Republic of Maldives
Ministry of Housing, Transport
and Environment (MHTE)
Maldives Energy Authority (MEA)
State Electric Company Limited (STELCO)

FEASIBILITY STUDY
FOR APPLICATION
OF PHOTOVOLTAIC POWER
ON MALE' AND HULHUMALE' ISLANDS
IN
THE REPUBLIC OF MALDIVES

FINAL REPORT
(SUMMARY)

NOVEMBER 2009

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD

SHIKOKU ELECTRIC POWER CO., INC.

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PREFACE

In response to a request from the Republic of Maldives, the Government of Japan decided to conduct the Feasibility Study for Application of Photovoltaic Power on Male’ and Hulhumale’ Islands and entrusted to the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Tadayuki Ogawa of Yachiyo Engineering Co., LTD. (yec) and consists of yec and Shikoku Electric Power Co., INC. four times between February and November, 2009.

The team held discussions with the officials concerned of the Government of Maldives and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

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

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

November 2009

Atsuo Kuroda
Vice President
Japan International Cooperation Agency

Mr. Atsuo Kuroda
Vice President
Japan International Cooperation Agency

LETTER OF TRANSMITTAL

November 2009

Dear Sir,
It is my great pleasure to submit herewith the Final Report of "The Feasibility Study for Application of Photovoltaic Power on Male' and Hulhumale' Islands in the Republic of Maldives".

The Study Team conducted field surveys in Maldives over the period between February and November, 2009 according to the contract with the Japan International Cooperation Agency (JICA).

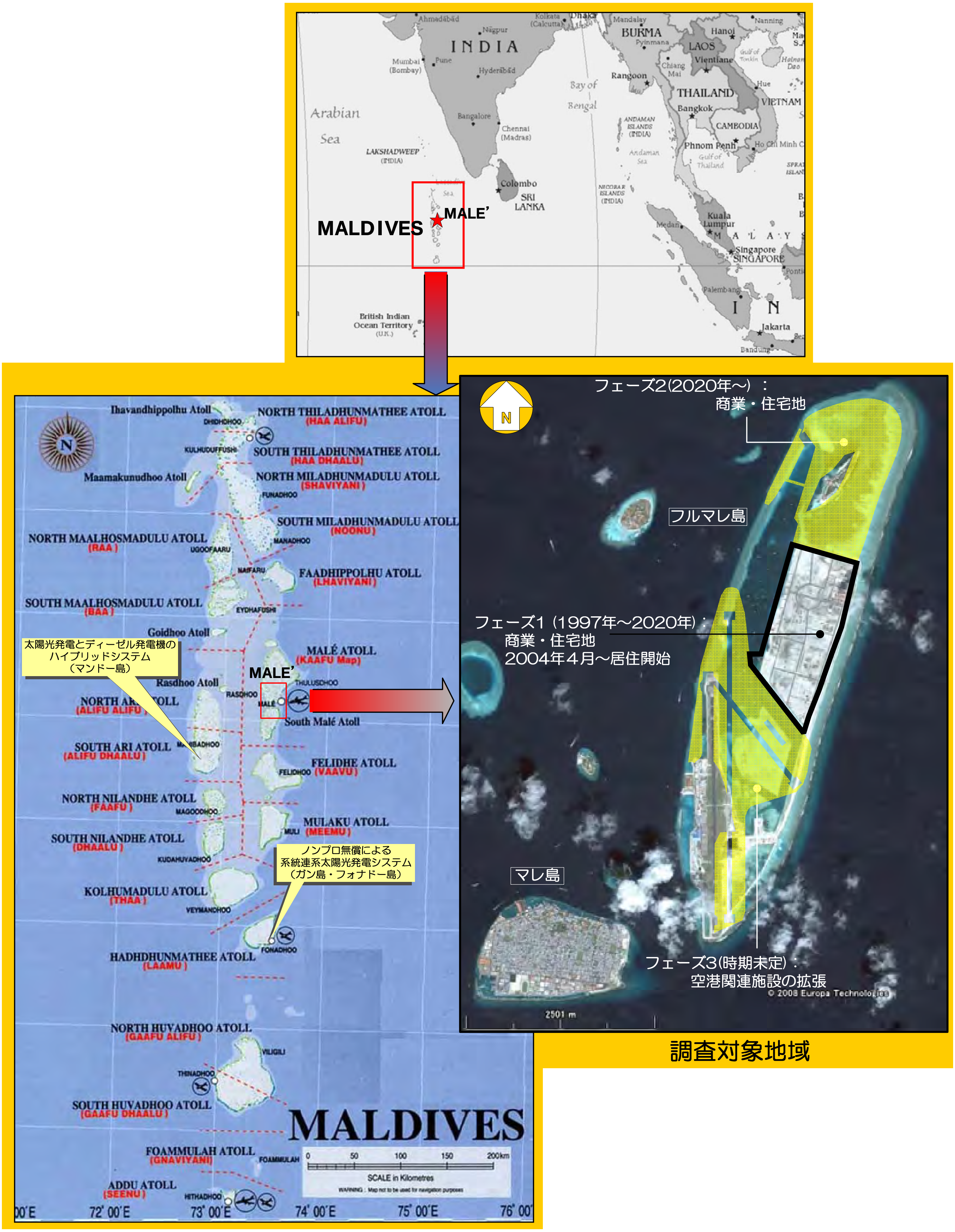
The Study Team compiled this report, which consists of the Technical, Economic and Financial Feasibility Study to introduce Grid-connected Photovoltaic (PV) System, Detail Design for Pilot Project, examination on Value-added Measures, and Long-term Action Plan, etc. through close consultations with officials concerned of the Government of the Republic of Maldives and other authorities concerned. In addition to compiling this report, technical transfer and human resource development have been conducted through collaboration work with counterpart engineers in Maldives, and counterpart training at concerned organizations in Japan for the capacity development in planning and designing of Grid-connected PV system.

On behalf of the Study Team, I would like to express my sincere appreciation to officials concerned of the Government of Maldives and other authorities concerned for their cooperation, assistance, and heartfelt hospitality extended to the Study Team.

We are also deeply grateful to the Japan International Cooperation Agency, the Ministry of Foreign Affairs, the Ministry of Economy, Trade and Industry, and the Embassy of Japan in Sri Lanka for their valuable suggestions and assistance during the course of the Study.

Yours faithfully,

Tadayuki Ogawa
Team Leader
The Feasibility Study for Application of
Photovoltaic Power on Male' and Hulhumale'
Islands in the Republic of Maldives



「モ」国全図及び調査対象地域位置図

Male’ Island

Site name
① STELCO Building
② STELCO Power House
③ Dharubaaruge
④ Velaanaage (Govt. Office)
⑤ Giyaasudheen School
⑥ Kalaafaanu School
⑦ Maldives Center for Social Education
⑧ Thaajuddeen School
⑨ New Secondary School for Girls
⑩ Indhira Gandhi Memorial Hospital (IGMH)
⑪ Faculty of Engineering
⑫ National Stadium
⑬ Majeedhiya School
⑭ Dharumavantha School
⑮ Fen Building
⑯ Water Tank
⑰ Faculty Education
⑱ Sports Grounds
⑲ Male’ South West Harbour Parking
⑳ Grand Friday Mosque
㉑ Jumhooree Maidhan
㉒ President’s Office

legend(凡例) ★: Possible Location (ポテンシャルサイト)
▮: Pilot Project Site (パイロットプロジェクトサイト)

Possible Locations for PV Installations – “Male’”

マレ島　連系PVシステム導入サイト位置図

Hulhumale' Island

① Lale International School
② Hulhumale Hospital
③ Ghaazee School
④ HDC

legend(凡例)

★ : Possible Location (ポテンシャルサイト)

Possible Locations for PV Installations – "Hulhumale'"

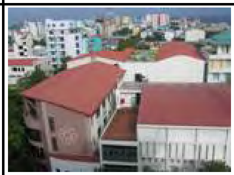
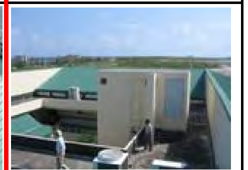
フルマレ島　連系**PV**システム導入サイト位置図

マレ島、フルマレ島ポテンシャルサイト評価表

島	Male'						
No.	1	3	5	6	7	8	9
サイト名	STELCO Building	Dharubaaruge (Public Works Building)	Giyaasudheen School	Kalaafaanu School	Maldives Center for Social Education	Thaajuddeen School	New Secondary School for Girls
設置場所	屋上	屋根	屋根, 屋上	屋根	屋根	屋根	屋根
設置可能面積 [m^2]	620	2,420	520	950	1,180	1,460	1,440
PV容量 [kWp]	45	85	40	85	100	130	100
年間発電電力量 [kWh]	45,739	100,382	48,378	117,069	120,945	157,228	90,778
日陰の影響	無し	無し	無し	無し	無し	無し	無し
既存建物の補強	不要	検討要	不要	不要	不要	不要	不要
パワーコンディショナーの設置場所	十分	既設以外の電気室確保必要	十分	屋外への設置が必要	十分	十分 (No.9と共用の屋外)	十分 (No.8と共用の屋外)
ケーブルルート	問題なし (既設倉庫&ダクト)	問題なし	問題なし	問題なし (屋外配線)	問題なし (既設屋根裏&ダクト)	問題なし (屋外配線)	問題なし (屋外配線)
接続フィーダ	FD9	FD3	FD6	FD3	FD6	FD6	FD6
トランス No.	20B	60	70	61	62	23	23
トランス容量 [kVA]	500	630	150	100	200	1000	1000
サイト所有者	STELCO	MHTE	Ministry of Education	Ministry of Education	Ministry of Youth	Ministry of Education	Ministry of Education
所有者からの承諾							
運用保守	容易	普通	普通	普通	普通	普通	普通
保安	問題なし	問題なし	問題なし	問題なし	問題なし	問題なし	問題なし
PR効果	中	中	中	中	高	中	中
費用							
サイト写真							
総評	/パネル支持架台が必要 /基礎と防水処理が必要 /多くの職員がおり、運用保守が容易	/既設建物は恒久設備でない /屋根面積が広い /竣工図が見つからない	/屋根材の交換が必要 /電気室のスペースが十分	/屋根材の交換が必要	/屋根材の交換が必要 /電気室の上部に十分なスペースあり	/屋根面積が広い /屋根のコーティング改良が必要	/屋根面積が広い
ランク	6	7	9	4	3	1	2

全サイト合計＝ 1605 kW
上位6サイト合計 = 480 kW

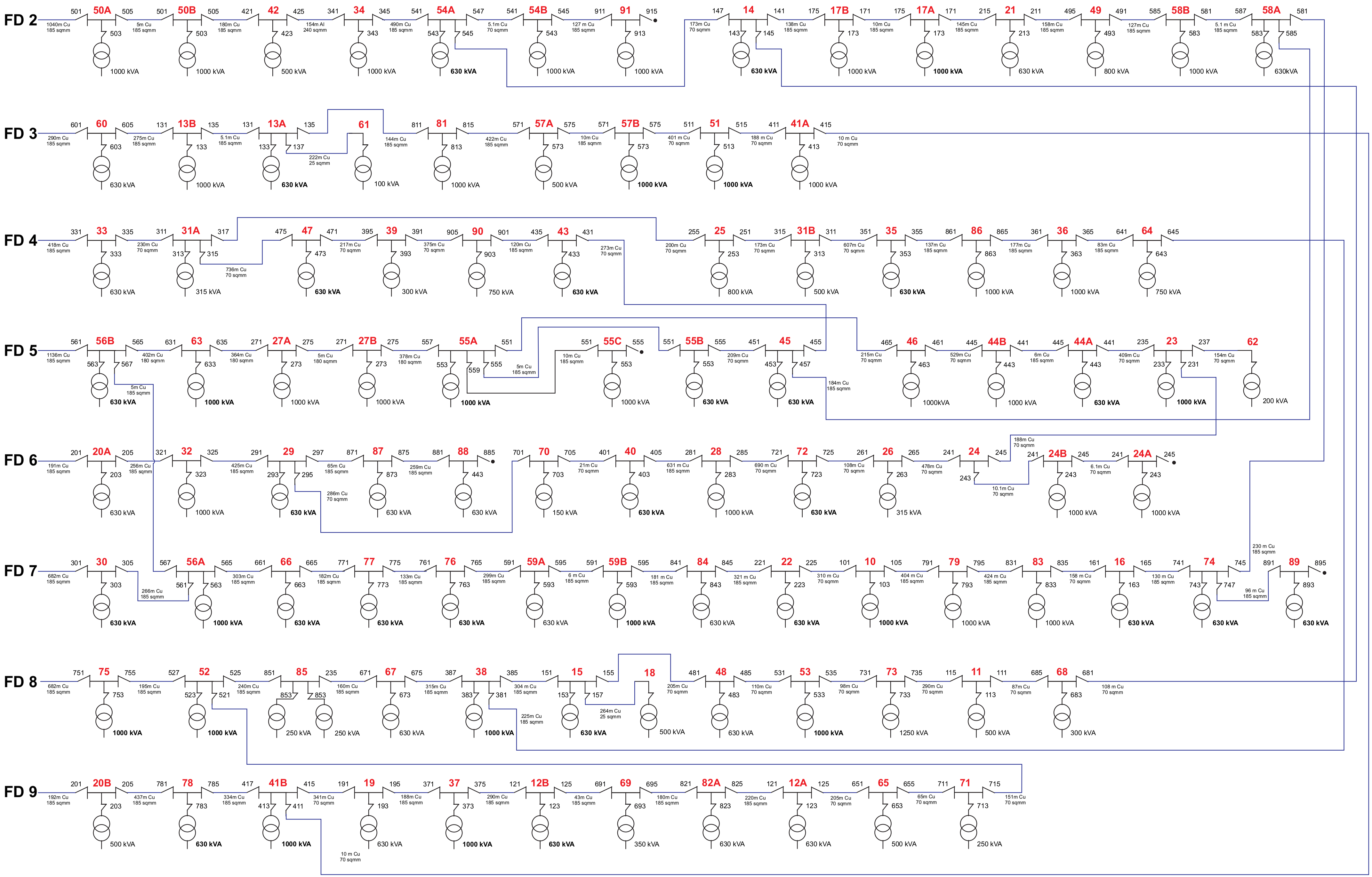
マレ島、フルマレ島ポテンシャルサイト評価表

島	Male'						Hulhumale'
No.	11	12	17	20	21	22	2
サイト名	Faculty of Engineering	National Stadium	Faculty of Education	Grand Friday Mosque	Jumhooree Maidhaan	President's Office	Hospital
設置場所	屋根，屋上	屋根	屋上	屋根	地上	屋根	屋根
設置可能面積 [m^2]	1,130	2,970	98	2,000	2,860	1,158	1,130
PV容量 [kWp]	80	400	10	30	60~160 (パネル配列方法による)	20	60
年間発電電力量 [kWh]	96,756	483,780	12,094	36,283	196,986	24,189	72,567
日陰の影響	無し	周辺建物とスタンドライトからの影響の考慮が必要	新校舎の建設計画の確認が必要	塔とモスク上部からの日陰の影響あり	無し	東西屋根に周辺建物からの日陰の影響あり	無し
既存建物の補強	検討要	必要	検討要	検討要		不要	検討要
パワーコンディショナーの設置場所	十分	十分	十分	十分	設置場所確保が必要	設置場所確保が必要	十分
ケーブルルート	問題なし	問題なし （屋外配線）	問題なし	問題なし （屋外配線）	問題なし （屋外配線）	問題なし （既設天井裏＆ダクト）	問題なし （既設天井裏＆ダクト）
接続フィーダ	FD4	FD9	FD7	FD2	FD2	FD8	FD2
トランス No.	25	41B	30	14	14	73	11
トランス容量 [kVA]	800	1000	630	630	630	1250	315
サイト所有者	Ministry of Education	Ministry of Youth	Ministry of Education	Ministry of Islamic Affairs	Male' Municipality or Ministry of Home	President Office	Ministry of Health
所有者からの承諾					利害関係者ならびに一般市民の了解が必要		
運用保守	容易	普通	普通	普通	普通	普通	普通
保安	問題なし	問題なし	問題なし	問題なし	問題なし	問題なし	問題なし
PR効果	中	高	中	高	高 （一般市民との協議の必要性あり）	高	Middle
費用		スタンド補強費用が高額					
サイト写真							
総評	/屋根の形状が複雑なため、特殊な架台が必要	/最もポテンシャルが大きいが構造物の補強費用が高額	/RC屋上のみ利用可能	/面積は広いもののほとんどの場所は周辺構造物からの影の影響あり	/PR効果が非常に高い /すべての利害関係者からの承認とりつけが困難	/PR効果が高い /建設詳細工程検討が必要 /屋根のコーティング改良が必要	/現状マレ島に比較して電力供給に余裕があるため優先度が低い
ランク	8	12	11	10		5	13

