添 付 資 料

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添付資料１

関係者（面会者）リスト

第１回現地調査

環境エネルギー省
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Maldives Energy Authority (MEA)

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Mr. Akram Waheed	Assistant Engineer

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Mr. Hussain Hameez	Director
Ms. Aishath Saneedha	Manager

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Mr. Ibrahim Athif	Managing Director
Mr. Ahmed Marsoom	Chief Engineer

JICA モルディブ支所

池城 直 氏	JICA モルディブ支所長

第 2 回現地調査

環境エネルギー省
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Mr. Ahmed Hilmy	Deputy Director
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Plankton Investment Pvt. Ltd.

Mr. Ibrahim Athif	Managing Director
Mr. Ahmed Marsoom	Chief Engineer

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池城 直 氏	JICA モルディブ支所長

添付資料４

系統評価試験

1. 系統評価試験の概要

3 離島（Dharavandhoo 島、Eydhafushi 島、Thulhaadhoo 島）において PV・DG ハイブリットシステム導入検討にあたっての系統評価試験を実施した。本検討は短周期における側面であり、長周期の下げ代（発電機の下限制約）に関する検討は実施していない。また、本内容は周波数要素のみであるので、電圧面については別途検討が必要である。

2. Dharavandhoo 島

① 系統の特徴

・全ユニット（3 台）ドループ制御
・同期制御盤がないため同一系統において複数台の運転が不可
・フィーダ総数は 4 フィーダ
・負荷の高い昼間は系統を 2 分割にして発電機を 2 台運転にし、各々単独運転。
・AFC 機能がないため周波数は基準周波数（50Hz）から大きく逸脱している
・総需要は 70～160kW
・発電機の運用目標範囲は定格の 50～80％としており、20％は予備力として考慮している。

② 試験概要

複数台運転ができないので発電機の負荷遮断による試験はできない。その代わりにフィーダ切替時の系統負荷のステップ状変化を利用して系統評価を行った。図 1 にユニットの系統簡略図を示す。高負荷帯は図 1 左のように系統を 2 分割して発電機 2 台運用している。低負荷となった場合は図 1 右のように G1 もしくは G2 の 1 台の発電機で島全体の負荷を賄う運用となる。

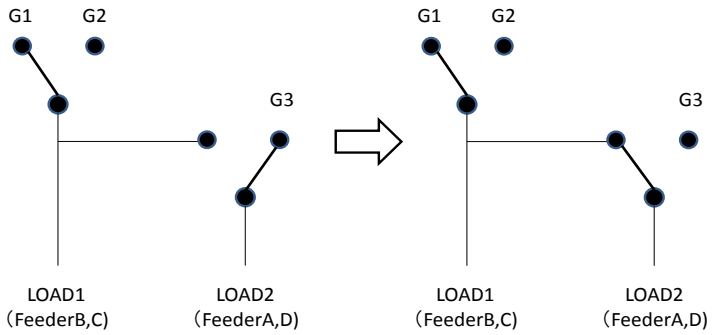


図 1 Dharavandhoo 島の試験方法概略図

③ 試験結果

試験条件および結果を以下の表と図 2 に示す。最下点周波数が 48.90Hz となり、事前周波数との偏差は 2.16Hz になった。この結果より系統定数は約 30%kW/Hz と算出できた。

試験条件

負荷移動時刻	2013/11/30　6:00頃	
並入発電機	1台(G1)	
フィーダ	B・C⇒B・C＋A・D	
定格発電機出力(kW)	G1	100
	G2	125
	G3	128
発電機出力(kW)	G1	33.71
	G2	－
	G3	－
総需要(kW)	33.71	

試験結果

事前周波数(Hz)	51.06
ボトム周波数(Hz)	48.90
負荷増分(kW)	65.11
ボトム周波数到達時間(s)	0.2
仕上周波数(Hz)	50.09

系統定数算出結果

定格出力ベース(%kW/Hz)	30.10
総需要ベース(%kW/Hz)	89.30

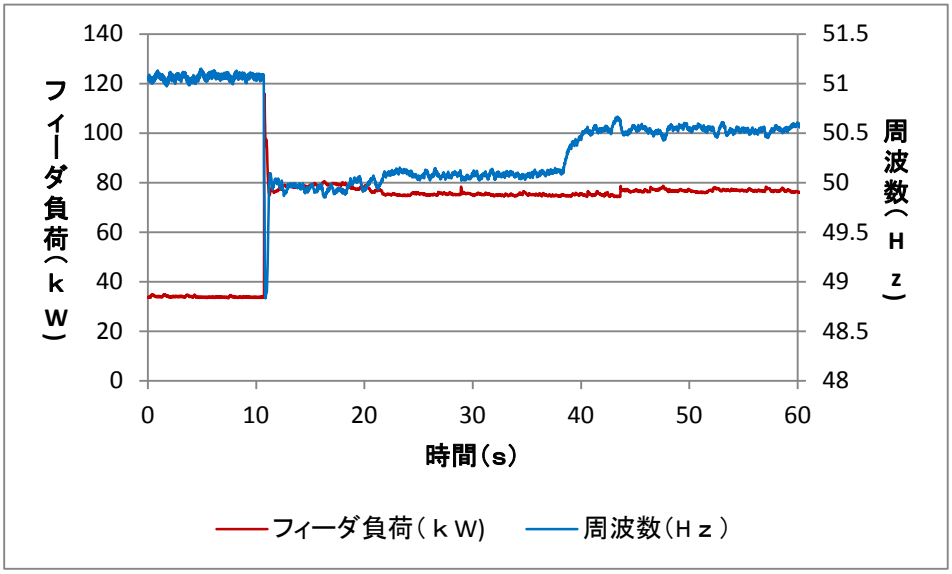


図 2 試験結果 (Dharavandhoo 島)

④ 考察

試験の結果からは約 65kW(慣性の部分を無視すると約 42kW)のステップ状のフィーダ負荷変動に対して G1 号機は追従し、基準周波数には維持できないが系統崩壊には至らない。Dharavandhoo 島では全ユニットがドループ制御によるもので、AFC 機能がないため周波数を基準周波数に維持できない。このような系統に PV を導入するとさらなる周波数の逸脱を助長することになるため、既設ディーゼル発電機の制御方法改良が PV 導入のための必要条件となる。

ディーゼル発電機故障を引き起こさない周波数低下の閾値が仮に 49Hz とすると、G1 運用時の短周期面における PV の最大導入量は約 30kW(=系統定数 30%kW/Hz ×G1 定格 100kW×周波数偏差 1Hz)となる。確率的要素を加味して日射の変動率(3σ等)を考慮すれば更なる導入は可能となる。

