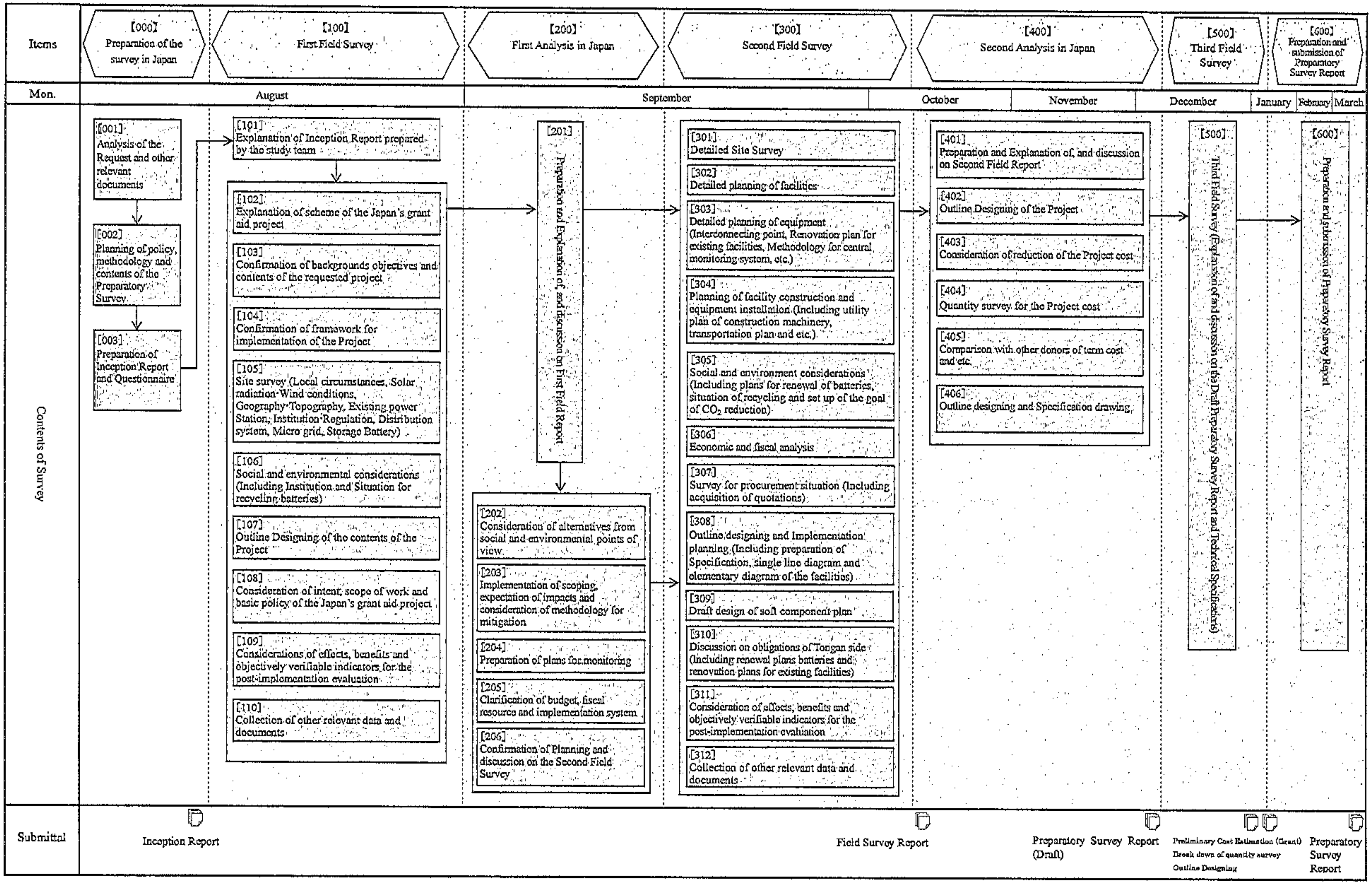


	Chart 1	Chart 2	Chart 3	Chart 4	Chart 5	Chart 6	Chart 6.1	Total
Established	9	6	13	40	20	48	11	147
Occupied	9	6	13	40	20	48	11	147
Vacancy	1	0	0	1	0	0	0	2
Trainees	0	0	2	0	1	0	4	7
Casuals	0	0	1	0	0	8	0	9



Schedule of the Preparatory Survey

JAPAN'S GRANT AID

The Government of Japan (hereinafter referred to as "the GOJ") is implementing the organizational reforms to improve the quality of ODA operations, and as a part of this realignment, a new JICA law was entered into effect on October 1, 2008. Based on this law and the decision of the GOJ, JICA has become the executing agency of the Grant Aid for General Projects, for Fisheries and for Cultural Cooperation, etc.

The Grant Aid is non-reimbursable fund provided to a recipient country to procure the facilities, equipment and services (engineering services and transportation of the products, etc.) for its economic and social development in accordance with the relevant laws and regulations of Japan. The Grant Aid is not supplied through the donation of materials as such.

1. Grant Aid Procedures

The Japanese Grant Aid is supplied through following procedures:

・Preparatory Survey
  - The Survey conducted by JICA
・Appraisal &Approval
  -Appraisal by the GOJ and JICA, and Approval by the Japanese Cabinet
・Authority for Determining Implementation
  -The Notes exchanged between the GOJ and a recipient country
・Grant Agreement (hereinafter referred to as "the G/A")
  -Agreement concluded between JICA and a recipient country
・Implementation
  -Implementation of the Project on the basis of the G/A

2. Preparatory Survey

(1) Contents of the Survey

The aim of the preparatory Survey is to provide a basic document necessary for the appraisal of the Project made by the GOJ and JICA. The contents of the Survey are as follows:

- Confirmation of the background, objectives, and benefits of the Project and also institutional capacity of relevant agencies of the recipient country necessary for the implementation of the Project.

- Evaluation of the appropriateness of the Project to be implemented under the Grant Aid Scheme from a technical, financial, social and economic point of view.
- Confirmation of items agreed between both parties concerning the basic concept of the Project.
- Preparation of an outline design of the Project.
- Estimation of costs of the Project.

The contents of the original request by the recipient country are not necessarily approved in their initial form as the contents of the Grant Aid project. The Outline Design of the Project is confirmed based on the guidelines of the Japan's Grant Aid scheme.

JICA requests the Government of the recipient country to take whatever measures necessary to achieve its self-reliance in the implementation of the Project. Such measures must be guaranteed even though they may fall outside of the jurisdiction of the organization of the recipient country which actually implements the Project. Therefore, the implementation of the Project is confirmed by all relevant organizations of the recipient country based on the Minutes of Discussions.

(2) Selection of Consultants

For smooth implementation of the Survey, JICA employs (a) registered consulting firm(s). JICA selects (a) firm(s) based on proposals submitted by interested firms.

(3) Result of the Survey

JICA reviews the Report on the results of the Survey and recommends the GOJ to appraise the implementation of the Project after confirming the appropriateness of the Project.

3. Japan's Grant Aid Scheme

(1) The E/N and the G/A

After the Project is approved by the Cabinet of Japan, the Exchange of Notes(hereinafter referred to as "the E/N") will be singed between the GOJ and the Government of the recipient country to make a pledge for assistance, which is followed by the conclusion of the G/A between JICA and the Government of the recipient country to define the necessary articles to implement the Project, such as payment conditions, responsibilities of the Government of the recipient country, and procurement conditions.

(2) Selection of Consultants

In order to maintain technical consistency, the consulting firm(s) which conducted the Survey will be recommended by JICA to the recipient country to continue to work on the Project's implementation after the E/N and G/A.

(3) Eligible source country

Under the Japanese Grant Aid, in principle, Japanese products and services including transport or those of the recipient country are to be purchased. When JICA and the Government of the recipient country or its designated authority deem it necessary, the Grant Aid may be used for the purchase of the products or services of a third country. However, the prime contractors, namely, constructing and procurement firms, and the prime consulting firm are limited to "Japanese nationals".

(4) Necessity of "Verification"

The Government of the recipient country or its designated authority will conclude contracts denominated in Japanese yen with Japanese nationals. Those contracts shall be verified by JICA. This "Verification" is deemed necessary to fulfill accountability to Japanese taxpayers.

(5) Major undertakings to be taken by the Government of the Recipient Country

In the implementation of the Grant Aid Project, the recipient country is required to undertake such necessary measures as Annex.

(6) "Proper Use"

The Government of the recipient country is required to maintain and use properly and effectively the facilities constructed and the equipment purchased under the Grant Aid, to assign staff necessary for this operation and maintenance and to bear all the expenses other than those covered by the Grant Aid.

(7) "Export and Re-export"

The products purchased under the Grant Aid should not be exported or re-exported from the recipient country.

(8) Banking Arrangements (B/A)

a) The Government of the recipient country or its designated authority should open an account under the name of the Government of the recipient country in a bank in Japan (hereinafter referred to as "the Bank"). JICA will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by the Government of the recipient country or its designated authority under the Verified Contracts.

b) The payments will be made when payment requests are presented by the Bank to JICA under an Authorization to Pay (A/P) issued by the Government of the recipient country or its designated authority.

(9) Authorization to Pay (A/P)

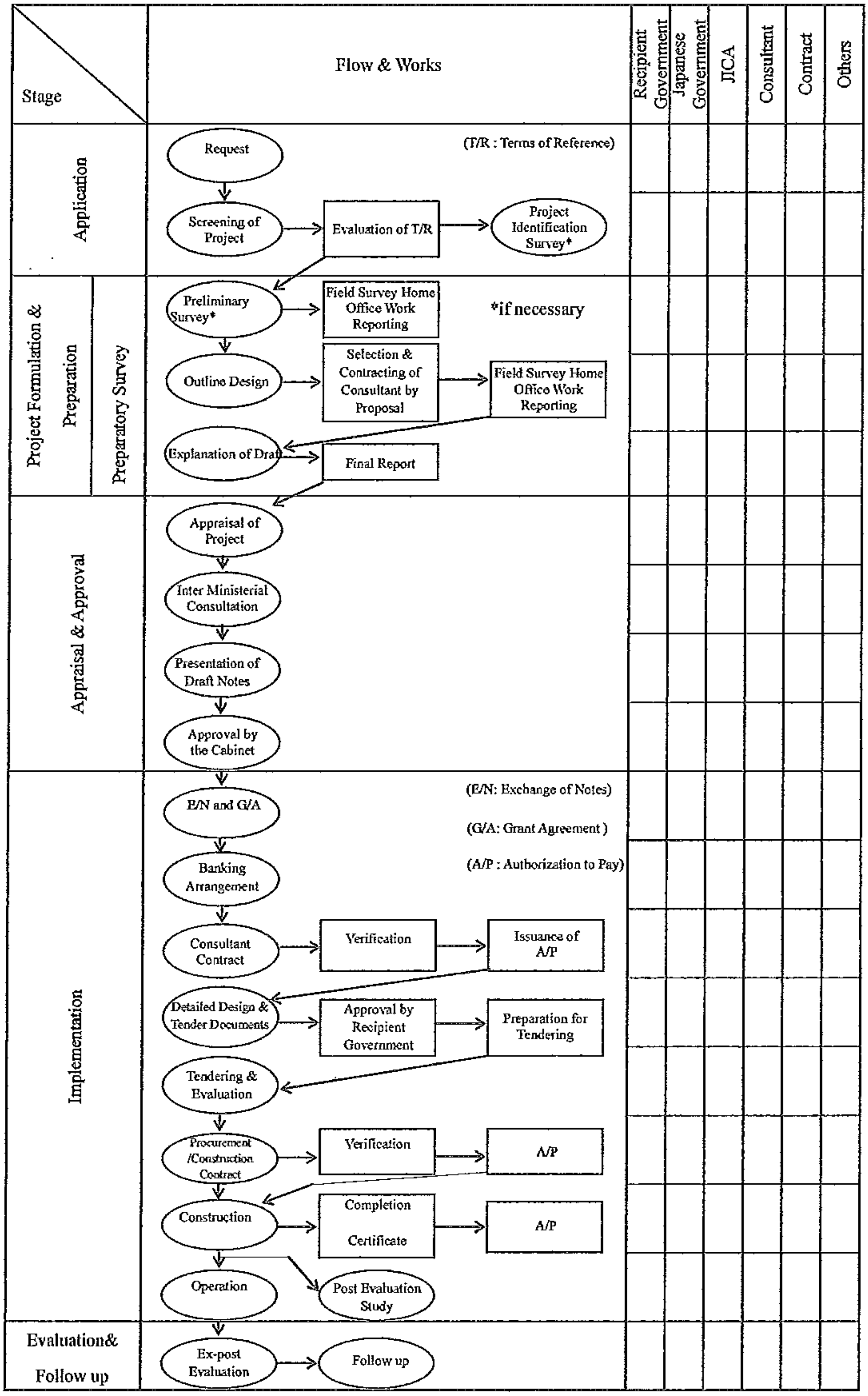
The Government of the recipient country should bear an advising commission of an Authorization to Pay and payment commissions paid to the Bank.

(10) Social and Environmental Considerations

A recipient country must carefully consider social and environmental impacts by the Project and must comply with the environmeutal regulations of the recipient country and JICA socio-environmental guidelines.

(End)

Flow Chart of Japan's Grant Aid Procedures



Major undertakings to be taken by each Government

No.	Items	To be covered by Grant Aid	To be covered by Recipient Side
1	to secure [a lot] /[lots] of land necessary for the implementation of the Project and to clear the [site]/[sites];		●
2	To construct the following facilities		
	1) The building	●	
	2) The gates and fences in and around the site		●
	3) The parking lot	●	
	4) The road within the site	●	
	5) The road outside the site		●
3	To provide facilities for distribution of electricity, water supply and drainage and other incidental facilities necessary for the implementation of the Project outside the [site]/[sites]		
	1)Electricity		
	a. The distributing power line to the site		●
	b. The drop wiring and internal wiring within the site	●	
	c. The main circuit breaker and transformer	●	
	2) Water Supply		
	a. The city water distribution main to the site		●
	b. The supply system within the site (receiving and elevated tanks)	●	
	3) Drainage		
	a. The city drainage main (for storm sewer and others to the site)		●
	b. The drainage system (for toilet sewer, common waste, storm drainage and others) within the site	●	
	4) Gas Supply		
	a. The city gas main to the site		●
	b. The gas supply system within the site	●	
	5) Telephone System		
	a. The telephone trunk line to the main distribution frame/panel (MDF) of the building		●
	b. The MDF and the extension after the frame/panel	●	
	6) Furniture and Equipment		
	a. General furniture		●
	b. Project equipment	●	
4	To ensure prompt unloading and customs clearance of the products at ports of disembarkation in the recipient country and to assist internal transportation of the products		
	1) Marine (Air) transportation of the Products from Japan to the recipient country	●	
	2) Tax exemption and custom clearance of the Products at the port of disembarkation		●
	3) Internal transportation from the port of disembarkation to the project site	●	
5	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the recipient country with respect to the purchase of the products and the services [be exempted] / [be borne by the Authority without using the Grant]		●
6	To accord Japanese nationals whose services may be required in connection with the supply of the products and the services such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work		●
7	To ensure that [the Facilities and the products]/[the Facilities]/ [the products] be maintained and used properly and effectively for the implementation of the Project		●
8	To bear the following commissions paid to the Japanese bank for banking services based upon the B/A		
	1) Advising commission of A/P		●
	2) Payment commission		●
9	To give due environmental and social consideration in the implementation of the Project.		●
10	To bear all the above expenses, other than those covered by the Grant, necessary for the implementation of the Project		●

*1 B/A : Banking Arrangement, A/P : Authorization to pay) *2 If the environmental screening category is C, No. 10 is unnecessary

Appendix 2

THE MAIN POINTS DISCUSSED

(1) Wind Turbine Generation System

GoT originally requested the introduction of Wind Turbine Generation system (500kW) and Solar PV system (500kWp). According to the request, the Team surveyed the candidate sites of the Wind turbine generation system, selected by TPL and Ministry of Land, Environment ,Climate Change and Natural Resources (MLECCNR), and had series of discussions with their representatives about wind synopsis data, land owner ship, access roads, distribution lines to be connected, environmental constraint, etc. Survey of existing conditions on the environmental constraint takes one (1) year at minimum. Accordingly, it takes one and half (1.5) year approximately to obtain permission from Japanese authorities, taking into account the required time for data analysis, assessment of the environmental impact, information disclosure, stakeholder meetings, review of EIA and so on. The time required for the EIA procedure does not meet the project schedule.

As the results of discussions, both sides agreed that the Wind turbine generation system would not be adopted in the project component. However, the team agreed on the analysis of the potential of Wind Turbine Generation system at the candidate site from the data acquired through the survey.

(2) Solar PV system

Since the Wind turbine generation system is excluded from the project component, both sides agreed that the capacity of the Solar PV system at Vaini shall be approximately 1.0 MWp to aid the achievement of the TERM's target and to ensure the introduction of renewable energy as much as possible.