MALE’ MEDIUM VOLTAGE RINGMAIN DISTRIBUTION SYSTEM

マレ島中圧（１１ｋＶ）配電系統図

Power Distribution Department / State Electric Company Ltd



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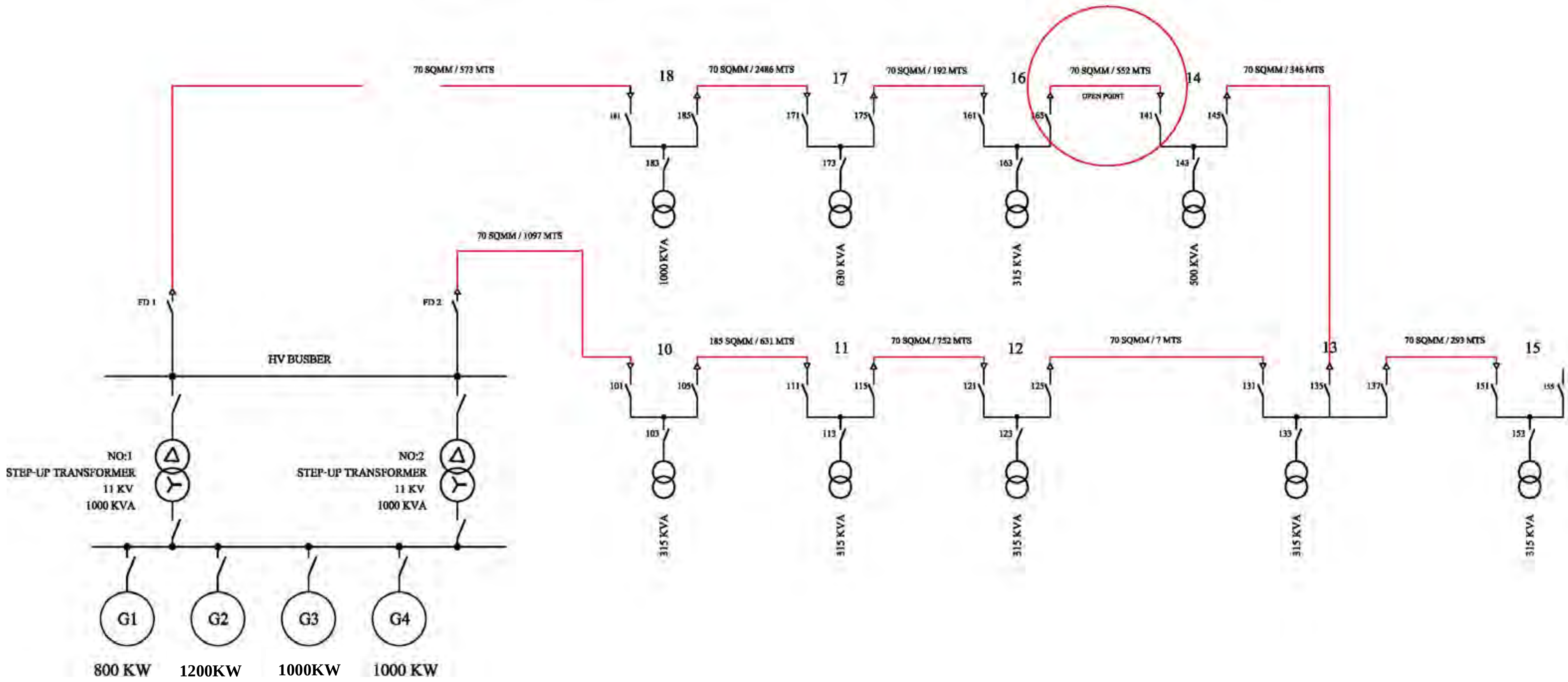


フルマレ島 中圧（１１kV）配電系統図

CONTENTS

CHAPTER 1 BACKGROUND AND BASIC CONCEPT OF THE STUDY

1.1 Background and Objectives of the Study

The Republic of Maldives (hereinafter referred to as Maldives) is an island nation situated southwest of India and Sri Lanka. It is composed of approximately 1,190 coral islands, of which 199 are inhabited. The national population is approximately 299,000 (2006 national census), of which 104,000 people or approximately 35% of the total population, live on Male' Island. Male' is home to the national capital functions and the most employment opportunities, however, problems of declining security and deteriorating living environment caused by this population concentration have become social problems on the island. The tourism industry of the Maldives was badly affected in the wake of the September 11-terrorist attacks in the United States, although the economy has displayed steady recovery since then. However, the Indian Ocean tsunami disaster of December 2004 caused 82 fatalities, 26 persons missing, destruction of around 2,000 homes and other massive damage especially in outer islands with little or no seawalls and other infrastructure. The financial cost of the tsunami damage amounted to approximately 62% of GDP and caused the GDP growth rate to plunge to minus 4.6% in 2005. Since then, however, the tourism and fisheries industries, which account for approximately 40% of GDP, have recovered and GDP growth rate of 19.1% and 6.6% was recorded in 2006 and 2007 respectively. As a result, there has been a construction boom in Male' and with more and more people who suffered damage on outer islands moving to Male' in search of employment and safer living conditions, which accelerated more population concentration.

Power supply on the 10 islands which including capital Male' is carried out by STELCO, which is 100% government financed electric utility, and power generation on Male' accounts for approximately 72% of generated power in inhabited islands (185,553 MWh) in 2006. Power demand in Male' is expected to grow rapidly at more than 11% per year, and it is forecasted that peak demand over the next five to seven years will reach more than double the capacity of generation facilities. Accordingly, STELCO is planning to procure new diesel generators, however, due to limited space any further expansion of power stations in Male' will be difficult. Moreover, with more than 80% of primary energy demand and almost all power generation depend on diesel fuel, the recent inflation in the price of diesel (22% in 2007) has badly affected the financial condition of STELCO and threatens the energy security of the country.

In response to these issues, the Government of Maldives (GOM) has reclaimed land (Hulhumale' Island: total area 7.85 square kilometers) off the coast of Male', and it is implementing a comprehensive development plan that includes the resettlement of residents in Male'. According to the plan, residential and commercial districts as well as cultural and education districts will be constructed. In addition, tourism districts will be built by introducing foreign capital. Thus it is forecasted that the power demand in Hulhumale' will grow rapidly from now on.

Furthermore, since Maldives is an island nation with an average altitude of just 1 m above sea level, it is one of the countries most prone to the effects of rising sea level caused by climate change. For this reason, in the Manifesto 2008~2013 and Strategic Action Plan, the current government aims to achieve the carbon neutral within 10 years time. GOM aims to reduce greenhouse gas emissions from diesel power station and to ensure energy security.

Under these circumstances, GOM issued a request to Government of Japan for implementation of a development study for the introduction of grid-connected photovoltaic (PV) system, as a way to improve energy efficiency and mitigate climate change for the purpose of realizing stable power supply in the medium to long term.

The objectives of the Study are as follows: (1) To conduct technical and economic/financial feasibility study (F/S) and confirm the conditions required in order to introduce the grid-connected PV system in Male' and Hulhumale' Islands; and (2) To examine the required legislation, systems, regulations and human resources development plan, etc. and finalize long-term plan and action plan for the introduction and proper operation of the grid-connected PV system. At the same time, detailed design for the introduction of grid-connected PV system will be conducted on five or six potential sites, with a view to building the capacity of the organizations primarily responsible for introducing the system.

1.2 Basic Concept of the Study

(1) In the Study, it is necessary to select potential sites for the grid-connected PV system and to complete detailed design for potential sites during a short period. Accordingly, the Study Team has already commenced the preliminary planning and design of PV systems based on available data. Detailed design will be commenced immediately after potential sites are finalized in the joint work with the counterparts.

(2) As a result of the final round of voting in the presidential election held in October 2008, President Maumoon Abdul Gayoom, who had held office for the previous 30 years, was defeated, and Mohamed Nasheed, the leader of the opposition Democratic Party of the Maldives, became the new president. In line with this, the Ministry of Environment, Energy and Water (MEEW), which was expected to be the counterpart Ministry, was reorganized and combined with the Ministry of Construction and Public Infrastructure (MCPI), Ministry of Environment, Energy and Water (MEEW), Ministry of Transport and Communication (MTC) and Ministry of Housing and Urban Development (MHUD) to make the new Ministry of Housing, Transport and Environment

(MHTE). Accordingly, in the first field survey, full explanations will be given to the counterpart agency concerning background of the Study, the Study concept, methodology and schedule, etc. in order to facilitate the smooth introduction of the Study.

(3) On the densely populated island of Male', where buildings are already crowded, potential sites for the grid-connected PV system will be selected from the wide variety of candidate sites such as buildings, public facilities, stadium, pedestrian walks and bus stops while taking the impact on existing 11 kV distribution grid into account. Meanwhile, on Hulhumale' Island, potential sites will be selected utilizing vacant spaces on the roof of public and commercial facilities which are under planning phase, in consideration of economic advantage and operation after commissioning.

CHAPTER 2 TECHNICAL FEASIBILITY STUDY

2.1 Power Demand Projection

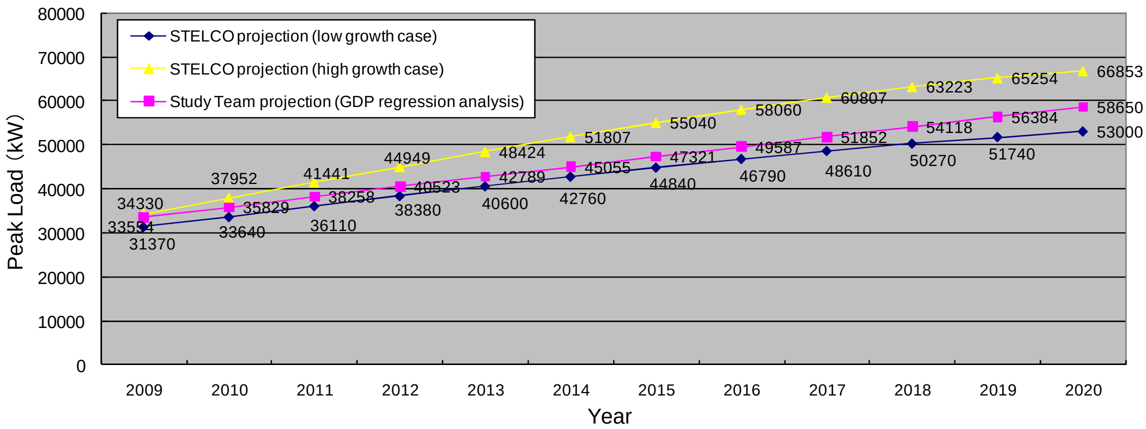
2.1.1 Male' Island

In the aftermath of the Tsunami disaster caused by Sumatra earthquake of December 2004, there has been steady migration of people from outer islands to Male' Island and the demand for electricity here has increased rapidly. The latest power demand projection conducted by STELCO was the Power Extension Study that was conducted by German consultant OLP in 2004, and this made a forecast of peak demand on Male' and Hulhumale' Islands up to 2020. For Male' Island, this study estimated two scenarios: a high growth case and a low growth case; however, even in the low growth case, peak load is expected to exceed the firm capacity of generator facilities (the capacity obtained after deducting the largest generator capacity from the 85% of total rated capacity) in 2013, indicating an urgent need to reinforce generating facilities. Accordingly, STELCO commenced the Fourth Power System Development Project under support from DANIDA (Denmark) in 2009. This entails the procurement and installation of two DEGs (8 MW) with construction of foundations for three units and is scheduled for completion in 2010. It is planned to procure and install the third unit under this project in 2011.

The Study Team conducted regression analysis based on the minimum square method utilizing GDP values (by the Ministry of Finance) from 1997 to 2007 and GDP projections from 2008 to 2011 as the first parameter and population statistics from 2000 to 2007 as the second parameter, and compared the findings with the above projection by STELCO. Generally speaking, since econometric models are constructed as an aggregate of numerous estimation expressions and definitional expressions, it is necessary to verify the model validity. In the Study, model validity was verified through using the following indicators:

Coefficient of determination (R^2) (expressing overall model certainty): 0.85 or more
Value t (estimated coefficient assessing reference accuracy): Absolute value of 2 or more

As a result of conducting regression analysis on peak load, $R^2 = 0.979$ and $t = 2.57$ were obtained and the validity of the constructed model was verified. In the future, these projection findings will be used to project peak load on each distribution line feeder and estimate the maximum PV capacity that can be connected to each feeder.

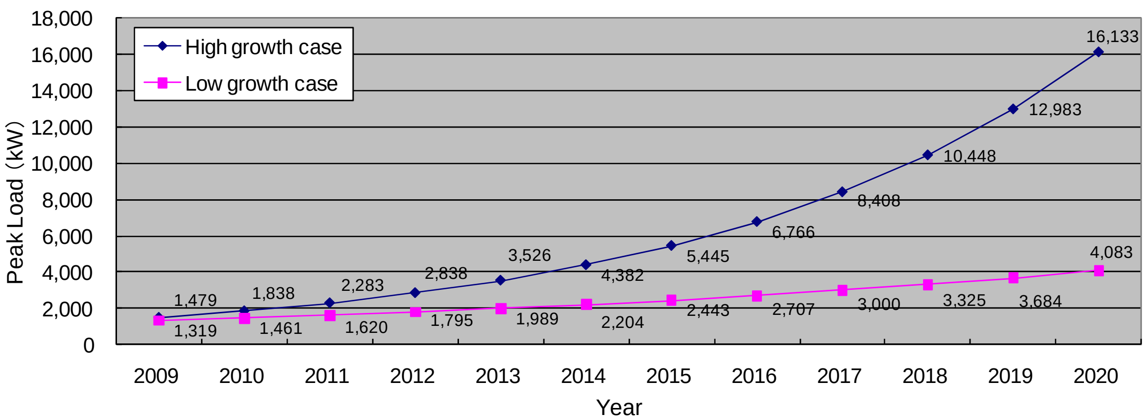


Source: Prepared by the Study Team

Figure 2.1.1-1 Power Demand Projection for Male' Island
(Comparison with the Study Team's Projection)

2.1.2 Hulhumale' Island

According to the Hulhumale' Development Corporation (HDC), although plans aiming for the relocation of 60,000 residents by 2020 are being sustained by the new government, future trends regarding the large-scale development of residential areas and industrial and business districts are unclear. Accordingly, demand projection was implemented for two cases, i.e. 1) the population growth rate (24.3%) required to achieve the target population proposed under the relocation program, and 2) the case assuming the peak load growth rate (10.8%) between 1987~2008 on Male' Island. As is shown in Figure 2.1.2-1, power demand in the high growth case is estimated to be approximately 16 MW in 2020, which is close to the findings of the low growth case by STELCO. Therefore, detailed analysis in the following sections will be carried out based on the high growth case estimated by the Study Team.



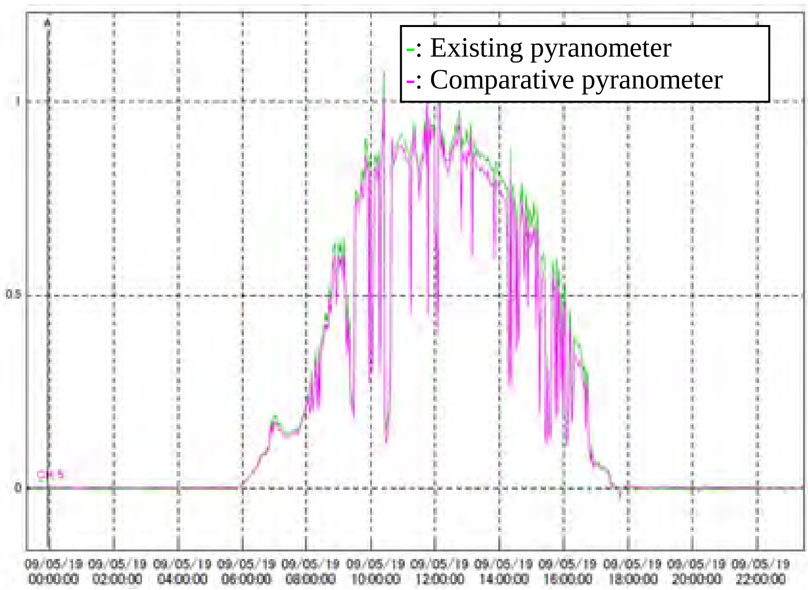
Source： Prepared by the Study Team

Figure 2.1.2-1 Estimated Power Demand on Hulhumale' Island (Study Team)

2.2 Collection and Analysis of Solar Irradiation Data, etc.

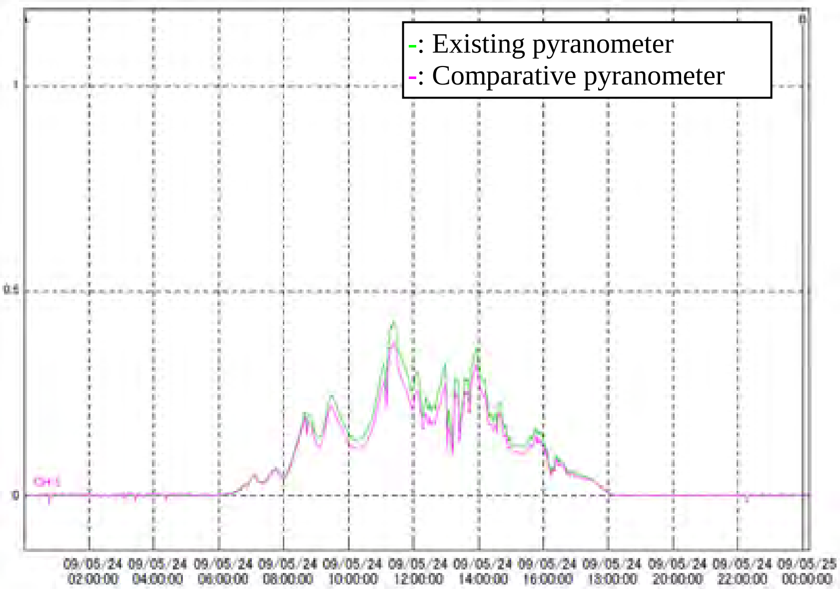
During the first field survey, the Study Team visited the Department of Meteorology and calculated monthly solar irradiation utilizing data measured in a joint effort between the former Ministry of Communication Science & Technology (MCST) and UNDP between August 1, 2003 and July 31, 2004.

Solar irradiation observations are not currently implemented due to breakdown of the data logger, however, the Study Team found that the pyranometer is operating independently. In order to confirm the reliability of the data, in the second field survey the Study Team took a calibrated pyranometer, installed it in the same place and compared the resulting data with data from the existing instrument. As is shown in Figure 2.2-1 and Figure 2.2-2, since both meters give almost the same data, reliability of the local pyranometer was confirmed and it was decided to adopt the measurements from August 1, 2003 to July 31, 2004 as the basic data.