図 2 の 40 秒時点の周波数が 50.5Hz に上昇している。これは発電運用者の判断でガバナを操作したことによるものである。並列運転ができない系統であるにも関わらず、ディーゼル発電機のガバナ制御がドループ制御となっており、日常的な負荷変動で周波数偏差が残存する状態となっている。このため発電運用者は、次の負荷変動による周波数変動を念頭におき、高い周波数で運転制御を行っていると考えられる。

(参考)全事象に対して 99.7%の事象を包含している値を 3σ値と定義している。最大値(全事象の100%)を用いた場合に比べて PV の導入量が拡大することになる。

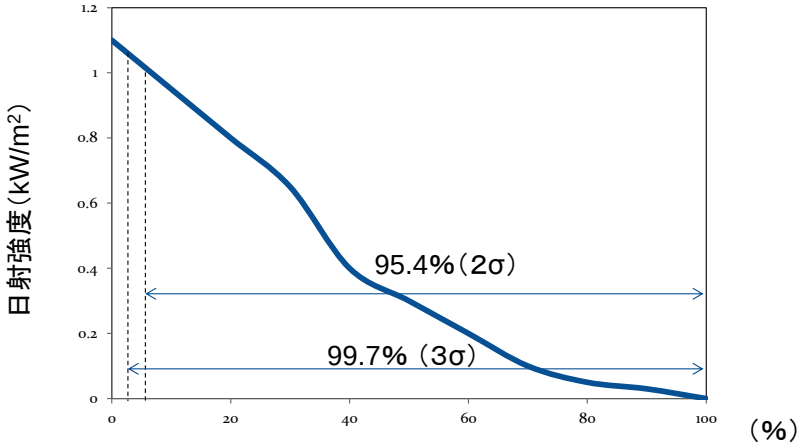


図 3 3σの概念

3. Eydhafushi 島

① 系統の特徴

・全ユニット（3 台）アイソクロナス制御
・ロードシェアリング制御により各ユニットの出力制御を実施している
・同期制御盤があるため発電機複数台の同時運用が可能
・フィーダ総数は 10 フィーダ
・総需要は 250～530kW 程度
・高負荷帯（昼間）は発電機 3 台運用。低負荷帯（夜間）は発電機 2 台運用。
・周波数は 50Hz で安定している
・発電機の運用目標範囲は定格の 50～80%としており、20%は予備力として考慮している。

② 試験概要

発電機 2 台運転となる負荷帯（16 時過ぎ）に G1 号機（約 50kW）を負荷遮断し、G2 及び G3 の性能評価を行った。計測器の制約から G1 の出力及び周波数のみを計測し、G2 及び G3 の出力については制御盤のメータを目視（写真参照）することで確認した。また、G1 のロードシェアリング機能を解除し、G1 出力を 100kW から徐々に出力低下させ、50kW 時点で負荷遮断を実施した。

③ 試験結果

試験条件および結果を以下の表と図 4 に示す。最下点周波数が 49.32Hz となり、事前周波数との偏差は 0.46Hz になった。この結果より系統定数は約 19%kW/Hz と算出できた。

試験条件

試験時刻	2013/12/1 16:21～16:25	
並入発電機	3台(G1,G2,G3)	
脱落発電機	G1	
定格発電機出力(kW)	G1	200
	G2	250
	G3	300
発電機出力(kW)	G1	48
	G2	123
	G3	110
総需要(kW)	281	

試験結果

事前周波数(Hz)	49.78
ボトム周波数(Hz)	49.32
脱落発電機出力(kW)	47.93
ボトム周波数到達時間(s)	0.3
仕上周波数(Hz)	49.80

系統定数算出結果

定格出力ベース(%kW/Hz)	18.98
総需要ベース(%kW/Hz)	37.14

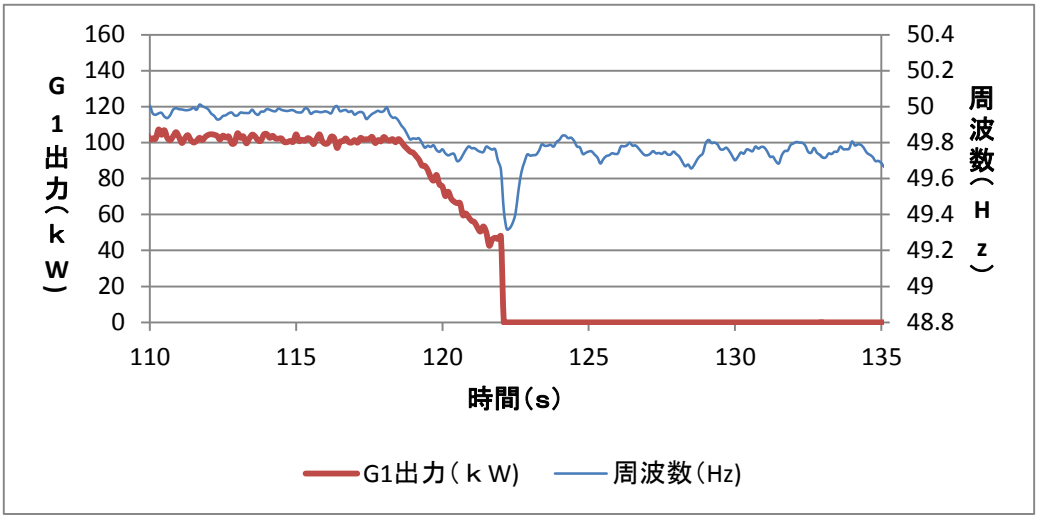


図 4 試験結果（Eydhafushi 島）

④ 考察

Eydhafushi 島はロードシェアリング制御を用いたアイソクロナス制御の発電機を運用しているので常時の周波数は 50Hz で保持しおり、比較的安定している。G1 負荷遮断直後の最下点周波数は 49.32Hz、偏差は約 0.5Hz となった。この結果から当該島の系統は比較的強いといえる。

ディーゼル発電機故障を引き起こさない周波数低下の閾値が仮に 49Hz とすると、G2 及び G3 運用時の短周期面における PV の最大導入量は約 100kW(=系統定数 19%kW/Hz ×G2･G3 定格合計 550kW ×周波数偏差 1Hz)となる。確率的要素を加味して日射の変動率（3σ等）を考慮すれば更なる導入は可能となる。

4. Thulhaadhoo 島

① 系統の特徴

- 全ユニット（3 台）アイソクロナス制御。G3 は現在定期点検中で運用除外
- ロードシェアリング制御により各ユニットの出力制御を実施している
- 同期制御盤があるため発電機複数台の同時運用が可能
- フィーダ総数は 12 フィーダ。6 フィーダ（フィーダ 7～12）は予備で運用していない。
- 総需要は 130～200kW 程度
- 通常発電機は 1 台運用。負荷帯により定格出力の大きさを考慮して運用ユニットを選定している。
- 周波数は 50Hz で安定している
- 発電機の運用目標範囲は定格の 50～80%としており、20%は予備力として考慮している。