(3) The Tongan side agreed to obtain approval from Mamma Mai, existing solar PV system (1.3MWp) to connect signal cables to the photovoltaic system and send its generating conditions to a micro-grid controller of the Project at Popua Power Station controlling energy flows and quality, and optimizing efficiency of the diesel engine generators.

(4) It would be necessary to integrate load sharing system between Caterpillar and Mak generators in Popua Power Station to effectively compensate load fluctuation from solar PV system. The Preparatory Survey team requested the Tongan side to provide necessary information by Sep. 10th 2012 to analyze the behavior of integrated load sharing system and to study necessary equipment and specifications for the system. The Tongan side agreed to do so.

HS N

(5) In addition to the Annex 7, both sides agreed that the following matters are included in the Undertakings of the GoT side

1) Renewal of Battery system
2) Treatment of Used batteries
3) Concluding the maintenance contract for Micro-Grid system
4) Ensuring the installation site(s) for Solar PV generation system including Micro-grid controller(s), Batteries, Power conditioners, etc.
5) Implementation of EIA and acquisition of the Environmental permission

(6) Project Title

The Project Title in Application Form submitted by the GoT was "The TERM Development and Implementation of a Micro-Grid System to the TPL Grid of Tongatapu".

JICA and the GoT agreed to change the Project Title to "The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map".

Appendix 3

List of Attendants

Tonga Energy Road Map

Mr. 'Inoke Finau Vala	TERM-IU Director
Mr. 'Akau' Ola	Term-C Advisor
Mr. Ofa Sefana	Acting Energy Planning Specialist
Mr. Slua Aatu	Environmental Information Officer
Mr. Moleni Tuuholoaki	Acting Director of Meteorology
Ms. Katherine Bakes	Operations Officer (World Bank)

Tonga Power Limited

Mr. John Van Brink	Chief Executive
Mr. Lano Fonua	Strategic Initiatives Manager
Mr.Michael Lani 'Ahokava	Power Generation Manager
Mr. Murray Sheerin	Power Station Superintendent
Mr. Ian Skelton	Planning and Design Manager
Mr. Nikolasi Fonua	Business Development Engineer

Ministry of Land, Environment, Climate Change and Natural Resources

Department of Environment and Climate Change

Ms. Mafile'o Masi	Acting Deputy Director
Ms. Kate Mcpherson	Environment Legislation Policy Officer
Ms. Lesieli Tuivai	Ecologist, Environmentalist

Planning & Urban Management Agency

Mr. 'Atunaisa. M. Fetokai	Deputy Physical Planner
Mr. Tevita L. Fotu	Urban Planner

LGIS Unit

Mr. Richard Atelea Kautoke	Sen. GIS Specialist

Ministry of Infrastructure

Laboratory, Civil Engineering Department

Mr. Ken Robinson	Material Engineer

Japan International Cooperation Agency

Mr. Hiroshi SUMIYOSHI	Team Leader
Mr. Yoshimasa SAKAMOTO	Planning Management

Consultants

Mr. Mitsuhisa NISHIKAWA	Yachiyo Engineering Co., Ltd.
Mr. Kyoji FUJII	Yachiyo Engineering Co., Ltd.
Mr. Hidekazu SATO	Yachiyo Engineering Co., Ltd.
Mr. Shinya KONDO	West Japan Engineering Consultants, Inc.
Mr. Kazunari NOGAMI	Yachiyo Engineering Co., Ltd.
Mr. Kenji OHARA	Yachiyo Engineering Co., Ltd.
Mr. Shigeki TAKASHIMA	Yachiyo Engineering Co., Ltd.
Mr. Masao YAMAKAWA	Yachiyo Engineering Co., Ltd.

THE MINUTES OF MEETINGS

ON

THE MISSION FOR THE PREPARATORY SURVEY

ON

THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

IN

THE KINGDOM OF TONGA

AGREED UPON BETWEEN

THE GOVENMENT OF THE KINGDOM OF TONGA

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

(EXPLANATION ON DRAFT FINAL REPORT)

Nuku'alofa, 20th December, 2012

Mr. 'Inoke Finau Vala TERM-IU Director Tonga Energy Road Map Agency the Kingdom of Tonga	Mr. Hiroo TANAKA Leader Preparatory Survey Team Japan International Cooperation Agency
Mr. Winston Halapua Acting Deputy Secretary Aid Management Division Ministry of Finance and National Planning	Mr. John Van Brink for Chief Executive Tonga Power Limited

The government of The Kingdom of Tonga (hereinafter referred to as "GoT") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") have made several preliminary discussions in order to identify priority projects in the field of power sector, and agreed to make preparation for the Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map (hereinafter referred to as "the Project").

From August to October 2012, JICA dispatched the Survey Team to The Kingdom of Tonga; and through discussions, field surveys and the result of technical examination in Japan, JICA prepared the Draft Final Report of the Survey which included the outline design of the Project.

Accordingly, JICA dispatched a mission on the Project (hereinafter referred to as "the JICA Mission") to The Kingdom of Tonga from 15th December, 2012 to 21st December, 2012 in order to explain the Draft Final Report and to consult with the officials of concerned authorities in The Kingdom of Tonga (hereinafter referred to as "the Preparatory Survey"), which was headed by Mr. Hiroo TANAKA, Deputy Director General and Group Director for Energy and Mining, Industrial Development and Public Policy Department, JICA.

GoT and the JICA Mission have confirmed the main points discussed during its visit described in Appendix 1.

It should be noted that implementation of the Preparatory Survey does not imply any decision or commitment by JICA to extend its grant for the project at this stage.

Appendix 1: Main Points Discussed
Appendix 2: List of Attendants

Appendix 1

THE MAIN POINTS DISCUSSED

I. CONTENTS OF THE DRAFT FINAL REPORT

GoT agreed and accepted in principle the contents of the Draft Final Report and the Draft Technical Specifications of the Survey explained by the Team.

II. RESPONSIBLE AND IMPLEMENTING ORGANIZATIONS

1. Responsible Organization

Tonga Energy Road Map Agency (TERM-A)

2. Executing Agency

Tonga Power Limited (The organization chart is shown in Annex 3. as owner of the affected and new assets.

*TERM Implementation Unit (TERM-IU) will have oversight of the Project.

III. COMPONENTS OF THE PROJECT

The components of this project are as follows;

	Components	Quantity
Procurement and Installation	1.Micro-grid system at Popua Power Station	
	1.1 Micro-grid control system	1 lot
	1.2 Power storage system	Enough capacity supply 500 kW for 30 sec. from SOC 50 %
	1.3 Station service panel	1 set
	2. Micro-grid system at Vaini Project Site	
	2.1 Micro-grid control system	1 lot
	2.2 Power storage system	Enough capacity supply 500 kW for 30 sec. from SOC 50 %
	2.3 Photovoltaic system (PV system)	1,000 kWp
	2.4 11 kV interconnection switchgear	1 lot
	2.5 Station service panel	1 set
	3. Optical fiber communication system	Approx. 15 km
Procurement	4. 11 kV interconnection switchgear at Popua Power Station	1 lot
	5. Spare parts	1 set
Construction	a. Building for electrical equipment at Popua Power Station	Gross floor area: Approx. 100 m^2
	b. Foundation of Photovoltaic Arrays	1 lot
	c. Building for electrical equipment at Vaini Project Site	Gross floor area: Approx. 190 m^2

IV. JAPAN'S GRANT AID SCHEME

GoT reconfirmed the Japan's Grant Aid Scheme and the necessary measures to be taken by the Tongan side explained by the JICA Mission as described in Annex 4, 5 and 6. GoT will take the necessary measures, as described in Annex 6, for smooth implementation of the Project as prerequisites for the Japan's Grant Aid to be implemented.

V. PROJECT COST

GoT agreed that the cost for the Project should not exceed the amount agreed on Exchange of Notes (E/N). GoT also agreed that the cost for the Project contains procurement cost of equipment, transportation cost up to the Project site, installation cost and the Consultant fees.

VI. CONFIDENTIALITY OF THE PROJECT

1. Detailed specifications of the Facilities and Equipment

GoT and the JICA Mission agreed that all the information related to the Project including detailed drawings and specifications of the facilities and equipment and other technical information shall not be disclosed to any outside parties (i.e. outside of JICA and the Tongan side) before the conclusion of all contract(s) for the Project.

2. Confidentiality of the Cost Estimation

The JICA Mission explained the estimated cost of the Project as described in Annex 7. GoT and the JICA Mission agreed that the estimated cost for the Project should never be duplicated or disclosed to any outside parties (i.e. outside of JICA and the Tongan side) before tender for the Project. GoT understood that the estimated cost for the Project attached as Annex 7 is not the final and is subject to change as a result of examination through revision of the Outline Design Study.

VII. POSSIBILITY OF CHANGE IN SCOPE, SCHEDULE AND COST OF THE PROJECT

The JICA Mission stressed that the scope, the schedule, and the cost for the Project are tentative and subject to change due to the domestic circumstances in Japan and in Tonga. GoT understood it.

VIII. OTHER RELEVANT ISSUES

1. Customs and Tax Exemption

Based on the previous Minutes of Meetings signed on 30th August 2012, the Tongan side agreed that the Tongan side shall be responsible for the exemption of all customs, tax, levies and duties incurred in Tonga for implementation of the project.

2. Undertakings of the GoT side

Based on the previous Minutes of Meetings signed on 30th August 2012, both sides reconfirmed that the following matters are included in the Undertakings of the GoT side in addition to the Annex 6.

1) Replacement and proper disposal measure of the Power Storage systems
2) Concluding the maintenance contract for Micro-Grid system with the Japanese manufacturer of the Project equipment
3) Ensuring the installation site(s) for the Solar PV generation system including Micro-grid controller(s), Storage Systems, and Power conditioners, etc.
4) Implementation of EIA and acquisition of the Environmental permission by the end of March, 2013.

3. Connecting signal cables from the existing solar PV system

Based on the previous Minutes of Meetings signed on 30th August 2012, the Tongan side reconfirmed to obtain approval from Maama Mai, existing solar PV system (1.3MWp) to connect signal cables to the photovoltaic system, in order to send its generating conditions to a micro-grid controller of the Project at Popua Power Station.

4. Analysis of the potential of Wind Turbine Generation system

The Draft Final Report includes an analysis of the potential of Wind Turbine Generation systems at the candidate sites from the data acquired through the survey. The JICA Mission explained the contents to the Tongan side.

5. Consistency to the Tongan Policy for Renewable Energy

The Cabinet of Tonga dissolved in 2009 a policy goal of "increasing the proportion of renewable energy to 50% of the entire electricity supply by 2020". GoT also formulated a Tonga Energy Road Map 2010-2020 (TERM) as an implementation policy to achieve the policy goal. Both sides agreed that the Project is one of effective measure to realize the policy.

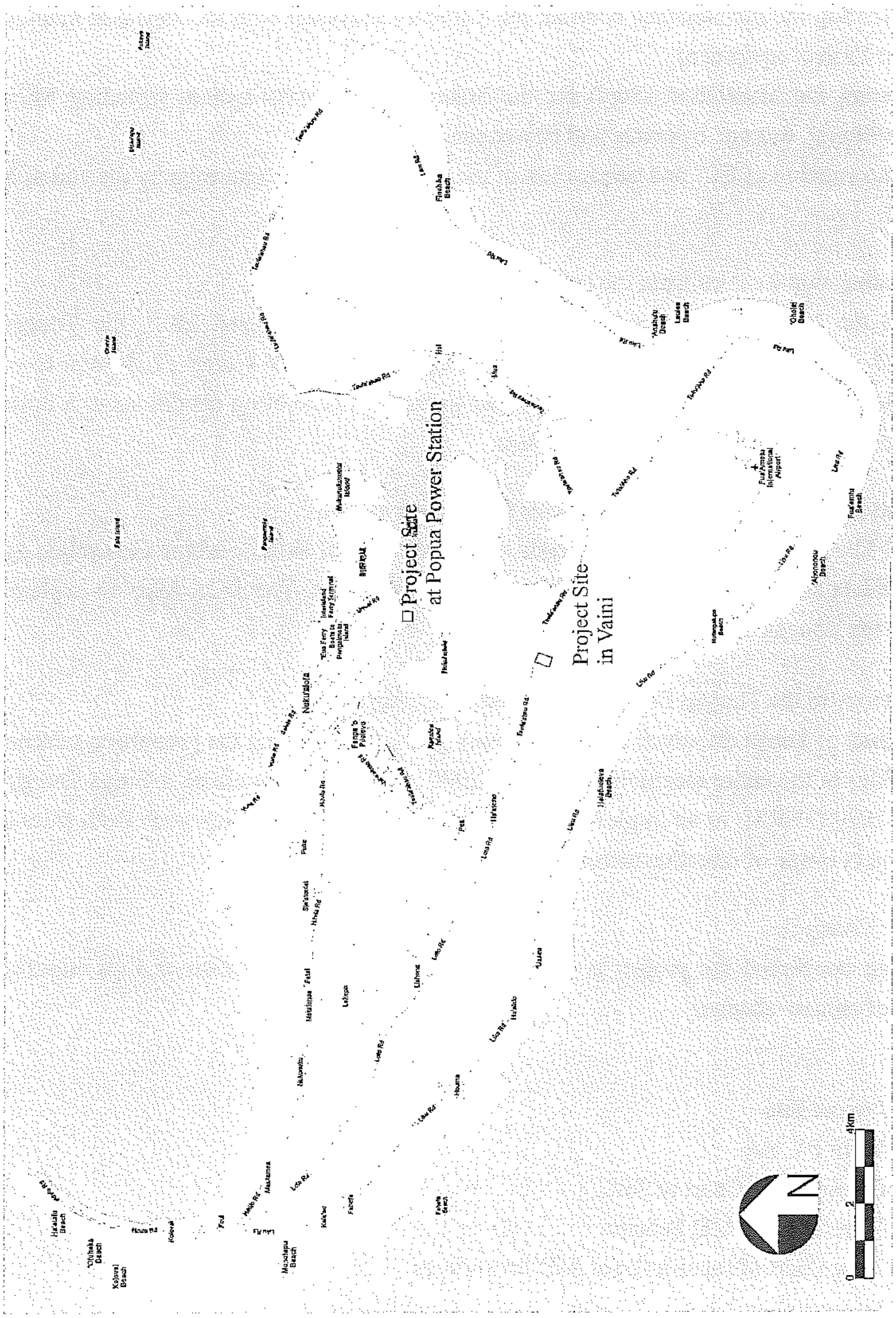
6. Climate Change

Both sides confirmed the project is expected to contribute to reduction of CO_2 emission and mitigation of climate change.