Source： Prepared by the Study Team

Figure 2.2-1 Pyranometer Accuracy Confirmation Findings (May 19, clear skies)



Source： Prepared by the Study Team

Figure 2.2-2 Pyranometer Accuracy Confirmation Findings (May 24, rain)

This global solar irradiation data were divided into direct solar irradiation and scattered solar irradiation using the solar irradiation estimation method devised by the New Energy and Industrial Technology Development Organization (NEDO) based on survey by the Japan Weather Association. The findings of these calculations shall be used as design parameters for projecting power generation in the grid-connected PV system.

Month	Daily Avg. Grobal Irradiation [kWh/m^2/day]
1	5.23
2	5.61
3	5.99
4	5.24
5	4.86
6	5.06
7	4.51
8	5.60
9	4.56
10	6.06
11	4.00
12	5.10
AVE	5.15

Source： Prepared by the Study Team

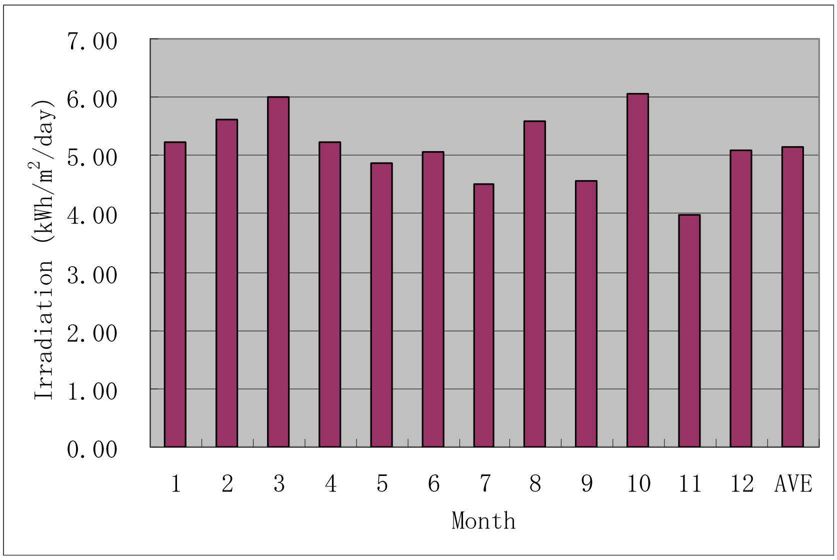
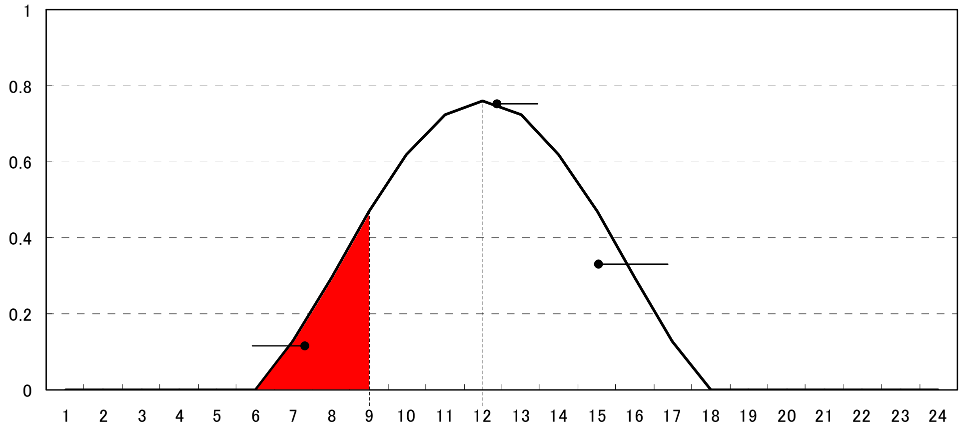


Figure 2.2-3 Horizontal Plane Solar Irradiation Data Applied in the Study

2.3 Examination and Measurement concerning Solar Irradiation Obstruction

Solar energy comprises direct solar irradiation which directly reaches the earth, as well as scattered solar irradiation (scattered by dirt, dust and clouds, etc. in the air) and reflected solar irradiation. However, reflected solar irradiation shall not be considered here because it varies according to conditions in each area.

Solar energy shall be examined as the sum of direct solar irradiation and scattered solar irradiation, and the hourly intensity of solar irradiation shall be calculated. Accordingly, hourly changes in solar irradiation intensity are approximated in the manner shown in the figure below.



Source： Prepared by the Study Team

Figure 2.3-1 Hourly Changes in Solar Irradiation Intensity

The above figure shows the amount of solar irradiation at the measurement point, assuming that shadow has an impact that invalidates solar irradiation between 06:00 and 09:00 and this invalid solar irradiation is deducted.

The following table shows direct solar irradiation and scattered solar irradiation values calculated by the Study Team upon quoting from the survey and research report on PV systems (survey and research of meteorological data for constructing PV utilization systems) by NEDO. For the purposes of this examination, data are taken from January, the month of the winter solstice, when shadows are the longest.

Table 2.3-1 Solar Irradiation in January on Male' Island

Month	Time	Horizontal Place Direct Arrival	Horizontal Plane Scattering	Horizontal Plane Total
1	1	0.000	0.000	0.000
1	2	0.000	0.000	0.000
1	3	0.000	0.000	0.000
1	4	0.000	0.000	0.000
1	5	0.000	0.000	0.000
1	6	0.000	0.000	0.000
1	7	0.063	0.064	0.127
1	8	0.165	0.130	0.295
1	9	0.281	0.188	0.469
1	10	0.389	0.231	0.620
1	11	0.465	0.259	0.724
1	12	0.492	0.268	0.760
1	13	0.465	0.259	0.724
1	14	0.389	0.231	0.620
1	15	0.281	0.188	0.469
1	16	0.165	0.130	0.295
1	17	0.063	0.064	0.127
1	18	0.000	0.000	0.000
1	19	0.000	0.000	0.000
1	20	0.000	0.000	0.000
1	21	0.000	0.000	0.000
1	22	0.000	0.000	0.000
1	23	0.000	0.000	0.000
1	24	0.000	0.000	0.000
				5.230

Source： Prepared by the Study Team

In cases where shadow occurs at a certain time at the target point, it is conservatively assumed that the intensity of solar irradiation at that time entails neither direct solar irradiation nor scattered solar irradiation. In the case where shadow has an impact between 06:00~08:00 in January in the target area, it is assumed that a total of 0.127 kwh/m^2 of solar energy between 06:00 and 07:00 and a total of 0.295 kwh/m^2 of solar energy between 07:00 and 08:00 cannot be acquired due to the shadow. Therefore, judging from the solar irradiation examination data given in the above table, this means that solar irradiation in January is 5.23 kwh/m^2/day, and the amount of solar irradiation available for power generation is this amount minus 0.127 kwh/m^2 and 0.295 kwh/m^2, i.e. 4.477 kwh/m^2/day.

Based on these findings, the estimated amount of solar irradiation at each site is calculated as follows.

Table 2.3-2 Estimated Solar Irradiation on each Potential Site

No	Site	Solar Irradiation	Invalid Solar Irradiation
Male' Island			
1	STELCO Building	5.23 kwh/m^2/day	No impact because panels will be on a frame supported by pillars at 3 m height
2	STELCO Power House	5.23 kwh/m^2/day	
3	Dharubaaruge	West building: 5.103 kwh/m^2/day East building: 4.386 kwh/m^2/day	West building: Impacted time 17:00-18:00, therefore 0.127 kwh/m^2 East building: Impacted time 6:00-9:00, 16:00-18:00, therefore 0.844 kwh/m^2
4	Velaanaage (Govt. Office)		
5	Giyaasudheen School	South school building: 5.23 kwh/m^2/day Gymnasium: 4.808 kwh/m^2/day	Impacted time 6:00-8:10, therefore 0.422 kwh/m^2
6	Kalaafaanu School	South school building: 4.808 kwh/m^2/day North school building: 4.339 kwh/m^2/day Gymnasium: 3.719 kwh/m^2/day	Impacted time 16:30-18:00, therefore 0.422 kwh/m^2 Impacted time 15:30-18:00, therefore 0.891 kwh/m^2 Impacted time 14:50-18:00, therefore 1.511 kwh/m^2
7	Maldives Center for Social Education	5.23 kwh/m^2/day	
8	Thaajuddeen School	South school building: 5.23 wh/m^2/day Central building: 5.23 kwh/m^2/day North school building: 5.23 kwh/m^2/day Gymnasium: 4.339 kwh/m^2/day	Impacted time 6:00-10:00, therefore 0.891 kwh/m^2
9	New Secondary School for Girls	North school building: 5.23 kwh/m^2/day West school building: 3.917 kwh/m^2/day Gymnasium: 4.386 kwh/m^2/day	Impacted time 6:00-11:00, therefore 1.313 kwh/m^2 Impacted time 6:00-8:00, 15:30-18:00, therefore 0.844 kwh/m^2
10	Indhira Gandhi Memorial Hospital (IGMH)	4.386 kwh/m^2/day	Impacted time 6:00-8:00, 16:30-18:30, therefore 0.844 kwh/m^2
11	Faculty of Engineering	5.23 kwh/m^2/day	
12	National Stadium	East stand: 5.23 kwh/m^2/day South stand: 5.23 kwh/m^2/day West stand: 3.719 kwh/m^2/day	Impacted time assumed as 14: 00-18: 30. 1.511 kwh/m^2
13	Majeedhiya School	5.23 kwh/m^2/day	
14	Dharumavantha School	- (Excluded due to numerous surrounding obstructions)	
15	Fen Building	3.719 kwh/m^2/day	Impacted time 14:00-18:30, therefore 1.511 kwh/m^2
16	Water Tank (MWSC)	5.23 kwh/m^2/day	

No	Site	Solar Irradiation	Invalid Solar Irradiation
17	Faculty Education	5.23 kwh/m^2/day	
18	Sports Grounds	5.23 kwh/m^2/day	
19	Male' South West Harbour Parking	5.23 kwh/m^2/day	
20	Grand Friday Mosque	5.23 kwh/m^2/day	
21	Jumhooree Maidhan	5.23 kwh/m^2/day	
22	President's Office	5.23 kwh/m^2/day	
Hulhumale' Island			
1	Lale International School	5.23 kwh/m^2/day	
2	Hulhumale Hospital	5.23 kwh/m^2/day	
3	Ghaazee School	5.23 kwh/m^2/day	
4	HDC	5.23 kwh/m^2/day	
5	Housing Flats	5.23 kwh/m^2/day	

Source： Prepared by the Study Team

2.4 Selection of Potential Sites for Introducing the Grid-Connected PV System

The Maldives side recommended that the following 27 sites, consisting of 22 on Male' Island and 5 on Hulhumale' Island, be used as survey targets in the Study. Upon discussing with the Maldives side, a number of sites were excluded because of concerns over the impact of shadow, difficulty in implementing survey due to private facilities or difficulty in obtaining drawings, etc., and it was eventually decided to implement technical examination on 14 potential sites.

Table 2.4-1 List of Selected Potential Sites

Island	No.	Site	Selection as Potential Site	Reason for Omission
Male' Island	1	STELCO Building	○	
	2	STELCO Power House	×	Concern that waste heat from the diesel generator will impair PV module efficiency
	3	Dharubaaruge (Public Works Building)	○	
	4	Velaanaag (Government Building)	×	Inability to obtain drawings during the works
	5	Giyaasudheen School	○	
	6	Kalaafaanu School	○	
	7	Maldives Center for Social Education	○	
	8	Thaajuddeen School	○	
	9	New Secondary School for Girls	○	
	10	Indhira Gandhi Memorial Hospital (IGMH)	×	Plans exist for rooftop rehabilitation
	11	Faculty of Engineering	○	
	12	National Stadium	○	
	13	Majeedhiya School	×	Impact of shade from surrounding trees
	14	Dharumayantha School	×	Impact of shade from surrounding buildings and trees
	15	Fen Building	×	Inability to obtain drawings because the building is privately owned
	16	Male' Water Supply	×	The upper part of the water tank cannot be used because of periodic inspections.
	17	Faculty of Education	○	
	18	West Stadium	×	Concerns exist over equipment safety.
	19	Male' South West Harbour Parking	×	The facility is privately owned.
	20	Grand Friday Mosque	○	
	21	Jumhooree Maidhaan	○	
	22	President's Office	○	
Hulhumale' Island	1	Lale International School	×	The school is a private school.
	2	Hospital	○	
	3	Ghaazee School	×	The roof is partly damaged.
	4	HDC Building	×	Installation is difficult on a curved roof.
	5	Housing Flats	×	There is no space for peripheral equipment. There are too many interested parties.

Source：Prepared by the Study Team

2.5 Assessment of Load Responsiveness in the Diesel Generator

The Study Team surveyed STELCO diesel power plants on Male' Island and Hulhumale' Island and confirmed the control method used on existing diesel generators. On both islands, the number of diesel generators in operation is left to the individual discretion of operators. On Male' Island, since a SCADA (Supervisory Control and Data Acquisition) system is used to monitor demand conditions in real time, the system can respond to demand changes relatively quickly, whereas on Hulhumale' Island, operators monitor and record the total generator output every hour and alter the number of units in operation so that spare operating capacity is 20% or more.

The number of governor-free diesel generators can be switched by the SCADA system, however, since the system is configured to trip when engine exhaust heat exceeds 550℃, an alarm is triggered and operation is switched to fixed output operation when 500℃ is reached. The diesel governor speed adjustment rate is stabilized at 4%.

The frequency control standard of STELCO is 50Hz±1.0% and, since the governor speed adjustment rate is 4%, it is possible to hold fluctuations to within the standard range up to 25.0%(1.0% / 4.0%) of the generator rated capacity during governor-free operation.

2.6 Examination and Measurement of Existing Distribution Transformer Capacity and Distribution System

Concerning the potential sites that were selected in 2.4, survey was carried out on the capacity of existing distribution transformers and distribution lines that will link the PV systems with the grid.

Out of the distribution transformers at the interconnection points, No. 61 Tr (Kalaafaanu School) and No. 62 Tr (Maldives Center for Social Education) are owned by the Ministry of Education and Ministry of Human Resources, Youth and Sports, respectively, while the others are all owned by STELCO.

Upon checking against the results of examining PV installation capacity on the potential sites as described in 2.10, it was confirmed that none of the existing transformers will be overloaded. However, concerning No. 61 Tr, since the high voltage power receiving equipment is broken down, it is scheduled to conduct repairs under the budget of the Ministry of Education.

Table 2.6-1 Survey Findings Regarding Capacity of Transformers at Interconnection Points

Island	Site No.	Site Name	PV Capacity [kWp]	Feeder No.	Distribution Tr No.	Tr Capacity [kVA]	Remarks
Male' Island	1	STELCO Building	45	FD9	20B	500	
	3	Dharubaaruge	85	FD3	60	630	
	5	Giyaasudheen School	40	FD6	70	150	
	6	Kalaafaanu School	85	FD3	61	100	High voltage power receiving equipment is broken down.
	7	Maldives Center for Social Education	100	FD6	62	200	
	8	Thaajuddeen School	130	FD6	23	1,000	
	9	New Secondary School for Girls	100	FD6	23	1,000	
	11	Faculty of Engineering	80	FD4	25	800	
	12	National Stadium	400	FD9	41B	1,000	
	17	Faculty of Education	10	FD7	30	630	
	20	Grand Friday Mosque	30	FD2	14	630	
	21	Jumhooree Maidhaan	60 - 160	FD2	14	630	
	22	President's Office	20	FD8	73	1,250	
Hulhumale' Island	2	Hospital	60	FD2	11	315	

Source： Prepared by the Study Team

Furthermore, in order to examine impact on the distribution system, calculation of simulated voltage flows was carried out based on distribution transformer demand data and line impedance data received from STELCO. In order to check for excessive voltage increase when solar backflows occur, minimum load (demand data) and solar generating capacity were calculated assuming installation of rated output with power factor of 1 at each interconnection point.
As for the bus voltage of power plant, the Team confirmed with STELCO that AVR (Automatic Voltage Regulator) setting of 11kV rated voltage generators is 11kV and tap setting of step-up transformers for 400V rated voltage generators is middle tap (11kV, fix)

Since all the simulation results fell within the standard voltage control scope, it was confirmed that PV interconnection will not have an adverse impact on distribution lines. This can partly be explained by the small capacity of PV interconnection, however, it is also largely down to the fact that the distribution network on Male' Island and Hulhumale' Island is a finely woven mesh, cable lengths are short and distribution line reinforcement works (heavy line conversion) are progressing. Furthermore, Table 2.6-2 shows the results of a survey of problems regarding PV connection to existing distribution lines conducted before the start of the Study. Since the MHTE, MEA and STELCO do not possess the know-how to examine these problems, it will be necessary to continuously implement transfer of technology regarding these issues in the future.