② 試験概要

G2 及び G4 を並入し、G4 出力 50kW の負荷遮断を行うことで G2 の性能評価を実施した。計測器の制約から G4 の出力及び周波数を計測し、G2 の出力について制御盤のメータをビデオ録画することで記録した。

③ 試験結果

試験条件および結果を以下の表と図 5 に示す。最下点周波数が 47.24Hz となり、事前周波数との偏差は 2.78Hz になった。この結果より系統定数は約 8%kW/Hz と算出できた。

試験条件

試験時刻	2013/12/1　16:40～16:50	
並入発電機	2台(G2,G4)	
脱落発電機	G4	
定格発電機出力(kW)	G1	－
	G2	250
	G3	200
	G4	200
発電機出力(kW)	G1	－
	G2	71
	G3	－
	G4	58
総需要(kW)	129	

試験結果

事前周波数(Hz)	50.02
ボトム周波数(Hz)	47.24
脱落発電機出力(kW)	57.97
ボトム周波数到達時間(s)	0.7
仕上周波数(Hz)	49.80

系統定数算出結果

定格出力ベース(%kW/Hz)	8.36
総需要ベース(%kW/Hz)	16.20

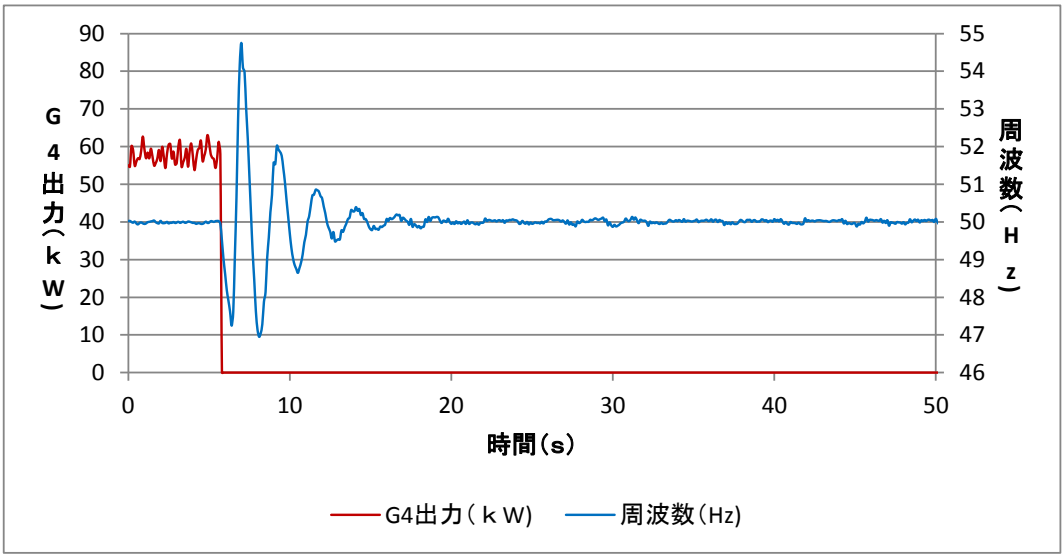


図 5 試験結果 (Thulhaadhoo 島)

④ 考察

図 5 より G2 号機は G4 負荷遮断直後に不安定でハンチングをおこした。G2 は最近不具合があり、ガバナを変更したばかりで制御チューニングが完了していないという話を現地技術者(Plankton 社)から伺った。今後、制御パラメータのチューニングを実施する予定であることから上述の現象は回避できると考えられる。

この結果を用いて PV の導入可能量を試算(条件は前述の島と同様)すると、約 20kW(=系統定数 8%kW/Hz ×G2 定格 250kW×周波数偏差 1Hz)となる。上述したように、本結果は G2 号機の最適制御パラメータ調整前の値であるので、チューニング次第で最大容量を拡大できると考えられる。

⑤ 参考試験

G4 号機をランプ状に約 5 秒かけて脱落させた場合の試験を行った。最終遮断時は約 15kW の負荷遮断を実施した。図 6 に結果を示す。

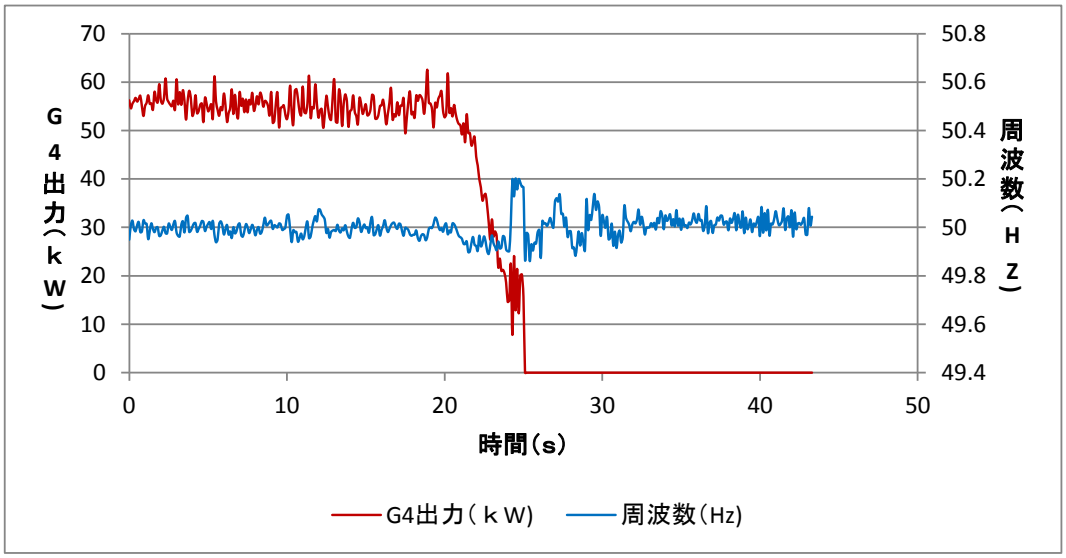


図 6 参考試験結果（Thulhaadhoo 島）

ランプ状に出力低下した場合における周波数は約 0.2Hz 以内の変動に収まっており、比較的安定している。約 15kW 遮断時に周波数偏差が約 0.3Hz となり、系統定数は約 20%kW/Hz と算出できた。PV 導入量を試算すると、約 50kW(=系統定数 20%kW/Hz ×G2 定格 250kW×周波数偏差 1Hz)となった。前述と同様に日射の変動率(3σ等)の確率的要素を含めて考慮すると更なる導入も可能といえる。