END

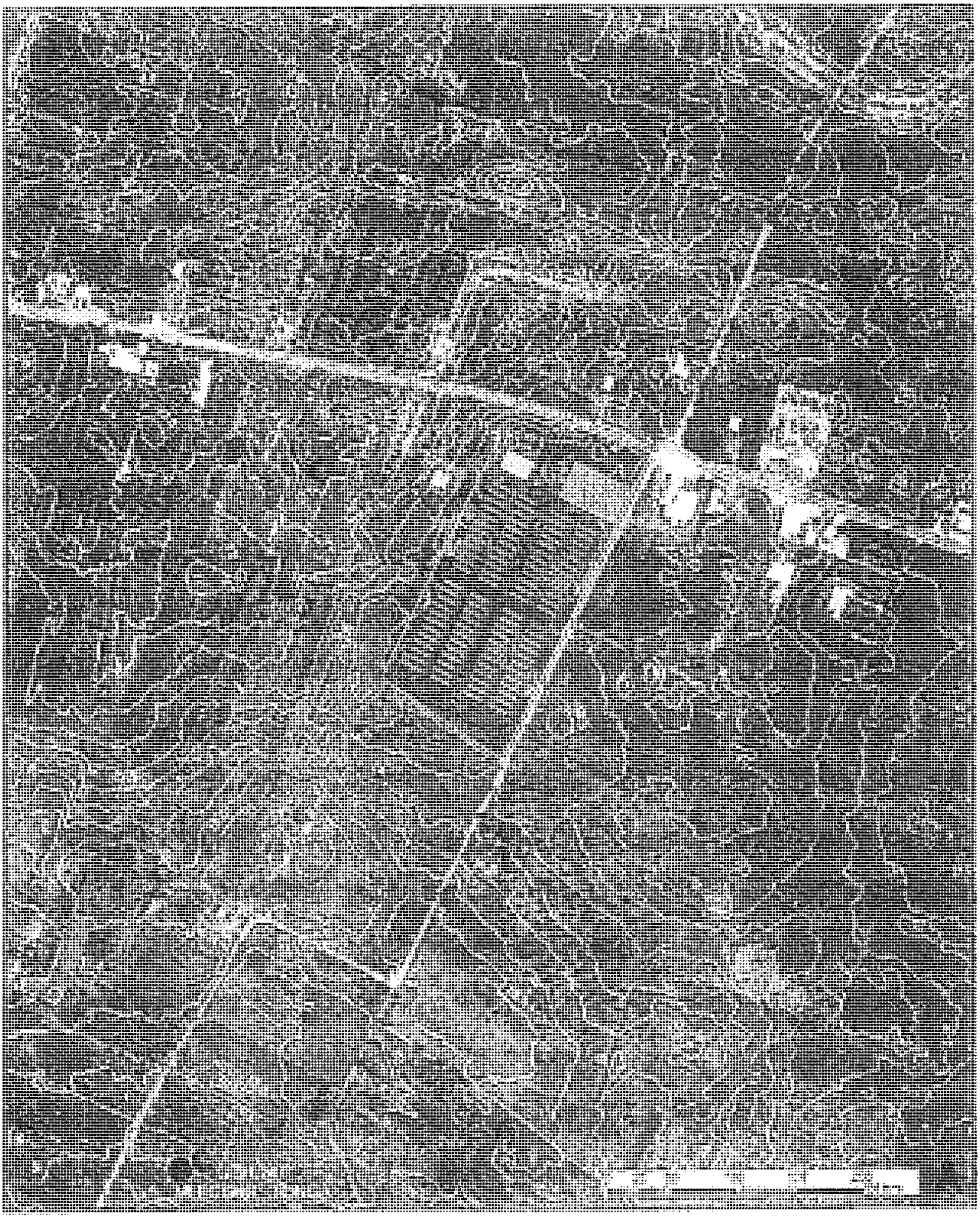
Annex 1: Project Site
Annex 2: Vaini PV Site
Annex 3: Organization Chart of TPL
Annex 4: Japan's Grant AID Scheme
Annex 5: Flow Chart of Japan's Grant AID Procedures
Annex 6: Major undertakings to be taken by each Government
Annex 7: Estimated Project Cost

Annex 1



Project Site

Annex 2



CANDIDATE PHOTOVOLTAIC SITE

Annex 3

Senior Management – Chart 1

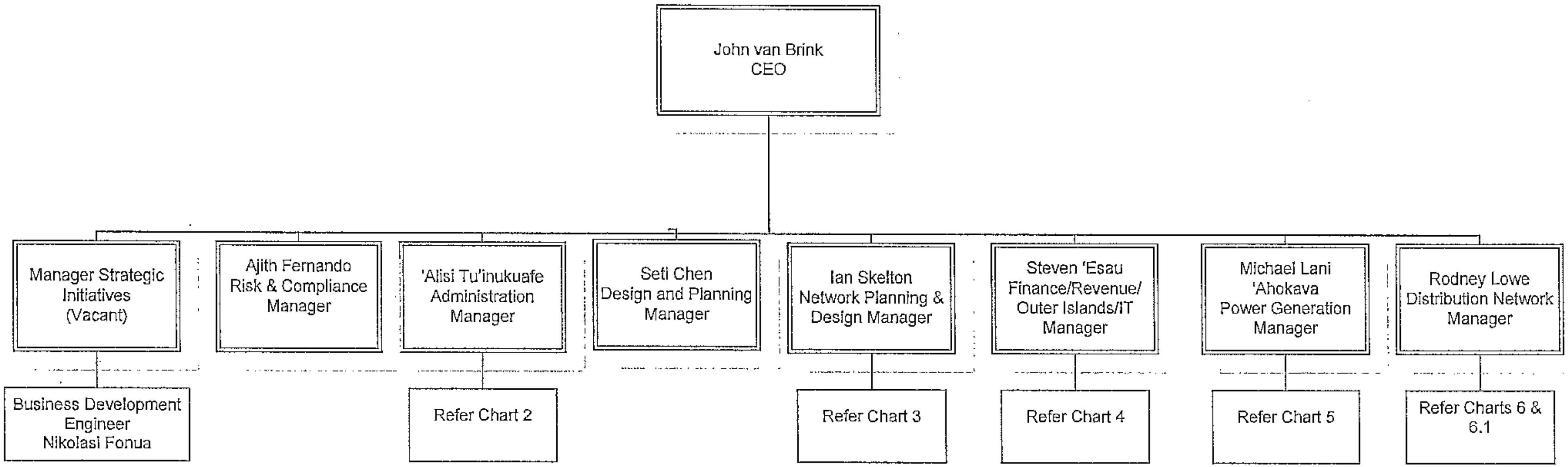


	Chart 1	Chart 2	Chart 3	Chart 4	Chart 5	Chart 6	Chart 6.1	Total
Established	9	6	13	40	20	48	11	147
Occupied	9	6	13	40	20	48	11	147
Vacancy	1	0	0	1	0	0	0	2
Trainees	0	0	2	0	1	0	4	7
Casuals	0	0	1	0	0	8	0	9

Annex 4

JAPAN'S GRANT AID

The Government of Japan (hereinafter referred to as "the GOJ") is implementing the organizational reforms to improve the quality of ODA operations, and as a part of this realignment, a new JICA law was entered into effect on October 1, 2008. Based on this law and the decision of the GOJ, JICA has become the executing agency of the Grant Aid for General Projects, for Fisheries and for Cultural Cooperation, etc.

The Grant Aid is non-reimbursable fund provided to a recipient country to procure the facilities, equipment and services (engineering services and transportation of the products, etc.) for its economic and social development in accordance with the relevant laws and regulations of Japan. The Grant Aid is not supplied through the donation of materials as such.

1. Grant Aid Procedures

The Japanese Grant Aid is supplied through following procedures:

- ･Preparatory Survey
  - - The Survey conducted by JICA
- ･Appraisal &Approval
  - -Appraisal by the GOJ and JICA, and Approval by the Japanese Cabinet
- ･Authority for Determining Implementation
  - -The Notes exchanged between the GOJ and a recipient country
- ･Grant Agreement (hereinafter referred to as "the G/A")
  - -Agreement concluded between JICA and a recipient country
- ･Implementation
  - -Implementation of the Project on the basis of the G/A

2. Preparatory Survey

(1) Contents of the Survey

The aim of the preparatory Survey is to provide a basic document necessary for the appraisal of the Project made by the GOJ and JICA. The contents of the Survey are as follows:

- Confirmation of the background, objectives, and benefits of the Project and also institutional capacity of relevant agencies of the recipient country necessary for the implementation of the Project.

- Evaluation of the appropriateness of the Project to be implemented under the Grant Aid Scheme from a technical, financial, social and economic point of view.
- Confirmation of items agreed between both parties concerning the basic concept of the Project.
- Preparation of an outline design of the Project.
- Estimation of costs of the Project.

The contents of the original request by the recipient country are not necessarily approved in their initial form as the contents of the Grant Aid project. The Outline Design of the Project is confirmed based on the guidelines of the Japan's Grant Aid scheme.

JICA requests the Government of the recipient country to take whatever measures necessary to achieve its self-reliance in the implementation of the Project. Such measures must be guaranteed even though they may fall outside of the jurisdiction of the organization of the recipient country which actually implements the Project. Therefore, the implementation of the Project is confirmed by all relevant organizations of the recipient country based on the Minutes of Discussions.

(2) Selection of Consultants

For smooth implementation of the Survey, JICA employs (a) registered consulting firm(s). JICA selects (a) firm(s) based on proposals submitted by interested firms.

(3) Result of the Survey

JICA reviews the Report on the results of the Survey and recommends the GOJ to appraise the implementation of the Project after confirming the appropriateness of the Project.

3. Japan's Grant Aid Scheme

(1) The E/N and the G/A

After the Project is approved by the Cabinet of Japan, the Exchange of Notes(hereinafter referred to as "the E/N") will be singed between the GOJ and the Government of the recipient country to make a pledge for assistance, which is followed by the conclusion of the G/A between JICA and the Government of the recipient country to define the necessary articles to implement the Project, such as payment conditions, responsibilities of the Government of the recipient country, and procurement conditions.

(2) Selection of Consultants

In order to maintain technical consistency, the consulting firm(s) which conducted the Survey will be recommended by JICA to the recipient country to continue to work on the Project's implementation after the E/N and G/A.

(3) Eligible source country

Under the Japanese Grant Aid, in principle, Japanese products and services including transport or those of the recipient country are to be purchased. When JICA and the Government of the recipient country or its designated authority deem it necessary, the Grant Aid may be used for the purchase of the products or services of a third country. However, the prime contractors, namely, constructing and procurement firms, and the prime consulting firm are limited to "Japanese nationals".

(4) Necessity of "Verification"

The Government of the recipient country or its designated authority will conclude contracts denominated in Japanese yen with Japanese nationals. Those contracts shall be verified by JICA. This "Verification" is deemed necessary to fulfill accountability to Japanese taxpayers.

(5) Major undertakings to be taken by the Government of the Recipient Country

In the implementation of the Grant Aid Project, the recipient country is required to undertake such necessary measures as Annex.

(6) "Proper Use"

The Government of the recipient country is required to maintain and use properly and effectively the facilities constructed and the equipment purchased under the Grant Aid, to assign staff necessary for this operation and maintenance and to bear all the expenses other than those covered by the Grant Aid.

(7) "Export and Re-export"

The products purchased under the Grant Aid should not be exported or re-exported from the recipient country.

(8) Banking Arrangements (B/A)

a) The Government of the recipient country or its designated authority should open an account under the name of the Government of the recipient country in a bank in Japan (hereinafter referred to as "the Bank"). JICA will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by the Government of the recipient country or its designated authority under the Verified Contracts.

b) The payments will be made when payment requests are presented by the Bank to JICA under an Authorization to Pay (A/P) issued by the Government of the recipient country or its designated authority.

(9) Authorization to Pay (A/P)

The Government of the recipient country should bear an advising commission of an Authorization to Pay and payment commissions paid to the Bank.

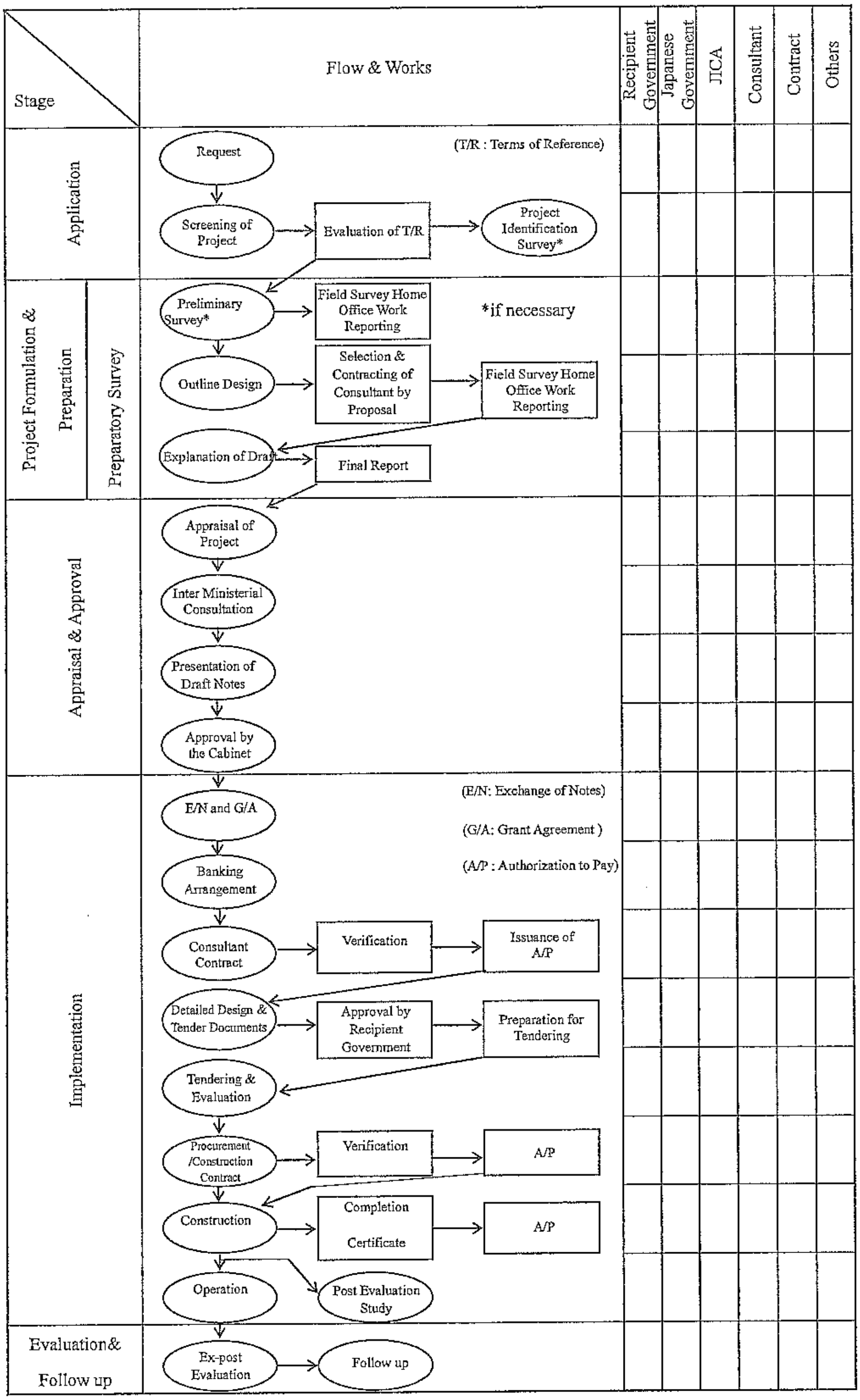
(10) Social and Environmental Considerations

A recipient country must carefully consider social and environmental impacts by the Project and must comply with the environmental regulations of the recipient country and JICA socio-environmental guidelines.

(End)

Annex 5

Flow Chart of Japan's Grant Aid Procedures



Annex 6

Major undertakings to be taken by each Government

No.	Items	To be covered by Grant Aid	To be covered by Recipient Side
1	to secure [a lot] /[lots] of land necessary for the implementation of the Project and to clear the [site]/[sites];		●
2	To construct the following facilities		
	1) The building	●	
	2) The gates and fences in and around the site		●
	3) The parking lot	●	
	4) The road within the site	●	
	5) The road outside the site		●
3	To provide facilities for distribution of electricity, water supply and drainage and other incidental facilities necessary for the implementation of the Project outside the [site]/[sites]		
	1)Electricity		
	a. The distributing power line to the site		●
	b. The drop wiring and internal wiring within the site	●	
	c. The main circuit breaker and transformer	●	
	2) Water Supply		
	a. The city water distribution main to the site		●
	b. The supply system within the site (receiving and elevated tanks)	●	
	3) Drainage		
	a. The city drainage main (for storm sewer and others to the site)		●
	b. The drainage system (for toilet sewer, common waste, storm drainage and others) within the site	●	
	4) Gas Supply		
	a. The city gas main to the site		●
	b. The gas supply system within the site	●	
	5) Telephone System		
	a. The telephone trunk line to the main distribution frame/panel (MDF) of the building		●
	b. The MDF and the extension after the frame/panel	●	
	6) Furniture and Equipment		
	a. General furniture		●
	b. Project equipment	●	
4	To ensure prompt unloading and customs clearance of the products at ports of disembarkation in the recipient country and to assist internal transportation of the products		
	1) Marine (Air) transportation of the Products from Japan to the recipient country	●	
	2) Tax exemption and custom clearance of the Products at the port of disembarkation		●
	3) Internal transportation from the port of disembarkation to the project site	●	
5	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the recipient country with respect to the purchase of the products and the services [be exempted] / [be borne by the Authority without using the Grant]		●
6	To accord Japanese nationals whose services may be required in connection with the supply of the products and the services such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work		●
7	To ensure that [the Facilities and the products]/[the Facilities]/ [the products] be maintained and used properly and effectively for the implementation of the Project		●
8	To bear the following commissions paid to the Japanese bank for banking services based upon the B/A		
	1) Advising commission of A/P		●
	2) Payment commission		●
9	To give due environmental and social consideration in the implementation of the Project.		●
10	To bear all the above expenses, other than those covered by the Grant, necessary for the implementation of the Project		●

*1 B/A : Banking Arrangement, A/P : Authorization to pay) *2 If the environmental screening category is C, No. 10 is unnecessary

(Confidential)
Estimated Project Cost

The cost of the Project will be (CONFIDENTIAL). The content of the project cost are shown separately for the Japanese borne portion and the Tongan side borne portion in accordance with the conditions in item 3. (3) below.

This cost estimate is provisional and subject to change as a result of examination by the Government of Japan for the approval of the Grant.