Table 2.6-2 Impacts of PV Interconnection on Existing Distribution Lines

Classification	No	Problem	Outline of Problem and Field Survey Contents	Survey Findings
Quality of electricity	1	Voltage deviation caused by reverse power flow	When there are reverse power flows from PV facilities to substations, there is possibility of system voltage rising around the interconnection points. So it is necessary to survey the existing distribution line capacity and load conditions and check for any reverse power flows.	According to the simulation of voltage flows following PV interconnection, it was confirmed that voltage deviations will not arise.
	2	Malfunction of step voltage regulators due to reverse power flow	When step voltage regulators are installed on distribution lines, reverse power flow may reverse the direction of tap control and deteriorate voltage worse.	Step voltage regulators are not installed in the Maldives.
	3	Voltage fluctuation at times of massive dropout (parallel off) of PV system	When massive dropout occurs due to external disturbance, since there is risk of deviation from the standard voltage range, the limitation of PV introduction level shall be investigated.	According to the simulation of voltage flows following PV interconnection, it was confirmed that voltage deviations will not arise.
	4	Voltage drop at times of PV system start-up	When the PV inverter is paralleled to the grid, there is a risk of sudden voltage drop. Required functions for inverters such as soft start need to be investigated.	The interconnection inverter will be equipped with a soft start function.
	5	Flickering voltage fluctuations	Due to sudden changes in solar irradiation, there are cases where flickering voltage fluctuations occur. The limitation of PV introduction level shall be investigated.	There is no problem because conversion to heavy duty lines is well advanced. It is necessary to verify changes in the power source quality before and after introduction.
	6	Voltage imbalance due to connection of single phase systems	Small inverters for ordinary households are usually single phase systems. However, if they are connected frequently on either phase, phase imbalance will cause equivalent reverse phase current to flow and have an adverse impact on equipment.	Adopt three-phase interconnection as a rule. If allowing single phase interconnection for small capacity inverters, carry out the balancing of the connected phase and rearrangement of load, etc.
	7	System frequency fluctuations caused by fluctuations of PV output	In case the PV output fluctuation exceeds limitation of the adjustment capacity of power system, fluctuation of frequency may cause adverse impact on consumer equipment. The limitation of PV introduction level shall be investigated.	Deal with by increasing the number of governor-free diesel generators in operation. Do not consider the installation of storage batteries with a view to equalizing PV output because of problems surrounding the disposal of batteries.
	8	Higher harmonics from inverter power source	It is necessary to stipulate the maximum allowed percentage of higher harmonic content as a specification requirement of the interconnected inverter. It is because the inverter interconnection causes higher harmonics which have an adverse impact on consumer equipment.	The Maldives has no current standards or regulations. Stipulations based on grid interconnection guidelines, etc. are required. Since there are no domestically made products, there is no need for a certification system.

Classification	No	Problem	Outline of Problem and Field Survey Contents	Survey Findings
	9	Increase in DC outflow	When the distortion by inverter rectification is large, DC content of power grid increases. So it is necessary to review short circuit capacity of circuit breakers. Therefore, the rectification method and distortion factor shall be stipulated as a required specification of the interconnected inverter.	Ditto
	10	Deterioration of Transient Stability	When massive PV systems are interrupted simultaneously at times of failure, transient stability of synchronous generators will be deteriorated. The limitation of PV introduction level shall be investigated considering the stability aspect.	Concerning transient phenomena, it is necessary to implement analysis of the power grid stability, however, this has not been implemented because it was not possible to acquire the transient constant of existing diesel generators in the Study.
Protection	1	Prevention of islanding operation	Survey the method to cut power supply (to prevent electric shock by public) through distributed generators for isolated system loads.	Make it a condition to have isolated operation detection functions (passive system and active system).
	2	Malfunction to detect islanding operation	Deterioration in detection sensitivity due to mutual interference by disturbance of active signals.	Make it a condition to have at least one passive system and one active system.
	3	Ground Fault Protection Ground Fault protection during the contact between medium and low voltage side of transformers	Ground fault detection by earth-fault protection relays is possible in case of mid-voltage interconnection. However, direct detection is not possible in case of low-voltage interconnection.	Adopt over-voltage ground relays as standard function in high voltage systems. In cases of low voltage interconnection, it can be omitted by implementing protection through detection of isolated operation following opening of the circuit breaker on the distribution line side.
	4	Protection against short-circuit faults ① Increase in short-circuit capacity	Since fault currents are also supplied from distributed generators, examine measures to prevent increasing short-circuit currents and causing equipment breakdowns.	Confirm that the shorting capacity of existing distribution line circuit breakers is sufficient with respect to the shorting current.
	5	Protection against short-circuit faults ② Difficulty of detecting short circuit faults at the end of feeders	When short-circuit faults occurs at the end of feeders, fault currents are supplied from distributed generators and it will reduce fault currents from distribution lines especially from higher voltage class. Thus it will make the fault detection difficult.	Make the over-current protection gate-off time of the grid interconnection inverter faster than the existing distribution line relay breaking time.
	6	Protection against short-circuit faults ③ Error trip of sound feeders by incoming current	There is a risk of error trip of sound feeders due to incoming currents from distributed generators. Confirm the composition of substation feeder and relays.	Make the over-current protection gate-off time of the grid interconnection inverter faster than the existing distribution line relay breaking time.
Operation Management	1	Malfunction of automatic power restoration in case of faults	Overload and voltage deviation may occur in distribution lines in case distribution automation system (or SCADA) is equipped with automatic power restoration system.	There is no automatic power switchover function in the event of failures.
	2	Malfunction of automatic feeder reclose	In case that distribution feeder has automatic reclose, there is a possibility of mismatch of time setting between it and re-interconnection of distributed generators. It is necessary to investigate the measures against this issue.	There is no automatic feeder reclose. It is necessary to equip a condition of receiving voltage confirmation for the restart.

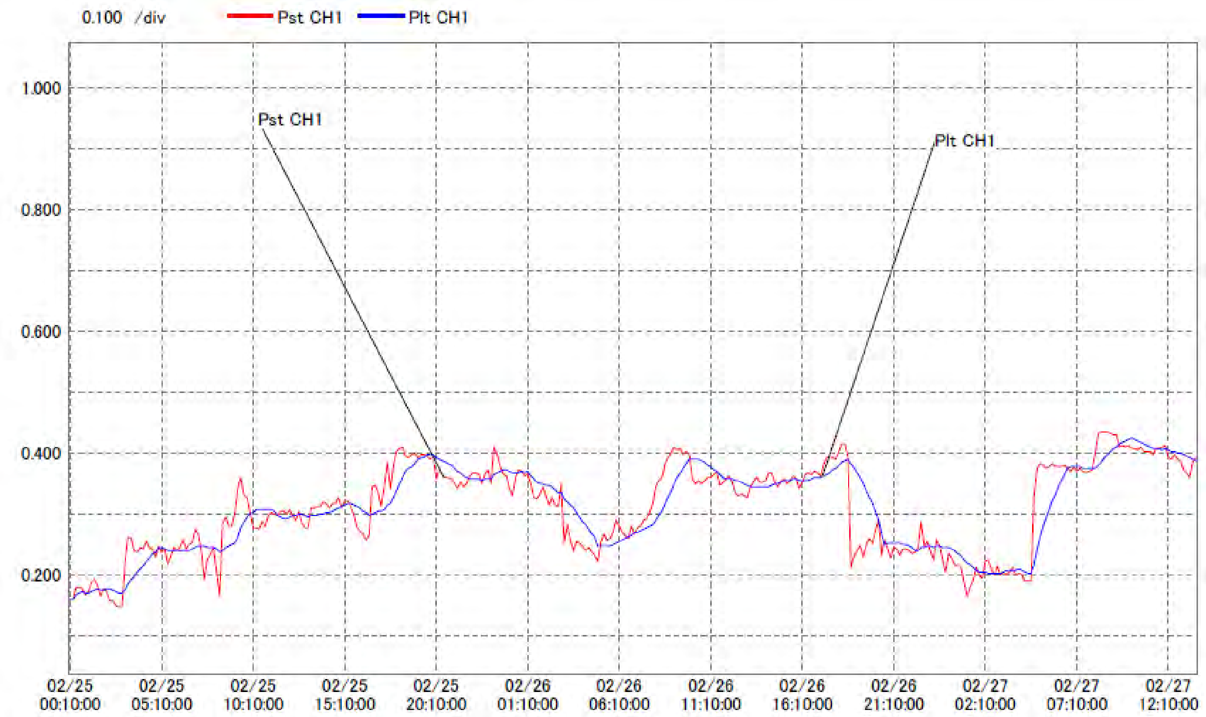
Classification	No	Problem	Outline of Problem and Field Survey Contents	Survey Findings
	3	Overload of distribution equipment by switching of distribution lines	Since output of distributed generators cannot be monitored and power flows cannot be predicted, overload of distribution lines may occur after switching operation. It is necessary to confirm the switching operation and monitoring and control of the power distribution company.	Examine installation of monitoring devices that can monitor PV output. It is necessary to review the demand management method that takes PV output into account.
	4	Difficulty in switching over without interruption	Imbalance of the interconnection capacity of distributed generators causes the phase angle of loop points to increase, and dropout of inverter may occur due to increase in cross current flows and growing change in voltage phase. This problem occurs when the capacity of PV systems is very large.	All loop change-over is conducted as power outage switchover.

Source： Prepared by the Study Team

2.7 Grid-Connected PV System Stability Assessment Technique

In order to assess the stability of the grid-connected PV system, power source quality of existing distribution lines was measured using the power supply quality analyzer brought from Japan. Out of the potential sites, the national stadium, which has the largest potential grid-connected PV capacity, was selected. The measurement results are indicated below.

Concerning the results of flicker measurement, it was confirmed that the IEC standard Pst<1, Plt<0.65 is satisfied.



Pst	:	Short-term flicker value	(flicker characteristic value measured over 10 minutes) Pst is a statistically sought index number. Pst = 1 indicates the voltage fluctuation where flickering of an incandescent light bulb thought to be unpleasant by 50% of people is generated.
Plt	:	Long-term flicker value	(flicker characteristic value measured over 2 hours)

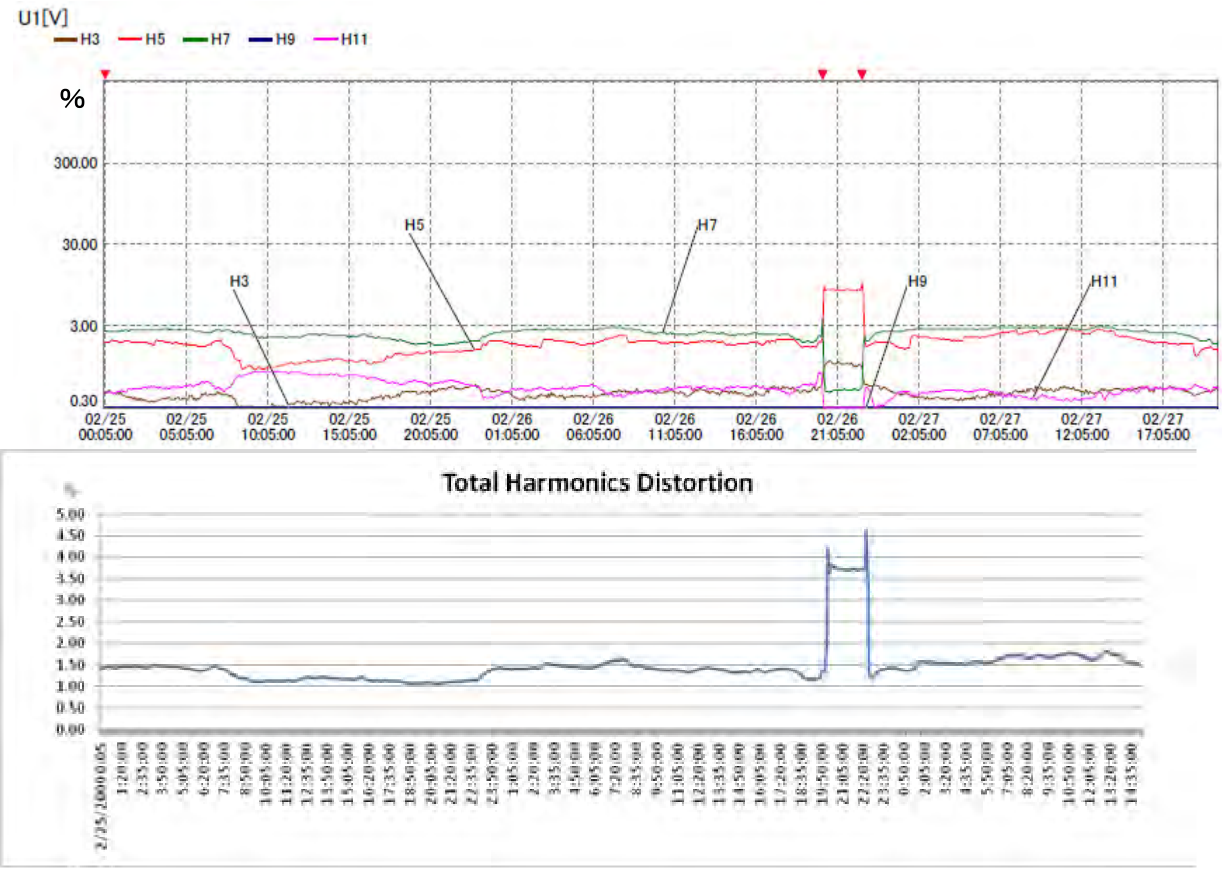
Source : Prepared by the Study Team

Figure 2.7-1 IEC Flicker Measurement Results (Pst, Plt)[Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

Concerning harmonics, according to the Japan Harmonics Control Measures Guidelines, voltage harmonics for each order ≦3% and total distortion ≦3% is required as the environmental target for Medium Voltage consumers. However, for the national stadium where measurement was conducted, fifth harmonics reached a maximum of 4.62% (effect mean value 10.55 V) and the total harmonics reached a maximum of 4.64% between 20:08~22:33 when the lights of the national stadium were turned on. These measured values exceed the regulation by Japan Harmonics Control Measures Guidelines

Control measures for harmonics need to be taken on the load side (use of a harmonics filter, multi-application of inverter, switching of harmonics), however, the Study revealed that the Maldives currently has no clear power quality standards and, since there is a possibility of interference occurring in capacitors and other power instruments, it will be necessary to examine standards and regulations in future.

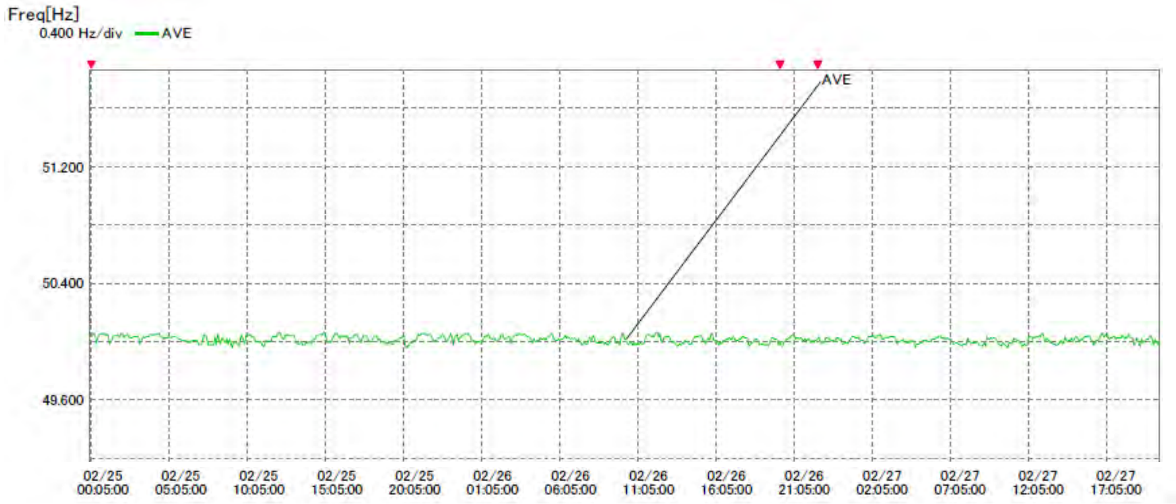
Accordingly, the grid interconnection inverter will need to have specifications that conform to Japanese guidelines for harmonics.



Source： Prepared by the Study Team

Figure 2.7-2 Results of High Frequency Voltage Distortion Measurement [Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

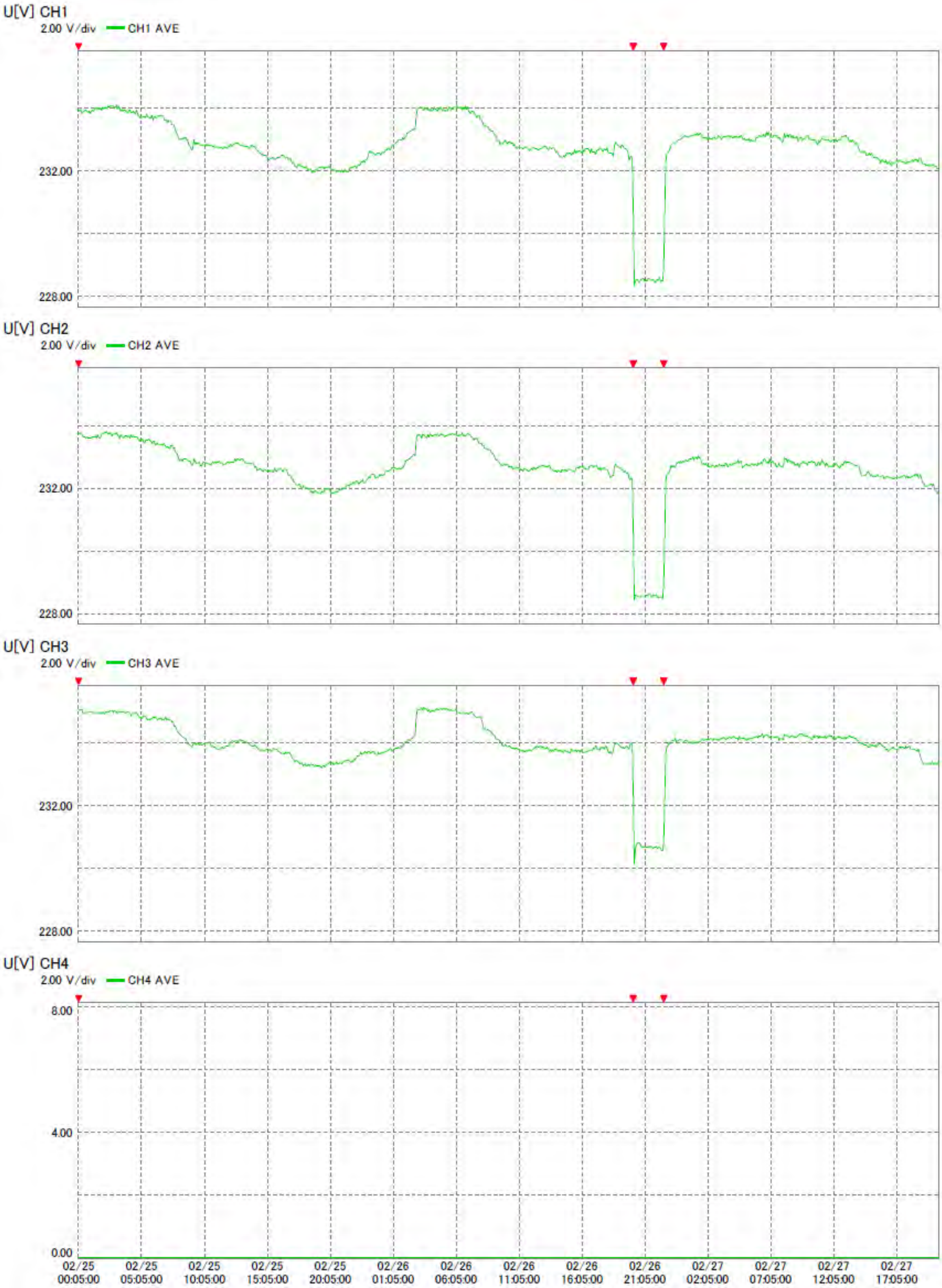
Concerning the frequency fluctuation, this is held to an extremely precise range of 49.96～50.06Hz and 50Hz±0.1%, and there is a low possibility of stoppages being caused by the detection of frequency fluctuations in the PV interconnection inverter.