試験結果

事前周波数	50.17
ボトム周波数	49.86
脱落発電機	15.70

系統定数

定格出力ベース(%kW/Hz)	20.62
総需要ベース(%kW/Hz)	39.97

5. まとめ

Dharabandhoo 島はドループ制御であるため周波数は 50Hz の適正周波数に維持することは困難な状況である。一方、Eydhafushi 島、Thulgaadhoo 島はアイソクロナス制御の発電機を運用していることから周波数は 50Hz で安定している。

周波数変動への耐量としてはどの島も系統定数が 20～30%kW/Hz 程度ある(Thulhaadhoo 島については今後ガバナの調整が必要)ことから比較的大きいといえる。その中でも系統規模の大きい Eydhafushi 島は 50kW の PV の導入をするうえで電力系統への影響が最も小さく、電力品質の観点からは最適な島といえる。

本結果は短周期面に焦点をあてた内容であるため､50kW の PV が導入可能かどうかについては、発電機の下げ代面や電圧安定性の面の技術的な要素を考慮する必要がある。

添付資料５

環境・エネルギー省(MEE)訪問
(第１回現地調査)

環境・エネルギー省(MEE)事務所

モルディブエネルギー庁(MEA)訪問
(第１回現地調査)

モルディブエネルギー庁(MEA)事務所
(MEE 事務所と同様)

FENAKA 社訪問(第１回現地調査)

FENAKA 事務所

Plankton 社訪問(第 1 回現地調査)

Plankton 社の工場視察

Dharavandhoo 発電所

Dharavandhoo 発電所のディーゼル発電機

Dharavandhoo 発電所の発電機制御盤

Dharavandhoo 発電所での電力計測の様子

Dharavandhoo 島の学校建屋(1 階建)

Dharavandhoo 島の学校建屋(2 階建)

Dharavandhoo 島の診療所

Dharavandhoo 島の診療所建屋

Dharavandhoo 島の政府オフィス

Dharavandhoo 島の政府オフィス標識

Dharavandhoo 島のモスク(正面)

Dharavandhoo 島のモスク(南側)

Dharavandhoo 島のエアポート

Dharavandhoo 島のエアポート従業員宿舎

Eydhafushi 発電所

Eydhafushi 発電所のディーゼル発電機

Eydhafushi 発電所の発電機制御盤

Eydhafushi 発電所での試験時の様子

Eydhafushi 島の学校建屋

Eydhafushi 島の学校建屋

Eydhafushi 島の大学宿舎建屋

Eydhafushi 島の大学宿舎建屋

Eydhafushi 島の病院

Eydhafushi 島の病院建屋

Eydhafushi 島の警察署

Eydhafushi 島の警察署

Eydhafushi 島のアトールオフィス正面

Eydhafushi 島のアトールオフィス

Eydhafushi 島のアトールチーフハウス(メイン)

Eydhafushi 島のアトールチーフハウス

Eydhafushi 島のモスク

Eydhafushi 島のモスク

Eydhafushi 島のユースセンター

Eydhafushi 島のユースセンター

Thulhaadhoo 発電所

Thulhaadhoo 発電所のディーゼル発電機

Thulhaadhoo 発電所の発電機制御盤

Thulhaadhoo 発電所での電力計測の様子

Thulhaadhoo 島の学校建屋

Thulhaadhoo 島の学校建屋

Thulhaadhoo 島の診療所

Thulhaadhoo 島の診療所建屋

Thulhaadhoo 島の政府オフィス

Thulhaadhoo 島の政府オフィス

Thulhaadhoo 島のモスク(1)

Thulhaadhoo 島のモスク(1)

Thulhaadhoo 島のモスク(2)

Thulhaadhoo 島のモスク(2)

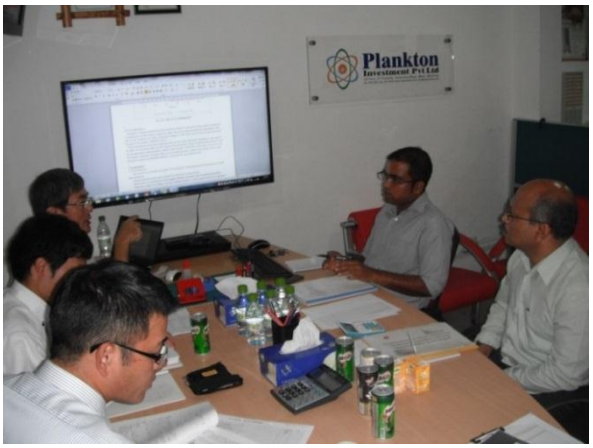
Thulhaadhoo 島のモスク(3)

Thulhaadhoo 島のモスク(3)

環境・エネルギー省(MEE)訪問
(第 2 回現地調査)

モルディブエネルギー庁(MEA)訪問
(第 2 回現地調査)

FENAKA 社訪問(第 2 回現地調査)



Plankton 社訪問(第 2 回現地調査)(12/25)

Plankton 社訪問(第 2 回現地調査)(12/27)

添付資料６

Minutes of the Meeting
Ministry of Environment and Energy,
Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium

Project Formulation Survey conducted by the Consortium regarding the promotion of technology of small and medium enterprises for developing solar power and diesel power generation hybrid systems in island regions.

Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium exchanged ideas and held a discussion with the Ministry of Environment and Energy, Maldives concerning the Ministry of Environment and Energy, Maldives' cooperation in the Feasibility Survey and Pilot Project for the "Small and Medium-Sized Enterprise Partnership Promotion" (hereinafter "Survey"), which the Consortium will make an entry for in 2014.
As a result of the discussion, in case the Consortium is authorized to carry out this survey in 2014, the Ministry of Environment and Energy, Maldives agreed to support it under the conditions described in this document. Moreover, the details of the survey shall be adjusted after it has been decided to conduct the survey.

1. Survey content:

As a solution to the energy problems which are unique to island countries in the Republic of Maldives, using technology developed in Okinawa, a demonstration project will be conducted to establish a hybrid system development technology which combines the existing DG power supply and a PV system.

2. Survey area:

Baa Atoll, Thulhaadhoo Is.

Tokuji Sunagawa

Mr. Tokuji Sunagawa
Denkyo Engineering Co., Ltd., President
Denkyo Engineering Co., Ltd.
Okinawa Enetech Co., Ltd　Consortium

Mr. Ahmed Ali
Director General
Ministry of Environment and Energy

Minutes of the Meeting
Maldives Energy Authority,
Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium

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Denkyo Engineering Co., Ltd., President
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Mr. Ajwad Musthafa
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Minutes of the Meeting
FENAKA Corporation Limited,
Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium

Project Formulation Survey conducted by the Consortium regarding the promotion of technology of small and medium enterprises for developing solar power and diesel power generation hybrid systems in island regions.

Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium exchanged ideas and held a discussion with FENAKA Corporation Limited (Maldives) concerning FENAKA's cooperation in the Feasibility Survey and Pilot Project for the "Small and Medium-Sized Enterprise Partnership Promotion" (hereinafter "Survey"), which the Consortium will make an entry for in 2014.
As a result of the discussion, in case the Consortium is authorized to carry out this survey in 2014, FENEKA agreed to support it under the conditions described in this document. Moreover, the details of the survey shall be adjusted after it has been decided to conduct the Survey.

1. Survey content:

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2. Survey area:

Baa Atoll, Thulhaadhoo Is.

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Mr. Mohamed Nimal
Managing Director
FENAKA Corporation Limited

FENAKA CORPORATION LIMITED

Minutes of the Meeting
Plankton Investment Pvt Ltd,
Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium

Project Formulation Survey conducted by the Consortium regarding the promotion of technology of small and medium enterprises for developing solar power and diesel power generation hybrid systems in island regions.

Denkyo Engineering Co., Ltd. / Okinawa Enetech Co., Ltd. Consortium exchanged ideas and held a discussion with the Plankton Investment Pvt Ltd concerning Plankton Investment Pvt Ltd's cooperation in the Feasibility Survey and Pilot Project for the "Small and Medium-Sized Enterprise Partnership Promotion" (hereinafter "Survey"), which the Consortium will make an entry for in 2014.
As a result of the discussion, in case the Consortium is authorized to carry out this survey in 2014, Plankton Investment Pvt Ltd agreed to support it under the conditions described in this document. Moreover, the details of the survey shall be adjusted after it has been decided to conduct the survey.

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As a solution to the energy problems which are unique to island countries in the Republic of Maldives, using technology developed in Okinawa, a demonstration project will be conducted to establish a hybrid system development technology which combines the existing DG power supply and a PV system.

2. Survey area:

Baa Atoll, Thulhaadhoo Is.

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Company Reg No: C - 457/2005

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Okinawa Enetech Co., Ltd Consortium

Mr. Ibrahim Athif
Managing Director
Plankton Investment Pvt Ltd

英 文 要 約

"Project Formulation Survey" under the Governmental Commission on the Projects for ODA Overseas Economic Cooperation in FY2013

Summary Report

Republic of Maldives

The Feasibility Study on the Development of Solar and Diesel Hybrid Power Generation Systems in Island Regions

March, 2014

Denkyo Engineer Co., Inc. and
Okinawa Enetech Co., Inc. Consortium

The content of this report is a summary of the project formulation survey, which was commissioned by the Ministry of Foreign Affairs of Japan in the FY 2013 and is carried out by the consortium (Denkyo Engineer Co., Inc. and Okinawa Enetech Co., Inc. Consortium). It does not represent the official view of the Ministry of Foreign Affairs.

Introduction

The Republic of Maldives (hereinafter referred to as "RM") is an island country located to the southwest of India and Sri Lanka, and it is made up of 1,192 coral reef islands. Power is supplied by diesel generators (hereinafter DG), and it is dependent on diesel fuel. The cost of power generation in small remote islands is higher than that of the metropolitan areas, so the reduction of diesel fuel consumption is a major issue.

Five specific issues are mentioned below. First of all, electricity rates in remote islands are expensive. The reduction of power generation efficiency due to the high cost of transporting fuel and low power demand can be considered as the cause. Therefore, the reduction of diesel fuel consumption in remote islands is an urgent issue to a greater extent than in metropolitan islands. The second issue is a vulnerable energy security. Both the metropolitan and remote islands have adopted DGs, which can be applied to small power systems, so the power configuration is dependent on diesel fuel. When power is supplied only by DG, the energy supply structure is susceptible to high oil prices which make it very vulnerable, so it is preferable to improve energy security through power diversification. The third issue is the influence of expanding renewable energy on power quality. The "Maldives National Energy Policy and Strategy," established in October 2010 by the Government, states that RM is committed to achieving carbon neutral by 2020 and seeks to improve energy security with the spread of renewable energy use and reduce greenhouse gas emissions. However, there is a concern that high penetration of RE could negatively impact power quality (frequency, voltage, etc.). Fourth is the issue of a hybrid system. In order to build hybrid systems, technical knowledge of DG, the existing power source, and a grid-connected PV generation system (hereinafter PV) and system development technology is required. Regarding system development technology, it is especially important to have technical skills to take advantage of the characteristics of both PV and DG to effectively combine them as well as to have experience working in power systems. The fifth issue is securing the sites for PV installation. A relatively large surface area is required for installing a PV system (approx. 10 m^2 per 1 kW), so it is important to secure sites for installation in order to promote the spread of PV systems. On the other hand, since RM is a country dotted with many small remote islands, land is very scarce, so securing land for PV installation becomes a challenge.

As a solution to the above issues, establishing a hybrid system development technology which combines the existing DGs with PV systems using technologies developed in Okinawa is considered the best. By establishing this technology, a high penetration of grid-connected PV generation systems without storage batteries on small remote islands can be expected.

The purpose of this survey is to develop a proposal for formulating an ODA project to establish the previously mentioned hybrid system development technology. In this survey, in addition to surveying protential sites for introducing hybrid systems, the feasibility of procuring equipment, construction, and operation after installation required for the introduction will be verified, and the optimal demonstration site will be selected. In addition, the aim is to develop a proposal for the "Private Sector Proposal-Based Dissemination and Demonstration Project," an ODA project, for the next fiscal year. On the other hand, since implementation by SMEs alone is difficult, this survey will be used to study the feasibility of overseas business expansion in RM and other island countries with similar geographical and climatic conditions.

I. Description of the current situation and development needs of the concerned development issues in the surveyed country (ies)

(1) Overview of political and economic conditions in RM

RM is an island country located to the southwest of India and Sri Lanka.

As a political overview, RM gained independence from the UK in 1965, and President Gayoom remained in office for 30 years from November 11, 1978, but due to democratic reform after 2004, a new democratic constitution was established in August 2008. Economy wise, tourism and fishing are the two major industries, and they account for about 40% of real GDP. Due to economic growth driven mainly by the tourism industry, and as of 2011, RM is no longer a least developed country (LDC).

Regarding the power situation, there are two power companies wholly owned by the Government of RM. One is State Electric Company Limited (hereinafter STELCO), which supplies electric power to 27 islands including the capital Malé Island, and the other is FENAKA, which provides not only power, but other public utilities such as water and waste management to 151 islands. There are other islands that supply their own power and resort islands which have resort-related companies that supply them with power.