1. Cost to be borne by the Japanese side:

Approximate Total cost for Japanese Portion

CONFIDENTIAL

2. Cost to be borne by the Tongan side: US$ 696,000 (=approximately JP¥ 56.7 million)

Cost Items	US$	(≒JP¥)
① Payment of bank commission based on banking ・Commission of an Authorization to Pay (A/P) ・Payment commission	US$20,000-	JP¥1,600,000-
② Clearance of trees, and exterior wall and gate work for the PV system site in Vaini area	US$46,000-	JP¥4,000,000-
③ Work to increase the size of the distribution wire of 11kV and connection work in Vaini area	US$40,000-	JP¥3,500,000-
④ Expansion work for 11kV switch board room at the Popua Power Station:	US$52,000-	JP¥4,500,000-
⑤ Installation work for Grid-connected switch gear for 11kV system:	US$100,000-	JP¥8,000,000-
⑥ Remodeling work for the existing power generating facilities at the Popua Power Station (Including Load Sharing of Generator 7 with other generators for maintaining fuel efficiency: UD$70,000)	US$90,000-	JP¥7,200,000-
⑦ Land lease/rental at Vaini site for First year (=TOP600,000+TOP10,000/year)	US$348,000-	JP¥27,900,000-
Approximate Total cost	US$696,000-	JP¥56,700,000-

3. Conditions for estimation
   (1) Time of estimation: December, 2012
   (2) Foreign exchange rates:
       1USD = JP¥80.40 (TTS mean value from April 2012 to September 2012)
       1TOP = JP¥45.80 (TTS mean value from April 2012 to September 2012)
   (3) Others:
       The above estimation was carried out in accordance with relevant rules and the guideline of the Japanese Grant Aid.

Appendix 2

List of Attendants

Tonga Energy Road Map

Mr. 'Inoke Finau Vala	TERM-IU Director
Mr. Sitiveni Finau	Communication Officer

Tonga Power Limited

Mr. John Van Brink	Chief Executive
Mr. Michael Lani 'Ahokava	Power Generation Manager
Mr. Nikolasi Fonua	Business Development Engineer

Japan International Cooperation Agency

Mr. Hiroo TANAKA	Team Leader
Mr. Yoshimasa SAKAMOTO	Planning Management

Consultants

Mr. Mitsuhisa NISHIKAWA	Yachiyo Engineering Co., Ltd.
Mr. Kazunari NOGAMI	Yachiyo Engineering Co., Ltd.
Mr. Shozo KURASHIMA	Yachiyo Engineering Co., Ltd.

A-5 Technical Memorandum

PREPARATORY SURVEY
ON
THE PROJECT FOR
DEVELOPMENT AND INTRODUCTION OF MICRO-GRID SYSTEM
FOR THE TONGA ENERGY ROAD MAP
IN THE KINGDOM OF TONGA

THE FIRST FIELD SURVEY

FIELD REPORT

August 30th, 2012

Mr. John Van Brink
Chief Exective
Tonga Power Limited

Mr. Mitsuhisa Nishikawa
Chief Consultant,
JICA Study Team

Table of Contents

1. Introduction

Japan International Cooperation Agency (hereinafter referred to as "JICA") dispatched a survey team to the Kingdom of Tonga to appraise the Project for Introduction of A Micro-Grid System with Renewable Energy for the Tonga Energy Road Map in the Kingdom of Tonga (hereinafter referred to as "the Project") which was requested by the government of Tonga as Japan's Grant Aid. The Project is aimed at introducing a micro-grid system with renewable energy to control energy flows and quality, and optimize efficiency of the diesel engine generators.

Tonga Power Limited (hereinafter referred to as "TPL") and JICA Preparatory Survey Team for the Project (hereinafter referred to as "the Team") had series of technical discussion to form a mutual understanding of the contents and the scope and preconditions for outline design of the Project at the stage of 1st preparatory survey and both parties agreed to record the following points as a conclusion of the discussions.

This Field Report contains the findings and results of 1st field survey. Components of the Project will be further examined and may be modified through the consultation with the Ministry of Foreign Affairs and JICA headquarters. It is important for both sides to understand that the Preparatory Survey is not a commitment for the future implementation of the Project.

2. Project Site Location

The project sites are located in Tongatapu Island in the Kingdom of Tonga.

Source: JICA Study Team

Figure 1 Project Site Location

The Project is composed of procurement and installation of approximately 1 MWp of photovoltaic system, power storage system and a micro grid controller to control energy flows and quality, and optimize efficiency of the diesel engine generators.

The Project site for the Photovoltaic (PV) system, and building for power conditioner system (PCS) and power storage system (Batteries) are shown in Figure 2 (areas: approximately 24,000 m^2). In the first field survey, the availability of the land is confirmed by TPL and the approval letter in Annex 3 to use the land for the Project was issued by the Minister of Land, Environment, Climate Change and Natural Resources who is responsible for administration of the area.

In addition, building for power conditioner system (PCS) and power storage system (Batteries) for the existing PV system of Mamma Mai, whose capacity is of 1.3 MWp, will be constructed at Popua Power Station beside the existing powerhouse for the Mak generator under the Project. It is agreed by TPL (areas: approximately 300 m^2) to use the area for the Project. However, the area is dependent on capacity of the power storage system of the Project. More definite size will be discussed in the Second Field Survey by the Tongan side and Preparatory Survey Team.

Source: JICA Study Team using GIS map by the Ministry of Land, Environment, Climate Change and Natural Resources

Figure 2 Project Site for PV system

3. Components for the Project

3.1 Components identified in the Minutes of Meetings

The Tongan and Japanese sides were signed on the Minutes of Meetings on 30th August, 2012 and the following components were finally requested by the Tongan side on it.

Table 1 Components identified in the Minutes of Discussions

	Components
Micro grid controller	• Generation and network control system integrated into TPL's SCADA at Popua power station • IP broadband and/or mesh type communications network that overlies TPL's Tongatapu network, connecting remote generation to the Popua SCADA system and micro grid controllers. • Integration of battery and load flow "smoothing" algorithms to monitor and control field assets and enable future demand side management
Storage System (Batteries)	• Batteries and controller located at either Popua or at Vaini PV Site, controlling energy flows and quality, and optimising efficiency of the diesel generators • Conversion of the TPL 2.88 MW MAK diesel generator governor to load following capability (requires manufacturer's involvement to modify governors, TPL has discussed requirements and scope with the manufacturer)
Solar PV system (1MWp)	• A single solar PV array at Vaini, in central Tongatapu, injecting into the TPL 11kV network, including spares • Network voltage management (regulator or other dynamic support)
Operation & Maintenance of the equipment	• Training TERM-IU staff and TPL staff • Operating and maintenance manuals and process documentation • O & M support

Source: Minutes of Meetings signed with JICA on the 30th August, 2012

3.2 Drawing Lists

The following drawings are attached in the end of this field report.

- E-01 Single Line Diagram
- E-02 Control System Diagram
- E-03 Connection of Communication Cable to the Existing Photovoltaic System
- A-01 Floor and Section Plan of Buildings
- A-02 PCS and Batteries Building in Vaini
- A-03 PCS and Batteries Building at Popua Power Station

3.3 Technical issues to be discussed

Based on agreement on the Minutes of Meetings signed on 30th August, 2012, the following technical issues were confirmed between the Tongan side and the Preparatory Survey Team.

(1) Acquisition of approval from Mamma Mai to connect signal cables to the existing PV system

The Tongan side agreed to obtain approval from Mamma Mai to connect signal cables to the existing photovoltaic system and send its generating conditions to the micro-grid controller of

the Project at Popua Power Station before the Second Field Survey. The Second Field Survey will be conducted in the middle of September.

(2) Submission of information from the Tongan side to the Preparatory Survey Team for improvement of load sharing system of the existing diesel engine generators

It would be necessary to integrate load sharing system between Caterpillar and Mak generators in Popua Power Station to effectively compensate load fluctuation from solar PV system. The Preparatory Survey Team requested the Tongan side to provide the following information by 10th September, 2012 to analyze the behavior of integrated load sharing system and to study necessary equipment and specifications for the system.

- Control system diagrams after integration for load sharing
- Required devices including communication cables for integration
- Specifications of the required devices for integration
- Installed locations of the devices at Popua Power Station

(3) Connection of the equipment of the Project to the existing SCADA system

To manage data from the equipment of the Project in the existing SCADA system, they should be connected to the hub ports of the SCADA system. The Tongan side agreed to secure the existing hub ports not in use currently for the Project. And The Tongan side also agreed to resister information of the equipment of the Project to the SCADA system by themselves after installation work and before commissioning of the Project so that the data may be inputted properly.

(4) Undertakings for procurement and installation of 11 kV switchgears for interconnection of the power storage system of the Project at the Popua Power Station

The power storage system of the Project at Popua Power Station cannot be connected to the PV system of Mamma Mai in low voltage because the existing equipment in low voltage belongs to Mamma Mai not to the Tongan side. Therefore, the power storage system shall be connected to the high voltage side.

The Tongan side plans to separate the generator bus and distribution bus currently mixed in a bus. The Tongan side requested the Preparatory Survey Team to locate 11 kV switchgears of the Project in the existing powerhouse at Popua Power Station to enable the extension work of switchgears by himself in the future. The Preparatory Survey Team agreed to do so. The outline drawing is attached in Annex 4 of this field report.

The Tongan side shall undertake modification work of the existing building such as preparation of cable trench, cable trays, walls, doors, windows and air conditioner. The modification work shall be completed prior to commencement of the work by the Japanese side, and installation work of 11 kV switchgears procured by the Japanese side.

(5) Upgrading the conductor size of the branch line to the Project site in Vaini

The Tongan side and Preparatory Survey Team conducted the route survey to evaluate feasibility of a dedicated 11 kV line for the PV system of the Project from the Project site in Vaini to Popua Power Station. The following three alternatives were confirmed in the survey.

- Route parallel with the existing Nuk 1 Feeder
- Route parallel with the existing Nuk 2 Feeder
- Submarine cables across the lagoon

In case of overhead lines parallel with the existing feeders, some areas, especially the part through downtown, do not have enough space for installation of an additional 11 kV line. In case of submarine cable, there is possibility to affect mangrove growing along the lagoon. As the results of the survey, it was confirmed that installation of the dedicated line is not feasible.

The both parties agreed to connect the PV system of the Project to the existing Vaini Feeder. However, the conductor of the branch line from the trunk line of Vaini Feeder to the Project site in Vaini is of AAAC 25 mm^2 (refer Figure 2). The Tongan side also agreed to upgrade the conductor size of the branch line (approximately 200 m) to the Project site from 25 mm^2 to 160 mm^2 to secure the enough capacity for the PV system of the Project.

(6) Capacity of the Power Storage system

The Preparatory Survey Team will analyze the collected data in the First Field Survey and consider appropriate capacity of the power storage system of the Project to control quality of supplied power and optimize efficiency of the diesel engine generators. The capacity will be discussed in the Second Field Survey based on the analysis. Therefore, the size of the buildings of the Project may be changed in accordance with the capacity of the power storage system.

(7) Topographic and geological survey in the Second Field Survey

Topographic and geological survey shall be conducted in the Second Field Survey for basic design of the Project. The Tongan side shall obtain relevant approvals to clear the Project site in Vaini from concerned parties, and finish clearing work of bush and trees enough for the survey <u>prior to the Second Field Survey</u>. <u>The Second Field Survey will be conducted in the middle of September</u>.

3.4 Wind Power Generation

Based on discussion with the Tongan side in the First Field Survey, the wind power generation was excluded from the components of the Project due to procedural grounds for Environmental Impact Assessment as mentioned in Item 4 of this field report.

However, based on the data observed in Lapaha Village by the Minister of Land, Environment, Climate Change and Natural Resources through 18 months, potential evaluation for wind power generation will be conducted from the technical viewpoint and the results will be included in the Preparatory Survey Report. At the same time, the potential in Niutoua will also be analyzed with wind condition characteristics and energy characteristics such as average wind velocity and energy density of wind power simulated based on the data observed in Lapaha Village and the surrounding topographic information.

4. Environmental and Social Consideration

4.1 Environmental Legal Framework

Existing environmental legislation relevant to the Project is shown below.

Table 2 Existing Environmental Legislation relevant to the Project

Legislation	Year Passed	Last Amended	Objective
Environmental Impact Assessment Act 2003	2003	-	To provide for the application of environmental impact assessment to the planning of development in Tonga
Environmental Impact Assessment Regulations 2010	2010	-	To regulate major development projects and the applications of notification consistent with the EIA Act 2003)
Waste Management Act 2005	2005		To manage and oversee the function of the Waste Management Board
Parks and Reserves Act 1976	1976	1979, 1988	To provide for the establishment of Parks and Reserves Authority and for the establishment, preservation and administration of Parks and Reserves
Hazardous Wastes and Chemicals Act 2010	2010		To provide for the regulation and proper management of hazardous wastes and chemicals in accordance with accepted international practices and the International Conventions applying to the use, transboundary movement and disposal of hazardous substances and for related purposes.
Renewal Energy Act 2008	2008	2010	To regulate the use of renewable energy in the Kingdom and related matters
Environmental Management Act 2010	2010		To establish the Ministry of Environment & Climate Change* to ensure the protection and proper management of the environment and the promotion of sustainable development

*The Ministry of Environment & Climate Change was incorporated into the MLECCNR as the Department of Environment & Climate Change due to the reorganization of government ministries in July 2012.
Source: Department of Environment & Climate Change

The Environmental Impact Assessment Act 2003 (EIA Act 2003) provided the power of the Ministry, the establishment and functions of the Environmental Assessment Committee, penalty, definition of major projects and so on. The major project is defined as a development activity which is likely to result in or increase pollution, or to have adverse impact on natural environment. A development activity which is classified as the major project is subject to conduct an appropriate environmental impact assessment. Development of electric generation station is defined as the major project even though renewal energy is used for the power generation. Therefore, the Project is subject to conduct an EIA.

4.2 Environmental Policies in TERM

The objective of TERM is to reduce vulnerability to high and variable petroleum price with introduction of renewable energy. In order to achieve the objective, a set of key principles have been set out in TERM. Social and environmental sustainability is one of the key principles, and it is explained as follows. "Environmental and Social sustainability encompasses both minimizing local negative social and physical environmental impacts of the energy sector, as well as aligning with global goals with respect to minimizing impact on climate change where possible. New energy investments under the TERM would be subject to *Environmental and Social Impact Assessment and Mitigation Plans* as necessary, as per international practice. Special consideration will be given to those groups with specific needs including youth, women, religious groups and those with special needs. Investments that have major negative environmental or social impacts or constraints that cannot be mitigated or solved will be avoided."

As mentioned above, TERM requires environmental and social impact assessment and mitigation plans as per international practice in order for development of electric generation station. In this regard, the JICA Guidelines for Environmental and Social Considerations shall be observed as well as the World Bank's Safeguard Policies and other standards of international financial organizations related to the environmental and social considerations of the Project.

4.3 Environmental Management Administration and EIA Procedures

The Environmental Management Act 2010, which created the former Ministry of Environment and Climate Change (MECC), empowered the Minister and the Director for Environment and Climate Change as well as Environmental Officers on environmental management. In relation to the EIA procedure, the Minister determines whether the proposed development is a minor or major project, and receives an assessment report and issues the approval with or without conditions, a request for further information, or a rejection. Meanwhile, the Director, who is the head of the Secretariat of the Environmental Assessment Committee (EAC) and chairs the Committee, inspects or investigates any facility or activity deemed to be causing potential impact on the environment. The Secretariat which is staffed with Environmental Officers receives application documents related to environmental impact assessment of the proposed project and gives advice on implementation of environmental study under the Director's instructions. It is deemed that the power and authority of those key actors are the same as before, although the former MECC was incorporated into the MLECCNR in July 2012.

The EIA Act 2003 has been enforced under the Environmental Impact Assessment Regulations 2010 (EIA Regulations 2010). The EIA Regulations provides the procedures of EIA for major projects classified under the EIA Act 2003. The EIA procedures, as shown in the Attachment 4.1, are divided into four steps; namely, notification, environmental impact assessment, review and final decision with or without conditions.

All development activities must be notified to the Minister who determines whether the proposed development is a major project or not. However, according to the Department of Environment and Climate Change (DECC), this Project can skip the notification because it is obviously the major project, and the proponent can step into the study of EIA, complete the EIA report and submit it to the Secretariat with an application. The Secretariat compiles a report based on the application and the EIA report, and then submits those documents to the EAC for the review. The EAC reviews the submitted documents and prepares/submits a recommendation to the Minister for final decision. According to the TPL, in case of the project of Popua 1MW Solar Firm, it took less than 3 months from the notification to the final decision by the Minister.

4.4 Available Renewal Energy in the Project

The GoT requested to the GoJ to introduce both solar PV system and wind turbine generator system as the renewal energy source of the Project. However, the wind turbine system is hardly adopted in the Project from the viewpoint of environmental constraint.

It is unlikely that the construction, existence and operation of solar PV system have serious impacts on social and natural environment. Meanwhile as for wind turbine generator system, the following environmental items should be appropriately evaluated prior to the construction because problems of those items might be caused by wind turbine due to its mechanism.

- Noise
- Low-frequency noise
- Radio disturbance
- Shadow flicker
- Disturbance of birds' migration routes
- Spoiling of landscape

As to disturbance of birds' migration routes especially, survey of existing conditions on the migration routes generally takes one year at minimum. Accordingly, it takes one and a half year approximately to obtain environmental permit, taking into account the required time for data analysis, assessment of the environmental impacts, information disclosure, stakeholder meetings, review of the EIA and so on. The time required for the EIA procedures does not meet the time schedule of the Project.