Source： Prepared by the Study Team

Figure 2.7-3 Results of Frequency Fluctuation Measurement
[Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

Concerning voltage fluctuation, there is some voltage drop when the stadium lights are turned on, however, the fluctuation scope is 228.3~234.1V, which falls within the nominal voltage range of 230±2% (the STELCO standard is±2.5％ of nominal voltage). Therefore, there is no problem regarding PV interconnection in this respect too.



Source： Prepared by the Study Team

Figure 2.7-4 Voltage Fluctuation Measurement Results

[Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

Also, it was surveyed whether or not PV operation information (DC voltage and current, AC voltage, current and frequency, active power, reactive power, solar irradiation intensity, etc.) can be incorporated into the SCADA system with a view to monitoring the operating status and assessing stability of the grid-connected PV system.

The SCADA system currently enables 40 out of 98 substations and seven diesel power plants on Male' Island to be remotely monitored and controlled by wireless, and the PLC (Programmable Logic Controller) has almost reached full capacity. Since it will be difficult to install a new monitoring station, it is desirable to install data loggers, etc. that can monitor and record the operating condition of the PV systems at all times.

2.8 Technique for Determining the Introduced Capacity of Grid-Connected PV Systems

As the technique for determining the grid-connected PV system capacity that can be technically introduced in the Maldives, it is necessary to examine and decide the possible capacity by means of the following two steps: Step 1: examination of constraints from the viewpoint of power system operation, and Step 2: examination of constraints from the viewpoint of distribution line operation. The results of examination in each step are as shown below.

[Step 1] Examination of constraints from the viewpoint of power system operation

Based on the results of assessing load responsiveness of diesel generators as described in 2.5, the available fluctuation of diesel generators with governor-free operation is as follows by utilizing 2009 case on Male' Island .

41.96MW ＊ (1.0% / 4.0%) = approximately 16.78MW

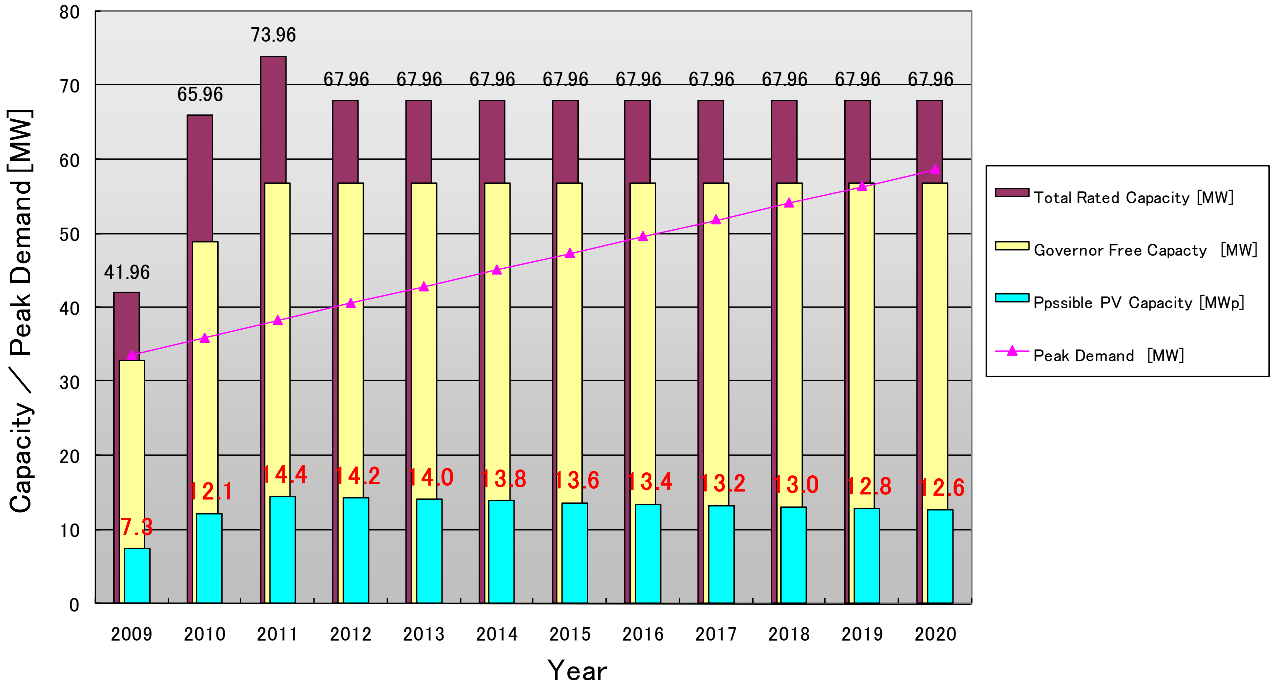
Here, the frequency control standard of STELCO is 50Hz±1.0% and, since the governor speed adjustment rate is 4%.

PV output fluctuation (kW) + Demand fluctuation (kW) ≤ available fluctuation of diesel generators with governor-free operation (kW)

From the above expression, assuming the demand fluctuation is around 7% of peak load based on STELCO operating performance, the available PV output fluctuation is as follows..

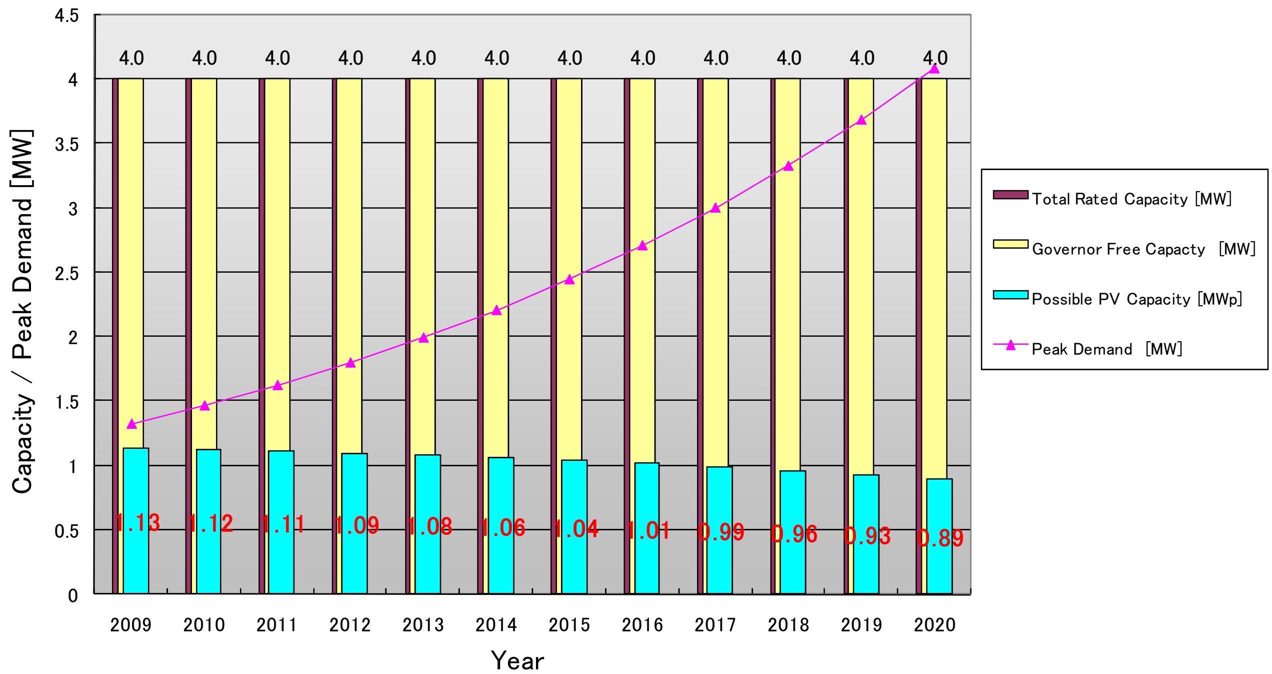
The available PV output fluctuation ≤ 16.78MW － 10.94MW = 5.84MW

Here, assuming that the fluctuation range of PV output is between 10~90% of rated output based on past cases, the potential grid-connected PV introduction capacity on Male' Island in 2009 is approximately 7.3MW. And in the same way, the potential grid-connected PV introduction capacity on Male' Island and Hulhumale' Island up to 2020 can be calculated as shown in the following figure.



Source : Prepared by the Study Team

Figure 2.8-1 Possible PV Capacity on Male' Island

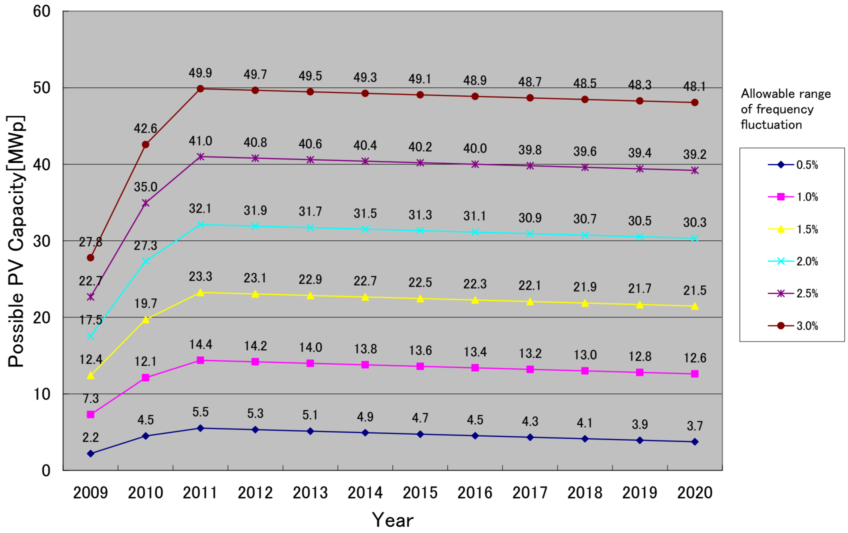


Source : Prepared by the Study Team

Figure 2.8-2 Possible PV Capacity on Hulhumale' Island

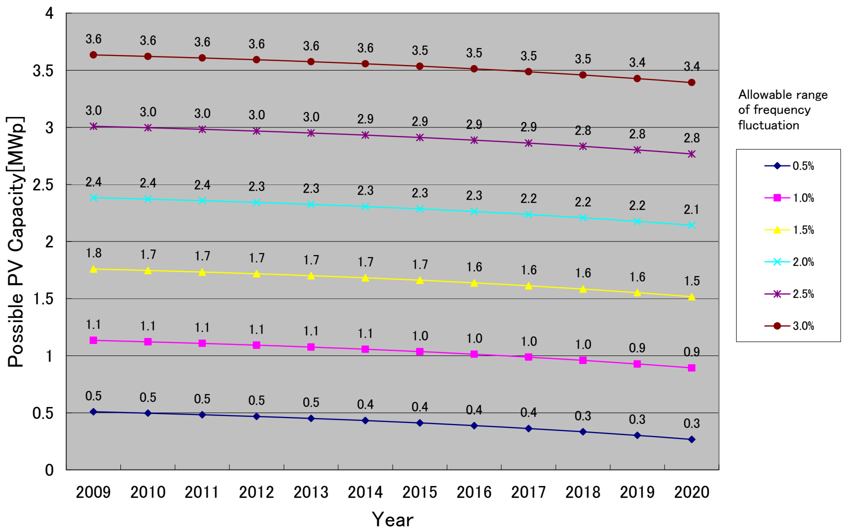
Moreover, in the actual operating stage, the governor-free capacity is limited in some cases due to the engine heating and periodic inspections, etc. described in 2.5. Accordingly, it will be necessary to carefully analyze PV output fluctuations from the actual operating data following PV introduction and, where the need exists, examine the implementation of steps to limit PV output in advance.

This examination is based on the frequency fluctuation control standard of STELCO. And the possible PV capacity is also changed in accordance with the standard. Therefore the sensibility analysis was executed using allowable frequency fluctuation as a parameter. The results are shown in below. However over 2% of range is not allowed at present condition due to the load sharing setting (1st step: 49Hz + 3 sec, 2nd step: 48.5Hz + 3 sec) of SCADA for power system stability and under frequency protection relay setting (47Hz + instant) for generators.



Source: Prepared by the Study Team

Figure 2.8-3 Relationship between Allowable Frequency Fluctuation and Possible PV Capacity on Male' Island



Source: Prepared by the Study Team

Figure 2.8-4 Relationship between Allowable Frequency Fluctuation and Possible PV Capacity on Hulhumale' Island

[Step 2] Examination of constraints from the viewpoint of distribution line operation

In the simulated calculation of voltage flow used in the examination described in 2.6, the PV interconnection capacity reaching the upper limit of the distribution line voltage control value was calculated under the harshest conditions of decoupling all load from each distribution line. As a result of the simulation, it was found that the rise in distribution line voltage was within the control standard even when PV energy was connected to the upper capacity limit of each distribution line. This can be explained by the fact that distribution lines are short in length (because of the small size of the island) and they have mostly been converted to heavy lines. From the results of examination, the limitations on distribution line operation are found to be as follows: on Male' Island, 5,330 kW on each distribution line and 42,640 kW over the entire distribution line network; and on Hulhumale' Island, 3,040 kW on each distribution line and 6,080 kW over the entire network.

Table 2.8-1 Examination Results regarding PV Connection Capacity to Distribution Lines (Male' Island)

Feeder No.	PV Connection Capacity [kW]	Peak Voltage [V]	Voltage Rise [V]	Fluctuation Rate [%]
FD2	5,330	11,083	83	0.75
FD3	5,330	11,070	70	0.64
FD4	5,330	11,028	28	0.25
FD5	5,330	11,096	96	0.87
FD6	5,330	11,225	225	2.05
FD7	5,330	11,118	118	1.07
FD8	5,330	11,109	109	0.99
FD9	5,330	11,089	89	0.81
Total	42,640	-	-	-

Source： Prepared by the Study Team

Table 2.8-2 Examination Results regarding PV Connection Capacity to Distribution Lines (Hulhumale' Island)

Feeder No.	PV Connection Capacity [kW]	Peak Voltage [V]	Voltage Rise [V]	Fluctuation Rate [%]
FD1	3,040	11,139	139	1.26
FD2	3,040	11,104	104	0.95
Total	6,080	-	-	-

Source： Prepared by the Study Team

From the above examination, it was concluded that values limited from the viewpoint of power system operation should be applied as the potential grid-connected PV capacity on Male' Island and Hulhumale' Island.

Moreover, regarding constraints in terms of the possible installation space, when the above examination results are converted into installation area, the possible installation capacity by 2020 on Male' Island (12.6 MW) requires space of approximately 90,000 m^2, while the possible capacity on Hulhumale' Island (0.89 MW) requires approximately 6,000 m^2. Since these areas account for 6.0% of total island area excluding streets, parks and cemeteries on Male' Island (1.5 km^2), there should be no problem whatsoever.

As for Hulhumale' Island, developing standard housings has approximately 750 m^2 of roof top areas. Therefore roof top areas of eight housing are almost equal to required areas for PV installation on Holhumale' Island.

Based on the results of this examination and the economic and financial feasibility study (refer to Chapter 3), the target grid-connected PV installation capacity by 2020 is set as follows.

Table 2.8-3 Target Grid-Connected PV Installation Capacity on Male' Island and Hulhumale' Island

(kW)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Male' Island	280	560	840	1,120	1,400	1,680	1,960	2,240	2,520	2,800
Hulhumale' Island	20	40	60	80	100	120	140	160	180	200

Source : Prepared by the Study Team

2.9 Standard Design Specifications of the Grid-Connected PV System

Taking into consideration the technical requirements examined in the Study and meteorological conditions and building strengths in the Maldives, the design standard specifications required of the grid-connected PV system are as indicated in the following table.