(2) Current development issues for the target fields in RM

Both the metropolitan areas and remote islands in RM have adopted DGs, which can be applied to small power systems, so the power configuration is dependent on diesel fuel. The cost of power generation in small remote islands is higher than in the metropolitan areas, so the reduction of diesel fuel consumption is a major issue.

The following are specific issues.

1) Expensive electricity rates in remote islands
2) Vulnerable energy security
3) Power quality degradation due to the expansion of renewable energy use
4) Hybrid system development technology
5) Securing sites for PV installation

(3) Plans, policies, and legal system for targeted areas in RM

The Government of RM pledged to achieve carbon neutral by 2020 and established the "Maldives National Energy Policy and Strategy" in October 2010. To achieve carbon-neutral, significant investments to RM's energy sector is expected. The RM Government established the SREP Investment Plan (SREP IP) as one of these investments, and the energy sector is in line to receive approximately 139 million USD. In addition, RM has been operating FIT (Feed-in Tariff), which sets the different purchase prices for power in seven regions, to promote private investment for the introduction of RE since March 2011. When connecting a PV system to the grid, one must comply with the Guidelines on Technical Requirements for Photovoltaic Grid-connection. In addition, one must apply according to the Manual for Photovoltaic Grid-connection Application and enter a power sales contract with the grid owner (power company).

(4) Case study analysis of ODA projects in targeted areas for MA and analysis of other donors

The RM is currently receiving ODA from Japan as well as from other donors such as ADB and CCTF in the energy sector. Moreover, for Japan's ODA project, “The Project for Clean Energy Promotion in Male” is currently in progress, and in the near future, there are plans to implement a grassroots grant aid ODA project “The Project for Provision of a Solar Power Generation System to Dhiffushi Island."

II. Possible applicability of the SME's products and technologies, and prospects for future business development

(1) The proposing companies and the strengths of proposed products and technologies expected to be used

In this project, we propose the use of PV/DG hybrid system development technology developed in Okinawa. Moreover this hybrid system is effective in promoting the expansion of PV introduction as it does not require storage batteries, which would make proper maintenance and sustainable operation difficult. Below are features of the hybrid system. Combining multiple commercial small capacity PCSs makes it possible for owners to handle failures on their own, so rapid recovery is possible and increased equipment utilization can be expected.

1) This system does not use storage batteries
2) A system with frequency stability measures through quantity control performed by the PCS that comes with the PV system
3) A system that takes into account low-load DG operation measures through quantity control of power conditioners (PCS)

(2) The evaluation of overseas business expansion for proposing companies

The concerned companies target island regions that have geographical and climatic conditions similar to Okinawa, and by aiming to expand business overseas using technology developed in Okinawa and their experience, they seek to improve their technical expertise.

(3) Contribution to the regional economy in Japan through overseas business expansion by the proposing companies

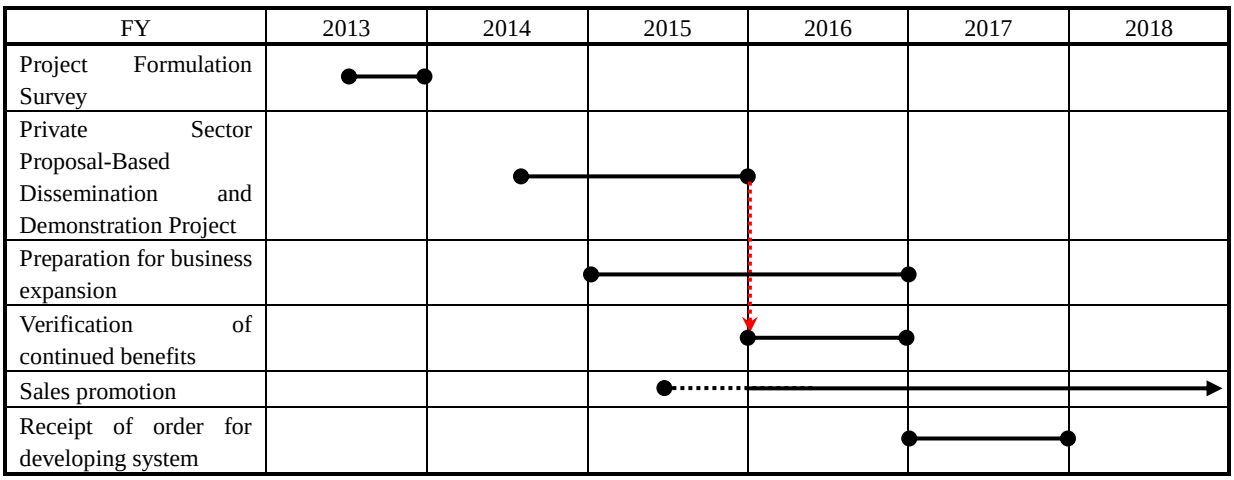
Okinawa Prefecture's policies include endorsement for companies in Okinawa to expand their business operations overseas. Moreover, a comprehensive partnership agreement between Okinawa Prefecture and JICA established in March 2012 assists companies expand business operations overseas and promotes private sector collaboration developing global industrial human resources. Therefore, overseas business expansion by SMEs in Okinawa is in line with the prefecture's policies for promoting the regional economy.

(4) The expected business mechanism

In order to build a relationship of mutual trust and a foundation to facilitate smooth business expansion, the proposed PV/DG hybrid system development demonstration project will be conducted jointly with Plankton, the local partner.

(5) The expected implementation structure and specific schedule for dissemination

To provide for expanding business in RM, the collaboration of the concerned companies and Plankton to develop PV/DG hybrid systems for power companies in RM with the aim of expanding business is expected. Regarding the schedule, we expect to conduct the demonstration project in the "Private Sector Proposal-Based Dissemination and Demonstration Project" spanning from FY2014 through FY2015.



(6) Risk management

Business expansion will be conducted with appropriate measures to avoid risks regarding intellectual property rights, environmental and social considerations, technology, etc.

III. Verification of adaptability of the SME's products and technologies to the surveyed country (ies) (Demonstration and pilot survey)

(1) Overview of introduction and trial of products and technologies or the demonstration activities to verify local adaptability including various tests (demonstration and pilot survey)

As potential sites to introduce a PV/DG hybrid system, we conducted a survey on Baa Atoll, Dharavandhoo Island, Eydhafushi Island, and Thulhaadhoo Island. In the field survey, (survey conducted on target remote islands) we checked the status of existing power facilities and their operation, the power grid, PV installation sites, and gathered information necessary for the construction of the PV/DG hybrid system. In addition, we introduced the technology for the proposed PV/DG hybrid system to the relevant agencies.