4.5 Land System

The prime feature of land system in the Kingdom of Tonga is that "all the land of the Kingdom is the property of the Crown", as declared in the Land Act. The Minister of the MLECCNR is responsible for the land administration of the Kingdom's land as the representative of the Crown. There are two types of landownership; one is the Crown Land and the other, estate so-called "Tofia". The Crown Lands include Royal Estates, Royal Family Estates, lands for public purposes such as road and cemetery, and so on, while the Tofias, which are entitled to privilege of hereditary transfer, have been given to only so many people such as nobles provided in the Land Act. People (or Commoner) can only lease the Crown Lands or Tofias with conditionality of less than 99 years' lease period because the Land Act places a ban on sale of the Kingdom's land.

4.6 Landownership of the Project Site

The project site for the solar PV system in Vaini is owned by Lord Ma'afu who is the Minister for the MLECCNR. Lord Ma'afu has accepted TPL's request for the lease of the land, and sent the confirmation letter to TPL (Refer to the Annex 3). Soon after the implementation of the Project is assured, TPL will make a contract of the lease with Load Ma'afu.

The documents of the lease contract shall be submitted to the MLECCNR for approval and registration. The submitted lease contract will be deliberated in the Cabinet and, if it is acceptable, the Minister of the MLECCNR will approve the lease contract with the Cabinet's consent. And then, the project site will be surveyed and registered by the MLECCNR. According to the Planning & Urban Management Agency of the MLECCNR, it generally takes one month from submission of the lease contract to the registration.

ANNEX

1. Members of the Team
2. Minutes of Meetings
3. Approval Letter of Land Use for the Project Site in Vaini
4. Outline of installation of 11 kV switchgears of the Project at Popua Power Station

ANNEX 1

Members of the Team

Members of the Team

Name	Assignment	Organization
Hiroshi SUMIYOSHI	Team Leader	Japan International Corporation Agency
Yoshimasa SAKAMOTO	Planning Management	Japan International Corporation Agency
Mitsuhisa NISHIKAWA	Chief Consultant / Distribution System Design	Yachiyo Engineering Co., Ltd.
Kyoji FUJII	Deputy Chief Consultant/ Operation of Diesel Engine Generator	Yachiyo Engineering Co., Ltd.
Hidekazu SATO	Micro-Grid System 1(Grid Control) / Battery Equipment Plan	Yachiyo Engineering Co., Ltd.
*1)Masahiko TAKEMURA	Micro-Grid System 2 (Grid Stability Analysis)	Yachiyo Engineering Co., Ltd.
*2)Shozo KURASHIMA	Renewable Energy 1	Yachiyo Engineering Co., Ltd.
Shinya KONDO	Renewable Energy 2	West Japan Engineering Consultants, Inc.
Kazunari NOGAMI	Procurement Plan/ Cost Estimation 1	Yachiyo Engineering Co., Ltd.
Kenji OHARA	Natural Condition Survey/ Cost Estimation 2	Yachiyo Engineering Co., Ltd.
Shigeki TAKASHIMA	Social and Environmental Considerations	Yachiyo Engineering Co., Ltd.
*2)Masuo WADA	Economic and Financial Analysis	Yachiyo Engineering Co., Ltd.
Masao YAMAKAWA	Coordinator/ Assistance for Micro-Grid Design	Yachiyo Engineering Co., Ltd.

Remarks: *1) He will attend Analysis in Japan.
*2) They will attend Second Field Survey.

ANNEX 2

Minutes of Meetings

THE MINUTES OF MEETINGS

ON

THE MISSION FOR THE PREPARATORY SURVEY

ON

THE PROJECT FOR INTRODUCTION OF A MICRO-GRID SYSTEM WITH RENEWABLE ENERGY FOR THE TONGA ENERGY ROAD MAP

IN

THE KINGDOM OF TONGA

AGREED UPON BETWEEN

THE GOVENMENT OF THE KINGDOM OF TONGA

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Nuku'alofa, 30th August, 2012

Mr. 'Inoke Finau Vala TERM-IU Director Tonga Energy Road Map Agency the Kingdom of Tonga	Mr. Hiroshi SUMIYOSHI Leader Preparatory Survey Team Japan International Cooperation Agency
Witness	Witness
Ms. Lesieli Tufui Faletau Acting Secretary Ministry of Finance and National Planning	Mr. John Van Brink Chief Executive Tonga Power Limited

The government of The Kingdom of Tonga (hereinafter referred to as "GoT") and the Japan International Cooperation Agency (hereinafter referred to as "JICA") have made several preliminary discussions in order to identify priority projects in the field of power sector, and agreed to make preparation for the Project for Introduction of a Micro-Grid System with Renewable Energy (hereinafter referred to as "the Project"). Accordingly, JICA dispatched a mission on the Project (hereinafter referred to as "the JICA Mission") to The Kingdom of Tonga from 14th August, 2012 to 1st September, 2012 in order to develop scope and implementing arrangements of a further survey which will study outline design of the Project (hereinafter referred to as "the Preparatory Survey"). The scope and implementing arrangements of the Preparatory Survey are described in the Appendix 1. The main points discussed during its visit are described in the Appendix 2.

It should be noted that implementation of the Preparatory Survey does not imply any decision or commitment by JICA to extend its grant for the project at this stage.

Appendix 1: Scope and Implementing Arrangements of the Preparatory Survey
Appendix 2: Main Points Discussed
Appendix 3: List of Attendants

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Appendix 1

SCOPE AND IMPLEMENTING ARRANGEMENTS OF THE PREPARATORY SURVEY

I. BACKGROUND AND OBJECTIVES OF THE PREPARATORY SURVERY

In April of 2012, GoT made a request for Grant Aid for the Project to the Government of Japan (GoJ). GoJ decided to conduct the Preparatory Survey and entrusted JICA to examine the viability of the Project and sent the Survey team, headed by Mr. Hiroshi SUMIYOSHI, Director, Energy and Mining Division, Natural Resources and Energy Group, Industrial Development and Public Policy Department, JICA.

II. OBJECTIVES OF THE PROJECT

The project aims to develop and introduce a Micro-Grid System with large scale of renewable energy in order to reduce consumption of fossil fuel for generating electricity, and to stabilize electricity.

The project will be conducted under the Japanese Grant Aid Program aiming at promoting "Green Growth", which the GoJ puts stress on, by introducing Japanese Technology.

The project will also contribute to achievement of Tonga Energy Road Map (TERM)-objective.

III. ITEMS REQUESTED BY GoT

1. Project Site
   Vaini, and Popua Power Station, Popua, in Tongatapu Island
   (shown in Annex 1 and 2)

2. Responsible Organization
   Tonga Energy Road Map Agency (TERM-A)

3. Executing Agency
   Tonga Power Limited (The organization chart is shown in Annex 3.) as owner of the affected and new assets.
   *TERM Implementation Unit (TERM-IU) will have oversight of the Project.

4. Materials and services
   GoT finally requested to GoJ the following components to achieve TERM.

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Outline of the final Request

Item	Components
Micro grid controller	• Generation and network control system integrated into TPL's SCADA at Popua power station • IP broadband and/or mesh type communications network that overlies TPL's Tongatapu network, connecting remote generation to the Popua SCADA system and micro grid controllers. • Integration of battery or capacitive storage and load flow "smoothing" algorithms to monitor and control field assets and enable future demand side management
Storage System (Batteries)	• Batteries and controller located at either Popua or at Vaini PV Site, controlling energy flows and quality, and optimizing efficiency of the diesel generators • Conversion of the TPL 2.88 MW MAK diesel generator governor to load following capability (requires manufacturer's involvement to modify governors, TPL has discussed requirements and scope with the manufacturer)
Solar PV system (1MWp)	• A single solar PV array at Vaini, in central Tongatapu, injecting into the TPL 11kV network, including spares • Network voltage management (regulator or other dynamic support)
Operation & Maintenance of the equipment	• Training TERM-IU staff and TPL staff • Operating and maintenance manuals and process documentation • O & M support

IV. SURVEY AREA

Tongatapu Island, the Kingdom of Tonga

V. SCOPE OF THE PREPARATORY SURVEY

1. Terms of Reference

The Team will formulate the Project so as to contribute to achievement of TERM.

The Team will examine carefully potential of wind power and photovoltaic generation in Tongatapu, and control method of the micro-grid system and capacity of power storage system introduced under the Project.

Based on the results of the Survey and discussion with the Tongan side, the Team will design the micro-grid system to reduce consumption of fossil fuel in power generation effectively.

The Preparatory Survey shall cover the following items:

(1) Implementation framework
(2) Requested components of the Project and their Priority
(3) Securement of lands for the Project
(4) Environmental and social considerations
(5) Positive impact of the Project and objectively verifiable indicators of the Project
(6) Technical Conditions for the Project
(7) General Information of Electric Power Sector
(8) Major Undertaking, including Tax and levy system
(9) Local conditions and capability for procurement, construction, installation and transportation
(10) Activities of other donors
(11) Soft Component
(12) Maintenance Contract

2. Desirable specialists for the Preparatory Survey

JICA will select and dispatch a survey team to carry out the Preparatory Survey. The team will include the specialists of the following field;.

(1) Distribution System Design
(2) Operation of Diesel Engine Generator
(3) Micro-Grid System (Grid Control, and Grid Stability Analysis)
(4) Renewable Energy
(5) Battery Equipment Plan
(6) Natural Condition Survey
(7) Social and Environmental Considerations
(8) Procurement Plan and Cost Estimation
(9) Economic and Financial Analysis

VI. SCHEDULE OF THE PREPARATORY SURVEY

The Preparatory Survey will be carried out in accordance with the tentative schedule attached in the Annex 4. The schedule may be subject to change during the preparation and the course of the survey.

VII. REPORTS

JICA will prepare and submit following reports in English to GoT.

1. Inception Report:

3 copies will be submitted at the commencement of the first work period in the Kingdom of Tonga.

2. Draft Final Report:

3 hard copies and soft copy (1copy is for TERM, another copy is for TPL and the other copy is for GoT) will be submitted 4 months after the commencement of the Preparatory Survey.

This report will cover:

(1) Outline of the Project,
(2) Basic Design of the Project,
(3) Outline of the undertakings of Tongan side,
(4) Operation and maintenance plan for the Project, and
(5) Cost estimation.

GoT shall submit its comments within one month after the receipt of the Draft Final Report.

3. Final Report:

3 hard copies and soft copy (1copy is for TERM, another copy is for TPL and the other copy is for GoT) will be submitted within one month after the receipt of the comments on the Draft Final Report.

VIII. JAPAN'S GRANT AID SCHEME

GoT understands the Japan's Grant Aid Scheme explained by the JICA Mission as described in Annex 5,6 and 7.

IX. UNDERTAKINGS OF THE GOVERNMENT OF THE KINGDOM OF TONGA

GoT shall act as a counterpart agency to the survey team and also as a coordinating body with other organizations concerned for the smooth implementation of the Preparatory Survey.

GoT shall, at its own expense, provide the survey team with the following items in cooperation with other organizations concerned:

(1) security-related information as well as measures to ensure the safety of the survey team;
(2) information as well as support in obtaining medical service;
(3) data and information related to the Preparatory Survey;
(4) counterpart personnel;
(5) suitable office space with necessary equipment and secretarial service;
(6) credentials or identification cards;
(7) entry permits necessary for the survey team members to conduct field surveys;
(8) support in making transportation arrangements;
(9) support in obtaining other privileges and benefits if necessary;
(10)assist the team in custom clearance, exempt from any duties with respect to equipment, instruments, tools and other articles to be brought into and out of Tonga in connection with the implementation of the survey; and
(11) GoT shall bear claims, if any arises, against the members of the survey team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in implementation of the Preparatory Survey, except when such claim arise from gross negligence or willful misconduct on the part of the member of the survey team.

X. CONSULTATION

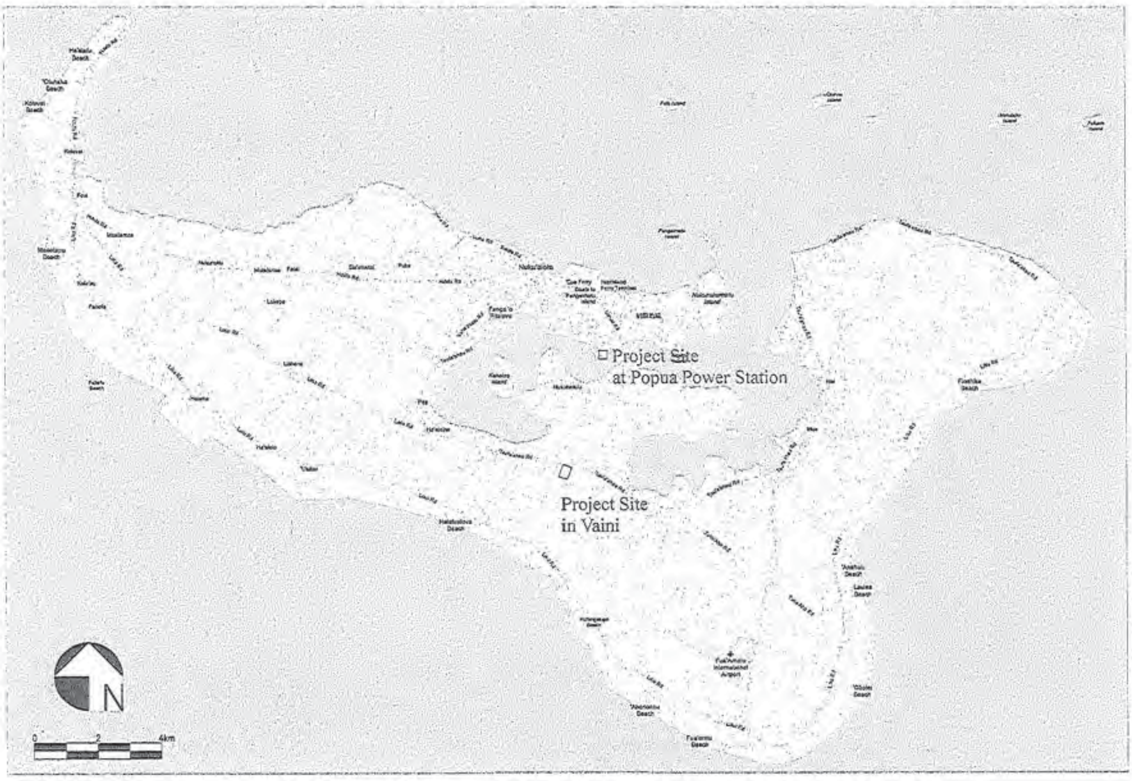
JICA and the GoT shall consult with each other in respect of any matter that may arise from or in connection with the Preparatory Survey.