Table 2.9-1 Standard Design Specifications of the Grid-Connected PV System

Equipment	Item	Required Specifications
PV module	(1) Applicable standard	IEC and equivalent standard
	(2) Environment of use	Area prone to salt damage
	(3) Ambient temperature	Up to +40℃
	(4) Installation method	Sloping roof type or flat roof type
	(5) Type	Crystal silicon
	(6) Module efficiency	No less than 12%
	(7) Module capacity	No less than 100W/sheet
PV module installation stand	(1) Support mode	Sloping roof type: attached to main buildings Flat roof type: S stand
	(2) Environment of use	Area prone to salt damage
	(3) Material	SS400 hot-dip zinc finish or equivalent quality
	(4) Design standard wind velocity	15m above ground, wind velocity 60m/s
Connection box	(1) Structure	Indoor/Outdoor, wall-hanging type or vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	Up to +40℃, no less than 70%
	(4) Peak input voltage	No less than the string unit nominal open voltage (V_{OC})
	(5) Number of input circuits	No less than the sub-array unit number of lines

Equipment	Item	Required Specifications
	(6) Input current	No less than the module nominal shorting current (I_{SC}) per circuit
	(7) Number of output circuits	1 circuit
	(8) Output current	No less than the sub-array nominal shorting current (I_{SC})
	(9) In-built instruments	- Distribution line circuit breaker: Number of circuits - Backflow prevention diode: Each string - Induction lightning protector: All input/output circuits, between lines, between ground
Collecting box * This may be omitted if there is one connection box or the number of power conditioners input circuits exceeds the number of connection boxes.	(1) Structure	Indoor/Outdoor, wall-hanging type or vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	Up to +40℃, no less than 70%
	(4) Peak input voltage	No less than the string unit nominal open voltage (V_{OC})
	(5) Number of input circuits	No less than the number of integrated connection boxes
	(6) Input current	No less than the connection box output current
	(7) Number of output circuits	1 circuit
	(8) Output current	No less than the sub-array nominal shorting current x number of input circuits
	(9) In-built instruments	- Distribution line circuit breaker: Number of circuits - Induction lightning protector: All input/output circuits, between lines, between ground
Power conditioners	(1) Structure	Indoor/Outdoor, vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	Up to +40℃, no less than 70%
	(4) Main circuit type	Self-exciting voltage type
	(5) Switching method	High frequency PWM
	(6) Insulation method	Commercial frequency insulated transformer type Non-insulation (no transformer) only allowed in cases of small capacity
	(7) Cooling method	Forced air cooling
	(8) Rated input voltage	Around the string peak output voltage (Vpmax)
	(9) Input operating voltage range	The string peak output voltage (Vpmax) and nominal open voltage (Voc) must be in the range.
	(10) Number of input circuits	No less than the number of collection boxes
	(11) Output electricity mode	3φ3W
	(12) Rated output voltage	AC202V
	(13) Rated frequency	50Hz
	(14) AC output current distortion factor	No more than 5% of total current and 3% of each harmonic
	(15) Power control method	Peak output follow-up control
	(16) Rated power conversion efficiency	No less than 90%

Equipment	Item	Required Specifications
	(17) Control function	- Automatic start/stop, soft start - Automatic voltage adjustment - Condensive reactive power control or output control function (only when there is risk of voltage deviations with reverse flow)
	(18) Grid connection protective function	- Over-voltage (OVR) - Under-voltage (UVR) - Frequency rise (OFR) - Frequency drop (UFR) - Over-voltage ground (OVGR) (can be omitted in case of low voltage interconnection) - Automatic reclose in case of recover from blackout (with a condition of receiving voltage confirmation) All settings and times shall be adjustable.
	(19) Isolated operation detection function	- Active type (1 or more of the following methods): ① Frequency shift type ② Active power fluctuation type ③ Reactive power fluctuation type ④ Load fluctuation type - Passive type (1 or more of the following methods) ① Power phase jump detection type ② 3rd harmonic voltage rise detection type ③ Frequency change rate detection type
Interconnection transformer	(1) Structure	Indoor/Outdoor, vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	+ Up to +40℃, no less than 70%
	(4) Primary voltage	3φ4W AC400V
	(5) Secondary voltage	3φ3W AC200V
	(6) Frequency	50Hz
	(7) Insulation class	Type B
	(8) Wire connection method	Y-△(Yd1)

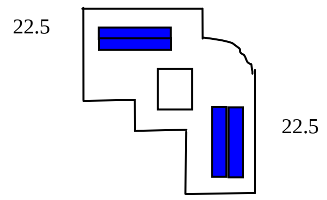
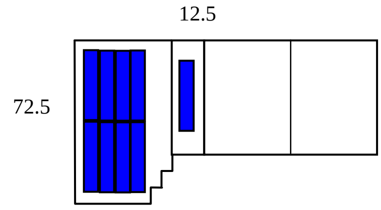
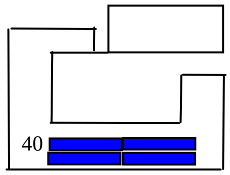
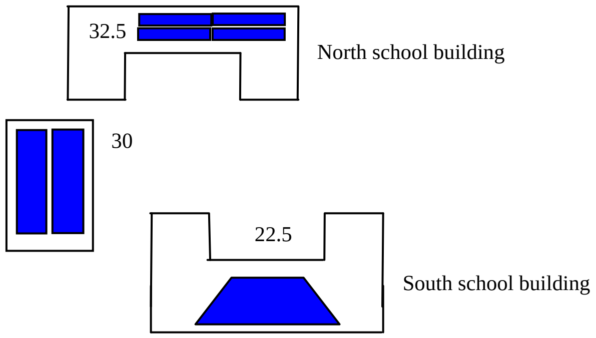
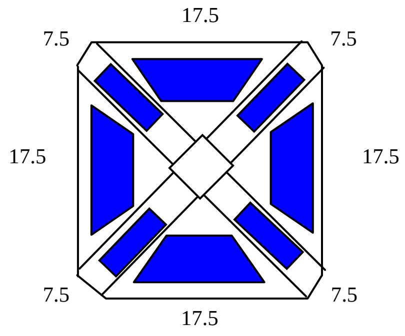
Source： Prepared by the Study Team

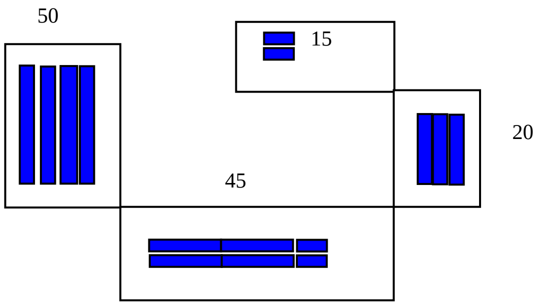
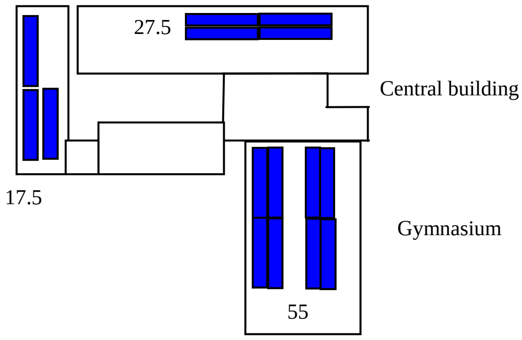
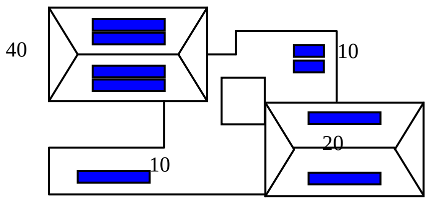
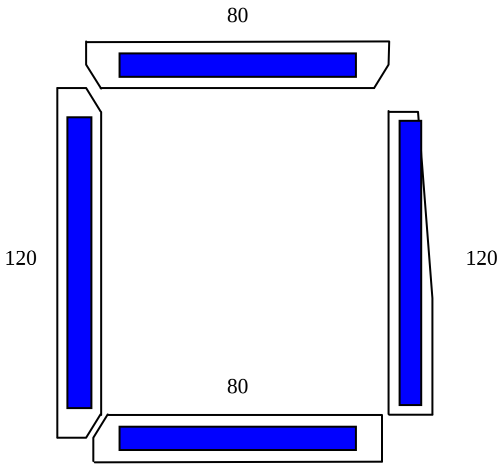
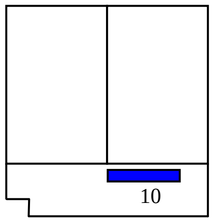
2.10 Potential Sites for Grid-Connected PV System Installation, and PV Installation Capacity

Concerning the potential sites selected in 2.4, field surveys were implemented on such items as the possible PV installation area, existing power receiving facilities and surrounding environment, etc. Concerning the PV installation capacity, the ideal array method was calculated upon considering the possible installation area and impact of obstructions to solar irradiation discussed in 2.3.

Tables 2.10-1 and 2.10-2 show the results of examining the PV array method, while the results of examination on PV installed capacity are as indicated in the comparison sheet of potential sites for PV installation as the start of this report.

Table 2.10-1 Results of PV Array Examination at Potential Sites on Male' Island

No.	Site	PV Installation Site
1	STELCO Building	
3	Dharubaaruge	
5	Giyaasudheen School	
6	Kalaafaanu School	
7	Maldives Center for Social Education	

No.	Site	PV Installation Site
8	Thaajuddeen School	
9	New Secondary School for Girls	
11	Faculty of Engineering	
12	National Stadium	
17	Faculty of Education	

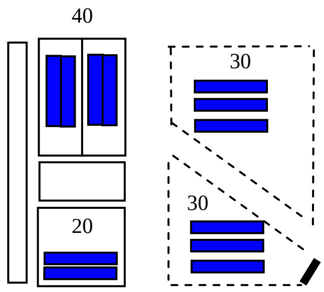
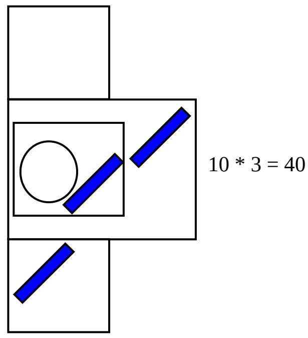
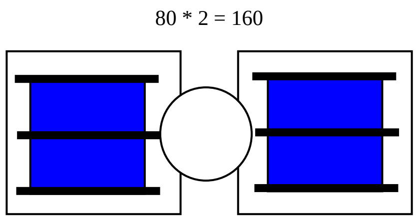
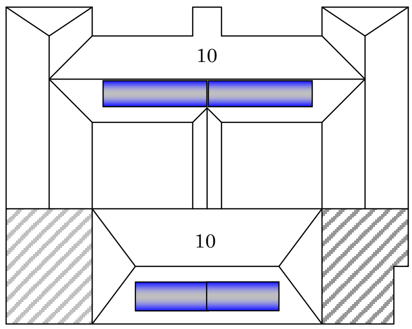
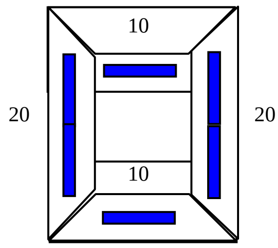
No.	Site	PV Installation Site
19	Male' South West Harbour Parking	
20	Grand Friday Mosque	
21	Jumhooree Maidhaan	
22	President's Office	

Table 2.10-2 Results of PV Array Examination at Potential Sites on Hulhumale' Island

No.	Site	PV Installation Site
2	Hospital	

2.11 Beneficial Effects of Grid-Connected PV System Introduction

2.11.1 Estimated Power Generation

The estimated amount of power generation at each potential site was calculated using the following expression:

$$Ep = \Sigma H_A / Gs * K * P$$

(Σ indicates the integrated value of estimated power generation calculated for each month).

Where, Ep = Estimated annual power generation (kWh/year)

H_A = Monthly average solar irradiation on the installation surface (kWh/m^2/day)

Gs = Solar irradiation intensity in standard conditions (kW/m^2) = 1 (kW/m^2)

K = Loss coefficient = $Kd * Kt * \eta_{INV} * \eta TR$

* DC correction coefficient Kd: Correction for loss caused by dirt on solar cells and fluctuations in solar irradiation intensity. This was set at 0.8 here, also taking the correction for solar cell characteristic disparity into account.

* Temperature correction coefficient Kt : Correction coefficient taking into account temperature increases and fluctuations in the conversion efficiency of solar cells due to solar irradiation.

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

  Where,

  α: Peak output temperature coefficient (%・$℃^{-1}$) = - 0.5 (%-$℃^{-1}$) [Crystal]

  Tm: Module temperature (℃) = $Tav + \Delta T$

  Tav: Monthly average temperature (℃)

  ΔT: Module temperature increase (℃)

Open rear type	18.4
Roof installed type	21.5

* Inverter efficiency ηINV : Inverter AC-DC conversion efficiency: set at 0.95 here

* Transformer efficiency ηTR : Transformer efficiency: set at 0.98 here considering that on-load and off-load loss are constant

For simplification, the horizontal surface amount of solar irradiation was adopted when calculating the monthly average amount of solar irradiation on the installed surface, and the impacts of obstructions discussed in 2.3 were taken into account. Concerning the impact of shade, this is conventionally examined upon considering the direct connection of PV modules, however, for the sake of simplification, in cases where roofs contain partial solar irradiation obstructions, conservative values were calculated assuming the whole roof to be affected.

Table 2.11.1-1 Estimated Annual Power Generation at Each Potential Site

Island	Site Name	PV Capacity [kWp]	Annual Power Generation [kWh/year]
Male'	STELCO Building	45	45,739
	Dharubaaruge	85	100,382
	Giyaasudheen School	40	48,378
	Kalaafaanu School	85	117,069
	Maldives Center for Education	100	120,945
	Thaajuddeen School	130	157,228
	New Secondary School for Girls	100	90,778
	Faculty of Engineering	80	96,756
	National Stadium	400	483,780
	Faculty of Education	10	12,094
	Grand Friday Mosque	30	36,283
	Jumhooree Maidhaan	160	196,986
	President's Office	20	24,189
Hulhumale'	Hospital	60	72,567

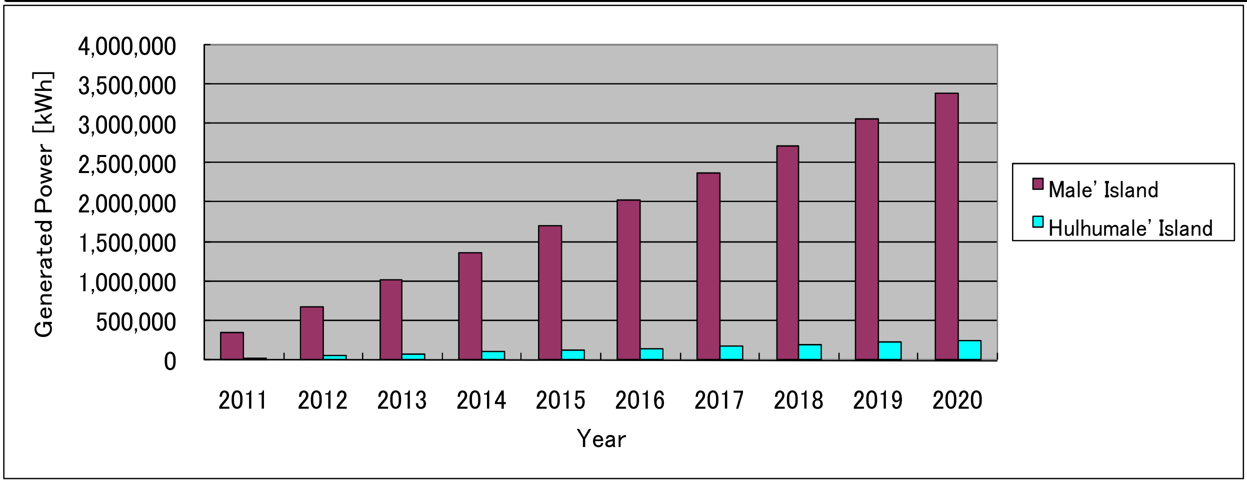
Source： Prepared by the Study Team

Next, movements in the annual amount of power generation were estimated for the years from 2010 to 2020 based on the introduction target discussed in 2.8

In conducting the examination, considering installation at the pilot project site on Male' Island in 2011, it was assumed that all other systems are installed on roofs where there is no impact of shade. The results of calculation are indicated below.

(kWh)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Male' Island	338,646	677,292	1,015,938	1,354,584	1,693,230	2,031,876	2,370,522	2,709,168	3,047,814	3,386,460
Hulhumale' Island	24,189	48,378	72,567	96,756	120,945	145,134	169,323	193,512	217,701	241,890



Source : Prepared by the Study Team

Figure 2.11.1-1 Movements in Power Generation by Year

2.11.2 Diesel Fuel Consumption Saving

Based on operating performance figures obtained from STELCO for diesel power plants on Male' Island and Hulhumale' Island for the past three years, fuel consumption per unit power generation (kWh) was calculated as follows.

Table 2.11.2-1 Fuel Consumption at Diesel Power Plants on Male' Island and Hulhumale' Island

Island	Item	2006	2007	2008	3-month Mean
Male'	Power generation [kWh]	156,107,764	177,052,316	195,105,695	-
	Fuel consumption [liter]	40,151,086	45,482,134	50,460,116	-
	Fuel consumption per kWh [liter/kWh]	0.26	0.26	0.26	0.26
Hulhumale'	Power generation [kWh]	4,106,410	5,810,041	7,324,293	-
	Fuel consumption [liter]	1,196,425	1,614,299	2,061,552	-
	Fuel consumption per kWh [liter/kWh]	0.29	0.28	0.28	0.28

Source： Prepared by the Study Team using data obtained from STELCO

Using the above results, the amount of fuel savings calculated based on the grid-connected PV power generation each year as estimated in 2.11.1 was calculated in the manner shown in Table 2.11.2-2.