(2) Results of the introduction and trial of products and technologies or the demonstration activities to verify local adaptability including various tests (demonstration and pilot survey)

A comparison table of the three remote islands surveyed as possible sites for the introduction of the PV/DG hybrid system (Dharavandhoo Island, Eydhafushi Island, and Thulhaadhoo Island) is shown below.

Items	Dharavandhoo Is.	Eydhafushi Is.	Thulhaadhoo Is.	coment
Population	1,050	3,142	2,742	MEE information
Electricity provider	FENAKA	FENAKA	FENAKA	
Area of Island (km2)	0.455	0.31	0.25	MEE information
Total installed Genset capacity (kW)	353	750	450	MEE information
Installed Generators output (kW)	#1 100	#1 200	#2 250	
	#2 125	#2 250	#3 (in reparation) 200	
	#3 128	#3 300	#4 200	
Peak load (kW)	150	532	195	
Minimun grid Load (kW)	70	250	130	
Monthly average power generation (kWh)	57,389	211,820	106,358	MEE information
Annual power generation (kWh)	688,668	2,541,840	1,276,294	MEE information
Annual fuel consumption (L)	282,000	864,000	337,500	MEE information
Annual lubricant oil consumption (L)	2,160	3,480	1,632	MEE information
Cost of power generation (Rf/kWh)	6.85	5.58	6.81	FENAKA information
DG syncronizing operation	not possible	Possible(Load shearing)	Possible(Load shearing)	
Electricity power quality	not good	good	good	
Existing power generation facility condition	not good	good	good	
Possible site for PV installation	school	school	school	
PV introduction output (kW)	50	50	50	
PV output ratio with respect to the peak load(%)	33.3%	9.4%	25.6%	

*The listed PV implementation capacity is the expected maximum capacity.

Among the remote islands surveyed, Thulhaadhoo Island's grid is relatively stable, and since it is a remote island with a grid of 150-200 kW, it is the most potential site for the introduction of the PV/DG hybrid system in the Private Sector Proposal-Based Dissemination and Demonstration Project next fiscal year. In addition, we expressed our desire to conduct the demonstration project in Thulhaadhoo Island next fiscal year to the relevant agencies and received their approval.

(3) Study on profitability

We conducted a study on the profitability for developing a PV/DG hybrid system on Thulhaadhoo Island.Specifically, a system study was conducted concerning the grid-connected PV system, hybrid control system, grid-connection equipment (dedicated line, etc.), communication equipment, modification of existing equipment, and the approximate costs were estimated. We estimated the approximate costs assuming materials that can be procured in RM will be procured there. In calculating approximate costs, materials will basically be procured in Japan and transported to the site. In addition, we performed the calculations based on outsourcing on-site construction to local companies. When carrying out the Private Sector Proposal-Based Dissemination and Demonstration Project next year, a detailed survey of Thulhaadhoo Island will be conducted again, and regarding materials that can be procured locally in RM, a detailed cost calculation based on local procurement also needs to be conducted. In addition, we believe a study on measures for even further cost reduction, etc. through this project is needed.

Since PV/DG hybrid systems will basically be considered by local power companies for implementation, when considering profitability, how effective they are in reducing the burning of diesel fuel and whether they can contribute to reducing the cost of power generation will be evaluated.

With the proposed PV/DG hybrid system, the simulation result for the annual amount of PV generated power when PCS quantity control is used is 62,141 kWh. PV equipment utilization rate was calculated at 14.2%. This is a high value when compared to Japan which has a PV

utilization rate of approximately 12%. According to these results, you can see that RM has a high potential, and a large amount of PV generated power can be obtained.

Since the annual amount of PV generated power that can be obtained from the PV/DG hybrid system is 62,141 kWh, if you set the life of the PV system at 20 years, the amount of PV generated power in 20 years will come to 1,242,820 kWh. The power generation cost for Thulhaadhoo Island is 6.81 Rf/kWh (equivalent to 46.68 Japanese Yen). When considering the rate of increase for power generation costs, with the amount of PV generated power over 20 years, a reduction of approximately 60,100,000 yen in DG power generation cost is possible.

You can see that the total for the initial costs for implement the PV/DG hybrid system, the cost of replacing PCSs, and maintenance costs over 20 years is lower than the reduction in power generation cost.

You can see from the results of the study conducted on profitability that profitability is not expected at this stage. The main reason for this is that in comparison to a simple grid-connected PV system, the proposed PV/DG hybrid system (50 kW PV system) requires regulation of supply and demand, a monitoring control panel to ensure power quality, and communications equipment. In addition, since voltage fluctuations and other impacts from connecting the PV system to the distribution line is unknown, a dedicated line to connect to the power plant bus is required, and since it's an island, heavy machinery, etc. (a crane for loading and unloading of materials, a carrier ship for heavy equipment, etc.) are not available, so they will need to be rented which further reduces profitability. On the other hand, we believe that if the problems of a dedicated line, rental of heavy equipment, etc mention above are resolved, the initial costs for introducing the PV/DG hybrid system can be reduced leading to increased profitability. Other cost reduction measures include excluding the transformer in the grid-connection panel by procuring PCSs that conform to the local electric standards. Continued studies on cost reduction based on these measures need to be conducted.

We anticipate that as PV systems spread, their prices will drop and thus making the PV/DG hybrid system more economical. We also expect the effectiveness of the PV/DG hybrid systems will prove itself when diesel fuel prices soar, and accordingly, lead to a departure from the vulnerable energy supply structure.

In the Private Sector Proposal-Based Dissemination and Demonstration Project which we aim to get next fiscal year, the actual cost of developing a PV/DG hybrid system will be confirmed, and we will also get an understanding of how much power is generated by PV in RM. However, conducting a study on reducing the overall cost related to introducing the PV/DG hybrid system based on the procurement of materials locally in RM, demonstration of maintenance methods, etc. to discover the business profitability is vital in engagements for future business expansion.

Simulation results for the effectiveness in reducing the amount of diesel fuel burned and reducing CO2 emissions showed a 337,500 L (4.86% of the annual diesel fuel consumption in Thulhaadhoo Island) reduction in the amount of diesel fuel burned and an emissions reduction of 44,458 kg-CO2.

IV. Expected development impact and effect on business development of the proposing SME (s) in the surveyed country (ies) through proposed ODA projects

(1) Consistency of the proposed products and technologies and development issues

The issues RM is facing are a power supply structure which is dependent on diesel fuel, and the smaller and more remote islands are, the higher the cost of power generation, which in turn leads to expensive electricity rates. Therefore, it is also susceptible to high oil prices which make it very vulnerable, so improving energy security through power diversification is urgent.