END

Annex 1: Project Site
Annex 2: Vaini PV Site
Annex 3: Organization Chart of TPL
Annex 4: Schedule of the Preparatory Survey
Annex 5 Japan's Grant AID Scheme
Annex 6: Flow Chart of Japan's Grant AID Procedures
Annex 7: Major undertakings to be taken by each Government

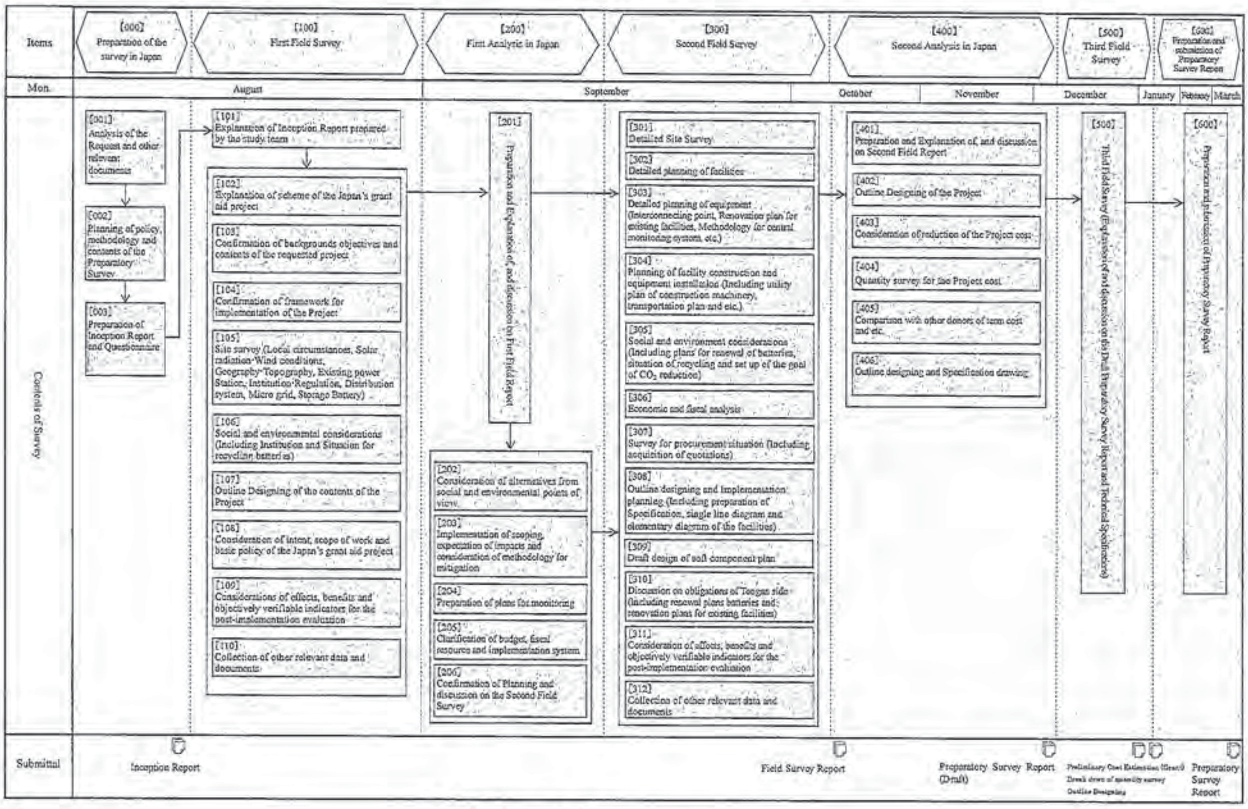
Annex 2

CANDIDATE PHOTOVOLTAIC SITE



Project Site

Annex 1



Schedule of the Preparatory Survey

Annex 4

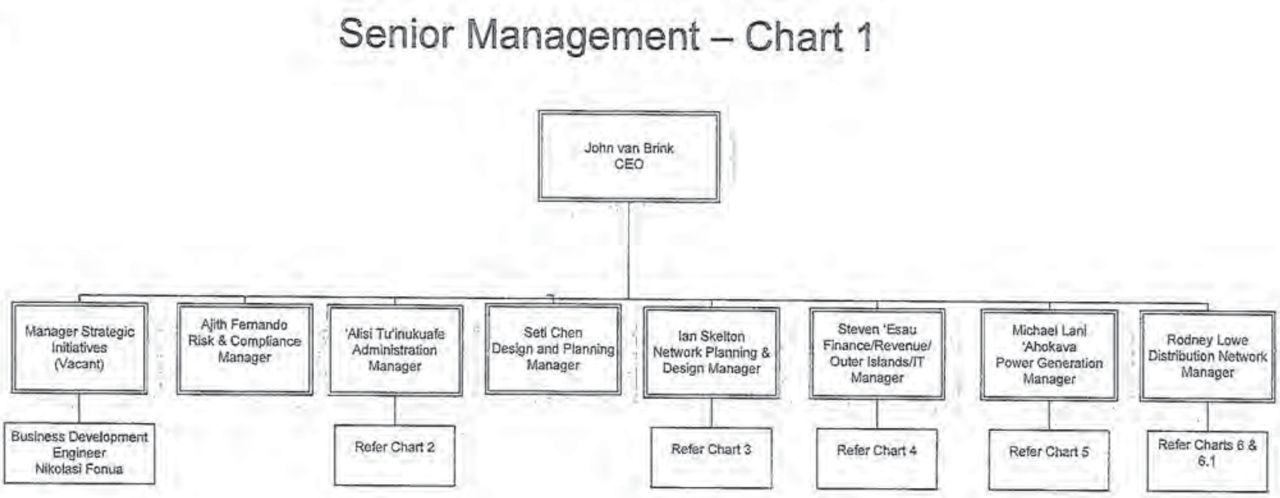


	Chart 1	Chart 2	Chart 3	Chart 4	Chart 5	Chart 6	Chart 6.1	Total
Established	9	6	13	40	20	48	11	147
Occupied	9	6	13	40	20	48	11	147
Vacancy	1	0	0	1	0	0	0	2
Trainees	0	0	2	0	1	0	4	7
Casuals	0	0	1	0	0	8	0	9

Annex 3

JAPAN'S GRANT AID

The Government of Japan (hereinafter referred to as "the GOJ") is implementing the organizational reforms to improve the quality of ODA operations, and as a part of this realignment, a new JICA law was entered into effect on October 1, 2008. Based on this law and the decision of the GOJ, JICA has become the executing agency of the Grant Aid for General Projects, for Fisheries and for Cultural Cooperation, etc.

The Grant Aid is non-reimbursable fund provided to a recipient country to procure the facilities, equipment and services (engineering services and transportation of the products, etc.) for its economic and social development in accordance with the relevant laws and regulations of Japan. The Grant Aid is not supplied through the donation of materials as such.

1. Grant Aid Procedures

The Japanese Grant Aid is supplied through following procedures:

・Preparatory Survey
  - The Survey conducted by JICA
・Appraisal &Approval
  -Appraisal by the GOJ and JICA, and Approval by the Japanese Cabinet
・Authority for Determining Implementation
  -The Notes exchanged between the GOJ and a recipient country
・Grant Agreement (hereinafter referred to as "the G/A")
  -Agreement concluded between JICA and a recipient country
・Implementation
  -Implementation of the Project on the basis of the G/A

2. Preparatory Survey

(1) Contents of the Survey

The aim of the preparatory Survey is to provide a basic document necessary for the appraisal of the Project made by the GOJ and JICA. The contents of the Survey are as follows:

- Confirmation of the background, objectives, and benefits of the Project and also institutional capacity of relevant agencies of the recipient country necessary for the implementation of the Project.

Annex 5

- Evaluation of the appropriateness of the Project to be implemented under the Grant Aid Scheme from a technical, financial, social and economic point of view.
- Confirmation of items agreed between both parties concerning the basic concept of the Project.
- Preparation of an outline design of the Project.
- Estimation of costs of the Project.

The contents of the original request by the recipient country are not necessarily approved in their initial form as the contents of the Grant Aid project. The Outline Design of the Project is confirmed based on the guidelines of the Japan's Grant Aid scheme.

JICA requests the Government of the recipient country to take whatever measures necessary to achieve its self-reliance in the implementation of the Project. Such measures must be guaranteed even though they may fall outside of the jurisdiction of the organization of the recipient country which actually implements the Project. Therefore, the implementation of the Project is confirmed by all relevant organizations of the recipient country based on the Minutes of Discussions.

(2) Selection of Consultants

For smooth implementation of the Survey, JICA employs (a) registered consulting firm(s). JICA selects (a) firm(s) based on proposals submitted by interested firms.

(3) Result of the Survey

JICA reviews the Report on the results of the Survey and recommends the GOJ to appraise the implementation of the Project after confirming the appropriateness of the Project.

3. Japan's Grant Aid Scheme

(1) The E/N and the G/A

After the Project is approved by the Cabinet of Japan, the Exchange of Notes(hereinafter referred to as "the E/N") will be singed between the GOJ and the Government of the recipient country to make a pledge for assistance, which is followed by the conclusion of the G/A between JICA and the Government of the recipient country to define the necessary articles to implement the Project, such as payment conditions, responsibilities of the Government of the recipient country, and procurement conditions.

(2) Selection of Consultants

In order to maintain technical consistency, the consulting firm(s) which conducted the Survey will be recommended by JICA to the recipient country to continue to work on the Project's implementation after the E/N and G/A.

(3) Eligible source country

Under the Japanese Grant Aid, in principle, Japanese products and services including transport or those of the recipient country are to be purchased. When JICA and the Government of the recipient country or its designated authority deem it necessary, the Grant Aid may be used for the purchase of the products or services of a third country. However, the prime contractors, namely, constructing and procurement firms, and the prime consulting firm are limited to "Japanese nationals".

(4) Necessity of "Verification"

The Government of the recipient country or its designated authority will conclude contracts denominated in Japanese yen with Japanese nationals. Those contracts shall be verified by JICA. This "Verification" is deemed necessary to fulfill accountability to Japanese taxpayers.

(5) Major undertakings to be taken by the Government of the Recipient Country

In the implementation of the Grant Aid Project, the recipient country is required to undertake such necessary measures as Annex.

(6) "Proper Use"

The Government of the recipient country is required to maintain and use properly and effectively the facilities constructed and the equipment purchased under the Grant Aid, to assign staff necessary for this operation and maintenance and to bear all the expenses other than those covered by the Grant Aid.

(7) "Export and Re-export"

The products purchased under the Grant Aid should not be exported or re-exported from the recipient country.

(8) Banking Arrangements (B/A)

a) The Government of the recipient country or its designated authority should open an account under the name of the Government of the recipient country in a bank in Japan (hereinafter referred to as "the Bank"). JICA will execute the Grant Aid by making payments in Japanese yen to cover the obligations incurred by the Government of the recipient country or its designated authority under the Verified Contracts.

b) The payments will be made when payment requests are presented by the Bank to JICA under an Authorization to Pay (A/P) issued by the Government of the recipient country or its designated authority.

(9) Authorization to Pay (A/P)

The Government of the recipient country should bear an advising commission of an Authorization to Pay

Annex 5

and payment commissions paid to the Bank.

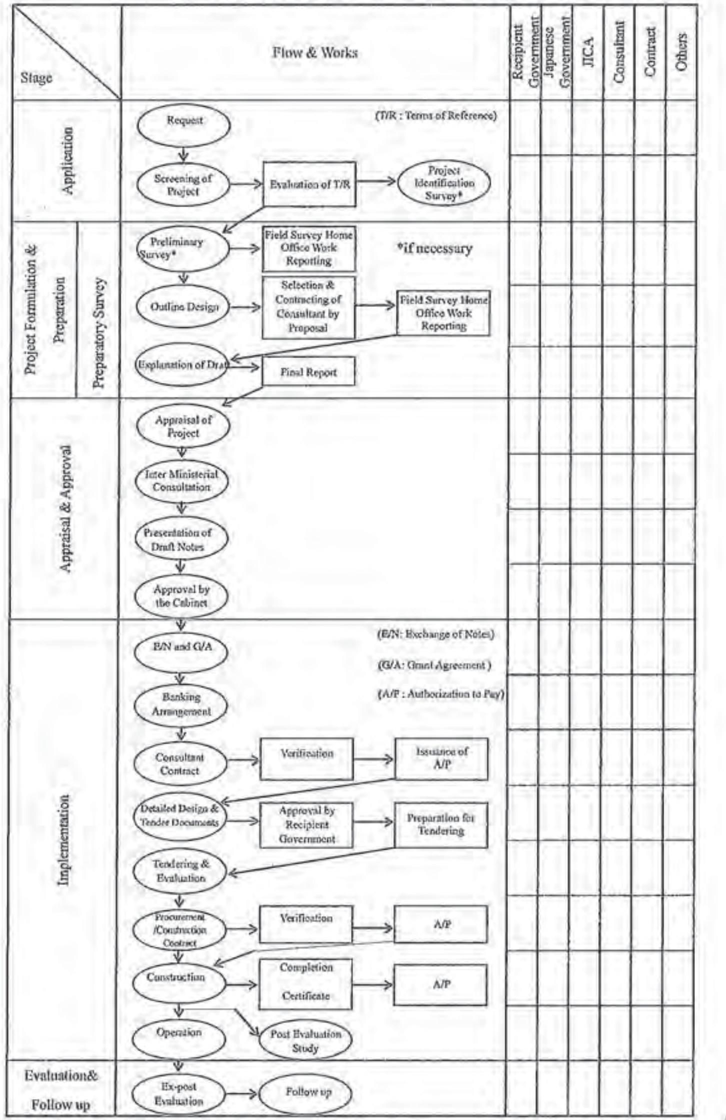
(10) Social and Environmental Considerations

A recipient country must carefully consider social and environmental impacts by the Project and must comply with the environmental regulations of the recipient country and JICA socio-environmental guidelines.

(End)

Annex 6

Flow Chart of Japan's Grant Aid Procedures



Annex 7

Major undertakings to be taken by each Government

No.	Items	To be covered by Grant Aid	To be covered by Recipient Side
1	to secure [a lot] /[lots] of land necessary for the implementation of the Project and to clear the [site]/[sites];		●
2	To construct the following facilities		
	1) The building	●	
	2) The gates and fences in and around the site		●
	3) The parking lot	●	
	4) The road within the site	●	
	5) The road outside the site		●
3	To provide facilities for distribution of electricity, water supply and drainage and other incidental facilities necessary for the implementation of the Project outside the [site]/[sites]		
	1)Electricity		
	a. The distributing power line to the site		●
	b. The drop wiring and internal wiring within the site	●	
	c. The main circuit breaker and transformer	●	
	2) Water Supply		
	a. The city water distribution main to the site		●
	b. The supply system within the site (receiving and elevated tanks)	●	
	3) Drainage		
	a. The city drainage main (for storm sewer and others to the site)		●
	b. The drainage system (for toilet sewer, common waste, storm drainage and others) within the site	●	
	4) Gas Supply		
	a. The city gas main to the site		●
	b. The gas supply system within the site	●	
	5) Telephone System		
	a. The telephone trunk line to the main distribution frame/panel (MDF) of the building		●
	b. The MDF and the extension after the frame/panel	●	
	6) Furniture and Equipment		
	a. General furniture		●
	b. Project equipment	●	
4	To ensure prompt unloading and customs clearance of the products at ports of disembarkation in the recipient country and to assist internal transportation of the products		
	1) Marine (Air) transportation of the Products from Japan to the recipient country	●	
	2) Tax exemption and custom clearance of the Products at the port of disembarkation		●
	3) Internal transportation from the port of disembarkation to the project site	●	
5	To ensure that customs duties, internal taxes and other fiscal levies which may be imposed in the recipient country with respect to the purchase of the products and the services [be exempted] / [be borne by the Authority without using the Grant]		●
6	To accord Japanese nationals whose services may be required in connection with the supply of the products and the services such facilities as may be necessary for their entry into the recipient country and stay therein for the performance of their work		●
7	To ensure that [the Facilities and the products]/[the Facilities]/ [the products] be maintained and used properly and effectively for the implementation of the Project		●
8	To bear the following commissions paid to the Japanese bank for banking services based upon the B/A		
	1) Advising commission of A/P		●
	2) Payment commission		●
9	To give due environmental and social consideration in the implementation of the Project.		●
10	To bear all the above expenses, other than those covered by the Grant, necessary for the implementation of the Project		●

*1 B/A : Banking Arrangement, A/P : Authorization to pay) *2 If the environmental screening category is C, No. 10 is unnecessary

Appendix 2

THE MAIN POINTS DISCUSSED

(1) Wind Turbine Generation System

GoT originally requested the introduction of Wind Turbine Generation system (500kW) and Solar PV system (500kWp). According to the request, the Team surveyed the candidate sites of the Wind turbine generation system, selected by TPL and Ministry of Land, Environment ,Climate Change and Natural Resources (MLECCNR), and had series of discussions with their representatives about wind synopsis data, land owner ship, access roads, distribution lines to be connected, environmental constraint, etc. Survey of existing conditions on the environmental constraint takes one (1) year at minimum. Accordingly, it takes one and half (1.5) year approximately to obtain permission from Japanese authorities, taking into account the required time for data analysis, assessment of the environmental impact, information disclosure, stakeholder meetings, review of EIA and so on. The time required for the EIA procedure does not meet the project schedule.

As the results of discussions, both sides agreed that the Wind turbine generation system would not be adopted in the project component. However, the team agreed on the analysis of the potential of Wind Turbine Generation system at the candidate site from the data acquired through the survey.

(2) Solar PV system

Since the Wind turbine generation system is excluded from the project component, both sides agreed that the capacity of the Solar PV system at Vaini shall be approximately 1.0 MWp to aid the achievement of the TERM's target and to ensure the introduction of renewable energy as much as possible.

(3) The Tongan side agreed to obtain approval from Mamma Mai, existing solar PV system (1.3MWp) to connect signal cables to the photovoltaic system and send its generating conditions to a micro-grid controller of the Project at Popua Power Station controlling energy flows and quality, and optimizing efficiency of the diesel engine generators.

(4) It would be necessary to integrate load sharing system between Caterpillar and Mak generators in Popua Power Station to effectively compensate load fluctuation from solar PV system. The Preparatory Survey team requested the Tongan side to provide necessary information by Sep. 10th 2012 to analyze the behavior of integrated load sharing system and to study necessary equipment and specifications for the system. The Tongan side agreed to do so.

(5) In addition to the Annex 7, both sides agreed that the following matters are included in the Undertakings of the GoT side

1) Renewal of Battery system
2) Treatment of Used batteries
3) Concluding the maintenance contract for Micro-Grid system
4) Ensuring the installation site(s) for Solar PV generation system including Micro-grid controller(s), Batteries, Power conditioners, etc.
5) Implementation of EIA and acquisition of the Environmental permission

(6) Project Title

The Project Title in Application Form submitted by the GoT was "The TERM Development and Implementation of a Micro-Grid System to the TPL Grid of Tongatapu".

JICA and the GoT agreed to change the Project Title to "The Project for Introduction of a Micro-Grid System with Renewable Energy for the Tonga Energy Road Map".