Table 2.11.2-2 Yearly Diesel Fuel Saving

(liter)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Male' Island	88,048	176,096	264,144	352,192	440,240	528,288	616,336	704,384	792,432	880,480	4,842,638
Hulhumale' Island	6,773	13,546	20,319	27,092	33,865	40,638	47,410	54,183	60,956	67,729	372,511

Source： Prepared by the Study Team

2.11.3 CO_2 Emission Reductions

Based on the diesel fuel savings calculated in 2.11.2, the following coefficient was used to calculate the amount of CO_2 emission reductions.

CO_2 reduction [kg] = Light oil CO_2 emission coefficient* x Diesel fuel saving
= 2.62 [kg-CO_2/liter] x Diesel fuel saving [liter]

* Concerning the emission coefficient, the Total Emissions Calculation Method Guidelines of the Ministry of Environment were quoted.

As a result, the amount of CO_2 emission reductions in each year was calculated as follows. In the case where the PV introduction target is achieved according to plan, the amount of CO_2 emission reductions over 10 years from 2010 to 2020 is 12,688 tons on Male' Island and 976 tons on Hulhumale' Island, resulting in a total reduction of 13,664 tons.

Table 2.11.3-1 Yearly CO_2 Reductions

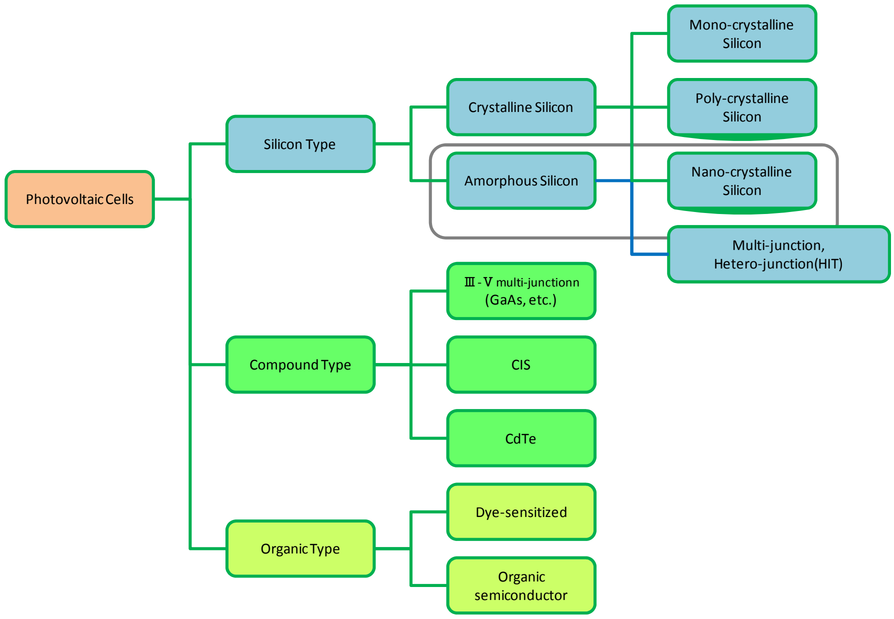
(kg)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Male' Island	230,686	461,371	692,057	922,743	1,153,428	1,384,114	1,614,800	1,845,485	2,076,171	2,306,856	12,687,710
Hulhumale' Island	17,745	35,490	53,235	70,980	88,725	106,470	124,215	141,960	159,705	177,450	975,978

Source: Prepared by the Study Team

2.12 Examination of Solar Cells and Assessment of Output

PV cells are categorized into silicon type, compound type and organic type by material. Based on the product record in 2008, approx. 99% of products are silicon type of PV and remaining is compound type and organic type. Compound type and organic type of PV cells are still in a research and development stage even though CIS PV cell, one of compound type is started to disseminate.



Source: AIST

Figure 2.12-1 Category of PV Cells by material

Silicon type of PV cell is categorized into crystalline silicon (mono-crystalline and poly-crystalline) and amorphous silicon (thin film silicon). As for the crystalline PV cell, mono-crystalline type was developed at Bell research institute, USA in 1954. Therefore the history after mass production is long and it is considered that the durability and reliability are high. In case of crystalline silicon type of PV cell, the life span is expected around 20 – 30 years. On the other hand, amorphous (thin film) silicon PV cell is the one which form thin film silicon on the glass or metallic plate. Although its conversion efficiency is less than crystalline, the flexibility of size and shape is merit. Amorphous silicon PV cell has characteristics of reaction to short wavelength light and approx. 10% output decrease under the condition of long period direct irradiation. Therefore it was used mainly for the calculators and watches using week light at indoor. Recently, it became to have practical durability even outside. Therefore it is sold for the outdoor purpose but its reliability has still not been verified yet because it just started the production.

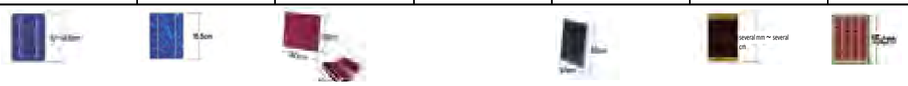
Moreover the cell efficiency of thin film type is less (approx. 10%) than crystalline type (approx. 15%). This means the thin film type cell needs 1.5 times of area comparing with crystalline type. Therefore the crystalline is effective under the condition of small land like Maldives

In addition, crystalline PV cell occupies 90% of market in Asia as shown in Table 2.12-2. The sales agents are selling mainly the crystalline PV cells. Therefore the crystalline silicon type has an advantage taking consideration into the marketability and ease to respond for trouble.

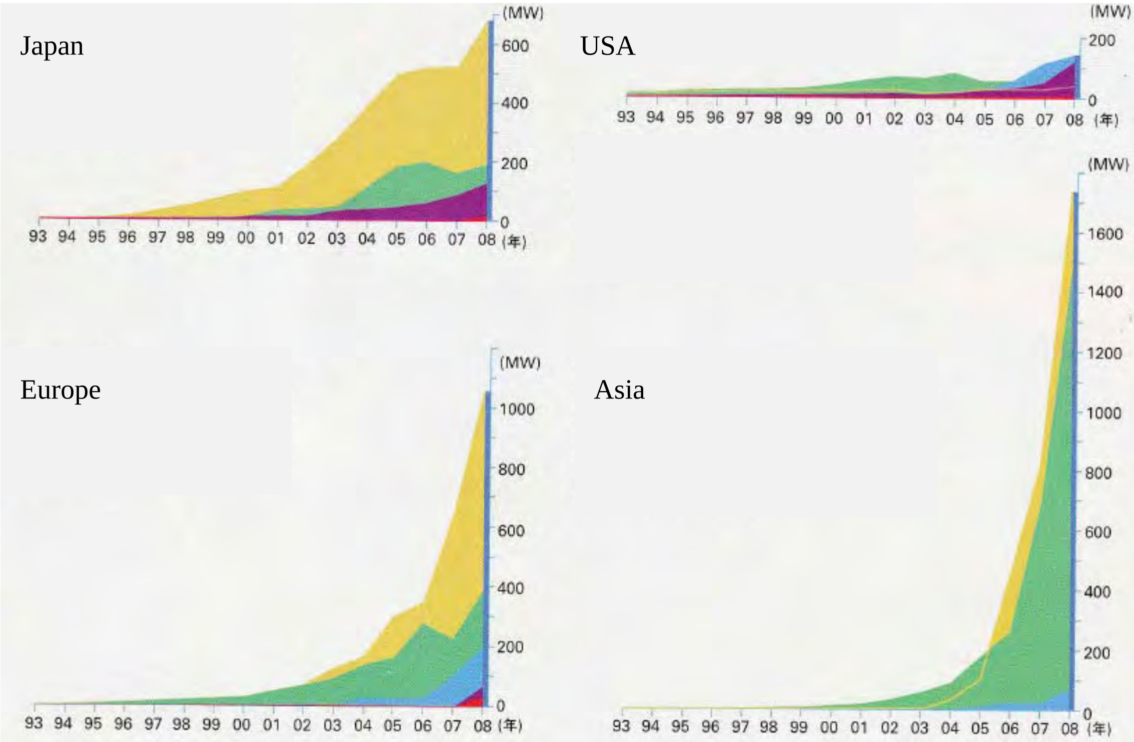
Reflecting with this, it is recommendable to apply crystalline silicon type of PV cells taking durability and reliability into consideration.

Table 2.12-1 Type of PV Cells and Characteristics

	Silicon				Compound		Organic	
	Crystalline silicon		Thin film silicon		CIS	Ⅲ-Ⅴ crystalline	Dye-sensitized	Oraganic thin film
	Mono-crystalline	Poly-crystalline	Amorphous	Multi-junction				
Characteristic	/ Utilize 200 μm～300 μm of thin mono-crystalline silicon plate / Most historic PV cell / Expensive but performance and reliability is high	/ Poly-crystalline plate with aggregate of small crystal / Cheaper than mono-crystalline and easy to produce / Most popular at present / Efficiency is lower than mono-crystalline type	/ 1 μm of thin film coating on a plate by amorphous silicon / Large area product is available / Mass-production / Performance has some issues comparing with crystalline silicon	/ Amorphous and small crystalline of laminated PV / Large area product is available / Mass-production / Perform under wide range of wavelength condition / less amount of silicon (approx. 1/100 of crystaline type) / Efficiency is higher than amorphous type	/ One of compound semiconductor / Thin film PV utilizing Cu (Cupper), In (Indium) and Se (Selenium) / Production process is simple / Expectation for high performance / R&D is on-going	/ Particular compound semiconductor plate utilizing Ga (gallium), As (Arsenic) etc. / High performance (30 - 40 % of efficiency) / High cost / Particular purpose such as space development / Reseach for cost reduction by concentrated PV system	/ Dye on titanium oxide (semiconductor) absorbs light and releases electron / Easy production / Expectation for low cost / Issues on efficiency and endurance	/ P-N junction of organic semiconductor / Expectation for low cost / Issues on efficiency and endurance
Module Efficiency ( ) means research stage	～19%	～15%	～6%	～12%	～11%	～31% (in case of concentrate)	(11%)	(5%)
Practicability	Practical application stage	Practical application stage	Practical application stage	Practical application stage	Practical application stage	Practical application stage	R&D stage	R&D stage
Manufacturer	Sharp, Sanyo (HIT Type)	Sharp, Kyocera, Mitsubishi	MHI, Kaneka	MHI, Kaneka, Fuji Electric, Sharp	Showa Shell, Honda	Sharp	Sharp, Fujikura, Sony, AISIN	Panasonic, ENEOS, Mitsubishi Chemical, Sumitomo Chemical



Source: Edited by the Study Team in reference to the materials by METI and NEDO in Japan



■ : Mono-crystalline、■ : Poly- crystalline、■ : Amorphous、■ : CdTe、■ : CIS

Source：Newton September 2009

Figure 2.12-2 Trend of PV introduction capacity in the world

2.13 Expected Model of Grid-Connected PV System Introduction

Since the total amount of installed capacity of the grid-connected PV systems on Male' Island and Hulhumale' Island will be limited to 13.49 MW, a scenario that entails disseminating the technology by 13.49 MW over 10 years until 2020 is considered. Regarding the parties responsible for introducing the technology, it is assumed that STELCO will take charge from 2011 to 2014 and that STELCO and the private sector will be jointly responsible from 2015 to 2020. Accordingly, the expected model of grid-connected PV system introduction shall be divided into two stages, i.e. the pilot project and the period up to 2014, and the period from 2015 to 2020.

In the pilot project and period up to 2014, since STELCO will be the agency responsible for introduction, two models of introduction can be considered: the model where STELCO introduces the grid-connected PV system as its own equipment into its own company buildings, and the model where STELCO introduces it as its own equipment into other companies' buildings. As for the period from 2015 to 2020, since the private sector will join STELCO on the implementing side and consideration is given to establishing an excess power purchasing system when introducing to the private sector, another model, i.e. the model where building owners introduce equipment as private generator systems and sell excess power to STELCO, can be considered in addition to the above two.

Table 2.13-1 Expected Model of Grid-Connected PV System Introduction in the Pilot Project and Period until 2014

No.	Model of Introduction	Installation Site	PV System Owner	Features, Issues, Requirements, etc.
①	STELCO installs PV systems in its own building as company property.	STELCO's own facilities	STELCO	- Since STELCO owns the PV systems, planning and design for the PV systems is easier. - Installation sites can be selected by STELCO.
②	STELCO borrows rooftops owned by other entities and installs its PV systems.	Properties owned by third parties	STELCO	- Related regulations and constraints, rental fees for property shall be considered. - Agreement concerning system operation and security are required. - Since STELCO owns the PV facilities, there is no need to consider tariff for reverse power.

Source： Prepared by the Study Team

Table 2.13-2 Expected Model of Grid-Connected PV System Introduction in the Period from 2015 to 2020

No.	Model of Introduction	Installation Site	PV System Owner	Features, Issues, Requirements, etc.
①	STELCO installs PV systems in its own building as company property.	STELCO's own facilities	STELCO	- Since STELCO owns the PV systems, planning and design for the PV systems is easier. - Installation sites can be selected by STELCO.
②	STELCO borrows rooftops owned by other entities and installs its PV systems.	Properties owned by third parties	STELCO	- Related regulations and constraints, and rental fees for property shall be considered. - Agreement concerning system operation and security is required. - Since STELCO owns the PV facilities, there is no need to consider tariff for reverse power.
③	Building owners install PV systems as their own generators and sell excess power to STELCO.	Properties owned by third parties	Property owners	- Since PV systems are usually operated as in-house generators, reverse power is relatively little and the impact on distribution lines is small. - It is necessary to determine the interconnection guidelines and other transparent standards regarding protective equipment and so on.

Source： Prepared by the Study Team

The metering of PV power generation will be treated as follows. STELCO will install standalone meter for PV system in case that STELCO own the PV system. A meter without protection for reverse rotation is installed at interconnection point in order to measure stand-by consumption during nighttime.

On the other hand, as mentioned above, excess power purchasing system will be applied for private sectors after 2015. In case that private sectors own the system, the Team concluded that it is better to install a new meter (with protection for reverse rotation) to measure selling electricity beside of an existing buying meter (with protection for reverse rotation). It is the reason why the power purchasing price is uncertain because it must be decided taking financial condition after privatization of STELCO into consideration.

Table 2.13- 3　Metering method for grid-connected PV system

PV System owner	Fig. No.	interconnection category	Procurement & installation of meter	Type of meter	Installation point for meter	Boundary of properties and responsibility	Metering method
STELCO	①	LV	STELCO	Without protection for reverse rotation (MEA accredited products)	LV side	All STELCO's properties	Standalone meter for PV power generation
	②	MV			MV side of interconnection transformer		
Except for STELCO	③	LV 1Φ(～40A)	STELCO (PV System owner must shoulder the cost)	With protection for reverse rotation (MEA accredited products)	LV side (between existing meter and distribution board)	Primary side of meter or incoming cable terminal of MDB is boundary. The distribution lines side' s cables belong to STELCO. The meters belong to the customer but installation, removal and replacement without approval from STELCO are prohibited	An additional meter (with protection for reverse rotation) to measure selling electricity must be install beside an existing meter (with protection for reverse rotation)
		LV 3Φ (～63A)					
	④	LV 3Φ (100～300A)	PV System owner (need STELCO's calibration) or can order to STELCO				
	⑤	MV (300A～)			MV side of receiving transformer		

Source: Prepared by the Study Team

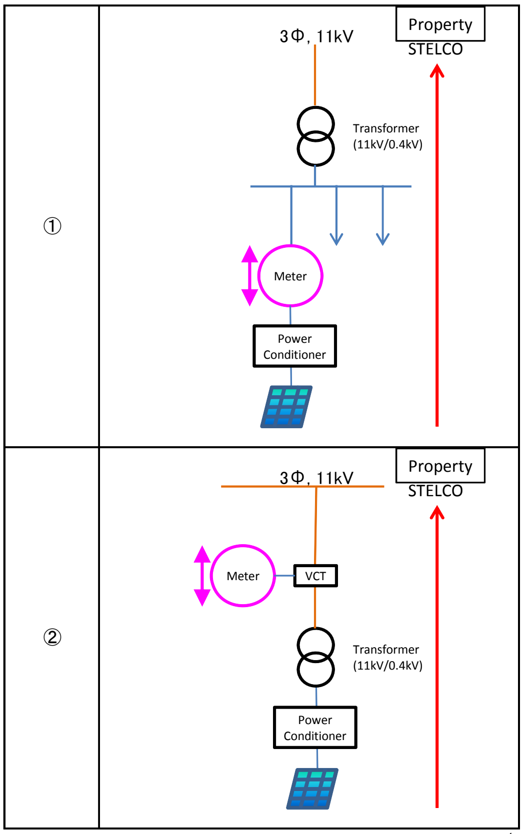


Figure 2.13- 1　Image for metering of grid-connected PV system（STELCO's installation）