Our proposal of developing a hybrid system which combines the existing DGs with PV systems using technologies developed in Okinawa is expected to solve the development issue in RM.

By developing a PV/DG hybrid system, introducing large amounts of grid-connected PV systems will be possible. As a result, it can contribute to climate change mitigation by reducing CO_2 emissions as it would reduce the burning of diesel fuel in RM.

(2) The development effect due to the application, utilization, and dissemination of products and technologies through the formulation ODA projects in RM.

The following specific effects are expected by utilizing PV/DG hybrid system development technology on small remote islands of RM.

1) Reduction of diesel fuel burned due to PV power generation
2) Improvement of the energy supply structure which is dependent on DG
3) Climate change mitigation through CO_2 reduction
4) The establishment of the hybrid system development technology in RM and business experience (improving the technology of local companies)
5) Promote the spread of and expand the introduction of PV in RM (increase the PV penetration rate in small power grids)
6) Lateral spread of hybrid systems to other remote islands (business expansion for SMEs)

(3) Business expansion for the concerned companies by conducting ODA projects

Since the concerned companies have no experience conducting business in foreign countries, they believe that by utilizing ODA projects, they can gain experience in conducting business overseas and use it as a stepping stone to expand their business. Through the overseas business experience, the concerned companies aim to train their employees for international business and prepare for future business expansion. In addition, improvement in technical expertise, etc. gained from the overseas experience is expected to be a promotional tool.

In addition, the ODA project needs to be conducted to identify issues on business expansion in RM unseen in the survey stage. It is important to know all possible issues in advance in expanding business.

Moreover, by conducting the ODA project jointly with the local partner, Plankton, both sides can build a relationship of mutual trust and aim to strengthen their collaboration for business expansion.
The operational feasibility of the PV/DG hybrid system needs to be verified by conducting demonstrations in the ODA for RM. In addition, we will explore the possibility of procuring materials

locally for the PV/DG hybrid system taking into consideration reducing initial costs and maintenance that can be provided locally.

V. Proposals for formulating ODA projects

(1) ODA Project Overview

In this survey, in developing a hybrid system which combines the existing DG power supply and a PV system, there is a need to verify the feasibility of procuring equipment, installation work, estimated costs, operation after installation, etc. as well as the establishment of technology for developing a hybrid system. In addition, we will consider conducting a demonstration in the "Private Sector Proposal-Based Dissemination and Demonstration Project" after this survey. Thulhaadhoo Island was selected as the target remote island, and the introduction of a 30-50 kW PV system is assumed.

(2) Specific content of assistance and development effects

In implementing the ODA project, we assume the implementing agencies (counterpart agencies) for the RM side will be MEE, MEA (a regulatory agency), and FENAKA(a company wholly owned by the Government). In addition, we assume we will outsource work to Plankton, the local partner company.

Period / Implementation Items	2014												2015											
	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
Private Sector Proposal-Based Dissemination and Demonstration Project Schedule (Refer to FY2013 records)		● Public announcement		● Provisional selection notice		● Contract Agreement																		
(1) Detailed survey (demonstration project sites) and local arrangements							●	●																
(2) Adjustments to detailed design, quotes, etc.								●	●				●											
(3) Shipping equipment and on-site construction													●	●			●							
(4) Trial operation, education on operation, etc.																	●	●						
(5) Soft component														●	●			●						
(6) Preparation of project reports																		●	●	●	●	●	●	●

Since the budget for the "Private Sector Proposal-Based Dissemination and Demonstration Project" is 100 million yen, the project expenses need to be kept within this limit. Based on the results of the approximate cost calculations for developing a PV/DG hybrid system on Thulhaadhoo Island, the approximate ODA funds were calculated at 99,958,320 yen. When we make an entry for the Private Sector Proposal-Based Dissemination and Demonstration Project next fiscal year, the ODA funds will need to be calculated in more detail.

The following specific development effects from conducting the PV/DG hybrid system demonstration project on Thulhaadhoo Island in the Private Sector Proposal-Based Dissemination and Demonstration Project are expected. Moreover, these are the development effects of introducing a 50 kW grid-connected PV system.

1) Annual power generated by PV: 62,141 kWh
2) Diesel fuel reduction: 16,405 L [4.86% of the annual fuel consumption in Thulhaadhoo Island (337,500 L)]
3) PV penetration rate for maximum system load: 25.6%
4) CO_2 reduction: 44,458 kg.

(3) Possibility of collaboration with other ODA projects

By establishing a hybrid system development technology which combines the existing DGs with PV systems, collaboration with other ODA projects in RM related to SREP IP, an enormous investment for the RM Government energy sector, is expected.

(4) Other relevant information

In this survey, we obtained the signature of the Director General of MEE, the counterpart agency in RM, on the Minutes of Meeting which stated that we will conduct a project on Thulhaadhoo Island. Therefore we are convinced that our consultations with MEE proceeded favorably. In addition, we believe our consultations with the parties related to the project (MEA, FENAKA, and Plankton) also proceeded smoothly.

(Project Formulation Survey) Republic of Maldives
The Feasibility Study on the Development of Solar and Diesel Hybrid Power Generation Systems in Island Regions

SMEs and Counterpart Organization

- Name of SME: Denkyo Engineer Co. , Inc.
- Location of SME: Okinawa Pref., Japan
- Survey Site・Counterpart Organization: Republic of Maldives, Ministry of Environment and Energy (MEE)

Concerned Development Issues

- Relatively high electric charges in remote islands due to higher cost of fuel transportation
- Vulnerable power supply system due to dependence on diesel fuel
- Concerns of power quality degradation due to widespread use of renewable energy
- Lack of technology and experience for developing hybrid systems

Products and Technologies of SMEs

Technology to develop a simple hybrid system that combines solar power and diesel generators (PV/DG)

- Hybrid system without storage batteries
- Hybrid system with frequency stability measures and low-load DG operation measures through multiple power conditioners (PCS) control
- Hybrid system that can be operated and maintained sustainably by the use of commercially available PCSs

Proposed ODA Projects and Expected Impact

- ODA projects: "Pilot Survey for Disseminating Small and Medium Enterprises Technologies" to reduce the cost of power generation in small remote islands and to establish a PV/DG hybrid system development technology
- Expected effect: Effectiveness in reducing the amount of diesel fuel burned through PV power generation, climate change measures through CO_2 reduction, expanded integration of PV systems on small remote islands, lateral spread of hybrid systems to other remote islands

Future Business Development of SMEs

- Business expansion utilizing PV/DG hybrid system development technology working with local companies
- Business expansion to island countries that have geographical , climatic and energy needs similar to Okinawa