Appendix 3

List of Attendants

Tonga Energy Road Map

Mr. 'Inoke Finau Vala	TERM-IU Director
Mr. 'Akau' Ola	Term-C Advisor
Mr. Ofa Sefana	Acting Energy Planning Specialist
Mr. Slua Aatu	Environmental Information Officer
Mr. Moleni Tuuholoaki	Acting Director of Meteorology
Ms. Katherine Bakes	Operations Officer (World Bank)

Tonga Power Limited

Mr. John Van Brink	Chief Executive
Mr. Lano Fonua	Strategic Initiatives Manager
Mr.Michael Lani 'Ahokava	Power Generation Manager
Mr. Murray Sheerin	Power Station Superintendent
Mr. Ian Skelton	Planning and Design Manager
Mr. Nikolasi Fonua	Business Development Engineer

Ministry of Land, Environment, Climate Change and Natural Resources

Department of Environment and Climate Change

Ms. Mafile'o Masi	Acting Deputy Director
Ms. Kate Mcpherson	Environment Legislation Policy Officer
Ms. Lesieli Tuivai	Ecologist, Environmentalist

Planning & Urban Management Agency

Mr. 'Atunaisa. M. Fetokai	Deputy Physical Planner
Mr. Tevita L. Fotu	Urban Planner

LGIS Unit

Mr. Richard Atelea Kautoke	Sen. GIS Specialist

Ministry of Infrastructure

Laboratory, Civil Engineering Department

Mr. Ken Robinson	Material Engineer

Japan International Cooperation Agency

Mr. Hiroshi SUMIYOSHI	Team Leader
Mr. Yoshimasa SAKAMOTO	Planning Management

Consultants

Mr. Mitsuhisa NISHIKAWA	Yachiyo Engineering Co., Ltd.
Mr. Kyoji FUJII	Yachiyo Engineering Co., Ltd.
Mr. Hidekazu SATO	Yachiyo Engineering Co., Ltd.
Mr. Shinya KONDO	West Japan Engineering Consultants, Inc.
Mr. Kazunari NOGAMI	Yachiyo Engineering Co., Ltd.
Mr. Kenji OHARA	Yachiyo Engineering Co., Ltd.
Mr. Shigeki TAKASHIMA	Yachiyo Engineering Co., Ltd.
Mr. Masao YAMAKAWA	Yachiyo Engineering Co., Ltd.

ANNEX 3

Approval Letter of Land Use for the Project Site in Vaini

JOHN VAN BRINK
Chief Executive Officer
Tonga Power Limited
Nuku'alofa

22nd August 2012

Dear John,

Request for Land at Vaini Village by Tonga Power Limited for Solar Energy Project

1. Further to your meeting yesterday with Lord Ma'afu regarding the above matter, I write to confirm the availability of land to be leased to Tonga Power Limited at Vaini.

2. The available land is comprised of 6 acres and described as Lot 54 of Block 77/93 at Vaini. A copy of the map is attached with a rough sketch of the area highlighted in green.

3. Should you require any further information on the matter, please do not hesitate to contact me.

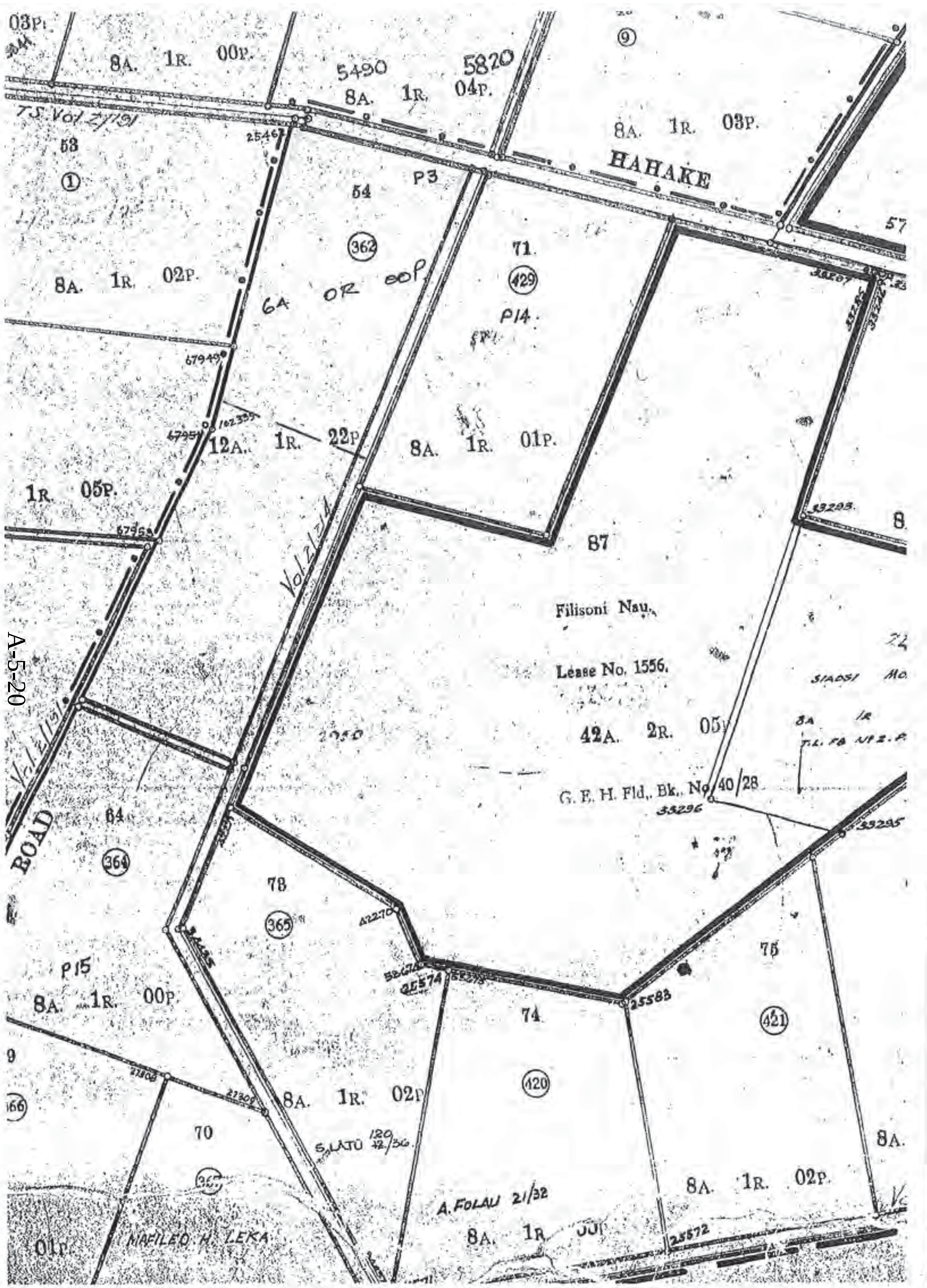
Yours sincerely,

Rosamond C. Bing

rosamond.bing@gmail.com
Legal Advisor for Lord Ma'afu

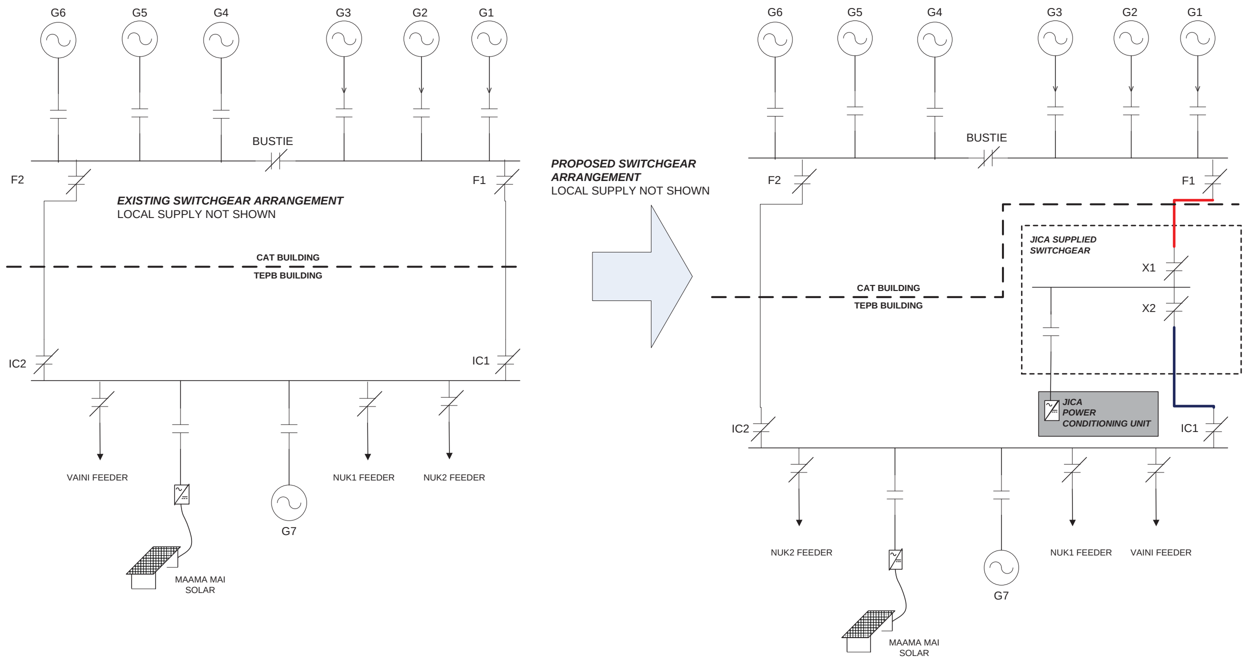
ANNEX 4

Outline of installation of 11 kV switchgears of the Project at Popua Power Station



TONGA POWER LTD : POPUA POWERSTATION

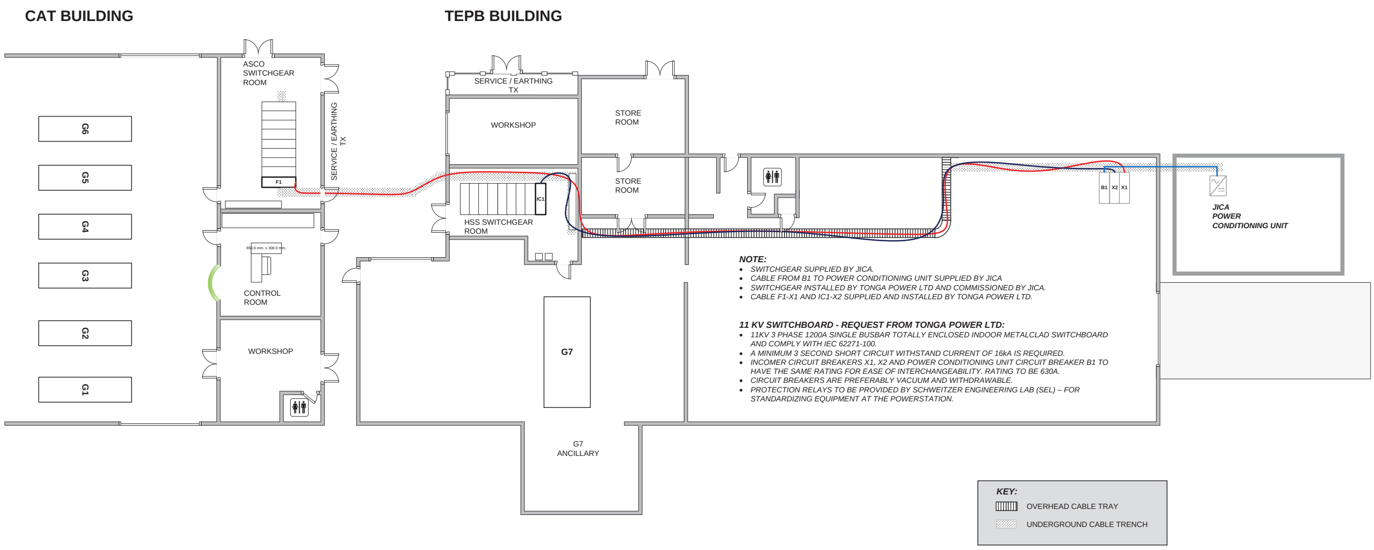
SWITCHGEAR ARRANGEMENT PROPOSAL FOR JICA SOLAR PV PROJECT



PG 1 of 3

TONGA POWER LTD : POPUA POWERSTATION

SWITCHGEAR ARRANGEMENT PROPOSAL FOR JICA SOLAR PV PROJECT



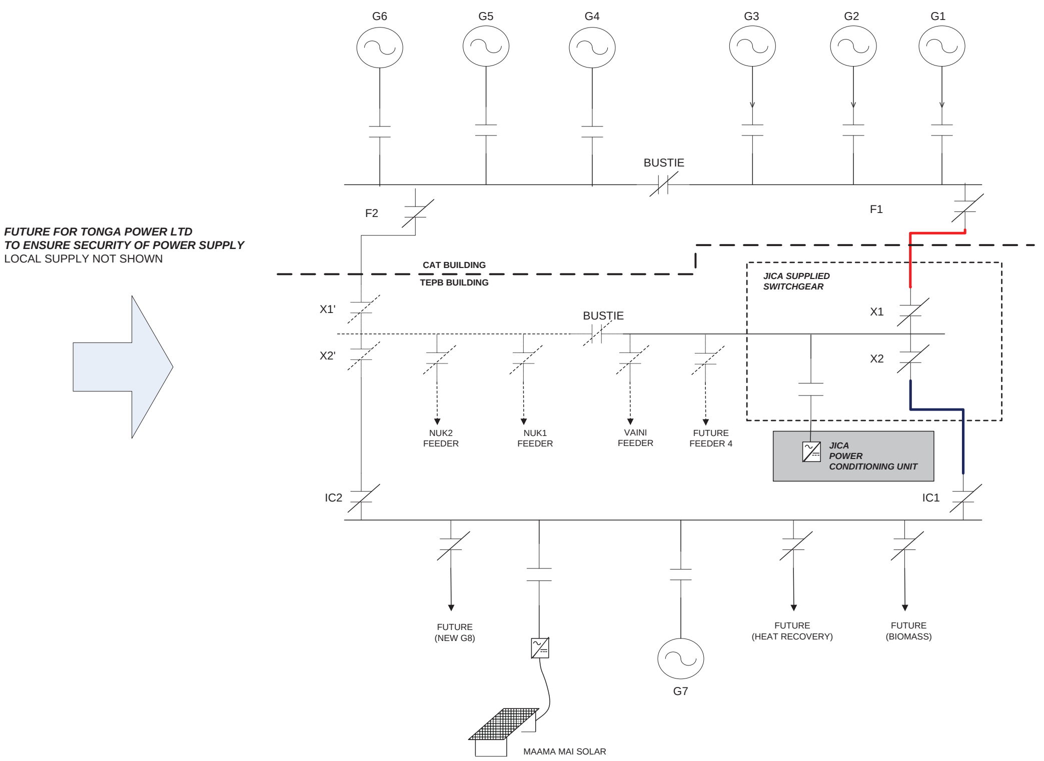
Drawings

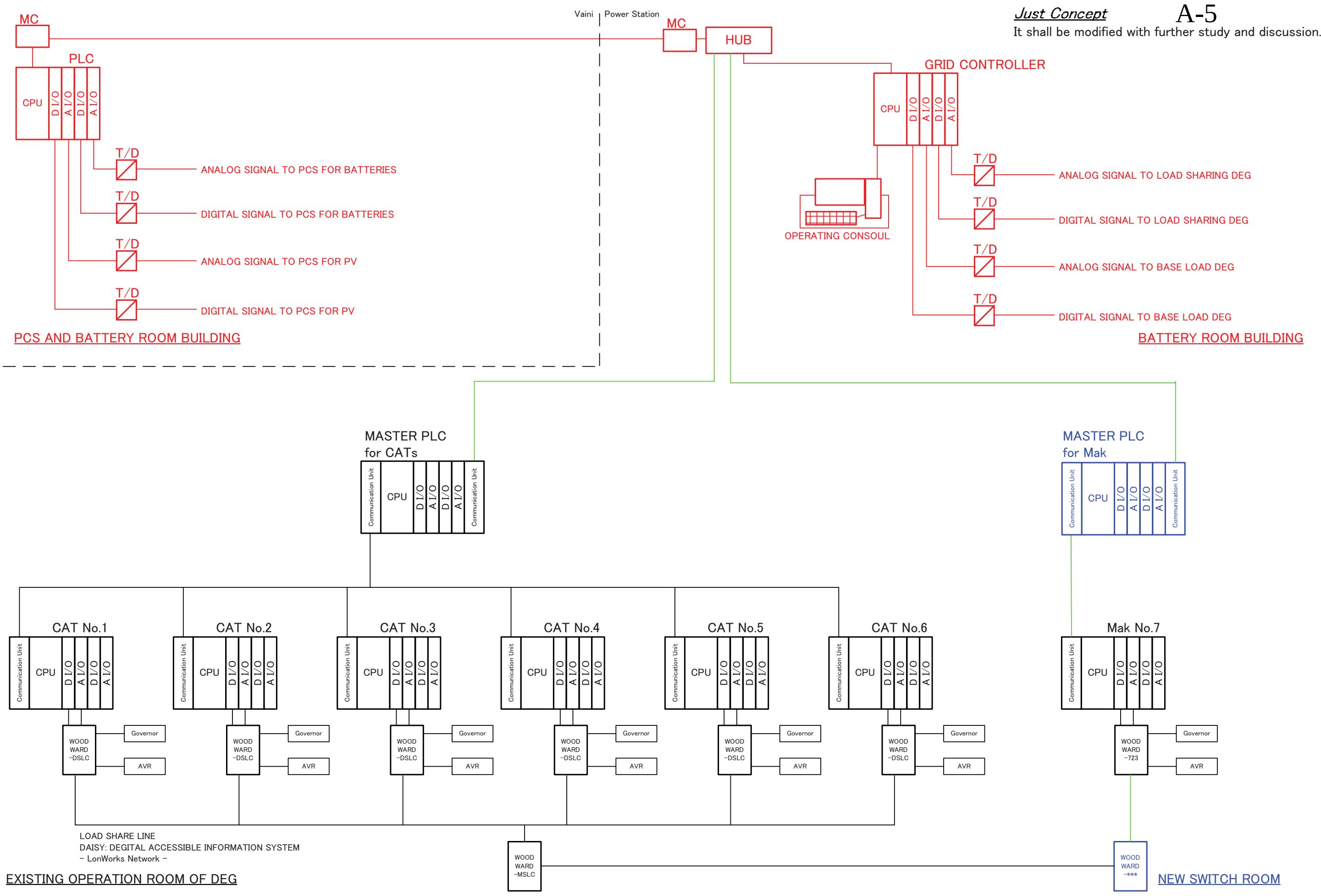
- E-01 Single Line Diagram
- E-02 Control System Diagram
- E-03 Connection of Communication Cable to the Existing Photovoltaic System
- A-01 Floor and Section Plan of Buildings
- A-02 PCS and Batteries Building in Vaini
- A-03 PCS and Batteries Building at Popua Power Station