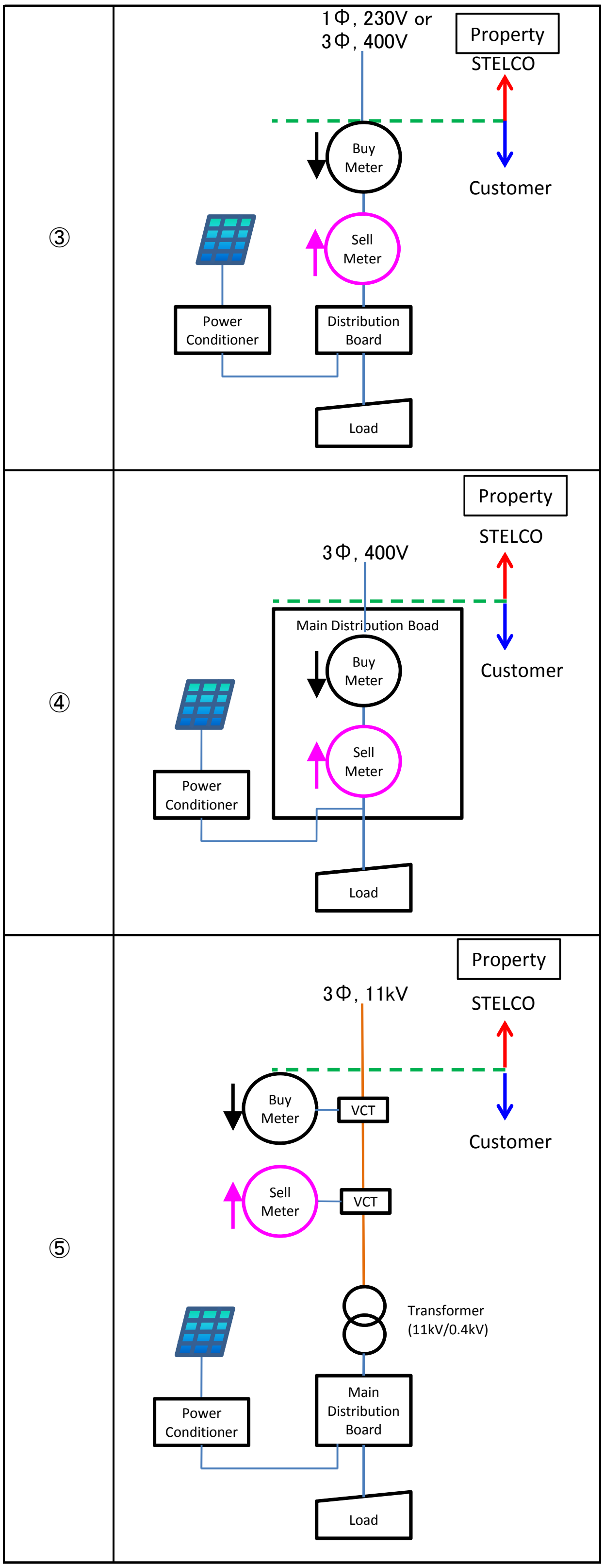


Figure 2.13- 2　Image for metering of grid-connected PV system（except for STELCO’s installation）

2.14 Legal Systems (Building Law, etc.) concerning Existing Buildings

Roofing specifications in the Maldives generally consist of sheets metal roofing on sloped roofs on both RC buildings (reinforced concrete structures) and S buildings (steel structures). In cases where rooftops are used as open spaces, water-proofing specifications are applied to RC slab. The National Building Code of the Maldives was established in August 2008, this provides broad performance stipulations. Maldives National Building Act first draft was announced in June. 2009. They invited a public comment and they are adjusting it toward the enactment. When new building or rebuilding works are implemented, the responsible engineering section of the MHTE individually reviews and gives planning permission for each applied building. New Zealand and British standards are used to provide the basis for conducting review. Provided that the calculations used to prove the safety of structures can be explained in engineering terms, it doesn't matter which country's standard are used. The loads that are assumed when designing PV panels and supporting members generally comprise permanent dead load and natural external forces such as wind load, seismic load and snow loads, etc.; however, since the Maldives has never experienced earthquake disasters (excluding tsunami damage) in the past, it was confirmed with the MHTE Engineering Section that seismic load doesn't need to be considered.

Table 2.14-1 Assumed Loads when Installing PV Panels

No.	Load type	Contents
1	Dead load	Combined weight of the PV modules and supports, etc.
2	Wind load	Vectorial sum of the wind load (also taking monsoon strong winds into account) acting on the PV modules and the load acting on frame and other supporting structures
3	Snow load	Vertical snow load on PV module surfaces (not considered in this study)
4	Seismic load	Horizontal seismic force acting on structures (on steel structure frame, this seismic force is generally smaller than wind load and is not considered in the Study).

Source： Prepared by the Study Team

2.15 Structural Analysis of Buildings and Conceptual Design of Building Reinforcements

With respect to the potential sites proposed by each concerned government agency, field surveys and surveys of existing design documents were conducted; and the panel support methods and installation methods were classified and examined according to the facilities and buildings recommended upon taking obstructed solar radiation, generating capacity, ease of reinforcement and rehabilitation and public relations effect, etc. into account. Basically, in cases of sheets metal roofing, panels shall be supported on the purlin, while in cases of installation on square roof and on the ground, supporting frame shall be constructed out of steel frames and supported with RC foundations. Structural analysis of buildings is intended to quantitatively determine the impact that PV panels (decided according to the generating capacity, etc.) have on existing buildings when the panel load is installed on the planned roofs. First, existing design documents will be used to gauge the roof materials, the method used to support roof materials and cross-sectional performance of support members, etc. Next, a structural model will be constructed according to the roof support method; stress analysis taking the weight of panels into account will be implemented, and judgment will be made concerning whether or not the stress level exceeds the permissible bearing force of the support members.

If stress is found to exceed the bearing force in the above examination, the shape and connections, etc. of structures will be reconfirmed in detail based on the existing design documents and field surveys and, upon compiling feasible reinforcement methods including iron sheet wrapping, special fiber sheet reinforcement, addition of buckling prevention materials and so on, the quantity, term and cost of reinforcement works will be identified.

Table 2.15-1 Contents and Results of Examination on PV Panel Supports

No	Site	Support Type (Installed floor)	Examination Contents	Examination Results
Male' Island				
1	STELCO Building	S frame (rooftop RC)	Examination of S frame and floor attachment method	S frame, rooftop floor, foundation works
2	STELCO Power House	purlin attachment (roof)	None (there is impact from waste heat)	-----
3	Dharubaaruge	purlin attachment (roof)	Examination of purlin and panel attachment	Existing design documents unknown (impossible)
4	Velaanaage (Govt. Office)	Unknown (work in progress)	None	-----
5	Giyaasudheen School	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
6	Kalaafaanu School	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
7	Maldives Center for Social Education	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
8	Thaajuddeen School	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
9	New Secondary School for Girls	purlin attachment (roof)	Examination of purlin and panel attachment	No reinforcement
10	Indhira Gandhi Memorial Hospital (IGMH)	purlin attachment (roof)S frame (rooftop RC)	None (rehabilitation plan exists)	-----
11	Faculty of Engineering	purlin attachment (roof)	Examination of purlin and panel attachment	Unusual attachment, existing design documents unknown (impossible)
12	National Stadium	purlin attachment (roof)	Examination of purlin and panel attachment and main members	Existing design documents unknown (impossible)
13	Majeedhiya School	purlin attachment (roof)	None (major shade obstruction)	-----
14	Dharumavantha School	purlin attachment (roof)	None (major shade obstruction)	-----
15	Fen Building	purlin attachment (roof)	None (viewing of design documents was refused)	-----

No	Site	Support Type (Installed floor)	Examination Contents	Examination Results
16	Water Tank (MWSC)	purlin attachment (roof)	None (rehabilitation plan exists)	-----
17	Faculty Education	purlin attachment (roof)	Examination of purlin and panel attachment	Existing design documents unknown (impossible)
18	Sports Grounds	S frame (rooftop RC)	None (difficulty with facility maintenance)	-----
19	Male' South West Harbour Parking	purlin attachment (roof)	None (semi private, semi public facility)	-----
20	Grand Friday Mosque	purlin attachment (roof)	None (major impact from tower and dome)	-----
21	Jumhooree Maidhan	S frame (RC foundation)	Examination of S frame, RC foundations and design	Consensus from related government agencies is difficult (impossible)
22	President's Office	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
Hulhumale' Island				
1	Lale International School	purlin attachment (roof) S frame (rooftop RC)	None (private sector facility)	-----
2	Hulhumale Hospital	purlin attachment (roof)	None (insufficient power supply)	-----
3	Ghaazee School	purlin attachment (roof)	None (weak roof)	-----
4	HDC	purlin attachment (roof)	None (unusual roof shape makes installation difficult)	-----
5	Housing Flats	purlin attachment (roof)	None (consensus of residents is difficult)	-----

Source： Prepared by the Study Team

2.16 Cost Estimation of Grid-Connected PV System Introduction

2.16.1 Estimation Conditions

The cost estimation is based on the average exchange rate of US$1 = 95.69 yen for the six month period from December 2008 to May 2009. The estimated condition are shown in the Table 2.16.1-1.

Table 2.16.1-1 Rough Project Cost Estimation Conditions

Contents	Estimation Conditions
(1) Equipment procurement cost	Equipment and material, transport, installation works (Existing structures reinforcement works cost) and procurement management cost, etc.
(2) Engineering service	Procurement Agent Fee and Consulting Services Fee

2.16.2 Project Cost

The project cost concerning introduction of the grid-connected PV system is approximately 1.95 million yen per kW (US$20,380/kW).

Table 2.16.2- 1　Breakdown for Project cost (Japanese supply)

Contents	Yen(thousand)/kW	composition ratio
(1) Equipment and material	1,335	68.5%
(2) Transport	52	2.7%
(3) Installation work	426	21.8%
(4) Procurement management cost	33	1.7%
(5) Engineering service	104	5.3%
Total	1,950	100%

As a result of Economic and Financial Feasibility Study in Chapter 5, the target grid-connected PV installation capacity by 2020 is 3,000kW. (Refer to Chapter 2, table 2.8-3)

Table 2.16.2-2 shows the project cost in each year taking the PV system price based on the NEDO “PV Roadmap toward 2030 (PV2030+)” into consideration, Prospects regarding future price movements in grid-connected PV systems are indicated in NEDO’s PV Roadmap toward 2030 (PV2030+). According to the roadmap, the cost of PV power generation will be 23 yen/kWh in 2010 and 14 yen/kWh in 2020.

and the project cost comes to approximately US$ 56.4 million in total.

Table 2.16.2-2　Grid-Connected PV System Installed Capacity and Project Cost

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capapcity (kW)			300	300	300	300	300	300	300	300	300	300	3,000
Project Cost (million US$)		6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2		56.4

Source： Prepared by the Study Team

2.17 Examination of Environmental and Social Consideration

2.17.1 Environmental and Social Consideration Systems in the Maldives

Concerning legal systems related to environmental and social consideration in the Maldives, the EIA Regulations 2007 were enacted under the former Ministry of Environment, Energy and Water (MEEW) according to Article 5 of the Environment Protection and Preservation Act (1993). These regulations require that environmental impact assessment (EIA) be implemented for the following projects:

(1) New, or large-scale additional, resort development projects
(2) Aquaculture and processing facilities, and artificial atoll development projects
(3) Agriculture, stockbreeding and large-scale forest felling projects
(4) Port construction, dredging, landfill and shore protection projects

(5) Trunk road construction projects
(6) Airport, heliport and hydroplane hub construction projects
(7) Large-scale housing development and factory construction projects
(8) Incinerator, waste disposal site and large-scale waste storage and separation facilities
(9) Bottling plant and water supply/sewage system projects
(10) Power plant and petroleum/gas, etc. fuel treatment and refining facility construction projects
(11) Seawater desalination facilities and hospital construction projects

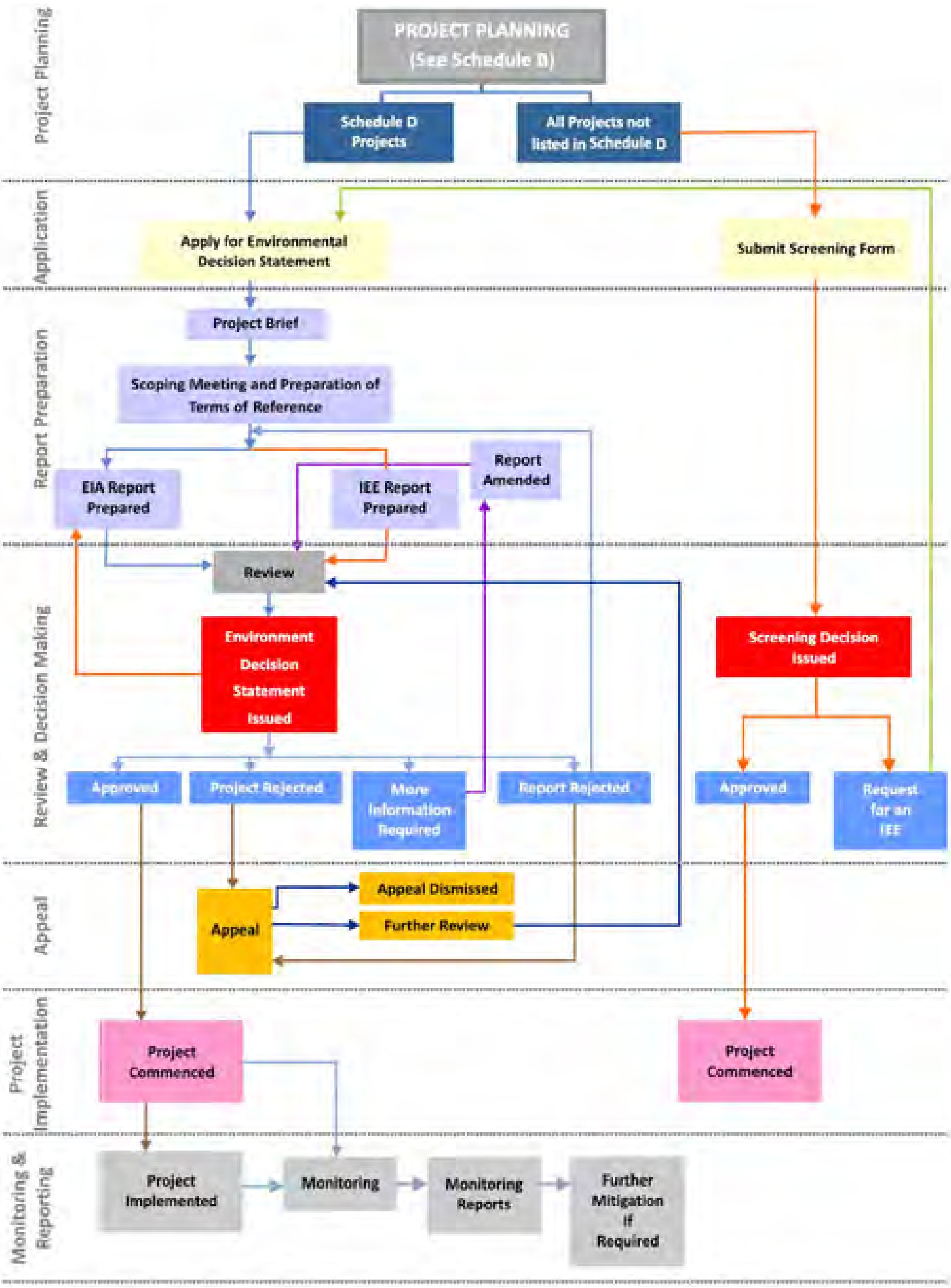
As is indicated above, EIA is required when constructing power plants. However, since this presumes the construction of diesel power plants, it will be necessary to submit a Development Proposal Screening Form to the Environmental Protection Agency (EPA) and undergo a screening review to determine whether or not grid-connected PV systems are subject to an EIA (or initial environmental examination: IEE). The result of screening will be notified to the project owner within 10 days from receipt of application, and in the case where an EIA or IEE is deemed necessary, the project owner will need to present an EIA/IEE Application Form (Form C2) and Project Brief to the EPA and commence the application procedure for an Environmental Decision Statement. On receiving the application form, the EPA will hold a scoping meeting together with representatives from related government agencies in order to discuss and confirm the expected environmental impacts of the proposed project. After the scoping meeting, the project owner will present the items (TOR) that need to be surveyed in the EIA or IEE to the EPA and, after receiving approval from the EPA, it will prepare the EIA or IEE report according to the TOR. The survey report will undergo review by the MHTE and external reviewers, and the result (one of the following) will be notified to the project owner by means of the Environmental Decision Statement. Figure 2.17.1-1 shows the work flow regarding EIA or IEE review to approval. All documents that need to be presented to the EPA will need to be prepared by a licensed EIA consultant in Maldives.

① Approval of the project application

② Request for renewed survey or provision of additional information concerning the contents of the submitted report

③ Refusal on the grounds of inadequate content of the EIA or IEE report

④ Refusal of the project application due to the possibility of project implementation exerting a massive impact on the environment



Source： "EIA Regulations 2007" MHTE

Figure 2.17.1-1 Environmental Impact Assessment
(or Initial Environmental Examination) Review Process

2.17.2 Agencies concerned with Environmental and Social Consideration

The Environmental Section of the MHTE is in charge of regulations, supervision and administration concerning environmental impact assessment, whereas the EPA implements review and approval work concerning the EIA or IEE for individual projects. The EPA has 78 employees as of June 2009 and it also implements research, education and enlightenment activities in the environmental field (biotechnology, biological diversity, water hygiene, marine hygiene, coastal area management, etc.).

2.17.3 Environmental and Social Consideration for Pilot Project Implementation

Envisaging implementation of the pilot project, the MHTE Energy Section, acting as the project owner, presented the designated screening form to the EPA. As a result of the EPA screening, a document was sent to the MHTE on June 1, 2009 notifying that the project will cause no major environmental impact and will not require an IEE.

Concerning the potential pilot project sites currently being proposed, it is not planned to introduce storage batteries for isolated operation switchover. Therefore, no environmental impact is expected for disposal and recycling of those batteries after their lifetime. However, it is required to pay full attention to the method of disposal of used batteries when grid-connected PV system is introduced with storage batteries for isolated operation switchover to secure higher reliability of power supply.