PG 3 of 3

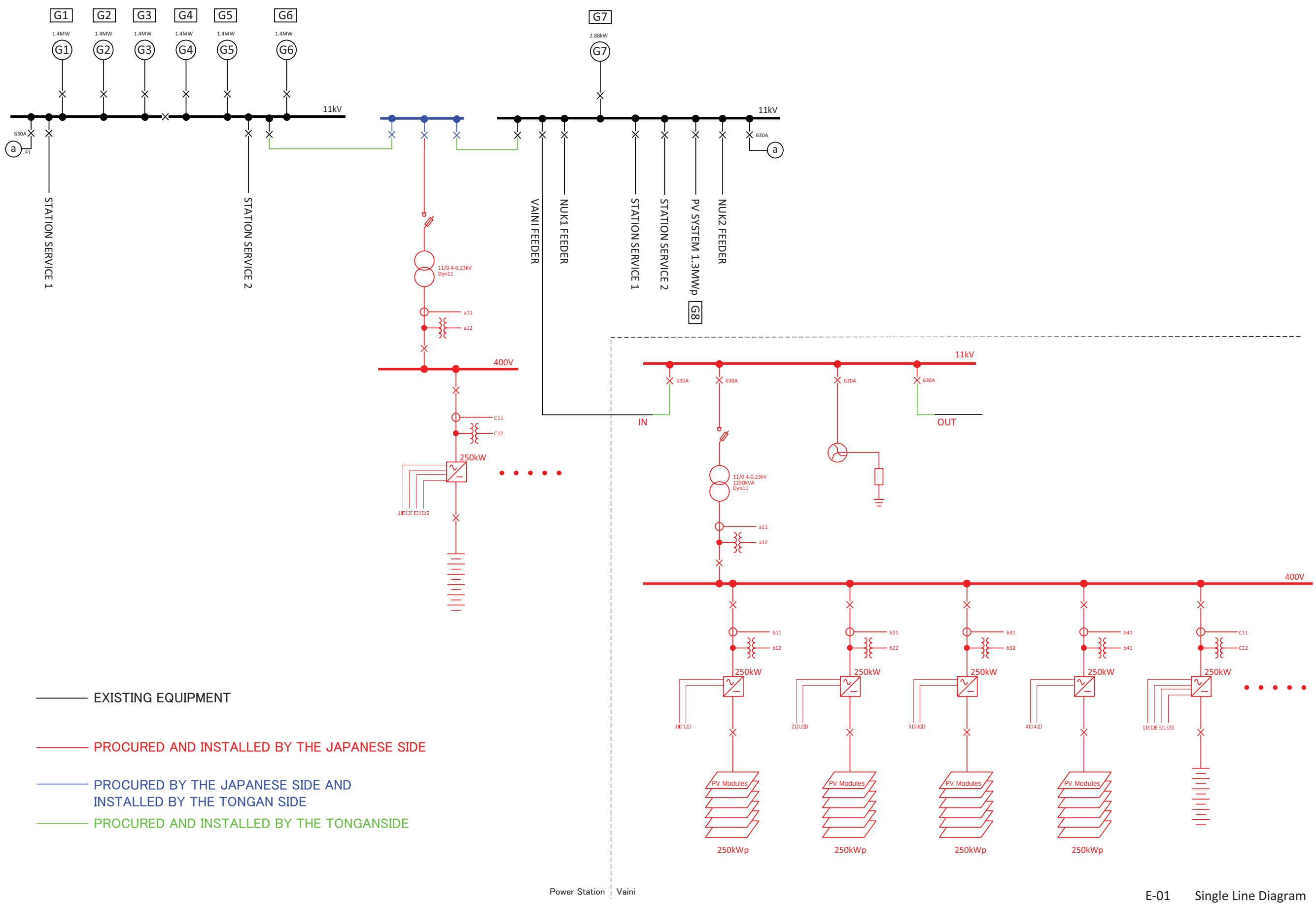
TONGA POWER LTD : POPUA POWERSTATION

SWITCHGEAR ARRANGEMENT PROPOSAL FOR JICA SOLAR PV PROJECT

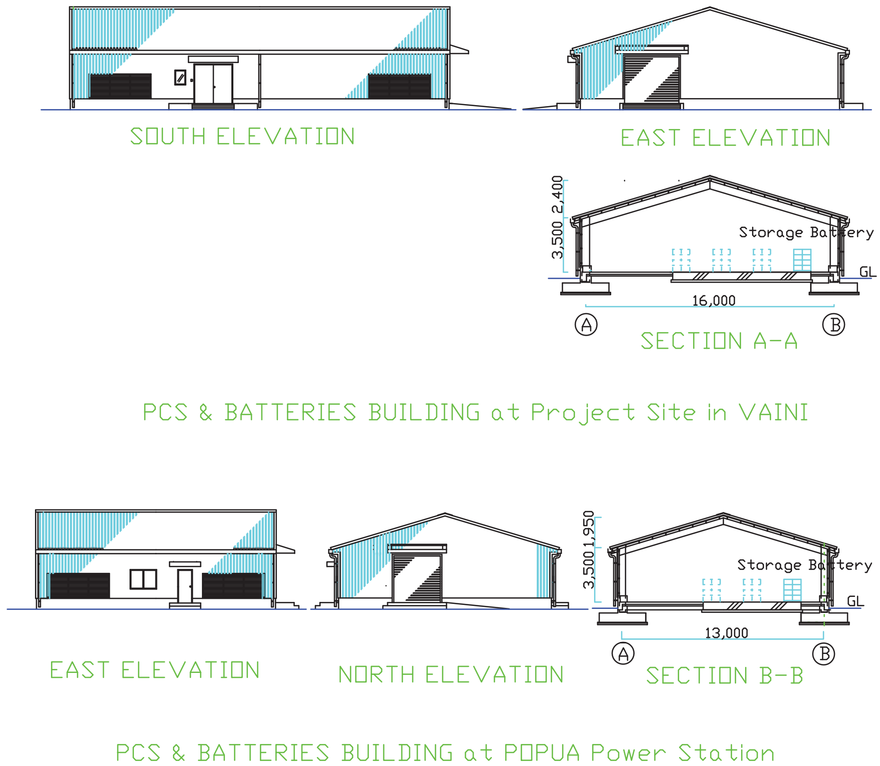




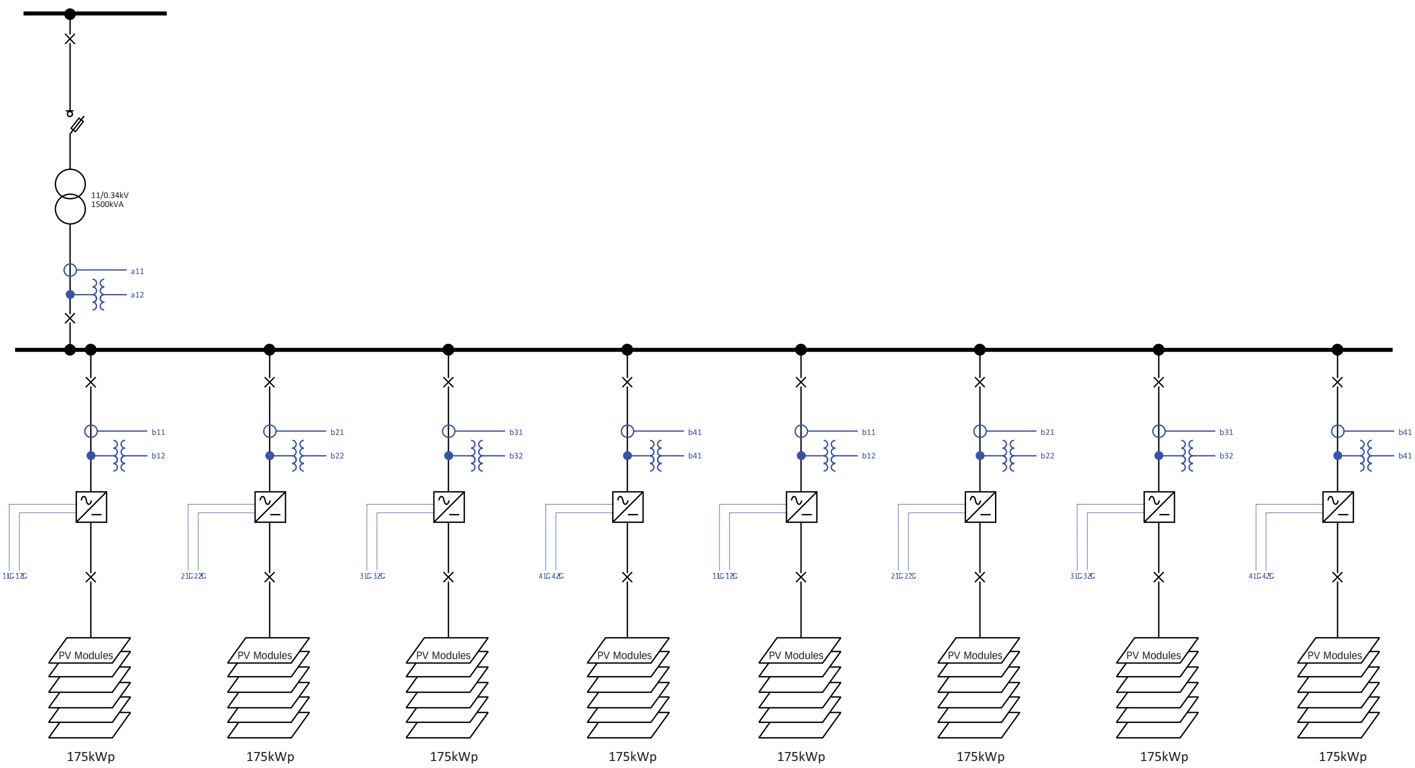
E-02 Control System Diagram



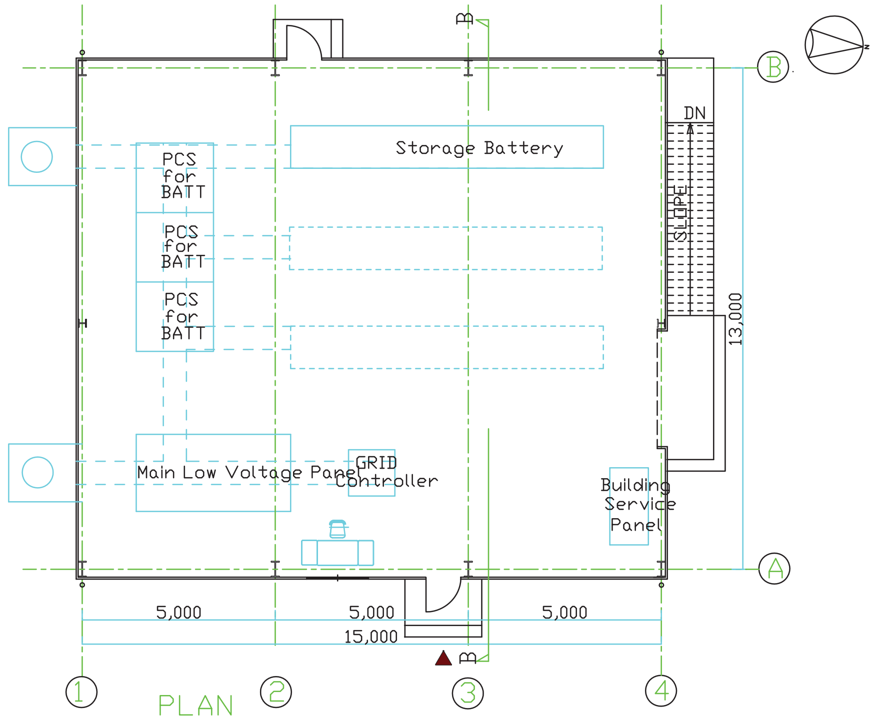
E-01 Single Line Diagram



A-01 FLOOR AND SECTION PLAN OF BUILDINGS

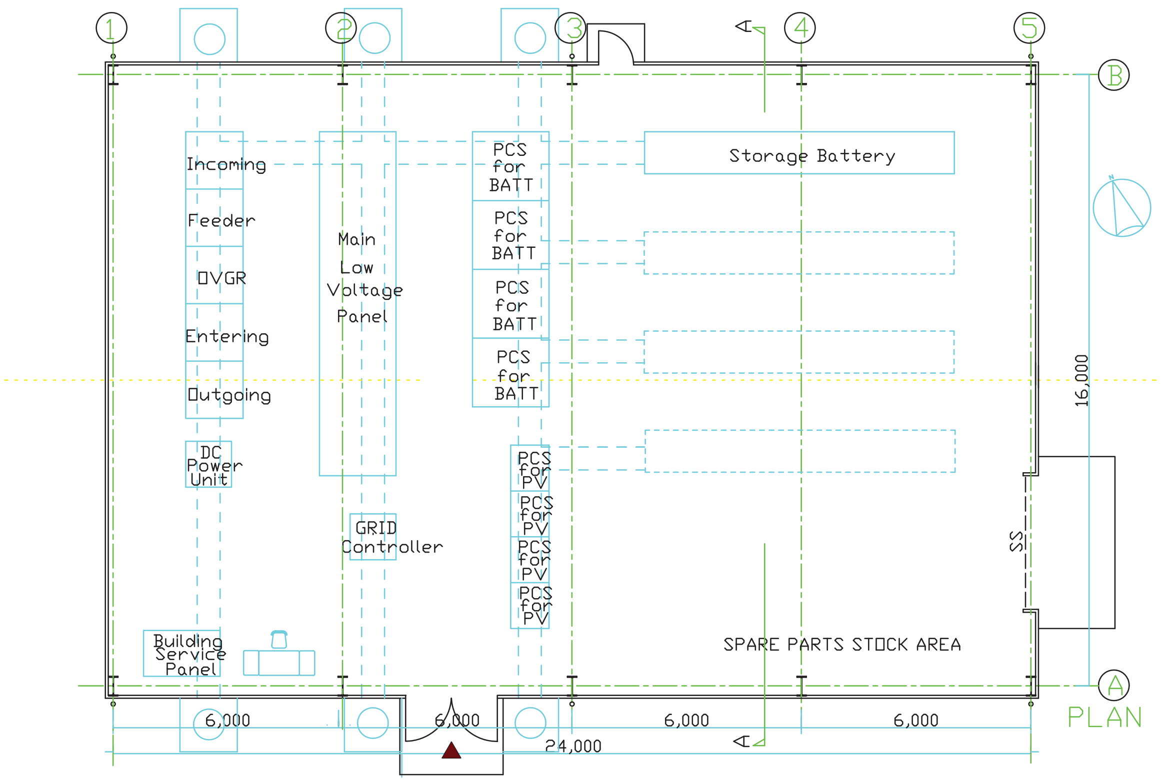


E-03 Connection of Signal Cable to the existing Photovoltaic System



PCS & BATTERIES BUIDING at POPUA Power Station

A-03 PCS & BATTERIES BUILDING AT POPUA POWER STATION



PCS & BATTERIES BUILDING at Project Site in VAINI

A-02 PCS & BATTERIES BUILDING IN VAINI